

Freeze Sealing and Ice Plugs

Q&A

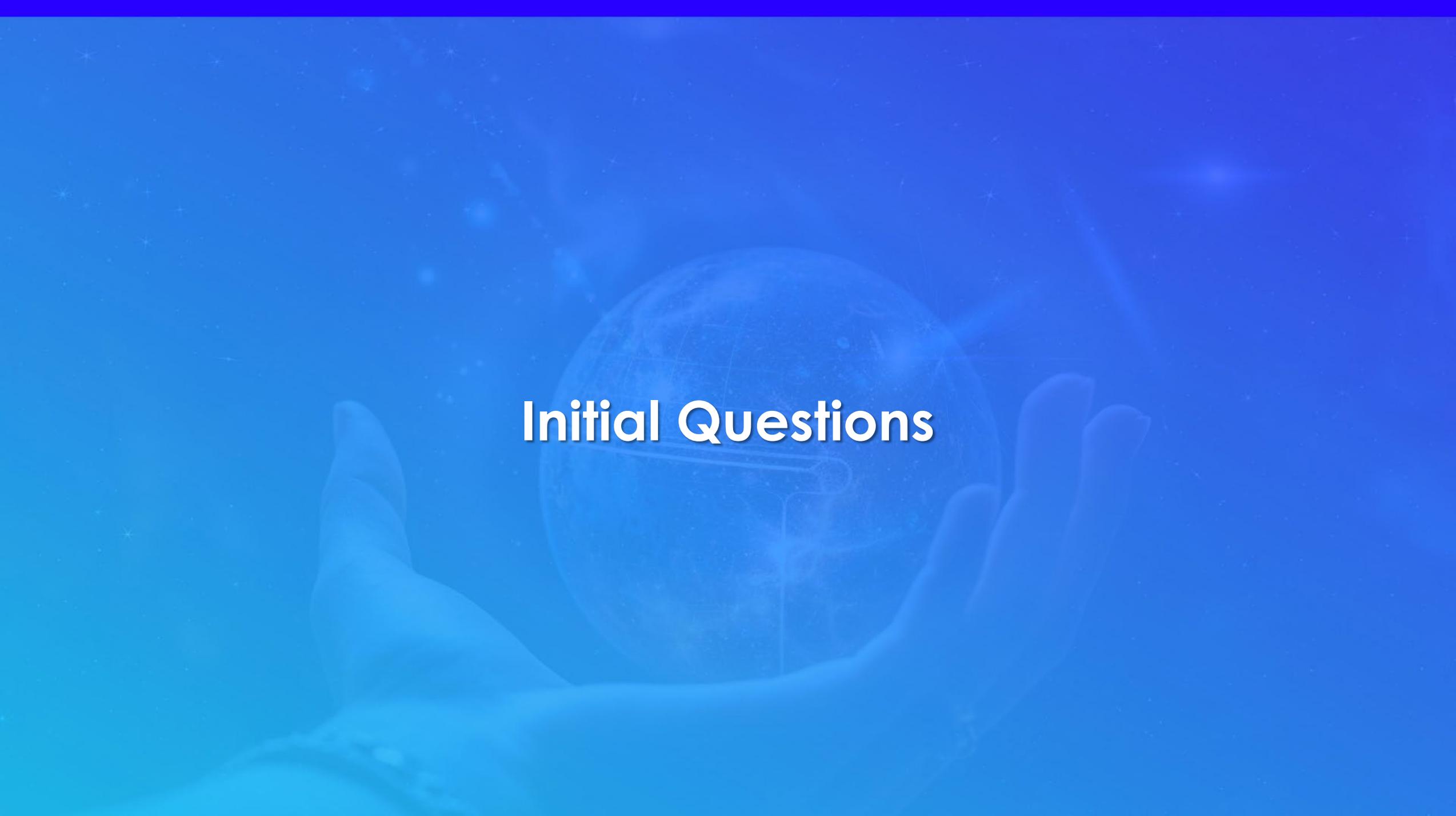


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Background

The following is a response to questions received on Freeze Seals. A Webex was conducted on December 1, 2025 to discuss the topic. This presentation captures all questions and answer discussed during the Webex. The responses to questions are based on content from EPRI report 1021507 which is publicly available.



Initial Questions

Question #1

The EPRI Guideline (Update of TR-016384-R1) states that ice plugging is feasible for 12-inch pipes in the primary circuit. We would like to ask EPRI experts what justification/analysis was performed for this statement (i.e., why is ice plugging considered feasible for 12-inch piping in the primary circuit), and whether any supporting analysis or calculation basis can be shared with us.

Question #1 – EPRI Response

- The report notes in Appendix A, Table A-1 that the information on freeze seals and sizes were performed by a vendor at stations in the US and Canada. The sizes quoted in the report match the data in this table. The actual performance of the freeze seals by the vendor was the basis for the table and hence the basis for the information in the report. Calculations differ greatly based on diameter, pressure, temperature of any adjacent operating systems and other factors such as type of freeze to be performed. Please note in Appendix B that a 12” freeze could take up to 10 hours to form and can take a significant amount of CO₂.

Question #2

For ice plugging operations on large-diameter pipes, does the pipe orientation (horizontal vs. vertical) make a difference during implementation? Is ice plugging permissible for vertical pipes?

Question #2 – EPRI Response

- The orientation is not the issue per se as is the ability to completely fill the piping with no voids. The piping must be water solid and this is accomplished via venting the line to remove the air. With a horizontal line you would have to have a vent on the top of the piping to ensure the pipe is full. Vertical lines are generally easier to ensure they are full.

Question #3

- Has ice plugging ever been performed on the primary circuit without defueling? If not, what are the risks associated with performing ice plugging on the primary circuit in a non-defueled state? What additional measures and assessments would be required to potentially advance ice plugging operations under this condition in the future?

Question #3 – EPRI Response

- Freeze seals have been performed on the primary plant on lines such as RHR, NI and other systems. We do not have any direct experience with Reactor Coolant piping itself. However, we believe it has been performed on small bore piping with available crimping tools on site as a backup in the event the freeze failed. In the EPRI freeze seal guide 1021507 appendix C, there are three documents that address compensatory actions to take when performing freeze seals. Freeze seals form a protective barrier by the formation of an ice block. That block must be maintained and as such there can be many factors that can impact its ability to move or melt. Use of a freeze seal on primary or reactor coolant piping which can drain the vessel below the nuclear fuel should be avoided. This application is considered a “last option”. NRC comments from the Inspection manual can be found in Appendix C of the EPRI report to give additional insights.

Question #4

- Has any verification/validation been conducted regarding the use of an ice plug as a primary circuit pressure boundary with fuel loaded in the core?

Question #4 – EPRI Response

- Page F-2 of EPRI 1021507 covers operational experience and notes that attempts were made to use a freeze seal on the pressurizer surge line however the freeze would not fully form. There is not a great deal of information that has been shared on freeze seals on Reactor coolant piping. As noted in question #3, the risk associated with any potential to drain below the level of fuel in the vessel inhibits most utilities from attempting freeze seals as an isolation method and most will default to an off-load of fuel.

Question #5

- Has research been conducted on ice plugging at weld seam locations? If so, what were the conclusions of this research?

Question #5 – EPRI Response

- Service Companies prefer to use a Mechanical Line Stop if a weld location is involved but note that they would perform an analysis of the weld location (i.e. Cryostop Web Page) and no information about specific freezes having been applied over weld locations is available.
- Section 2.8.1 of EPRI 1021507, page 2-25 states *“There is no information available on the effects that freeze sealing or extreme temperatures have on welds. However, for stainless steels, depending on the material’s chemistry and the original fabrication process of the weld, the material might be sensitized (particularly if no post-weld heat treatment was performed). Weld sensitization results in an increased precipitation of metal carbides at the grain boundaries, which reduces the material’s resistance to intergranular stress corrosion cracking and intergranular fracture in general. Exercise is to be performed at a stainless-steel weld location. Prior knowledge of the weld fabrication history—such as multiple repairs or volumetric examination—would possibly indicate if additional caution should be taken to ensure that no impact or excessive loading is induced on the material during the freeze sealing operation. **In general, it is good engineering practice to place freeze seals away from any welds in the pipe.**”*

Question #6

- After ice plugging a large-diameter pipe, what detection methods are available to monitor the thawing and migration path of the ice plug inside the pipe?

Question #6 – EPRI Response

- Thermocouples are used to monitor the formation and maintaining of the freeze plug. Once frost bands were established (Section 4.6), Section 4.7 (Maintaining the Freeze Seal) notes: *“Every 15 minutes, log temperatures, O2 levels, LN2 bottle levels, glycol levels, the condition of frost bands, and so on as applicable. No one indication is adequate to ensure freeze plug integrity”*.
- Section 3.7.5 of 1021507 notes that *“Ensure that thermocouples are installed upstream and downstream of the jacket. Also, be sure that there is a thermocouple to measure the temperature of the LN2/CO2 in the jacket. It is essential that the temperature be monitored on the pipe walls inside the freeze chamber. Insulate the thermocouples so that the readings indicate surface temperature, not refrigerant temperature. The freeze plug jacket temperature will be monitored to ensure that LN2 flow is maintained.”*

Question #7

- If research or implementation of ice plugging has been performed at weld seam locations, what supplementary non-destructive testing or other measures are required post-plugging to verify the ice plug's impact on the weld's internal structure and stress?

Question #7 – EPRI Response

- Freezes should not be placed over welds as the impact is not bounded fully with research as each weld is unique. Nondestructive testing that should be used to evaluate post freeze impacts includes Liquid Penetrant or Magnetic Particle (section 3.6.3.2). However, the full extent of NDE for areas such as a weld should be coordinated through experts in the EPRI NDE or Weld Group.

Question #8

- Have ice plugging tests been conducted on metallic materials commonly used for primary circuit pressure components? If so, what was the observed impact on their material properties?

Question #8 – EPRI Response

- Yes, a great deal of research has been performed on Freeze seals and the impact on metals used in the primary circuit. The specific steels are reviewed in section 2.9 of 1021507 and include Carbon Steels and Austenitic Stainless Steels.

Question #9

- In US NPPs, apart from emergency use, is there experience with performing ice plugging during a normal refueling outage without defueling, in order to conduct low-low water level maintenance? Is this practice widely applied?

Question #9 – EPRI Response

- The application of the use of Freeze Seals below the vessel waterline which could impact the level of water in the core with fuel loaded in the core would not be widely applied. Instances where the impact could drain the core would deem a core fuel offload be performed due to the high risk.

Question #10

- How is the frictional resistance of an ice plug determined?

Question #10 – EPRI Response

- Section 2.4 of 1021507 discussed friction and formation of the Ice Plug. Section 2.5.1 calculates the forces applied. Appendix B has charts that denoted the pipe diameter and the suggested length of the freeze jacket to ensure a large enough Ice Plug to ensure the plug has acceptable friction.

Question #11

- How is the thawing rate of an ice plug controlled, and what heating methods can be used?

Question #11 – EPRI Response

- Section 4.8.2 of 1021507 discusses Thawing. Normal melting is preferred however heat tape, strip heaters and infrared lamps have been used. Open flame is not recommended. An engineering evaluation should be performed if rapid heating is required. This evaluation would usually require additional NDE examinations.

Question #12

- Has experimental research been conducted on the stress induced on the pipe during ice plug formation?

Question #12 – EPRI Response

- Stresses induced on piping has been studied and is covered in section 2.7 “Physical Effects Caused by Freeze Sealing Piping Materials”

Question #13

- Are there limitations or application experiences for ice plugging operations when boron concentration is high?

Question #13 – EPRI Response

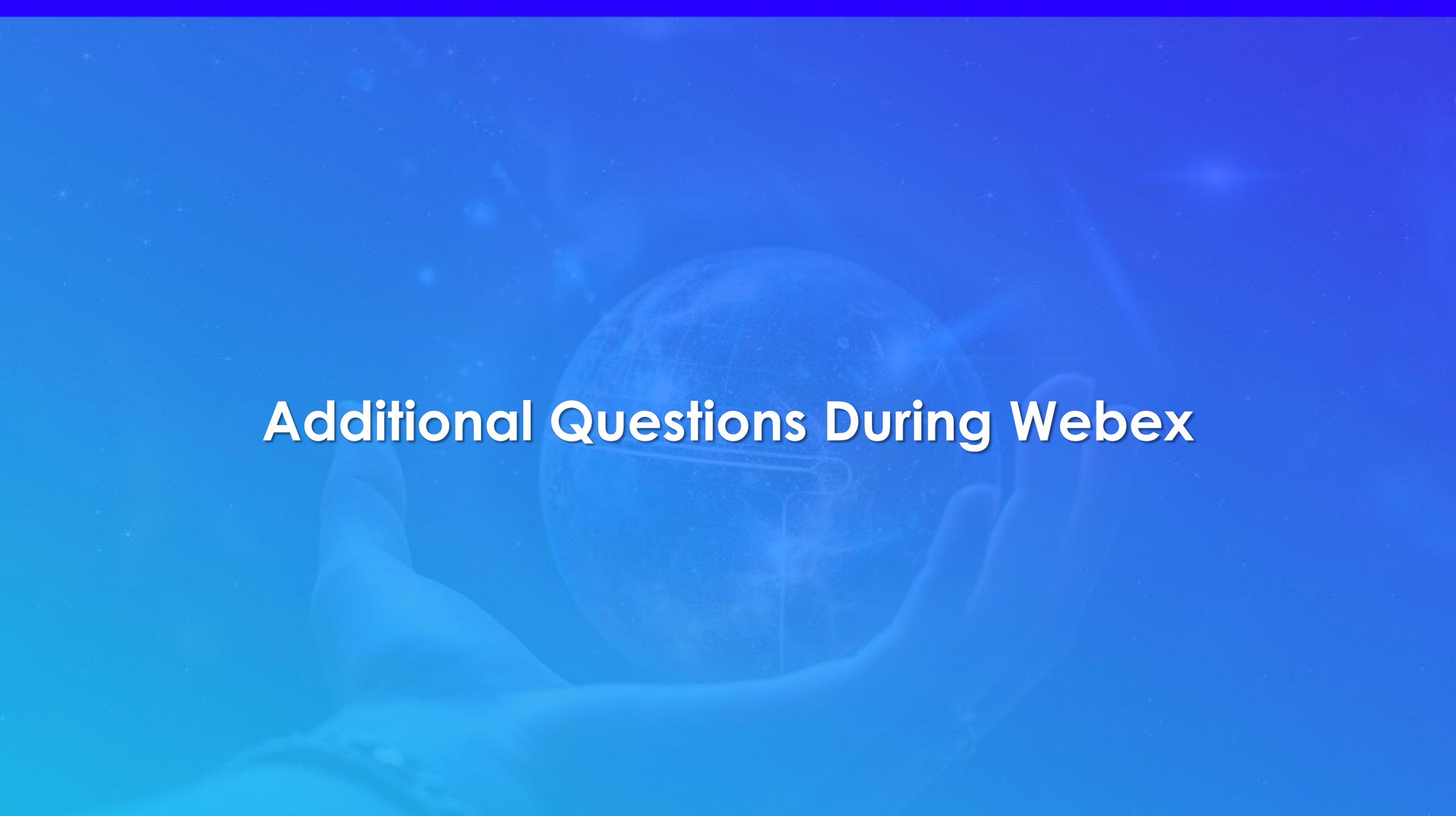
- Freeze seals are determined by temperature and frost bands. The presence of boron in solution is not noted as a factor other than the potential impact to time when performing a freeze.

Question #14

- The EPRI report (Update of TR-016384-R1) was published 15 years ago. Has it been revised or updated since then? Have there been any changes or upgrades to ice plugging tools/equipment?

Question #14 – EPRI Response

- In 2017 an freeze seal animation was created by EPRI (3002010656) to be used as training aide to describe the process. During the creation of this tool the process of Freeze Sealing was reviewed, and it was determined the guide 1051507 was still accurate and relevant therefore no revision was required. A review of the current vendor web sites and industry practices does not reflect significant change.



Additional Questions During Webex

Question 15

- Are there requirements for specific materials that can be used for ice plugs? Ex. Is stainless steel allowed?

EPRI Response:

- Both stainless and carbon have been used. Reference Appendix A in the EPRI guide and specifically section 2.7. The biggest difference is the temperature used and time of ice formation. Ex – carbon steel will have a lower temperature limit of -40C

Question 16

- What if the pipe has an internal corrosion coating/liner, would it effect the freeze?

EPRI Response:

- EPRI would advise against using ice plugs in pipes with internal coatings. Two main reasons, 1) the quality of the ice plug could be impacted and the concern would be the ice plug being negatively impacted by a pipe with a coating as coatings are an "unknown" factor and 2) it is likely the freeze application could impact the coating itself allowing the fluid to leak through the coating and expediting piping degradation

Question 17

- Are there any laboratories in the US that demonstrate the technology?

EPRI Response:

- No. One can google “freeze seal or ice plugs in piping” and see examples of applications. As an alternative, EPRI created an [freeze seal animation](#) that demonstrates the process as noted in in previous questions.

Question 18

- When using a freeze seal, are there any special approvals needed?

EPRI Response

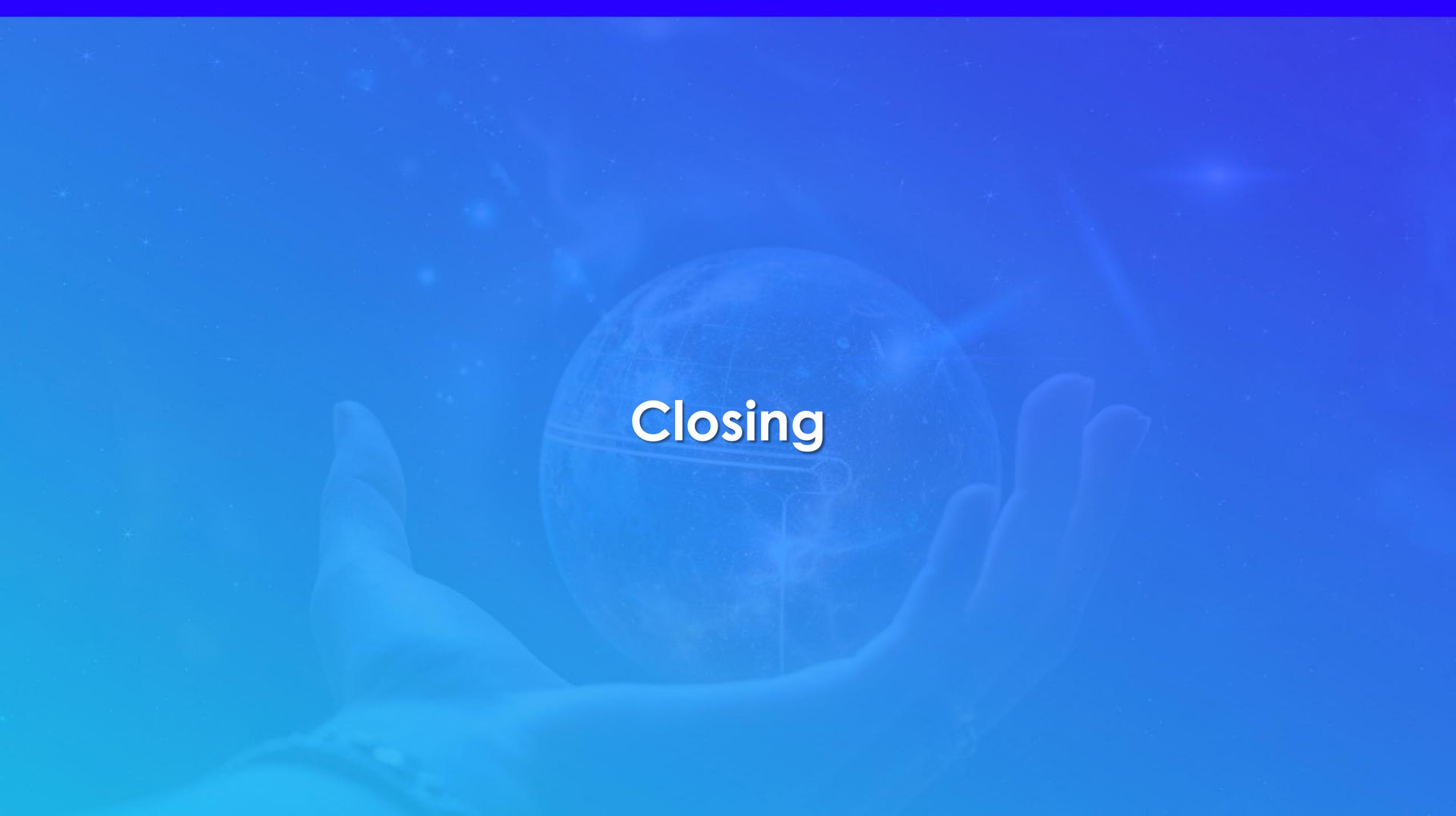
- No special approvals are needed. However, most stations would have a designated procedure for use as outlined in the NRC Technical Manual

Question 19

- Can you further explain the clamping device used in Question #3?

EPRI Response:

- Hydraulic crimper was available for use IF leakage occurred and needed to be stopped. This is referred to as compensatory actions as noted in the NRC Inspection Manual in Appendix C.

The image is a blue-tinted graphic. In the center, a pair of hands is shown from the wrists up, holding a globe of the Earth. The globe is semi-transparent, showing the continents and latitude/longitude lines. The background is a deep blue with a subtle pattern of white stars and faint, glowing lines, suggesting a cosmic or digital theme. The overall mood is serene and global.

Closing

Summary

- Freeze seals are safe viable barriers, however since they require specific actions to be maintained, they are often a last resort for isolation.
- Use of a freeze seal to allow maintenance below the level of the core which could expose fuel if the seal was lost would be viewed as an extreme high risk based on the potential impact to nuclear fuel and the public therefore are not recommended. In general, EPRI is not aware of any large bore freeze seals having been used on Primary Reactor Coolant Piping with the fuel not having been offloaded.



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