Operability Assessment Process Form

6.13.1

a. PIF # : **B1997-01313** Assessment Expected Due Date/Time: **05/15/97 1700**

Operability Determination (check one): ☒ **Operable** ☐ Inoperable ☐ Operable, but degraded

Approved **Compensatory Actions** - List those approved (also see attached list):

YES ☐

NO ☒

Approved **Corrective Actions** - List those approved (also see attached list):

YES ☐

NO ☒

OPERABILITY ASSESSMENT RECOMMENDATION:

6.13.2 Preparer/Evaluator: Bradley Adams 5/14/97 5/15/97

6.13.3.b Regulatory Assur. Supv: 5/15/97

System Engineering Supv: R. Freidel 5/15/97

Site Eng. Support Supv: 5/15/97

Operating Engineer: 5/15/97

OPERABILITY ASSESSMENT APPROVAL:

6.13.5.d Shift Engineer:

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6.13.1 **General Information**:

b. Affected Station(s): Byron

c. Unit(s): 1

d. Description of problem, failure, defect, degraded or nonconforming condition:

As part of the licensing of 3.0 volt IPC during B1P02 (Fall 1995), selected steam generator tube intersections were expanded and the tubes subsequently plugged, making the tubes act like tie rods. Per the Byron Technical Specification (TS) 4.4.5.4, operability for steam generators is determined by the performance of an augmented inservice inspection program and application of the TS listed acceptance criteria. TS 4.4.5.4.a.11 specifically addresses use of the 3.0 Volt Interim Plugging Criteria (IPC).

3.0 Volt IPC was first implemented at Byron and Braidwood Stations in Fall 1995 outages at each unit, respectively. As a result of recent steam generator inspections performed at Braidwood Station, circumferential indications were identified at the top of the tubesheet for 49 of 85 steam generator tubes that were locked for the basis of 3.0 Volt IPC implementation. This inspection occurred after 412 days of operation for Braidwood Unit 1 above 500 °F. In addition, Braidwood determined that the allowable as-found IPC tube leakage exceeded the cycle predicted value. The predicted value was 6.99 gpm and the actual leakage identified at Braidwood was found to be 11.5 gpm. 11.5 gpm was still below the allowable IPC leakage limit of 26.8 gpm for Braidwood Unit 1.

This operability assessment is being generated to document the applicability of the identified cracking at Braidwood Station as it applies to Byron Unit 1. Byron Unit 1 has similar locked tubes that have been modeled to operate for a period of approximately 630 days above 500 °F. This period would encompass unit operation until steam generator replacement which is scheduled for B1R08, commencing Fall 1997. Note that an initial operability screening for Byron Unit 1 was documented in BSE 10-1, Attachment B (97-034, Rev. 1), dated April 24, 1997 (Reference 1). The initial operability screening for Byron Unit 1 concluded that there was reasonable assurance of operability in light of both operability issues; circumferential cracking and as-found IPC leakage. This assessment reaffirms the original determination of operability for both issues.

A more thorough description of the background of the locked tube circumferential cracking issue is contained in the evaluation attached to this assessment, "Byron Unit 1 Full Cycle Operation Assessment," (Reference 2). This document was generated by ComEd Engineering in support of this operability assessment. A root cause investigation of the as-found IPC leakage issue identified at Braidwood is currently

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ongoing. This assessment evaluates the current operability of Byron Unit 1 with respect to the IPC leakage. However, any additional concerns resulting from the Braidwood root cause investigation of the predicted end-of-cycle IPC leakage will be addressed by Byron Station engineering, as appropriate.

e. Component(s) Affected:

Byron Unit 1 Steam Generators

f. Identification Number(s)(EPN, part/serial number, etc.):

1RC01BA, 1RC01BB, 1RC01BC, 1RC01BD

Evaluation:

g. Describe the safety function(s) or safety support function(s), answering the following as part of the description:

1. Does the affected SSC receive/initiate an RPS or ESF actuation signal? **No**
2. Is the affected SSC in the main flow path of an ECCS or support system? **No**
3. Is the affected SSC used to:
   (a) Maintain containment integrity? **No**
   (b) Shutdown the reactor? **Yes**
   (c) Maintain it in a shutdown condition? **Yes**
   (d) Prevent or mitigate the consequences of an accident that could result in off-site exposures comparable to 10CFR100 guidelines. **Yes**
4. Does the SSC provide required support (i.e. cooling, lubrication, etc.) to a TS required SSC? **Yes**
5. Is the SSC used to provide isolation between safety trains, or between safety and non-safety ties? **Yes**
6. Is the SSC required to be operated manually to mitigate a design basis event? **No**
7. Technical specifications? **3/4.4.5.4**
8. UFSAR or pending revisions? **Various including Section 15.1.5 (MSLB)**

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Ensure the safety function(s) of the SSCs are included in the description:

The purpose of the steam generators at Byron Station is to provide a means for transfer of heat from the primary reactor coolant to the secondary cooling system. In addition, the steam generator tubes also serve as an RCS barrier to separate primary coolant from the rest of the plant. The steam generators serve as a heat sink for a number of postulated events in the B/B Chapter 15 accidents, including the Main Steamline Break (MSLB) accident, Section 15.1.5.

In combination with the auxiliary feedwater system and steam generator power-operated relief valves, the steam generators can be used to perform the safety function of removing residual heat following an accident and cool the plant down below 350°F, until the Residual Heat Removal System (RH) is made available.

The specific purpose of hydraulic locking of steam generator tubes is to limit deflection of the Tube Support Plate (TSP) under postulated accidents, which effectively limits the burst probability and tube leakage due to Outside Diameter Stress Corrosion Cracking (ODSCC) in the steam generator tubes.

h. Describe the effect the concern has on the SSC safety function(s):

During the A1R06 outage at Braidwood, locked tubes were unplugged and inspected. This inspection identified circumferential degradation at the Top of the Tubesheet (TTS) region in 49 of 85 locked tubes. This inspection occurred after 412 days of Braidwood Unit 1 operation above 500 °F. Byron Unit 1 has similar tubes which were installed to support 3.0 Volt IPC. Byron Unit 1 is currently modeled assuming approximately 630 days operation above 500 °F. This would encompass the time the locked tubes were installed until steam generator replacement during B1R08, commencing in Fall 1997. The specific operability concern centers around the load carrying capacity of the Byron Unit 1 steam generator tubes locked at various TSP intersections to ensure that the design and licensing basis requirements for 3.0 Volt IPC are satisfied in light of the inspection findings at Braidwood Station. 3.0 Volt IPC requires that locked tubes be capable of carrying an axial force of 500 lbs. during a MSLB accident. This limits deflection of the TSP to enhance the structural and leak integrity of the tubes. Note that the attached evaluation (Reference 2) contains more detail of the specific operability concern for circumferential cracking based on the Braidwood inspection results.

The additional issue identified at Braidwood Station for as-found IPC leakage creates an operability concern for the predicted Byron Unit 1 end-of-cycle 8 IPC leakage. The 3.0 Volt IPC primary to secondary leakage limit at MSLB conditions is 26.8 gpm for

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Braidwood Unit 1 and 36.5 gpm for Byron Unit 1. At Braidwood, the as-found values exceeded the predicted leakage (11.5 gpm as-found versus 6.99 gpm predicted). During IPC implementation, the Byron Unit 1 end-of-cycle 8 IPC leakage was predicted to be 19.0 gpm. This prediction assumed the end-of-cycle would occur on March 1, 1998. End-of-cycle 8 is actually scheduled for November 7, 1997, which is 113 days shorter that the assumed cycle duration. Accounting for the shortened cycle length, the MSLB leakage predication would be scaled to approximately 15.5 gpm. The operability issue deals with the potential that the predicted IPC leakage is non-conservative.

i. Tech Spec SSC affected:

☒ **Yes** ☐ No

Tech Spec Section(s): **3/4.4.5.4 & Bases**

j. Equipment Degraded:

☐ Yes - Enter Degraded Equipment Log or Equivalent ☒ **No**

k. UFSAR System affected:

☒ **Yes** ☐ No

UFSAR Sections: **Various including Section 15.1.5.3 (MSLB)**

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l. Does the SSC meet its required design function?

☒ Yes ☐ No

m. Justification:

ComEd Engineering has performed an operability assessment (Reference 2) for Byron Unit 1 operation until the upcoming B1R08 refueling outage in which the steam generators will be replaced. For the locked tube circumferential cracking issue, the engineering assessment concluded the following:

1. **The Byron Unit 1 end-of-cycle 8 projected distribution of locked tube TTS circumferential indications is bounded by the circumferential indication structural limit developed from non-burst test data;**
2. **A steam generator tube with degradation at the structural limit has an axial load carrying capacity which provides a margin of greater than 2.8X to the 500 lb. load carrying requirement of the 3.0 Volt IPC licensing basis;**
3. **At end-of-cycle 8 for Byron Unit 1, locked tubes will have necessary axial load carrying capacity required for 3.0 Volt IPC;**
4. **In the unlikely event of complete failure of all locked tubes, TSP displacement will be limited to 0.10" due to the natural locking of steam generator tubes at the TSPs. This will ensure that tube integrity is maintained at the TSPs where 3.0 Volt IPC has been implemented.**

An assessment for Byron Unit 1 of the locked tube circumferential cracking issue identified during the Braidwood Unit 1 inspection, has determined that no additional corrective actions are required for Byron Unit 1 pending the steam generator replacement outage for Unit 1 in November 1997.

For the IPC leakage operability issue, the original operability screening (Reference 1) concluded that the potential exceedance of the predicted IPC leakage at the end-of-cycle 8 for Byron Unit 1 did not represent an operability concern. This assessment reaffirms that original determination. There is reasonable assurance that the Byron Unit 1 steam generators are operable with respect to IPC leakage until the November 1997 refueling outage based on the following:

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1. **Conservative growth rate distribution was used for the Byron Unit 1 end-of-cycle 8 IPC leakage prediction because the most conservative steam generator growth distribution was supplemented with the large growth rates from the other three steam generators, and growth rates were multiplied by four (4) to normalize to 1 Effective Full Power Year (EFPY) due to the short operating period from B1P02 to B1R07 (December 1995 to April 1996);**
2. **Leakage and tube burst probability prediction for prior outages were accurate when compared to as-found conditions and therefore, this provides reasonable assurance that the similar cycle 8 predictions are accurate;**
3. **The MSLB TS allowable leakage calculated for IPC implementation conservatively assumed that the RCS dose equivalent (DE) Iodine level was 0.35 µCi/gm. Byron Unit 1 is currently operating in the 6 x 10^{-4} µCi/gm range for DE Iodine which is a factor of 580X less than assumed in the analysis.**
4. **Byron Station has previously submitted a Technical Specification amendment on January 31, 1997 which lowers the allowable DE Iodine level to 0.20 µCi/gm. This change, once approved by the NRC, would effectively increase the allowable IPC leakage limit from 36.5 gpm to 64.0 gpm;**
5. **Finally, the Byron Unit 1 IPC leakage prediction was originally performed for a cycle that has now been shorted by 113 days per the current schedule and therefore, this provides additional margin in the analysis.**

Note that the above provides justification for reasonable assurance of operability for the Byron Unit 1 steam generators with respect to as-found IPC leakage. However, a separate Problem Identification Form (PIF #1997-01600) has been generated which will address disposition of the Braidwood root cause investigation as it applies to Byron Unit 1. Any further operability concerns that are identified for Byron Unit 1 will be addressed, as appropriate.

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Disposition:

1. **IF** the failed, DEGRADED or NONCONFORMING SSC prevents the accomplishment of the safety function(s) of a Tech Spec SSC specifically described by that TS, **THEN** the SSC does **NOT** meet its required design function(s). Check **NO** and recommend to the shift engineer to declare the equipment inoperable;

2. **IF** the failed, DEGRADED or NONCONFORMING SSC alters a SSC from its description in the UFSAR **AND** the evaluation concludes that it does **NOT** affect the ability to meet the required design function(s) in the TS **AND** the intention is to continue operating the plant in that condition, **THEN** check **YES** and a 50.59 evaluation is required and should be attached to this attachment. A review shall be performed to determine if a UFSAR update is required;

3. **IF** the failed, DEGRADED or NONCONFORMING SSC does **NOT** affect the ability to meet the required design function(s) and does **NOT** alter a SSC from its description in the UFSAR, **THEN** check **YES** and document the recommended corrective actions to restore full qualification on this attachment.

BJA 5/14/97

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n. **REFERENCE DOCUMENT LIST**

1. **BSE 10-1, Attachment B, Operability Assessment Screening (97-034, Rev. 1) in response to PIFs # B1997-01313, dated April 29, 1997.**

2. **"Byron Operability Assessment of Braidwood Locked Tube TTS Indications,", ComEd Nuclear Engineering Services letter, CHRON #215199, dated May 12, 1997.**

Operability Assessment Process Form

o. **COMPENSATORY ACTION ITEM LIST**

Compensatory action(s) or mitigating condition(s) required to ensure operability:

☐Yes ☒ **No** (refer to Corrective Action Item List)

Listed below are compensation or mitigating conditions that are required to support operability of:

Compensatory Action #1:

Responsible Dept./Supv.:
Action Due:
NTS:

Compensatory Action #2:

Responsible Dept./Supv.:
Action Due:
NTS:

Compensatory Action #3:

Responsible Dept./Supv.:
Action Due:
NTS:

Compensatory Action #4:

Responsible Dept./Supv.:
Action Due:
NTS:

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q. **CORRECTIVE ACTION ITEM LIST**

Corrective Action(s) required?

☐Yes ☒ **No** (refer to the Compensatory Action Item List)

If any of these items cannot be accomplished in the specified time notify the Operations Manager.

Corrective Action #1:

Responsible Dept./Supv.:
Action Due:
NTS:

Corrective Action #2:

Responsible Dept./Supv.:
Action Due:
NTS:

Corrective Action #3:

Responsible Dept./Supv.:
Action Due:
NTS:

Corrective Action #4:

Responsible Dept./Supv.:
Action Due:
NTS:

May 12, 1997
In Reply Refer to Chron #: 215199

To: D. B. Wozniak
Byron Engineering Manager

Subject: Byron Operability Assessment of Braidwood Locked Tube TTS Indications

The Steam Generator and Reactors Vessel Projects group has completed the technical basis for the Byron operability assessment of steam generator tube circumferential indications detected in locked tubes at Braidwood Unit 1 during the current refuel outage (A1R06). The technical basis concludes that there will be significant margin to the design basis load requirements of locked tubes at Byron Unit 1 at the end-of-cycle eight.

The technical basis for the operability assessment is attached.

Prepared by: [signature] 5/12/97
R. Gesior
SG&RVP

Prepared by: [signature] 5/12/97
M. Sears
SG&RVP

Approved by: [signature] 5/13/97
J. Blomgren
SG&RVP Manager

cc: J. Smith
J. Meister
B. Adams
D. Saccomando
M. Sears
Chron

Byron Unit 1 Full Cycle Operation Assessment

Background

Steam generators (SGs) are determined to be operable by the performance of an augmented inservice inspection program and application of the acceptance criteria described in the Technical Specification 4.4.5.4. Technical Specification Section 4.4.5.4.a.11 specifically addresses the use of the 3.0 Volt Interim Plugging Criteria (IPC). This criteria is described in the WCAP-14273 (Reference 1) "Technical Support of an Alternate Plugging Criteria with Tube Expansion at Tube Support Plate Intersections for Braidwood 1 and Byron 1 Model D-4 Steam Generators." WCAP-14273 discusses limiting the deflection of the tube support plate (TSP) to obtain negligible tube burst probabilities along with minimizing primary-to-secondary leakage from a tube containing Outside Diameter Stress Corrosion Cracking (ODSCC) at the TSP intersection. Limiting deflection of a TSP is accomplished by hydraulically expanding select steam generator tubes at various support plate intersections which effectively "locks" the tube to the TSP. The tubes containing these expansions are subsequently plugged and function as additional tie rods to limit the vertical movement of the TSPs under postulated accident conditions. As discussed in WCAP-14273, limiting vertical movement of the TSPs restricts the potential freespan exposure of an ODSCC flaw to less than 0.10 inches.

WCAP-14273 also contains the axial load requirement for each locked tube location during a main steam line break (MSLB). The maximum load has been determined to be less than 500 lbs (Reference WCAP-14273 Table 8-13). Confirmatory calculations using the RELAP5 hydraulic code also show the maximum load to be less than 500 lbs (Reference 2).

3.0 Volt IPC was first implemented during the Braidwood Unit 1 Fall 1995 Refuel outage (A1R05), and the Fall 1995 Byron Unit 1 mid-cycle inspection (B1P02). The tubes selected for locking were hydraulically expanded during these outages. The selected tubes were required to be free from defects at the Top of Tubesheet (TTS) region. An inspection with a plus point probe showed each tube was free of defects.

During the Braidwood Unit 1 Refuel 6 Outage (A1R06), the locked tubes were unplugged and inspected using the plus point probe to determine if degradation had occurred since the time of installation. Although no defects were found at the TSP expansions themselves, circumferential degradation was found at the TTS region in 49 of the 85 locked tubes. This inspection occurred after 412 days of Braidwood Unit 1 operation above 500°F. The relative size of the TTS indications is much smaller than other TTS indications seen in previous Braidwood Unit 1 outages. Structural integrity of previous TTS indications was demonstrated through in situ pressure testing of selected indications. In addition, eight of the largest circumferential indications detected in locked tubes during the current A1R06 outage were in situ pressure tested and shown to have adequate

structural integrity to meet the 3.0 Volt IPC design bases (i.e., able to carry at least 500 lbs axial load during a MSLB). Details of this testing are provided in the Additional Structural Assessment section contained later in this report.

Byron Unit 1, which also has locked tubes installed in support of 3.0 Volt IPC, is expected to operate for a period of approximately 630 days above 500°F from the time the locked tube were installed and inspected until steam generator replacement in B1R08:

B1P02 to B1R07	=	+104 Days > 500°F
B1R07 to B1R08	=	+540 Days > 500°F
Maintenance Outage	=	- 14 Days > 500°F
		630 Days > 500°F

This operability assessment is being performed to demonstrate that the design and licensing basis requirements of 3.0 Volt IPC will be maintained for the remainder of Byron Cycle 8 in light of the TTS degradation seen in the locked tubes at Braidwood Unit 1.

Licensing/Design Basis

Steam generators are determined operable by the performance of an augmented inservice inspection program and application of the acceptance criteria as described in the Technical Specification 4.4.5.4. Technical Specification Section 4.4.5.4.a.11 specifically addresses the use of the 3.0 Volt Interim Plugging Criteria (IPC). This criteria is described in the WCAP-14273 "Technical Support of an Alternate Plugging Criteria with Tube Expansion at Tube Support Plate Intersections for Braidwood 1 and Byron 1 Model D-4 Steam Generators." WCAP 14273 discusses limiting the deflection of the tube support plate (TSP) to obtain negligible tube burst probabilities along with minimizing primary to secondary leakage from a tube containing Outside Diameter Stress Corrosion Cracking (ODSCC) at the TSP intersection. Limiting deflection of a TSP is accomplished by hydraulically expanding select steam generator tubes at various support plate intersections which effectively "locks" the tube to the TSP (this assumes the tubes are free to move axially and are not naturally locked in place due to the crevice between the TSP and tube being packed). The tubes containing these expansions are subsequently plugged and function as additional tie rods to limit the vertical movement of the TSPs under postulated accident conditions. As discussed in WCAP-14273, limiting the vertical movement of the TSPs restricts the potential freespan exposure of an ODSCC flaw to less than 0.10 inches. In order to limit displacement to 0.10", a maximum axial load of 500 lbs is required to be carried by the locked tube during a MSLB.

Braidwood Locked Tube Inspection Results

All 85 locked tubes were unplugged and inspected during the Spring 1997 Braidwood Unit 1 Refuel 6 outage (A1R06). The TTS and TSP expansion locks were inspected using a plus point probe and rotating pancake coil (RPC) probe. No degradation was seen at the

TSP locks. Circumferential degradation was seen at the TTS region in 49 of the 85 tubes inspected. Table 1 provides a complete listing of the inspection results for all 85 tubes inspected. The largest TTS circumferential indication found in a locked tube during the Braidwood Unit 1 inspection is tube R44C84 in Steam Generator 1C:

1.83 Max Volts (0.080" RPC)	0.53 Avg Volts (0.080" RPC)
2.34 Max Volts (plus point)	0.55 Avg Volts (plus point)

Root Cause of Locked Tube Degradation

After finding a higher frequency of TTS circumferential indications in locked tubes as compared to non-locked inservice tubes (58.8% of the locked tube population as compared to 10.6% of the inservice tubes), ComEd performed a root cause investigation. The investigation (Reference 7) evaluated the following areas:

- Materials
- Stress
- Environment
- Fabrication
- Growth

The root cause investigation concluded that the higher frequency of TTS circumferential indications in the locked tubes compared to the non-locked tubes is due to the additional stress that was imposed on the TTS location during the expansion locking process. Only a small increase in stress is required to cause initiation and growth of the previously undetected flaws in the TTS region over the detection threshold due to the presence of residual stresses from the tube expansion process. The tube locking process, independent of configuration, provides enough additional axial stress to result in a shorter time to crack initiation compared to inservice tubes. The most compelling evidence for this conclusion is that tubes with locks at the lowest elevation (3H) have a higher axial stress than other tube lock configurations. This would indicate that increased stress causes larger cracks in tubes with locks at 3H.

The additional axial stress due to locking tubes, estimated to be between 2.5 to 30 KSI from calculation and strain gauge testing, tends to increase ODSCC. The lower temperature at the hot leg TTS region of a plugged tube as compared to an inservice tube (approximately 50 degrees lower in temperature) tends to reduce ODSCC. Another factor, which is difficult to quantify, is the difference in heat flux between the operating tubes and the locked tubes. This is expected to result in more benign chemical conditions at the TTS crevices of locked tubes than at the TTS crevices of operating tubes. The net effect of the additional locking stress overcomes the stress reducing effects due to temperature and heat flux. Therefore, the overall effect is a higher frequency of TTS circumferential indications in the locked tubes as compared to the inservice tubes.

The same conditions determined to be the root cause of the increased frequency of TTS circumferential indications in locked tubes at Braidwood exist at Byron due to the similarity in design of the steam generators, design and installation of tube locks and operating conditions. Therefore, TTS circumferential cracking of locked tubes is expected to occur at Byron at a similar rate of degradation.

Byron End-of Cycle 8 Indication Distribution

Methodologies consistent with NRC GL 95-05 (Reference 6) were used to predict an end-of-cycle 8 (EOC-8) distribution for TTS circumferential indications in locked tubes. The inputs, assumptions, methodologies and results are documented in Reference 5 and are discussed in detail later in this assessment. The predicted Byron Unit 1 EOC-8 locked tube TTS circumferential indication distribution (Figures 3 - 6) results in the following largest predicted indication for the best estimate and most conservative combination of inputs:

Best Estimate:

2.00 Max Volts (0.080" RPC) 0.89 Avg Volts (0.080" RPC)

Most Conservative:

3.10 Max Volts (0.080" RPC) 1.03 Avg Volts (0.080" RPC)

Note: These values represent the voltage value where the integral of the tail from the Monte Carlo distribution is equal to one tube.

Results are from 0.080" RPC data because sufficient data (e.g., growth rates) does not exist for analysis using the plus point probe.

Results from the Best Estimate and Most Conservative methods are bounded by the structural limits as discussed in the next section.

Byron Locked Tube End-of-Cycle Assessment

An assessment has been performed to predict the EOC load carrying capacity of Byron Unit 1 steam generator tubes locked at various TSP intersections to ensure that the design and licensing basis requirements of the 3.0 Volt IPC are satisfied. As discussed earlier, the implementation of IPC requires that the locked tubes be capable of carrying an axial force of 500 lbs during an MSLB. This limits deflection of the TSP to enhance the structural and leak integrity of the tube.

Draft Regulatory Guide (RG)1.121 (Reference 8) identifies the requirements for operating tube integrity. At the TTS, the limiting case is three times normal operating

differential pressure (3×NOdP), where 3×NOdP has been calculated to be 4035 psi. A tube satisfying the requirements of RG 1.121 can carry an axial force equal to the pressure times the internal cross sectional area of the tube or 1397 lbs (4035 psi × π ×$(0.332)^2$). Therefore, demonstrating that a tube meets the requirements of RG 1.121 will ensure that the tube is capable of carrying a load equal to 2.8 times the design basis axial load (1397÷500). Meeting this criteria also ensures that the RG 1.121 requirement of maintaining a margin of 1.4 to MSLB loads is satisfied.

A relationship between the voltage of a TTS circumferential indication and its corresponding burst pressure was determined by ComEd using ComEd and Industry data. This relationship is used to develop a structural limit to assess whether tubes with TTS circumferential indications meet the requirements of RG 1.121. Tube pulls and in situ pressure testing have been used by ComEd for determining structural integrity of inservice steam generator tubes.

A total of 16 Byron and Braidwood tubes with TTS circumferential indications have been removed from the steam generators, burst tested, and destructively sized using metallographic techniques to assess the tube's strength. Additionally, the structural integrity of 21 Byron and Braidwood tubes with TTS circumferential indications has been assessed by in situ pressure testing at pressures which exceed 3×NOdP (4035 psi). The information from these tests have been added to the industry information which is used to assess a tube with TTS circumferential indications structural integrity based upon eddy current testing (ECT) results. A conservative structural limit has been developed (Reference 3 and 9) to relate SG tubes non-burst test pressures (proof test results normalized to industry 95%/95% lower tolerance limit (LTL) properties at 650°F) to 0.080" RPC maximum and average voltages (Figures 1 and 2). A structural limit from non-burst test results provides a conservative result since the tubes were not tested to there full capability (i.e., they did not burst). From this relationship, the structural limit at 3×NOdP (4035 psi) is determined to be: 3.7 maximum Volts, (0.080" RPC maximum voltage) and 1.27 average Volts (0.080" RPC average voltage). The estimated size of locked tube indications at EOC-8 are assessed against these structural limits to show that the tube integrity requirements of RG 1.121, 3×NOdP, are satisfied. Therefore, the design basis requirements of the 3.0 Volt IPC are also satisfied. The voltages are determined from the 0.080" RPC ECT results using the voltage integral software normalized to 20 Volts on a 100% axial EDM notch.

The predicted EOC-8 distribution of TTS circumferential indications in locked tubes falls below the structural limit. Therefore, locked tubes will have a margin of greater than 2.8 to the 3.0 Volt IPC design basis requirement of 500 lbs axial load capacity during an MSLB. The RG 1.121 requirement to maintain a margin of greater than 1.4 to MSLB loads is also satisfied.

Additional Structural Assessment

The largest indications seen in the locked tubes during the Braidwood Unit 1 Spring 1997 outage (Table 1), are approximately half the size of the largest TTS circumferential indication seen in nonlocked tubes during the Braidwood Unit 1 Fall 1996 outage. The largest nonlocked tube circumferential indication is;

3.5 Max Volts (0.080" RPC)	1.2 Avg Volts (0.080" RPC)
7.07 Max Volts (plus point)	2.25 Avg Volts (plus point)

This tube and nine other tubes of lesser size were in situ pressure tested to a maximum pressure of 5050 psi (4035 psi (2×NOdP) ×1.08 (temperature) ×1.066 (locked tube) + 350 psi margin) without axial separation occurring. A tube pressurized internally to 4385 (4035 +350) psi corresponds to an axial load determined as follows:

> A tube in situ pressure tested to 4385 psi carries an axial force equal to the pressure times the internal cross sectional area of the tube or 1518 lbs (4385 psi × $\pi \times (0.332)^2$).

As long as the axial load carrying capacity of the tube exceeds that required to maintain the TSP from displacing less than 0.10 inch (500 lbs), the 3.0 Volt IPC design/licensing basis is maintained and there is no operability concern with the locked tube. Therefore, a tube in situ pressure tested and demonstrated to have structural margin at 4385 psi has a margin of 3 to the locked tube design basis requirement of 500 lbs axial force.

During the Braidwood Unit 1 Refuel 6 Outage (A1R06), seven locked tubes containing bounding indications were in situ pressure tested. A test pressure of 2780 psi was selected to impose an axial force on the indication with a margin of approximately 2 to the required MSLB load of 500 lbs. A test pressure of 2780 psi corresponds to an axial load, calculated with the same method as above, of 963 lbs which is a factor of nearly 2 above the required axial load during an MSLB of 500 lbs. The actual pressure used for the test included temperature and locked tube corrections (2780 psi ×1.08 (temperature) ×1.066 (locked tube) = 3200 psi).

Additionally, the largest TTS circumferential indication in a locked tube (SG 1C R44C84) was in situ pressure tested to 4900 psi (which includes temperature and locked tube corrections). This test pressure provided a margin of greater than 3 to the locked tube design basis requirement of 500 lbs axial force.

The in situ pressure testing was performed consistent with the draft EPRI Guidelines for Performing In Situ Testing of Steam Generator Tubes (Reference 10), for tubes which are locked at the TSP.

Additionally, to confirm the locked tube axial load at a TTS flaw during in situ pressure

testing, a finite element model of the steam generator locked tube configuration was prepared. Testing conditions were simulated for the locked tube being tested and for neighboring inservice tubes in a naturally locked condition (i.e., locked due to crevice packing). The stiffness of neighboring inservice tubes, the TSPs and the tube being tested were modeled. The axial load applied to deep and shallow flaws during testing at the TTS were calculated. The results (Reference 11) show that the loads applied to a flaw at the TTS are consistent with the discussion above and are consistent with corrections made for temperature and presence of a locked tube.

Therefore, based on the in situ pressure testing results of TTS circumferential indications in Braidwood locked and inservice tubes, the tubes with the predicted Byron EOC-8 distribution of locked tube TTS indications will be capable of carrying an axial load greater than a factor of 2.8 above the 500 lbs required during MSLB conditions.

Byron Unit 1 EOC-8 Locked Tube TTS Indication Prediction Methodology

In order to estimate the EOC distribution of locked tubes at Byron Unit 1, four different methodologies were used to identify the most conservative estimation of the EOC distribution. Additionally, the methodologies were benchmarked against the Spring 1997 (A1R06) Braidwood locked tube inspection results of indications that have been in service for 412 days of operation above 500°F to ensure that the estimated distributions are conservative relative to actual inspection results. The four methodologies are described below:

Method 1 (Best Estimate)

A. The TTS area of each tube being considered for the locking process was inspected with a plus point probe during B1?02. No defects were identified. Since the inspections performed at Byron and Braidwood were performed with the same techniques, the threshold of detection would be expected to be essentially equivalent at Byron and Braidwood. Additionally, the stress, material, environment and temperature are essentially the same between the two units. Therefore, the rate of initiation and growth of TTS circumferential cracks is expected to be comparable. The root cause of locked tube TTS indications has been identified as increased axial stress from the locking process. Because this stress is the driver of the crack initiation and growth, the period that the locks have been in service provides the best indication of the length of time the cracks have been present.

B. For this method, a threshold of detection level is determined from previous Byron and Braidwood inspection results and is used as the beginning-of-cycle (BOC) distribution for the 85 locked tubes. The threshold used is 0.3 maximum Volts (0.080" RPC voltage) and 0.1 average volts (0.080" RPC voltage).

C. It is assumed that all locked tubes begin with an indication at the detection

threshold. These indications are modelled for 630 days of growth using Monte Carlo simulation techniques including uncertainties for probe wear (7.5% from Reference 12) and analyst uncertainty (30% maximum voltage and 32% average voltage from Reference 13). This growth period is the number of days above 500°F from when the locked tubes were installed and inspected in 10/95 until shutdown for the SG replacement outage in mid-December 1997.

D. In order to provide an assessment with Byron data, growth rates from the Byron Unit 1 look-backs were used. The following growth rate distributions were summed to develop the growth rate distribution used in this method:

1. Byron 1995 SG B indications which were determined as no detectable degradation (NDD) in 1994:
normalized growth rate = $365 \times (V_{1995} - 0)/342$; only growth rates for tubes which grew from NDD were used to represent the condition of the locked tubes (i.e., confirmed to be NDD in the 10/95 inspection).

2. Byron 1996 SG C indications which were present in 1995 but NDD in 1994:
normalized growth = $365 \times (V_{1995} - 0)/342$; only growth rates for tubes which grew from NDD were used to represent the condition of the locked tubes (i.e., confirmed to be NDD in the 10/95 inspection).

3. Byron 1996 SG C indications which were NDD in 1994:
normalized growth = $365 \times (V_{1996} - 0)/448$; only growth rates for tubes which grew from NDD were used to represent the condition of the locked tubes (i.e., confirmed to be NDD in the 10/95 inspection)

4. Braidwood Unit 1 1997 locked tube indications which were NDD in 10/95:
normalized growth = $365 \times (V_{1997} - 0)/412$

The eighty five indications with the threshold value of 0.3 Volts were modeled for growth using Monte Carlo sampling techniques with probe wear and analyst uncertainties (NDE uncertainty) and growth rates described above. The results are presented in Table 2. The growth rates used in the analysis (i.e., from NDD) are conservative when compared to actual measured cycle-to-cycle growth. Growth rate distributions used in the analysis as well as a comparison of growth rates from NDD and from a measured size are shown in Figures 7 - 10.

Method 2

A. Method 2 uses the Braidwood Unit 1 locked tube EOC distribution and models distribution growth forward from 412 days to 630 days (an additional 218 days). This period represents the time which Byron Unit 1 will operate with the locked tubes in service beyond the period that the locked tubes were placed in service at

Braidwood Unit 1. Braidwood Unit 1 locked tubes, which were NDD in the 4/97 inspection, were assumed to be at the threshold voltage discussed in Method 1. It is acceptable to use the Braidwood Unit 1 EOC distribution because the stress, material, environment and temperature are essentially the same between the two units. Therefore, the rate of initiation and growth of TTS circumferential cracks is expected to be comparable. The root cause of locked tube TTS indications has been identified as increased axial stress from the locking process. Because this stress is the driver of the crack initiation and growth, the period that the locks have been in service provides the best indication of the length of time the cracks have been present.

B. The same growth rates and NDE uncertainty used in Method 1 above were used to model the distribution growth for the additional 218 days using Monte Carlo techniques.

The eighty five indications with the Braidwood Unit 1 locked tube EOC distribution discussed above were grown for 218 days using Monte Carlo sampling techniques with NDE uncertainty and growth rates described above. The results are presented in Table 2.

Method 3 (Most Conservative)

A. Method 3 uses the same Braidwood Unit 1 locked tube EOC distribution as Method 2 and models the distribution growth for 630 days in addition to the 412 days from Braidwood Unit 1 (Method 2 grew the indications 218 days). 630 days represents the duration which the locked tubes at Byron Unit 1 were in service from when they were installed and inspected. This BOC distribution is conservative because a plus point inspection of the tubes was performed prior to the tube locking process and all tubes were found to be NDD.

B. The beginning of cycle distribution was grown using growth rates from the Braidwood Unit 1 locked tubes. These growth rates were determined as discussed in Method 1, Section D.4. Additionally, the same NDE uncertainties applied in Methods 1 and 2 were used.

The eighty five indications with the Braidwood Unit 1 locked tube EOC distribution discussed above were modeled for 630 days of growth using Monte Carlo sampling techniques with NDE uncertainty and growth rates described above. The results are presented in Table 2.

Method 4

A. Method 4 uses the same beginning of cycle distribution as Method 1 where a threshold of detection level is determined from Byron and Braidwood inspection results and is used as the beginning-of- cycle distribution (BOC) for 85 locked

tubes. The threshold used is 0.3 max volts (0.080" RPC voltage) and 0.1 avg. volts (0.080" RPC voltage).

B. The BOC distribution was modeled for 630 days growth using the Braidwood Unit 1 locked tube growth rates, which are the same growth rates as Method 3, and the NDE uncertainties described in Method 1.

The eighty five indications with the threshold distribution discussed above were modeled for 630 days growth using Monte Carlo sampling techniques with NDE uncertainty and growth rates described above. The results are presented in Table 2.

Braidwood Benchmark

In order to ensure that the methods discussed above provide conservative results the methodology described in Method 1 above was applied to the Braidwood Unit 1 case and compared to the Spring 1997 as-found distribution of locked tube indications. The inputs are described below:

A. The TTS area was inspected with the plus point probe and analyzed during the Braidwood Unit 1 mid-cycle inspection (A1M05). No defects were detected.

B. For this evaluation a threshold of detection level is determined from Byron and Braidwood inspection results and is used as the beginning of cycle distribution (BOC) for 85 locked tubes. The threshold used is 0.3 max volts (0.080" RPC voltage) and 0.1 avg. volts (0.080" RPC voltage).

C. It is assumed that all locked tubes begin with an indication of this size and are modeled for 412 days growth using Monte Carlo simulation techniques including uncertainties for probe wear (7.5%) and analyst uncertainty (30% max voltage and 32% average). This is the number of days above 500°F from when the locked tubes were installed and inspected in October 1995 until shutdown for the Spring 1997 refuel outage (A1R06).

D. In order to provide an assessment with actual Braidwood Unit 1 data, growth rates from the Braidwood Unit 1 look-backs were used, the following describes the growth rate development:

   1. Braidwood Unit 1 1996 look-back in four SGs for indications which were NDD in 10/95:
      normalized growth = $365 \times (V_{1996} - 0)/293.76$; only growth rates for tubes which grew from NDD were used to represent the condition in which the locked tubes were, i.e. confirmed to be NDD in the 10/95 inspection.

2. Braidwood Unit 1 1997 locked tube indications which were NDD in 10/95, normalized growth $= 365 \times (V_{1997} - 0)/412$

The eighty five indications with the threshold value discussed above were grown using Monte Carlo sampling techniques using NDE uncertainty and growth rates described above. The results are presented in Table 2 along with the as-found distribution of indications.

Benchmark of the Best Estimate methodology on Braidwood Unit 1 TTS circumferential indications in locked tubes against as-found indications demonstrates that the methodology is conservative and appropriate for use at Byron.

Conclusion

Based upon the most limiting EOC predicted distribution (Method 3), the largest indication at Byron Unit 1 in a locked tube after 630 days of operation (integrating the Monte Carlo distribution tail to 1 tube) will be 3.10 maximum Volts (0.080" RPC maximum voltage) and 1.03 average Volts (0.080" RPC average voltage). This size indication is well below the structural limits described above (3.7 maximum Volts and 1.27 average Volts) and is bounded by the largest indications in situ pressure tested. Based upon this result, there is a margin of 2.8 to the design basis load requirement of 500 lbs axial force on a single tube.

The methods used to determine the Byron Unit 1 locked tube EOC distribution were applied to Braidwood Unit 1 which were then compared to the as-found distribution of Braidwood Unit 1 locked tube indications after 412 days above 500°F inservice. It was determined that the methods used to calculate the Byron EOC distribution provides a result which is conservative with respect to the as-found distribution of indications at Braidwood.

Lowest Tube Lock Location Versus Required Load Capacity

As discussed in the root cause section, Braidwood locked tubes with a lock at the lowest support plate (3H), have the most degradation as determined by plus point maximum voltages. As discussed above, the design basis maximum axial load requirement on a locked tube is 500 lbs during an MSLB. From a different perspective, the lowest lock elevation for a tube which is required to carry the 500 lbs is 8H. The axial load required for a tube with a lock at 3H is 224 lbs at the TTS (Reference 2). Therefore, tubes where the most severe degradation is expected to occur, 3H, are only required to carry approximately 45% of the load used in the locked tube EOC assessment. Therefore, there is considerable additional margin for all locking configurations installed at Byron.

Evaluation of TSP Crevice Load Carrying Capacity (Defense in Depth)

Steam generator replacement at Byron 1 is scheduled for Fall 1997. This equates to approximately 630 days above 500°F since the time the TSP locks were installed. ComEd believes there is sufficient data to provide reasonable assurance that these locks would be capable of carrying the required 500 lbs axial load to limit TSP displacement over the 630 day time period. As additional "defense in depth," ComEd believes that TSP displacement would be limited to less than 0.10" during an accident condition due to the buildup of deposits between the tube and TSP, commonly referred to as crevice packing. During normal operation of the steam generators, bulk water deposits and corrosion products collect in the TSP-to-tube crevice causing crevice packing. ComEd believes that the Byron 1 TSPs are effectively "locked" in place due to corrosion products and that TSP displacement will be maintained less than 0.10" during an accident condition based on the following:

- ODSCC is known to form during plant operation. In all eddy current inspections performed thus far at Byron and throughout the industry, axial ODSCC indications have been shown to be contained within the thickness of the TSP. This is further supported by the Byron 1 and Braidwood 1 tube pull results which show the ODSCC to actually be centered within the TSP. The eddy current inspections are conducted during cold shutdown. If the TSPs were free to move between all modes, the eddy current inspections would be expected to detect indications outside the TSP thickness.

- During the Byron 1 Refuel 6 outage, a test program to determine if the tubes were locked at the TSPs was performed on a total of 8 tubes in 2 SGs. Testing was performed after completion of secondary side chemical cleaning. The testing involved centering an eddy current probe at an upper TSP elevation and heating the tube in the region of the lower TSPs. If the tubes were not locked at the TSPs, thermal growth would have caused the tube to lengthen which would have been detected by the eddy current probe at the upper TSP. Results indicate that seven of the eight tubes were clearly locked at the TSPs. The results from one of the eight tubes indicate that it was not locked at the TSPs. A summary of the theoretical compressive loads is given below. The minimum load is based on the tube crevice locking at the location of the detection probe (7H or 5H) and the maximum load is based on the tube crevice locking at the lowest plate (3H).

S/G	Row/Col	TSP	Cycle	Min Load	Max Load
B	31-53	07H	LOW TEMP	411 LBS	1233 LBS
B	25-22	07H	LOW TEMP	411	1233
B	15-107	05H	LOW TEMP	617	1223
B	15-70	05H	LOW TEMP	617	1223
B	38-62	05H	LOW TEMP	617	1223
A	6-63	07H	LOW TEMP	Not Locked	Not Locked
A	6-63	07H	HIGH TEMP	Not Locked	Not Locked
A	8-48	07H	LOW TEMP	411	1233
A	7-62	07H	LOW TEMP	411	1233

The testing listed above occurred directly after Byron 1 chemical cleaning during the Refuel 6 Outage in Fall 1994. Since that time, Byron 1 has operated several years. Therefore, the TSP crevice packing is expected and the load carrying capability of the packed crevices is greater.

A similar test was performed on a Westinghouse Model D-2 SG at another utility which indicated all 9 tubes tested were locked at the TSPs

- During the Byron 1 Refuel 6 outage, a total of three tubes were removed for. The breakaway forces after tungsten inert gas (TIG) relaxation of the tubesheet expanded area ranged from 1194 to 2885 lbs. Although the breakaway forces are unable to distinguish between the force required to break the tube away from the tubesheet verses breakaway from the TSPs, the data suggests that the tubes are locked at the TSP intersections.

- Further data to support the load carrying capability of the TSP crevice region can be obtained from an intact section of tubing and support plates which was removed from the Dampierre-1 steam generators, reference EPRI Report NP 7480-L (Reference 14). The assemblies from Dampierre-1 include the tube, TSP and the crevice deposits, which retained the tube in the TSP during the removal operations. According to Electricite de France (EdF), the Dampierre-1 SGs are not considered to be particularly dirty in terms of sediment or corrosion and the crevice deposits are considered to be typical of SGs with drilled carbon steel support plates. Tests were performed on some tube sections with and without chemical cleaning of the assemblies. Thus, the data also allows the assessment of chemical cleaning on crevice deposits removal as well as the associated effects on leakage and forces for TSP displacement.

  Dampierre-1 uses Framatome Model 51B SGs which are similar in design and fabrication to a Westinghouse Model 51. These SGs contain 7/8" mill annealed Inconnel 600 tubing with 3/4" drilled carbon tube steel support plates. Dampierre-1 commenced operation in 1980 and the SGs were replaced in 1990. All Volatile Treatment (AVT) water chemistry was used throughout operation. Ammonia was used for pH control until 1984 ($8.8<pH<9.2$) and morpholine pH control after 1984 ($9.1<pH<9.3$). The overall water chemistry at Byron 1 is considered similar.

  Two tube/TSP intersections removed from Dampierre-1 were destructively examined by Westinghouse. A third tube/TSP assembly was retained as an archive specimen. One tube assembly was destructively examined without chemical cleaning and the second tube was chemically cleaned to assess the effects of cleaning on the deposits in the tube to TSP crevice. Both tubes were metallographically examined to assess the morphology and density of the deposit-packed crevice.

Dampierre-1 Conclusions

The Dampierre-1 test results described above lead to the following conclusions:.

- Forces of about 3000 lb per TSP intersection at room temperature are required to displace a tube relative to the TSP for non-dented intersection with packed crevices.
- Forces to move the tube relative to the TSP are reduced by about 20% at operating temperatures compared to room temperature test results.
- Forces required for TSP displacement are approximately independent of displacement for displacements up to the 0.39 inch maximum measure displacement.
- The forces required for TSP displacement are only moderately reduced (about 50%) by chemical cleaning.
- Results for tubes removed with the TSP from an operating SG show larger pull forces for TSP displacement than found for laboratory specimens with highly accelerated TSP corrosion.

TSP Crevice Load Carrying Capacity Conclusions

Based on the information stated above, ComEd believes that the Byron 1 steam generator tubes are in a "locked" condition relative to the TSPs due to crevice packing. An analysis to determine the load each tube would be required to carry in order to limit TSP displacement to no more than 0.10" was performed based on TSP packing and existing support structures, without any credit given for the TSP hydraulic expansion locking as described early in this report. This analysis relied on a previous analysis which was performed for a Westinghouse Model 51 Steam Generator. A comparison between the Model 51 and Model D-4 (Byron 1 design) steam generators was performed which determined that the Model 51 TSP accident axial loads from the TSPs are bounding for the Model D-4 design. The results conclude that a maximum load carrying capability of 31 lbs, with an average of approximately 18 lbs, would be required at a TSP intersection to limit displacement during an accident.

ComEd believes there is sufficient data to suggest that the Byron 1 crevices are packed to a point sufficient to carry the maximum projected load during an accident of 31 lbs by a significant amount. Therefore, the 3.0 Volt IPC design and licensing requirements of limiting TSP displacement to less than 0.10" will be maintained and there is reasonable assurance that the Byron 1 steam generators are operable.

Overall Conclusions

1. The Byron Unit 1 EOC-8 projected distribution of locked tube TTS circumferential indications is bounded by the circumferential indication structural limit developed from non-burst test data.

2. A tube with degradation at the structural limit has an axial load carrying capacity which provides a margin greater than 2.8 to the 500 lb load carrying requirement of the 3.0 Volt IPC design basis.

3. At the EOC-8 Byron Unit 1 locked tubes will have the necessary axial load carrying capacity required for 3.0 Volt IPC.

4. With complete failure of all locked tubes, TSP displacement will be limited to less than 0.10" due to the natural locking of steam generator tubes at the TSP. This will ensure that tube integrity is maintained at the TSPs where 3.0 Volt IPC has been implemented.

In summary, an assessment of the results of the Braidwood Unit 1 locked tube inspections as they relate to Byron Unit 1 full cycle operation has determined that no corrective actions are required for Byron Unit 1 pending replacement of the SGs in November 1997.

References

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2. Westinghouse Letter, CAE-97-141/CCE-97-181 "Summary of Expanded Tube Forces for Steam Generators for RELAP Pressure Loads," May 6, 1997

3. Response to Request for Additional Information Pertaining to the Byron Cycle Length Byron Station Unit 1 NRC Docket Number 50-454, dated December 2, 1996.

4. CCmail from Dave Eder to Jack Feimster, Byron Operating days over 500 degrees since B1P02, dated 4/07/97.

5. Calculation BYR97-231, Byron Unit 1 Prediction of End-of-cycle voltage distributions for steam generator tube TTS circumferential indications in locked tubes, Rev. 0

6. NRC Generic Letter 95-05, "Voltage Based Repair Criteria For Westinghouse Steam Generator Tubes Affected By Outside Diameter Stress Corrosion Cracking", August 3, 1995, US NRC, Washington, DC

7. Braidwood Unit 1, Locked Tube TTS Circumferential Indication Root Cause Determination, 4/28/97

8. U.S. Nuclear Regulatory Commission Draft Regulatory Guide 1.121, Bases for Plugging Degraded PWR Steam Generator Tubes, August 1976

9. Calculation Brw-96-456-M, Industry Steam Generator Tube Circumferential Indication Burst and Leak Limits, Rev. 2

10. EPRI Guidelines for Performing In Situ Testing of Steam Generator Tubes, TR-107197, Draft, December 1996

11. Westinghouse Calculated Axial Stress & Force Results in Tube Subjected to In Situ Pressure Test, April 25, 1997

12. Calculation Brw-96-455-M, RPC Probe Wear Assessment for Steam Genertor Tubes, Rev. 1

13. Calculation Brw-96-525-M, Calculation of Steam Generator Tube ECT Inspection Analyst Variability Using the Voltage Integral Software, Rev. 0

14. EPRI Report NP 7480-L Addendum 1, August 1996, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates Database for Alternate Repair Limits."

Byron Operability Assessment Table 1

SG	Braidwood Unit 1 All SG's 1997 Locked Tube Indications									
SG	Row	Col	97 RPC ARC	97 RPC Max	97 RPC Avg	97 RPC Depth	97PlPtArc	97 Pl Pt Max	97Pl Pt Avg	97Pl Pt Depth
A	42	86	148	0.98	0.28	47	169	1.72	0.33	38
	21	40	213	0.68	0.35	19	272	0.75	0.32	23
	2	38	187	0.26	0.1	91	277	0.6	0.19	74
	5	7	236	0.60	0.22	69	244	0.57	0.21	40
	20	56	90	0.34	0.19	33	360	0.56	0.22	74
	19	42	199	0.46	0.23	21	161	0.45	0.19	40
	26	23	188	0.30	0.15	76	262	0.33	0.11	64
	25	90	120	0.23	0.11	54	120	0.38	0.16	29
	26	92	204	0.24	0.11	58	360	0.42	0.17	48
	19	73	185	0.28	0.12	42	328	0.4	0.14	43
	2	75	212	0.58	0.21	49	228	1.01	0.27	42
	6	108					110	0.27	0.09	33
B	45	83	100	0.41	0.13	52	151	0.85	0.21	85
	6	109	151	0.35	0.11	77	188	0.64	0.18	75
	20	56	169	0.31	0.14	34	267	0.59	0.23	82
	2	78	121	0.33	0.19	46	167	0.5	0.19	60
	2	97	205	0.23	0.09	9	301	0.46	0.2	62
	27	93	297	0.35	0.14	71	352	0.43	0.18	62
	23	75	161	0.30	0.12	68	190	0.41	0.13	83
	2	37	174	0.27	0.09	11	165	0.29	0.11	36
C	2	14	234	0.36	0.12	20	276	0.45	0.17	40
	2	41	264	0.69	0.3	76	223	0.81	0.35	46
	2	76	173	0.42	0.26	59	140	0.64	0.29	49
	2	100	103	0.34	0.13	53	94	0.42	0.16	36
	5	108	220	0.55	0.21	38	220	0.84	0.33	55
	6	108					89	0.48	0.24	52
	20	73	187	0.36	0.17	57	238	0.68	0.25	54
	21	40	182	0.35	0.16	20	238	0.37	0.15	41
	22	73	215	0.48	0.25	64	262	0.65	0.33	44
	23	40	150	0.27	0.12	20	262	0.49	0.28	54
	26	89					131	0.55	0.23	57
	44	84	187	1.83	0.53	61	178	2.34	0.55	71
	47	60	108	0.38	0.23	44	121	0.49	0.21	63
D	25	22	230	0.81	0.28	33	360	1.51	0.49	63
	23	40	315	0.60	0.25	38	360	1	0.33	70
	2	16	194	0.36	0.14	19	239	0.62	0.25	68
	6	5	236	0.45	0.16	19	218	0.54	0.19	78
	26	92	298	0.34	0.13	19	356	0.52	0.25	70
	2	101	244	0.39	0.17	19	164	0.47	0.17	63
	2	40					90	0.29	0.16	36
	5	110	351	0.40	0.16	52	351	0.98	0.27	38
	5	108	305	0.66	0.26	7	337	1.13	0.4	34
	27	91	245	0.40	0.24	19	254	0.29	0.13	35
	42	85	237	0.39	0.19	19	278	0.71	0.31	41
	21	75	152	0.31	0.16	19	162	0.44	0.19	34
	20	57	194	0.34	0.15	19	342	0.34	0.13	24
	25	23	131	0.27	0.11	20	104	0.32	0.11	30
	22	74					283	0.25	0.1	19
	6	7	216	0.48	0.2	60	234	0.67	0.21	76
	Max		351	1.83	0.53	91	360	2.34	0.55	85
	Average		198.43	0.45	0.19	41.14	230.12	0.63	0.23	51.71
	Count	49	44	44	44	44	49	49	49	49

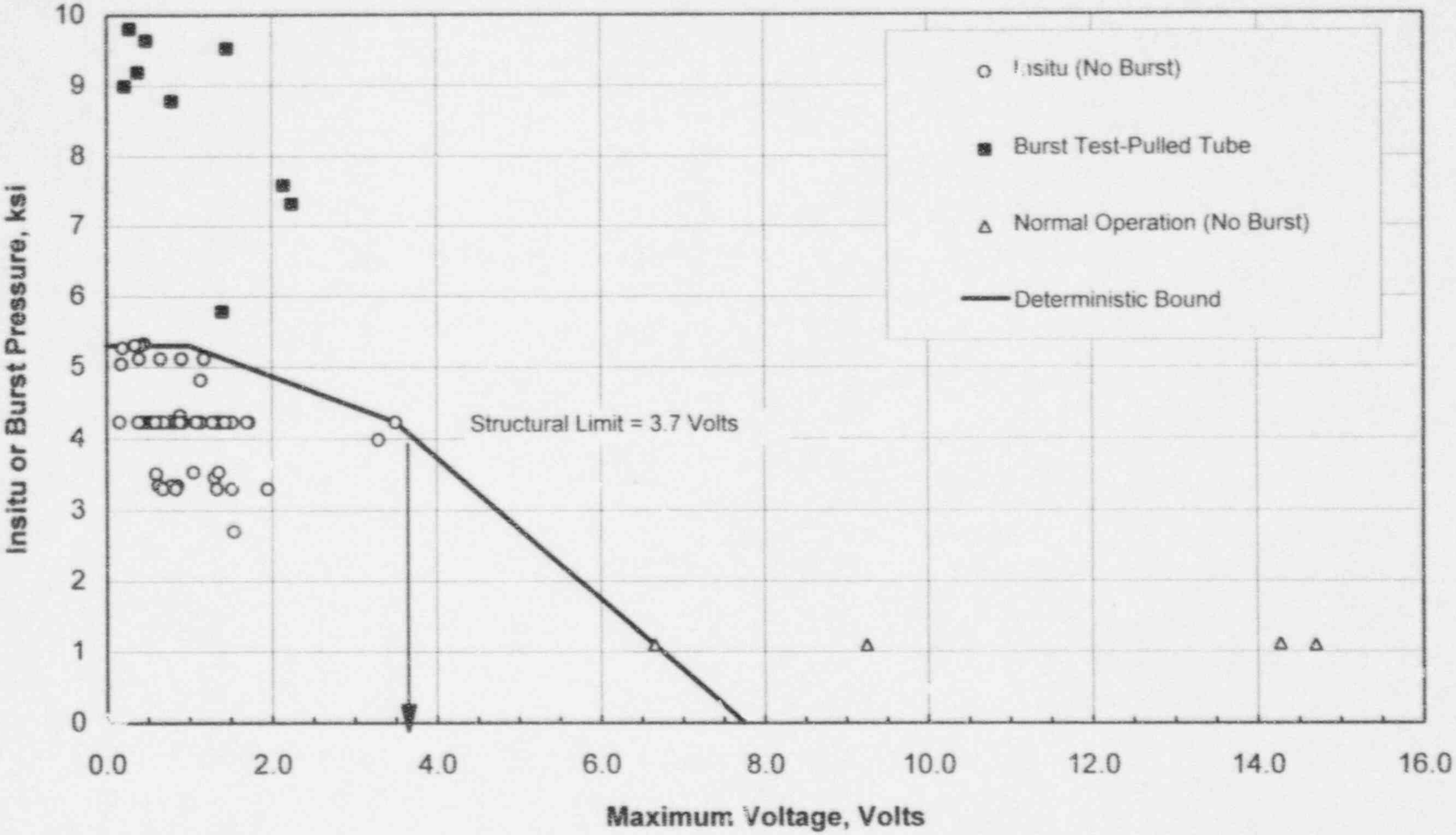
Plus Pt NDD 0

RPC NDD 5

Byron Operability Assessment
Table 2
Byron Unit 1 Locked Tube Predicted EOC Distribution

Method	Voltage Distribution	Growth Rate	Days Above 500°F	Voltage at 1 Whole Tube Max Volts	Voltage at 1 Whole Tube Avg. Volts	Voltage at Integrated to 1 Tube Max Volts	Voltage at Integrated to 1 Tube Avg. Volts	Voltage at Integrated to 0.3 Tubes Max Volts	Voltage at Integrated to 0.3 Tubes Avg. Volts
	Structural Limit			**3.7**	**1.27**				
	Braidwood As-Found NDE	n/a	412	1.83	0.53				
	Byron Predicted EOC								
1 (BYN-1&2) Best Esimate	Threshold (0.3 Max, 0.1 Avg.)	BYN+BWD LT	630	n/a		2.00	0.89	2.25	0.95
2 (BYN-3&4)	BWD Locked Tubes + (0.3 Max, 0.1 Avg.)	BYN+BWD LT	218	n/a		2.30	0.81	2.90	0.96
3 (BYN-7&8) Most Conservative	BWD Locked Tubes + (0.3 Max, 0.1 Avg.)	BWD LT	630	n/a		3.10	1.03	3.40	1.16
4 (BYN-5&6)	Threshold (0.3 Max, 0.1 Avg.)	BWD LT	630	n/a		2.61	0.82	2.88	0.89
	Braidwood Bench Mark								
BWD-1&2	0.3" Threshold	BWD, Inc LT	412	1.50	0.65	1.83	0.77	2.03	0.81

Non-Burst Structural Limit for Maximum Voltage
Figure 1



Conclusion:

Non-Burst Structural Limit = 3.7 Volts

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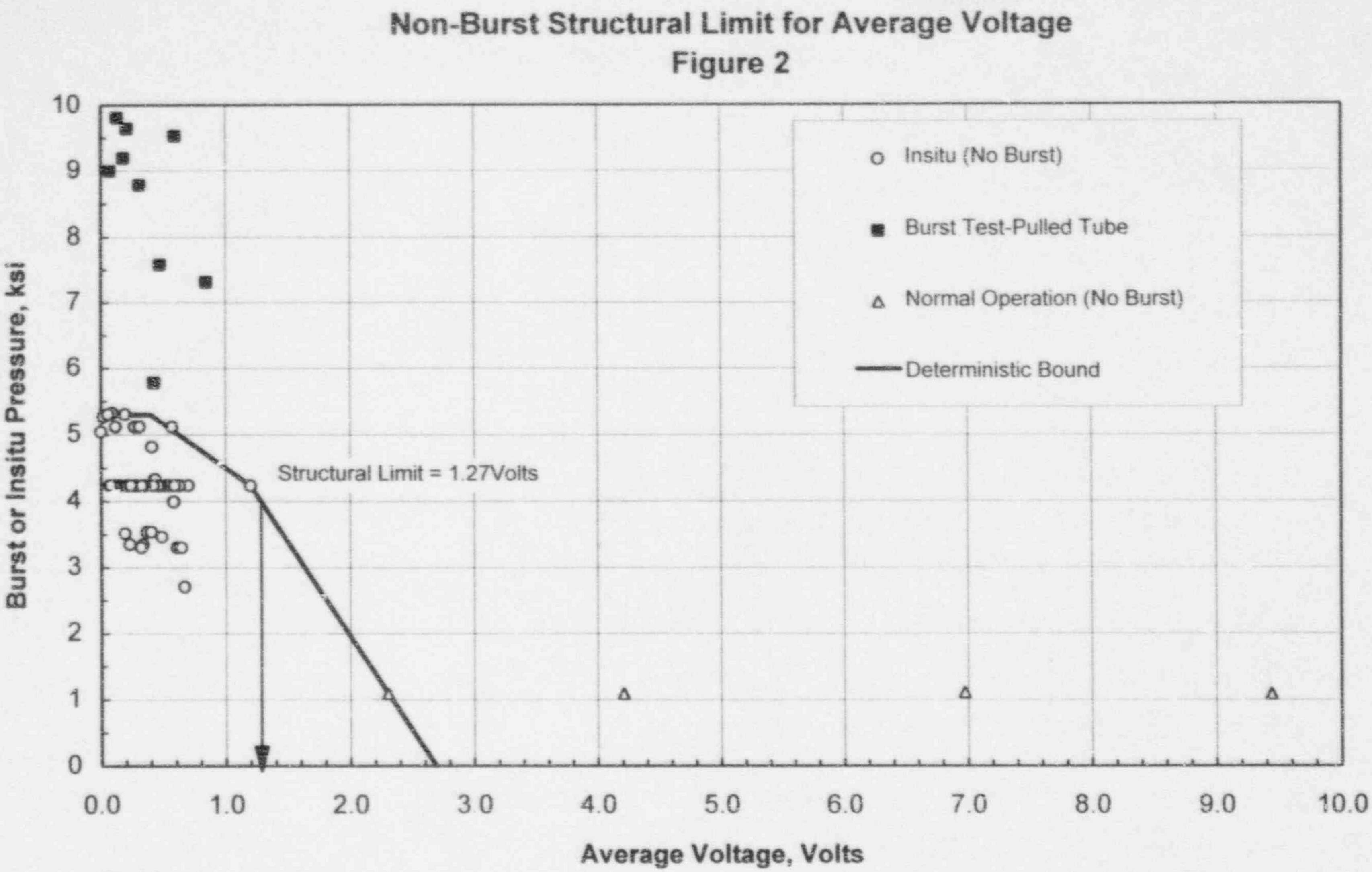

Conclusion:

Non-Burst Structural Limit = 1.27 Volts

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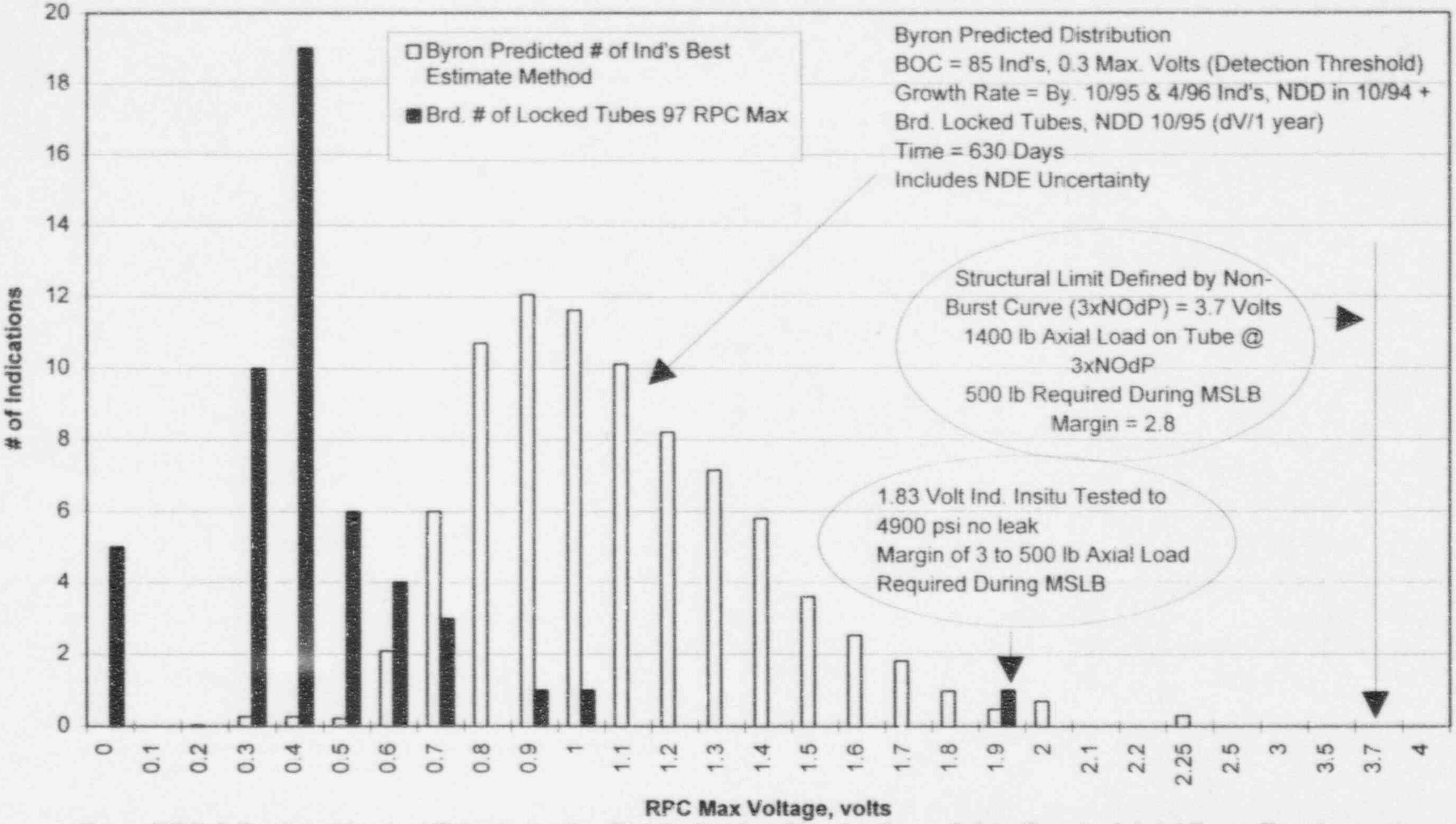
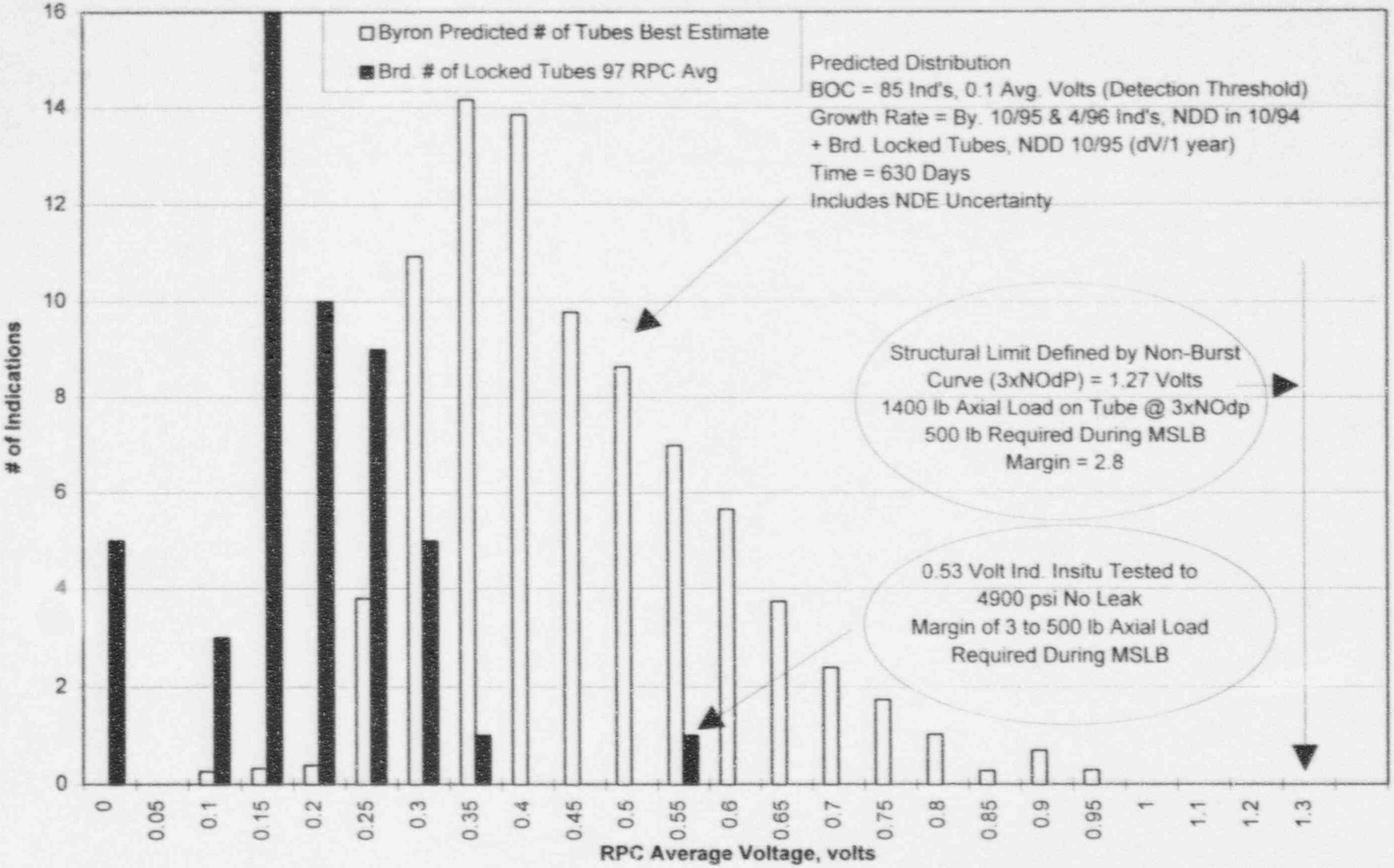
Byron Unit 1 EOC-8 Predicted Locked Tube Indication Distribution RPC Max Volts
Best Estimate
Figure 3



Byron EOC-8 Predicted Locked Tube Indication Distribution has Margin of over 2.8 to Required Axial Force Requirements

Byron Unit 1 EOC-8 Predicted Locked Tube Indication Distribution RPC Avg. Voltage
Best Estimate
Figure 4



Byron EOC-8 Predicted Locked Tube Indication Distribution has Margin of over 2.8 to Required Axial Force Requirements

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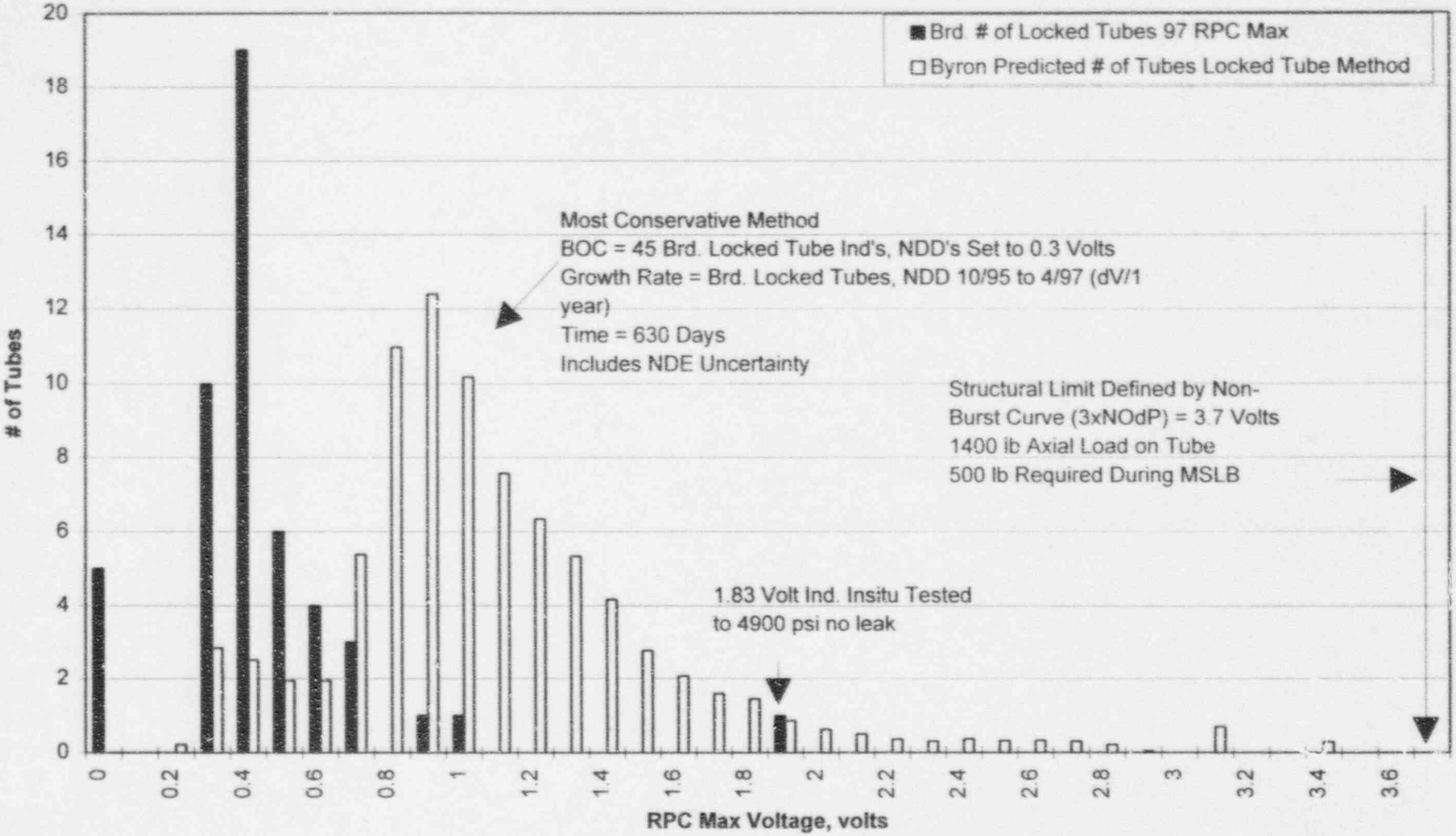
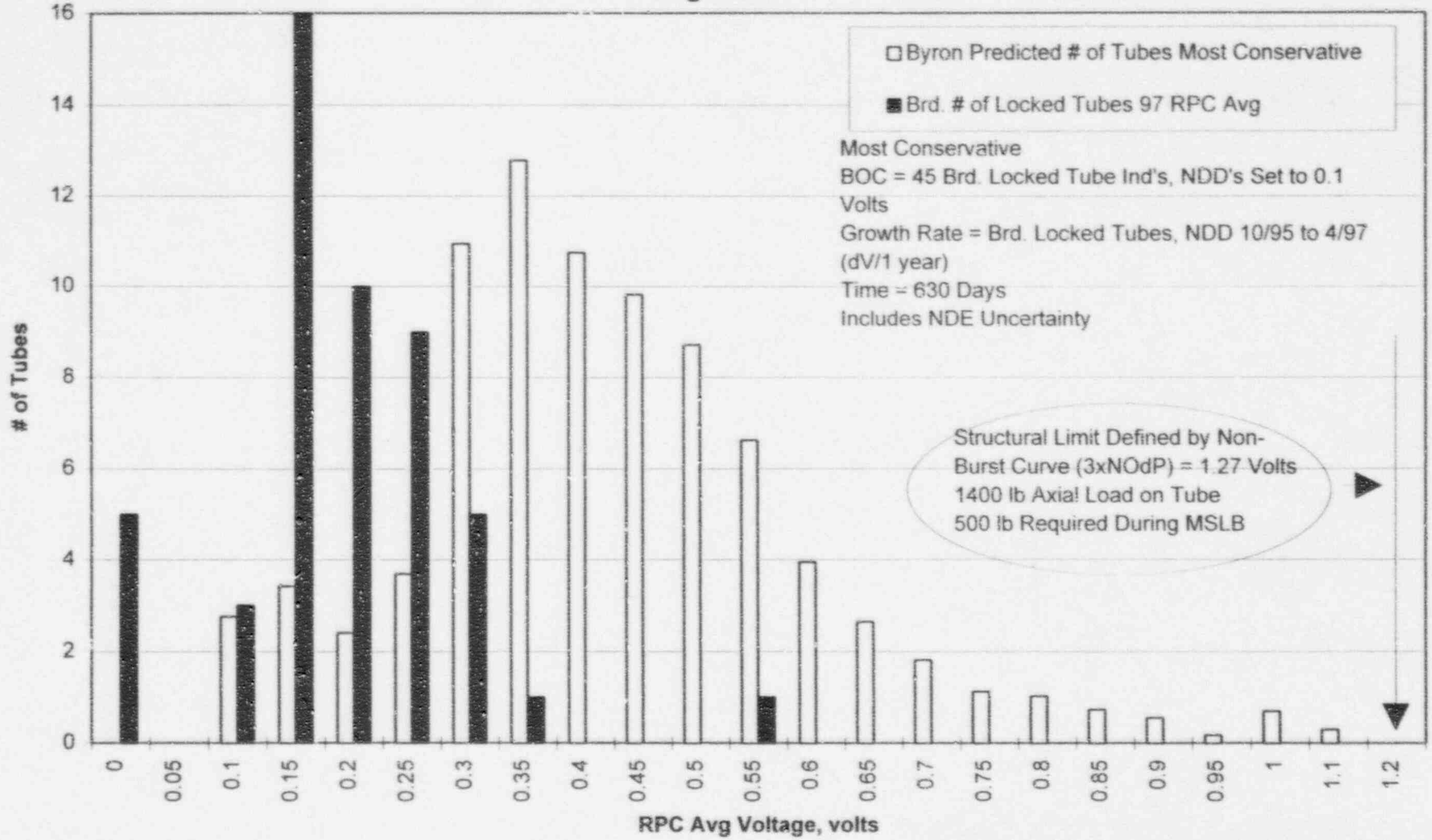
Byron Unit 1 EOC-8 Predicted Locked Tube Indication RPC Max Voltage, Most Conservative Method
Figure 5



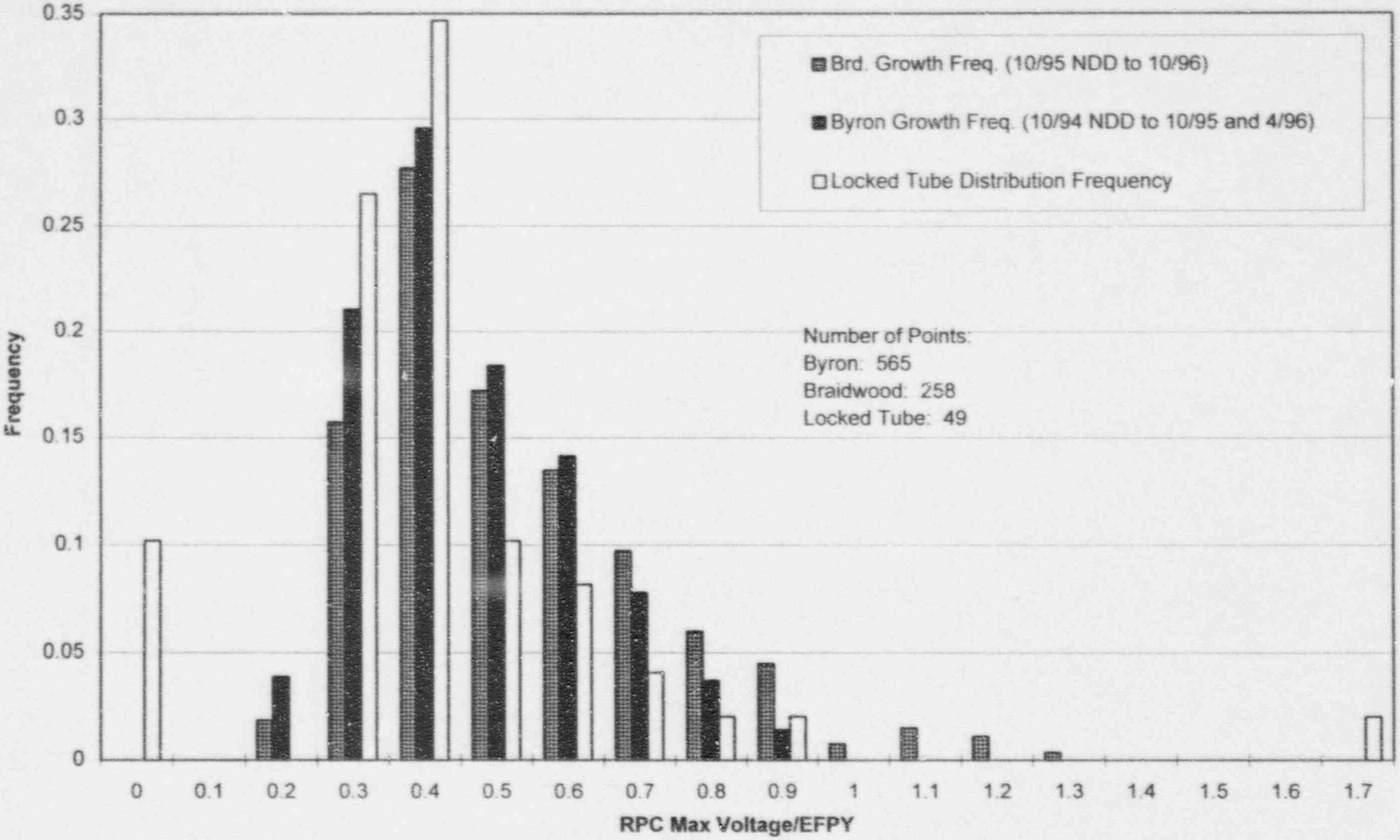
5/13/97 11:25 AM ~ME0D44.XLS FIG 5

Byron Unit 1 EOC-8 Predicted Locked Tube Indication Distribution RPC Avg. Voltage, Most Conservative Method

Figure 6



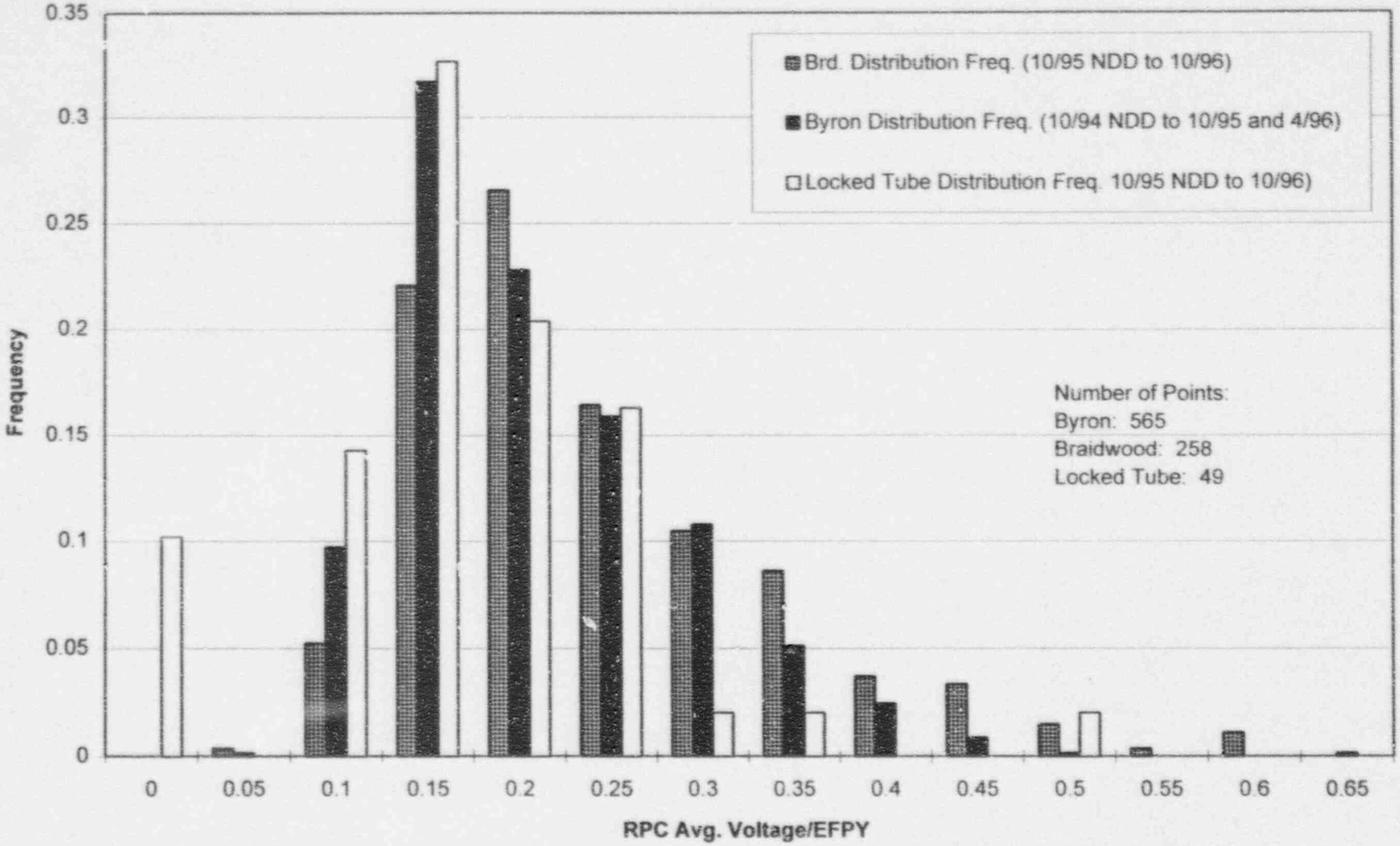
Byron and Braidwood ODSCC Circ. Crack Growth Rates Max Voltage (Ind's from NDD)
Figure 7



Byron and Braidwood Growth Rates are Comparable to Locked Tube Growth Rates
Braidwood Tail Reflects Larger Fast Growing Indications Removed From Service Last Outage
Byron Large Fast Growing Ind's Removed from Service in 1994 No Large Ind's Detected 10/95 or 4/96

5/13/97 11:12 AM ~ME1823.XLS Fig 7

Byron and Braidwood ODSCC Circ. Crack Growth Rates Avg. Voltage (Ind's from NDD)
Figure 8



Byron and Braidwood Growth Rates are Comparable to Locked Tube Growth Rates
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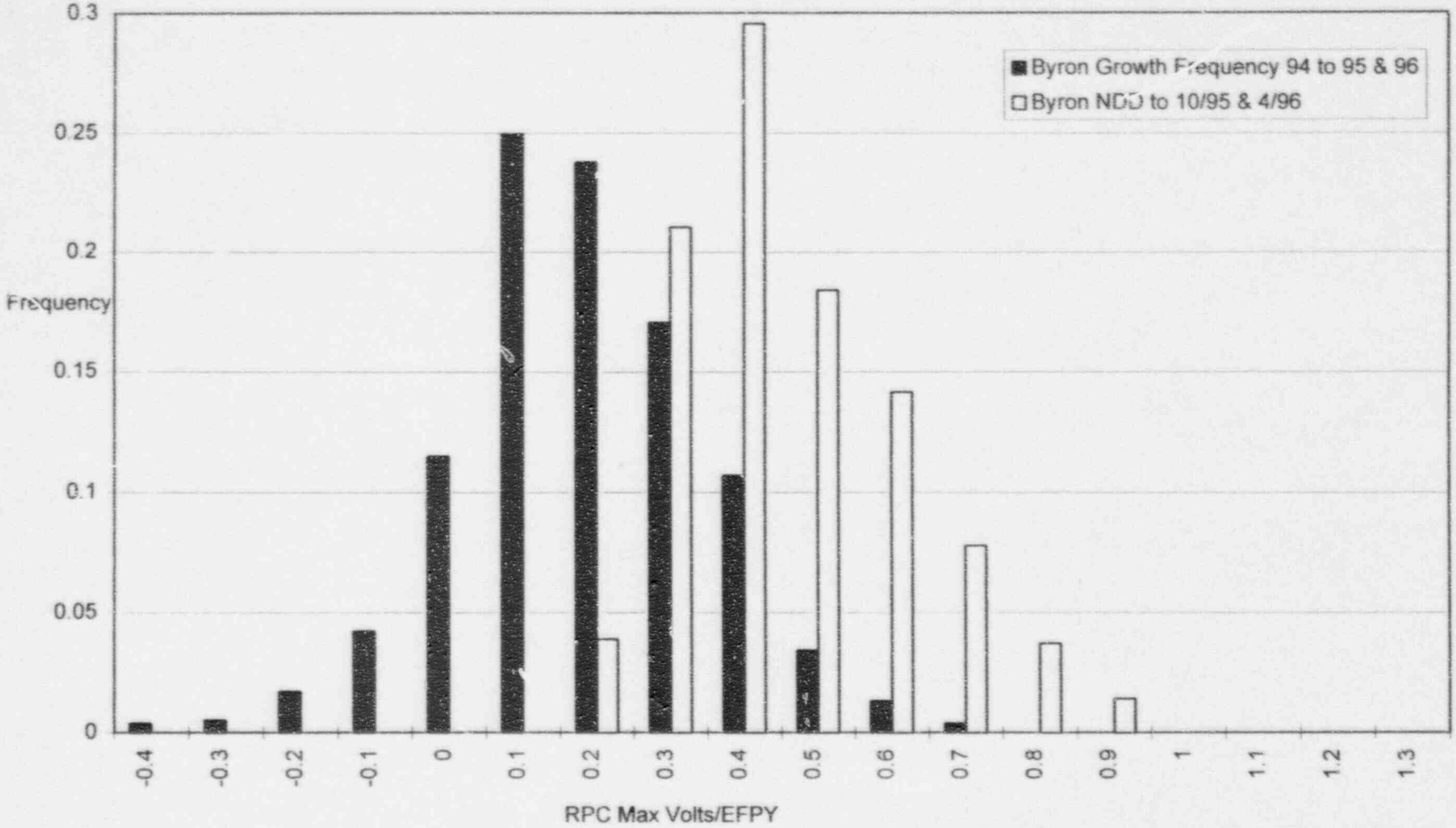
5/13/97 11:12 AM ~ME1823.XLS Fig 8

Comparison of Byron 1994 to 1995 & 1996 Growth Rates vs. 1994 NDD to 1995 & 1996 Max Volts

Figure 9



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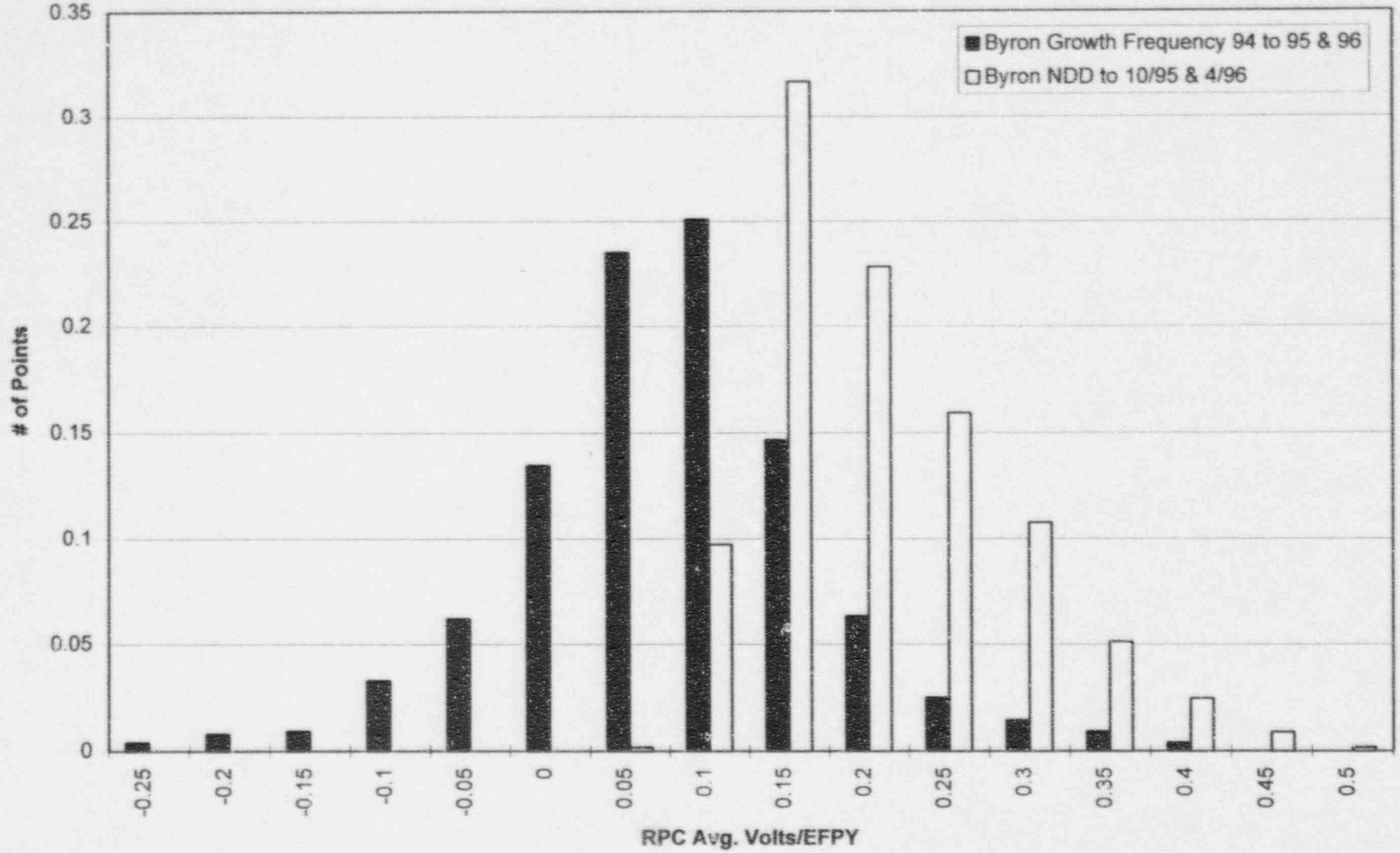
Comparison of Byron 1994 to 1995 & 1996 Growth Rates vs. 1994 NDD to 1995 & 1996 Average Volts

Figure 10



5/13/97 11:12 AM ~ME1257.XLS fig 10