An Overview of the Ultrasupercritical Boiler Materials Development Program

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Goals of the USC Materials Consortium

- Identify advanced materials that achieve cost competitive, environmentally acceptable coal based electric power generation that includes the use of high sulfur coals.
- Enable domestic boiler manufacturers to globally compete for the construction and installation of high efficiency coal fired power plants.

Specific Objectives of the USC Materials Project

- Identify materials performance issues that limit operating temperatures and thermal efficiency of coal-fired electricity generating plants;
- Identify improved alloys, fabrication processes and coating methods to operate at steam temperatures up to 760°C (1400°F) and steam pressures to 37.9 MPa (5500 psi);

Specific Objectives of the USC Materials Project (cont'd.)

- Work with alloy developers, fabricators, equipment vendors and power generators to develop cost targets for the commercial deployment of alloys and processes developed;
- Lay the groundwork for ASME Code approval of new materials.

Principal Team Participants

NETL

Energy Industries Of Ohio

OCDO

EPRI
Providing Science and Technology Solutions to Our Global Energy Cust

OAK RIDGE NATIONAL LABORATORY

ALSTOM

FOSTER WHEELER

B&W

Babcock Power Inc.
BabcockPower

Other Participants

- Alloy Developers
  - Haynes, Sumitomo, Special Metals, VDM, and others
- Other Specialized Contractors for Testing and Analysis

Each participant brings special expertise and capabilities to the team, and all share in the results

Schedule and Funding

- Duration: Oct 2001 – Sept 2006

- Funding:
  - USDOE/NETL $15.2MM
  - OCDO/OAQDA $2.0MM
  - Cost share by members $2.7MM
  - Alloy vendors (in kind) $0.1MM

USC BOILER MATERIALS PROGRAM

EPRI Project Manager: R. Viswanathan

DOE Project Manager: R. Romanosky/U. Rao

EIO Project Manager: R. Purgert

OCDO Project Manager: H. Johnson

Benefits of the USC Materials Project

This program will advance developments in

- Ultrasupercritical coal combustion systems,
- Integrated gasification combined cycle plants
- Hybrid cycles incorporating partial gasification and fluid bed combustion

Benefits of the USC Materials Project (cont.)

- The near term benefits could solve high-temperature materials problems in present power generation systems.
- The long term benefit would be the development of new high temperature materials capable of providing for higher efficiency cycles critical to the success of the Vision 21 concept.

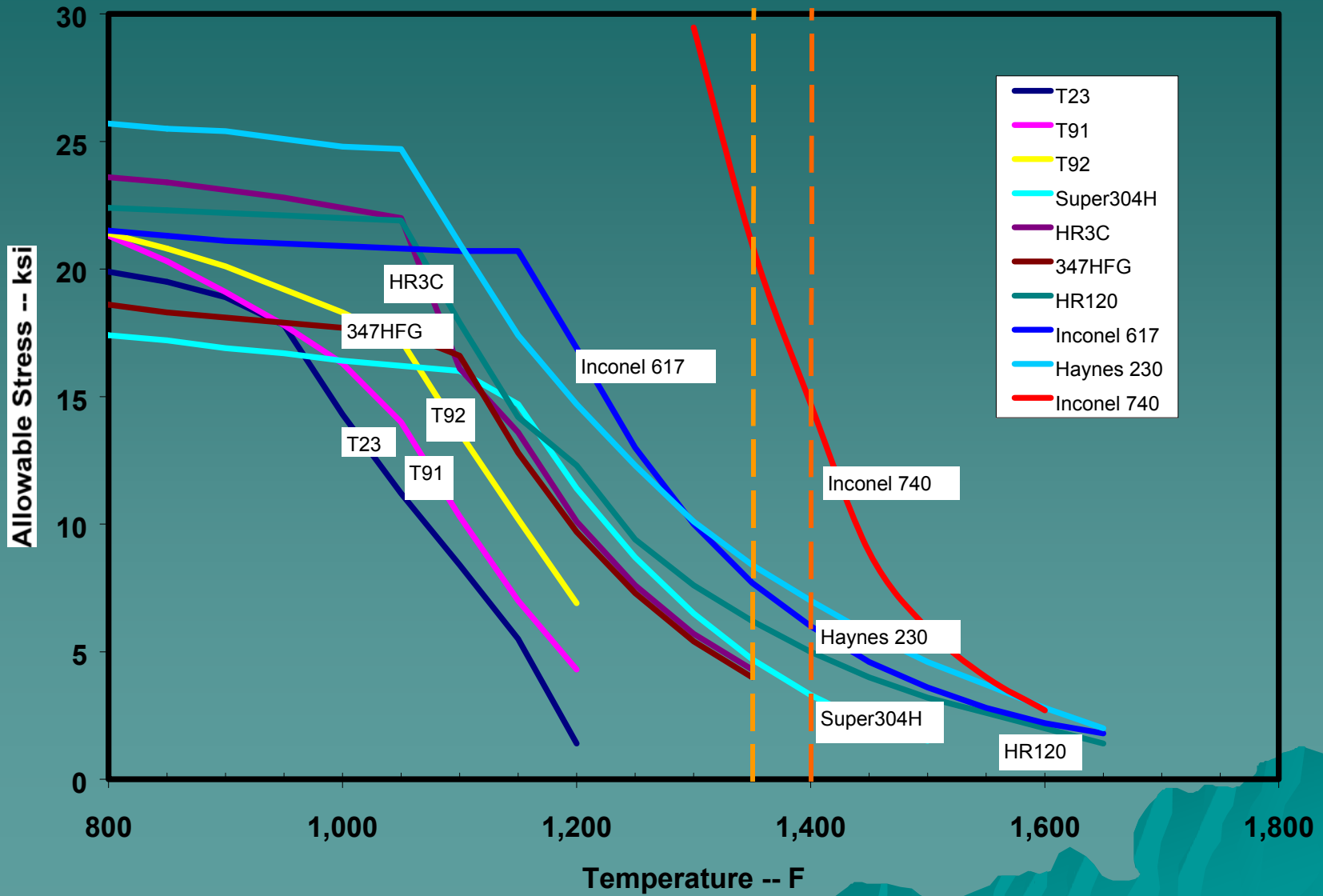
Program Tasks

- Task 1 Conceptual Design—EPRI/Others
- Task 2 Mechanical Properties—EPRI/ORNL
- Task 3 Steamside Oxidation—B&W
- Task 4 Fireside Corrosion—Foster Wheeler
- Task 5 Welding Development—Alstom
- Task 6 Fabricability—B&W
- Task 7 Coatings—Alstom
- Task 8 Design Data Codes—B&W
- Task 9 Project Management—EIO/EPRI/All

Candidate Materials

- IN 740 (47Ni-25Cr-20Co-Nb)
- Alloy 230 (55Ni-22Cr-14W-5Co)
- HR6W (43Ni-23Cr-6W-Ti & Nb)
- CCA617 (45Ni-22Cr-12Co-9Mo)
- S304H (18Cr-9Ni-3Cu-Nb & N)
- Save 12 (11Cr-3W) ferritic

Allowable Stresses



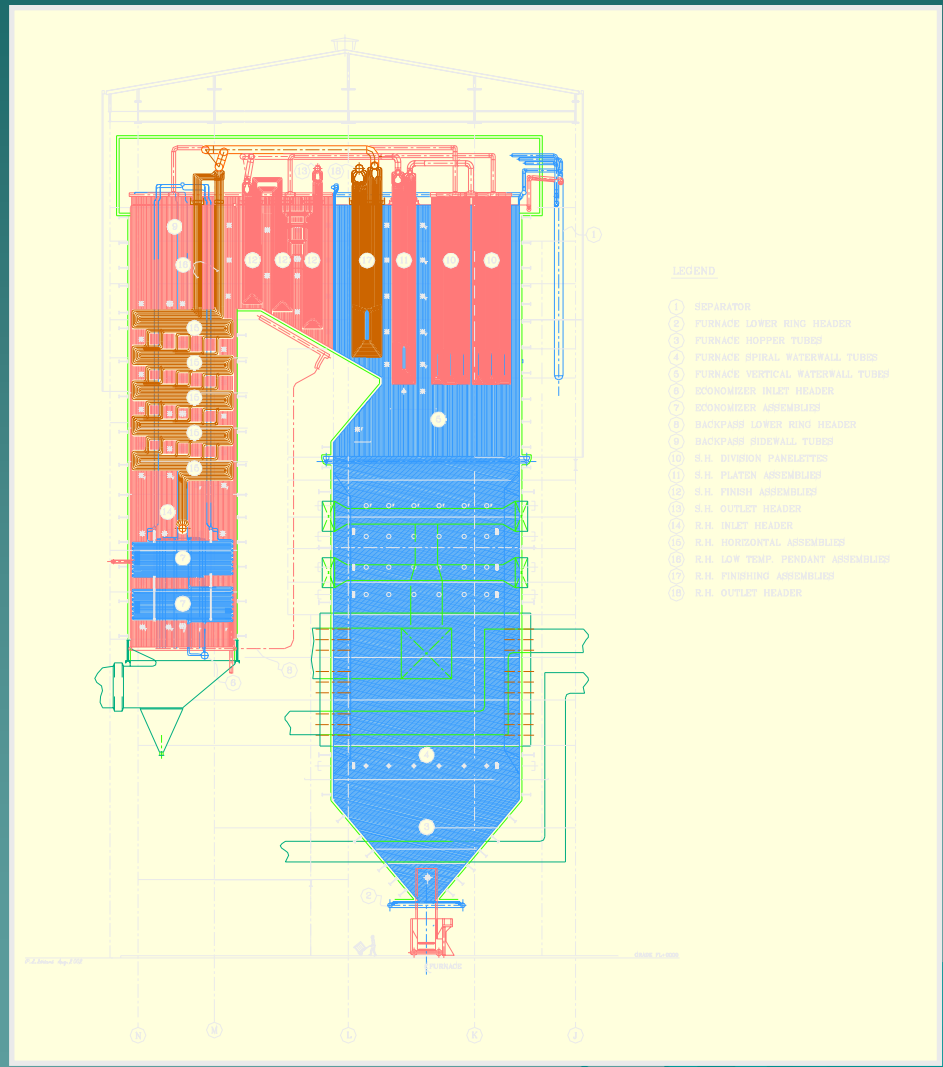
Size Comparison

5500 PSI, 1350 F, 1.5” OD

Inconel 740 **Haynes 230** **Inconel 617**

Task 1: Conceptual Design

- Task Complete
- 37.9 MPa (5500 psig)
- 732/760ºC (1350/1400ºF)
- 45.2% Efficiency
- Key Material: IN740

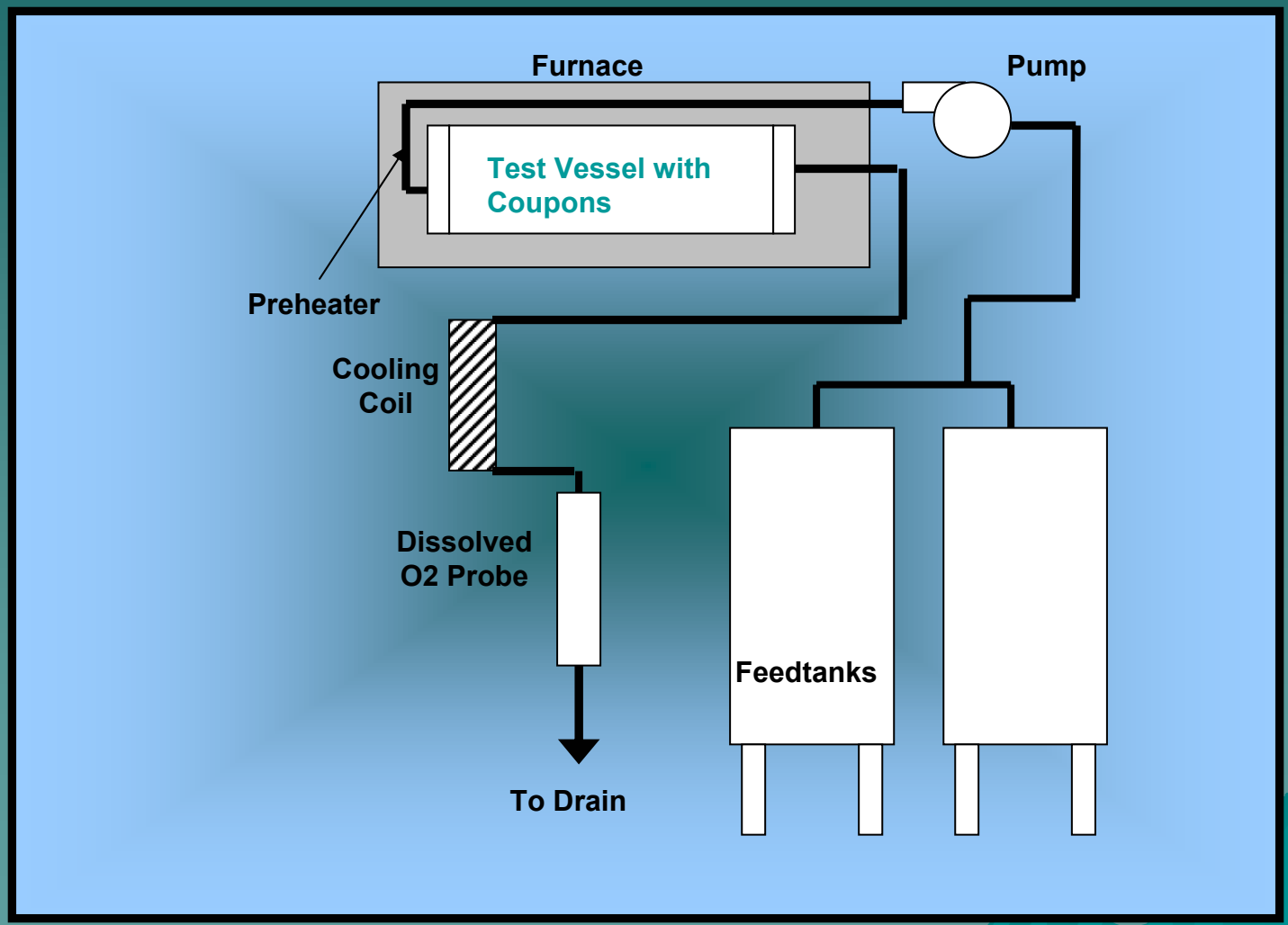


Estimated Plant Efficiencies for Various Steam Cycles (Ref. P. Weitzel and M. Palkes)*

Description	Cycle	Reported at European Location (LHV/HHV)	Converted to U.S. Practice[4] HHV
Subcritical	16.8 MPa/538°C/538°C		37
Supercritical	24.5 MPa/565°C/565°C/565°C[3]		40.9
ELSAM (Nordjyland 3)	28.9 MPa/580°C/580°C/580°C	47/44	42
State of the Art Supercritical (LEBS)	31.5 MPa/593°C/593°C/593°C[3]		42.3
Thermie	38 MPa/700°C/720°C/720°C	50.2/47.7	46.43
DOE/OCDO USC Project	38.5 MPa/760°C/760°C 38.5 MPa/760°C/760°C/760°C		46.5 47.5 - 48

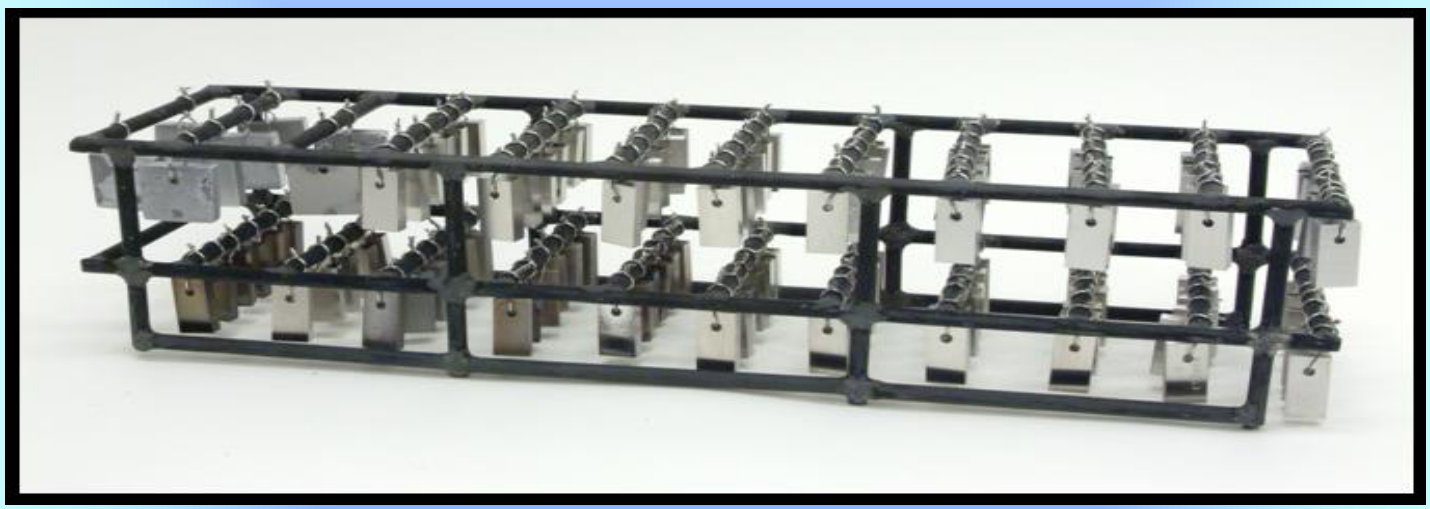
3. Eastern bituminous Ohio coal.
4. Reported European efficiencies are generally higher compared U.S. due to differences in reporting practice (LHV vs HHV), coal quality, auxiliary power needs, condenser pressure and ambient temperature and many other variables. Numbers in this column for European project numbers are adjusted for U.S. conditions to facilitate comparison.

Task 3: Steam Oxidation Tests



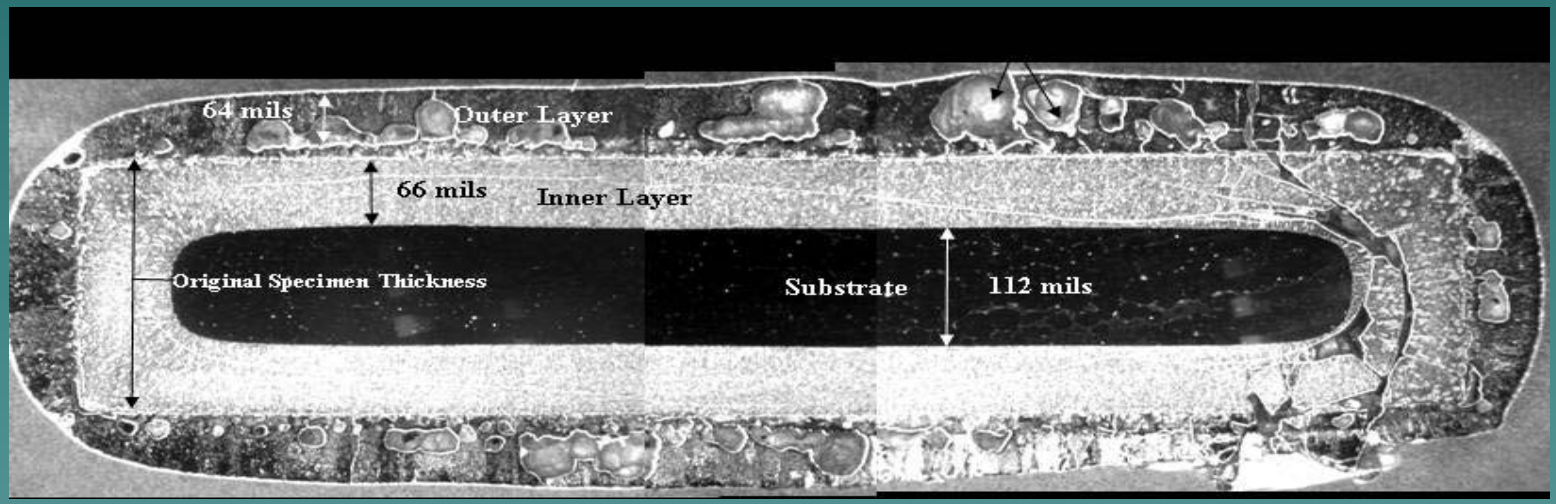
Task 3: Steam Oxidation Tests

650°C Test



Task 3: Steam Oxidation Tests

- Trial #2 – Results



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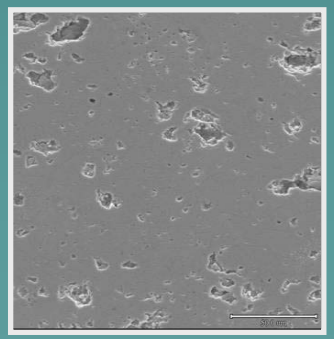
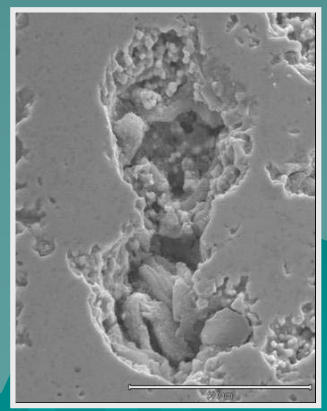


Inner Layer Porosity

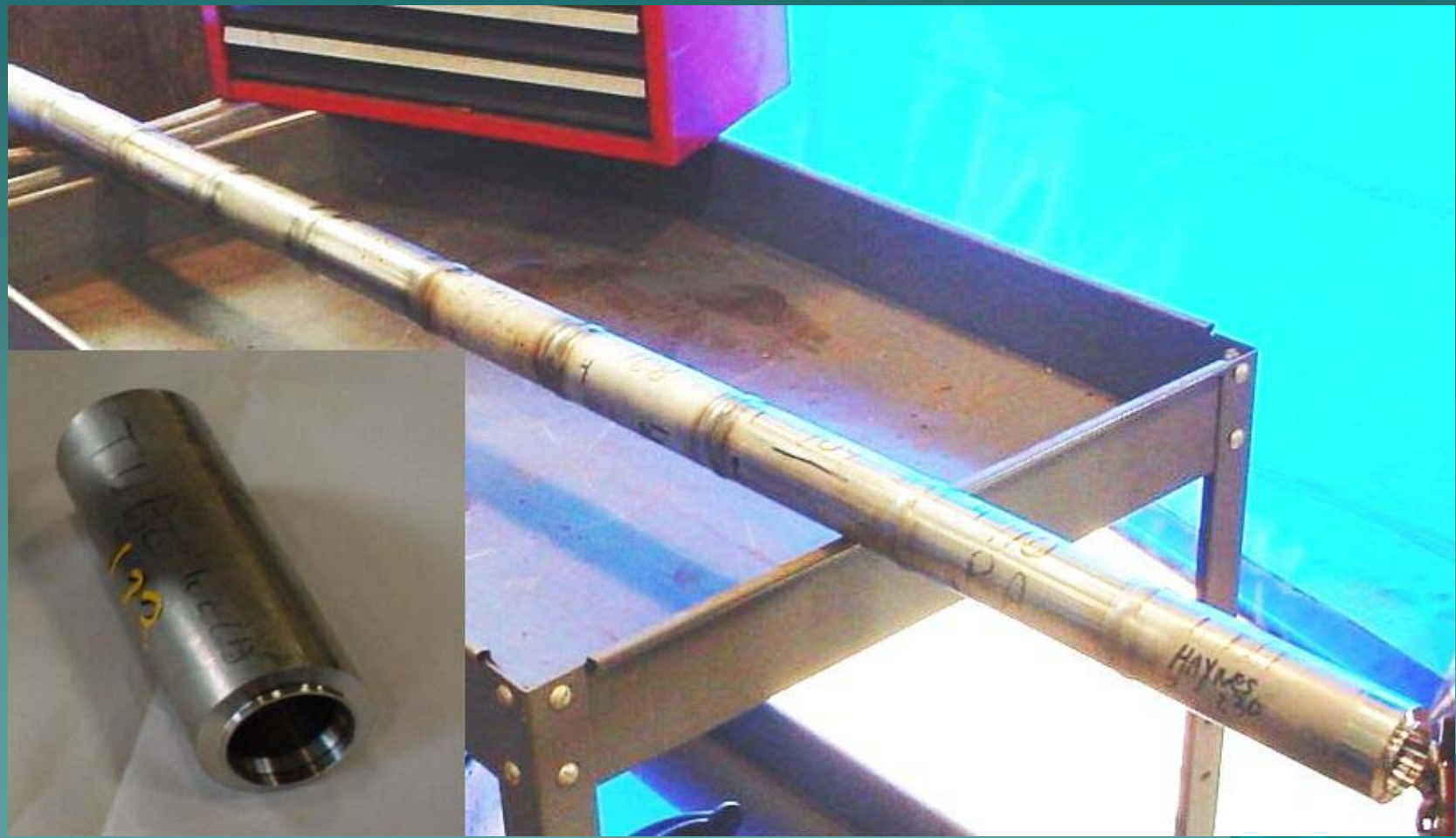
Outer Layer Porosity



Task 4: Fireside Corrosion

Test Loop Fabrication

Orbital Welds to Join Sections



Task 4: Test Loop Fabrication
Closer View of Orbital Welds

Task 4: Weld Overlay & Machining
Test Loop Sections

Task 6: Fabricability
Cold U-bending Trials
Dies with Bend Radii (R) = 3”, 5”, 7-1/2”

- Strain = 100(r)/R (Sect.1ASME B&PV Code, PG-19)
  r = tube radius = 1”, R = bend radius
- For R = 3”, Strain = 33.3%
- For R = 5”, Strain = 20.0%
- For R = 7-1/2”, Strain = 13.3%

Cold U-bending Trials

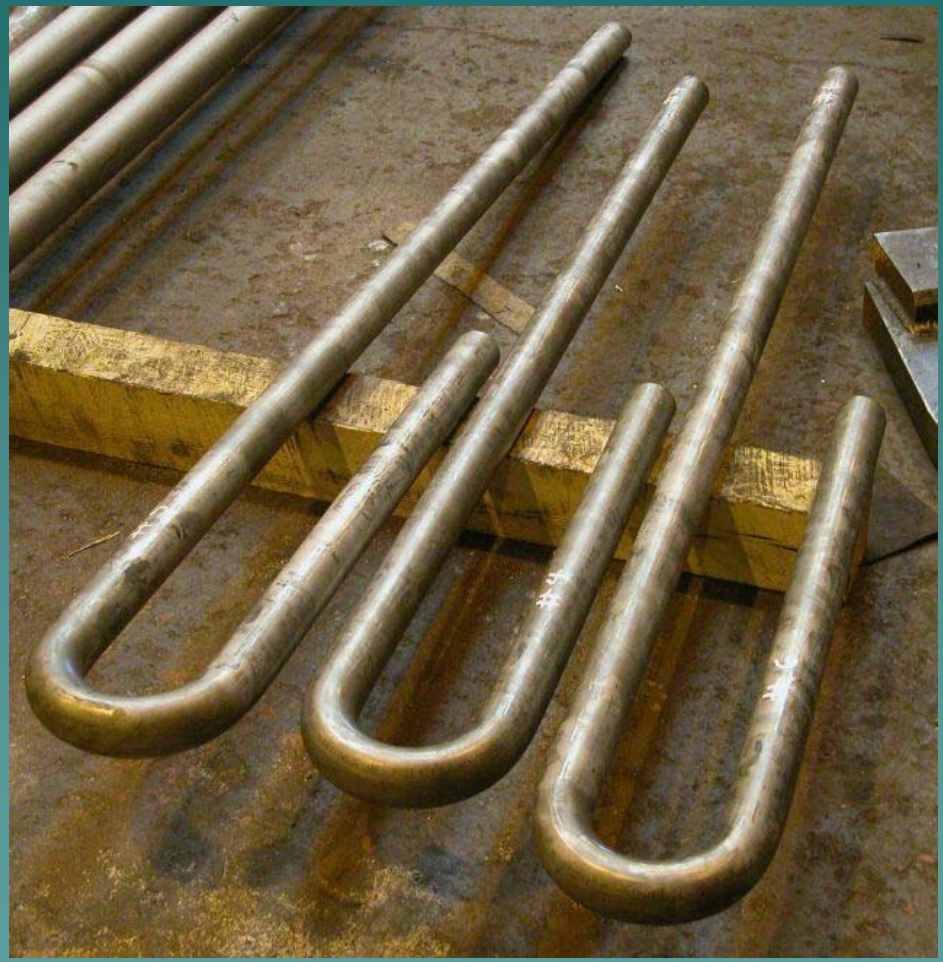
Alloy 230 Results: R = 3”, 5”, 7-1/2”

Cold U-bending Trials

Alloy 230 Results: R = 3”, 5”, 7-1/2”

Cold U-bending Trials

Alloy 230 Results: R = 3”



Hot Resizing Trials
Alloy 230 Results: R = 2-1/4”

Hot Resizing Trials
Alloy 230 Results: R = 2-1/4”

To Summarize

- A new US effort is underway to advance steam cycle materials sponsored by USDOE and OCDO
- A strong team has been assembled to test new materials and fabrication methods in the lab and field
- This will lead to a long-term goal of advanced, highly-efficient cycles capable of competing on the world market for coal-fired power plants