Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, Pennsylvania 16066
USA

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Direct tel: (412) 374-5130

e-mail: hosackkl@westinghouse.com

LTR-NRC-20-43

July 27, 2020

Subject: Fuel Criterion Evaluation Process (FCEP) Notification of the 17x17 Advanced Debris Filter Bottom Nozzle (ADFBN) Design (Proprietary/Non-Proprietary)

Enclosed are the proprietary and non-proprietary versions of the report, "Fuel Criterion Evaluation Process (FCEP) Notification of the 17x17 Advanced Debris Filter Bottom Nozzle (ADFBN) Design."

This submittal contains proprietary information of Westinghouse Electric Company LLC ("Westinghouse"). In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Nuclear Regulatory Commission's ("Commission's") regulations, we are enclosing with this submittal an Affidavit. The Affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the proprietary aspects of this submittal or the Westinghouse Affidavit should reference AW-20-5069 and should be addressed to Korey L Hosack, Manager, Licensing, Analysis, and Testing, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 1, Suite 133, Cranberry Township, PA 16066.

Korey L. Hosack, Manager
Licensing, Analysis, and Testing

cc: Ekaterina Lenning (NRC)
Dennis Morey (NRC)

Enclosures:
1. Affidavit AW-20-5069
2. Fuel Criterion Evaluation Process (FCEP) Notification of the 17x17 Advanced Debris Filter Bottom Nozzle (ADFBN) Design (Proprietary)
3. Fuel Criterion Evaluation Process (FCEP) Notification of the 17x17 Advanced Debris Filter Bottom Nozzle (ADFBN) Design (Non-Proprietary)

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COMMONWEALTH OF PENNSYLVANIA:
COUNTY OF BUTLER:

(1) I, Korey L. Hosack, have been specifically delegated and authorized to apply for withholding and execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse).

(2) I am requesting LTR-NRC-20-43 Enclosure 2 be withheld from public disclosure under 10 CFR 2.390.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged, or as confidential commercial or financial information.

(4) Pursuant to 10 CFR 2.390, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse and is not customarily disclosed to the public.

(ii) Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar technical evaluation justifications and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

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(5) Westinghouse has policies in place to identify proprietary information. Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage (e.g., by optimization or improved marketability).

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

(6) The attached documents are bracketed and marked to indicate the bases for withholding. The justification for withholding is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds

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in confidence identified in Sections (5)(a) through (f) of this Affidavit.

I declare that the averments of fact set forth in this Affidavit are true and correct to the best of my knowledge, information, and belief.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: 2020 07 27

Korey L. Hosack, Manager
Licensing, Analysis, and Testing

LTR-NRC-20-43
Enclosure 3

Fuel Criterion Evaluation Process (FCEP) Notification of the 17x17 Advanced Debris Filter Bottom Nozzle (ADFBN) Design

(Non-Proprietary)

July 2020

Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

Fuel Criterion Evaluation Process (FCEP)
Notification of the 17x17 Advanced Debris Filter Bottom Nozzle Design
(Non-Proprietary)

1.0 Background

The current Westinghouse 17x17 fuel designs utilize the 17x17 Standardized Debris Filter Bottom Nozzle (SDFBN) design (Reference 1) which is a square structure that serves as the bottom structural element of the fuel assembly and directs the coolant flow distribution to the fuel assembly bundle region. The 17x17 SDFBN design is shown below in Figure 1. The 17x17 SDFBN is fabricated from wrought Type 304L stainless steel and consists of a perforated adapter plate and four angle legs with bearing plates. Side skirts act to help support the bottom nozzle legs to preclude the legs from bending, primarily during fuel handling activities. The legs and side skirts form a plenum for the inlet coolant flow to the fuel assembly. The adapter plate of the 17x17 SDFBN helps to direct flow into the fuel bundle region through a plethora of small flow holes [ ]a,c which are specifically designed to filter debris and prevent it from reaching the fuel bundle region where the debris could potentially lead to debris-induced fretting failures. The bottom nozzle is fastened to the fuel assembly guide thimble tubes by thimble screws that penetrate through the bottom nozzle adapter flow plate and mate with an inside fitting in each of the 24 guide thimble tubes per fuel assembly. Each thimble screw is retained in position by a locking cup that is expanded into the detents (lobes) on the bottom side of the bottom nozzle adapter plate. Axial loads (holddown) imposed on the fuel assembly and the weight of the fuel assembly are transmitted through the bottom nozzle to the lower core plate. Indexing and positioning of the fuel assembly is controlled by alignment holes in two diagonally opposite bearing plates that mate with locating pins in the lower core plate. Any lateral loads on the fuel assembly are transmitted to the lower core plate through the locating pins.

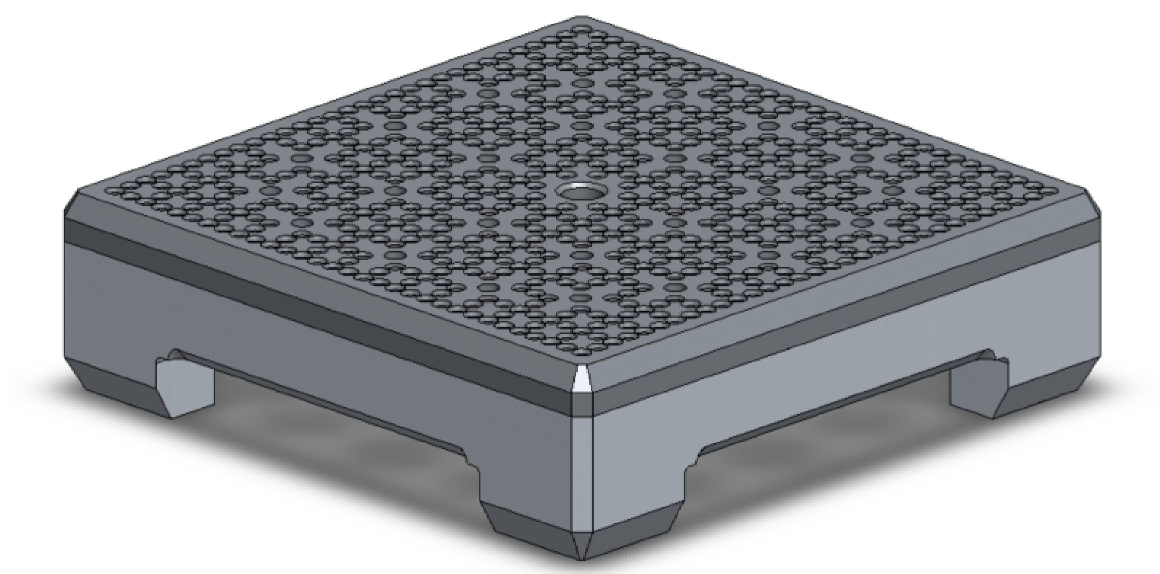

Figure 1: Westinghouse 17x17 Standardized Debris Filter Bottom Nozzle

As shown in Figure 1, there is a gap between the bottom of the side skirts and the lower core plate that the SDFBN sits on which is a potential path for debris to travel around the bottom nozzle. Specifically, debris in the coolant flow under the bottom nozzle can pass under the side skirts and into the gaps between adjacent fuel assemblies where it can then travel into the fuel bundle region potentially leading to debris-induced fretting failures. Westinghouse closely tracks fuel failures and the current fuel designs with the Debris Filter Bottom Nozzle (DFBN)/SDFBN bottom nozzles have excellent performance with respect to minimizing debris-induced fretting failures. However, some recently observed debris-induced fretting failures have been seen on the outer rows of the fuel assembly indicating that debris may be bypassing the DFBN/SDFBNs, passing through the gaps between DFBN/SDFBNs and then into the fuel bundle region.

Based on the above, a project was initiated to develop a new advanced DFBN/SDFBN design that would specifically address the concern of debris traveling under the DFBN/SDFBN side skirts and into the fuel bundle region. The result of this project was the development of the 17x17 Advanced Debris Filter Bottom Nozzle (ADFBN).

1.1 Description of Change

The 17x17 ADFBN design is shown in Figure 2 on the following page. This new advanced design focused solely on improving the side skirt design for the purpose of filtering debris to preclude it from bypassing the bottom nozzle. No other changes were implemented to the ADFBN design, including no changes to the bottom nozzle adapter plate, through which the majority of the RCS flow travels [ ]a,c The bottom nozzle side skirt was lowered so that it is just above the lower core plate. This reduced the gap below the side skirt from the current 17x17 SDFBN value of [ ]a,c The side skirts of the current 17x17 SDFBN design had the [ ]a,c gap to [ ]a,c Therefore, with the lowering of the side skirts for the 17x17 ADFBN design, it was necessary to [ ]a,c to allow for insertion, torqueing, and crimping of the thimble screw adjacent to each pocket for each of the four side skirts.

The design of the 17x17 ADFBN lowered side skirt addresses several important interfacing requirements. [ ]a,c but also filter the flow so as to trap any debris and preclude it from passing through this region of the bottom nozzle.

Secondly, [ ]a,c

Lastly, the 17x17 ADFBN design was developed so that it would have the same [ ]a,c as the existing 17x17 SDFBN. Meeting this requirement ensures that there is minimal impact in the implementation of the new 17x17 ADFBN design.

a,c

Figure 2: 17x17 Advanced Debris Filter Bottom Nozzle

2.0 Design Categories

In support of the implementation of the 17x17 ADFBN design, all of the applicable design and safety criteria were specifically evaluated as part of the design development process. The design functions of the fuel assemblies, within the context of 10 CFR 50.59 and NEI 96-07, are to serve as the primary fission product barrier, to allow full control rod insertion within the credited rod drop time, and to maintain a coolable geometry. The fuel rod matrix and cladding provide the primary fission product barrier. The fuel assembly skeleton is primarily responsible for maintaining a coolable geometry. The top nozzle and guide tubes allow for control rod insertion. The bottom nozzle serves as the bottom structural element of the fuel assembly and directs the coolant flow distribution to the fuel assembly bundle region.

The bottom nozzle serves a number of different design functions including the following:

1 The bottom nozzle legs and side skirts form a plenum which directs the reactor coolant flow distribution upward through the flow holes in the adapter plate to the channels between the fuel rods in the fuel assembly.

2 The adapter plate of the bottom nozzle prevents the downward ejection of the fuel rods from the fuel assembly.

3 Axial holddown loads imposed on the fuel assembly and the weight of the fuel assembly are transmitted through the bottom nozzle to the lower core plate.

4 The bottom nozzle reduces the possibility of debris passing into the fuel rod bundle region of the fuel assembly which could cause debris-induced fretting failures.

5 The bottom nozzle positions the fuel assembly on the lower core plate by two diagonally opposite alignment holes which mate with pins in the lower core plate. This allows any lateral loads on the fuel assembly to be transmitted to the lower core plate through the lower core plate pins.

The design functions related to structural support after fuel assembly insertion into the core are assured by meeting defined limits on stresses and deformations caused by various loads, including normal and abnormal loads caused by Condition I and II events (normal and upset loads) and abnormal loads caused by Condition III and IV events (emergency and faulted loads).

The new 17x17 ADFBN design was specifically evaluated from a licensing perspective by following the NRC approved Westinghouse Fuel Criteria Evaluation Process (FCEP), WCAP-12488-A and WCAP-12488-A Addendum 1-A Revision 1 (Reference 2). The following provides the sections from this document for the design categories and the associated parameters that were specifically evaluated to demonstrate that the 17x17 ADFBN design is an acceptable design.

A. Fuel System Damage and Fuel Rod Failure Criteria

a. Clad Stress
b. Clad Strain
c. Clad Fatigue

i. Fuel Clad Fretting Wear
j. Fuel Rod Clad Rupture (Burst)
k. Fuel Pellet Overheating

d. Clad Oxidation
e. Zircaloy Clad Hydrogen Pick-up
f. Fuel Rod Axial Growth
g. Clad Flattening
h. Rod Internal Pressure
l. Non-LOCA Fuel Clad Temperature
m. LOCA Fuel Clad Temperature
n Departure from Nucleate Boiling (DNB)
o. Fuel Assembly Hold-Down Force
p. Thermal-Hydrodynamic Stability

B. Fuel Coolability

a. Clad Embrittlement During Locked Rotor/Shaft Break Accident
b. Clad Ballooning and Flow Blockage
c. Violent Expulsion of Fuel (Rod Ejection)
d. Fuel Assembly Structural Response to Seismic/LOCA Loads

C. Nuclear Design

a. Shutdown Margin
b. Fuel Storage Sub-criticality
c. Stability
d. Reactivity Feedback Coefficients
e. Power Distribution
f. Maximum Controlled Reactivity Insertion Rate

2.1 Evaluation

Each of the parameters list above has been examined and those potentially impacted by the 17x17 ADFBN design are addressed in the following sections.

Category A Fuel Damage and Fuel Rod Failure Criteria

Parameters "a-i," in this category, including the change to parameter "e" in WCAP-12488-A Addendum 1-A Revision 1, are not impacted by the 17x17 ADFBN design since the fuel rod was not altered. Parameters "j-m" are not impacted because the 17x17 ADFBN design is at the entrance to the core and does not have any effect on the transient fuel temperatures. Parameters "n," "o," and "p" are not impacted because the 17x17 ADFBN design has the same [ ]a,c as the 17x17 SDFBN design.

Category B Fuel Coolability Criteria

Parameters "a-c" in this category are not impacted by the 17x17 ADFBN design since the fuel rod and transient fuel temperatures are unchanged. Parameter "d" is not impacted because the 17x17 ADFBN has the same [ ]a,c as the 17x17 SDFBN. In addition, for parameter "d", the fuel characteristics remain unchanged, the core plate motions remain unaffected, and the structural design requirements for the 17x17 ADFBN design are unchanged.

Category C Nuclear Design

No parameters in this category are impacted by the 17x17 ADFBN design since the implementation of the 17x17 ADFBN does not affect the input assumptions, models or methodology that are used in the analyses or create conditions more limiting than those enveloped by the current analyses for the respective discipline.

Therefore, based on the above, from a licensing perspective, none of the above FCEP criteria will require prior NRC review before implementing the 17x17 ADFBN.

3.0 Summary of Tests Performed

To ensure that the new 17x17 ADFBN meets all applicable design and safety criteria for the bottom nozzle design, a number of different tests was performed. These tests ranged from pressure drop testing to determine the 17x17 ADFBN loss coefficient to testing performed to evaluate the 17x17 ADFBN design's debris capture effectiveness. These two key tests performed in support of the 17x17 ADFBN are summarized as discussed below.

3.1 Pressure Drop Testing Summary

As the side skirts of the 17x17 ADFBN were specifically lowered to improve the debris filtration effectiveness of the bottom nozzle, it was important to examine any potential effects this change might have on the overall bottom nozzle pressure drop. Therefore, hydraulic testing was performed with the 17x17 ADFBN bottom nozzle attached to a 17x17 fuel assembly in the Fuel Assembly Compatibility Test System (FACTS) loop. This test loop accommodates a full size 17x17 fuel assembly and measures the pressure drop at various elevations along the axial direction of the fuel assembly for a range of flow conditions. The design objective for the testing was [

]a,c

The testing involved full-scale FACTS pressure drop testing of the 17x17 ADFBN design along with baseline testing of the current 17x17 SDFBN design. The testing results, as shown below in Figure 3, [

]b,c

[ ] b,c

Figure 3: FACTS Loop Pressure Drop Test Results

3.2 Debris Filtration Testing Summary

The side skirts of the 17x17 ADFBN were lowered to specifically improve the debris filtration effectiveness of the bottom nozzle. Therefore, to demonstrate that the lowering of the side skirts helped improve the debris filtering effectiveness of the bottom nozzle, specific debris testing was developed to evaluate the effectiveness of the lowered side skirts of the 17x17 ADFBN design. [

][a,c]

a,c

Figure 4: Two Fuel Assembly halves for Debris Testing

Once test setup was finalized, tests were run with the current 17x17 SDFBN design and with the 17x17 ADFBN design. Debris of varying sizes and shapes were utilized in the testing. [

][b,c] Thus, it is concluded based on this testing, that lowering the side skirts in the design of the 17x17 ADFBN shows significant debris filtering improvement compared to the current 17x17 SDFBN design.

3.3 GSI-191 Assessment of Debris Accumulation on Downstream Effects

Pressurized water reactor (PWR) containment buildings are designed to both contain radioactive material releases and facilitate core cooling during a postulated loss-of-coolant-accident (LOCA) event. In some LOCA scenarios, to support long-term core cooling, water discharged from the break and containment spray is collected in a sump (or sumps) for recirculation by the emergency core cooling system (ECCS) and containment spray system (CSS).

The coolant in the sump will contain debris from insulation, both particulate and fibrous, and protective coatings damaged by the jet formed by the release of coolant from the break and from the transport of residual containment debris from upper containment regions into the sump. Also, there will be chemical products from the interaction of boric acid, buffer agents and other materials inside containment.

Following a LOCA, this debris mix could collect on the sump screen and create resistance to recirculating flow that provides long-term core cooling. This debris could also be ingested into the ECCS and flow into the reactor coolant system (RCS) and eventually reach the core. These issues have been broadly grouped under Generic Safety Issue 191 (GSI-191) (Reference 3).

Significant work has been performed by the industry to address the issues associated with GSI-191. These have included PWR Owners Group programs which performed testing to assess the effect of the collection of debris and chemical precipitates in core components on head loss across the core at flow rates representative of when ECCS is realigned to the recirculation mode from the containment sump. The results of this testing program are presented in WCAP-17057-P/NP, *GSI-191 Fuel Assembly Test Report for PWROG*, dated March 2009 (Reference 4) and in WCAP-17788-P/NP, Volume 6 (Reference 5). These reports provide significant information, including an examination of the collection of debris loads evaluated from plant data on a fuel assembly and on individual fuel assembly components at flow rates representative of both hot-leg and cold-leg break flow rates.

For the implementation of the 17x17 ADFBN, the adapter plate through which [ ]^{a,c} of the RCS flows travels remains unchanged. As this flow path is the primary flow path for flow both during normal operating conditions and for accident conditions and it remains unchanged, it is concluded that the 17x17 ADFBN will have no adverse impact on the GSI-191 debris testing that has been performed to date nor will it impact the conclusions presented in WCAP-17057-P/NP and WCAP-17788-P/NP.

4.0 Safety Assessment

As part of the development of the 17x17 ADFBN, all of the applicable safety and design criteria were evaluated and were found to be acceptable. The [ ]a,c relative to the current 17x17 SDFBN design and most importantly, debris testing has demonstrated that the debris filtering effectiveness is improved as a result of [ ]a,c

5.0 Conclusions

It is concluded that the 17x17 ADFBN design will have no adverse effect on the performance of the fuel assembly in the design categories listed in Section 2.0 of this document. All applicable design and safety criteria for the 17x17 ADFBN are met. Therefore, the 17x17 ADFBN design can be implemented under the Fuel Criteria Evaluation Process, which calls for NRC notification on an information-only basis.

References

1. Westinghouse letter to NRC LTR-NRC-11-33, "Fuel Criterion Evaluation Process (FCEP) Notification of the Standardized Debris Filter Bottom Nozzle (SDFBN) Design (Proprietary/Non-Proprietary)," dated July 13, 2011.

2. Davidson, S. L., (Ed.), et al., *Westinghouse Fuel Criteria Evaluation Process*, WCAP-12488-A, Revision 0, dated October 1984 and *Addendum 1 to WCAP-12488-A Revision to Design Criteria*, WCAP-12488-A Addendum 1-A Revision 1, dated January 2002.

3. Generic Safety Issue (GSI-191), *Assessment of Debris Accumulation on Pressurized Water Reactor (PWR) Sump Performance*.

4. Baier, S., *GSI-191 Fuel Assembly Test Report for PWROG,* WCAP-17057-P/-NP, Revision 1, dated September 2011.

5. Swartz, M. M. and Spring, J.P., *Comprehensive Analysis and Test Program for GSI-191 Closure (PA-SEE-1090) – Subscale Head Loss Test Program Report,* WCAP-17788-P/NP, Volume 6, Revision 1, December 2019.