



## **AREVA NP Inc.**

### **Engineering Information Record**

**Document No.:** 51 - 9168622 - 000

### **Sequoyah 2C17 W-Star 90-Day Report**



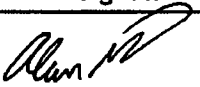


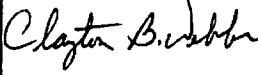
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## 1.0 INTRODUCTION

This report documents the results of the tubesheet inspections at Sequoyah Unit 2 (SQN2) relative to the W\* Alternate Repair Criterion (ARC). SQN2 has an approved W\* ARC for both the hot leg and cold tubesheet regions of the steam generator tubes. Although SQN2 does not use the ARC to leave tubes with indications in the W\* region in service, it does use the W\* methodology to limit the inspection scope and to calculate leakage from indications within the tubesheet.

The 2C17 inspection was the last scheduled inspection of the SQN2 steam generators. The steam generators are scheduled to be replaced during the 2C18 outage.

## 2.0 REPORTING REQUIREMENTS

Per the SQN2 Technical Specifications, the calculated steam line break leakage from the application of both the voltage-based ARC for support plate indications and the W\* inspection methodology shall be submitted to the NRC within 90 days of returning the steam generators to service (Mode 4). The condition monitoring and operational assessment leakage evaluations are provided in Sections 4.1 and 4.3, respectively.

In addition to reporting leakage, there are other reporting requirements specific to the W\* inspection methodology. Following is a list of these reporting requirements along with the section and/or table where these items are addressed in this report.

1. The number of indications within the tubesheet region – Section 3.0 and Table 3-1
2. The locations of the indications relative to the bottom of the WEXTEx transition (BWT) and the top of the tubesheet – Table 3-1
3. The orientation (axial, circumferential, skewed, or volumetric) of the indications – Section 3.0 and Table 3-1
4. The severity of the indications – Table 3-1 and Section 5.0
5. The origin of the indications (inside diameter or outside diameter) – Section 3.0 and Table 3-1
6. An assessment of whether the results were consistent with expectations with respect to the number and severity of flaws – Section 5.0

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### 3.0 INSPECTION RESULTS

This section provides a brief summary of the results of the eddy current inspections including quantity, location, and orientation of the detected indications. A list of the indications detected is provided in Table 3-1.

No evidence of tube slippage was observed on the hot leg or cold leg sides of the tubesheet. This was determined by reviewing the eddy current results for overexpansions located more than 0.5" above the top of the tubesheet. No such overexpansions were reported.

#### Hot Leg Inspection Results

The 2C17 inspection included +Point™ inspections of all in-service hot leg tubesheet locations with a minimum inspection extent of 2" above to 8" below the secondary face of the tubesheet. Eight tubes were identified as having expansion transitions more than 0.88" below the top of the tubesheet. As required by the W\* ARC, the +Point™ data for these tubes were reviewed to ensure that the inspection distance also included a minimum of 7.12" below the location of the expansion transition. Based on this review, none of the eight tubes with partial tubesheet expansions (PTEs) required re-inspection (i.e., the original tubesheet inspection extent also included a minimum of 7.12" below the PTE location). This is typical since the actual extent of data acquired is typically 1 to 2 inches greater than the target extent (i.e., with a target inspection extent of 8" below the top of the tubesheet, the actual extent acquired is typically in the 9" to 10" range below the top of the tubesheet). This is done to ensure that the minimum extent is acquired and to limit the number of retests required.

Table 3-1 provides a listing of all hot leg tubesheet indications detected during the inspection. This table only shows those indications located at or below the top of the tubesheet. ODSCC (Outer Diameter Stress Corrosion Cracking) indications located above the top of the tubesheet are not included in the table or in the W\* leakage evaluation. It should also be noted that this table includes all indications at or below the top of the tubesheet regardless of the location relative to the bottom of the WEXTEx transition (i.e., indications below the top of the tubesheet but above the transition are shown in the table and included in the leakage results documented herein).

As shown in the table, there were a total of 11 indications reported at or below the top of the hot leg tubesheet. All 11 of these indications were located within an inch of the top of the tubesheet. The 11 indications are categorized as follows: one indication was attributable to axial PWSCC (Primary Water Stress Corrosion Cracking), five indications were attributable to axial ODSCC, one indication was attributable to circumferential PWSCC, and four indications were attributable to circumferential ODSCC.

#### Cold Leg Inspection Results

The 2C17 inspection of the cold leg tubesheet included a 20% sample of the in-service tubes with +Point™ probes. The minimum inspection extent was from 2" above to 10.5" below the secondary face of the tubesheet. No tubes were identified as having expansion transitions more than 2.88" below the top of the tubesheet. Therefore, no tubes required additional testing below CTS -10.5".

No indications were detected in the initial 20% sample of the cold leg tubesheets. Therefore, no expansions of the cold leg tubesheet inspection scope were required.

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**Table 3-1: Indications Located At or Below the Top of the Tubesheet**

SG	Row	Col	Ind*	Ind Location	BWT** Location	Volts	Length (inches or degrees)	Depth	Characterization
SG22	6	31	SCI	HTS -0.05"	HTS -0.39"	0.83	23°	49%TW	Circumferential PWSCC
SG22	8	76	SCI	HTS -0.02"	HTS -0.30"	0.35	32°	NA	Circumferential ODSCC
SG22	22	28	SAI	HTS -0.06"	HTS -0.45"	0.17	0.15"	NA	Axial ODSCC
SG22	22	28	SAI	HTS -0.08"	HTS -0.45"	0.13	0.12"	NA	Axial ODSCC
SG22	23	69	SCI	HTS -0.04"	HTS -0.29"	0.17	40°	NA	Circumferential ODSCC
SG22	30	54	SCI	HTS -0.14"	HTS -0.47"	0.15	20°	NA	Circumferential ODSCC
SG23	1	67	SAI	HTS -0.44"	HTS -0.28"	0.35	0.12"	61%TW	Axial PWSCC
SG23	18	51	SAI	HTS +0.00"	HTS -0.36"	0.17	0.15"	NA	Axial ODSCC
SG23	19	48	SAI	HTS -0.29"	HTS -0.46"	0.94	0.18"	100%TW	Axial ODSCC
SG24	6	32	SCI	HTS -0.01"	HTS -0.29"	0.14	59°	57%TW	Circumferential ODSCC
SG24	27	41	SAI	HTS -0.26"	HTS -0.36"	0.16	0.18"	NA	Axial ODSCC

\* SAI = Single Axial Indication  
SCI = Single Circumferential Indication

\*\* BWT = Bottom of WEXTEx Transition

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## 4.0 LEAKAGE RESULTS

This section provides both the condition monitoring (CM) and operational assessment (OA) leakage for both the hot leg and cold leg tubesheet regions. This section also provides a comparison of the 2C17 CM leakage to the leakage predicted from the prior OA. Summaries of the leakage calculations are included in Tables 4-1 and 4-2. These tables also include the calculated leakage from the voltage-based ARC for ODSCC at TSPs and leakage from other sources. The leakage from other sources is a calculated leakage to account for leak-limiting plugs that are installed in the SQN2 steam generators. As shown in the tables, both the CM and OA leak rates are below the SQN2 postulated steam line break limit of 3.7 gpm.

### 4.1 Condition Monitoring Leakage

This section provides the condition monitoring leakage under postulated steam line break (SLB) conditions. Table 4-1 provides the condition monitoring (CM) leakage summary as well as a comparison to the leakage predicted from the prior operational assessment.

In general, the leakage calculations for indications within the tubesheet region are comprised of three separate components. Indications in the W\* region are one component. Postulated indications in the region below the W\* region but within 12" of the top of the tubesheet are another component. The third component includes postulated indications more than 12" below the top of the tubesheet. The postulated leakage for these regions is discussed separately for both hot leg and cold leg tubesheet indications.

#### Hot Leg: W\* Region

For indications detected in the upper 8 inches of the tubesheet on the hot leg side, the leakage is based on the distance below the BWT. For 2C17, all tubesheet indications were within 1" of the top of the tubesheet. Per Reference [1], which is based on Revision 2 of WCAP-14797, indications within 1" of the BWT should be assumed to leak at a rate of 0.05 gpm. Some of the reported tubesheet indications were above the BWT. These indications were also included in the leakage evaluation at a leak rate of 0.05 gpm.

#### Hot Leg: 8" to 12" Below Top of Tubesheet

Since the region below the W\* region is not required to be inspected, a postulated number of undetected indications is assumed. For the region of tubing from 8" to 12" below the top of the tubesheet, the postulated number of indications is based on the cumulative number of indications reported from 0" to 8" below the top of the tubesheet. Including indications reported during the 2C17 inspection, a total of 176 indications have been reported in this region. Per the W\* methodology, it is assumed that 25% of this total number of indications is present in each of the four steam generators in the 8" to 12" region. These postulated indications are assumed to leak at a rate of 0.0045 gpm.

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#### Hot Leg: More Than 12" Below Top of Tubesheet

For the region of tubes more than 12" below the top of the tubesheet, all in-service tubes are assumed to leak at a rate of 0.00009 gpm.

#### Cold Leg: W\* Region

During the 2C17 outage, no cold leg tubesheet indications were detected in any of the four steam generators. Since the initial sample included 20% of the in-service tubes in each steam generator, the W\* methodology requires that four indications be assumed to be present in each steam generator to account for indications that may be present in the uninspected tube populations. These four indications are all conservatively assigned the leak rate for indications within 1" of the BWT (0.05 gpm).

#### Cold Leg: 10.5" to 12" Below Top of Tubesheet

For the region of tubing from 10.5" to 12" below the top of the tubesheet, the postulated number of indications is based on the cumulative number of indications reported from 0" to 10.5" below the top of the tubesheet. A total of 4 indications have been reported in this region (all from the 2C16 outage). Per the W\* methodology, it is assumed that 10% of this total number of indications is present in each of the four steam generators in the 10.5" to 12" region. Similar to what was done for the 2C16 report, since 10% of four indications gives 0.4 indication per steam generator, no indications were assumed to be present in this region.

#### Cold Leg: More Than 12" Below Top of Tubesheet

For the cold leg tubesheet region more than 12" below the top of the tubesheet, the postulated number of tubes with indications is different than the hot leg since no cold leg tubesheet indications were detected. Per the W\* methodology, since no indications were detected during the 2C17 inspection, only the in-service Row 1 tubes that have been deplugged and returned to service are assumed to have indications in this region. It should be noted that no other tubes at SQN2 have been deplugged and returned to service. The in-service Row 1 tubes are assumed to leak at a rate of 0.00009 gpm.

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**Table 4-1: Condition Monitoring Leakage**

Degradation Category	CM Leakage (gpm at MSLB)				Prior OA Leakage (gpm)
	SG21	SG22	SG23	SG24	
GL 95-05 ARC Leakage	0.108	0.118	0.227	0.427	1.67
W* 0"-8" Hot Leg Leakage	0	0.3	0.15	0.1	0.221
W* 8"-12" Hot Leg Leakage	0.198	0.198	0.198	0.198	0.174
W* >12" Hot Leg Leakage	0.296	0.286	0.289	0.288	0.296
W* 0"-10.5" Cold Leg Leakage	0.2	0.2	0.2	0.2	0.052
W* 10.5"-12" Cold Leg Leakage	0	0	0	0	0
W* >12" Cold Leg Leakage	0.006	0.005	0.006	0.007	0.296
All Other Sources	0.001	0.001	0.001	0.001	0.1
Total Leakage	0.809	1.108	1.071	1.221	2.809

#### 4.2 Comparison of CM Leakage to Predicted Leakage

As shown in Table 4-1, the total 2C17 CM leakage was bounded by the total leakage predicted in the prior OA. However, in some specific cases, the 2C17 CM leakage exceeded the leakage predicted by the prior OA.

For hot leg leakage in the W\* region (0" to 8" below TTS), the CM leakage for SG22 (0.3 gpm) exceeded the prior OA leakage of 0.221 gpm. Therefore, adjustments were made to the method used to project OA leakage in this region. These adjustments are discussed in Section 4.3.

The hot leg leakage for the 8" to 12" category also exceeded the value from the prior OA. The leakage in this region is based on the number of hot leg tubesheet indications reported to date. Due to an error in the number of historical indications used in the prior OA, the CM leakage in this region was underpredicted. This error has been corrected. This correction is also reflected in the OA projection provided in Section 4.3.

The cold leg CM leakage in the W\* region also exceeded the leakage from the prior OA. As explained below, this is more reflective of the process for calculating CM leakage than an underprediction of the number of indications detected. Implementation of the cold leg W\* requires a minimum 20% sample inspection of the in-service tubes. Per the approved W\* methodology, if no indications are detected during the initial 20% sample, then four indications are assumed to be present in the remaining, uninspected population for each steam generator. These indications are conservatively assumed to leak at the rate associated with an indication within 1" of the BWT (or 0.05 gpm). Therefore, the CM leakage for 2C17, with no indications detected, is 0.2 gpm for each

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steam generator. During the previous (2C16) inspection, the inspection scope was expanded to include all in-service tubes based on the findings in the original 20% sample. Since indications were detected during 2C16 and the scope was expanded to include all in-service tubes, a different method of projecting conditions for 2C17 was used. The prediction of 2C17 conditions was based on the assumed undetected indications at 2C16. The locations and quantities of the assumed undetected indications were based on the locations and quantities of the indications detected during the 2C16 inspection. Using this method, as documented in Reference [2], yielded an OA projection of 0.052 gpm for 2C17 conditions. As seen in the table, this is less than the 0.2 gpm CM leakage when no indications are detected. To avoid this underprediction in the future, the OA projection for this region will be the greater of 0.2 gpm (when no indications are detected) or the leakage determined from the assumed undetected population (as was done in 2C16).

### 4.3 Operational Assessment Leakage

This section provides the operational assessment (OA) leakage under postulated steam line break (SLB) conditions for the postulated worst steam generator. These results are provided in Table 4-2.

Similar to the CM, the leakage calculations for indications within the tubesheet region are comprised of three separate components. The postulated OA leakage for these regions is discussed separately for both hot leg and cold leg tubesheet indications.

#### Hot Leg: W\* Region

As shown in Table 4-1, the prior operational assessment from Reference [2] slightly underestimated the 2C17 condition monitoring leakage for this region. Therefore, some adjustments were made to the methods used to determine the OA leakage. As discussed in Reference [2], the prediction of 2C17 conditions was based on an assumed population of undetected indications using a probability of detection (POD) of 0.6. However, this method did not include any allowance for newly-initiated indications. Therefore, the OA prediction documented herein will apply a POD of 0.6 to the detected population of tubes and will also include an allowance for newly-initiated indications.

Based on the 2C17 inspection results, SG22 had the highest CM leakage of 0.3 gpm. This CM leakage was based on 6 indications located near the top of the tubesheet with each indication assigned a leak rate of 0.05 gpm. For the OA projection of 2C18 indications, it will be assumed that the worst steam generator will have six indications initiate during Cycle 18 with all six indications located within 1 inch of the BWT (Bottom of the WEXTEx Transition). The assumption of six indications located near the BWT is deemed to be conservative based on a review of previous inspection results. In addition, it will be assumed, based on a POD of 0.6, that four indications were present, but not detected during the 2C17 inspection. These undetected indications will also be assumed to be located within 1 inch of the BWT. This gives an OA projection of 10 indications located within an inch of the BWT giving a leak rate of 0.5 gpm (10 indications x 0.05 gpm each).

In order to benchmark this methodology, this same logic was applied to the 2C16 results. Using this same logic, the 2C17 projected leakage in this region would have been 0.37 gpm which bounds the limiting 2C17 CM leakage of 0.3 gpm. Therefore, this updated method is considered to be conservative and appropriate.

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Hot Leg: 8" to 12" Below Top of Tubesheet

As discussed in Section 4.1, the postulated number of indications in this region is based on the cumulative number of indications reported from 0" to 8" below the top of the tubesheet. Through the 2C17 inspection, 176 indications have been detected in this region. For the OA projection of 2C18 conditions, a projection of the number of indications (in the 0" to 8" region) at 2C18 must be made. For this projection, a linear regression of the cumulative number of indications for the 2C8 through the 2C17 inspections was performed. Extending this regression line to 2C18 yields a projection of 195 cumulative indications through 2C18. This gives an estimated 48.75 cumulative indications per steam generator in the 8" to 12" region. Rounding this number to 49 indications and multiplying by the leak rate of 0.0045 gpm gives an OA leak rate of 0.221 gpm in each steam generator.

Hot Leg: More Than 12" Below Top of Tubesheet

For the region of tubes more than 12" below the top of the tubesheet, all tubes returned to service for Cycle 18 are assumed to leak at a rate of 0.00009 gpm. The value shown in Table 4-2 is the number for the least plugged steam generator since this will give the highest leak rate.

Cold Leg: W\* Region

As discussed in Section 4.2, the CM leakage for this region exceeded the projection from the prior OA. This underprediction was due to the difference in the way the leakage calculations are performed when indications are detected as compared to when no indications are detected. Also as discussed in Section 4.2, to avoid this underprediction in the future, the OA projection for this region will be the greater of 0.2 gpm (when no indications are detected) or the leakage predicted based on the assumed undetected population.

Only four indications have been detected in this region to date. All four of these indications were detected in the 2C16 inspection which was the first +Point™ inspection of the cold leg tubesheet region. Since no additional indications were detected in 2C17 based on an inspection of 20% of the in-service tubes, no indications are expected at 2C18 (if an inspection is required). Even if an inspection is required at 2C18 and cold leg tubesheet indications are detected, no more than four indications would be expected in any one steam generators based on previous inspection results. Therefore, the OA leakage will be conservatively set to 0.2 gpm as discussed above.

Cold Leg: 10.5" to 12" Below Top of Tubesheet

As discussed in Section 4.1, the postulated number of indications in this region is based on the cumulative number of indications reported from 0" to 10.5" below the top of the tubesheet. Through the 2C17 inspection, four indications have been detected in this region. As discussed above, based on a review of past inspection results, no new indications are expected in the cold leg W\* region at 2C18. Therefore, the total cumulative population of indications through 2C18 is projected to remain at four indications.

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Per the W\* leakage methodology, it is assumed that 10% of this total number of indications is present in each of the four steam generators in the 10.5" to 12" region. Similar to what was done for the 2C16 report, since 10% of four indications gives 0.4 indication per steam generator, no indications were assumed to be present in this region at 2C18.

#### Cold Leg: More Than 12" Below Top of Tubesheet

For the cold leg tubesheet region more than 12" below the top of the tubesheet, the postulated number of tubes with indications is different than the hot leg since no indications were detected during the 2C17 inspection. Per the W\* methodology, since no indications were detected during the 2C17 inspection, only the Row 1 tubes that have been unplugged and returned to service are assumed to have indications in this region. It should be noted that no other tubes at SQN2 have been unplugged and returned to service. For the OA, the Row 1 tubes that were returned to service for Cycle 18 are assumed to leak at a rate of 0.00009 gpm. Since SG24 has the most Row 1 tubes returned to service (78 tubes), this steam generator will give the highest OA leakage for this region of 0.007 gpm (78 x 0.0009).

**Table 4-2: Operational Assessment Leakage**

Degradation Category	Postulated Worst SG (gpm)
GL 95-05 ARC Leakage	1.24
W* 0"-8" Hot Leg Leakage	0.5
W* 8"-12" Hot Leg Leakage	0.221
W* >12" Hot Leg Leakage	0.295
W* 0"-10.5" Cold Leg Leakage	0.2
W* 10.5"-12" Cold Leg Leakage	0.05
W* >12" Cold Leg Leakage	0.007
All Other Sources	0.001
Total Leakage	2.514

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## 5.0 ASSESSMENT OF SEVERITY AND NUMBER OF FLAWS

As discussed in Section 2.0, implementation of the W\* ARC requires that an assessment of the quantity and severity of the flaws be provided. In addition, an assessment of whether the results of the inspection were consistent with expectations must also be provided. This section provides these assessments.

As shown in Table 3-1, eleven indications of stress corrosion cracking were reported at or below the top of the tubesheet. Per the previous operational assessment [2], a total of 13 indications were projected for 2C17. Therefore, the quantity of indications detected during the 2C17 inspection is bounded by the prior OA. This quantity is also consistent with the number of hot leg tubesheet indications (ten) detected during the 2C16 inspection.

The severity of the indications was evaluated relative to both CM limits and expectations based on previous inspection results. Per the EPRI Steam Generator In Situ Pressure Test Guidelines [3], the first screen for both structural and leakage integrity is based on eddy current voltage. It should be noted that, even though some of the indications are wholly contained within the tubesheet and restricted from burst, this assessment evaluates all 11 indications for structural integrity as if they were located in the freespan and received no reinforcing effect from the tubesheet. For structural integrity, the initial voltage screening value is 0.4v for axial flaws and 0.5v for circumferential flaws. As shown in Table 3-1, one axial indication and one circumferential indication exceeded the initial screening voltages. Both of these indications were subsequently depth-sized. The axial indication in Tube 19-48 in SG23 had a measured depth of 100%TW and a measured length of 0.18". Based on the short measured length, this flaw would not be a structural integrity concern even if it was located in a freespan region of the tube. The circumferential indication in Tube 6-31 in SG22 had a measured depth of 49%TW and a measured length of 23 degrees. With a PDA (Percent Degraded Area) of less than 5%, this indication also doesn't present a structural concern.

The initial voltage screen for leakage integrity is specific to the type of degradation and the tubing dimensions. None of the indications detected exceeded the threshold voltages above which in situ testing may be required to show leakage integrity.

Based on the above discussion, none of the indications detected during the 2C17 inspection presented structural or leakage concerns.

To assess whether the results are consistent with expectations, a comparison of the 2C17 results to the results from 2C16 was performed. During the previous inspection (2C16), a total of 10 hot leg tubesheet indications were detected. A review of the voltages of the 2C16 indications shows that the largest voltage was 0.72v. This was for an axial PWSCC indication located near the top of the tubesheet. In addition, there were five other 2C16 indications (both axial and circumferential) with voltages of 0.40v or greater. These voltages are consistent with the 2C17 voltages shown in Table 3-1. Therefore, it is concluded that the severity of the flaws is consistent with the expectations for indications in the tubesheet region.

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### 6.0 CONCLUSIONS

In conclusion, the inspection and assessment requirements associated with implementation of the W\* ARC have been met and are documented in this report.

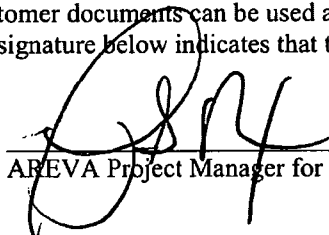
The total CM and OA leak rates under postulated steam line break conditions are below the SQN2 limit of 3.7 gpm. However, during comparison of the 2C17 CM leak rates to the leak rates projected from the prior OA, it was noted that the leak rate was underpredicted in some cases. Therefore, corrective actions were taken in preparation of the OA projections documented in Section 4.3.

The severity of the indications detected during 2C17 was compared to the indications detected during 2C16. Based on this comparison, it was concluded that the inspection results were consistent with expectations.

### 7.0 REFERENCES

1. TVA Surveillance Instruction for Sequoyah Unit 2, Document Number 2-SI-SX1-068-114.3, "Steam Generator Tubing Inservice Inspection and Augmented Inspections", Revision 0015.
2. Letter from TVA to the NRC, "Unit 2 Cycle 16 – 90 Day Steam Generator Report for Voltage-Based Alternate Repair Criteria and W\* Alternate Repair Criteria", NRC ADAMS Accession Number ML100550767, February 2009.
3. EPRI Report 1014983, "Steam Generator In Situ Pressure Test Guidelines, Revision 3", August 2007.

Note: Reference 1 is a TVA procedure that is not available in the AREVA Records Center. Per AREVA procedure 0402-01, customer documents can be used as references with the Project Manager's approval. The Project Manager's signature below indicates that this TVA document can be used as a valid reference.



9.12.11  
\_\_\_\_\_  
AREVA Project Manager for Sequoyah Unit 2