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In-Riser Ion Exchange: Resorcinol-Formaldehyde Maturation

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EM Office of Environmental Management
safety ◆ performance ◆ cleanup ◆ closure

Agenda

- Objectives
- Background
- Original Design
- Media Considered
- Current Conceptual Design
- Recent Progress
- Current Activities
- Project Goals

Objectives

- Develop in-tank system to decontaminate HLW salt solution at SRS and Hanford to accelerate salt processing and tank closure
- Vitrify Cs-137 or transfer to compliant tanks
- Support spherical RF maturation for various DOE applications

frequently referred to as Small Column Ion Exchange (SCIX)

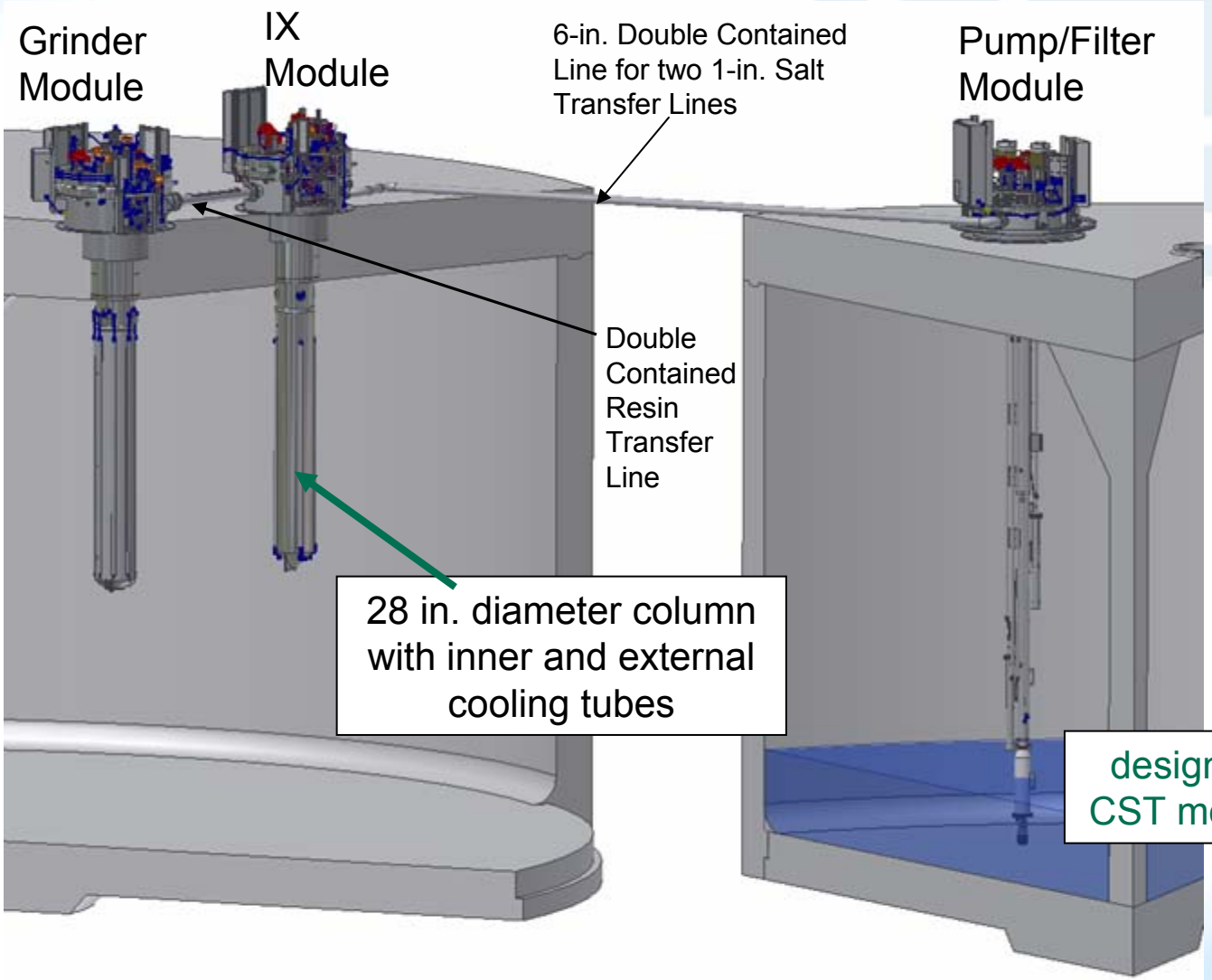
Current concept: in-riser IX similar to Cesium Removal Columns in use for years at SRS

Background

- In-riser concept began as backup to SRS Caustic Side Solvent Extraction (CSSX)
- NETL initiated and DOE EM completed a design for in-riser, non-elutable configuration
  - **media: Crystalline Siliocotitanate (CST)**
  - **included Rotary Microfilter, IX column, and grinder for media disposal**
- Spherical RF developed as part of Hanford Waste Treatment Plant R&D and selected as baseline WTP IX media
- SRS Systems Engineering Evaluation for in-riser IX applications (EPRR) and development of Hanford Interim Pretreatment System resulted in examination of spherical RF
- EM-21 currently funding spherical RF maturation studies to support utilization of RF at both SRS and Hanford

EPRR - Enhanced Processes for Radionuclide Removal
- program focused on in-tank riser IX at SRS
- conducted most recent testing and evaluations

Original ORNL Design

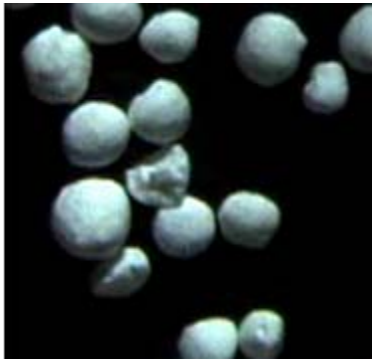


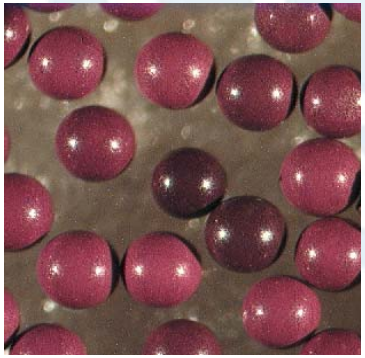
design based on CST media at SRS

Ion Exchange Media Considered

EPRR evaluated both media

granular
CST



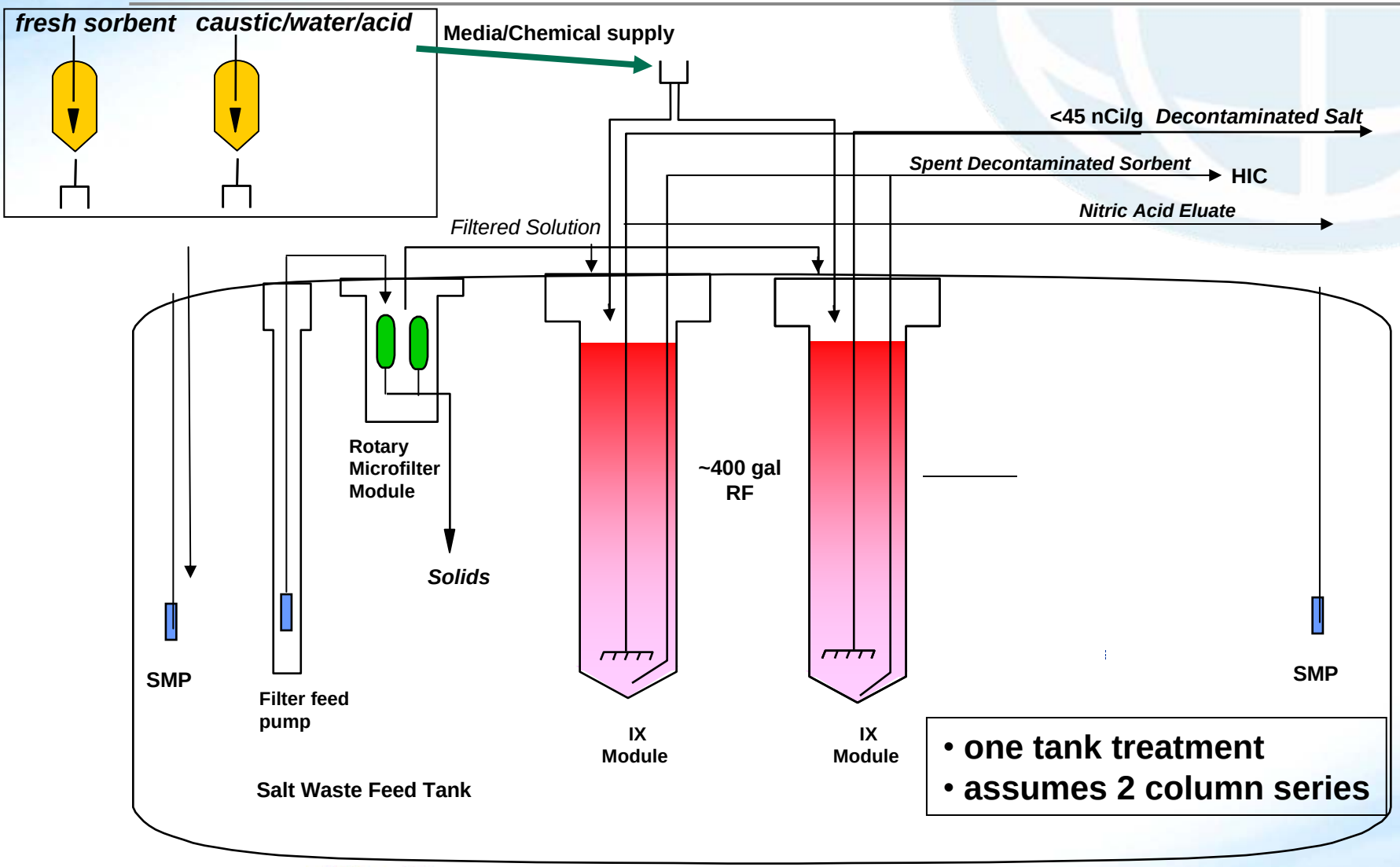


spherical
RF

	CST	RF
Elutable	no	yes
Grinder needed	yes	no
Kinetics	moderate	fast
Radiation tolerance	high	moderate
Source term	high	moderate
Secondary rad waste stream	no	yes
Shrink/swell during cycles	no	yes

numerous other characteristics also impact media selection

Current RF Concept



Recent Progress (EPRR work completed)

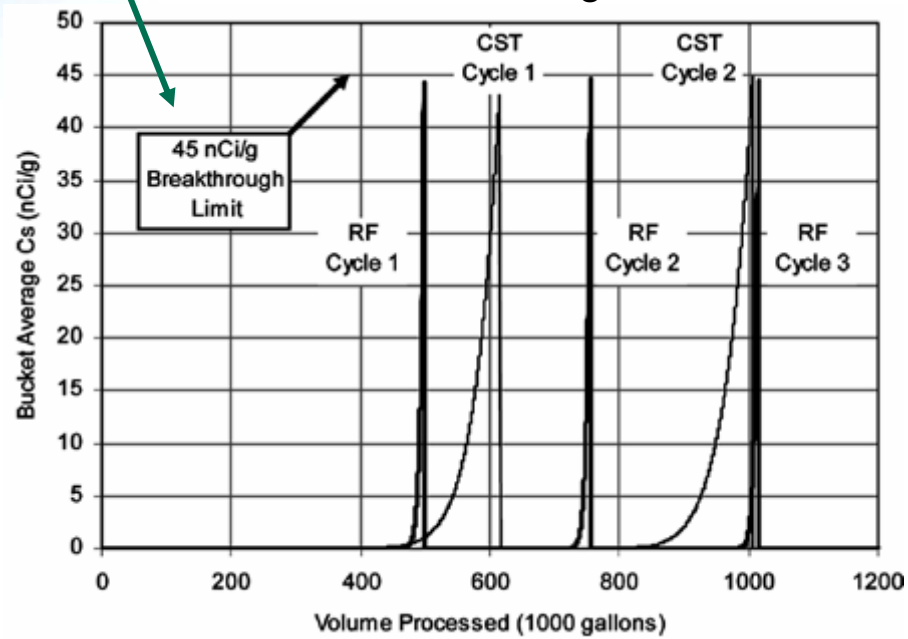
- Performance comparisons of CST vs RF using available IX models
- Hydraulic testing of RF using annular design and high L/D
- Thermal modeling of CST and RF columns
- Literature review and gap analysis for CST and RF
- Hazard Assessments
- Flowsheet development
- Media and configuration comparisons and recommendations

EPRR - CST vs RF Performance Comparisons

bucket average

Nominal Conditions: 25 ºC,10 gpm, 15 ft. tall

Tank C Breakthrough Profiles



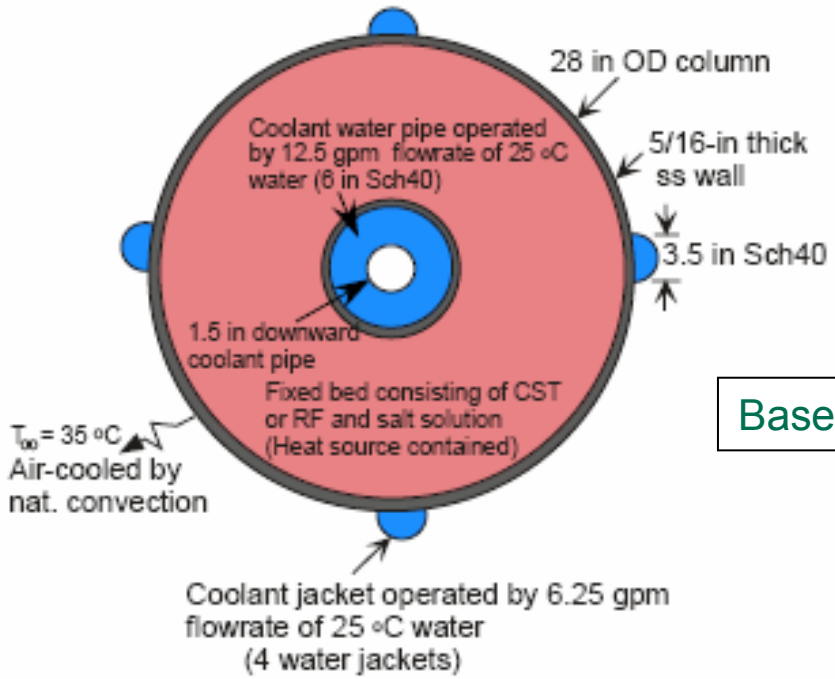
Tank	Media	Steady State Vol. Processed (1000 gallons)
A	CST	212
	RF	169
B	CST	193
	RF	247
C	CST	390
	RF	257

compositions evaluated are dissolved saltcake (6 M Na^+)

- Parameters varied included flow rate, temp, and height
- Preferred media varies with feed, generally comparable results
- CST exhibited highest Curie loading (225 Ci Cs^{137}/L bed)
- RF faster loading kinetics

Modeling by F. Smith - SRNL

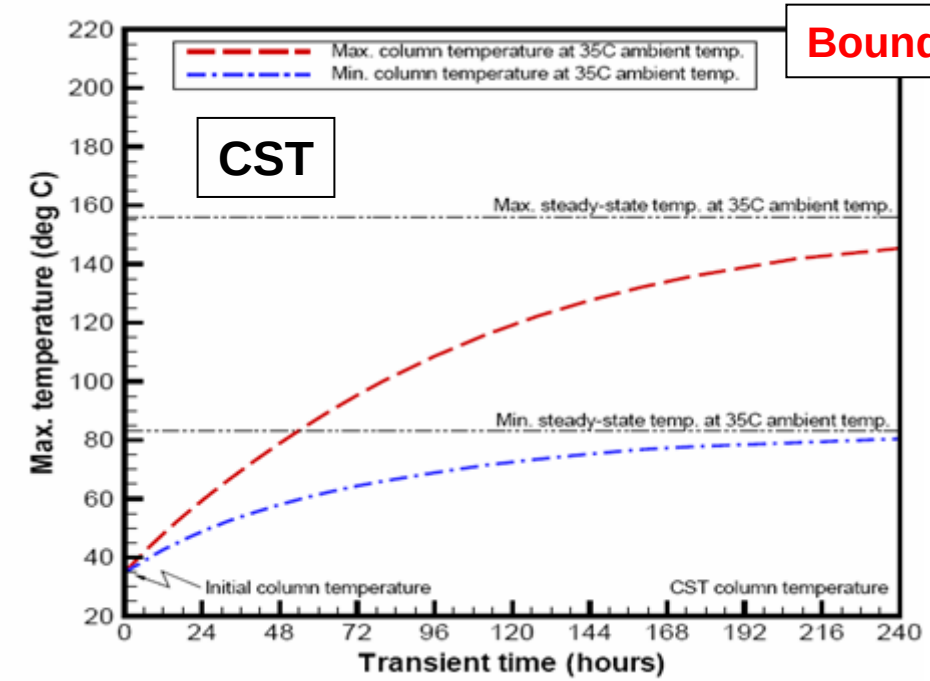
EPRR Thermal Modeling

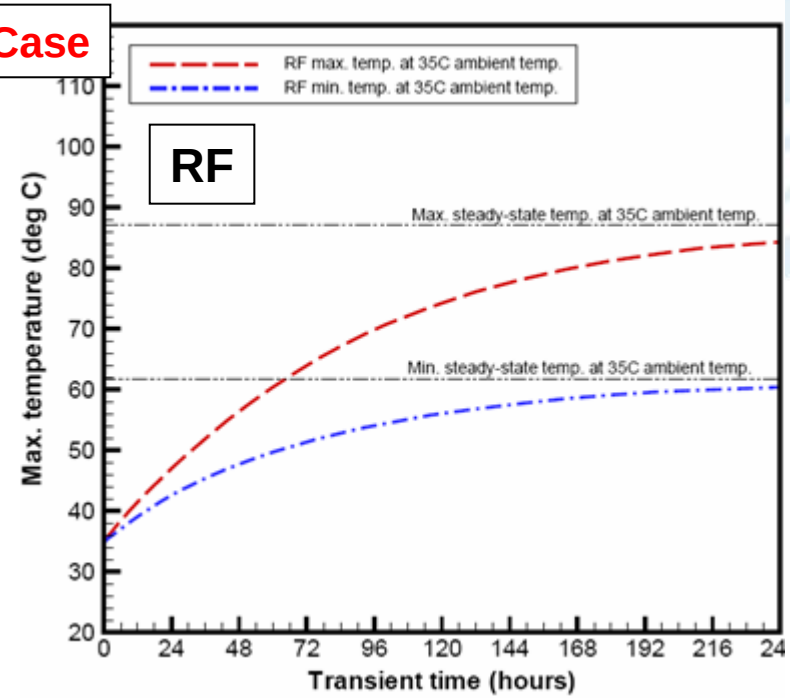


Baseline Design

- Case 1 - stagnant liquid and coolant flow (bounding)
- Case 2 - stagnant liquid, cooling system fully operational
- Case 3 - 5 gpm feed flow (ΔT down column)

EPRR Thermal Modeling Results





- Maximum steady state temp.: CST - 156 ºC, RF - 88 ºC
- Salt solution boiling temp.: 130 ºC
- Assigned media temp. limit: 65 ºC
- CST max. temp. approaches 65 ºC in 24 hours
- RF max. temp. approaches 65 ºC in 72 hours

Modeling by S. Lee - SRNL

RF Maturation Needs

- Cs isotherm model refinement (general)
- Performance in high caustic feed (WTP need)
- Used resin hydraulic performance (WTP)
- Alternate elution strategies (EPRR, WTP has nitric acid recovery)
- Real waste testing with SRS supernate (EPRR)
- Off-gassing and degradation after radiolytic exposure beyond 100 MRad (EPRR)
- Basis for maximum radionuclide loadings (EPRR)
- Column design optimization for RF (EPRR/IPS)
- Additional oxygen degradation testing (IPS)

water/nitrate reduction largest issue for SRS

SRS waste higher Cs and lower K - higher dose

Impacted Programs:

- **Enhanced Processes for Radionuclide Removal (EPRR)**
- **Hanford Waste Treatment Plant (WTP)**
- **Hanford Interim Pretreatment System (IPS)**

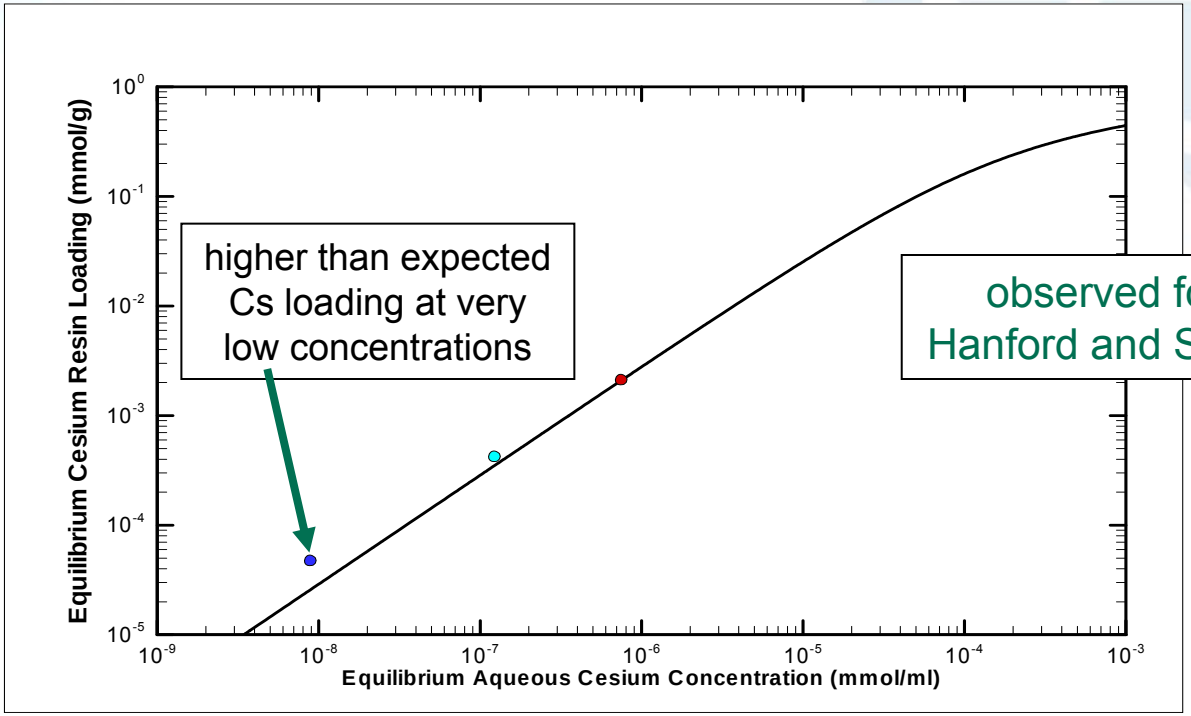
Current ORNL Activities (EM-21 Program)

- Elution optimization testing (completed)
  - **nitric acid optimization (concentration, flow rate, staccato flow)**
  - **alternative acids (formic, boric)**
- Simulant batch contact testing (supports isotherm refinement)
  - **cesium loading isotherm determinations**
  - **resin titration**
  - **baseline simulant and high caustic**
- Resin irradiation (initial irradiation at SRNL)
  - **up to 250 MRad**
  - **off-gas analysis (volatile and semi-volatile - organic evolution)**
  - **chemical performance impacts**
  - **physical performance impacts (oxygen exposure also)**
    - **bead integrity**
    - **hydraulic testing**

Current SRNL Activities (EM-21 Program)

- SRS real waste testing
  - **representative dissolved saltcake from target tank**
  - **batch contact and column testing**
  - **model validation**
  - **spent resin characterization (SRS waste has higher Hg)**
- Isotherm refinement and validation
  - **ORNL simulant isotherm and resin titration data**
  - **SRNL simulant and real waste batch contact data**
- Thermal modeling - designs excluding central cooling tube
- Alternative non-acid eluates - avoids resin form conversion and acid handling
- Maximum loading evaluations (paper study)

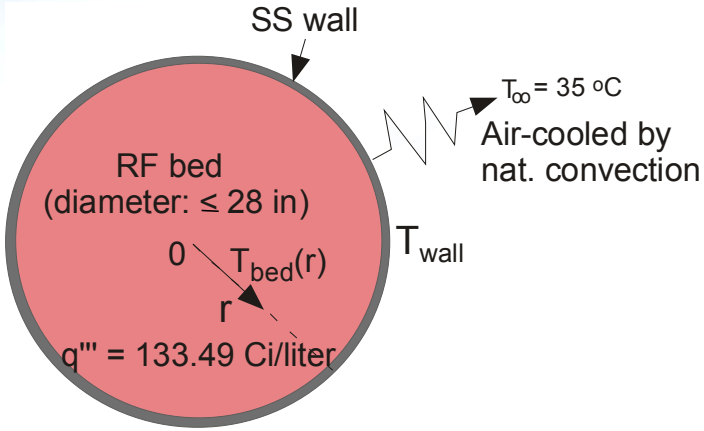
RF Isotherm Model Issues



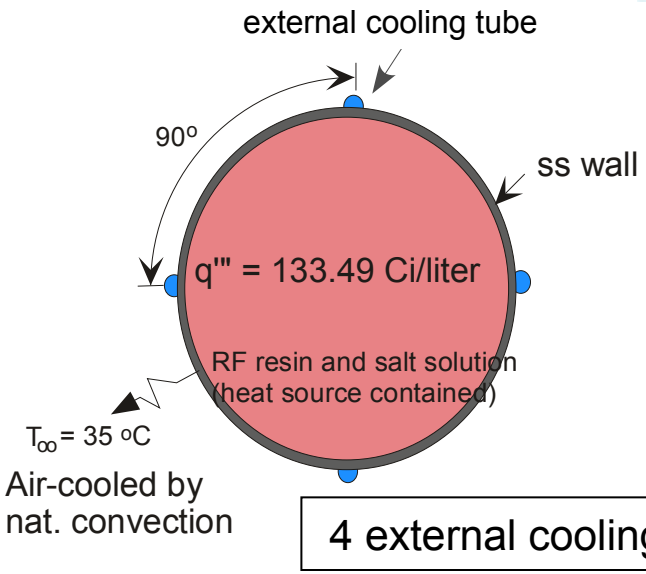
- **Recent tests (semi-production scale batches) indicate enhanced selectivity at very low Cs**
- **Model improvements made, but further improvement needed**
- **Significantly impacts leading-edge Cs breakthrough, bucket average breakthrough, volume processed per cycle**
- **Refinements/validation based on ORNL simulant and SRNL real waste data**

Modeling by L. Hamm and S. Aleman - SRNL

Thermal Modeling to Evaluate Column Design Simplification



no active cooling



4 external cooling tubes

- Potential column design simplification involving removal of central cooling tube
- Issue: heat concentrated in column center
- Goal: determine maximum acceptable diameter for various design alternatives
- Designs considered:
  - **no active cooling**
  - **4 and 8 external tubes (3.5 in. Schedule 40 half-pipes)**
  - **3 larger external tubes**
  - **full cooling jacket**

Program Goals

- Demonstrate RF performance with actual SRS tank waste
- Refine and finalize RF performance model
- Resolve issues identified in EPRR Systems Engineering Evaluation and Hazards Analysis
- Provide information and guidance on design and configuration options for in-riser applications with RF
- Bridge technology gaps and mature RF to comparable level to CST
- Set stage for final design and deployment at SRS and Hanford
- Provide needed data for Hanford WTP

Program Highlights

- Highly selective, engineered IX media (spherical RF) developed and studied over 2.5 decades in DOE sites, commercial entities, and academia
- EM-21 program designed to support multiple technology applications through contributions from 3 DOE sites (ORNL, SRS, Hanford) with bi-weekly conference calls and an integrated schedule
- Approach enhances likelihood that single technology could be used at both SRS and Hanford

Questions and Answers/Contact Information

Q & A

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