Materials for Advanced Ultra-Supercritical Steam Boilers

Federal – State – National Laboratory
Non Profit – For Profit
Cost Sharing Consortium

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ORNL

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Portland, OR
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MAKING OHIO COAL THE CLEAN CHOICE

ELECTRIC POWER RESEARCH INSTITUTE

imagination at work

FOSTER WHEELER

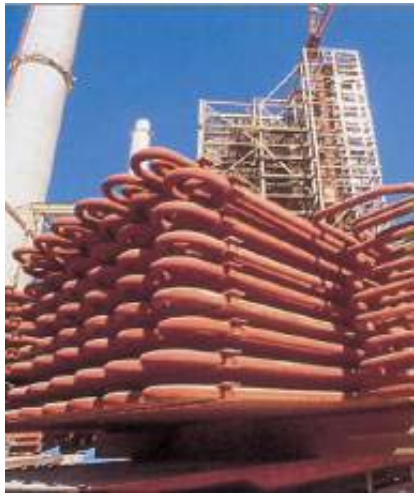
RILEYPower
A Babcock Power Inc. Company

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

U.S. DEPARTMENT OF ENERGY

Estimated Total Amount of Tubing for a Generic A-USC Boiler

- Carbon Steel Grades – 420,000lf; 3,750,000 lbs
- T12 Alloy Steel Grade – 500,000 lbs
- T23 to T92 Alloy Grades – 2,600,000 lbs
- Traditional Stainless Steels – 1,600,000 lbs
- Solid-solution Ni-based alloys – 1,100,000 lbs
  - 1.750” OD X 0.400” MW
  - 2.00” OD X 0.165”/0.355” MW
- Precip.-strengthened Ni-based – 850,000 lbs
  - 1.750” OD X 0.290”/0.400” MW
  - 2.00 OD X 0.280”/0.400”MW



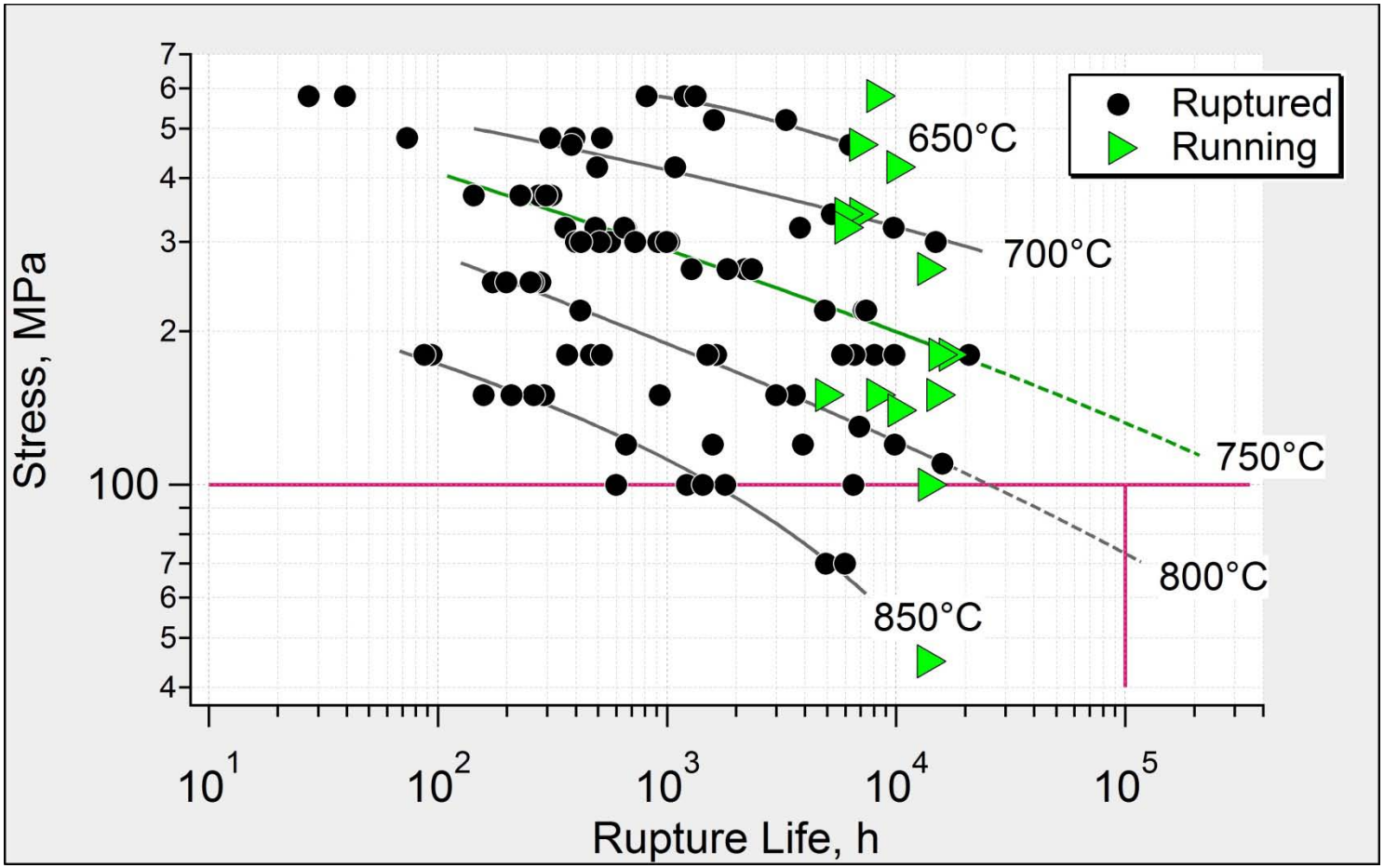
Images courtesy of The Babcock & Wilcox Company, www.babcock.com

Creep-Rupture Testing and Characterization are Highest Priority

- Characterize and understand creep behavior & mechanisms
  - ASME Code Cases: Inconel 740 & Haynes 282
  - Supplement minimum required data for code-approved alloys: e.g., alloys 230 & 617
  - Identify and understand fabrication & welding issues: e.g., effects of cold-work on creep, weld strength factors
- Provide creep data for boiler design activities

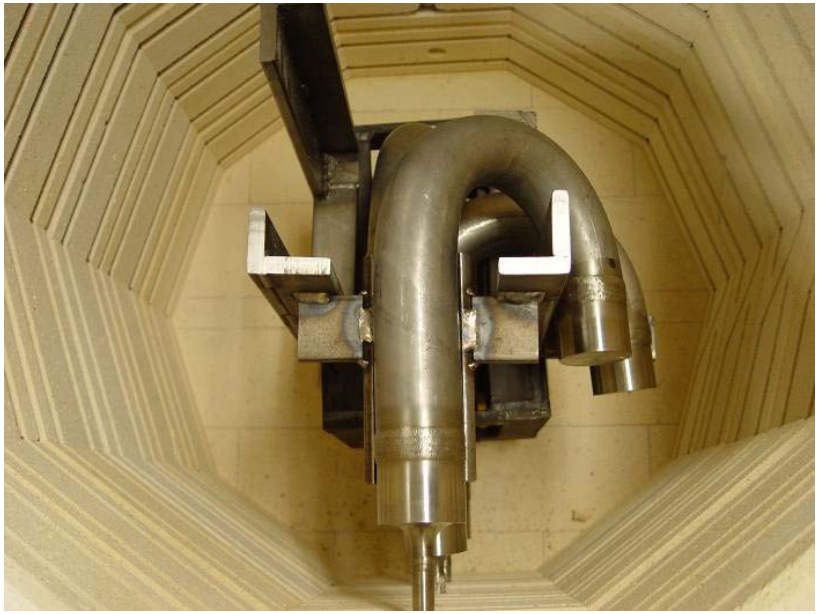
Build confidence for using new high-strength alloys in new applications

Longer-time tests of 740 are confirming strength retention up to ~ 20,000 h



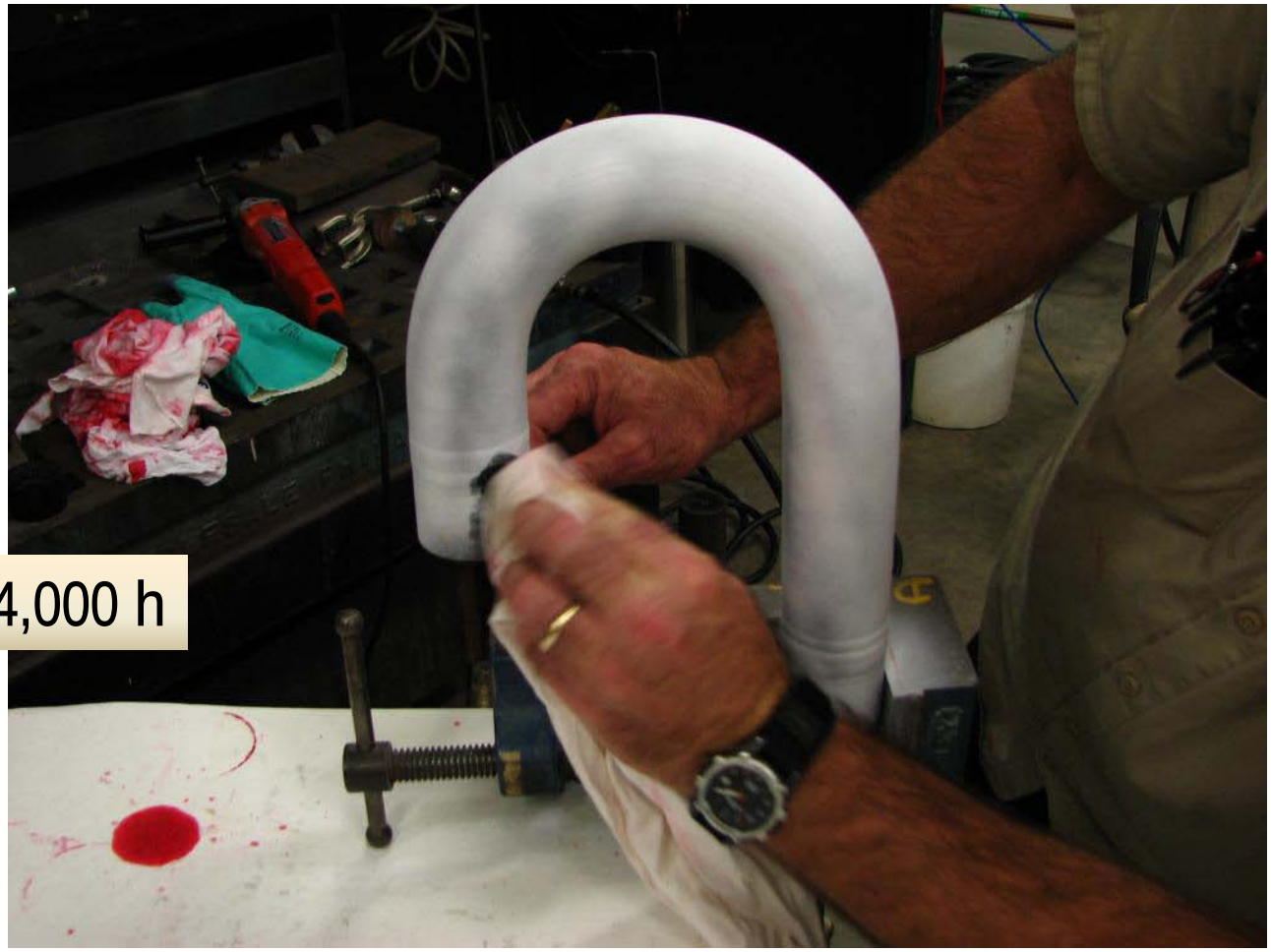
- On-going tests emphasize longer times, ~ 10,000+ h
- Critical for ASME Code approval

Pressurized Tube Bend Creep Tests Are Aiding Determination of Cold-Work Limits



- Currently the ASME B&PV Code allows cold forming strains of 10-15% for austenitic steels (Section I, PG-19)
- Cold-bent tubes are being creep tested to provide guidance for determining fabrication rules for Ni-base alloys
  - 740 tested; scheduled for retesting
  - 617 running at 775°C, 5600 psi (80-90 MPa), t → 15,000 h

Dye penetrant examination indicated 617 tube bends are free of OD cracks

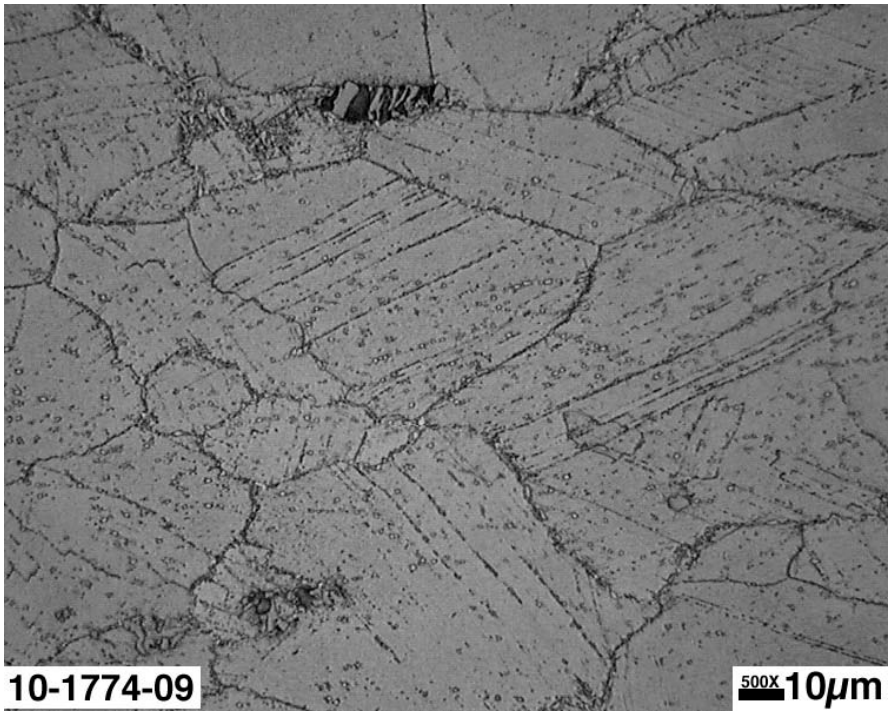


t ~ 14,000 h

- Stains and failure conditions are monitored with periodic shutdowns

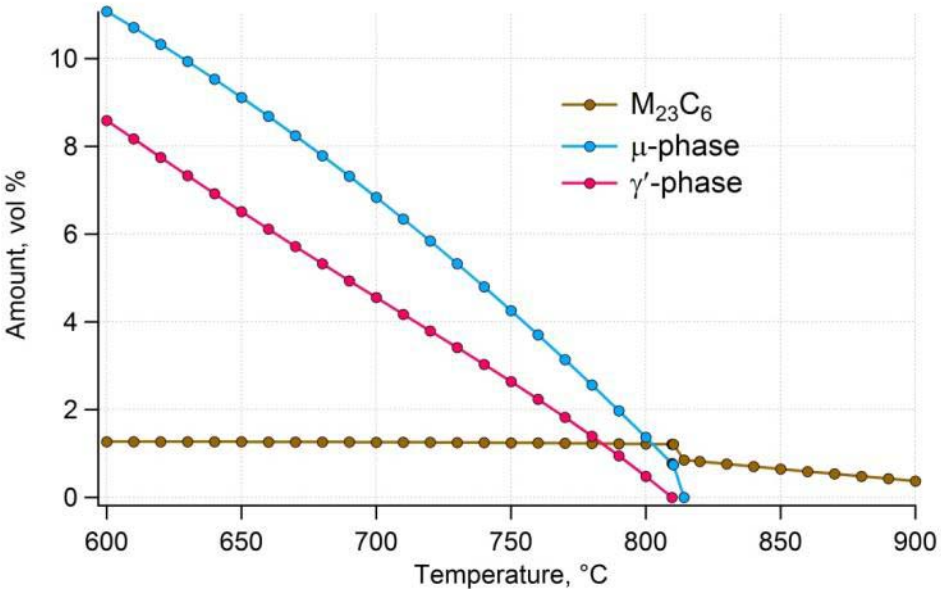
Long-time tests provide unique opportunities for understanding basic behavior

33,155 h at 650°C



At 650°C, 617 will likely contain:

- ~ 6.5% γ′- phase
- ~ 9% μ - phase



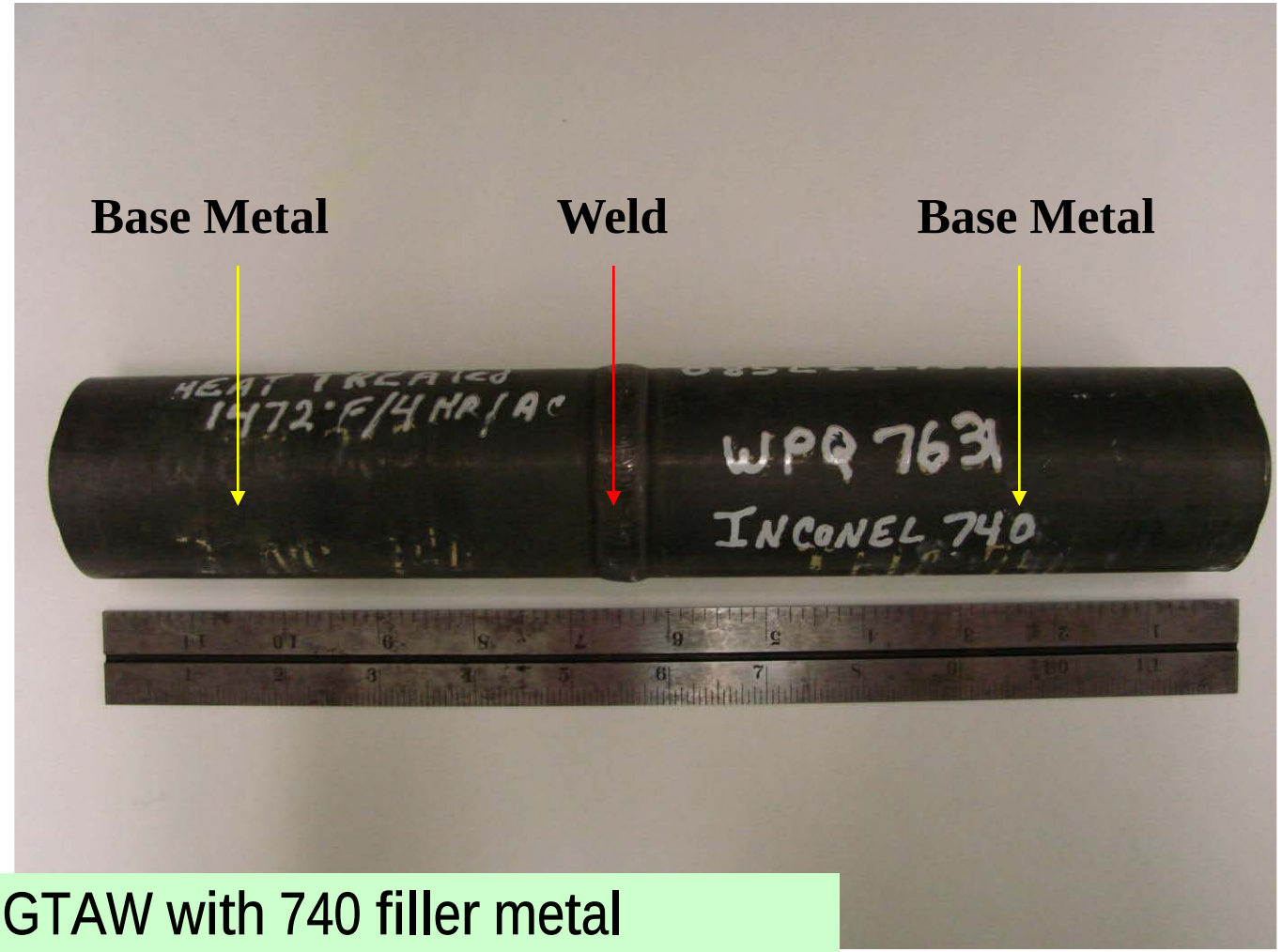
- Microstructure analysis for phase identification is in-progress

617 weldments made by Alstom are being used to characterize critical strength properties

CCA 617

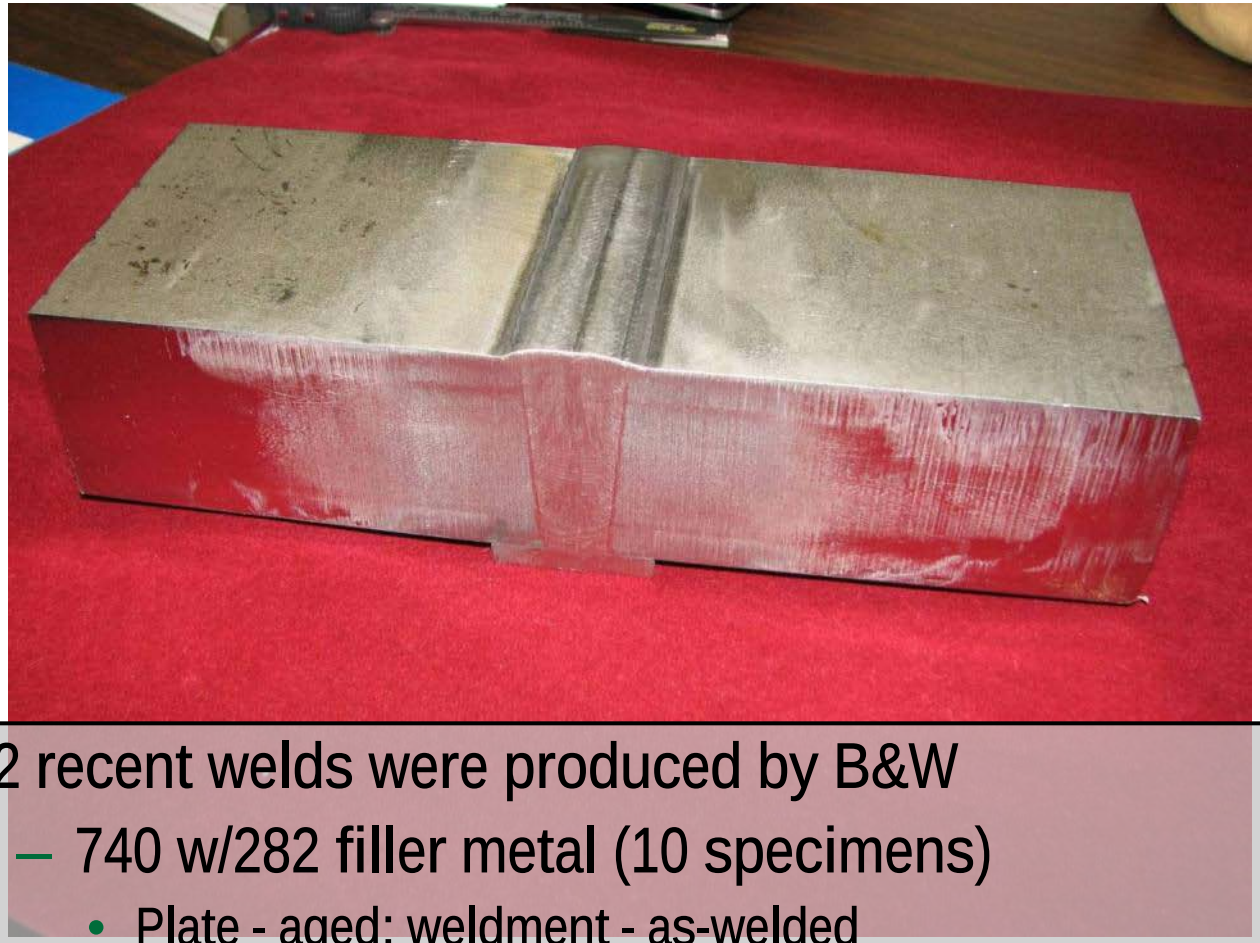
Product Form	Weld Type	Process	Filler	Comments
2-inch OD Tube	Butt	Orbital GTAW	CCA 617	Qualified, samples sent to ORNL
2-inch Plate	Butt	SAW	CCA 617	Qualified, samples sent to ORNL
		SMAW	CCA 617	Inclined plates for slag control, samples sent to ORNL. Evaluating welding suggestions received from UTP.
			Inconel 117	Weld metal fissures, needs more work

Weld Strength Factor issues are under study for 740



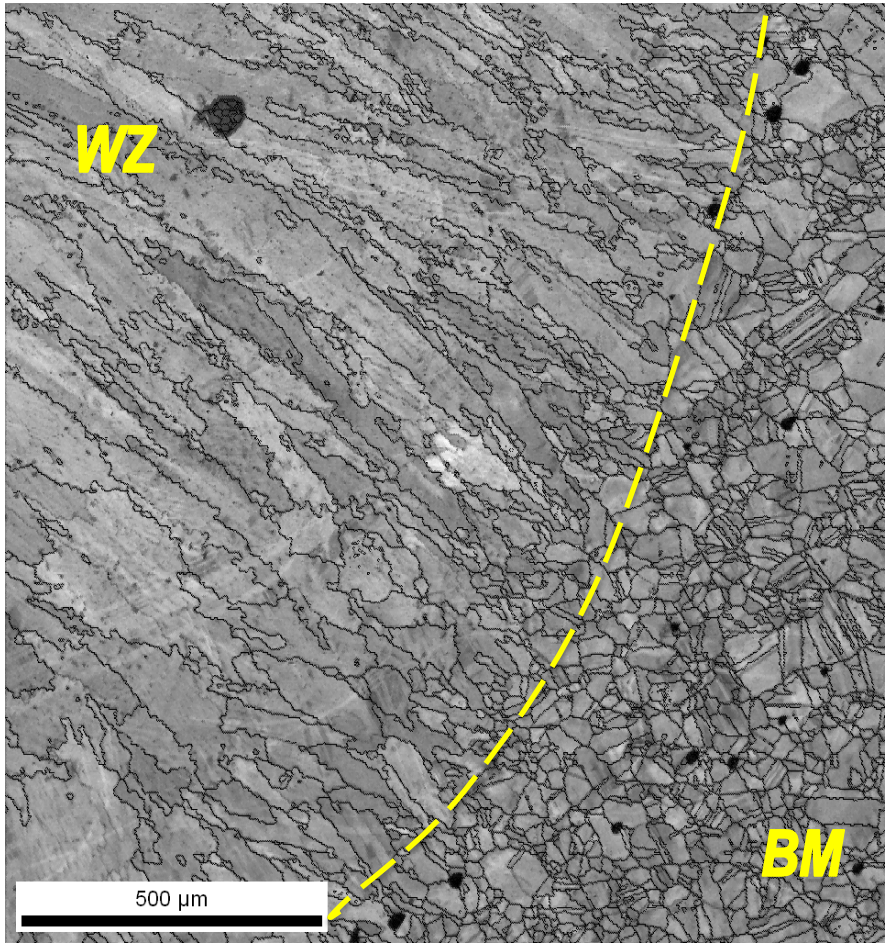
- GTAW with 740 filler metal
- 2-inch-OD x 0.4-inch-wall 740 tube

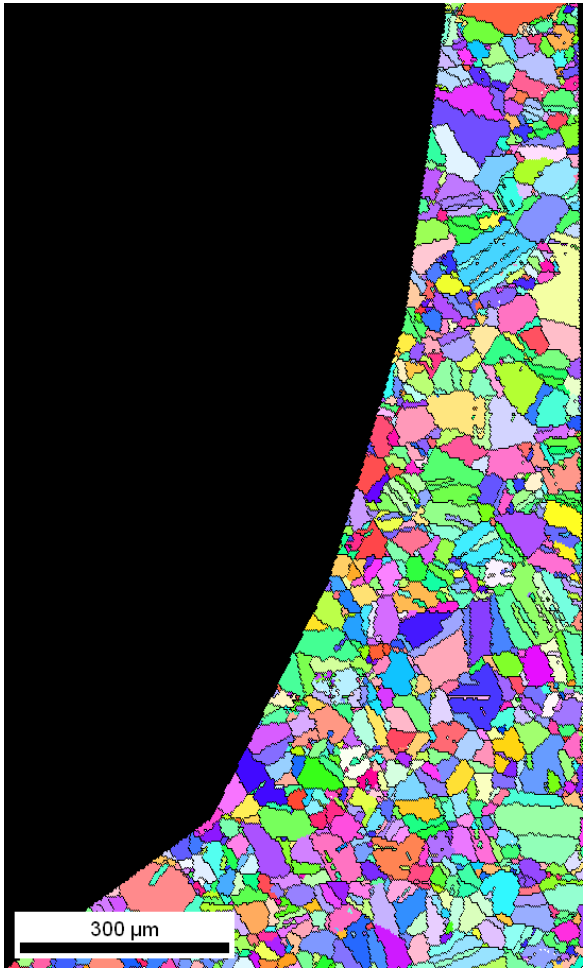
Understanding and improving WSFs of 740 continues to be a focus



- 2 recent welds were produced by B&W
  - 740 w/282 filler metal (10 specimens)
    - Plate - aged; weldment - as-welded
  - 282 w/282 filler metal (15 specimens)
    - Plate - solution annealed; weldment – as-welded

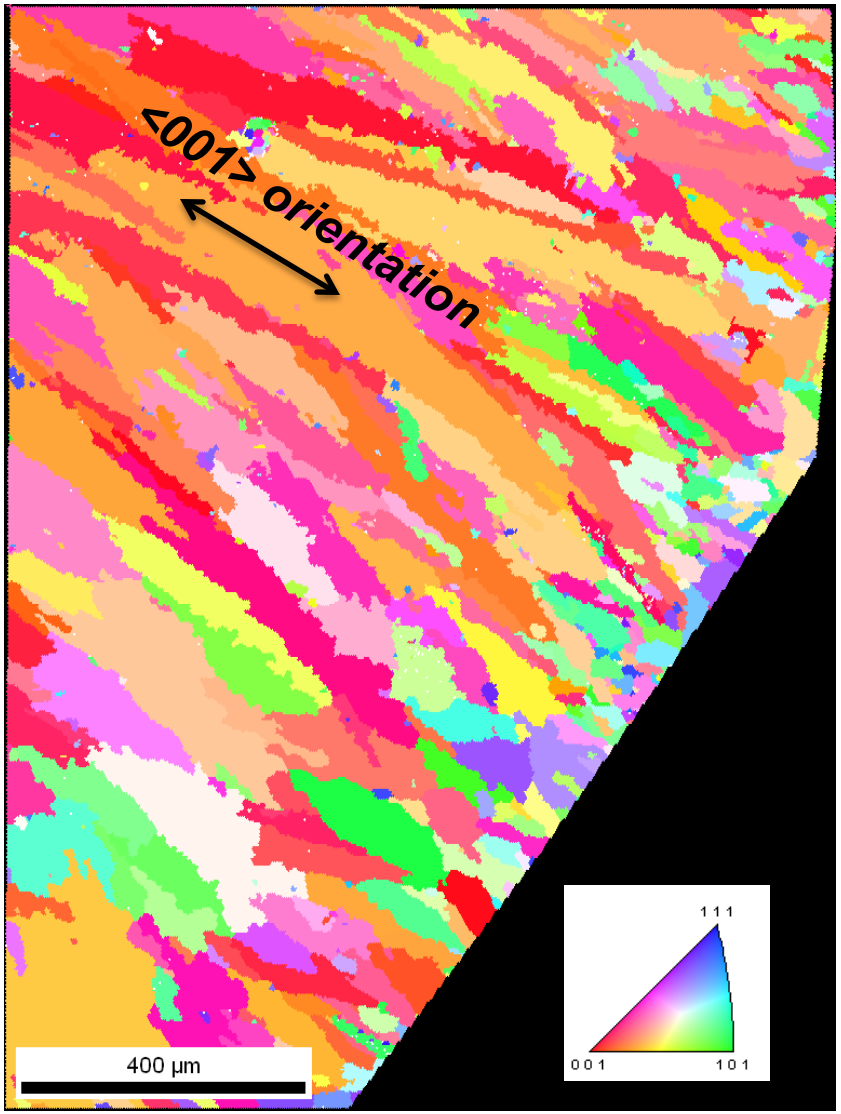
OIM assessed texture differences between 740 base metal and weld deposit

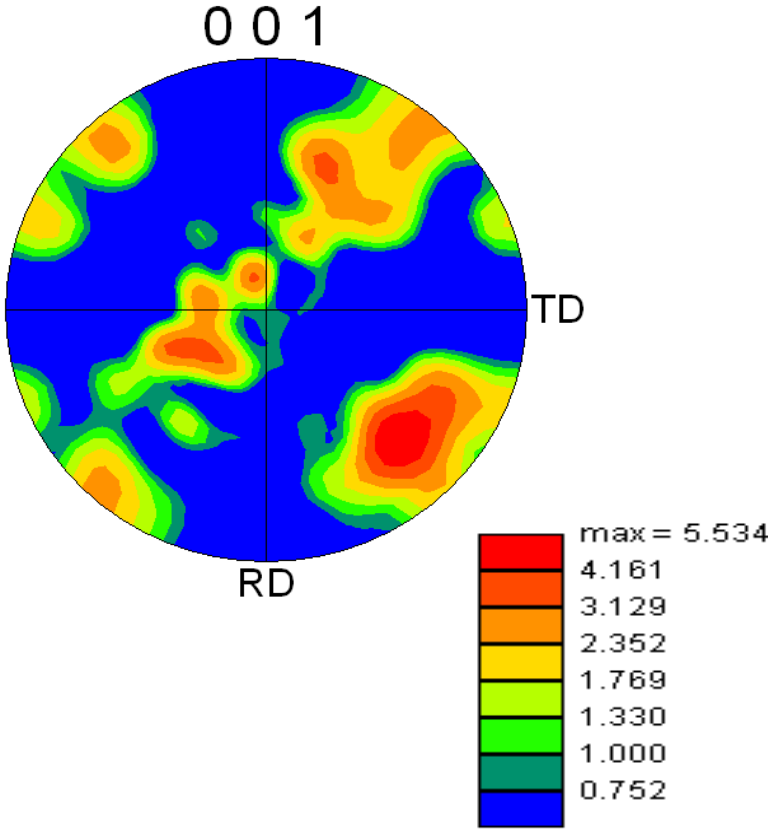




- Base metal is characterized by random crystallographic texture
- Isotropic properties are expected

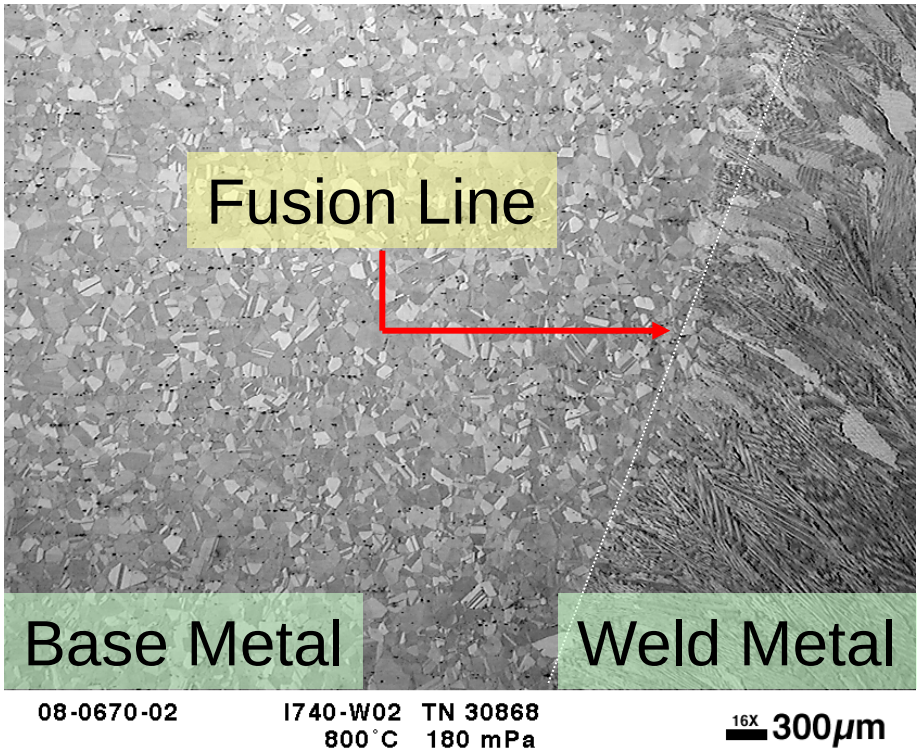
Weld zones are characterized by strong crystallographic texture

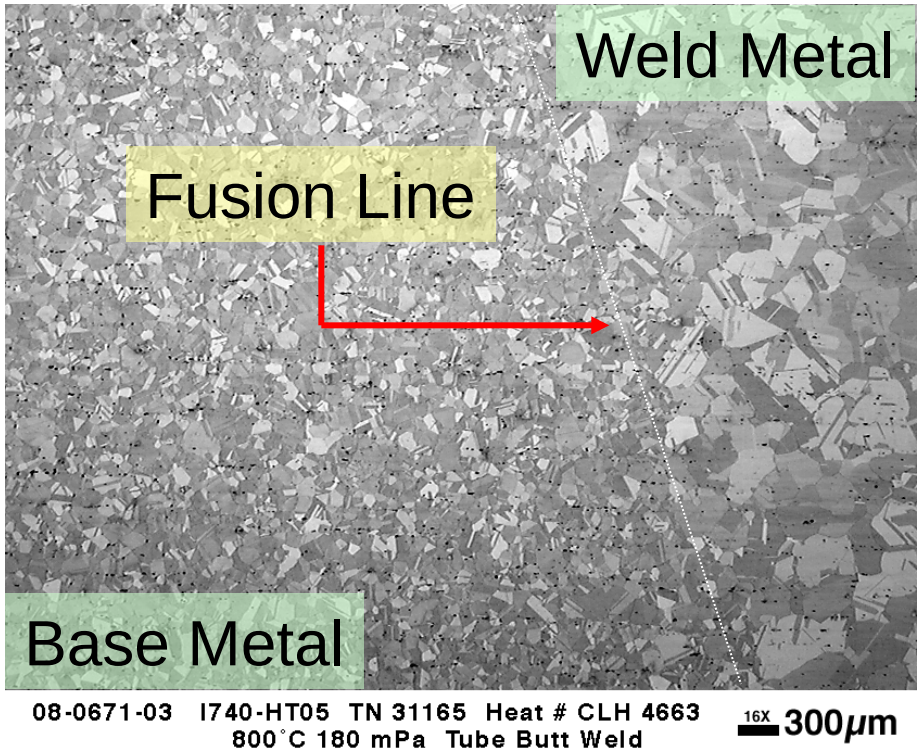




- Local properties of weld deposits will not be isotropic
- Ni-based strength has strong dependence on texture

Weld Microstructures Can Be Modified By Heat Treatments

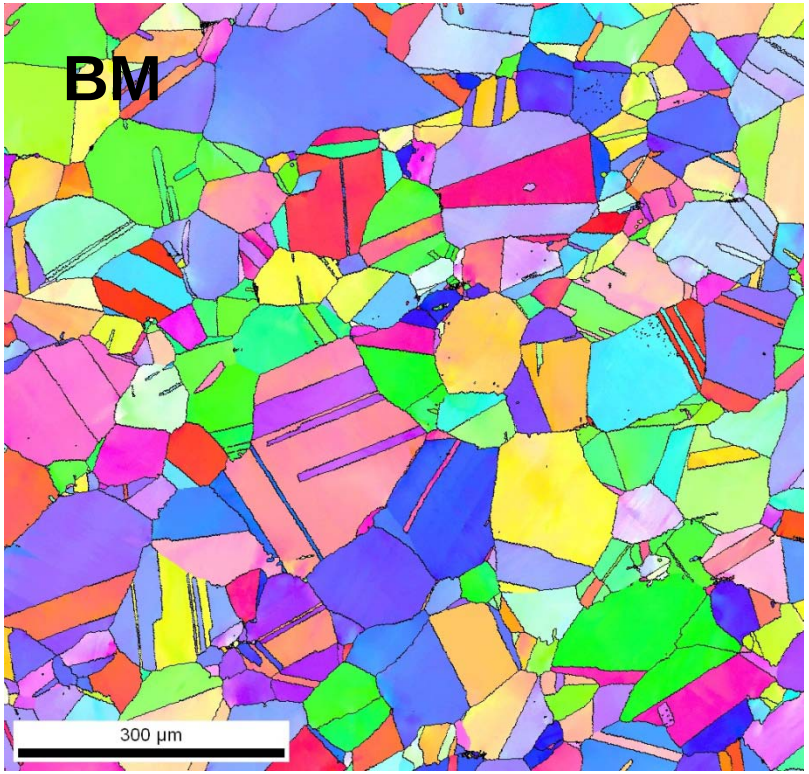




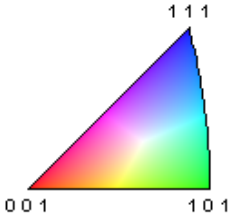
HT #1
Aged at 800°C/4 h

HT #2
Solution anneal at 1120°C/1 h
Aged at 800°C/4 h

Solution treatment caused recrystallization and randomization



Nickel



- Benefit for rupture life at high T/low σ may be marginal

Substantial progress is being made to qualify Ni-based alloys for A-USC

- Long-term creep-rupture testing
  - Inconel 740
    - ASME Code Case data package submitted for initial consideration
  - Alloy 282
  - Alloys 230 & 617
- Weldment strength studies
  - Understand sources of, and minimize Weld Strength Factors
- Cold-work effects
  - Characterize, understand, and minimize cold-strain effects on creep properties

Building confidence to use new high-strength alloys

OAK RIDGE National Laboratory

FY2011 Milestones & Status:

- Results from intermediate-time tests of third heat of Inconel 740 will be summarized at Quarterly review meeting
  - 12/2010, completed
- A draft creep data package will be prepared for an ASME Code Case for Inconel 740
  - 06/2011, completed
- Microstructure analysis of cold-worked materials will be summarized at Quarterly review meeting
  - 09/2011, on-schedule
- Results from microstructure characterization of long-time aged 740 will be presented at Quarterly review meeting
  - 12/2011, completed

Quarterly reports are also associated with Quarterly review meetings