Spent Fuel Database/ Advanced Neutron Absorber Update

NSNFP Strategy Meeting
Washington, DC

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Spent Fuel Database Background

- Spent Fuel Database (SFD) provides a central source of DOE SNF data for national-level planning for management and licensing of DOE SNF
- SFD Version 5.0.1 provided basis for LA input
- Enhancement to data traceability and transparency is in progress
- Software revisions to support the traceability enhancement and data retrieval continue

SFD Status

- SFD Version 6.1.2 issued December 2006
- Revision to NSNFP procedure for management of SFD to be issued March 2008
- Next version of SFD expected June 2008
- All records will be reviewed over the next several years
- Revisions to the SFD are expected to be issued each year
- SFD remains OUO; not likely to change

Future Enhancements

- Potential SFD enhancements include:
  - Tracking individual handling units; primarily after fuels are loaded into canisters
  - Support for shipping and repository acceptance
  - Basket configurations for repository disposal
  - Inclusion of HLW

ANA Overview

Problem

- Some types of US DOE spent nuclear fuel (SNF) contain highly enriched uranium
- Final disposition of this SNF the repository requires criticality control during the pre- and post- closure regulatory period

Approach

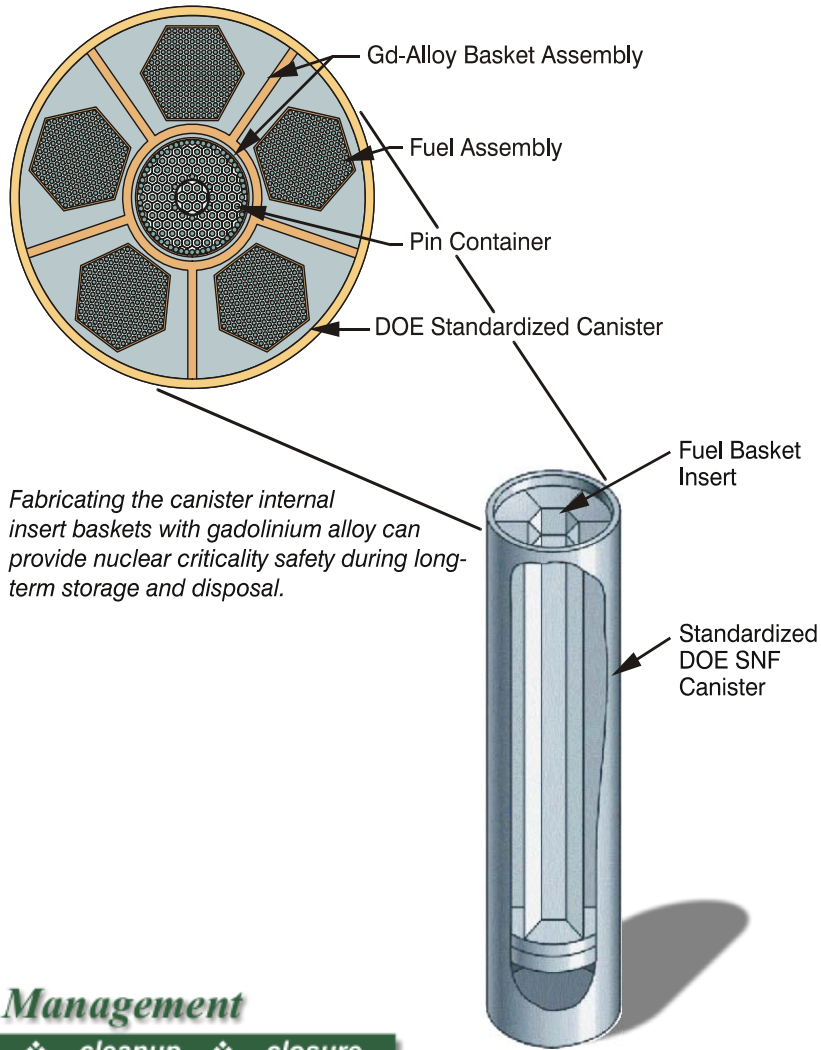
- SNF will be packaged in standardized canister with baskets fabricated from corrosion resistant neutron absorbing materials

Benefits

- Decreased number of DOE SNF packages going to repository with reduced handling and materials costs.
- Allows DOE SNF to be accepted for disposition

DOE Standardized Canister

Fast Flux Test Reactor Fuel Canister

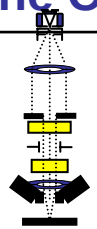


Fabricating the canister internal insert baskets with gadolinium alloy can provide nuclear criticality safety during long-term storage and disposal.

HLW/DOE SNF Waste Package

Project Workflow

Define Compositions



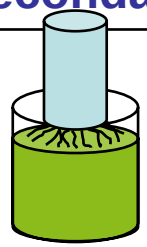
Laboratory Evaluations

Fe-Ni-Cr-Gd
Ni-Cr-Mo-Gd

Primary Melting and Casting

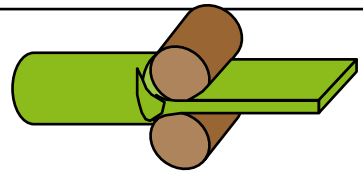
Vacuum Induction Melting (VIM)

Secondary Melting/Refining



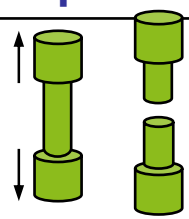
Vacuum Arc Remelting (VAR)

Hot Working/Rolling



Hot Ductility
Forging
Rolling

Properties Testing



Tensile
Charpy Impact
Corrosion
Weldability
Neutronics

Codes and Standards

ASTM Specification
ASME Code Section III
Commercialization

Consensus Body Approvals

- ASTM Material Specification B932-04 for Ni-Cr-Mo-Gd Alloy has been issued
- ASME code case (N-728) for non-welded use completed
- Criticality benchmark experiment completed and published
- ASTM E01-08 (draft) Analysis of Ni, Gd, and High Temp alloys

Reduction of 250lb Ingots

FY 2008 Activities

- Initiated standard chemical analysis procedures (ASTM)
- Weld development program initiated
- Mill annealing studies
- Located supplier for 2000 lb ingot

Discussion of Results

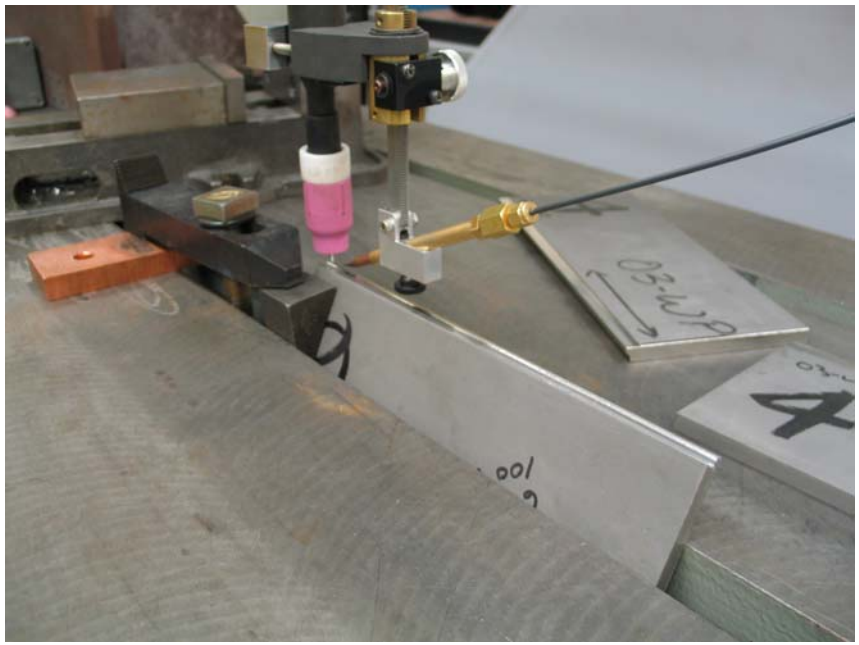
- **ASTM Chemical analysis standard**
  - ASTM standardized chemical analysis developed
  - ANA materials under round-robin testing
- **Weld development**
  - Initial weld studies show that achieving required minimum bend, Charpy impact energy, and lateral expansion properties will be difficult in the as-welded condition
  - Options are being pursued to achieve improved as-welded mechanical properties, e.g., buttering, weld parameter space modification
  - Origin of impact requirements descends from borated stainless steel code case development; it is unclear if this is appropriate for fitness for service for this alloy
- **Initial mill annealing studies completed**
  - Mechanical property indicates temperature as primary factor with time as a secondary factor

Weld Process Development

- **GTAW - Detrimental microstructures does not appear to be avoidable within the GTAW envelope**
  - Because of available weld wire sizes, the need for reliable sidewall fusion and wire melting, and constraints on dilution for hot cracking reasons, heat input choices are limited
  - Fusion and near heat-affected zones contain gadolinides with undesirable morphologies (an as-cast, blocky structure) that can reduce mechanical properties 50% or more
  - A post-weld heat treatment cycle can recover this loss of ductility, but the required temperatures (~1150°C) and water quenching (to avoid potential second phase formation in the C4 matrix) are impractical for large structures such as fuel baskets
- **Buttering - Basket components can built using standard industry practices**
  - A simple weld design to allow a low dilution, weld overlay build up with a weld wire that does not contain gadolinium such as alloy 59 or C-4
  - The initial shapes can them be annealed and prepared for the final welding
  - Final assembly takes place by welding areas of essentially zero Gd content, and as-welded properties are expected to be close to those of ordinary C4 material

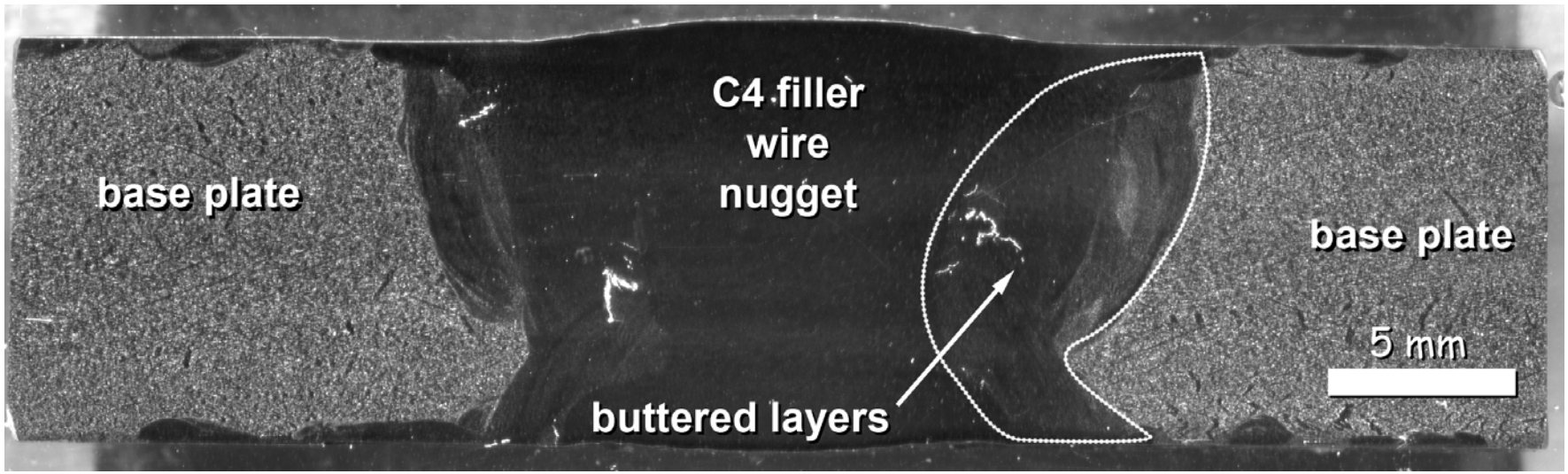
Weld Process Development

(Buttering, "J" groove, GTAW, 0.045" C4 weld wire)



Buttered Weld Joint

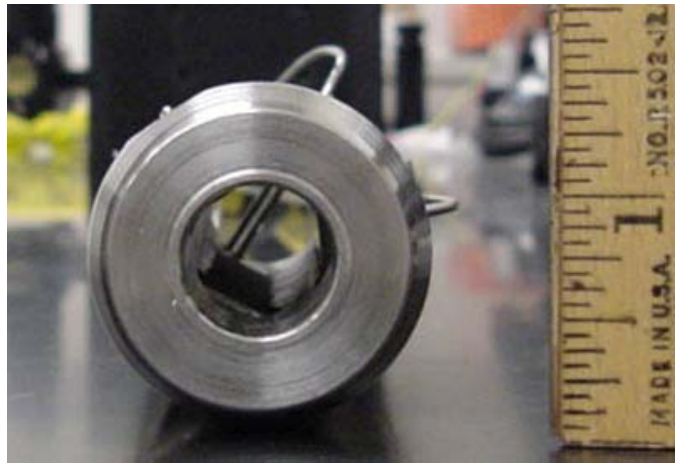
("J" groove, GTAW, 0.045" C4 weld wire)

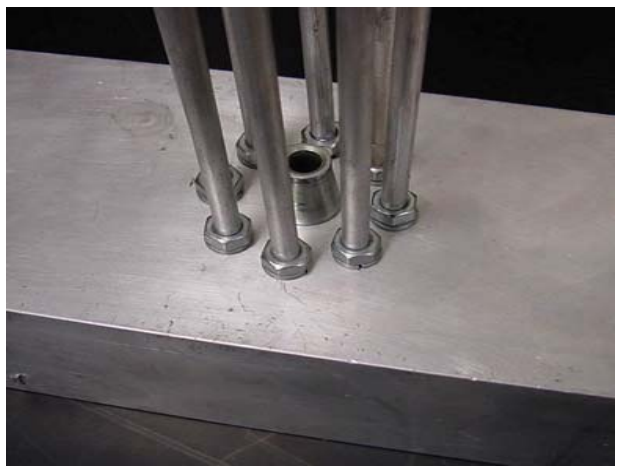


Mill Annealing

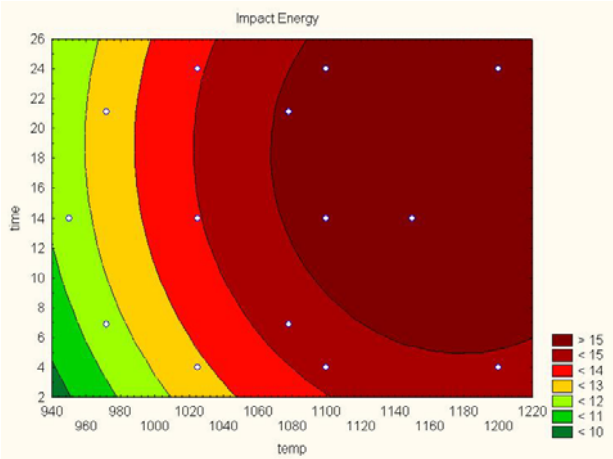
- As-rolled plate typically has impact values of 12-14 ft-lbs; code minimums are 15 ft-lbs and 20 mils lateral expansion
  - Optimize material properties - both charpy impact and lateral expansion
  - Better understanding of mechanism for improving material properties
- Variable parameters include time, temperature and number of reheats

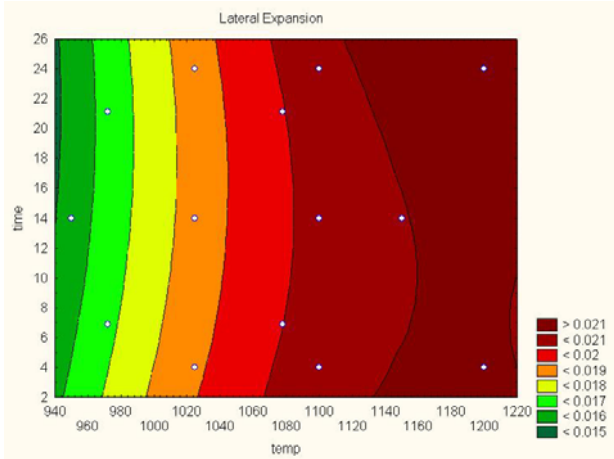
Mill Annealing Studies

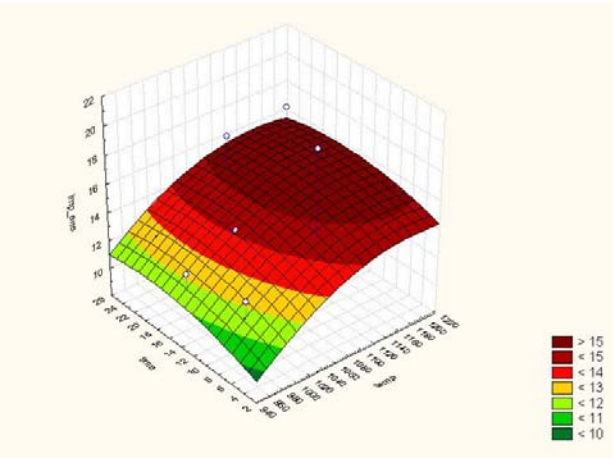


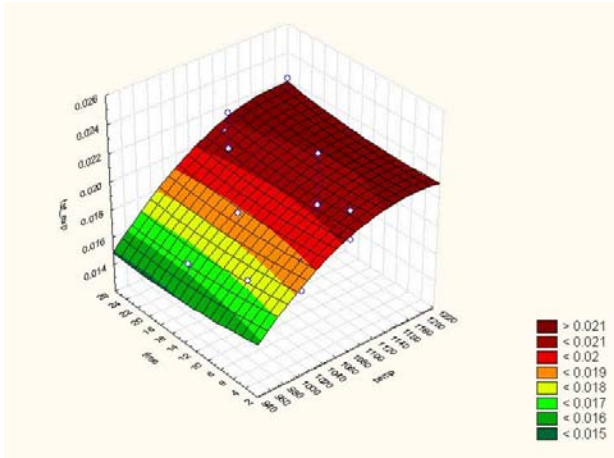


Mill Annealing Results









Annealing Statistical Results

- Bounded time and temperature for both impact energy and lateral expansion.
  - For impact energy, the maximum is achieved at 17.8 hours and a temperature of 1173^{0}C. Temperature has a very significant effect on impact energy and time has little effect.
  - For lateral expansion, the same is true in regards to the effect of temperature and time. The stationary point is a saddle point and occurs at 8.7 hours and a temperature of 1188^{0}C.
- Confirmatory testing underway
  - Single annealed three sets with additional property measurements

Summary

- **Ni-Cr-Mo-Gd alloys can be made with conventional ingot metallurgy techniques**
- **The alloy meets all performance requirements**
  - Mechanical properties will meet ASME requirements
  - Thermal neutron absorption performance of prototype alloys is exceptional and consistent with published data
  - Development is continuing on improving as-welded mechanical properties
- **Included in LA for DOE SNF**
  - PCSA - Basket geometry only
  - Post Closure – Gd content only