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**GE14 AND SVEA-96+ THERMAL-HYDRAULIC COMPATIBILITY REPORT - NON-PROPRIETARY VERSION**
**HOPE CREEK GENERATING STATION**
**FACILITY OPERATING LICENSE NPF-57**
**DOCKET NO. 50-354**

Reference: GNF-A Proprietary Report, NEDC-33107P, "GEXL80 Correlation for SVEA96+ Fuel," dated September 2003

By letter dated September 8, 2003, PSEG Nuclear LLC (PSEG) provided the proprietary "GE14 and SVEA-96+ Thermal-Hydraulic Compatibility Report" in support of the NRC's review of the referenced submittal.

Attachment 1 to this letter contains a non-proprietary version of the report for inclusion in the Public Document Room.

Should you have any questions regarding this matter, please contact Mr. Paul Duke at 856-339-1466.

Sincerely,

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Attachment

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# GE14 AND SVEA-96+ THERMAL-HYDRAULIC COMPATIBILITY REPORT
(non-proprietary version)

# PSEG Nuclear LLC

## Nuclear Fuel Section Report NFS-0233

## GE14 and SVEA-96+ Thermal Hydraulic Compatibility Report

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# 1 Introduction

The purpose of this report is to provide independent verification to the conclusion made by the fuel vendor (GNF) that the GE14 and SVEA-96+ fuels are thermal- hydraulically compatible.

Westinghouse provided the thermal-hydraulic modeling data for legacy fuel SVEA-96+ (ref. 1) and GNF for the GE14 fuel (ref. 2). As part of the new fuel introduction work scope, GNF provided a report containing several mixed core evaluations to support the conclusion that the two distinct fuel designs are thermal hydraulically compatible (ref. 3). PSEG has taken the data from each fuel vendor and modeled each fuel type using the industry computer code FIBWR2 (ref. 7) as an independent means of verifying the conclusions of GNF.

This report first summarizes FIBWR2 benchmark results of full cores of each fuel type at various power and flow conditions. The FIBWR2 model for each fuel type was benchmarked with the thermal-hydraulic analysis results provided by the respective fuel vendor. Then, the report summarizes the core performances for a number of transition, or mixed, cores at the same power and flow conditions to verify the fuel vendor's conclusions regarding the thermal hydraulic compatibility of the SVEA-96+ and GE14 fuel designs.

# 2 FIBWR2 Computer Code and Model

The FIBWR2 computer code was developed in 1992 by Scientech, Inc. for a group of utilities called the FIBWR2 Owners Group. The FIBWR2 code is a newer version of the FIBWR code developed in 1981 with added functionality, e.g. transient simulation capability. However, for the evaluations performed in this report, only the steady state thermal hydraulic calculation capability was required. PSEG has used the FIBWR2 computer code historically as an independent tool for confirming or validating fuel vendor analyses.

To perform a steady state thermal hydraulic evaluation, FIBWR2 requires core-wide parameters such as core power, core flow, core exit pressure, and core inlet subcooling. Using the core-wide parameters and fuel design specific data such as upper and lower tie plate loss coefficients, spacer loss coefficients, and bundle leakage flow, FIBWR2 calculates a pressure and bundle flow distribution for the steady state core.

In the last three Hope Creek cycles, the FIBWR2 computer code, with SVEA-96+ and GE9 models, has been compared to the core thermal-hydraulic performance during startup after each refueling outage. FIBWR2 has always calculated results that compared well to the core monitoring system in these mixed core applications.

# 3 Full Core Evaluations

## 3.1 Fuel Design Input

The SVEA-96+ fuel design is a 10x10 fuel array consisting of four mini-bundles, which reside in a channel box. The channel structure has a central water cross that displaces 4 fuel rod positions, 1 from each mini-bundle, and 4 water wing structures that extend from the central water cross to the channel wall. The channel structure is firmly attached to the lower tie plate. The composition of the mini-bundles includes upper and lower tie plates, 7 spacers, and 24 full length fuel rods. A handle attaches to the top of the channel box for lifting and transporting the fuel assembly.

As part of the previous Hope Creek fuel vendor transition, Westinghouse (then ABB-CE) supplied SVEA-96+ thermal hydraulic performance data, as well as local loss coefficients, in reference 1 at several power and flow conditions for a rated reactor power of 3293 MWt, using the proprietary computer code CONDOR. The FIBWR2 model of reference 4 was benchmarked against this data. Table 3.1 displays the pressure loss coefficients that were provided for the upper and lower tie plate and the spacers. The inlet loss coefficients are values traditionally used at Hope Creek to model the central and peripheral bundle orifices, relative to the reference flow area. Table 3.2 displays a sample comparison of the SVEA-96+ information from the CONDOR simulations and the FIBWR2 results using a 1.4 chopped cosine axial power shape. The table demonstrates that FIBWR2 SVEA-96+ model has been adequately established.

**Table 3.1 - Loss Coefficients for SVEA-96+ Fuel**

| Parameter | SVEA-96+ value |
|---|---|
| Reference area ($in^2$) | [ ] |
| Lower Tie Plate loss coefficient | [ ] |
| Upper Tie Plate loss coefficient | [ ] |
| Spacer loss coefficient | [ ] |
| Central bundle orifice loss coefficient | [ ] |
| Peripheral bundle orifice loss coefficient | [ ] |

## Table 3.2 - FIBWR2 Comparison to CONDOR Results

| Common Property | CONDOR | FIBWR2 | Difference | % Difference (absolute) |
|---|---|---|---|---|
| Core Power (MWt) | [ ] | 3293.04 | [ ] | [ ] |
| Core Flow (Mlbm/hr) | [ ] | 100.00 | [ ] | [ ] |
| Inlet Enthalpy (BTU/lbm) | [ ] | 525.90 | [ ] | [ ] |
| Core Exit Pressure (psia) | [ ] | 1029.00 | [ ] | [ ] |
| Total Active Flow (Mlbm/hr) | [ ] | 84.694 | [ ] | [ ] |
| Bypass Flow (Mlbm/hr) | [ ] | 10.460 | [ ] | [ ] |
| Water Tube(s)+ Flow (Mlbm/hr) | [ ] | 4.846 | [ ] | [ ] |
| Total Pressure Drop (psid) | [ ] | 20.281 | [ ] | [ ] |
| CSP++ Pressure Drop (psid) | [ ] | 15.411 | [ ] | [ ] |

+ Water Tube(s) = Water Cross + Water Wings
++ CSP = Core Support Plate

The GE14 fuel design consists of 92 fuel rods arranged in a 10x10 array, with 2 water tubes displacing 8 fuel rod positions. Fourteen of the 92 fuel rods are part length. Additional components in a GE14 assembly include: upper and lower tie plates, 8 spacers, a handle that attaches to the upper tie plate for lifting, and a channel box that slides over the fuel rods and has a spring loaded fit against the lower tie plate.

As part of the current fuel vendor transition, GNF supplied GE14 thermal hydraulic performance data in reference 2 at several power and flow conditions for a rated power of 3952 MWt, the extended power uprate (EPU) power level, using the proprietary computer code ISCOR. The FIBWR2 model of reference 5 was benchmarked against this data. Table 3.3 displays the pressure loss coefficients that were provided for the upper and lower tie plate and the spacers. The inlet loss coefficients are values traditionally used at Hope Creek to model the central and peripheral bundle orifices, relative to the reference flow area. Table 3.4 displays a sample comparison of the GE14 information and the FIBWR2 results using a 1.4 chopped cosine axial power shape. Again, the FIBWR2 GE14 model is adequately established.

**Table 3.3 - Loss Coefficients for GE14 Fuel**

| Parameter | GE14 value |
|---|---|
| Reference area ($in^2$) | [[ ]] |
| Lower Tie Plate loss coefficient | [[ ]] |
| Upper Tie Plate loss coefficient | [[ ]] |
| Spacer loss coefficient – fully rodded region | [[ ]] |
| Spacer loss coefficient – above part length fuel rods | [[ ]] |
| Central bundle orifice loss coefficient | [[ ]] |
| Peripheral bundle orifice loss coefficient | [[ ]] |

**Table 3.4 - FIBWR2 Comparison to ISCOR Results**

| Common Property | ISCOR | FIBWR2 | Difference | % Difference (absolute) |
|---|---|---|---|---|
| Core Power (MWt) | [[ ]] | 3952.00 | [[ ]] | 0.001 |
| Core Flow (Mlbm/hr) | [[ ]] | 99.000 | [[ ]] | 0.004 |
| Inlet Enthalpy (BTU/lbm) | [[ ]] | 524.9 | [[ ]] | 0.0 |
| Core Exit Pressure (psia) | [[ ]] | 1034.8 | [[ ]] | 0.001 |
| Total Active Flow (Mlbm/hr) | [[ ]] | 83.114 | [[ ]] | 0.005 |
| Bypass Flow (Mlbm/hr) | [[ ]] | 11.882 | [[ ]] | 0.235 |
| Water Tube(s) Flow (Mlbm/hr) | [[ ]] | 4.004 | [[ ]] | 0.350 |
| Total Pressure Drop (psid) | [[ ]] | 22.106 | [[ ]] | 1.567 |
| CSP Pressure Drop (psid) | [[ ]] | 17.229 | [[ ]] | 0.586 |

## 3.2 Axial Power Shape Input

Table 3.5 lists the 25-node axial power shape that was used for the FIBWR2 evaluations in the remainder of this report. This inlet peaked axial power shape was chosen to relatively maximize the two-phase pressure drop in the core, compared to the chopped cosine axial power shape. However, to assure that the conclusion drawn from this evaluation will not be axial power dependent, an analysis with inverted power shape (i.e. top peaked) at rated power and increased core flow condition is also performed for evaluation. Results of the power shape sensitivity are contained in Appendix A

**Table 3.5 - Axial Power Shape Input for FIBWR2**

| Node (1= bottom of active fuel) | Bottom Peaked Axial Power Shape |
|---|---|
| 1 | 0.501068 |
| 2 | 0.703130 |
| 3 | 0.874083 |
| 4 | 1.016474 |
| 5 | 1.132547 |
| 6 | 1.224284 |
| 7 | 1.293446 |
| 8 | 1.341615 |
| 9 | 1.370236 |
| 10 | 1.380653 |
| 11 | 1.374157 |
| 12 | 1.352023 |
| 13 | 1.315552 |
| 14 | 1.266111 |
| 15 | 1.205177 |
| 16 | 1.134375 |
| 17 | 1.055521 |
| 18 | 0.970661 |
| 19 | 0.882116 |
| 20 | 0.792518 |
| 21 | 0.704855 |
| 22 | 0.622512 |
| 23 | 0.549308 |
| 24 | 0.489543 |
| 25 | 0.448034 |

## 3.3 Reactor Conditions

Hope Creek intends to operate in the EPU/MELLLA operating domain with a rated reactor power of 3952 MWt. Several power and flow points within the EPU/MELLLA domain are also evaluated in this report to verify the conclusion that the SVEA-96+ and GE14 fuel types are thermal hydraulically compatible. The evaluation points were chosen near the boundaries of the EPU/MELLLA operating domain, as well as power/flow conditions relevant during startup or control rod sequence exchanges. Table 3.6 lists the reactor conditions evaluated.

**Table 3.6 - Evaluated Reactor Conditions**

| | | | | | | |
|---|---|---|---|---|---|---|
| Core Thermal Power MWt<br>% of rated | 3952<br>100 | 3952<br>100 | 2205.2<br>55.8 | 1185.6<br>30 | 1185.6<br>30 | 2766.4<br>70 |
| Core Flow (Mlbm/hr)<br>% of rated | 105.0<br>105 | 99.0<br>99 | 39.2<br>39.2 | 105.0<br>105 | 39.2<br>39.2 | 70.0<br>70 |
| Inlet Enthalpy, BTU/lbm | 526.3 | 524.9 | 493.7 | 522.9 | 504.8 | 512.5 |
| Core Mid-plane Pressure, psia | 1036.0 | 1034.8 | 953.3 | 934.1 | 926.8 | 976.6 |

The reactor condition of 100% power and 105% core flow represents the extent of the Hope Creek Increased Core Flow evaluation boundary. The two conditions, 100% power/99% core flow and 55.8% power/39.2% core flow represent the upper and lower points respectively along the EPU/MELLLA upper boundary. The reactor condition of 70% power and 70% core flow is evaluated to represent conditions encountered during a control rod sequence exchange. The condition of 30% power and 39.2% core flow represents a point in the normal startup path of the reactor. The point of 30% power and 105% flow is chosen to represent the most mismatch between power and flow.

## 3.4 Results

Tables 3.7-3.12 list a portion of the FIBWR2 simulation results for full cores of SVEA-96+ and GE14 fuel. Each FIBWR2 simulation consists of 661 average power bundles, 92 peripheral – low power bundles and one hot bundle with a 1.56 radial peaking factor. The following trends were observed when comparing a full core of SVEA-96+ fuel to a full core of GE14 fuel:

- The core pressure drop for a full core of GE14 fuel is *higher* than the core pressure drop for a full core of SVEA-96+ fuel at all reactor conditions. The maximum difference in core pressure drop was (19.96-18.41) 1.55 psid (~8.5%) for the 30% power 105% core flow reactor condition. Near rated conditions, the difference is reduced to 1.15 psid (~5.4%). A similar trend was also observed by GNF (Reference 3).

- The core active flow (water through the active fuel zone) for each fuel type is essentially the same for all reactor conditions (all conditions within 1.5% of core flow).

- The core bypass flow (excluding water tube flow) for a full core of GE14 fuel is *higher* than the core bypass flow for a full core of SVEA-96+ fuel, while the water tube flow for GE14 is *lower* than for SVEA-96+ fuel, at all reactor conditions. These two parameters are complimentary due to differences in the construction of each fuel type. The GE14 fuel channel slides over the assembly with a spring loaded fit against the lower tie plate. The spring loaded fit allows for water to enter the bypass region after it is above the lower tie plate. The water tube entrances for the GE14 fuel are above the lower tie plate, so water that exits between the channel and the lower tie plate cannot enter the water tubes. [

  ] When the differences of core bypass flow and water tube flow are considered concurrently, the differences are of the same magnitude as the differences seen in core active flow (all conditions with 1.5% difference for bypass and water tube flow).

- The hot bundle active flow for a full core of the GE14 fuel type is essentially the same as the hot bundle active flow for a full core of the SVEA-96+ fuel type. The magnitude of the difference is a maximum of 2% for the 70% power 70% flow case. Given the performance of the other parameters evaluated in this report, this 2% difference in hot bundle active flow is insignificant. A similar trend was also observed by GNF in reference 3.

- An evaluation of the bulk bypass exit void fraction was also performed to ensure that introduction of the GE14 fuel design will not result in significant boiling in the bulk bypass region. For all reactor conditions evaluated, the bypass voiding results are consistent with those predicted by GNF in reference 3.

**Table 3.7 – 100% Power, 105% Core Flow Full Core Results**

| Property | Full Core SVEA | Full Core GE14 |
|---|---|---|
| Core Power (MWt) | 3951.99 | 3951.99 |
| Core Flow (Mlbm/hr) | 105 | 105 |
| Inlet Enthalpy (BTU/lbm) | 526.3 | 526.3 |
| System Pressure (psia) | 1036 | 1036 |
| Total Active Flow (Mlbm/hr) | 87.94 | 87.89 |
| Bypass Flow (Mlbm/hr) | 11.6 | 12.79 |
| Water Tube(s) Flow (Mlbm/hr) | 5.46 | 4.31 |
| Total Pressure Drop (psid) | 22.96 | 24.28 |
| CSP Pressure Drop (psid) | 18.09 | 19.39 |
| Hot Channel Active Flow (klbm/hr) | 101.9 | 102.9 |

**Table 3.8 – 100% Power, 99% Core Flow Full Core Results**

| Property | Full Core SVEA | Full Core GE14 |
|---|---|---|
| Core Power (MWt) | 3951.99 | 3951.99 |
| Core Flow (Mlbm/hr) | 99 | 99 |
| Inlet Enthalpy (BTU/lbm) | 524.9 | 524.9 |
| System Pressure (psia) | 1034.81 | 1034.81 |
| Total Active Flow (Mlbm/hr) | 82.71 | 82.74 |
| Bypass Flow (Mlbm/hr) | 11.07 | 12.13 |
| Water Tube(s) Flow (Mlbm/hr) | 5.23 | 4.13 |
| Total Pressure Drop (psid) | 21.21 | 22.37 |
| CSP Pressure Drop (psid) | 16.34 | 17.49 |
| Hot Channel Active Flow (klbm/hr) | 94.7 | 95.8 |

**Table 3.9 – 30% Power, 105% Core Flow Full Core Results**

| Property | Full Core SVEA | Full Core GE14 |
|---|---|---|
| Core Power (MWt) | 1185.6 | 1185.6 |
| Core Flow (Mlbm/hr) | 104.99 | 105 |
| Inlet Enthalpy (BTU/lbm) | 522.9 | 522.9 |
| System Pressure (psia) | 934.1 | 934.1 |
| Total Active Flow (Mlbm/hr) | 91.82 | 91.8 |
| Bypass Flow (Mlbm/hr) | 9.16 | 9.97 |
| Water Tube(s) Flow (Mlbm/hr) | 4.02 | 3.23 |
| Total Pressure Drop (psid) | 18.41 | 19.96 |
| CSP Pressure Drop (psid) | 13.51 | 15.06 |
| Hot Channel Active Flow (klbm/hr) | 120.1 | 120.6 |

**Table 3.10 – 30% Power, 39.2% Core Flow Full Core Results**

| Property | Full Core SVEA | Full Core GE14 |
|---|---|---|
| Core Power (MWt) | 1185.6 | 1185.6 |
| Core Flow (Mlbm/hr) | 39.21 | 39.21 |
| Inlet Enthalpy (BTU/lbm) | 504.8 | 504.8 |
| System Pressure (psia) | 926.8 | 926.8 |
| Total Active Flow (Mlbm/hr) | 36.01 | 36.35 |
| Bypass Flow (Mlbm/hr) | 2.22 | 2.1 |
| Water Tube(s) Flow (Mlbm/hr) | 0.97 | 0.75 |
| Total Pressure Drop (psid) | 6.26 | 6.41 |
| CSP Pressure Drop (psid) | 1.42 | 1.56 |
| Hot Channel Active Flow (klbm/hr) | 44.9 | 45.8 |

**Table 3.11 – 55.8% Power, 39.2% Core Flow Full Core Results**

| Property | Full Core SVEA | Full Core GE14 |
|---|---|---|
| Core Power (MWt) | 2205.22 | 2205.22 |
| Core Flow (Mlbm/hr) | 39.2 | 39.2 |
| Inlet Enthalpy (BTU/lbm) | 493.7 | 493.7 |
| System Pressure (psia) | 953.34 | 953.34 |
| Total Active Flow (Mlbm/hr) | 34.65 | 35.16 |
| Bypass Flow (Mlbm/hr) | 3.06 | 2.89 |
| Water Tube(s) Flow (Mlbm/hr) | 1.48 | 1.15 |
| Total Pressure Drop (psid) | 6.75 | 6.87 |
| CSP Pressure Drop (psid) | 1.89 | 1.98 |
| Hot Channel Active Flow (klbm/hr) | 39.2 | 40.2 |

**Table 3.12 – 70% Power, 70% Core Flow Full Core Results**

| Property | Full Core SVEA | Full Core GE14 |
|---|---|---|
| Core Power (MWt) | 2766.4 | 2766.4 |
| Core Flow (Mlbm/hr) | 70 | 69.99 |
| Inlet Enthalpy (BTU/lbm) | 512.5 | 512.5 |
| System Pressure (psia) | 976.6 | 976.6 |
| Total Active Flow (Mlbm/hr) | 59.13 | 59.52 |
| Bypass Flow (Mlbm/hr) | 7.39 | 7.73 |
| Water Tube(s) Flow (Mlbm/hr) | 3.48 | 2.75 |
| Total Pressure Drop (psid) | 12.58 | 13.12 |
| CSP Pressure Drop (psid) | 7.7 | 8.23 |
| Hot Channel Active Flow (klbm/hr) | 67.1 | 68.4 |

# 4 Mixed Core Evaluations

The results of the full core evaluations in section 3.4 described a series of expectations regarding the similarity in thermal-hydraulic performance of the GE14 and SVEA-96+ fuel designs. This section of the report will investigate the compatibility between GE14 and SVEA-96+ through a series of mixed cores, progressing from the full core of SVEA-96+ fuel to a full core of GE14 fuel. The core loadings evaluated in this section are shown in Table 4.1.

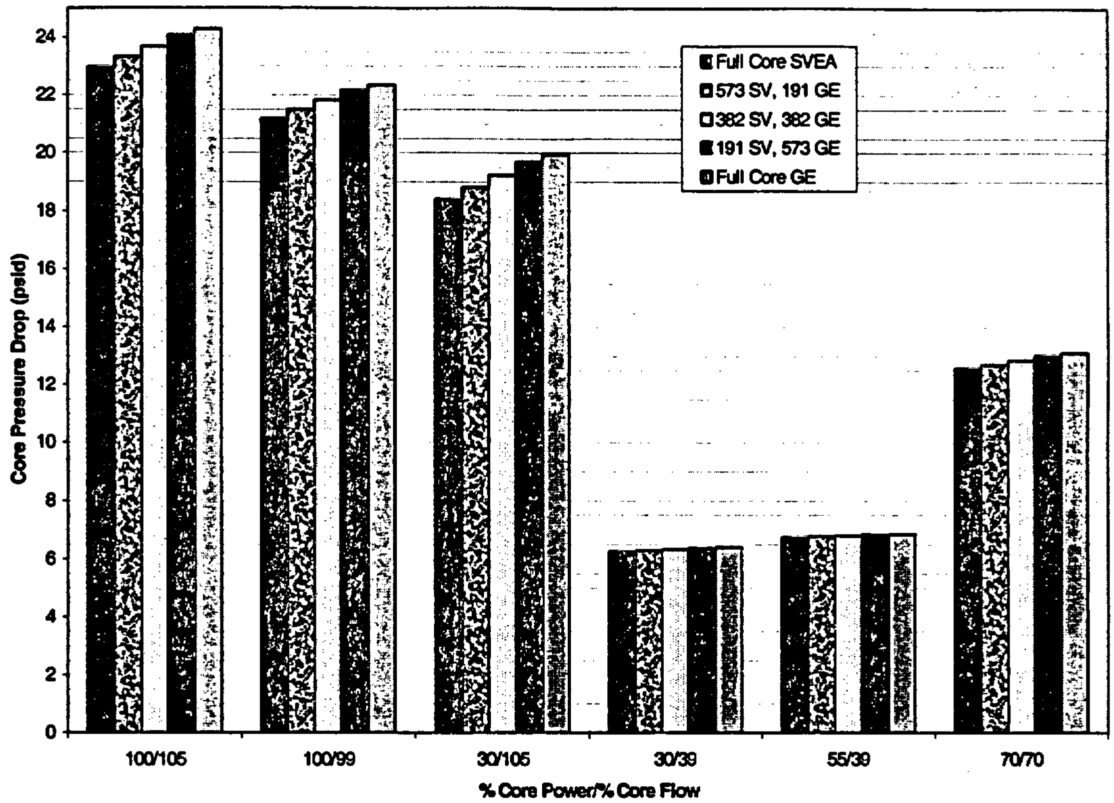
**Table 4.1 – Core Loadings for Mixed Core Evaluations**

| Core Composition – Number of Assemblies | |
|---|---|
| SVEA-96+ | GE14 |
| 573 | 191 |
| 382 | 382 |
| 191 | 573 |

Tables 4.2-4.7 display the FIBWR2 simulation results for each of the core loadings in Table 4.1 at each of the reactor conditions listed on Table 3.6. The mixed core simulations project the performance of both fuel types during transition cores going from a full core of SVEA-96+ fuel to a full core of GE14 fuel. During the core transition, only SVEA-96+ assemblies are placed in positions on the core periphery. Each of the core loadings contains these 92 SVEA-96+ peripheral assemblies, one hot SVEA-96+ bundle with a 1.56 peaking factor, one hot GE14 bundle with a 1.56 peaking factor, and the remainder of each fuel type to reach the respective bundle quantities in Table 4.1. The following trends were observed to occur in the mixed core evaluations:

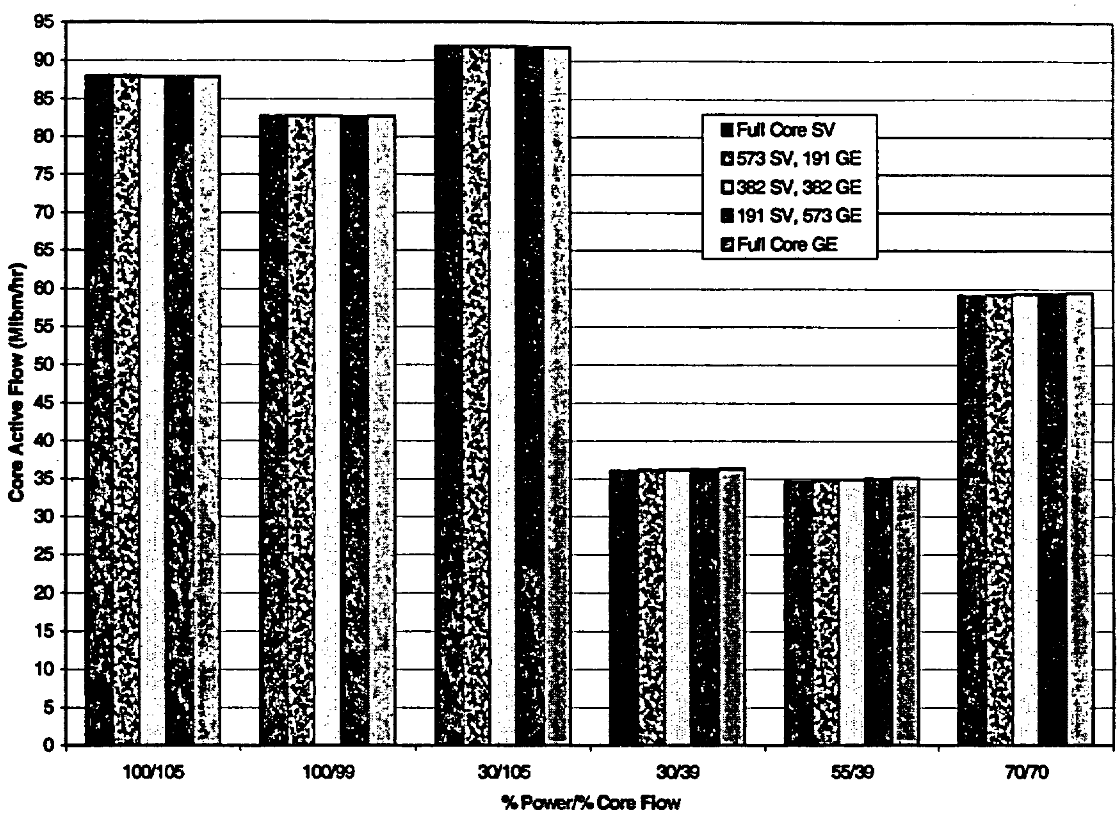
- As discussed in section 3.4, the core pressure drop for a full core of GE14 fuel is *higher* than the core pressure drop for a full core of SVEA-96+ fuel at all reactor conditions. The mixed core results show that as the fraction of GE14 assemblies increases, the core pressure drop increases to approach the GE14 full core value. The linearity of core pressure drop as a function of GE14 assembly fraction as shown in Figure 4.1 indicates that the introduction of GE14 fuel assemblies into the SVEA-96+ full core does not significantly affect the original SVEA-96+ performance while GE14 fuels maintain their own performance as if they are in the full GE14 cores. This result is expected since the thermal-hydraulic performance of these two fuel types is similar, as demonstrated in the previous section. The same relative results were obtained by GNF in reference 3.

## Figure 4.1 – Core Pressure Drop Performance



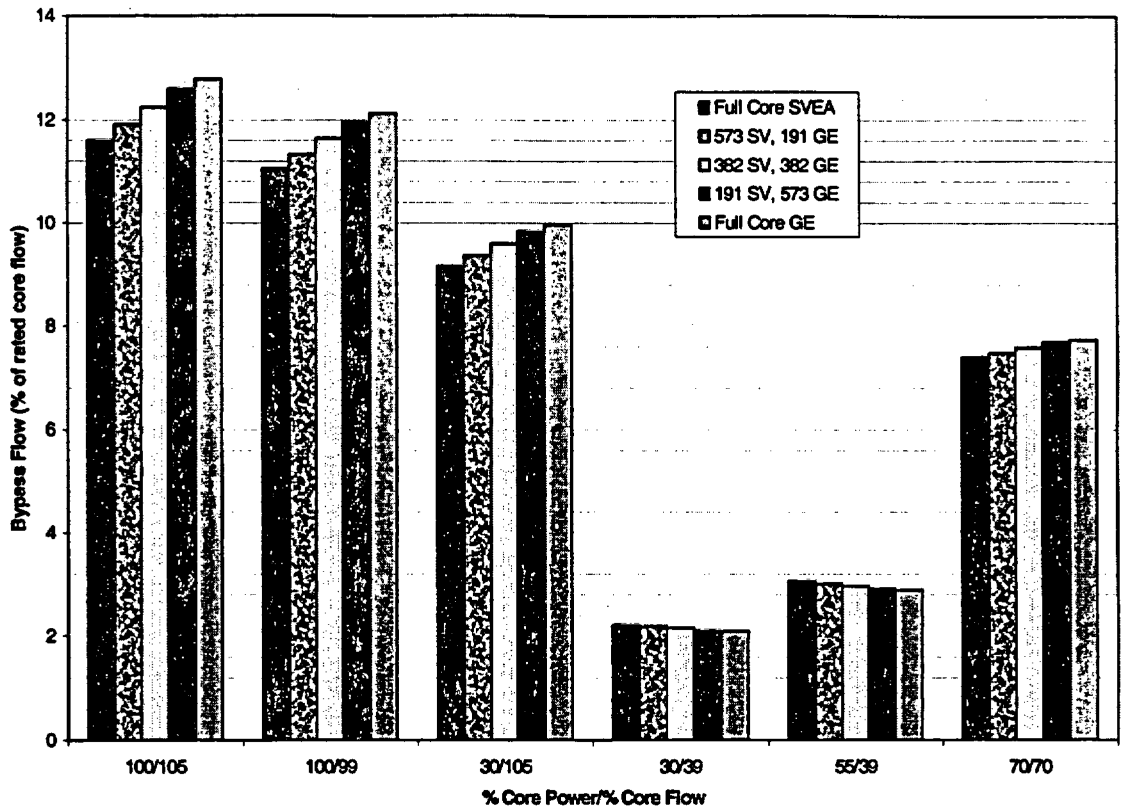

- The core active flow (water through the active fuel zone) for the mixed core is essentially the same for all reactor conditions (all conditions within 1.5% of core flow). Figure 4.2 displays the core active flow change as a function of core loading for each of the reactor conditions evaluated. Reference 3 shows similar trends with respect to core active flow predicted by GNF.

**Figure 4.2 – Core Active Flow Performance**




- As discussed in section 3.4, the core bypass flow (excluding water tube flow) for a full core of GE14 fuel is *higher* than the core bypass flow for a full core of SVEA-96+ fuel. The mixed core evaluations demonstrate a clear progression towards the full core GE14 values observed in Tables 3.7-3.12. This is due to differences in the construction of each fuel type as described in section 3.4. As the fraction of GE14 fuel increases, more flow paths are available from the fuel channel to the bypass region. Figure 4.3 displays the bypass flow as a function of core loading for each of the reactor conditions evaluated. The differences in fuel design though, do not adversely affect the performance of a neighboring fuel assembly.

## Figure 4.3 – Bypass Flow Performance




- Due to the differences in pressure drop of the two fuel designs, the hot bundle active flows in the mixed core evaluations are affected in the following ways: The GE14 hot bundle active flow in the 573 SVEA-96+, 191 GE14 core is approximately 4% less than the full core GE14 evaluations in section 3. As the number of GE14 assemblies increases, the GE14 hot bundle flow increases towards the full core value. Since the GE14 fuel design has a slightly higher pressure drop, the SVEA-96+ hot bundle active flow is more than the full core result in section 3, by about 1.5% in the 573 SVEA-96+, 191 GE14 core loading. As the number of GE14 bundles increases, the SVEA-96+ hot bundle active flow actually increases to approximately 5% higher than the full core SVEA-96+ results. Figures 4.4-4.6 display the hot channel active flow performance of each fuel type in the mixed cores, compared to the full cores. As in reference 3, essentially no change in hot bundle active flow is observed for the 30% power, 39.2% core flow case or for the 55.8% power, 39.2% core flow case.

**Figure 4.4 – Hot Channel Active Flow Performance – 573 SVEA-96+, 191 GE14 Core Loading**

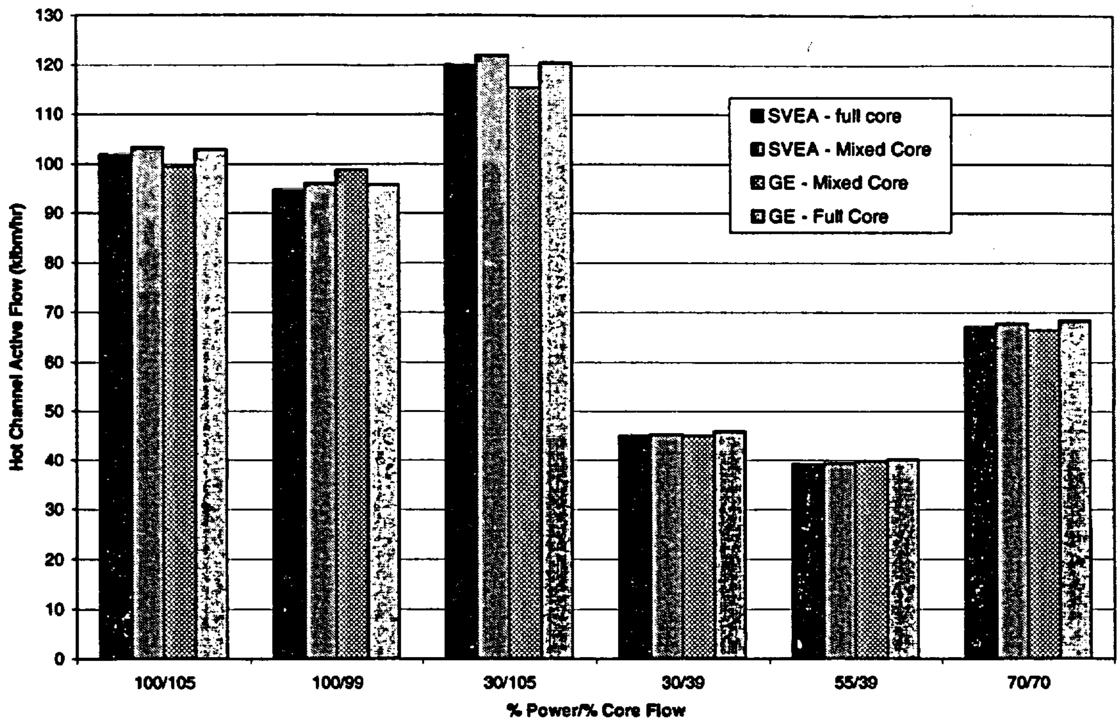



**Figure 4.5 – Hot Channel Active Flow Performance – 382 SVEA-96+, 382 GE14 Core Loading**

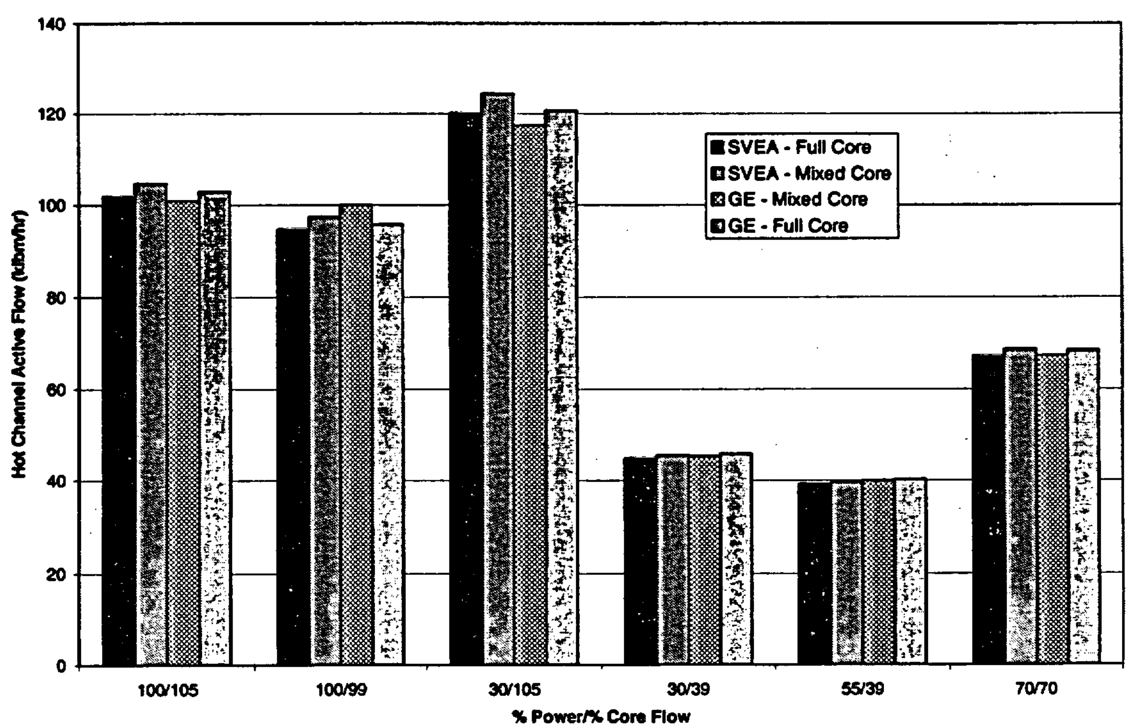
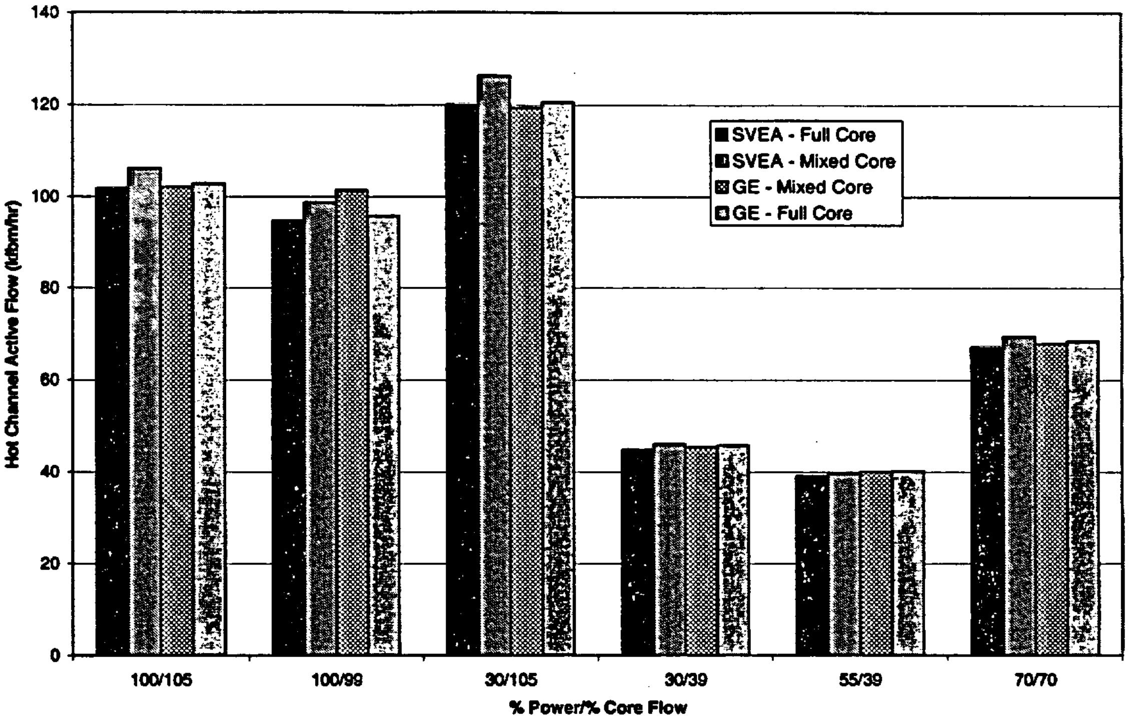


**Figure 4.6 – Hot Channel Active Flow Performance – 191 SVEA-96+, 573 GE14 Core Loading**




- As with the full core evaluations in section 3, it was confirmed that the mixed cores evaluated show results similar to GNF with respect to bypass voiding.

## Table 4.2 - 100% Power, 105% Core Flow Mixed Core Results

| Property | 573 SVEA, 191 GE14 | 382 SVEA, 382 GE14 | 191 SVEA, 573 GE14 |
|---|---|---|---|
| Core Power (MWt) | 3951.99 | 3951.99 | 3951.99 |
| Core Flow (Mlbm/hr) | 105 | 105 | 105 |
| Inlet Enthalpy (BTU/lbm) | 526.3 | 526.3 | 526.3 |
| System Pressure (psia) | 1036 | 1036 | 1036 |
| Total Active Flow (Mlbm/hr) | 87.92 | 87.9 | 87.86 |
| Bypass Flow (Mlbm/hr) | 11.92 | 12.24 | 12.59 |
| Water Tube(s) Flow (Mlbm/hr) | 4.045 SV<br>1.119 GE | 2.604 SV<br>2.254 GE | 1.141 SV<br>3.411 GE |
| Total Pressure Drop (psid) | 23.32 | 23.67 | 24.07 |
| CSP Pressure Drop (psid) | 18.44 | 18.79 | 19.18 |
| Hot Channel Active Flow (klbm/hr) | 103.3 SV<br>99.4 GE | 104.7 SV<br>100.8 GE | 106.2 SV<br>102.1 GE |

## Table 4.3 - 100% Power, 99% Core Flow Mixed Core Results

| Property | 573 SVEA, 191 GE14 | 382 SVEA, 382 GE14 | 191 SVEA, 573 GE14 |
|---|---|---|---|
| Core Power (MWt) | 3951.99 | 3951.99 | 3951.99 |
| Core Flow (Mlbm/hr) | 99 | 99 | 99 |
| Inlet Enthalpy (BTU/lbm) | 524.9 | 524.9 | 524.9 |
| System Pressure (psia) | 1034.81 | 1034.81 | 1034.81 |
| Total Active Flow (Mlbm/hr) | 82.71 | 82.71 | 82.69 |
| Bypass Flow (Mlbm/hr) | 11.35 | 11.65 | 11.96 |
| Water Tube(s) Flow (Mlbm/hr) | 3.868 SV<br>1.071 GE | 2.489 SV<br>2.158 GE | 1.089 SV<br>3.265 GE |
| Total Pressure Drop (psid) | 21.52 | 21.83 | 22.18 |
| CSP Pressure Drop (psid) | 16.65 | 16.96 | 17.29 |
| Hot Channel Active Flow (klbm/hr) | 96.0 SV<br>98.8 GE | 97.4 SV<br>100.1 GE | 98.7 SV<br>101.4 GE |

## Table 4.4 - 30% Power, 105% Core Flow Mixed Core Results

| Property | 573 SVEA, 191 GE14 | 382 SVEA, 382 GE14 | 191 SVEA, 573 GE14 |
|---|---|---|---|
| Core Power (MWt) | 1185.6 | 1185.6 | 1185.6 |
| Core Flow (Mlbm/hr) | 105 | 105 | 105 |
| Inlet Enthalpy (BTU/lbm) | 522.9 | 522.9 | 522.9 |
| System Pressure (psia) | 934.1 | 934.1 | 934.1 |
| Total Active Flow (Mlbm/hr) | 91.81 | 91.8 | 91.77 |
| Bypass Flow (Mlbm/hr) | 9.37 | 9.6 | 9.84 |
| Water Tube(s) Flow (Mlbm/hr) | 2.980 SV<br>0.837 GE | 1.908 SV<br>1.697 GE | 0.797 SV<br>2.581 GE |
| Total Pressure Drop (psid) | 18.82 | 19.25 | 19.7 |
| CSP Pressure Drop (psid) | 13.92 | 14.34 | 14.79 |
| Hot Channel Active Flow (klbm/hr) | 122.1 SV<br>115.6 GE | 124.2 SV<br>117.5 GE | 126.3 SV<br>119.4 GE |

## Table 4.5 - 30% Power, 39.2% Core Flow Mixed Core Results

| Property | 573 SVEA, 191 GE14 | 382 SVEA, 382 GE14 | 191 SVEA, 573 GE14 |
|---|---|---|---|
| Core Power (MWt) | 1185.6 | 1185.6 | 1185.6 |
| Core Flow (Mlbm/hr) | 39.21 | 39.21 | 39.21 |
| Inlet Enthalpy (BTU/lbm) | 504.8 | 504.8 | 504.8 |
| System Pressure (psia) | 926.8 | 926.8 | 926.8 |
| Total Active Flow (Mlbm/hr) | 36.1 | 36.18 | 36.27 |
| Bypass Flow (Mlbm/hr) | 2.19 | 2.16 | 2.11 |
| Water Tube(s) Flow (Mlbm/hr) | 0.714 SV<br>0.208 GE | 0.445 SV<br>0.427 GE | 0.163 SV<br>0.660 GE |
| Total Pressure Drop (psid) | 6.3 | 6.34 | 6.39 |
| CSP Pressure Drop (psid) | 1.45 | 1.5 | 1.54 |
| Hot Channel Active Flow (klbm/hr) | 45.2 SV<br>44.9 GE | 45.6 SV<br>45.3 GE | 46.0 SV<br>45.5 GE |

## Table 4.6 - 55.8% Power, 39.2% Core Flow Mixed Core Results

| Property | 573 SVEA, 191 GE14 | 382 SVEA, 382 GE14 | 191 SVEA, 573 GE14 |
|---|---|---|---|
| Core Power (MWt) | 2205.2 | 2205.2 | 2205.2 |
| Core Flow (Mlbm/hr) | 39.2 | 39.2 | 39.2 |
| Inlet Enthalpy (BTU/lbm) | 493.7 | 493.7 | 493.7 |
| System Pressure (psia) | 953.34 | 953.34 | 953.34 |
| Total Active Flow (Mlbm/hr) | 34.79 | 34.92 | 35.07 |
| Bypass Flow (Mlbm/hr) | 3.01 | 2.97 | 2.91 |
| Water Tube(s) Flow (Mlbm/hr) | 1.079 SV<br>0.317 GE | 0.665 SV<br>0.640 GE | 0.245 SV<br>0.972 GE |
| Total Pressure Drop (psid) | 6.79 | 6.81 | 6.85 |
| CSP Pressure Drop (psid) | 1.92 | 1.95 | 1.97 |
| Hot Channel Active Flow (klbm/hr) | 39.4 SV<br>39.7 GE | 39.6 SV<br>39.9 GE | 39.7 SV<br>40.1 GE |

## Table 4.7 - 70% Power, 70% Core Flow Mixed Core Results

| Property | 573 SVEA, 191 GE14 | 382 SVEA, 382 GE14 | 191 SVEA, 573 GE14 |
|---|---|---|---|
| Core Power (MWt) | 2766.4 | 2766.4 | 2766.4 |
| Core Flow (Mlbm/hr) | 70 | 70 | 70 |
| Inlet Enthalpy (BTU/lbm) | 512.5 | 512.5 | 512.5 |
| System Pressure (psia) | 976.6 | 976.6 | 976.6 |
| Total Active Flow (Mlbm/hr) | 59.23 | 59.32 | 59.41 |
| Bypass Flow (Mlbm/hr) | 7.48 | 7.58 | 7.69 |
| Water Tube(s) Flow (Mlbm/hr) | 2.562 SV<br>0.726 GE | 1.628 SV<br>1.463 GE | 0.682 SV<br>2.214 GE |
| Total Pressure Drop (psid) | 12.72 | 12.87 | 13.03 |
| CSP Pressure Drop (psid) | 7.84 | 7.98 | 8.14 |
| Hot Channel Active Flow (klbm/hr) | 67.8 SV<br>66.5 GE | 68.6 SV<br>67.3 GE | 69.4 SV<br>67.9 GE |

# 5 Conclusions

The purpose of this report was to provide independent verification to the conclusions reached by GNF that introduction of the GE14 fuel type will not adversely affect the performance of the SVEA-96+ fuel also, that the GE14 and SVEA-96+ fuel types are thermal- hydraulically compatible as evaluated in the Hope Creek core.

Data provided by Westinghouse and GNF was used by PSEG to develop FIBWR2 computer code models to perform the various evaluations. Section 3 of this report contained full core evaluations of both the SVEA-96+ and GE14 fuel types, which were used to develop preliminary expectations regarding the performance of the two fuel types in mixed core applications. Section 4 of the report contained a number of mixed core evaluations meant to simulate a progression from a full core of SVEA-96+ fuel to a full core of GE14 fuel. The parameters evaluated and discussed in section 3 were re-visited in section 4 and conclusions were made consistent with the expectations established.

The axial power shape sensitivity evaluated in Appendix A provides support to the conclusion that the thermal hydraulic compatibility of the two fuel designs is not dependent on axial power shape. The two power shapes evaluated (bottom and top peaked) are expected to be typical for operation of Hope Creek in the upcoming cycles, for beginning and end of cycle.

Although no specific evaluations were performed in this report, it is concluded that the introduction of the GE14 fuel type will not degrade the CPR performance of the SVEA-96+ fuel type in the Hope Creek core. This conclusion is reached based on the core and bundle parameters that were explicitly evaluated in the report and general knowledge of fuel critical power performance. For example, the hot channel active flow of the SVEA-96+ fuel type was observed to increase as the core fraction of GE14 fuel type increases (section 4 and Figures 4.4-4.6). At the same power, pressure, and inlet subcooling, an increase in channel active flow will enhance the CPR performance of that assembly.

Based upon the full core and mixed core evaluations contained in this report, PSEG has independently verified the conclusions reached by GNF in reference 3 that the introduction of the GE14 fuel will not adversely impact the performance of the SVEA-96+ fuel, and that the two distinct fuel designs are thermal hydraulically compatible.

# 6 References


1. Nuclear Fuel Section Design Input File HCA.5-0020, "SVEA-96+ Thermal Hydraulic Characteristics" August, 2000.
2. Nuclear Fuel Section Design Input File HCG.5-0004, "GE14 Thermal Hydraulic Characteristics" July, 2003
3. Nuclear Fuel Section Vendor Technical Document NFVD-GE-2003-002-00, "GE14 Thermal Hydraulic Compatibility with Hope Creek Legacy Fuel" September, 2003.
4. Nuclear Fuel Section Design Analysis File HCT.6-0031, "SVEA-96+ FIBWR2 Benchmarking" August 2000.
5. Nuclear Fuel Section Design Analysis File HCT.6-0042, "GE14 FIBWR2 Benchmarking" August 2003.
6. Nuclear Fuel Section Design Analysis File HCT.6-043, "Verification of the GNF Mixed Core GE14/SVEA-96+ Assembly Compatibility Report." September, 2003.
7. Nuclear Fuel Section Software Configuration Management File SCM-0114, "FIBWR2 Version 1.08c (with GEXL and ABBD2.0) Installation Package for DS20." April, 2002.

# Appendix A – Axial Power Shape Sensitivity

The evaluations in this report used a bottom peaked axial power shape as shown in Table 3.5. The bottom peaked shape was chosen to maximize the two-phase pressure drop within a fuel assembly relative to other power shapes. In order to confirm the conclusions made throughout the report are valid for other axial power shapes, evaluations were performed with a top peaked axial power shape and the results are discussed in this appendix. Table A.1 displays the axial power shape used for the evaluations in this appendix. Evaluations in this appendix were performed for the 100% power, 105% core flow condition, and demonstrate that trends seen in sections 3 and 4 of this report are consistent, regardless of power shape. Table A.2 displays the results of several core parameters as a function of core loading. These results show trends consistent with those in sections 3 and 4.

**Table A.1 – Top Peaked Axial Power Shape**

| Node (1=bottom of active fuel) | Top Peaked Axial Power Shape |
|---|---|
| 1 | 0.448034 |
| 2 | 0.489543 |
| 3 | 0.549308 |
| 4 | 0.622512 |
| 5 | 0.704855 |
| 6 | 0.792518 |
| 7 | 0.882116 |
| 8 | 0.970661 |
| 9 | 1.055521 |
| 10 | 1.134375 |
| 11 | 1.205177 |
| 12 | 1.266111 |
| 13 | 1.315552 |
| 14 | 1.352023 |
| 15 | 1.374157 |
| 16 | 1.380653 |
| 17 | 1.370236 |
| 18 | 1.341615 |
| 19 | 1.293446 |
| 20 | 1.224284 |
| 21 | 1.132547 |
| 22 | 1.016474 |
| 23 | 0.874083 |
| 24 | 0.703130 |
| 25 | 0.501068 |

## Table A.2 – Top Peaked Axial Power Shape Performance for All Core Loadings

| Property | Full Core SVEA | 573 SVEA, 191 GE14 | 382 SVEA, 382 GE14 | 191 SVEA, 573 GE14 | Full Core GE14 |
|---|---|---|---|---|---|
| Core Power (MWt) | 3951.99 | 3951.99 | 3951.99 | 3951.99 | 3951.99 |
| Core Flow (Mlbm/hr) | 105 | 105 | 105 | 105 | 105 |
| Inlet Enthalpy | 526.3 | 526.3 | 526.3 | 526.3 | 526.3 |
| System Pressure (psia) | 1036 | 1036 | 1036 | 1036 | 1036 |
| Total Active Flow (Mlbm/hr) | 88.51 | 88.56 | 88.6 | 88.64 | 88.73 |
| Bypass Flow (Mlbm/hr) | 11.24 | 11.5 | 11.77 | 12.05 | 12.2 |
| Water Tube(s) Flow (Mlbm/hr) | 5.26 | 3.890 SV<br>1.057 GE | 2.497 SV<br>2.131 GE | 1.090 SV<br>3.221 GE | 4.06 |
| Total Pressure Drop (psid) | 22.21 | 22.5 | 22.8 | 23.13 | 23.31 |
| CSP Pressure Drop (psid) | 17.33 | 17.63 | 17.92 | 18.24 | 18.42 |
| Hot Channel Active Flow (klbm/hr) | 104.1 | 105.3 SV<br>102.8 GE | 106.5 SV<br>104.0 GE | 107.8 SV<br>105.3 GE | 112.1 |