Water Treatment Challenges at the Fukushima-Daiichi Nuclear Facility

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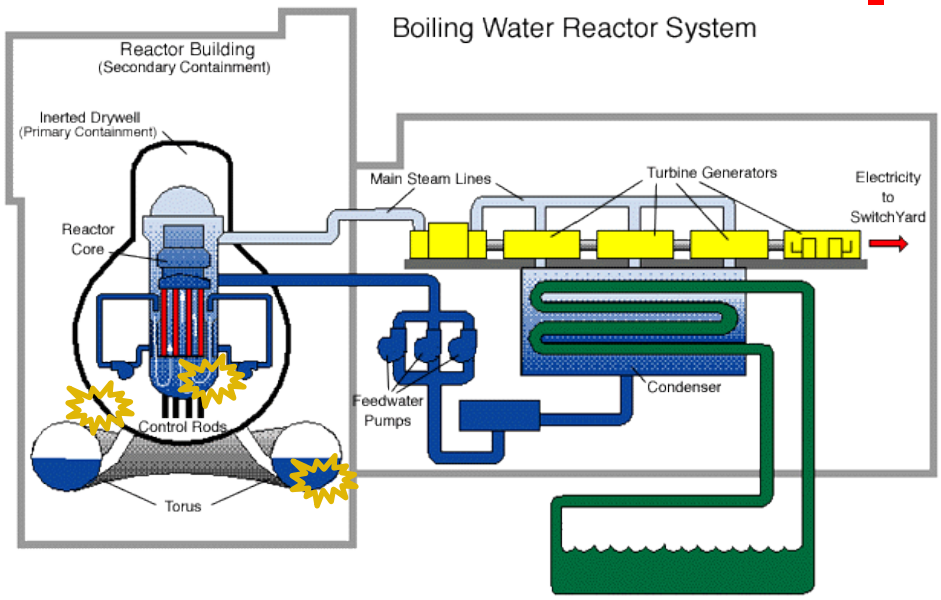
March - 2015

The Emergency Response

- Removal of radioisotopes in a Seawater Solution
- Deliver it in less than 8 weeks
- Start-up in less than 12 weeks
- Ensure its safe!
  - Dose Rates
  - Thermal
  - Operational Safety



Post Accident Reactor Cooling

AVANTech Response was Critical

Why AVANTech?

U.S. Wastewater Recycling Operations

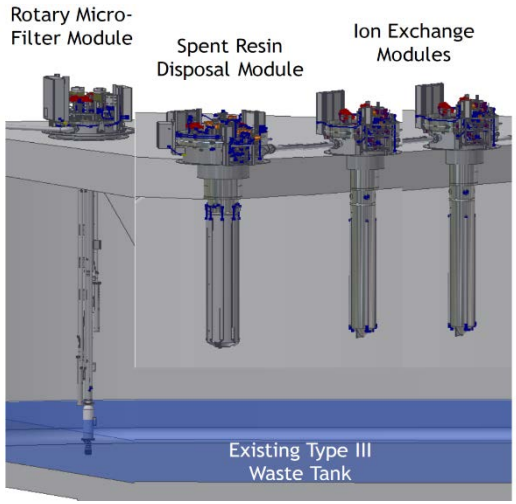
DOE/DOD Experience

International Experience

Worldwide Expertise in Nuclear Wastewater Treatment !

Deployment of DOE Technology

- **SCIX – SRR**



SRNL
SAVANNAH RIVER NATIONAL LABORATORY™

Strategic Alliance with AVANTech

U.S. DEPARTMENT OF ENERGY

50,000 R/h on IX resin

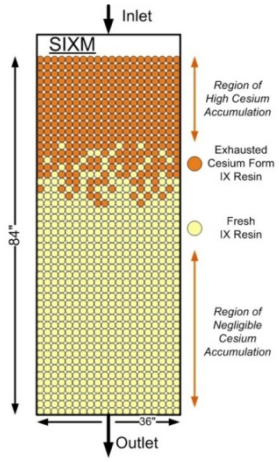
- **Crystalline Silicotitanate**
- **Important Underpinning**
  - **CST Testing at DOE Sites**
  - **Comprehensive CST Evaluation**
    - ✓ **Thermal**
    - ✓ **Radiological**
    - ✓ **Material Stability**

Rx Core Melt - Emergency Response

Emergency Response: The AVANTech Technical Approach

Challenge 1 – Activity Capture

- **Engineered Zeolite**
  - Primary Ion Exchange
  - Distribution Coefficient (Kd) ≈ 2,000 in seawater
  - Good Axial Cesium Distribution
- **Crystalline Silicotitanate**
  - Polishing Ion Exchange
  - Distribution Coefficient (Kd) > 20,000
  - Needed to achieve complete activity removal with a single pass



Axial Cesium Loading

Cs Limited to 200,000 Ci (7.5E+15 Bq)

Challenge 2 – Shielding

Integral Shielding
≈ 6" Pb Equiv.

Loaded Wt.:
≈ 23 mt (50,000 lb)

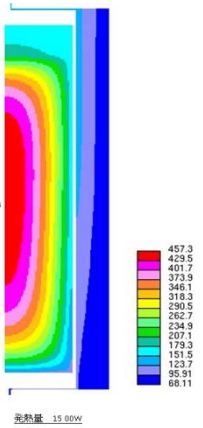
Challenge 3 – Heat Generation

- **Passive Cooling**
- **Contact Handled**
- **Long Term Storage**

Temperature Profile

855 °F Centerline

Centerline/ Core Temperature



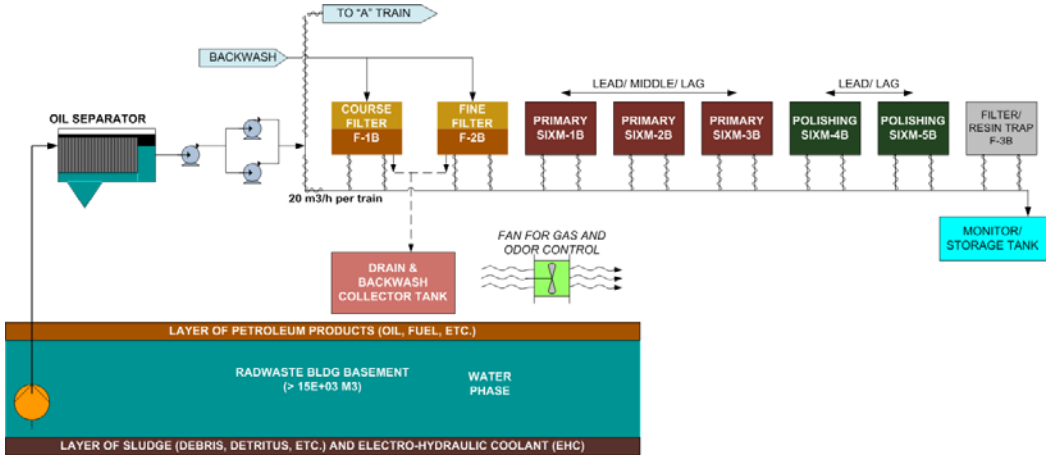
Safely Managing 200,000 Curies of Radioactive Material

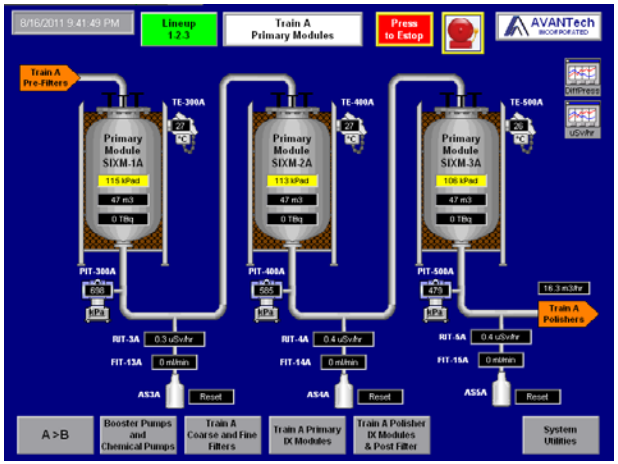
Emergency Response: Process Solution

SARRY

- Pipe Racks
- SIXMs
- Flexible Hoses
- H_2 Vents

- Automatic Alignment
- DP (kPad)
- Throughput (m3)
- Rad Loading (TBq)
- Trending

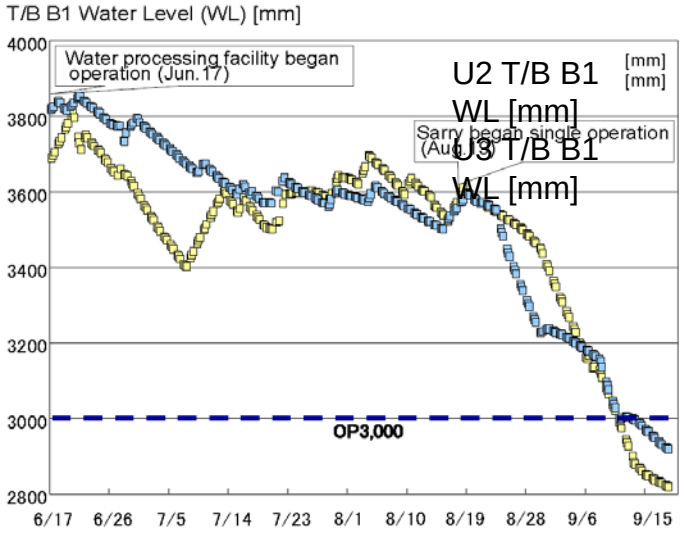




Process Optimizes Media and Decontamination Factor

Emergency Response - Results

- Accumulated Water Volume Control

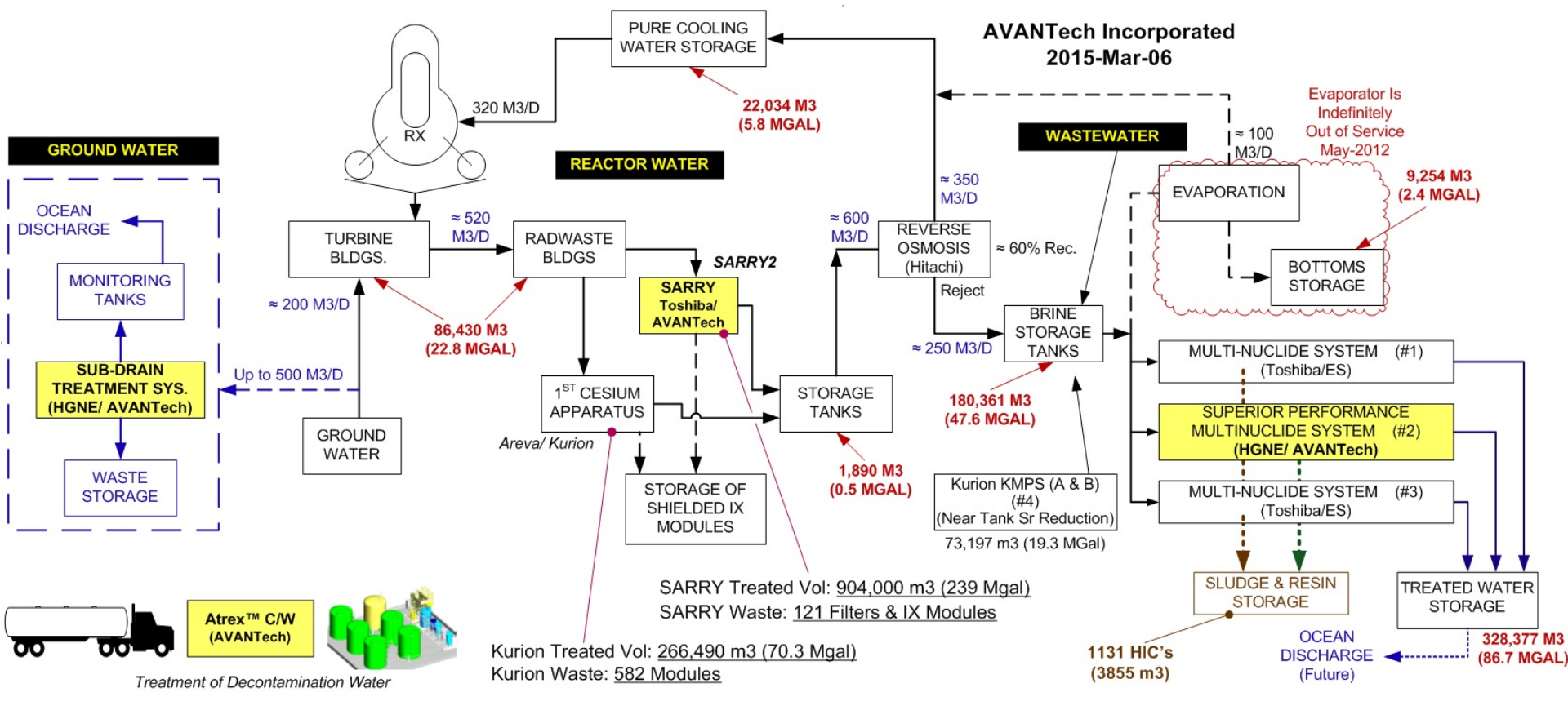


- SARRY Processed 80% of Water
  - **Non-detectible CS-137 effluent**
  - **DF > 2 million**

- SARRY Generated 13% of Waste

Results by all Standards Exceeded Clients Expectations

Fukushima Wastewater Overview

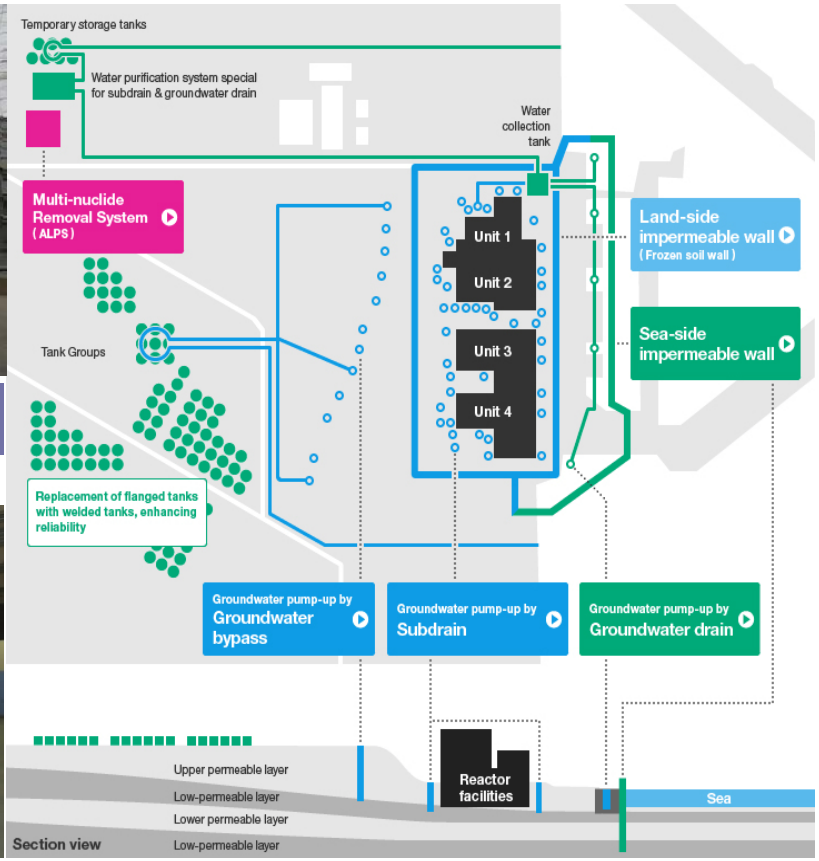


Water Treatment Continues to Be a Challenge

Liquid Waste Implementation Plan

High Performance ALPS

Subdrain



SARRY

Tankage

Critical Support has been Provided by the Avantech Team

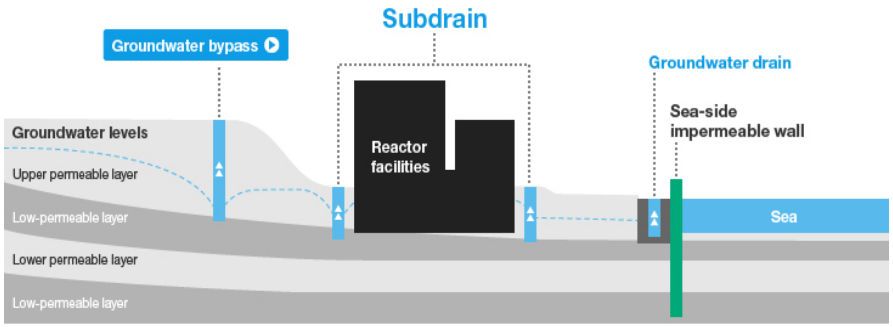
Groundwater Remediation

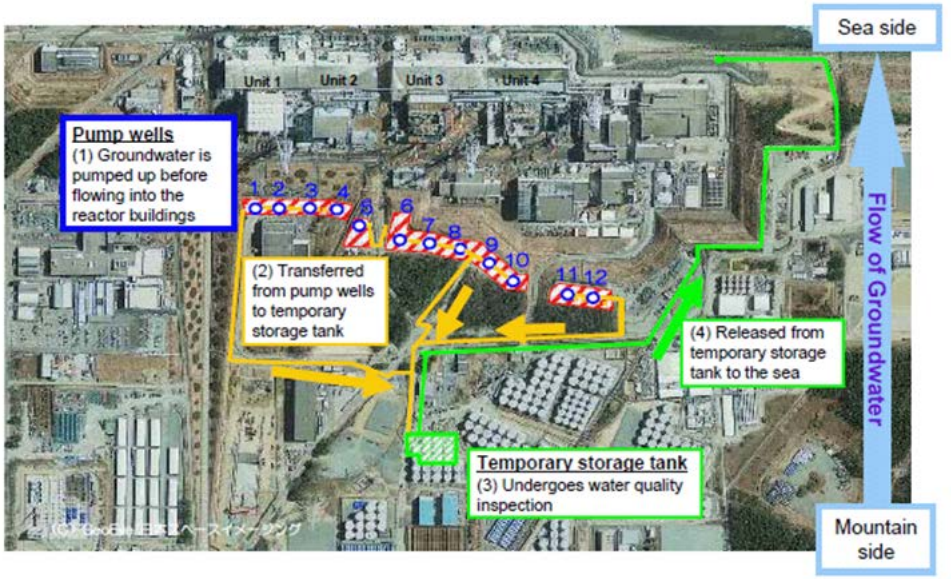
Groundwater Problem

- Groundwater In-leakage of 300 tons per day
- Increased Contaminated Water
- Increased Waste Volumes

Groundwater Goals

- Rad Removal for Risk Reduction
- High TDS Influent
- Minimize Waste Generation
- Minimize Consumables

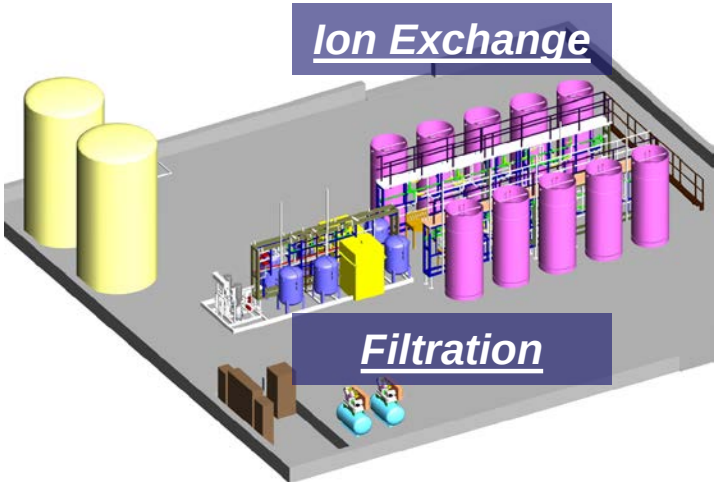




Lower Groundwater to Reduce In-Leakage

Groundwater Remediation

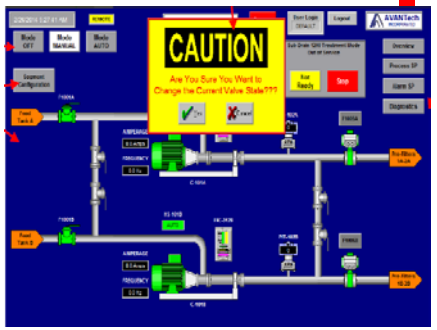
- System Technology
  - Gross Filtration
  - Fine Filtration
  - Ion Exchange
- System Design Inputs
  - 1,200 m3 per day (220 gpm)
  - Chemistry
    - Cl- 800 ppm
  - Activity
    - Cs-134: 0.8 Bq/ml
    - Cs-137 2.1 Bq/ml
    - Sb-125: 0.03 Bq/ml
    - Sr-90: 3.0 E-02 Bq/ml
- Laboratory Scale Validation of Media



Designed, Built, Factory Tested at AVANTech

Groundwater Remediation

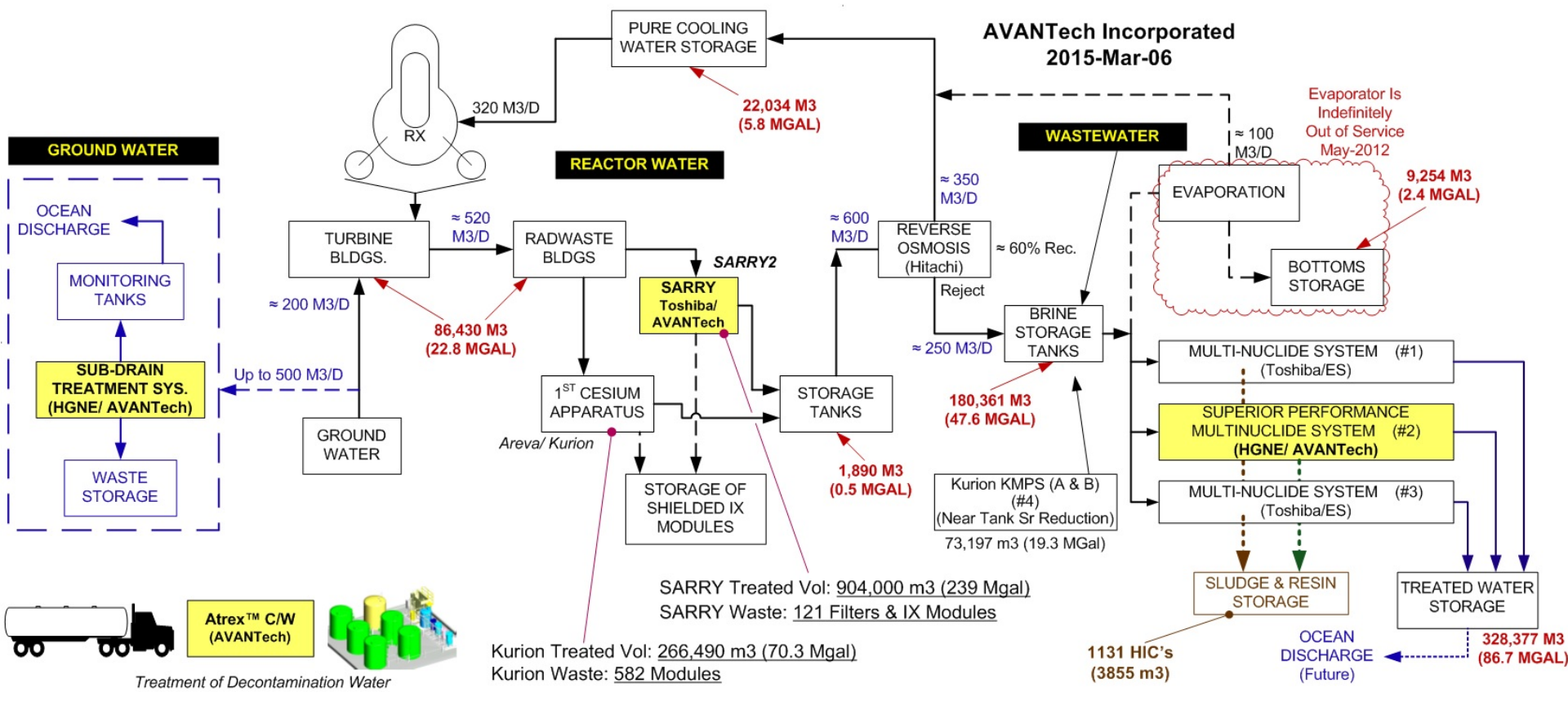
- Operations
  - Plug-n-Play Installation
  - Automated
  - Material Handling Similar to SARRY
- Actual Results
  - Effluent less than Regulatory Value
  - Minimal Waste Generation
  - Brine Operations – 10/14



Controlling In-Leakage to Meet the Site Objectives

Installed Equipment

Fukushima Wastewater Overview



Water Treatment Continues to Be a Challenge

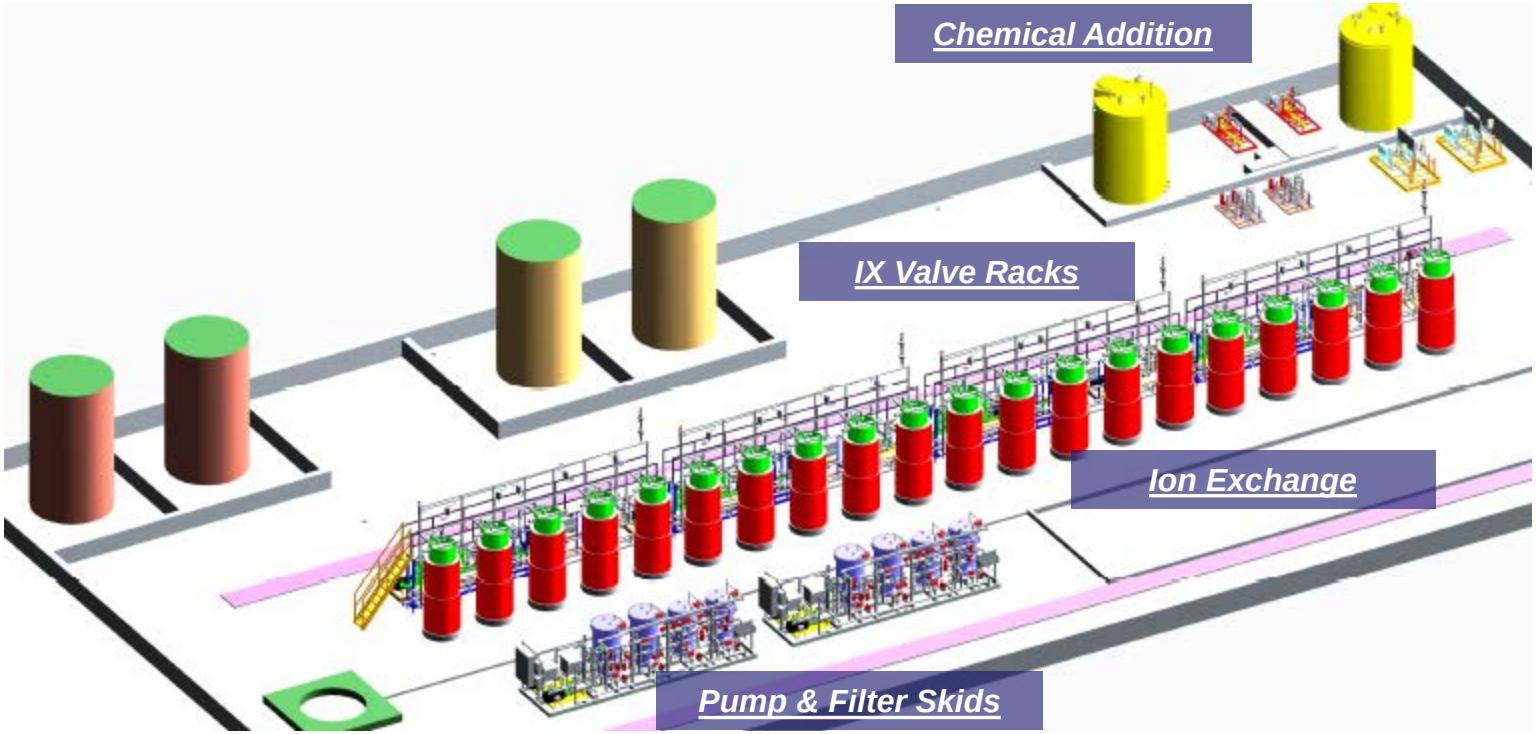
Multi-Nuclide Removal Technologies

Item	**Improved ALPS**	**High performance ALPS**	Existing ALPS
Treatment vol.	at least 250 m3 /day/unit	at least 500 m3 /day/unit	250 m3 /day/unit
No. of systems	3 units	1 unit	3 units
Pre-treatment method	Coagulating sedimentation method	Filter method	Coagulating sedimentation method
No. of absorption towers	18 towers	20 towers	14 towers + 2 towers
Seismic resistance class	Equivalent to Class B	Equivalent to Class B	Equivalent to Class B
Removal capabilities	62 nuclides to ND level (excl. tritium)	62 nuclides to ND level (excl. tritium)	Same as the left
Waste generation	N/A	To the extent of 1/20 of the existing ALPS	N/A

- Multiple Operations to Minimize Downtime
- Multiple Technologies to Optimize Performance
- Processing Results Reflect Capacity

Approximately 50% of the Brine Has Been Processed

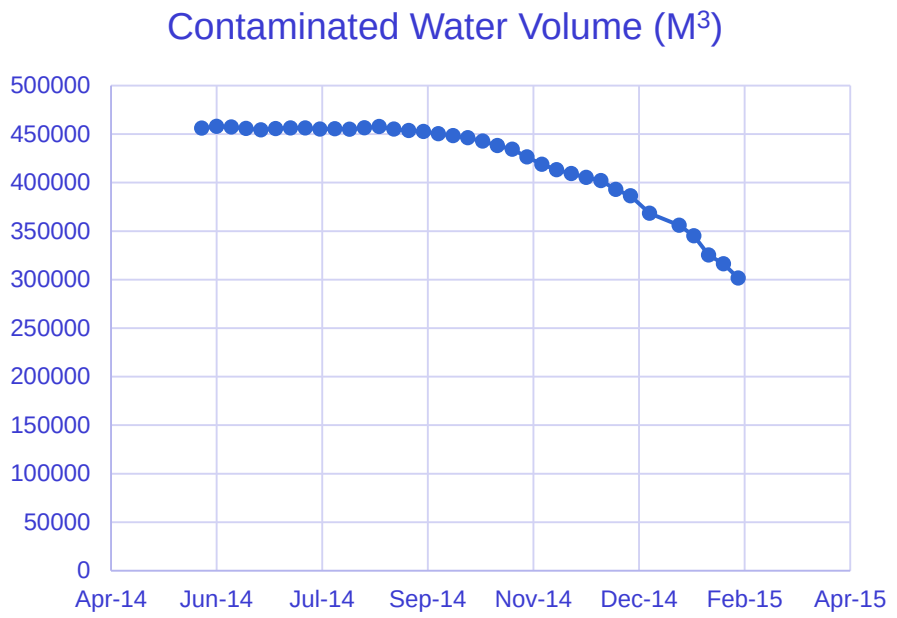
AVANTech Multi-Nuclide Removal



Preliminary Layout of Multinuclide Removal Facility

AVANTech Multi-Nuclide Removal

- Operations
  - October 2014 Start
  - >15 million gallons processed
  - On-going Analysis of results
- Continued Development
  - Resin Optimization Plan
  - Filtration Optimization On-going
- Consumables Support In-Place



Focus is on Long Term Progress and Continuous Improvement

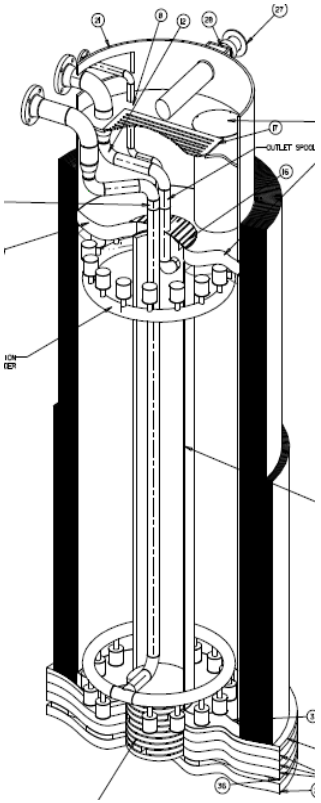
AVANTech Multi-Nuclide Removal

- System Solution
  - Gross Filtration
  - Fine Filtration
  - Ion Exchange
- System Design Inputs
  - 500 m3 per day (92 gpm)
  - Chemistry
    - Cl- 6000 ppm Average
    - Ca 300 ppm
    - Mg 400 ppm
    - pH: 7.5
  - Activity
    - Cs-134: 1E2 Bq/ml
    - Cs-137 1E2 Bq/ml
    - I-129: 9 E-02 Bq/ml
    - Co-60: 6.6E-01 Bq/ml
    - Sb-125: 5E2 Bq/ml
    - Mn-54: 7.9E-1 Bq/ml
    - Ru-106: 2E2 Bq/ml
    - Sr-90: 1E6 Bq/ml



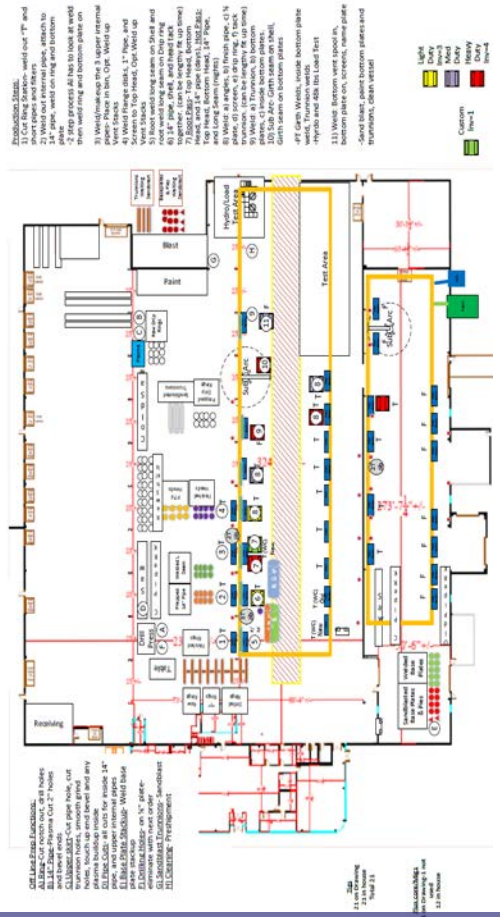






IX Vessel Customized for Application

AVANTech Advanced Manufacturing



Project 13-20 Vessel Weld Data Sheet

Date:	10/20/14				**Page:**	10	of 17
Traveler No:	1320-15 (A23)						
Avantech Project:	1320						
Fabrication DWG No.:	1T405-1320-D				**UNS# S32205 BASE METAL**		
Weld Map DWG No:	1T405-1320-D-WELDMAP						
WPS:	2	AT-FCAW-08-SS	3	AT-GMAW-FCAW-09-SS	5	AT-FCAW-12-CS-SS	
WPS:	7	AT-FCAW-05-CS	9	AT-GTAW-18-DSS	10	AT-SAW-27-DSS-2205	
WPS:	11	AT-SAW-21-CS	12	AT-GMAW-FCAW-23-DSS-2205	13	AT-GMAW-FCAW-06-CS	
WPS:	14	AT-GTAW-20-DSS-SS	15	AT-SAW-30-DSS-SS-2205	16	AT-FCAW-29-DSS-SS-2205	
WPS:	17	AT-FCAW-35-DSS-CS-2205	21	AT-FCAW-41-DSS-2205			

REQUIREMENTS

Weld ID Number		25 A23		29 A23		30 A23		31 A23	
WPS No.		14	14	16	16	2	2	9	9
Welding Condition	Fit-up Weld Out	☑ WPS No. ☑		☑ WPS No. ☑		☑ WPS No. ☑		☑ WPS No. ☑	
		☑ Current (A) Check ☑		☑ Current (A) Check ☑		☑ Current (A) Check ☑		☑ Current (A) Check ☑	
		☑ Voltage (V) Check ☑		☑ Voltage (V) Check ☑		☑ Voltage (V) Check ☑		☑ Voltage (V) Check ☑	
		☑ Shield Gas ☑		☑ Shield Gas ☑		☑ Shield Gas ☑		☑ Shield Gas ☑	
		■ Backing Gas ■		■ Backing Gas ■		■ Backing Gas ■		■ Backing Gas ■	
		☑ Position Check ☑		☑ Position Check ☑		☑ Position Check ☑		☑ Position Check ☑	
		Check Date & ID		Check Date & ID		Check Date & ID		Check Date & ID	
		Fit-up	Weld Out	Fit-up	Weld Out	Fit-up	Weld Out	Fit-up	Weld Out
	Welder ID	N3	N3	G4	G4	G4	R5	G4	G4
	Date	2-19-15	2-19-15	2-19-15	2-19-15	2-19-15	2-19-15	2-25-15	2-25-15
Filler Metal Heat No.	Fit-Up	079566		2304622		13935371		QR219	
	Weld-Out	079566		2304622		13935371		QR219	
Base Metal Heat No.		A-15-1422-010		A-14-1422-2433		A-15-1422-251		A-15-1422-263	
		A-14-1422-2460		A-14-1422-2460		A-15-1422-251		E131142	
Fit-Up (Initial/Date)		☑ Dimension ☑ Angle ☑ Visual ☑ Accept AH 2-19-15		☑ Dimension ☑ Angle ☑ Visual ☑ Accept AH 2-19-15		☑ Dimension ☑ Angle ☑ Visual ☑ Accept AH 2-19-15		☑ Dimension ☑ Angle ☑ Visual ☑ Accept AH 2-25-15	
Root Pass Visual Inspection (Initial/Date)		☑ Accept AH 2-19-15		☑ Accept AH 2-19-15		☑ Accept AH 2-19-15		☑ Accept AH 2-25-15	
In-Process Inspection (Initial/Date)		☑ Accept AH 2-19-15		☑ Accept AH 2-19-15		☑ Accept KAC 2-19-15		☑ Accept AH 2-25-15	
Final Visual Inspection (Initial/Date)		☑ Accept AH 2-19-15		☑ Accept AH 2-19-15		☑ Accept KAC 2-19-15		☑ Accept AH 2-25-15	
Final NDE (Initial/Date)		■ Accept N/A		■ Accept N/A		■ Accept N/A		■ Accept N/A	

*N/A if not applicable

FINAL REVIEW AND APPROVAL

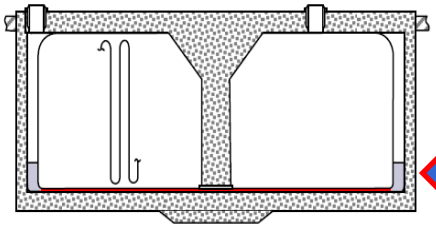
AVANTECH QUALITY MANAGER DATE

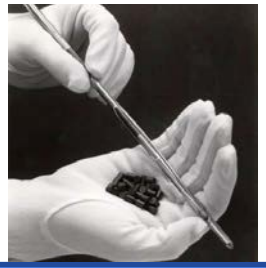
Facility Layout | ***Facility Operation*** | ***Automated Documentation***

Production Capacity Increase of 400%

Future Cs Applications?

- **Similarities**





Radioisotopes from Fuel

SRS-MCU Feed Cs = 0.25 Ci/gal*	Hanford Feed Cs = 0.78 Ci/gal	SARRY Feed Cs = 0.60 Ci/gal
SRS- CSSX DF(Cs) = 2E+2	SIXM DF(Cs) = 5E+3	SIXM DF(Cs) = 2E+6
Final Waste Can 40,000 Ci	SIXM 150,000+ Ci	SIXM 150,000+ Ci

If you can Conceive and Believe You can Achieve

* SCIX Design: 1 Ci/gal