CGN - Radiation Safety Webcast

NUCLEAR

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September 22, 2025

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Agenda

- Introduction to Dose Reduction Techniques for High-Dose Operations
- Advanced Decontamination Technology
- Efficient calculation methods for shielding design
- Advanced Materials Solutions – Sub-Micron Filtration Innovation

Introduction to Dose Reduction Techniques for High-Dose Operations

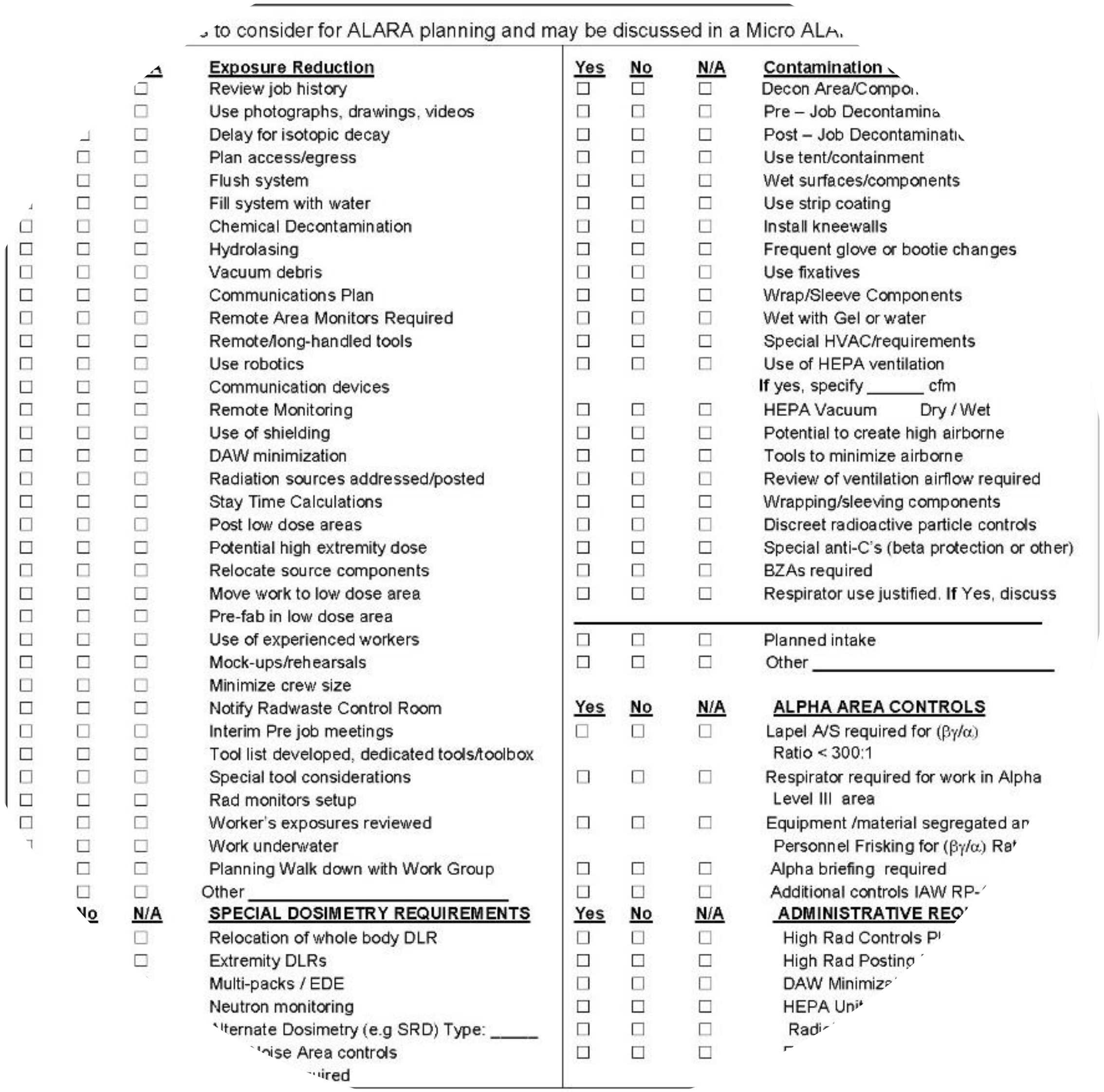
Introduction to Dose Reduction Techniques for High Dose Projects

- Use dedicated planners
- Use As Low As Reasonably Achievable (ALARA) Planning Checklist
- Conduct Mock-up Training
- Use of Remote Tooling
- Implement Remote Monitoring
- Shielding
- Remove Source Term

Planning/Plan – Dedicated Planners

- Established a dedicated team to plan the work that
  - Includes experienced members of the craft and ALARA Planners
  - Embed ALARA planners into plant outage or project work groups
  - Report to ALARA group, physically stationed with work group
  - Plan, perform pre and post job debriefs, capture Lessons Learned directly from workers that performed the task, track and report work group dose
- Benefits:
  - Formal and informal interaction with work group
  - More efficient worker deployment and work execution
  - Improved worker ownership of dose
  - More accurate documentation for future reference
  - Builds trust and better understanding of ALARA value
  - Optimal task performance efficiency and quality = reduced duration in radiation field and elimination of reworks = minimal practical exposure
- Associated EPRI Document:
  - EPRI plant ALARA Assessments – 2020 Review and Lessons Learned, 3002018404

ALARA Checklists

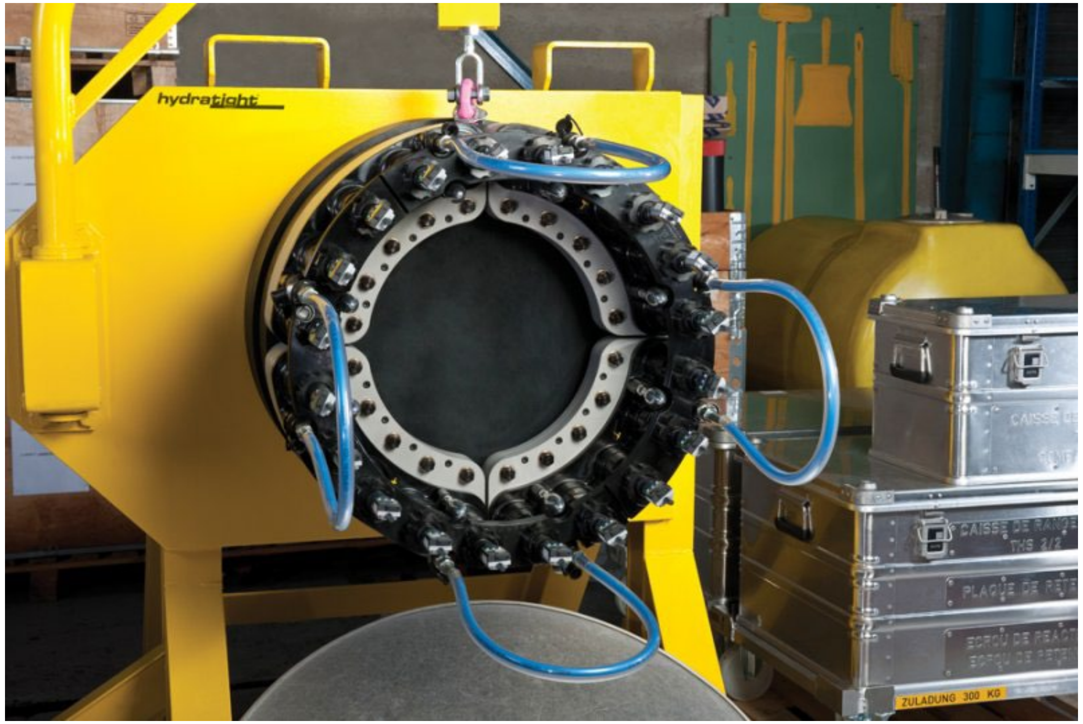

to consider for ALARA planning and may be discussed in a Micro ALA

Exposure Reduction	Yes	No	N/A	Contamination
Review job history	☐	☐	☐	Decon Area/Compo
Use photographs, drawings, videos	☐	☐	☐	Pre – Job Decontamina
Delay for isotopic decay	☐	☐	☐	Post – Job Decontaminati
Plan access/egress	☐	☐	☐	Use tent/containment
Flush system	☐	☐	☐	Wet surfaces/components
Fill system with water	☐	☐	☐	Use strip coating
Chemical Decontamination	☐	☐	☐	Install kneewalls
Hydrolasing	☐	☐	☐	Frequent glove or bootie changes
Vacuum debris	☐	☐	☐	Use fixatives
Communications Plan	☐	☐	☐	Wrap/Sleeve Components
Remote Area Monitors Required	☐	☐	☐	Wet with Gel or water
Remote/long-handled tools	☐	☐	☐	Special HVAC/requirements
Use robotics	☐	☐	☐	Use of HEPA ventilation
Communication devices				If yes, specify ______ cfm
Remote Monitoring	☐	☐	☐	HEPA Vacuum Dry / Wet
Use of shielding	☐	☐	☐	Potential to create high airborne
DAW minimization	☐	☐	☐	Tools to minimize airborne
Radiation sources addressed/posted	☐	☐	☐	Review of ventilation airflow required
Stay Time Calculations	☐	☐	☐	Wrapping/sleeving components
Post low dose areas	☐	☐	☐	Discreet radioactive particle controls
Potential high extremity dose	☐	☐	☐	Special anti-C's (beta protection or other)
Relocate source components	☐	☐	☐	BZAs required
Move work to low dose area	☐	☐	☐	Respirator use justified. If Yes, discuss
Pre-fab in low dose area				
Use of experienced workers	☐	☐	☐	Planned intake
Mock-ups/rehearsals	☐	☐	☐	Other ______
Minimize crew size				
Notify Radwaste Control Room	Yes	No	N/A	ALPHA AREA CONTROLS
Interim Pre job meetings	☐	☐	☐	Lapel A/S required for (βγ/α) Ratio < 300:1
Tool list developed, dedicated tools/toolbox				
Special tool considerations	☐	☐	☐	Respirator required for work in Alpha Level III area
Rad monitors setup				
Worker's exposures reviewed	☐	☐	☐	Equipment /material segregated ar
Work underwater				Personnel Frisking for (βγ/α) Ra
Planning Walk down with Work Group	☐	☐	☐	Alpha briefing required
Other ______	☐	☐	☐	Additional controls IAW RP-
SPECIAL DOSIMETRY REQUIREMENTS	Yes	No	N/A	ADMINISTRATIVE REQ
Relocation of whole body DLR	☐	☐	☐	High Rad Controls P
Extremity DLRs	☐	☐	☐	High Rad Posting
Multi-packs / EDE	☐	☐	☐	DAW Minimiz
Neutron monitoring	☐	☐	☐	HEPA Uni
lternate Dosimetry (e.g SRD) Type: ______	☐	☐	☐	Radi
ise Area controls	☐	☐	☐	
ired				

- Planners use the ALARA checklist with the workgroup to ensure a consistent method to evaluate dose reduction techniques are considered
- Checklist includes:
  - Dose reduction methods
  - Contamination and airborne controls
  - Administrative controls
  - Dosimetry requirements
- Considered during planning phase and incorporated into the ALARA plan for the job
- Associated EPRI Document:
  - EPRI Plant ALARA Assessments – 2020 Review and Lessons Learned, 3002018404

Conduct Mock-up Training/Experienced Craft

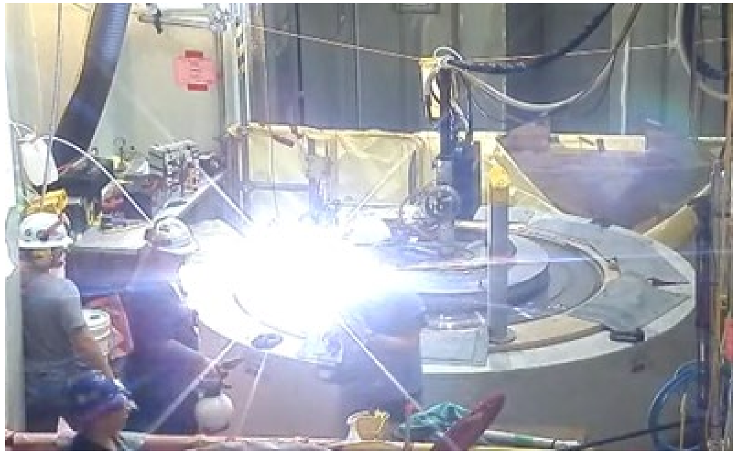
- Mockups is used to provide training to personnel performing he work. Mockups are used for:
  - Manway and/or hand-hole cover removal
  - Nozzle dam installation
  - Torquing
  - internal valve work and valve disassembly
- Training and mockup should resemble the working conditions
  - Workers are required to dress out
  - Use or simulated use of dosimetry and dose rates
- Use Experienced workers who have performed the work previously
- Associated EPRI Document:
  - EPRI Pressurized Water Reactor Steam Generator Dose Reduction, 3002008164



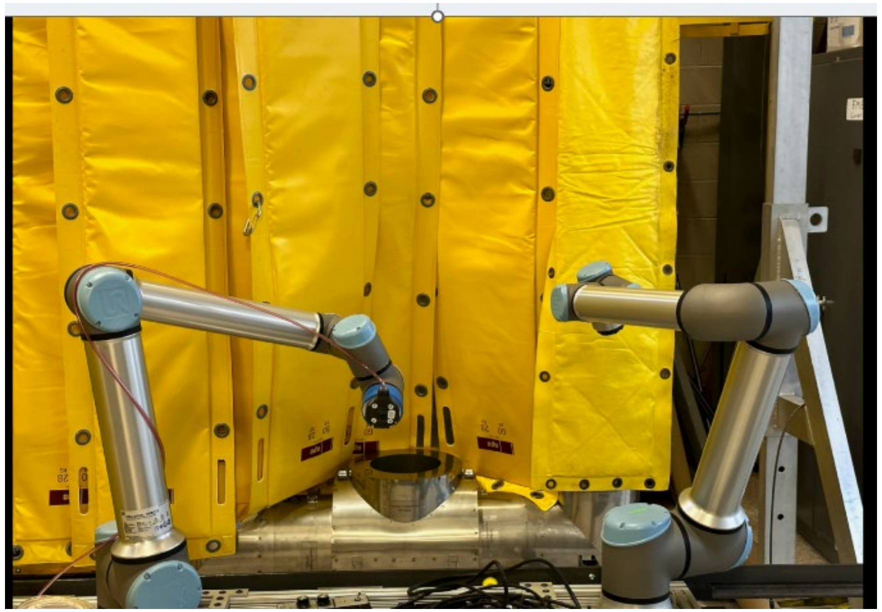
Mock-up of Steam Generator Manway Torquing

Use Remote Tooling

- Use remote operated tooling to place workers outside the dose rate fields
  - Automatic welding
  - Remote valve internal grinding tools
  - Remote steam generator inspection tube inspection tools
- Robots and robotics are becoming more prevalent for use during these high dose evolutions
- Associated EPRI Reports:
  - Dose Reduction Best Practices, ALARA Use Case, Report to be published in 2026



Remote Welding



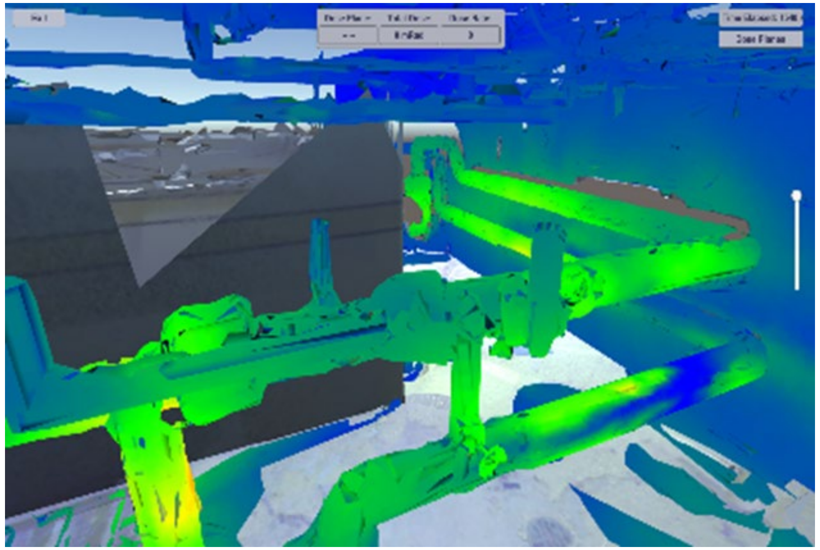
Use Remote Monitoring

- System should include the following key components:
  - Audio communications with workers and RP technicians
  - Cameras
  - Electronic dosimeters and air samplers
- Utilize remote monitoring to monitor:
  - Worker accumulated dose and the radiation fields
  - Communicate with the workers
  - Visual observation of the work
  - Area dose rates and airborne activity
- A dedicated area is established for remote monitoring
- High dose/high risk work should have dedicated RP staff to monitor the work
- Associated EPRI Report:
  - Remote Monitoring Technology Guide for Radiation Protection, 3002005480

Use Specific Shielding for the Task

- Several innovative shielding applications and materials have been developed to reduce worker dose
  - Tungsten shielding
  - 3D printed shielding
  - Specifically designed shielding for valve body and bonnets
  - Magnetic shielding
- Graphical analysis methods have been developed to analyzed optimum placement of shielding
- Associated EPRI Reports:
  - Shielding Technology Update – Report to be published in 2026

Molded Shielding for Valve Body



Example Image produced to evaluate shielding placement

Remove Source Term

- Reduce the dose rates in the area by removing source term
  - Hydrolazing valve internals
  - Flushing hot spots and piping
  - Perform chemical decontamination
  - PWR shutdown sequence
- These practices can result in a dose rate reduction of up to 5
- Associated EPRI report:
  - Recent Chemical Decontamination Experience: 2012 Radiation Management and Source Term Technical Strategy Group Report, 3002000555

Other Dose Reduction Measures to Consider

- Review Previous Job History Files
- Use photographs and videos to indoctrinate workers and RP Techs
- Plan for access and egress to the area
- Use Robotics
- Pre-fabricate in low dose waiting areas
- Ensure crew sizes are minimized
- Decontaminate the area prior to the start of the job and periodically during the job

Advanced Decontamination Technologies:

Ultrasonic Decontamination

Laser Ablation Decontamination

Nuclear Industry Experience with Ultrasonic Cleaning and Decontamination

- Research Overview:
  - Documents application of ultrasonic cleaning technologies
  - Describes mechanism, equipment, and qualification
  - Reviews components cleaned: valve internals, piping, steam generators
  - Highlights dose rate and radiation exposure reduction
- Key Findings:
  - Effective removal of hot spots in <15 minutes
  - External deployment unclogs resin blockages without system isolation
  - Internal deployment during outages reduces cumulative radiation exposure
  - Proven safe for materials through testing
- Why This Matters:
  - Reduces hot spots, dose rates, and radiation exposure
  - More effective and cost-efficient than flushing or chemical decontamination

Nuclear Industry Experience with Ultrasonic Cleaning and Decontamination. EPRI, Palo Alto, CA: 2023. 3002026551.

Nuclear Industry Experience with Ultrasonic Cleaning and Decontamination

Figure 3-2
Typical NU-DEC™ Transducer Assembly Components (Clamp style; NPS 2; DN 50 configuration shown)

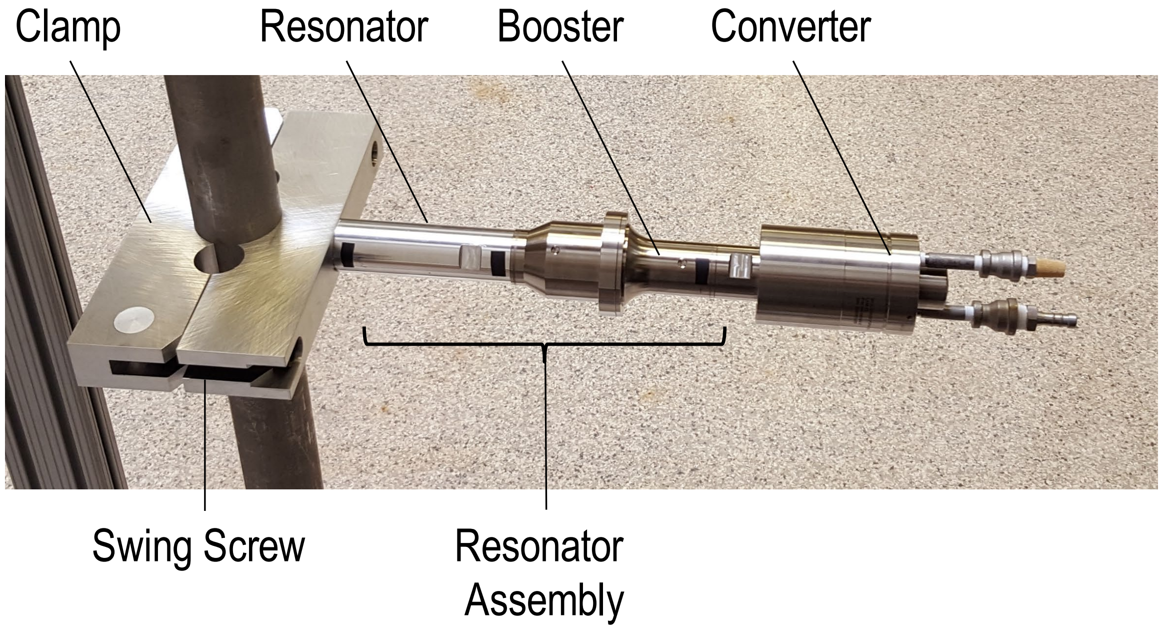
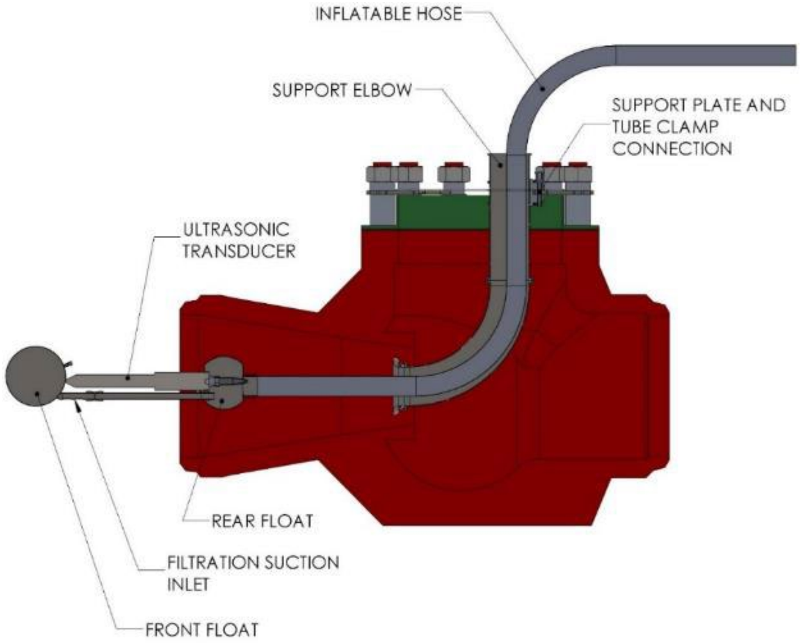


Figure 6-1
Transducer Probe Assembly for LaSalle FCV Cleaning



Nuclear Industry Experience with Ultrasonic Cleaning and Decontamination. EPRI, Palo Alto, CA: 2023. 3002026551.

Nuclear Industry Experience with Ultrasonic Cleaning and Decontamination

Survey Location	FCV 60A			FCV 60B		
	Contact Dose Rate		Percent Reduction	Contact Dose Rate		Percent Reduction
	Before Cleaning	After Cleaning		Before Cleaning	After Cleaning	
Top plane of valve body	40 mSv/hr (4 rem/hr)	17 mSv/hr (1.7 rem/hr)	57.5%	37 mSv/hr (3.7 rem/hr)	17 mSv/hr (1.7 rem/hr)	54.0%
Middle of inside of valve body	100 mSv/hr (10 rem/hr)	60 mSv/hr (6 rem/hr)	40.0%	148 mSv/hr (14.8 rem/hr)	57 mSv/hr (5.7 rem/hr)	61.5%
Bottom of inside of valve body	155 mSv/hr (15.5 rem/hr)	65 mSv/hr (6.5 rem/hr)	58.0%	156 mSv/hr (15.6 rem/hr)	73 mSv/hr (7.3 rem/hr)	53.0%
General area of valve work platform	50 mSv/hr (0.5 rem/hr)	1.5 mSv/hr (0.15 rem/hr)	70.0%	4.3 mSv/hr (0.43 rem/hr)	1.5 mSv/hr (0.15 rem/hr)	65.0%

Nuclear Industry Experience with Ultrasonic Cleaning and Decontamination. EPRI, Palo Alto, CA: 2023. 3002026551.

Barriers/Challenges to Increased Industry Use

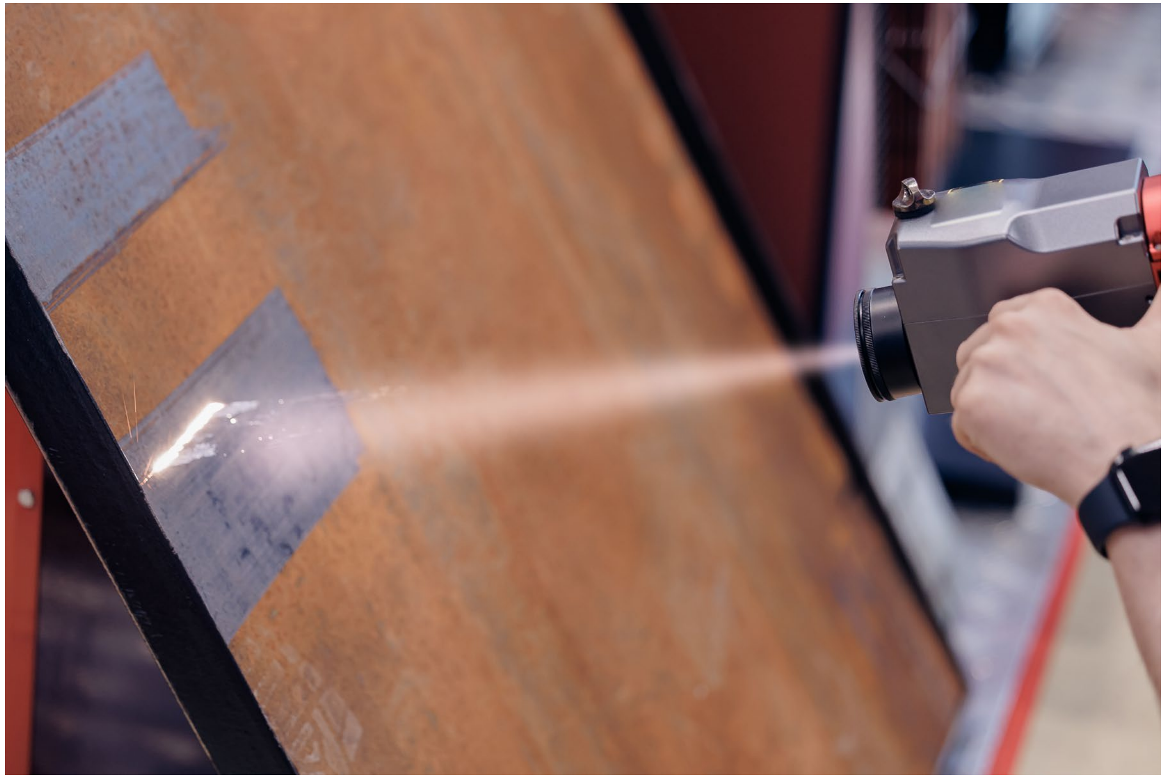
- Despite wide interest, engineering evaluation and acceptance of ultrasonic cleaning is often a barrier to implementation.

- Currently, no generic reference or standard exists for use on safety related components or piping.

Decontamination with Laser Ablation

- EPRI does not have any direct reports that focus on laser ablation for radiological decontamination.

- EPRI has hosted and participated in various industry meetings where radiological decontamination by Laser Ablation has been presented.



2024-06-20, TRYDENT Laser Abatement Services (LAS) attended and made a presentation at the RMST TSG Workshop.

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Decontamination with Laser Ablation

- In 2019, Constellation's LaSalle Clean Energy Center completed a project using laser ablation to decontaminate and free release 40,000 lbs of stainless-steel turbine blading.

Barriers/Challenges to Increased Industry Use

High powered lasers create additional industrial safety hazards.

Laser effectiveness is a line of site tool. Ineffective for nooks, crannies, and jagged surfaces.

The contamination removed from the material is not effectively collected on typical filtration equipment (e.g., a high efficiency particulate air (HEPA) filter.

Efficient calculation methods for shielding design in NPP

Shielding Calculations

Two types of shielding calculations are typically performed:

- Design Calculations – how much shielding can be installed
- Cost Benefit Calculations – does it make sense to install

EPRI Report "Guidance for Optimal Performance of Shielding Programs, Report 3002003165

- Briefly describes these two calculations
- Report provides an overview of the basics for a temporary shielding program

Shielding Calculations - Design

Design Calculations are performed for the following circumstances:

Temporary Shielding installations – typically less than 90 days (maintenance and outages)	Long Term installations – those that are installed for greater than 90 days but will not be permanent installations	Permanent – those shielding installations that are designed to be permanent via the plant modification process

NPPs will typically require Engineering to be involved in the review and design of long term shielding installations and permanent shielding installations

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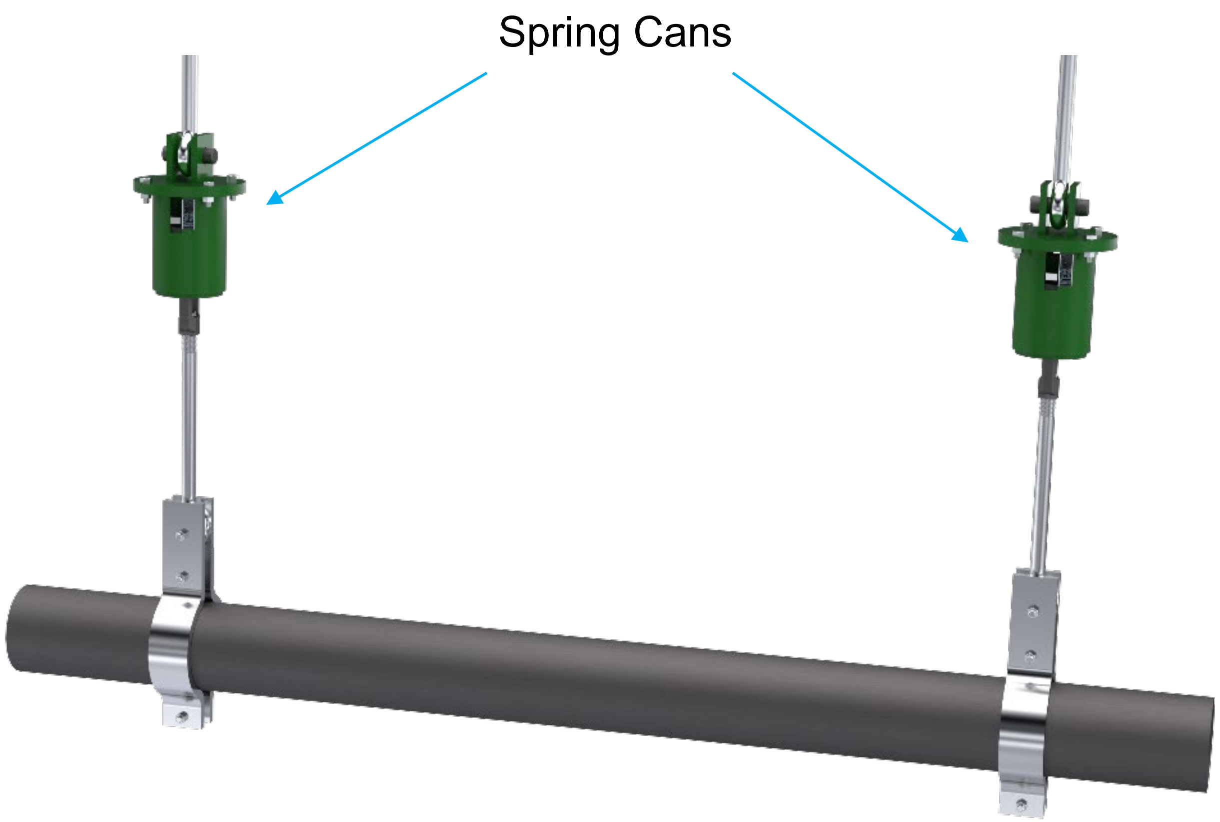
Shielding Calculations

- Short-Term Shielding Calculations – New applications
  - Many site will require engineering to review new installations
  - Several sites have developed programs where RP can evaluate the how much shielding can be installed without engineering involvement
  - This is accomplished by development of an engineering specification document that determines the allowable weight that can be installed on the pipe or floor without a formal review by the Engineering.
- The specification allows RP to develop shielding packages within the pre-determined weight allowance

Typical Pipe Configuration Considerations



- Filled versus empty piping
- Pipe supports, snubbers and spring cans
- Type of pipe – such as schedule 40 stainless steel
- Use of temporary supports

Shielding Calculations – Process Example

1

Request for new temporary shielding install

- Usually submitted to support work or for a refuel outage
- Submitted by RP planner or the workgroup

2

RP or the workgroup completes temporary shield request

- Documents the location and purpose
- May include a cost benefit analysis

3

Determine the specific location, system, and configuration

- Inside or outside of containment or safety related system
- Determine if pipe will be filled or drained

4

Review the specification and determine the maximum shielding that can be installed

- Specify the amount of shielding that can be installed
- Example – 30 lbs/linear ft

5

Complete the shield request and document requirements

- Process allows RP to evaluate and document shielding installs without engineering

Note: Temporary shielding installations outside the scope of the specification or if additional shielding is required, must be analyzed by engineering

Benefits

- RP can quickly determine the feasibility and amount of shielding that can be installed on the pipe
  - This can save dose especially for emergent and time sensitive activities
- Saves Engineering resources
  - Once the specification is developed – engineering does not need to review the temporary shield requests that are within the bounds of the specification

Advanced Materials Solutions
Sub-Micron Filtration Innovation

Resins and Filters Sourcebook

- Provides data for CVCS and SG Blowdown resins and filters
- Includes CVCS filter size rating for the plants included
- Data as of 2013
- PWR Chemistry and LILW Technical Strategy Groups are beginning work to prepare an updated version of the Sourcebook (2026 completion)

Pressurized Water Reactor Chemical Volume and Control System and Steam Generator Blowdown Resins and Filters Sourcebook

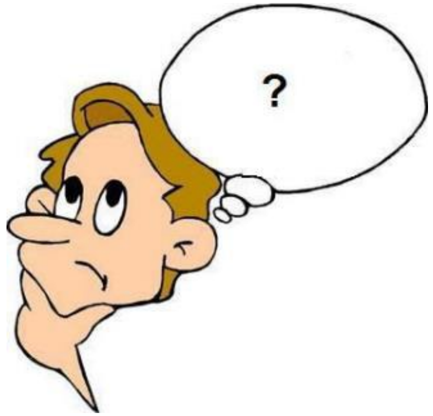
2013 Edition

3002001731

Evaluation of Commercial Filters for Improved Reactor Coolant Purification: PWR Chemistry Technical Strategy Group Report (3002015882)

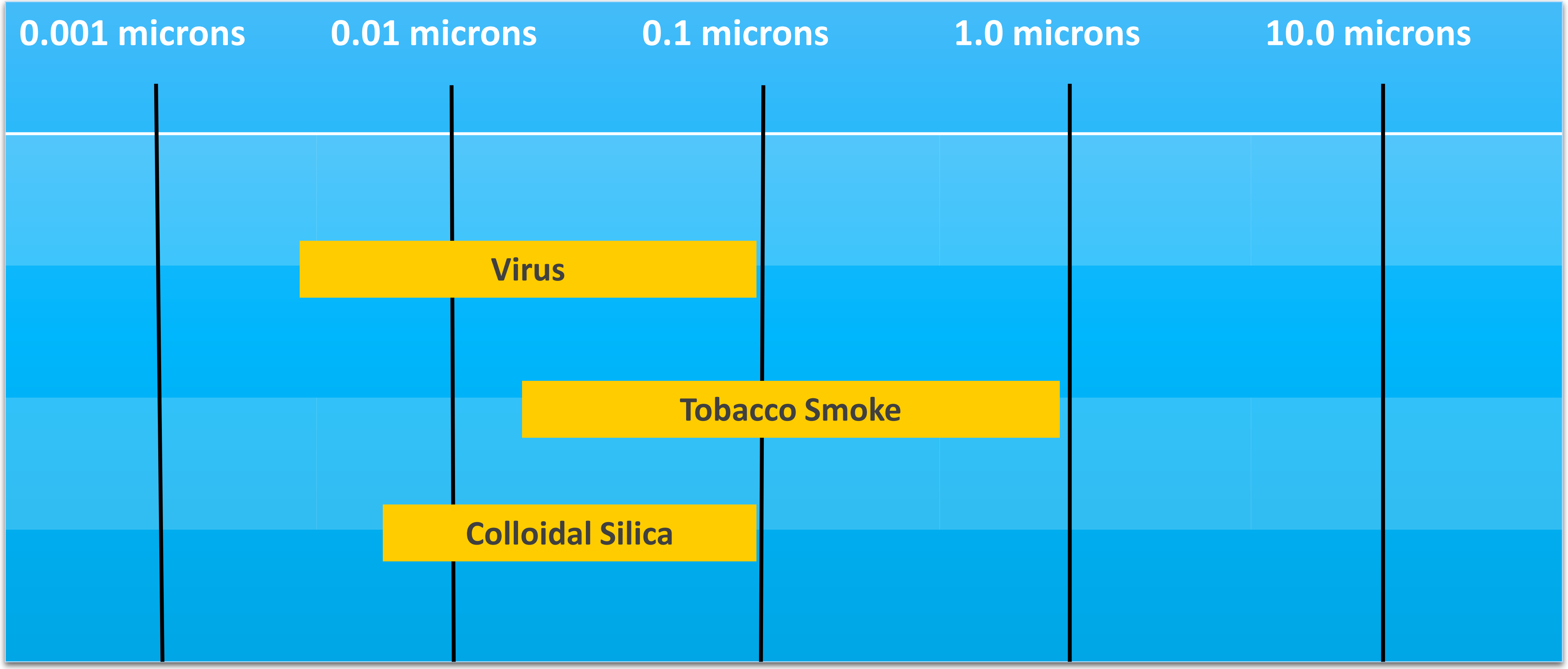
Background for the Filtration Evaluation Project

- Downward trend in pore size of filters used in CVCS systems since 1990s
- Introduction of sub-micron filters and potential for increased metal removal - reduced dose rates
- Filters expected to separate by electrostatic and sieving mechanisms
- Suppliers test their filters under differing conditions
- Technical objective:
  - Evaluate three filters, Manufacturer A's (0.05µm and 0.1 µm) and Manufacturer B's Nanofiber filter, <u>using identical chemical challenges</u>
    - Physical characterization of filter media
    - Performance testing of filter media (water flux and initial retention efficiency, testing employing magnetite suspensions under simulated PWR chemistry)

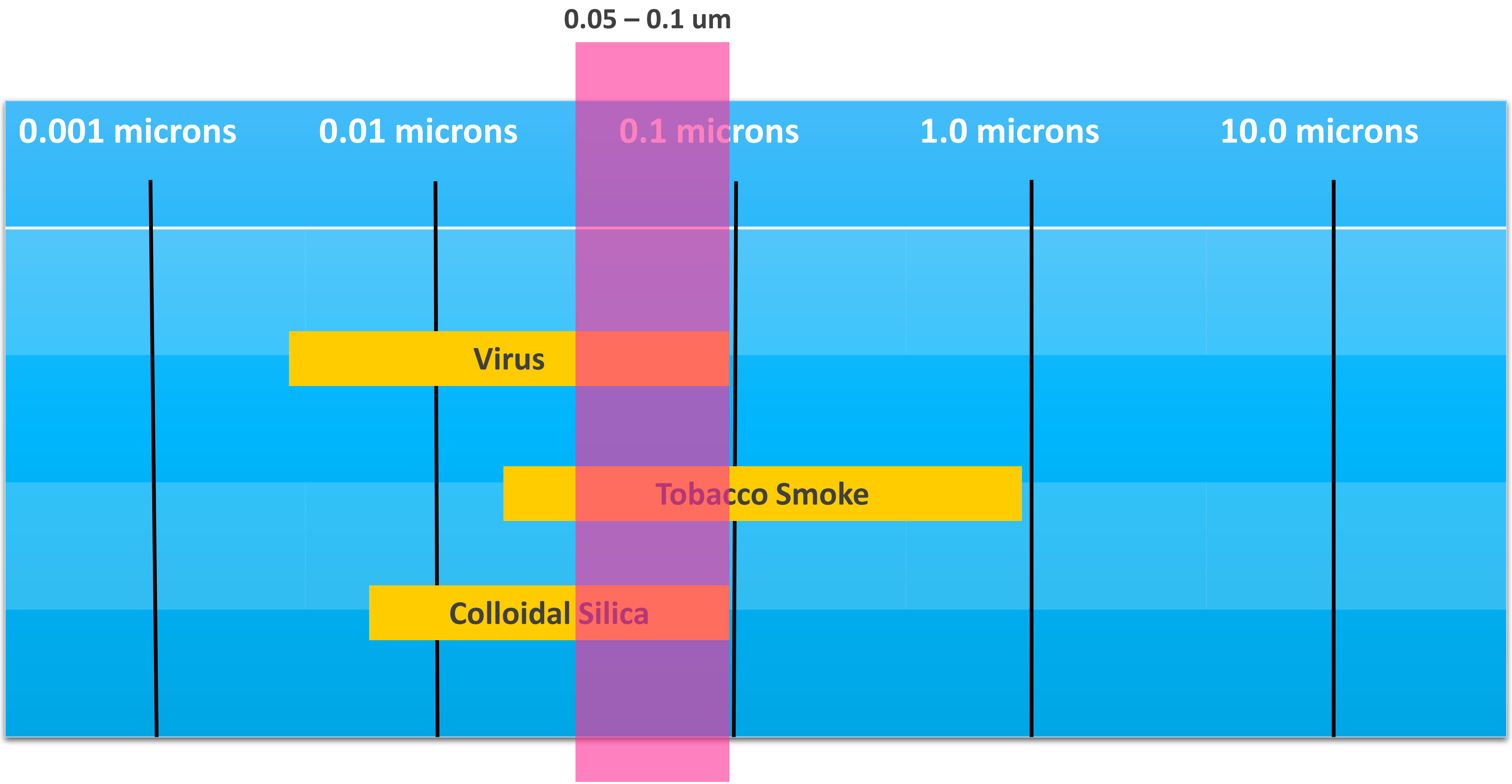


Provide the information needed to make informed filter selection decisions

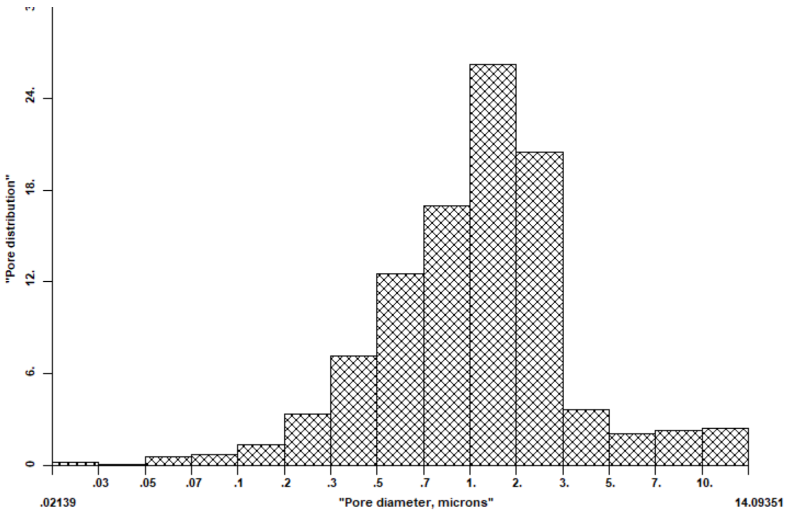
Filtration Spectrum



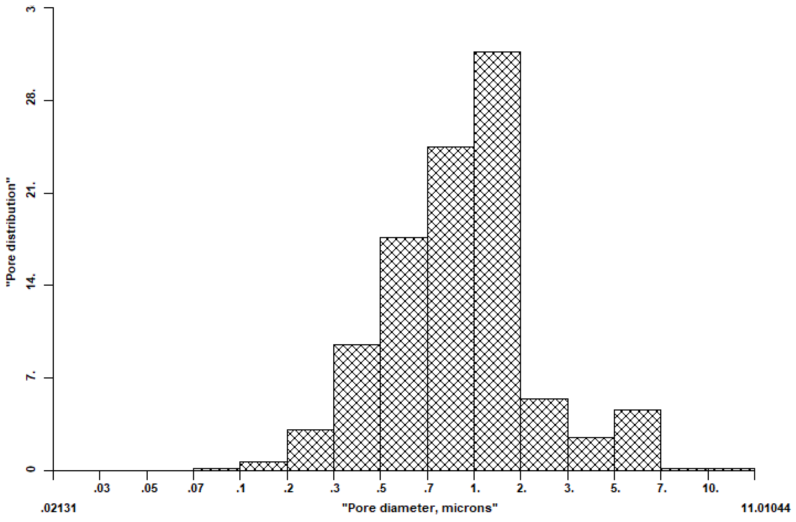
Filtration Spectrum



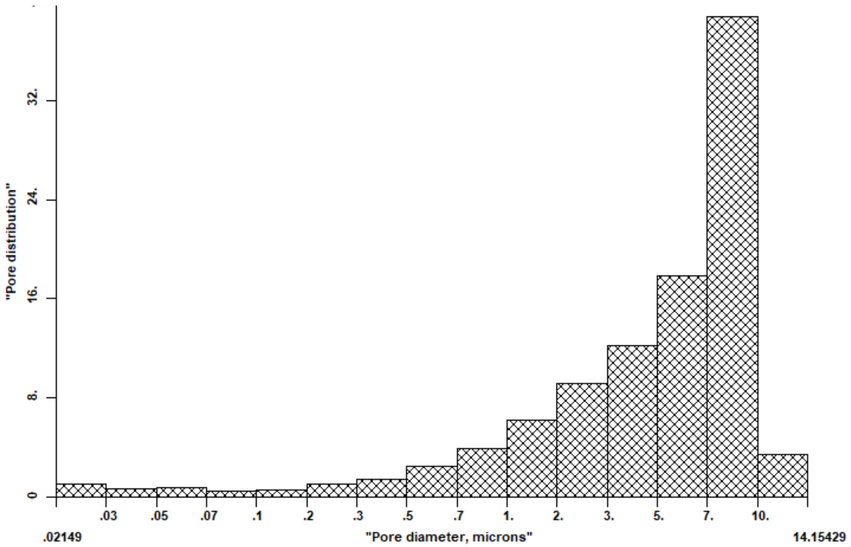
Physical Characterization – Pore Size Distribution



Manufacturer A 0.1 micron



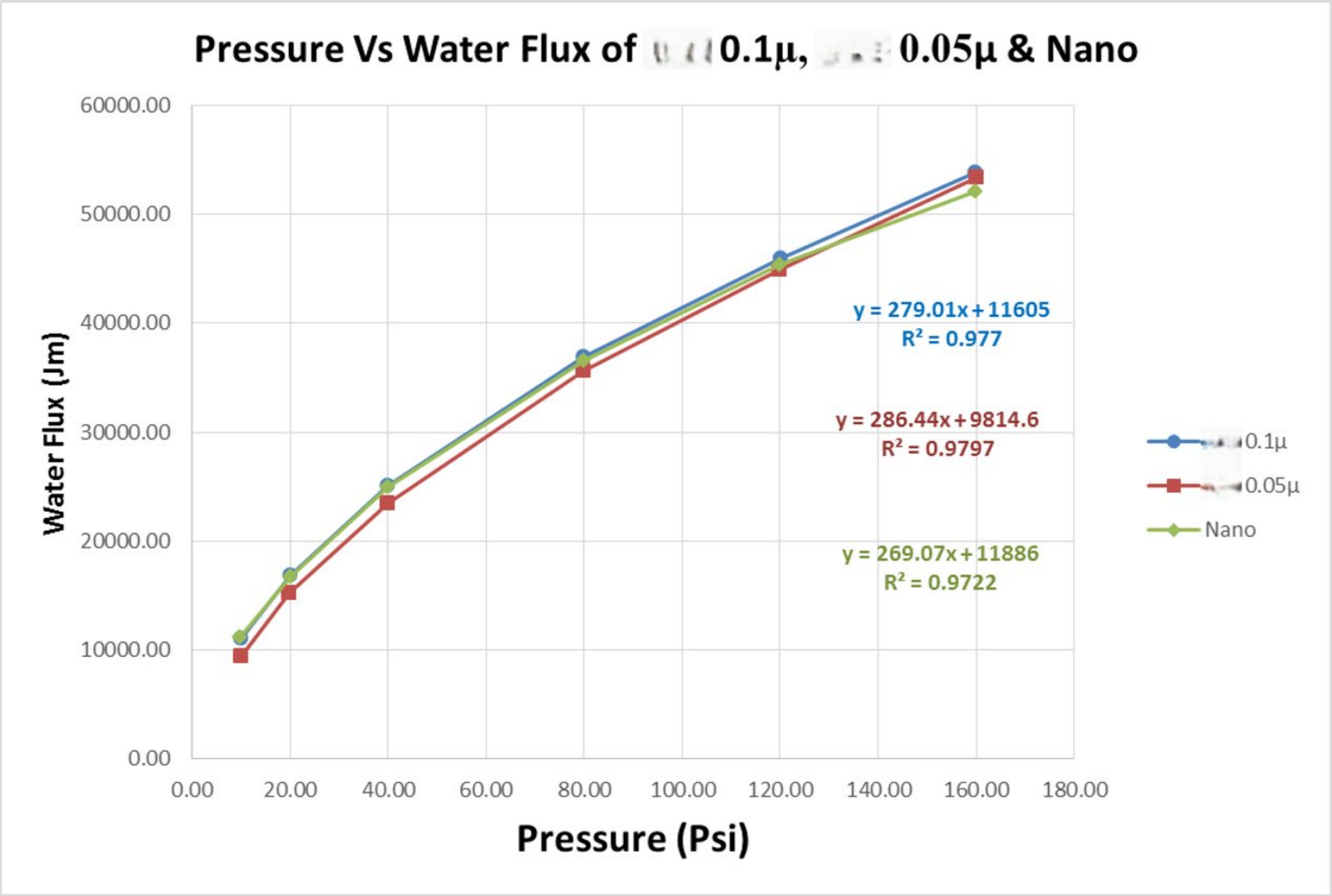
Manufacturer A 0.05 micron



Nanofilter

Property	Manufacturer A 0.1µm Filter	Manufacturer A 0.05µm Filter	Manufacturer B Nanofiber Filter
Smallest detected pore diameter (µm)	0.1826	0.1724	0.1603
Mean flow pore diameter (µm)	0.3148	0.2962	0.8986
Bubble point/largest detected pore diameter (µm)	8.6866	8.4596	10.4738

Performance Testing of Filter Media-Water Flux, Unloaded



- Pure Water Flux ($Kg/m^2.hr$)

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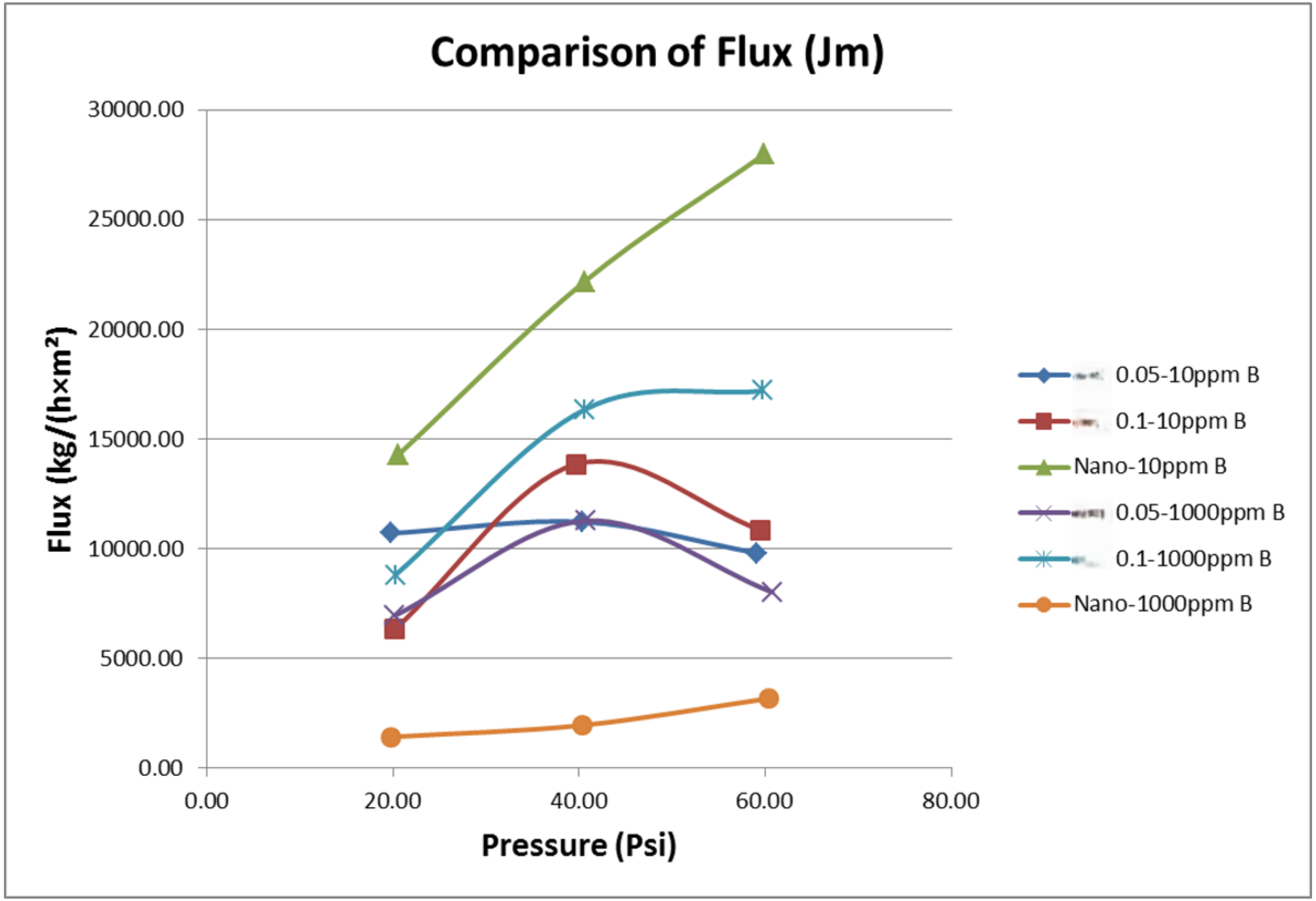
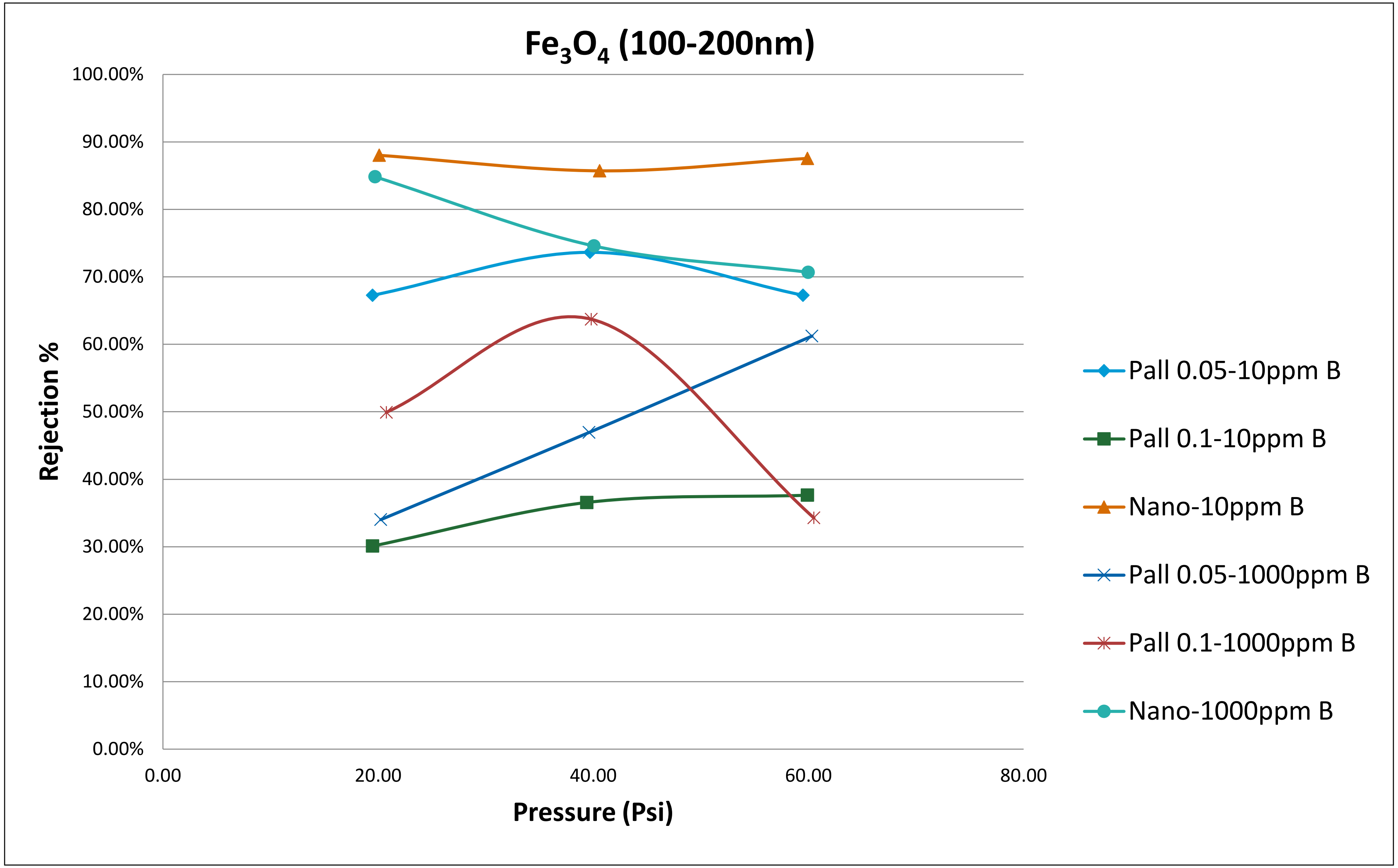
Performance Testing of Filter Media- Water Flux, Loaded

36ppm Fe, Particle size 40-45 nm



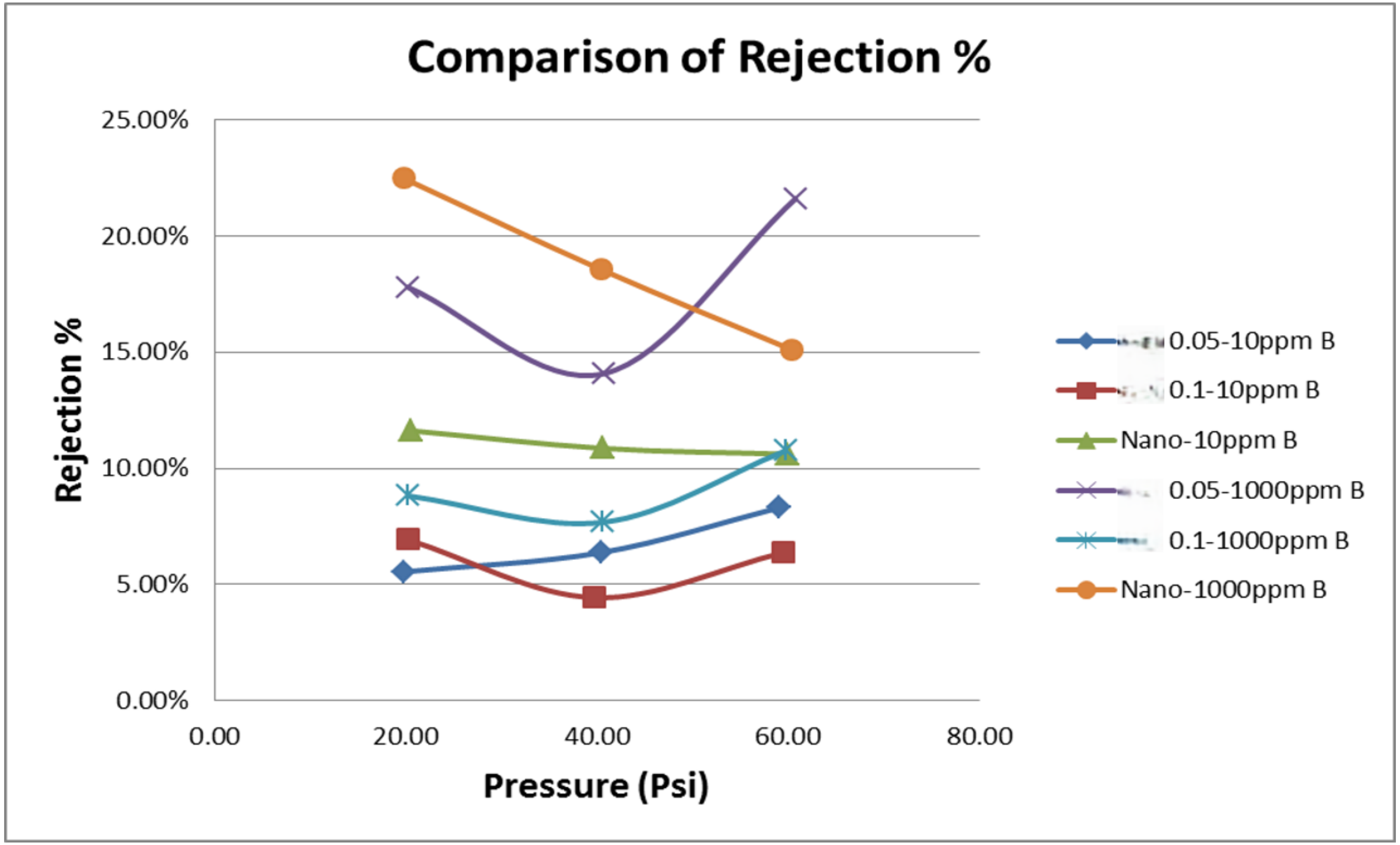
Large difference in Nano filters at 10 ppm B and 1000 ppm B

Performance Testing of Filter Media- % Rejection



Performance Testing of Filter Media- % Rejection

Fe_3O_4 (40-45 nm)



Nanofilter and 0.05um Manufacturer A have highest rejection

Physical Characterization - Leachability Testing

Parameters (ppm)	1000ppm B+3.5ppm Li				10ppm B+3.5ppm Li			
	Mfr. A 0.1	Mfr. A 0.05	Nano	Blank	Mfr. A 0.1	Mfr A 0.05	Nano	Blank
Boron	977	941	948	968	10.2	10.5	10.3	9.89
Calcium	0.187	0.077	0.087	0.045	0.125	0.065	0.039	0.036
Magnesium	0.167	0.14	0.155	0.145	0.024	0.003	0.022	0.005
Manganese	0.015	-	-	-	0.007	0.216	-	-
Silicon	**0.125**	0.069	**0.239**	0.044	**0.341**	**0.216**	**0.142**	0.069
Sodium	0.924	0.755	0.444	0.362	0.452	0.402	0.14	0.137
Sulfur	0.41	-	3.2	0.398	0.098	0.095	3.01	-
Chloride	0.37	8.13	0.118	0.027	0.373	**10.6**	0.091	0.041
Sulfate	1.08	-	9.79	1.04	0.146	0.018	9.04	0.0172
Nitrate	0.078	0.023	0.101	-	0.069	0.02	0.063	-
TOC	0.893	1.02	4.06	0.49	0.958	17.3	4.55	0.412
Conductivity	2.68	3.36	3.16	2.29	2.44	3.81	2.84	2.19

Red indicates concentrations of concern.

Overview

Performance testing conducted on 3 commonly used sub-micron CVCS filtration options:

- Average pore size and volume
- Distribution of pore size
- Water flux vs. pressure; loaded and unloaded
- Rejection
- Leachability

The information needed to make an informed filter selection decision

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