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-19-35

June 25, 2019

Subject: Submittal of Presentation Slides for the Westinghouse-NRC Pre-Submittal Meeting on Topical Report WCAP-18443-P, "Qualification of the Two-Dimensional Transport Code PARAGON2" (EPID: L-2019-TOP-0016) (Proprietary/Non-Proprietary)

Enclosed are the proprietary and non-proprietary versions of the slides to be presented at the Westinghouse-NRC pre-submittal meeting scheduled for June 27, 2019 for Westinghouse Topical Report WCAP-18443-P, "Qualification of the Two-Dimensional Transport Code PARAGON2."

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 the this submittal or the Westinghouse Affidavit should reference AW-19-4910 and should be addressed to Camille T. Zozula, Manager, Infrastructure & Facilities Licensing, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 1, Suite 165, Cranberry Township, PA 16066.

Korey L. Hosack, Manager
Product Line Regulatory Support

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

Enclosures:

1. Affidavit AW-19-4910
2. Proprietary Information Notice and Copyright Notice
3. Presentation Slides for the Westinghouse-NRC Pre-Submittal Meeting on Topical Report WCAP-18443-P, "Qualification of the Two-Dimensional Transport Code PARAGON2" (L-2019-TOP-0016) (Proprietary)
4. Presentation Slides for the Westinghouse-NRC Pre-Submittal Meeting on Topical Report WCAP-18443-P, "Qualification of the Two-Dimensional Transport Code PARAGON2" (L-2019-TOP-0016) (Non-Proprietary)

AFFIDAVIT

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 the proprietary portions of LTR-NRC-19-35, Enclosure 3 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.

(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:

AFFIDAVIT

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

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: 20190625

Korey L. Hosack, Manager
Product Line Regulatory Support

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and non-proprietary versions of a document, furnished to the NRC in connection with requests for generic review and approval.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary 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 in confidence identified in Sections (5)(a) through (5)(f) of the Affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

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Enclosure 4

Presentation Slides for the Westinghouse-NRC Pre-Submittal Meeting on Topical Report WCAP-18443-P, "Qualification of the Two-Dimensional Transport Code PARAGON2" (L-2019-TOP-0016)

(Non-Proprietary)

June 2019

Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

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Westinghouse Nuclear Safety Culture

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WCAP-18443-P, "Qualification of the Two-Dimensional Transport Code PARAGON2"

Mohamed Ouisloumen
Ho Lam
Michael Gavalek
Parvez Khambatta

NRC – Westinghouse Pre-submittal Meeting
June 27, 2019

Westinghouse

Agenda

- Introductions
- Need for Topical Report Submittal to the NRC
  - Intended Applications, and Outline of the Topical Report
- PARAGON2 Methodology
  - Cross-section library
  - Description of PARAGON2 modules
- PARAGON2 Benchmarking
  - Comparison to Monte Carlo
  - Critical & PIE experiments
- PARAGON2/ANC Plants Analyses
  - Comparison to Measured plants data
  - Safety Limits & Licensing Criteria
- Licensing Approach
- Schedule & Customer Needs and Benefits

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Need for Topical Report submittal to the NRC

- PARAGON1 is a lattice physics code that provides the basic cross-sections for the core neutronics code
- PARAGON2 is a replacement for the PHOENIX-P and PARAGON1 codes as a standalone application or a data supplier for nodal codes (such as ANC) for PWR core design applications.
  - No interface changes are required for existing codes packages that use lattice codes
  - All PWR licensed methodologies remain applicable when using PARAGON2
  - Current uncertainties for safety analysis and Tech Spec surveillance remain applicable

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Need for Topical Report submittal to the NRC (cont.)

- The PARAGON2 neutronics lattice physics code was developed to improve the accuracy of current core design code systems, NEXUS/ANC, and APA

[a,c]

The methodology and models implemented in PARAGON2 require licensing.

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Need for Topical Report submittal to the NRC (cont.)

- For all plant types, PARAGON2 is intended to:

[ ]a,c

  - Improve ANC and BEACON™ code predictions
  - Consistently improve predictions for all fuel types (from 14x14 to 17x17)

Outline of Topical Report

- Topical Report Approach
  - Self-contained or explanatory
  - Large database of critical experiments and isotopic measurements
  - Monte Carlo benchmarks
  - Large number of sample calculations for operating plants
  - Confirmation of previously approved uncertainties

Outline of Topical Report (cont.)

- Report Organization:
  - Introduction
  - Description of the PARAGON2 methodology
  - Benchmarking & qualification of the methodology performed via comparisons to
    - critical experiments and isotopic measurements
    - assembly calculations with Monte Carlo method calculations
  - Qualification for core design applications is performed via comparisons against measured plant data
  - Summary & Licensing Criteria

PARAGON2 Methodology – Overview

Mohamed Ouisloumen

PARAGON1 versus PARAGON2

a,c

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Major changes are in energy variable treatment

Westinghouse Core Design Code Packages

- APA – ALPHA/PARAGONx/ANC
  - Based on boron-letdown cross-section representation
  - ALPHA is pre-processor lattice code (driver)
  - ANC – Nodal Diffusion Code (NRC Licensed code)
- NEXUS/ANC
  - Based on once-through cross-section representation
  - NEXUS is pre and post processor for PARAGONx
  - NEXUS components: NEXrun, NEXpre, ALPHA/PARAGONx, NEXLink
- The only change in these systems is the adoption of the new PARAGON2
- PARAGON1 was approved by NRC in 2004 (WCAP-16045-P-A)

PARAGON2 Methodology – Cross section library

- Cross-section Library – UFEML (Ultra-Fine Energy Mesh Library)
  - Based on ENDF/B7.1 with some isotopes from JEFF3.2
  - Employs **6064** energy groups
  - NJOY used has a module that generates the scattering matrices using the Resonance Scattering Model (RSM) for all isotopes with high order anisotropic moments (except H in H_2O and graphite)
  - Isotopic Cross-sections tabulated as a function of temperature only
    - Range covered [ ]a,c with [ ]a,c points
    - [ ]a,c
  - [ ]a,c

First Principle Physics – No adjustments of the basic nuclear data

Impact of RSM on Neutronics Parameters

- Compared to Asymptotic model RSM tends to increase the Doppler as a function of temperature (more negative FTC)
  - [ ]^{a,c} difference in Doppler Coefficients of Reactivity
- Large impact on local multigroup fluxes. The magnitude depends on the presence of resonant isotopes in fuel composition mixture
- More details:
  - M. Ouisloumen and R. Sanchez, Nuclear Science and Engineering 107, 189-200 (1991).
  - M. Ouisloumen, A. M. Ougouag and S. Z. Ghrayeb, “Anisotropic Resonance Scattering Model for the Neutron Transport Equation”, Nuclear Science and Engineering 179, 59-84 (2015).

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PARAGON2 Benchmarking and Qualification

Mohamed Ouisloumen

Comparison to Monte Carlo - Benchmarking

- Extensive comparison of PARAGON2 against SERPENT2 continuous energy was conducted using:
  - All PWR assembly lattice types (Westinghouse & CE Designs)
  - Common Industry and Westinghouse Proprietary Burnable Absorbers
  - Uranium Enrichment up to [ ]a,c
  - Fuel type: [ ]a,c
- Comparison includes HZP and HFP depletion
  - Reactivity and Pin Power distribution
- Overall PARAGON2 reproduces the Monte Carlo continuous energy solution
  - Reactivity within [ ]a,c
  - Pin power within [ ]a,c
  - Consistent good prediction for all fuel types, lattice types, fuel compositions and fuel enrichments, i.e. no apparent biases

PARAGON2 Reproduces Continuous Energy Monte Carlo Solution

Comparison to Monte Carlo – Benchmarking (cont.)

a,c

Excellent CZP, HZP and BOC HFP PARAGON2 predictions

Integral Experiments – Qualification

- Large number of experiments are analyzed
  - Integral Experiments – 4 experiments
  - Critical experiments – 66 cores
- Integral Experiments analyze pin cell or pellet:
  - Hellstrand Experiments: ^{238}U Resonance Integrals vs. temperature and rod size for Metal and Oxide fuel
  - TRX Experiments: Radial ^{238}U Resonance capture for UO_2, U-metal and U-Zr
  - CRIEPI-Experiment for isotopics (U & Pu) and radial burnup distribution – UO_2 sample ~ 74.5 GWD/MTU with ~150 GWD/MTU at pellet periphery
  - 101 Pin Cells Strawbridge-Barry Critical Experiments for reactivity
    - Cover wide range of PWR conditions: Enrichments, pellet diameter, water to uranium ratio, lattice pitch, etc. – Same results as PARAGON

Good PARAGON2 predictions for all fuel types

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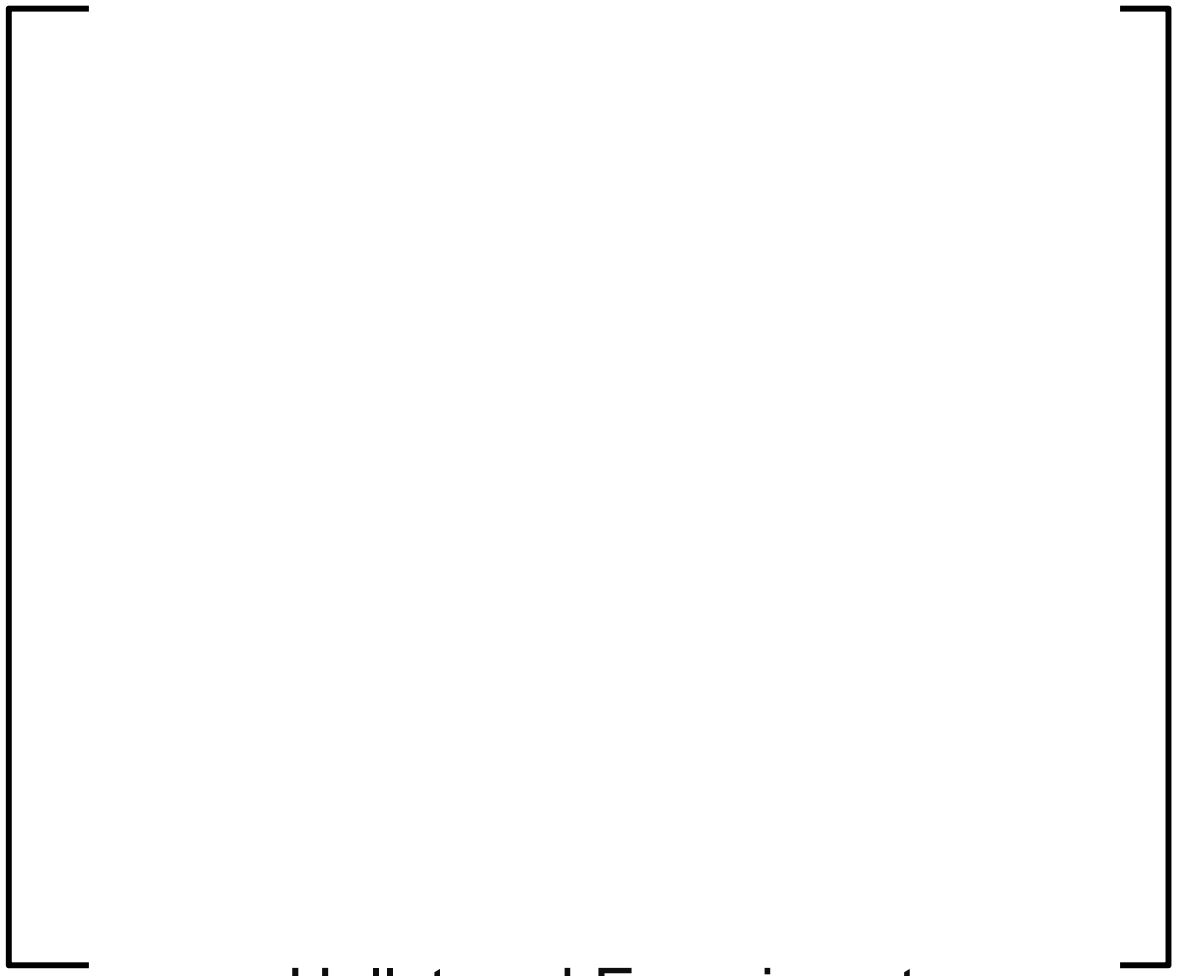
Integral Experiments – Example Results

a,c



Hellstrand Experiment

Integral Experiments – Example Results

a,c

TRX Experiment

Integral Experiments – Example Results (cont.)

CRIEPI – Experiment

Sample burnup ~ 74.5 GWD/MTU

Peripheral burnup ~ 150 GWD/MTU

^{235}U Enrich. 3.8 wt%

[a,c]

Critical Experiments – Qualification

- Large number of heterogeneous Critical Experiments cores analyzed:
  - Babcock & Wilcox Critical Experiments
    - 29 cores
    - Various fuel rods, guide tubes, and BAs.
    - Results of reactivity and power distribution measurements for typical PWR lattices at cold conditions: [ ]a,c
  - KRITZ High Temperature Experiments
    - 12 cores
    - Critical experiment temperatures up to 518K [ ]a,c
  - MOX Critical Experiments
    - KRITZ-2
      - 1 Core, 2 Conditions: Hot & Cold
    - VENUS-2
      - 1 Core, 1 Condition: cold
    - [ ]a,c

Critical Experiments – Qualification (cont.)

- Large number of heterogeneous Critical Experiments cores analyzed:
  - Toshiba NCA Critical Experiment
    - 5 cores
    - Enrichments up to 4.9 wt%, Tungsten rods and Gadolinia BA
    - [ ]a,c
  - RPI Critical Experiments
    - 4 Cores
    - CE configuration with Erbium BA
    - [ ]a,c
  - Critical Experiments with enrichment > 5 wt%
    - Reactivity measurement only
    - Enrichment: [ ]a,c
    - Comparison to MCNP:
      - Average delta reactivity [ ]a,c
      - RMS Pin power [ ]a,c

Overall good reactivity and pin power distribution predictions

PIE Experiments – Qualification

- PIE samples are modeled in PARAGON2 to benchmark depletion capabilities
- PIE Data from Spent Fuel Isotopic Composition (SFCOMPO 2.0) database excluding Saxton-Yankee, which uses legacy Westinghouse data
- Benchmarks were selected to cover wide range of:
  - Burnup Range: 27.35 to 74.57 GWD/MTU
  - PWR Fuel Lattice Designs: W & CE NSSS
  - Enrichment: 2.556 to 4.657 wt%
- Saxton-Yankee are pin cell models. Results are as good as in PARAGON1
- For SFCOMPO new cases, 2D assemblies were modeled using power histories, discharge burnup and T/H local conditions as much as possible.

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PIE Experiments – Results

- Overall, the relative measured minus predicted isotopic number densities are:
  - [ ]a,c
  - [ ]a,c

PIE Predictions are Acceptable

PARAGON2 – Plant Qualification

Michael E. Gavalek

Plant Qualification – Plant Characteristics

- Extensive testing to ensure accuracy of PARAGON2 when used in plant simulations (data from 14 nuclear plants)
  - Plant Design: Westinghouse, Combustion Engineering
  - Loop Design: 2-, 3-, and 4-loop
  - Enrichment: 0.71 – 5.00 wt%
  - Fuel Lattice
    - Westinghouse: 14x14, 15x15, 16x16, 17x17
    - Combustion Engineering: 14x14, 16x16
  - Fuel Rod Diameters: 0.360, 0.374, 0.382, 0.400, 0.422, 0.440 in
  - Burnable Absorbers: IFBA, WABA, Hf, Pyrex, Erbia, Gadolina, Tritium Producing Burnable Absorber Rods (TPBARs), Boron Displacing Rods (B_4C), and combinations of the above
  - Cycle Length: 12, 18, 24 months
  - RCCA Material: Ag-In-Cd, B_4C, W, and combination

Plant Qualification – Benchmark Parameters

- HZP Startup Physics
  - All Rods Out (ARO) HZP Critical Boron Concentration
  - ARO Isothermal Temperature Coefficient (ITC)
  - Total Control Rod Worths (RW)
- HFP Depletion
  - ARO Critical Boron Concentration (CB)
  - Radial Assembly Average Power Distributions
  - Axial Core Average Power Distributions
- Safety Related Parameters
  - Steamline Break (All Rods In - Worst Stuck Rod, F_Q, $F_{\Delta H}$, F_Z)
  - Dropped Rod Accident (Dropped Worth, F_Q, $F_{\Delta H}$, F_Z)
  - Ejected Rod Accident (Ejected Worth, F_Q)
  - HFP EOL ARO Moderator Temperature Coefficient

Plant Qualification – HZP Startup Results

[a,c]

All parameters demonstrate good agreement between PARAGON2 and measurements

Plant Qualification – HFP Depletion Results

a,c

All parameters demonstrate good agreement between PARAGON2 and measurements

Plant Qualification – Safety Related Parameters

a,c

All parameters demonstrate good agreement between PARAGON1 and PARAGON2 and are within current allowances in safety analysis

Plant Qualification – Uncertainty Confirmation

- Westinghouse currently applies a [ ]^{a,c} $F_{\Delta H}$ uncertainty and a [ ]^{a,c} F_Q uncertainty for safety analyses and Tech Spec surveillance.
- The $F_{\Delta H}$ and F_Q uncertainties were approved by the NRC in WCAP-7308-L-P-A
- Using data generated within the topical report, $F_{\Delta H}$ and F_Q uncertainties were confirmed following methods outlined in WCAP-7308-L-P-A to ensure that PARAGON2 does not introduce additional uncertainties

Peaking factor uncertainties currently used in safety analyses are bounded by PARAGON2

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Licensing Approach, Schedule & Customer Needs and Benefits

Parvez N. Khambatta

Westinghouse

Licensing Approach

- Regulatory Requirements
  - 10 CFR 50.34, “Contents of applications; technical information”
  - NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, Section 4.3, Nuclear Design.

Licensing Approach (cont.)

- Requested SER statement:
  - *Based on the qualification data as documented in the TR, PARAGON2 may be used as a standalone code, or as a direct replacement for all the previously licensed Westinghouse PWR lattice codes, such as PHOENIX-P and PARAGON, wherever they are licensed for use with NRC approved methodologies.*

- Other TRs that reference the Westinghouse nuclear design code system would remain applicable with PARAGON2.

Licensing Approach (cont.)

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a,c

[ ]a,c (cont.)

a,c

[ ]a,c (cont.)

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[ ]

[ ]a,c

[ ]a,c

[ ]a,c

Schedule & Customer Needs and Benefits

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