



UNITED STATES
NUCLEAR REGULATORY COMMISSION

WASHINGTON, D.C. 20555-0001

May 3, 2000

LICENSEES: Tennessee Valley Authority

FACILITIES: Watts Bar Nuclear Plant, Unit 1

SUBJECT: SUMMARY OF FEBRUARY 9, 2000 MEETING ON REACTOR VESSEL
SURVEILLANCE SPECIMEN TESTING (TAC No. M89606)

On February 9, 2000, members of the U.S. Nuclear Regulatory Commission (NRC) staff met with representatives of the Tennessee Valley Authority (TVA), to discuss TVA's response, dated May 27, 1999, to the reactor vessel surveillance specimen J-R testing issue from Supplemental Safety Evaluation Report No. 14 (SSER-14) issued in December 1994 for the Watts Bar Nuclear Plant, Unit 1 (WBN). A list of attendees and a copy of TVA's presentation material is provided in the enclosures.

BACKGROUND

Section IV.A.1.a. of Title 10, *Code of Federal Regulations* (10 CFR) Part 50, Appendix G, requires that, "Reactor vessel beltline materials must have Charpy upper-shelf energy in the transverse direction for base material.....of no less than 75 foot-pounds (ft-lb) initially and must maintain Charpy upper-shelf energy throughout the life of the vessel of no less than 50 ft-lb, unless it is demonstrated in a manner approved by the Director, Office of Nuclear Reactor Regulation, that lower values of Charpy upper-shelf energy will provide margins of safety against fracture equivalent to those required by Appendix G of Section XI of the ASME [American Society of Mechanical Engineers] Code."

Prior to the issuance of the operating license for WBN, in the letters of July 7, 1992, and January 28, 1993, TVA indicated that the unirradiated upper-shelf energy (USE) value for the material used to fabricate reactor vessel forging 05 would be below 75 ft-lb, and projected that the end-of-life (EOL) USE value would be below 50 ft-lb. On October 15, 1993, TVA submitted an elastic-plastic fracture mechanics evaluation (equivalent margins analysis or EMA). The Westinghouse report attached to TVA's October 15, 1993 submittal indicated that the initial unirradiated USE would be 62 ft-lb and that the EOL USE would be 44 ft-lb.

The NRC staff's evaluation of the EMA in Section 5.3.1 SSER-14 reached the conclusions that the appropriate methodology, modeling procedures and acceptance criteria had been used and that margins of safety equivalent to those required by the ASME Code, Appendix G had been demonstrated. The NRC staff's conclusions also contemplated that further testing of compact fracture toughness specimens during the WBN reactor vessel surveillance program would provide verification of the EMA.

The results of the testing of the material from the first reactor vessel surveillance capsule (Capsule U), that was removed from the WBN reactor vessel during the Cycle 1 refueling outage, were submitted with a letter dated October 13, 1998. In response to further NRC staff review of that submittal, TVA stated in a letter dated May 27, 1999, that it had unintentionally omitted the additional J-R testing as documented in SSER-14. TVA proposed an alternate testing program that was based on further testing of unirradiated materials prior to further testing of irradiated compact fracture toughness specimens. The staff had reservations about the value of this proposal since the staff believes that, since the plant has now been operating for several cycles, the fracture toughness of the reactor vessel beltline materials would best be characterized by tests of irradiated material.

SUMMARY OF MEETING

TVA's presentation in this meeting summarized information to demonstrate that the WBN reactor vessel is in compliance with the NRC's regulations in Section IV of Appendix G to 10 CFR Part 50. TVA reviewed the requirements of Appendix G, the initial findings for forging 05 of an unirradiated Charpy USE of 62 ft-lb and an EOL USE of 43.4 ft-lb and the results of the equivalent margins analysis as discussed above.

In addition, TVA reviewed the irradiated Charpy USE data for forging 05, as developed from Capsule U which was removed from the vessel during the first refueling outage. The licensee's evaluation of the data, summarized in the attached slides, concludes that the EOL value of USE would not go below the Appendix G threshold value of 50 ft-lb. Additional data will be available from Capsule W, which is scheduled for removal in September 2000, with results scheduled to be available in October 2001. TVA concluded that based on Capsule U data, WBN is in compliance with 10 CFR Part 50, Appendix G, for at least 8.6 effective full power years (EFPY), whereas, as of September 2000, WBN will be at 4 EFPY. Additional analysis of forging 05 will be performed when the material in Capsule W is tested.

At the conclusion of the meeting, the NRC staff informed TVA that, at the present time, the staff considers WBN to be in compliance with the 10 CFR Part 50, Appendix G regulation. However, the staff expressed a concern regarding the unirradiated Charpy USE value of 62 ft-lb versus the Capsule U irradiated results. The NRC staff suggested that, in an attempt to add further understanding to this issue, TVA could review all fabrication and heat treatment records from the unirradiated and irradiated Charpy data to determine whether the unirradiated or the irradiated data best characterizes the WBN reactor vessel. If such a records search does not resolve the staff's concern about the 62 ft-lb Charpy data, TVA could resolve the staff's concern by verifying (e.g., conducting fracture toughness tests on compact test specimens) that the WBN forging 05 will have fracture toughness equivalent to that projected at EOL in the EMA.

The licensee was concerned that the irradiated compact fracture toughness specimens geometry was not in compliance with the American Society for Testing and Materials (ASTM) standard for fracture toughness testing and would not provide acceptable test results (TVA slide 8). The staff recommended that to respond to this concern, TVA may wish to (1) propose to the ASTM standard development committee that the WBN irradiated specimens geometry

and analysis method be incorporated into the ASTM standard, and, (2) submit the analysis method for staff review in accordance with Section III. B of Appendix G, 10 CFR Part 50.

With these discussions concluded, the meeting was closed.

/RA/

Robert E. Martin, Senior Project Manager, Section 2
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-390

- Enclosures: 1. Attendance List
- 2. TVA Handouts

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OFFICE	PDII-2\PM	PDII-2\LA	NRREMCB	PDII-2\SO	
NAME	RMartin	BClayton	WBateman	RCorreia	
DATE	04/13/00	04/11/00	04/17/00	04/12/00	04/10

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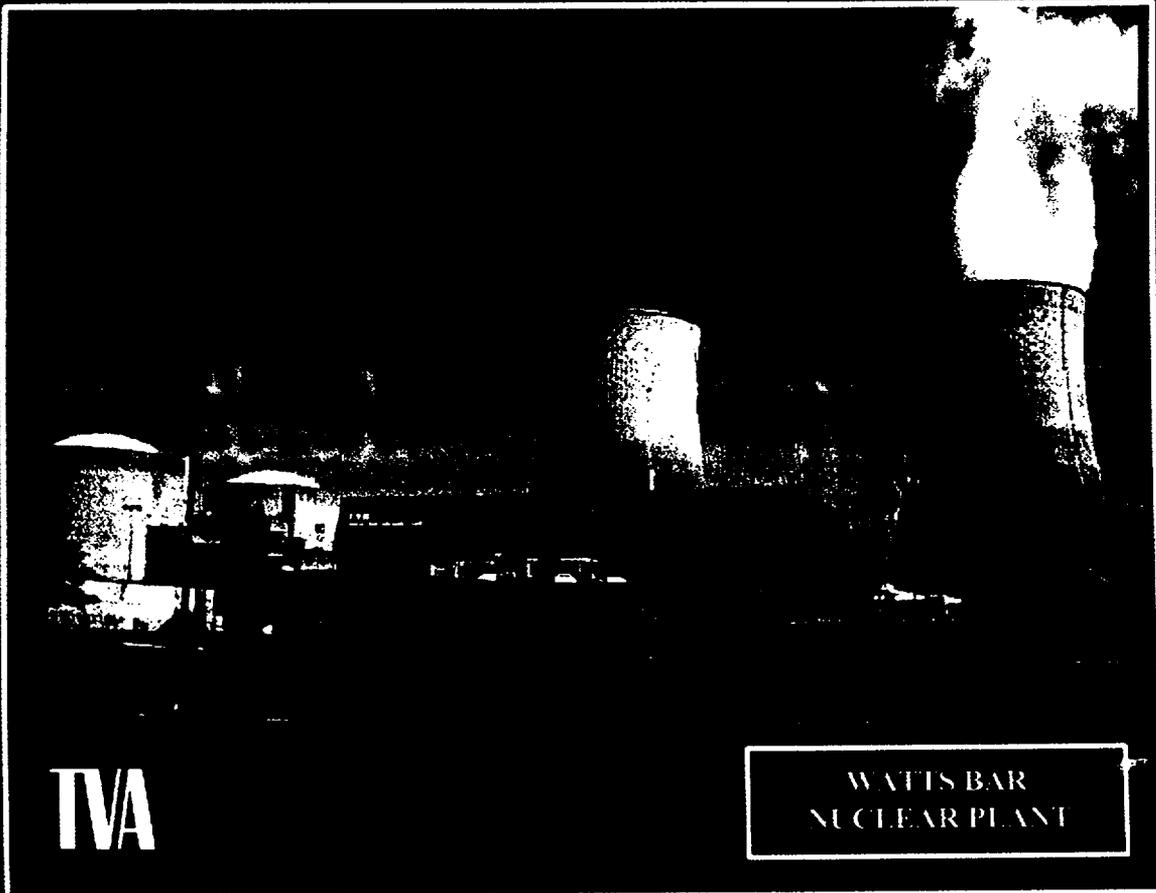
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ATTENDEES

MEETING OF FEBRUARY 9, 2000
WITH TVA

<u>NAME</u>	<u>ORGANIZATION</u>
Bob Martin	NRR/DLPM
Keith Wichman	NRR/DE/EMCB
Barry Elliot	NRR/DE/EMCB
Herb Berkow	NRR/DLPM
Jim Medoff	NRR/DE/EMCB
Warren Bamford	Westinghouse
Allen Hiser	NRR/DE/EMCB
John Kammeyer	TVA/Design Eng Manager
Robert Briggs	TVA/Design
Rebecca Mays	TVA/WBN Licensing
Paul Pace	TVA/WBN Licensing Mgr
Richard Correia	NRR/DLPM
W. H. Bateman	NRR/DE/EMCB

**TVA/NRC MEETING
REACTOR VESSEL INTEGRITY
J-R TESTING**



**FEBRUARY 9, 2000
1:00 P.M.
NRR HEADQUARTERS
ROCKVILLE, MARYLAND**

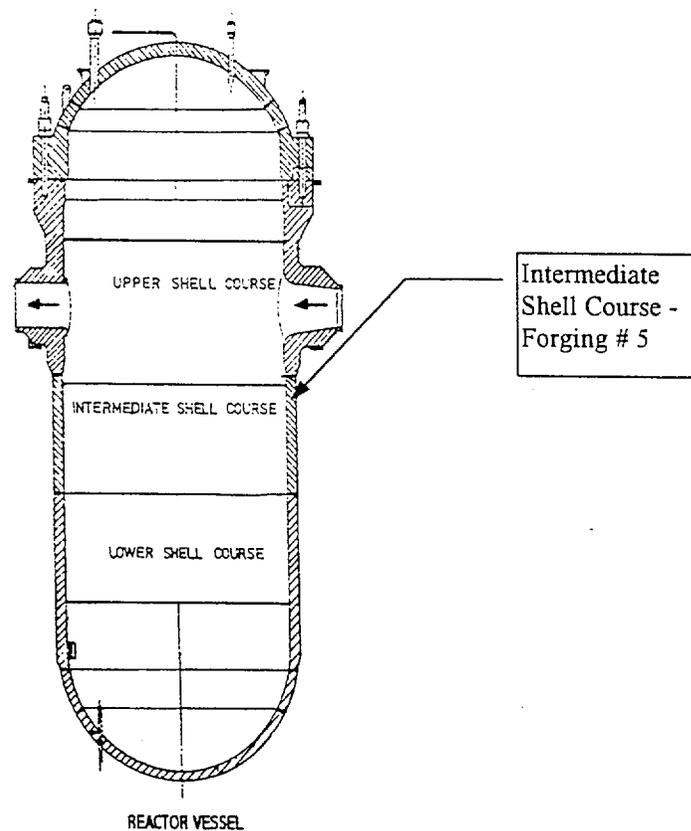
BACKGROUND

- REACTOR VESSEL
 - Built by Foreign Manufacturers
 - Forged by Fried. Krupp Huttenwerke AG.
 - Heat Treated by Rotterdam Dockyard Company.
 - A total of 10 US vessels built by this manufacturer.

Surry Units 1 and 2	Catawba Unit 1
Sequoyah Units 1 and 2	North Anna Units 1 and 2
Watts Bar Units 1 and 2	McGuire Unit 2
 - Built from ASTM Standard A508 Class 2 material - same as many other US built vessels
 - Constructed to Westinghouse E-Spec 676-413 Revision 2 (1969)
 - 10 CFR 50 Appendix G initial USE values issued July 7, 1973.
 - All of the above plants built to Westinghouse E-Spec Revision 2 or earlier.
 - E-Spec Rev. 2 had no specification for copper content.
 - Beltline material of WBN vessel has 0.17% copper content.- Not unusual for vessels manufactured at the time.
 - Vessel Code of Record - 1971 ASME Section III up to Winter 1971 Addendum

BACKGROUND (continued)

- REACTOR VESSEL (continued)
 - RG 1.99, Rev.2 analysis before initial licensing predicted base material at Intermediate Shell Forging 05 would be less than the 50 ft-lb upper shelf energy at end-of-life required by 10 CFR 50 Appendix G



BACKGROUND (continued)

- WBN SER (June 1982)

“The CVN impact tests from the material in the surveillance capsule will be used to establish limitations on the pressure and temperature of Unit 1 that will ensure that the intermediate shell forging’s material properties remain above the safety margins required by Appendix G, 10 CFR 50. In addition, the marginal upper shelf fracture toughness of this forging will be reevaluated using the improved engineering method and safety criteria developed under generic Task A-11. The staff has determined that an exemption from the minimum upper shelf energy requirements ... of Appendix G is justified.”
(page 5-11)

- Lower Shell Forging 04 within 10 CFR limits.
- Upper Shell Forging 06 within 10 CFR limits.
- Intermediate Shell Forging 05 below 10 CFR limits.
 - WBN Unit 1 Upper Shelf Energy value was 62 ft-lbs initially in the axial direction.
 - WBN Unit 1 Upper Shelf Energy value was predicted to be 43.4 ft-lbs end-of-life (EOL) in axial direction.
- NRC stated that an exemption to Appendix G was justified.

BACKGROUND (continued)

Exemption Request for Appendix G, IV.A.1

- TVA requested exemption in letter dated January 28, 1993
 - Provided surveillance capsule program.
 - Provided factors that indicated the predicted decrease may be conservative.
 - Noted WOG project underway to perform bounding analyses for Westinghouse Plants (later issued as WCAP-13587 and included WBN).
 - Committed that if results of 1st two capsules indicated the USE fell below acceptance criteria, TVA would perform necessary analysis required by Appendix G.

- Following a teleconference with NRC, TVA withdrew exemption request in a letter dated October 15, 1993.
 - Exemption no longer needed because of Appendix G rule change.
 - Provided an equivalent margin analysis based on the Westinghouse generic bounding analysis, WCAP-13587, which was later assessed by NRC and documented in letter dated April 21, 1994.
 - Analysis demonstrated that Charpy V-Notch (CVN) test result values as low as 43 ft-lb, would meet the acceptance criteria of the ASME Code, as contained in Code Case N512, and now also in Appendix K.

BACKGROUND (continued)

WBN SSER 14 (December 1994)

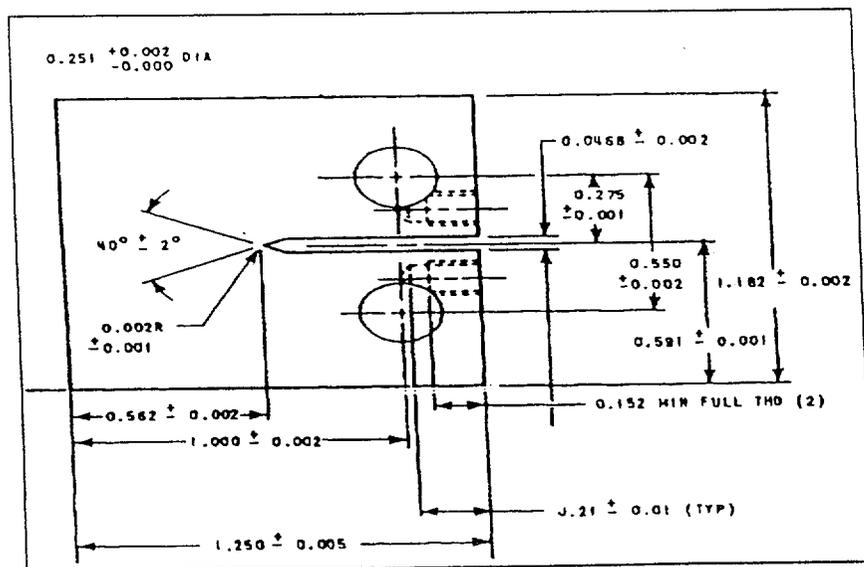
- Intermediate shell forging provides the margins of safety required in ASME Code. (pg 5-2)
- *“... the staff finds that the applicant has complied with all the requirements in the current Appendix G without exemption. Thus, the exemptions previously approved in SER are no longer needed.”* (pg 5-2)
- Staff requested: (1) that the analyses include any unirradiated or irradiated J-R curve data from forging 05 or J-R curve data from material similar to forging 05 ... (2) a description of the planned fluence management program... (pg 5-3)
 - TVA/Westinghouse representatives unaware of archived WBN vessel material to perform unirradiated J-R testing.
 - Surveillance program provided in the January 23, 1993 letter.
 - Surveillance program in accordance with 10 CFR 50, Appendix H using the guidance of ASTM E185.
- Staff performed independent analysis and stated methodology, modeling procedures, and acceptance criteria [of the Westinghouse equivalent analysis] fall within the scope of Draft Regulatory Guide DG-1023 (issued as RG 1.161, April 1995) and ASME Code Case N-512. (pg 5-9)

BACKGROUND (continued)

WBN SSER 14 (December 1994) OPEN ISSUE

The previously requested J-R curve data for forging 05 were not available. The staff understands that the applicant will submit this information when the first specimens are removed from the reactor vessel. The actual fracture toughness data from these specimens will be used to verify the equivalent margins analysis. (pg 5-9)

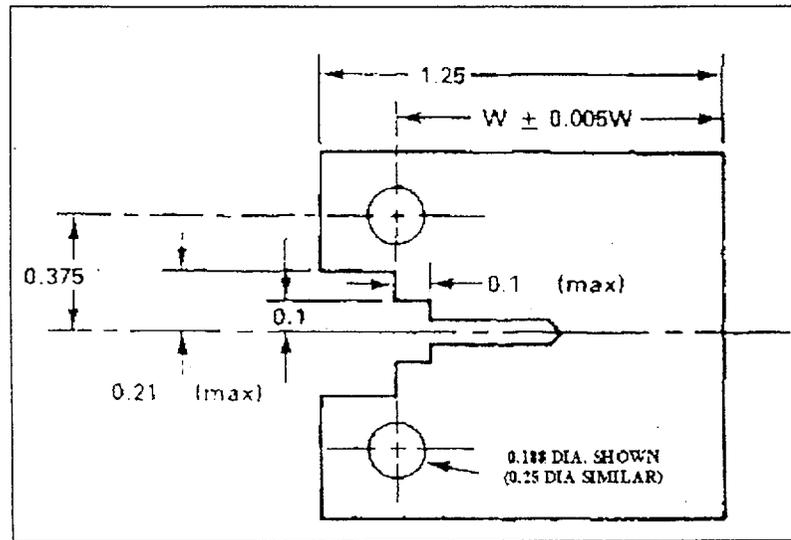
- Problems that have occurred.
 - Because TVA did not make a formal commitment to submit the J-R curve information the action was not tracked to completion.
 - WBN surveillance capsule CT coupons configured for testing in accordance with ASTM E399-1974.
 - TVA submitted analysis results from first specimen in accordance with 10 CFR 50 Appendix H.



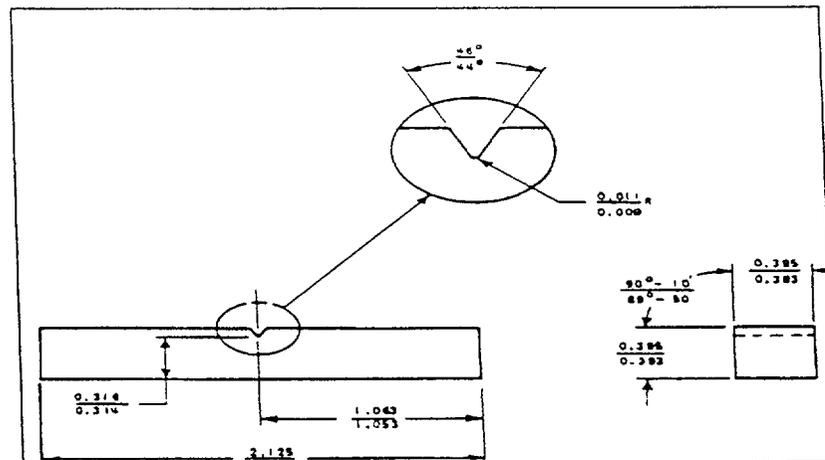
WBN CAPSULE U REMAINING CT SPECIMEN
CONFIGURATION

BACKGROUND (continued)

- J-R test coupons can not physically be configured from CT coupons to perform J-R curve testing according to today's best practice.



TYPICAL J-R TEST SPECIMEN



TYPICAL CHARPY V-NOTCH SPECIMEN

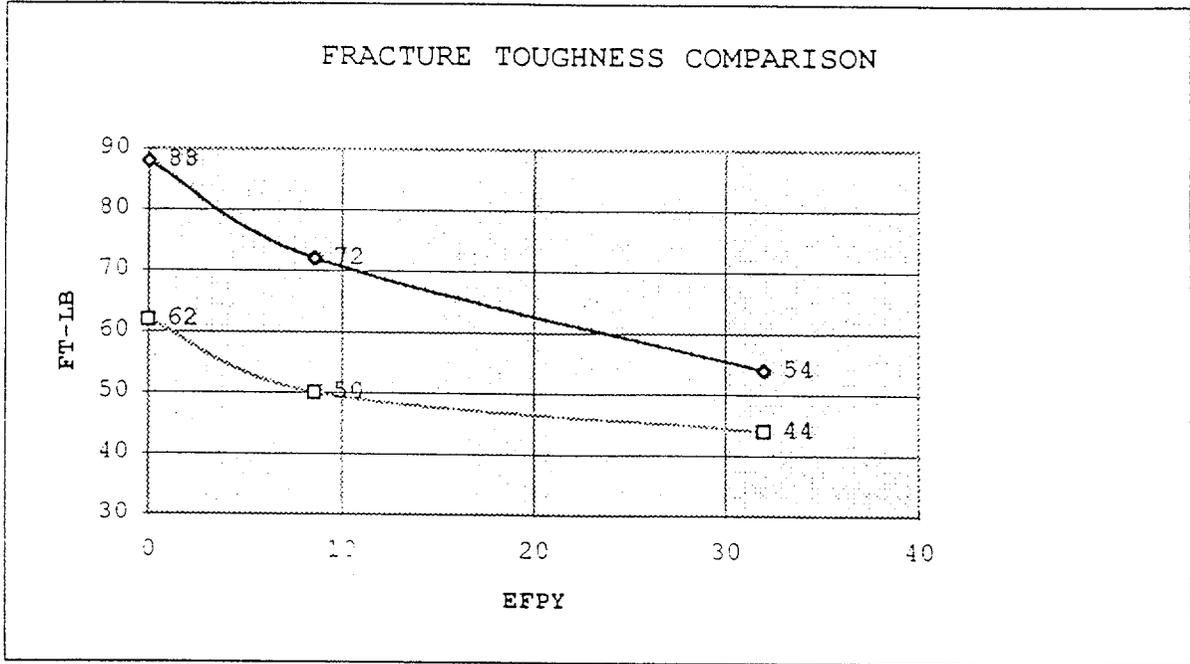
COMPLIANCE WITH 10 CFR 50, APPENDIX G

Appendix G Requirement - 1995

IV.A.1. - Reactor vessel beltline materials must have Charpy USE of no less than 75 ft-lb initially and must have maintain upper shelf energy [USE] throughout the life of the vessel of no less than 50 ft-lb, ...

- Supplementary testing of Forging 05 before service showed 62 ft-lb in the axial direction.
- RG 1.99 Rev. 2 analysis initially predicted 43.4 ft-lb EOL.
- Surveillance Capsule U CVN analysis shows USE to be 72 ft-lbs and 54 ft-lbs EOL.
- Surveillance Capsule U radiation level corresponds to 8.6 EFPY of vessel service.
- Surveillance Capsule U shows RG 1.99 Rev. 2 analysis to be conservative.
- Surveillance Capsule U shows WBN is in compliance with 10 CFR 50, Appendix G.

COMPLIANCE WITH 10 CFR 50, APPENDIX G
(continued)



TOP LINE

88 Ft-Lb at 0 EFPY based on 65% Rule of Tangential USE (132 Ft-Lb)

72 Ft-Lb at 8.6 EFPY based on Capsule U results

54 Ft-Lb at 32 EFPY based on projections from Capsule U

BOTTOM LINE

62 Ft-Lb at 0 EFPY based on unirradiated testing of non/quasi-representative material

50 Ft-Lb at 5.5 EFPY based on Reg Guide 1.99 Rev. 2 projections

44 Ft-Lb at 32 EFPY based on Reg Guide 1.99 Rev. 2 projections

COMPLIANCE WITH 10 CFR 50, APPENDIX G

Appendix G Requirement - 1995

V.B. - "Reactor vessels may continue to be operated only for that service period within which the requirements of Section IV of this appendix are satisfied using predicted value of the adjusted reference temperature and the predicted value of USE at the end of the service period to account for the effects of radiation on the fracture toughness of the beltline materials."

- Surveillance Capsule U shows that Section IV is still satisfied.
- WBN still in compliance with Appendix G.

COMPLIANCE WITH 10 CFR 50, APPENDIX G
(continued)

Appendix G Requirement - 1995

V.C - In the event that the requirements of Section V.B ... can not be satisfied, reactor vessels may continue to be operated provided all of the following requirements are satisfied:

3. An analysis is performed that conservatively demonstrates, making appropriate allowances for all uncertainties, the existence of equivalent margins of safety for continued operation.
- TVA provided equivalent margin analysis October 1993.
 - Equivalent margin of safety analysis indicates an acceptable margin of safety for Charpy USE as low as 43 ft-lbs.
 - Analysis used the correlations with CVN energy provided in NUREG/CR-5729, "Multivariable Modeling of Pressure Vessel and Piping J-R Data" to determine the J-R curve for the WBN vessel.
 - Model acceptable because sulfur content (0.016 wt-%) of forging 05 is less than 0.018 wt-%.
 - NRC noted in SSER approach was acceptable and was considered the more appropriate model.
 - NRC agreed that adequate margin of safety existed after performing their analysis using guidance in draft regulatory guide DG-1023 (Currently Regulatory Guide 1.161, issued June 1995).

COMPLIANCE WITH 10 CFR 50, APPENDIX G
(continued)

Appendix G Requirement - 1995

V.E - The proposed programs for satisfying the requirements of Sections V.C. and V.D. ... must be submitted, as specified in 50.4 for review and approval on the individual case basis at least three years prior to the date when the predicted fracture toughness levels will no longer satisfy the requirements of Section V.B.

- Actual data from the first surveillance capsule, Capsule U which was removed at the first refueling outage indicates that values will be above 50 ft-lbs at EOL.
- Second capsule, Capsule W will be removed in the 3rd refueling outage scheduled for September 2000.
- Surveillance Capsule W expected to show that the WBN reactor vessel clearly meets 10 CFR 50 Appendix G requirements.

APPENDIX G COMPLIANCE SUMMARY
(continued)

- Regulatory Guide 1.161 criteria does not differentiate for foreign manufactured vessels.
- Regulatory Guide 1.161 endorses NUREG/CR-5729 methodology used in the equivalent margins analysis.
- Equivalent Margin Analysis justified EOL upper shelf energy as low as 43 ft-lbs.
- Analysis submitted in accordance with Appendix H from Surveillance Capsule U pulled in 1st Refueling Outage.
 - Capsule U pulled at 1st outage, corresponds to 8.6 EFPY. WBN actual service in September 2000 is 4.0 EFPY
 - Capsule U specimens projected that EOL is 54 ft-lbs.
 - Capsule U data indicates that the Regulatory Guide 1.99, Rev. 2 prediction for forging 05 is very conservative.
- Based on testing results from Capsule U, WBN Unit 1 reactor vessel forging 05 is not expected to go below 50 ft-lb before EOL.
- Surveillance Capsule U analysis indicates 72 ft-lb. USE in axial direction and 107 ft-lb USE in tangential direction.
- Based on Capsule U, WBN is in compliance with 10 CFR 50, Appendix G, for at least 8.6 EFPY. As of September 2000, WBN will be at 4 EFPY.

FRACTURE TOUGHNESS CHARACTERIZATION OPTIONS

1. Test irradiated specimens from Capsule U

Pro:

- Satisfy SSER 14 open issue.
- Irradiation effects could be characterized.

Cons:

- Specimen geometry is not optimum requiring machining of highly irradiated specimen.
- No unirradiated toughness to compare.
- Limited radiation exposure of specimen.
- High cost of testing.

2. Test unirradiated specimens from archive material.

Pros:

- Specimen geometry can be controlled - More reliable results.
- Provides a baseline for follow-up tests as appropriate.
- Helps to resolve the unusual results in the earlier analysis.
- More cost effective testing.

Cons:

- Modification of SSER 14 open issue.
- Does not consider irradiation effects.

FRACTURE TOUGHNESS
CHARACTERIZATION OPTIONS
(continued)

3. Continue "normal" capsule monitoring program by testing Capsule W in accordance with Appendix H.

Pros:

- Justified by Capsule U data.
- Most cost effective.

Cons:

- Modifies SSER 14 open issue.

CONCLUSION/RESOLUTION

- WBN Unit 1 is in compliance with Appendix G
- Good technical sense to resolve the SSER 14 open issue (testing the unirradiated specimens or wait for results of Appendix H testing of Capsule W).
- Surveillance Capsule W to be extracted in 3rd Refueling Outage scheduled for September 2000.
- Surveillance Capsule W provides a second data point which will provide credible evidence for future predictions (RG 1.99, Rev. 2).
- Surveillance Capsule W represents 32 EFPY of vessel operation at 1/4T.
- Capsule W data to be submitted in accordance with 10 CFR 50 Appendix H in October 2001.

Tennessee Valley Authority

WATTS BAR NUCLEAR PLANT

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