Overview of VSL Background and Capabilities

Vitreous State Laboratory
The Catholic University of America
Washington, D.C. 20064

Vitreous State Laboratory

- Established in 1968
- Interdisciplinary R&D program focusing on applied materials science & glass chemistry and physics
- Approximately 85 staff
  - Ph.Ds in chemistry, physics, chemical engineering, radiochemistry, materials science, glass science, metallurgy, geology, geochemistry, electrical engineering, biophysics
  - Round-the-clock pilot plant operations staff
- Modern 55,000 ft^2 facility
- Licensed for radioactive and hazardous materials
- NQA-1, DOE/RW-0333P, and SW846 QA Program
- Extensive chemical, physical, and materials characterization and pilot-scale testing facilities
- Current collaborations include Smithsonian Institution, NIST, NRL, Geophysical Lab, Brookhaven, LBNL, PNNL, and SRNL

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VSL Project History

- 1960s, - 70s
  - Various defense programs
- 1970s, 80s
  - Fiber optics
  - Nuclear waste vitrification
  - Glass-based ion exchange media
    - Duratek spin-off (now Energy*Solutions*)
- 1980s, 90s
  - West Valley, SRS M-Area, Hanford …
    - Fernald, Weldon Spring, Oak Ridge, Idaho, Paducah, Los Alamos…
  - Enhanced melter technology developed
  - Vitrification, water treatment, incineration pilot plants
- 1990s - present
  - Hanford WTP
  - Idaho Calcine Vitrification – High throughput, high waste loading
  - SRS Tank Waste
  - Numerous others…

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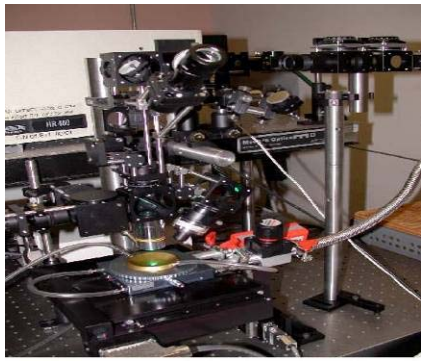
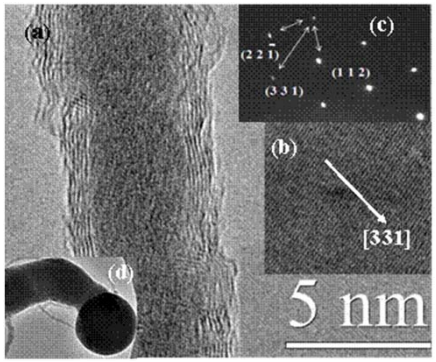
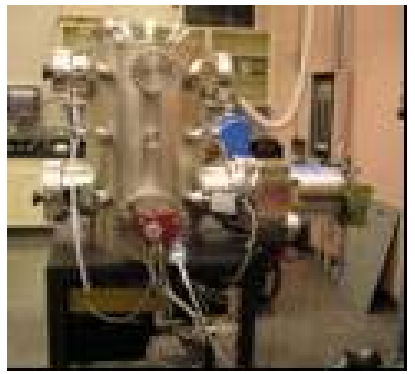
Principal Current R&D Areas

- Nuclear and hazardous waste stabilization
- Glass and ceramic materials development
- Materials corrosion and characterization
- Off-gas treatment
- Water treatment
- Cements, flyash
- Geopolymers
- Biophysics
- Nano-materials
- Thermoelectrics
- Spintronics







Materials Fabrication, Analysis and Characterization

- DCP-ES, ICP-ES, MS, GC-MS, XRF, IC, ISE, TOC, AA, FT-IR, UV/VIS, radiochemistry, gamma spectroscopy
- SEM-EDXS/WDS, TEM-EDXS/WDS, XRD, Mössbauer, DTA, FT-IR, Raman microscopy
- e-beam lithography, CVD, MBE, electrospinning, glass fiber draw tower, synthetic flyash fabrication, cell culture, glass/ceramic processing, etc.
- High-temperature (melt) viscosity, electrical conductivity, electrochemistry, calorimetry, DSC/DTA, density, thermal diffusivity, thermal conductivity
- Electrical and thermal conductivity, thermopower
- Slurry characterization: rheology, yield stress, particle size distribution, zeta potential, TDS/TSS
- Cementitious materials: Compressive strength, leach testing, etc.
- Materials Corrosion: metals, refractories, ASTM test protocols
- Extensive glass leach testing: PCT, VHT, TCLP, MCC, ANSI, Soxhlet, ISO, Flow, etc.
  - Thousands of tests in progress extending up to **32 years** of continuous leaching

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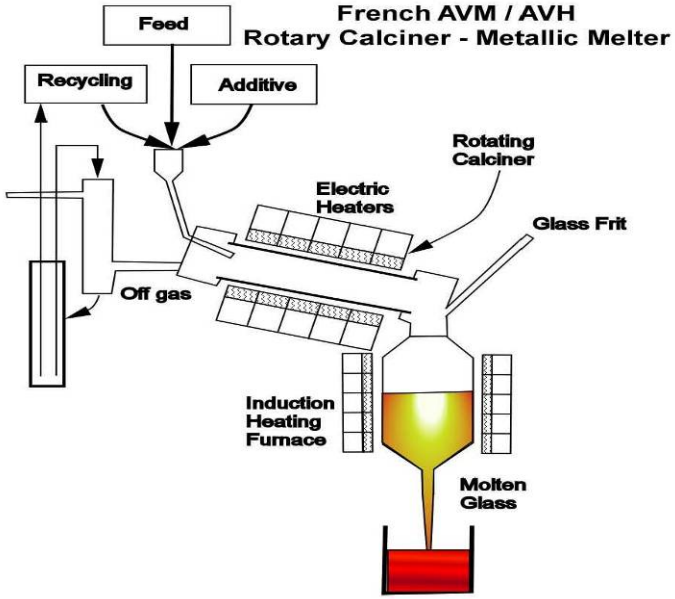
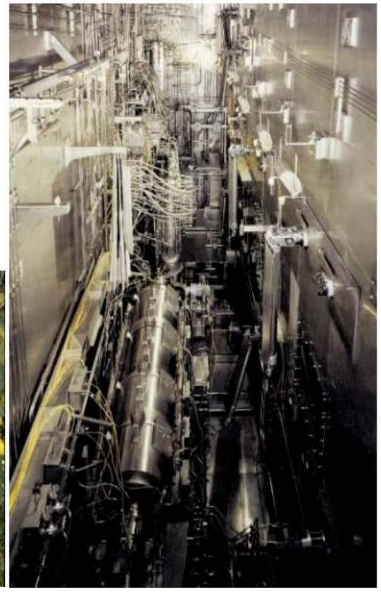
Vitrification

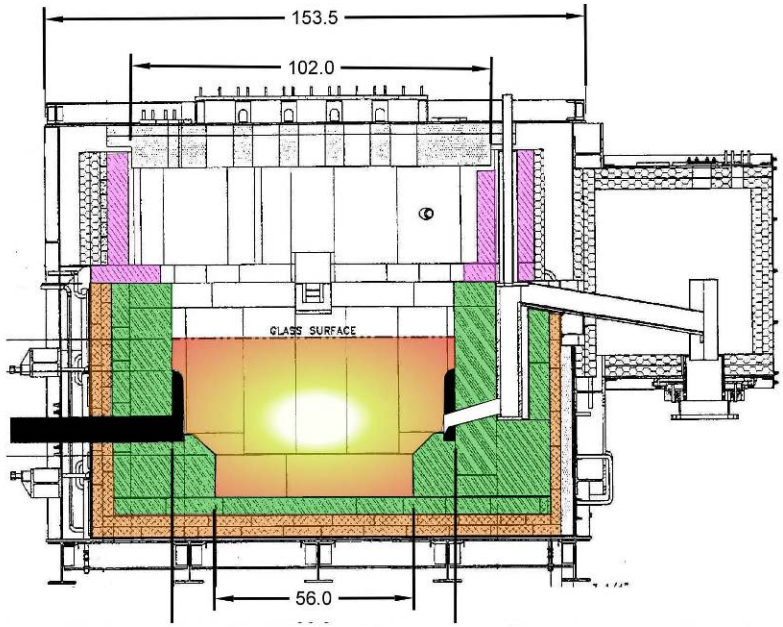
- Immobilization of waste by conversion into a glass
  - Internationally accepted treatment for HLW
- Why glass?
  - Amorphous material – able to incorporate a wide spectrum of elements over wide ranges of composition; resistant to radiation damage
  - Long-term durability – natural analogs
  - Relatively simple process – amenable to nuclearization at large scale
- There are numerous glass-forming systems – why *borosilicate* glass?
  - Relatively low-melting temperature
    - Materials of construction, component lifetimes
  - Potential for high chemical durability
  - ASTM C 162: "Borosilicate glass - any silicate glass having at least 5% of boron oxide (B_2O_3)"

Vitrification: Conversion to Glass

The Internationally Accepted Baseline for Stabilizing HLW







JHCM Technology:

US DOE 1970s – present

- Germany, Japan

- VSL innovations

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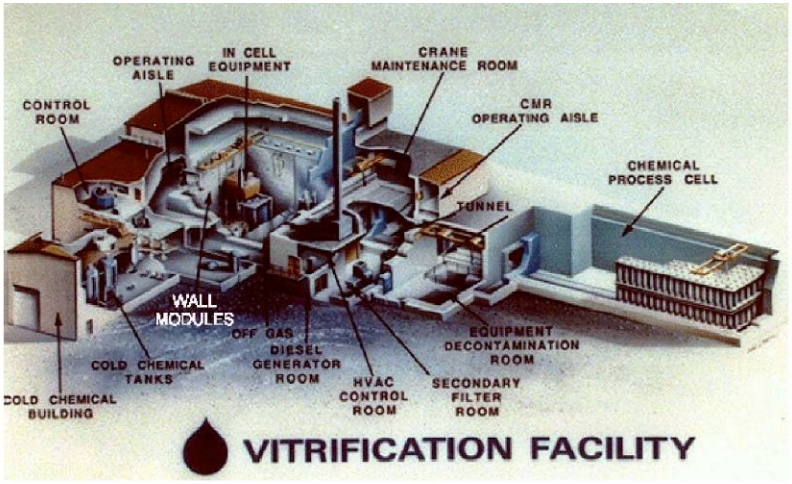
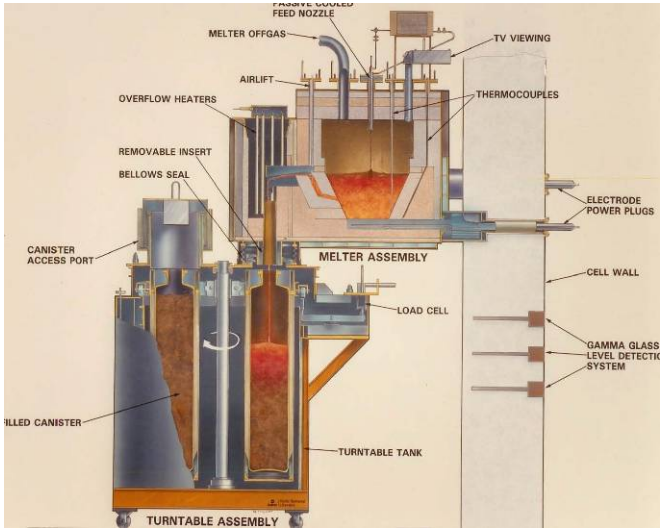
Waste Vitrification Testing at VSL

- Computer-based formulation design and crucible melts
- VSL JHCM Systems:
  - *The largest array of JHCM test systems in the US*
  - *The largest JHCM test platform in the US*
    - Two DM10s (0.02 m^2)
    - Two DM100s (0.11 m^2) + one spare
    - DM1200 (Hanford HLW Pilot, 1.2 m^2; ~50% DWPF scale)
      - Predecessor DM1000 (1.2 m^2) operated for ~ 7 years
  - JHCM testing since 1985; several systems decommissioned
- Off-Gas
  - Three systems, flexible reconfiguration
  - Prototypical Hanford pilot-scale off-gas system
  - Extensive characterization, CEM and US EPA protocols
- Complete Analytical Chemistry Support
  - Inorganics, organics, radionuclides
- Complete Glass Characterization

West Valley Demonstration Project

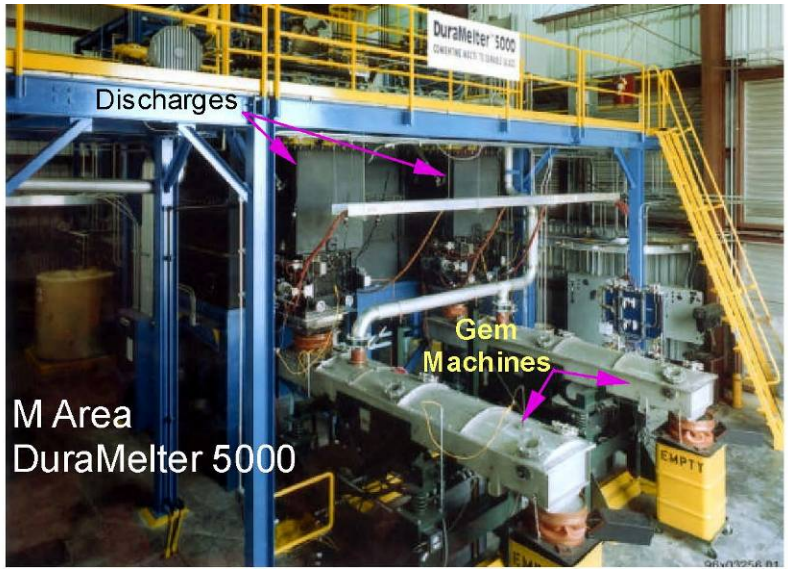
- Only US commercial reprocessing facility
- VSL Support 1985 – 1993
  - Glass formulation and testing
  - Melter testing
- ~660,000 gal HLW containing 24 million curies converted to 275 canisters of glass (~550 MT) using VSL glass formulation
- Vitrification facility decommissioned



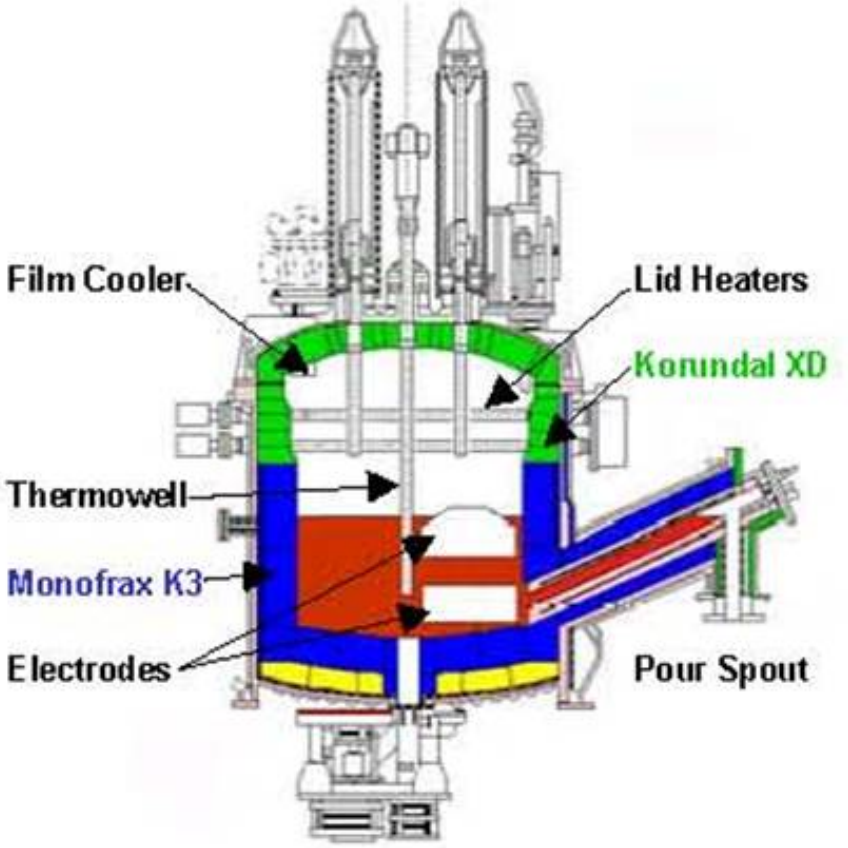


SRS M-Area Vitrification Facility

- 660,000 gal of mixed LLW from plating operations in 11 tanks
- Duratec-VSL team won competitive procurement, 1995 – 1999
  - R&D, flow-sheet, glass formulation, design, build, operate, deactivate
  - Fixed price
  - All waste converted to stable delisted glass
  - Still the largest radioactive JHCM to have operated in the US



Defense Waste Processing Facility (DWPF)

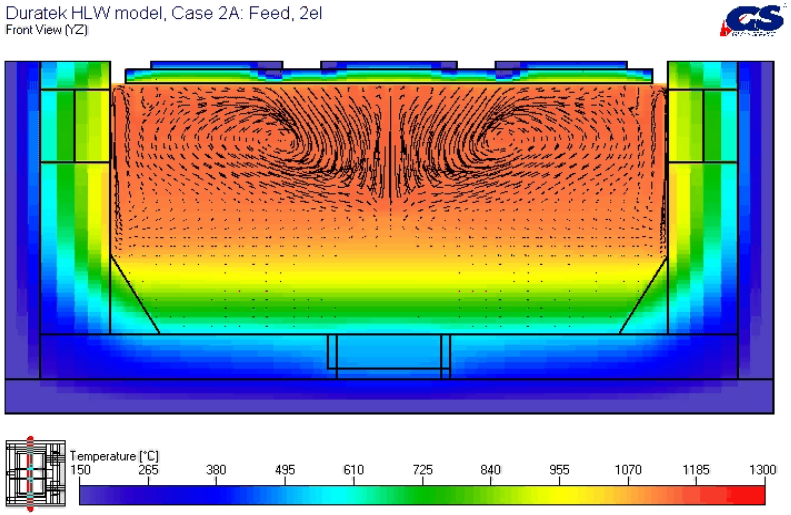


Facility has been operating on DOE site in South Carolina since 1996.

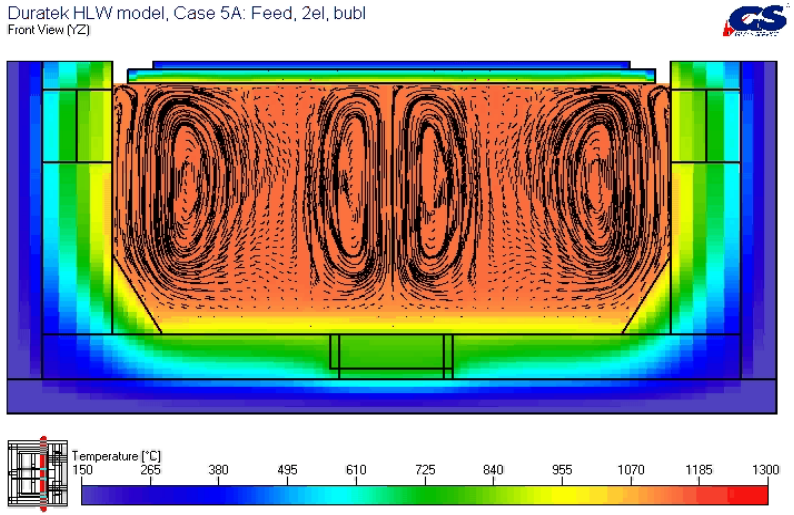
Since 2009, VSL-ES have been providing R&D support to enhance its performance to expedite completion of waste treatment ~Doubled melter throughput with bubblers

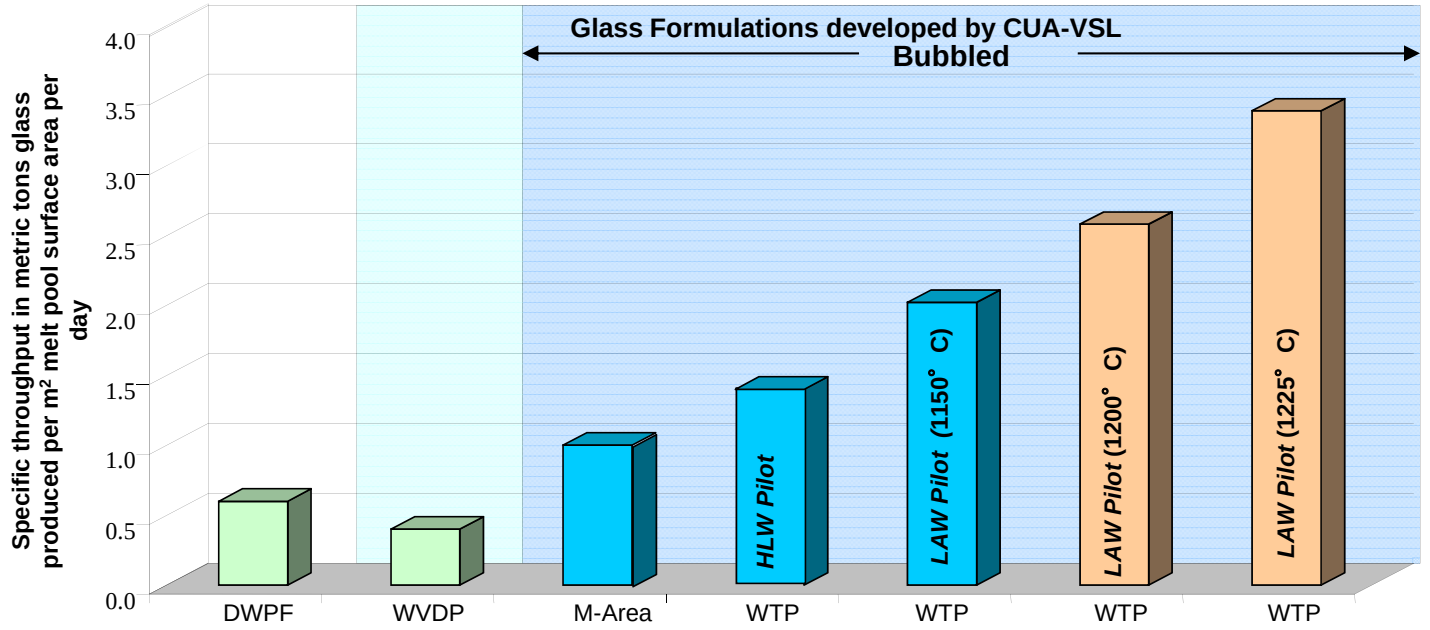
High Throughput Vitrification Technology

Unagitated JHCM (West Valley, DWPF pre-Oct. 2010)



Agitated JHCM (M-Area, WTP LAW, WTP HLW)

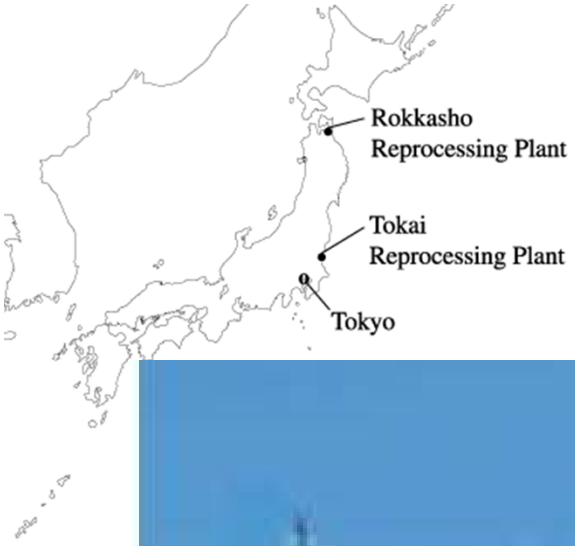




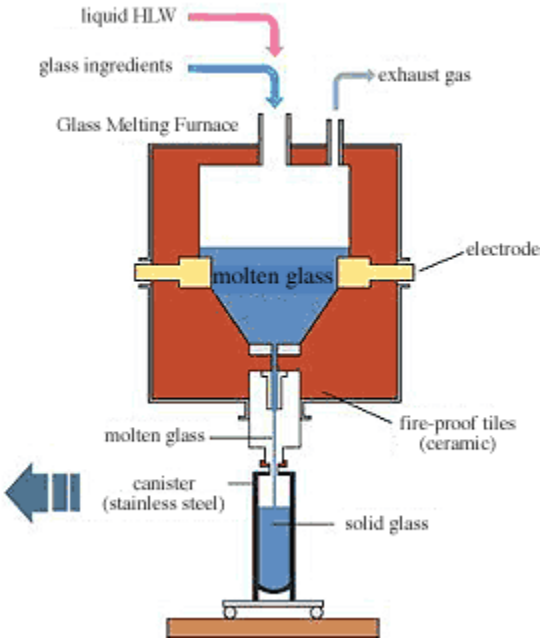
Rate Boost with Bubblers – Invented at CUA-VSL

VSL-Energy*Solutions* Support for Savannah River (SRR)

- Bubblers for DWPF
  - Concept design, lab tests, final design, fabrication
    - Bubblers, thermowell, level detector, thermocouples
- DWPF Feed Make-Up (CPC)
  - Alternate reductant flow-sheet
  - Decon frit dewatering
- DWPF Glass Formulation and Testing
- Saltstone
  - Restart and capacity upgrade technical reviews
  - Improved formulations
  - Vault coatings
  - Testing to support new vault design options
- Modular Salt Processing
  - Full-scale IX-column testing
  - In-tank grinder testing

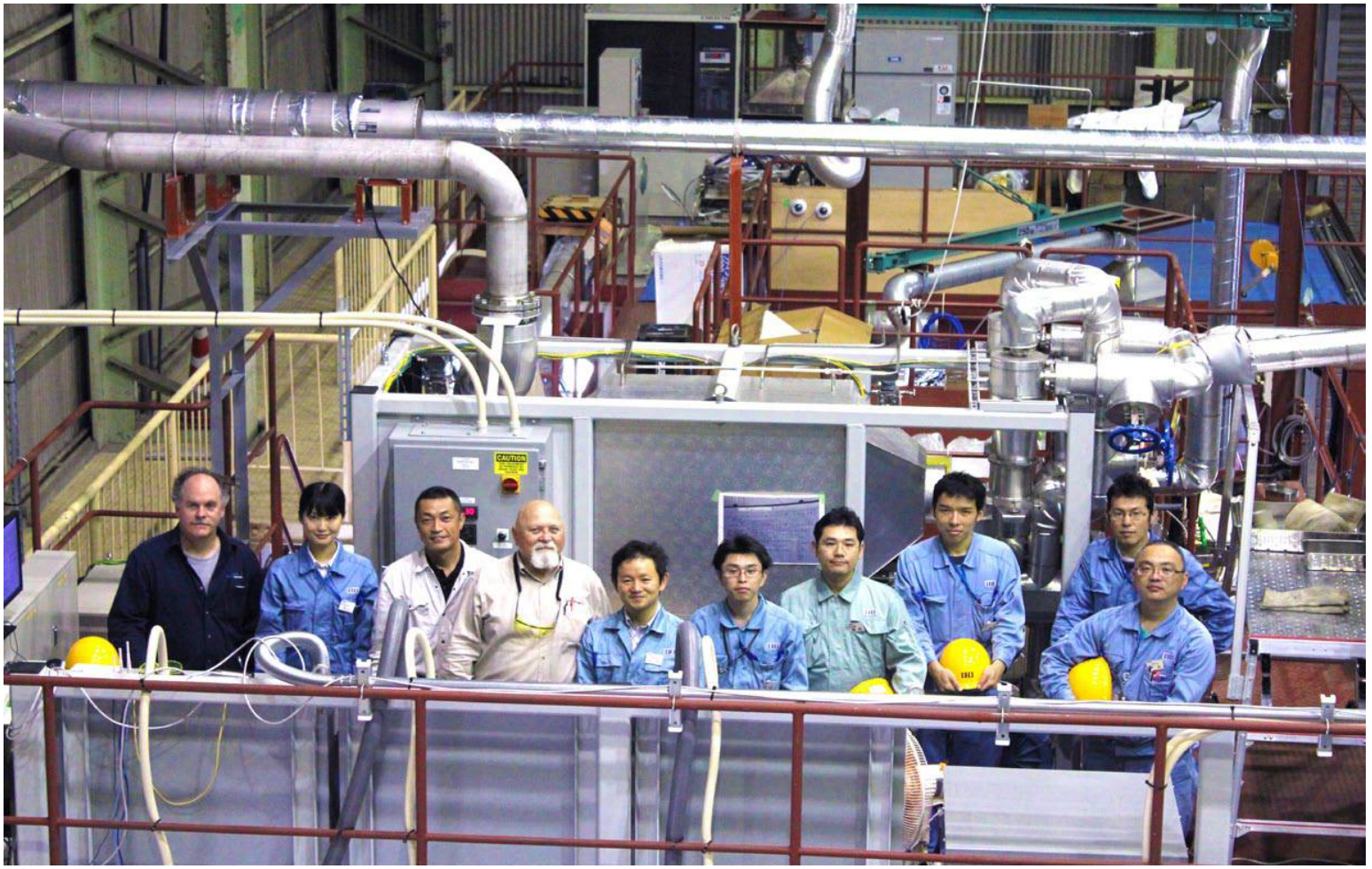


Rokkasho, Japan



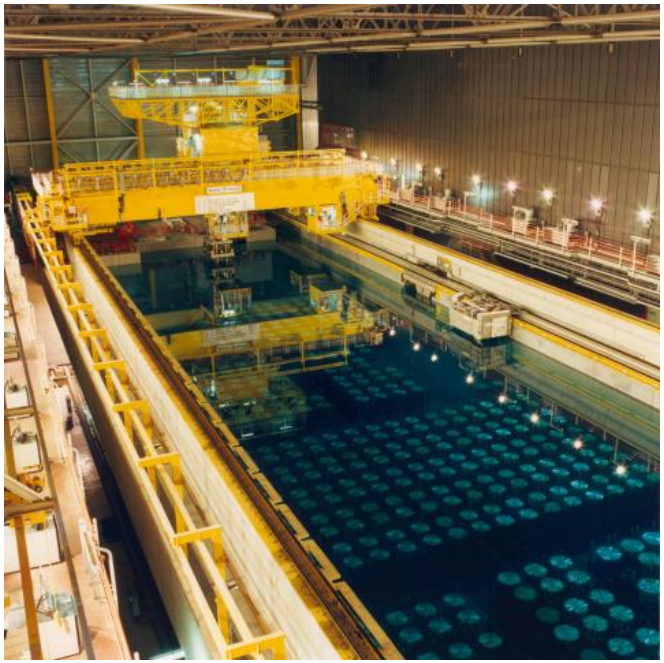
VSL-ES have been providing glass formulation and testing support since 2005

VSL Complete Installation, Testing and Training for ES/VSL Melter Test System at IHI, Japan – July 2012

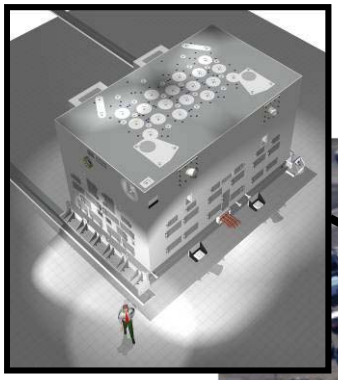


Sellafield, UK

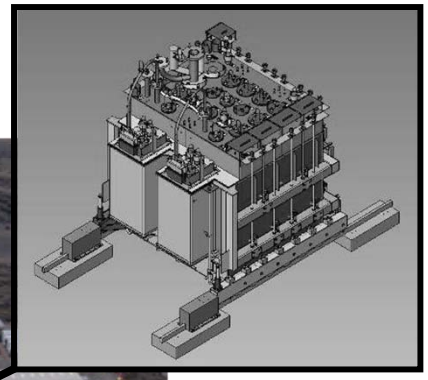
- Glass formulation development, melter testing, and product quality testing for:
  - Magnox and high-Zr HLW
  - Several ILW streams



The Hanford Waste Treatment Plant is Based on VSL/Energy*Solutions*' Vitrification Technology



LAW Melter



HLW Melter

Hanford Vitrification Support

- Continuous support to the WTP since 1996
  - World's largest nuclear waste vitrification facility
- Developed core active melt pool mixing melter technology
- LAW and HLW glass formulation
  - Baseline glass formulations and required data packages
  - Glass property-composition models
  - Compliance strategy
  - Operating envelope
- Small- and pilot-scale melter testing
  - Demonstrate ability to process each tank waste + likely process variability
  - Design confirmation data
  - Flow-sheet development data
  - Regulatory data
  - Safety data
  - Waste form qualification data
- Specific risk areas
  - E.g., noble metals, sulfate separation, materials corrosion, feed rheology, simulant validation, feed mixing and sampling systems, etc.

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Hanford WTP Support

- LAW melter vendor tests 1994-1995
  - VSL/Energy*Solutions* demonstrated viable LAW glasses and melt rates
  - Only vendor to meet Tri-Party Agreement Milestone
- Privatization approach – VSL/Energy*Solutions* on BNFL team
  - Part A: 1996 -1998
  - Part B1: 1998 – 2000
- Contract transition period
  - VSL/Energy*Solutions* sub-contract placed under CH2MHill
- BNI RPP-WTP design/build/commission contract
  - 2001 – present
- DOE ORP/HQ Support
  - 2003 – present
- Tank Farm Contractor (WRPS)
  - 2009 - present

Hanford WTP Vitrification Support

- WTP LAW and HLW Optimization and Enhancements
  - Advanced glass formulation development to achieve high waste loadings with high processing rate
- Next Generation Melter Testing
- Tc Retention in LAW
  - Single-pass baseline retention and enhancements
  - Effects of recycle
- LAW Glass Testing for IDF PA
- Low Temperature Waste Forms (DuraLith)
  - WTP secondary wastes, recycle, and LAW
- Mixing Testing
  - Vitrification feed preparation systems
  - Low Order Accumulation Model testing (LOAM)
  - Large Scale Integrated Testing (LSIT)

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Summary

- Diverse, highly skilled staff
- Extensive, flexible, interdisciplinary development and testing capabilities
- Regulatory and QA systems in place
- Excellent safety, QA, financial, and NRC records
- Deliverable-focused
  - Execute complex work scopes to meet sponsor's technical, cost, and schedule objectives
- Extensive pilot plant deployment and operating experience
  - ~1000 run days for WTP alone
- Proven R&D and technology transfer abilities
- Long and successful mutually beneficial commercial partnerships

CUA Vitreous State Laboratory Internship Program

Program intended for HS, college students, undergraduate and graduate students interested in hands-on training in science through summer or long-term internship

College Students from:
Carnegie Mellon (Physics)
Catholic University (Chemistry, Physics, Engineering)
Eastern University (Environmental Science)
Georgetown (Physics)
Georgia Tech (Nuclear Engineering)
Mount Union College (Bio-Engineering)
University of Arizona (Optics)
University of Maryland
Virginia Tech (Physics)
KMUTT (Thonburi, Thailand)
ESCOM (Compiegne, France)
ENSE3 (Grenoble, France)
Ecole des Mines (Nantes, France)

High School Students from:
Bethesda/Chevy Chase HS (MD)
Paint Branch HS (MD)
Wootton HS Rockville, MD
Montgomory Blair HS, (MD)
McLean HS (VA)
St. Mary's Ryken HS (MD)
George C. Marshall HS (VA)
St. John's College HS (DC)
Trinity School, Falls Church (VA)
The Barrie School (MD)
Colnolie School of the Holy Child (MD)
Richard Montgomery HS (MD)
Montgomory Blair HS (MD)
Oakcrest HS, McLean (VA)
Trinity School, Falls Church (VA)
Wootton HS, Rockville, MD

Final Presentations

Recent Internship Research Subjects

- Measuring the Dissolution Rate of LAW Glass Using Single-Pass Flow-Through Test
- X-Ray Diffraction Studies of Bismuth-Containing High Level Waste Glass Formulations
- Radial p-n Junction Solar Cells: *n*-type CdS on *p*-type Cd/PbTe microwires by chemical bath deposition
- Characterization of Silica Gel in Geopolymers
- Structural and Magnetic Properties of Heusler Alloy Nanostructures
- Improving Technetium Retention in Hanford LAW Glass
- New Leach Test Method 1314 and Comparison to Glass Leaching by PCT, VHT, TCLP
- The Effect of Magnesium on Vitrified Hanford Low Activity Wastes
- Conductivity of Glasses with Two Transition Metals
- Influence of Calcium on the Strength of Geopolymer Cements
- Characterization of Reactivity of Fractionated Fly Ash by Leaching Test
- Synthesis of Coordination Complex Precursors: Growth and Characterization of Ferromagnetic Nanowires
- Photovoltaic Research: Semiconductor thin films, p-n diodes and solar cells
- Thermoelectricity in Ceramic Oxides
- Biochemical Preparation for DNA Pulling Experiments
- Bone Tissue Engineering
- Radio-Sensitizing Human Colorectal Cancer Cells
- Effect of Calcium in Fly Ash on Geopolymer Properties
- Rate laws of fly ash glass leaching at high water/solid ratio
- Rate laws of fly ash leaching: Effect of geopolymerization

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M.S. Program in Nuclear Environmental Protection

at

The Catholic University of America

School of Arts and Sciences

Overview and details available at

http://nep.cua.edu

Questions: Contact the Program Director Dr. Werner Lutze

At

wernerl@vsl.cua.edu

Or call

Phone 202-319-5499, cell 202-549-5478

Program and duration

- Suite of courses currently taught over four semesters (2 years) :
  - NEP 520: Health Physics
  - NEP 521: Radiochemistry
  - NEP 522: Materials Science of Nuclear Waste Forms
  - NEP 523: The Nuclear Fuel Cycle
  - NEP 601: Radioactive Waste Management and Disposal – HLW
  - NEP 602: Radioactive Waste Management and Disposal – LLW
  - NEP 615: Laws, Regulations, and Responsibilities
  - One Elective
    - NEP 621: Groundwater Remediation
    - NEP 624: Instruments and Methods Lab
    - Several other existing courses at CUA
  - NEP 'Final Project'

- 30 credit hours
- 3 credits per course (24 total) plus 6 for Final Project

Courses taught by long-term experts in the field from

CUA/VSL

The Department of Energy

Industry

Program started in 2010

Program development financially supported by the U.S. Nuclear Regulatory Commission

Specifically designed
for professionals to provide immediate marketability and career opportunities in the nuclear-related field

Courses also offered individually

So far, all students have been full-time employees; several found new jobs after graduation

Final Project (6 credits)

NEP 795: A minimum 6-week full-time research project at VSL with a final report to be submitted and and presented

NEP 796: A minimum 6-week full-time internship in the US nuclear industry or internationally with a final report to be submitted and presented

NEP 797: A research project any place with 6 weeks of guidance, final report to be submitted and presented.

Examples of Final Projects completed:

Proposed Policy Position for the Office of Environmental Management for Non-conforming High-level Waste Canisters at West Valley Demonstration Project

Disposition Alternatives for the High Flux Isotope Reactor (HFTR) Spent Nuclear Fuel

Novel Formulations of Oxo-Halide Glasses - A study of Chloride Uptake

Installation of Melter Refractory and Insulation Materials into the DWPF Melter 4

What we need: More students