Canadian Nuclear Safety Commission	**Commission canadienne de sûreté nucléaire**
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Best Western Pembroke Inn & Conference Centre 1 International Drive Pembroke, Ontario	Best Western Pembroke Inn & Conference Centre 1, promenade International Pembroke (Ontario)
Commission Members present	**Commissaires présents**
Dr. Michael Binder Dr. Sandy McEwan Dr. Soliman A. Soliman Dr. Sandor Demeter Mr. Rob Seeley	M. Michael Binder Dr Sandy McEwan M. Soliman A. Soliman Dr Sandor Demeter M. Rob Seeley
Secretary:	**Secrétaire:**
Mr. Marc Leblanc	M. Marc Leblanc
General Counsel:	**Avocate générale :**
Ms Lisa Thiele	Me Lisa Thiele

TABLE OF CONTENTS

Pembroke, Ontario / Pembroke (Ontario)

--- Upon commencing on Tuesday, January 23, 2018 at 10:33 a.m. / La réunion débute le mardi 23 janvier 2018 à 10 h 33

Opening Remarks

MR. LEBLANC: Good morning, Ladies and Gentlemen. Bonjour à tous. Welcome to the public meeting of the Canadian Nuclear Safety Commission.

We have simultaneous interpretation. Please keep the pace of speech relatively slow so that the interpreters have a chance to keep up.

Des appareils pour l'interprétation sont disponibles à la réception. La version française est au poste 2 and the English version is on channel 1.

Please identify yourself before speaking so that the transcripts are as complete and clear as possible.

La transcription sera disponible sur le site Web de la Commission dès la semaine prochaine.

I would like to note that this proceeding is being video webcast live and that archives of these proceedings will be available on our website for a threemonth period after the closure of the proceedings.

As a courtesy to others in the room, please silence your cell phones and other electronic devices.

Monsieur Binder, président et premier dirigeant de la CCSN, va présider la réunion publique d’aujourd'hui.

President Binder.

LE PRÉSIDENT : Merci, Marc.

Good morning and welcome to the meeting of the Canadian Nuclear Safety Commission.

Welcome to all of you who are joining us via webcast and teleconference.

My name is Michael Binder, I am the President of the Canadian Nuclear Safety Commission.

I would like to start by recognizing that we are holding this Commission Meeting in Algonquin Traditional Territory.

I would like to start by introducing the Members of the Commission.

To my right is Dr. Soliman; to my left are Dr. Sandy McEwan, Dr. Sandor Demeter and Mr. Rob Seeley.

We already heard from the Commission Secretary Marc Leblanc and we also have with us Ms Lisa

Thiele, Senior General Counsel to the Commission.

MR. LEBLANC: The *Nuclear Safety and Control Act* authorizes the Commission to hold meetings for the conduct of its business.

The meeting agenda was published on December 21st.

This will be a rather short meeting, with two items on the agenda, to provide to the Members an update on the status of power reactors in Canada. This update is provided at every Commission proceedings.

The second item is a technical update on fuel channel fitness for service in Canadian nuclear power plants.

The minutes of the December 13-14 Commission meeting will be presented for approval at the next meeting in March.

Mr. President.

CMD 18-M2

Adoption of Agenda

THE PRESIDENT: With this information, I would like to call for the adoption of the agenda by the Commission Members.

For the record, the agenda is adopted.

Let us proceed with the Status Report on Power Reactors, which is under Commission Member Document CMD 18-M3.

I understand we have representatives from industry, from the nuclear power plants, in the room.

We also have people joining us via teleconference, so let's start by testing the technology.

OPG, can you hear us?

MS HERRERA: Yes, we can hear you.

THE PRESIDENT: Thank you.

NB Power?

MR. KHOUAJA: NB Power, Point Lepreau, is here.

THE PRESIDENT: Thank you.

I see the Bruce representative here, so I guess we are ready to proceed.

I understand that, Mr. Frappier, you're going to make the presentation. Over to you.

CMD 18-M3

Oral presentation by CNSC Staff

MR. FRAPPIER: Thank you.

Thank you and good morning, Mr. President, Members of the Commission.

For the record, my name is Gerry Frappier. I'm the Director General of the Directorate of Power Reactor.

With me today, via teleconference as you mentioned, are members of the licensees, and also our Power Reactor Regulatory Program Division directors, who are back in Ottawa, plus technical support staff who are available to respond to questions on the Status Report of Power Reactors, as presented in CMD 18-M3.

This document was finalized on January 15, so I have a few verbal updates I would like to give to the Commission now.

First, the fuelling for Pickering Units 4 and 7 have returned to full availability. Unit 4 was at 94.5 percent of full power as of yesterday morning, and Unit 7 reported full power yesterday morning.

Darlington Unit 1 went into a planned outage on January 20 to reconnect the service transformer, and it is in the process of returning to full service expected today or tomorrow. Darlington can give us more detail.

Darlington Unit 2, which is under

refurbishment, has now ended the end-fitting removal, that's been completed, so the next important step will be to begin removal of pressure tubes. That project is moving along.

This concludes the status report on power reactors. CNSC staff are now available to answer any questions the Commission members may have.

THE PRESIDENT: Thank you.

Let's start with Dr. McEwan.

MEMBER McEWAN: Thank you, Mr. President.

I guess my question is a very generic one. For the severe weather events in Point Lepreau, how easy is it in those difficult environments for CNSC staff to actually monitor how everything is going? Do you do sort of a debrief at the end to look at if any issues developed?

MR. FRAPPIER: Gerry Frappier, for the record.

I'll ask Hatem to provide some more details.

The reason we put that in there by the way, with winter here now, and we have that experience even here today, we wanted to give the Commission some feeling as to how the nuclear power plants, both Point Lepreau -- Bruce has a similar program, but they have very definitive operational procedures that they do when they know a storm is coming that provides an environment where there's not as much going on, people can concentrate on the weather phenomena. They do walkdowns, as we've talked about, to make sure there's nothing laying around that might blow and cause whatever problems.

With respect to the CNSC, I would ask Hatem to provide us with some information on what we do to confirm.

THE PRESIDENT: Does anybody want to add?

MR. KHOUAJA: As Mr. Frappier said --

THE PRESIDENT: Go ahead.

MR. KHOUAJA: Can you hear me okay?

THE PRESIDENT: Get closer to the mike, please.

MR. KHOUAJA: Okay.

Before I pass the microphone to NB Power, to our site supervisor, Anu Persaud, I just want to add to what Mr. Frappier said.

The CNSC site staff, part of their role, besides the monitoring during the event, is also they have a meeting with the supervisors to discuss the incident, which is, in this case, how they cope with the weather, and they always meet with senior management to discuss the event.

Just to summarize the role that CNSC staff, our site staff play is mostly monitoring and lessons learned after the event.

I'll pass it to Anu Persaud, if she wants to add something to what I said.

MS PERSAUD: For the record, my name is Anu Persaud. I'm the CNSC site supervisor at the Point Lepreau station.

As Mr. Khouaja mentioned, we typically monitor these situations prior to the start of a storm, throughout the storm, and after the storm. What we are looking for is to ensure that NB Power follows their procedures in order to prepare for any effects of the storm and implement any mitigating measures that might be required, such as station walkdowns, preparing staff in order to respond, having supplemental staff available in the case of a minimum shift- complemented challenge.

During the storm in question, we monitored all of those things prior to the storm starting, as well as we were in constant contact with the stations throughout the storm to ensure that there were no adverse conditions or impacts on the stations. We also confirmed after the storm to ensure that there were no impacts on the station as a result of the storm.

THE PRESIDENT: Thank you.

Dr. Demeter.

MEMBER DEMETER: To follow on the theme, I was going to ask if there's been any trends noted in the number of times that the severe weather protocol had to be put in place over the last five years. Has there been a trend? Has it been infrequent? Maybe the numbers are too small to actually assess a trend.

MR. FRAPPIER: Gerry Frappier, for the record.

I don't have that information with me. I'm not sure if anybody online wants to comment, either from industry or RPDs, as to whether this is increasing or decreasing, I think is the question.

THE PRESIDENT: You should ask the snowbelt people from Bruce. I know they've had a lot of experience with this. Maybe they can come and shed some light on that.

MR. SAUNDERS: Frank Saunders, for the record.

In Bruce, it primarily is snow that causes severe weather events, it could be other things, but mostly it's snow. We haven't done any official trending, but certainly the tendency has been decreasing for sort of long periods where you can't access the site. Those are the ones that are the most troublesome, is when you get two or three days where you simply can't changeout staff and other things because the roads are closed. That does not happen, at least in my recollection, as frequently as it used to.

We do have more storms. We have the severe weather team stood up perhaps more frequently because there is more snow and storms in general, but the severity, in my view, would be less.

We are doing quite a lot of work these days around lake temperatures and other things, studying that and understanding where it's going and what it means to us. That does actually very much impact the whole notion of winter storms in Bruce County. It's not so much the snow that comes with the storm, it's what it picks up off the lake that generally gives us the problem, so hard to say for sure.

I think you need a lot of years in the weather business before you can really say you have a trend, but if the trend is toward warming temperatures, then generally you would think that means less snow, but like I say, being beside the lake that's not necessarily true. If the lake is warmer, it could mean more snow.

THE PRESIDENT: Any events recently, throughout the whole NPP, that actually shut down the operation? I remember that New Brunswick went through some severe weather. The grid I think was down. I'm just curious to know if anybody got -- did that force the plants to shut down?

MR. SAUNDERS: Frank Saunders, for the record.

Certainly nothing at Bruce. The last time we were shut down from an external event was the power outage in 2003, I believe. In reality, the unit stayed on at that point in time, just the grid wasn't available for us. The Bruce B units anyway stayed on and we were able to power up the local area even though the larger grid was offline, so we had power in Bruce within a few hours. It was quite comfortable. When I got back from Toronto, I was able to fill up my car. I was getting pretty low.

Generally, these plants are really robust. It takes a major event. I don't see any that would shut you down, other than the fact that the grid may not be available for you to use.

THE PRESIDENT: So Point Lepreau, in the recent weather, did you have to shut down because the grid was not available?

MR. GEOFROY: Point Lepreau has not been required to be shut down due to the grid being unavailable or due to severe weather. This most recent storm that we were referring to, we often go into quiet mode, which would be a defence of operation, but as we were indicating, these plants are very robust and did not require us to shut down.

THE PRESIDENT: Thank you.

Dr. Soliman.

MEMBER SOLIMAN: Thank you very much.

Some background about the Unit 4 shutdown?

MR. SAUNDERS: Frank Saunders, for the record.

This was a primary pump seal replacement.

The last time we were here I think we were talking about a seal failure that surprised us, that we weren't expecting. In this case, this was not the case, we were tracking the seal. It's leak rate started to increase and so we did what we do in those circumstances, we took the unit down and replaced the seal.

This is what we do with all the seals when it refers to the gland water, I mean one of the things we look at is the gland water, whether you're seeing increasing pressure or temperature on the gland water. Increasing water rates tell us that one part of that seal is passing. They always pass at a very low level, that's the way they're designed, but as it starts to move up, we have an action plan as the level goes up to actually take them down and repair them.

That was the story here, so it was sooner than we would have thought the seal should have failed, but it didn't surprise us in the sense of we knew it was coming.

THE PRESIDENT: Thank you.

Dr. Seeley.

MEMBER SEELEY: Just a general question on the Darlington Unit 2 refurbishment of 960 tubes to be removed next. Roughly, how much time is planned for the tube removal?

MR. FRAPPIER: Gerry Frappier, for the record.

I'd ask perhaps Robin Manley, or somebody from OPG could answer that better.

MR. MANLEY: This is Robin Manley, for the record

I am not sure that I actually have an answer to that with me today, but perhaps I could arrange to make sure that CNSC staff are briefed on it and we could bring that back on a later date. I'm sorry, I don't have that number off the top of my head.

MR. FRAPPIER: Perhaps, I don't know, Nathalie, if you have the schedule.

Certainly, that's all been laid out in the schedule. There's a very detailed program schedule, I just don't have it available to me right now, but it will take some time. I'm not even sure when they will start. They're not starting like the day after, there's preparation work to be done, but we can certainly get that information for the Commission.

MEMBER SEELEY: Yes. It was a general question just leading to how are we doing on this overall refurbishment versus the schedule for the program, so maybe you could comment on that more broadly.

MR. MANLEY: Robin Manley, for the record.

I can comment that we remain on schedule for the overall project. Certain elements actually advanced ahead of the schedule, but overall, we're on track.

MEMBER SEELEY: And timing for return to service?

MR. MANLEY: Robin Manley, for the record.

Again, I'm sorry, I do not have that off the top of my head, but it is in 2019.

THE PRESIDENT: Maybe you can update us on the stoppage that occurred because of concerns with safety. I understand that operations stopped and I understand then it came back. Any kind of lessons about some of the issues that actually were surprising to everybody?

MR. MANLEY: Robin Manley, for the record.

The Commission did hear a briefing about that last time, and it has since been in the news media to some extent. As we reported at the last Commission meeting, this action was taken by the joint venture, with the support of OPG proactively, so as to ensure that the low-level events that are considered as precursors to a more serious event are taken very seriously by staff. We make sure that people understand that we're not willing to risk people's lives, we're not willing to risk someone being seriously injured, and so we're going to stop the work and make sure that message gets across to people so that we have the right behaviours in place. If that means that we have to stop the job for a few days so that we can talk to our people and reinforce that message, we'll do it.

I think you may have seen in the media our president and CEO Jeff Lyash was quoted as to how significant it was to him in his past experience in other facilities and other parts of his careers when someone was seriously injured or killed on the job. We're not willing to take that chance, so we stop the work and make sure that people understand before we go back to work. I think that's really the lesson learned, how important safety and protecting the workers is to everyone there.

THE PRESIDENT: I guess I was fishing for did you notice any change?

MR. MANLEY: Robin Manley, for the record.

Again, I don't have a point of data that I can give you yet. I think we're continuing to very carefully monitor for any indications of safety behaviours. I have not heard of anything that would indicate a problem. The indications I have are that this was considered to be a very useful activity to have undertaken to reinforce the behaviours that we want. So far, it seems to have been successful, but in safety you can never say you're done, right, one bad day is a bad day, so we continue to monitor carefully and we will take aggressive action to make sure that everyone understands the importance of following all the safety rules and procedures so that we don't have a serious event.

THE PRESIDENT: Thank you.

Any other questions?

I have just one. I was curious about

Point Lepreau. I didn't understand the relationship there between the Hanson Stream pump house and the actual NPP. It's seven kilometres away, so what's the connection here?

MR. FRAPPIER: Gerry Frappier, for the record.

I'd ask New Brunswick Power to give you a detailed answer on the role it plays.

MR. POWER: For the record, this is Mark Power.

The Hanson Stream pump house, we get our freshwater supply -- so we have water from a reservoir out there that’s natural and we pump it into the station for our freshwater supply.

THE PRESIDENT: Is that the water intake for the NPP?

MR. POWER: No, it is not.

THE PRESIDENT: I am missing something again. You were breaking up on us. Can you repeat the explanation? What's the role of this particular pump house?

MR. POWER: This is our freshwater supply to the station for our water treatment plant. It's not the cooling water for the station.

THE PRESIDENT: If that goes down, there is no safety issue here?

MR. POWER: No, there is not.

THE PRESIDENT: Okay. Thank you.

Anybody else? Any other questions?

MR. FRAPPIER: Gerry Frappier, for the record.

Through the magic of Blackberry here I've got the questions that were asked.

The OPG Level 1 schedule shows that it's going to take 34 days to remove the pressure tubes, and the end of refurbishment is scheduled for September 2019

THE PRESIDENT: Okay. Questions anybody?

Thank you. Thank you very much.

The next item on the agenda is a technical update on fuel channel fitness for service in Canadian nuclear power plants, as outlined in CMD 18-M4.

Mr. Frappier, again. The floor is still yours.

CMD 18-M4

Oral presentation by CNSC Staff

MR. FRAPPIER: Thank you.

Good morning again, Mr. President and

Members of the Commission.

For the record, my name is Gerry Frappier. I'm the Director General of Power Reactor Regulation.

With me today are Mr. Glen McDougall, a specialist from the Operational Engineering Assessment Division, Mr. John Jin, the director of that division, and Mr. Milan Ducic, a regulatory program officer within the Pickering Regulatory Program Division.

The purpose of today's presentation is to give the Commission members a technical briefing on the science behind the regulatory oversight of fuel channels' fitness for service. This is being done in anticipation of licensing hearings for Pickering and Bruce that are going to be coming up later this year, so that the Commission could have some technical background.

This of course not the first time we've talked about pressure tubes to the Commission. Since 2014, the issues related to fuel channels and pressure tube degradation have been discussed before the Commission on a number of occasions. I would like to draw your attention to the list of Commission Member documents that are on the screen, which contain more detailed information from both CNSC staff and NPP licensees that have been produced in the past.

With that, I'll now pass the presentation to Mr. Glen McDougall, who will deliver the overall presentation.

MR. MCDOUGALL: Good morning. My name is Glen McDougall, and I'm a specialist in the Operational Engineering Assessment Division of the Directorate of Assessment and Analysis.

Before beginning, I'd like to clarify that the following deck is being presented for communication purposes, it does not reflect the full depth or breadth of CNSC staff's knowledge or compliance-monitoring activities.

The purpose of today's presentation is threefold: first, to provide a brief overview of the CANDU fuel channel, focusing on a key component, the pressure tube; second, to offer a glimpse into the means by which CNSC staff ensure that licensee processes and activities achieve their intended goal, which is safe pressure tube operation; and, third, building on the above information, to summarize the focus of CNSC staff's current evaluations. These conclusions will be included in the Part 1 CMDs being prepared to inform Commission decisions about the latest Bruce and Pickering relicensing applications.

First, an overview of the CANDU fuel channel.

This figure shows a fuel channel in cross-section. The horizontal pressure tube identified in red, which holds the fuel and through which pressurized heavy water coolant passes, the calandria tube, separated from the hot pressure tube by spacers, sits in a large tank of heavy water called the calandria vessel. The spacers keep the hot pressure tube separated from the cool calandria tube and allow for the flow of dry carbon dioxide gas. By monitoring the moisture level of this so-called annulus gas, operators can identify potential pressure tube leaks.

The pressure tubes are tightly positioned within the reactor vessel by heavy stainless steel end fittings, which also allow for coolant to flow to and from the pressure tube through feeder pipes.

The number of pressure tubes varies from as few as 380 in Pickering B units to 480 in the Bruce and Darlington units.

Please see the appendix for more details about Canada's CANDU fleet.

The conditions under which pressure tubes operate also vary according to the vintage of the reactor design, with lower temperatures and pressures in early CANDU units like Pickering A, and higher values in the Darlington units.

First off, my apologies for the typo in this slide. I must have missed this. It's supposed to read, "Technical concepts".

Before proceeding to a description of the pressure tube degradation and how CNSC staff regulate safe operation, I'd like to review some key concepts.

Any conversation about pressure tube technology will touch on a number of interrelated themes, but rather than review all of them I will touch on three. By doing so, I hope to offer some context for today's presentation as well as prepare the Commission Members for discussions they may hear during the upcoming Bruce and Pickering Part 1 like hearings.

In the next few slides I will briefly address three concepts. First, what do we mean by the phrase 'Fitness for Service'?

Second, I'll quickly discuss the presence of hydrogen in pressure tubes and the uptake of its sister isotope deuterium.

And finally, in any discussion about pressure tubes people will frequently refer to two units of operating time and I'd like to clarify the distinction.

The first concept is pressure tube fitness for service. In a CANDU reactor high temperature pressurized coolant flows through a number of components collectively known as the primary heat transport system. Because this system is responsible not only for collecting heat from the nuclear reaction, but also efficiently transferring heat to the secondary system via steam generators, the integrity of the primary heat transport system is vital. This is especially true of the pressure tubes which contain hot fuel.

The CANDU safety case relies on pressure tubes to remain leak free under normal operating conditions and to maintain fuel cooling under postulated accident conditions.

When CANDU engineers designed pressure tubes they had a specific goal in mind; over their lifetime the tubes would exhibit an extremely low probability of failure irrespective of whether they were subject to normal operating conditions or accident conditions. With this in mind, the engineers incorporated redundancies into the pressure tube design. First, they designed the pressure tubes not to leak. However, bearing in mind that pressure tubes might experience in-service degradation leading to a crack, the designers deliberately incorporated features to make pressure tubes resistant to unstable cracking.

Once pressure tubes have been fabricated, installed and commence operation one might ask: can they still perform the way the designer originally intended? So when staff reviews a licensee's fitness for service assessment, our goal is to answer that question.

Before leaving this slide I'd like to clarify the phrase 'In-Service Degradation'. For the rest of this deck, I will use it to describe degradation that occurs as a result of reactor operation.

At this point it's important to distinguish between the two types of pressure tube assessments that CNSC staff review. First, assessments that are done to confirm that inspected pressure tubes are fit for continued service. In accordance with their Licence Condition Handbook, a licensee is obliged to conduct periodic inspections and compare the results against CSA acceptance criteria. If the inspection finding does not meet those criteria, the licensee must submit a fitness for service assessment for the inspected pressure tube for CNSC acceptance. These assessments cover approximately 30 per cent of the pressure tubes in service in Ontario.

In addition, CNSC requires that licensees perform pressure tube risk assessments to address the 70 per cent of tubes that have yet to be inspected. These assessments include two that I will describe in more detail in just a minute; namely, leak before break assessments and fracture protection assessments.

Both leak before break and fracture protection assessments start from a worst case assumption that somehow a crack has occurred in a pressure tube without operators being aware of it. The licensee then calculates the probability that the hypothetical pressure tube will rupture. All of the assessments must meet the acceptance criteria established in the compliance verification criteria of the Licence Condition Handbook.

Based on the results of these assessments of both inspected and uninspected pressure tubes, CNSC staff assembles a composite view of the safety of 100 per cent of the core.

As a second concept I'd like to discuss hydrogen and deuterium in pressure tubes because we'll see that this is an important issue in the concept of fracture toughness which we'll be discussing in a minute.

While there are three hydrogen isotopes, only two of them really have an impact on pressure tubes. Hydrogen, whose chemical symbol is a capital H, is built into every tube during its manufacture. And deuterium, symbolized by capital D, is picked up by pressure tubes when they are in contact with high temperature heavy water.

Corrosion reactions result in two things: first, a thin layer of oxide appears on the pressure tube surface and, second, a small amount of the deuterium from the corrosion reaction finds its way into the tube. The amount of deuterium is so small it is reported in parts per million. For simplicity, rather than talking about a given pressure tube having so many parts per million of hydrogen and so many parts per million of deuterium, industry rolls the two into a single value and talks about the hydrogen equivalent concentration or HEQ. So, for the rest of this presentation you'll hear me talk about HEQ.

The hydrogen equivalent concentration is not uniform over the length of a pressure tube. In this figure we see a snapshot view of the hydrogen that you would find along a pressure tube as it operates in the reactor. The deuterium pick-up shown in red is affected by the variation in coolant temperature which is the blue curve and the variation in fast neutron flux which is shown in the green curve over the length of the tube. The method of installation of the tube at its ends also has an impact on hydrogen pick-up.

Knowledge of this behaviour is important for pressure tube assessments. In particular, hydrogen equivalent concentration is the key parameter for establishing the fracture toughness of a pressure tube. Hence, the circled areas at the end of the pressure tube indicate places that require enhanced regulatory focus because of reduced fracture toughness. And I'll be giving you much more detail on that in a couple of slides.

Finally, I'd like to distinguish between two units of reactor operating time that Bruce and Pickering representatives may use during the Part 1 re-licensing hearings.

Hot hours, which is the cumulative time the primary heat transport system is above about 200 degrees C and effective full power hours, which is the fraction of the hot hours when the reactor is at full power. Each of these units has a slightly different application.

To illustrate the difference between the units, this slide indicates the number of hot hours in a calendar year and the corresponding effective full power hours for a typical Canadian reactor.

Under the influence of high coolant temperatures, high pressure and bombardment by energetic neutrons pressure tubes experience a number of types of degradation. These include changes in dimension, for example, elongation of the pressure tubes; contact or interference with other reactor components, for example, the liquid safety system injection nozzles or LSS nozzles; flaws in pressure tubes; and changes in material properties of the tubes such as fracture toughness.

It is important to recognize that when they designed the CANDU pressure tube engineers took most of these degradation mechanisms into account. Specifically, they deliberately compensated for the potential impact of certain kinds of degradation by over-designing the tube.

I'd now like to switch gears from a purely technical discussion of how pressure tubes work and how they age to a summary of CNSC staff's oversight of licensee performance under the fitness for service safety and control area.

This slide offers a high-level summary of key elements of CNSC's regulatory oversight of pressure tube degradation. To comply with CNSC requirements, licensees are obliged to understand each pressure tube degradation mechanism; to make appropriate plans to assess the risk posed in their particular units by each mechanism; to perform inspections and material surveillance to confirm the extent and severity of the mechanism in their particular units; and, finally, to use the collected data to demonstrate defective pressure tubes will continue to meet acceptance criteria into the future.

And that's an important point. When staff looks at the fuel channel fitness for service -- or, pardon me, pressure tube fitness for service assessments, we're not interested primarily in what's happening today, we're always forward looking.

To illustrate how CNSC staff's oversight process works, I'd like to take a closer look at two examples.

First, a form of degradation where CNSC requirements oblige the licensee to prepare a fitness for service assessment based on in-service inspection data. So, for this example we'll look at pressure tube flaws.

Second, a mechanism that by its nature cannot be measured in-service and that's fracture toughness, which we'll see in a few minutes. Licensees use predicted fracture toughness values as a basis for core-wide assessments of the risk of operating uninspected pressure tubes.

Let's start with Example 1. The vast majority of pressure tube flaws are fairly innocuous. Once created, they exist as mere blemishes on the pressure tube surface having neither economic nor safety implications. However, a very small fraction of flaws could potentially have serious consequences.

First, the flaws created during normal reactor operation. If local stresses and the hydrogen level are appropriate, this flaw could become a small crack and one mechanism capable of doing this is referred to as delayed hydride cracking and that's symbolized as DHC.

Under certain circumstances, this crack can grow through the pressure tube wall allowing pressurized coolant to leak into the leak detection system.

Finally, under specific conditions it's conceivable that that same through wall crack could extend along the length of the pressure tube. And at this point CNSC defines two possible outcomes. We can either have leak before break, which is the target that all licensees are expected to meet, or we could have a condition referred to as break before leak.

Before we leave this slide, it's important to recognize two things about the Canadian fleet. First, no Canadian pressure tube has exhibited active cracking since 1986.

And second, while some Canadian pressure tubes have demonstrated a leak before break, only one tube has ever exhibited break before leak. That was in 1983 and it involved a pressure tube material that is no longer in service in Canada.

This slide illustrates the progression of steps between initiation of a pressure tube flaw and a potential small break loss of coolant accident.

Through careful consideration of this progression, CNSC staff has devised a series of regulatory barriers. Should a licensee wish to begin and continue to operate a pressure tube, each of these barriers must be successfully traversed. Each of the barriers has established acceptance criteria defined by the Compliance Verification Criteria in the LCH.

Considering these figures in turn, on the left-hand side of the figure we see a new pressure tube that has yet to begin service. To qualify for installation, the tube must be designed in accordance with the CSA standard. The tube must be installed per utility procedures and then be subject to an inaugural inspection in accordance with another CSA standard.

If CNSC staff is satisfied with the results of this inspection, barrier one has been crossed. So the pressure tube can begin service.

Moving to the right, we see the inside

surface of the same pressure tube where a flaw has developed.

In accordance with CSA Standard N285.4, the licensee must periodically inspect a sample of their pressure tubes to look for flaws just like this.

If the flaw meets CSA acceptance criteria, the pressure tube is considered unconditionally fit for service. On the other hand, if the flaw does not pass those criteria, the licensee must submit a fitness for service evaluation, basically a detailed assessment of the risk that the flaw could initiate delayed hydride cracking at some point.

The assessment not only covers the present time but a defined period into the future.

If CNSC staff accepts that assessment, barrier two has been crossed and the licensee can operate the affected tube out to a specified deadline, at which point they must re-inspect the flow to ensure that DHC has not initiated.

Moving again to the right we see a different pressure tube. As noted on slide 20, this tube represents the second group that CNSC staff is responsible for assessing, tubes which have yet to be inspected.

Since no inspection results exist for

these tubes, CSA Standard N285.8 obliges the licensee to perform a different kind of assessment.

A leak before break, or LBB assessment, is one of the two pillars of the safety case for CANDU pressure tubes.

I will describe the second in a few minutes' time.

An LBB assessment asks a simple question: Assuming a pressure tube has a crack and it has just begun to leak, would operators be able to identify the leaking pressure tube and safely shut down a reactor before that crack could grow to an unstable length?

If the LBB assessment predicts that operators would be successful, CNSC staff agrees that LBB has been demonstrated and barrier three has been crossed.

If, however, the assessment predicts that the crack would reach an unstable length before operators could shut down the reactor, staff refers to this situation as break before leak.

Once again I would like to emphasize that while some Canadian pressure tubes have demonstrated leak before break, only one tube has ever demonstrated break before leak.

In preparation for the next slide, I would like to remind the Commission of the earlier slide I had depicting the elements of an acceptable pressure tube aging management program.

The licensee must understand, plan, perform and finally demonstrate that the pressure tubes meet acceptance criteria.

With respect to pressure tube flaws this table summarizes the CSA standards and CNSC regulatory documents defining requirements for each of the aging management elements.

It also provides examples of the activities licensees undertake to address CNSC requirements.

Notable examples include the preparation and submission of periodic inspection program plans which detail the scope and schedule of pressure tube inspections, and the preparation and submission of fitness for service assessments done in accordance with the CSA standard and providing detailed analysis supporting a claim that the pressure tube can be safely operated into the future.

We have now seen how CNSC staff assesses one type of degradation identified during periodic inspections of pressure tubes. I would now like to contrast that with a second kind of assessment aimed at quantifying the risk of continued operation of pressure tubes for which no inspection data is available.

One example of this is fracture toughness, a key property of pressure tubes.

At this point it is important to re-emphasize an earlier comment. While pressure tubes are designed to be leak free for life, CANDU designers allowed for the remote possibility of a crack. They deliberately built in features that would resist the growth of a through wall crack irrespective of how it got there.

Fracture toughness is a measure of that resistance.

Practically speaking, if a crack develops in a high toughness tube, it will take a while to grow to an unsafe length and that is the time during which operators can identify the leaking tube and take action to safely cool and shut down the reactor.

Fracture toughness is a key input to pressure tube risk assessments, like leak before break and fracture protection. However, since toughness can be measured only once a tube has been removed from the reactor, licensees need another way to get the values they need for doing risk assessments. So they rely on models which predict tube-specific fracture toughness values based on a number of parameters.

As we will see in the next slide, temperature is one such parameter.

Because pressure tube toughness differs considerably over two temperature ranges, industry has developed separate models.

Fracture toughness is a property shared by most structural materials; for example, the steel used in the vessels of light water reactors, or LWR.

This figure illustrates the changes in toughness that occur as the temperature of a vessel increases from shutdown through to normal operating conditions.

Initially the material exhibits brittle fracture behaviour. In this lower shelf regime should a crack exist, it would quickly propagate without any increase in pressure being required. As the temperature rises, the material toughness increases dramatically and the fracture behaviour transitions from brittle to ductile.

A good analogy is the garden hose. In the middle of the winter, for example, when you’re flooding the children’s hockey rink the hose would easily rupture if you accidentally opened the tap a little too quickly. However, when spring temperatures arrive, a sudden pressure increase might make the hose leak a little bit but it would not rupture.

Returning to the example of reactor pressure vessel steels, once the material reaches upper shelf temperatures, it exhibits purely ductile behaviour. The fracture toughness is quite high. So even if a crack existed, the tube would resist its growth. Under these conditions the crack will not grow unless the load is increased.

This last regime is where CANDU pressure tubes need to be operated. This ensures that the crack resistance of the tubes will be at a maximum in the event of a design basis accident.

One might ask: Do CANDU’s pressure tubes still have sufficient toughness to safely perform their design function? And the answer is for the near term, yes.

However, research and development has confirmed that as hydrogen equivalent levels continue to increase, pressures tubes will exhibit a steady reduction in toughness.

To manage the risks associated with this decline, licensees must consider two requirements.

First, during normal operation 100 per cent of the pressure tubes must be on the upper shelf.

Fortunately, research has shown that neither hydrogen levels nor temperature affect the pressure tube behaviour once you are on that upper shelf.

However, when pressure tubes are operated below 250 degrees C, for example during heat-up and cool-down of the reactor, the situation is more challenging.

Based on a detailed understanding of how toughness changes with both hydrogen content and temperature, operators must carefully control heat transport system pressure to ensure that at each step pressure tubes will be sufficiently tough.

I would like to take a moment to focus on that particular scenario, the heat-up and cool-down of the reactor.

To ensure that they can meet a key CNSC requirement, licensees establish a so-called heat-up/cool-down envelope which operators must observe as they pressurize and depressurize the heat transport system.

To create this envelope licensees employ a fracture protection assessment which determines the maximum pressure that the postulated crack could sustain without becoming unstable.

So again I have to emphasize this is looking at the worst case scenario. You have a crack in a pressure tube and you have not identified it. So to develop the heat-up/cool-down envelope the licensees start by assuming that there is a tube out there that has that crack.

A key input into this assessment is fracture toughness. As I mentioned earlier, the temperature range over which heat-up and cool-down occurs, known as the transition regime, is tricky because the toughness varies both with temperature and with hydrogen equivalent level.

Early in life it was pretty straightforward to devise a heat-up and cool-down envelope. Pressure tubes contained only a small amount of hydrogen, so they were pretty tough.

In contrast, steady increases in pressure tube hydrogen equivalent levels makes the current situation a bit more complicated. With falling fracture toughness levels, licensees have found it more difficult to define the heat-up/cool-down envelope that will allow them to pass a fracture protection assessment.

In monitoring licensee management of this challenging situation, CNSC staff focuses on the size of the safety margin, and that is the amount of space there is between the upper bound of the heat-up/cool-down envelope and the maximum allowable pressure that is determined by a fracture protection assessment.

Finishing off with fracture toughness, I could repeat a similar table to what was shown in Slide 24. But in the interests of time I can simply confirm that the regulatory requirements governing pressure tube risk assessments are quite similar to those imposed on licensees when they do fitness for service assessments.

And second, I can confirm that licensee performance in doing these risk assessments reflects a level of effort and focus comparable to the level that they devote to addressing fitness for service assessments.

Finally, I would like to take this opportunity to compare CNSC staff's evaluation of the 2014 licensee requests to operate beyond 210,000 effective full power hours with their current request, which the Commission will be examining in the coming months, and that is to extend pressure tube life beyond 247,000 EFPH.

This slide compares the technical basis for CNSC staff's recommendations to the Commission for extending operation beyond 210,000 effective full power hours, compares them with the issues that staff is currently considering in preparing the Commission Member Documents for the upcoming Part I hearings for Bruce and

Pickering.

The figure examines six broad groups of pressure tube degradation, as well as a licensee initiative to upgrade the methodologies they use to do risk assessments.

Taking a closer look, we see the following.

For most of the mechanisms a green bar is shown, both in the lead-up to the units crossing the 210,000 EFPH hash mark, which is shown in blue, and their approach to 247,000 EFPH, a hash mark shown in red. This confirms that for each of those degradation mechanisms, staff has carefully reviewed licensee provisions to manage the associated risk and has met all applicable acceptance criteria.

The lighter green bars, which extend beyond 247,000 EFPH, indicate that while staff will continue monitoring licensee performance on each and every one of those degradation types, we do not anticipate a change in the outcome.

For pressure tube flaws we see a yellow bar preceding and following the 247,000 EFPH hash mark, and that is followed by a light green bar out to end of life.

This represents CNSC staff’s ongoing

review of licensee provisions to address two specific issues associated with pressure tube flaws. At the present time our judgment is that industry will complete the necessary work to return the pressure tube flaw bar to green in the near future.

Finally, the figure depicts three bars that have remained yellow since 2014: degradation of one type of annulus spacer, the so-called tight fitting spacer; changes in pressure tube fracture toughness; and licensee proposals for new risk assessment methodologies.

When Bruce Power and OPG announced plans to extend station life beyond 210,000 EFPH they formed a partnership with the former Chalk River Laboratories, known as the Fuel Channel Life Management Program. This special research and development program was intended to produce the understanding, inspection and analysis tools they would need to support safe pressure tube operation beyond 210,000 EFPH.

The focal point of that program was the three issues that I mentioned just a second ago.

So the next slide compares the status of those three issues in 2014 with where things stand at the present time.

Taking the issues in turn, with respect to degradation of tight fitting spacers, industry has devoted considerable time and effort to this issue, and over the past six years it has borne fruit.

Industry has removed and carefully examined in-service spacers, developed a suite of predictive models for their degradation behaviour, and has begun preparing fitness for service procedures for publication in a Canadian Standards Association document.

In short, staff rates industry’s current performance as green and we don’t anticipate any downturn in industry’s performance on this particular item.

In terms of proposed new methodologies for core assessments, leak before break and fracture protection assessments, industry has submitted several technical basis documents and engaged in extensive meetings to address CNSC staff concerns.

Based on this, two assessment methodologies have been accepted for use, and CNSC staff’s review of a third methodology is nearing completion.

Overall, CNSC staff is confident that following a continued but brief period of enhanced regulatory monitoring, we will be in a position to rate industry’s performance as green.

Finally with respect to fracture

toughness, while industry has completed considerable work over the last four years, there are outstanding issues with one of the models that they are currently using; for example, the treatment of uncertainties.

As well, there are new issues, including the development of an extension to that model capable of predicting fracture toughness out to 160 PPM hydrogen equivalent, which is the new end of life target.

For this reason, CNSC staff believes that this issue must remain yellow, and this will be reflected in the Commission Member documents that you will be receiving in the lead-up to the relicensing hearings.

At this point I will turn the presentation back to Mr. Frappier.

MR. FRAPPIER: Thank you, Glen.

Gerry Frappier, for the record.

So to close out this presentation I would like to summarize a couple of key points: first some notes on the process by which CNSC staff has and will continue monitoring licensees' practices related to pressure tube degradation; and second, what will be the focus of CNSC staff's regulatory attention with respect to pressure tubes, that is, the declining fracture toughness.

To ensure licensees' fitness for service programs for pressure tubes meets regulatory requirement, CNSC has a comprehensive and effective approach to oversight. We expect licensees to have an in-depth understanding of pressure tube degradation and we require routine inspections of pressure tubes.

CNSC staff has a comprehensive and effective regulatory oversight, and in particular over the proposed ten-year operating licence requested by OPG and Bruce Power, staff intends to provide annual updates to the Commission via the Regulatory Oversight Report.

In terms of fracture toughness, CNSC staff can confirm that research and development on the toughness issue continues under the joint Bruce Power/OPG/CNL project. Since the time licensees first requested Commission approval to operate pressure tubes beyond 210,000 effective full power hours to the present, CNSC's regulatory expectations have not changed: that is, licensees must routinely demonstrate that pressure tubes remain capable of meeting all of the original design intent.

And finally, should the licensees propose revised or new fracture toughness models in support of future pressure tube operation, CNSC staff will expect them to demonstrate that the predictions are conservative.

That completes staff's presentation. We are available to answer any questions that the Commission Members might have.

Thank you for your attention.

THE PRESIDENT: Thank you.

So let's jump to the question session with Dr. Demeter.

MEMBER DEMETER: Thank you for that informative and highly technical presentation.

My question is more qualitative.

So we've got an industry that's looking at beyond end of life remediation to demonstrate safety of certain components and how to test for that.

In an international sense are we leading the way in this or are there other countries that have similar technologies where we can learn from? Or are we setting the stage for them to learn from us?

MR. FRAPPIER: Gerry Frappier, for the record, before I pass it off to Mr. McDougall or perhaps John Jin.

So a couple of aspects to your question. One is with respect to pressure tubes themselves. They apply to CANDU reactors. And with respect to the fleet of CANDU reactors, Canada is certainly in the lead with respect to -- Canadian industry, I should say, is the leader with respect to doing the research required and putting in place the approaches that they are going to do to ensure the pressure tubes are safe.

The CNSC as a regulator has been ahead of everybody as far as putting in requirements and ensuring that there is regulatory oversight that will take account as the pressure tubes go beyond the original design intent.

However, having said that, other regulators are very much interested in what we're doing and I would suggest tend to adopt both the CSA standards and the reg docs as we develop them with respect to this.

So in that sense we're leading.

There is also the aspect of all the metallurgy associated with this. Pressure tubes are a metal and other reactors also have metals that are in high radiation fields and have all kinds of degradation mechanism.

There is a whole bunch of international groups, I would say, and programs associated with looking at all kinds of degradation mechanisms, including metallurgy.

From that perspective, perhaps I would ask either Mr. John Jin or Glen to talk about our relationship with respect to the rest of the world in metallurgical terms.

MR. McDOUGALL: Glen McDougall, for the record.

I guess there are two different things that we can talk about in terms of the international community.

As Mr. Frappier mentioned, there are the other CANDU operators throughout the world. And at present we are in the lead in Canada in terms of the operating time for our pressure tubes and the extent to which the utilities are engaged in end of life research programs, if you want to call it that.

An example of that, or just to emphasize that point, I would like to note the number of visits that we have had from foreign regulators and, in a couple of instances, from foreign utilities who have travelled to Ottawa to pick our brains about what industry is doing about operating beyond 210,000 EFPH.

In terms of the other sources of pressure tube or material behaviour information from which we might be able to benefit in Canada, to the best of my knowledge there are only two other countries in the world that have any experience in operating zirconium alloy pressure tubes.

One is in Japan and the other is Russia. In both of those cases there is only a marginal amount of information that we can borrow or share with them because the nature of the materials that they use are -- they are sufficiently different from CANDU pressure tubes.

I believe that AECL and Chalk River or, pardon me, CNL staff, still engage from time to time with operators of those reactors in other countries, but that's basically on a very fundamental scientific level.

THE PRESIDENT: Can I jump on still in the international? In the U.S. they keep talking about number of years, right? So they are going now and they are looking for 60 to 80. You guys never mentioned years as a proxy for aging, I guess.

So how different is the analysis the U.S. NRC does to go from 60 to 80, for example? If they are ever going to go to -- I think that -- I don't know if they already approved an 80 facility, but I know they are talking a lot about this. But they did do a lot of analysis to go to 60.

MR. FRAPPIER: Gerry Frappier for the record, before I pass it off to Dr. John Jin.

So we do talk about age in terms of years as well, not so much for pressure tube conversation but in general. So we're going to be coming for -- our licensees currently are applying for a 10-year licence extension.

We will do all our analysis associated with aging management and whatnot on all the different components and structures that are at a nuclear power plant based on that 10 years, so the periodic safety review that you will hear lots about coming soon. We'll look at 10 years as a timeframe and whether all components and structures and that are acceptable for that timeline.

With respect to pressure tubes, as was just explained, the key parameter is really effective full power hours, and to a certain extent, hot hours, and those become very important indicators of the aging of pressure tubes. So we tend to focus more on those than the actual years that the pressure tubes have been around, especially if you consider some of the units were shut down for some amount of time and that's a whole different degradation mechanism at that point.

But perhaps Dr. Jin would like to add to this.

DR. JIN: Thank you, Mr. Frappier.

My name is John Jin. I am the Director of the Operational Engineering Assessment Division. My division is looking after the fitness service of the major pressure band component including the pressure tubes.

Regarding the licensing status of the United States for the PWR there are many PWRs that have been approved for the relicensing up to 60 years from 40 years. Industry is looking for the second relicensing from 60 to 80 years but, as far as I know, it is still in the stage of preparation for the licence application. But there has not been approval from the U.S. NRC, to my knowledge. But in the industry they are very active in conducting our research and development to prove that the system structure components will be okay until 80 years.

Regarding the regulatory practice for looking after the aging of components, including the pressure tubes or transfer from the previous question, we are aligned with the international practice regarding the aging management. In the PIP, or periodic safety review process, we adopted the CNSC regulatory document, REGDOC-263 which requires an aging management program.

That REGDOC-263 is aligned with the IAEA safety guide, special safety guide 25. It provided all the requirements that the licensees have to prove that they have reliable and effective aging management program. That requires a level of understanding of their organization and a level of inspection programs and what research programs should be prepared.

So CNSC are aligned with the international practices in terms of aging management.

THE PRESIDENT: Anything?

Mr. Seeley?

MEMBER SEELEY: Yeah, maybe just on the risk and/or assessment of the health of the tubes.

So the HR or EFPH-type hours or hours of service is obviously a key input to risk assessment and some of the modelling. I am curious to know a little more about this, the Type 2 inspections, you know, what goes into a Type 2 inspection.

MR. FRAPPIER: Gerry Frappier for the record.

Type 2 inspections are inspections that the CNSC does, and perhaps I'll ask either Dr. Jin or Glen McDougall to express that, which is different than the periodic inspections that the licensee does on the pressure tubes themselves.

So you were looking for what we do or what they do?

MEMBER SEELEY: Let's start with the periodic.

MR. FRAPPIER: Okay. So with the periodic inspections, perhaps Dr. Jin, you could explain what industry does but then we could also ask our industry colleagues to give some detail.

DR. JIN: My name is John Jin, for the record.

If it is about the periodic inspections program, during the presentation made by Mr. Glen McDougall, he mentioned several times about the inspection program to ensure that the pressure tubes condition is still maintained, not validated under fitness service or engineering assessments.

So in the periodic inspection program the requirements of the CNSC staff, CNSC adopt CSA standards as part of the regulatory framework which is CSA N35.4. It provides all the requirements for the periodic inspection in terms of inspections frequency, scope of inspections or inspections methodologies.

So industry submits periodic inspection programs before implementing and CNSC staff review that and accept it, if it is comprehensive enough.

In addition to that, their licensees conduct periodic inspections using the periodic inspection program and the licensees submit the inspection report after every inspection campaign within 60 days. CNSC staff review that. That is one of the vehicles to monitor the condition of pressure tubes.

MR. FRAPPIER: Gerry Frappier for the record.

Just to add perhaps a little bit of structure, if you look to the last page in your presentation of the appendix, I think it's Slide 49, you have a list there of some of the activities mandated by the CSA standard inspection -- in-service inspection. So it's called "source of pressure tube data" and there is a bit of a list there.

I am not sure if industry would like to add anything to what Dr. Jin said.

THE PRESIDENT: Before you do this, a couple of times you are talking about inspection of a pressure tube. I want to understand what it means. You take the pressure tubes out or you inspect it online? How do you do that when the thing is hot, if you like?

And number two is if you see a flaw, do you replace it?

So I want a little bit more statistics about how you do a 30 percent sample, how many flaws do you detect?

MR. FRAPPIER: So there's --

THE PRESIDENT: You know there is a little bit more detail about what do they do here.

MR. FRAPPIER: Gerry Frappier for the record.

Certainly, how much detail to be put into a presentation and into the CMD; we have had lots of discussions. Yeah, and so certainly there is different types of inspections, some with the pressure tubes in the core, some with the pressure tubes removed. Some is non-destructive and some is destructive testing.

Perhaps Mr. McDougall could give us some detail around those.

MR. McDOUGALL: Yes, if I could direct your attention to Slide 47, it's at the very end of your deck.

Mr. President, there are basically two different types of inspections that go on with pressure tubes. Both of them are requirements of a CSA standard.

The first, and the most frequent, are periodic inspections, which licensees are obliged to do in during inspections outages or, pardon me, during outages in the reactor. They remove the fuel from the pressure tubes and they insert specialized tooling that is designed to measure a number of different parameters in the tube.

For example, they will look for pressure tubes flaws. They will look for evidence that the pressure tube is touching its calandria tube. They will measure the location of the spacer between the pressure tubes and the calandria tube.

There is also specialized tooling that can collect a tiny sample of the pressure tube material for chemical analysis. That's the way that licensees monitor the hydrogen levels in their pressure tubes.

THE PRESIDENT: Maybe we can hear from the industry about -- so it says 30 percent, I thought, at some point here. What is the rate of flaw detection?

MR. SAUNDERS: Frank Saunders for the record.

Yeah, the size of the sample varies, based on the need for our models to predict. So you know you have a minimum number. You always do, but based on your analysis of the tubes you do more or fewer samples. Those periodic inspections programs are set that way.

We have, in fact, invested a lot of money in terms of very high-tech equipment that they will do these inspections quite quickly and quite reliably now. We do not detect many flaws, as you would expect. Otherwise, we would be taking the tubes out of the reactor.

We do detect -- we do find sometimes indications of things that might be a flaw. That does occur. I am not sure of the frequency.

I think -- I have Mr. Newman on the phone as well, who is our chief engineer who probably has that number closer.

When we do find something like that we do what we call a replica, which means we take an impression essentially off of the tubes so that we can take that out and actually look at whether the flaw is really there and what kind of shape it's in.

Are you on the line, Gary? Do you have anything you want to add to that?

--- Technical difficulties

MR. NEWMAN: That's right. It really is pressure tubes and in terms of the number of indications that are under --

--- Technical difficulties

MR. NEWMAN: -- evaluations and tools which would identify --

THE PRESIDENT: Sorry. Sorry to interrupt. You are breaking up on us. We can't understand you.

MR. NEWMAN: Okay. I am not sure how to fix that.

THE PRESIDENT: Try again.

MR. NEWMAN: Okay. Let me have another try here.

So as Frank indicated, the number of indications that we have in a given pressure tube really is dependent on its operating history. So we could have a small number or we could have -- or this maybe is half a dozen indications in something, but it really depends on the severity of the indication in terms of the implications to, you know, fitness for service, as Mr. McDougall described earlier.

But every indication that we see, we see the full fitness for service evaluation and, as already indicated, if we can't meet those requirements then the pressure tubes would be replaced. However, that really doesn't happen very often because our fitness for service technology is actually quite well developed, as already discussed.

THE PRESIDENT: Okay, I'll bite. How many pressure tubes have you replaced in the last five years?

MR. NEWMAN: Usually we replace them for the purposes of surveillance. I think Mr. McDougall touched on that in terms of -- and also Mr. Frappier that we would remove tubes for surveillance purposes where we had actually taken them and destructively analyzed them. We typically will do that, you know, every half-dozen years or so, and that each utility will do that.

We have taken one or two pressure tubes out over the last five years for other reasons where we find indications that we want to study. And so we have done that as well. That would -- I am just speaking on behalf of Bruce Power.

THE PRESIDENT: Mr. Frappier?

MR. FRAPPIER: Gerry Frappier for the record.

So just to put this a little bit into context, so the CSA standard requires each facility to do a minimum of 10 pressure tubes for this in-service testing. We get all those results, so we typically get about -- the results of 40 pressure tubes that have been tested per year.

As was mentioned, it is very rare to find flaws that require the pressure tubes to be replaced, based on this inspection. In fact, the last one was at Point Lepreau in 2002. So we are talking sort of 15 years we haven't had any.

However, the CSA standard also requires

what's called material surveillance. A couple of people have talked about that. And material surveillance is they will actually take a pressure tube out, not because they have to because of the flaws in the pressure tubes, but because we require them to for them to be able to do more detailed material testing. That would be destructive testing, so they take the pressure tube out, along with the spacers, and then they can do a suite of more intense examination of the pressure tube, again to make sure there's nothing happening that is surprising to industry or to ourselves.

So those, in combination work to get us a complete picture on the evolution and degradation of pressure tubes.

THE PRESIDENT: Mr. Seeley...?

MEMBER SEELEY: Okay, so the operator has their suite of testing that they do and it is a physical removal of the fuel. They inspect with cameras, radiology, whatever, a number of parameters. A number of tubes -- is there are a number of tubes required? You said 10?

MR. FRAPPIER: Ten.

MEMBER SEELEY: Ten per year.

And then the Type 2 inspections which were the CNSC, is that more of an operating envelope and all the parameters versus a physical inspection of the tubes that the operator has done?

MR. FRAPPIER: Gerry Frappier for the record.

Yes. So if now look at the Type 2 inspections that our inspectors do with support from the experts in Ottawa, it's much more looking at programmatic and the actual results. We're not hands-on with materials.

But perhaps Mr. McDougall could provide some details.

MR. McDOUGALL: Glen McDougall for the record.

Yes, I think the best way to look at this is it's like a pyramid. At the top of the pyramid is CNSC requirements. In our requirements, there is a licence condition that states the licensees have to have a fitness for service program.

We examine that program primarily through the documents and the activities that it generates. So we will review a number of key documents that the licensees produce not only to explain to themselves how they demonstrate fitness for service but also to explain to the regulator why it meets our requirements.

We also look at an awful lot of their

activities. As you have seen, there are non-destructive examinations of pressure tubes, there are destructive examinations periodically of removed tubes. But there is an awful lot of analysis that goes into all the data that you get. The data very rarely speaks for itself. It has to be analyzed and put in context.

So the nature of our Type 2 inspections is to go and look at how the licensees do the very activities which they claim to be doing. So if they have a fitness for service program that says, "We will follow such and such a CSA standard to demonstrate that our pressure tubes are fit for service, CNSC Staff will literally take the CSA standard and compare the licensee's activities against it, point by point, and so the objective of the Type 2 inspection will be to make sure that the licensee's activities are actually living up their own expectations.

MEMBER SEELEY: Yeah, so I guess I'm getting to my real question, which was really just to understand the inspection programs, number one, okay, physical and data and risk-based. So the tubes have a life of 210 or 247,000 EP, whatever effective full-power hours roughly, design, and you want to extend the life of these tubes beyond those hours.

Will those inspection programs remain the same? Will they be changed? Will they be more rigorous? What's in the works?

MR. FRAPPIER: Gerry Frappier for the record.

I would ask Dr. John Jin to respond to that one.

DR. JIN: My name is John Jin for the record.

To answer for the previous question, I think there is some confusion between Type 2 inspections and periodic inspections.

The inspection in the periodic inspection is the inspection using very sophisticated tools using ultrasonic or radio, that type of thing, to monitor the condition of the component.

The inspections in the Type 2 inspections is kind of -- it's part of the methodology for technical assessment. Most of our job can be done on desktop review of the submissions from the licensee, including the inspection report or engineering assessments for fitness of service. But sometimes we need to visit the site to confirm that the activity of the licensee is conducted according to the manual or according to the program. That is a Type 2 inspection.

So we do both. For the inspection program for the fitness operating beyond the original or same design life or in the life extension, yes, we do our regulatory oversight under the directive from the previous Commission Hearing.

For this relicensing we have been conducting the periodic safety review process to confirm the condition of the components for the next licensing period, up to the target of its life. We identified all the necessary regulatory activities to confirm that. So it is much more enhanced, the regulatory oversight comparing with the previous one. The licensee has been conducting a comprehensive research project in addition to the data. They will have to report more frequently or with more information to the CNSC staff going forward.

MR. FRAPPIER: Gerry Frappier.

If I could just add to that, so when the licensee was requested to go beyond the 210,000 hours a few years ago, that was presented in front of the Commission and we did recommend some additional -- mostly frequency, I would say, increase in frequency of reporting, and that we would report to the Commission on an annual basis on that.

With them now requesting to go beyond 247,000 hours, we do expect that we will be requesting a more robust set of activities but that will be subject to the licencing hearing that's coming up as to whether it's satisfactory to the Commission or not. I am sure we will be talking about that at the relicensing.

MR. ELDER: Peter Elder for the record. I am Vice-President of the Technical Support Branch and Chief Science Officer.

If Glen could bring up Slide 23 so we know what is right there, this is -- you notice this is a loop. So there are periodic inspections and in-service inspections. You take the feedback from your models into the design of your next campaign of inspection. So you take your inspection results and your model, any updates to your model, and this influences the number of inspections you have to do.

So when we're talking about in the end -- it said on the CSA standard -- it says a minimum of 10 tubes. It's a minimum. You go above that minimum if you have indicators or if you have any knowledge that would say, "I need to do more to support my model and to validate my model and make sure it's still consistent".

So we expect as you go further into -- depending on what they present us, but we look very closely at the inspection frequency and the inspection frequency does change based on the results you get from your inspections. And we have gone -- and this is the same approach we do to all periodic inspections. There is a feedback loop to degradation to the models and that will change, and does change your inspection frequency.

THE PRESIDENT: Okay.

Dr. Soliman...?

MEMBER SOLIMAN: Thank you very much.

Thank you for the presentation. It is very informative for a very hard subject, really.

I had a generic question, and maybe it is not mentioned here. It's about one of the safety load cases which we call "end fitting ejection".

When we have a crack propagating in the axial direction of the pressure tube, when it reaches the rolled joint it turns circumferential and the end fitting could eject. This scenario has been studied at AECL at length back in the nineties and there was some initiative to redesign the rolled joint in such a way that when the crack reaches the rolled joint it will arrest the crack so it will not propagate in the circumferential direction.

Is there any progress on that and any studies that have been done on that issue?

MR. FRAPPIER: Gerry Frappier for the record.

Yes, you are correct, and the concern about end fitting ejection was quite an item a while back and has been studied and analyzed quite extensively. I'd ask Mr. McDougall to give us some details around that.

MR. McDOUGALL: The issue of end fitting ejection was studied as part of a generic action item. I believe that action item has been closed. I don't have the material in front of me, but I'd be pleased to provide a synopsis of the basis for closure of that item if the Commission would like that.

MR. ELDER: Peter Elder for the record again.

This is one of the items that were covered in our CANDU safety issues, because we went back and looked at all the generic action items and made sure if they weren't closed that there was progress. So it has been closed since the 1990s. It's certainly not one of the one of the two CANDU safe issues that remains open.

So there were some studies done and we have concluded it and closed and eliminated the needs analysis in that accident scenario.

That said, just to say one other thing on this one, as Glen has pointed out at the beginning a lot of this work is to make sure that we don't get even into the design basis accidents with the pressure tubes. So we're doing a lot of work to make sure you don't even get to the design basis accidents.

Pressure tube failure is analyzed in detail as a design basis accident, and what we're looking at in terms of its behaviour as a design basis accident is that it then doesn't propagate to a more serious accident.

So the systems, the safety systems, are designed to handle a single pressure tube failure, and they must continue to make that -- meet those requirements that all of the systems can handle a pressure tube failure.

THE PRESIDENT: Thank you.

MEMBER SOLIMAN: Thank you.

THE PRESIDENT: Dr. McEwan.

MEMBER McEWAN: Thank you, Mr. President.

The term "hydrogen equivalent concentration" assumes that hydrogen and deuterium behave the same under the circumstances in the pressure tubes. My memory is that intervenors in the past have suggested that might not be the case.

Can you sort of elucidate/explain, please?

MR. McDOUGALL: The interaction of the hydrogen with the pressure tube is a chemical reaction, and so strictly speaking the metal in the pressure tube does not know the difference between the hydrogen and deuterium. The only exception to that rule is that -- this is getting really into the weeds technically, but there is something known as an "isotope effect". It has to do with the mass of the isotope that is diffusing through the pressure tube. That does have to be taken into account in really complicated modelling calculations.

If I remember the intervention correctly, the issue is whether industry had a good handle on whether deuterium was the primary isotope that finds its way into pressure tubes or whether there was also a contribution from hydrogen itself. There are a couple of recognized sources for hydrogen in some of the older CANDU reactor designs.

I'm aware of research that's been done in the industry to look into that question. I think the important thing to remember is that from the CNSC's perspective when we look at fitness for service assessments we don't care whether it's hydrogen or it's deuterium. We look at it as hydrogen equivalent and we say: what is the fate of that overall amount of hydrogen in the tube? To what extent does it affect the ability of the tube to perform its function?

So we don't really differentiate between the two. That tends to be more a fundamental research area of concern.

MEMBER McEWAN: So there is no difference in the chemistry, if you like, in the heat-up/cool-down periods, which I think you said are also important in terms of risk -- if that's the right word -- to the pressure tube?

MR. MCDOUGALL: That is correct. The key thing during heat up and cool down, the reason why hydrogen has an influence on pressure tube behaviour, is because at lower temperatures, when the concentration gets high enough, the hydrogen actually forms a separate chemical entity in the pressure tube material. It forms what's called a "hydride". And because this is, again, a chemical reaction, hydrides can be made of hydrogen, they can be made of deuterium, they can be made of some mix of the two. But the main reason we worry about them, from a pressure tube safety point of view, is that they're brittle. They share none of the properties of the original pressure tube material, which is tough and it's ductile. The hydrides are neither.

So the main influence of hydrogen on fracture toughness is because during the heat-up and cool-down regime the temperatures are low enough that the facture toughness is now being dominated by the presence of this brittle phase.

When you get to normal operating temperatures and the temperatures are high enough that the hydrogen is now dissolved back into the metal, the hydrides are not existing. This is the reason why you don't see a strong hydrogen effect when temperatures are higher and you're under normal operating conditions.

MEMBER McEWAN: So to be clear, the hydride formation is reversible?

MR. MCDOUGALL: Glen McDougall for the record.

Up to a point it is. There does become a point where the hydrogen concentration is high enough that the hydrides become a permanent feature of the tube. But that happens only in a very, very small part of the pressure tube, where the hydrogen levels have to be quite significant, and there's been quite a bit of industry R and D done to examine what the impact of that situation is on pressure tube integrity.

MEMBER McEWAN: Thank you.

THE PRESIDENT: Thank you.

Questions?

So just one last point. I think I like your chart 31, but I'm not sure I understand it yet. So just explain to me the yellows in there, because lots of yellows that started between 0 and 210, which I didn't understand, what was the concern when the pressure tube was still within design?

MR. FRAPPIER: Gerry Frappier for the record.

Before I hand it over to Mr. McDougall for details, just to be clear, what the yellow means is that the regulator is very interested in it. We're very interested in it because we project that eventually that could become a problem, and we want to make sure that we're ready for that.

So it's not an indication necessarily there's a problem right today, it's a: this is the focus area for the regulator to be basically ensuring that industry understands, plans, executes, all those things that we're talking about.

But for the specifics on some of the ones that were before 210, perhaps Mr. McDougall could explain.

MR. McDOUGALL: Thank you for the question, Mr. President.

I deliberately inserted some of those

yellow squares before 210,000 EFPH to demonstrate the typical progression for how our interaction is with industry.

If you consider the one labelled "Bruce Unit 3", at the very top-most bar, typically what happens is that industry recognizes that they have a degradation mechanism, that it's either becoming more serious or they get an improved understanding of its impact on safe pressure tube operation. They respond by doing research. We respond by clarifying our regulatory expectations. When the licensees have met our expectations, then the bar essentially turns back to green.

So in that particular case, Bruce Unit 3 had a particular issue with elongation of their pressure tubes. The pressure tubes actually increase in length as you operate, and up to a point, the reactor design is designed to accommodate that. But there is a particular issue with Bruce Unit 3 where they ran out of room to accommodate the problem. So Bruce Power went away, investigated options for dealing with that, and one of the options they came up with was a new maintenance practice.

So after extensive consultation with the regulator, they devised a process, and implemented the process. CNSC Staff’s enhanced regulatory scrutiny ended when the licensee completed the maintenance and demonstrated to us that they had resolved the problem.

THE PRESIDENT: So from that chart, if I understand correctly, the real area of concern now is the fracture toughness. And are you happy with the way you can measure the eddy current, I guess, or the hydrogen equivalent?

MR. McDOUGALL: Yes. There are three particular aspects of the enhanced regulatory scrutiny staff are undertaking currently. The first is to routinely monitor the hydrogen equivalent levels at the two parts of the pressure tube where this reduction in facture toughness is the most significant, and that's the very ends: very near the inlet and very near the outlet.

The second thing we do is we ensure that the licensees' models that they are developing to predict fracture toughness that they are still able to keep ahead of the hydrogen levels that the licensees are measuring right now and that they're predicting for the future.

The third part that's very important is validating these models, because as we noted earlier they only remove a certain number of pressure tubes to be destructively examined, which is the only real source of facture toughness data.

It turns out that those tubes by themselves will not provide you enough data to properly validate a predictive model, so the licensees have had to come up with some innovative ways of providing data for model validation. So we're having an ongoing conversation with industry about the nature of the validation activities, and just last year they produced a new plan going forward to 2021 demonstrating the tests that they intend to continue doing to convince us that their models are valid for future use.

MR. FRAPPIER: Gerry Frappier.

If I could just wrap that up a little because I think this slide is very, very keen. It's one of the main messages we wanted to leave you with today. Because although there's lots of degradation mechanisms, as seen there, and a lot of research has gone on and a lot of attention from the regulator on all of them, we believe that coming for the relicensing of both Pickering and Bruce the key focus, as indicated here, is going to be on fracture toughness.

That's going to be a bit of a different conversation than has occurred in the past, where a lot of it was about elongation, about physical changes, about, you know, spacers, and spacers moving all over the place.

But if we look forward, past the 247,000 hours, then the key item becomes facture toughness. That's something that is new for a lot of people, but it will certainly be an item we're going to have to talk about at the relicensing hearings.

THE PRESIDENT: Okay. Thank you.

Any final words industry wants to share with us?

MR. SAUNDERS: I think in general just a couple of points that I think probably go without saying, but I'll say them anyway. I mean pressure tubes are really important to us, not just for the safety reasons, but for also for our ability to predict ongoing operations. So you can be sure that we are going to continue to invest in the effort and the R & D to make sure that we have models that truly predict what the pressure tubes are doing.

I think it's also important to just understand the end-of-life comment. I mean when designers design a plant, they give you a sort of minimum design life. That's primarily for the investors and the people that are operating the plant, because you want to know: how much money am I going to have to continue to invest to keep the plan operating?

It doesn't necessarily mean that piece of equipment will just suddenly cease to be useful when you get to end of life. It means you need to monitor it. And we have the asset management and the testing programs in place so that we can do that over a whole range of equipment -- not just pressure tubes, but pressure tubes clearly are a key component in the reactor and we couldn't operate without them.

So they will continue to get all the attention they need to make sure we can predict their operations and their life limits, if they exist.

THE PRESIDENT: Okay. Thank you. We will break for lunch. This closes the meeting. We will reconvene at one o'clock with a public hearing.

Thank you.

--- Whereupon the meeting adjourned at 12:16 p.m. / La réunion s'est terminée à 12 h 16