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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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KAIROS POWER LICENSING SUBCOMMITTEE

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TUESDAY

JULY 6, 2021

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The Subcommittee met via Teleconference, at 1:00 p.m. EDT, David A. Petti, Chair, presiding.

COMMITTEE MEMBERS:

DAVID A. PETTI, Chair

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VICKI M. BIER, Member

DENNIS BLEY, Member

CHARLES H. BROWN, JR., Member

VESNA B. DIMITRIJEVIC, Member

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WALTER L. KIRCHNER, Member

JOSE MARCH-LEUBA, Member

JOY L. REMPE, Member

MATTHEW W. SUNSERI, Member

ACRS CONSULTANTS:

MICHAEL L. CORRADINI

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

WEIDONG WANG

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P R O C E E D I N G S

(1:00 p.m.)

CHAIR PETTI: The meeting will now come to order. This is a meeting of the Kairos Power Licensing Subcommittee of the Advisory Committee on Reactor Safeguards. I am David Petti, chairman of today's subcommittee meeting.

ACRS members in attendance are Charles Brown, Walt Kirchner, Joy Rempe, Matt Sunseri, Vicki Bier, Greg Halnon, Jose March-Leuba, Dennis Bley, Consultant Mike Corradini, Member Ron Ballinger, Consultant Stephen Schultz, Member Vesna Dimitrijevic. Weidong Wang of the ACRS staff is the Designated Federal Official for the meeting.

During today's meeting, the subcommittee will review and assess staff's safety evaluation on Kairos Power KP-FHR Fuel Methodology Topical Report, Revision 3. The subcommittee will hear presentations by and hold discussions with the NRC staff, Kairos Power representatives, and other interested persons regarding this matter.

The part of the presentations by the applicant and the NRC staff may be closed in order to discuss information that is proprietary to the licensee and its contractors pursuant to 5 U.S.C.

552(b)(c)(4).

Attendance at the meeting that deals with such information will be limited to the NRC staff and its consultants, Kairos Power, and those individuals and organizations who have entered into an appropriate confidentiality agreement with them. Consequently, we need to confirm that we only have eligible observers and participants in the closed part of the meeting.

The rules of participation in all ACRS meetings, including today's, were announced in the Federal Register on June 13th, 2019. The ACRS section of the U.S. NRC public website provides that chatter, bylaws, agendas, letter reports, and full transcripts of all full and subcommittee meetings including the slides presented here.

The meeting notice and agenda for this meeting were posted there. We have received no written comments or requests to make an oral statement from the public.

The subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions as appropriate for deliberation by the full committee. The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register.

A transcript of the meeting is being kept and will be made available as stated in the Federal Register Notice.

Due to the COVID pandemic, today's meeting is being held over Microsoft Teams for ACRS, NRC staff, and the licensee attendees. There is also a telephone bridge line allowing participation of the public over the phone.

When addressing the subcommittee, the participants should first identify themselves and speak with sufficient clarity and volume so they may be readily heard. When not speaking, we request that participants mute their computer microphone or phone.

With that, we'll now proceed with the meeting and I'd like to start by calling up NRC Staff, Sam.

MR. CUADRADO DE JESUS: Yes, good afternoon. I'll be covering for Stu Magruder, the program manager who is not available this week. I believe for the technical staff we'll have my branch chief, William Kennedy, Duke, making some introductory remarks.

Duke, are you there?

MR. KENNEDY: Yes, I'm here. Okay, well, good afternoon, everyone. I'd like to give a few introductory remarks here.

Again, my name is William Kennedy. I'm the acting branch chief of the Advance Reactor Licensing Branch. So the staff is looking forward to discussions with and feedback from the ACRS members today on the draft safety evaluation for the Kairos Power topical report, KP-HFR field performance methodology.

And as you'll hear, this topical report is important for Kairos' safety case and is related to other topical reports such as the mechanistic source term and field qualification reports.

Note that this meeting is the third time the staff and Kairos Power have had the opportunity to brief the ACRS on Kairos' topical reports and staff has appreciated the helpful comments from the ACRS on topical reports covering the reactor coolant, scaling methodology, and licensing modernization project implementation.

The staff looks forward to working with Chairman Petti and the rest of the members and staff over the next several years as we complete reviews of more Kairos Power topical reports and prepare for license applications for facilities that we use the Kairos Power design.

I'd just like to highlight that the working relationship between NRC staff and Kairos has been excellent and similar to previous reviews of Kairos Power topical reports, we've used public meetings as a means for addressing technical issues without the need for many requests for additional information.

And finally, I'd just like to say thank you to the technical staff from the Advanced Reactor Technical Branch for their efforts to produce a high quality draft safety evaluation and also thanks to the staff from the Office of Research for their valuable support. So that concludes my introductory remarks. Thanks, Sam.

MR. CUADRADO DE JESUS: Yes, you are welcome. Thank you, Duke.

I also want to say that for the closed portion of the meeting, we'll have the tech staff give the presentation. That will be Jeff Schmidt, who is the lead for the topical report review, and we'll also have a report from Boyce Travis and Antonio Barrett. That's for the closed portion of the meeting.

Back to Kairos. Thank you.

MR. TOMKINS: Okay, this is Jim Tomkins from Kairos Power. And we have a couple of presentations we're going to do today. Micah Hackett will be presenting an overview of Kairos, our design, and topical report. And Blaise Collin, during the closed session will be talking in detail about the topical report.

So we welcome this opportunity. We're interested in feedback. And I will say we intend to use this topical report both for our Hermes reactor and for eventual full size KP-FHR. So this is very important to us and very important to the safety case for Kairos Power.

With that, I'm going to turn it over to Micah Hackett who is our director of fuels and he's going to provide an opening.

MR. HACKETT: Thank you, Jim. I'm going to start with Kairos Power's mission statement which is to enable the world's transition to clean energy, with the ultimate goal to dramatically improving people's quality of life while protecting the environment.

While many of you are probably familiar already, and I understand there are a few new committee members who may not have a full understanding, so I'll quickly go through some background on the fluoride salt-cooled, high temperature reactor concept.

It is a pebble bed reactor. A pebble bed reactor is based on the TRISO fuel particle. I believe all of you are familiar already, but we are planning to use a UCO or uranium oxycarbide kernel. The kernel is then surrounded by a number of layers of pyrolytic carbon and silicon carbide. And this forms the basis of a fuel form that through the AGR program has demonstrated the ability to retain fission products and be very robust even in accident conditions.

This TRISO fuel particle is then contained with an annular pebble and I will show that sign in a later slide here. We're coupling that TRISO fuel technology with a liquid fluoride self coolant, the same coolant used as the base in the liquid fuel MSRE reactor demonstrated at Oak Ridge National Laboratory. This is the lithium fluoride beryllium fluoride coolant that will enable us to have a low pressure reactor system. We do not need to pressurize the reactor in order to maintain the coolant and the fuel. And all of these are technologies that have been demonstrated in some part or fashion through other reactor technologies and what is unique is that Kairos is combining three different technology sets into a new reactor design concept.

I want to spend a moment talking through some of our recent progress and highlights. Kairos started at the end of 2016. By 2018, we had built out an entire office and laboratory in Alameda, California that became our rapid prototyping and technology development facility. This facility has allowed us to be able to use water-based experiments, high temperature oil-based experiments as surrogates for many of the different systems and components that we wanted to test the design for a full scale reactor program. But we have learned a great deal of information at a smaller scale about how our technology will work and how all of these parts and pieces will come together through this rapid prototyping laboratory.

We also designed and built out within this a lab specifically for containing beryllium so that we can use FLiBe and do both FLiBe chemistry experiments and also a significant amount of materials testing within our facility here at Alameda. So this is a dedicated facility where folks can go in and work with FLiBe and be protected while doing so.

Last year, we procured a site in Albuquerque, New Mexico. This was an existing facility to which we have made a very large addition as the T-facility. And the T-facility will again be a dedicated beryllium facility where we will build out by the end of this year the engineering test unit. So we will have a non-nuclear representation of what our Hermes reactor will look like, not fully prototypic, but testing out again many of the different component systems from which we want to learn and understand how the technology will work so that we can de-risk the program as much as possible.

CHAIR PETTI: So I have a question on the T-facility. Is it an individual component test facility sort of thing or is it integrated in that you might have multiple components and be looking at integral behavior?

MR. HACKETT: That's a great question and the answer will (audio interference).

CHAIR PETTI: Okay.

MR. HACKETT: So what we're focused on right now is an integrated test unit that is the engineering test unit that I spoke of.

We also will have many single components where we will do -- and single effects testing on specific components where we want to learn and do more (audio interference).

CHAIR PETTI: What is the size of the facility? Do you know?

MR. PETERSON: Sixty-five feet tall, 100 feet wide and 400 feet long. That's the addition.

MR. HACKETT: This was Per Peterson. And I'll just repeat really quickly what he shared. One hundred feet wide, 400 feet long, 65 feet tall, that's the dimension of this new addition that we have completed construction on.

MEMBER REMPE: Are you planning some tests of the graphite pebbles' interactions with the molten salt at this S-lab to see if there's any degradation and then how will you consider any sort of radiation that's in such a test -- after you've completed such a test?

MR. HACKETT: I'll start with the last part of that. This is a non-nuclear facility. So the radiation pieces --

MEMBER REMPE: I understand that. I have a question even if you find out there's no interactions in non-nuclear environment, where will you look for any sort of radiation effects on the results?

MR. HACKETT: So there have been experiments done at MIT looking at the effect of radiation and graphite in a FLiBe environment. So we will leverage that information.

MEMBER REMPE: To what clearance level?

MR. HACKETT: Off the top of my head, I don't know what the peak fluence levels that they have tested their graphite up to.

MEMBER REMPE: And then are you going to do some non-nuclear tests at the S-Lab to try and see if there's any other effects that you need to capture such as temperature or other things?

Because again, if you're claiming that the FLiBe is a barrier for radiation transport, one needs to make sure that barrier doesn't degrade other barriers, right?

MR. HACKETT: So I'll try to address multiple parts of that and I appreciate the question and understand the basis for the question.

We do have a lot of tests that we are planning with graphite in FLiBe in multiple different facilities or multiple different tests. The engineering test unit is one where we will have essentially a prototype of what our first demonstration reactor will look like and we will be circulating the graphite pebble in the FLiBe salt.

As far as interaction, we do know quite a bit from MSRE on graphite in FLiBe salt coolant and any effects of a radiation on that graphite. So we understand how a radiation plus graphite plus FLiBe interact based on the MSRE experiment.

We have experiments such as tribology testing and salt infiltration testing. The tribology testing is already operational, but it is not something that we go into detail here in this presentation or in this meeting, but we are testing the effects of where an abrasion or friction, for example, of the graphite fuel pebble in a FLiBe salt coolant.

So that's giving you just a quick overview of the different types of effects testing that we are planning.

MEMBER REMPE: Thank you.

CHAIR PETTI: Micah, just a clarification. The pebble is not graphite, right? It's matrix material.

MR. HACKETT: It's material that's partially graphitized. That's correct.

CHAIR PETTI: Partially, right. Yes.

MR. HACKETT: Correct.

CHAIR PETTI: Thank you.

MR. HACKETT: Yes.

MEMBER BALLINGER: This is Ron Ballinger. Are you, folks, I guess in parallel, accumulating experience with beryllium and the like that might be applicable for a larger facility on an industrial scale that's going to be helpful?

MR. HACKETT: Absolutely. And I can say from our partner, Materion, who is a leading producer of beryllium and has developed all of the safety programs on safe handling of beryllium, our partnership with them has taught us a great deal. We are putting that learning to practice here in our S-laboratories that I'm showing. It will be put into use in our T-facility so that way we are learning how to be able to work with beryllium products safely without risking the health of our employees or creating additional hazards.

MEMBER BALLINGER: I'm sure you're concerned of your employees. I would be more concerned about your customers' employees.

MR. HACKETT: Understood and I think part of the purpose of protecting our employees would be, of course, by protecting our employees and learning how we're protecting our employees, any future folks who might come into the facility would also be protected.

MEMBER BALLINGER: Okay. Thank you. Just, if you know, if we build one of these things and operate it commercially that's a little bit different than a very, very, very controlled environment for testing.

MR. HACKETT: Yes, I agree completely and I think the S-Lab is our first opportunity for really learning in a very controlled environment. But then the T-facility, as a much larger facility, that is not similar to the size and scale of what our demonstration reactor facility will look like. That will give us an opportunity to prove out our ability to maintain health and safety at a facility that's at scale.

MEMBER BALLINGER: Thank you.

CHAIR PETTI: So the procedures you use, the T-facility will kind of inform the procedures that you -- operating procedures you use in your demo.

MR. HACKETT: Absolutely.

CHAIR PETTI: Yes.

MR. HACKETT: So continuing on, we have announced our decision earlier this year on the Hermes reactor site selection so this is where we plan to place our first demonstration reactor. This will be on the East Tennessee Technology Park next to the Oak Ridge National Laboratory in Tennessee.

Just to briefly mention some of the external awards and work that we are doing with different partners. We were awarded an NRC funding opportunity announcement, I'm sorry, not an NRC -- a DOE funding opportunity announcement on licensing risk reduction.

We have been in engagement with the NRC. We are in a cooperative development agreement with TVA on collaboration for Hermes. And finally, we are an award winner from a tier 2 award for DOE's advanced reactor demonstration program on a risk reduction award that will be used to support the Hermes demonstration reactor deployment.

For the design approach in the reactor concept itself, we have robust inherent safety. That comes from multiple different areas of the reactor design. Ones that I will mention here is the fact that with our annular pebble design, and the fact that we have a liquid coolant in both operating conditions and in accident conditions, we have very large margins in the fuel temperature between what peak fuel temperatures will be in our fuel and what types of fuel has already demonstrated in safety case to be able to withstand peak temperature before failure.

And so we are not crediting the pebble itself or any retention of fission products, but the trace of particle does retain fission products. And in addition, the coolant also has excellent retention of most fission products. And that combined with a low pressure system where we do not have concern with high pressure release and effective passive decay heat removal, all of these are features of the FHR design that allow us to have that inherent safety in the concept.

A big part of the flowing nuclear force is being able to achieve a lower capital cost in order to be economically competitive although a major strategy in our program is to design and iterate in that design through slowly scaling our concepts here starting with this engineering test unit demonstration experiment that was deployed in Alameda with non-nuclear water-based systems. We learned a great deal about that in order to design and now under construction for the engineering test unit, again, will be a non-nuclear FLiBe-based system. And the learnings from that, similar size and scale, will inform our Hermes reactor demonstration program.

And then, of course, Hermes is just another step in our ability to achieve the fullest commercial scale. We are planning, as a follow on to the Hermes reactor, a full-scale unit that will mimic in scope and prototyping the full scale commercial reactor that will be a non-nuclear unit. This is our U-facility reactor demonstration unit and that will be full scale, allow us to exercise the supply chain and construction in order to then inform how to construct a full size commercial plant.

DR. CORRADINI: This is Corradini. I have a question. Is there a public document? Because each of these are progressive step in advancing the technology as to the objectives. You kind of went through it in a summary fashion, but is there a public document that one can read to understand the objective of each of these test facilities before you get to the commercial plant scale, the demonstration?

MR. HACKETT: Yes, that's a great question. I would have to follow up offline. We have made presentations like this publicly.

MR. TOMKINS: There is a technical report on the testing program that we submitted.

DR. CORRADINI: Okay. So if you could just give us a reference to that, that would be very helpful because I think your summary is good, but trying to put it all together after your oral discussion would be helpful with some written public document.

MR. TOMKINS: Yes, that was Jim Tomkins speaking. I just mentioned that we did submit a technical report on our testing program, although I don't know that it has everything that's in this slide in it. But that laid out kind of our plans for testing. I'll get that to Weidong.

DR. CORRADINI: Thank you very much.

MR. HACKETT: So moving on, I had mentioned already the TRISO fuel in our pebble form and discussed the core designs with the pebble bed concept. The pebbles are designed to be positively buoyant in FLiBE so that they slope at all times in the FliBE. That, of course, means that they are inserted at the bottom of the reactor and extracted at the top of the reactor.

We do plan to eventually use a mixture of both fuel and moderator pebbles in order to operate the reactor at the optimal moderation. And the fuel pebble itself contains the -- this is the diagram on the right --- in the annular region we have the TRISO coated fuel particles that are embedded in a partially-graphitized matrix. And the baseline fuel design that we are using is the AGR coated particle (audio interference).

The pebble handling system itself monitors the condition of the burn up so that we have an opportunity to extract pebbles if they become damaged before reinserting them back into the core. And also that when the pebbles reach the full burn up that we have an opportunity to be able to extract them and insert new fresh fuel pebbles.

MEMBER REMPE: So let me just ask the question again since we have this nice picture here. You have data showing that the matrix shell can resist any sort of interactions with the coolant. And then is it so secure that you feel comfortable that you know it doesn't also have any sort of interaction with the density graphite?

And then, have you ever gone far enough to say I know it won't even interact with the silicon carbide if something were to happen?

I mean how much data do you have for that? I'm not sure I know all the details of the MIT test.

MR. HACKETT: Sure. So I'll just share that we are collecting that data now, so we do not have all of that data to share and to present today.

But we are in the process of collecting all of that test data to be able to demonstrate those concerns that you highlighted.

MEMBER REMPE: Because yes, if you're going to have -- you have these two barriers and if there's any concern about one barrier degrading another barrier, we really ought to know about it.

MR. HACKETT: Absolutely.

MR. TOMKINS: This is Jim Tomkins again. We have a fairly extensive laboratory testing program that's part of our fuel qualification. This meeting today is not actually talking about qualification of the fuel. This is really talking about the qualification of our fuel performance model.

MEMBER REMPE: But that model must account for any degradation, right?

MR. HACKETT: Correct.

MR. COLLIN: This is correct. The assumption is that these -- this is Blaise Collin by the way. The assumption of this board is that our laboratory testing program will inform us about potential interactions between the FLiBe and the pebble. At this point, we assume that these interactions are not degrading the performance of the fuel, but obviously, depending on the findings of these tests, we would have potentially to account for such interactions. But at this point, we assume that the systems do not interact in a deleterious way.

MR. HACKETT: And I'll just share that between MSRE showing compatibility between FLiBe and graphite, and again, this is not full graphite. It is just partially graphetized, but between that experience and ATTR experience of pebble circulating, of course, in helium, but circulating nevertheless, we do have some confidence that our tests will be successful, but of course, it is upon us to conduct those tests.

Any other questions on that? So talking about the purpose of our fuel performance methodology and the topical report. The methodology for our fuel performance is to determine the probability of TRISO fuel particle failure and fission product release that support the KP-FHR source term basis. That is the objective of the fuel performance model that we are discussing here today.

The methodology limits the validation of representative conditions for the KP-FHR and Kairos Power has requested NRC to review and approve the use of KP-BISON fuel performance analysis methodology and uncertainty qualification methodology for conducting fuel fluent analysis that supports the KP-FHR safety analysis.

And Blaise will be going into a lot more detail later in this meeting. That just sets the stage for all of Blaise's much more technical discussion on the fuel performance model.

The methodology is really the fuel's ability to -- of the nuclear fuel to sustain radiation damage while maintaining integrity of those physical barriers that prevent the release of fission products. So KP-BISON is an analytical model based on the INL BISON code. It is using constitutive equations while in analytical relationships. All of that has been developed based on experimental data, much of it collected from the ACR program and, of course, programs prior to that in order to assess probability of failure of those different particle layers, as well as the potential release for fission products regardless of whether or not the layers have failed.

KP-BISON is used to predict performance of our trace of fuel under the normal operating conditions as well as postulated events. And the methodology is based on the KP-FHR fuel design specifically. It does include a consideration of the fuel coolant uncertainties in order to calculate that probability of failure and fission products released.

MEMBER REMPE: So I had some questions about the prior slide. Correct me if I'm wrong and I sort of asked this question when you guys came before ACRS a while back. But this is the first time a design developer with the DOE codes for a licensing application or a topical report.

And I asked last time and they said it was unclear that representative from Kairos. But if you were to go forward and have a plant, how would this work? Is DOE going to give you some sort of authorization that you can sell the suite of codes in the long term to a plant owner/operator?

And then I guess I had some questions about the QA aspects of what you're planning on doing since clearly, you still have to get data to valid the code.

I assume the INL code was developed or the DOE code was developed with appropriate QA, so at least it's verifying even if they don't have all the data for it. But then how will -- what's your process going to be for the V&V?

MR. HACKETT: Brandon, are you on the line?

MR. HAUGH: Yes, I can take this. This is

Brandon Haugh, the director of Model Installation for Kairos Power.

Great question, Joy. Thanks. So on the commercial terms of that, we have options in our agreement with DOE. We sort that when we get there. So that exact method of how licensing would work and how in a commercial sense is, I'm going to say a future discussion. But it's in the terms of what we discussed with DOE.

On the code QA, you are correct. It was developed under an NQA-1 compliant software quality program and it's been audited and the audit is at INL.

Now we were going to commercially dedicate those codes within our own quality assurance program and audit INL in their program and then we'll carry it to the finish line, as you said, through validation.

That validation data we have a plan that's been issued internally and is a reference to this topical report and it determines, you know, how we're going to do that validation based on the current available data through the HER program. And then as we gain operational experience and other things that's described in our fuel qualification plan, more data could become available.

MEMBER REMPE: So I get that validation is going to have to come when the data become available, but given the fact that you started out with an NQA-1 verified code, why didn't you go ahead and verify it before you submitted this topical report?

MR. HAUGH: We've been in the process of doing that in partnership with INL, so through the code development process or our industry FOA award, we've been working hand in hand through verifying each piece of the tool as it's implemented, so that verification occurs while code is being developed.

Validation is ongoing, so we are working through that now and it's a continuing effort over the coming years.

We wanted to get the basis for our work and licensing certainty is why we took kind of this two-step approach to the topical report while the limitations and conditions (audio interference) we can mediate the upfront methodology and getting understanding of that was very important to us. One, because it's the first time this code is being used for this type of fuel in a commercial sense in front of the regulator and two, getting -- understanding of how the code will be used and the scope of its use in our validation and safety case allows us to have certainty moving forward that we're doing the correct work in validation to make sure that we meet those requirements versus us having to guess ahead of time and then get regulatory buy-in later, maybe we do too little or too much work.

MR. TOMKINS: And I might add, this is Jim Tomkins again, that verification and validation is a defined open item in this topical which we have to close and we will do it at a later date.

CHAIR PETTI: So just a point of clarification that might help when you guys come to the full committee in September, you see that we've been bumping into topics sort of peripheral to what we're hearing about today, sort of a road map of stuff that you're planning to submit later that lays out the landscape could be helpful, I think, for members to understand. You know, yes, we know about this one over here. We're planning to submit that, you know, in the future. But everyone sees the full picture.

MR. TOMKINS: So we have submitted a regulatory engagement plan which has that information in it. I think we've updated that at least once, so you know, NRC can provide you that or we can get it to you. It lays out all the topicals we're doing and kind of when we're submitting them.

Does that answer --

CHAIR PETTI: Yes.

MEMBER HALNON: This is Greg Halnon. I have a question and both are on slide 8. And I'm one of those that I'm not sure how far along you are on your design for the actual plant, but how did you define an envelope of operating conditions and define postulated events so that we know that performance behavior is well bounded by your analyses?

MR. HAUGH: Yes, I'll go ahead and take a stab at that. His is Brandon Haugh, another good question.

So we looked at the envelope conditions of how we're designing the plant at the top level requirements so the operating conditions and surrounding and then using for Hermes is a test reactor, the basis in NUREG-1537, so constructed deterministic events bound to those using an MHA process.

So when we get the applicability of these tools within kind of a box of what the plant lives within.

MEMBER HALNON: So when you get to the actual building of the plant, I guess it's probably more in the design certification of the licensing process where you take a look at the full plant, make sure the postulated events you did under this methodology is bounded by the actual assumed operational occurrences that occur during -- with the actual plant design?

MR. HAUGH: Yes, yes, as we went through that final design or moved through those design phases (audio interference) called out in terms of either technical specifications or conditions we have to live within. That's one of the bases of the safety case.

MEMBER HALNON: Okay, if you can't drive to within the envelope here, you'll have to redo the analysis then.

MR. HAUGH: Exactly.

MEMBER HALNON: Okay, thanks.

MEMBER REMPE: Again, I guess the road map would help me, but are you planning to bring this back in with an updated topical report after you validated and verified it and after you have data for postulated events, as well as normal operating conditions?

MR. TOMKINS: Yes. If that's what the committee desires, yes.

MEMBER REMPE: I mean that is your plan. I mean the staff has put a lot of limitations and conditions on their approval and it sounds like you almost have to come back again, doesn't it?

MR. HACKETT: Yes, that is part of the plan, after we perform the verification and validation, we will be updating the topical report in another revision, including all that information and that will be submitted to the NRC at a future date.

And so Joy, coming back to one of your earlier questions about validation, the data, this is the final slide in the introduction of KP-BISON. The plan is to validate this model through the use of historical radiation data, much of it coming from AGR-1 and 2 manufacturing and radiation campaign and that includes the topical report that EPRI led in coordination with INL and submitted to the NRC.

So much of the AGR 1 and 2 radiation data is included in that topical and is going to be used for part of the verification/validation program of the KP-BISON. And a lot of that is being done through our model development as Brandon already mentioned through the DOE iFOA licensing award that we received in 2019. And the purpose of that was really to accelerate the licensing pathway through the DOE NEAMS program.

Any other questions on that or anything else for the introduction?

MR. CUADRADO DE JESUS: Jim, this is Sam.

I see here a revision to the engagement plan was provided on December 2020. Is that the latest version I guess?

MR. HACKETT: I think so, yes.

MR. CUADRADO DE JESUS: Okay, so I can send that to Weidong.

MR. TOMKINS: All right, we're done at this point.

Weidong, what's the next step? Do we switch for the -- or do you take it from here?

MR. WANG: Hi. This is Weidong. I think the next is for public comments because we are in a closed meeting for the next two or three hours, so I suggest to ask for any public comments at this point.

CHAIR PETTI: There's no other staff slides at this point, is that true?

MR. CUADRADO DE JESUS: Correct.

CHAIR PETTI: Okay. Great. So let's open the public line.

MR. DASHIELL: The public line is open for comments.

CHAIR PETTI: Any comments from the public? Well, not hearing any, I guess we can close the open meeting and everybody get on the closed meeting link. We'll see everybody in about five minutes hopefully. Okay, we'll see everybody there.

(Whereupon, the above-entitled matter went off the record at 1:43 p.m.)

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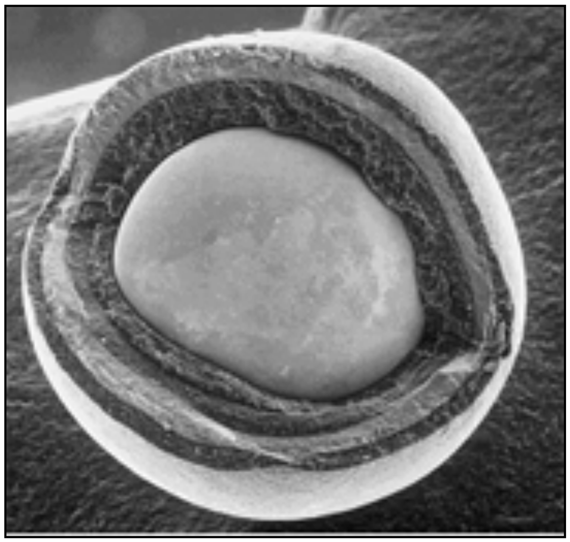
KP-FHR Fuel Performance Methodology Topical Report

ACRS Kairos Power Licensing Subcommittee
OPEN SESSION

JULY 6, 2021

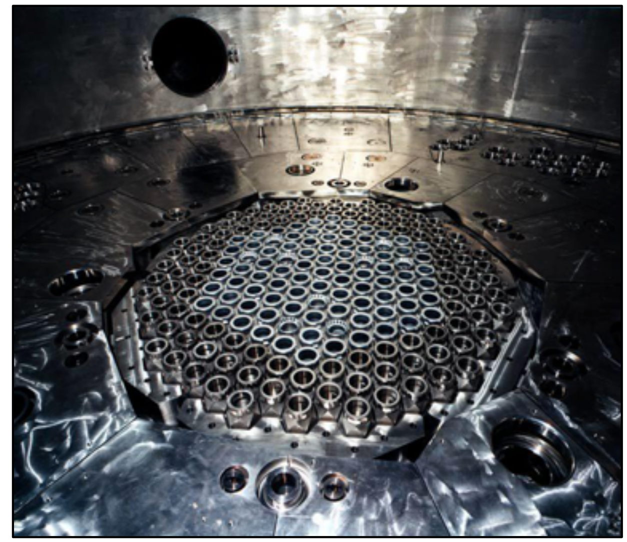
Fluoride Salt-Cooled High-Temperature Reactor (FHR) Technology Basis

Coated Particle Fuel
TRISO



Liquid Fluoride Salt Coolant
Flibe ($2LiF-BeF_2$)

Low-Pressure Reactor Vessel
(FFTF core shown)



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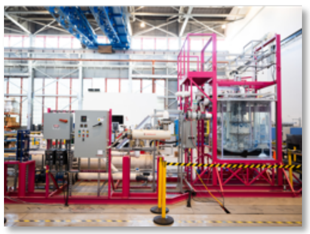
Kairos Power Highlights of Recent Progress

Internal Milestones and Accomplishments:



R-Lab
Rapid Prototyping and Technology Development

S-Lab
Flibe Chemistry and Materials Testing Lab

T-Facility
Engineering Test Unit
New Mexico Expansion

Hermes Reactor Site Selection
East Tennessee Technology Park

External Awards and Validation:

Nuclear Regulatory Commission
Pre-Application Engagement

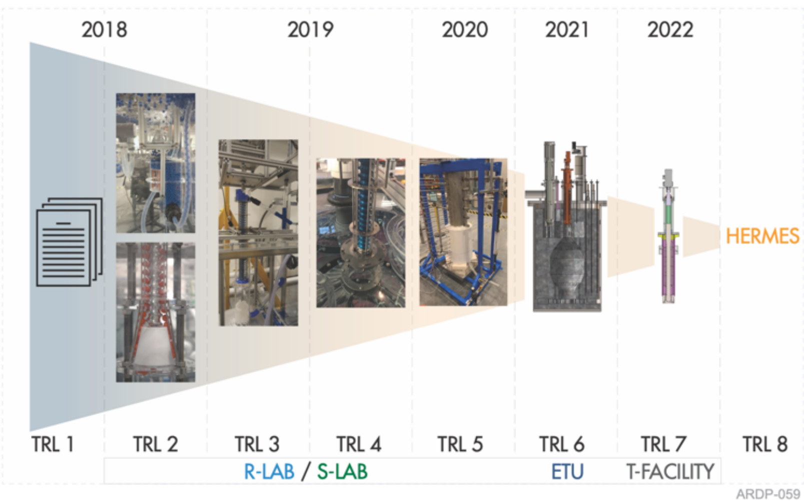
TVA TENNESSEE VALLEY AUTHORITY + Kairos Power

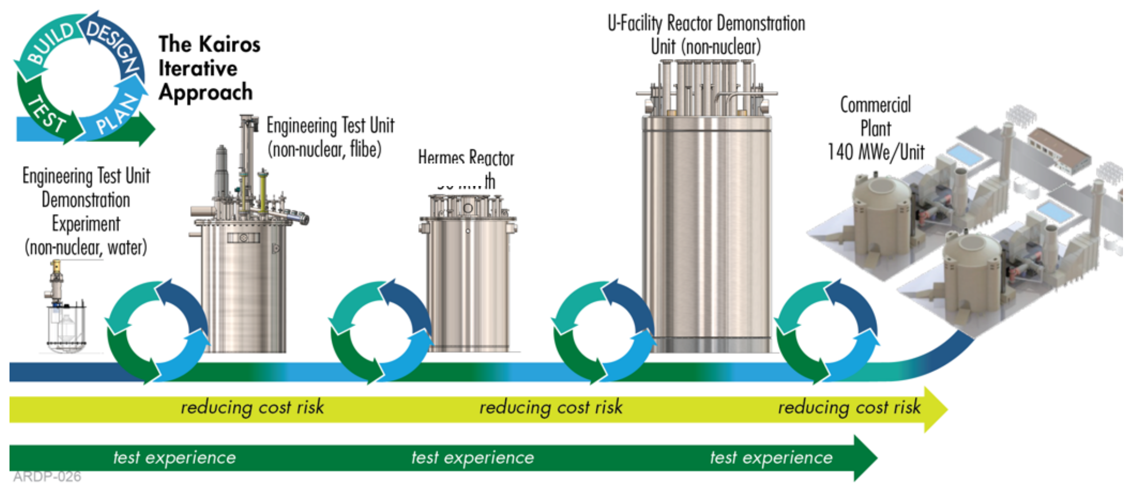
Cooperative Development Agreement
Development & Demonstration Collaboration for Hermes

DOE Advanced Reactor Demonstration Program (ARDP)
Risk Reduction Award

Kairos Power Design Approach for **Hermes Demonstration** Reactor

- **Robust Inherent Safety**
  - Uniquely large ***fuel temperature margins***
  - Retention of fission products in primary coolant
  - Low-pressure system
  - Effective passive decay heat removal
- **Lower Capital Costs**
  - Reduce requirements for high-cost, nuclear-grade components and ***structures*** through FHR intrinsic safety and plant architecture
  - Leverage conventional materials, existing industrial equipment, and conventional fabrication and construction methods





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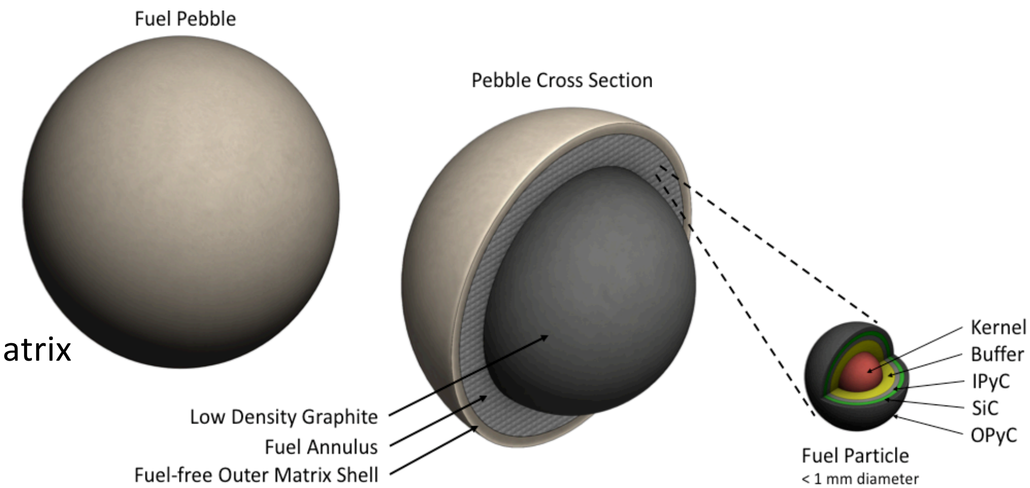
KP-FHR Uses TRISO Fuel in Pebble Form

- Core design is a pebble bed concept within a graphite reflector
  - Pebbles are positively buoyant in Flibe
  - Mixture of fuel and moderator pebbles operates with optimal moderation
- Fuel particles:
  - Tri-structural isotropic (TRISO)-coated fuel particles embedded in a partially graphitized matrix
  - Baseline fuel uses AGR coated particle design
- Pebble handling system monitors condition and burnup
  - Fuel reaches full depletion in 1.4 effective full power years
  - Rapid depletion reduces total fuel inventory and enables accelerated development of advanced fuel designs



4.0-cm diameter, annular fuel pebble is the same size as a ping-pong ball

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Purpose of Fuel Performance Methodology Topical Report

- The methodology is used to determine the probability of TRISO fuel particle failure and fission product release to support the KP-FHR source term basis
- The methodology is limited to validation of representative conditions for the KP-FHR
- Kairos Power is requesting NRC review and approval to:
  - Use the KP-BISON fuel performance analysis methodology and uncertainty quantification methodology for conducting fuel performance analysis for a KP-FHR to support the KP-FHR safety analysis.

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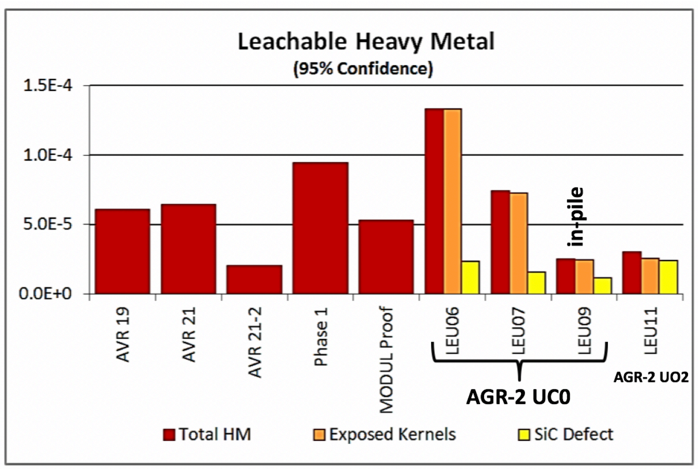
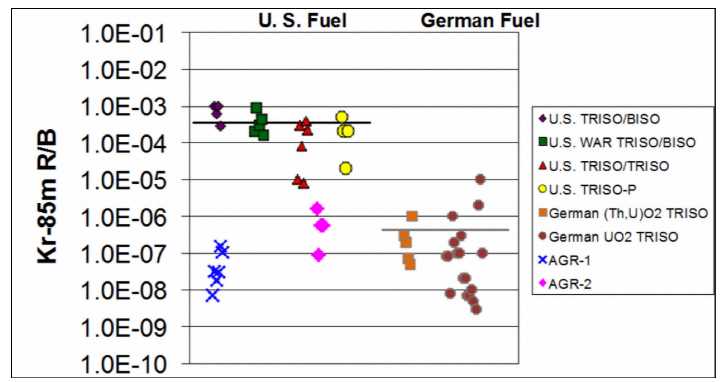
Fuel Performance Methodology

- Fuel performance is the ability of nuclear fuel to sustain irradiation damage while retaining the integrity of the fuel's physical barriers to fission product release.
- KP-BISON is an analytical model, based on the INL BISON code, that uses constitutive equations and analytical relationships developed from experimental data to assess the probability of failure for the particle coating layers, and the potential release of fission products.
- KP-BISON is used to predict the performance behavior of TRISO fuel under KP-FHR normal operating conditions and postulated events.
- The Kairos' fuel performance methodology is based on the KP-FHR fuel design and includes a consideration of fuel performance uncertainties to calculate probability of failure and fission product release to inform the fuel contribution to the source term.

AGR Irradiation Data Informs Fuel Performance Model

- KP-BISON is validated through use of historical irradiation data, especially from the AGR-1 and AGR-2 manufacturing and irradiation campaigns and topical report from EPRI.
- Model development received a **DOE iFOA licensing award** in 2019 to accelerate the KP-BISON licensing pathway through the DOE NEAMS program in collaboration with INL and LANL





D.A. Petti et al., *A Summary of the Results from the DOE Advanced Gas Reactor (AGR) Fuel Development and Qualification Program*, INL/EXT-16-40784

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