V. C. Summer High Burnup LTA

Inspection Report

July 2005

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Executive Summary

A high burnup test program was established at VC Summer to characterize ZIRLO™ performance at high levels of fuel burnup. After two cycles of irradiation, assembly N34 was selected as the test assembly for the high burnup program. Pre-characterization inspections were performed to measure peripheral rod oxide, grid oxide, assembly growth, rod growth, and RCCA drag. Assembly N34 was loaded in Cycle 14 at the center core position for its third cycle of irradiation. At the end of Cycle 14 in October 2003, assembly N34 had achieved an assembly-average burnup of [ ][a,c]. In January 2005, Westinghouse personnel performed inspections on assembly N34 to collect the ZIRLO™ performance data. Inspections included visual exams, assembly growth, assembly bow, RCCA drag, grid growth, grid oxide, rod growth, rod bow, rod oxide, profilometry, gamma scanning, and grid cell size.

1.0 Background

A fuel inspection was performed at VC Summer in January 2005 to collect data on high burnup performance. Assembly N34 was the subject of the inspection. This assembly was irradiated at interior core positions in Cycles 11, 12, and 14. Figure 1-1 shows the core positions of N34 in these cycles. At the end of its third cycle of operation, N34 had achieved an assembly-average burnup of [ ]a, c.

Assembly N34 is designed with [

]a, b, c.

A pre-characterization exam was performed on N34 at EOC-12. Measurements of peripheral rod oxide, grid oxide, assembly length, rod growth, and RCCA drag were performed. Assembly N34 also had its top nozzle replaced with an RRTN. So the present top nozzle has been irradiated for only one cycle.

The January 2005 inspection consisted of the following exams performed on assembly N34: assembly and rod visuals, assembly growth, assembly bow, RCCA drag, grid growth, grid oxide, grid vane removal, grid cell size, rod growth, peripheral rod oxide, single rod oxide, profilometry, and gamma scan. Profilometry and single rod oxide were performed on [ ]a, c fuel rods that were removed from the assembly. Grid cell size was measured for each grid [ ]a, c. Gamma scanning was performed on [ ]a, c. Figure 1-2 identifies the [ ]a, c selected for gamma scan inspection.

All data obtained in the January 2005 inspection are reported in this document.

Figure 1-1
Core Position of Assembly N34 during Cycles 11, 12 and 14

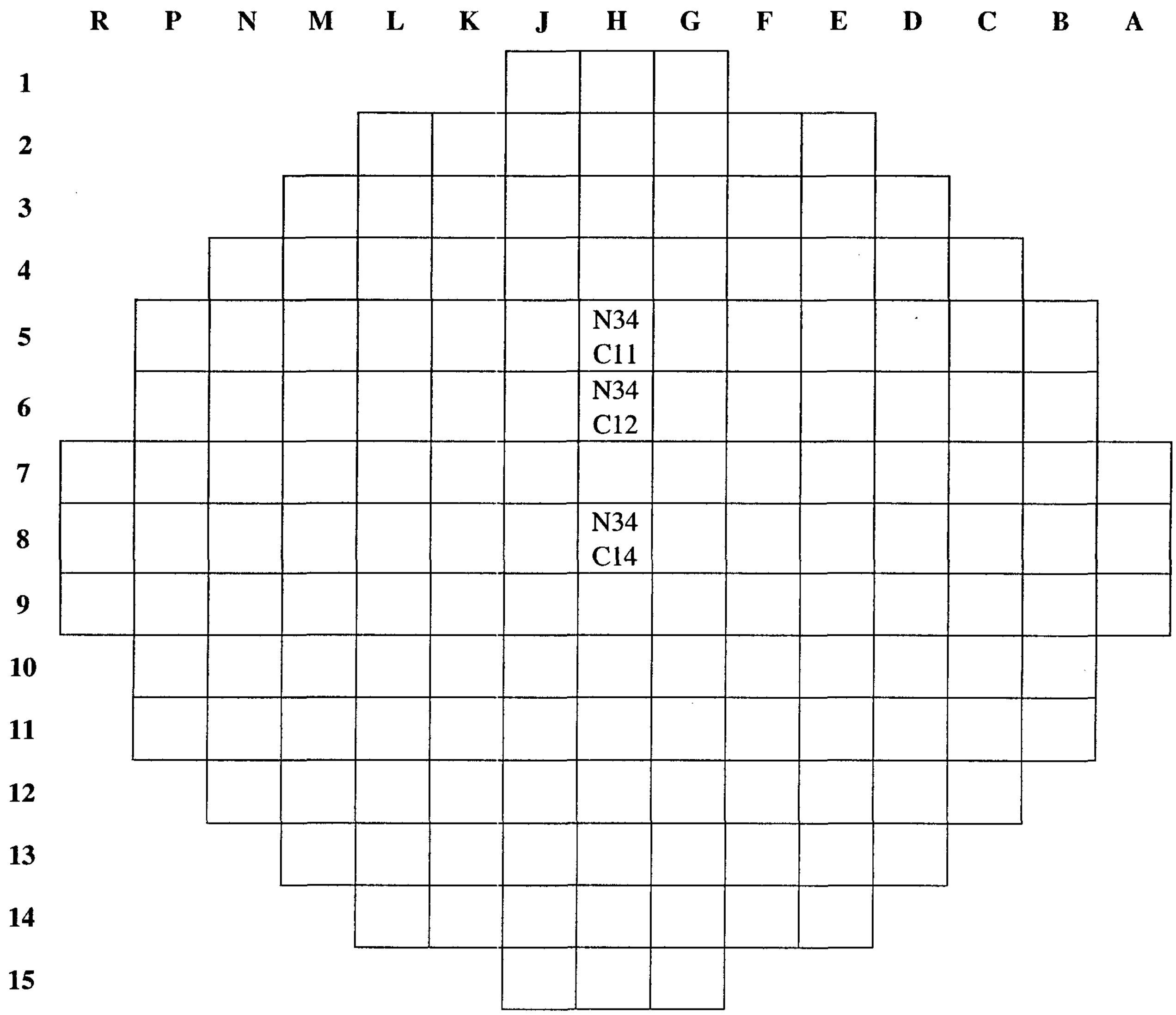

Figure 1-2
Fuel Rods Removed from Assembly N34 for Individual Rod Inspections **a, b, c**

[ ]

2.0 Work Scope and Objectives

2.1 Assembly Examinations

Assembly Visual

A half-face visual inspection of assembly N34 was performed with an underwater camera. Each half-face of the assembly was viewed over the entire axial length of the assembly. The purpose of the visual exam was to: 1) review the overall condition of the fuel assembly, 2) record the shoulder gap at the top of the assembly to allow rod length calculations, and 3) record the fuel rod channel spacing to allow for rod bow calculations. Rod growth results are reviewed to verify that enough growth margin is present for high burnup ZIRLO™ fuel and data can be compared to pre-characterization results from EOC-12.

Assembly Length

The length of assembly N34 was measured by performing relative measurements on the assembly and on a standard of known length. The purpose of the inspection was to determine the amount of assembly growth and confirm that the growth for a high burnup ZIRLO™-skeleton assembly is less than the [ ]^{a,c}. The results will add high burnup data to the ZIRLO™ growth database. The assembly growth result can be compared to the pre-characterization result from EOC-12.

Assembly Bow

Assembly bow was measured on Faces 1 and 2 of assembly N34. The purpose of this inspection was to determine the magnitude and shape of any assembly bow. The results will be added to the bow database to help understand bowing characteristics of ZIRLO™ assemblies. Bow results will also provide information on the risk of incomplete rod insertion (IRI) for high burnup ZIRLO™ assemblies.

RCCA Drag

RCCA drag was measured while withdrawing RCCA R20 from assembly N34. The purpose of the inspection was to determine the amount of rodlet-thimble friction, which may be indicative of guide thimble tube bow. Drag results will provide information on the risk of IRI for high burnup ZIRLO™ assemblies.

Grid Growth

Measurement of assembly N34 spacer grid outer dimensions was attempted using the UT Grid Envelope system. No meaningful data was obtained despite several attempts. Plans to collect the data at another time are being considered. The purpose of the inspection was to calculate grid growth. [

]^{a,c}.

Grid Oxide

Oxide corrosion thickness was measured on all mid-grids on Face 1 of assembly N34. The face of the assembly was brushed with Scotch-brite pads before measurements were taken. The purpose of the inspection was to measure corrosion on a non-heat producing structural element. [

]^{a,c}. Results can be compared to the pre-characterization results from EOC-12.

Peripheral Rod Oxide

Fuel rod oxide corrosion was measured on [ ]^{a,c} on Face 1 of assembly N34. The face of the assembly was brushed with Scotch-brite pads before measurements were taken. Corrosion was measured only on the exterior face of the fuel rods. The purpose of the inspection was to measure corrosion levels on ZIRLO™ fuel rod cladding. Results will help define ZIRLO™ corrosion performance at high burnup and will be added to the ZIRLO™ corrosion database. Results can be compared to the pre-characterization results from EOC-12.

Grid Vane Removal

[ ]^{a,c} grid vanes were removed from selected grids on Face 1 of assembly N34. [ ]^{a,c} vanes were removed from Grids 2, 4, 6, and 7 and IFMs 2 and 3. The grid vanes were stored in a shielded canister and shipped to a hot cell for examination. The hot cell examination has not yet been performed, so the data will be reported at a later date. [

]^{a,c}.

2.2 Single Rod Examinations

A. Disassembly and Rod Removal

Assembly N34 was disassembled and selected fuel rods were removed for inspection. The top nozzle was be removed, [ ]^{a,c} were withdrawn and stored in the fuel rod storage basket (FRSB). The fuel rods removed were [ ]^{a,c}. After the rod moves were completed, the top nozzle was re-installed with the [ ]^{a,c} cell locations remaining empty.

During top nozzle removal, six lock-tubes were placed in front of a camera for visual inspection. The inspections were performed with the lock-tubes still captured on the lock-tube tool. The entire exterior surfaces of the lock-tubes were examined and the lock-tube dimples were inspected for any evidence of wear. After nozzle removal, a camera was positioned to view the exterior and interior of the flexure tubes. Interior and exterior areas of the flexures were inspected for evidence of wear. The purpose of the inspection was to collect information regarding the extent of wear at the nozzle/grid sleeve interface to support integral quality assessment (IQA) demands.

For inspections C to G, a rod will be removed from the FRSB, brought to each inspection station until complete, and then returned to the FRSB. Once all other rod inspections are completed, each of the rods will be removed for gamma scanning and then returned to the FRSB.

Individual rod inspections were performed on the [ ] ^{a,c} fuel rods in the FRSB. A high-magnification visual exam, rod length measurement, rod cleaning, diameter measurement, and corrosion measurement were performed on each of the [ ] ^{a,c} fuel rods. Rod cleaning was performed by [

] ^{a,c}. All inspections were performed in succession on a given rod until completed. The rod was then returned to the FRSB and the next rod removed and inspected. Once these inspections were completed, [ ] ^{a,c} rods were selected for the gamma scan inspection. [ ] ^{a,c}.

When all rod inspections were completed, the top nozzle was again removed from assembly N34. Grid cell size measurements were performed at all the empty cell locations. When completed, the fuel rods were re-inserted in assembly N34 and the top nozzle was re-installed.

B. Grid Cell Sizing

Grid cell size measurements were performed for all spacer grids [
] ^{a,c}. The purpose of this inspection was to determine the amount of growth and/or thermal relaxation experienced by the grid cells in the respective spacer grids. This data provides information on the fretting performance of ZIRLO™ spacer grids and ZIRLO™ fuel rods at high levels of burnup.

C. Fuel Rod Visual

A high-magnification camera was used to inspect the [ ] ^{a,c} fuel rods removed from assembly N34. The purpose of this inspection was to review the condition of the selected fuel rods. Each rod was inspected for evidence of crud, corrosion, hydride, wear, or damage.

D. Fuel Rod Growth

Fuel rod length was measured for the [ ] ^{a,c} fuel rods removed from assembly N34 by using an encoder in the FRHT (fuel rod handling tool) controller to track distance traveled. The purpose of this inspection was to measure fuel rod growth of interior rods and compare growth calculated by this method to peripheral rod growth determined by shoulder gap.

E. Single Rod Oxide

Oxide corrosion thickness was measured on the [ ] ^{a,c} fuel rods removed from assembly N34. Measurements were performed after the rods were cleaned. The purpose of this inspection was to measure the fuel rod clad corrosion thickness on fuel rods with different burnups and positions in the assembly. Results will help define ZIRLO™ corrosion performance at high burnup and will be added to the ZIRLO™ corrosion database.

F. Profilometry

Rod diameter was measured on the [ ] ^{a,c} fuel rods removed from assembly N34. Measurements were performed after the rods were cleaned. The purpose of the inspection was to measure the amount of creep (in or out) experienced by the fuel rods. Creep can be affected by fuel pellet swelling (dependent on pellet density) and internal pressure. Fuel rods in assembly N34 have pellets with [

]$^{a, b, c}$. Data will help define high burnup ZIRLO™ creep performance and will be added to the ZIRLO™ database.

G. Gamma Scan

Measurements of the gamma radiation count rate were conducted on [ ]$^{a, c}$ of the fuel rods removed from assembly N34. The rods selected were [ ]$^{a, c}$. The purpose of this inspection was to examine the condition of the fuel pellet stack. Length of the pellet stack and the presence of gaps in the pellet stack can be determined by the positions of low counts. This will help determine the amount of pellet densification/swelling. Continued pellet swelling after pellet-clad contact can cause cladding creep (out). [

]$^{a, c}$.

3.0 Inspection Results

3.1 Assembly Visual Inspection

A half-face visual exam was performed on all faces of assembly N34. The purpose was to confirm the mechanical integrity of the fuel assembly. The assembly was viewed for grid appearance, fuel rod appearance, and nozzle appearance, plus any evidence of wear, fretting, or debris. Crud and corrosion appearance, especially on fuel rods, was examined for any evidence of unusual accumulation, or existence of blistering or spallation.

[

][a, b, c].

[

][a, b, c]. No evidence of debris, fretting wear, or other damage was found anywhere on the assembly.

[

][a, b, c].

No evidence of debris was observed around or underneath the bottom nozzle. During removal of the top nozzle, six lock tubes were inspected for evidence of wear. All lock tubes showed vertical scratch lines that appear to be the result of installation and/or removal. One lock tube had a shiny area that may have been the result of rubbing wear. All lock tube dimples were viewed and showed no evidence of wear. Assembly N34 had its top nozzle replaced with a RRTN after Cycle 12. So these lock tubes have experienced only one cycle of operation. Flexures were also viewed for evidence of wear. No abnormal wear was observed.

During the fuel assembly visual, the top of peripheral fuel rods were viewed in relation to the top nozzle. This was performed to allow measurements of the gap between the fuel rods and the top nozzle. All fuel rods had approximately [ ][a, b, c] of space before contacting the top nozzle. This gap, along with the measured length of the fuel assembly, and heights of the top and bottom nozzles, allows the length of the peripheral fuel rods to be determined.

Fuel rod spacing was also noted during the fuel assembly visual exam. The distances between peripheral rods were measured at different axial positions in each span. These measurements allowed fuel rod bow to be calculated.

3.2 Assembly Growth

Fuel assembly length measurements were performed on N34.

The measurements were made using a standard of known length, which consists of two sections of aluminum pipe with standard 17x17 top and bottom nozzles, and a measuring device that utilizes a digital readout from an LVDT. The standard was placed in a specified fuel storage rack, and a reference length reading was established. Immediately after completion of the measurement of the standard, assembly N34 was placed in the same spent fuel rack location and the length was measured. The difference between the standard measurement and the assembly measurement is added to the known length of the standard to determine the actual length of the fuel assembly. The pool temperature was also recorded to correct assembly length measurements for thermal expansion.

The assembly growth was calculated by comparing the pre-irradiation (as-built or nominal) dimensions with the post-irradiation measured values. Table 3.2-1 shows the measured assembly growth data.
[

]$^{a, b, c}$. Fuel assembly N34 meets the guideline after three cycles of irradiation and cumulative burnup of [ ]$^{a, c}$ MWD/MTU.

Figure 3.2-1 plots the normalized measured assembly growth data as a function burnup for fuel with ZIRLO™ thimble tubes. The figure compares the N34 data with other V.C. Summer data and data from other plants. V.C. Summer data constitutes a large part of the database.

Figure 3.2-2 plots the normalized measured assembly growth data as a function burnup for 17P+ fuel with ZIRLO™ thimble tubes. N34 growth is compared with other V.C. Summer P+ data and P+ data from other 17x17 plants. This plot shows that the growth of N34 is fairly consistent with growth projections that might be made based on past growth experience for 17P+ fuel.

a, b, c

Table 3.2-1
Measured Length of F/A N34 (after three cycles of irradiation)

[ ]

Figure 3.2-1
V. C. Summer LTA Exam, ZIRLO Assembly Growth Data

a, b, c

[ ]

Figure 3.2-2
V. C. Summer LTA Exam, 17P+ Assembly Growth Data

a, b, c

[ ]

3.3 Assembly Bow

Assembly bow measurements were performed on assembly N34. Bow data was obtained at each spacer grid location from Faces 1 and 2.

[

]a,c.

[

]a,c.

[

]a,c.

[

]a,c.

[

]a,c.

[

]a,c.

Table 3.3-1
Assembly N34 Bow Data
(inches of concavity from the nominal assembly envelope)

[ ] a, b, c

Figure 3.3-1
Bar Graph of N34 Assembly Bow (Face 1)

a, b, c

Figure 3.3-2
Bar Graph of N34 Assembly Bow (Face 2)

a, b, c

Figure 3.3-3
Maximum Bow for Assemblies with ZIRLO™ Guide Thimble Tubes

[ ] a, b, c

3.4 RCCA Drag

Assembly N34 was drag tested with RCCA R20. This is the same RCCA that was used in a previous drag test on assembly N34 after Cycle 12. [

]a, c.

The N34 drag data for the past two inspections is shown in Table 3.4-1. [

]a, c:

- [ ]a, c
- [ ]a, c

[

]a, c.

Table 3.4-1
Assembly N34 Drag Test Data

[ ]a, b, c

3.5 Grid Growth

Assembly N34 has ZIRLO™ mid-grids and IFMs. It was planned to obtain spacer grid outer dimensions using the UT Grid Envelope system. The data would help to define ZIRLO™ grid growth performance at high burnup levels. [

]a, c.

However, the Grid Envelope system failed to operate properly and no usable data was obtained. It is possible that this data may be obtained at a future date.

3.6 Grid Oxide

[

]a, c.

[

]a, c.

[

]a, c.

[ ]a, b, c.

Table 3.6-1
Grid-Averaged Corrosion Thickness for Assembly N34
(after 2 and 3 cycles of irradiation)

a, l

[ ]

Figure 3.6-1
Bar Graph of Grid-Averaged N34 Corrosion Thickness at EOC-14

a, (

[ ]

3.7 Grid Vane Removal

[

]^{a, c}.

[

]^{a, c}.

[

]^{a, c}.

[

]^{a, c}.

Table 3.7-1
Grid Vane Removal Summary

a, b, c

Figure 3.7-1
Illustration of Vane Lettering for a Grid Strap **a, b, c**

[ ]

Figure 3.7-2
Illustration of Vane Lettering for an IFM Strap **a, b, c**

[ ]

3.8 Rod Visual Inspections

Each fuel rod removed from assembly N34 was examined visually with a high magnification camera. [

]^{a,c}. Visual exams were performed by viewing the fuel rods from tip to tip at two circumferential orientations, 0° and 180°. Table 3.8-1 lists each fuel rod, some of its characteristics, and summarizes the visual exam results.

Table 3.8-1
Notes for Fuel Rod Visual Exams

a, b, c

[ ]

3.9 Rod Growth

A low magnification visual was performed on all four faces of assembly N34 using an underwater camera. [

]^{a,c}.

[

]^{a,c}:

[ ]^{a,c}

where;

[

]^{a,c}

[ ]^{a,c}

[ ]^{a,c}

[ ]^{a,c}

[

]^{a,c}.

The rod length of [ ]^{a,c} individual rods was also measured using an encoder in the motorized fuel rod handling tool. [

]^{a,c}.

Table 3.9-1
Summary of Peripheral Fuel Rod Growth for F/A N34
(at EOC-12 and EOC-14)

a, b, c

[ ]

Table 3.9-2
Single Fuel Rod Growth for F/A N34
(measured by encoder)

a, b, c

[ ]

Table 3.9-3
Detailed Shoulder Gap and Rod Growth Data

a, b, c

Figure 3.9-1
Comparison of N34 Average Rod Growth to Other Fuel Assemblies

a, b, c

Figure 3.9-2
VC Summer N34 Fuel Rod Growth as Determined by Rod Gap Data and Single Fuel Rod Measurements

a, b, c

3.10 Rod Bow

[

] a, c:

[ ] a, c

where [ ] a, c

[

] a, c

[ ] a, c

[

] a, b, c.

3.11 Rod Oxide

Peripheral Rod Oxide

This section summarizes the results of the peripheral fuel rod oxide measurements performed on assembly N34. [

]a, c.

[

]a, c.

Table 3.11-1 summarizes the results of the oxide measurements. [

]a, c.

Single Rod Oxide

[

]a, c.

[

]a, c.

[

]$^{a, b, c}$.

[

]$^{a, b, c}$.

Table 3.11-1
Summary of N34 Peripheral Rod Oxide Data

a, b, c

[ ]

Table 3.11-2
VC Summer Assembly N34 Single Rod Oxide Data

a, b, c

[ ]

Figure 3.11-1
Assembly N34 Fuel Rod Corrosion vs. ZIRLO™ Corrosion Database **a, b, c**

[ ]

3.12 Profilometry

The profilometry system consists of a measuring head, a motorized fuel rod handling tool, a standard with known diameters, and a computerized data acquisition system. [

]a, c.

The profilometry measurements were performed on [

]a, c.

[

]a, c.

Oxidation Corrected, Post-Irradiation Rod Diameter – General

[ ]a, c

[ ]a, c

where [ ]a, c
[ ]a, c
[ ]a, c
[
]a, c

[
]a, c

[ ]a, c

[ ]a, c

where [ ]a, c
[ ]a, c
[ ]a, c
[ ]a, c

[
]a, c.

[

]a, b, c.

Oxidation Corrected, Post-Irradiation Rod Diameter - High Power Region

[

]a, b, c.

[

]a, b, c.

Ovality

[

]a, b, c.

Ridging

[

]a, b, c.

Table 3.12-1
Summary of Profilometry Data

a, b, c

[

]

Figure 3.12-1
Average Diameter Plot for [ ]$^{a, c}$

a, b, c

[ ]

Figure 3.12-2
Ovality Plot for [ ]$^{a, c}$

a, b, c

[ ]

Figure 3.12-3
Average Diameter Plot for [ ]$^{a, c}$

a, b, c

[ ]

Figure 3.12-4
Ovality Plot for [ ]$^{a, c}$

a, b, c

[ ]

Figure 3.12-5
Average Diameter Plot for [ ] [a, c]

a, b, c

[ ]

Figure 3.12-6
Ovality Plot for [ ] [a, c]

a, b, c

[ ]

Figure 3.12-7
Average Diameter Plot for [ ] [a, c]

a, b, c

[ ]

Figure 3.12-8
Ovality Plot for [ ] [a, c]

a, b, c

[ ]

Figure 3.12-9
Average Diameter Plot for [ ]a, c

a, b, c

[ ]

Figure 3.12-10
Ovality Plot for [ ]a, c

a, b, c

[ ]

Figure 3.12-11
Average Diameter Plot for [ ][a, c]

a, b, c

[ ]

Figure 3.12-12
Ovality Plot for [ ][a, c]

a, b, c

[ ]

Figure 3.12-13
Average Diameter Plot for [ ]$^{a, c}$

a, b, c

[ ]

Figure 3.12-14
Ovality Plot for [ ]$^{a, c}$

a, b, c

[ ]

Figure 3.12-15
Average Diameter Plot for [ ]$^{a, c}$

a, b, c

[ ]

Figure 3.12-16
Ovality Plot for [ ]$^{a, c}$

a, b, c

[ ]

Figure 3.12-17
Average Clad Creep in High Power Region

a, b, c

[ ]

3.13 Gamma Scan

Gamma scanning of fuel rods was performed at V.C. Summer using the FROGS (Fuel **RO**d Gamma Scanner) system. Assembly N34 was loaded into the V.C. Summer core and irradiated for three cycles (Cycles 11, 12 and 14). The third cycle (Cycle 14) ended in October 2003. In January 2005, after about 15 months of post-irradiation cooling time, N34 was disassembled and gamma scanning was performed using the FROGS system.

[

]^{a,c}.

Fuel Stack Length Determination

The obtained gamma scans were interpreted to determine stack length. Functional requirement was to determine the stack length within ± 0.1% (i.e., 0.144" = 144 mils) uncertainty.

Due to the high resolution and good performance of the FROGS system, it is possible to determine the stack length from the scan data in a straightforward manner. Essentially, at all interfaces (top/bottom end of axial blankets, or, blanket/fuel interface), there is a steep change in the count rate occurring over a very limited portion of the fuel rod axial movements (0.040" - 0.050"). The mid-point of that change corresponds to the interface position, and it can be determined with sufficient accuracy to satisfy and even exceed functional requirements.

[

]^{a,c}.

[

]^{a,c}.

[ ]^{a,c}.

[

]^{a,c}.

Pellet Gap Detection and Quantification

In addition to fuel stack length determination, the second objective of gamma scanning was to detect if any gaps are present (have developed) between pellets, and to evaluate size of these gaps. [

] a, c.

[

] a, c.

[

] a, c.

[

] a, b, c.

[

] a, c.

[

] a, c.

Table 3.13-1
Fuel Characteristics of Assembly N34

a, b, c

[ ]

Table 3.13-2
List of Scanned Fuel Rods

a, b, c

[ ]

Table 3.13-3
Position of Interfaces Determined from Gamma Scans

a, b, c

[ ]

Table 3.13-4
Length of Fuel Sections and Stack Length

a, b, c

[ ]

Table 3.13-5
Axial Position and Size of Identified Gaps

a, b, c

[ ]

Table 3.13-6
Net Stack Length

a, b, c

[

]

Figure 3.13-1

Full Length Axial Gamma Scan of [ ]$^{a, c}$ **a, b, c**

Figure 3.13-2
Full Length Axial Gamma Scan of [ ]$^{a, c}$

a, b, c

[ ]

Figure 3.13-3

Full Length Axial Gamma Scan of [ ] [a, c]

a, b, c

[ ]

Figure 3.13-4
Full Length Axial Gamma Scan of [ ]$^{a, c}$

a, b, c

[ ]

Figure 3.13-5

[ ] a, b, c

a, b, c

[ ]

Figure 3.13-6

Close-up of Gaps in [ ] a, c

a, b, c

[ ]

Figure 3.13-7
Close-up of Gaps in [ ] [a, c]

a, b, c

3.14 Grid Cell Size

The grid cell size measurements were determined from the drag measurements that were obtained by withdrawing a step pin through a designated grid cell. [

]$^{a, c}$.

[

]$^{a, c}$.

[

]$^{a, b, c}$.

[

]$^{a, b, c}$.

[

]$^{a, b, c}$.

Table 3.14-1
Grid Cell Size for Eight Cell Locations from Assembly N34

a, b, c

[ ]

Table 3.14-2
Grid Cell Gap Data

a, b, c

[ ]

Figure 3.14-1
Grid Cell Sizes by Grid

a, b, c

[ ]

Figure 3.14-2
Cell Size Comparison for 17x17 ZIRLO™ OFA Grid Design

a, b, c

[ ]

4.0 Summary

Assembly Visual Inspection

[

]a, b, c.

Assembly Growth

[

]a, b, c.

Assembly Bow

[

]a, b, c.

RCCA Drag

[

]a, b, c.

Grid Growth

Grid growth measurements were attempted using the UT Grid Envelope system. The system did not operate properly and no usable data was obtained. This data is still desirable and should be acquired at the next available opportunity.

Grid Oxide

[

]a, b, c.

Grid Vane Removal

[

]a, b, c.

Fuel Rod Visual Inspections

[

] a, b, c.

Fuel Rod Growth

[

] a, b, c.

Fuel Rod Bow

[

] a, b, c.

Fuel Rod Oxide

[

] a, b, c.

Profilometry

[

] a, b, c.

Gamma Scan

[

]a, b, c.

Grid Cell Size

[

]a, b, c.

Appendix A

Peripheral Rod Oxide Data Table

Table A-1
Corrosion Data for Peripheral Fuel Rods from Face 1 a, b, c

Table A-1 (cont.)
Corrosion Data for Peripheral Fuel Rods from Face 1 a, b, c

Table A-1
Corrosion Data for Peripheral Fuel Rods from Face 1

a, b, c

Appendix B

Single Rod Oxide Data Tables

Table B-1
Corrosion Data for [ ] [a, c]

a, b, c

[ ]

Table B-1 (cont.)
Corrosion Data for [ ]a, c

a, b, c

Table B-1 (cont.)
Corrosion Data for [ ] a, c

a, b, c

[ ]

Table B-1 (cont.)
Corrosion Data for [ ] [a, c]

a, b, c

[ ]

Table B-2
Corrosion Data for [ ] [a, c]

a, b, c

Table B-2 (cont.)
Corrosion Data for [ ] [a, c]

a, b, c

[ ]

Table B-2 (cont.)
Corrosion Data for [ ]a, c

a, b, c

Table B-2 (cont.)
Corrosion Data for [ ]a, c a, b, c

[ ]

Table B-3
Corrosion Data for [ ]$^{a, c}$

a, b, c

[ ]

Table B-3 (cont.)
Corrosion Data for [ ] a, c

a, b, c

[ ]

Table B-3 (cont.)
Corrosion Data for [ ] [a, c]

a, b, c

Table B-3 (cont.)
Corrosion Data for [ ] [a, c]

a, b, c

[ ]

Table B-4
Corrosion Data for [ ][a, c] a, b, c

[ ]

Table B-4 (cont.)
Corrosion Data for [ ] [a, c]

a, b, c

[ ]

a, b, c

Table B-4 (cont.)
Corrosion Data for [ ]a, c

Table B-4 (cont.)
Corrosion Data for [ ]^a, c^

a, b, c

[ ]

Table B-5
Corrosion Data for [ ]a, c

a, b, c

Table B-5 (cont.)
Corrosion Data for [ ] a, c

a, b, c

[ ]

Table B-5 (cont.)
Corrosion Data for [ ][a, c]

a, b, c

[ ]

Table B-5 (cont.)
Corrosion Data for [ ][a, c]

a, b, c

[ ]

Table B-6
Corrosion Data for [ ] a, c

a, b, c

[ ]

Table B-6 (cont.)
Corrosion Data for [ ]$^{a, c}$

a, b, c

Table B-6 (cont.)
Corrosion Data for [ ] a, c

a, b, c

[ ]

Table B-6 (cont.)
Corrosion Data for [ ] [a, c]

a, b, c

[ ]

Table B-7
Corrosion Data for [ ][a, c]

a, b, c

[ ]

Table B-7 (cont.)
Corrosion Data for [ ][a, c]

a, b, c

a, b, c

Table B-7 (cont.)
Corrosion Data for [ ]a, c

Table B-7 (cont.)
Corrosion Data for [ ] [a, c]

a, b, c

[ ]

Table B-8
Corrosion Data for [ ] [a, c]

a, b, c

Table B-8 (cont.)
Corrosion Data for [ ] [a, c]

a, b, c

[ ]

Table B-8 (cont.)
Corrosion Data for [ ][a, c]

a, b, c

Table B-8 (cont.)
Corrosion Data for [ ] [a, c]

a, b, c

[ ]

Table B-9
Averaged Single Rod Corrosion Data

a, b, c

Table B-9 (cont.)
Averaged Single Rod Corrosion Data

a, b, c

Table B-9 (cont.)
Averaged Single Rod Corrosion Data

a, b, c

Table B-9 (cont.)
Averaged Single Rod Corrosion Data

a, b, c

Appendix C

Profilometry Data Tables

Table C-1
Profilometry Data for [ ]a, c

a, b, c

Table C-1 (cont.)
Profilometry Data for [ ] [a, c]

a, b, c

Table C-1 (cont.)
Profilometry Data for [ ][a, c]

a, b, c

[ ]

Table C-1 (cont.)
Profilometry Data for [ ]^a, c^

a, b, c

[ ]

Table C-2
Profilometry Data for [ ] a, c

a, b, c

[ ]

Table C-2 (cont.)
Profilometry Data for [ ]^a, c^

a, b, c

[ ]

Table C-2 (cont.)
Profilometry Data for [ ] a, c

a, b, c

[ ]

Table C-2 (cont.)
Profilometry Data for [ ] [a, c]

a, b, c

[ ]

Table C-3
Profilometry Data for [ ] [a, c]

a, b, c

[ ]

Table C-3 (cont.)
Profilometry Data for [ ][a, c]

a, b, c

[ ]

Table C-3 (cont.)
Profilometry Data for [ ] [a, c]

a, b, c

[ ]

Table C-3 (cont.)
Profilometry Data for [ ]a, c

a, b, c

[ ]

a, b, c

Table C-4
Profilometry Data for [ ] [a, c]

[ ]

Table C-4 (cont.)
Profilometry Data for [ ]$^{a, c}$

a, b, c

[ ]

Table C-4 (cont.)
Profilometry Data for [ ] a, c

a, b, c

[ ]

Table C-4 (cont.)
Profilometry Data for [ ] a, c

a, b, c

[ ]

Table C-5
Profilometry Data for [ ] [a, c]

a, b, c

[ ]

Table C-5 (cont.)
Profilometry Data for [ ]$^{a, c}$

a, b, c

Table C-5 (cont.)
Profilometry Data for [ ][a, c]

a, b, c

[ ]

Table C-5 (cont.)
Profilometry Data for [ ]^{a, c}

a, b, c

[ ]

Table C-6
Profilometry Data for [ ]^a, c^

a, b, c

[ ]

Table C-6 (cont.)
Profilometry Data for [ ] a, c

a, b, c

Table C-6 (cont.)
Profilometry Data for [ ] [a, c]

a, b, c

Table C-6 (cont.)
Profilometry Data for [ ] a, c

a, b, c

[ ]

Table C-7
Profilometry Data for [ ][a, c]

a, b, c

Table C-7 (cont.)
Profilometry Data for [ ] a, c

a, b, c

[ ]

Table C-7 (cont.)
Profilometry Data for [ ] a, c

a, b, c

[ ]

Table C-7 (cont.)
Profilometry Data for [ ]$^{a, c}$

a, b, c

[ ]

Table C-8
Profilometry Data for [ ] [a, c]

a, b, c

Table C-8 (cont.)
Profilometry Data for [ ]a, c

a, b, c

[ ]

Table C-8 (cont.)
Profilometry Data for [ ][a, c]

a, b, c

[ ]

Table C-8 (cont.)
Profilometry Data for [ ] [a, c]

a, b, c

[ ]

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