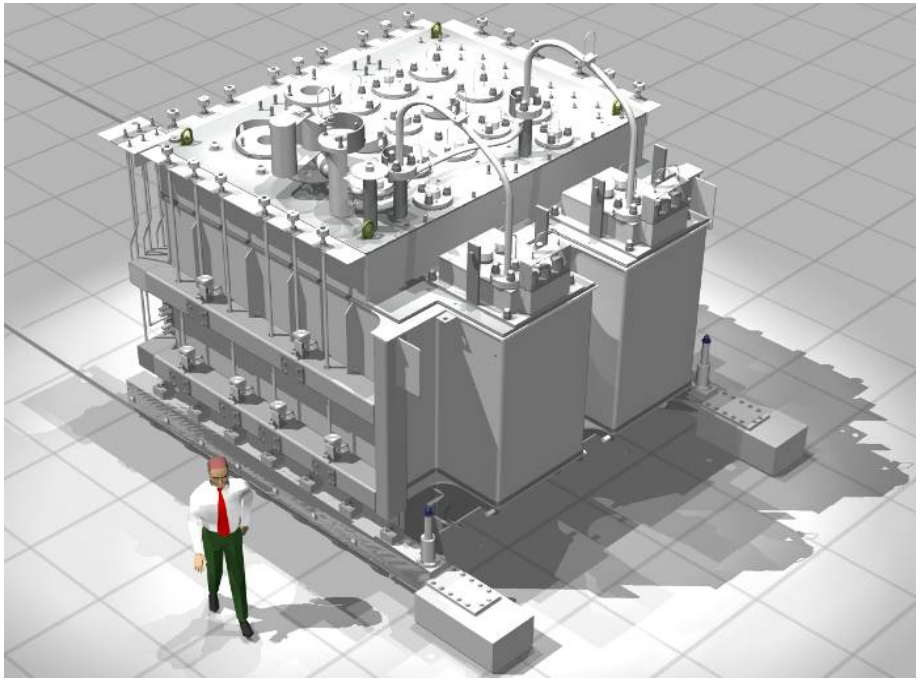


EM Waste Processing Technical Exchange 2010

Advanced Joule-Heated Melter Technology Development

November 17, 2010

Eric C. Smith* & Bradley W. Bowan

Energy*Solutions*, Inc.

Keith S. Matlack & Ian L. Pegg

The Catholic University of America, Vitreous State Laboratory

Print

Close

The authors gratefully acknowledge the United States Department of Energy's Office of Environmental Management, and Washington River Protection *Solutions* for funding this work

Print

Close

Agenda

- AJHM Program
- Design
- Testing
- Results

WTP LAW Melter During Fabrication

Background

- **Baseline Melter Production:**
  - Total HLW = 6 Metric tons glass per day (MT glass /day)
    - 2 melters 3.75 m^2 glass pool surface area
    - 3 MT glass/day each (**800** kg/m^2/d)
    - Weight: 100 tons
    - Dimensions: 13'-11" (L) x 13'-2" (W) x 12'-2" (H)
    - Bubbled but not optimal configuration
  - Total LAW = 30 MT glass/day
    - 2 melters 10 m^2 glass pool surface area
    - 15 MT glass/day each (**1500** kg/m^2/d)
    - Weight: 330 tons
    - Dimensions: 29'-6" (L) x 21'-6" (W) x 15'-9" (H)
    - 7630 L molten glass pool
    - Optimized bubbling system

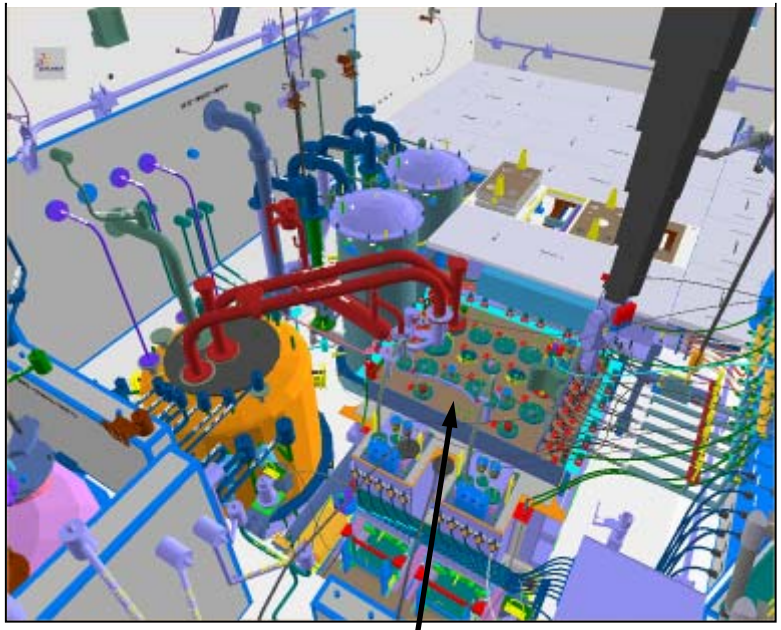
Completed HLW Melters

Completed LAW Melter

AJHM Program

- **Goal: Increase glass production rate for existing melter foot-print with minimal impact on WTP:**
  - HLW = 8 MT glass/day
    - 2 melters; 4 MT glass/day each (33% increase)
  - LAW = 42 MT glass/day
    - 2 melters; 21 MT glass/day each (40% increase)
- **Approach:**
  - Incorporate proven technologies into the design to optimize the glass production rate
  - Individual changes are multiplicative improvements to baseline rate
- **Team:**
  - **Energy*Solutions*** (ES) – Design engineer for WTP baseline melters
  - **Vitreous State Laboratory** (VSL) – Developer of the original WTP vitrification flowsheet chemistry and glass compositions

HLW Melter in Cell (model)



HLW Melter

CUA

ENERGYSOLUTIONS

Print

Close

AJHM Design

AJHM design performed in two stages: Basic and Enhanced

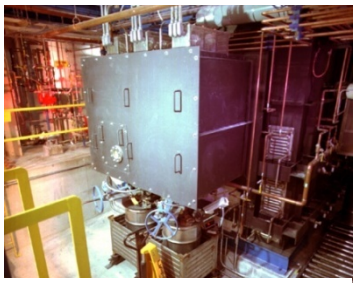
- **Basic AJHM – Incorporates technologies that have been previously demonstrated at scale to have <u>low risk</u> of failure and <u>high probability</u> of success:**
  - Increase glass pool surface area
  - Optimize glass pool bubbling (HLW)
  - Raise glass operating temperature (up to 1250°C)
- **Enhanced AJHM - Modular technologies that can be added to the basic AJHM to further raise processing rates, if needed, but which require large scale demonstration:**
  - Methods to add energy to the cold cap
  - Methods to add energy to the feed prior to introduction in the melter
  - Enhancement of first stage of off-gas treatment system

Basic AJHM: Increase Glass Pool Surface Area

- **Glass production rates is directly proportional to glass surface area**
  - Rate of feed evaporation and melting is surface area controlled
- **Energy*Solutions* has collected extensive data on the effects of glass pool surface area scaling:**
  - Partnered with the VSL:
    - Operates several small scale melters
    - World leader in glass and feed composition development
  - Designed, constructed, and operated several large scale melter systems including the largest ever operated in the US

DM100

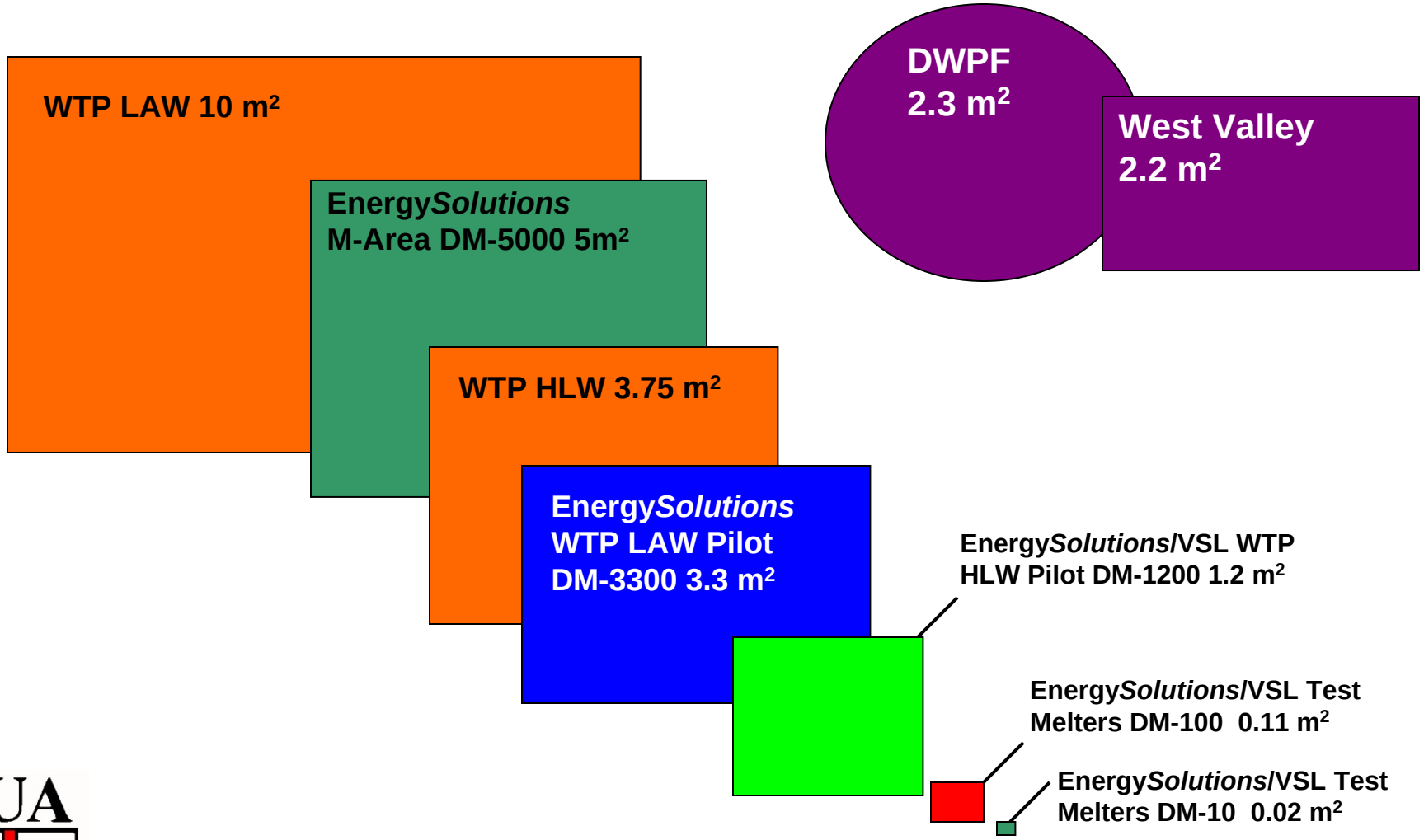
DM1200



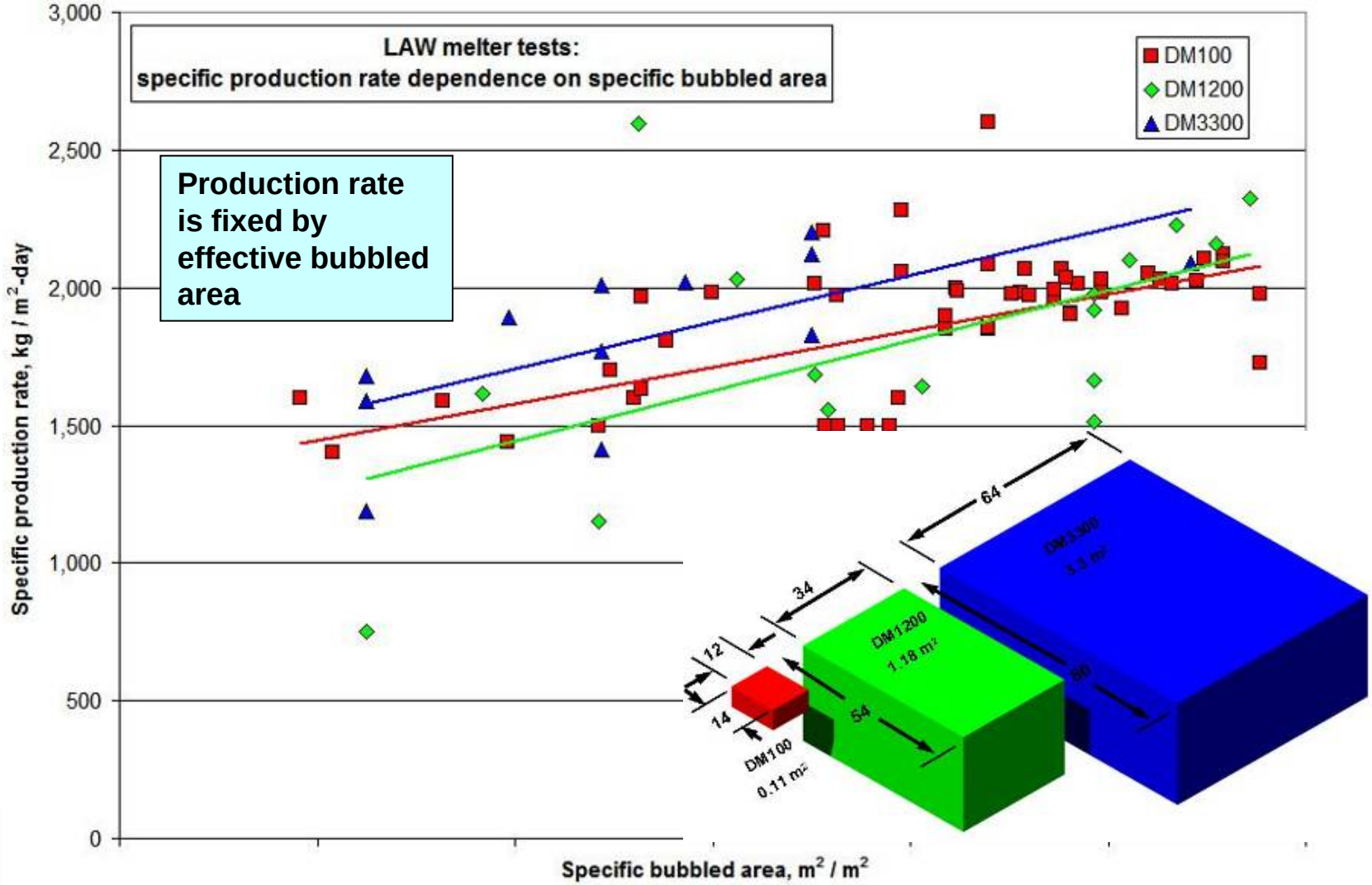
DM3300

DM5000

Melter Scaling – Existing Melter Size

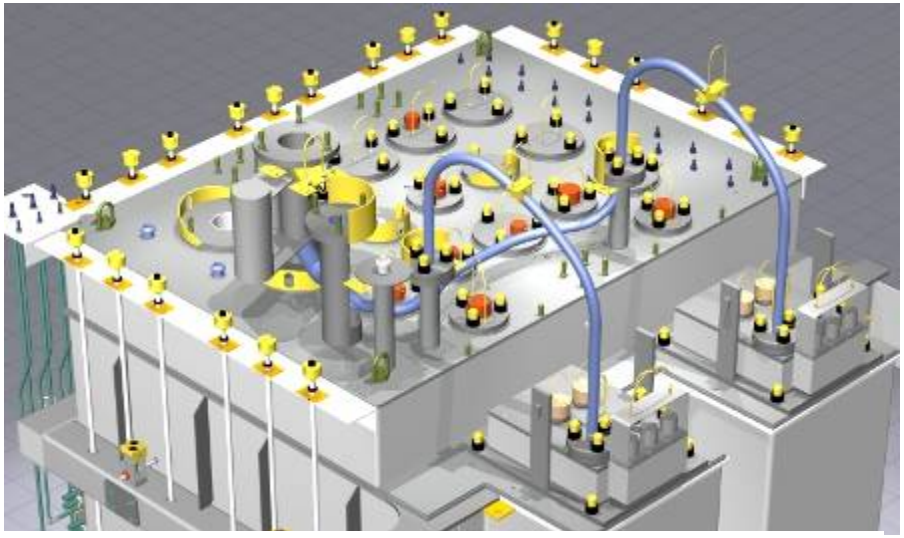


Effect of Glass Pool Surface Area Enlargement



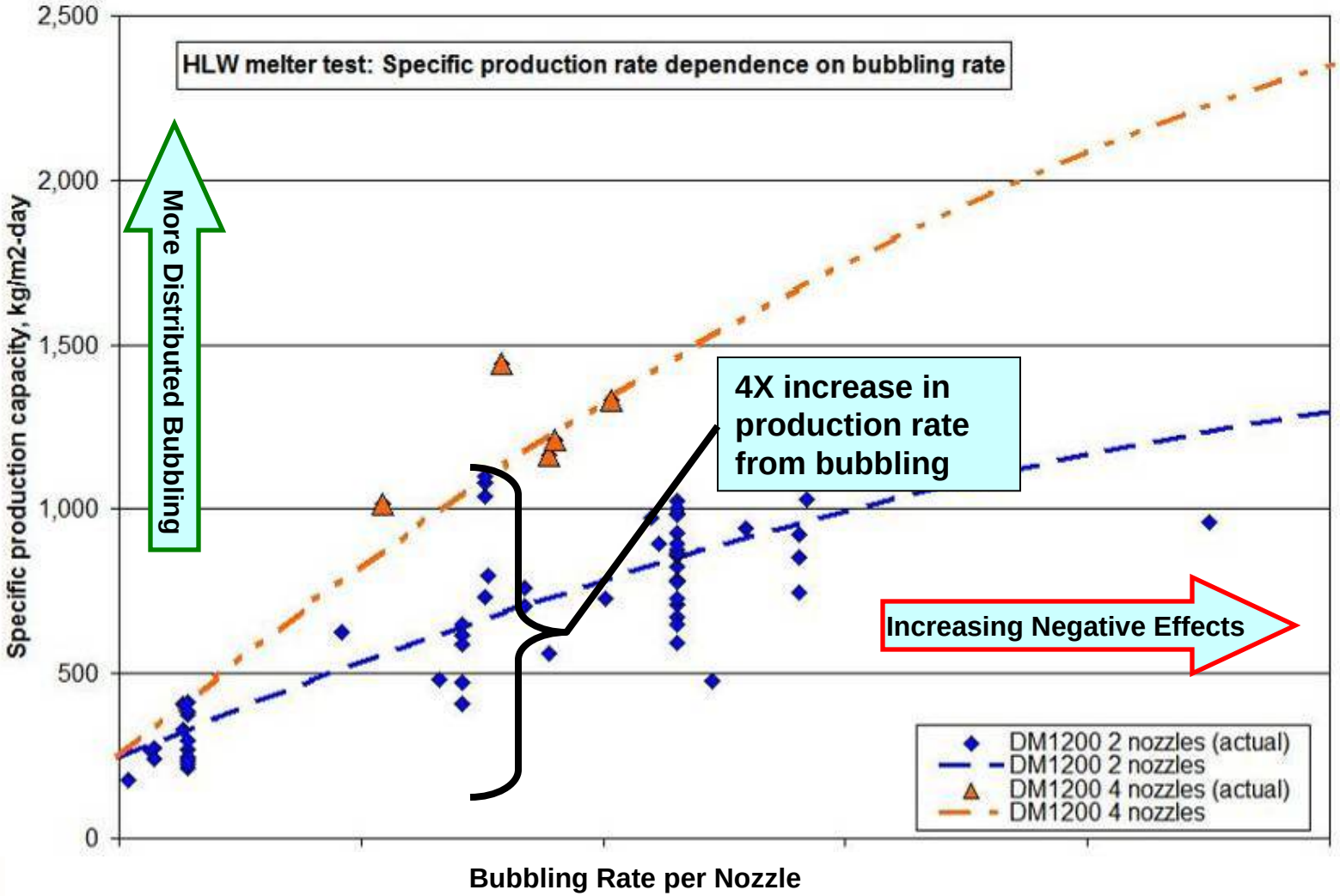
Basic AJHM: Optimize Glass Pool Bubbling

- **Glass pool bubblers used to enhance waste processing rates**
  - Extensive data available on effectiveness of bubbling (up to 4X increase)
  - Bubbling must be optimized to obtain higher production without negative effects (e.g., feed entrainment to off-gas is increased with high bubbling rate)
- **Melter must be designed to place bubblers in the correct location**
  - Other features must be adjusted to allow this to happen



Baseline HLW Melter Lid

Effect of Bubbling



CUA

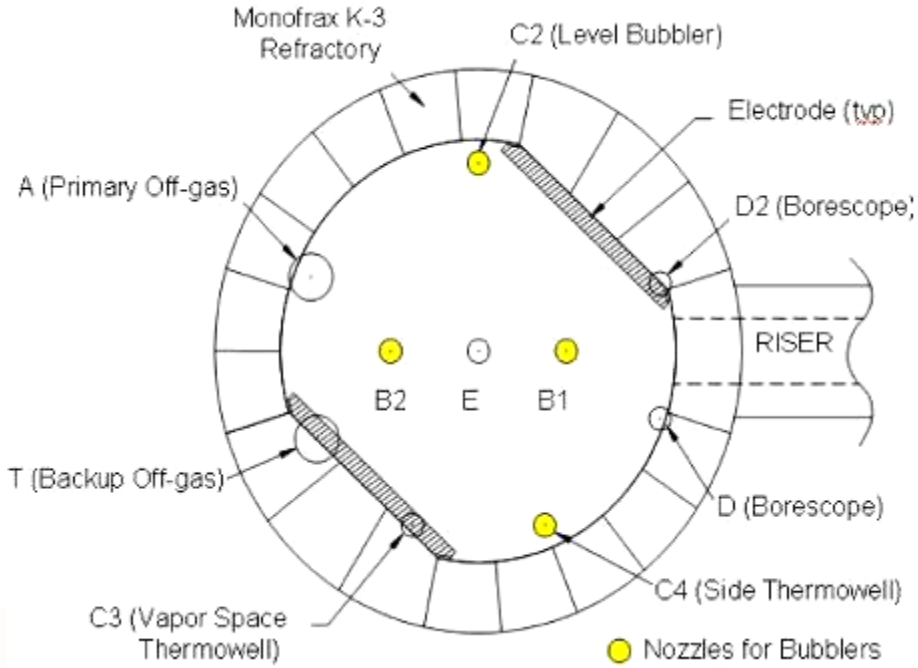
ENERGYSOLUTIONS

Print

Close

Recent HLW Experience

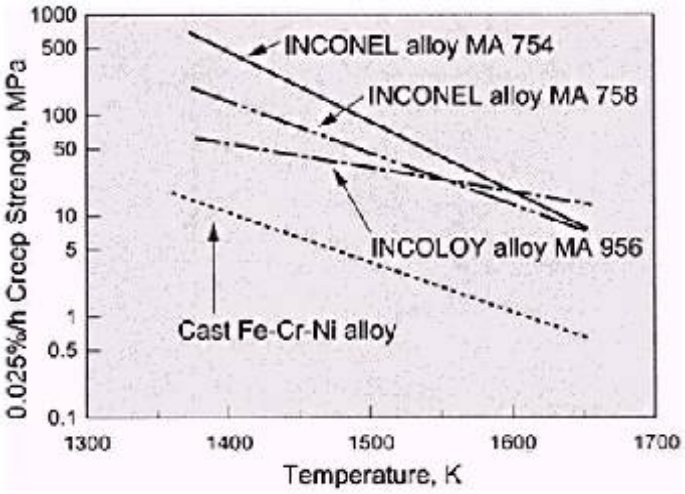
- **Bubblers have been added to DWPF to increase the glass production rates**
  - 4 bubbler assemblies added through existing penetrations (not optimal configuration)
  - Glass production rate has increased by >50%



DWPF Melter Bubbler Installation

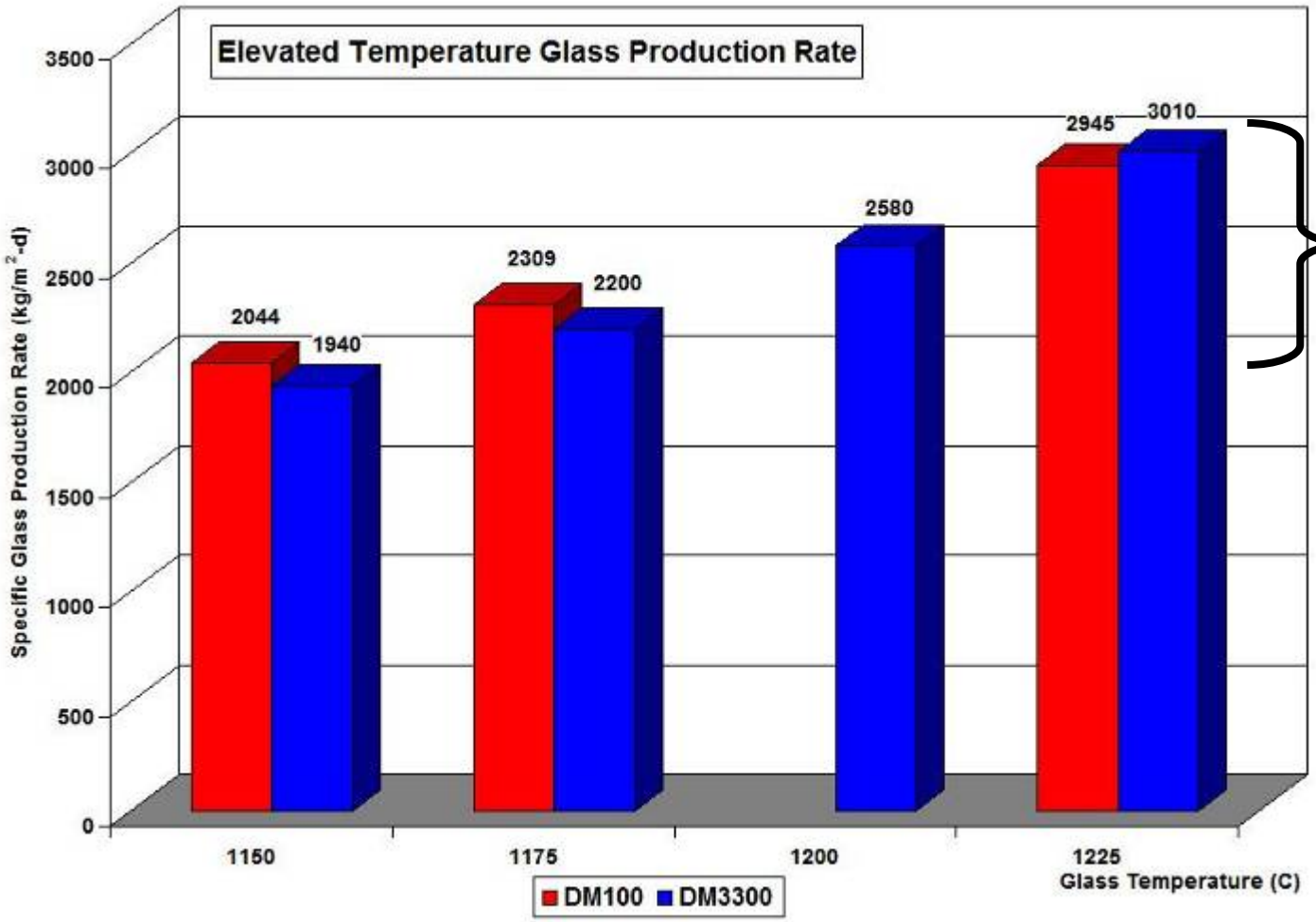
Basic AJHM: Increasing Glass Pool Temperature

- **Increasing the operating temperature of the glass pool has been shown to produce very large increases in glass production rates.**
  - Data has been obtained over a range of melter scale to underpin production rate values:
    - Small scale testing at VSL – DM10, DM100
    - Large scale testing by ES – DM3300
  - The temperature increase is limited by the melter metallic glass pool components:
    - Electrodes and replaceable components are fabricated from Inconel 690 (melting point ~1350°C)
    - Materials have been identified that can operate at up to 1250°C (Inconel MA-758).
      - VSL test melter (DM10) with electrodes fabricated from alloy has been operating for more than 5 years with temperatures up to 1250°C



Creep Strength Comparison

Increasing Glass Pool Temperature Test Data



Production rate increase: by ~1% for every 1°C increase in glass temperature

CUA

ENERGYSOLUTIONS

Print

Close

Enhanced AJHM

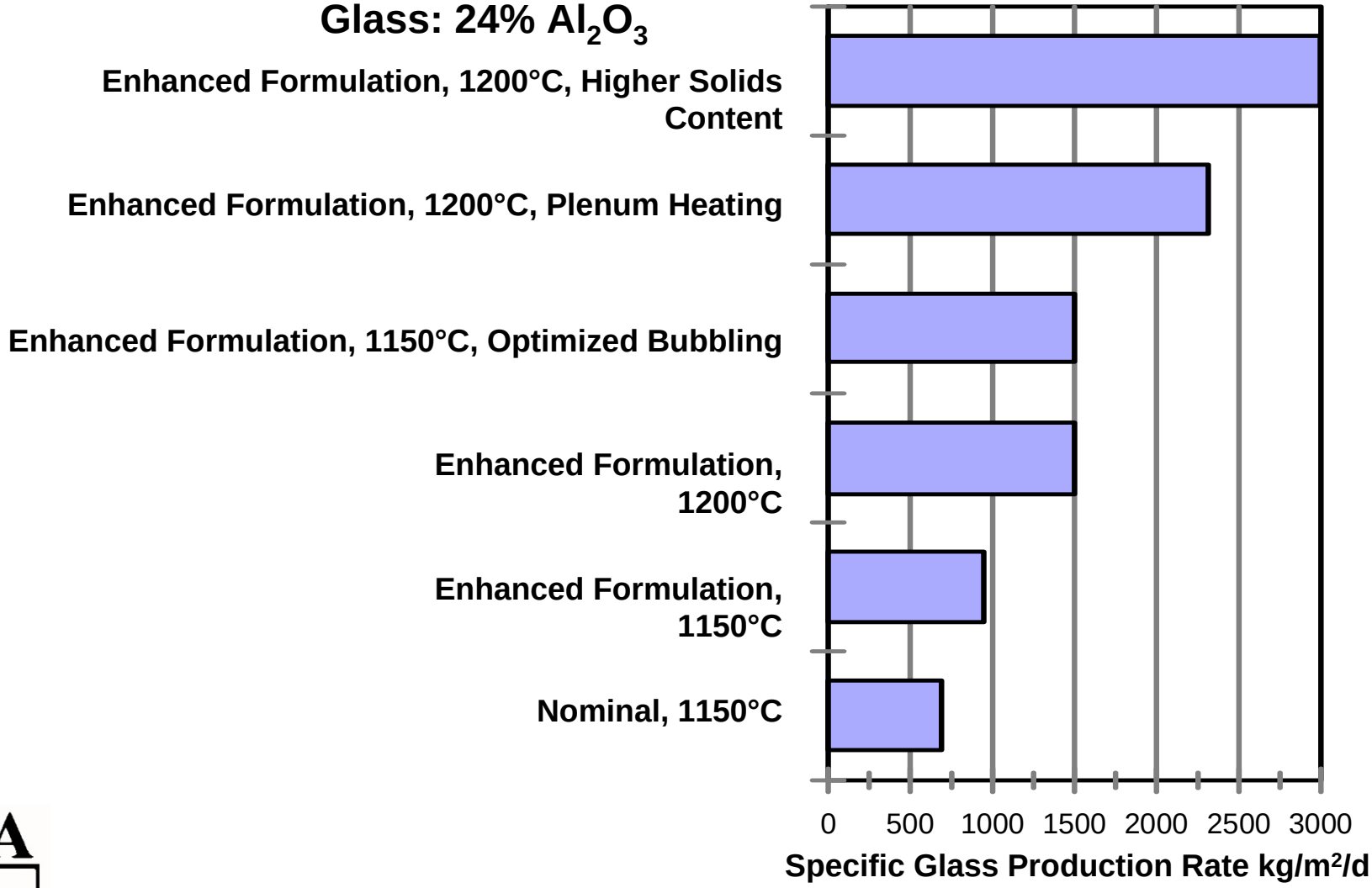
- **Enhanced AJHM starts with the Basic AJHM and further increases the process rate through the addition of innovative technologies (i.e., “add ons”)**
- **Initial design work evaluated technologies that could potentially increase the production rate**
  - Technologies with potential to increase production rates were determined
  - Technologies with unacceptable impact on plant design were dropped from further consideration
- **Enhancement focus on three areas:**
  - Heating feed pile from above - Increase heat transfer to the cold cap
    - Microwave boosting selected for advancement to pilot testing
    - Plasma boosting selected for advancement to pilot testing
  - Pre-react the feed to reduce heat input required
    - Pre-heating feed selected for advancement to pilot testing
  - Enhance the performance of the initial stages of the off-gas system
    - “Ruggedized” film cooler selected for advancement to pilot testing

Testing

- **Small-Scale Testing is on-going to support AJHM Development**
  - Completed six DM100 melter tests and eight DM10-HT (up to 1250ºC) melter tests:
    - Hanford high-Al HLW feed (45 wt% waste loading, 24 wt% Al_2O_3) – Elevated temperature, Enhanced formulation, Optimized bubbling, Additional plenum heating, Increased solid content
    - Hanford AZ-101 (high iron) HLW – Elevated temperature, Enhanced formulation, Optimized bubbling
    - Hanford High Chromium/Sulfur HLW – Elevated temperature, Enhanced formulation, Optimized bubbling
  - Two more DM100 melter tests are scheduled for early December

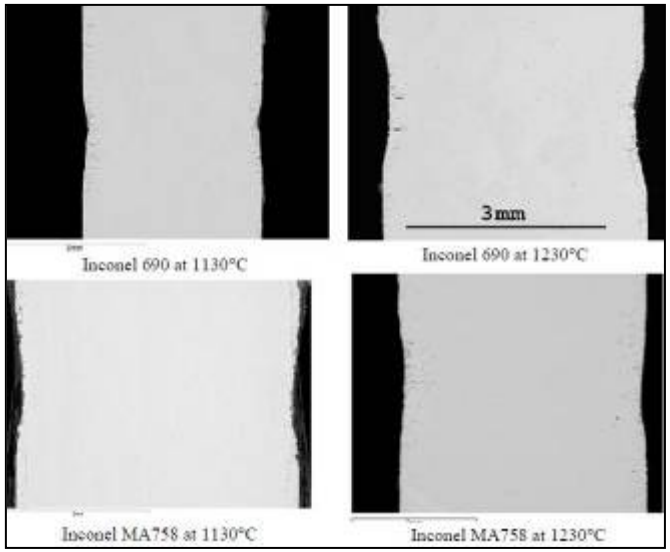
HLW High Aluminum Waste

Glass: 24% Al_2O_3

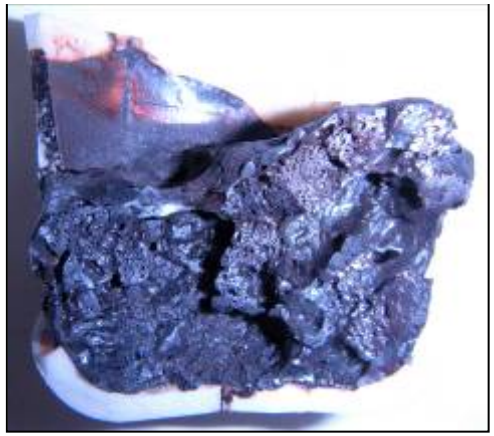


Testing

- **Small-Scale Testing (continued)**
  - Corrosion testing of 12 high-temperature alloys in progress for potential inclusion in the AJHM
    - Testing in progress, analysis to follow
    - Previous testing has identified Inconel MA-758 as a promising alloy based on maintaining strength at temperature (93% of melting temperature) along with corrosion resistance
  - Small-scale testing of microwave heater in progress
    - Initial results are promising – very rapid feed melt rates
    - Completion of bench scale testing needed for evaluation of technology
    - Large scale melter testing planned for pilot plant



Previous Corrosion Test Results



Microwave Heating Sample

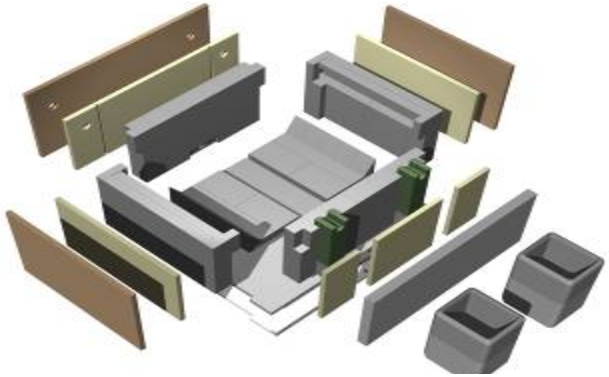
Results - Success

- **The AJHM production rate will be capable of meeting the goals with minimal impact to WTP:**
  - LAW AJHM: same foot print and interfaces as existing melter
    - Basic design = **34** MT/d per melter (conservative). Goal = 21 MT/d/melter
      - Increased surface area = 50%
      - Increased temperature = 50% (100%)
      - Bubbling already optimized
    - Enhanced design = Awaiting testing but further increases expected
    - Production rate can be easily "turned down" to match plant capacity
  - HLW AJHM: same foot print and interfaces as existing melter
    - Basic design = **8.6** MT/d per melter (conservative). Goal = 4 MT/d/melter
      - Increased surface area = 27%
      - Increased temperature = 50% (100%)
      - Optimize Bubbling = 50% (400%)
    - Enhanced design = Awaiting testing but further increases expected
    - Production rate can be easily "turned down" to match plant capacity
  - Significant improvements in the glass formulations are possible to increase waste loading (fewer canisters produced) and waste processing rates

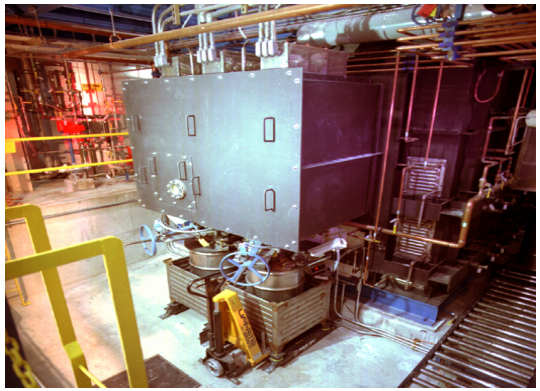
Continuing Work

- **The AJHM development work is planned to continue through FY2011 and FY2012:**
  - Glass formulation – enhanced formulation development work continues
  - Melter design – conceptual design of the full sized LAW / HLW melters will begin to allow development of cost data
  - Pilot scale testing – Pilot facility will be established and testing performed to underpin AJHM design

Glass Formulation



Melter Refractory Design



Pilot Testing

Conclusions

- **If the AJHM is implemented at the WTP,**
  - The AJHM will be capable of meeting the facility production rate goals with excess melter capacity
  - The melters will not be the limiting component in determining the facility waste processing rate. Other factors will limit rate such as:
    - The rate of waste retrieval from the tanks
    - The rate waste can be pretreated
    - The capacity of the various feed makeup and sampling system
    - The capacity of the canister handling system
    - The capacity of the off-gas systems

Question and Answers

- **Questions?**

- **Contact Information:**

  - Eric Smith
    ESmith@EnergySolutions.com

  - Brad Bowan
    BBowan@EnergySolutions.com

  - Keith Matlack
    keithm@vsl.cua.edu

  - Ian Pegg
    ianp@vsl.cua.edu

CUA

ENERGYSOLUTIONS

Print

Close