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LTR-NRC-18-64

September 17, 2018

Subject: Submittal of Presentation "Westinghouse EnCore® Accident Tolerant Fuel (ATF) Development and Licensing Approach" (Proprietary/Non-Proprietary)

Enclosed are the proprietary and non-proprietary versions of the presentation, "Westinghouse EnCore® Accident Tolerant Fuel (ATF) Development and Licensing Approach" for a meeting to be held on September 18, 2018.

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 Application for Withholding Proprietary Information from Public Disclosure and 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 Application for Withholding or the Westinghouse Affidavit should reference AW-18-4805, and should be addressed to Edmond J. Mercier, Manager, Fuels Licensing and Regulatory Support, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 2, Suite 256, Cranberry Township, PA 16066.

A handwritten signature in black ink, appearing to read "Edmond J. Mercier", with a long horizontal flourish extending to the right.

Edmond J. Mercier, Manager
Fuels Licensing and Regulatory Support

Enclosures

EnCore is a trademark or registered trademark of Westinghouse Electric Company LLC, its Affiliates and/or its Subsidiaries in the United States of America and may be registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited. Other names may be trademarks of their respective owners.



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AW-18-4805

September 17, 2018

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: LTR-NRC-18-64 P-Attachment "Westinghouse EnCore® Accident Tolerant Fuel (ATF) Development and Licensing Approach" (Proprietary)

Reference: Letter from Edmond J. Mercier to the Document Control Desk, LTR-NRC-18-64, dated September 17, 2018.

The Application for Withholding Proprietary Information from Public Disclosure is submitted by Westinghouse Electric Company LLC ("Westinghouse"), pursuant to the provisions of paragraph (b)(1) of Section 2.390 of the Nuclear Regulatory Commission's ("Commission's") regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary information for which withholding is being requested in the above-referenced presentation is further identified in Affidavit AW-18-4805 signed by the owner of the proprietary information, Westinghouse. The Affidavit, which accompanies this letter, sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b)(4) of 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to the proprietary aspects of the Application for Withholding or the accompanying Affidavit should reference AW-18-4805, and should be addressed to Edmond J. Mercier, Manager, Fuels Licensing and Regulatory Support, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 2, Suite 256, Cranberry Township, PA 16066.

A handwritten signature in black ink, appearing to read "Edmond J. Mercier", is written over a horizontal line.

Edmond J. Mercier, Manager
Fuels Licensing and Regulatory Support

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

SS

COUNTY OF BUTLER:

I, Edmond J. Mercier, am authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC (“Westinghouse”) and declare that the averments of fact set forth in this Affidavit are true and correct to the best of my knowledge, information, and belief.

Executed on:

9/17/2018



Edmond J. Mercier, Manager
Fuels Licensing and Regulatory Support

- (1) I am Manager, Fuels Licensing and Regulatory Support, Westinghouse Electric Company LLC (“Westinghouse”), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rule making proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.
- (2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Nuclear Regulatory Commission’s (“Commission’s”) regulations and in conjunction with the Westinghouse Application for Withholding Proprietary Information from Public Disclosure accompanying this Affidavit.
- (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 the provisions of paragraph (b)(4) of Section 2.390 of the Commission’s regulations, 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.
 - (ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitute Westinghouse policy and provide the rational basis required.

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.
- (iii) There are sound policy reasons behind the Westinghouse system which include the following:
- (a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.
 - (b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.
 - (c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

- (d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.
 - (e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.
 - (f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.
- (iv) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390, is to be received in confidence by the Commission.
- (v) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.
- (vi) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in LTR-NRC-18-64 P-Attachment “Westinghouse EnCore® Accident Tolerant Fuel (ATF) Development and Licensing Approach” (Proprietary), for a meeting to be held on September 18, 2018, for submittal to the Commission, being transmitted by Westinghouse letter LTR-NRC-18-64. The proprietary information as submitted by Westinghouse is that associated with development and licensing of EnCore® accident tolerant fuel and may be used only for that purpose.
- (a) This information is part of that which will enable Westinghouse to develop and license enhanced accident tolerant fuel technologies.
 - (b) Further, this information has substantial commercial value as follows:

- (i) Westinghouse plans to sell the use of similar information to its customers for the purpose of implementing enhanced accident tolerant technologies into operating reactors.
- (ii) Westinghouse can sell support and defense of industry guidelines and acceptance criteria for plant-specific applications.
- (iii) The information requested to be withheld reveals the distinguishing aspects of a methodology which was developed by Westinghouse.

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.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended.

Further the deponent sayeth not.

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and non-proprietary versions of a document, furnished to the NRC in connection with Westinghouse development and licensing of accident tolerant fuel products.

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 (4)(ii)(a) through (4)(ii)(f) of the Affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

COPYRIGHT NOTICE

The reports transmitted herewith each bear a Westinghouse copyright notice. The NRC is permitted to make the number of copies of the information contained in these reports which are necessary for its internal use in connection with generic and plant-specific reviews and approvals as well as the issuance, denial, amendment, transfer, renewal, modification, suspension, revocation, or violation of a license, permit, order, or regulation subject to the requirements of 10 CFR 2.390 regarding restrictions on public disclosure to the extent such information has been identified as proprietary by Westinghouse, copyright protection notwithstanding. With respect to the non-proprietary versions of these reports, the NRC is permitted to make the number of copies beyond those necessary for its internal use which are necessary in order to have one copy available for public viewing in the appropriate docket files in the public document room in Washington, DC and in local public document rooms as may be required by NRC regulations if the number of copies submitted is insufficient for this purpose. Copies made by the NRC must include the copyright notice in all instances and the proprietary notice if the original was identified as proprietary.

**Westinghouse EnCore[®] Accident Tolerant Fuel (ATF)
Development and Licensing Approach
(Non-Proprietary)**

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Westinghouse EnCore[®] Accident Tolerant Fuel (ATF) Development and Licensing Approach

September 18, 2018



Introductions and Purpose

- Introductions
- Purpose
 - Provide overview of current state of EnCore[®] fuel development and licensing approach
 - Obtain feedback on the approach from NRC staff to inform further refinement of the licensing strategy
 - Discuss key interactions to support EnCore fuel licensing
 - PIRT exercises
 - Cooperative interactions between Westinghouse and NRC to support clarification of regulatory framework and refinement of EnCore fuel licensing strategy

Agenda

- Westinghouse's EnCore ATF Program
- EnCore Technologies
 - Description
 - Benefits
 - Licensing Approach
 - Status and Timeline
 - Near-Term and Long Term Technologies
 - Innovative Data Collection and Analysis Tools
- PIRT Exercises
- Cooperative Approach for Licensing EnCore Fuel



Westinghouse's EnCore[®] ATF Program

EnCore[®] includes both incremental and game changing products to enable a sensible path to achieve full ATF benefits.

EnCore[®] Products:

- **Advanced Cladding**
 - Cr-coated zirconium – increases maximum temperature by up to 200°C
 - General Atomics SiC – increases maximum temperature by up to 800°C
- **Advanced Fuel**
 - ADOPT[™] fuel pellets – increases density []^{a,c} and reduces pellet-cladding interactions
 - ATF Pellet - U₃Si₂ increases thermal conductivity and improves fuel cycle economics through increased ²³⁵U density (~17%)

Chromium-Coated
Zr Cladding



Silicon Carbide (SiC)
Composite Cladding



Photo courtesy of General Atomics

Product Evolution

ADOPT[™] Pellets



Uranium Silicide
(U₃Si₂) Pellets

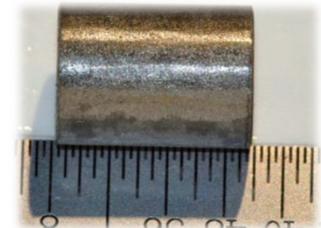


Photo courtesy of Idaho National Labs

Development continues on schedule

Near-Term Technologies

ADOPT Pellets

Chromium-coated Cladding

ADOPT Pellets: Description

- Advanced Doped Pellet Technology
- UO_2 pellet with additions of chromium and aluminum oxides
 - []a,c
- Greater densification and diffusion during sintering



ADOPT Pellets: Benefits

- Higher density
 - []^{a,c} additional uranium per assembly
- Better thermal stability
- Lower transient fission gas release and at high burnups
- Better oxidation resistance (in presence of air and water)
- Expect increased PCI margins at high temperatures
 - Ability of dopants to trap corrosive fission products
 - Higher fuel creep rate to mitigate PCMI (softer pellet)
 - Unique pellet cracking patterns may relieve clad stress



PCI: Pellet-Cladding Interaction
PCMI: Pellet-Cladding Mechanical Interaction

ADOPT Pellets: Status of Development

- Westinghouse has extensive experience delivering ADOPT fuel pellets in region quantities
 - Manufactured in Westinghouse's facilities in Sweden



ADOPT pellets for initial regions in the US will be fabricated in Sweden

ADOPT Pellets: Licensing Approach

- ADOPT Pellets topical report will be submitted
- Anticipate current methods remain applicable:
 - Nuclear Design, Fuel Rod Design, Thermal-Hydraulic Design, Non-LOCA Transient Analysis, LOCA accident analysis, LOCA M&E, Steamline Break M&E, etc.
- Topical report will address key models and behavior to demonstrate compliance with SRP 4.2
 - Material properties, thermal conductivity model, fission gas release, swelling model, fuel melt, pellet characteristics, behavior during accident, etc.

LOCA: Loss of Coolant Accident
M&E: Mass and Energy
SRP: Standard Review Plan



ADOPT Pellets: Information for Licensing Submittal



ADOPT Pellets: Timeline



Coated Cladding: Description

- Thin []^{a,c} adherent and dense chromium layer
- Applied using cold spray, followed by polishing
- Substrate cladding tubes and fuel assemblies unchanged



Coated Cladding: Benefits

- Reduced oxidation during normal operation
 - Longer life and increased margins allow use of higher density fuels
- Improved corrosion resistance in steam and air at high temperature
 - Reduced exothermic reaction energy
 - During and beyond design basis conditions
 - Increased LOCA peak cladding temperature and long-term time limit
 - Improved RIA deposition limits
- Drastic reduction in hydrogen generation and pickup
 - Benefits for draft 10 CFR 50.46c rule
 - Potential for higher transient strain limit
 - Reduced embrittlement in dry storage
- Improved performance for ballooning and burst
- Enhanced resistance to wear (debris, grid-to-rod)



LOCA: Loss of Coolant Accident
RIA: Reactivity Initiated Accident

Coated Cladding: Status of Development

- Preparation of LTR insertion in Byron Unit 2
- Cold spray coating process developed and scaled up

d,e



Process for chromium coating of full length cladding tubes developed and qualified

Coated Cladding: Status of Development

a,c



Coated Cladding: Licensing Approach

- Coated cladding topical report will be submitted
- Anticipate current methods remain applicable:
 - Nuclear Design, Fuel Rod Design, Thermal-Hydraulic Design, Non-LOCA Transient Analysis, LOCA accident analysis, LOCA M&E, Steamline Break M&E, etc.
- Topical report will address key models and behavior to demonstrate compliance with SRP 4.2 and PIRT rankings
 - Material properties, creep model, oxidation, hydrogen pickup, LOCA burst, hydraulic performance, coating adherence, etc.

Coated Cladding: Information for Licensing Submittal

a,c



Coated Cladding: Timeline

d,e



Long-Term Technologies

U_3Si_2 Pellets

SiC Cladding

U_3Si_2 Pellets: Description and Benefits

- Uranium silicide (U_3Si_2) fuel pellets
- U_{235} density increase ~17% higher than for UO_2
 - Reduced batch size, longer cycles or lower enrichments
- Increased thermal conductivity
 - Increased resistance to centerline melting during transients
- Improved irradiation behavior (swelling, gas release, ...)
 - Increased pellet-cladding interaction margin

U₃Si₂ Pellets: Development Status and Plans

- U₃Si₂ fuel pellets included in Byron LTR
– []^{a,c}
- Fabrication of pellets for LTR by Idaho National Laboratory
- []^{a,c}

U₃Si₂ Pellets: Licensing Approach

- Number and content of topical reports is being determined
 - Necessary updates to analytical methods
 - PIRT rankings and regulatory requirements



Licensing strategy for U₃Si₂ pellets is being shaped as material performance and regulatory requirements are better understood

U₃Si₂ Pellets : Timeline

d,e



SiC Cladding: Description and Benefits

- SiC-SiC ceramic matrix composite (CMC)
 - Partnership with General Atomics
- No ballooning and bursting
 - Retention of tensile strength up to 1700°C
 - Slow degradation above 1700°C
- Eliminate oxidation driven temperature spikes
 - Slow reaction with steam to >1700°C
- Drastic reduction of hydrogen generation
- Maintains integrity under most severe beyond design basis accident conditions
- Improved economics for normal operation
 - Reasonably small cross section for thermal neutrons
- Predictable irradiation behavior
 - Swelling is small (<2%) and predictable



SiC Cladding: Development Status and Plans

- Currently testing out-of-pile
 - Corrosion testing
 - Permeability
 - Mechanical testing
 - Pellet-cladding interaction
 - Joining techniques
 - Surface finishing
- Irradiation testing ongoing
- Preparing for insertion of LTRs in []^{d,e}

SiC Cladding: Licensing Approach

- Number and content of topical reports is being determined
 - Necessary updates to analytical methods
 - PIRT rankings and regulatory requirements



Licensing strategy for SiC cladding is being shaped as material performance and regulatory requirements are better understood

SiC Cladding: Timeline

d,e



Innovative Data Collection and Analysis Tools

Advanced Modeling and Simulation

Online Data Collection



Advanced Modeling and Simulation

- Main objective is determination of physical properties of irradiated materials
- Based on first principles rather than being totally empirical
 - More confidence in extrapolations
- Westinghouse involvement on industry programs
 - NEAMS – DOE program on basic property prediction
 - CASL – Virtual reactor design



DOE – Department of Energy
CASL – Consortium for Advanced Simulation of Light Water Reactors
[]d,e



Advanced Modeling: Application to EnCore Fuel

d,e



Advanced Modeling: Licensing

- Per NRC and DOE memorandum of understanding, NRC staff will work proactively with DOE on data and codes used to understand and characterize ATF material technologies
 - DOE instrumental in advanced modeling codes
- Westinghouse application of advanced modeling will be described in EnCore fuel material topical reports
 - Available for audit as part of topical report review

NRC will have opportunity to review and assess use of advanced modeling and simulation



Online Data Collection

a,c



Online Data Collection for EnCore Fuel



Online Data Collection Licensing

a,c



PIRT Exercises

Chromium Coated Cladding

- Vendor development process will identify new phenomena important to safety
- Consider approaches other than NRC PIRT to identify high ranked phenomena and State of Knowledge
 - Review of vendor development activities and data
- NRC PIRT activities should focus on new phenomena
 - NRC plans to review the EPRI gap analysis before identifying the next steps
 - Westinghouse will fully support NRC PIRT activities

NRC PIRT Reviews

- How will NRC and vendors collaborate in PIRT process?
 - Can NRC and vendors conduct PIRT activities jointly or will separate PIRT activities be more appropriate?
 - PIRT scope should balance NRC complete information needs against schedule constraints to get initial reloads in cores
 - Possible to identify and rank all phenomena initially, but address the phenomena in a phased approach, determined by when benefits are to be licensed
- Recognize NRC's efforts to ensure protection of proprietary information
 - How will vendor-specific discussions proceed?
 - Will expert elicitation be part of vendor discussions?
- Vendor-specific PIRT for vendor-specific long-term technologies
 - At least, ensure vendor expertise is considered during expert elicitation activities

Westinghouse Involvement

- Westinghouse seeks to have an active role in NRC PIRT activities
 - Will rely on internal development processes to identify key phenomena important to safety
 - May include independent vendor-led PIRT activity
 - Provide input to the NRC PIRT process
 - Stakeholder in the public portions
 - Proprietary input in vendor closed discussions
 - Will develop materials to ensure compliance with regulatory framework resulting from NRC PIRT activities



Cooperative Approach for Licensing EnCore Fuel

Critical Topics

Westinghouse recognizes the need for frequent communication with the NRC on key topics

- Test data
 - Demonstration of material performance
- Model Development
 - Accuracy compared to compiled data
- Advanced Modeling and Simulation
 - Comparison to collected data
- Online Data Monitoring
 - Data collection and accuracy



NRC/Westinghouse Project Goals

- Good planning and communication support long term continuity
- Regular Communications
 - Recurring meetings to discuss development and key issues: Quarterly or more frequently if needed
 - Topical report best practices: Pre-submittal meetings, Safety Evaluation drafted when request for additional information are issued, regular topical status meetings, etc.
- Accurate Information
 - Establish Westinghouse SharePoint site to share data and information not ready for submittal
- Openness and accuracy
 - Document summaries of meetings on the docket noting key decision points
 - Westinghouse proprietary information will be appropriately removed



Westinghouse will keep NRC informed of preparations for topical report submittal

EnCore[®] Fuel

We're changing nuclear energy ... again

