# Harris Nuclear Plant ECCS Strainer Pre-Test Meeting
June 06, 2022

DUKE ENERGY®

# Duke Energy Attendees

Ryan Treadway (Manager, Nuclear Fleet Licensing)
Dennis Earp (Nuclear Fleet Licensing)
David Dobson (Fleet Engineering)
Bradley Morrison (GL 2004-02 Project Manager)
Pat Chriscoe (Manager Nuclear Engineering)
Mark Grantham (Director Nuclear Engineering)
Chad Kidd (GM Nuclear Engineering)
Wes McGoun (GL 2004-02 Responsible Engineer)
Michael Flanagan (Sargent and Lundy)
Helmut Kopke (Sargent and Lundy)
Bruce Letellier (Serco)
Andrew Roudenko (Serco)
Mark Macali (Serco)
Joshua Anderson (Alden Research Laboratory)

# Agenda

- Introduction
- Regulatory Communication Perspective
- Meeting Objectives
- Test Objectives
- Plant Overview
- Test Facility Design
- Debris Targets
  - Particulate
  - Fiber
  - Chemical
- Key Test/Analysis Assumptions
- Test Matrix
- Schedule

## Regulatory Communication Perspective

- Previous strainer testing performed in 2007 and 2010
- HNP responses to Generic Letter 2004-02 and subsequent NRC requests for additional information (RAI) specifically excluded resolution of in-vessel effects (ML101670028, June 2010)
- While HNP has not yet resolved the fuel blockage issue, it has committed to follow methodology provided in WCAP-17788-P
- HNP clarified approach to coatings behavior outside the Zone of Influence (ZOI), following June 2012 NRC meeting (ML12240A230)
- The most recent formal communication occurred in late 2013 (ML13136A146)

# Regulatory Communication Perspective (cont)

- The following potentially impacted results from 2010 strainer testing:
  - Unqualified free run cable identified in 2012 (RFO17); increased blocked strainer area
  - Unqualified inorganic zinc identified during forced outage in spring 2013 (between RFO17 and RFO18)
  - Additional unqualified coatings identified in 2013 (RFO18)
  - Additional fiber caused by relocating Reactor Coolant System (RCS) cross-over leg break to Steam Generator (SG) nozzle identified in 2018
  - Containment reanalysis in 2018 resulted in slightly higher chemical product loading
- Each of these five issues were entered into the Corrective Action Program and it was determined that strainer performance remained acceptable
- Additional post-test debris was partially offset by the Min-K insulation removal in 2012
- Containment walkdown inspection processes and procedures revamped in 2013 to emphasize debris source identification and management
- Currently reanalyzing debris generation and transport to determine bounding debris quantities in preparation for a third strainer test

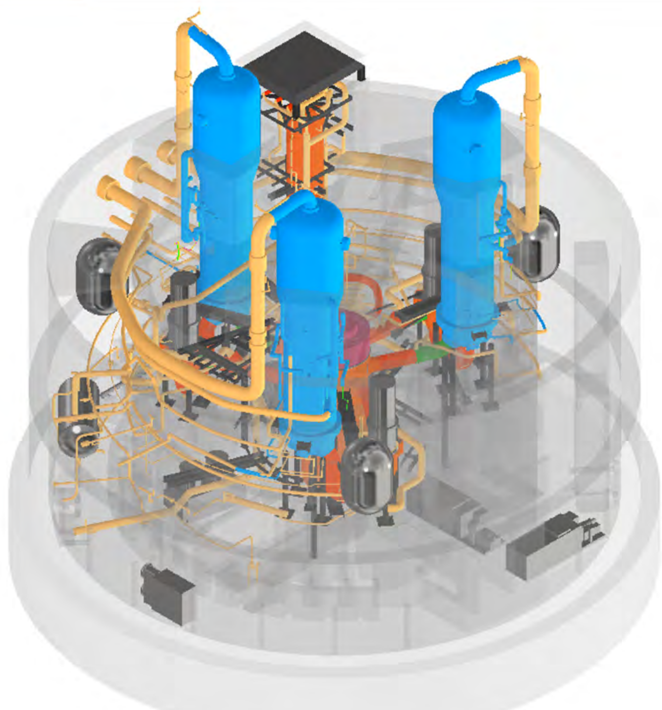
# Meeting Objectives

- Inform NRC staff of ECCS strainer testing activities to be performed in support of closing Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized Water Reactors"
- Describe test facility, debris preparation, test procedures
- Identify debris loading targets
- Obtain feedback on important test and analysis assumptions
  1. Test scaling approach
  2. Coatings failure assumptions
  3. Fiber erosion fraction
  4. Surrogate particulate formulation
  5. Surrogate chemical products
  6. Treatment of MICROTHERM®
  7. Vortex suppression
- Communicate strainer test schedule

# Test Objectives

- Repeat strainer testing provides opportunities to:
  - Comprehensively address the containment debris sources identified following 2010 strainer testing
  - Verify strainer performance for refined deterministic debris loads (high-fidelity full-containment CAD model and CASA Grande debris generation)
  - Characterize strainer performance in prototypical recessed sump-pit geometry
  - Obtain high-quality data needed to correlate fiber penetration to strainer debris load
  - Establish debris loading schedules to support potential risk-informed license amendment request (LAR)
- Strainer Testing Scope:
  - Full Debris Load (RCS cross-over leg break at SG nozzle)
  - Thin-Bed Load (full load particulate + minimum fiber)
  - Fiber Penetration (fiber only, using single-pass bag filters)
  - Exploratory cable debris transport and capture

# Plant Overview

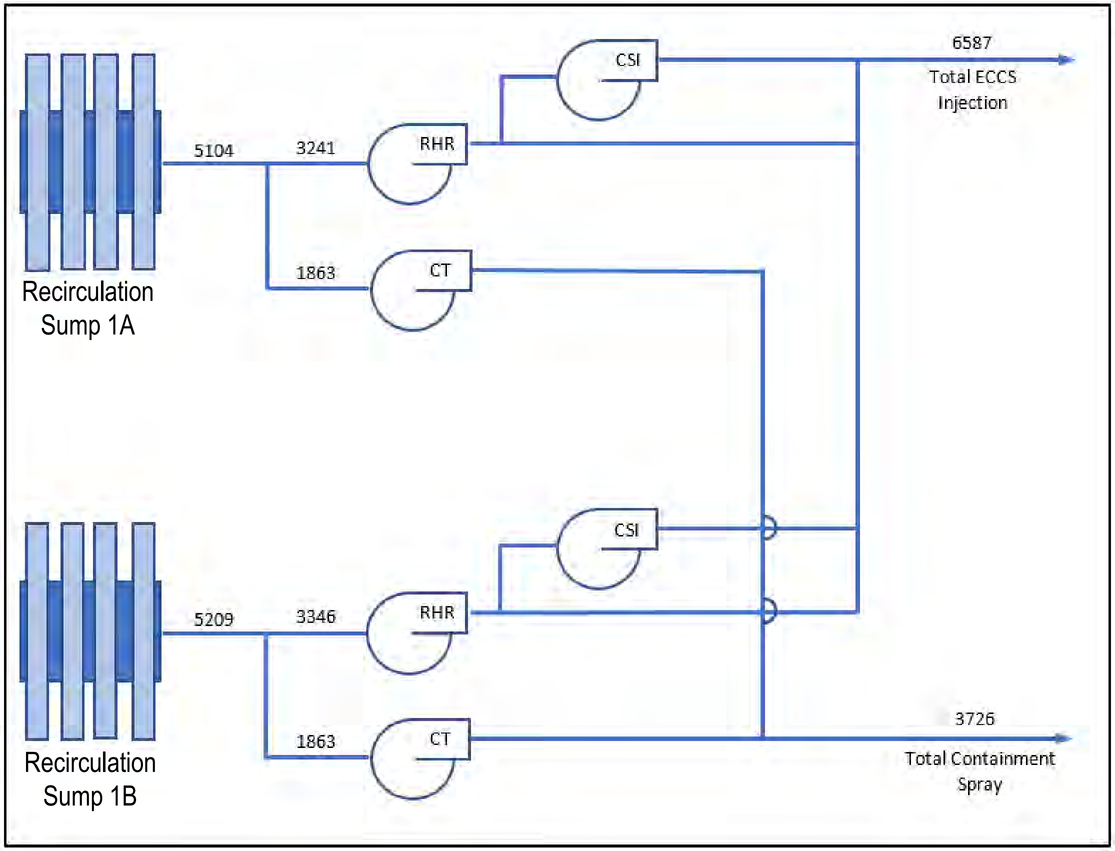


| | |
|---|---|
| Thermal Wrap® | |
| Mirror (Diamond Power) RMI | |
| Transco RMI | |
| Nukon | |
| Darchem | |

- Single-Unit, Westinghouse, 3-Loop PWR with upflow in barrel-baffle region with Areva fuel (HTP transitioning to GAIA)
- Buffer is sodium hydroxide injected through sprays to achieve sump pool pH range of 8.5 to 9.4
- Recirculation sump strainers are Enercon double top-hat design without bypass eliminator mesh
  - Installed in 2007
  - 3000 $ft^2$ in each of two sumps
  - 70 top-hat modules in each sump
- Containment CAD model developed

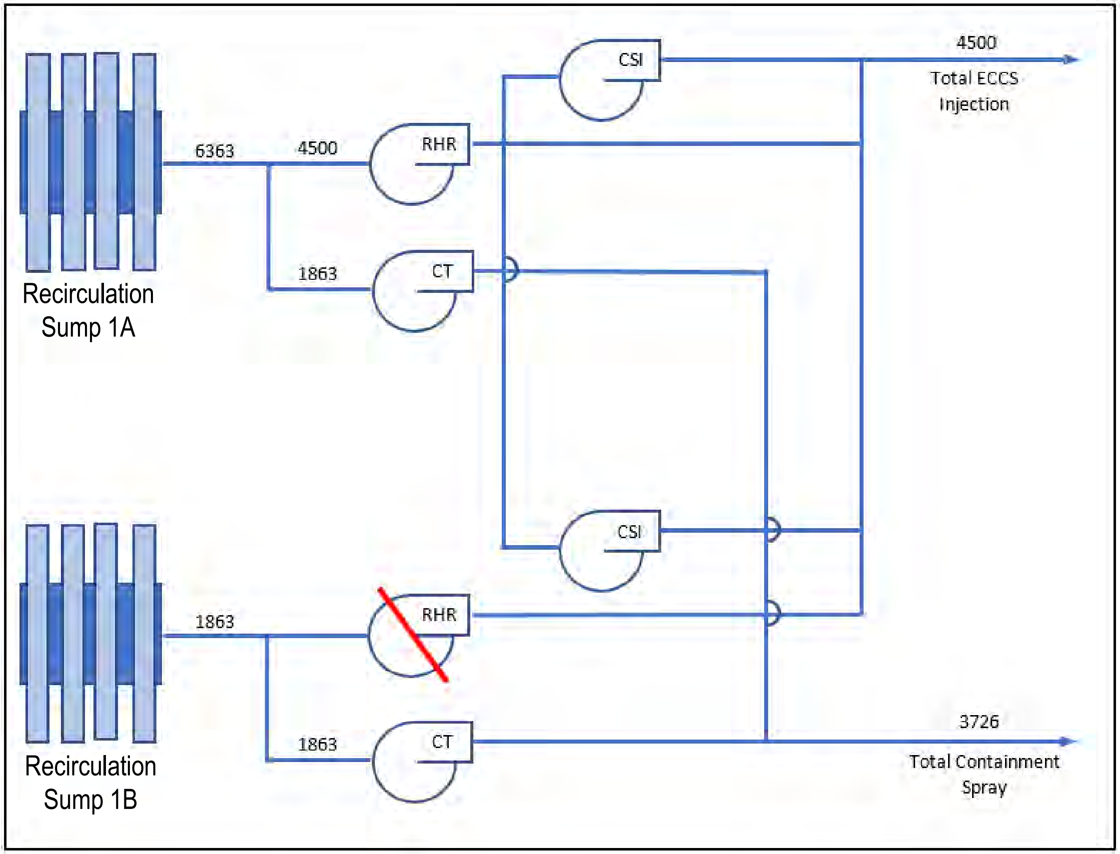
# Plant Overview (cont)

- No Failures Case
  - Both sumps in service with approximately equal flow
  - Of primary interest for fiber penetration because of maximum strainer area and lowest average fiber load



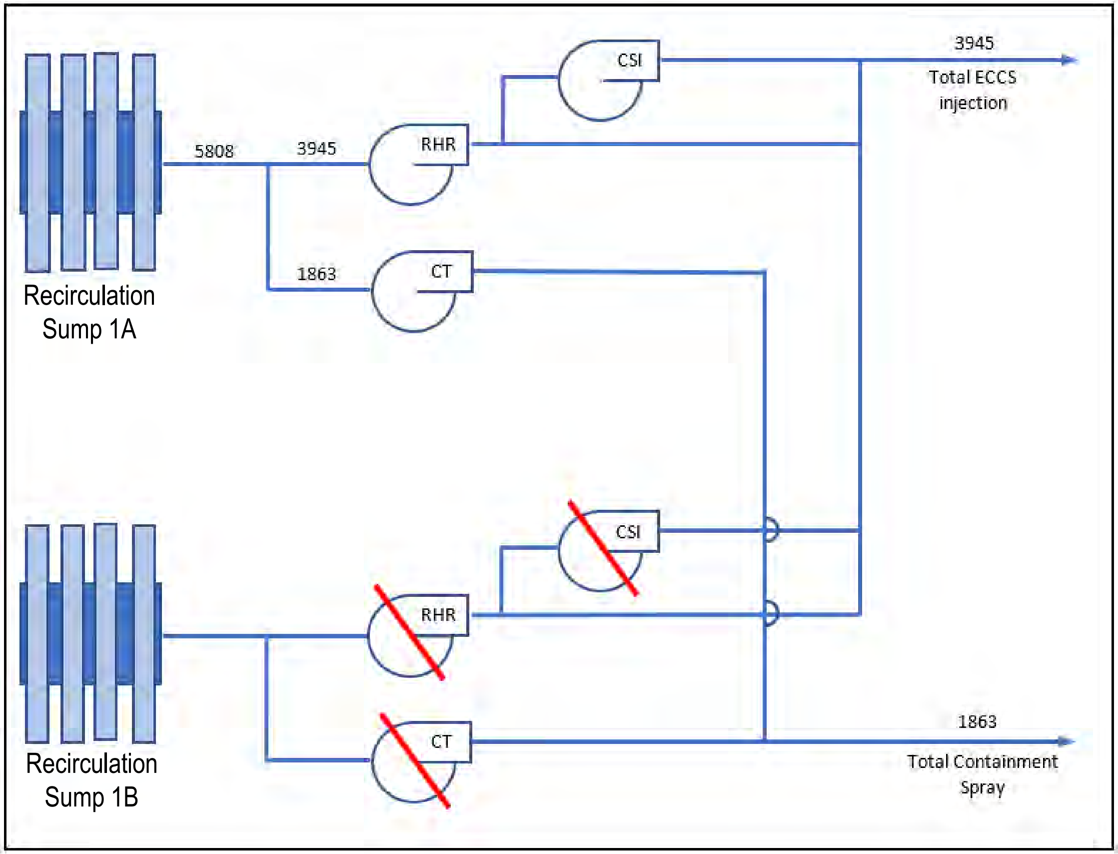
# Plant Overview (cont)

- RHR Pump Failure Case
  - Both sumps in service with only the CT pump operating in the sump with the failed RHR pump
  - Highest single strainer flow rate (by 10%), but debris is divided across two strainers

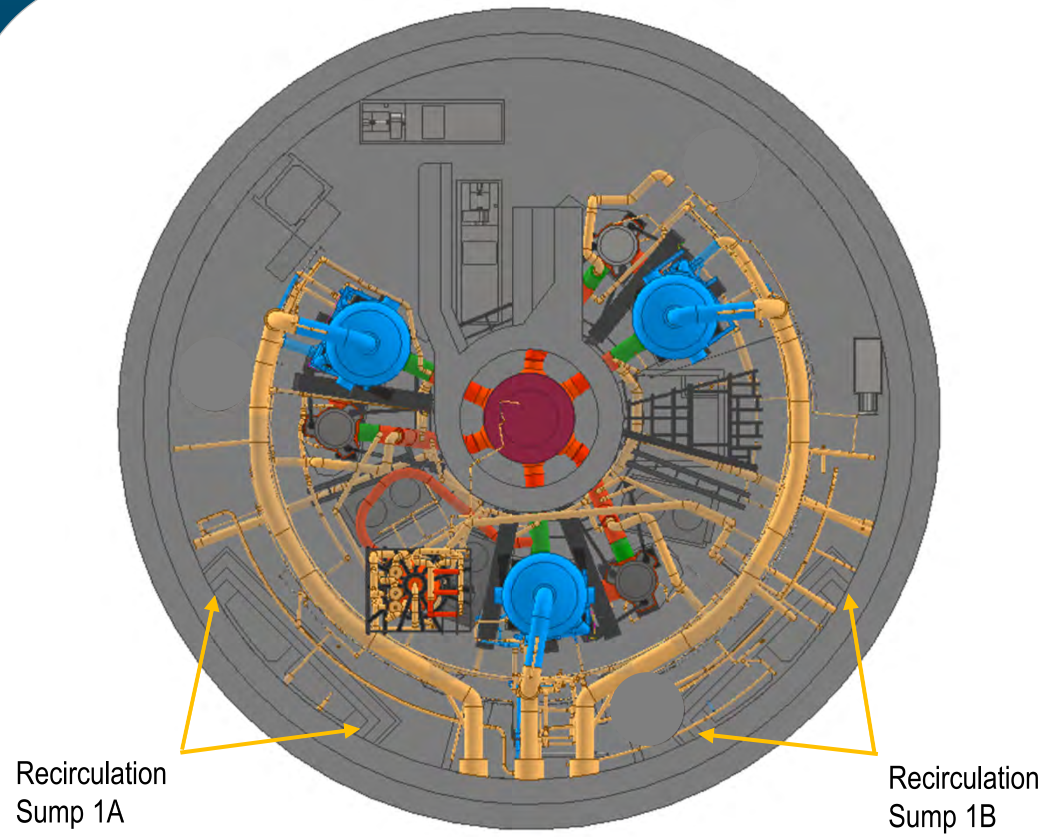


# Plant Overview (cont)

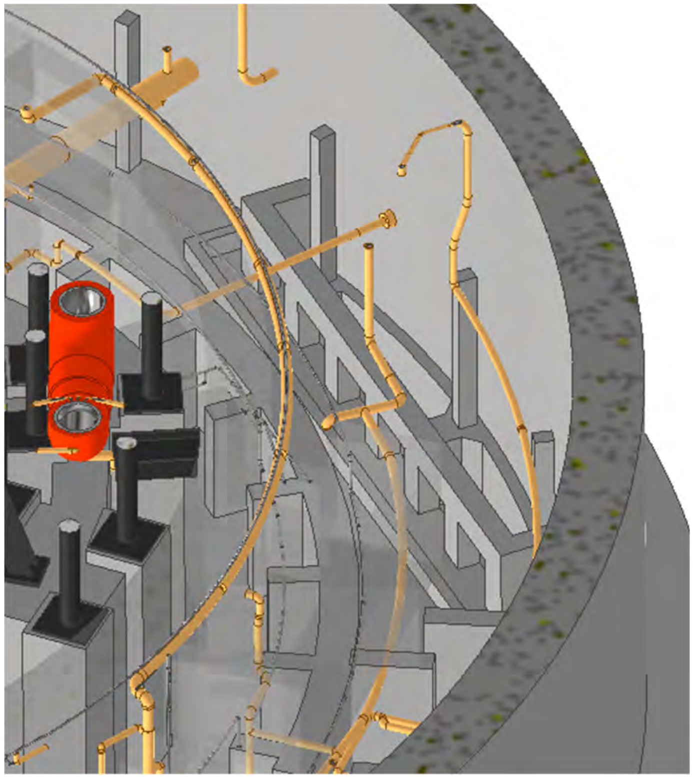
- Train Failure Case
  - Single sump in service
  - Selected as the bounding HL test condition, consistent with previous analysis, testing and NRC correspondence (ML101250456)
  - Sump flow of 5808 gpm => 0.004 to 0.005 ft/s face velocity



# Plant Overview (cont)




Containment Elevation 221'



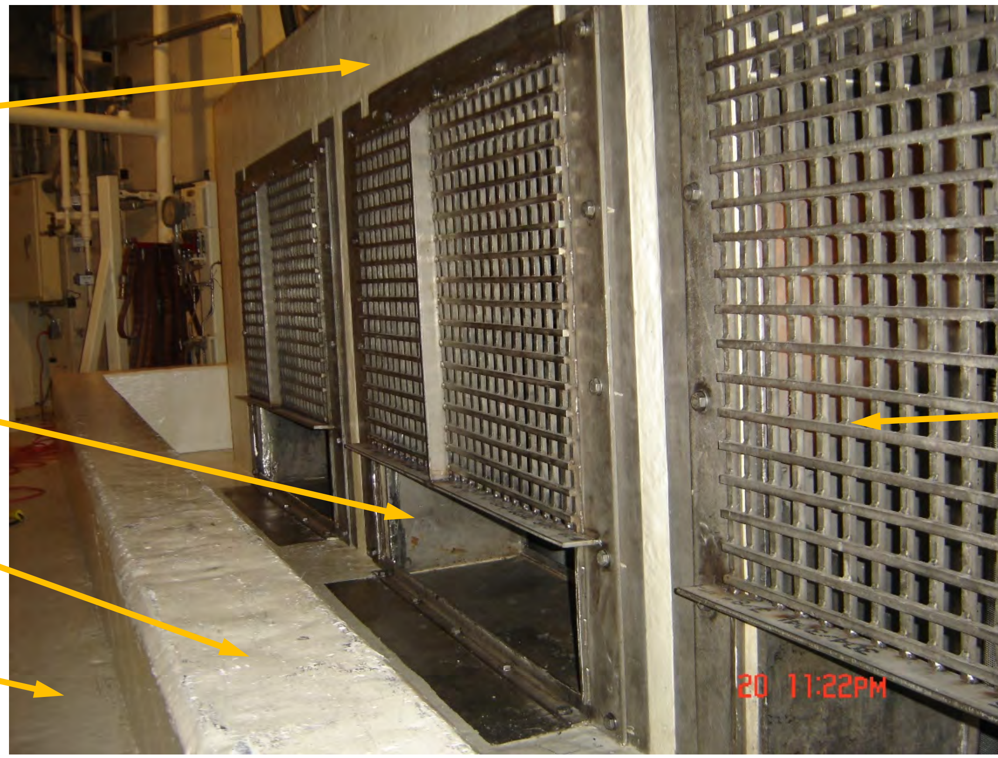
# Plant Overview (cont)

Sump Wall

Openings to Sump Pit

18” tall x 9” wide berm

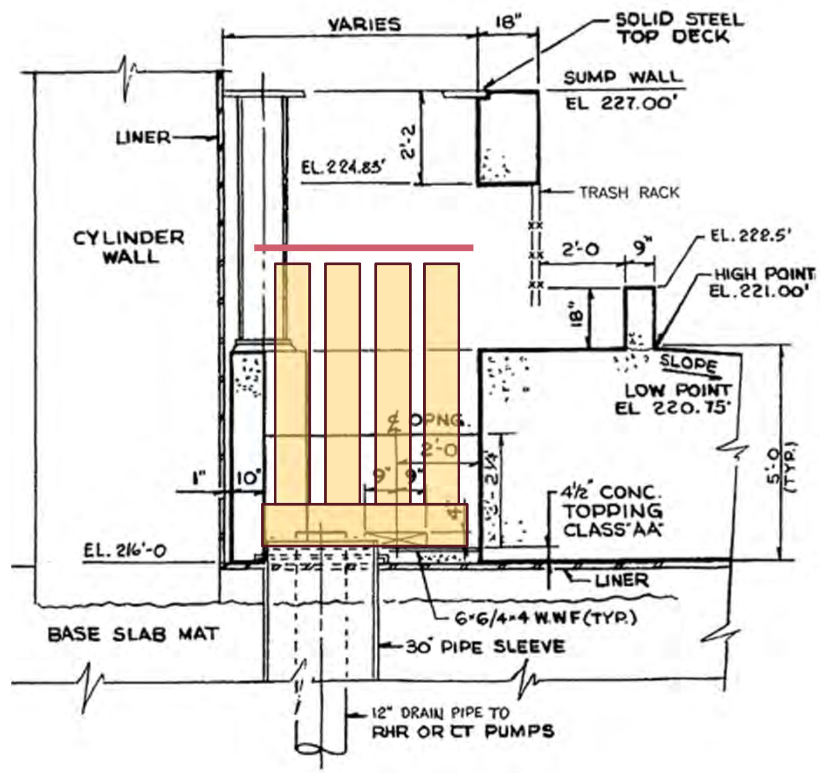
Containment Floor El 221’




Trash Racks

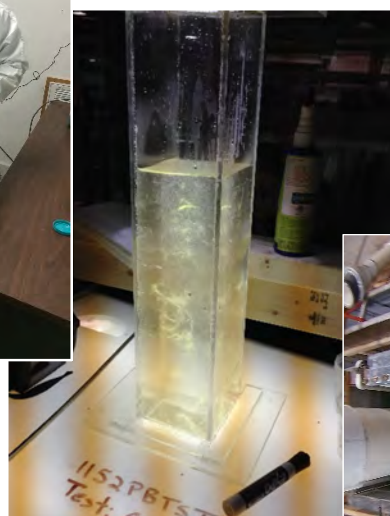
# Plant Overview (cont)

- Floor reference El 221’
- Top-hats stand on two plenums above either the RHR or CT pump suction
  - Plenums are hydraulically connected via an opening in the concrete divider wall that separates the two plenums allowing combined RHR and CT flow across total sump strainer area
- Top-hats are 66” tall
- Top-hats rise 2’-3” above 221’ floor
- Top-hat rise 0’-9” above berm
- Top-hats are fully submerged under all recirculation conditions



# Test Facility Design and Operation

- Alden Research Laboratory



Debris Preparation

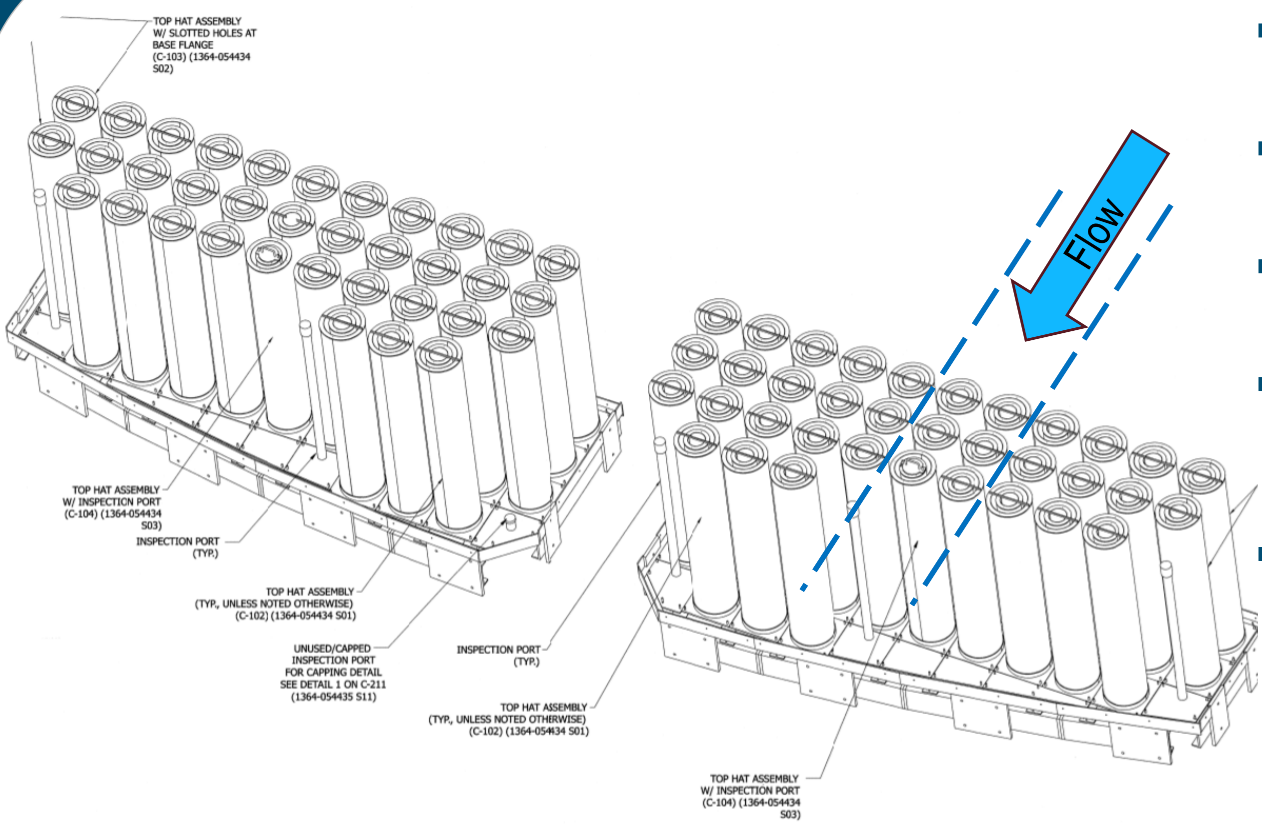
Debris Introduction Hopper


Flume Design

Strainer Cleaning

Chemical Product Formation

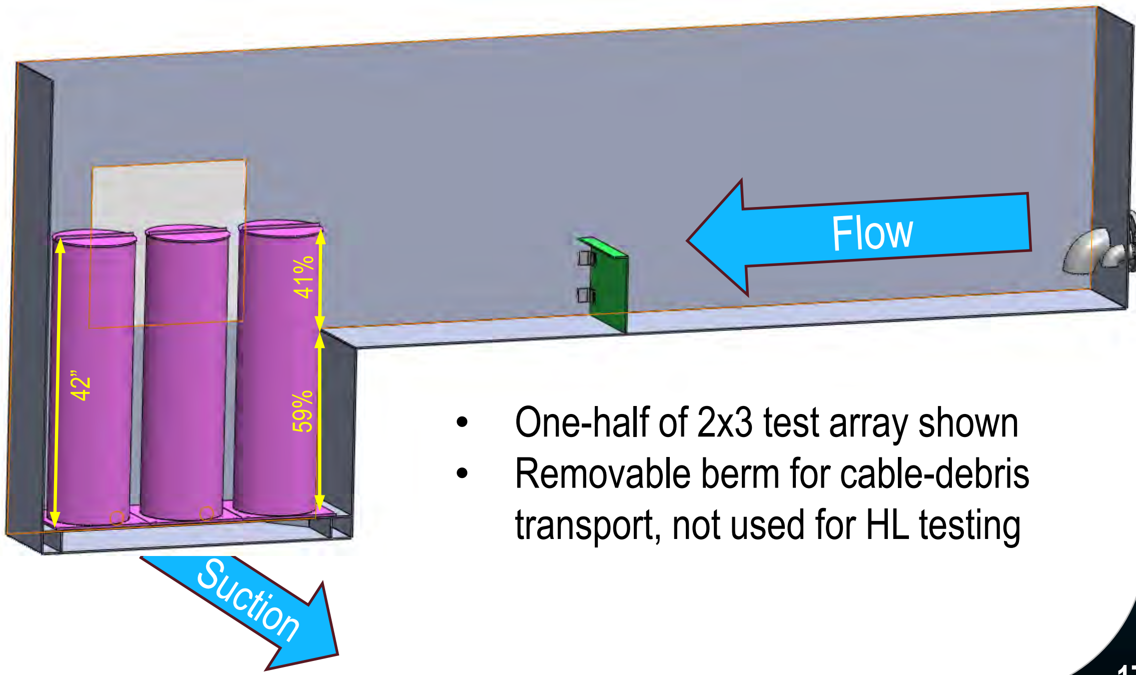
# Hydraulic Scaling




- Enercon double top-hat strainers (70 per sump)
- Total Area = 3000 $ft^2$ per sump
- Plant modules 66” tall, Test modules 42” tall (full diam)
- Approx test section denoted between dashed lines (2x3 array)
- Test scale ≈ 6% (after subtracting misc debris area)

# Conceptual Test Tank

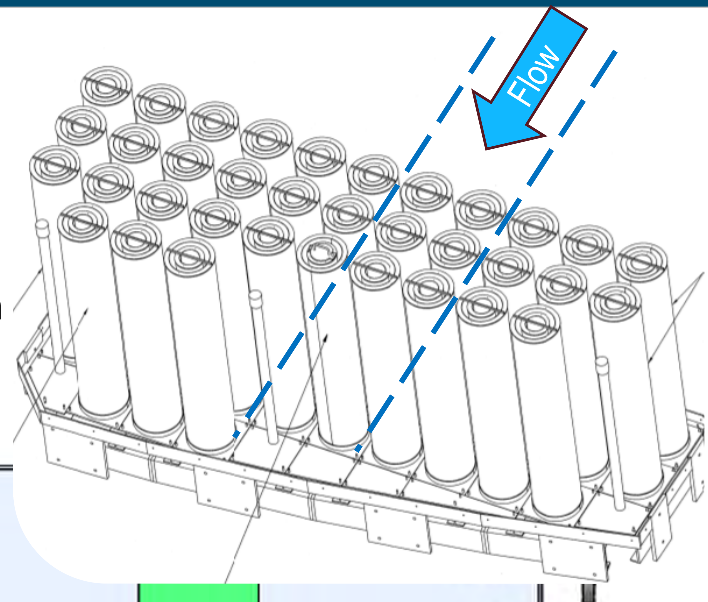
- Design goals:
  - Uniform upstream debris mixing
  - Near 100% debris transport
  - Maximum strainer face velocity (0.004 ft/s to 0.005 ft/s)
  - Typical submergence (6" to 12") permits access to top and inner module suction surfaces
    - Minimum submergence (4.5") checked for vortex formation
  - Plenum with one-side suction point (not shown) designed to prevent debris settling
  - Same percentage of length above (41%) and below (59%) floor as found in plant

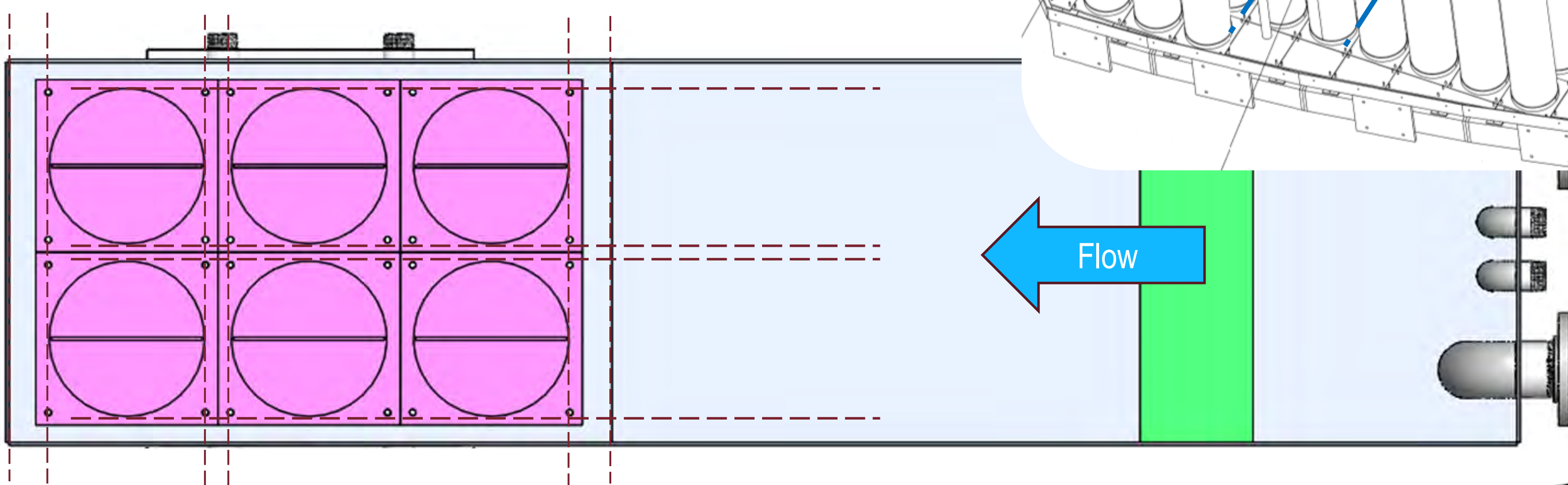



- One-half of 2x3 test array shown
- Removable berm for cable-debris transport, not used for HL testing

# Conceptual Test Tank (cont)

- Sidewall gaps equal to 1.5 x separation between internal modules allows debris access and possible bridging late in debris load
  - Not an exact symmetry plane
- Backwall gap represents nominal installation geometry, which varies along curved containment wall
- Leading sump-pit wall preserves actual plant installation gap between forward sump-pit edge and first top-hat modules



## High-Level Test Procedures/Assumptions

- Water temperature of approximately 120°F maintained throughout all tests
- Borated, pH-buffered, deionized water used as the test solution prior to addition of debris and chemical products.
- Aluminum Oxyhydroxide chemical precipitate manufactured by WCAP-16530-NP procedure, subject to maximum concentration limits, settling rates, and storage times
- Fiber fines will be the only fiber type/size tested
  - Formed of single-sided, heat-treated, Nukon® fiberglass insulation following 2012 NEI guidance (water-jet separation)
- Commercial silicate abrasives used for coatings particulate surrogate
- Purchased latent particulate debris with standard size distribution

## High-Level Test Procedures/Assumptions (cont)

- Head-loss and fiber penetration tests performed at maximum expected face velocity of 0.005 ft/s
- Standard debris load order used for Thin-bed test:
  - particulate + incremental fiber to initiate filtration
  - stop fiber addition when head loss slope transitions to volumetric bed filtration
  - chemical precipitate batches up to maximum planned load
- Standard debris load order used for Full-debris test:
  - mixed fiber and particulate batches up to maximum planned load + chemical precipitate batches up to maximum planned load
- Intermediate hold points and stability sweeps established for conventional debris prior to chemical addition
- Final head loss stability defined by less than 1% increase in 30-min observation period

# Generic Debris Generation and Transport Assumptions

- Following industry guidance provided in NEI 04-07 and WCAP-16530-NP
  - small variations to be discussed by topic
- Bounding debris limits established by CASA Grande analysis of DEGB at all containment welds using refined and verified CAD model
- Bounding sump pool transport fractions supported by Flow3D™ velocity/turbulence-field calculations for several break flow locations and strainer velocity configurations

# Preliminary Debris Load Targets

- Debris generation and transport calculations give plant-scale debris targets at the strainer
- Steam Generator (SG) case has particle-to-fiber mass ratio of approx. 2.3
- Reactor Nozzle (RN) case has less than 1/16th inch theoretical fiber thickness, and includes approx. 1/16th inch theoretical thickness of MICROTHERM™

| Debris Type | SG Case B-1 | | | Reactor Nozzle | |
|---|---|---|---|---|---|
| | At Sump (lbm) | At Sump ($ft^3$) | | At Sump (lbm) | At Sump ($ft^3$) |
| Total Nukon-equivalent Fiber[1] | 748.73 | 311.97 | | 28.50 | 11.88 |
| Total Microtherm™ | 0.00 | 0.00 | | 188.42 | 12.08 |
| Total 21-mil chip Coating | 0.00 | 0.00 | | 0.00 | 0.00 |
| Total 10-micron Particulate | 1559.17 | 7.44 | | 1509.38 | 6.46 |
| Total Dirt/Dust | 143.65 | 0.85 | | 160.55 | 0.95 |
| AlOOH Precipitate[2] | 65.70 | | | 54.15 | |

Note 1: Incudes latent fiber

Note 2: Includes and replaces sodium aluminum silicate (SAS)

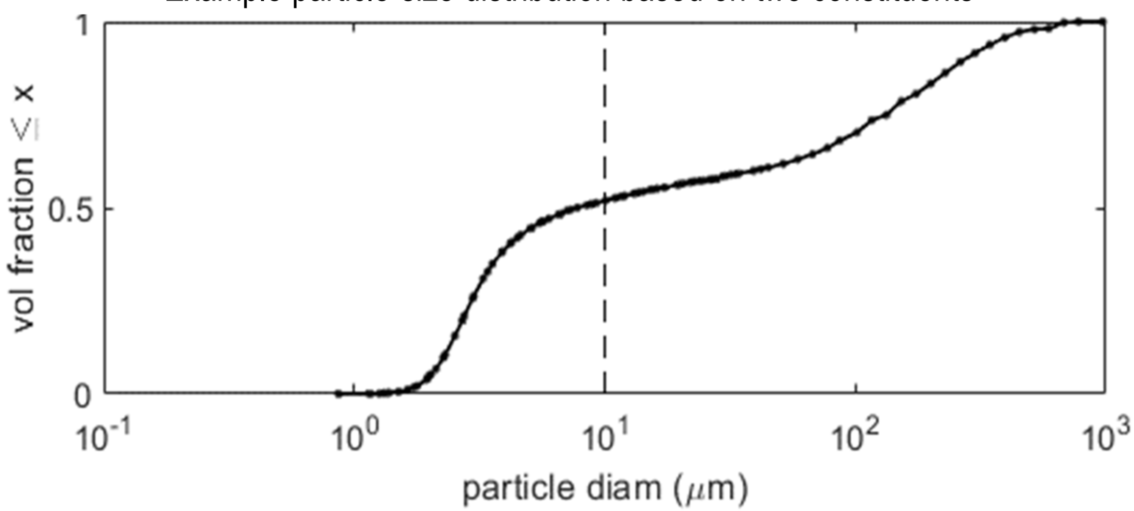
# Coatings Particulate

- Outside ZOI:
  - Degraded Qualified epoxy DBA coatings systems and epoxy DBA coating systems Unqualified for reasons of incomplete documentation of preparation, application, or inspection, are assumed to fail as 21-mil chips, which is the nominal thickness of original DBA coating specification
    - Chips of this thickness do not experience significant transport
  - All OEM coatings conservatively assumed to fail as 10-µm particulate, even though some of this material is known to be epoxy, which EPRI reports to have relatively low failure rates
- Inside ZOI
  - Qualified epoxy DBA coatings systems fail as 10-µm particulate inside 4-L/D ZOI.
  - 10-L/D for all other qualified coatings systems
  - Degraded Qualified and Unqualified DBA epoxy coatings systems fail as 10-µm particulate inside 10-L/D ZOI
- Clarification of HNP treatment of epoxy coatings (as described above) was provided in ML12240A230 (HNP Letter HNP-12-088)
- DBA epoxy coatings failure as chips outside the ZOI has been used by HNP since first Generic Letter 2004-02 response

# Coatings Particulate Surrogate

- Commercial silicate abrasives will be used as surrogates for coatings particulate
- A mixture of size distributions will be designed to achieve a high volume percentage of particulates less than 10-µm diameter, and a span of larger "scaffold" particle sizes needed for effective filtration

Example particle-size distribution based on two constituents



## Fiber Erosion

- 30-day erosion fraction lower than NEI-04-07 recommendation applied to small and large submerged fiber debris based on proprietary Alion Science testing of small fiber debris pieces and confirmation of test applicability to HNP sump conditions.

## Chemical Precipitates

- Borated, buffered (target pH 9.42), deionized water will be used as the test solution prior to addition of debris and chemical products
- Chemical product inventories based on 30 days post-accident duration using containment temperature and pH histories and a conservative spray duration (60 hrs with minimum safeguards, but assume 72 hrs)
- Aluminum oxyhydroxide (AlOOH) will be used as a surrogate for both AlOOH and sodium aluminum silicate (SAS) predicted by the WCAP-16530-NP spreadsheet calculator
  - Simplifies chemical product production
  - Avoids potential redissolution of SAS at high pH
- AlOOH will be produced according to WCAP-16530-NP procedures for maximum concentration, storage time, and settling
- WCAP-16530-NP reports nearly equal settling rates and filterability properties for equal aluminum concentrations of AlOOH and SAS
- Conversion of SAS to AlOOH surrogate quantity to be made on equivalent aluminum basis to ensure hydraulically equivalent surrogate (23 g of AlOOH equivalent to 100 g of SAS)

# Unqualified Cable Jacket Debris

- Unqualified cable jacket material plus electrical tape equal 277 $ft^2$ of the total 417 $ft^2$ of the assumed miscellaneous debris area
- Approximately 14% of the single-strainer area is assumed lost to miscellaneous debris prior to arrival of any other debris types
- There is no plausible mechanism for assumed 100% of cable area to arrive prior to other debris
- Testing with mixed cable debris would be judged as a non-conservative bed disruption.
- Observations of cable debris transport properties (with berm) may be performed to add context for limited debris transport description

# MICROTHERM™

- MICROTHERM™ applied to reactor nozzles only
- 2010 strainer testing included ~1/16th inch of MICROTHERM™ and did not experience strainer coverage
- Microtherm peak tested HL was > 10x less than full load HL and > 20x less than thin bed HL (which passed all strainer reqs)

- Significant open area indicates that RN break condition is not sensitive to:
  - Increased particulate
  - Increased miscellaneous debris

- MICROTHERM™ load not changed.
- HNP is not planning to repeat the MICROTHERM™ test condition

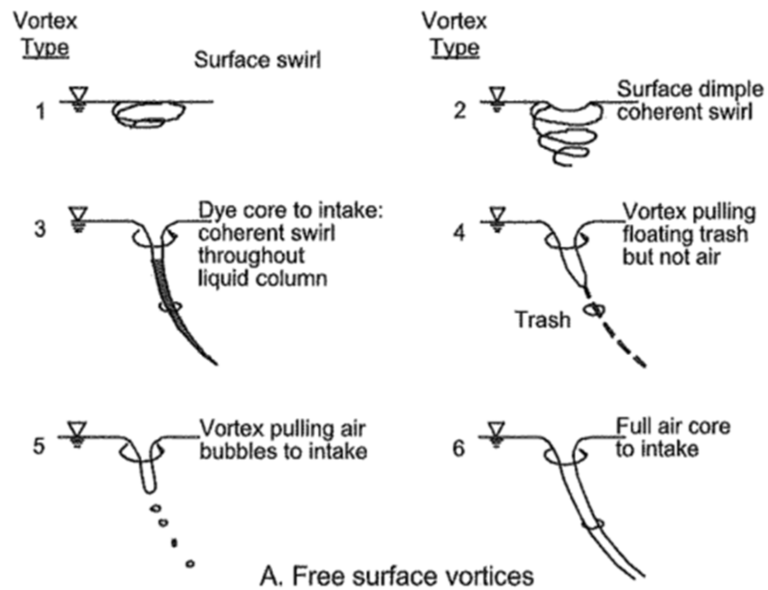


Post Chemical Drain Down

# Vortex Suppression

- Vortex suppression is ensured by steel grating mounted 4" above top-hat modules
- Previous testing observed Type 1 and Type 2 surface disturbances with no evidence of air ingestion
- Testing with vortex suppression grating will capture debris and limit maximum head loss
- Mounting a grating following conventional debris bed formation may disrupt bed

- Proposed solution:
  - Test without vortex suppression
  - Perform drawdown to minimum submergence
  - Repeat any test experiencing Type 5 or 6 vortices using vortex suppression grating




ANSI/HI 9.8-2012

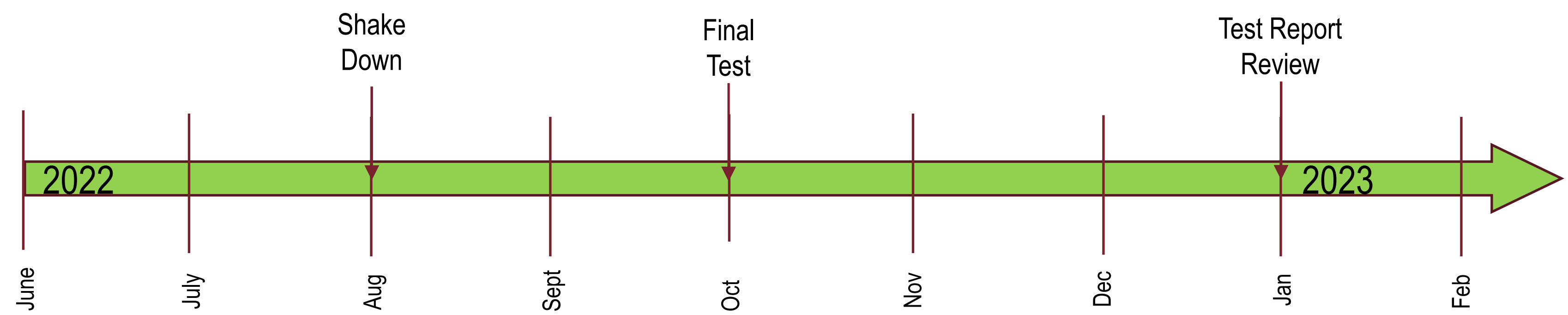
# Test Matrix

- Exploratory tests will include approach to full debris + full chem
- Exploratory tests will include fiber penetration sensitivity
- Exploratory/Contingency tests may include qualitative characterization of cable jacket debris transport
- Focus replicate data collection on fiber penetration correlation

| | Test Type | Repetitions | Comments |
|---|---|---|---|
| | **Shakedown/Exploratory** | | |
| 1.a | Shakedown/Exploratory | 1 | 1 sensitivity test concurrent with test-loop commissioning. |
| 1.b,c | Additional Sensitivity Head Loss Shakedown Exploratory Tests | 2 | As directed |
| | **Full-Load Head Loss** | | |
| 2.a | Full-Load Head Loss | 1 | 1 Required Qualification Full-Load Head Loss Test, (intended as DBA deterministic qualification test). |
| 2.b | Contingency Head Loss | 1 | 1 Additional Qualification Head Loss Test as directed |
| | **Thin-Bed Head Loss** | | |
| 3.a | Thin-Bed Head Loss | 1 | 1 Required Qualification Thin-Bed Head Loss Test. |
| | **Fiber Penetration** | | |
| 4.a | Fiber Penetration | 1 | 1 Required Qualification Fiber Penetration Test. |
| 4.b | Additional Qualification Fiber Penetration | 1 | As directed |
| 4.c | Additional Sensitivity or Qualification Fiber Penetration Test | 1 | As directed |

# Test Schedule

- Alden Research Laboratory is actively finalizing Test Plans and Flume Design
- Shakedown/commissioning tests slated to begin in Aug 1, 2022 timeframe
- Active testing will proceed semi-continuously for approximately 8 weeks through Oct 1, 2022
  - Some down time scheduled for staff personal time and filter-bag processing
- Test reports due for review by Dec 31, 2022
- Test reports released in final form by March 1, 2023



# Questions?

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