GeomeIt® In Container Vitrification (ICV™)

Latest Developments and Overview of Operational installations

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NUCLEAR SOLUTIONS

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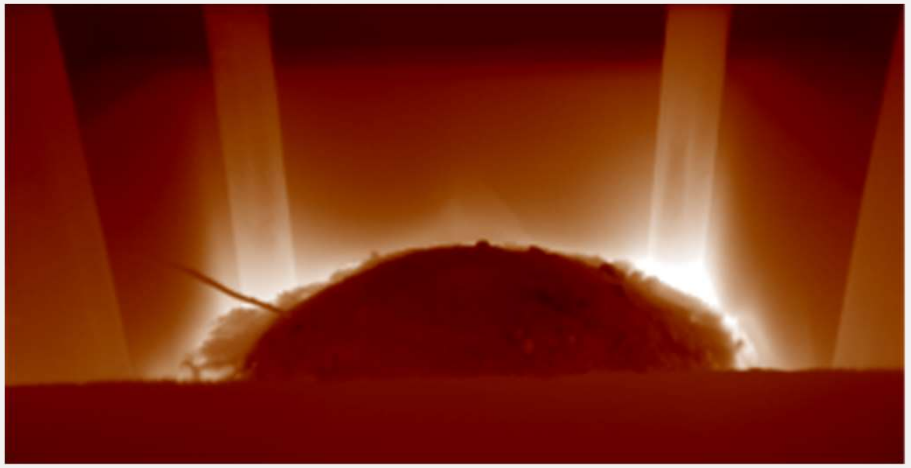


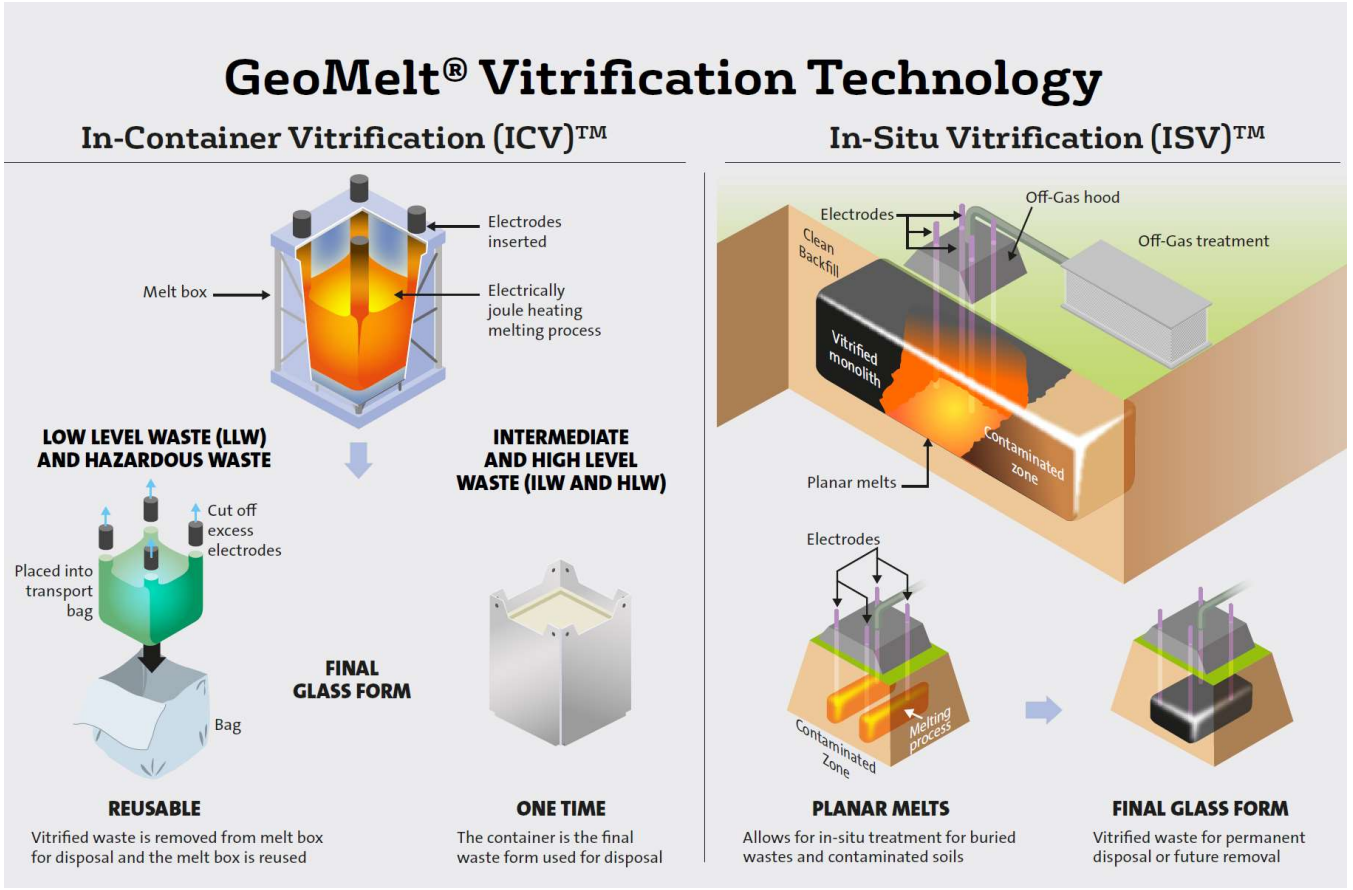
VEOLIA NUCLEAR SOLUTIONS

Worldwide, Veolia provides water, waste and energy management solutions.

By leveraging the strong reputation in these areas, through VNS, Veolia is galvanizing our solutions to some of the nuclear industry's most challenging environmental clean up projects to contribute to a safer, cleaner world.

VNS has a comprehensive range of technologies and services for facility management, decommissioning, and the treatment of radioactive waste. Our offers are organised into three pillars.

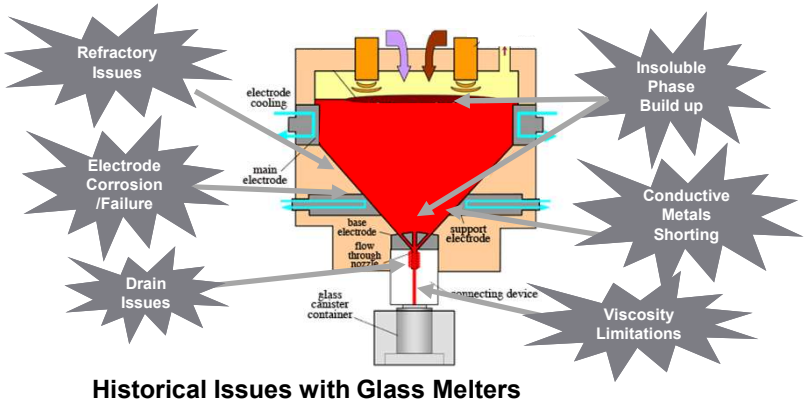
PRINCIPLES OF THE GEOMELT® TECHNOLOGY

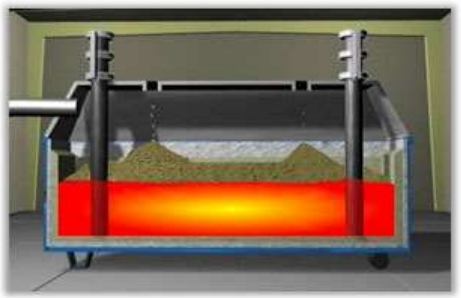


GEOMELT® BENEFITS (1)

- **Radioactive** and **Problematic** Waste Treatment
- Broad **Temperature** processing range
- **Volume Reduction** up to 80%
- **Stable** for Thousands of Years
- Over **26,000 Tonnes of Waste Processed** - Over half **radioactive contaminated**
- Process can also be designed to be **mobile, modular or a fixed-based** facility.
- **Low-Lifecyle Management Cost** Compared to Alternative Technologies
- **In-Situ (ISV™)** – Up to 1,000 metric ton melt
- **In-Container (ICV™)** – Up to 50 metric ton Melt

GEOMELT® BENEFITS (2)



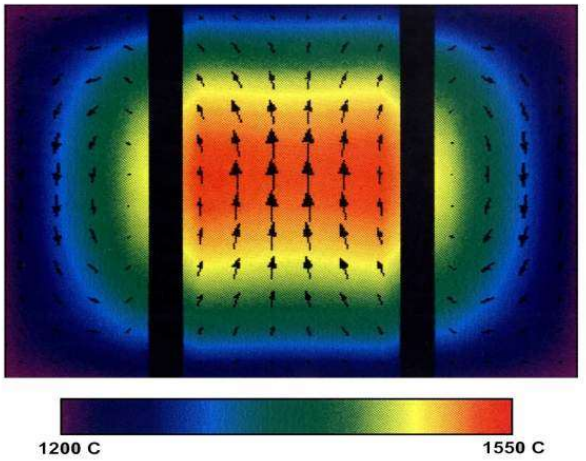


Historical Issues with Glass Melters		Benefit of GeoMelt® Design
Refractory Liner Issues for one Melt	→	Minimized due to batch process – Liner only used
Glass Drain Issues required	→	Eliminated due to batch process – No draining
Conductive Metals Causing Shorting avoidance of shorting conditions	→	Low risk due to movable electrodes allows
Viscosity Limitations flexibility in temperature	→	Low risk due to no need to drain the melter and
Insoluble phase buildup from one melt	→	Minimized as batch approach only allows for buildup
Electrode Corrosion/Failure need to last one melt and	→	Low risk due to batch process – electrodes only
		Moveable electrodes allow for feeding of electrodes in case of corrosion/failure
Melter Issues Cause Facility Downtime	→	Batch process allows facility to continue to operate

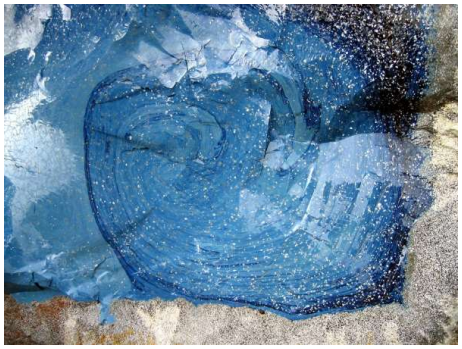
Designed To Eliminate / Mitigate Conventional Melter Issues

VITREOUS PRODUCT HOMOGENEITY

- Thermal gradients within melt establish convective flows
- Convective flows serve to mix melt during processing forming a homogeneous product
- Essentially eliminates criticality concerns in final waste form by preventing concentrating mechanisms
- Convective mixing ensures that sampling is representative of entire melt. Reduces number of samples to verify characterization

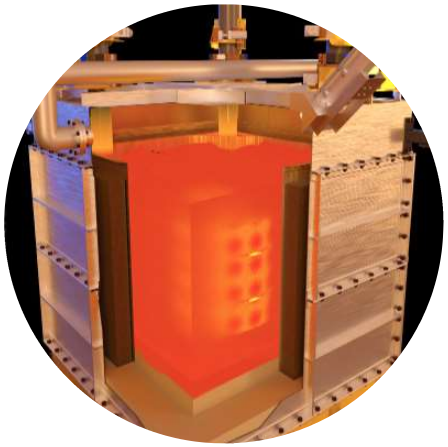


Numerical simulation showing flow velocities



Flow patterns during asbestos treatment

HISTORY OF GEOMELT®



- Core technology developed by US Department of Energy (DOE) at the Pacific Northwest National Lab (PNNL) in the early 1980's
- Commercialized in 1993
- Period of technology advancement
- Growth period of testing and validating processing options for various waste types
- Technology acquired by Veolia in 2016
- Continued priority in R&D investment

Pacific Northwest
NATIONAL LABORATORY

CURRENT GEOMELT® ICV™ UNITS WORLDWIDE

Engineering (pilot) scale

Horn Rapids
- Nominally 200 kg
- Non-Rad demonstration
- Two or four electrodes
- Rectangular or square
- Variety of simulant testing capable

NNL Pilot
- Nominally 200 kg
- Radioactive demonstration
- 4 electrodes
- Higher capacity off-gas system
- Partner's facility

Limay Pilot
- Nominally 500 kg
- Qualification Testing for High Activity Waste Non-Rad. License
- High Energy Materials demonstrations (e.g. IXR, reactive metals)
- Sophisticated off-gas measurement

Industrial scale

Perma-Fix NW Facility
- 10 ton
- Commercial Facility
- Treatment of Low Level Waste
- Radiation License
- Hazardous License
- Partner provides pretreatment capability

Daiei Kankyo Facility
- 9,5 ton
- Commercial Facility
- Treatment of hazardous waste
- Sublicensee operated
- Operator also has several other waste processes on site

GeoMelt® Andrews
- 10 ton
- Commercial Facility
- Treatment of Low Level Waste
- Radiation License
- Hazardous License
- Partner provides some support activities

HORN RAPIDS (RICHLAND, WA) 200 kg DEMONSTRATION SYSTEM

Melter

Off-Gas Treatment System

System View

NNL 200 kg DEMONSTRATION SYSTEM

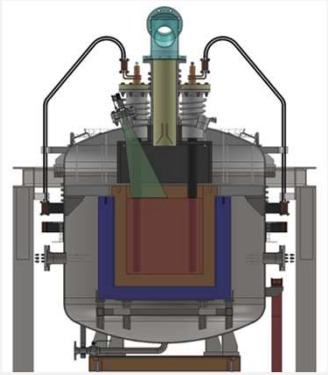
GeoMelt® System installed in the active rig hall at NNL's Central Laboratory on the Sellafield Site

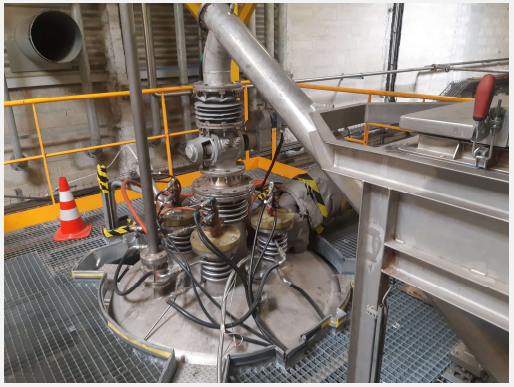
Melter and Electrical Transformer

Off-Gas Treatment System


GeoMelt Vitrification Open for Business at Sellafield

LIMAY (FRANCE) 500 kg GEOMELT® DEMONSTRATION SYSTEM



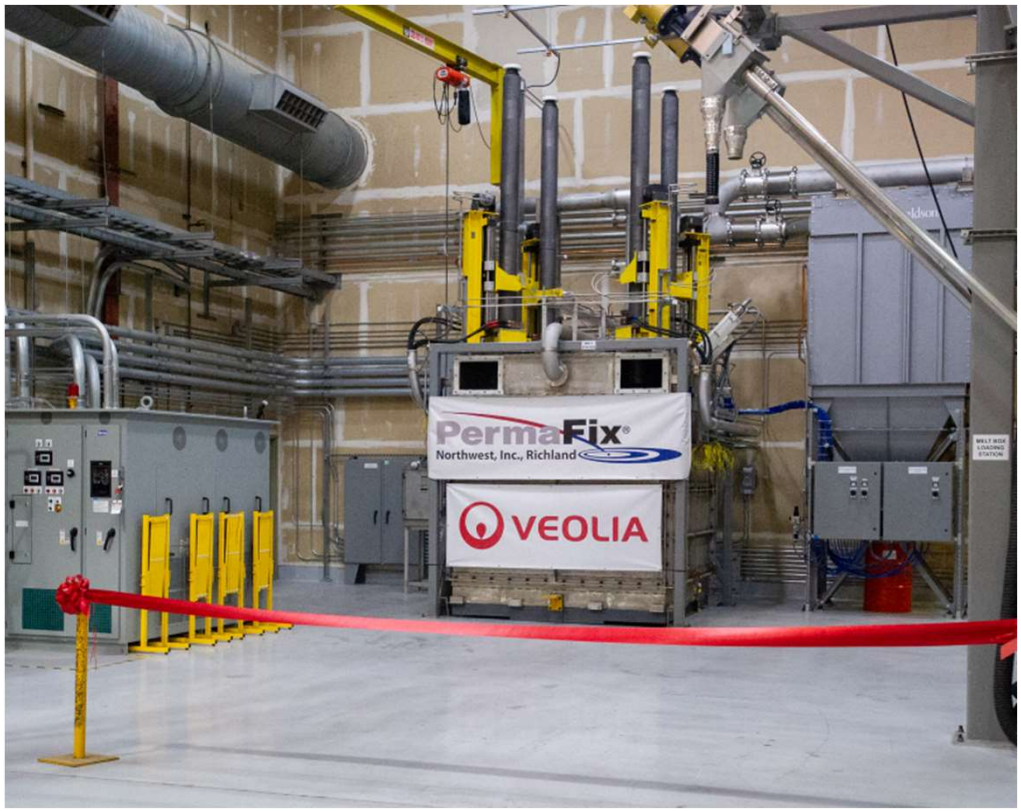


HAZARDOUS WASTE 9,5t FACILITY IN JAPAN

Mie Recycle Center Technologies

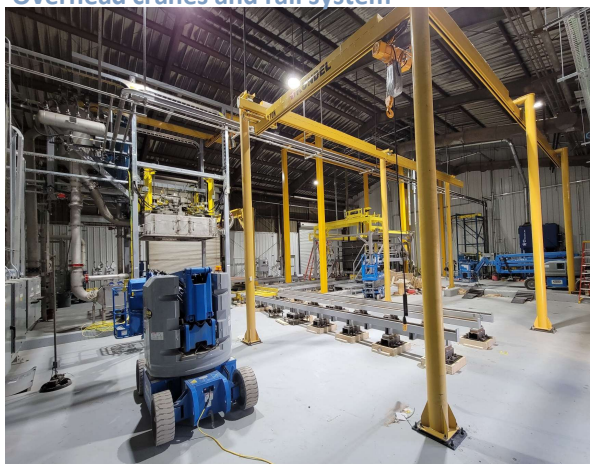
- GeoMelt® plant
- Rotary Kiln Incinerator plant
- Drying plant
- Sintering furnace
- Refuse Paper and Plastics Fuel production facilities
- Sludge solidification plant
- Wood chip production plant
- Plastic recycle plant
- Neutralization treatment plant
- Shredding and separation plant
- Electrical equipment recycle plant
- Compost factory
- Controlled type final disposal site
- Others: (Asbestos dismantling line, Sorting station, Analysis center, Storage station, Water treatment plant)

GEOMELT® 10t UNIT AT PERMAFIX NORTHWEST (RICHLAND WA)



GEOMELT® ANDREWS (TX) 10t FACILITY

Overhead cranes and rail system



Melt box on tugger at load station

Off-gas system

Melt Station

ONGOING DEVELOPMENTS (1)

→ WASTE CONTAINING METALLIC SODIUM

- Na reacts strongly with water
- A gentle and controlled oxidation is possible during GEOMELT vitrification

$$4\ Na + SiO_2\ (sand) \rightarrow 2\ Na_2O + Si$$

$$2\ Na_2O + 2\ SiO_2 \rightarrow 2\ Na_2SiO_3\ (melted\ glass)$$

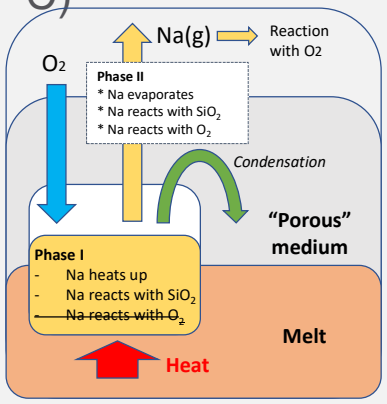
- Competition with sodium evaporation (boiling point= 883 °C)
- To promote oxidation and limit evaporation

  ⇒ Modeling

  ⇒ Lab scale DTA / TGA and crucible tests

  ⇒ Pilot tests

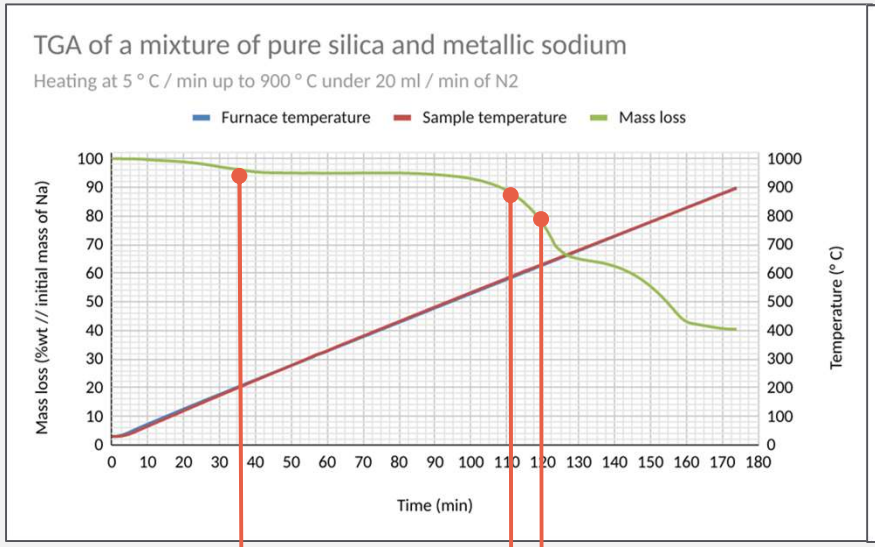
  ⇒ Full scale tests with increasing Na amounts

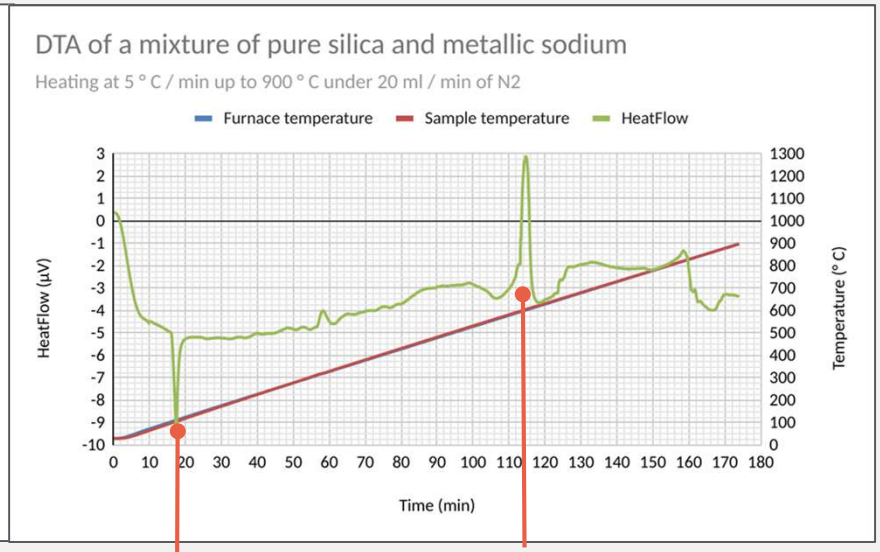


ONGOING DEVELOPMENTS (2)

→ WASTE CONTAINING METALLIC SODIUM

⇒ DTA / TGA ANALYSIS





Paraffin oil volatilization
up to 300 ° C (5.1 %wt)

Superimposition of Na reaction with silica

Na volatilization from 430 ° C

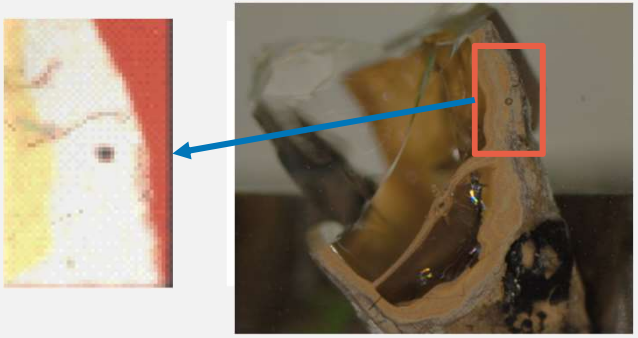
Strong exothermic peak
between 580 and 630 ° C
→ **Na reaction with silica**

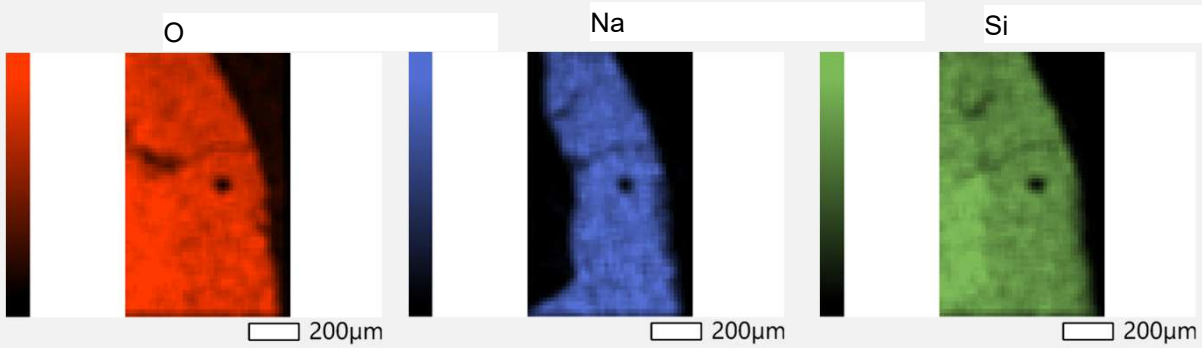
Melting of Na at 98 ° C

ONGOING DEVELOPMENTS (3)

→ WASTE CONTAINING METALLIC SODIUM

⇒ SEM PICTURES

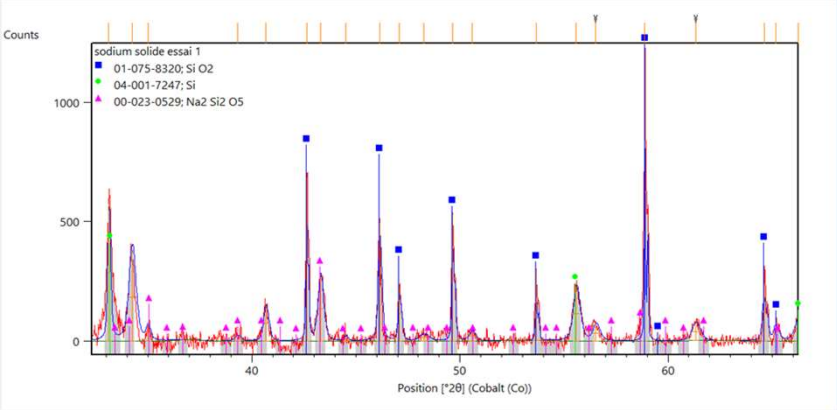




ONGOING DEVELOPMENTS (4)

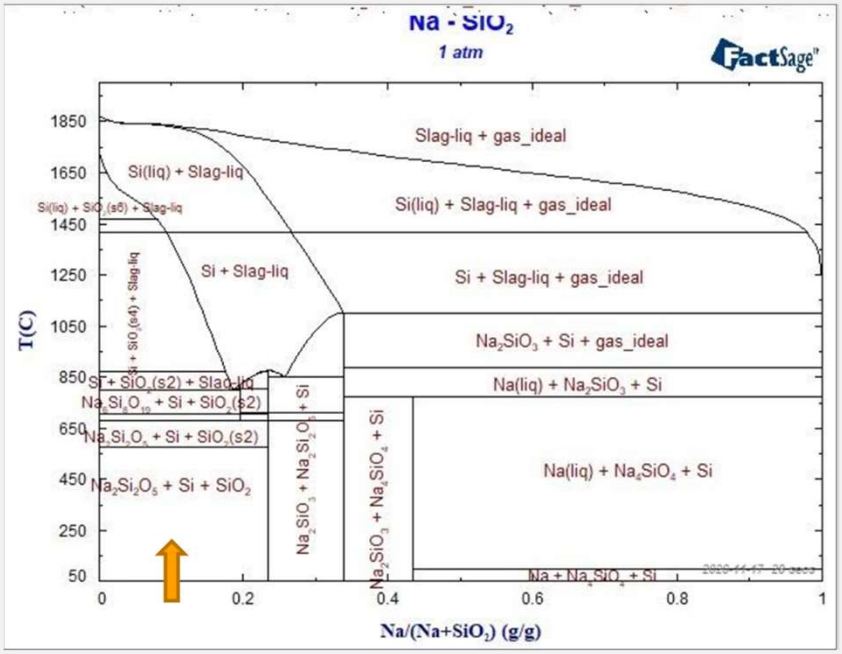
→ WASTE CONTAINING METALLIC SODIUM

⇒ XRD IDENTIFICATION



Identified compounds : Na_2SiO_5 SiO_2 Si

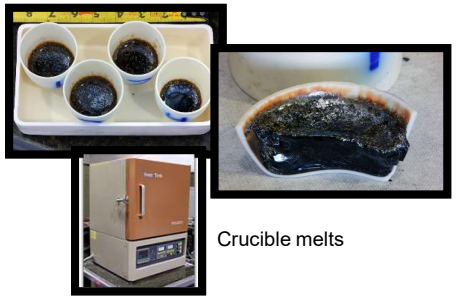
$4\ Na + 5\ SiO_2 \rightarrow Si + 2\ Na_2Si_2O_5$



ONGOING DEVELOPMENTS (5)

→ INL – Veolia Reactive Metals Demonstration Program

- Idaho National Laboratory partnered with Veolia to demonstrate application of GeoMelt ICV for reactive metal contaminated waste
  - *Initiated in July 2016*
  - *Phased demonstration – currently in phase five*
  - *Progressive phased approach*
- Phase 1
  - *Mitigated risk approach followed*
  - *Proof of principle focused on drums*
  - *Crucible testing, Bench-scale testing followed by Engineering-scale testing*



Crucible melts

Engineering-scale Melt setup - Scaled drums

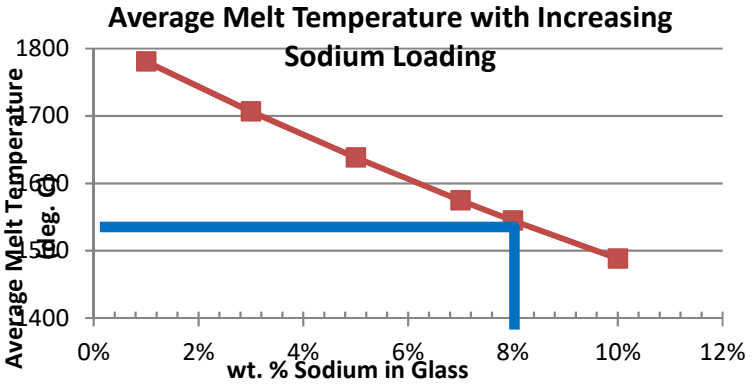
Completed melt with metal ingot

10-gal drum prior to treatment at Engineering-scale

ONGOING DEVELOPMENTS (6)

→ INL – Veolia Reactive Metals Demonstration Program

- Phase 2 focused on maximizing sodium loading in glass
  - *Glass can contain high levels of sodium as an oxide*
  - *Increasing sodium oxide reduces metal temperature*
- Phase 3 focused on more complex waste configurations
  - *INL Zero Power Physics Reactor (ZPPR) plates*
  - *Sodium components maintenance shop (SCMS) materials*



SCMS Item Demonstration

ZPPR Plate Demonstration

ONGOING DEVELOPMENTS (7)

→ INL – Veolia Reactive Metals Demonstration Program

Phase 4 and 5 continued with progressively more difficult configurations and includes NaK

EBR-II sodium bonded blanket subassembly

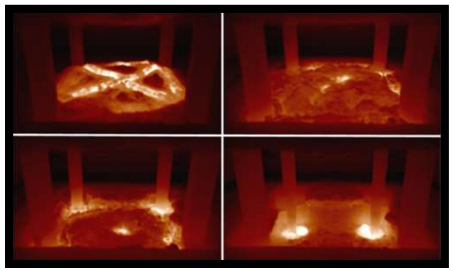
SCMS heat exchanger

NaK (78%/22%) testing in SCMS container

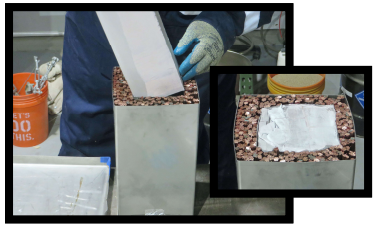
Simulated sodium pump used in a Fuel Element Rupture Detection (FERD) system

SCMS heat exchanger engineering scale test

Mock EBR-II blanket with misch metal



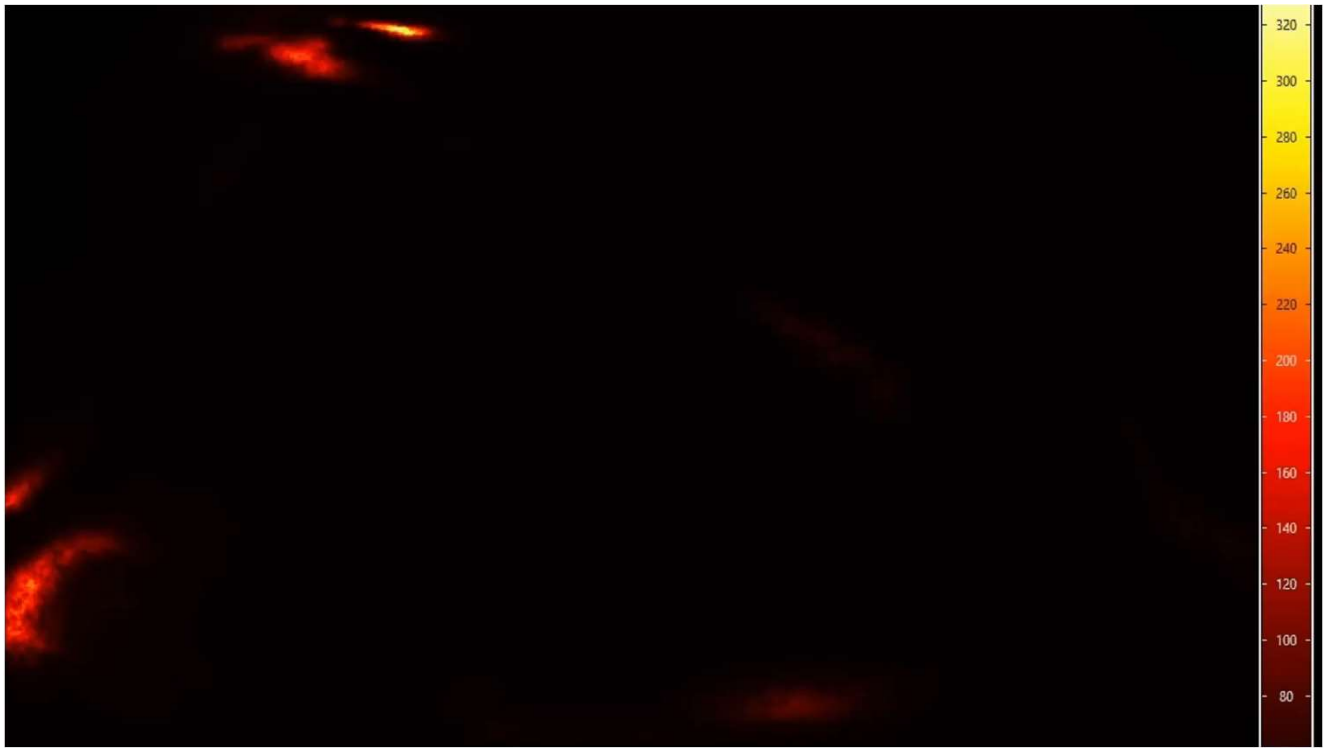
Treatment of a Simulated SCMS Item Containing NaK



Simulated FERD Na Pump

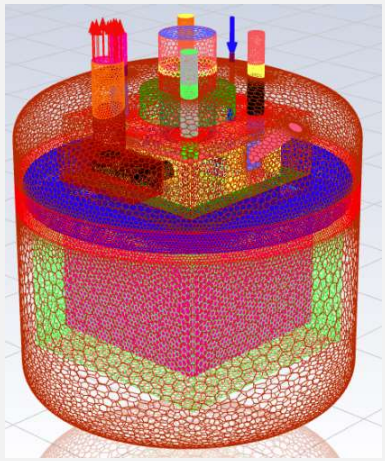
ONGOING DEVELOPMENTS (8)

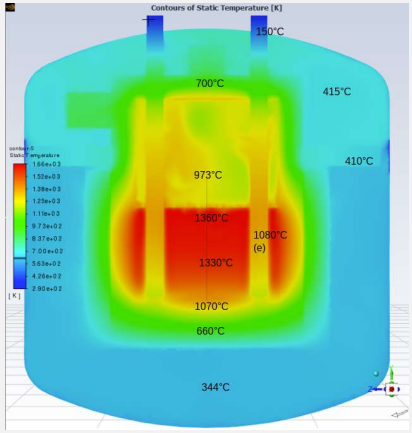
→ Melting video of LLW waste containing reactive metals



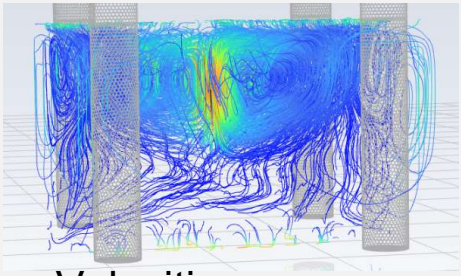
ONGOING DEVELOPMENTS (9)

→ GEOMELT MODELING

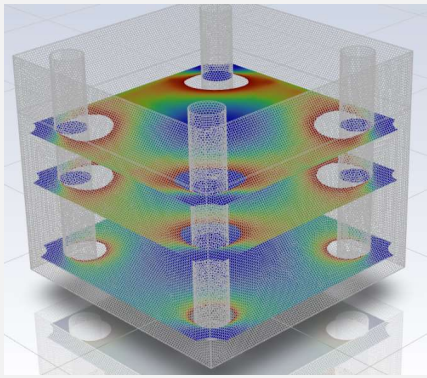




Temperatures



Velocities



Joule effect

ONGOING DEVELOPMENTS (10)

INTERDEPENDENT MODELS OF THE GEOMELT PROCESS

- Glass recipe
- Solubility of problematic species

- Process control model

Power

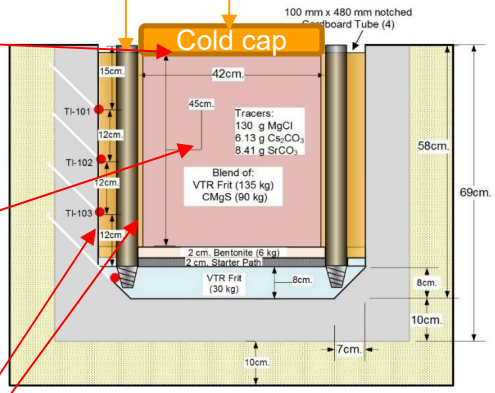
Feed materials

- Gas generation
- Volatility of problematic species

Off-gas treatment

- Off-gas treatment process

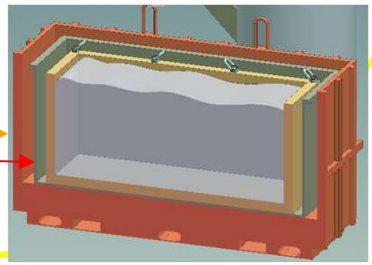
- Cold cap model (couple thermal & gas generation)



Melter

- Thermal model
- Thermohydraulics
- Viscosity
- Resistivity
- Redox / alkalinity

Produced glass package



- Leaching
- Mechanical properties

- Interface reactions

ONGOING DEVELOPMENTS (11)

COLLABORATIVE RESEARCH PROJECT (2022-2025)

- Adaptation of the GEOMELT® ISV™ and SPV™ technologies to French an European technical, regulatory and environmental needs :
  - Optimal containment : to assess and limit radionuclides and other pollutants diffusion during melts preparation, melting and storage of the vitrified waste,
  - Formulation of new vitreous materials to meet the specifications of the ANDRA waste storage centers that will be their final outlet.
- To create new on-site storage possibilities (for very low-level waste) in France, in order to preserve current storage capacities.
- To demonstrate the feasibility of the process on a real contaminated CEA site.
- To evaluate the environmental, societal, technical and economic performances of the whole in situ vitrification process (cycle life analysis).
- To establish a business plan for the process industrialization.

VEOLIA

QUESTIONS ?

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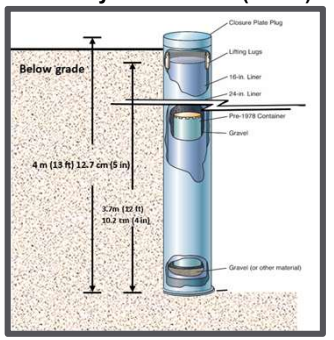
→ INL –reactive alkali metal waste inventory

- Primary source of alkali metal contaminated waste and SNF is from previous liquid metal fast reactor program
  - Experimental Breeder Reactor – II (EBR-II)
    - Operated at INL from 1965 to 1994
    - 62 MW(t) sodium cooled
    - Sodium bonded HEU fuel
- Reactor operations, maintenance and reactor deactivation generated waste, SNF, and components requiring treatment prior to disposal
  - Contact and remote handled waste streams
  - All contained within metal containers
  - Sodium and NaK contaminated
- Associated chemical reactivity creates handling, treatment, and disposition challenges
- Complex configurations present significant treatment challenges

Zero Power Physics Reactor (ZPPR) Plates



Radioactive Scrap and Waste Facility (RSWF) Large Liner

Sodium Contaminated Maintenance Shop (SCMS) Items

EBR-II Sodium Bonded Subassembly