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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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ACCIDENT ANALYSIS: THERMAL HYDRAULICS SUBCOMMITTEE

+ + + + +

OPEN SESSION

+ + + + +

THURSDAY

APRIL 21, 2022

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The Subcommittee met via Teleconference,
at 8:30 a.m. EDT, Jose March-Leuba, Chairman,
presiding.

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COMMITTEE MEMBERS:

JOSE MARCH-LEUBA, Chairman

RONALD G. BALLINGER, Member

VICKI M. BIER, Member

CHARLES H. BROWN, JR. Member

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WALTER L. KIRCHNER, Member

DAVID A. PETTI, Member

JOY L. REMPE, Member

MATTHEW W. SUNSERI, Member

ACRS CONSULTANT:

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

HOSSEIN NOURBAKHS

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P R O C E E D I N G S

8:30 a.m.

CHAIRMAN MARCH-LEUBA: This meeting will now come to order.

This is a meeting of the Accident Analysis Thermal-Hydraulic Subcommittee. I am Jose March-Leuba, the Subcommittee Chairman.

Because of COVID-19 concerns, this meeting is being conducted in a hybrid manner. In addition to in-person attendance at the NRC Headquarters, the meeting is broadcasted via MS Teams.

Members in attendance are: Ron Ballinger, Vicki Bier, Charles Brown, Vesna Dimitrijevic, Greg Halnon, David Petti, Joy Rempe, and Matt Sunseri. In addition, we have our consultant, Steve Schultz, on the line.

Today, we are reviewing Topical Report WCAP-18482-P, Revision 0, by Westinghouse Electric Company, entitled, "Westinghouse Advanced Doped Pellet Technology (ADOPT) Fuel."

Portions of our meeting will be closed to the public to protect Westinghouse proprietary information.

We have not received requests to provide comments, but we will have an opportunity for spur-of-

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1 the moment public comments before the beginning of the
2 closed section of the meeting.

3 The ACRS was established by a statute and
4 is governed by the Federal Advisory Committee Act,
5 FACA. As such, the Committee can only speak through
6 its published letter reports.

7 The rules for participation in all ACRS
8 meetings were announced in The Federal Register on
9 June 13th, 2019. The ACRS section of the U.S. NRC
10 public website provides our Charter, Bylaws, agendas,
11 letter reports, and full transcripts of the open
12 portions of all full and subcommittee meetings,
13 including the slides presented there.

14 The Designated Federal Official today is
15 Hossein Nourbakhsh.

16 A transcript of the meeting is being kept.
17 Therefore, speak into the microphones clearly and
18 state your name for the benefit of the court reporter.

19 Especially if you are joining the meeting
20 using the bridge line, please keep the microphone on
21 mute when not in use.

22 Members, this is not boilerplate. After
23 reviewing the Safety Evaluation, my conclusion will be
24 to write a positive ACRS letter recommending that the
25 staff issue the SER. However, a full Committee letter

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1 will require a new presentation and will delay SER
2 publication by a couple of months, which I don't think
3 is warranted.

4 Therefore, I am proposing that, according
5 to our Bylaws, we use the P&P-approved meeting summary
6 procedure. I, as Subcommittee Chairman, will write a
7 couple of paragraphs that will be included in the
8 official summary of this meeting, if the full
9 Committee P&P approves it by a vote. Think of it as
10 a "letter lite."

11 During the presentations today, keep in
12 mind if any item rises to the importance of requiring
13 a letter, in which case we will follow standard
14 procedure and write a letter. Basically, if our
15 letter will have said, "Great job. Issue it," it is
16 not worth delaying SER publication. If our letter
17 would have substantive comments, then we need to be
18 aware that the delay is necessary.

19 At the end of the meeting, I will poll you
20 about your opinion. Once more, this situation is
21 covered in our Bylaws.

22 Finally, because of the possible position
23 of a conflict of interest, Member Rempe will be
24 limited in her participation into this discussion
25 regarding that obtained from the (audio interference)

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1 fuel testing and evaluation activities.

2 At this point, I'll request Mathew
3 Panicker from the NRC staff to present his opening
4 remarks.

5 Mathew?

6 MR. PANICKER: Thank you.

7 My name is Mathew Panicker. I am in the
8 Nuclear Metrics and Fuel Solutions of the Division of
9 Safety Systems. And I will be making the remarks for
10 DSS.

11 The Doped Fuel Topical Report from
12 Westinghouse is the first of probably seven TRs that
13 is being reviewed by the ACRS now. This was submitted
14 in May 2020, and we accepted it for comprehensive
15 review in June 2020. And the staff had several
16 opportunities to talk to Westinghouse during the audit
17 and the RAI responses, the last of which was a
18 supplemental submitted in November 2021.

19 The other Topical Report related to ATF is
20 WCAP-18446. It is "Incremental Extension Burnup Limit
21 for Westinghouse and CE Fuel Designs." And this is
22 another one.

23 The DSS is engaging Research to develop
24 the FAST code in order to support the ATF-related
25 Topical Reports for confirmatory calculations. And

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1 there are other activities that the staff is doing.
2 They are preparing to review and license ATF fuels for
3 high burnup, increased enrichment, and they are all
4 related by the ATF Project Plan, which was updated in
5 September 2021 to reflect the industry's increased
6 focus on high burnups and increased enrichment fuel in
7 relation to ATF fuels.

8 Also, the ATF Project Plan describes a new
9 licensing burden, various increased stakeholder
10 engagement individually affiliated with new
11 technologies for any applications that are submitted.
12 So, we can understand, and possibly develop, the
13 issues like, of course, licensing delays.

14 In addition, the plan describes all the
15 stuff in our series: performing regulatory activities
16 for the application service, such as utilizing the
17 PIRT process to support the development of LARs or
18 other regulatory activities prior to submittal.

19 That's all I have now. If there are any
20 questions?

21 CHAIRMAN MARCH-LEUBA: Thank you, Matt.
22 We'll reserve the questions for the other
23 presentation, unless somebody has one.

24 So, at this point, we'll introduce Zach
25 Harper from Westinghouse to do the introductory

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1 remarks for Westinghouse and introduce your team.

2 MR. HARPER: Thank you.

3 Good morning, everyone.

4 My name is Zach Harper. I appreciate the
5 ACRS's time today and appreciate the opportunity for
6 Westinghouse to present our advanced doped pellet
7 technology.

8 We have hard copies of the open and closed
9 presentation. If you need one, just let me know.

10 We have some team members here in the room
11 that we may end up calling on as subject matter
12 experts, and we also have a few team members on the
13 phone.

14 With me today are Kallie Metzger and Luke
15 Hallman. Kallie will present the open portion of the
16 meeting, and Luke will be the primary presenter for
17 the closed portion.

18 So, again, thank you for the opportunity,
19 and we look forward to the discussion.

20 DR. METZGER: Thank you, Zach.

21 Again, my name is Kallie Metzger. I'm the
22 Manager of the Accident Tolerant Fuel Program within
23 Westinghouse.

24 And I'd like to thank the Nuclear
25 Regulatory Commission staff, as well as the Advisory

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1 Committee on Reactor Safeguards, for having us today
2 for this opportunity and the discussion.

3 Today's presentation material covers our
4 Westinghouse Topical on the Advanced Doped Pellet
5 Technology, or ADOPT, fuel, WCAP-18482.

6 To provide a little context for the ADOPT
7 fuel pellet, it fits into our portfolio of accident
8 tolerant fuels. We refer to the accident tolerant
9 fuel program as the EnCore fuel program because, much
10 like an encore, it's a response to our customer demand
11 for products with increased safety and economic
12 performance.

13 The portfolio is comprised of both
14 advanced cladding solutions as well as advanced fuel
15 technology products, and we are delivering the
16 accident tolerant fuel program in two phases. The
17 first phase includes chromium-coated zirc cladding
18 alongside ADOPT fuel pellets, and our second phase
19 includes silicon carbide composite cladding, as well
20 as advanced high density uranium nitride pellets.

21 The advanced cladding solutions, both
22 coated cladding zirconium alloys as well as silicon
23 carbide cladding, provide increased safety and
24 operational margin, and the chrome-coated zirconium
25 clad may enable high burnups.

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1 Similarly, the advanced fuel pellet
2 solutions, both ADOPT and uranium nitride, provide
3 higher density, enabling fuel cycle cost benefits, and
4 our ADOPT fuel pellets can also support high burnup.

5 A bit --

6 MEMBER REMPE: You know how ACRS members
7 are; we just interrupt.

8 (Laughter.)

9 DR. METZGER: Sure.

10 MEMBER REMPE: It's been a while since
11 we've had this opportunity to do this in person. So,
12 I thought I'd kind of start off a bit apologetic when
13 I finally did it.

14 But you're saying you have increased
15 safety margin and reduced cost. So, you're actually
16 offering these fuel assemblies to the plants for a
17 lower cost?

18 DR. METZGER: Well, I think that the
19 detail about the cost, there's nuance to it. But the
20 ability to have increased uranium loading in the fuel
21 pellet provides an economic benefit for increased fuel
22 cycle length and increased --

23 MEMBER REMPE: So, you're hoping, but
24 they're aren't giving a reduction like 20 percent off
25 or so? I was just curious in all that. And we're

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1 still trying to evaluate the margin, but I'm sorry, I
2 just had to ask.

3 (Laughter.)

4 DR. METZGER: Absolutely. Understandable.

5 MEMBER BALLINGER: I would add that,
6 tongue in cheek, "Encore" is the name of a casino in
7 Boston.

8 MEMBER REMPE: A good one?

9 (Laughter.)

10 MEMBER BALLINGER: I have no idea, but
11 there's a lot of gambling going on there.

12 (Laughter.)

13 DR. METZGER: I daresay. Understood.
14 I'll get that back to the margining team.

15 (Laughter.)

16 So, a bit more about our ADOPT fuel
17 pellet. ADOPT stands for Advanced Doped Pellet
18 Technology. And it's a standard UO₂ fuel pellet doped
19 with small amounts of alumina and chromia. These
20 additives facilitate densification and diffusion
21 during centering, resulting in a higher density and
22 enlarged grain size compared to standard UO₂ fuel
23 pellets. This translates to benefits for higher
24 uranium density loading for improved fuel cycle
25 economics; larger grain size, providing improved

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1 pellet-clad interaction at high temperatures;
2 increased oxidation resistance, and reduced transient
3 fission gas release.

4 Our Topical Report is focused on bringing
5 ADOPT to the U.S. PWR market.

6 Yes?

7 CHAIRMAN MARCH-LEUBA: I notice you didn't
8 mention extension of burnup here, even though that's
9 related.

10 DR. METZGER: That is covered, I believe,
11 in a separate Topical. This current Topical aims to
12 request burnups.

13 CHAIRMAN MARCH-LEUBA: But, in your
14 experience, does the doping of the pellet improve
15 burnup?

16 DR. METZGER: I believe that's covered in
17 our closed session, yes.

18 In terms of our operating experience,
19 ADOPT is a mature product. It is a fuel. It is a
20 commercial product for our European market with
21 extensive operating experience. We have over 23 years
22 of irradiation experience, 17 years of delivery on
23 reload scale; commercial operating experience with
24 burnups greater than 62 megawatt days per kgU, and
25 we've delivered more than 3400 fuel assemblies, or

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1 over 680 metric tons of ADOPT fuel pellets. So, the
2 key takeaway is that ADOPT is a mature, standard,
3 commercial product.

4 MEMBER REMPE: Can you talk a little bit
5 about how much that experience is with PWRs versus
6 BWRs?

7 DR. METZGER: Sure. The bulk of our
8 operating experience in the European market has been
9 in support of BWRs. We do have experience with PWRs,
10 and that's the focus of the Topical and the WCAP
11 today.

12 MEMBER REMPE: And so, in the BWR,
13 historically, in the fuel they have a barrier coating.
14 Does any of that ADOPT fuel have a barrier coating
15 that you've had in the European market?

16 MR. MITCHELL: Dave Mitchell.

17 Yes, most of it had the barrier coating --

18 MEMBER REMPE: Would you talk on the mic?

19 CHAIRMAN MARCH-LEUBA: And say your name.

20 MR. MITCHELL: My name is David Mitchell
21 with Westinghouse.

22 Yes, most of the ADOPT fuel in Europe is
23 BWRs with lined cladding.

24 MEMBER REMPE: Okay. And so, can you talk
25 about it? Are you going to have that liner here? So,

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1 I mean, I'm just kind of thinking about. You're using
2 BWR --

3 MR. MITCHELL: No, the liner will not be
4 used in BWRs.

5 MEMBER REMPE: Okay. So, you're relying
6 on experience with BWR fuel with liner cladding, and
7 then, you're going to apply that for this Topical
8 Report?

9 MR. MITCHELL: Yes, because the standard
10 PCI methodologies that we have would be based on UO2
11 and would be conservative for ADOPT.

12 MEMBER REMPE: Okay. Thank you.

13 CHAIRMAN MARCH-LEUBA: And in all those 23
14 years of experience, and realizing that BWRs, mostly
15 when you have a leak or a failed fuel, it is mostly
16 from the outside, the lose part. Have you seen any
17 improvement on fuel failures? Or no significant
18 statistics, difference?

19 MR. MITCHELL: I think they take place at
20 different times. So, you can't back out the
21 difference in fuel integrity. ADOPT certainly is not
22 a detriment to it.

23 CHAIRMAN MARCH-LEUBA: Right, but nothing
24 that sticks out as this is going to cause more fuel
25 failure?

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1 MR. MITCHELL: No.

2 CHAIRMAN MARCH-LEUBA: Thank you.

3 MEMBER SUNSERI: Is there a technical
4 reason why there's such a delay in transitioning from
5 Europe to the U.S.? I mean, 23 years of experience
6 overseas -- no technical reason?

7 DR. METZGER: No technical reason.

8 MEMBER SUNSERI: Okay. Thank you.

9 DR. METZGER: Okay. And finally, a bit
10 more about our Topical and what's contained therein.

11 WCAP-18482 is a Topical Report to enable
12 the efficient licensing and region implementation of
13 Westinghouse ADOPT fuel. The Topical includes limits
14 of applicability. It discusses the interaction with
15 other Topical Reports and licensing considerations for
16 implementation; discusses our available qualification
17 data, and demonstrates applicability of existing
18 analytical methods and models, including nuclear
19 design, fuel rod design, thermal-hydraulic design, and
20 safety analysis. There will be additional detail
21 provided on these different areas in Luke Hallman's
22 closed topic presentation.

23 With that, I'll close out my opening
24 remarks and thank everyone again for this opportunity
25 and the discussion.

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1 CHAIRMAN MARCH-LEUBA: Okay. Remembering
2 that we are still in the open session, any more
3 questions for Westinghouse? We'll have an opportunity
4 to ask technical questions in the closed session.

5 (No response.)

6 Hearing none, who's doing the -- Mathew,
7 are you, or is Paul Clifford to do the presentation?

8 MR. PANICKER: Yes, I will do the open
9 session. Okay?

10 CHAIRMAN MARCH-LEUBA: Okay. NRC, go
11 ahead, whoever. So, you can go ahead.

12 MR. PANICKER: Next slide, please.

13 Yes, Westinghouse submitted this Topical
14 Report for ADOPT fuel in May 2020, and the staff
15 started reviewing it from June after accepting it.
16 The TR alludes, in general, to the type of additives
17 as a dopant, which are chromia, chromia oxide, and
18 alumina, alumina oxide. The TR has details on
19 microstructure, thermal and mechanical properties. In
20 addition, programs and experience where Westinghouse
21 has used this fuel in testing and reactors in Europe.

22 The fuel behavior: corrosion, swelling,
23 rod growth, fission gas release, Reactor Initiated
24 Accidents are described in the WCAP report.

25 The licensing criteria consists of fuel

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1 rod design; safety analysis, both past and current
2 accident LOCA and non-LOCA, and containment integrity.
3 It has got a section on radiological consequence, and
4 finally, nuclear design and thermal-hydraulic design
5 when this fuel is used as the basis in the licensees'
6 facilities.

7 Next slide, please.

8 A short history of how the review of the
9 ADOPT Fuel Topical Report developed. There was a
10 virtual regulatory audited conducted by NRC staff, and
11 the documents were available to the staff for a very
12 long time, because of the mature nature of the audit.

13 Additionally, based on the audit, we
14 developed a request for additional information, and
15 the responses were received in two installments. And
16 because one or two of the issues had open issues,
17 Westinghouse supplemented them in November 2021.

18 Next slide, please.

19 This is a list of guidance used by the
20 staff to review this Topical Report: GDC 10, 246,
21 regarding the performance ECCS or LOCA considerations;
22 also, Appendix K, the LOCA analysis can be based on
23 extended care; GDC 35, which deals with emergency core
24 cooling, and the SRP is the guidance which was used
25 for reviewing it. Those are the categories or those

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1 are the requirements, the guidelines for reviewing the
2 fuel system design; and also, containment functional
3 design is in Section 6.2.1, SRP Chapter 15, that deals
4 with transients and accident analysis.

5 Next slide, please.

6 So, ATF provides information and details
7 on microstructure, specific heat, thermal
8 conductivity, melting compression, thermal expansion,
9 elastic moduli, creep and hardening, and the details
10 on the revision programs and experience.

11 Next slide, please.

12 MEMBER REMPE: So, this is Joy, and I have
13 a question before you go to the next slide.

14 MR. PANICKER: Yes.

15 MEMBER REMPE: You know, historically,
16 when we look at power uprates, or whatever, we're
17 always interested in thermal conductivity degradation
18 as a function of burnup. Can you talk a little bit
19 about the type of data they provided in the open
20 session, or do we need to wait until the closed
21 session to hear about that?

22 MR. PANICKER: Thermal conductivity
23 depends on diffusivity -- we have to talk about it in
24 the closed session.

25 MEMBER REMPE: We can wait until the

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1 closed session. Thank you.

2 MR. PANICKER: Uh-hum.

3 Next slide.

4 So, we looked at all this characterization
5 and licensing activity for fuel rods, FFRD, Reactivity
6 Initiated Accidents, gaseous swelling and cladding
7 strain, and then, all these listed for licensings:
8 clad strain, fuel rod internal pressure, clad fatigue,
9 clad oxidation, clad hydrogen pickup, axial growth,
10 clad-free standing, pellet overheating, pellet-clad
11 interaction, and interface to other safety analyses.

12 Next slide, please.

13 The staff responded that the TR provided
14 sufficient information on properties and
15 characterization of doped fuel, supplemented by the
16 responses through RAIs. The staff reviewed the ADOPT
17 fuel rod design criteria and safety analyses for both
18 LOCA and non-LOCA accident methodologies.

19 I think that's the end of this.

20 Next slide, please.

21 CHAIRMAN MARCH-LEUBA: I believe that's
22 the last one. Then, the next one is in --

23 MR. PANICKER: That's the last one, yes.

24 CHAIRMAN MARCH-LEUBA: So, Members, any
25 questions for the staff in the open session?

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1 (No response.)

2 At this point, I'd like to acknowledge
3 that Vice Chairman Walter Kirchner has joined us on
4 the conference, for the record.

5 I don't hear any questions. I would like
6 to make a comment for the record.

7 I find this Topical Report to be extremely
8 complex, but it is complex because it is very
9 complete. It is really rare that we review a fuel
10 product with 23 years of operating experience, and
11 that hasn't really been running in Europe for that
12 long. So, I find this an excellent work, and I wish
13 we could do more of these. Unfortunately, it's
14 impossible to do because you have to put your fuels
15 first somewhere. But I have no problems with your
16 Topical Report.

17 Any more comments and comments?

18 (No response.)

19 Then, I'm going to open the line for the
20 public.

21 Any member of the public that wants to
22 place a comment on there record and the transcript,
23 please identify yourself and say so. If you are in
24 the Teams meeting, just unmute yourself. If you are
25 on the bridge line, just press *6.

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1 We will wait five seconds for somebody to
2 make a comment.

3 (Pause.)

4 No comments.

5 This will conclude the open session of the
6 meeting, we will move to the more detailed technical
7 analysis in the closed session, which is different
8 phone numbers.

9 So, we are going to recess this session
10 for a moment, go off the transcript, and we will come
11 back at 9:15 in the closed session.

12 Please try to log into the new session
13 early because it always takes time to allow everybody
14 in from the lobby.

15 Thank you very much.

16 We are in recess for 15 minutes.

17 (Whereupon, at 8:55 a.m., the foregoing
18 matter went off the record in open session and went
19 back on the record in closed session at 9:15 a.m.)

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ACRS Thermal-Hydraulic Phenomena Subcommittee Meeting

Westinghouse Advanced Doped Pellet Technology (**ADOPT™**) Fuel,
WCAP-18482-P/NP

Kallie Metzger, Ph.D.

Manager, Accident Tolerant Fuel Program

April 21, 2022

EnCore[®] Fuel

We're changing nuclear energy ... again



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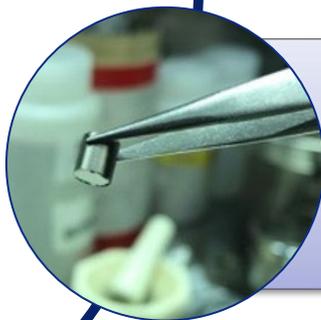
Westinghouse's EnCore[®] Fuel Program

The EnCore[®] Fuel program is developing and commercializing advanced fuel products to improve safety and economic performance



Advanced Cladding

- Cr-Coated Zirconium – increases safety and operational margin, and may enable high burnup
- Silicon Carbide Cladding – safety and operational benefits



Advanced Fuel

- ADOPT[™] fuel pellets – higher density, benefits to fuel cycle costs, and may support high burnup
- Advanced Pellet (UN) - provide improved fuel cycle economics, thermal properties, and lower operating temperatures



**Chromium-Coated
Zr Cladding**



**SiGA[™] Silicon
Carbide (SiC)
Composite Cladding**

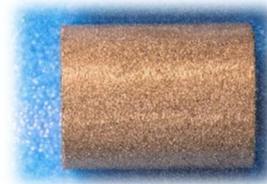


Product Evolution

ADOPT[™] Pellets



**Uranium Nitride
(UN) Pellets**



U¹⁵N Fuel

Photo courtesy of Los Alamos National Lab

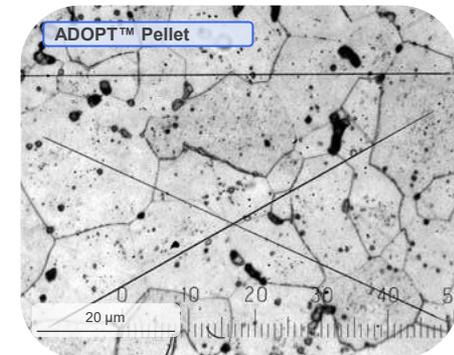
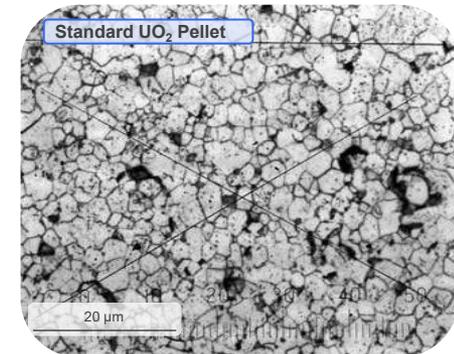
Introduction to ADOPT Fuel

ADOPT (Advanced DOped Pellet Technology):
standard UO_2 fuel doped with small amounts of
 Cr_2O_3 & Al_2O_3

Additives facilitate densification & diffusion during
sintering resulting in a **higher density & enlarged
grain size** compared to undoped UO_2

- **Benefits:**

- Higher uranium density for improved fuel cycle economics
- Larger grain size provides improved Pellet-Cladding Interaction (PCI) margin at high temperatures
- Increased oxidation resistance
- Reduced transient fission gas release



Topical Report is focused on bringing ADOPT technology to the US PWR market

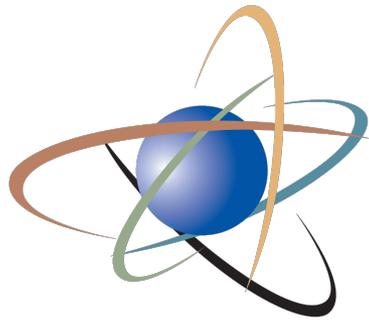
Operating Experience

- **ADOPT** fuel is a commercial product for the European market with extensive BWR operating experience and superior performance compared to standard UO_2 .
 - 23 years of irradiation experience
 - 17 years of deliveries in reload scale
 - Commercial OE with burnups greater than 62 MWd/kgU
 - More than 3400 fuel assemblies delivered
 - More than 680 metric tons of ADOPT pellets delivered

ADOPT is a standard commercial product

Westinghouse Topical Report Overview

- WCAP-18482-P/NP is a topical report to enable efficient licensing and region implementation of Westinghouse **ADOPT** Fuel
 - Proposes limits of applicability
 - Discusses interaction with other topical reports and licensing considerations for implementation
 - Discusses available qualification data
 - Demonstrates applicability of existing analytical methods and models including:
 - Nuclear Design
 - Fuel Rod Design
 - Thermal-Hydraulic Design, and
 - Safety Analysis



U.S.NRC

UNITED STATES NUCLEAR REGULATORY COMMISSION

Protecting People and the Environment

**U. S. Nuclear Regulatory Commission
Staff's Evaluation of Westinghouse Electric Company Topical
Report WCAP-18482-P/WCAP-18482-NP, Revision 0, "Westinghouse
Advanced Doped Pellet Technology (ADOPT™) Fuel"**

**Mathew Panicker, Paul Clifford
Nuclear Methods and Fuel Analysis
Division of Safety Systems
Office of Nuclear Reactor Regulation**

**ACRS Subcommittee Meeting Public Session
April 21, 2022**

Background

- Westinghouse Electric Company submitted topical report (TR) WCAP-18482-P/WCAP-18482-NP, Revision 0, “Westinghouse Advanced Doped Pellet Technology (ADOPT™) Fuel” in May 2020.
- The TR includes:
 - Additives: Cr_2O_3 (Chromia) and Al_2O_3 (Alumina)
 - Microstructure of ADOPT
 - Thermal Properties
 - Mechanical Properties
 - Irradiation Programs and Experience
 - ADOPT fuel behavior: Corrosion, Swelling, Rod growth, Fission gas release, Reactivity Insertion Accident (RIA)
 - Licensing Criteria: Fuel rod design, Safety Analyses (loss-of-coolant accidents (LOCA), Non-LOCA), Containment Integrity
 - Radiological Consequence Analyses
 - Nuclear Design, Thermal-Hydraulic Design

Overview and History

- WCAP-18482-P/WCAP-18482-NP, Revision 0, “Westinghouse Advanced Doped Pellet Technology (ADOPT™) Fuel” submitted in May 2020
- The NRC staff performed acceptance review and accepted TR for review in June 2020
- Virtual regulatory audit was conducted by the NRC staff in November 2021
- Requests for Additional Information (RAIs) were issued in February 2021
- RAI responses:
 - Responses to RAIs 2, 3, 4, 5, 6, 7, 8, 12, 13, and 14 were received in March 2021
 - Responses to RAIs 1, 9, 10, 11, and supplemental information for RAI 6 were received in June 2021
 - Revised responses to RAIs 7a, 11, and supplemental response to RAI 9 were received in November 2021

Regulatory Evaluation

- GDC 10, “Reactor design” - SAFDLs not exceeded during NO and AOO
- 10 CFR 50.46(a)(1)(i) - each boiling or pressurized light water nuclear power reactor fueled with uranium oxide pellets within cylindrical zircaloy or ZIRLO® cladding must be provided with an emergency core cooling system (ECCS) that must be designed so that its calculated cooling performance following postulated loss-of-coolant accidents (LOCA) conforms to the criteria set forth in Section 50.46(b)
- 10 CFR Part 50, Appendix K
- GDC 35, “Emergency core cooling” - Provide emergency core cooling following LOCA
- SRP Section 4.2, “Fuel System Design”
 - No damage to fuel during NO and AOOs
 - Fuel damage not severe to prevent CR insertion
 - Number of fuel rod failures not underestimated for Pas
 - Core coolability is maintained
- Other:
 - Fuel assemblies compatible with co-resident fuel
 - Fuel assemblies to withstand handling and shipping loads
- SRP Section 6.2.1, “Containment Functional Design”
- SRP Chapter 15.0, “Transient and Accident Analyses”



ADOPT Fuel Thermal and Mechanical Properties

- ADOPT TR provides information on:
 - Microstructure
 - Specific heat
 - Thermal conductivity
 - Melting temperature
 - Thermal expansion
 - Elastic moduli
 - Creep and hardening
 - Irradiation programs and experience

Characterization of ADOPT Fuel Performance and Licensing Criteria

- Fuel rod growth
- FFRD
- Reactivity Initiated Accident (RIA) performance
- Gaseous swelling and cladding strain
- Fuel Performance and Licensing
 - Clad stress
 - Clad strain
 - Fuel rod internal pressure
 - Clad fatigue
 - Clad oxidation
 - Clad hydrogen pickup
 - Axial growth
 - Clad free standing
 - Pellet overheating
 - Pellet-clad Interaction
 - Interface to other safety analyses

ADOPT Fuel Conclusions

- TR provides sufficient information on properties and characterization of ADOPT fuel
- The NRC staff reviewed ADOPT fuel rod design criteria and safety analyses for both LOCA and non-LOCA methodologies

List of Acronyms

ACRS	Office of the Advisory Committee on Reactor Safeguards
AOO	Anticipated Operating Occurrences
CFR	Code of Federal Regulations
CR	Control Rod
FFRD	Fuel Fragmentation, Relocation, Dispersal
GDC	General Design Criteria
NO	Normal Operation
NRC	U.S. Nuclear Regulatory Commission
RAIs	Requests for Additional Information
SAFDLs	Specified Acceptable Fuel Design Limits
SRP	NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants"