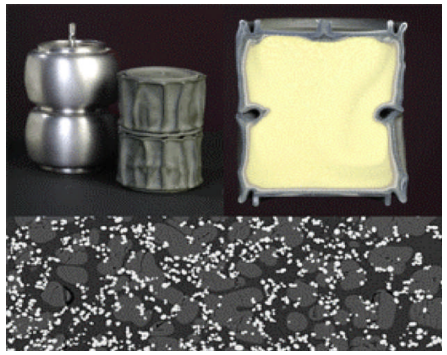
Assessment of Hot-Isostatic Pressing Technology for Idaho Calcines



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Environmental Management

safety ❖ performance ❖ cleanup ❖ closure

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Introduction

DOE baseline treatment option for HLW is vitrification into single phase borosilicate glass

- Vitrification is suitable for a large proportion of HLW
- However, not all waste can be cost effectively incorporated in glass

Major Risk:

- No alternative HLW treatment option is currently available to DOE

Cost savings & risk reduction:

- HLW represents the highest cost liability to DOE-EM cleanup mission
- Consequently optimizing approach to HLW cleanup through complementary treatment technology(s) provides DOE-EM with opportunity for greatest cost savings and risk reduction for problematic HLW

Benefits of Complementary Waste Forms

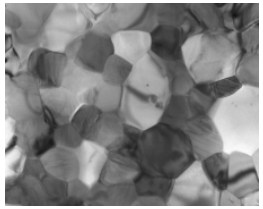
No single technology is suitable to economically handle the total HLW cleanup challenge.

Parallel deployment of hot isostatic pressing to produce tailored ceramic and hybrid glass-ceramic waste forms (or simply volume reduction) can overcome the limitations of baseline approach for wastes difficult to vitrify and create opportunities to:

- Reduce risk
- Deliver significant life-cycle cost savings
- Add flexibility and provide defense-in-depth treatment options
- Utilize flexible process technology capable of addressing multi-mission needs

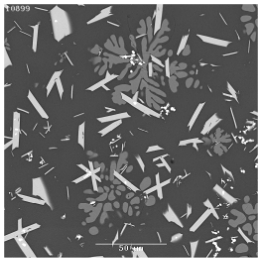
Complementary Waste Form Options

For wastes difficult to incorporate in glass:



Multiphase ceramic

(titanates, zirconates, phosphates & silicates)



Glass-ceramic

(durable glass plus ceramic phases)

Metal encapsulation

(intimate contact with irregular shaped waste)

Can all be prepared on a common process line

… determined by waste characteristics

Project Objectives

- ✓ Demonstration of the risk reduction benefits that tailored waste forms and flexible HIP technology can provide to treatment of problematic legacy wastes.

- ✓ Immediate focus is to evaluate feasibility of the HIP technology to cost-effectively treat HLW Idaho calcines as input into a DOE NEPA Record of Decision on an alternative treatment technology to direct disposal of calcine without further treatment.

- ✓ Broader focus is to conduct proof-of-concept demonstrations for wide range of problematic wastes across the DOE complex in 2009 (subject to future funding) for future facility mission needs.

Strategic Approach

Idaho HLW Calcines:

- ***Regulatory risk*** - prepare simulated alumina and zirconia calcine containing RCRA heavy metals that closely match the physical and chemical characteristics of the actual Idaho calcine for purpose of evaluation.
- ***Waste form performance*** - produce and characterize HIP waste form samples to evaluate the technical and regulatory risks associated with waste form performance per requirements of the WASRD.
- ***Hot-cell demonstration*** - demonstrate hot-cell processing of waste form samples utilizing INL's hot-cell HIP facility with simulated (and possibly actual) HLW calcine.

Engineering Design:

- Prepare and cost a process-engineering outline for a HIP calcine treatment facility, including a full or partial retrofit in IWTU
- Review industrial maturity, safety, and reliability of industrial scale HIP systems.

Technical Status and Results

Idaho HLW Calcines:

- 300 lb (~130 kg) high quality simulated alumina-calcine has been prepared in a pilot-scale fluidized bed calciner.
- Three distinct Al-calcine simulants containing low-, medium- and high-mercury concentrations were prepared. Simulant contains all other non-radioactive chemical components at maximum levels.
- Alumina-calcine has been shipped to ANSTO.
- Production of the zirconia calcine with three cadmium concentrations has been completed.

Sample of simulated alumina calcine showing fines (bottom ~10% of total), product (vast majority) and agglomerates (~1%).

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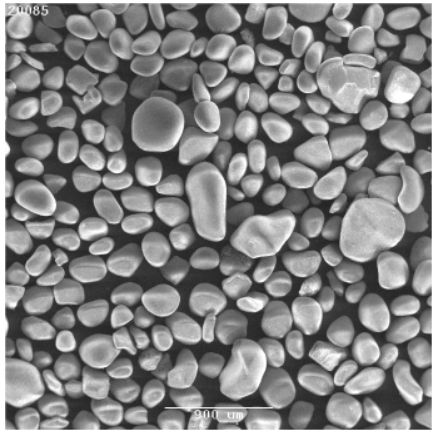
Technical Status and Results

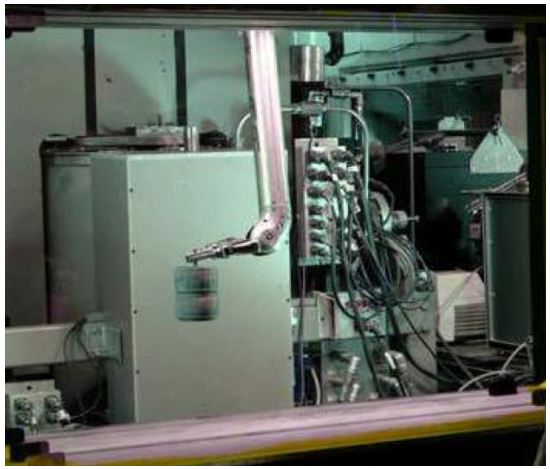
Idaho HLW Calcines (cont.):

- ANSTO has received and is characterizing Al-calcine
- QA audit being conducted at ANSTO by BEA week of July 28, 2008

- INL HIP installed in 1990s to treat EBR-II spent fuel
- HIP facilities safety readiness assessment checks are progressing well. HIP components are being calibrated or replaced as necessary



SEM image of Al-calcine product received by ANSTO



INL's HFEF hot-cell HIP facility

Technical Status and Results

Engineering Design:

- A flexible HIP facility conceptual design capable of both calcine treatment or direct HIPing of calcine (should that direct disposal be permitted) is in development.

Two approaches being pursued:

- A conceptual engineering design to retrofit the HIP facility into the existing IWTU foot-print has been developed. More detailed IWTU design information has just been made available that will enable this design to be confirmed as feasible.

- A complementary, predominantly Greenfield, proposal is also in development. This option will still make limited use of the existing IWTU, but be more analogous to the new facility proposed for direct packaging of calcine (facility expansion). This option would be more amenable to serve multiple missions.

Technical Status and Results

Industrial Review of US HIP Industry:

Safety:

- Over 50 years industrial production operational experience
- Primary safety concern raised by industry was asphyxiation (argon blanket), which had resulted in a number of deaths. This is not a concern for hot-cell deployment.

Case Study - Bodycote:

- Operates 9 HIP systems with diameters between 30 - 64 inches (up to twice as large as those proposed for calcines teratment) in the US and an additional 7 in Europe.
- All these HIPs operate at or above 100 MPa (15 ksi) and over 1200°C (2200 F), exceeding calcine requirements.
- Work pieces over 10,000 lbs processed, and operate in a 24/7 production environment
- A number of these HIPs are over 30 years old, with no immediate replacement plans

64 inch diameter production HIP with top head removed

Project Impact - Idaho Calcines

Flexible HIP process offers:

If DOE requires treatment of the calcine:

- ~$5 billion dollar repository cost savings compared to glass
- HIP glass-ceramic with a waste loading of up to 80%
- ~70% reduction in MGR disposal canisters compared to glass
- Vast reduction in utilization of DOE's MGR allocation (3 fold decrease compared to glass)

If DOE does not require treatment of the calcine

- The calcine can be HIPed directly (no additives)
- 50% volume reduction, compared to direct disposal reduces impact on DOE's repository allocation by a factor of two
- ~$2 billion dollar repository disposal fee cost saving compared to direct disposal

Flexible HIP process enables cost savings to be delivered independently of disposition path and so helps mitigate uncertainties associated with calcine disposition.

Project Impact - Legacy Wastes

Potential significant life-cycle cost savings from flexible waste form technology capable of treating a wide range of wastes difficult to incorporate in glass, including:

* Transuranic, Cs/Sr, Tc & GNEP wastes
* Sludges, alpha ashes, impure actinides
* Corroded fuel pins, iodine

Potential for a multi-use facility that takes advantage of flexibility of tailored waste form and HIP technology to address future DOE-EM/NE mission needs.

HIP technology can be used to complement other DOE technologies, such as steam reforming to produce a monolithic, rather than granular, solid for disposal.

Proof-of-concept demonstrations to quantify these benefits slated for 2009 (subject to funding)

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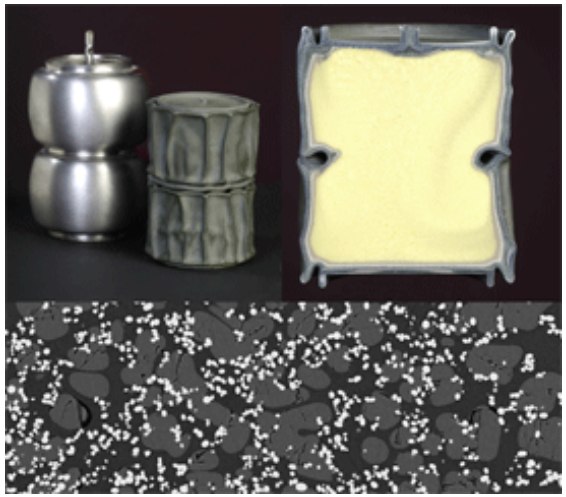
HIP Tailored Waste Forms

- **Need**
  - Vitrification is the only treatment option currently available to DOE for treatment of HLW.
  - HLW treatment presents the highest cost liability to DOE-EM
  - Not all HLW can be cost effectively incorporated into glass (e.g Idaho calcine). Many wastes contain components that are either problematic to glass matrix or the melter itself, via low solubility, detrimental impact on glass viscosity, electrical resistivity, corrosivity or volatility.
- **Solution**
  - Parallel deployment of hot-isostatically pressed (HIP) tailored ceramic and hybrid glass-ceramic waste form capability that overcome limitations of baseline approach for wastes difficult to vitrify.



Tailored HIP glass-ceramic for HLW calcine

- **Results**
  - Demonstration of the benefits that tailored waste forms and flexible HIP technology may provide to both direct disposal and treatment of HLW calcines at Idaho is underway. This includes development of conceptual engineering design and cost estimate. Testing is being performed both at ANSTO and the INL hot-cell HIP facility.
- **Impact**
  - Life-cycle cost savings for treatment of wide range of problematic HLW difficult to vitrify. Flexible technology that can be applied to address multiple mission needs, and deliver defense-in-depth HLW treatment options to DOE-EM.
  - For Idaho calcine, HIP tailored waste forms offer potential to deliver $5 billion repository cost saving compared to glass (70% reduction in MGR canisters), or alternatively a $2 billion respository disposal cost saving (through 50% volume reduction) and reduction in allocation usage should direct disposal prove regulatorily feasible.

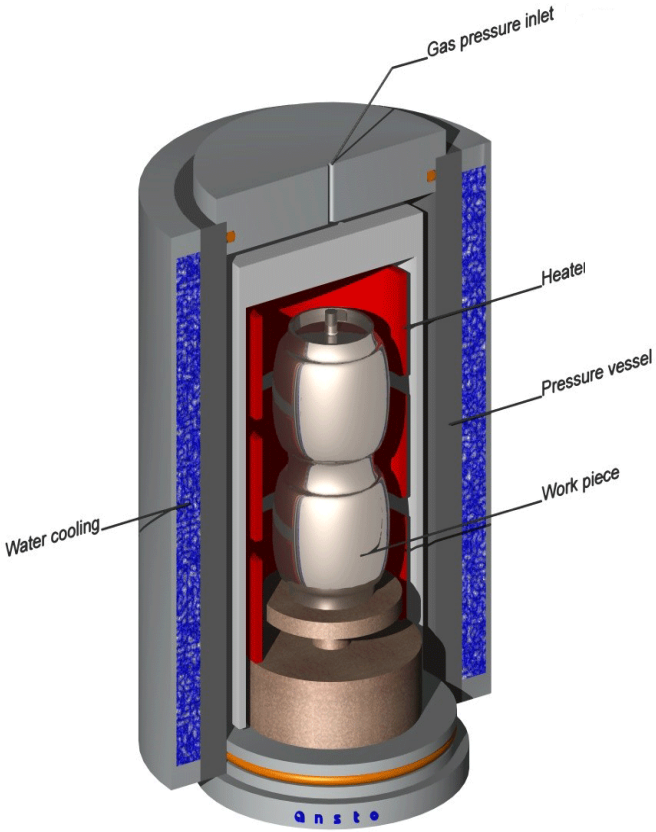
Background hot-isostatic pressing

HIP patented in the US by Romp in 1941. Battelle patented HIP process to diffusion bond nuclear fuel in 1964.

Technology consists of a pressure vessel containing an electrically heated furnace.

Components are placed in a sealed can inside the furnace and isostatically pressed with argon to maximum density

Pressure vessels are built to stringent TUV and ASME codes, and include active and passive safety systems.



Hot-isostatic pressing

- Industrially mature - 50 years safe operating experience world wide, processing tonnages of metallic and ceramic components
- Used in nuclear industry - HIP is installed in a hot-cell at INL, and is used in in the US, by BWXT for naval fuel
- Higher waste loadings - not limited by waste form electrical properties or viscosity
- Flexible technology capable of producing a range of waste forms
- Maximum volume reduction - minimal MGR costs
- Zero emissions from the high temperature densification process - no need for extensive off gas system