Docket No. 50-213
B14870

Attachment 2

Haddam Neck Plant

Mechanical Design Description
(Non-Proprietary Version)

June 1994

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Transmittal of
Mechanical Design Description

(Non-Proprietary)

June 1994

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1.0 Introduction and Background

1.1 Introduction

Northeast Utilities and Connecticut Yankee plan to insert Westinghouse 15x15 VANTAGE 5H fuel assemblies (w/o IFMs) containing fuel rods clad with Zircaloy-4 alloy; and guide thimble tubes and instrumentation tubes and mid-span grids fabricated with Zircaloy-4 alloy, into the Haddam Neck Plant core. This report provides a reference safety evaluation and compatibility justification supporting the licensing basis for insertion of these VANTAGE 5H fuel assemblies in the Haddam Neck Plant.

The initial irradiation of a fuel region containing all the VANTAGE 5 design features occurred in the Callaway Plant in November 1987. The Callaway VANTAGE 5 licensing submittal was made to the NRC on March 31, 1987. NRC approval was received in October 1987. The initial irradiation of a fuel region containing the VANTAGE 5H design features occurred in Salem Unit 1 in June 1989. The Salem Unit 1 and 2 VANTAGE 5H licensing submittal was made to the NRC in November 1988. NRC approval was received in May 1989.

Several of the VANTAGE 5 design features, such as axial blankets, reconstitutable top nozzles, extended burnup modified fuel assemblies and Integral Fuel Burnable Absorbers have been successfully licensed as individual design features and are currently in operating Westinghouse plants. The Haddam Neck Plant, commencing with Cycle 19, will be operating with a core containing the following VANTAGE 5H features:

- Low Pressure Drop (LPD) Zircaloy-4 mid-grids,
- Integral Fuel Burnable Absorbers (IFBAs),
- Reconstitutable Top Nozzle (RTNs),
- Assembly Dimensional Modifications for extended burnup,

In addition, the Haddam Neck Plant VANTAGE 5H fuel assemblies will contain the Debris Filter Bottom Nozzle (DFBN), anti-snag inconel end grids and Zircaloy-4 mid-grids, and longer tapered fuel rod end plugs (debris resistant design).

All analyses, design codes and methodology referenced herein are approved by the US NRC for nuclear plant licensing.

1.2 Background

In 1983, Westinghouse submitted a topical report to the NRC for the VANTAGE 5 Fuel Assembly design(1). The VANTAGE 5 fuel assembly design received NRC approval in a 1985 SER(2). In 1988, Westinghouse submitted Addendum 2 to the VANTAGE 5 topical report(3). This addendum addressed the VANTAGE 5H fuel assembly design. The VANTAGE 5H fuel assembly design received NRC approval in a 1988 SER(4).

1.3 Areas Assessed

The following areas have been assessed during the safety evaluation process: mechanical/material, fuel rod and portions of the thermal-hydraulic design. These areas are discussed in detail in Section 3.

2.0 Licensing Basis

2.1 Acceptance Criteria Basis

Based on the design criteria(1)(3), the acceptance criteria for this safety/compatibility assessment are specified herein for mechanical/material, fuel rod and thermal-hydraulic design.

NRC-Imposed Limitations on the use of WCAP-10444:

The NRC Staff reviewed Westinghouse's WCAP-10444, "Reference Core Report VANTAGE 5 Fuel Assembly," and concluded in a Staff Safety Evaluation Report (SER)(2) that the generic topical report was an acceptable reference to support plant-specific applications for use of VANTAGE 5 fuel, provided thirteen conditions identified in the SER were addressed by the licensees. These conditional requirements are specified below and addressed as applicable to the areas being assessed in this report. These conditional requirements remain applicable to the VANTAGE 5H fuel assembly design.

NRC Conditional Requirement 1: The statistical convolution method described in WCAP-10125 for the evaluation of initial fuel rod to nozzle growth has not been approved. This method should not be used in VANTAGE 5.

> *The statistical convolution method has been approved by the NRC for fuel evaluation. WCAP-10125-P-A is applicable to VANTAGE 5/VANTAGE 5H fuel rod designs.*

NRC Conditional Requirement 2: For each plant application, it must be demonstrated that the LOCA/seismic loads considered in WCAP-9401 bound the plant in question; otherwise additional analysis will be required to demonstrate the fuel assembly structural integrity.

> *An evaluation of the VANTAGE 5H (w/o IFMs) fuel assembly structural integrity considering the lateral effects of a LOCA and seismic accident has been performed. The results, as discussed in Section 3.0 of the safety assessment, show that VANTAGE 5H (w/o IFMs) is structurally acceptable for an all VANTAGE 5H core and a transition core consisting of both B&W and VANTAGE 5H fuel assemblies.*

NRC Conditional Requirement 3: An irradiation demonstration program should be performed to provide early confirmation performance data for the VANTAGE 5 design.

> *A demonstration program was successfully performed to determine early performance data on the VANTAGE 5 fuel assembly design features. The VANTAGE 5 demonstration program at commercial reactors is described in Section 1.0 of the safety assessment.*

NRC Conditional Requirement 4: For those plants using the ITDP, the restrictions enumerated in Section 4.1 of this report (WCAP-10444 SER) must be addressed and information regarding measurement uncertainties must be provided.

> *The restrictions are not applicable for the Haddam Neck Plant since all uncertainties associated with the plant operating parameters are not statistically combined to the DNBR limit. Therefore, information regarding plant specific measurement uncertainties need not be provided.*

NRC Conditional Requirement 5: The WRB-2 correlation with a DNBR limit of 1.17 is acceptable for application to 17x17 VANTAGE 5 fuel. Additional data and analysis are required when applied to 14x14 or 15x15 fuel with an appropriate DNBR limit. The applicability range of WRB-2 is specified in Section 4.2.

> *The WRB-2 DNB correlation is not being applied to 15x15 fuel. The WRB-1 DNB correlation is being applied. The 15x15 VANTAGE 5 fuel is within the applicability range of the WRB-1 DNB correlation.*

NRC Conditional Requirement 6: For 14x14 and 15x15 VANTAGE 5 fuel designs, separate analyses will be required to determine a transitional mixed core penalty. The mixed core penalty and plant-specific safety margin to compensate for the penalty should be addressed in the plant Technical Specifications Bases.

> *The mixed core penalty for Cycle 19 has been determined to be 3%. This value will be documented in the Technical Report Supporting Cycle Operation.*

NRC Conditional Requirement 7: Plant-specific analysis should be performed to show that the DNBR limit will not be violated with the higher value of $F_{\Delta H}$.

> *Plant specific analysis will be performed to show that the DNBR limit will not be violated with the higher value of* $F_{\Delta H}$. *A summary of these analyses will be provided in the Technical Report Supporting Cycle Operation.*

NRC Conditional Requirement 8: The plant-specific safety analysis for the steam system piping failure event should be performed with the assumption of loss of offsite power if that is the most conservative case.

> *The safety analysis for the steam system piping failure does consider the potential for a loss of offsite power.*

NRC Conditional Requirement 9: With regard to the RCS pump shaft seizure accident, the fuel failure criterion should be the 95/95 DNBR limit. The mechanistic method mentioned in WCAP-10444 is not acceptable.

> *The safety analysis for the RCS pump shaft seizure does use the 95/95 DNBR limit as one of the acceptance criteria.*

NRC Conditional Requirement 10: If a positive MTC is intended for VANTAGE 5, the same positive MTC consistent with the plant Technical Specification should be used in the plant-specific safety analysis.

> *The safety analysis does use the same positive MTC consistent with the plant Technical Specification.*

NRC Conditional Requirement 11: The LOCA analysis performed for the reference plant with higher F_Q of 2.55 has shown that the PCT limit of 2200 °F is violated during transitional mixed core. Plant specific LOCA analysis must be done to show that with the appropriate value of F_Q, the 2200 °F criteria can be met during use of transitional mixed core.

> *Plant specific LOCA analyses will be performed to show that, with the appropriate value of F_Q, the 2200 °F criteria can be met during use of transitional mixed core. A summary of these analyses will be provided in the Technical Report Supporting Cycle Operation.*

NRC Conditional Requirement 12: Our SER on Westinghouse's extended burnup topical report WCAP-10125 is not yet complete; the approval of the VANTAGE 5 design for operation to extended burnup levels is contingent on NRC approval of WCAP-10125. However, VANTAGE 5 fuel may be used to those burnups to which Westinghouse fuel is presently operating. Our review of the Westinghouse extended burnup topical report has not identified any safety issues with operation to the burnup value given in the extended burnup report.

> *WCAP-10125 has been approved[5]. The extended burnup methodology contained in this topical has been applied and is addressed in Section 3.0 of this compatibility assessment.*

NRC Conditional Requirement 13: Recently, a vibration problem has been reported in a French reactor having 14 foot fuel assemblies; vibration below the fuel assemblies in the lower portion of the reactor vessel is damaging the movable incore instrumentation probe thimbles. The staff is currently evaluating the implications of this problem to other cores having 14 foot long fuel bundle assemblies. Any limitations to the 14 foot core design resulting from the staff evaluation must be addressed in plant specific evaluations.

> *The Haddam Neck Plant has a 10-foot long fuel assembly bundle. There has been no fuel assembly vibration problems observed in 10-foot cores. Therefore, the above condition is not applicable.*

In addition to the above conditional requirements, the objectives specified in the US NRCs SRP require that the fuel design meet the following criteria:

1.) *Provide assurance that the fuel system is not damaged as a result of normal operation and anticipated operational occurrences,*

2.) *Provide assurance that fuel system damage is never so severe as to prevent control rod insertion when it is required,*

3.) *Provide assurance that the number of fuel rod failures is not underestimated for postulated accidents, and*

4.) *Provide assurance that coolability is always maintained.*

Compliance with these requirements is demonstrated in Section 3 of this report.

3.0 Fuel Assembly Design/Safety Assessment

3.1 Fuel Assembly Mechanical Design Introduction

The Haddam Neck Plant fuel assembly is a 10-foot, 15x15 VANTAGE 5H (V5H) type design (refer to Figure 1). The assembly contains 204 Zircaloy-4 clad fuel rods. The fuel rod design uses a longer bottom end plug for added debris resistance. The structural skeleton is comprised of 20 Zircaloy-4 guide thimble tubes and one instrumentation tube. The guide thimble tubes have a double dashpot and four flow holes.

Seven grids are used in the fuel assembly skeleton design; one Inconel 718 grid at each end and five total Zircaloy-4 Low Pressure Drop (LPD) structural mid-grids. All grids are of the same basic design as is used currently in the 12-foot 15x15 VANTAGE 5H fuel design. Vaned mid-grids are used at all locations with exception of the lowermost mid-grid. Similar to the current B&W fuel design, the Westinghouse lowermost mid-grid will be vaneless. Both end grids are vaneless. All grid span distances are shorter than that of the 12-foot fuel design with the exception of the top grid span which is slightly longer.

Top and bottom nozzles are also very similar to the existing 12-foot fuel design. Both the Reconstitutable Top Nozzle (RTN) and the Debris Filter Bottom Nozzle (DFBN) are modified slightly to assure correct in-core interface while maintaining adequate fuel cavity space for the desired fuel column length.

A brief summary of the Westinghouse design features contained in the Haddam Neck Plant 15x15 VANTAGE 5H Cycle 19 reload are given below. These features are presented in more detail in Section 3.2.

Low Pressure Drop (LPD) Zircaloy-4 mid-grids: The VANTAGE 5H (w/o IFMs) Low Pressure Drop Zircaloy-4 mid-grid design is based on the OFA Zircaloy-4 mid-grid design and operating experience. The grid strap thickness, type of strap welding, basic mixing vane design and pattern, method of guide thimble tube attachment, type of fuel rod support (6 point), material and envelope are identical to the OFA Zircaloy-4 mid-grid. The evaluation of the VANTAGE 5H (w/o IFMs) grid performance is based on the extensive design and irradiation experience with previous grid designs and full grid testing completed with the VANTAGE 5H (w/o IFMs) grid design(6).

Integral Fuel Burnable Absorber (IFBA): The Integral Fuel Burnable Absorber (IFBA) coated fuel pellets are identical to the enriched uranium dioxide pellets except for the addition of a thin boride coating on the pellet cylindrical surface along the central portion of the fuel stack length. IFBAs provide power peaking and moderator temperature coefficient control(7)(8).

Reconstitutable Top Nozzle (RTN): The Reconstitutable Top Nozzle differs from the standard top nozzle design in two ways: a groove is provided in each thimble thru-hole in the nozzle plate to facilitate attachment and removal; and the nozzle plate thickness was reduced to provide additional space for fuel rod growth(9). In conjunction with the RTN, a longer tapered fuel rod bottom end-plug is used to facilitate removal and re-insertion of the fuel rods.

Extended Burnup Design: The Cycle 19 fuel assemblies will incorporate the extended burnup design features, i.e., reduced thickness of both the top and bottom nozzle end plates and a shorter bottom nozzle. The fuel rod is sized appropriately to meet burnup requirements(9). In addition, to counter the effects of extended burnup, the bottom grid spring shape/profile will be modified to give a higher spring force at Beginning-of-Life (BOL). Evaluations have been performed to determine the effects of modifying the bottom grid spring to provide a higher spring force. The modifications to the bottom grid spring has no adverse effect on the thermal-hydraulic performance. The structural support of the fuel rod end is enhanced with the increased bottom grid spring forces. Therefore, the resistance of the fuel rod to crossflow excitations is improved. The ability of the grid to withstand externally applied loads has not changed.

Top and Bottom Anti-snag grids: The top and bottom anti snag grid design contains an outer strap which is modified to help prevent assembly hangup due to grid strap interference during fuel assembly removal. This is accomplished by changing the grid strap corner geometry and adding guide tabs on the outer grid strap. These grid strap changes do not result in any changes in pressure drop from the previous grid design.

Longer Tapered Fuel Rod End-plug (debris-mitigation design): The Cycle 19 VANTAGE 5H fuel assemblies incorporate the longer tapered fuel rod end-plug (debris-mitigation design). The longer tapered bottom end-plug will assure that the bottom grid springs are contacting the solid end-plug and not the cladding. Therefore, debris caught by the bottom grid will act against the solid end-plug and not the cladding.

Debris Filter Bottom Nozzle (DFBN): The Debris Filter Bottom Nozzle (DFBN) is designed to inhibit debris from entering the active fuel region of the core and thereby improves fuel performance by minimizing debris related fuel failures. The DFBN is a low profile bottom nozzle design made of stainless steel, with reduced plate thickness and leg height. In addition, the DFBN incorporates a reinforcing skirt to enhance reliability during postulated adverse handling conditions while refueling. The design meets fuel assembly/rod design criteria as presented in Reference 9.

This report utilizes the NRC Standard Review Plan, Section 4.2 Fuel System Design basis/evaluation described in Reference 10, and can be used as a reference document in support of the mechanical design of the Haddam Neck Plant reload with 15x15 VANTAGE 5H fuel. The Mechanical Design Evaluation in this report provides a description, the design bases and an evaluation of the VANTAGE 5H fuel assembly and fuel rod, and a summary of the mechanical and hydraulic testing used to support the design of the Haddam Neck Plant 15x15 VANTAGE 5H fuel.

3.2 Mechanical/Material Design

3.2.1 Fuel Assembly Mechanical Design Evaluation

3.2.1.1 Fuel Assembly and Fuel Rod Growth Allowance

Design Bases - The fuel rod and fuel assembly design must preclude axial interference between the fuel rod and the top and bottom nozzles due to thermal expansion and irradiation growth. Furthermore, there must be no axial interference between the fuel assembly and the upper and lower core support structures due to thermal and irradiation growth.

Evaluation - The fuel rod and fuel assembly length have been sized to allow sufficient growth space by using Westinghouse fuel rod/fuel assembly growth design methodology, Reference 11. Growth predictions are based upon accumulated Westinghouse in-core experience including results of cooperative Westinghouse utility high burnup demonstration programs. The overall length of the fuel assembly has been established to accommodate assembly growth. The distance between the top and bottom nozzle plate has been set to accommodate the expected increased fuel rod growth for lead rod average burnups of up to [ ]$^{a, c}$.

Typical values for the EOL assembly growth and fuel rod growth are [ ]$^{a, c}$ and [ ]$^{a, c}$, respectively.

3.2.1.2 Fuel Assembly Compatibility with In-Core and Plant Equipment Interface

Design Bases - The fuel assembly design must be mechanically compatible with the current B&W fuel assemblies, incore instrumentation, core components, reactor internals interfaces and fuel loading, handling, storage and shipping equipment.

Evaluation - An evaluation of interfaces and geometry of the 15x15 VANTAGE 5H fuel assembly has been made and found to be compatible with the mechanical interfacing features of the Haddam Neck Plant and current fuel.

3.2.1.3 Fuel Assembly Shipping and Handling Loads

Design Bases - The design acceleration for fuel assembly handling and shipping loads has been set at 6g lateral and 4g axial. Fuel handling acceleration at both the manufacturing facility and reactor sites has been determined to be well below the 4g value.

Evaluation - Analyses and tests of the fuel assembly have been conducted to verify that the effect of 6g lateral loads and 4g axial loads on the fuel assembly components are acceptable.

3.2.1.4 Fuel Assembly Structural Integrity

Design Bases - The fuel assembly design shall ensure that structural failure will not occur for the severity of loading expected throughout the life of the fuel. The main structural concerns are the assurance that gross distortions of the guide tubes and grids and other structural components do not interfere with RCCA insertion for core shutdown and that a coolable geometry will be maintained.

Evaluation - Under postulated faulted condition transients, the strength of the guide tubes is sufficient to preclude gross distortion. The induced stresses experienced by the guide thimbles are bounded by the existing 15x15 12-foot assembly design. Additionally, testing conducted to evaluate the Low Pressure Drop grid strength characteristics under a fault condition transient showed that grid deformation will not occur during transition core operation or full Westinghouse core operation.

3.2.1.5 Resistance to Vibration Damage

Design Bases - Forces tending to induce fuel assembly vibration can occur and the fuel assembly design must be such that damage due to these forces does not occur.

Evaluation - The Haddam Neck Plant 15x15 VANTAGE 5H fuel design has incorporated the rotated mid-grid design change of other Westinghouse fuel assembly designs. This change is intended to minimize the potential of flow induced fuel assembly vibration and resultant fuel rod fretting failures that has occurred in some plants. Confirmatory testing was performed on the 15x15 Haddam Neck Plant fuel assembly design which showed that the assembly design in not subject to flow induced vibration.

3.2.2 Top Nozzle

Description - The top nozzle functions as the upper structural and alignment member of the fuel assembly and as a plenum area for coolant flow out of the assembly and into the upper core internals. The VANTAGE 5H assembly uses the Reconstitutable Top Nozzle (RTN) which differs from the Standard design in two ways: 1) a groove is provided in each thimble thru-hole in the nozzle plate to facilitate attachment and removal; 2) the nozzle plate thickness is reduced to provide additional axial space for fuel rod growth. The RTN is illustrated in Figure 2.

Description and operation of the joints are as follows:

The RTN uses a stainless steel nozzle insert that is mechanically connected to the top nozzle adapter plate by means of a pre-formed circumferential bulge near the top of the insert. The insert engages a mating groove in the wall of the adapter plate thimble tube thru-hole. The insert has four equally spaced axial slots which allow the insert to deflect inwardly at the elevation of the bulge, thus permitting the installation or removal of the nozzle. The insert bulge is positively held in the adapter plate mating groove by placing a lock tube with a uniform ID identical to that of the thimble tube into the insert.

To remove the top nozzle, a tool is first inserted through the lock tube and expanded radially to engage the bottom edge of the tube. An axial force is then exerted on the tool which overrides the local lock tube deformations and withdraws the lock tube from the insert. After the lock tubes have been withdrawn, the nozzle is removed by raising it off the upper slotted ends of the nozzle inserts which deflect inwardly under the axial lift load. With the top nozzle removed, direct access is provided for fuel rod examination or replacement. Reconstitution is completed by the remounting of the nozzle and the insertion of new lock tubes.

Design Bases - The nozzles must maintain structural and dimensional integrity during shipping, handling, and reactor events of Condition I (Normal Operation), Condition II (Incidents of Moderate Frequency), Condition III (Infrequent Incidents), and Condition IV (Limiting Faults). For shipping and handling, the nozzles must maintain dimensional stability after experiencing 4g axial and 6g lateral loads. For Conditions I, II, III, and IV, the nozzles are designed using the ASME Code III as a guideline for acceptable stress values and structural integrity.

Evaluation - Functional gaging and analysis have been performed to demonstrate the RTN's precise fit with the fuel alignment plate and handling tools. Nozzles have been tested to verify that the functional and structural capabilities of the RTN have been met. Analyses and test results have been found to be within the design limits.

3.2.3 Bottom Nozzle

Description - An illustration of the Debris Filter Bottom Nozzle (DFBN) is shown in Figure 3. The nozzle is fabricated from Type 304 stainless steel.

The bottom nozzle functions as the lower structural and alignment member of the fuel assembly and as a plenum area for coolant flow into the assembly. The VANTAGE 5H assembly uses the skirted Debris Filter Bottom Nozzle (DFBN) to reduce the possibility of fuel rod damage due to debris-induced fretting. The relatively large flow holes in the standard nozzle are replaced with a new pattern of smaller flow holes. The holes are sized to minimize passage of debris particles large enough to cause damage while providing sufficient flow area, comparable pressure drop, and continued structural integrity of the nozzle. Tests to measure pressure drop and demonstrate structural integrity verified that the 304 stainless steel DFBN is compatible with the current nozzle design.

The DFBN is fastened to the fuel assembly guide thimbles with stainless steel screws. The screw have a thin-walled skirt at the head which is crimped into mating lobes of the DFBN to prevent loosening. This screw fastening design of the DFBN provides removal capability and reconstitution via the bottom nozzle in addition to the top nozzle.

The dimensions and tolerances used in the bottom nozzle design have been selected to assure satisfactory alignment and fit with the positioning pins of the lower core support plate.

Design Bases - The nozzles must maintain structural and dimensional integrity during shipping, handling, and reactor events of Conditions I, II, III, and IV. For shipping and handling, the nozzles must maintain dimensional stability after experiencing 4g axial and 6g lateral loads. For Conditions I, II, III, and IV, the nozzles are designed using the ASME Code III as a guideline for acceptable stress values and structural integrity.

Evaluation - Functional gaging and analysis has been performed to demonstrate the precise fit of the bottom nozzle with the lower core support plate. Prototype nozzles have been tested to verify that the functional structural capabilities of the bottom nozzle have been met. Analyses and test results have been found to be within the design limits.

3.2.4 Fuel Assembly Grids

Description - Two types of grids are used in the Haddam Neck Plant VANTAGE 5H fuel assembly to provide fuel rod and guide tube positioning and retention. Inconel grids are used at the top and bottom of the assembly. Zircaloy-4 grids are spaced between the Inconel grids to maintain the lateral position of the fuel rods. The grids are positioned to be compatible with the current B&W fuel.

Both types of grids are egg-crate type structures assembled from metal straps. Geometric features are die stamped and formed on the straps to produce the desired geometries such as springs and dimples. An illustration of the grid strap details is shown on Figure 4. The Inconel straps are fastened together using a furnace brazing process while the Zircaloy-4 straps are electron-beam welded. The outer straps of the grids incorporate anti-snag features to aid in fuel assembly handling.

Design Bases (Position Control) - The grid assemblies shall accurately position the fuel rods, guide tubes and instrumentation tube in the fuel assembly.

Evaluation - Grid assemblies of the type used in the Haddam Neck Plant VANTAGE 5H fuel assembly are designed and fabricated according to well established methods and processes. They have shown by test and years of in-core experience to meet the design requirements.

Design Bases (Grid Impact Strength) - The Haddam Neck Plant VANTAGE 5H grid assemblies must be able to withstand seismic and handling, static and dynamic loads.

Evaluation - The Zircaloy-4 Haddam Neck Plant VANTAGE 5H grids were tested to determine mechanical strength characteristics (stiffness and 95% confidence level on the true mean impact strength). Testing showed that grid deformation will not occur during transition core operation or full Westinghouse core operation and that a coolable geometry will be maintained.

3.2.5 Guide Tubes and Instrumentation Tube

Description - The guide tubes and instrumentation tube are structural members which also provide channels for the control rods and neutron sources. The guide tubes in conjunction with the grids and nozzles constitute the basic fuel assembly structure. They are mechanically fastened to the grids by locally expanding the guide tube into the grid sleeves. The top end is locally expanded to the top nozzle inserts that are retained in the top nozzle by lock tubes. The bottom end is welded to an internally threaded end plug that accepts a screw that secures the bottom nozzle. Westinghouse design thimble ID above the dashpot is smaller than that of B&W's design. It does provide adequate interface. The dashpot length was sized to prevent spider hub impact on SCRAM while still assuring that the Haddam Neck Plant drop time requirements will be met. The Westinghouse instrumentation tube ID is larger than that of B&W's but is our standard OFA design. Acceptable interface with the Haddam Neck Plant flux thimbles will exist without binding or flow induced vibration based on Westinghouse experience at other 15x15 plants.

Design Bases - The guide tubes must maintain structural and dimensional integrity during shipping and handling and Conditions I, II, III and IV events. For all loading conditions the guide tubes are designed using the ASME Code Section III as a guideline for acceptable stress values and structural integrity.

Evaluation - Analyses and tests have been performed which simulated the guide tube loads under the defined conditions. The results confirm that the Code stress criteria have been met.

3.3 Fuel Rod Mechanical Design Evaluation

3.3.1 Fuel Rod Description

An illustration of the Haddam Neck Plant VANTAGE 5H fuel rod design is shown in Figure 5 and a listing of the Haddam Neck Plant VANTAGE 5H Fuel Design Parameter is provided in Table 1.

The fuel rod consists of a 120.3 inches pellet stack of enriched UO_2 fuel pellets which are hermetically sealed into Zircaloy-4 tubing. A portion of the fuel stack, in some rods, will contain pellets coated with [ ]^{a,c} (IFBA rods). A plenum and spring are provided at the top of the fuel stack to accommodate rod internal pressure increases due to fission gas release and differential growth of the fuel and clad. The spring also assures that the pellet stack location is maintained during shipping and handling. Before sealing the rod, it is filled with helium gas to aid in heat transfer and clad support.

A comprehensive description and discussion of the benefits and use of fuel pellets that have been coated with [ ]^{a,c} are presented in Reference 7. IFBA rods will use a very thin, [ ]^{a,c}, [ ]^{a,c} coating on the enriched fuel pellets. Neutron absorption by the coating material provides a burnable absorber which is an integral part of the fuel rod. The absorber coating uses boron that is isotopically enriched in the B^{10} isotope(8).

All design bases identified in Section 3.3 for the fuel rod must also be satisfied for fuel rods containing IFBA coated uranium dioxide pellets which have additional helium gas release as the boron coating is depleted.

3.3.2 Rod Internal Pressure

Design Bases - The internal pressure of the lead rod in the reactor will be limited to a value below that which could cause (1) the diametral gap to increase due to outward cladding creep during steady-state operation, and (2) extensive DNB propagation to occur during accident conditions.

Evaluation - The rod internal pressure has been evaluated using the Westinghouse fuel rod design code, Reference 11, and design methodology, Reference 5, and meets the above requirements. Typical values for the upper bound end-of-life rod internal pressure are [ ]^{a,c} for the IFBA rods, and [ ]^{a,c} for the non-IFBA rods for lead rod average burnups up to [ ]^{a,c}.

3.3.3 Clad Strain

Design Bases - For steady-state operation, the total tensile creep strain shall be less than 1 percent from the unirradiated condition. For each transient event the circumferential, elastic plus plastic (inelastic) total strain shall not exceed a tensile strain range of 1 percent from the existing steady-state condition.

Evaluation - The design has been evaluated using Westinghouse fuel rod design code, Reference 11, and design methodology, Reference 5, and meets the above requirements. Typical design values for the end-of-life transient strain is [ ]^{a,c} for the IFBA rods and the non-IFBA rods.

3.3.4 Clad Stress

Design Bases - The volume average effective stress calculated with the Von Mises equation considering interference due to uniform cylindrical pellet-clad contact, caused by pellet thermal expansion, pellet swelling and uniform clad creep, and pressure differences, is less than the 0.2 percent offset yield stress with due consideration to temperature and irradiation effects under Condition I and II events. While the clad has some capability for accommodating plastic strain, the yield stress has been accepted as a conservative design limit.

Evaluation - The design has been evaluated using Westinghouse fuel rod design code, Reference 11, and design methodology, Reference 5, and meets the above requirements. Typical clad steady state and transient stresses for both IFBA and non IFBA fuel rods have more than [ ]^{a,c} margin to the design limit.

3.3.5 Clad Corrosion

Design Bases - The clad surface temperature (oxide-to-metal interface) shall not exceed:

a. [ ]^{a,c} for steady-state operation
b. [ ]^{a,c} for short-term transient operation

The hydrogen pickup in the Zircaloy-4 cladding and structural components must not exceed [ ]^{a,c} at end of life.

Evaluation - The design has been evaluated using Westinghouse design code, Reference 11, and design methodology, Reference 5, and found to meet the design limits. For lead rod average burnups up to [ ]^{a,c} typical values for the Haddam Neck Plant VANTAGE 5H fuel design are: steady-state clad temperature less than [ ]^{a,c}; transient clad temperature less than [ ]^{a,c}; clad hydrogen pickup less than [ ]^{a,c}; guide tube/grid hydrogen pickup less than [ ]^{a,c} and guide tube/grid metal wastage less than [ ]^{a,c}.

3.3.6 Fuel Temperature

Design Bases - The maximum fuel temperature shall be less than the melting temperatures of the fuel. The melting temperature of uranium dioxide fuel is 5080 °F in the unirradiated condition and reduces 58 °F per 10,000 MWD/MTU fuel burnup.

Evaluation - The design has been evaluated using Westinghouse fuel rod design code, Reference 11, and design methodology, Reference 5, and found to meet the design limits. The design evaluation has established that a design limit local heat flux of [ ]^{a,c} will insure that the fuel temperature criterion will be satisfied.

3.3.7 Clad Fatigue

Design Bases - The calculated fatigue life shall not exceed the design failure life.

Evaluation - The design has been evaluated using Westinghouse design code, Reference 11, and design methodology, Reference 5, and found to meet the design limits. Based on a daily load follow between 100% and 15% of full power operation plus 10 cold shutdowns per plant operating cycle, typical fatigue life fraction usage factors are less than [ ]^{a,c} for non-IFBA fuel rods and [ ]^{a,c} for the IFBA fuel rods.

3.3.8 Clad Flattening

Design Bases - The fuel rod design shall preclude clad flattening during the projected long-term exposure.

Evaluation - Westinghouse design codes, References 11, 12 and design methodology, Reference 5, confirm that current fuel rod designs employing 95% T.D. fuel with improved in-pile stability and high helium backfill pressures will not undergo clad flattening.

3.3.9 Rod Growth

Design Bases - Considering the effects of fuel rod irradiation growth, guide tube growth, creep and thermal expansion, the net fuel rod growth must not result in rod contact with both nozzle plates at the design rod burnup.

Evaluation - The design has been evaluated using Westinghouse fuel rod design code, Reference 11, and design methodology, Reference 5, and found to meet this design requirement. The Haddam Neck Plant fuel rod growth evaluation shows that there is sufficient margin to the fuel rod growth design limit at a lead rod burnup of [ ] ^{a,c}.

3.3.10 Fuel Rod Wear

Design Bases - The spring and dimple support of the fuel rods must be sufficient to prevent large amplitude vibration motion of the fuel rods, and therefore, the potential for accelerated wear of the fuel rod induced by fluid forces. The clad wear depth shall be limited to less than the nominal Westinghouse guideline of [ ] ^{a,c} of the cladding wall thickness.

Evaluation - Previous long term wear testing of the 15x15 VANTAGE 5H design has shown fuel rod wear to be less than maximum allowable. This testing was conducted at higher flow rates and with a test assembly having grid span distances greater than those of the Haddam Neck Plant 15x15 VANTAGE 5H design. Additionally, the test setup provided conditions which bounded the hydraulic differences that are described in Section 3.5. Thus, cladding wear of the Haddam Neck Plant fuel rod will meet existing 15x15 VANTAGE 5H design applications.

3.3.11 Fuel Rod Bow

Rod bow is a function of grid span length, the fuel cladding Young's Modulus, the fuel cladding cross-sectional moment of inertia and the assembly average burnup. Rod bow in the Haddam Neck Plant 15x15 VANTAGE 5H fuel assembly is bounded by that of prior Westinghouse 15x15 designs due to the reduced grid span length in this assembly. The grid span length in the Haddam Neck Plant 15x15 VANTAGE 5H fuel assembly is [ ] ^{a,c} compared to the typical grid span length of

[ ]^{a,c}. This reduction in grid span length reduces the rod bow DNBR penalty from [ ]^{a,c} to [ ]^{a,c} at [ ]^{a,c} assembly average burnup. Beyond this burnup, credit is taken for an $F^N_{\Delta H}$ burndown effect in which the fuel is not capable of achieving limiting peaking factors due to the decrease in fissionable isotopes and the buildup of fission product inventory.

3.4 Mechanical Testing

A Haddam Neck Plant VANTAGE 5H test program was conducted to confirm the mechanical design adequacy of the assembly and to assure compatibility during the mixed core transition. Grid mechanical testing was performed to evaluate strength and stiffness characteristics. Grid hangup testing verified the fuel can be loaded in the mixed core without damage. Additionally, fuel assembly holddown spring testing was conducted to verify that fuel assembly holddown requirements are met.

3.5 Hydraulic Testing

As part of the verification testing of the Haddam Neck Plant VANTAGE 5H fuel assembly design, full-scale hydraulic flow tests were performed to evaluate hydraulic characteristics of the assembly. This testing was conducted at the Fuel Assembly Compatibility Test System (FACTS) facility in Columbia, South Carolina. Test results showed that the Haddam Neck Plant VANTAGE 5H fuel assembly pressure drop to be comparable to that of the B&W fuel design. The difference being within the bounds of previous Westinghouse experience with mixed core configurations.

4.0 Conclusions

The results of the evaluations documented herein on the Haddam Neck Plant 15x15 VANTAGE 5H (w/o IFMs) fuel assemblies has confirmed that:

a. The VANTAGE 5H fuel assemblies design is mechanically compatible with the current 15x15 B&W fuel assemblies, RCCAs, reactor internals interfaces, fuel handling equipment and fuel storage racks.

b. The VANTAGE 5H fuel assemblies will meet all fuel rod design criteria for lead rod burnups up to the licensing limit of 60 GWD/MTU.

c. Based on the measured fuel assembly hydraulic resistance, it is concluded that the use of the VANTAGE 5H fuel assemblies in the Haddam Neck Plant is acceptable based on previous Westinghouse experience with mixed core configurations.

The Haddam Neck Plant Technical Specifications ensure that the plant operates in a manner that provides acceptable levels of protection for the health and safety of the public. Therefore the regulated margin of safety as defined in the Bases of the Technical Specifications is not affected by the use of VANTAGE 5H fuel assemblies in Haddam Neck Plant. The cycle specific safety analyses using the VANTAGE 5H fuel will be summarized in the Technical Report Supporting Cycle Operations.

5.0 References

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8. Letter from W. J. Johnson (Westinghouse) to M. W. Hodges (NRC), "Application of Enriched Boron in the Westinghouse Integral Fuel Burnable Absorber Design," NS-NRC-89-3454, September 6, 1989.

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10. "NRC Standard Review Plan," NUREG-0800, Revision 2, July 1981.

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Table 1

Haddam Neck Plant VANTAGE 5H Fuel Design Parameters

	15x15 VANTAGE 5H fuel assemblies	a, c
Assembly envelope, in		
Assembly length, in		
No. of fuel rods/assy		
Fuel rod pitch, in		
No. of guide tubes/assy		
Guide thimble OD, in		
Guide thimble ID, in		
Guide thimble material		
No. of instru. tubes/assy		
Instru. tube OD, in		
Instru. tube ID, in		
Grid attachment to skeleton		
Grids: Material		
Mid-grids structural (5) material		
End grids structural (2) material		
Grid Inner Strap Thickness, in		
Mid-grids (Zirc)		
End grids (Inconel)		
Grid Outer Strap Thickness, in		
Mid-grids (Zirc)		
End grids (Inconel)		
Grid Height Inner Straps Less Vanes, in		
Mid-grids (Zirc)		
End grids (Inconel)		

Table 1

Haddam Neck Plant VANTAGE 5H Fuel Design Parameters

(Cont.)

	15x15 VANTAGE 5H fuel assemblies a, c
Bottom Nozzle	
Top Nozzle	
Fuel Rod	
Debris resistant design	
Overall length, in	
Active length, in	
Plenum length, in	
Fill Gas	
End plug material	
Assembly loading (kg U)	
Fuel Cladding	
Outside diameter, in	
Thickness, in	
Inside diameter, in	
Material	
Fuel Pellet	
Diameter, in	
Length, in	

Figure 1

Haddam Neck Plant VANTAGE 5H Fuel Assembly

a, c

Figure 2

Reconstitutable Top Nozzle

a, c

Figure 3

Debris Filter Bottom Nozzle

a, c

Figure 4

Grid Strap

a, c

[ ]

Figure 5

Fuel Rod

a, c