Status of Advanced Neutron Absorber Development

NSNFP Strategy Meeting
Richland, WA

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Project Overview

Problem

- Some types of US DOE spent nuclear fuel (SNF) contain highly enriched uranium
- Final disposition of this SNF the repository may require criticality control during the regulatory period

Approach

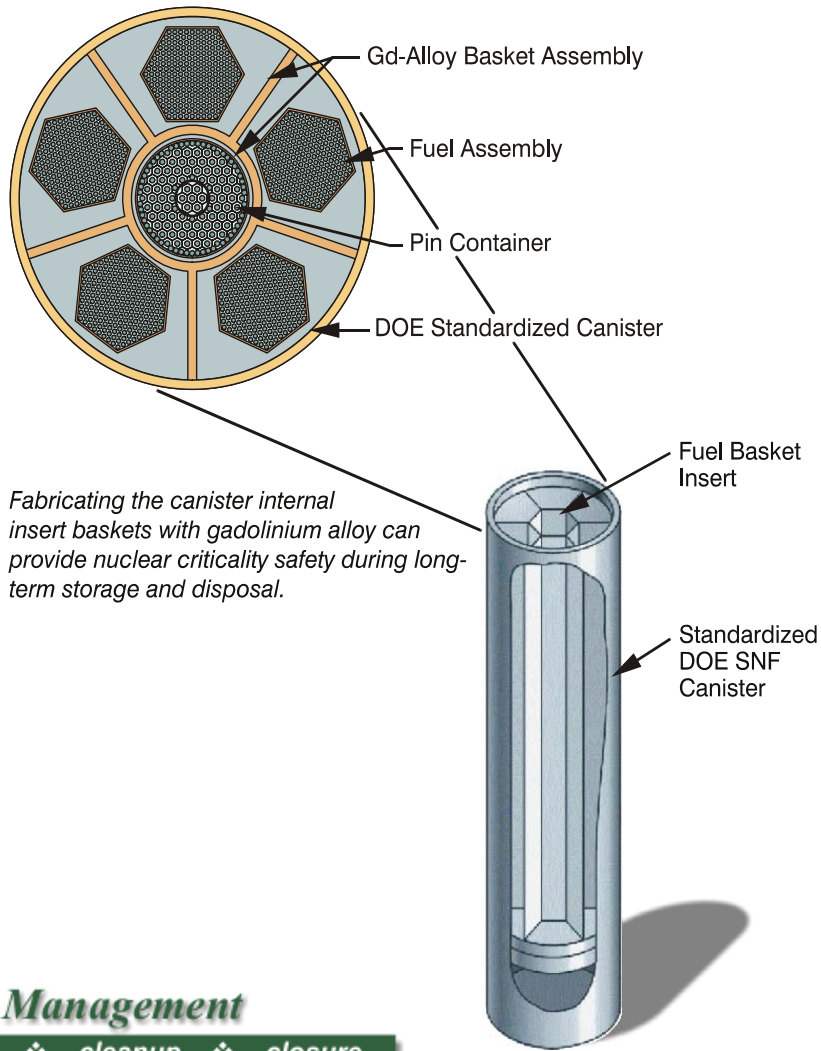
- SNF will be packaged in standardized canister with baskets fabricated from corrosion resistant neutron absorbing materials

Benefits

- Decreased number of DOE SNF packages going to repository with reduced handling and materials costs.

DOE Standardized Canister

Fast Flux Test Reactor Fuel Canister

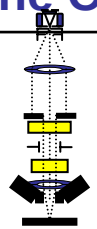


Fabricating the canister internal insert baskets with gadolinium alloy can provide nuclear criticality safety during long-term storage and disposal.

HLW/DOE SNF Waste Package

Project Workflow

Define Compositions



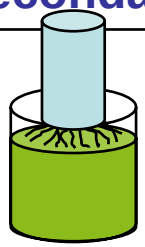
Laboratory Evaluations

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

Primary Melting and Casting

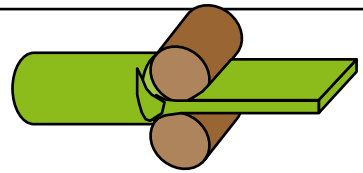
Vacuum Induction Melting (VIM)

Secondary Melting/Refining



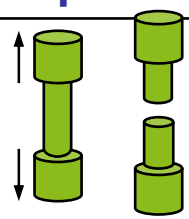
Vacuum Arc Remelting (VAR)

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 E E01-08 (draft) Analysis of Ni, Co, and High Temp alloys

Reduction of 250lb Ingots

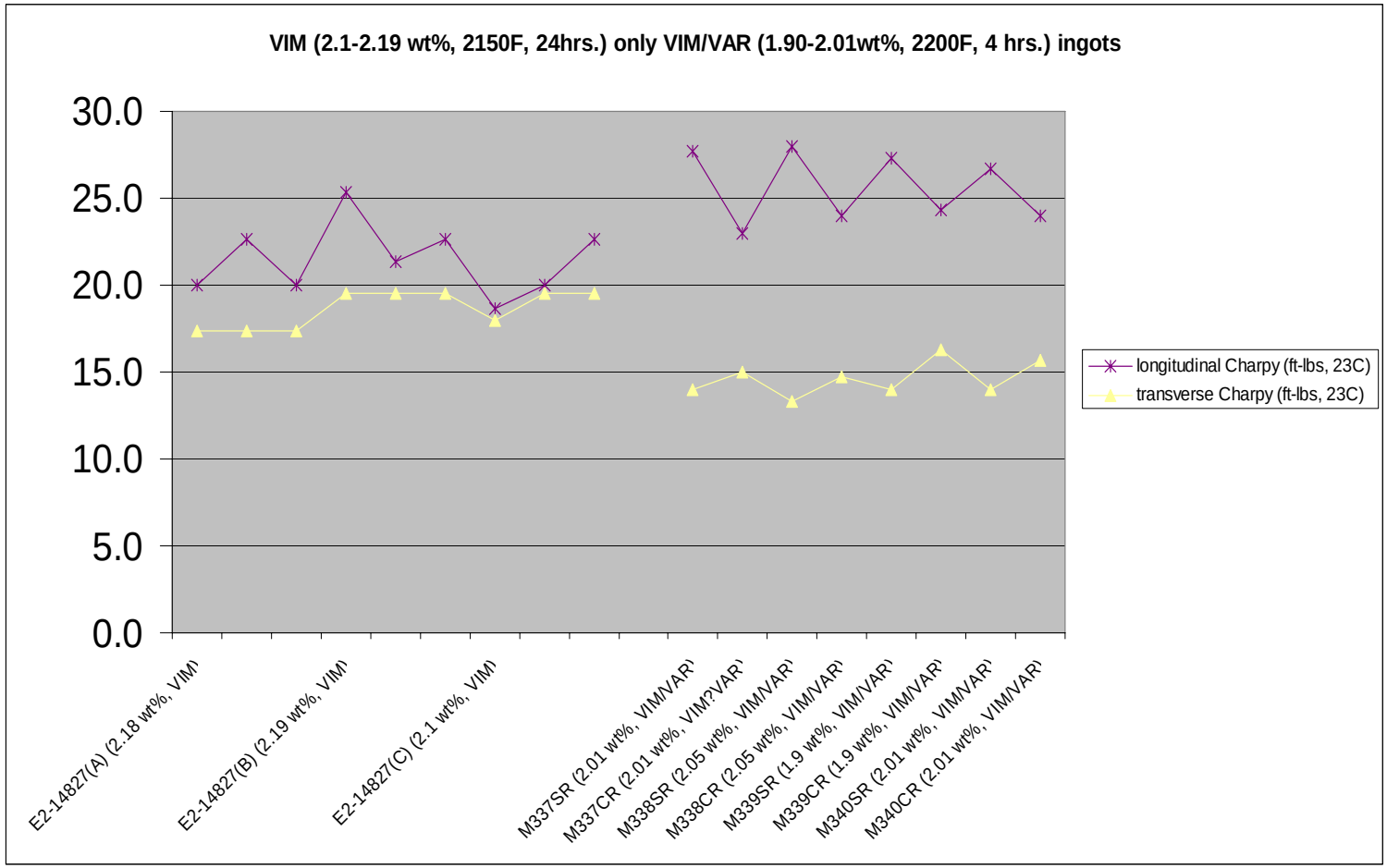
FY-07 Accomplishments

- Completed mechanical properties on 250lb ingots
- Initiated standard chemical analysis procedures (ASTM)
- Weld development program initiated
- Completed furnace lining interaction investigations
- Completed analytical investigation on de-ox/de-sulfur practice
- Completed interim neutron transmission measurements
- Located supplier for 3000 lb ingot

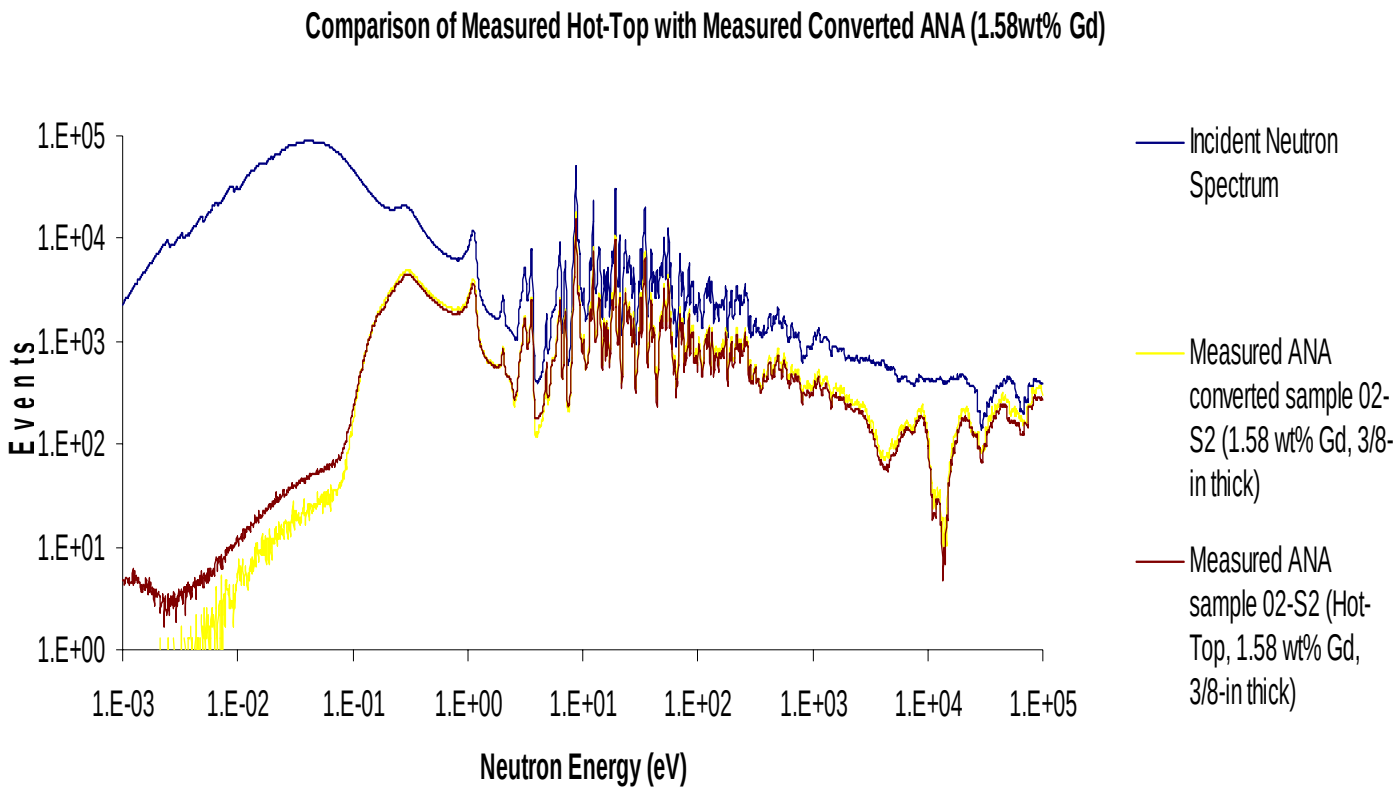
Discussion of Results

- Mechanical properties affected by production methods
- ASTM Chemical analysis standard
  - ASTM standardized chemical analysis developed
  - ANA materials under round-robin testing
- Neutronic transmission measurements
  - ENDF/B-VII.0 (300K) libraries can be used for modeling with good agreement to measurements
  - ANA demonstrates advantages over borated SS at low energies (<1.0 eV)
  - Limited neutron effects in the as-cast versus converted (>3/8-in thick)
- Weld development
  - weld studies show that achieving plate mechanical properties will be difficult
  - Options remain for avoiding post-weld heat treatment
- Initial annealing studies completed, data being evaluated

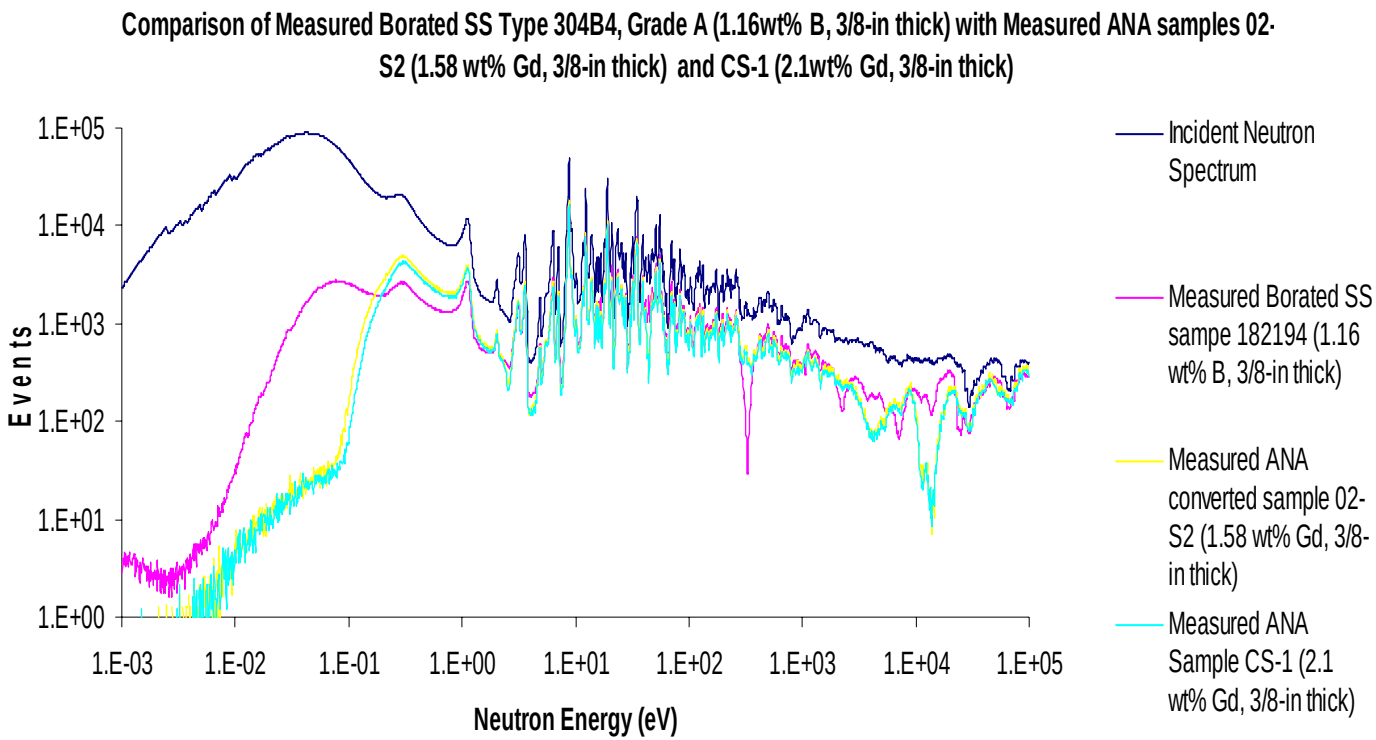
Mechanical Properties Improvements



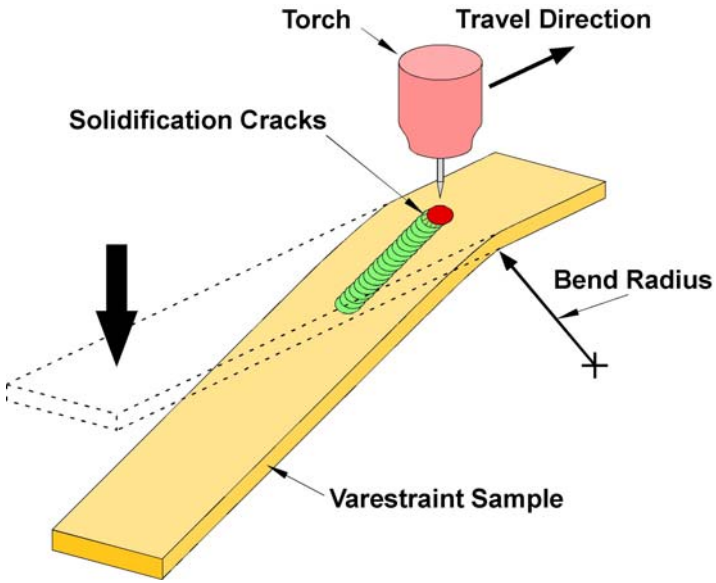
Neutronic Measurements

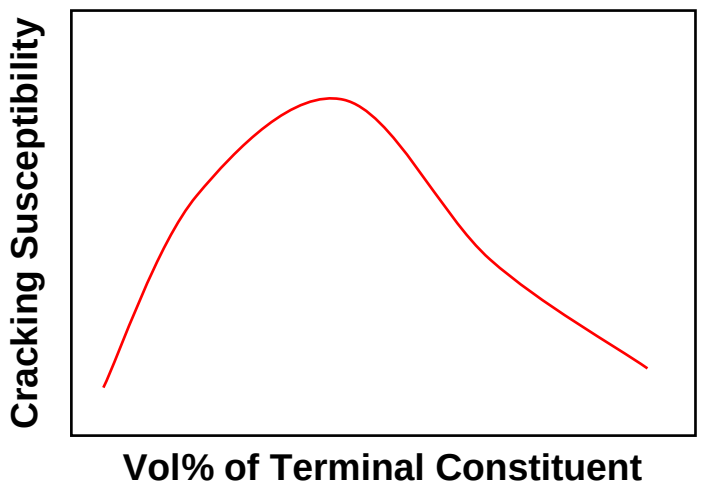


Neutronic Measurement Comparisons



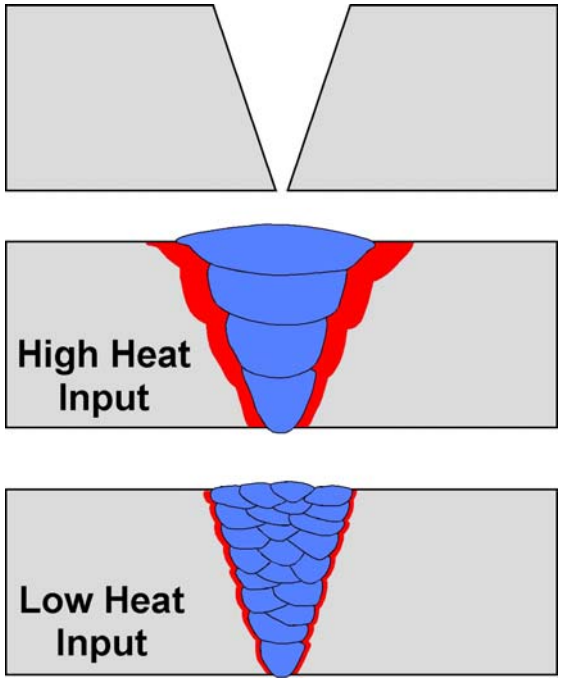
Welding Process Development





- Although hot cracking has not been extensively encountered, the effect of dilution of Gd into the filler metal is a concern
- Cracking susceptibility is being assessed by Varestraint testing on alloy from 0.5-2.5 wt% Gd in 0.5% increments
- The primary focus of Varestraint testing is to identify dilution ranges which may be most susceptible to solidification cracking
- This applies to both direct plate welding and buttered joint concepts

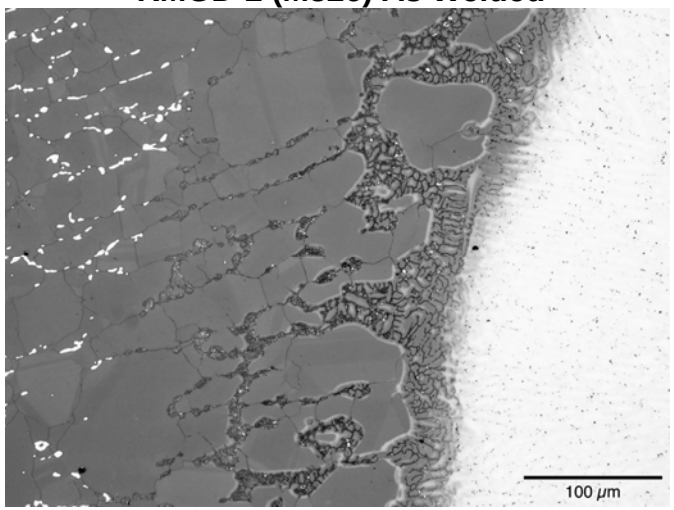
Welding Parameters



- **The key area of interest in ANA welds is the HAZ, and control of the properties in that region**
- **The width of this region is controlled but parameter selection and procedures such as number of passes and pass sequencing**
- **Ongoing activities are directed at development of weld parameter selection guidelines**
- **Primary focus in on as-welded properties and response to PWHT, but must also consider production issues**
- **Alternative options such as joint buttering also being assessed**

Weldment Microstructure

RMGD-2 (M326) As Welded



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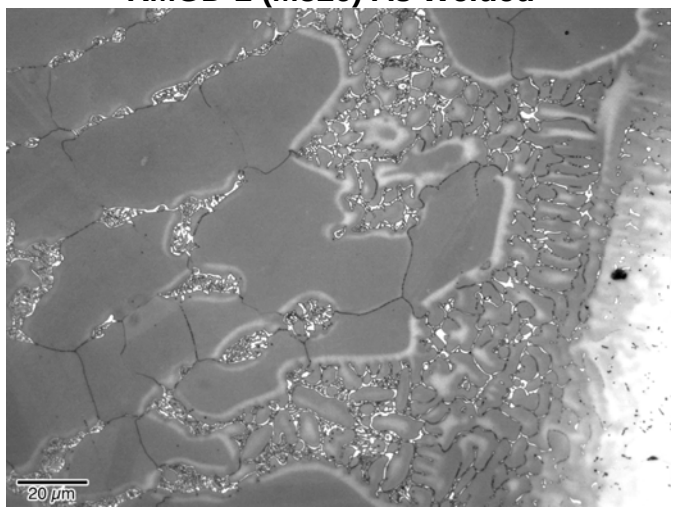
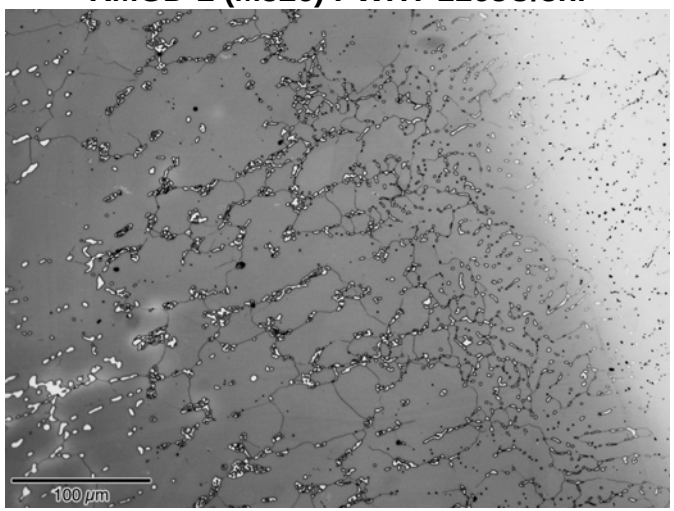


RMGD-2 (M326) PWHT 1163C/8hr



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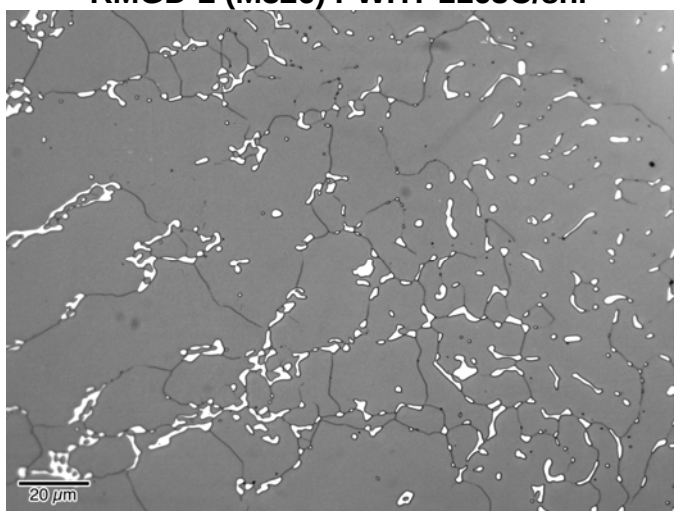
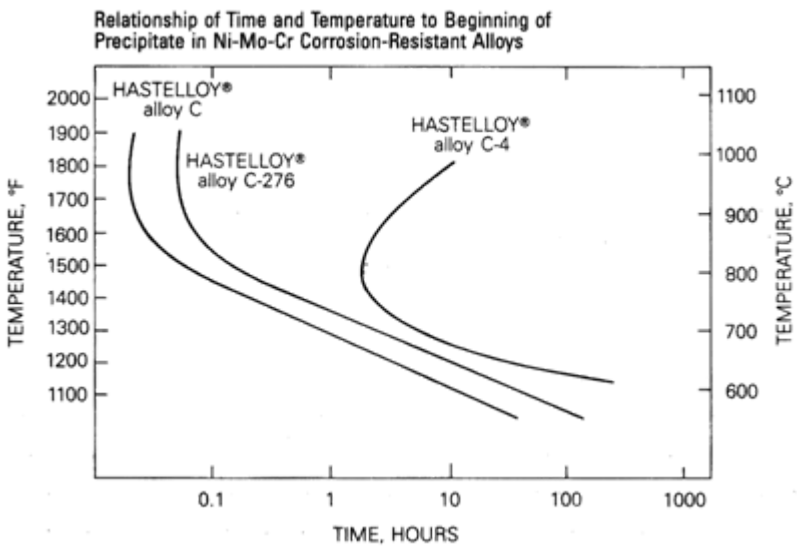


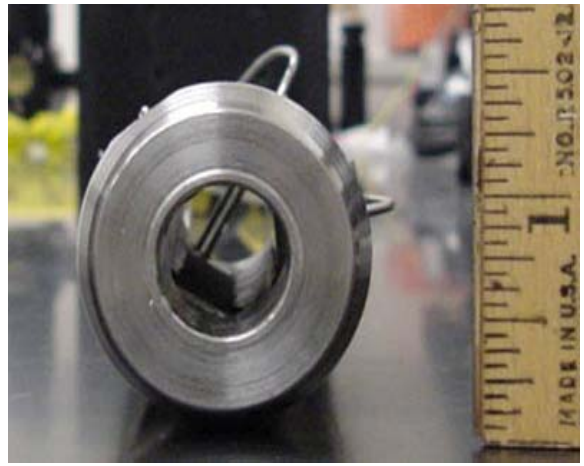
- **Gadolinide is interconnected along fusion line in as-welded condition**
- **PWHT results in appreciable spheroidization of the gadolinide**
- **This is consistent with the ductility increase with PWHT**

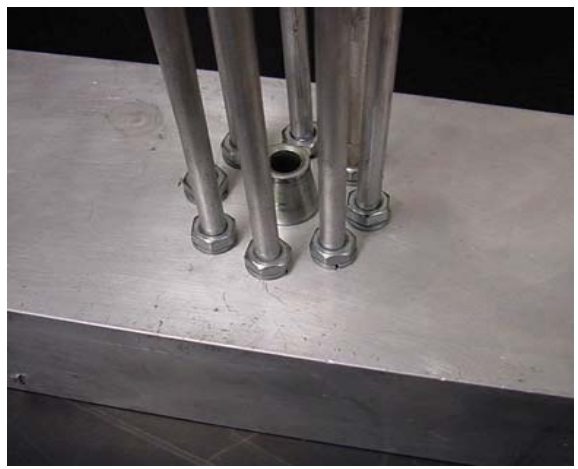
Welding process development - PWHT



- **An additional consideration is that the matrix Ni-Cr-Mo composition is susceptible to the formation of brittle intermetallic phases in the temperature range of 650-1000°C**
- **To avoid the formation of these phases, the weldment must be rapidly cooled though this temperature range**
- **The required cooling rate depends on section thickness, but we have conservatively been using a water quench**
- **This complicates PWHT of large structures**
- **This approach may be too conservative for the Alloy C-4 matrix**
- **We are therefore determining cooling rate requirements for the ANA alloy**

Mill Annealing Studies





Summary

- Ni-Cr-Mo-Gd alloys can be made with conventional ingot metallurgy techniques
- The alloys will meet all performance requirements
  - Mechanical properties will meet ASME requirements
  - Thermal neutron absorption performance of prototype alloys is exceptional and consistent with published data
  - As-cast versus converted material performance differences are small
- Included in LA for DOE SNF
- Budgeting for 3000 lb ingot in FY-08