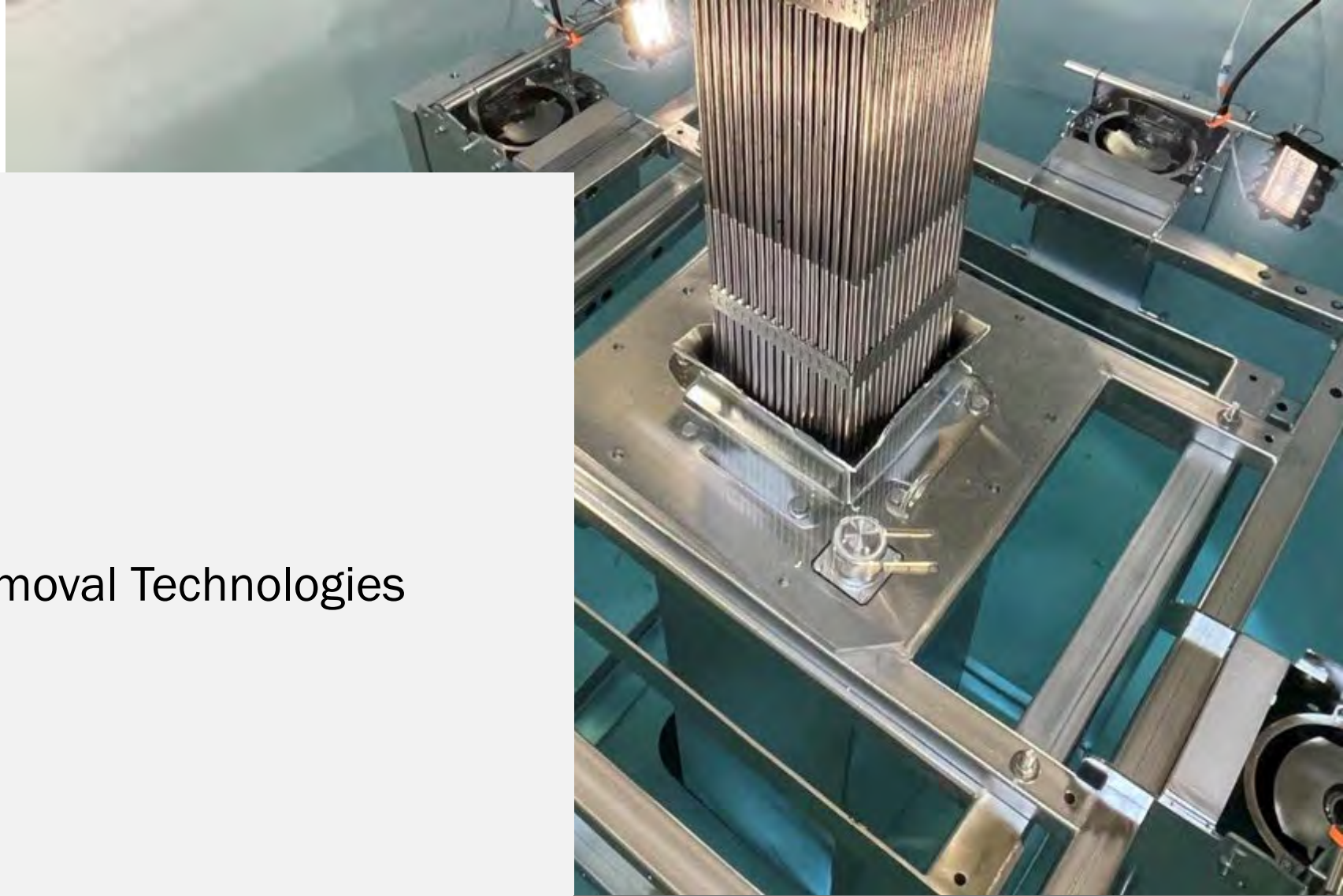




Reducing CRE

Advanced Source Term Removal Technologies

Chuck Marks, Ph.D., P.E.

ANS Webinar
October 15, 2025



Innovation for the next chapter
in nuclear energy

Chuck Marks, Ph.D., P.E.

President, Dominion Engineering, Inc.

- At Dominion Engineering, Inc. since 1998; President since Jan. 2025
- 25+ years specializing in nuclear plant chemistry, materials science, and component degradation modeling
- B.S. in Chemical Engineering, Tufts University; Ph.D. in Chemical Engineering, University of Maryland, College Park
- Technical Editor, EPRI PWR Primary & Secondary Water Chemistry Guidelines
- Led numerous source term assessments (PWR, BWR, CANDU)
- Multiple outage support deployments (secondary side cleaning)
- Lives in McLean, VA with his wife; enjoys running his daughter's Girl Scout troop



Chuck Marks, Ph.D., P.E.

Dominion Engineering was acquired by Allied Power in 2023

Allied Power Platform:



Advanced Source Term Removal Technologies

Dominion Engineering, Inc. Proprietary

Agenda

- Introduction
- Where do you put the source term?
- Removing local source term
- Attacking the source
- Whole system source term reduction
- Wrap Up

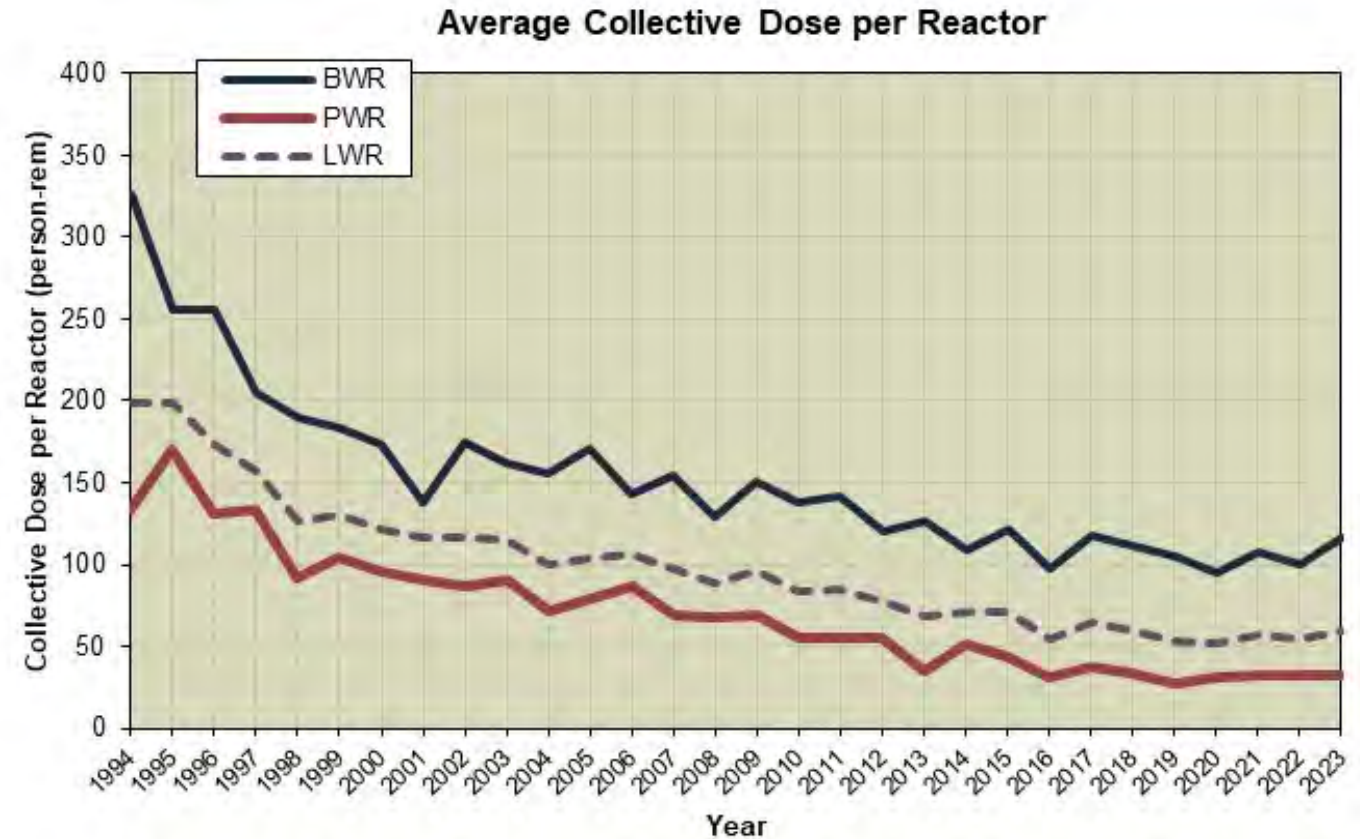


Collective Radiation Exposure

Radiation Safety

- CRE is an industry metric for radiation exposure of plant personnel
- Individuals are protected by annual limits
- CRE provides a metric for overall performance

Long Term Trends in CRE: Better but Stalled

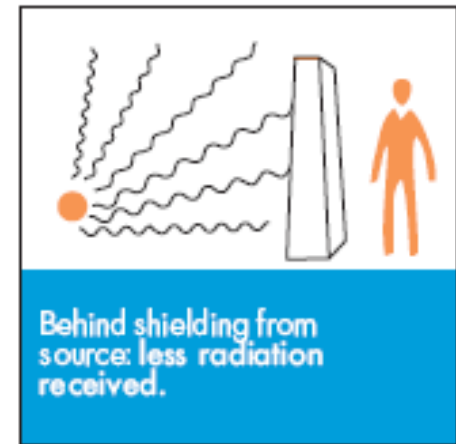
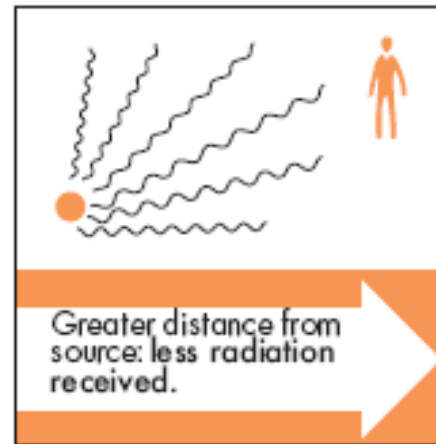
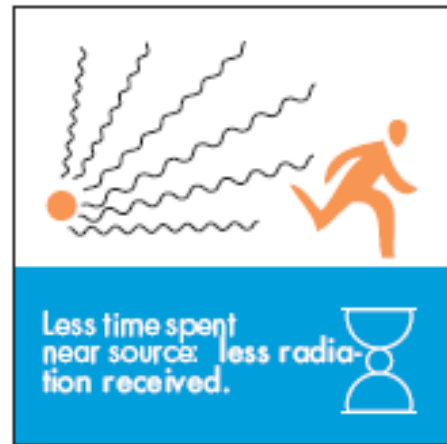


Source Term

Effects on CRE

- CRE can be mitigated by less time, more distance, and more shielding
- CRE can also be mitigated by lowering the source term
 - Provides benefits for contingencies (e.g., extended time)
 - Might provide benefits for cost and critical path

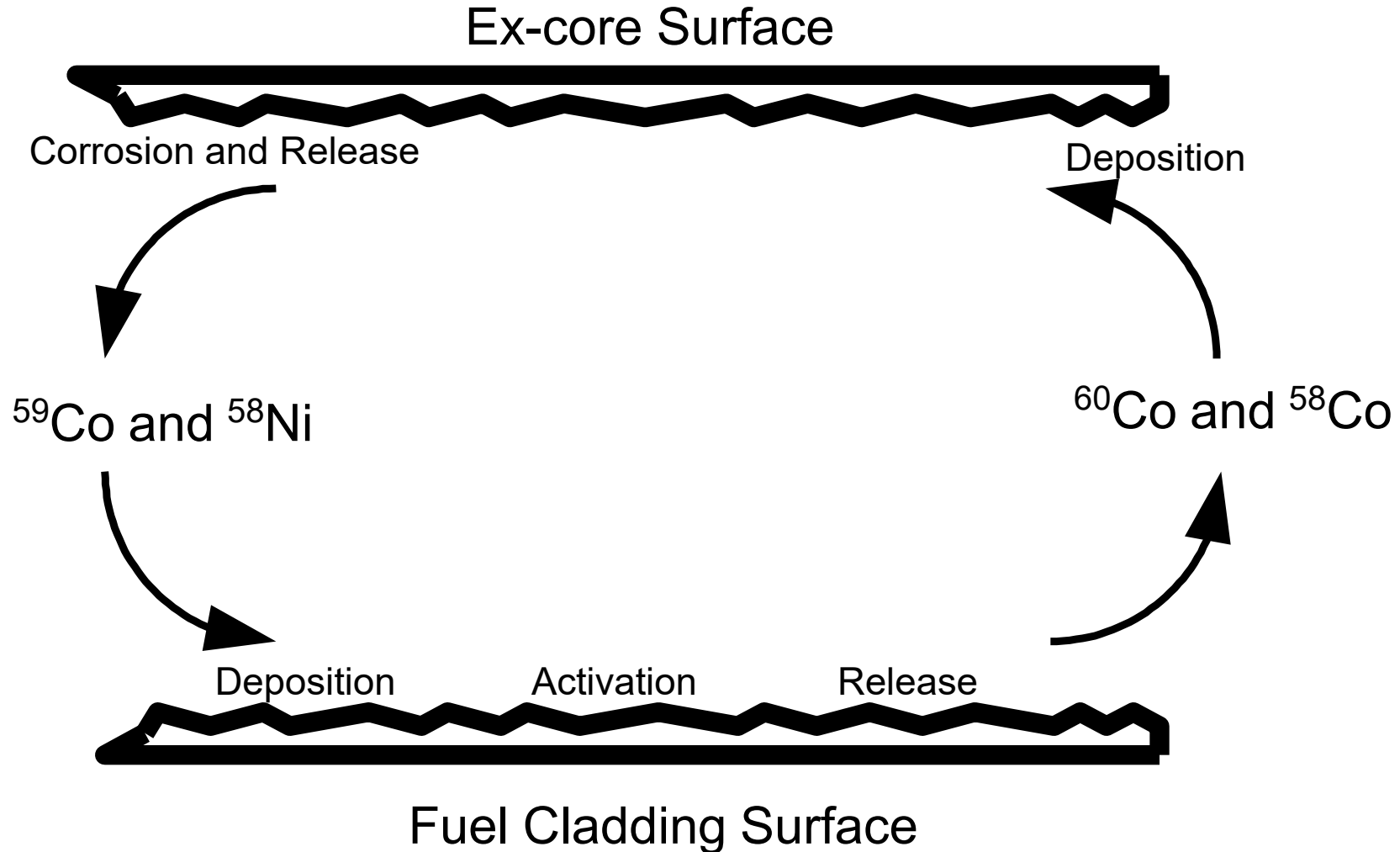
**Lower
Source
Term**



US NRC

What Is Source Term?

Activated Corrosion Products



CRE Mitigation

Holistic Approach

- Time – Distance – Shielding
- Source Term

Source Term is Everyone's Job

Chemistry

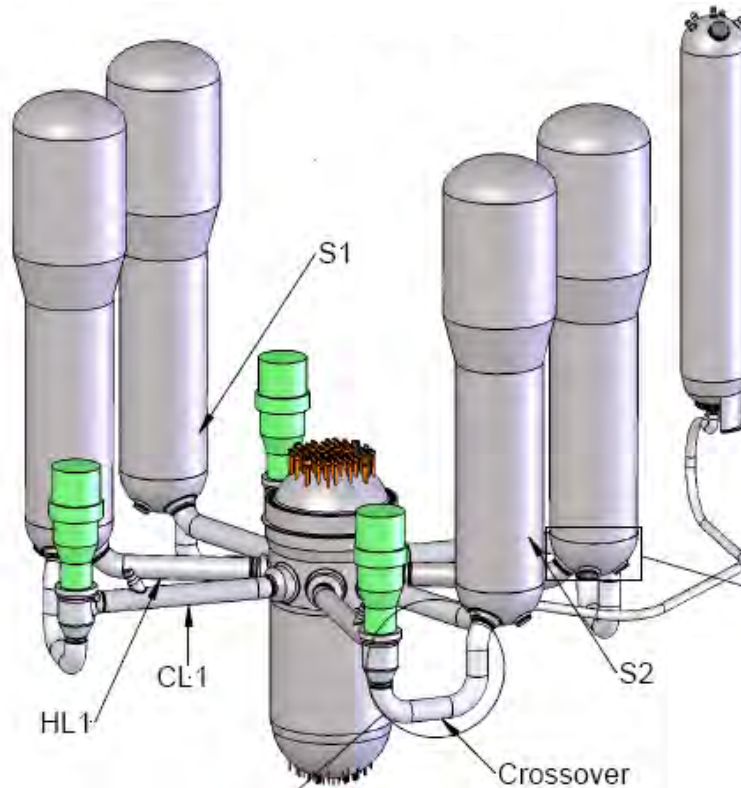
Ops

RP

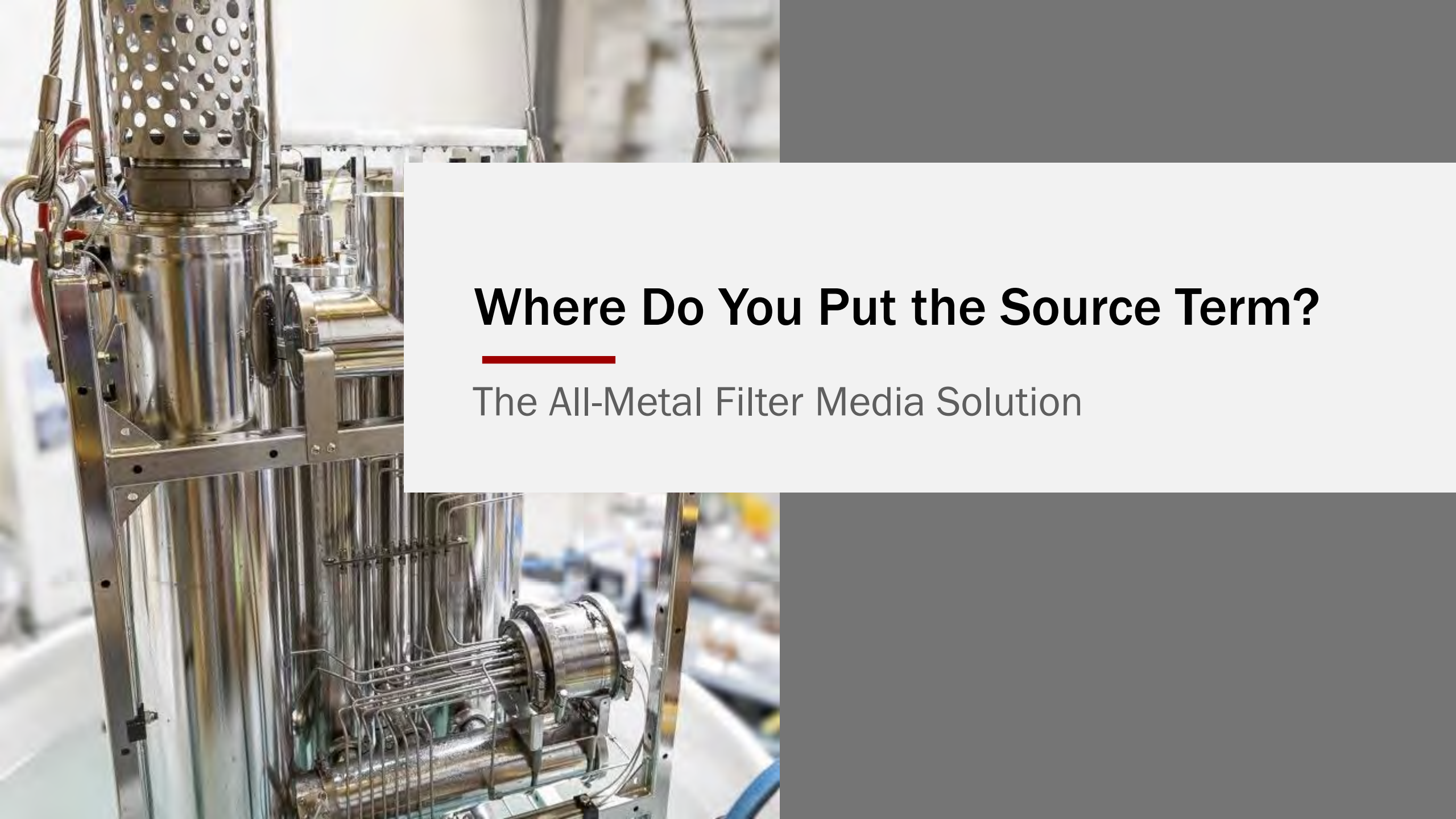
Procurement

Outage management

Reactor engineering



- Success Starts with a Source Term Assessment
- Is there a general issue?
 - Is it hot spots?
 - Is it your reactor design?

The background of the slide features a close-up photograph of industrial machinery, specifically a large, vertical, stainless steel filter media vessel. The vessel has a perforated top section and various pipes, valves, and electrical conduits attached to it. The lighting is bright, highlighting the metallic surfaces. The text is overlaid on a white rectangular area in the center-right of the image.

Where Do You Put the Source Term?

The All-Metal Filter Media Solution

The All-Metal Filter Media Origin Story

I Don't Want Your Irradiated Crud

- In the late 1990s, Dominion applied its expertise in ultrasonic cleaning to the issue of PWR crud induced power shifts (CIPS)
 - Formerly called axial offset anomaly
 - Boron hides out in fuel deposits, changing the neutronics of the core
- Partnering with EPRI, Dominion developed ultrasonic fuel cleaning for PWRs
 - A CIPS mitigation technique with recognized source term advantages
- Source term benefits led to a trial application at Quad Cities, a BWR
- The best available technology at the time was pleated plastic filters
- Plastic filters were not adequate to BWR UFC needs, leading to the development of the all-metal filter media (AMFM) for UFC

All-Metal Filter Media

AMFM Benefits

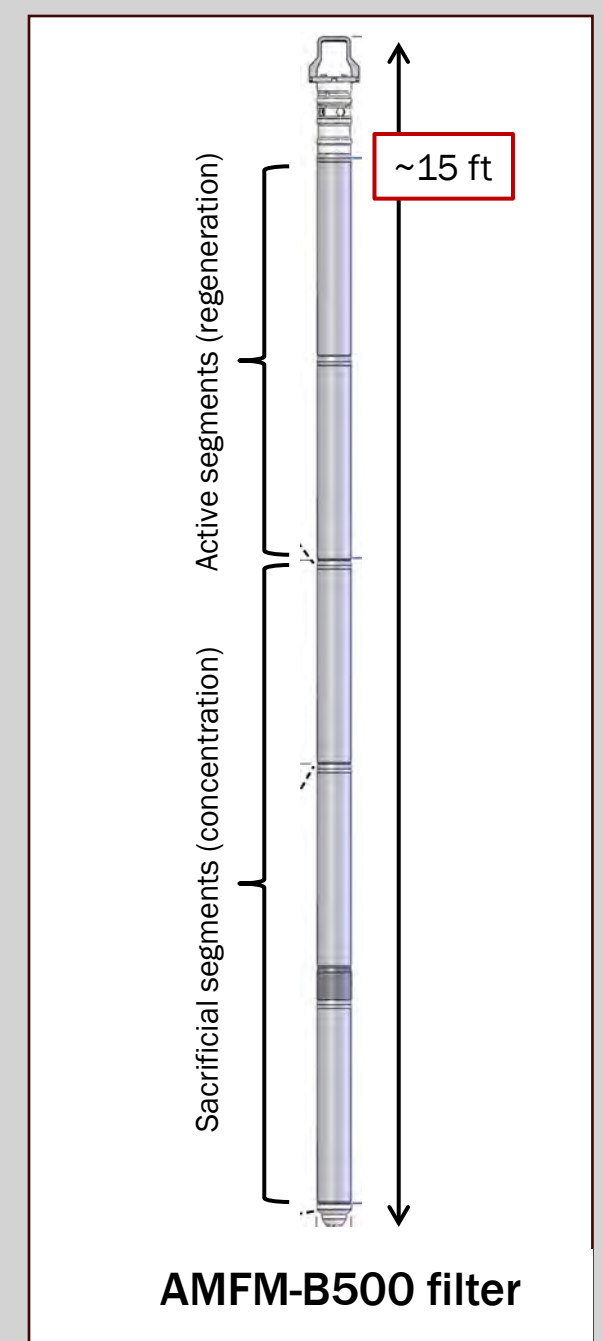
- No degradation
 - No time limit
 - Resistant to radiation
 - Resistant to chemical exposures
 - No (practical) temperature limits
- No chemical contamination
 - No residual chloride or silica
 - Washed clean during factory acceptance testing
- No weight limits
 - Can be loaded solid



All-Metal Filter Media

Regenerable

- Regeneration technology allows the utilization of the entire filter volume, not just the media surface
- Capacity increase >100x
- Regeneration cycles can be automatically programmed or initiated manually depending on the application
- Always underwater or behind shielding package



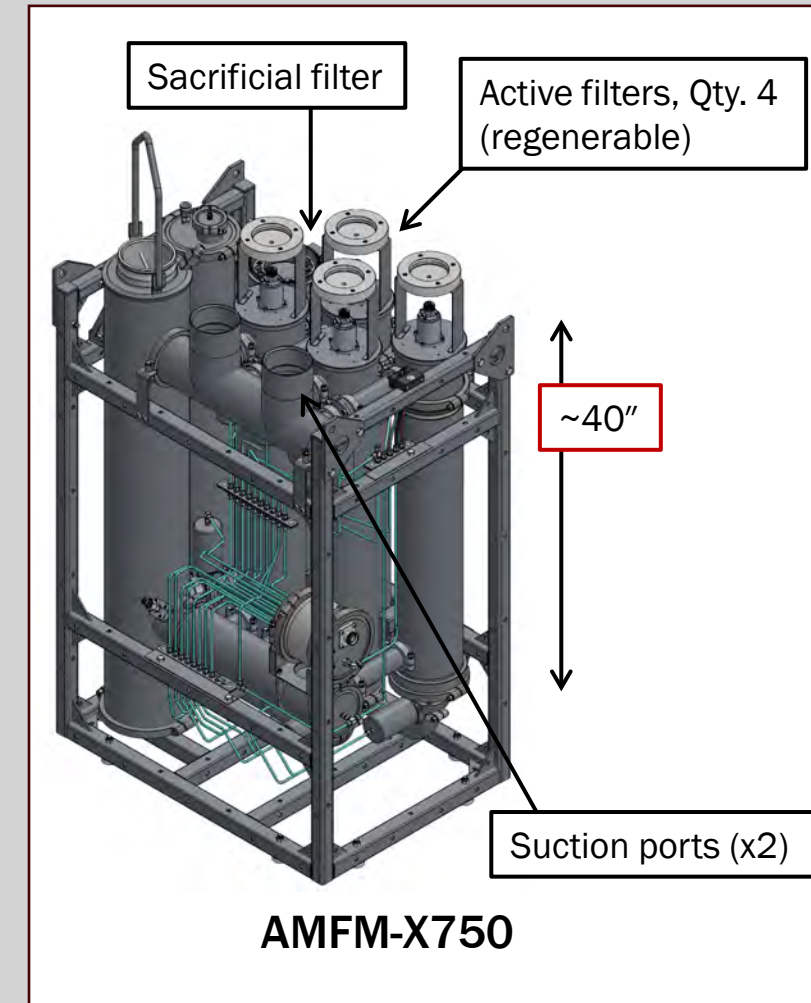
AMFM-B500 filter

All-Metal Filter Media

Multiple Form Factors Optimized for Application

- PWR or BWR fuel assembly form factor
 - Handle with existing tooling
 - Store in SFP racks
 - Disposal with spent fuel
 - No time limit on storage (no degradation)
- Direct to 10B cask

Problem Solved!





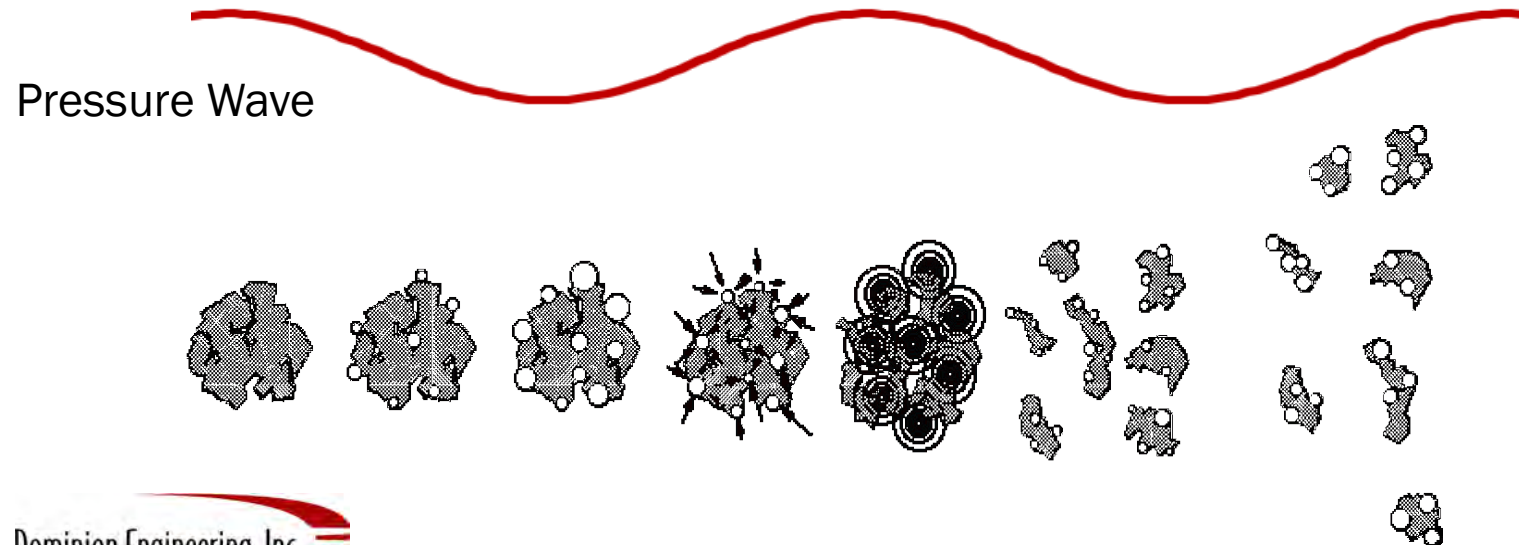
Removing Local Source Term

Leveraging Ultrasonics

Ultrasonic Basics

Physics behind Cleaning Technology

- Ultrasonic cleaning works by inducing cavitation on dirty surfaces
 - High frequency sound waves (25 kHz) are directed to the surface to be cleaned
 - Alternating high and low pressure from sound waves cause small bubbles to form and oscillate on the fuel surfaces (cavitation)
 - Collapsing bubbles form small jets of high velocity water that break apart deposits



**Crud remains in solid form.
Filterable!**

Ultrasonic Basics

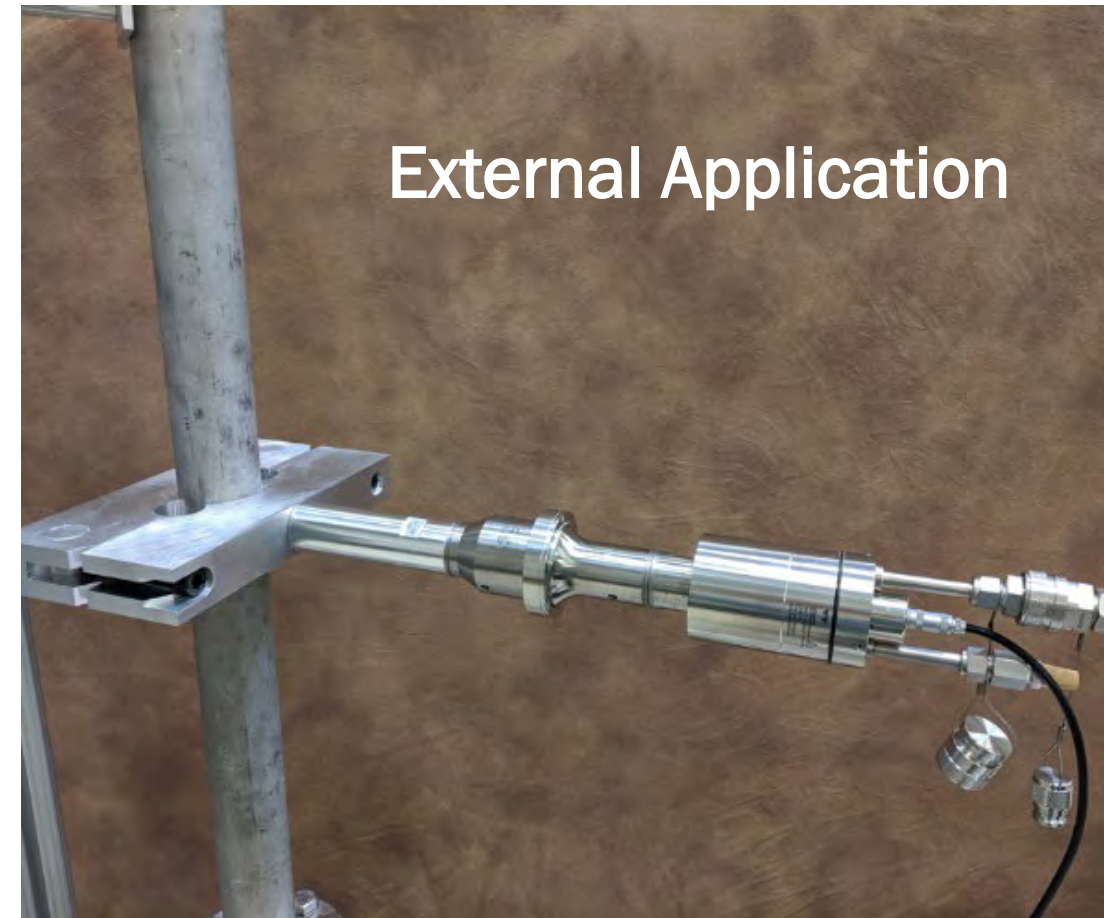
Disruption of Deposits and Oxides

Video In Attachment



Ultrasonic Cleaning Process

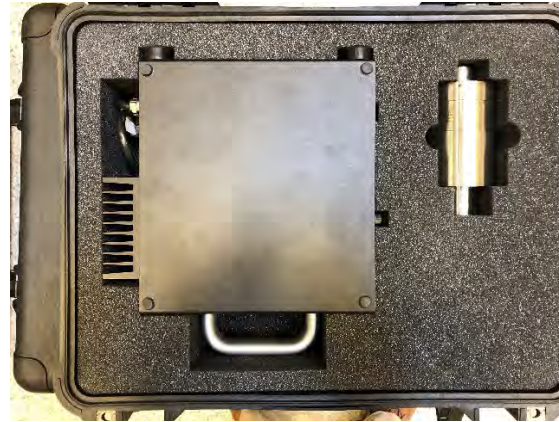
- Prerequisites
 - Insulation must be removed from piping
 - Water must be present in the piping (can be flowing or static, fully (preferable) or partially filled)
 - Water must be near ambient temperature (e.g., $<65^{\circ}\text{C}$) and pressure (e.g., <7 bar-g)
- NU-DEC™ transducer assembly is installed on piping
- Equipment is energized
 - Cleaning time is typically about 10-15 minutes
 - 3 to 5 feet of axial pipe length is effectively cleaned
- Equipment is then moved to the next cleaning location



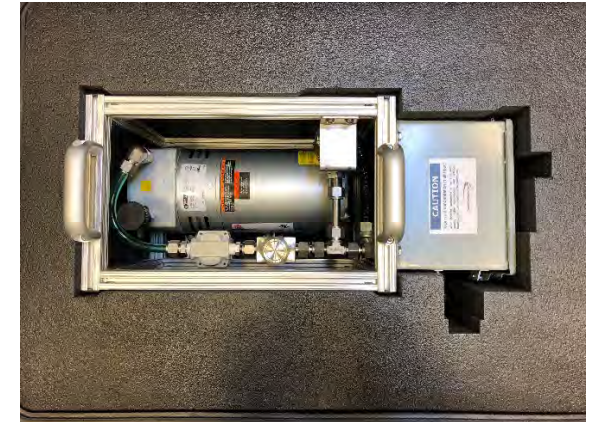
Typical NU-DEC™ Equipment Set

- Base System

- Ultrasonic generator
- NU-DEC™ transducer clamp assembly
- Compressor (for transducer cooling air)
- Power cables, hoses, impedance analyzer
- Tool kit



Portable ultrasonic generator



Portable compressor

- Optional:

- Additional clamp assemblies for different pipe sizes
- 4000-Watt portable battery pack
 - Eliminates need for temporary power carts
 - Simultaneously powers ultrasonic generator and compressor
 - 3.6 kW-h capacity (more than a typical work shift of NU-DEC™ decontamination)
 - Overnight recharge on 120V outlet



Power cables / air hose



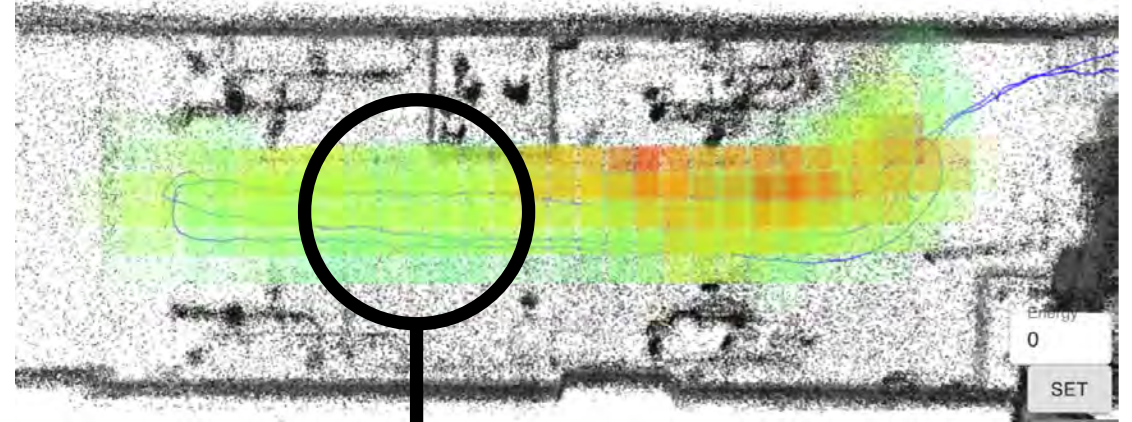
NU-DEC™ transducer clamp assembly
(NPS 2" shown)

Typical Results

Small Diameter Piping

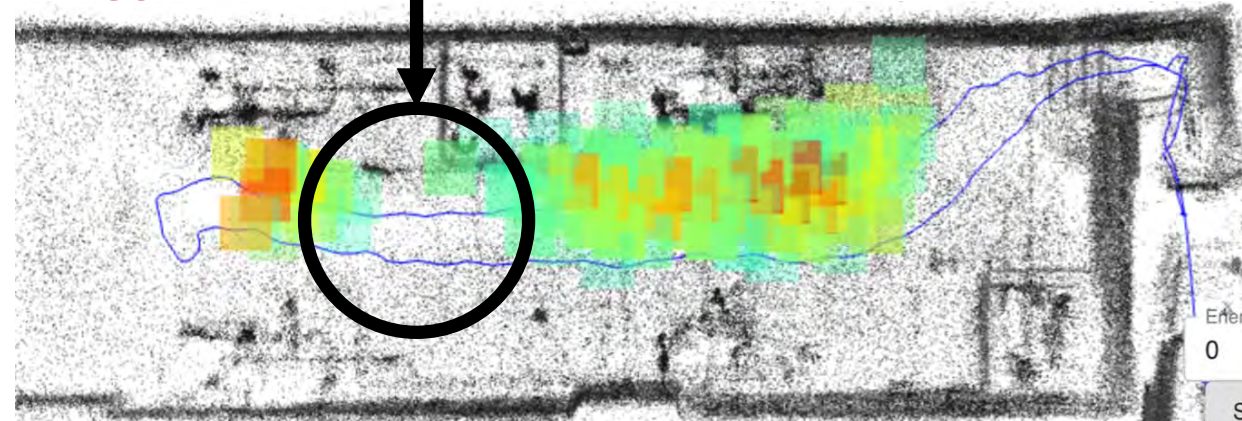


Before



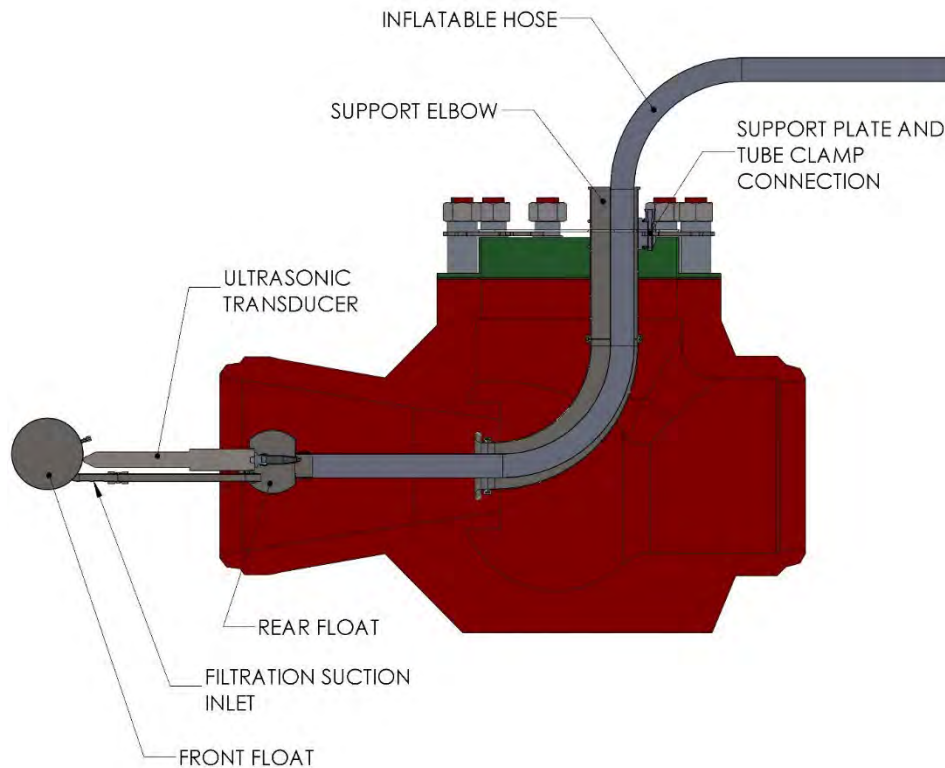
Transducer location shows essentially complete activity removal

After



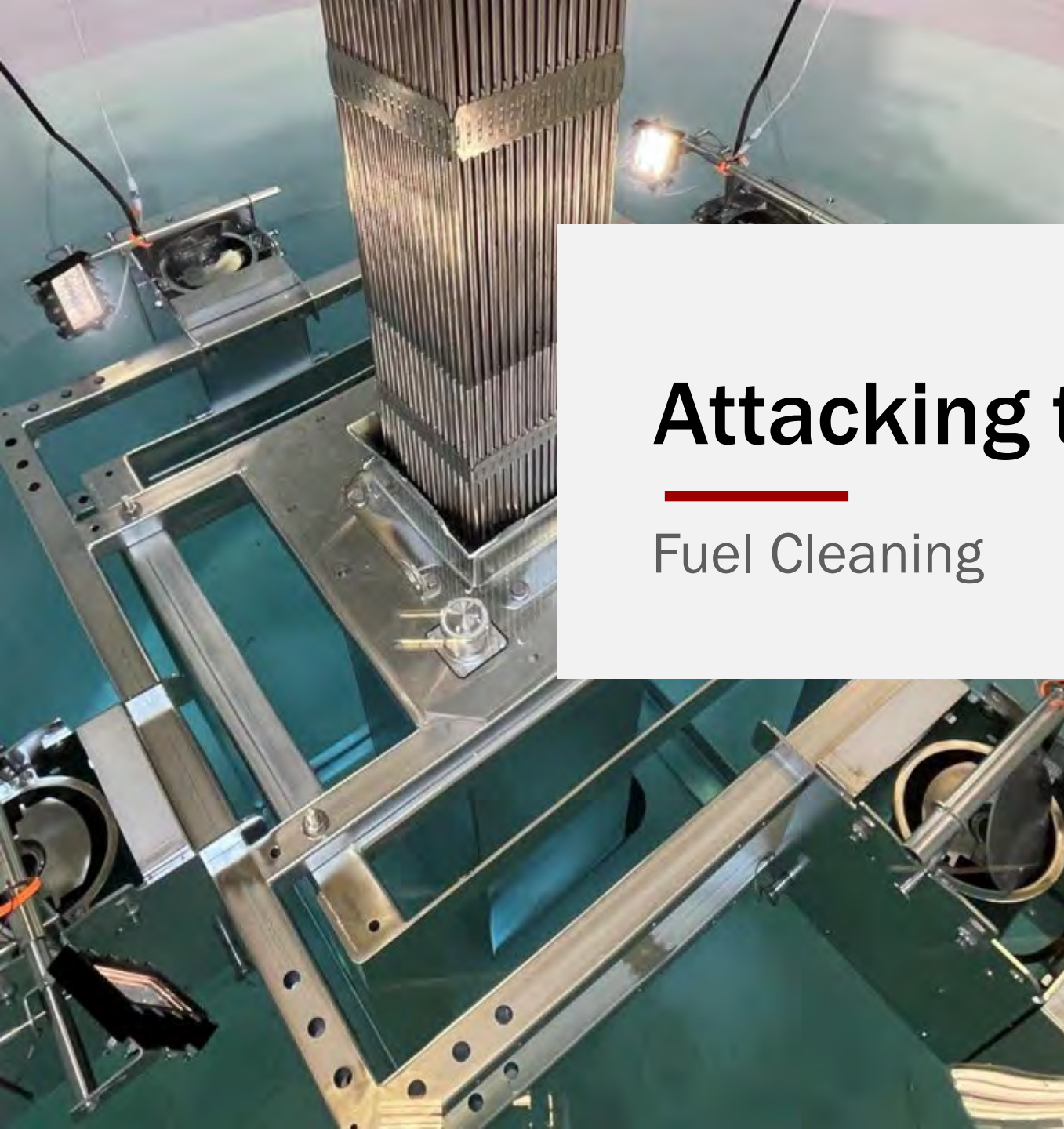
Example Application – Internal Cleaning Results

- Transducer was operated for 10 min then moved 12-18”.



FCV Piping A Dose Reduction			
Survey Location	Area Dose Rate (mR/h)		Dose Reduction
	Before Cleaning	After Cleaning	
Upstream piping (outside shielding)	280	234	16.5%
Downstream piping (outside shielding)	383	275	28%

FCV Piping B Dose Reduction			
Survey Location	Area Dose Rate (mR/h)		Dose Reduction
	Before Cleaning	After Cleaning	
Upstream piping (outside shielding)	230	171	25.5%
Downstream piping (outside shielding)	463	223	51.8%



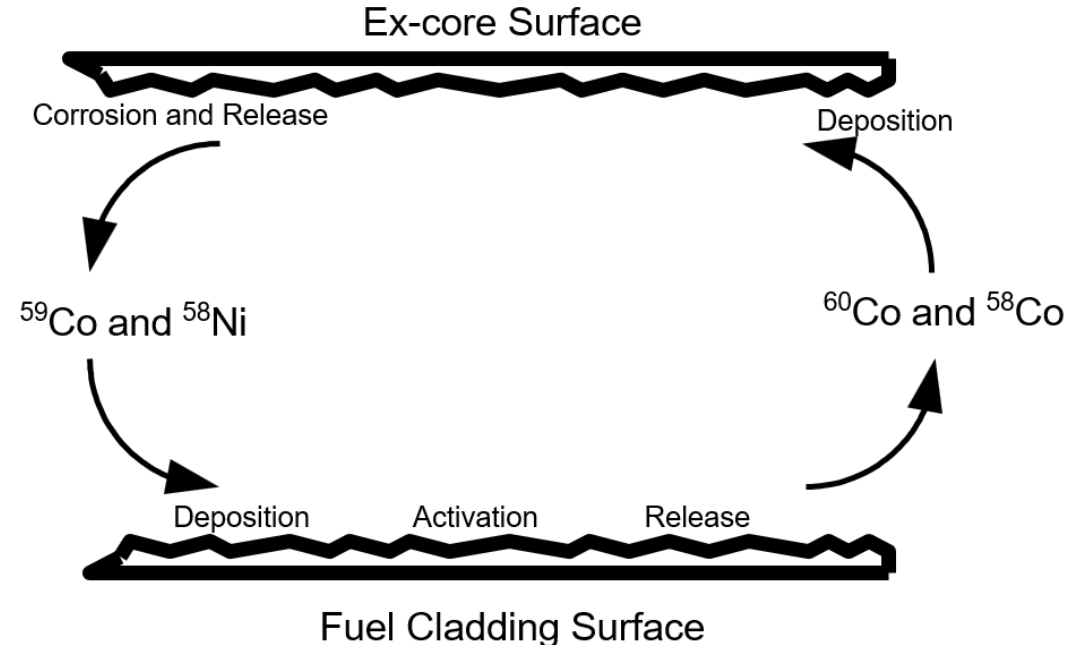
Attacking the Source

Fuel Cleaning

Attacking the Source in Source Term

All Activation Products Come from the Core

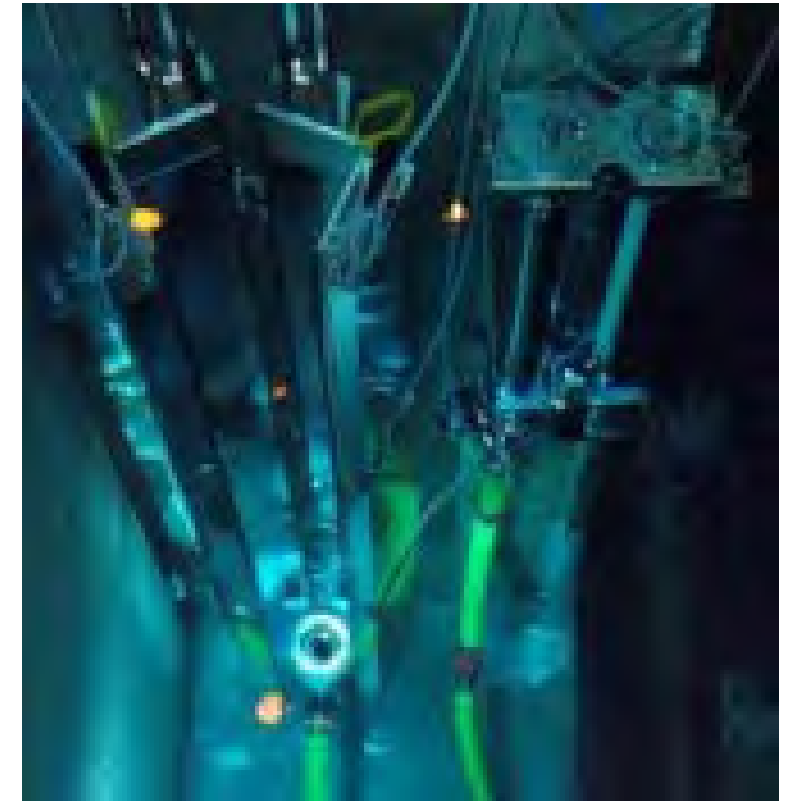
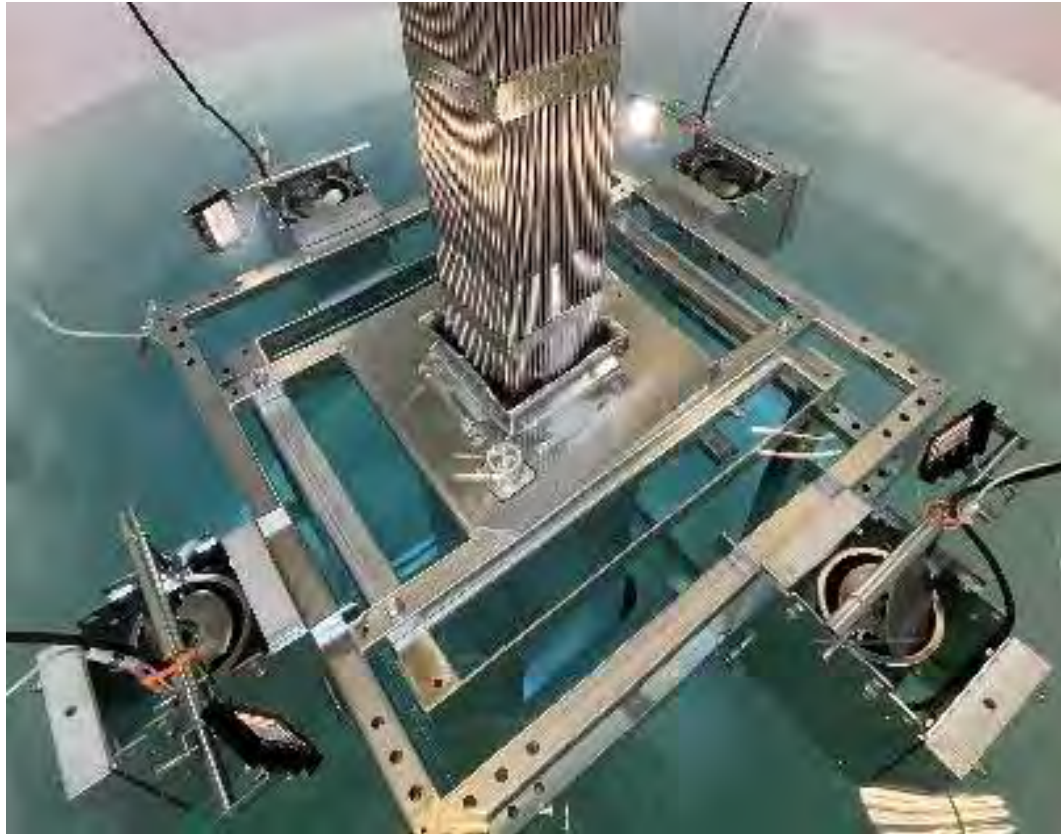
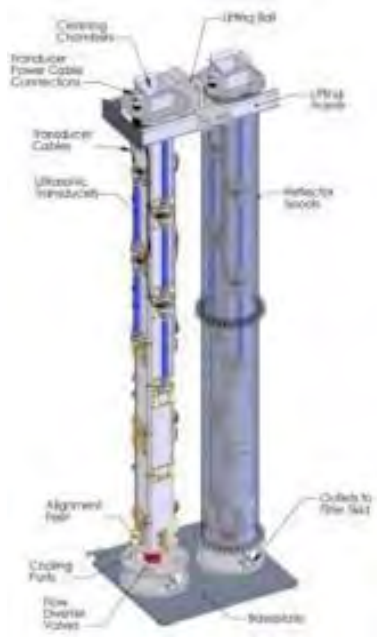
- By far the largest source of activated corrosion products is in the core
- Clear indications that loosely held corrosion products are the source of coolant activity
 - Significant activity increases with changes in boiling conditions
 - Release of activity during coastdown
 - Saturated specific activity on shutdown release



Get it off the fuel!

Ultrasonic Fuel Cleaner Configurations

Right Sizing for the Application / Continuous Improvement

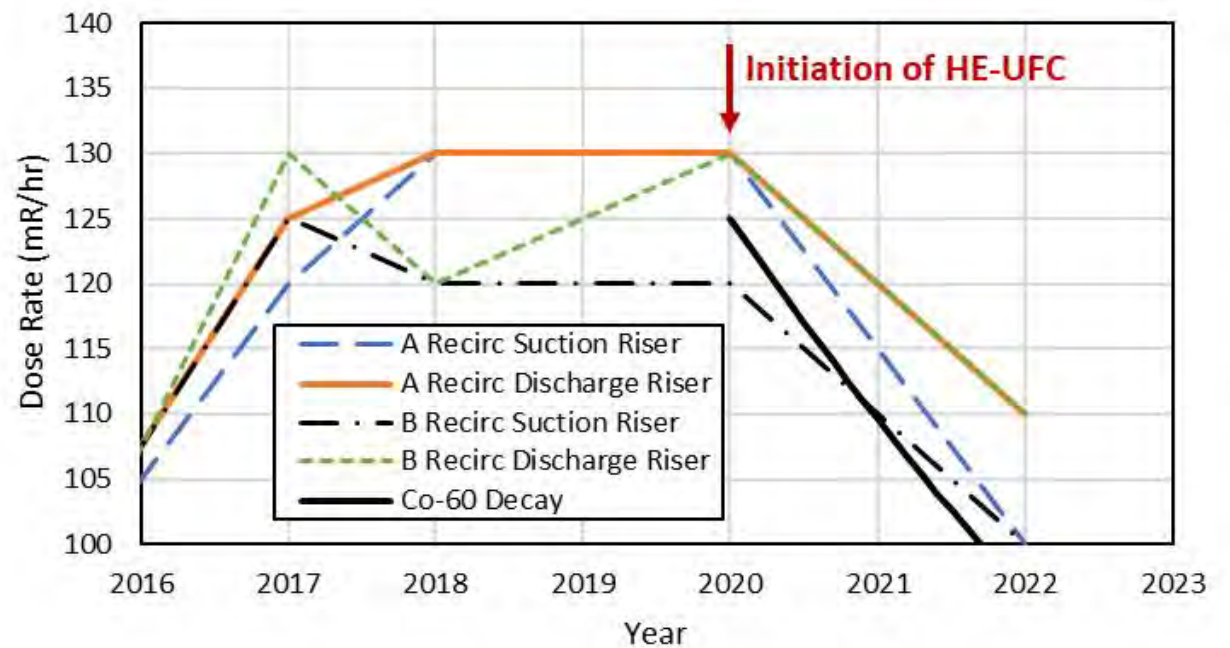


Typical Results

Long Term Effect on Other Locations

- Pre-2020: Dose rates increased or plateaued across all riser locations, reaching ~130 mR/hr by 2020.
- 2020: Marked by the initiation of HE-UFC™, indicated with a red arrow.
- Post-2020: A sharp decline in dose rates is observed across all measured points, consistent with the gradual slope of natural Co-60 decay—highlighting the effectiveness of HE-UFC™ in reducing source term.
- 2022 levels: Drop to approximately 110 mR/hr or lower, demonstrating sustained effect.

Decreased Source Term After Fuel Cleaning Initiation





Whole System Source Term Reduction

Chemical Decontamination

Chem Decon

When Every Spot Is a Hot Spot

- Industry standard monitoring points (BRAC and SRMP) provide a global assessment of the source term issue
- These points are not necessarily related to where work must be done and workers protected
- When they are high, they indicate a global problem that probably cannot be addressed by hot spot mitigation
- Chem decon may be the only solution in such cases

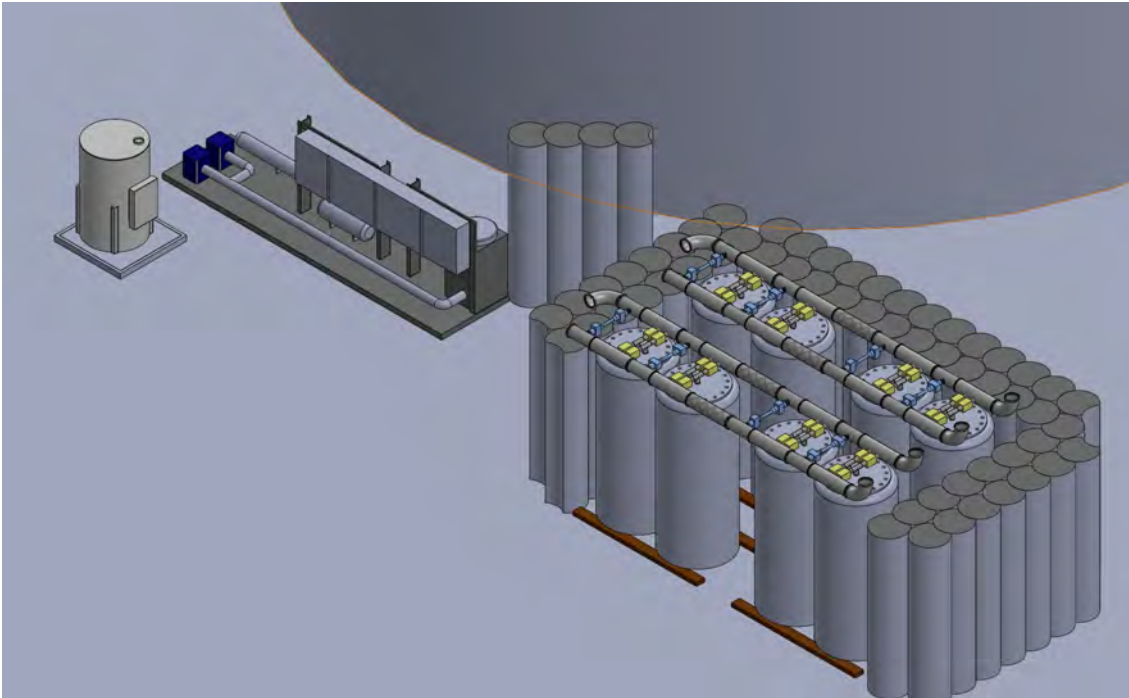


Experience and Innovation

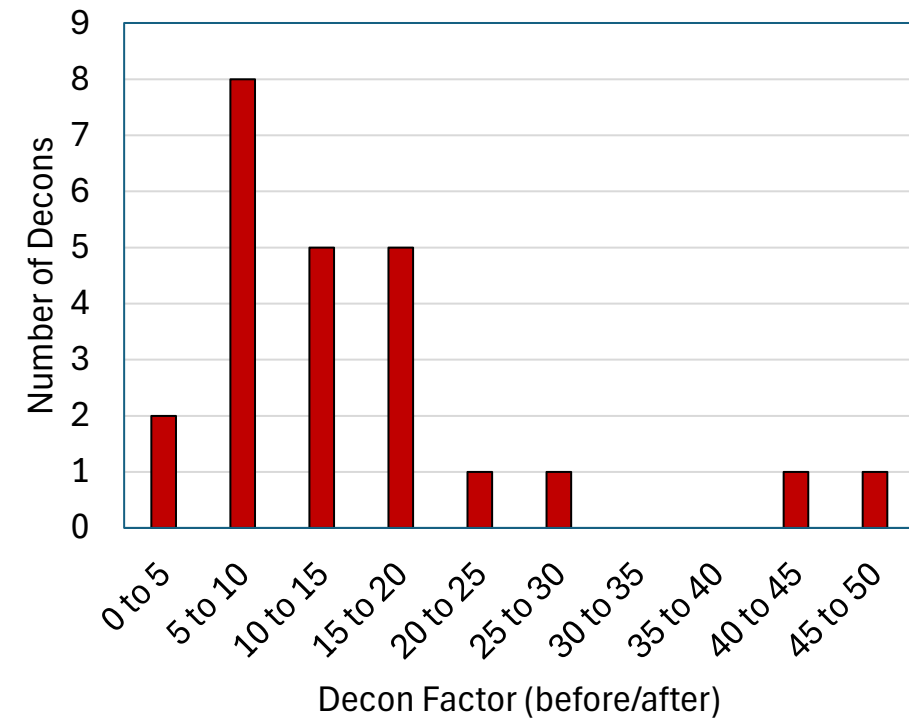
- Dominion personnel have been leading innovation in the decon business for over 20 years
- Dozens of applications, in the US and abroad
- Equipment design-build
- Process design
- Execution

Chem Decon

Typical Layouts and Results

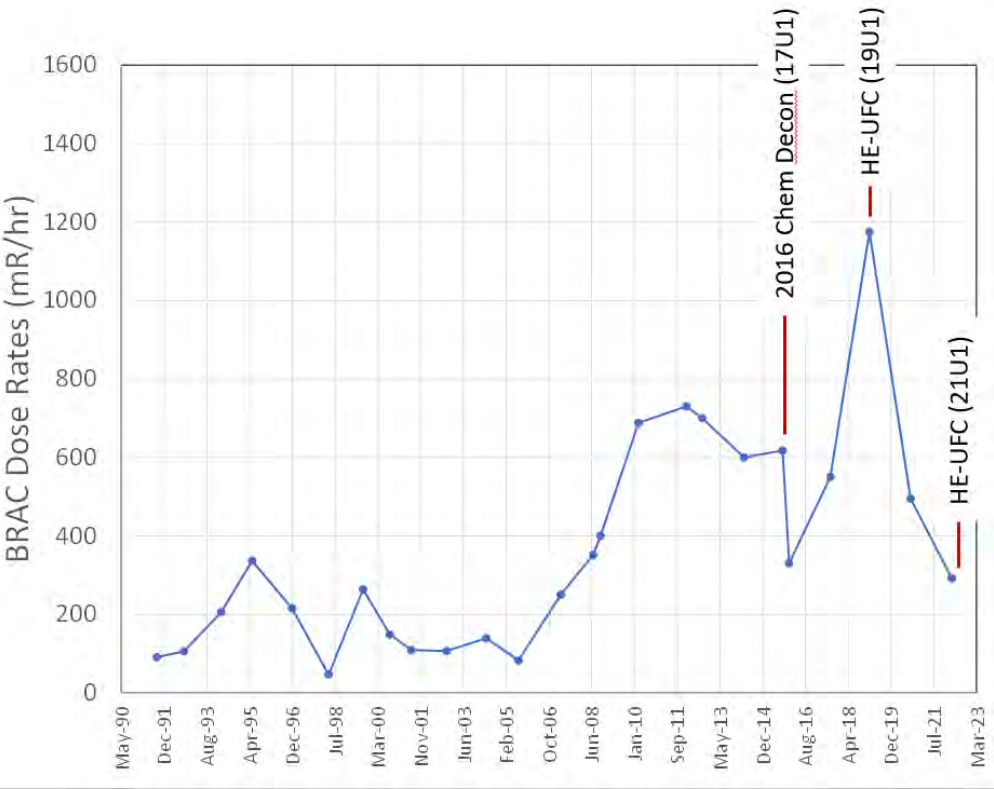


Typical Decon Factors of 5-20



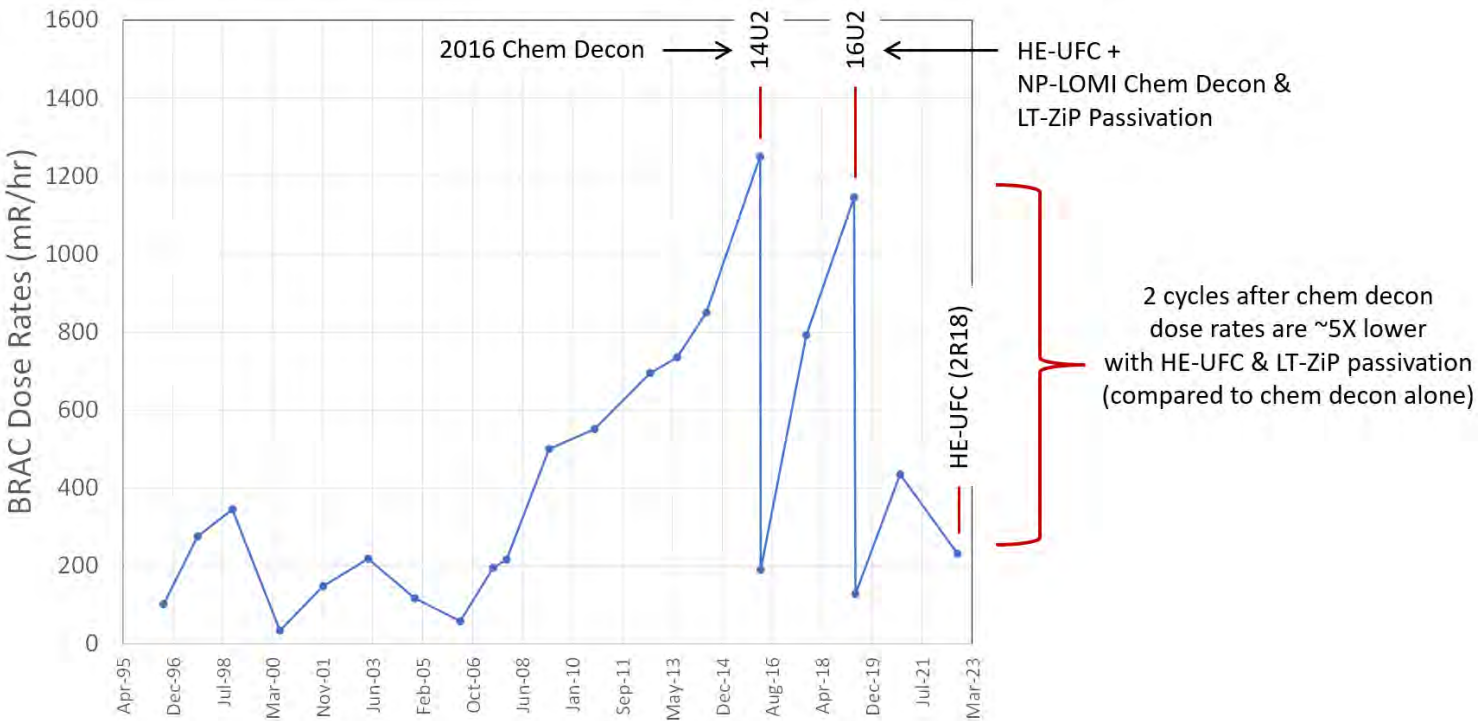
Typical Results

HE-UFC™ Impact on BRAC Dose Rates



Unit A

Better Together



Unit B



A hand holding a blue marker is writing on a whiteboard. The whiteboard has several mathematical equations written on it. In the top left, there is a blue equation $2x - 5 = 0$. Below it, another blue equation $2x = 5 - 0$ is visible. In the bottom left, there is a red equation $B = \begin{bmatrix} 6 \\ -5 \\ 6 \end{bmatrix}$. The background is a blurred view of a city street with buildings and a car.

Wrap Up

Wrap Up

Targeted Innovations for CRE Control

- Begin with understanding the problem
 - Local versus general
 - Preferred disposal path
- Leverage key innovative technologies in filtration and ultrasonics
- Target localized mechanical or general chemical decontamination
- Optimize to reduce waste costs
- Economically remove source term to lower CRE



Q&A

Discussion



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Thank You!

