Status Of Integrated Waste Treatment Unit

Kevin O'Neill
Idaho Cleanup Project

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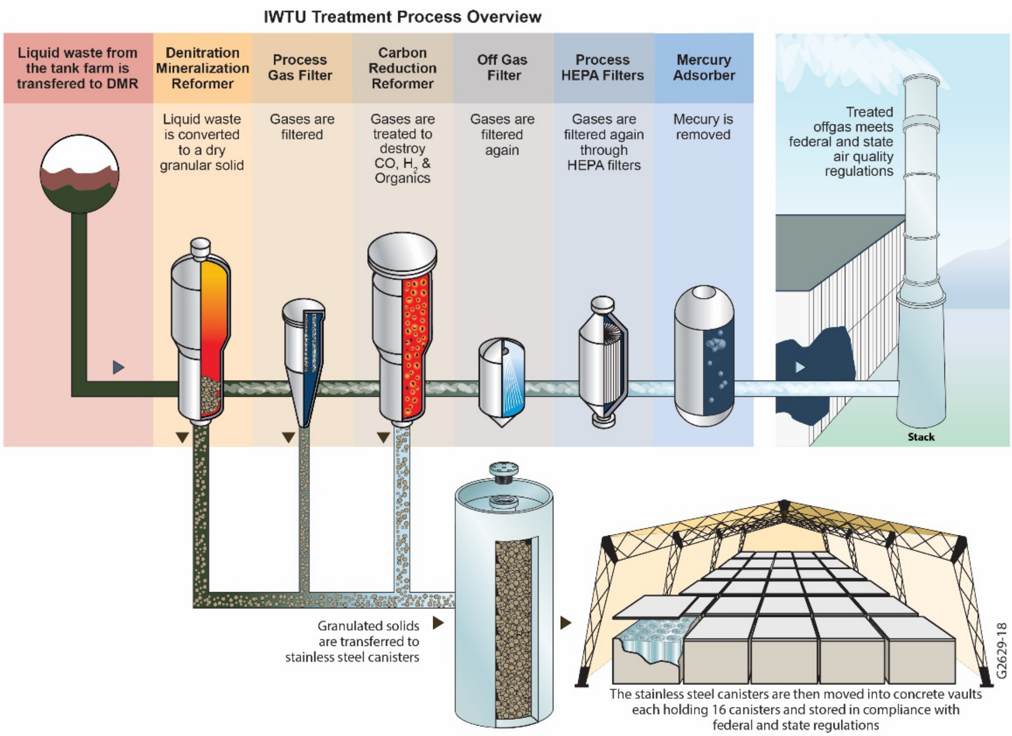
OFFICE OF ENVIRONMENTAL MANAGEMENT

IWTU Background

- There are about 900,000 gallons of liquid radioactive waste stored in three stainless steel underground tanks at the Idaho Nuclear Technology and Engineering Center.
- The Integrated Waste Treatment Unit (IWTU) was constructed to treat the waste, but design and mechanical problems have prevented the beginning of waste treatment.

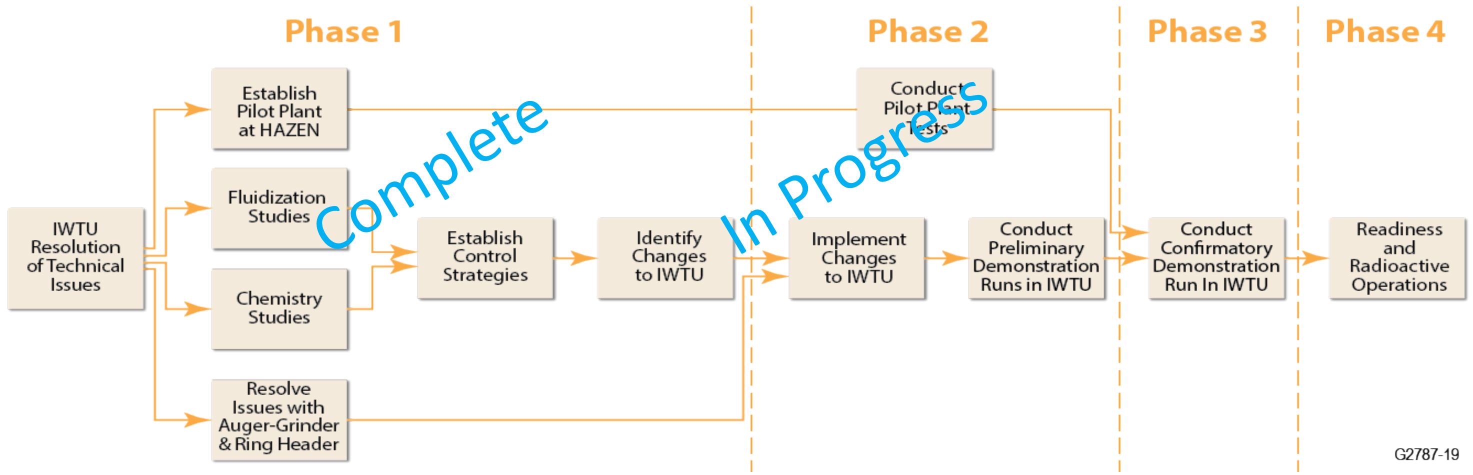


IWTU Overview / Objectives

- IWTU is a 53,000 sq. ft. facility designed to treat 900,000 gallons of Sodium Bearing Waste (SBW) using the Fluidized Bed Steam Reforming process.
- The process will convert SBW into a solid, granular, carbonate product for on-site storage pending final disposition.
- IWTU construction completed in 2011 and CD-4 achieved in 2012.
- Process instabilities and equipment problems identified during non-radiological testing operations to date have delayed the transition to radiological operations.
- Instabilities are associated with the primary reaction vessel, the Denitration Mineralization Reformer (DMR), and include particle size control, difficulties maintaining fluidizing conditions and scale formation within the DMR.
- Problems have also included various equipment quality and reliability issues.

Approach to Address Remaining Issues

- Fluor Idaho was awarded the contract to manage the Idaho Cleanup Project and assumed operational control in June, 2016. IWTU start-up was added to its contract soon after.
- DOE directed Fluor to develop a plan to address IWTU deficiencies and to ready it for radiological operations
- Fluor established a systematic, mechanistic based approach involving 4 phases to address issues with the IWTU
- A team of specialists was assembled to work with IWTU staff, including experts in fluidized bed technology that have solved similar problems in industry
- Flour established a Technical Review Group consisting of subject matter experts from National Labs, industry and academia to provide input and advice



Small Scale Tests, Engineering Evaluations and Modeling

Pilot and IWTU Test Runs

Confirm Fixes

Rad Ops

Phase 1 - Approach and Results (June-October 2016)

- Carried out engineering assessment of plant equipment and reliability issues as well as DMR fluidization and wall scale problems.
- Established a Technical Review Group consisting of subject matter experts from National Labs, academia and industry to provide review and advice.
- Identified the knowledge gaps and developed a strategy to address those gaps.
- Developed working hypothesis for DMR issues.
- Validated the NETL CFD model of the DMR fluidization.
- Conducted engineering evaluations, bench-scale tests and modeling to assess the issues and identify potential fixes.
- Developed the design for and initiated construction of a pilot plant.
- Conducted various bench scale kinetics and chemistry tests.
- Conducted root cause analysis of the auger-grinder failure, conducted full-scale testing to confirm the causes of failures, and developed a design for a new auger-grinder.

Phase 1 provided a fundamental understanding of the problems and closed many knowledge gaps

Summary Status of the 5 Main Issues

Issue: Wall Scaling
Status: Impact has been reduced. Improved understanding of wall scale formation and control mechanisms.

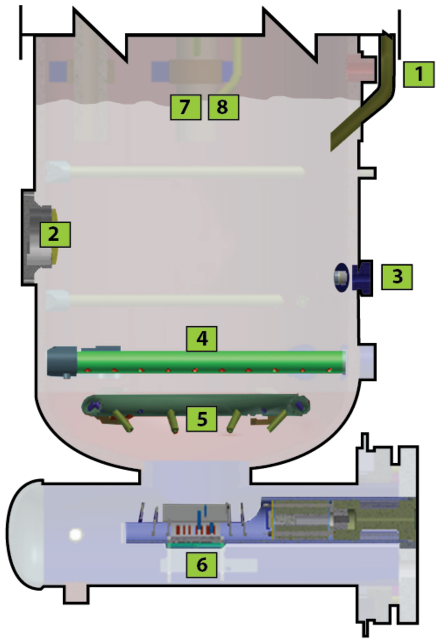
Wall Scale	
Observation	Wall Scale
Impact	Build-up of Scale Deposits
Root Cause	Slow Conversion of Feed
Solution 3 7 8	Reduce the Feed Rate Use all Three Waste Feed Injectors Increase DMR Operating Temp Increased DMR Bed Depth

Impact Reduced

Formation of Sandcastles	
Observation	Sandcastles / Agglomerations
Impact	Temperature and Fluidization Instabilities
Root Cause	Slow Conversion of Waste Feed Insufficient Fluidization Insufficient Particle Size Control
Solution 1 2 3 4 5	Refine Fluidization Strategy Modify Fluidizing Gas Rails Implement Seeding Control Requires Manway Access Insure sufficient CO_2

Understood

Issue: Formation of Sandcastles
Status: Sandcastle formation mechanisms understood. Implementing changes in IWTU.



Auger Grinder Failure	
Observation	Auger-Grinder Locked Up
Impact	Inability to Transfer Product Results in Plant Shutdown
Root Cause	Build-up on Rotating Parts Insufficient Mechanical Design Lack of Adequate Purge
Solution 6	Auger Grinder Root Cause Analysis Industry Expert Consultant Extensive Prototype Testing Improved Purge Gas Strategy Improve Mechanical Design Recovery Capability

Resolved

Issue: DMR Instabilities
Status: Mechanisms understood. DMR instabilities are due to sandcastles.

DMR Instabilities	
Observation	Temperature Excursions
Impact	Instabilities, Shutdowns
Root Cause	Defluidization Channeling of Gases Wall Scale
Solution 1 4 5 7 8	Refine Fluidization Strategy Modify Fluidizing Gas Rails Implement Particle Size Control

Understood

Ring Header Damage	
Observation	Erosion of Ring Header
Impact	Breach Would Defluidize DMR
Root Cause	Jet from Fluidizing Gas Rails
Solution 2 4 5	Modify Fluidizing Gas Rails Replace Ring Header Requires Manway Access

Resolved

Issue: Ring Header Damage
Status: DMR access approach resolved. Manway installation in process. Will replace damaged ring with new component.

Issue: Auger-Grinder Failure
Status: Issues were successfully addressed in the March 2017 run.

Phase II, Simulant Run 1

- The primary objective of Phase II, Simulant Run 1 was to test the new auger-grinder.
  - Newly redesigned auger-grinder operated as designed.
  - More than 18,000 gallons of simulant were converted to a granular solid and were successfully transferred by the auger-grinder.
  - No indication of cementation or seizing.
- Some of the same chemistry/physical challenges within the DMR were noted during Simulant Run 1, however this was anticipated.
  - Such issues will be addressed through equipment modifications, replacement, and additions during the current outage, and tested during Simulant Run 2.

Product generated during most recent simulant run.

Issue: Auger-Grinder Failure

- Issue
  - Auger-grinder is located at the bottom of the DMR and conditions the product for pneumatic transfer to the packaging area.
  - The auger-grinder failed during all previous simulant runs.
- Cause
  - Steam forms a cementitious material that builds up on the auger-grinder, eventually causing it to fail.
- Approach to Resolve
  - Root cause analysis and testing to confirm failure mechanism.
  - Extensive prototype testing.
  - Inputs obtained from industry experts.
  - New design has improved mechanical features.
  - Incorporates purge strategy to minimize presence of steam.
- Status
  - Issue resolved. Successfully tested in IWTU in March 2017.
  - Production unit being fabricated.

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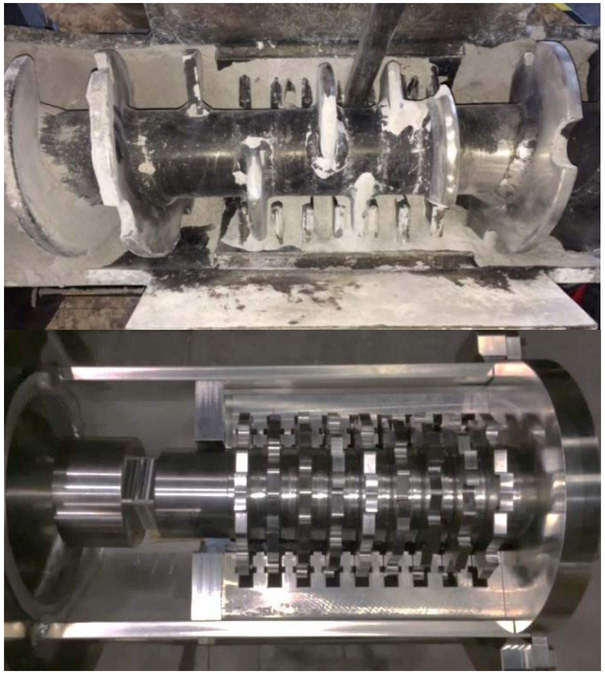

Old auger-grinder with cement formations (top) and new auger-grinder (bottom) successfully tested in March 2018

Issue: Wall Scaling

- Issue
  - Scale deposits on the inside surfaces of the DMR have been a regular outcome of IWTU runs, including early pilot plant testing in 2006-2007.
  - Scale could accumulate and interfere with stable operations.
- Cause
  - Unreacted feed transfers from bed particles to vessel wall surfaces.
  - Caused by slow reaction kinetics and other reaction by-products.
- Approach to Resolve
  - Extensive investigations by SRNL to evaluate formation mechanisms.
  - Testing at bench-scale and with pilot plant to evaluate wall scale control strategies.
- Status
  - Progress made in minimizing scale. Scale in IWTU run in March 2017 was about half the thickness as the scale in prior runs.
  - The general trend over the last few IWTU runs is the scale is becoming thinner and chemically less complex with each subsequent run.
  - Testing to investigate scale formation and control in pilot plant currently on-going and very promising.

Wall Scale	
Observation	Wall Scale
Impact	Build-up of Scale Deposits
Root Cause	Slow Conversion of Feed
Solution 3 7 8	Reduce the Feed Rate Use all Three Waste Feed Injectors Increase DMR Operating Temp Increased DMR Bed Depth

Sample of scale from March 2017 test of IWTU.

Issue: Ring Header Damage

- Issue
  - Ring header in DMR provides fluidizing gases in the DMR. It was damaged in a test run in 2015. Need access into DMR to remove damaged ring and install new fluidization fixtures.
- Cause
  - Damage to ring due to erosion (jet impingement) as a result of sandcastles during 2015 testing.
- Approach to Resolve
  - Extensive project to develop manway access into the DMR. The installed DMR vessel did not include ability for manned access.
  - Extensive engineering, modeling, mock-up testing, and external experts supporting the manway design and installation.
- Status
  - Manway successfully designed. Vessel opening made in May 2017 with water jet cutting technique. Manway flange currently being welded to the DMR vessel.

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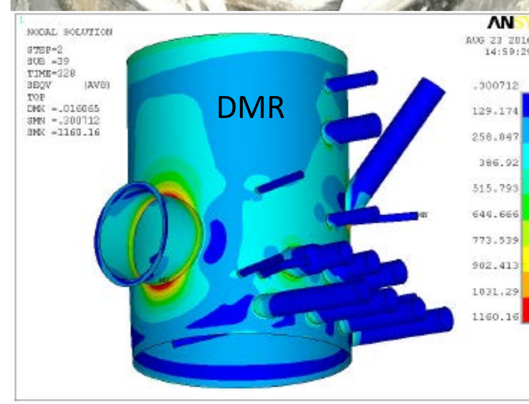

DMR vessel manway hole (above) with stress analysis output (bottom).

Issue: Formation of Sandcastles

- Issue
  - In areas of insufficient fluidization in the DMR, particles can settle or agglomerate and disrupt gas flow and mixing, resulting in temperature variations in the DMR, formation of sandcastles, further de-fluidization and other operational impacts.
- Cause
  - Insufficient fluidization and mixing.
  - Agglomeration of cohesive or sticky particles due to slow or incomplete waste feed conversion reactions.
- Approach to Resolve
  - Extensive work by INL to understand reaction kinetics.
  - Modeling by NETL to understand fluid dynamics and mixing in the DMR.
  - Bench-scale and pilot plant testing to investigate sandcastle formation and mitigation.
- Status
  - Sandcastle formation mechanisms understood.
  - Evaluating physical modifications to lower DMR to increase fluidization.

Formation of Sandcastles	
Observation	Sandcastles / Agglomerations
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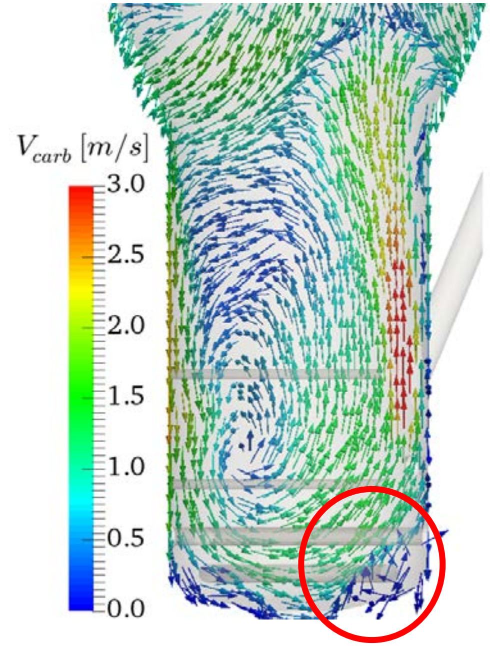

Modeling showing area of weak fluidization (red circle) where sandcastles form.

Issue: DMR Instabilities

- Issue
  - DMR instabilities typically observed as uneven temperatures within the fluidized bed. This is indicative of inadequate fluidization and mixing.
  - When operating normally, a fluidized bed has very uniform temperatures in all areas of the bed.
- Cause
  - Instabilities primarily related to sandcastles which disrupt fluidization, causing uneven temperatures.
- Approach to Resolve
  - Modeling by NETL to understand DMR fluid dynamics and mixing.
  - Extensive pilot plant testing to confirm preferred operating parameters.
- Status
  - Test data and modelling confirm existing DMR design results in inadequate fluidization in DMR lower region.
  - Engineering evaluation currently underway on three mechanical options to increase DMR lower region fluidization.

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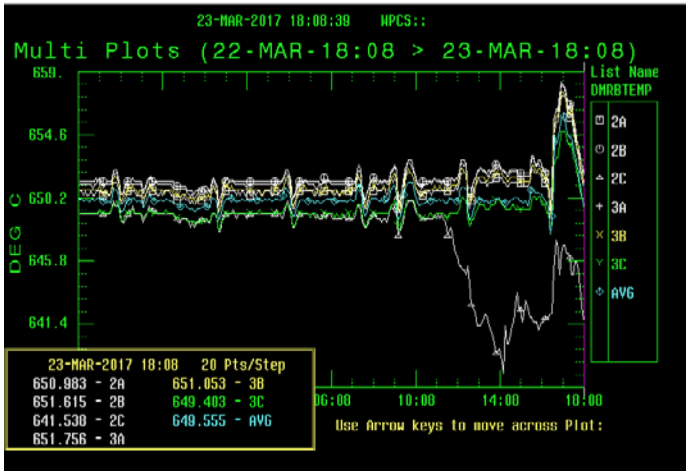
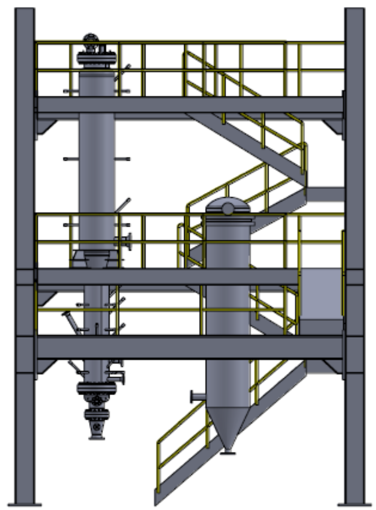


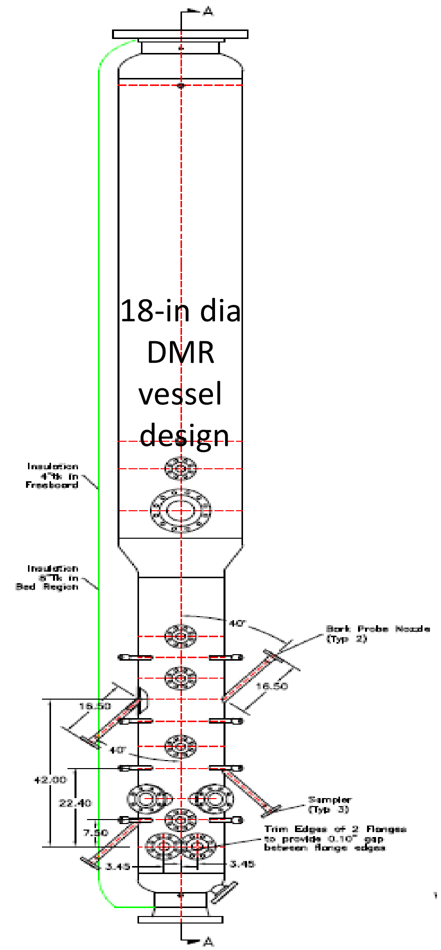
DMR temperature plot showing rapid divergence of temperatures within DMR bed, which is typical of the instabilities.

Use of Hazen to Resolve Chemical/Physical Challenges

- Testing at Hazen, Colo. facility using a 2-inch-diameter DMR bench-scale unit and an 18-inch diameter DMR pilot plant.
- Allows testing the process flowsheet, operational parameters, and equipment modifications prior to testing at IWTU.
- Completed 9 test series to date on 18-inch pilot plant (9,650 gallons SBW waste feed simulant with 745 operating hours).
- Tests to date evaluating process control , i.e. bed seeding effects, CO_2 addition, coal feed rate, wall scale/sand castle/ bark formation, bed height and temperature effect, SBW simulant chemistry.
- Evaluating the data from the tests series to determine what are the most important correlations to wall scale formation.



(Above) 18-in diameter DMR vessel (left) and Process Gas Filter (right)



Upcoming Activities

- Complete engineering/testing of proposed DMR lower region equipment modifications to address lower region fluidization.
- Complete installation of manway.
- Install CO2 gas heater/steam separation in DMR.
- Continue next series of Hazen testing (fluidization mechanical options).
- Outage I ongoing in preparation for next simulant run.