Looking Back and Charging Forward: Twenty Years of Materials Progress on the Fossil Energy Research Program

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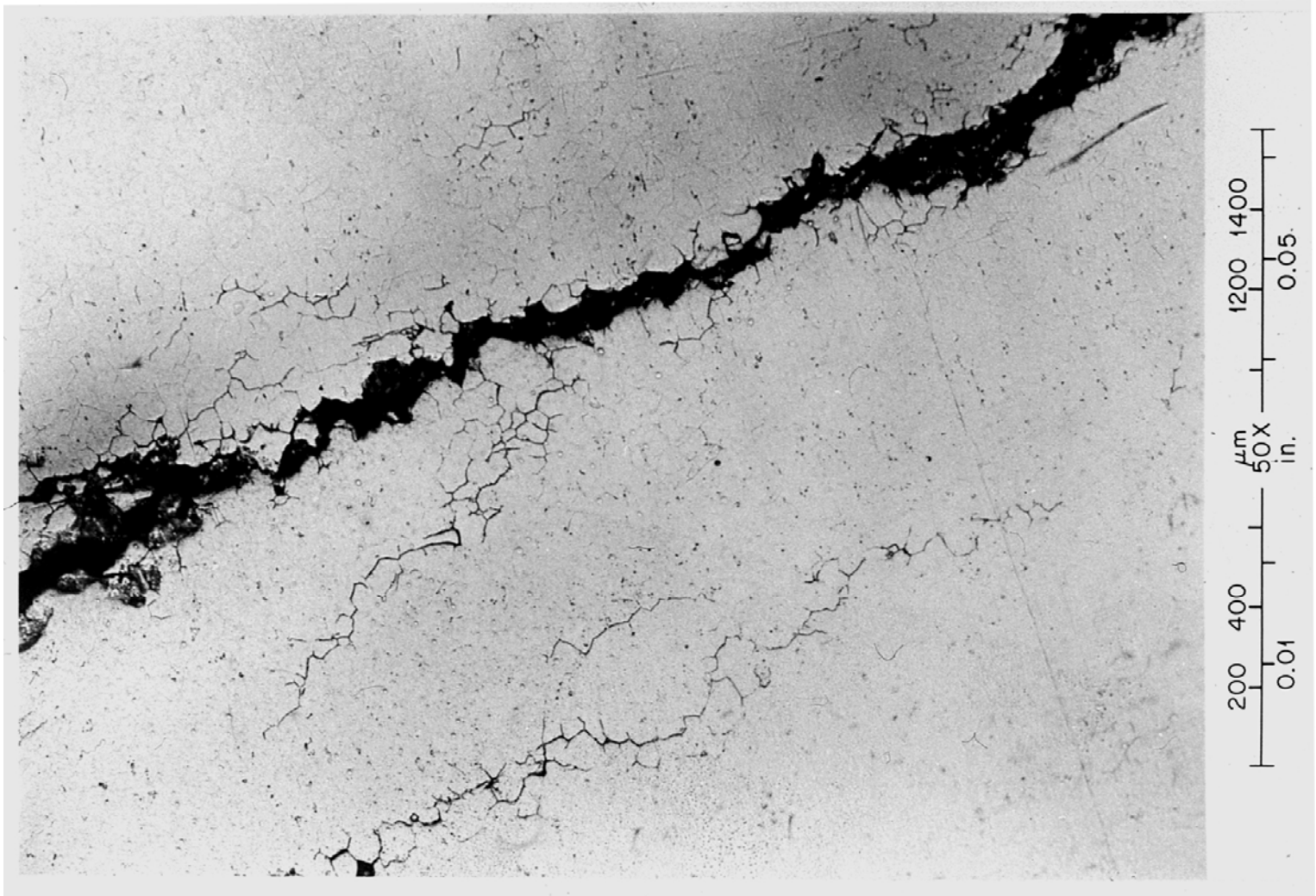
Much of the Early Work Addressed Materials Failures in Pilot Plants

- Direct Coal Liquefaction Plants
- Coal Gasification Plants
- Atmospheric Fluidized Bed Combustors
- Pressurized Fluidized Bed Combustors
- Hot Gas Filters
- Pumps
- Piping
- Valves
  - Ball valves
  - Pressure let-down valves

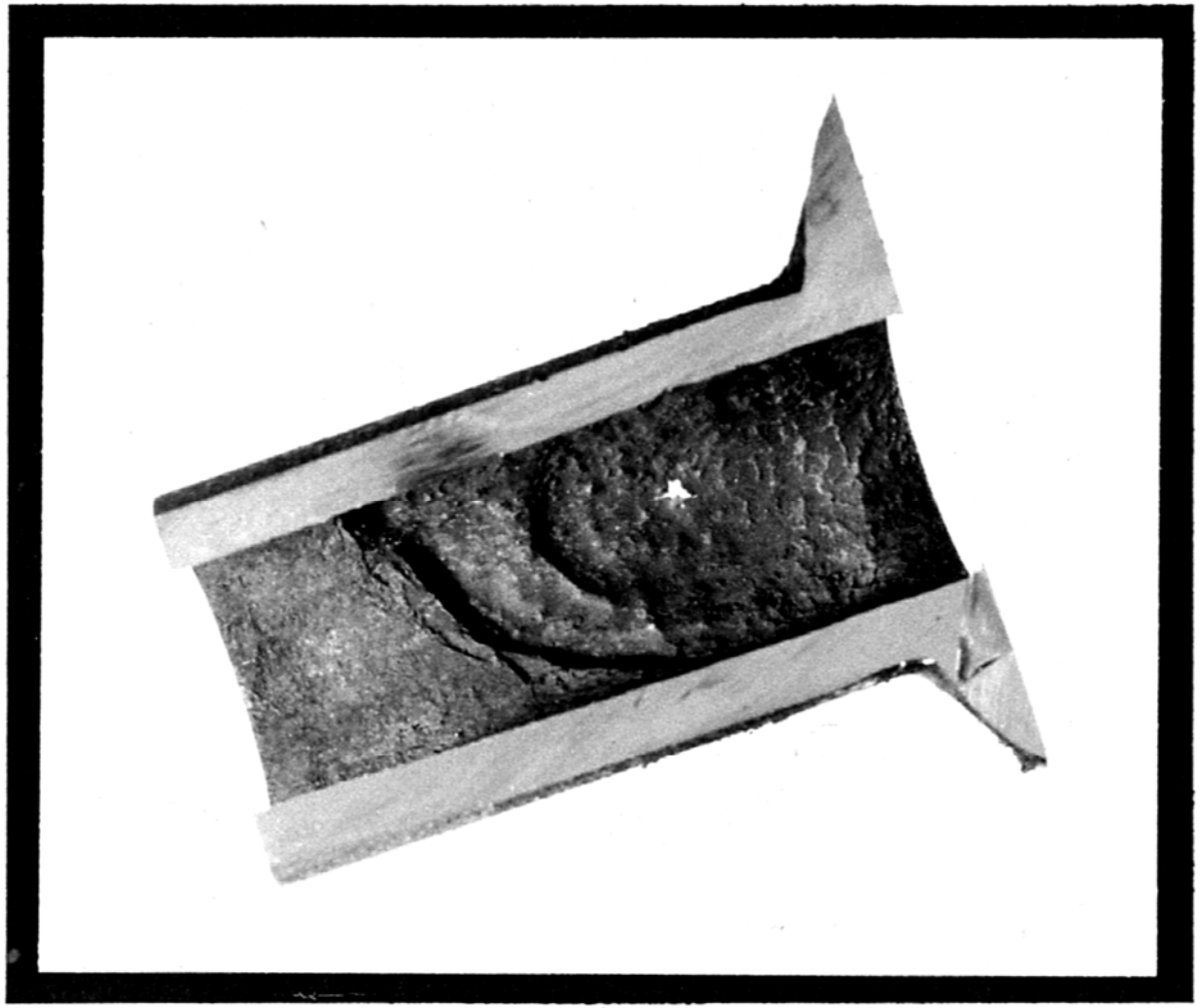
(Erosion, Corrosion, and Wear Received Much Attention)

There Was Fractionation Column Corrosion

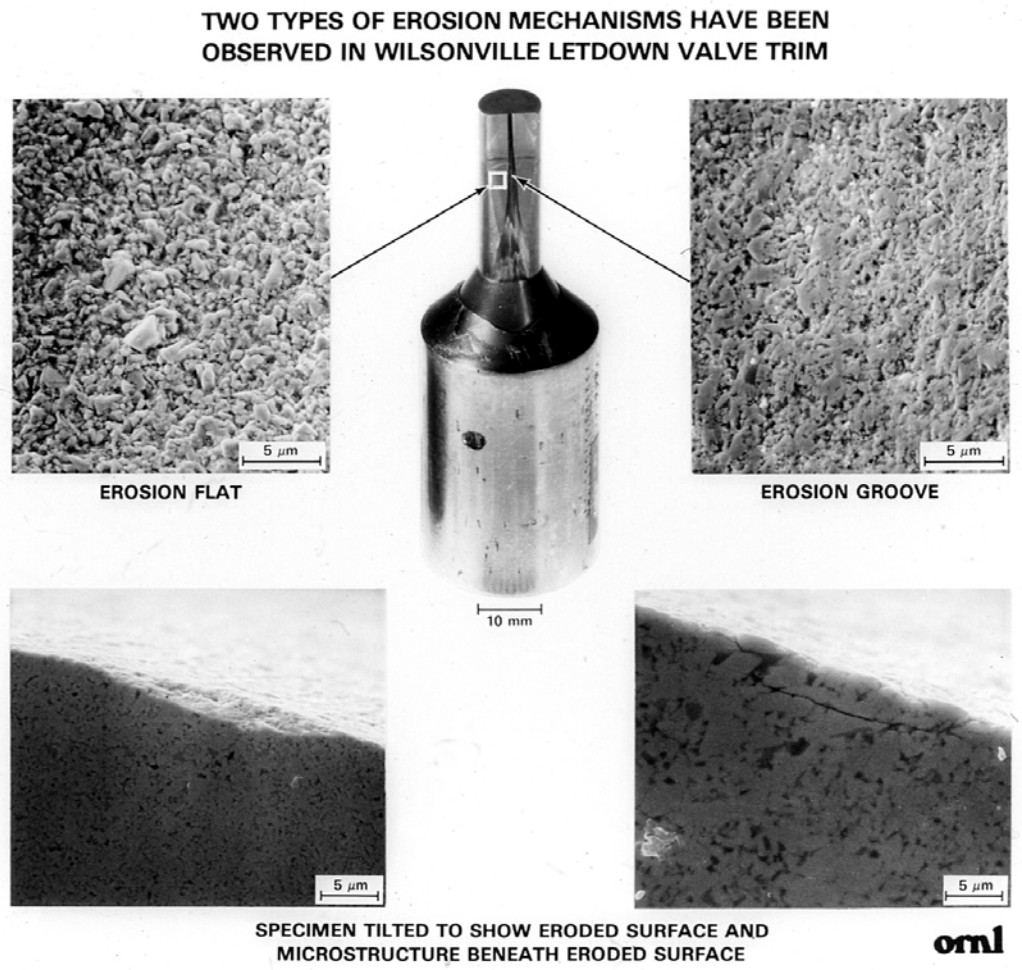
Stress Corrosion Cracking Was Pervasive



Erosion-Corrosion Was Ruining Process Lines

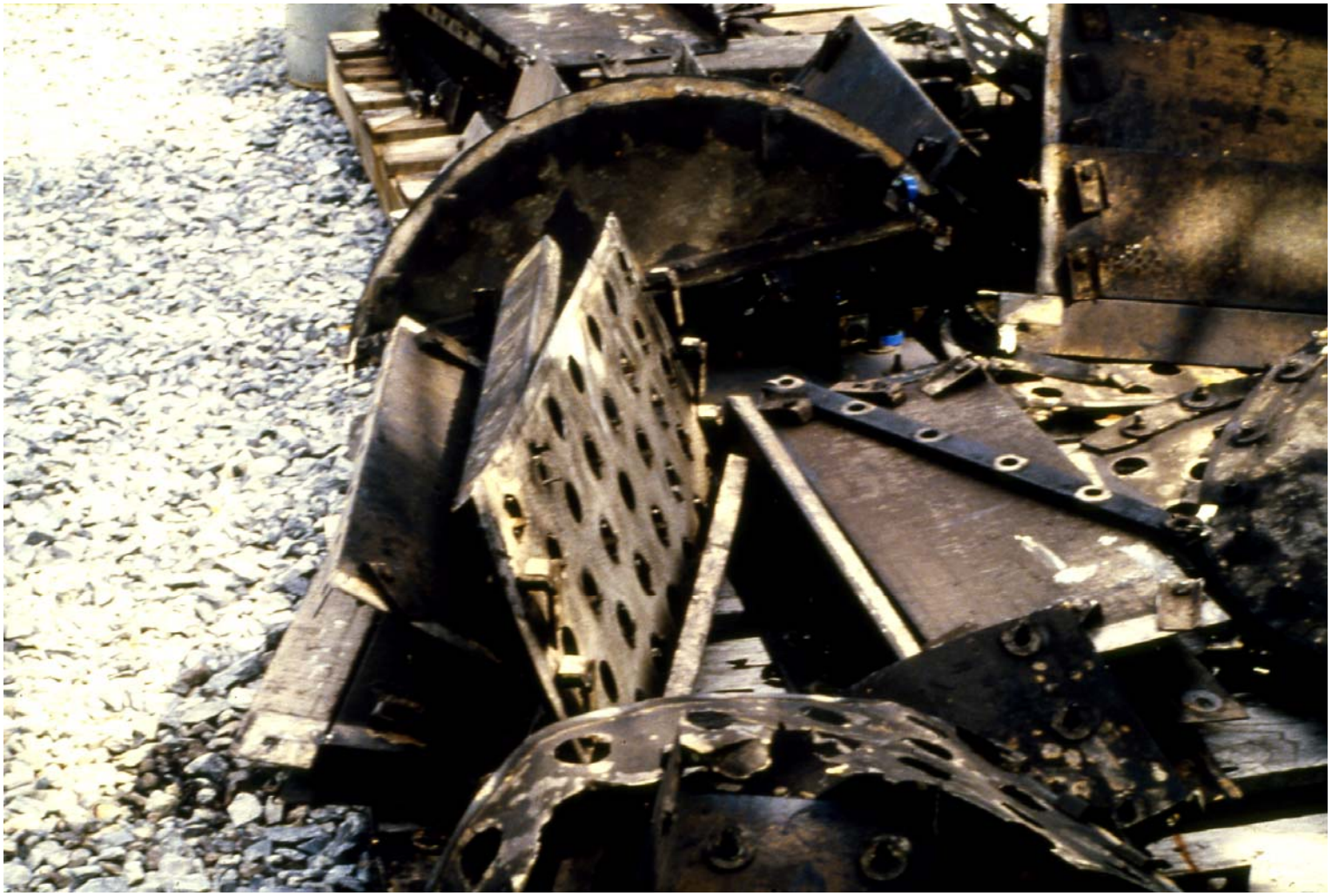


Pressure Letdown (Control) Valves Weren't Working



Pumps Weren’t Pumping

Systems Were Literally Falling Apart



(We Needed Materials Solutions Before Plants Were Built)

Some Concepts Present Particularly Difficult Materials Problems

- Direct Coal-Fired Turbines
- Coal Fueled Diesels
- Externally Fired Combined Cycles
- Integrated Gasification Combined Cycles
- Hot Gas Filtration
- Gas Separations
- Ultrasupercritical steam cycles
- FutureGen

Sometimes These Issues Seemed Overwhelming…

…and we needed direction, but of course…

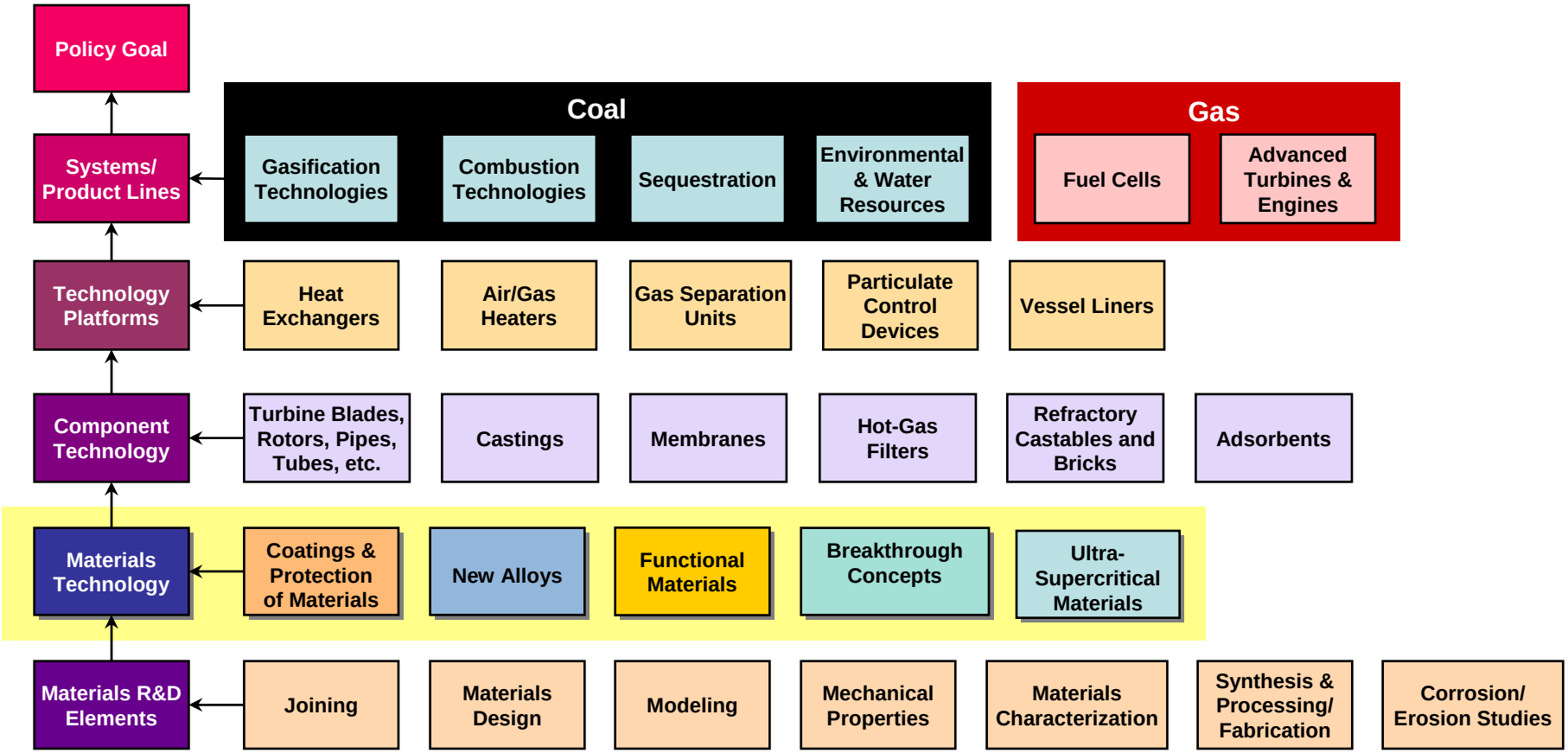
Real Men Don't Ask For Directions

Somehow reason prevailed and…

A Disciplined Approach was Used to Systematically Address Materials Issues

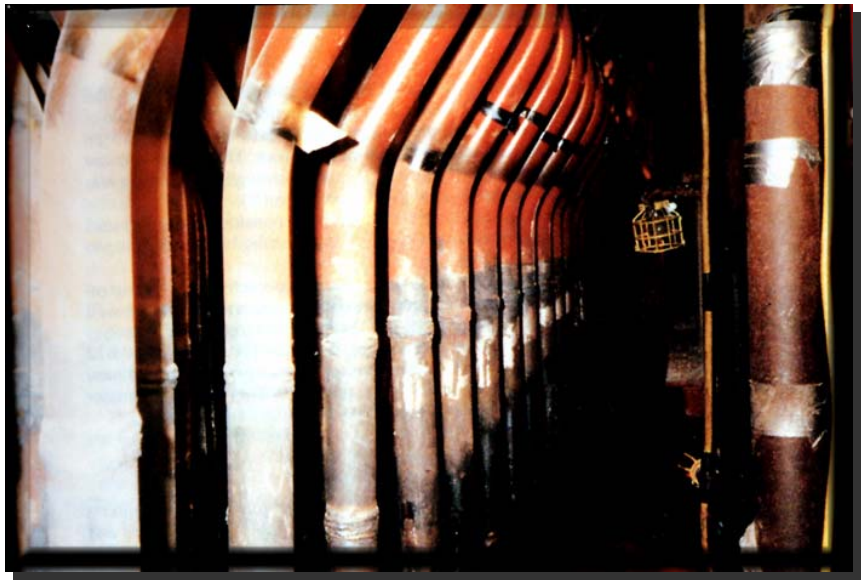
- Commitment to long-range R&D
- Invention/Discovery to Technology Transfer
- Cross-cutting approach
- Extend the Envelope of Materials Performance
- Team with Other DOE Programs
  - BES
  - EERE
- National Laboratory/Industry/University Collaborations
  - Seven National Laboratories
  - Thirty Universities
  - Fifty Industrial/Not-for-Profit Research Institutes

A Comprehensive R&D Plan Was Developed



The “Super 9 Chrome” Alloy Development and Commercialization is a Marvelous Success Story

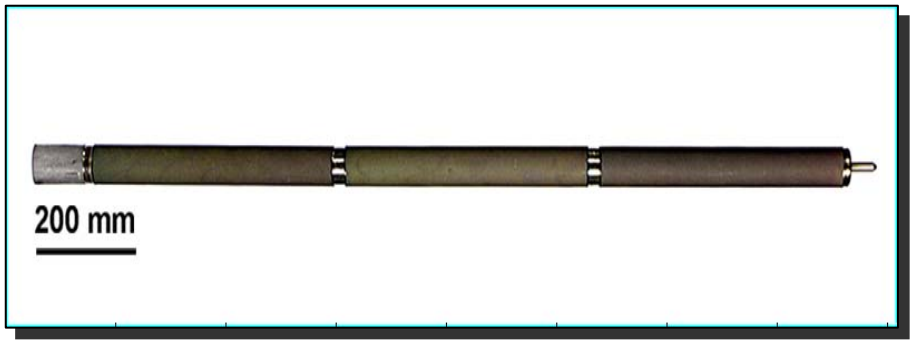
- Recognized worldwide as one of the most significant ferritic steel developments for pulverized coal power plants
- ASME Boiler and Pressure Vessel Code material
- Significantly improved power plant performance and efficiency
- Now in use in numerous plants around the world
- Produced and fabricated in the United States, Japan, and Europe
- Estimated sales exceed $1.0 billion



Photograph of an actual installation of Super 9 Chrome steam lines in the TVA Kingston (Tennessee) Steam Plant

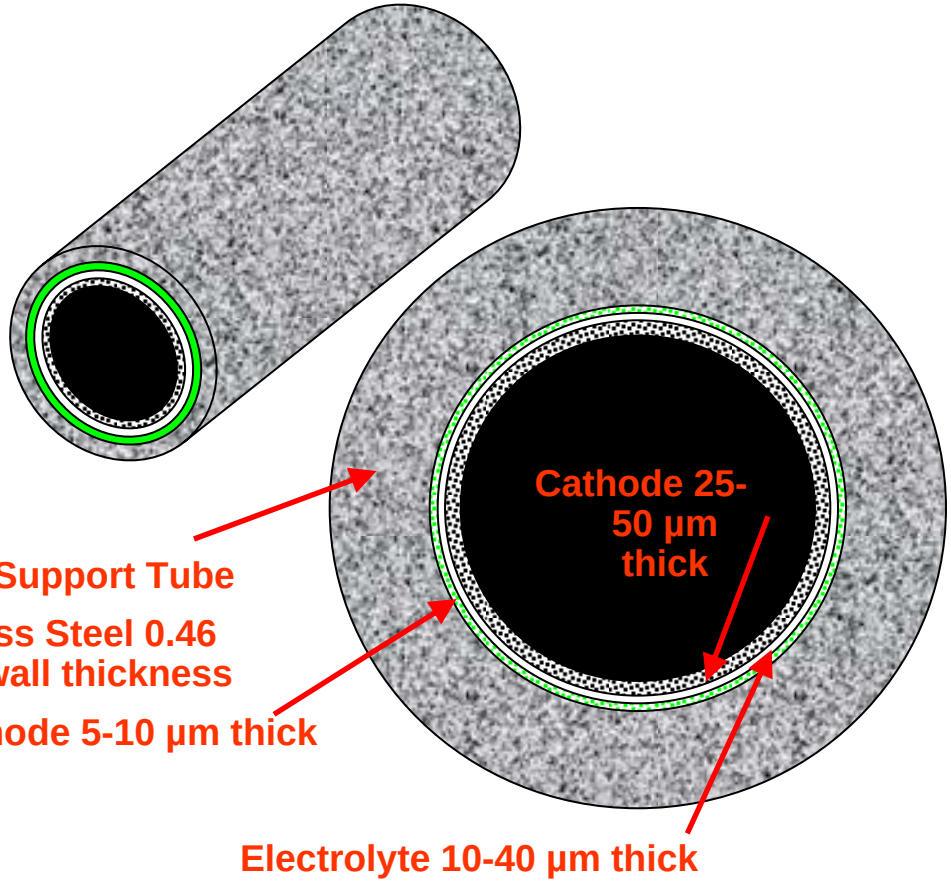
Pall Corporation has Commercialized Iron Aluminide Hot Gas Filters

- Filters are used in coal combustion and coal gasification environments
- Applicable for use to 800°C
- Evaluations have been conducted in several facilities including the Power Systems Development Facility (Wilsonville, AL)
- A full complement of iron aluminide filters is used in the Wakamatsu (Japan) pilot plant
- This development has effectively solved many of the technical hot-gas filter issues in coal gasification
- Over 1500 recently sold for a major IGCC plant

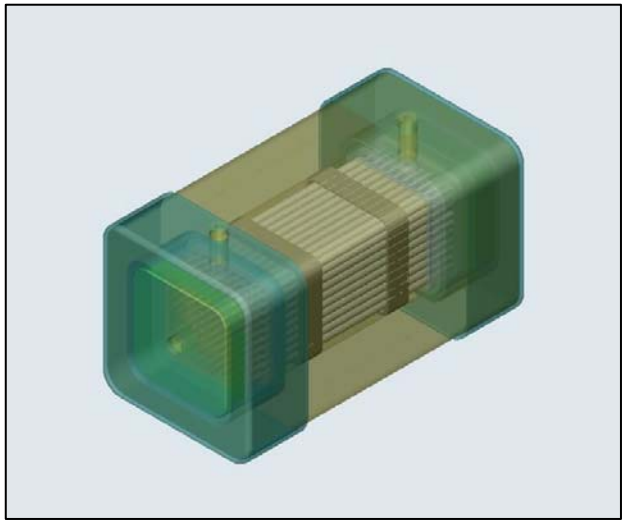


Photograph of a commercial iron aluminide filter manufactured by Pall Corporation in their Cortland, NY, plant

ORNL and Worldwide Energy are Collaborating on a Novel Fuel Cell Concept Based on the ARM-Developed Membrane Technology



The ORNL/WE Porous Metal Supported Tubular SOFC has Several Unique Characteristics



- Metallic support:
  - allows for simple braze and weld sealing
  - provides rigid high strength support
  - in contact with fuel so no oxidation
  - acts as anode-side current collector
- Design eliminates need for separate interconnect
- Membranes co-fired onto metallic support
  - No vapor phase deposition of any kind required
- Fuel cell membrane on inside of tube and in compression - stronger configuration
- Conventional materials can be used with proprietary support

The WE Porous-Metal-Supported SOFC Offers Several Advantages over Planar SOFCs

- Easily and simply sealed
- Robust handling
- Tolerant to thermal cycling
- Low-cost fabrication
- Eliminates interconnect
- Not susceptible to chromium migration
- Rapid start up
- Lower material costs
- Improved mechanical properties
- Simplified stack design

The Approach Has Worked Well and Resulted in Large Returns on Investment

- Twelve R&D 100 Awards
- Over Twenty Commercial Licenses
- Over $2.0 Billion in Sales of Components Based on Program Developments
- Numerous Transitions to Technology Programs

Can We do as Well in the Next Twenty-five Years?

- The USA and the world will face great energy challenges with ever increasing environmental constraints
- Advanced fossil energy power systems will be needed
- The Advanced Research Materials Program is poised to have even greater impacts on future energy systems
  - Novel materials for gas separation
  - Fuel cell materials
  - Next generation stainless steels with higher strength and better oxidation resistance
  - Advanced coatings
  - Prescriptive materials design and lifetime prediction for extreme environments