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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

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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FRIDAY

FEBRUARY 21, 2020

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2D10, 11545 Rockville Pike, at 8:30 a.m., David Petti, Chair, presiding.

COMMITTEE MEMBERS:

DAVID PETTI, Chair

RONALD G. BALLINGER, Member

DENNIS BLEY, Member

CHARLES H. BROWN, JR., Member

VESNA B. DIMITRIJEVIC, Member

WALTER L. KIRCHNER, Member

JOSE MARCH-LEUBA, Member

JOY L. REMPE, Member

PETER RICCARDELLA, Member

MATTHEW W. SUNSERI, Member

ACRS CONSULTANTS:

MICHAEL L. CORRADINI

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

WEIDONG WANG

C-O-N-T-E-N-T-S

P-R-O-C-E-E-D-I-N-G-S

(8:00 a.m.)

MEMBER PETTI: This is a meeting of the Kairos Power Licensing Subcommittee of the Advisory Committee on Reactor Safeguards.

I'm David Petti, chairman of today's subcommittee meeting.

ACRS members in attendance are Vesna Dimitrijevic, Walt Kirchner, Ron Ballinger, Pete Riccardella, Matt Sunseri, Joy Rempe, Jose March-Leuba, and we expect Dennis and Charlie Brown later.

We have consultants, Mike Corradini and Steve Schultz, and Weidong Wang of the ACRS staff as the designated federal official for this meeting.

During today's meeting, the subcommittee will receive a presentation on the design overview of the Kairos Power fluoride salt-cooled high temperature reactor, a new generation for a nuclear reactor, and review two Kairos topical reports on the scaling methodology for the Kairos Power Testing Program, and the reactor coolant for the Kairos power reactor.

The subcommittee will have presentations by and hold discussions with the staff, the Kairos power representatives, and other interested persons.

The rules for participation in all ACRS

meetings, including today's, were announced in the Federal Register on June 13, 2019.

The ACRS section of the U.S. NRC public website provides our charter, our bylaws, agendas, letter reports, and full transcripts of all full and subcommittee meetings, including the slides that will be presented today.

The meeting notice and agenda for this meeting were posted there. We've received no written statements or request to make an oral statement from the public.

The first part of today's meeting is open to public attendance.

The second part of the meeting will be closed in order to discuss information that's proprietary to the licensee and its contractors, pursuant to 5 U.S.C. 552BC4.

Attendance at these portions of the meeting that deal with such information will be limited to the NRC staff, and those individuals and organizations who have entered into an appropriate confidentiality agreement with them.

Consequently, we will need to confirm that we have only eligible observers and participants in the room for the closed portions of the meeting.

The subcommittee will gather information, analyze the relevant issues and facts, and formulate proposed positions and actions as appropriate by deliberation by the full committee.

The rules for participation in today's meeting have been announced in the Federal Register. There's a transcript of the meeting being kept, and again, will be made available.

Therefore, we request that participants in the meeting use the microphones located throughout the meeting room when speaking.

Press on it until you get the green button light to go on so that the transcribe can hear.

Participants should first identify themselves and speak with sufficient clarity and volume so that they may be heard.

We will now proceed with the meeting, and I'd like to start by calling on the NRR staff to introduce our guests.

DR. CORRADINI: Brian, do you want to?

MR. SMITH: Good morning, my name is Brian Smith, I'm the deputy director of the Division of Advanced Reactors and Non-Power Production and Utilization Facilities. It's a long title.

We cover a lot. Not only advanced

reactors, but also for the research reactors, as well as the moly-99 production facilities, so a broad scope.

My staff and I are very pleased to be here today to meet with you to talk about our review of these two topical reports. We look forward to whatever questions you may have, and any feedback you have on our review.

We've been interacting with you over the last several years on advanced online water reactor issues, primarily guidance development, so we see this meeting as a milestone of sorts. No longer talking about guidance, but talking about specific topical reports submitted by a reactor developer.

So milestones, kind of big day. I want to thank Kairos in advance for the overview they're going to do of their design.

I looked through the slides. It looks like it'll be very beneficial to the ACRS, and the staff, as well.

We want to thank the ACRS for assigning Dr. Petti as the lead for this Kairos review. We look forward to interacting with him and the rest of the ACRS on future reviews of topical reports submitted by Kairos, as well as any future applications that may

reference the Kairos design.

In performing these reviews, we used staff from both NRR, as well as the Office of Research, and I want to thank them for their efforts in developing what I thought were high quality documents.

Finally, I want to note that the working relationship between the staff and Kairos was great, and that we were able to get through these reviews without having to issue any requests for additional information. So that's it for me. Thank you.

DR. CORRADINI: So can I --

MEMBER KIRCHNER: Yeah.

DR. CORRADINI: I'm sorry.

MEMBER KIRCHNER: Brian, I just want to ask a question. As you approached this review with Kairos or other potential applicants, are you now using as a point of reference the advanced reactor design criteria?

MR. SMITH: Yes.

MEMBER KIRCHNER: That's kind of your substitute for the GDCs, in terms of having some reference point to look at different aspects of the design?

MR. SMITH: Yes. We developed the --- obviously that document. I think we coordinated with

you guys on that. Recognizing that a lot of the GDC may not apply to some of these new designs.

In fact, Kairos has submitted a topical report to us that describes their proposed principle design criteria.

DR. CORRADINI: Within that context?

MR. SMITH: Yes sir.

DR. CORRADINI: So, does that also imply that the application will use the Licensing Modernization Program -- I don't know the right name for this thing, so I'm going to call it the short name, the LMP, in terms of the process?

MR. SMITH: Yes, there's actually another topical report that we have in house from Kairos that lays out their approach for utilizing the LMP.

MEMBER BLEY: Did I hear you right? You expect to not have a request for information?

MR. SMITH: For these two topical reports that we reviewed --

MEMBER BLEY: You had none?

MR. SMITH: We did not issue any.

MEMBER BLEY: What led to that?

MR. SMITH: The interactions that we had with their staff directly.

MEMBER BLEY: Okay, so you had meetings

essentially?

MR. SMITH: Yes, we did.

DR. CORRADINI: We had a couple other meetings earlier this week, emphasizing that it's good the staff has informal discussions ahead of time.

Is this part of the reason that you eliminated the need for RAIs, that you guys had enough up-front discussions, in terms of --

MR. SMITH: Yes.

DR. CORRADINI: Okay.

MEMBER MARCH-LEUBA: And that's a really good thing.

I mean, I've always been pushing for audits as opposed to RAIs, where you're having informal communications, and then you eventually document it somewhere.

A lesson learned from all the reactor we're reviewing now, and since you're in the process, that particularly reactor has then the SER, a lot of areas where all the or the existing regulations don't apply to me because all the safety features I have that make my reactor more safe, which is great.

But they tend to forget what are the special characteristics of my reactor that make it less safe?

And they don't really focus on that, and they don't have a table on -- at least it says none. They really didn't focus on the special characteristics of the reactor.

And this is something I'm just giving you notice, like are you start sending description or anything, I want to be looking for what's missing, and I'm hoping that you have, too. Okay?

MR. SMITH: Okay.

MEMBER MARCH-LEUBA: Because I mean, honestly, if you look at it from that lens, you will see a lot of that doesn't apply to me, that doesn't apply to me, that doesn't apply to me, and nowhere they say ah, but this should apply to me and you never thought of it.

MR. SMITH: Right. For these new advanced non-light water reactor designs --

MEMBER MARCH-LEUBA: It clearly --

MR. SMITH: There's a lot of requirements in Part 50 that are specific to light water reactor designs, so there will be a good number of exemptions, we expect, from if not, probably all of that.

MEMBER MARCH-LEUBA: But I would expect that just one or two requests to add requirements because of the special characteristics of my reactor,

right?

MR. SMITH: Sure.

MEMBER MARCH-LEUBA: So at least a good condition of why there wasn't any.

DR. CORRADINI: Can I just follow up? You said something that maybe I should have assumed. Is the applicant in a process of defining they're going with a Part 50 versus a Part 52?

MR. HASTINGS: Yes, and we're going to talk about that.

DR. CORRADINI: Is this an appropriate -- later today?

MR. HASTINGS: Okay, fine.

MEMBER PETTI: All right. So, just one more thing before we get started.

Because you guys are trying to catch a flight later today -- many of you -- we were thinking of making lunch just 30 minutes.

Go downstairs, you can bring something back and eat here, but to try to compress that time to make sure you guys have a margin to catch your airplane. Okay.

DR. CORRADINI: All right. Thank you.

MEMBER PETTI: Yep, no problem.

DR. CORRADINI: Go ahead.

MR. HASTINGS: Good morning. I'm Peter Hastings, I'm the vice president of Regulatory Affairs and Quality for Kairos Power.

On behalf of our entire team, thanks to the subcommittee for the invitation to introduce Kairos, our plans for developing, deploying the fluoride salt-cooled high temperature reactor.

You'll see it referred to in these presentations as the KP-FHR. And our first two topical reports that are before you for review.

Joining me today are our chief technology officer, Ed Blandford, our chief nuclear officer, Per Peterson.

They're cofounders of Kairos Power, along with our CEO, Mike Laufer, who was unable to join us this morning.

Also here are Darrell Gardner, our senior director of licensing, Alan Kruizenga, director of salt chemistry, and Nico Zweibaum, senior manager of the engineering testing, all of whom will be presenting later today.

And we're also joined by Drew Peebles, our manager of safety integration, and senior licensing engineers, John Price and Margaret Ellenson.

Next slide.

Kairos Power is a mission-driven company, and we begin every substantive interaction that we have with a reiteration of that mission, which is to enable the world's transition to clean energy, with the ultimate goal of dramatically improving people's quality of life while protecting the environment.

This is very important to us.

To put this meeting into context of that mission, NRC approval of our design is a key component of meeting the mission, and the ACRS participation in that process is obviously an important aspect of the approval.

Next slide.

This morning's public session will consist of a relatively brief overview of our design and development efforts, an overview of our two topical reports, scale and methodology, and reactor coolant, salt.

This portion is scheduled for about an hour.

We may try to accelerate that in the interest of getting to the more meaty parts of the presentation.

Then we'll go into closed session and drill down the proprietary details on each of these

topics.

Next slide. Our design is a hybrid that borrows attributes from other designs.

We use remarkably robust coated particle TRISO fuel -- it's historically used in gas reactors -- demonstrated to withstand extreme temperatures that are well beyond the threshold of current nuclear fuels.

Unlike gas reactors, we use molten salt coolant with a very high potential for absorbing and retaining radionuclides.

Our coolant is also chemically inert and not reactive with water or air.

We combine these attributes with a low pressure primary system into a design with substantial safety margins, which enables us to think differently about the size of our safety footprint.

Because cost of new nuclear builds is one of the primary barriers to deployment, the small safety footprint supports aggressive cost targets that allows us to think seriously about competing with natural gas, which is our primary initial market in the United States.

Cautionary tale about the design details you'll see here, they're intended to provide context

for the review of the topical reports.

The design is currently in the conceptual phase, and so a lot will change over the course of the next several months, but this is sort of a snapshot in time of where we are.

Next slide.

Kairos Power is a privately funded company focused on the commercialization of the FHR.

We were founded in 2016, emerging from a UC Berkeley concept that was part of a DOE sponsored integrative research project.

We're based in the San Francisco Bay Area, and have doubled our staff in the past couple of years to about 120 full-time staff currently.

As I mentioned, our primary market is U.S. electricity, with an expectation to deploy broadly in the 2030s, or sooner.

We're pursuing our mission by way of a determined and intentional approach to designing a reactor with a combination of remarkable safety margins and economic performance that enables direct competition with natural gas.

Next slide.

MEMBER MARCH-LEUBA: Well, you mentioned that -- you said U.S. energy. Have you been affected

at all by tariffs and export control? Do you have any partners outside the U.S.?

MR. HASTINGS: We're not affected by that at this time.

MEMBER MARCH-LEUBA: Okay.

MR. HASTINGS: We'll turn now to a very high-level overview of the design and development of the KP-FHR.

Next slide.

As I mentioned earlier, our primary initial target is competition with natural gas.

Competing with gas requires that we think differently, and cost of the plant is an important aspect of our deployment plan.

We expect to take advantage of the FHR's robust inherent safety resulting from large temperature margins in the fuel, the large retention capacity of FliBe coolant for fission products, the lack of a high pressure primary system, and passive decay heat removal, which eliminates the need for safety-related power.

All combine to reduce capital cost and enable broader use of conventional components, conventional materials, and fabrication and construction techniques, in lieu of higher cost

nuclear-grade versions.

Next slide.

Our baseline licensing strategy for our first deployment includes substantial pre-application engagement, which Brian mentioned we've been very active with the NRC staff in the last little over a year.

Followed by a two-step Part 50 construction permit and operating license.

In pre-application space, we've been highly engaged with the staff with submittal of several topical reports, the first two of which are before you today, and the balance of which are all about questions you asked.

Our principle design criteria, a regulatory gap analysis, and so forth.

During the pre-application phase, we also plan to submit a preliminary safety information document, or PSID, which is a platform that's been used a handful of times in the past for substantive non-topical pre-app review.

The PSID will look somewhat like an early application, and will result in a preliminary non-binding review by the staff in a preliminary safety evaluation.

This vehicle's intended to provide early feedback on key technical issues, not dissimilar from the Canadian Vendor Design Review, but with additional flexibility in terms of content.

DR. CORRADINI: Has --

MR. HASTINGS: Mm-hmm?

DR. CORRADINI: Not to slow you down much. What's an example most recently the NRC has had this, and has exercised this so they're aware of how to respond?

MR. HASTINGS: It has been some time. There was one for the MHTGR, there was one for PRISM, and there was a third one that I always forget.

DR. CORRADINI: So we're talking the '80s?

MR. HASTINGS: Yeah.

PARTICIPANT: Eighties, yes.

DR. CORRADINI: Okay, well the only reason I ask is personally, this is a very logical approach, but I'm just making sure the staff is aware and ready for your first blue box.

MR. HASTINGS: They are. We've discussed it.

You may recall a couple of years ago, there was a lot of discussion about the development of a VDR-type process by the staff.

(Simultaneous speaking.)

DR. CORRADINI: I remember you were here talking about it.

MR. HASTINGS: And the staff were off to develop such a program, and we sort of collectively all came to the conclusion at about the same time that if we use the PSID format, it really provided everything we needed with actually more flexibility than the VDR process because it has a very fixed format around 19 topics.

The PSID can sort of be whatever you want it to be.

DR. CORRADINI: Okay.

MR. HASTINGS: And so, we're working with the staff now to narrow down what the topics are going to be --

DR. CORRADINI: Within it?

MR. HASTINGS: Within the PSID.

MEMBER BLEY: Okay. And you said it's a non-binding document?

MR. HASTINGS: Correct. So --

MEMBER BLEY: But it means you get some advanced review, but if what comes out next isn't the same, you might be starting over?

MR. HASTINGS: Exactly.

MEMBER BLEY: Okay.

DR. CORRADINI: Yeah, but to follow up Dennis' question, I assume the whole purpose of this is to identify things that are issues early and --

MR. HASTINGS: To address them. It's all about de-risking the programmatic portion of the process.

MEMBER REMPE: Do you have a schedule in mind of how long you'll take for the pre-application phase versus the construction permit application?

MR. HASTINGS: We do. That schedule is a work in progress.

Our current plan is for a PSID early 2021, with a CPA a couple of years after that. Those numbers are moving around a bit, frankly.

MEMBER REMPE: Thanks.

DR. CORRADINI: Okay. Thank you.

MEMBER BROWN: Non-binding doesn't necessarily mean you all might make changes, but NRC, even though they provide feedback, they could change their minds --

MR. HASTINGS: It's --

MEMBER BROWN: Based on a subsequent thing, that oh, we've thought about this some more.

So I mean, it's a two-way street when it

comes to non-binding? I just wanted to make sure I understood that.

MR. HASTINGS: Right. Yeah, that's correct.

MEMBER BROWN: Since I haven't seen one of these.

MR. HASTINGS: Yeah. And we understand that risk, but it is all about de-risking the program.

MEMBER BROWN: No, no objection to the ---

(Simultaneous speaking.)

MR. HASTINGS: So the more we can get, the better, obviously then.

MEMBER BROWN: Okay, thank you.

MEMBER KIRCHNER: Could I ask a question of the staff just to -- a little quick digression. What would you do if you get a PSID?

Would you do what was done in the '80s and do like a preliminary SER kind of document? And then how would you review that?

MEMBER BLEY: I seem to remember they did a new reg as that part was done.

(Simultaneous speaking.)

MEMBER KIRCHNER: Yeah, but I was --

MR. MAGRUDER: Right, yeah. This is Stu Magruder, I'm the lead project manager in NRR for the

project.

And what we're planning to do is similar to what we did for PRISM and MHTGR is to write what we call a draft or preliminary safety evaluation report.

It would be published.

We would hope to brief you and get a letter from the ACRS on that before we issued it, but as Dr. Brian said, this would be all based on preliminary information.

It's not a final answer, but it would serve to kind of identify if there are any showstoppers or significant issues that Kairos would need to pursue in different areas.

MEMBER MARCH-LEUBA: But the topical reports each will have a safety evaluation report with it, and those are binding, right?

Once you issue the SER, they can use it.

MR. MAGRUDER: Yes. We'll talk about that obviously later today, but you're absolutely right. There's more regulatory certainty with topical report SERs and --

(Simultaneous speaking.)

MEMBER MARCH-LEUBA: It has more --

MR. MAGRUDER: So this is all part of their plan.

MEMBER MARCH-LEUBA: It has more value in a sense. I mean, it's final.

MR. MAGRUDER: Yes.

MEMBER MARCH-LEUBA: And once the position --

(Simultaneous speaking.)

MR. MAGRUDER: Although, there are, of course, as you'll see, there are limitations and conditions in our SERs --

(Simultaneous speaking.)

MEMBER MARCH-LEUBA: Which are actually --- are also final. Right?

(Simultaneous speaking.)

MEMBER BROWN: How does that affect the non-binding nature of the PSID if there's topical reports that have a formal locked-in SER?

DR. CORRADINI: I guess it would be similar to other examples, which is they've committed to doing it a certain way within the limitation and conditions, and that's holes, however the design moves around.

MEMBER MARCH-LEUBA: Unless they want to change --

MEMBER BROWN: I'm saying just yeah, the non-binding nature is a little bit -- it's not totally

non-binding if you have a topical report SER.

MR. HASTINGS: Right, so it's a continuum, right? From a PSID to a topical to another application.

(Simultaneous speaking.)

MEMBER BROWN: That's fine, I just wanted to --- it's another thing that got thrown into the hopper.

MEMBER MARCH-LEUBA: They always have the possibility of issuing Revision 1 of the topical report.

MEMBER BROWN: Yeah, I got it.

MEMBER BLEY: Or issue a technical report that adapts that one --

DR. SCHULTZ: And the limitations and conditions will be very important for both parties.

MR. HASTINGS: All true. And if there's a topic that rises to the level of a topical report in terms of maturity and readiness to receive a formal review, you wouldn't see much discussion of that in the PSID, other than pointing to it.

MEMBER MARCH-LEUBA: Given the fact that this is new technology for some of us, I mean, we are too young to remember molten salt reactors --

MR. HASTINGS: Speak for yourself.

PARTICIPANT: No, we're not.

MEMBER BLEY: We have a couple people of that sort.

MR. HASTINGS: Speak for yourself.

MEMBER MARCH-LEUBA: Yeah, well I was making a joke.

The methodology of topical reports, how you analyze it and what correlations, you use and everything. I assume you're waiting for the results from the experiments to finalize those. Is that correct, or are you working already on those?

MR. HASTINGS: Both. So many of our topicals are in two phases where the initial topical is methodological or phenomenological, and the revision later would be with supporting qualified data.

MEMBER MARCH-LEUBA: So you're moving ahead and doing Part A, and then just leaving the appendices to be done?

MR. HASTINGS: In many cases, that's correct.

MEMBER MARCH-LEUBA: That's good, because for other reactors, which shall not be named, we're reviewing methodology now after this here has been issued. So, that's not desirable. You're doing much

better. Thank you.

MR. MAGRUDER: Let me just add one more thing. Brian reminded me that I should point out that with regard to issue finality or kind of staff's conclusions, this is different from Part 52, where you have a design certification document and the staff is actually bound by what we write in our SE for that. This is under Part 50 space, there's no issue finality for these types of issues.

I mean, obviously when we issue an operating license eventually, there will be, but up to that point, there's no issue finality like there is in Part 52.

MEMBER REMPE: So, your comment about well, yeah, maybe there's more finality, but we've got some limitations and conditions that might come into play.

And when I was looking through your SERs, there are some interesting limitations and conditions regarding -- like, because this is new -- well, it's not new technology, but we've not been using it for a lot of years -- if you see something different, we may have some additional changes.

And have you ever done that in a topical report review before, or in recent years?

Because I thought in some ways it's like a get out of jail free card that you've put in, there's a limitation and condition. Have you done that before? Because I don't recall something as different as that in past reviews.

MR. MAGRUDER: So, I'll let the technical reviewers talk specifically about that, but I think these topicals did present some challenges because there were so many new features and so many things that we're waiting on.

MEMBER REMPE: Right.

MR. MAGRUDER: And so, there was a lot of good discussion among the staff about how to write it.

MEMBER REMPE: But you have examples where you've done that in -- I hadn't seen that before, and it's a little -- I mean, maybe back in the MHTGR and PRISM days, they did that too, but I didn't recall it.

MR. MAGRUDER: I don't know of any specific examples, but we can talk more later about that.

MEMBER PETTI: Certainly in the MHTGR days, there were a long list of things that drove that program for the next decade.

MEMBER REMPE: But this one, it's just like, eh, if you see some new phenomena, we answer

questions.

I mean, they had specific items of where they were looking into.

MEMBER PETTI: Right. Well, because the technologies were a little more mature.

MEMBER REMPE: Right.

MEMBER PETTI: Right. Keep on going.

MR. HASTINGS: All right, next slide.

The goals of a licensing strategy are straightforward.

The chairman has said in several public forums that if we can't find a way to take advantage of increased safety in advanced designs, we all will have failed, and we certainly agree with that.

Kairos' intents to take advantage of the significant safety margins of the FHR design, not only to compete with natural gas as a way to accomplish our mission of enabling the world's transition to clean energy, but also to achieve the enabling goals that you see here.

First, to get early acceptance of the FHR safety case in order to retire programmatic risk as early as possible, which is most of what we've been talking about already this morning.

Second, to minimize the safety footprint,

enabling both economic competitiveness and true focus on safety significant aspects of the plan.

And third, to build flexibility into the process invigorating the design so that every tweak in the design going forward doesn't constitute another significance licensing action, to the extent we can achieve that.

So with that, I'll turn things over to Dr. Ed Blandford, who will discuss Kairos' testing and development overview.

DR. CORRADINI: Ah, there we go.

DR. BLANDFORD: Excellent, good morning. Thank you. As Peter mentioned, my name is Ed Blandford. I am the cofounder and chief technology officer of Kairos Power. I'm going to provide a quick overview of our testing and development program.

Next slide.

So, this slide we present in a number of public forums. It pretty much encapsulates everything that we do at Kairos.

At the top, it outlines what we would consider a conventional development cycle, where we have a plan, design, build, test sequence.

And I think many people would agree one of the challenges in the civilian nuclear community is

really trying to break down the cycles and really accelerate development.

But Kairos' focus is really on the bottom part of that slide that shows how we go through that process through an iterative development effort, and so this really encapsulates a lot of the activities that we're doing today.

Peter had talked through our licensing approach.

That's an example of that sort of iterative, putting the early topical reports in front of the staff, and walking through our technology.

So this really encapsulates a lot of our development program.

Next slide.

We recognize the importance of demonstrating our technology.

This is a very, very big part of our DNA, it's a very big part of who we are and what we're focused on.

We recognize that this is a new technology, but it's an area that we see a lot of opportunities.

We also recognize that there's a need for testing facilities to support our development program.

So in this slide, it shows the progression of a series of test facilities that Kairos is currently invested in.

It's already stood up, or is in the process of standing up.

And it really starts with the first two letters. It's a little bit of a QRSTU.

It starts with what we call our Rapid Lab, which is a rapid analysis prototype and iterative design lab.

This is located in our headquarters in Alameda.

It's a part of our facility where we're able to iterate quickly, so we use rapid prototyping technologies to produce components, iterate the surrogate fluids, and really inform elements of the design that are important.

It allows us to move quickly.

In parallel, we understand the importance of working at the high temperature and working with the prototypical fluids, and so we also have what we call our Salt Lab, which is a facility that we're standing up in our Alameda lab.

We're about, I think, two weeks away from actually operating our first salt experiment utilizing

the beryllium salts. Slide. In parallel, we also have what's called our Testing Facility or our T-Facility.

This is actually a location that we're about to open up in the state of New Mexico, in Albuquerque, and this is an area where we plan on doing larger scale qualification testing.

And so, we're very hard at work trying to stand up that facility and those capabilities.

DR. CORRADINI: If this is an appropriate time to ask, where's that in New Mexico within the laboratory structure?

DR. BLANDFORD: It's in Albuquerque.

DR. CORRADINI: Okay, but --

DR. BLANDFORD: So it's a private facility, so there's been a little bit of press, so it's in the public domain.

DR. CORRADINI: Okay, fine.

DR. BLANDFORD: But it's at -- it's called the Mesa Del Sol development site.

DR. CORRADINI: Okay, thank you.

DR. BLANDFORD: And then lastly, there's a user facility, and this is an area where we would anticipate training end users in terms of operations and maintenance.

That's the one facility that we're working towards today that doesn't physically exist right now.

Next slide.

MEMBER KIRCHNER: Before you go on?

DR. BLANDFORD: Uh-huh?

MEMBER KIRCHNER: So, your slide says non-nuclear.

DR. BLANDFORD: Correct.

MEMBER KIRCHNER: So, have you a shortlist or development and test plan for those aspects that actually have a nuclear component?

DR. BLANDFORD: Good question. So, we've committed to both a nuclear and a non-nuclear test program, and we'll get into a little bit more of the details later on today.

It's difficult for us to go in those nuclear facilities today, and so we believe a combination of our nuclear testing, where we leverage a lot of the DOE complex to deal with radiations and do the type of work that we need to do compliments the non-nuclear test program. So it's a combination of both.

MEMBER MARCH-LEUBA: Can you speak up louder? They cannot hear you.

DR. BLANDFORD: Oh, I'm sorry.

MEMBER MARCH-LEUBA: Can we ask them to increase the volume?

DR. CORRADINI: Yeah, that might be a crappy microphone. Try the one next to you.

(Simultaneous speaking.)

DR. BLANDFORD: All right. Is this better?

DR. CORRADINI: Yes.

DR. BLANDFORD: Okay. Sorry, apologies.

DR. CORRADINI: Just get closer to Peter. You're colleagues. However much you feel like you have to.

MEMBER REMPE: What about the fuel fabrication capability, because it's not exactly what we've seen even in our national communities.

There's some differences in the fuel, and where will that be made?

DR. BLANDFORD: That's a good question. I believe we're going to be submitting our fuel qualification topical report.

I'm not sure the exact schedule for when we're submitting that, but that'll be a time for us to really jump into the details of that.

So right now, some of that information is actually proprietary, so.

DR. SCHULTZ: Yeah, excuse me, the operations and training, the user facility, how is that -- are you going to talk about that today? Conceptually, it sounds like a great idea.

DR. BLANDFORD: Sure.

DR. SCHULTZ: But, how far have you gone with identifying the details of that?

DR. BLANDFORD: The details of it we don't have fully fleshed out yet.

Conceptually, I can speak we're at a high level.

So it's basically a full scale version of the primary side of the plant, and it's an opportunity for us to train operators with the real equipment, from the whole spectrum of effectively inservice inspections, component replacements, and getting familiar with the technology.

The concept is at a high level.

DR. SCHULTZ: Great idea, thank you.

MEMBER MARCH-LEUBA: And are you thinking of a single module in a remote location, or are you thinking of a multi-module with a single control room and 25 units?

DR. BLANDFORD: I think that's to be determined, and it's an area that we'll check --

(Simultaneous speaking.)

MEMBER MARCH-LEUBA: But you're staying open -- that would affect a lot of the training and the design of the control room obviously.

DR. BLANDFORD: Sure. And just to clarify, the U-Facility and concept goes well beyond control room, you know, training simulator.

This was really working on the hardware, so that would be a singular module that we would be looking at.

DR. CORRADINI: Ah, thanks. This might be for the closed session.

So from the standpoint of using this, I'll call it challenging coolant, which has its own chemical safety issues, where is there experience in the United States of this in the past?

DR. BLANDFORD: So, and this is something that we can probably talk about in private session.

DR. CORRADINI: Okay, then we can wait. Okay, fine.

DR. BLANDFORD: But we recognize that, and it's important to have the right partnerships and work with the right people that have the prior experiences.

DR. CORRADINI: Okay, fine.

MEMBER BLEY: You mentioned the training.

Do you have people on the staff as you work in that area who have actual operating experience?

DR. BLANDFORD: We do.

MEMBER BLEY: You know, engineers think they're best at this, but they often get surprised.

PARTICIPANT: Very much so.

DR. BLANDFORD: I would be remiss to that. So, our vice president of engineering, Mark Peres, was a former operator at FFTF.

We do have people on staff that do have operational experience, and that's very valuable for us. So I'm going to go ahead and pass this off to Dr. Nico Zweibaum.

DR. ZWEIBAUM: Good morning, everyone. Is this mic better? Okay. Very good.

As Ed said, my name is Nico Zweibaum. I am the senior manager of engineering testing at Kairos Power, and I was also one of the preparers for scaling methodology topical report, which I'm going to give a brief overview of right now.

Next slide, please.

So, what was the purpose of that topical report? We are describing the methodology we intend to use to scale both integral effects tests, referred to as IETs, and separate effects tests, or SETs, that

will support the KP-FHR evaluation model assessment base.

The report goes through the justification for the use of surrogate fluids that enable direct and comprehensive local measurements of the phenomena that are under investigation, and the use of surrogate fluids is due to their higher compatibility for high accuracy instrumentation that is readily available, for instance, to measure temperature and flow velocities.

The intent of that report was to communicate and request the NRC review and approval to use our scaling methodology with surrogate fluids described in the report, namely, heat transfer oils and water for testing, including in the assessment base of evaluation models that support our safety analysis.

Next.

So what is the scope of that report? First off, we are basing our scaling methodology on the well-known hierarchy called two-tiered scaling methodology, or H2TS.

This generic scaling methodology was previously developed for and approved by the NRC. We selected it for scaling of our thermal fluids, IETs

and SETs, and the methodology includes quantification of distortions in the scaling.

The report addresses scaling of our primary heat transport system, thermal fluids, IETs for the KP-FHR plant at normal operating conditions with forced flow, as well as transients that involve natural circulation.

And it describes the use of specific classes of heat transfer oils that are deemed acceptable surrogate fluids for these integral effects tests.

In addition, the report also addresses scaling of specific phenomena in component level separate effects tests that would also use a specific class of heat transfer oil or water as acceptable surrogate fluids.

The figure to the right is mainly provided for illustration, but is from the NRC's Regulatory Guide 1.203 on evaluation methods, development, and assessment process.

And I apologize for the very small font, but the element 2 of that process includes scaling efforts and identification of integral effects tests and separate effects tests that are supposed to support our safety analysis methodology, and this is

really what that scaling report is about, is addressing those parts of element 2 of the EMDAP process.

DR. CORRADINI: This makes perfect sense. The one thing though about your two surrogates are that they don't freeze and they don't get gooey.

So, is it your job to worry about that, or the next person down the line's job to worry about that?

DR. ZWEIBAUM: Well, so the report really addresses what happens outside of that range.

DR. CORRADINI: Okay.

DR. ZWEIBAUM: It --

DR. CORRADINI: Okay, that's fine.

DR. ZWEIBAUM: Yeah.

DR. CORRADINI: Okay.

MEMBER PETTI: So, I have a question just to help me understand. As I understand H2TS, I mean, it was really focused on the coolant, right, in the light water reactor, right?

So I've got a heat flux with a -- from the fuel rods that don't move that's static. Here, your fuel is moving.

This does not really apply to the movement of the fuel in the core. Is that a fair statement?

DR. ZWEIBAUM: So, our scaling approach does.

It is true that H2TS doesn't touch this specific topic, but the scaling that we've developed includes pebble movement in the coolant, and this will be one of the types of separate effects tests that we will talk about today.

MEMBER PETTI: Not heated?

DR. ZWEIBAUM: That is right.

The movement of the fuel in the core is largely decoupled from the heat transfer aspects because the fuel moves at a very slow pace in the core ---

(Simultaneous speaking.)

DR. CORRADINI: So it's basically just a density ---- it's just basically a buoyancy density?

MEMBER PETTI: Okay, did I misread something? I read that the pebbles are really cruising.

(Simultaneous speaking.)

MEMBER PETTI: Yes. We'll put that on the list when we get into the closed session.

DR. ZWEIBAUM: Sure.

MEMBER PETTI: Maybe I misread it, but I thought that the fluids were a lot more than, say, a

gas reactor pebble bed.

DR. ZWEIBAUM: Yeah, we can talk about that in the closed session.

MEMBER PETTI: Okay.

MEMBER KIRCHNER: But for the scaling purposes, you're just assuming the pebbles are static?

DR. ZWEIBAUM: As far as the heat transfer separate effects tests, that's right.

MEMBER REMPE: So, what about the fact that in the real reactor that there is nuclear heat coming out of the pebbles, or decay heat, if you're doing some sort of transient?

How do you simulate that, because I didn't see that in the scaling report.

DR. ZWEIBAUM: So that would be the heat source that we would have to scale, whatever the heat generation levels are.

So, the level of either full power or decay heat power would come from our neutronic simulations. Is that --

MEMBER REMPE: But you're looking at fluid flow, and it seems like that would be an effect on the fluid flow, and so you're separating that out?

DR. ZWEIBAUM: No, we are treating the heat source as a -- well, simulated heat source,

obviously, in our scale tests, but scaled from the heat generation that would happen from nuclear fission in the core.

MEMBER REMPE: So I guess I didn't see how you're going to heat them in the scale tests, and so when you get -- you can wait until the closed session, but I did not see how you were going to introduce that into the --

DR. ZWEIBAUM: Yeah, we can talk --

MEMBER REMPE: Whatever you're simulating.

DR. ZWEIBAUM: We can talk about it more in the closed session, but one thing to note is that this report is really about the methodology, and not necessarily about the engineering that would allow us to meet that methodology.

But, I'd be happy to talk about it a little bit more in the closed session.

MEMBER PETTI: Yeah, you see members jumping to the details, right, because this is kind of theoretical, and so.

DR. ZWEIBAUM: Sure. So, this is really the meat of our validation testing program right now.

We are using those scaling methods to support acceleration of our validation testing road map.

And we talked about the combination of separate effects tests and integral effects tests all use reduced scale in terms of size, power, temperature, surrogate fluids, and surrogate materials.

Both are under development in our Rapid Lab facility in Alameda that Dr. Blandford talked about.

We already have a number of separate effects tests that are up and running as of now.

For illustration here, you have pictures of a few of our fluid dynamics tests using room temperature water and 40 percent geometric scale, as well as heat transfer tests that use a surrogate heat transfer oil to 72 degrees Celsius matches the properties of our FliBe coolant at 600 C, also at reduced geometric scale.

And coming up towards the end of this year would be our first integral effects tests facility, which would be a half height roughly facility scaled to our primary heat transport system.

MEMBER MARCH-LEUBA: I'm curious. It's relatively easy to heat up a rod because you can connect from the top and the bottom.

How do you heat up your balls?

DR. ZWEIBAUM: I guess we can talk about that in the closed session.

(Simultaneous speaking.)

MEMBER REMPE: And keep them heated, is the question too.

DR. ZWEIBAUM: Huh?

MEMBER REMPE: And keep them heated. You could start with them hot, but yeah.

MEMBER MARCH-LEUBA: Okay, we'll talk in the closed session.

DR. ZWEIBAUM: Yes.

MEMBER MARCH-LEUBA: Obviously, you had some patents in that? You should.

DR. ZWEIBAUM: And so this combination of the separate effects test and integral effects test is really the basis for validation of our evaluation models, which would lead us to the KP-1 demonstration and reactor full scale FliBe coolant, and TRISO fuel pebbles.

Next, please. So first, about IETs.

At a high level, the scaling methodology we use, this is the analysis for using the surrogate fluid, mainly heat transfer oil, for the KP-FHR primary heat transport system.

The classes of licensing basis events that

are illustrated in the topical report include steady-state normal operation, which is forced circulation operation, as well as transients that involve the loss of force flow in a transition to natural circulation.

This would include pump trips, losses of heat sink, station blackouts, and so on.

The methodology in the report is illustrated using an idealized version of our primary heat transport system and scaled IET.

You have this very simplified schematic here that shows this configuration with the pebble bed reactor core, primary salt pump, hot leg piping going into an intermediate heat exchanger, then cold leg returning to the core.

Although this is a simplified model that's illustrated in the methodology, the methodology can be extrapolated to a number of different branches in several loops, as would be the case in the current KP-FHR design.

Next.

Also in the report is our scaling methodology for a number of separate effects tests.

These are used to develop closure models and correlations for phenomena that happen at the module or component level, and the topical report

covers generic fluid dynamics and heat transfer phenomena, as well as some KP-FHR design specific phenomena.

And those six types of phenomena are examples of what's covered in the report, namely forced circulation fluid dynamics, convective heat transfer, conjugate heat transfer with solid structures, twisted elliptical tube experiments, pebble bed granular flow dynamics experiments, and forced median impact bed heat transfer experiments that are relevant to our core.

MEMBER PETTI: Can I ask a question? You know, there's lots of literature out there for packed beds and correlations.

I mean, do you think that they'll end up working and you'll spend just a lot of time, you know, providing some data to show that for your situation, that they'll be one close from the chemical engineering industry?

DR. ZWEIBAUM: So the existing experience with those packed bed correlations don't directly apply to the ranges we're operating at.

Namely, the Prandtl number of our fluid is much higher than what's being reported in the literature for both gas-cooled reactors, obviously,

and also outside of the nuclear industry for other experiments.

So this is the reason why we need to run our own tests --

(Simultaneous speaking.)

MEMBER PETTI: Okay, so it's for the Prandtl number?

DR. ZWEIBAUM: To get out of that.

MEMBER PETTI: Great, thanks.

DR. CORRADINI: So, neither your first bullet in forced circulation fluid dynamics, nor your fifth bullet on, I'll call it pebble bed movement, have historical or past literature basis?

Do you guys have to do it from scratch? That's what I was gathering from Dave's question that you can rely on past --

(Simultaneous speaking.)

DR. ZWEIBAUM: So yeah, a lot of this is not breaking new ground. Obviously, for circulation fluid dynamics, it's a pretty well-known topic for several centuries.

The idea was really to compile all of this in our own methodology to make sure that the staff agrees that this is indeed the right approach in our case.

DR. CORRADINI: All right, thank you.

MEMBER RICCARDELLA: So, I assume that the primary purpose of these tests and scaling is the qualified computer codes that you're going to use to analyze it, right?

And then --

DR. ZWEIBAUM: Yes, this is the purpose of the EMDAP process.

MEMBER RICCARDELLA: And then if it works on the test, then presumably it works when you apply these codes to the reactor, right?

DR. ZWEIBAUM: That is right.

MEMBER MARCH-LEUBA: And have you considered the fact that we have so much margin on the fuel pellets that if you miss your heat risk coefficient by a factor of two, who cares? You just raise the temperature of the fuel and keep cranking.

DR. ZWEIBAUM: That is very beneficial to us, obviously, and you'll see in the --

MEMBER MARCH-LEUBA: And you probably would take advantage of that?

DR. ZWEIBAUM: Yes, we would be in the --

(Simultaneous speaking.)

MEMBER MARCH-LEUBA: Because that would be a hard sell, a very logical sell, and I will support

you in it, but it is going to be a hard sell.

Pressure drop, obviously you need to know, did you want to have amount of circulation, but not easy to measure. The heat risk coefficient you can have four or a factor of two and nothing happens.

DR. ZWEIBAUM: Okay.

MEMBER MARCH-LEUBA: Just put it in there. It's going to be a hard sell.

DR. KRUIZENGA: I'm Alan Kruizenga. I'm the director of salt chemistry at Kairos Power, and I'm the primary preparer of the reactor coolant topical report, and then we'll just go over just a couple of slides so you have a little bit of an idea of what we're looking at, and what the purpose of --

MEMBER MARCH-LEUBA: Alan, is that microphone working? Because you don't sound as good as me.

DR. KRUIZENGA: I mean you've got a really nice voice.

(Laughter.)

DR. CORRADINI: Move closer.

DR. KRUIZENGA: He sounds really good, so I -- how about now, is that better?

DR. CORRADINI: That's much better.

DR. KRUIZENGA: Okay, great, excellent.

All right, perfect.

So, as has been said already this morning, we're using FliBe as a coolant for our reactor.

There's a few reasons, and they've been covered a little bit already, but really it's the fact that it's a coolant that helps provide enhanced safety properties, it has a high boiling point, it has high thermal inertia, minimal short-term, long-term activation products in the salt itself.

And it's been optimized over time through use during the molten salt reactor experiment back in Oak Ridge.

The high density fluid has good heat capacity, again with that thermal inertia, pace, the viscosity is comparable to water in a factor of 5, and it's stable under radiation at high temperatures.

And then lastly, from a safety perspective, it's a good solvent for fission products. So that's one of the reasons it was viewed as favored.

MEMBER BLEY: How about worker safety?

DR. KRUIZENGA: That's a great question.

MEMBER BLEY: Thank you.

DR. KRUIZENGA: I mean I think you're more referring from a chemical perspective?

MEMBER BLEY: Yeah.

DR. KRUIZENGA: So certainly, we're aware of that.

That's something -- like, I have personally, along with many others in the company, have spent a lot of time trying to work with the right partners to develop good procedures and practices that are compliant, and keep our workers safe, so it's extremely important.

DR. CORRADINI: Alan, where is the industrial experience in the United States in terms of using beryllium compound fluids?

Because that's I think what Dennis is getting at.

MEMBER BLEY: Yeah.

DR. SCHULTZ: And developing safety programs --

DR. CORRADINI: And developing safety programs.

DR. SCHULTZ: Related to that.

DR. KRUIZENGA: So, as far as chemical processing -- so we could talk a little bit more in the closed section, but I'll give you just kind of a quick snippet.

Just even from the extraction, beryllium ore has to go through a series of aqueous processing

to get in a state that it can ultimately be made into beryllium metal.

So there is some precedent, at least in the chemical manufacturing industry, that beryllium is in a liquid state and has to be taken precautions appropriately for that.

I don't know if that's helpful, but there is some precedence, and this isn't at a high temperature, again, which is different for our application.

MEMBER KIRCHNER: This is in the category that Jose was mentioning. You know, full disclosure would say up front that beryllium is a hazard.

DR. KRUIZENGA: Beryllium is a chemical hazard.

MEMBER KIRCHNER: Then you're going to have to take counter measures or whatever to deal with it.

DR. KRUIZENGA: Yes.

MEMBER KIRCHNER: Because the industry by and large has shunned working with beryllium. I mean, other than in a metal form.

MEMBER BLEY: Well, even in a metal form. I mean --

MEMBER KIRCHNER: Even in a metal form.

MEMBER BLEY: In electronics it was used

a lot, but there are a lot of --

MEMBER KIRCHNER: I know one business that used a lot of beryllium.

MEMBER BLEY: Sick and dead people around, in my experience.

MEMBER MARCH-LEUBA: And ordinarily it is actually forbidden to even mention the name.

MEMBER PETTI: Does the flowing activate? I remember --

DR. KRUIZENGA: It does, but it's got a quite short half-life. I think it's less than a minute or so.

MEMBER PETTI: Yeah, so it's like sort of N16 in a water reactor sort of, right? Okay. So --

DR. CORRADINI: What activates it?

MEMBER PETTI: Flowing 19 I think, right?

DR. KRUIZENGA: I think so. I think that's right.

DR. CORRADINI: And it's about a minute and a half long?

DR. KRUIZENGA: Yeah, about a minute.

MEMBER RICCARDELLA: Okay. Would you briefly describe the process how it achieves a negative temperature coefficient?

DR. KRUIZENGA: Yeah, so the density

decreases as it goes up in temperature.

MEMBER MARCH-LEUBA: Yeah so, say again?

DR. KRUIZENGA: As you go up in temperature, the change in density reduces the moderation.

MEMBER RICCARDELLA: And it is a moderator? I thought the graphite was the moderator, no?

DR. KRUIZENGA: The graphite is the primary moderator.

MEMBER KIRCHNER: The graphite is the primary moderator.

DR. KRUIZENGA: Beryllium does have some moderation capability, though.

(Simultaneous speaking.)

MEMBER KIRCHNER: It becomes a second order effect on reactivity transients and such.

MEMBER RICCARDELLA: Okay.

DR. CORRADINI: Go ahead.

MEMBER MARCH-LEUBA: You can hear from the questions that everybody's going to complain about beryllium, so can you give us a short 30 second answer unclassified why you chose beryllium?

Is it for neutron efficiency, or is it for chemical viscosity, transparency? Is there a particular reason that you didn't use regular salt?

And just put it to rest so we keep asking you --

DR. KRUIZENGA: Yeah. So I have more information in the closed session, but --

MEMBER MARCH-LEUBA: Wait.

DR. KRUIZENGA: Okay, great.

MEMBER BLEY: Well, let me ask one other.

DR. KRUIZENGA: Sure.

MEMBER BLEY: I don't know the chemistry, but if you get water near the fluoride salt, can you get HF coming out?

DR. KRUIZENGA: You can get some trace amounts of HF.

MEMBER BLEY: Only trace amounts?

DR. KRUIZENGA: We haven't fully quantified --

(Simultaneous speaking.)

MEMBER BLEY: Now you keep the water away from it?

DR. KRUIZENGA: We do keep the water away from it, and we're aware of it, and that's part of our ongoing work.

MEMBER BLEY: Because that's pretty dangerous stuff too.

MEMBER MARCH-LEUBA: What's your

intermediate salt?

DR. KRUIZENGA: It's a nitrate salt, it's a solar salt.

(Simultaneous speaking.)

DR. KRUIZENGA: No.

MEMBER REMPE: You almost look like you're going to go to the next slide, and I know you didn't get to go through your bullets because we interrupted you, but before you leave this slide, I was interested in what data support the fission product retention claims, and how much it was.

And then I'm thinking back about with the MHTGR and NPR days, and it's not just fission products one might be wanting to be concerned about, but also if you have say stainless steel somewhere in your system, the chromium can migrate through it and attack the silicon carbide and the TRISO particles.

Have you considered those effects in your testing program?

DR. KRUIZENGA: We have, and we've considered it. We're aware of it.

MEMBER REMPE: Okay.

DR. KRUIZENGA: So it's come up during some of our like, internal PIRT processes. So, it's been identified, but we are aware of it.

MEMBER REMPE: Okay, so you'll need to have something to add extra protection on that.

MEMBER PETTI: I'd like to come back to this in the closed session to talk about some numbers and things.

MEMBER BLEY: You just caught my ear with something, your internal PIRT processes. Do you have an external PIRT process too?

Have you brought, you know, outside folks in to help you --

DR. KRUIZENGA: Well, we've --

MEMBER BLEY: Think about key issues.

DR. KRUIZENGA: So, can we defer that to the closed session?

MEMBER BLEY: Sure, absolutely.

DR. KRUIZENGA: We can give a lot more. Then we can give some more information about it.

So the purpose really of this coolant report is to establish a common basis specifically for the chemical specification we have for the fluid, and then the thermophysical properties that we're going to use as part of the safety analysis.

So, the scope again is the thermophysical properties of the fluid, the chemical specification, so that we're on a common basis for understanding as

we go through some of the future licensing work, what the properties are.

DR. CORRADINI: And as well as the allowable span that you can tolerate before things become unacceptable?

DR. KRUIZENGA: Right. Yeah, there are bars, so --

MEMBER BLEY: All of you have emphasized it earlier, and in your reports, you kind of treat the salt as an extra barrier against fission product release.

Are there any nuclear chemical affects that can change that ability to hang on to the fission products?

DR. KRUIZENGA: I think this would be maybe a good one to talk in the closed session, so.

MEMBER BLEY: Perfect.

MEMBER PETTI: So Alan, in terms of the specification, do you see this as an initial specification, and that it might evolve over time?

As you do some experiments, you might add -- I mean, there were just some things that weren't in there as limits that I could see, potentially in the future as you do testing and you become more knowledgeable, you might add more to the

specification?

DR. KRUIZENGA: I think that's our basis. We just need a place to start, and I think Joy kind of brought it up.

We're learning new things, so we expect that we'll manipulate as we have to.

MEMBER PETTI: Right.

DR. KRUIZENGA: That is it.

PARTICIPANT: Never show a slide like that.

(Laughter.)

DR. CORRADINI: Or you can just defer the questions to the closed session.

MEMBER BLEY: I guess it'll come up in the fuel qualification topical, but you're using a different TRISO or some different properties in your TRISO fuel than the stuff my colleague over here did years of testing on.

Will that be the time to talk about what that matters to us, and to you?

DR. KRUIZENGA: Yes.

MEMBER BLEY: Okay.

MEMBER PETTI: Okay. Well, I guess at this point in the agenda, we're a little ahead of schedule.

DR. CORRADINI: Weidong is checking --

MEMBER PETTI: Oh. We're a few minutes ahead of schedule, but it's time for public comments. Do we have anybody in the audience to make a comment?

DR. CORRADINI: Hold on.

MEMBER PETTI: And I assume the phone line's on?

DR. CORRADINI: Weidong is checking out.

MEMBER PETTI: Okay, Weidong's checking out.

DR. CORRADINI: You may want to just see if anybody's out there.

MEMBER PETTI: Yes. Anybody on the open line?

DR. CORRADINI: We're right on time.

PARTICIPANT: Yes, sir.

MEMBER PETTI: Any questions?

PARTICIPANT: Comments.

MEMBER PETTI: Comments? Sorry.

PARTICIPANT: No questions at this time. Thank you.

MEMBER PETTI: Thank you. We can take a small break. We'll be back here at 9:15. Okay? Great.

PARTICIPANT: No.

MEMBER MARCH-LEUBA: Those of us that

don't speak Greek fluently, what does Kairos mean? I do because I checked it out.

PARTICIPANT: Dave, you don't have to go to 9:15, you can accelerate it.

MEMBER PETTI: Oh okay. We'll just take five minutes, and then we'll go into closed session.

DR. BLANDFORD: Do you want me to answer his --

MEMBER PETTI: Yes, please go ahead and answer.

DR. BLANDFORD: Sure, so Kairos is an Ancient Greek term for the right or opportune moment, and so it ties into our business case about where we see the market going, so.

I've heard it can be pronounced Kairos, and true Greeks will say it that way, so.

DR. CORRADINI: Luckily you have no true Greeks on the group.

DR. BLANDFORD: Not right now, no.

PARTICIPANT: You have one at home.

DR. BLANDFORD: Yeah.

(Off-microphone comments.)

MEMBER PETTI: Yeah, a five minute break.

(Whereupon, the above-entitled matter went off the record at 8:58 a.m.)

Kairos Power

OVERVIEW OF KAIROS POWER, SCALING METHODOLOGY AND REACTOR COOLANT TOPICAL REPORTS

ACRS SUBCOMMITTEE MEETING, FEBRUARY 21, 2020

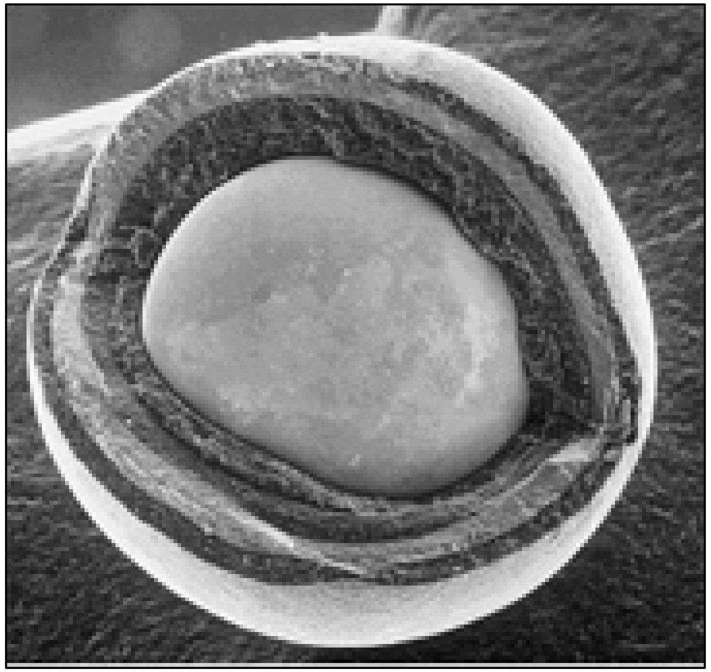
Kairos Power’s mission is to enable the world’s transition to clean energy, with the ultimate goal of dramatically improving people’s quality of life while protecting the environment.

Outline

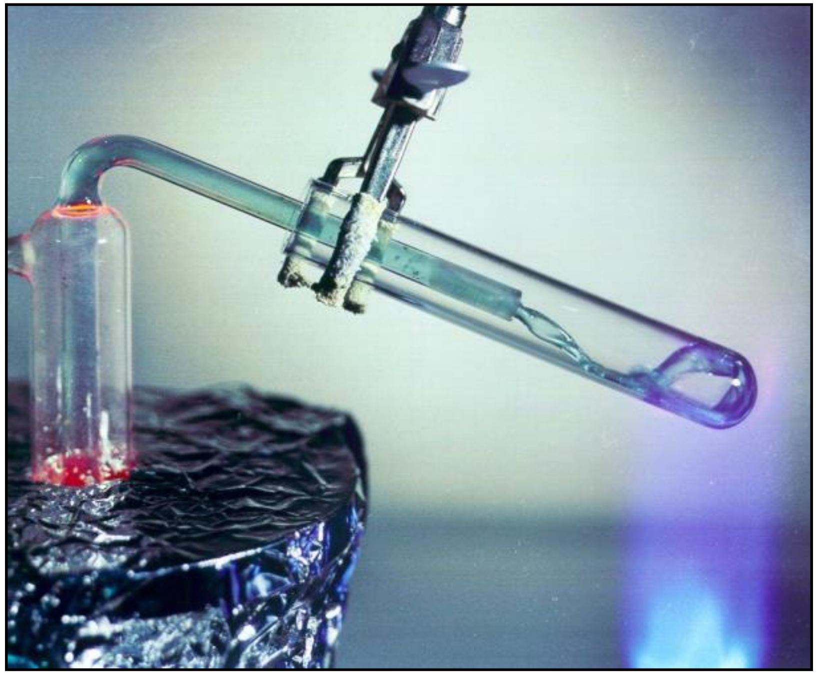
- Overview of Kairos Power and KP-FHR Design and Development
- Scaling Methodology Topical Report
- Reactor Coolant Topical Report

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

Coated Particle Fuel
TRISO



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



Overview of Kairos Power

- Privately funded nuclear energy engineering and design company focused on the ***commercialization*** of the fluoride salt-cooled high temperature reactor (FHR)
  - Founded in 2016
  - Based in San Francisco Bay Area
  - Builds on UC Berkeley Concept Development and R&D
  - ~120 full-time employees (***and growing***) selected from diverse industries
- Development schedule driven by US demonstration by 2030 (***or earlier***) and rapid deployment ramp in 2030s
- Leverages technology from past advanced reactor designs, coupled together to provide a competitive design

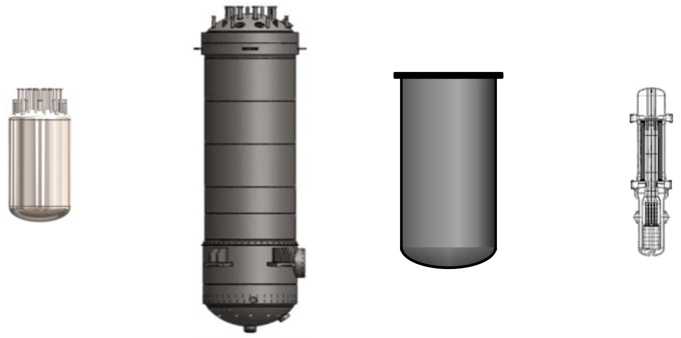
Kairos Power Headquarters
Alameda, CA

Kairos Power

Design and Development Overview

KP-FHR Features: Safe, Compact, Economical

- **KP-FHR Inherent Safety and Economic Potential are Uniquely Aligned to Replace U.S. Natural Gas Capacity**
- **Robust Inherent Safety**
  - Large fuel temperature margins
  - Fission products retained by fuel and primary coolant
  - Low-pressure system
  - Passive decay heat removal
- **Lower Capital Costs**
  - Reduced reliance on high-cost, nuclear-grade components and structures through KP-FHR intrinsic safety and plant architecture
  - Leverage conventional materials, existing industrial equipment, and conventional fabrication and construction methods
- **Improved Operating Economics**
  - High efficiency
  - Flexible deployment of low-cost nuclear heat



KP-1	HTR-PM	ARC-100	NuScale
Flibe	Helium	Sodium	Water
320 MW_{th}	250 MW_{th}	260 MW_{th}	200 MW_{th}
140 Mw_e	100 MW_e	100 MW_e	60 MW_e

** Reactor vessels drawn to approximate scale.*

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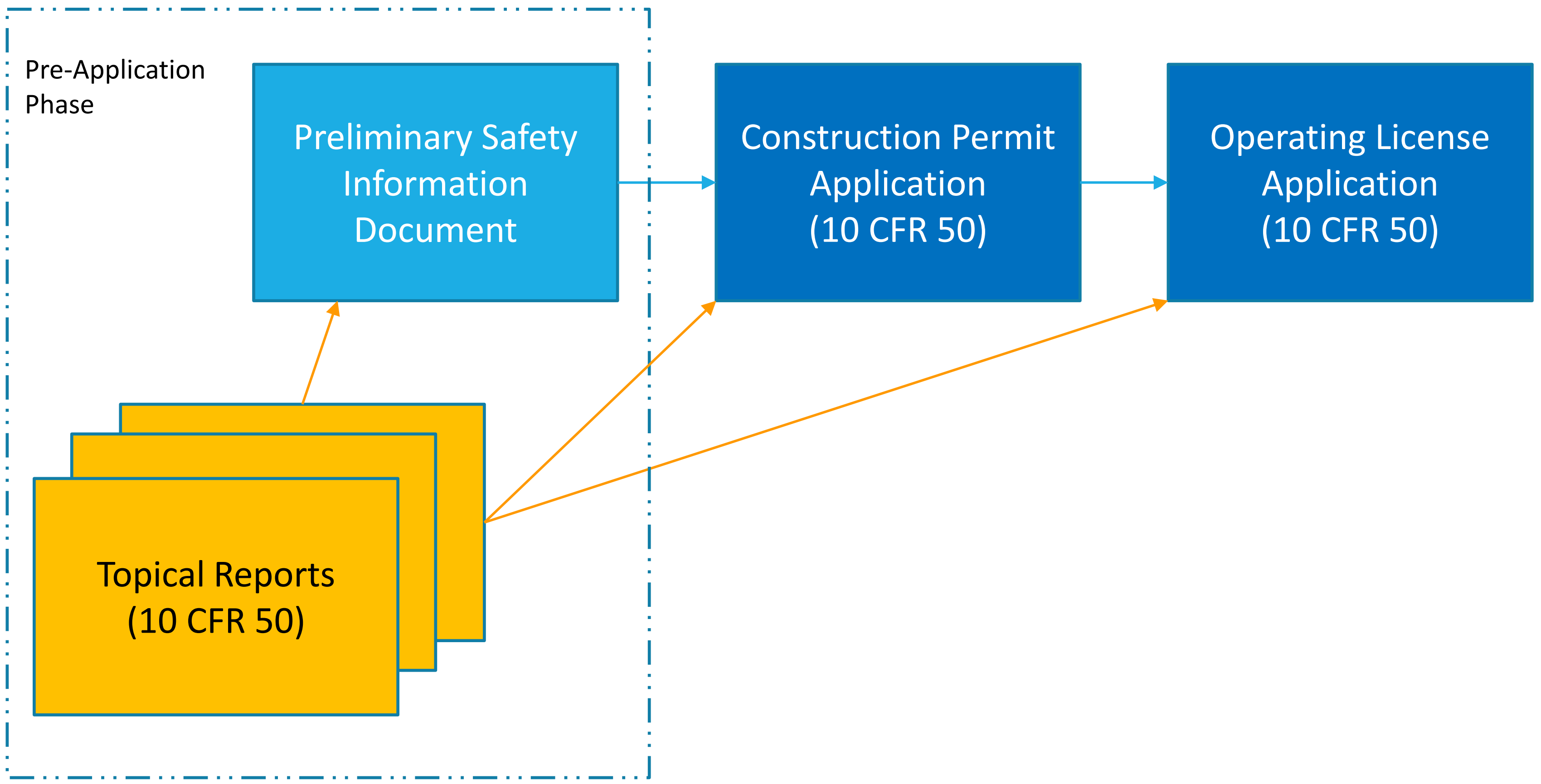
Baseline Licensing Strategy for KP-1



Licensing Overview

- Kairos Power intends to leverage the intrinsic safety characteristics of the KP-FHR fuel and coolant that provides uniquely large safety margins under accident conditions to achieve three high level goals:
  - Goal 1: Achieve Early Acceptance from NRC of Fundamental KP-FHR Safety Case
  - Goal 2: Minimize Unique Safety-Related Design Requirements for the KP-FHR
  - Goal 3: Retain Flexibility for Design Modifications for Future KP-FHR Iterations

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Testing and Development Overview

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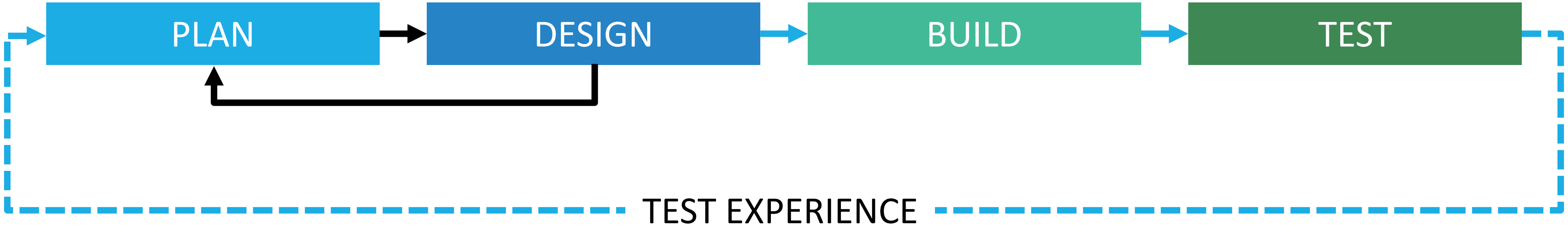
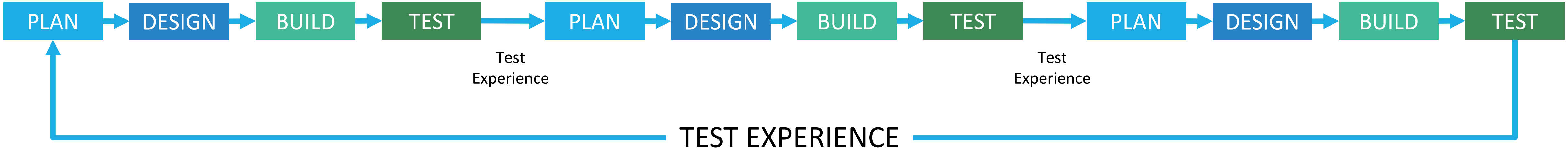
Kairos Power Nuclear Development Paradigm Shift

Conventional Nuclear Development Cycle



Kairos Power Accelerated Test Cycles for Innovation and Optimization



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Kairos Power Testing Program - Facilities

Rapid Technology Demonstration Requires **Non-Nuclear** Development and Qualification Facilities

- **R — RAPID LAB**: Rapid Analysis, Prototyping, and Iterative Design Lab (R-LAB)
- **S — SALT LAB**: Salt Handling and Loop Testing Lab (S-LAB)
- **T — TESTING FACILITY**: Component Testing Facility (T-FACILITY)
- **U — USER FACILITY**: User Operations & Maintenance Training Facility (U-FACILITY)

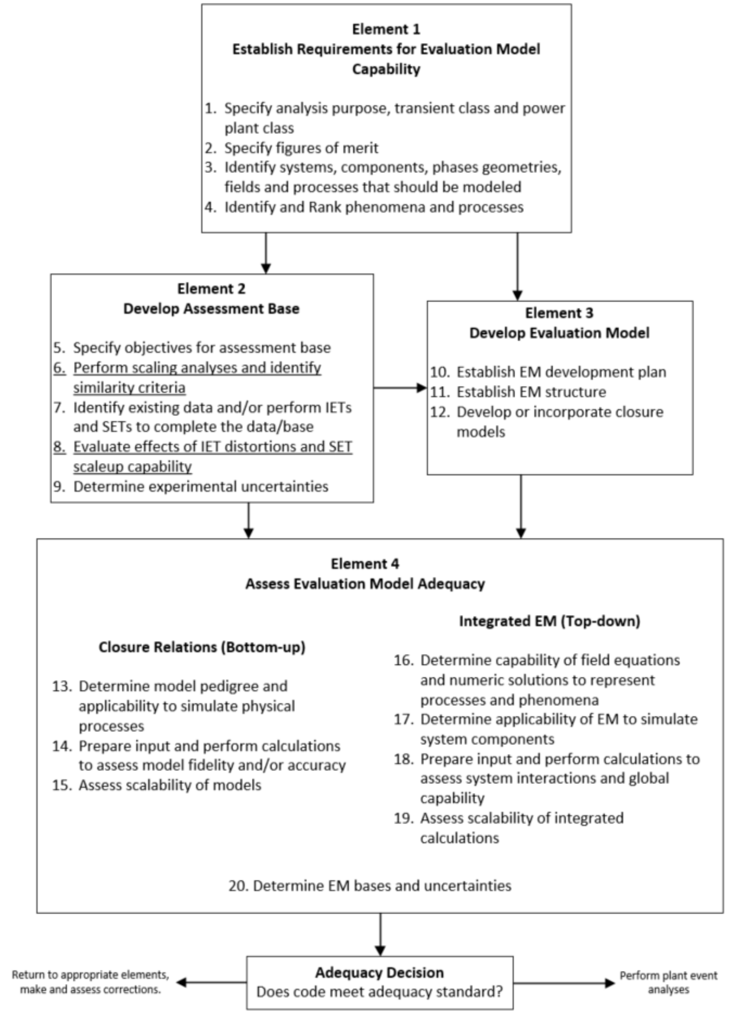
Scaling Methodology Topical Report

Purpose of the Scaling Methodology Topical Report

- The methodology is used to scale integral effects tests (IETs) and separate effects tests (SETs) supporting the KP-FHR evaluation model assessment base
- Surrogate fluids enable direct and comprehensive, local measurements of the phenomena under investigation due to higher compatibility of high-accuracy instrumentation (e.g., temperature and flow velocity)
- Kairos Power is requesting NRC review and approval to:
  - Use the scaling methodology with surrogate fluids described in the report (heat transfer oil and water) for testing included in the assessment base of evaluation models supporting KP-FHR safety analysis

Scope of the Scaling Methodology Topical Report

- Based on the Hierarchical Two-Tiered Scaling (H2TS) methodology
  - Generic scaling method previously developed for and approved by the NRC
  - Selected by Kairos Power for scaling of thermal fluids IETs and SETs
  - Includes quantification of distortions
- Addresses scaling of primary heat transport system thermal fluids IETs for the KP-FHR at normal operation conditions (forced flow) and transients involving natural circulation
  - Use of specific class of heat transfer oil as acceptable surrogate fluid for IETs
- Addressed scaling of specific phenomena- and component-level SETs
  - Use of specific class of heat transfer oil or water as acceptable surrogate fluids for SETs



Source: U.S. NRC (2005). Transient and Accident Analysis Methods. Regulatory Guide 1.203.

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Scaling Methods Support Acceleration of Kairos Power's Validation Testing Roadmap

KP-SETs

R-Lab

2020

Fluid dynamics tests
Room-temperature water
40% geometric scale

Heat transfer tests
Heat transfer oil (72°C)
Reduced geometric scale

\+

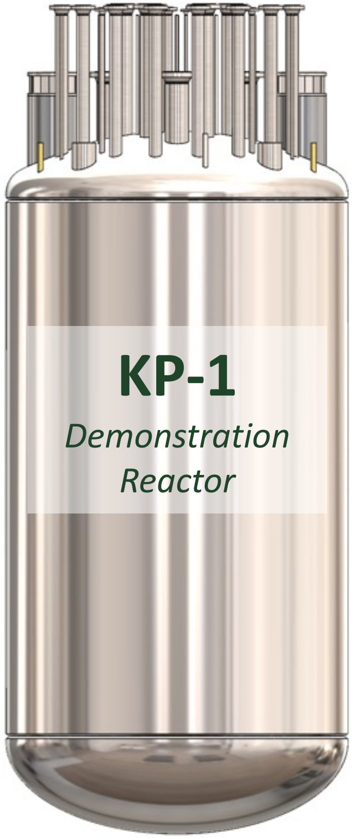
KP-IETs

R-Lab

2020

½ Height

Validation of KP-FHR Evaluation Models

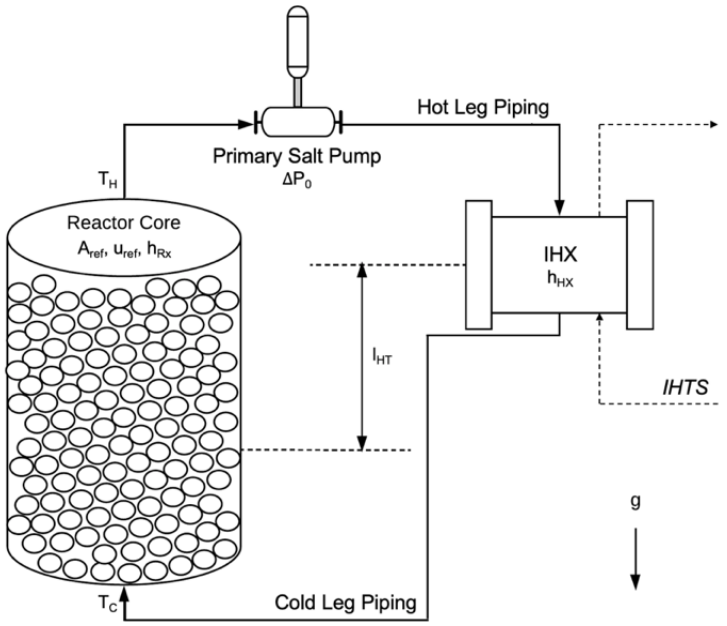


Reduced scale (size, power, temperature)
Surrogate fluids
Surrogate materials

Full scale
Flibe coolant (550-650°C)
TRISO fuel pebbles

IET Scaling Methodology

- Scaling analysis for a surrogate fluid (heat transfer oil) IET of the KP-FHR primary heat transport system
- Classes of licensing basis events illustrated in the topical report:
  - Steady-state, normal forced-circulation operations
  - Transients involving loss of forced flow and transition to natural circulation (e.g., pump trip, loss of heat sink)
- Illustrated using an idealized model of the KP-FHR primary heat transport system and scaled IET:



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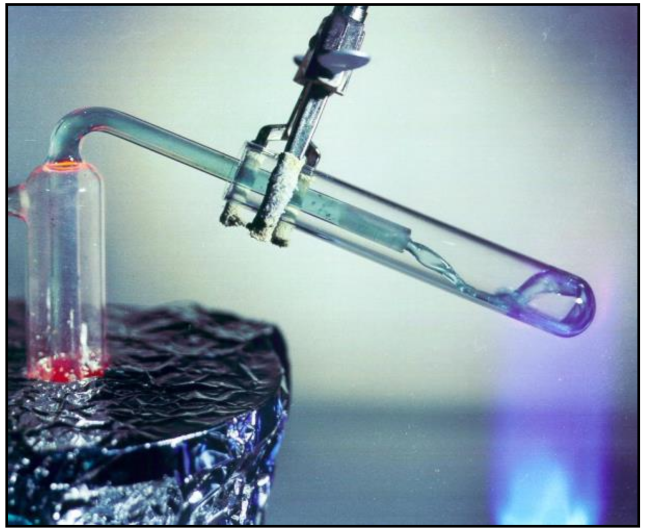
SET Scaling Methodology

- SETs are used to develop closure models and correlations for module/component-level phenomena
- Topical report covers generic fluid dynamics and heat transfer phenomena, and KP-FHR design specific phenomena:
  - Forced circulation fluid dynamics
  - Convective heat transfer
  - Conjugate heat transfer with solid structures
  - Twisted elliptical tube experiments
  - Pebble bed granular flow dynamics experiments
  - Porous media and packed bed heat transfer experiments

Reactor Coolant Topical Report

KP-FHR uses Flibe ($2LiF:BeF_2$) as a coolant

- Flibe coolant provides enhanced safety features relative to LWR designs.
  - Large thermal inertia minimizes rapid temperature transients
  - Negative temperature coefficient of reactivity supports reactivity control
  - Minimal short-term and long-term activation
- Flibe is an optimization for nuclear reactor operation
  - High density and heat capacity (i.e. thermal inertia)
  - Viscosity comparable to water
  - Stable under radiation and at high temperatures
- Flibe supports safety basis as a barrier to fission product release.
  - Absorbs fission products that escape the TRISO protective layer, providing additional functional containment protection.



$LiF\text{-}BeF_2$ mixture (Flibe)

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Reactor Coolant Topical Report

Purpose:

- Establish a common basis for safety related analysis between the NRC and Kairos Power
- Kairos Power requested NRC review and approval of Flibe specifications and thermophysical properties.

Scope and Use:

- Thermophysical properties of Flibe
- Chemical Specification used in KP-FHR
  - Methods and assumptions for setting specification limits
- Specifications and properties for future safety analyses in license applications.

Questions