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RS-21-015 10 CFR 50.55a

February 10, 2021

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

Byron Station, Units 1 and 2
Renewed Facility Operating License Nos. NPF-37 and NPF-66
NRC Docket Nos. 50-454 and 50-455

Braidwood Station, Units 1 and 2
Renewed Facility Operating License No. NPF-72 and NPF - 77
NRC Docket Nos. STN 50-456 and STN 50-457

Subject: Response to Request for Additional Information Related to Relief Request for Braidwood I4R-11 and Byron I4R-18

References:
1. Letter from D. Murray (Exelon Generation Company, LLC) to U.S. NRC, "Submittal of Relief Request I4R-11 for Braidwood Station, Units 1 and 2, and Relief Request I4R-18 for Byron Station, Units 1 and 2, Concerning Containment Unbonded Post-Tensioning System Inservice Inspection Requirements," dated July 24, 2020.
2. Email from J. Wiebe (U.S. Nuclear Regulatory Commission) to P. A. Henderson (Exelon Generation Company, LLC), "RAIs Regarding Relief Request for Braidwood I4R-11 and Byron I4R-18," dated December 30, 2020.

By application dated July 24, 2020 (Reference 1), Exelon Generation Company, LLC (EGC) requested NRC approval of Relief Request I4R-11 for Braidwood Station, Units 1 and 2, and Relief Request I4R-18 for Byron Station, Units 1 and 2, concerning containment unbonded post-tensioning system inservice inspection requirements. These requests are associated with the fourth Inservice Inspection (ISI) interval for Braidwood Station and Byron Station.

In an NRC email dated December 30, 2020 (Reference 2), the NRC determined that additional information is needed to complete its review. The attachments to this letter provide the requested information. As discussed during the clarification call held with the NRC on January 12, 2021, the response to the request for additional information (RAI) is requested within 30 days of the clarification call.

There are no regulatory commitments contained within this letter. Should you have any questions concerning this letter, please contact Mr. Phillip A. Henderson at (630) 657-4727.

Respectfully,

Dwi Murray
Sr. Manager – Licensing
Exelon Generation Company, LLC

Attachments:

1. Response to Request for Additional Information
2. Revised Pages from Containment Post-Tensioning System Inservice Inspection Technical Report, Revision 1

cc: NRC Regional Administrator, Region III
NRC Senior Resident Inspector – Braidwood Station
NRC Senior Resident Inspector – Byron Station

ATTACHMENT 1

Response to Request for Additional Information

ATTACHMENT 1
Response to Request for Additional Information

By application dated July 24, 2020 (Reference 1), Exelon Generation Company, LLC (EGC) requested NRC approval of Relief Request I4R-11 for Braidwood Station, Units 1 and 2, and Relief Request I4R-18 for Byron Station, Units 1 and 2, concerning containment unbonded post-tensioning system inservice inspection requirements (ADAMS Accession No. ML20206L135).

By email dated December 30, 2020 (Reference 2), the NRC determined that additional information is needed to complete its review. This attachment provides the requested information.

References:

1) Letter from D. Murray (Exelon Generation Company, LLC) to U.S. NRC, "Submittal of Relief Request I4R-11 for Braidwood Station, Units 1 and 2, and Relief Request I4R-18 for Byron Station, Units 1 and 2, Concerning Containment Unbonded Post-Tensioning System Inservice Inspection Requirements," dated July 24, 2020

2) Email from J. Wiebe (U.S. Nuclear Regulatory Commission) to P. A. Henderson (Exelon Generation Company, LLC), "RAIs Regarding Relief Request for Braidwood I4R-11 and Byron I4R-18," dated December 30, 2020.

NRC RAI 55

The request for relief for Containment Unbonded Post-Tensioning System Inservice Inspection Requirements in Accordance with 10 CFR 50.55a(z)(1), Section 4, Reason for Request, states "ASME Section XI, Subsection IWL requires periodic visual examination and physical testing of Containment Building concrete as well as physical testing of post-tensioning systems."

The staff finds that ASME Section XI, Subsection IWL does not require periodic physical testing of Containment Building concrete. Describe what kind of physical testing of concrete is required and whether it has been performed. If yes, where are the test results documented.

EGC Response to NRC RAI 55

EGC agrees that ASME Section XI, Subsection IWL does not require periodic physical testing of the Containment Building concrete. The statement contained in Reference 1 cover letter and Section 4, Reason for Request, describing the required inspections of the Containment Building concrete and post-tensioning systems is revised as follows:

"ASME Section XI, Subsection IWL requires periodic visual examination and physical testing of the post-tensioning system, as well as, periodic visual examination of the Containment Building concrete."

NRC RAI 57

PART B - CONTAINMENT DESCRIPTION, ISI PROGRAM, and SUMMARY of PROPOSED PROGRAM CHANGES, Containment ISI Program Summary Description, states "Also, limited scope visual examinations that addressed Unit 2 water intrusion issues were performed at Byron in 1987 and 1988. Limited scope visual examinations that addressed Unit 1 and Unit 2 water intrusion issues were performed at Braidwood in June – August 1987 and October - November 1990."

Describe how the water intruded into the containment buildings and the results of these limited scope visual examinations activities.

EGC Response to NRC RAI 57

(a) Water did not enter into the containment buildings. Specifically, water did not pass through the liner and into the containment; it permeated through concrete (concrete is moderately porous) and entered the rolled seam (not watertight) tendon ducts.

(b) Limited scope examinations to assess the extent of water intrusion were performed following the completion of the regularly scheduled examinations and, for purposes of the technical report, are considered to be an extension of the latter (extension of the regularly scheduled exams). Therefore, the results of the limited scope exams are included with the results of the regularly scheduled exams.

Water intrusion is documented on Byron (report Part D) Table 13 and Braidwood (report Part E) Table 14.

As stated in the 4.1 subsections of both report Parts D and E, corrosion found on Byron and Braidwood enclosed anchorage components was not active. It was concluded to have existed at the time of construction and, therefore, unrelated to the observed water intrusion in tendon ducts.

NRC RAI 58

The licensee states the following:

1. "Byron and Braidwood have completed nine and eight, respectively, pre-stressing system surveillances on each unit. These were based on Regulatory Guide 1.35 or 10CFR50.55a / ASME Section XI Subsection IWL,"

2. "the Regulatory Guide 1.35 requires "Examination sample size - six dome, five vertical, and ten hoop tendons,"

3. "Regulatory Guide 1.35 was withdrawn in August 2015 following the incorporation, by reference, of ASME Section XI, Subsection IWL into NRC Regulation 10CFR50.55a," and

4. "the examination intervals and wire testing addressed in the 1973 original issue of Regulatory Guide 1.35 are now, 45 years later, still incorporated effectively unchanged into the current edition of ASME Section XI, Subsection IWL."

Based on the above, provide responses to the following questions #58;

1. Byron Unit 1, the sample sizes for dome tendons are five for years 1 and 5, and three for years 10, 20, and 30 (see Byron Table 7), for vertical tendons are six for years 1 and 5, and three for years 10, 20, and 30 (see Table 5), and for hoop tendons are ten for year 1, eight for year 5, and four for years 10, 20, and 30 (see

Byron Table 3). Provide an explanation for those sample sizes that are less than that of the current edition of ASME Section XI, Subsection IWL.

2. Byron Unit 2, the sample sizes for dome tendons are five for years 1 (see Byron Table 8), three for years 10, 20, and 30 (see Byron Table 8), for vertical tendons are eight for year 1, six for year 5, and four for years 15, 25, and 35 (see Byron Table 6), and for hoop tendons are twelves for year 1, ten for year 5, and five for years 15, 25, and 35 (see Byron Table 4). Provide an explanation for those sample sizes that are less than that of the current edition of ASME Section XI, Subsection IWL.

3. Braidwood Unit 1, the sample sizes for dome tendons are four for years 1, seven for years 5, three for years 10 and 20, and four for year 30 (see Braidwood Table 7), for vertical tendons are six for years 1 and 5, and three for years 10, four for year 20, and three for year 30 (see Braidwood Table 5), and for hoop tendons are nine for year 1, eight for year 5, and four for years 10, five for year 20, and four for year 30 (see Braidwood Table 3). Provide an explanation for those sample sizes that are less than that of the current edition of ASME Section XI, Subsection IWL.

4. Braidwood Unit 2, the sample sizes for dome tendons are five for years 1 and 5, and three for years 15 and 25 (see Braidwood Table 8), for vertical tendons are six for years 1 and 5, and three for year 10, four for year 20, and three for year 30 (see Braidwood Table 5), and for hoop tendons are nine for year 1, eight for year 5, and four for year 10, five for year 20, and four for year 30 (see Braidwood Table 3). Provide an explanation for those sample sizes that are less than that of the current edition of ASME Section XI, Subsection IWL.

5. There are ten numerical values listed in Table 3 for Unit 1 year 1 hoop tendon forces, but only seven forces are plotted in figure 1. There are 8 numerical values listed in Table 3 for Unit 1 year 5 for hoop tendon forces, but only four are plotted in figure 1. Provide an explanation for the discrepancy.

EGC Response to NRC RAI 58

(a) With respect to sub-questions 1 through 4, Byron Station, Units 1 and 2, and Braidwood Station, Units 1 and 2, Technical Specifications governed tendon sample sizes until compliance with ASME Section XI, Subsection IWL was required in accordance with 10 CFR 50.55a (61 FR 41303) after September 9, 1996, starting with the 20th year examinations at Byron Unit 1 and the 15th year examinations at Braidwood Unit 2 (Reference the Technical Report, Part B, Section 2).

Starting with the 20th year examinations at Byron Unit 1 and 15th year examinations at Braidwood Unit 2, tendon sample sizes were required in accordance with IWL-2421 and Table IWL-2521-1 for a sample size of 2%, with a minimum of 3 and maximum of 5 tendons of each type requiring examination. Starting with the 30th year examinations at Byron Unit 1 and Braidwood Unit 1, the sampling requirements were modified in accordance with Table IWL-2521-2 for a sample size of 2%, with a minimum of 3 and maximum of 5 tendons of each type requiring examination. Starting with the 30th year examinations at Byron Unit 1 and Braidwood Unit 1, the sampling requirements were modified in accordance with Table IWL-2521-2 to address tendons affected by repair/replacement activities, where temporary openings were repaired following steam generator replacements. These activities resulted in the removal and replacement of 38 vertical and 32 hoop tendons in each of these units to facilitate cutting the containment cylinder wall opening needed for exchanging the steam generators. With this confirmation, revision to pages 46 and 131 of the technical report are provided as corrections to typographical errors regarding vertical tendon population in Attachment 2. The revisions are delineated with revision bars.

A review of the tendons selected for examination in accordance with ASME Section XI, Subsection IWL has determined that the required sample sizes met, or exceeded the sample sizes required by Subsection IWL, as shown in the following Tables 1 and 2.

<table>
<tr><th colspan="5">Table 1
Byron Station, Units 1 and 2
Tendon Sample Sizes Required by ASME Section XI, Subsection IWL</th></tr>
<tr><td colspan="5">Except as noted below, the required minimum sample sizes for each examination are as follows (as required by Table IWL-2521-1, based on a 2% sample size):
• 4 Verticals (Based on 162 Vertical Tendons)
• 3 Domes (Based on 120 Dome Tendons)
• 5 Hoops (Based on 201 Hoop Tendons)</td></tr>
<tr><th rowspan="2">Tendon Group</th><th colspan="4">Tendons Selected for Examination</th></tr>
<tr><th>Unit 1
20th Year
(2004)</th><th>Unit 2
25th year (2009)</th><th>Unit 1
30th Year (2014)</th><th>Unit 2
35th Year (2019)</th></tr>
<tr><td>Unit 1 Verticals not Affected by Steam Generator Replacement (SGR)</td><td>V47, V88, V110[2]</td><td rowspan="5">Unit 2 Physical Inspection Year</td><td>V82, V88, V121[5]</td><td rowspan="5">Unit 2 Physical Inspection Year</td></tr>
<tr><td>Unit 1 Verticals Affected by SGR</td><td>V15[1], V162[1]</td><td>V15[1, 3]2, V160[1, 3]</td></tr>
<tr><td>Unit 1 Hoops not Affected by SGR</td><td>H55BA, H24CB, H58AC, H6BA[2]</td><td>H42AC, H45BA, H57CB, H58AC[4]</td></tr>
<tr><td>Unit 1 Hoops Affected by SGR</td><td>H37BA[1], H38CB[1]</td><td>H30CB[1, 3], H38BA[1, 3]</td></tr>
<tr><td>Unit 1 Dome</td><td>D124, D307, D219</td><td>D124, D138, D312</td></tr>
<tr><td>Unit 2 Vertical</td><td rowspan="3">Unit 1 Physical Inspection Year</td><td>V290, V232, V295, V306</td><td rowspan="3">Unit 1 Physical Inspection Year</td><td>V208, V290, V315, V356</td></tr>
<tr><td>Unit 2 Hoop</td><td>H60ED, H55DF, H21DF, H12ED, H65EF</td><td>H8DF, H48DF, H29ED, H60ED, H27FE</td></tr>
<tr><td>Unit 2 Dome</td><td>D636, D619, D510</td><td>D407, D531, D636</td></tr>
</table>

Notes:

(1) These tendons were excluded from those shown in Part D, Tables 3 and 5 of the Technical Report because these tendons were affected by repair/replacement activity associated with Steam Generator replacement repairs and are not representative of tendons that have been in service since commercial operation of the plant.

(2) The required sample size during this examination was satisfied by examination of the tendons identified here, as well as the additional tendons affected by SGR.

(3) Starting with the Unit 1 30^{th} year examinations, the sample size for tendons affected by repair/replacement activities is determined by Table IWL-2521-2.

(4) The number of hoop tendons required to be examined during this inspection is based on 2% of the hoop tendons not affected by SGR. The revised population of unaffected tendons allowed a sample size of 4 to be selected.

(5) The number of vertical tendons required to be examined during this inspection is based on 2% of the vertical tendons not affected by SGR. The revised population of unaffected tendons allowed a sample size of 3 to be selected.

<table>
<tr><th colspan="5">Table 2
Braidwood Station, Units 1 and 2
Tendon Sample Sizes Required by ASME Section XI, Subsection IWL</th></tr>
<tr><td colspan="5">Except as noted below, the required minimum sample sizes for each examination are as follows (as required by Table IWL-2521-1, based on a 2% sample size):
• 4 Verticals (Based on 162 Vertical Tendons)
• 3 Domes (Based on 120 Dome Tendons)
• 5 Hoops (Based on 201 Hoop Tendons)</td></tr>
<tr><th rowspan="2">Tendon Group</th><th colspan="4">Tendons Selected for Examination</th></tr>
<tr><th>Unit 2
15th Year
(2001)</th><th>Unit 1
20th Year (2006)</th><th>Unit 2
25th Year (2011)</th><th>Unit 1
30th Year (2016)</th></tr>
<tr><td>Unit 1 Verticals not Affected by SGR</td><td rowspan="5">Unit 2 Physical Inspection Year</td><td>V30, V50, V95, V133</td><td rowspan="5">Unit 2 Physical Inspection Year</td><td>V30, V76, V112[3]</td></tr>
<tr><td>Unit 1 Verticals Affected by SGR</td><td>None inspected[2]</td><td>V16[1],[5], V143[1],[5]</td></tr>
<tr><td>Unit 1 Hoops not Affected by SGR</td><td>H35AC, H59AC, H53CB, H67CB, H50BA</td><td>H16CB, H21BA, H50BA, H67AC[4]</td></tr>
<tr><td>Unit 1 Hoops Affected by SGR</td><td>None inspected</td><td>H42CB[1],[5], H44BA[1],[5]</td></tr>
<tr><td>Unit 1 Dome</td><td>D102, D115, D219</td><td>D132, D219, D332, D137</td></tr>
<tr><td>Unit 2 Vertical</td><td>V232, V308, V333, V357, V236, V249</td><td rowspan="3">Unit 1 Physical Inspection Year</td><td>V203, V308, V243, V342</td><td rowspan="3">Unit 1 Physical Inspection Year</td></tr>
<tr><td>Unit 2 Hoop</td><td>H22DF, H36ED, H45DF, H56FE, H57DF, H4ED</td><td>H57DF, H16ED, H24ED, H46FE, H62FE</td></tr>
<tr><td>Unit 2 Dome</td><td>D438, D537, D622</td><td>D436, D504, D622</td></tr>
</table>

Notes:

(1) These tendons were excluded from those shown in Part E, Tables 3 and 5 of the Technical Report because these tendons were affected by repair/replacement activity associated with Steam Generator replacement repairs and are not representative of tendons that have been in service since commercial operation of the plant.

(2) In 2006, there were no specific requirements for examination of tendons affected by repair/replacement activities in the ASME Code, Section XI Code of record in use at that time. Note that the requirements now found in Table IWL-2521-2 were incorporated into the 2002 Addenda of the ASME Code, Section XI.

(3) The number of vertical tendons required to be examined during this inspection is based on 2% of the vertical tendons not affected by SGR. The revised population of unaffected tendons allowed a sample size of 3 to be selected.

(4) The number of hoop tendons required to be examined during this inspection is based on 2% of the hoop tendons not affected by SGR. The revised population of unaffected tendons allowed a sample size of 4 to be selected.

(5) Starting with the Unit 1 30th year examinations, the sample size for tendons affected by repair/replacement activities is determined by Table IWL-2521-2.

(b) With respect to sub-question 5, all points on Table 3 for Unit 1 year 1 hoop tendon forces and Unit 1 year 5 for hoop tendon forces are plotted in Figure 1.

Since the data points were close in values, as a result, they were superimposed on each other such that they cannot be distinguished on the plots. Specifically, three of the lift-off forces measured during the 1st year examination, as listed on Part D (Byron) Table 3, are 1,310, 1,310 and 1,311 kips and have a spread of only 1 kip. The three symbols plotted for these are effectively superimposed and cannot be distinguished from one another on the plot (Figure 1). Two of the measured forces are 1,257 and 1,258 kips and have a spread of 1 kip. Again, the symbols for these are effectively superimposed and cannot be distinguished from one another on the plot (Figure 1).

Three of the forces measured during the 5th year are 1,206, 1,207 and 1,209 kips and have a spread of 3 kips. The three symbols are partially superimposed but close inspection shows that these do overlap. The same is true for the closely spaced values of 1,216 and 1,218 kips (2 kip spread) as well as the closely spaced values of 1,226 and 1,228 kip (also a 2 kip spread).

It is to be noted that the trend line and LCL computations use all of the data listed in Table 3. Notes provided in Figure 1 provided in this letter describes the plotted numerical values listed in Table 3 for Unit 1 year 1 and 5 for hoop tendon forces. Therefore, there is no discrepancy between the numerical values listed in Table 3 and Figure 1.

NRC RAI 59

The licensee developed and proposed formulas indicating that the pre-stressing forces in the cylinder both in the hoop and vertical directions and in the dome of the containments have been decreasing gradually with time. The formulas predict that the pre-stressing forces will remain above the required minimum magnitudes for the next ten years. This is the main argument used by the licensee to extend the ASME Code's five year surveillance intervals to ten years. However, the prestressing forces in the following figures do not match the licensee's formula predicted. The prestressing forces in the following figures have been decreased or increased or flattened at different time intervals, sometimes sharply and other times gradually, with no predictable trends (increase or decrease or flat) and magnitudes from time to time. Therefore, the use of the formulas to predict the future prestressing lost in the containment as the justification for extending the ASME Code's five-year surveillance intervals to ten-year intervals may not be valid.

Figure 1 - Byron Unit 1 Hoop Tendon Force Trend & LCL / 1 - 30 Year Surveillance Results indicate that the prestressing force is decreased from year 1 to year 5 and decreased more to year 10, but then is reversed to increase from year 10 to year 29 and is decreased again to year 30.

Figure 8 - Byron Unit 1 Vertical Tendon Force Trend & LCL / 5 - 30 Year Surveillance Results indicate that the prestressing force is increased from year 5 to year 10 and then flattened to year 20 and then decreased from year 20 to year 30.

Figure 10 - Byron Unit 2 Vertical Tendon Force Trend & LCL / 1 - 35 Year Surveillance Results indicate that the prestressing force is decreased sharply from year 1 to year 5 and then flattened to year 15 and then another sharply decreased to year 25 and then slightly increased to year 35.

Figure 13 - Byron Unit 1 Dome Tendon Force Trend & LCL / 1 - 30 Year Surveillance Results indicate that the prestressing force is decreased sharply from year 1 to year 5 and then increased from year 5 to year 10 and then decreased to year 20 and then increased slightly to year 30.

Figure 16 - Braidwood Unit 2 Dome Tendon Force Trend & LCL / 1 - 35 Year Surveillance Results indicates that the prestressing force is reduced from year 1 to year 5 and is increased from year 5 upward through years 15 and 25.

Figure 17 - Byron Unit 2 Dome Tendon Force Trend & LCL / 5 - 35 Year Surveillance Results indicates that the prestressing force is increased from year 5 to year 15 and then decreased from year 15 to year 25 and 35.

Provide an explanation for such irregular phenomena of prestressing loss or gain with time in containments. Also provide additional justification why it is acceptable to extend the surveillance intervals from the ASME Code's five year surveillance intervals to the proposed ten year intervals.

EGC Response to NRC RAI 59

There is no formula, as such, used in developing the Byron and Braidwood prestressing force trends. The log-linear function used to generate statistically meaningful force trends is a pre-stressed concrete technology standard based on the results of laboratory tests, performed over many years, on concrete design mix specimens and specimens of tendon wire representing different heats of steel. These tests have consistently shown that the following parameters vary essentially linearly with the logarithm of time, with possible flattening of the characteristic over a time span measured in decades.

- Concrete shrinkage strain when specimens are maintained at fixed temperature and humidity.
- Concrete creep strain when specimens are maintained under a fixed load at a fixed temperature and sealed to eliminate moisture loss and attendant shrinkage.
- Steel stress when relaxation test specimens are maintained at a fixed elongation and fixed temperature.

These log-linear characteristics[1] are used during containment design to predict pre-stressing force loss with time. The pre-stressing system is then designed to ensure that the level force will meet the design specification requirements at the end of plant life (initially specified as 40 years). Designs are generally based on the conservative postulates that temperature, humidity and loading conditions are such as to maximize expected concrete shrinkage / creep strains and pre-stressing steel stress loss.

The same log-linear characteristic is used in post-tensioning ISI reports to trend tendon group mean force through the subsequent examination. And, it is used in the technical reports

[1] Flattening of the log-linear characteristic, as is often observed in plots of surveillance data acquired over a several decade time span, results in a conservative design, i.e., one with lower than forecast loss of pre-stressing force.

supporting the TMI-1, Vogtle 1 & 2, and Millstone 2 relief requests, all of which were approved by the NRC (ML19226A023, ML19182A077, and ML20287A471).

In addition, use of the log-linear characteristic to forecast tendon forces is addressed in USNRC Regulatory Guide 1.35.1, Figure 2.

If all tendons were tensioned simultaneously and subsequently maintained under steady and uniform environmental conditions, then forces measured during a surveillance would plot on the trend line; i.e., the force measured for each tendon[2] would represent the mean.

As tendons are tensioned in a prescribed sequence over a period of several months and as field conditions differ from controlled laboratory conditions, forces in individual tendons do deviate from the mean. Several major causes of these deviations are listed below.

- Strain induced in the concrete and, consequently, in the tensioned tendons due to subsequent tensioning of remaining tendons.
- Shrinkage strain accrued subsequent to tensioning of a given tendon.
- Creep strain accrued subsequent to tensioning of a given tendon.
- Minor variations in initial seating force.
- Age of the concrete at the time of tensioning a given tendon. For example, an upper hoop tendon will experience more early creep strain than a lower hoop tendon since upper-level cylinder concrete is placed well after lower-level concrete and, therefore, will experience more creep strain under the same load applied at the same time.
- Spatial and temporal variation in environmental factors, principally temperature and humidity, that affect shrinkage, creep and relaxation rates. For example, tendons tensioned during the heat of the summer will experience somewhat more early loss due to creep and relaxation than those tensioned during the cooler months.

In addition, there may be deviations from surveillance to surveillance resulting from changes in the methods[3] used to measure tendon force as well as deviations, generally negligible, due to random measurement error.

These deviations from the mean appear as scatter on the force vs log time plots in the technical report. Scatter exhibited on the Byron and Braidwood plots is similar to that seen on plots of tendon forces measured at other plants. Three such plots are attached; one for Byron (Figure 1), one for Braidwood (Figure 7) and one figure from a technical report supporting the relief

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[2] Containment geometry will, in fact, result in some deviation from the mean. E.g., the lowest hoop tendons will experience a relatively little loss in force due to concrete creep since radial movement of the lower wall is restrained by the base mat.

[3] Methods used to measure tendon force have evolved over time. Early methods include shim prying (generally yields a small under estimate of force) and shim sounding (generally yields an over estimate). A possibly somewhat later method, feeler gage pull out, usually yields a small over estimate. The most recent and most accurate method, force / displacement plotting, is seldom used.

request submitted by Millstone Unit 2 (ML19352B898). It is to be noted that all measured forces plotted on these figures lie above the minimum required level for group (hoop, dome vertical) mean force.

The forces in individual tendons are shown on the common tendon[4] plots in the technical report (e.g., Byron Figures 3, 6, 9, 12, 15 and 18) to follow a log-linear trend with reasonably little scatter. This provides confirmation that the mean pre-stressing force trend is also essentially log-linear.

Since the use of a log-linear force trend is justified by common tendon data, it is only necessary to account in an acceptable statistical manner for the scatter of data about a linear trend line. This is done by using the linear regression methods developed in statistical theory and presented in statistics texts (e.g., the Miller and Freund text cited as Byron Reference 8.15 and Braidwood Reference 8.8). The statistically 'expected', or most probable, force trend is represented by a linear function, $F(t) = a – b * Log (t)$, with coefficients a and b computed by the method of least squares and using all available surveillance lift-off force data.

Since the data set size is still small relative to the number of tendons in a group (e.g., 37 or fewer sample tendons vs 201 hoop tendons) it is likely that the true trend of the group mean will differ from that computed for the relatively small sample. While the actual true trend can only be determined by measuring the force in every tendon during each surveillance, a high probability lower limit on the true mean force at any point in time can be computed for any specified probability level. The technical report uses a probability level of 95%. The 95% level was selected to be consistent with that used to set an upper limit on containment leakage rates computed during tests prescribed by Appendix J to 10CFR50. The computed (also using the methods developed in the Miller and Freund text) lower limit is termed the 95% lower confidence limit[5] or 95% LCL. The difference between the trend line and LCL values is a function of both the number of data points and the degree of scatter.

The LCL is represented by the red font dashed curves on the tendon force plots.

Since individual surveillance samples are small (3 to 12 tendons) relative to the tendon group population, the average force computed for a given sample is not a meaningful proxy for the group (hoop, vertical, dome) mean. The sample could as easily include only tendons with forces above the group mean as those with forces below the mean. Therefore, a long-term trend cannot be based on the difference in the average forces computed for two consecutive surveillances. A long-term trend, and the associated LCL curve, must be constructed using all available data or, as discussed in the addendum at the end of this response, using a data set that excludes force measurements acquired during the earliest surveillances.

The scatter of measured forces observed on the Byron and Braidwood figures is characteristic of lift-off force data in general and is similar to that illustrated by the plots included in the technical reports supporting the TMI-1, Vogtle 1 & 2, and Millstone 2 Relief Requests, which were approved by the NRC.

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[4] A tendon (one in each group) included in consecutive surveillance samples.

[5] The 95% LCL on true mean force can be defined by the statement below.

'There is a 95% probability that the true mean force lies above the 95% LCL value.'

Finally, it is to be noted that all 95% LCL curves plotted using year 5 and forward measured lift-offs show positive margin above minimum required group mean force at year 100 (since the applicable SIT) which is well beyond the end of the expected 80-year limit on unit operating life. Margins are tabulated in technical report Parts D (Byron) and E (Braidwood) Sub-sections 2.4. The margins are listed, for reference, in the table below.

95% LCL Margin, kip, Above Minimum Required Group Mean Force				
Group \ Unit	Byron 1	Byron 2	Braidwood 1	Braidwood 2
Hoop	45	18	62	76
Vertical	153	102	52	306
Dome	56	64	16	188

Summary and Conclusions

1. The log-linear function used to forecast group mean tendon forces is not unique to the Byron/Braidwood Relief Requests technical report. It is based on the trends demonstrated by innumerable concrete creep, concrete shrinkage and pre-stressing steel relaxation tests performed over many decades.

   The function is used in containment design and in post-tensioning system ISI reports to project group mean force out to the deadline for completion of the subsequent examination. The same function is used in the technical reports supporting the TMI-1, Vogtle 1 & 2, and Millstone 2 Relief Requests, all of which were approved by the NRC.

   And, Regulatory Guide 1.35.1, Figure 2 uses a log-linear function to represent tendon force loss over time.

2. The scatter exhibited on the Figures 1, 7, and Millstone Unit 2 as well as the remaining plots in the technical report is the result of numerous effects that are not all quantified. It is expected, is typical of that evident on the plots in ISI reports and is similar to that shown on the plots included in the technical reports supporting the TMI-1, Vogtle 1 & 2, and Millstone 2 Relief Requests.

   As is normal in treating scattered data, confidence limits are computed to establish statistically meaningful bounds on the best (least squares) fit trend line values. The 95% confidence level used in the technical report is based on the 95% level used to set a limit on containment leakage rates computed for tests performed under Appendix J to 10CFR50.

3. The 95% LCL curves computed using surveillance year 5 and forward measured lift-offs show positive margin above minimum required group mean force at year 100 (since the applicable SIT) for all Byron and Braidwood tendon groups.

4. Finally, it is concluded that the data and analyses (Figures 1, 8, 10, 13, 16, 17 referred to in NRC RAI 59) in the technical report remain valid and, with the clarifications provided in this response, fully support the extension of the Byron and Braidwood containment ISI interval from 5 to 10 years with no compromise to nuclear safety. The ongoing structural integrity and ability of each containment to fulfill the intended safety function will continue to be

demonstrated by periodic examinations. The examination interval will be changed to reflect the excellent past performance of the containment structures as demonstrated by the many surveillances completed to date.

Addendum – Observed Flattening

Typically, concrete creep and shrinkage tests are conducted over a period of 6 months. Tendon wire (or strand) relaxation tests are conducted over a period of 1,000 hours (~42 days). The results of these tests almost always follow a log-linear trend with relatively little scatter.

Tendon force measurements acquired over much longer terms of up to 40 years show that the log-linear postulate is conservative in that it forecasts greater than actual loss of force. This flattening trend is sometimes visually evident on long term plots that exhibit minimal scatter. It can be demonstrated statistically by comparing the slopes lines fitted to all surveillance data with those of lines fitted to data acquired during the year 10 (or, in some cases, year 5) and subsequent surveillances. The latter almost always have a flatter (less negative) slope and greater LCL as is illustrated by the following table which lists forecast hoop, vertical and dome group mean forces and LCL's for each of the 4 units (Byron 1 & 2 and Braidwood 1 & 2) at T = 100 years (time since the unit pre-operational structural integrity test). Mean force and LCL values are computed using data acquired during all surveillances as well as that acquired during the 5th year and subsequent surveillances.

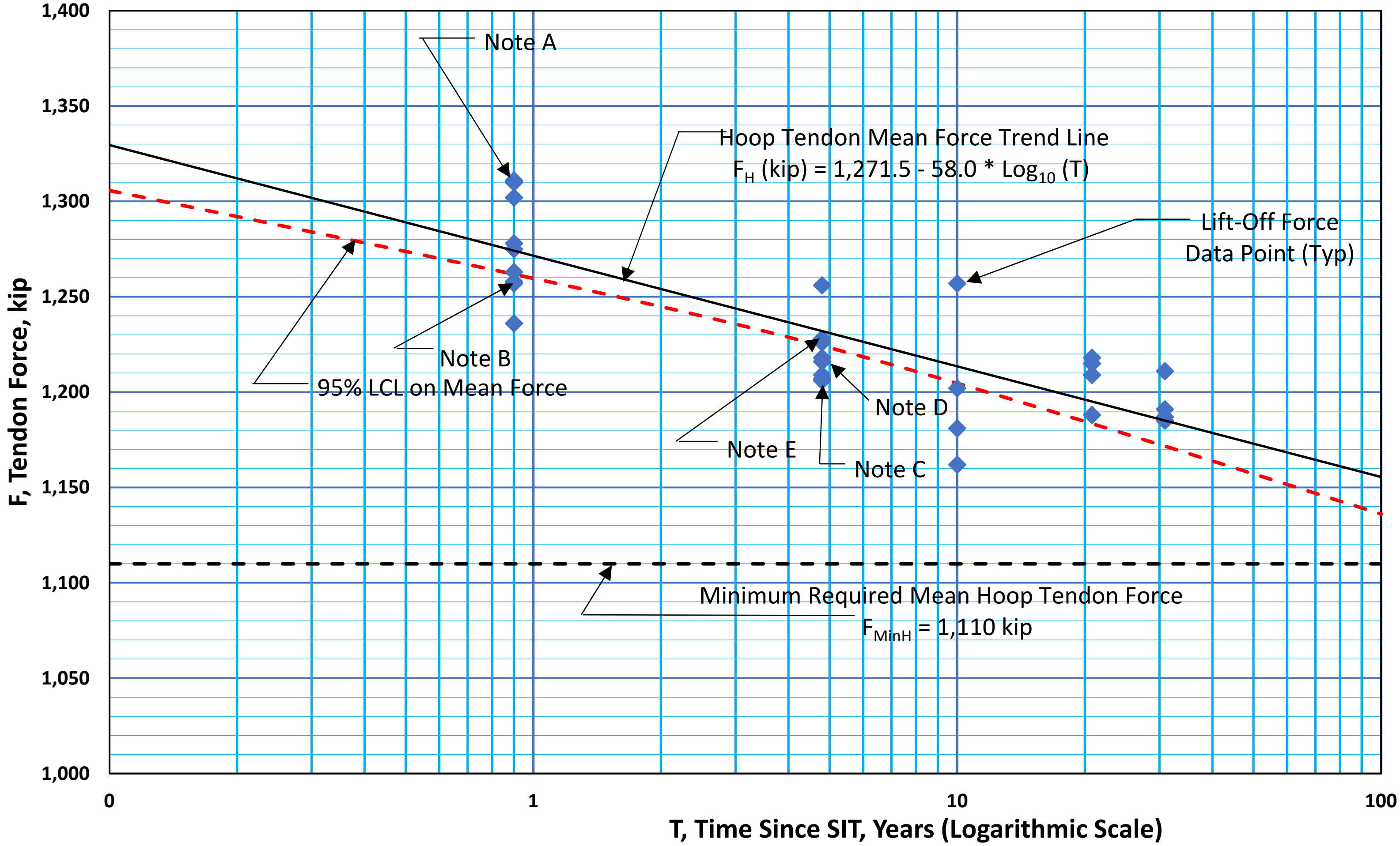
Plant	Unit	Tendon Group	Group Mean, kip, at 100 Years		Group LCL, kip, at 100 Years	
			For Data From Year 1	For Data From Year 5	For Data From Year 1	For Data From Year 5
Byron	1	Hoop	1,156	1,181	1,136	1,155
	2		1,128	1,148	1,104	1,128
	1	Vertical	1,218	1,249	1,194	1,213
	2		1,180	1,194	1,157	1,162
	1	Dome	1,199	1,223	1,165	1,166
	2		1,199	1,207	1,174	1,174
Braidwood	1	Hoop	1,220	1,256	1,162	1,172
	2		1,224	1,254	1,184	1,186
	1	Vertical	1,200[a]	1,166[a]	1,166[a]	1,112[a]
	2		1,380	1,418	1,344	1,366
	1	Dome	1,169	1,174	1,133	1,126
	2		1,303	1,351	1,268	1,298

Note: Computed group mean and LCL are significantly impacted by one questionable tendon force recorded during the 5th year surveillance.

Forces and LCL's computed for the truncated data sets are, with 3 exceptions as shown in the highlighted cells, equal to (Byron Unit 2 dome tendon group LCL) or greater than, those computed using all surveillance data. This adds further support to the observation that the mean pre-stressing force tends to decrease more slowly as the logarithm of time increases.

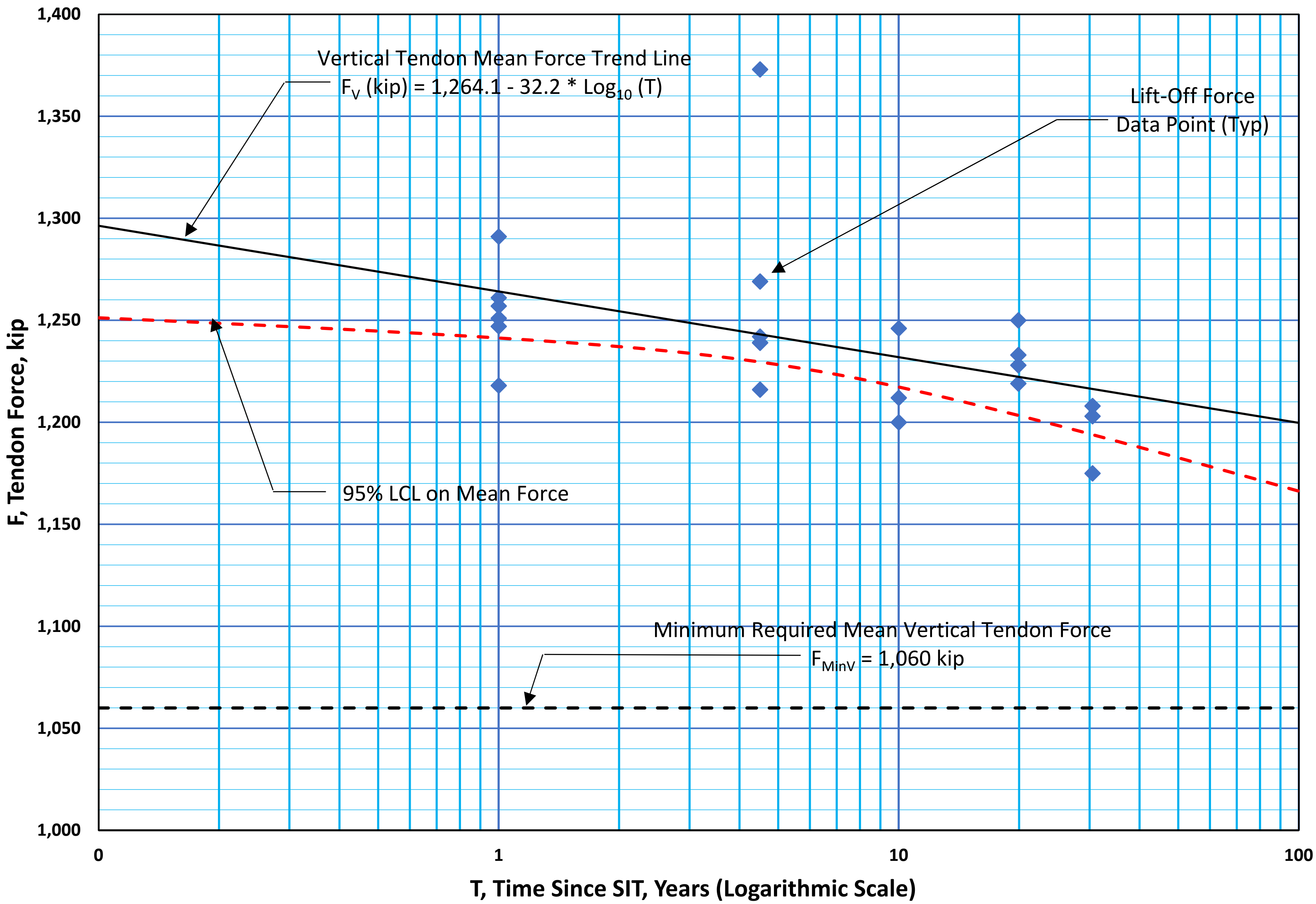
It is to be noted that all group LCL values listed above (and, consequently, all group means) exceed the minimum pre-stressing levels specified for the respective groups.

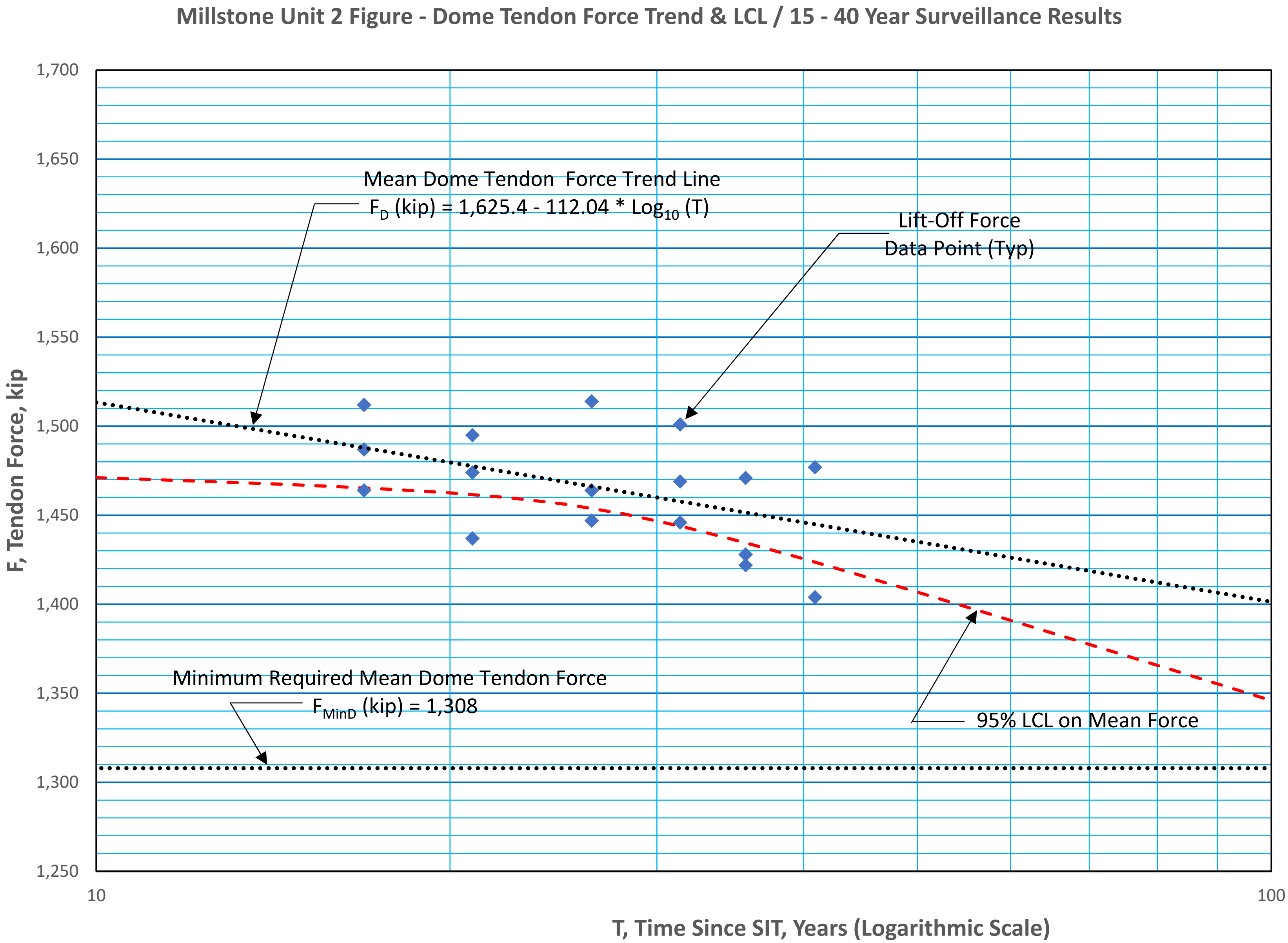
Figure 1 - Byron Unit 1 Hoop Tendon Force Trend & LCL / 1 - 30 Year Surveillance Results



Note A - Overlapping / superimposed symbols represent 3 plotted forces; 1,310, 1,310 & 1,311 kips as listed in Table 3
Note B - Overlapping symbols represent 2 plotted forces; 1,257 & 1,258 kips as listed in Table 3
Note C - Overlapping symbols represent 3 plotted forces; 1,206, 1,207 & 1,209 kips as listed in Table 3
Note D - Overlapping symbols represent 2 plotted forces; 1,216 & 1,218 kips as listed in Table 3
Note E - Overlapping symbols represent 2 plotted forces; 1,226 & 1,228 kips as listed in Table 3

Figure 7 - Braidwood Unit 1 Vertical Tendon Force Trend & LCL / 1 - 30 Year Surveillance Results




Millstone Unit 2 Figure - Dome Tendon Force Trend & LCL / 15 - 40 Year Surveillance Results
1,700
1,650
1,600
1,550
1,500
1,450
1,400
1,350
1,300
1,250
F, Tendon Force, kip
Mean Dome Tendon Force Trend Line
F_D (kip) = 1,625.4 - 112.04 * Log_{10} (T)
Lift-Off Force
Data Point (Typ)
Minimum Required Mean Dome Tendon Force
F_{MinD} (kip) = 1,308
95% LCL on Mean Force
10
100
T, Time Since SIT, Years (Logarithmic Scale)

NRC RAI 60

PART C - BACKGROUND OF CURRENT ISI REQUIREMENTS AND BASIS FOR PROPOSED ALTERNATIVES, Basis for Proposed Alternatives / Relief from 10CFR50.55a and IWL Requirements, Section 4.2 System Hardware Condition History, states two conditions, "A number of wires were severely corroded and found to be no longer effective as pre-stressing elements," and "A unique combination of steel chemistry and high hardness led to the failure of anchor heads in both units of a two-unit plant. Several failures have occurred at random times over the past four decades."

Were any one of the conditions identified during the containment in-service inspection (CISI) activities? Have any of these conditions occurred at the Byron or Braidwood plant? If yes, describe in detail how the condition was identified and resolved.

EGC Response to NRC RAI 60

These conditions have not been found at Byron or Braidwood. Technical report Part C Subsection 4.2 stated that the extensive wire corrosion (initially observed during a regularly scheduled IWL examination) and anchor head failure (initially found during an Appendix J pre-ILRT visual examination) conditions are each unique to a single plant site in question. Additionally, anchor heads with the specific composition and heat treatment concluded to have led to the observed failures are unique to the site in question.

NRC RAI 61

Surveillance records indicate that some tendons in Byron and Braidwood have exceeded the free water limit of 0.2 liters as the licensee stated. For examples, Byron, Unit 1, had 0.5 liters of free water for tendon H27BA at Buttress A during the July 1986 surveillance, Unit 2 had 7.7 liters of free water for tendon H7FE at Buttress E, 6.6 liters of free water for tendon H2FF at Buttress F, and 6.1 liters of free water for tendon H3FE at Buttress E during the September 2019 surveillance. Braidwood, Unit 1, had 3.2 liters of free water for tendon H1AC at buttress C, and Unit 2, had 17.2 liters of free water for tendon H5FE at buttress F, during the July 1986 surveillance. Although all sample analyses have shown the free water to be alkaline or neutral with pH of 7 or greater and, therefore, noncorrosive, there is no guarantee that condition will always be the case in the future. The significant amount of free water found during the most recent September 2019 surveillance for Byron Unit 2 should be a concern. The licensee proposed a program to alleviate that concern of extending the surveillance interval from five years to ten years.

Page 69 of the Byron/Braidwood Technical Report states "Also, an augmented surveillance program of limited intermediate examinations to monitor free water19 conditions, as well as the condition of the dome coatings and dome drainage, will be initiated." Footnote 19 states "It has been reasonably assumed that water intruding into the lower hoop tendon ductwork is ground water. The validity of this assumption will be checked by a water chemist or other qualified professional. It is expected that this evaluation will be based on the quantitative analysis of a water sample collected at a tendon anchorage (see the following paragraphs) and a ground water sample collected at a location as specified by the chemist."

Provide an explanation of the augmented surveillance program to monitor the free water conditions, as well as the condition of the dome coatings and dome drainage. Footnote 19 states "this evaluation will be based on the quantitative analysis of a water sample collected at a tendon anchorage (see the following paragraphs)." However, there are no paragraphs in the text because that is the end of the chapter. Provide the missing text as stated.

<u>EGC Response to NRC RAI 61</u>

Byron and Braidwood stations monitoring plan of tendon free water, dome coatings and dome drainage conditions are as follows:

- ASME Section XI, Subsections IWL-2421 and IWL-2525 prescribe the requirements to monitor free water conditions. Monitoring of dome coatings and dome drainage exceed ASME Section XI, Subsection IWL scope requirements.
- Implementation of tendon free water monitoring and grease sampling augmented inspection programs are in accordance with license renewal (LR) commitments described in Byron and Braidwood Stations Updated Final Safety Analysis Report (UFSAR) Supplement (License Renewal), Appendix F, Section A.2.1.30, "ASME Section XI, Subsection IWL," (ML18355A506). These augmented inspection programs were developed based on Byron and Braidwood historical containment structural conditions and the programs surpass the prescriptive ASME Section XI, Subsection IWL requirements to monitor and address free water conditions for tendons.
- Monitoring of dome coatings and dome drainage will be performed during the performance of the baseline and follow up surveillances for free water conditions.
- Based on the data gathered during these surveillances, a graduated monitoring plan will be developed for free water, dome coatings and dome drainage conditions.

In addition, the ‘subsequent paragraphs’ referenced in footnote 19 were intended to be the main text paragraphs following the point where the footnote is cited. The reference to ‘subsequent paragraphs’ is unclear since the footnote itself has no additional paragraphs. Therefore, revision to pages 69 and 150 of the technical report is provided in Attachment 2 as clarification. The revisions are delineated with revision bars.

ATTACHMENT 2

Revised Pages from Containment Post-Tensioning System Inservice Inspection Technical Report, Revision 1

38 Vertical tendons - V1 through V18 and V143 through V162

32 Hoop tendons - H29BA through H44BA and H29CB through H44CB

ASME Section XI, Subsection IWL paragraph IWL-2521.2 specifies that a separate sample of these tendons be examined during surveillances subsequent to the completion of re-tensioning. The forces in the SGR tendons have been altered by re-tensioning and are, therefore, addressed separately when evaluating trends and LCL's.

Samples of SGR tendons were examined during the 20th and 30th year surveillances in 2004 and 2014, respectively. The lift-off forces measured during each surveillance are shown below.

SGR Hoop Tendon Lift-Off Force					
Surveillance Year	T, Time Since SIT, Years	Hoop Tendons		Vertical Tendons	
		Tendon / Average	F_M, Measured Force / Loss[b], kip	Tendon / Average	F_M, Measured Force / Loss[b], kip
20	20.8	H37BA	1,316 / 99	V15	1,290 / 127
		H38CB	1,322 / 96	V162	1,376 / 55
		Average	**1,319 / 98**	**Average**	**1,333 / 91**
30	30.9	H30CB	1,332 / 61	V152	1,318 / 118
		H38BA[a]	1.320 / 81	V160[a]	1,367 / 52
		Average	**1,326 / 71**	**Average**	**1,342 / 85**

Note a: Tendon de-tensioned for test wire removal and re-tensioned.

Note b: Loss is re-tensioning seating force, as documented in Reference 8.16, less F_M.

The samples, two tendons in each group during each surveillance, are small which precludes formulating definitive conclusions regarding rate of loss in the SGR tendon population. Nonetheless, on the basis of the limited data available, it is reasonable to postulate that mean force in the hoop and vertical SGR tendons is relatively stable. This is expected since concrete creep and shrinkage strains are largely accounted for at year 20 (more than 20 years after the completion of pre-stressing operations) and tendon relaxation recovery between de-tensioning and re-tensioning is relatively limited.

will be initiated. Anchorages included in the program are those where water in excess of 0.2 liters was collected during one or both of the two most recent surveillances.

The augmented program will include detailed requirements for the following:

- Base frequency of augmented surveillance and criteria for more frequent examinations at anchorages with accelerating water intrusion and / or developing corrosion.
- Scope of surveillance examination / testing (free water collection / pH testing, CPM collection / testing, visual observation of corrosion, need for more extensive examination and other as applicable).
- Chemical analysis, by a water chemist or other qualified professional, of both lower hoop and vertical tendon free water samples, as well as analysis of ground water, to establish whether or not ground water is the source of free water collected at the ends of these tendons.
- Criteria for reducing the frequency of, or ending, augmented surveillance at specific anchorages.
- Frequency and scope of dome coating / drainage examinations.

Examination and testing results will be evaluated by the Responsible Engineer who will determine if more extensive examinations and / or corrective action is needed.

In addition to the above, a one-time sample of Unit 1 below grade tendons (those in rings 1 through 7) will be added to the random sample designated for the 45th year surveillance. Condition of these tendons and anchorage areas will be evaluated by the RE who will specify further examinations and / or corrective action as deemed necessary.

All of the above margins, which range from a minimum of 16 kip to 358 kip, are positive at T = 100 years. This provides a strong measure of assurance that mean pre-stressing forces provided by the hoop, vertical and dome tendon groups will remain above the minimum required levels well past the presumed 80 year maximum unit operating lifetime.

The above margin summary fully supports the proposed extension of the Byron post-tensioning system examination interval from five years to ten years with tendon force measurements (ASME Section XI Table IWL-2500-1, Examination Category L-B, Item L2.10) alternating between Unit 1 and Unit 2 as shown in Part E sub-section 1.1 above.

2.5 Steam Generator Replacement (SGR) Tendons

The 1998 Unit 1 steam generator replacement project (Unit 2 generators have not been replaced) required cutting an opening in the containment cylinder wall. This, in turn, required de-tensioning and subsequent re-tensioning of the following tendons.

38 Vertical tendons - V1 through V18 and V143 through V162

32 Hoop tendons - H29BA through H44BA and H29CB through H44CB

ASME Section XI, Subsection IWL paragraph IWL-2521.2 specifies that a separate sample of these tendons be examined during surveillances subsequent to the completion of re-tensioning. The forces in the SGR tendons have been altered by re-tensioning and are, therefore, addressed separately when evaluating trends and LCL's.

Samples of SGR tendons were examined during the 15th and 30th year surveillances in 2001 and 2016, respectively. The lift-off forces measured during each surveillance are shown below.

SGR Hoop Tendon Lift-Off Force

Surveillance Year	**T, Time Since SIT, Years**	**Hoop Tendons**		**Vertical Tendons**	
		Tendon / Average	**F_M, Measured Force / Loss[b], kip**	**Tendon / Average**	**F_M, Measured Force / Loss[b], kip**
15	15.0	H40CB	1,227 / 201	V160	1,323 / 90
30	30.5	H44BA	1,270 / 113	V16[a]	1,328 / 96
		H42CB[a]	1,287 / 120	V143	1,304 / 81
		Average	**1,278 / 116**	**Average**	**1,316 / 88**

Note a: Tendon de-tensioned for test wire removal and re-tensioned.

Note b: Loss is re-tensioning seating force, as documented in Reference 8.2, less F_M.

needed, a corrective action (e.g., end cap gasket replacement and duct refilling / top-off) plan will be prepared by, and implemented in accordance with the requirements of, the RE.

7.2 Enhanced Examination of Domes and Tendons Subject to Water Intrusion

An augmented surveillance program of limited intermediate examinations to monitor free water conditions, as well as the condition of the dome coatings and dome drainage, will be initiated. Anchorages included in the program are those where water in excess of 0.2 liters was collected during one or both of the two most recent surveillances.

The augmented program will include detailed requirements for the following:

- Base frequency of augmented surveillance and criteria for more frequent examinations at anchorages with accelerating water intrusion and / or developing corrosion.
- Scope of surveillance examination / testing (free water collection / pH testing, CPM collection / testing, visual observation of corrosion, need for more extensive examination and other as applicable).
- Chemical analysis, by a water chemist or other qualified professional, of both lower hoop and vertical tendon free water samples, as well as analysis of ground water, to establish whether or not ground water is the source of free water collected at the ends of these tendons.
- Criteria for reducing the frequency of, or ending, augmented surveillance at specific anchorages.
- Frequency and scope of dome coating / drainage examinations.

Examination and testing results will be evaluated by the Responsible Engineer who will determine if more extensive examinations and / or corrective action is needed.

Also, as noted in 3.1, Level E corrosion was found on the wires extracted from below grade tendons H2CB, H2DF and H1BA. At least one wire will be extracted from each of these tendons during the 40th year surveillance. Extracted wires will be examined for damage and corrosion. If Level D (4) or greater corrosion, or any active corrosion, is found, the condition will be evaluated by the Responsible Engineer who will specify further actions as deemed necessary.

Tensile tests will be performed on specimens cut from any wire that has Level D (4) or greater corrosion. The test specimens will include the most highly corroded segments