STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

Waste Isolation Pilot Plant Radioactive Release

DOE-FIU SCIENCE & TECHNOLOGY
WORKFORCE DEVELOPMENT PROGRAM

Date submitted:

September 30, 2015

Principal Investigators:

Ryan Sheffield (DOE Fellow Student)
Florida International University

James Poppiti, Mentor
Department of Energy Headquarters

Florida International University Program Director:

Leonel Lagos Ph.D., PMP®

Submitted to:

U.S. Department of Energy
Office of Environmental Management
Under Cooperative Agreement # DE-EM0000598

FIU | Applied Research Center
FLORIDA INTERNATIONAL UNIVERSITY

ABSTRACT

During the summer of 2015, Mr. Ryan Sheffield conducted an internship with the U.S. Department of Energy Office of Environmental Management (DOE-EM) at the Department of Energy Headquarters (DOE-HQ) in Germantown, Maryland. Under the mentorship of Dr. James Poppiti, Ryan's main role was to study and analyze the radioactive release that occurred at the Waste Isolation Pilot Plant (WIPP) in February of 2014; Ryan then assisted Dr. Poppiti in developing an article based on these events, to be published in the Operational Radiation Safety journal. WIPP is the final disposal location for the nation's transuranic waste. It is located near Carlsbad, NM, in a salt mine half of a mile underground. On February 14, 2014, a continuous air monitor (CAM) alarmed, indicating airborne radioactive activity. Proper precautions were taken to ensure the safety of the workers, and investigations commenced to find the source of this release. Mr. Sheffield also worked with John Moon to assist in coordinating the Integrated Project Team workshop at the DOE Hanford Site. Apart from the aforementioned tasks, Mr. Sheffield also shadowed various DOE employees within EM-23, Waste Treatment Plant/Tank Farm program office, to various meetings discussing the operations of DOE.

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

"The mission of the Energy Department is to ensure America's security and prosperity by addressing it energy, environmental and nuclear challenges through transformative science and technology solutions" (Department of Energy). Throughout Mr. Ryan Sheffield's time as a DOE Fellow in the DOE-FIU Science and Technology Workforce Development Program, Mr. Sheffield had only seen the Environmental Management perspective of this enormous organization. During his summer internship at the Department of Energy Headquarters, despite working in an office within Environment Management, all the entities within the Department of Energy were just down the hall. The overall Department of Energy has the following disparate missions:

- Energy: "Catalyze the timely, material, and efficient transformation of the nation's energy system and secure U.S leadership in clean energy technologies."
- Science and innovation: "Maintain a vibrant U.S. effort in science and engineering as a cornerstone of our economic prosperity with clear leadership in strategic areas."
- Nuclear safety and security: "Enhance nuclear security through defenses, nonproliferation, and environmental efforts."
- Management and operations excellence: "Establish an operational and adaptable framework that combines the best wisdom of all Department stakeholders to maximize mission success."

As can be seen in the organization chart in Figure 1, there are 3 principal offices that report to the Office of the Secretary: Office of the Under Secretary for Nuclear Security, Office of the Under Secretary for Science and Energy, and Office of the Under Secretary for Management and Performance. Under the Office of the Under Secretary for Management and Performance lies the Assistant Secretary for Environmental Management, as can be seen highlighted in yellow in Figure 1.

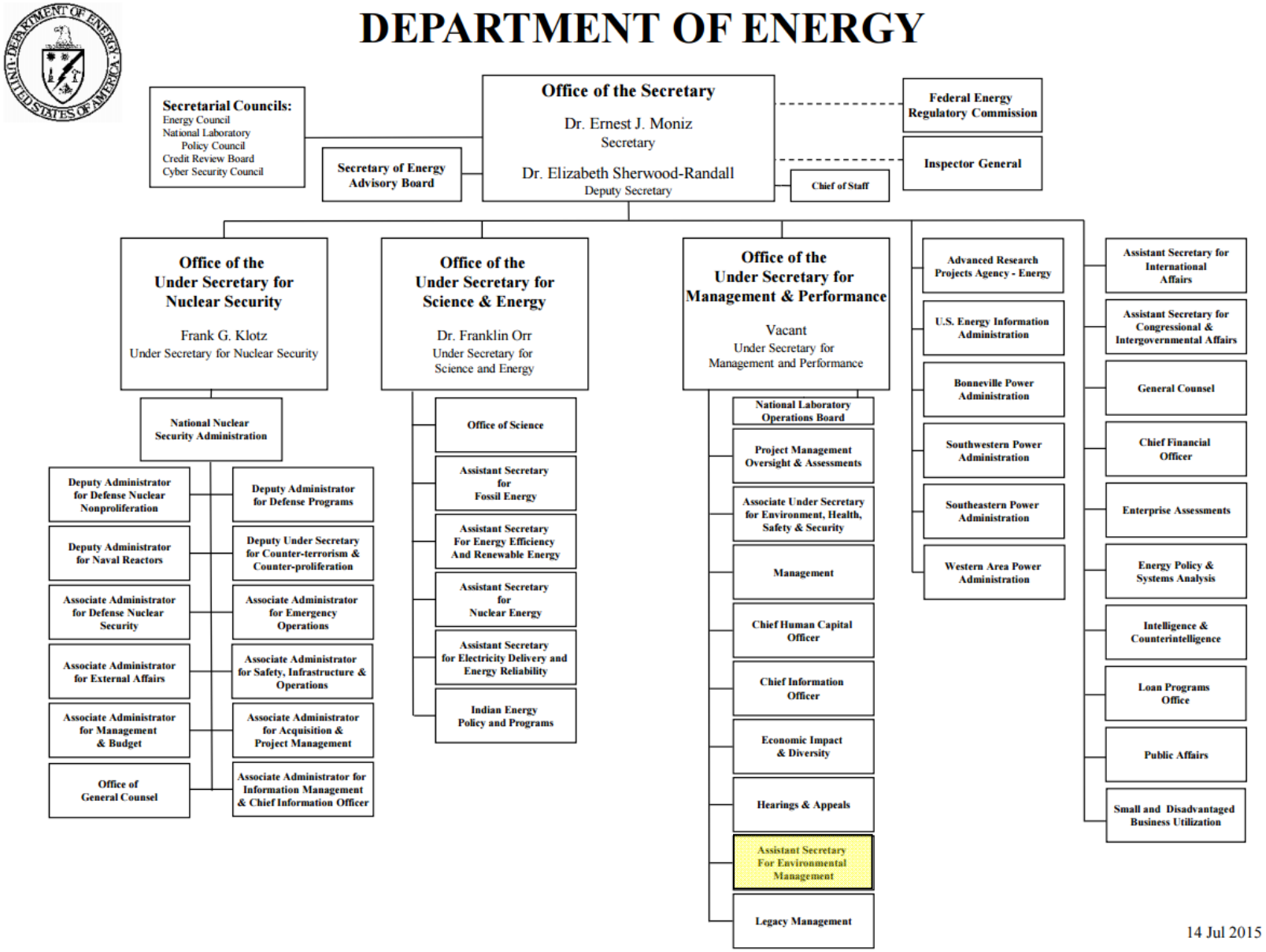


Figure 1. DOE organization chart.

Mr. Sheffield had the opportunity to meet and attend a meeting with Monica Regalbuto, recently appointed Assistant Secretary for Environmental Management. The organization chart for the Office of Environmental Management can be seen in Figure 2. Within the organization chart for DOE-EM, all the DOE EM sites can be seen. Mr. Sheffield has worked primarily with the DOE Hanford Site in Washington State, reflected on the chart as ORP (Office of River Protection), whose site manager is Kevin Smith. Mr. Sheffield had the opportunity to assist in coordinating an Integrated Project Team Workshop at the Hanford Site, as well as visit during his internship. The Office of River Protection site can be seen in Figure 2, highlighted in yellow.

Within the DOE Mission Units is EM-20, Office of Tank Waste & Nuclear Material, whose Deputy Assistant Secretary is Kent Picha; Mr .Sheffield had the opportunity to attend a couple of meetings with Mr. Picha as well. Below EM-20 is EM-23, Office of WTP/TF Program, where Mr. Sheffield interned. The Office of WTP/TF Program can be seen highlighted in Figure 2. Mr. Sheffield worked under Dr. James Poppiti in EM-23, assisting Dr. Poppiti in writing an article describing the radioactive release event that took place at the WIPP, as well as day-to-day operations such as meetings and conference calls.

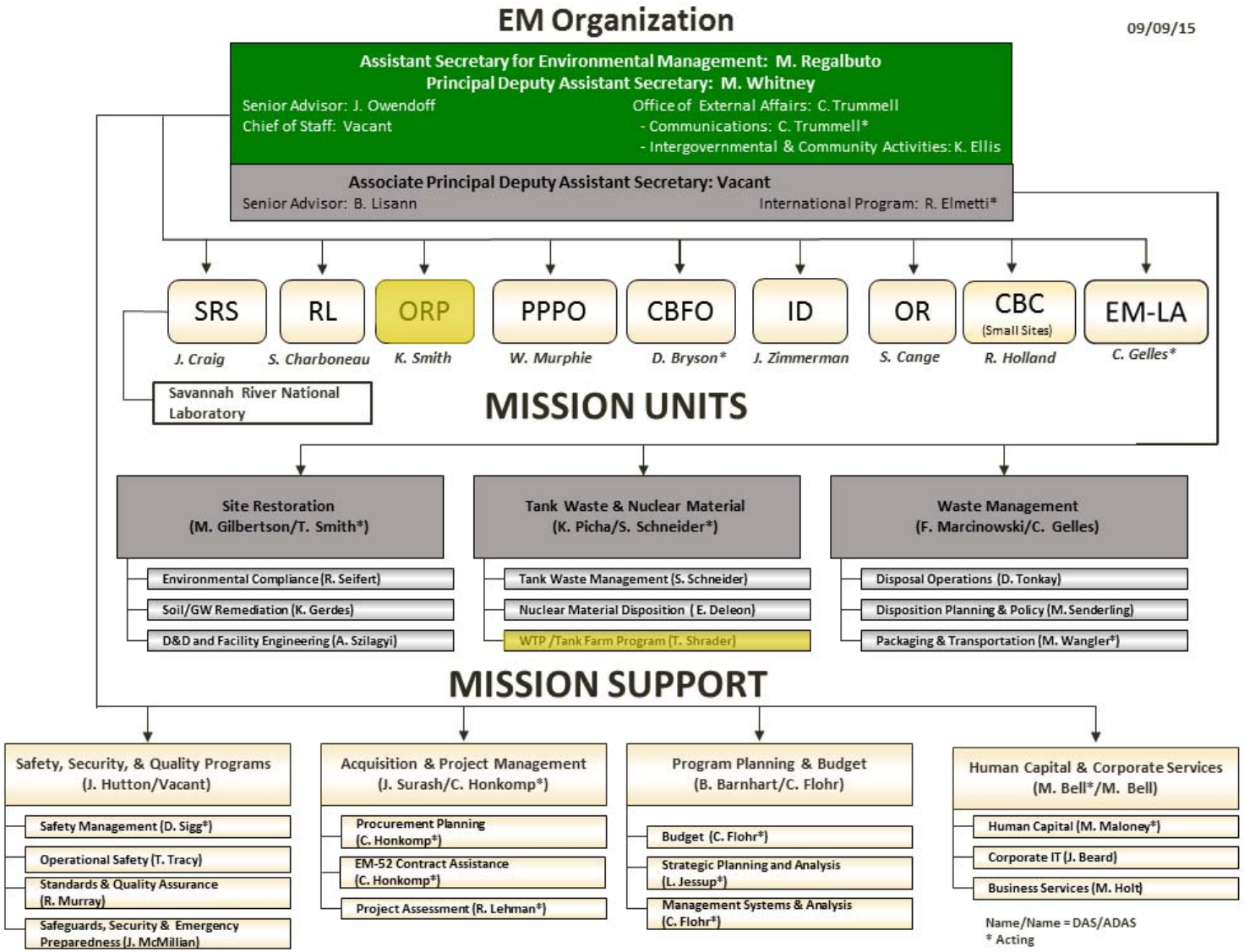


Figure 2. DOE-EM organization chart.

2. EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Initiative, an innovative program developed by the US Department of Energy's Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2015, a DOE Fellow intern Ryan Sheffield spent 10 weeks doing a summer internship at DOE Headquarters in Germantown, MD, under the supervision and guidance of Dr. James Poppiti. The intern's project was initiated on June 1, 2015, and continued through August 7, 2015 with the objective of analyzing the WIPP accident and assisting Dr. Poppiti in publishing an article about the event, as well as attending the day-to-day meetings and conferences held at HQ.

3. INTERNSHIP DESCRIPTION

3.1 Waste Isolation Pilot Plant Article

Mr. Sheffield's primary task while at the Department of Energy Headquarters for the summer was to assist his mentor, Dr. James Poppiti, in writing an article based on the events that took place last year at the Waste Isolation Pilot Plant (WIPP). WIPP is the final destination for the nation's transuranic waste, and is located in a salt mine half of a mile underground in Carlsbad, NM. A radioactive release occurred due to an exothermic reaction caused by incompatible chemicals. This article has been submitted for publication in the Operational Radiation Safety Handbook. For further information on this publication, please refer to the references of this report.

3.2 Vitreous State Laboratory Tour

During Mr. Sheffield's time at the Department of Energy Headquarters, he had the opportunity to tour the Vitreous State Laboratory (VSL) at Catholic University of America in Washington, DC. This was a great opportunity to gain insight on the operations of the melters that are used in the process of creating glass, a method used to treat nuclear waste. This laboratory has various scales of melters, all operational and with supporting equipment in place. For further information on the VSL, please refer to Appendix A for the presentation of the facility.

3.3 Integrated Project Team Workshop

Mr. Sheffield worked with Mr. John Moon in coordinating an Integrated Project Team Workshop at the DOE Hanford Site. This was a great opportunity for Mr. Sheffield to travel to the Hanford Site, as his research at the Applied Research Center focuses on this site, and seeing it in person provides a helpful perspective in the execution of the research project. The workshop was comprised of presentations from DOE HQ employees, as well as from employees at the Hanford Site. The intention of these presentations was to exchange valuable information that could improve the operation. An underlying goal of this workshop was to improve communication between DOE HQ and the site, as this is believed to be very important for success. Photographs taken while touring the facility can be seen in Figures 3 and 4.

Figure 3. Mr. Sheffield (on right) at the cold test facility at Hanford.

Figure 4. Pulse jet mixer full-scale test facility at Hanford.

3.4 Day to Day Meetings

At the Department of Energy Headquarters, meetings and conference calls are a vital component of daily activities. Mr. Sheffield participated in daily calls with the office he was working in, EM-23, providing updates of each member's progress. Mr. Sheffield also participated in weekly calls regarding the WIPP incident, which provided valuable insight for assisting Dr. Poppiti with the publication article. Apart from these routine meetings, there were also frequent meetings on different topics that Mr. Sheffield had the opportunity to sit in on, giving a valuable perspective of the breadth of the Department of Energy's mission.

5. CONCLUSION

The Department of Energy plays a vital role in the progression of this country. The Office of Environmental Management within DOE has a very important mission, with which Mr. Sheffield had the opportunity to intern. Mr. Sheffield had the opportunity to interact with others within DOE regarding some very important components of DOE's mission, such as the Hanford Site Waste Treatment Plant and Tank Farms, the Waste Isolation Pilot Plant, and many others. This internship undoubtedly has assisted Mr. Sheffield in not only educating him on the whole operation that DOE concerns itself with, but also specifically the Hanford Site where Mr. Sheffield's research at the Applied Research Center is focused on.

6. REFERENCES

Department of Energy. Accessed on September 14, 2015. Site: http://www.energy.gov/mission

Poppiti, J. & Sheffield, R. (2015). Waste Isolation Pilot Plant accident. Operational Radiation Safety. Under review.

The Catholic University of America. Accessed on September 14, 2015. Site: http://www.cua.edu/research/

APPENDIX A. VSL Tour Presentation

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

CUA

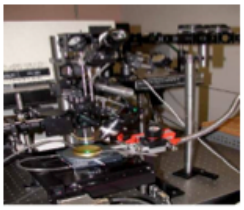
VSL Project History

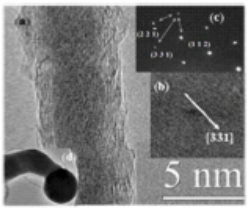
- 1960s, - 70s
  - Various defense programs
- 1970s, 80s
  - Fiber optics
  - Nuclear waste vitrification
  - Glass-based ion exchange media
    - Duratek spin-off (now Energy*Solutions*)
- 1980s, 90s
  - West Valley, SRS M-Area, Hanford
    - Fernald, Weldon Spring, Oak Ridge, Idaho, Paducah, Los Alamos
  - 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

CUA

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





CUA

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

CUA

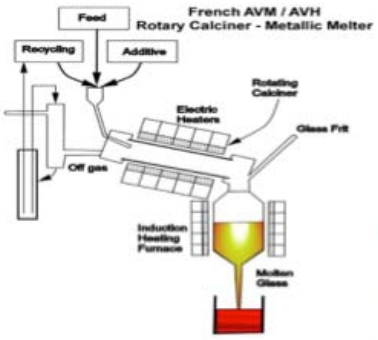
Vitrification

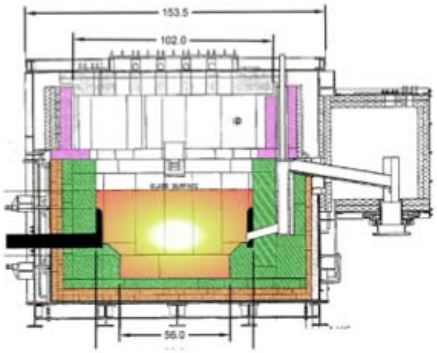
- Immobilization of waste by conversion into a glass
  - Internationally accepted treatment for HLW
- Why glass?
  - Amorphous material – able to incorporate a wide spectrum of elements over wide ranges of composition; resistant to radiation damage
  - Long-term durability – natural analogs
  - Relatively 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)"

CUA

Vitrification: Conversion to Glass

The Internationally Accepted Baseline for Stabilizing HLW





JHCM Technology:
US DOE 1970s – present
- Germany, Japan
- VSL innovations

CUA

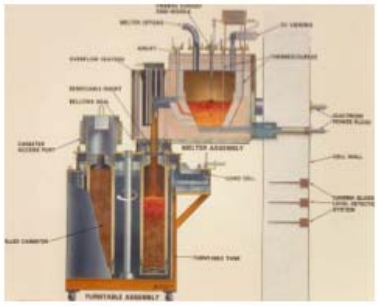
Waste Vitrification Testing at VSL

- 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

CUA

West Valley Demonstration Project

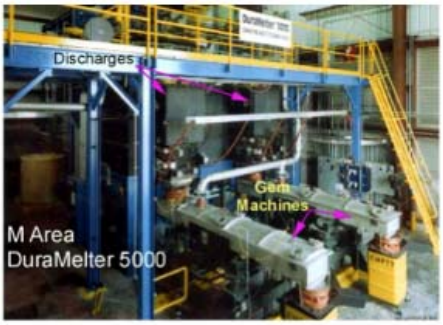
- Only US commercial reprocessing facility
- VSL Support 1985 – 1993
  - Glass formulation and testing
  - Melter testing
- ~660,000 gal HLW containing 24 million curies converted to 275 canisters of glass (~550 MT) using VSL glass formulation
- Vitrification facility decommissioned



CUA

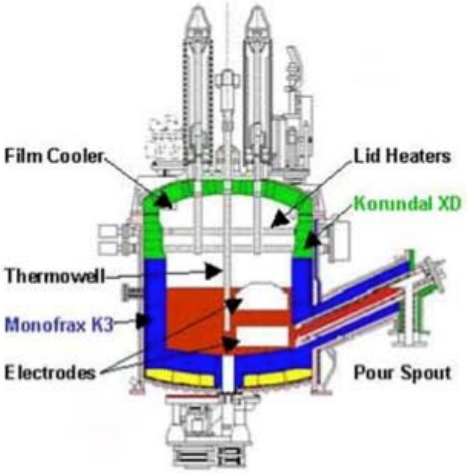
SRS M-Area Vitrification Facility

- 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



CUA

Defense Waste Processing Facility (DWPF)



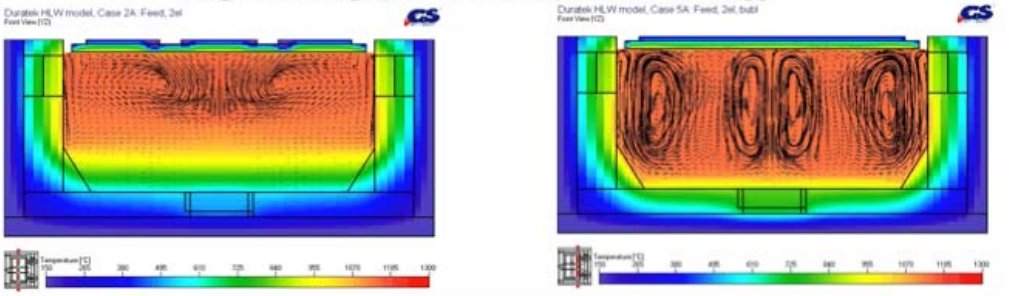
Facility has been operating on DOE site in South Carolina since 1996.

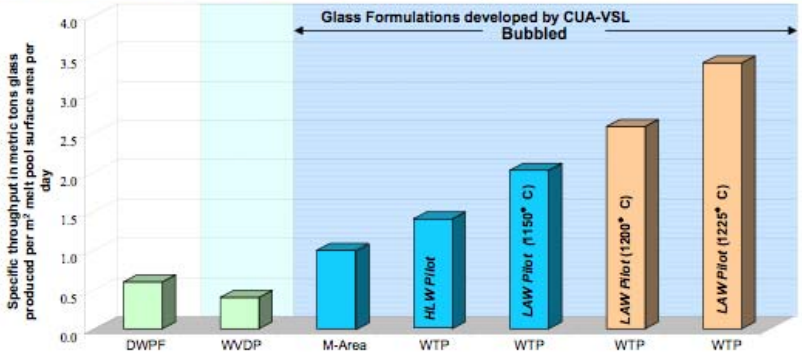
Since 2009, VSL-ES have been providing R&D support to enhance its performance to expedite completion of waste treatment ~Doubled melter throughput with bubblers

High Throughput Vitrification Technology

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

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





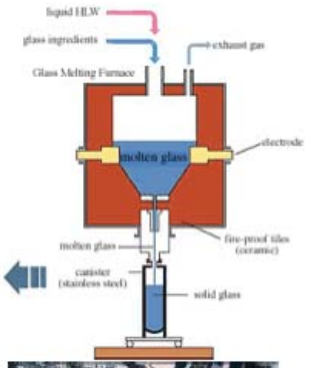
Rate Boost with Bubblers – Invented at CUA-VSL

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

CUA

Rokkasho, Japan

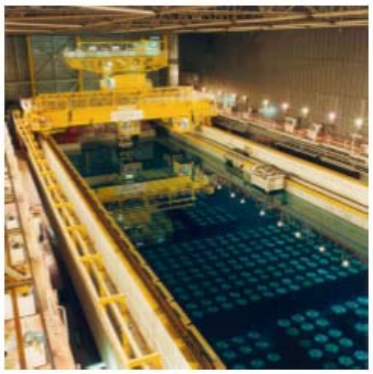


CUA

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

Sellafield, UK

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



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

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

CUA

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.

CUA

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

CUA

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)

CUA

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
Montgomery 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)
Montgomery 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

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

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

CUA

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

Questions: Contact the Program Director Dr. Werner Lutze
At
wernerl@vsl.cua.edu
Or call
Phone 202-319-5499, cell 202-549-5478

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

CUA

What we need: More students

CUA