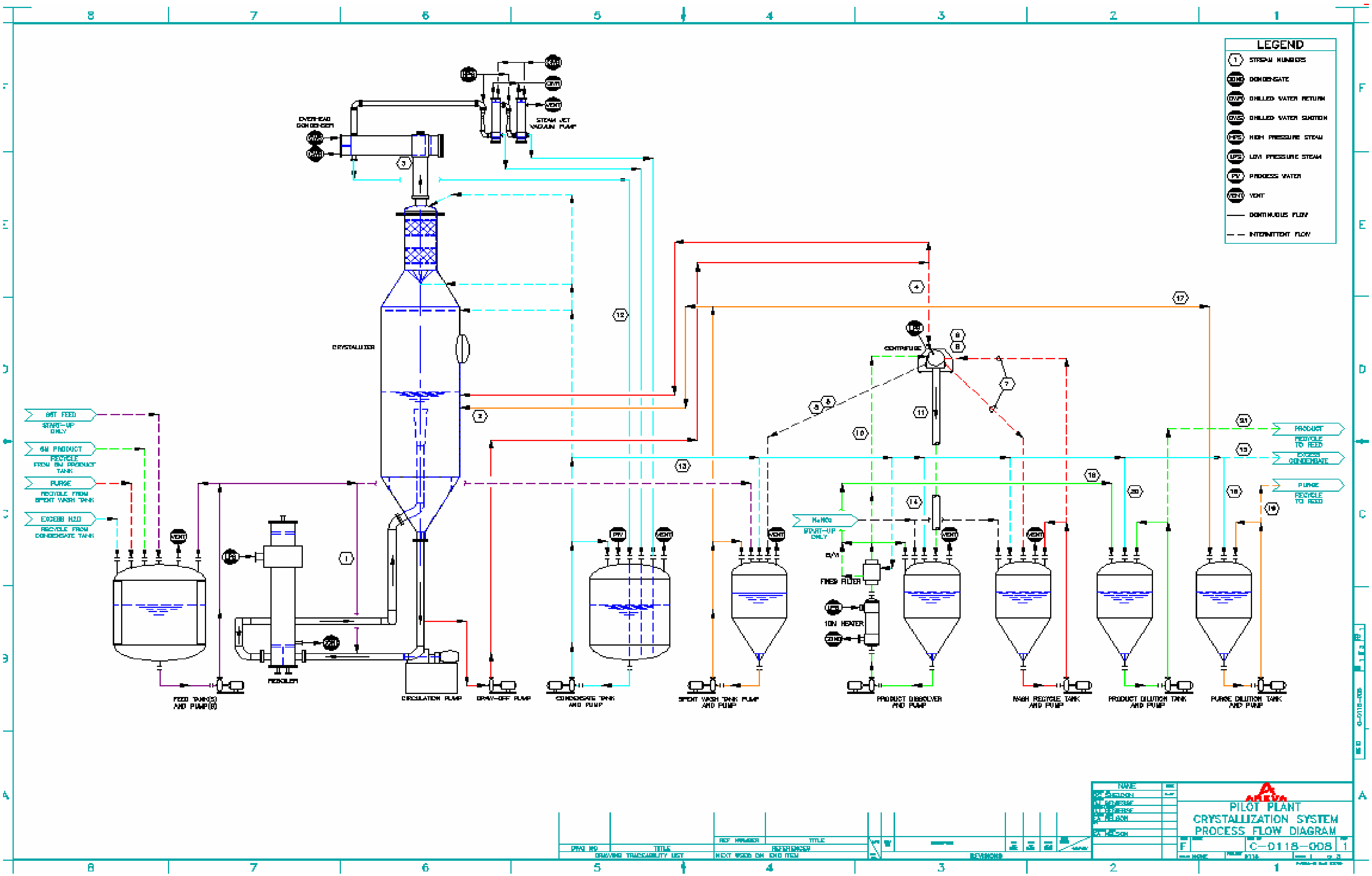
Fractional Crystallization Pilot Plant Test Program Objectives

- Investigate the feasibility of using Fractional Crystallization (FC) to pretreat Hanford tank waste.
- Perform design, fabrication, construction and testing to mitigate significant risks associated with FC, including:
  - Resolution of uncertainties and
  - Validation of assumptions
- Define design parameters necessary to develop a FC pretreatment plant conceptual design.

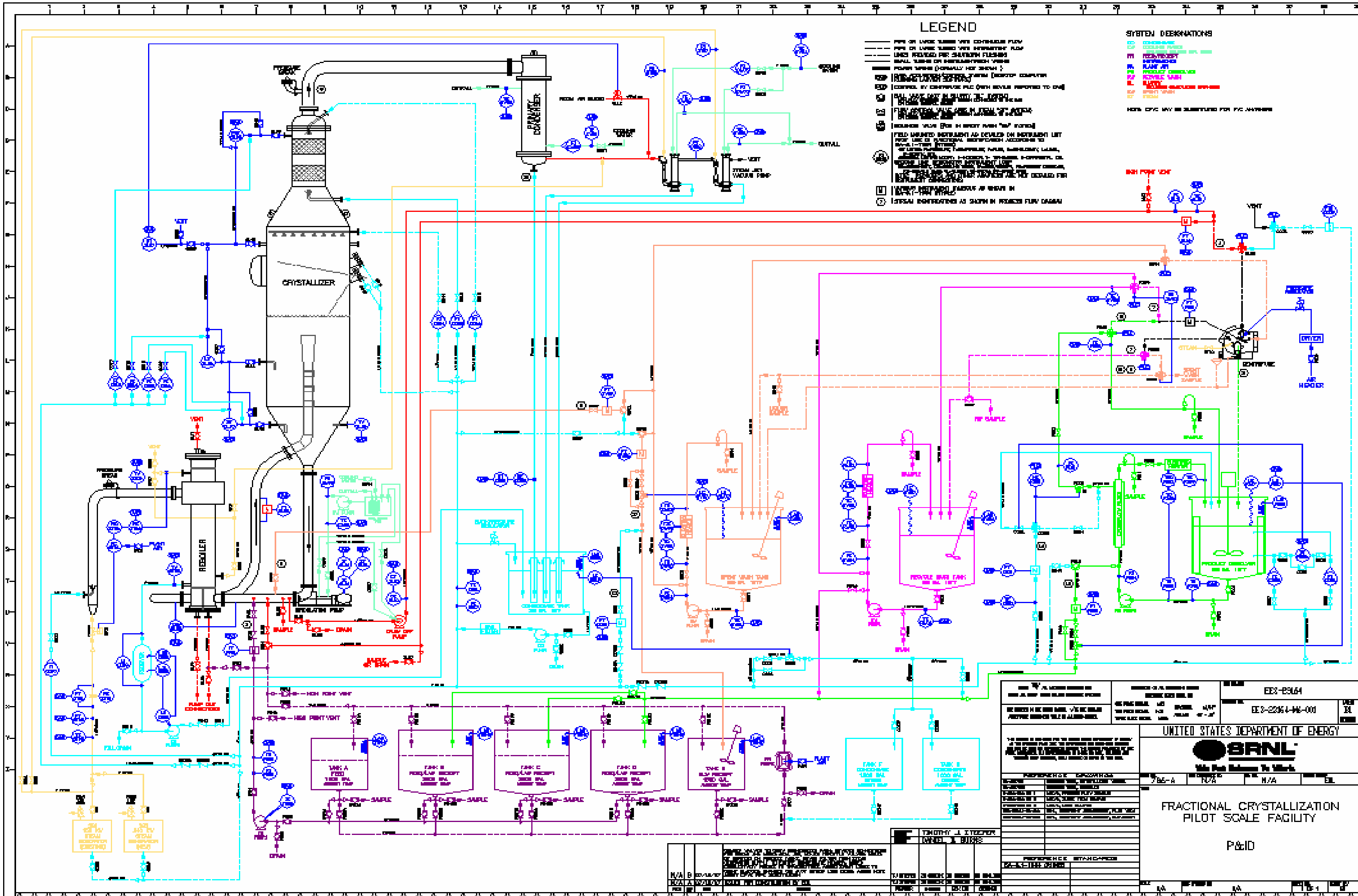
Fractional Crystallization Pilot Plant Physical description of the facility

- Continuous fractional crystallization pilot system with reconstitution of produce streams to produce feed.
- The testing will include all equipment, systems, and process unit operations shown on the Pilot Plant Crystallization System Process Flow Diagram (PFD) (AREVA Drawing C-0118-008).
- The pilot system will be installed within and interface with SRNL EDL building and site utility systems such as steam, cooling water, electrical power, telephone, and computer LAN.
- 1000 sq ft, 46 ft high, space reserved for unplanned changes
- Total simulant volume 10,000 gallons
- Tanks (in gallons): 3 x 2500, 4 x 1500, 4 x 500
- Slurry, steam and condensate systems fabricated from stainless steel, balance of system plastic

Fractional Crystallization Pilot Plant
Physical description of the facility



Fractional Crystallization Pilot Plant
Physical description of the facility



Fractional Crystallization Pilot Plant
Scale of the facility

- Many dimensions full scale, crystallizer diameter is about 1 / 2 scale
- Capacity is 1 / 5 scale
  - Feed Stream is 1.5 gpm of simulated dissolved tank salt cake waste and 6.2 M Na
  - Produces 1 gpm of pretreated LAW
  - The baseline Supplemental Pretreatment Facility must produce 5 gpm to support the baseline 200W Supplemental Treatment Plant
  - Scale determined by ***prototypic***, ***off-the-shelf*** equipment
- Some tanks are greater than full scale to support testing
- More tanks, valves and instruments are installed in pilot to support test objectives

Fractional Crystallization Pilot Plant Test Duration

- Test Phases (Expected Duration, Planned Duration)
  - **Benchmark Tests (2, 4)**
    - Partial simulant, system checkout with chemicals, retention time and shutdown Tests
  - **Baseline Tests (2, 4)**
    - Full simulant, final adjustment of centrifuge
  - **Process Parameter Variation Tests (2, 4)**
    - Tests process parameters to the limits of the expected operational range
  - **Feed Variability Tests (2,4)**
    - Feed Variation to bound all anticipated feed
  - **Casualty Tests (1, 4)**
    - To determine the effect(s) of off-normal conditions on system operation and how the system can be recovered or be placed in safe condition

Fractional Crystallization Pilot Plant Operation

- The fractional crystallization pilot plant system will be operated by SRNL operators and technicians
- SRNL personnel will be trained by system and component vendors
- Operations will be performed 24/7, 4 rotating shifts
- Shift crew will include SRNL test director, Crystallization vendor rep, and operators, 4 individuals on rotating shift

Fractional Crystallization Pilot Plant Simulant

- The base simulant is a non-radioactive filtered salt solution formulated to match actual waste used in laboratory tests.
- During the benchmark tests (the first chemical runs), Cr and Cs are unnecessary and will be omitted (Cr is hazardous and the non-radioactive Cs component could unnecessarily complicate the benchmark runs).
- Baseline tests will be run with the full base simulant
- Simulated feed will be reconstituted from process streams to allow continuous testing.
- During feed envelope testing, additional feed components will be added, one at a time, to investigate the impact on system performance. Components include, Al, PO_4, SO_4, Free OH, (H)EDTA, NTA.

Fractional Crystallization Pilot Plant Areas of Discussion

- Phase I Design/Construct/Install
  - Site Considerations
    - Stay off site, site problems unrelated to the pilot can stop progress
    - Consider environmental (weather, etc) impacts
    - Pre-licensed Test Facility
    - Watch out for legacy site issues
  - Design Agent
    - Consider design by A/E rather than tech provider
    - Don’t assume that full resources of the mother company will be available to support a small local office
    - Be careful of sole source and intellectual property constraints
    - Off ramps in subcontracts with A/E and tech provider

Fractional Crystallization Pilot Plant
Areas of Discussion

- Phase I Design/Construct/Install, continued
  - Design Considerations
    - Define uncertainties, assumptions and risks and decide what risks will be mitigated by pilot testing
    - Recognize the risks associated with scale
    - Use prototypic, off-the-shelf equipment when possible, may determine system scale
    - Use estimators to review evolving designs to control cost, design to cost
    - Innovation in safety systems is risky
    - Early and frequent external reviews, HQ sponsored is best

Fractional Crystallization Pilot Plant Areas of Discussion

- Phase II Checkout/Water Runs/Acceptance Testing
  - Acceptance Testing/Startup Considerations
    - Simple to complex
    - Tailor simulant to meet the needs of test
    - Simulant component impurities can be important
    - Simulant aging can be important
    - Bring in equipment vendors to support startup
  - Analytical Considerations
    - Multiple independent labs can reduce risk
    - Check out all analytical tests at smaller scale
    - Use the same analytical technique at different labs
    - Train analytical staff to the same techniques used for lab scale testing

Fractional Crystallization Pilot Plant Areas of Discussion

- Phase III Testing
  - Test Preparation
    - Use equipment vendors with tech providers to help train operators
    - Spare parts, not just consumables
    - Perform graded Readiness Review
  - Testing
    - Start with simple tests and move to complex tests
    - Takes at least twice as long as you think it should
    - Expect infant mortality problems for the duration of testing
    - Expect and mitigate the consequence of operational errors
    - Optional testing at the end

Cold Test Facility Objectives

- Provide test bed for evaluation of new technologies.
- Provide proving grounds for procedures
- Provide training facility for and validation and qualification of procedures and personnel.
- Provide basis for decisions to further develop, abandon, or deploy new equipments.
- Provide visitors center for tank farms and ORP mission orientation

Cold Test Facility

- Full Scale, single shell tank
- Vertical and horizontal dimensions are correct for 500,000 gallon to 1,000,000 gallon tanks.
- Not an underground tank. Chose not to back fill.
- Lap floor vs butt welded for actual tanks.
- Mild carbon steel, but not same g[illegible]he in-field tanks.
- Did not install dome on the tank.

Cold Test Facility Operation

- The CTF has been in operation since 2002.
- Initially operated under control of Technology Development R&T group --- Transitioned to Closure Operations in 2004
- Operated under cooperative agreement with Hammer.
- Vendors and other organizations allowed to use facility with pro-rated use costs.
- Test control has been done under engineering control – shifted recently to Qualified Field Work Supervisor control of all test evolutions.

CTF Simulant

- The base simulants have all been non-radioactive and non-hazardous: Kaoline clay, sand, gravel, Hanford Soil, plaster, grouts, etc.
- Physically correct simulants: this is generally not a chemical process test bed.

CTF Phase II – Startup & Acceptance

- Startup Considerations
  - Start simple
  - Tailor simulant to meet the needs of test
  - Safety: Hanford safety expectations apply (vendor electrician violated site lock and tag standards: it is still a Prime Contractor responsibility

- Acceptance
  - Agree in advance what is minimum acceptable status for acceptance from the customer
  - Customer involvement is essential

CTF Phase III - Acceptance

- **Agree in advance what is minimum criteria for acceptance from the customer**
- **Customer involvement is essential**

CTF Phase III
Operations, Testing, Training

- Testing Considerations
  - Multiple independent vendors working same problem significantly reduces risk
  - Don’t do it all yourself: hire PNNL or others to perform data collection and modeling that is not your prime competency. If you don’t do the task routinely then hire someone who does.
- Training Considerations
  - Make it as real as possible: insist on command and control and con-ops during training: practice how you will play
  - Vendors know their equipment; operators know how to operate in the Hanford environment. Use each for their relative strength, make their weaknesses irrelevant.

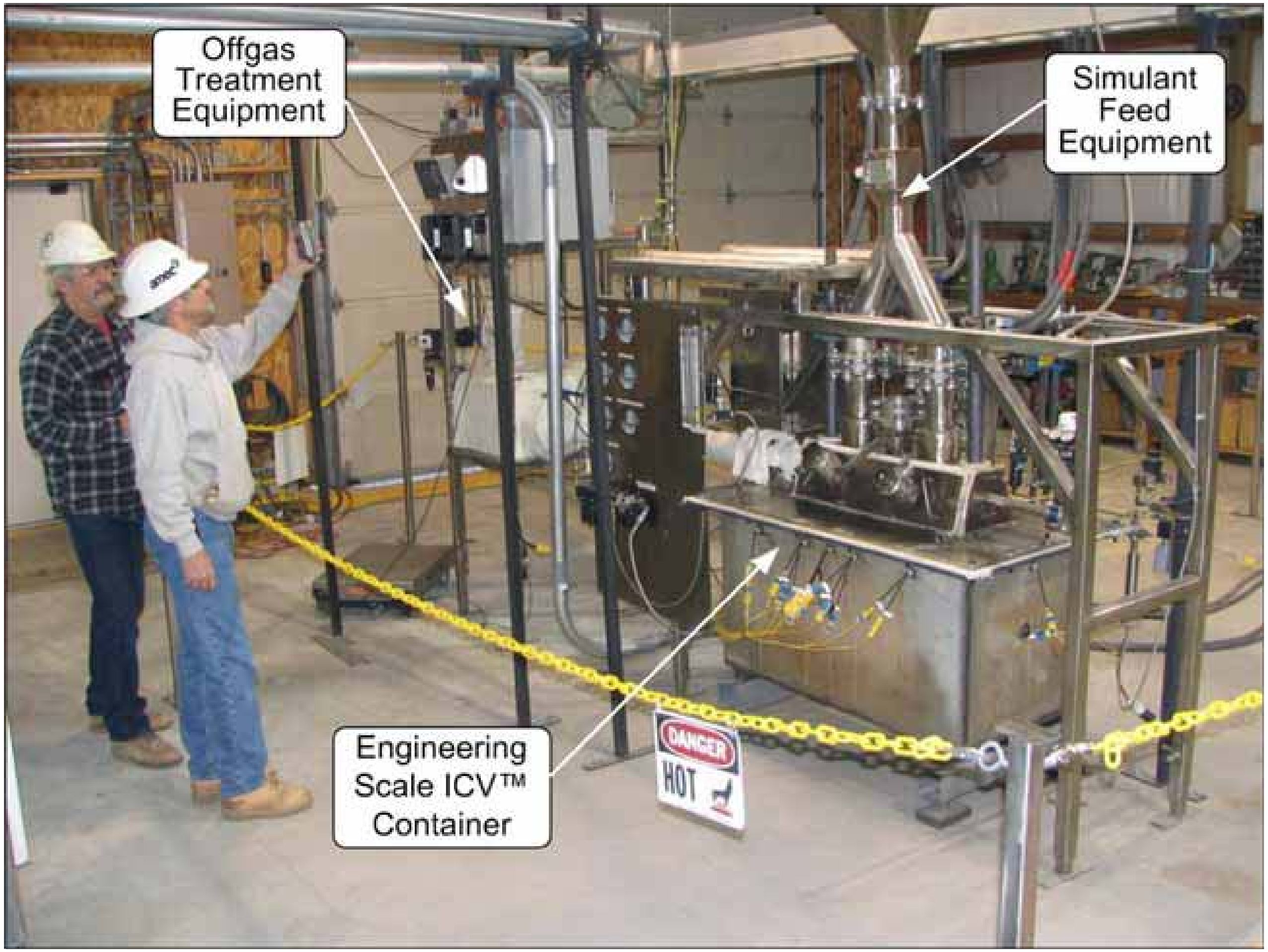
Demonstration Bulk Vitrification Scale Testing Lessons Learned

DBVS conducted testing at engineering and full-scale

Engineering Scale Testing

- Purpose is to validate laboratory/crucible results and evaluate process performance
- 1/6th scale (linear)
- Focused on In-Container Vitrification (ICV™) process (feed and off-gas systems less prototypical)
- Processed 120-350 kg of feed per test
- Test durations 32-74 hours

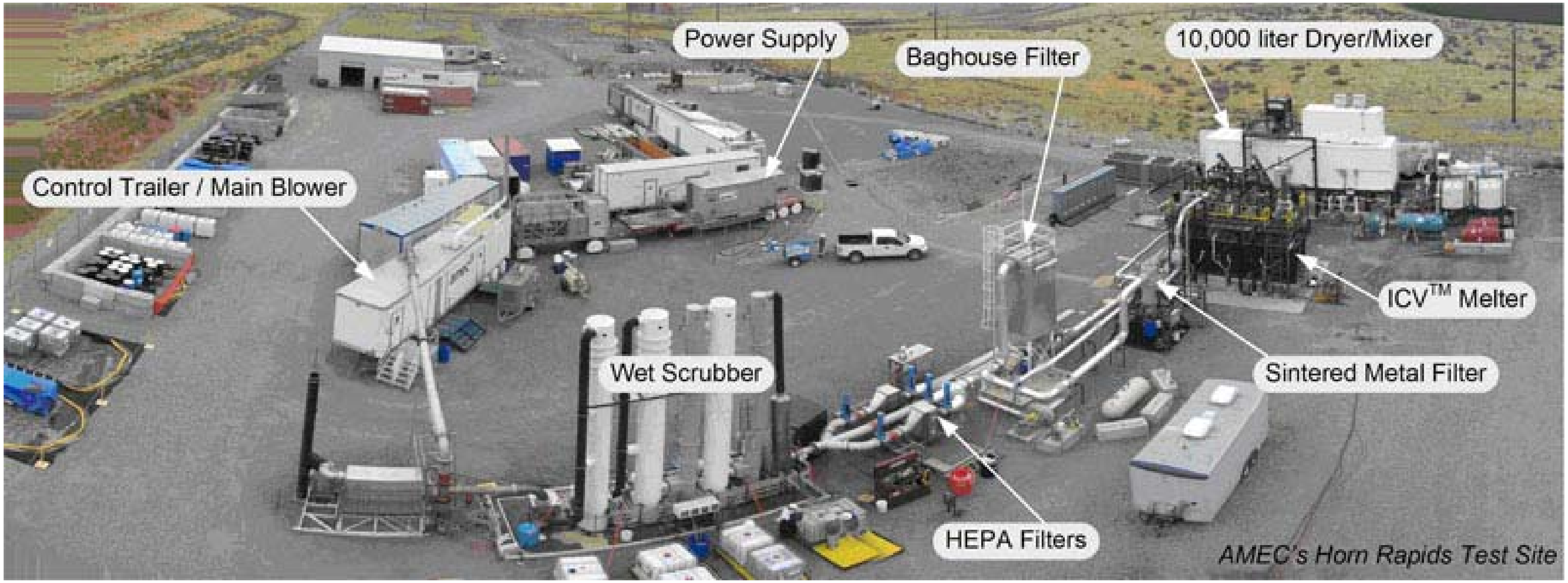
Engineering Scale Test Equipment



Full Scale Testing

- Purpose is to validate engineering scale results and evaluate process performance
- While focus remained on In-Container Vitrification (ICV™) process, support systems became more prototypical
- Processed 40-60,000 kg of feed per test
- Test durations 90-210 hours

Full Scale Test Equipment



Lessons Learned – Scale-up

- Engineering scale refractory design did not accurately replicate full scale thermal properties
  - Did not replicate iron formation observed at full scale
  - Did not replicate the molten ionic salt issue observed at full scale
- Revised design modeled thermally to confirm it accurately mimicked full scale
- Engineering scale off-gas system had excess capacity
  - Masked full scale melt gas production issues
  - Did not replicate plugging observed at full scale

Lessons Learned – Scale-up

- Engineering scale tests accurately predicted feed system plugging
  - Modifications to full scale equipment reduced but did not eliminate plugging
- Engineering scale test equipment located indoors – effects of weather on full scale equipment under appreciated

Lessons Learned – Design/Construct/Install

- Handle like a standard construction project
- Maintain design configuration control to ensure test objectives are met
- Having the same people doing the pilot plant design as the facility design ensures fidelity in the design
- Locating off-site speeds construction

Lessons Learned – Checkout/Acceptance Testing

- Ensure a clear understanding of calibration requirements
- Scope of testing must include control systems and support systems (e.g. HVAC, steam, cooling water)

Lessons Learned - Testing

- Prepare detailed test plan with measurable objectives
- Perform appropriate readiness reviews
- Provide project presence during test activities (24/7)
- Ensure responsive design support (especially for PLC control systems)
- Be prepared for additional tests (go where the data leads you)

Lessons Learned (LL) in Development/Scale-up Testing for TRU Packaging and Bulk Vitrification Projects

- Testing purpose: buy down risk of technology application
- Less formal than highly prescriptive tank farm acceptance testing program (FAT, CAT, OAT - based upon NQA-1 Sect 11 and App. 2.17 for commercial nuclear systems)
- Defined as part of overall project lifecycle Test Plan (Example: Bulk Vitrification: RPP-PLAN-28251)
- Maximize common approach/hardware among supplemental treatment projects for risk reduction cost efficiency

Risk Resolution

Major Risks	Need/Purpose	Resolution
Drying technology (both projects)	Validate equipment and develop operational strategy	Simulant testing at scale, prototypic/full size, and OAT
Vitrification performance	Validate product performance	Simulant and waste testing in multiple scales
Simulant adequately represents waste (both projects)	Validate simulant properties	Formal development program with multiple simulants (off-the shelf; chemical/physical)
System integration for first-of-a-kind modular application (both projects)	Commission system outside of radioactive/tank farm environment and validate modular strategy	Offsite subsystem and system assembly with integrated testing, maximizing prototypic operation

10,000L Dryer Development Testing

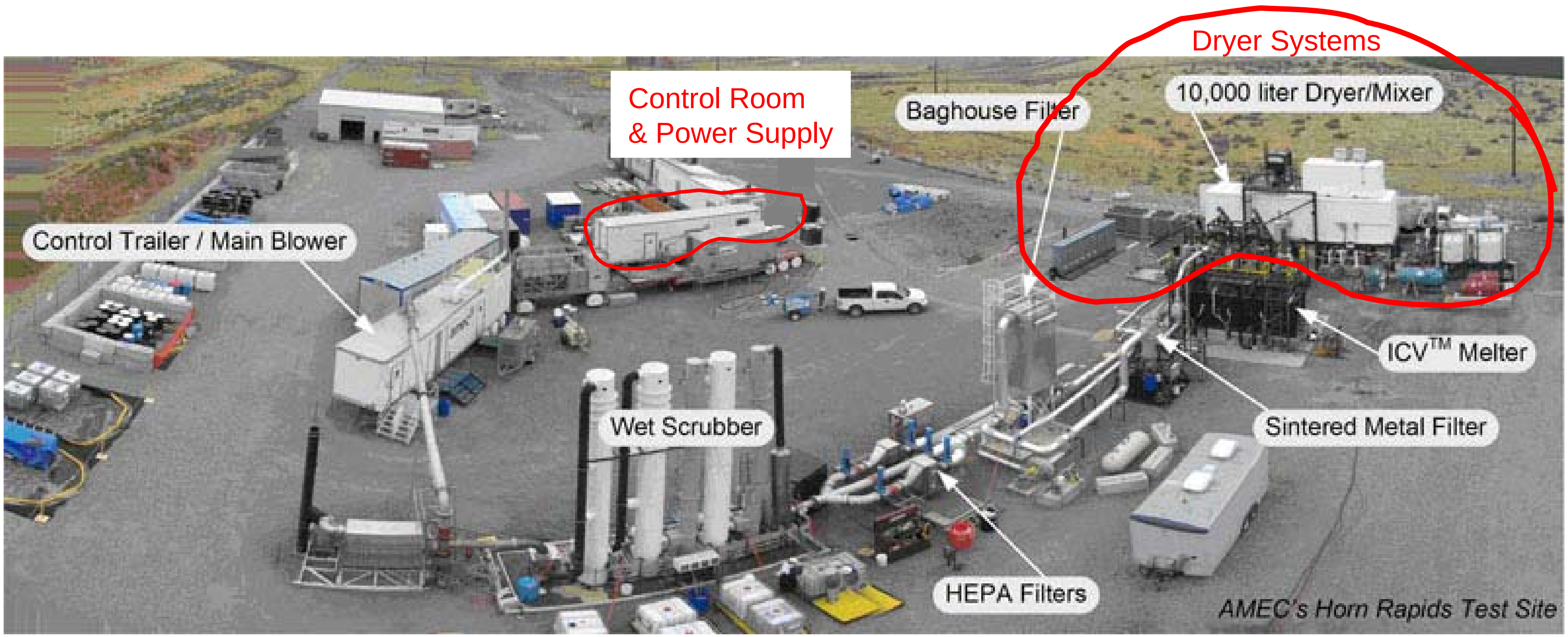
FY03	**5L and 130L Tests** – *Purpose: Feasibility development by AMEC and NUKEM*
FY04	**5L and 130L Tests** – *Purpose: Design options, process strategy for TRU Packaging Project*
	5L and 130L Tests – *Purpose: Design options, process strategy for Bulk Vitrification Project*
FY05	**22L Tests** – *Purpose: Validate prior tests during blend preparation for full-scale melt*
	Factory Acceptance Tests – *Purpose: Basic fabrication acceptance of Dryer #1 procurement*
FY06 & FY07	**22L Tests** *Purpose: Develop Molten Ionic Salt (MIS) issue resolution in conjunction with dryer performance*
	130L Tests *Purpose: Obtain additional dry-batch process control data to reduce risks during full scale testing and validate new MIS formulation*
FY07	**Full-scale Qualification Testing of Actual Dryer Equipment** *Purpose: Demonstrate process control methodology/gather performance data at full scale* *Validate dryer and support system design by integrating with HRTS melt operations* *Obtain data for validation of safety basis and flowsheet assumptions*
	Full-scale Integrated Testing with Vitrification System *Purpose: Demonstrate operation as part of integrated vitrification feed system during conductance of full scale simulant vitrification test*

BULK VITRIFICATION (FY05–FY07)

Dryer Qualification Testing LL Details

General Testing Data

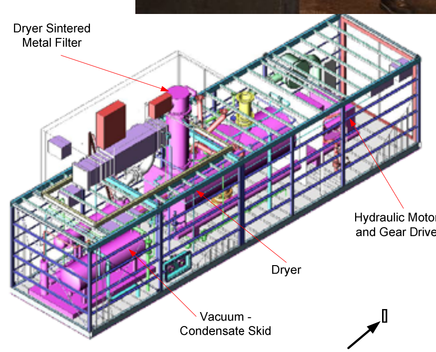
- Tested on days, May – July 2007 at AMEC Nuclear Ltd, GeoMelt Division Horn Rapids Test Site (off-Hanford site)
- Dryer Modular Systems Tested: *mixer/dryer, vacuum & condensate, feed delivery, steam, chiller, hydraulics, loadout*



Dryer Qualification Testing Hardware

<u>Littleford-Day mixer/dryer</u>: 10k liter, high vacuum (40-90 torr), low temperature (130-180°F), hydraulic motor, fixed shell with center shaft and blades, liquid ring vacuum pump and condenser system, sintered metal filters, modified ISO cont.

5 Liter unit



Dryer Qualification Testing LL Details

Risk Area: Limited Simulant – Wanted Limited Waste

Solutions

1. Three Phase Approach:
- Basic startup, nothing in dryer
- Drying soil and water
- Drying simulant and GFMs

2. Involved senior management support at test site

Results

1. Very Successful
- Resolved major hardware issues prior to using simulant

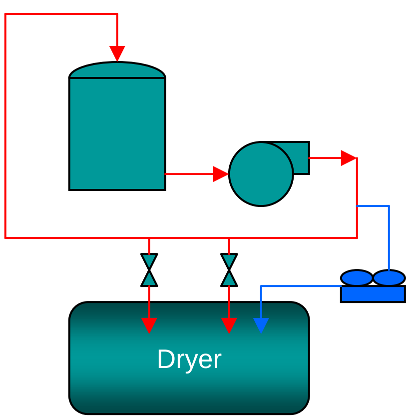
2. Efficient interface
- Ex.) Requested 6 weeks, got 4, reduced to 3 when schedule compressed, took 8 – “do it safe, do it right”

Dryer Qualification Testing LL Details

Risk Area: Scale testing demonstrated better liquid feed flow process than in current design

Solution

Added optional metering pump and planned for evaluation in test



Results

Option testing valuable

- Initial design worked surprisingly well, but metering pump worked better; needed to apply additional design & maintenance to keep metering pump optimized (filters, repair)

Dryer Qualification Testing LL Details
Risk Area: Scale testing relied upon manual sampling

Solution

Installed temporary vendor-recommended Strahman valve in spare port

Results

Sample data extremely valuable to benchmark process

Dryer Qualification Testing LL Details

Risk Area: Scale testing with new formulation demonstrated capability of both better and worse pelletization

Solution

Established best process control conditions & planned for additional / optional batch production

Results

Upfront planning provided great flexibility for evaluation

Modified process parameters and equipment changes were unsuccessful

Dryer Qualification Testing LL Details

Risk Area: New equipment for engineers/operators

Solutions

1. Usage of draft procedures for "user-testing," with daily updates

2. Extensive daily pre-job discussions

3. Teaming: continual & multiple engineering support for both Qualification and Integrated Test

Sintered Metal Filters

4. Multiple Inspections

5. Phased approach

6. Trend everything

Results

1. No injuries – 5400 mh

2. Operating experience invaluable for engineers

Better Idea…quick post job review

Dryer Qualification Testing LL Details

Issues

FAILED DRYER SEALS
Use of "Improved" hardware in first-of-a-kind application

INSUFFICIENT HYDRAULICS
Design improvement was not conservative; marginal scale testing performance ignored because of different equipment; 5 tiered contract