

Flux Thimble Call – Thursday March 26, 2015

Exelon Introduction – prior to discussion of Set 48 DRAIs

Thanks to everyone for taking the time to discuss this topic once again. We recognize there is some frustration, likely amongst all of us, regarding the fact that we have been unable to close this issue.

We have reviewed the latest draft RAI package, and would like to have some discussion on it. But prior to launching into that, we would like to briefly discuss our bigger picture view, which includes two potential resolution paths.

The reason that there are 2 paths is because we are very near term in obtaining the eddy current data for Braidwood Unit 1. Our outage starts next week, so by the end of next week we should be able to demonstrate that our corrective actions are effective and that we have the data.

The **first path** relates to the draft RAI package. We will want to go through that with you today, and ensure we have a good understanding of the remaining details that you need from us in light of what we have already provided. We see the need to ultimately credit this resolution path being predicated on us being unable to get a comprehensive set of eddy current data during next week's Braidwood outage activities. In that case, we would agree that we would need to submit information involving GALL exceptions or perhaps a plant-specific AMP, in order to address a condition where we are still unable to collect eddy current data on the flux thimble tubes. In that case, flux thimble tube replacement would be a key feature. We will need to make sure we close the gap regarding establishing confidence in the thimble tube replacement frequency, which involves answering some of the DRAI questions, such as those related to wear rates and operating experience.

The **second path** that we are proposing, and the one that we view as the more likely resolution vehicle, is that Braidwood collects a full set of eddy current test data next week, and demonstrates that the Flux Thimble Tube Inspection AMP is operating consistently with the GALL, the WCAP and NRC Bulletin 88-09. In this case, our proposed approach for closure of this issue would be different. Rather than responding to the Set 48 RAI package, we would generate an LRA supplement in which we would:

- Provide the staff with an update including the results of the Braidwood Unit 1 eddy current testing.
- Discuss the corrective action(s) that were determined effective at restoring the ability to collect eddy current data, and why this provides reasonable assurance that the AMP will be effective for Braidwood Unit 2 as well.
- Reinforce the fact that in our 2/23/15 letter RS-15-071, we established (and are retaining) a commitment (Enhancement 1) to ensure that the Flux Thimble Tube Inspection program is operating fully consistent with the GALL, Bulletin 88-09 and WCAP. We recognize that the staff may choose to impose a license condition on this activity, providing greater regulatory assurance that it will be accomplished.
- In addition, we are thinking that the backstop commitments having to do with tube replacements (Enhancements 2 and 3, originally established in November 2014 in Exelon

letter RS-14-336) would no longer be required; therefore, we would propose to eliminate them in the supplement.

Pause, for discussion.....

Also, before we move on, we would like to acknowledge that we understand there is some concern about the consistency of information in our responses, or changes to the “story” having happened over time. We would like to briefly address this.

- First, we have provided a lot of information over the past several months on this topic, including:
 - RS-14-165, June 9, 2014
 - RS-14-313, October 31, 2014
 - RS-14-336, November 22, 2014
 - RS-15-071, February 23, 2015
- Importantly, this is a live issue, in that although a lot of the testing and test-related information is historic, the testing and data collection difficulties have been relatively recent, and as you know, resolution activities are in progress within the corrective action process and have undergone some evolution and change over the past several months or so – so this is important to keep in mind
- On the data collection issue, we have been learning and updating you as we have gone through the months
- And in summary, if you have specific concerns about information that you think is conflicting, beyond what you have written into the draft RAI, please communicate that today so we can address it.

**Request for Additional Information
for Byron-Braidwood License Renewal Application
Updated Set 48**

Draft RAI B.2.24-1c, Flux Thimble Tube Inspection follow-up

Applicability: Braidwood

Note: This RAI is composed of three sections (1-3), each of which deals with a background, issue, and request. This RAI draft is intended to replace the first draft sent March 20, 2015, in its entirety.

Background 1:

In its response dated February 23, 2015, the applicant stated that historical flux thimble wear experienced at Braidwood is bounded by industry operating experience for which the GALL Report AMP was evaluated. The applicant further stated that a plant-specific AMP is not necessary, since its plant-specific condition and age-related operating experience is bounded by the conditions and operating experience for which GALL Report AMP XI.M37 was evaluated.

In its RAI response dated October 31, 2014, the applicant stated that widespread inability to obtain flux thimble tube eddy current data occurred suddenly at Braidwood Station Units 1 and 2 and involved flux thimble tubes of various in-service times. The applicant also stated that while Byron Units 1 and 2 and Braidwood Units 1 and 2 have the same basic flux thimble design (i.e., dimensions), the Byron Units have not had significant difficulty completing eddy current examinations.

In its October 31, 2014 response, the applicant stated that causal factors which include moisture and lubricant could account for the difficulties getting eddy current data, and it would consider activities to mitigate this issue. In its response dated February 23, 2015, the applicant stated that moisture and lubricant were not likely the causal factors and that deformation of the flux thimble tubes such that the internal dimension of the tubes is affected could prevent the eddy current probe from being fully inserted. The applicant also stated that deformation could occur because of mishandling, and is unlikely to result in deformation of all 58 flux thimble tubes. The applicant concluded that the most logical scenario is that the eddy current testing equipment or testing process is the likely cause of the recent issues related to obtaining eddy current testing data.

Issue 1:

The staff noted from the applicant's responses that its program failed to obtain useful data from most of its flux thimble tubes during the recent outage inspections since 2012, due to restrictions inside the flux thimble tubes. The staff is concerned that the applicant has yet to identify the root cause and, as a result, is not able to implement effective corrective actions to resolve the problem. In addition, the applicant has experienced higher than expected wear rates at Braidwood, including wear recently requiring replacement of flux thimble tubes.

The staff performed an industry operating experience search and did not note occurrences of widespread issues with inability to get eddy current data. In addition, since the 1980's when flux thimble wear became an issue, industry's use of chrome plated replacement tubes has greatly reduced wear rates which does not seem to be the

case with the chrome plated replacement flux thimble tubes at Braidwood. The staff is also concerned that the increasing trend in the numbers of uninspectable flux thimble tubes, unique to Braidwood, may be due to an age-related deformation of the tubes (i.e., reduction in inside diameter).

Request 1:

- (a) Provide technical justification that the operating experience for which the GALL Report AMP was evaluated is applicable to the plant-specific operating experience at Braidwood, considering the high wear rates, and multiple issues with eddy current examinations.

From our response RS-15-071, Enclosure A, page 8 first paragraph: Element 10, Operating Experience: GALL Report AMP XI.M37 is based on the requirements established in NRC IE Bulletin 88-09 which was developed in response to industry operating experience of flux thimble tube thinning in Westinghouse reactors due to flow-induced wear. This industry operating experience was summarized in NRC Information Notice 87-44. In response to these documents, the Westinghouse Owner's Group developed WCAP-12866. WCAP-12866 analyzed industry operating experience and developed a model to predict wear growth as well as guidance for an effective program to manage flow-induced wear of flux thimble tubes. Industry operating experience described in Information Notice 87-44 and WCAP-12866 includes examples of single cycle wear in excess of 27%. For example, Supplement 1 of Information Notice 87-44 identifies a nuclear station where "indications approaching 40% through-wall loss" had developed over a single cycle of operation. Furthermore, Braidwood plant-specific operating experience shows that flux thimble tube wear growth aligns with the wear trends predicted in WCAP-12866, as described in the response to Request 2.

- (b) Explain if higher than normal wear rates have been observed with chrome plated replacement tubes.

Understand the request

- (c) Provide root cause analysis and corrective actions related to the inability to obtain useful inspection data.

Is additional information concerning root cause and corrective actions necessary if a plant-specific AMP is submitted crediting only periodic replacement of flux thimble tubes rather than a combination of inspections and replacements?

- (d) Explain if there is a new age-related mechanism in addition to wear that is causing obstruction of eddy current probe insertion.

Understand the request

- (e) If the applicant's operating experience is unique and not bounded by the operating experience for which the GALL Report AMP XI.M37 was evaluated, explain why a plant-specific AMP is not required to manage the aging effects during the PEO.

Understand the request.

Background 2:

In the LRA, the applicant described its program as an existing program which is consistent with the GALL Report AMP XI.M37, "Flux Thimble Tube Inspection." In its February 23, 2015, response to the staff's follow-up RAI, the applicant described its program elements as "will be consistent" with the GALL Report AMP XI.M37 program elements.

Issue 2:

The staff reviewed the applicant's claim of program consistency by comparing the applicant's program with the GALL program. The staff noted that several program elements in the applicant's program are not consistent with those of the GALL program. Specifically, the applicant's program failed to obtain useful data from most of its flux thimble tubes during the recent outage inspections since 2012, and proposes an enhancement to replace its tubes every three cycles if flux thimble tube inspection data cannot be obtained. Based on the applicant's existing operating experience, there is a possibility that the issues with the eddy current examinations will recur during the period of extended operations.

Based on this, the applicant will be replacing the flux thimble tubes at an acceptable frequency instead of inspecting them. In such a case, the applicant's program would have exceptions to the following elements of the GALL AMP:

Element 3. Parameters Monitored/Inspected. GALL Guidance recommends that flux thimble tube wall thickness is monitored to detect loss of material from the flux thimble tubes. The applicant's program would not be able to monitor material loss, or wear.

Element 4. Detection of Aging Effects. GALL Guidance recommends an inspection methodology (such as ECT) used to detect loss of material. The applicant's program would not be able to detect the aging effect of wear.

Element 5. Monitoring and Trending. GALL Guidance recommends that flux thimble tube wall thickness measurements are trended and wear rates are calculated and projected based on plant-specific data. The applicant's program would not be able to provide trending and monitoring.

Request 2:

Identify all of the program's exceptions to GALL Report AMP XI.M37, "Flux Thimble Tube Inspection" when flux thimble tube inspection data cannot be obtained. Discuss how the proposed enhancement, to replace tubes at an acceptable frequency, will address the exceptions. Revise the program accordingly.

Is Request 2 needed if a plant-specific AMP is submitted?

Background 3:

In its response dated February 23, 2015, the applicant stated multiple times that "No flux thimble tube has been replaced due to age-related degradation in less than four (4) cycles," and that "None of the 116 flux thimble tubes were required to be replaced due to age-related degradation in less than four (4) refueling cycles."

In its response, the applicant also stated multiple times that plant-specific historical wear rates were used to project tube wear and were applicable. The applicant further stated that industry operating experience indicates that flux thimble tube wear decreases over the flux thimble tube service life. In addition, the applicant provided an enhancement to its aging management program to replace flux thimble tubes every three cycles when inspection data cannot be obtained.

Issue 3:

In Table 2, on Page 13 of its response, the applicant indicated that three tubes had to be replaced after only one cycle of service due to wear which is age-related. This appears to contradict to the applicant's statement that "No flux thimble tube has been replaced due to age-related degradation in less than four (4) cycles."

From our response RS-15-071, Enclosure A, page 13 last paragraph:

As described in Table 1, three (3) flux thimble tubes were replaced after one (1) cycle due to indications of high wear after the initial cycle of plant operation. The three (3) replacement flux thimble tubes for these flux thimble tubes remained in service for at least 15 cycles, therefore the high initial wear was considered to be associated with startup activities and is event driven rather than aging.

The applicant's justification for the enhancement does not consider worst case wear scenarios. For example, it had experienced higher than expected wear rates but does not consider high wear rates in consecutive cycles.

From our response RS-15-071, Enclosure A, page 12 last paragraph:

There have been only three (3) instances in which a flux thimble tube had to be replaced due to age-related degradation after being installed for four (4) cycles. The indicated wear for these three (3) flux thimble tubes ranged from 55% to 72%. Based on this, it was concluded that conditional replacement of flux thimble tubes on a three (3) refueling cycle frequency if eddy current testing data is not obtained in accordance with the Flux Thimble Tube Inspection program requirements is conservative. However, as stated in the *Issue*, there have been isolated instances in which wear exceeding 27% has been experienced over a single cycle. It should be noted that industry operating experience has shown that flux thimble tube wear due to flow induced vibration decreases exponentially over the flux thimble tube service life. Using the methodology provided in WCAP-12866 for predicting flux thimble tube wear and the conservative exponent defined in WCAP-12866, 56.3% wear is predicted after three (3) cycles when 27% wear is experienced in the first cycle.

The applicant cited industry operating experience that wear rates decrease following high wear in earlier cycles. The staff noted that the applicant also experienced an increase in wear rates following cycles of low wear rates.

From our response RS-15-071, Enclosure A, page 12 last paragraph:

Although there have been isolated instances of higher wear in flux thimble tubes that had historically experienced low wear, these instances have been limited to one (1) or two (2) flux thimbles tubes during a testing interval and have not repeated over multiple test intervals. The three (3)-cycle replacement if eddy current data is not collected will minimize the possibility a flux thimble tube will experience a postulated mid-service life jump in wear by limiting the time a flux thimble tube will remain in service if eddy current data is not collected. Any wear prior to or after a postulated mid-service life jump in

wear would also be minimized by limiting the time a flux thimble tube can be installed if eddy current data is not collected.

In addition, during its review of industry operating experience, the staff noted that there is industry operating experience which indicates that high wear rates may be sustained in multiple cycles. Specifically, the staff noted that a similar plant encountered multiple tube failures prior to the completion of three cycles of operation (LER-272/1981-028). A three-cycle replacement period appears to be inadequate.

Industry OE LER-272/1981-028 was not directly addressed in the previous RAI responses but was included in the OE section of WCAP-12866 which was referenced in the previous RAI responses. Event occurred in 1981 before the issuance of IE Bulletin 88-09 which established the requirement to monitor flux thimble tube wear. As described in NRC Bulletin 88-09: "The amount of vibration the thimble tubes experience is determined by such plant-specific factors as the gap distance from the lower core plate to the fuel assembly instrument tube, the amount of clearance between the thimble tube and the guide or instrument tube, the axial component of the local fluid velocity, the thickness of the thimble tube, and the moment of inertia of the thimble tube. A review of the available data indicates that it is not possible to accurately predict thimble wear rates. Thus, it appears that the only effective method for determining thimble tube integrity is through plant-specific inspections and periodic monitoring." Therefore, inspection or replacement frequencies must be based on plant-specific data rather than industry data. Unless the parameters identified above (e.g., gap distance, clearance, flow velocity) are the same, industry operating experience described in LER-272/1981-028 is not directly applicable at Braidwood. The Braidwood parameters are different than the Salem parameters (e.g., gap between tube OD and column ID at Salem is larger than at Braidwood, core flow per assembly is different, and Salem 1 was a downflow plant at the time of the event whereas Braidwood are upflow plants. Ref. Table 5 of WCAP-12866).

Request 3:

- a) Explain why initial wear resulting in replacement of three flux thimble tubes after one cycle is not flow related wear and will not recur.

From our response RS-15-071, Enclosure A, page 13 last paragraph:
As described in Table 1, three (3) flux thimble tubes were replaced after one (1) cycle due to indications of high wear after the initial cycle of plant operation. The three (3) replacement flux thimble tubes for these flux thimble tubes remained in service for at least 15 cycles, therefore the high initial wear was considered to be associated with startup activities and is event driven rather than aging.

- b) Explain why replacing flux thimble tubes every three cycles when examination data are not obtained is adequate, in light of the plant-specific high wear rates, and industry operating experience which indicates that high wear rates could continue into subsequent cycles and result in tube failures in less than three cycles.

From our response RS-15-071, Enclosure A, top of page 14:
In summary, the justification for the adequacy of the enhanced Flux Thimble Tube Inspection aging management program is based on the plant-specific operating experience, as discussed above, that shows:

- the program requires periodic eddy current testing to be performed during the period of extended operation and the compensatory action to replace a flux thimble tube after three (3) cycles of operation only applies if useful eddy current data cannot be obtained for a flux thimble tube,
- no flux thimble tube has been replaced due to age-related degradation in less than four (4) cycles and there have been only three (3) instances of replacement at four (4) cycles due to age-related wear,
- flux thimble tubes replaced in three (3) cycles or less were replaced due to issues other than flow induced wear,
- single cycle wear of 27% or greater is rare,
- consecutive cycles with wear of 27% or greater does not occur, and
- overall wear of the Braidwood flux thimble tubes does not follow a linear trend but
- rather follows the exponentially decreasing trend predicted in WCAP-12866.

Color Legend:

Yellow – focus of information

Blue – excerpts from previous RAI responses

Green – general comments or pointer to information from public records