PROGRAM facts

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Power Systems Advanced Research

07/2008

ADVANCED RESEARCH MATERIALS PROGRAM

Description

The Advanced Research (AR) Materials Program addresses materials requirements for all fossil energy systems, including materials for coal fuels technologies and for advanced power generation technologies such as coal gasification, heat engines such as turbines, combustion systems, and fuel cells. The program is led by the National Energy Technology Laboratory (NETL) within the Office of Fossil Energy (FE) of the U.S. Department of Energy (DOE). It is implemented through research and development (R&D) agreements with other national laboratories, industry, and academia.

The program strategy is to provide a materials technology base to assure the success of coal-derived fuels and advanced power generation systems being pursued by DOE FE. These systems include the demonstration of multiple commercial-scale Integrated Gasification Combined Cycle (IGCC) or other clean coal power plants with cutting-edge carbon capture and storage (CCS) technology under the Department's restructured FutureGen approach. The foundation of this technology base is centered in high-temperature materials research and in developing materials for ultra supercritical (USC) steam and gas separation systems.

Technology transfer mechanisms include early industry R&D participation to ensure timely commercial assessment, outreach activities to seek corporate partners, cooperative process scale-ups or application evaluations, and industrial partnerships. Widespread participation by industrial partners, universities, non-profit agencies, and national laboratories helps maintain U.S. materials technology capabilities and competitiveness.

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Advanced Research — To support coal and power systems development, NETL's Advanced Research Program conducts a range of pre-competitive research focused on breakthroughs in materials and processes, coal utilization science, sensors and controls, computational energy science, and bioprocessing — opening new avenues to gains in power plant efficiency, reliability, and environmental quality. NETL also sponsors cooperative educational initiatives in University Coal Research, Historically Black Colleges and Universities, and Other Minority Institutions.

CURRENT CORE RESEARCH PROJECTS

Albany Research Center
Albany, OR
- Steam turbine materials and corrosion
- Low-chrome/chrome-free refractories for slagging gasifiers

Ames Laboratory
Ames, IA
- New processing developments in metallic powders for fossil energy applications

Argonne National Laboratory
Argonne, IL
- Materials performance in CO_2 environments
- Development of non-destructive evaluation methods for ceramic coatings
- Fireside and steamside corrosion of alloys for USC plants

Babcock & Wilcox
Barberton, OH
- USC materials plant trials

Electric Power Research Institute
Palo Alto, CA
- Nanocoatings for USC applications

Energy Industries of Ohio
Independence, OH
- Boiler materials for USC coal power plants
- Steam turbine materials for USC coal power plants

Foster Wheeler Development Corporation
Livingston, NJ
- In-plant corrosion probe tests

Idaho National Laboratory
Idaho Falls, ID
- Microstructure and properties of HVOF-sprayed Ni-50Cr coatings

Lehigh University
Bethlehem, PA
- High-temperature corrosion resistance of coatings in low NO_x environments

Goals

The general goals of the Materials Program are to bridge the gap between basic and applied research, foster development of innovative advanced power systems, and improve efficiency and environmental performance while reducing costs. The program's charter is generic and crosscutting, having broad applicability to a range of conventional and advanced fossil energy technologies. The program has long-range objectives, encompassing materials R&D from invention/discovery to the exploratory stage to ultimate commercialization. The payoffs from program initiatives are potentially high as they provide critical supporting technology for advanced fossil energy systems.

Key program objectives include:

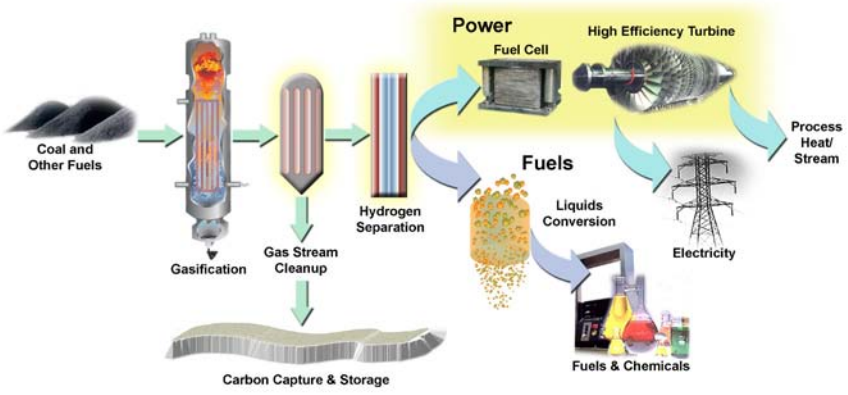
- Development of new alloys that offer improved corrosion and erosion resistance, and have unique mechanical properties;
- Development of high-performance materials, particularly alloys, that can perform reliably at temperatures well over 1,000 °C;
- Development of advanced metallic and ceramic coatings to provide thermal and environmental protection;
- Protection of materials to counter degradation resulting from harsh fossil energy environments;
- Development of functional materials, particularly gas separation materials such as activated carbons and inorganic membranes, both porous and ion-transport types;
- Pursuit of breakthrough concepts, based on mechanistic understanding from any discipline, for routes to the development of materials with capabilities beyond those currently available.

Accomplishments

Some of the most interesting recent advances have come from long-term research to qualify and develop advanced materials for use in improved, USC steam boilers. Examples of accomplishments include the following:

- Babcock & Wilcox researchers have identified ferritic steels that resist steam oxidation at high temperatures as well as — or better than — more expensive austenitic steels.
- Researchers at ALSTOM Power have shown that applying advanced coatings to less expensive alloy compositions provides an alternative to using costly, highly alloyed materials for next-generation boiler designs.
- Investigators at Riley Power Inc. developed and met ASME standards for a welding procedure for an advanced steel known as SAVE 12. This high-chrome alloy is a candidate material for construction of advanced coal-fired boilers.

- University of Cincinnati researchers found that ceramics based on mixed metal niobates and tantalates are particularly promising as protective coatings against aggressive environments associated with the high temperatures needed to produce greater boiler efficiencies.
- Researchers at Oak Ridge National Laboratory (ORNL) developed a neural net program to guide heat treatment procedures for advanced alloys. These improved methods can increase the energy efficiency of the process and minimize waste.
- Over $1.5 billion in sales have been made of components made from the ORNL-developed 9Cr-1 Mo alloy identified commercially as T91 and P91.
- A hot-gas filter by Pall Corporation made of ORNL's iron aluminide alloy has been commercialized; approximately 2000 are now in use.
- Over 15 products have been commercialized by Pall Corporation based on the ORNL inorganic membrane technology.
- ORNL continuous fiber ceramic composite filter technology has been licensed to the 3M Company.
- ORNL carbon fiber composite molecular sieve and electrical swing adsorption technology has been licensed to Zetek Corporation for removal of CO_2 from gas streams.
- Commercialization by REMAXCO Corporation is in progress for silicon carbide fibrils made by the vapor-liquid-solid, or VLS, process.
- Technology transfer and commercialization are in progress by Worldwide Energy of a porous metal supported solid oxide fuel cell based on the ORNL inorganic membrane technology.
- Inorganic microporous inorganic hydrogen separation membrane technology has been transferred to the DOE-FE coal gasification and fuels program.
- Advanced alloys are being transferred to a commercialization project by Shell Exploration and Production Company on an ongoing basis.



Advanced materials are essential to coal fuel and advanced power generation systems

CURRENT CORE RESEARCH PROJECTS (cont.)

Los Alamos National Laboratory
Los Alamos, NM
- Metal membranes for hydrogen separation

Oak Ridge National Laboratory
Oak Ridge, TN
- Advanced ceramics and alloys research
- Alumina forming austenitic stainless steel
- Assessment of USC boiler materials
- Oxidation resistant coatings
- Oxide dispersion strengthened (ODS) alloys
- Metallic slurry coatings
- USC steam turbine materials

Pacific Northwest National Laboratory
Richland, WA
- Brazing technology for gas separation membranes

ReMaxCo Technologies, Inc.
Oak Ridge, TN
- Pilot facility for production of silicon carbide fibrils

Tennessee Technological University
Cookeville, TN
- Aluminide coatings for power generation applications

University of California – San Diego
La Jolla, CA
- Optimization of ODS-Fe3Al and MA956 alloy heat exchanger tubes

University of Liverpool
Liverpool, UK
- Control of defects and microstructure in ODS alloys

University of North Dakota Energy and Environmental Research Center
Grand Forks, ND
- Corrosion and joining of FeCrAl alloys for very high-temperature heat exchangers

CURRENT CORE RESEARCH PROJECTS (cont.)

University of Tennessee
Knoxville, TN
- Effects of W on the microstructures of TiAl-based intermetallics

West Virginia University
Morgantown, WV
- Influence of impurities on ductility of Cr-based alloys and in-situ mechanical property measurement

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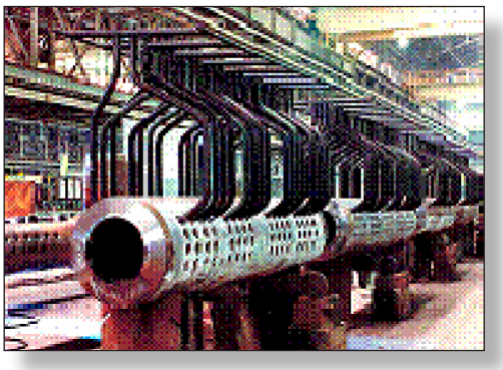
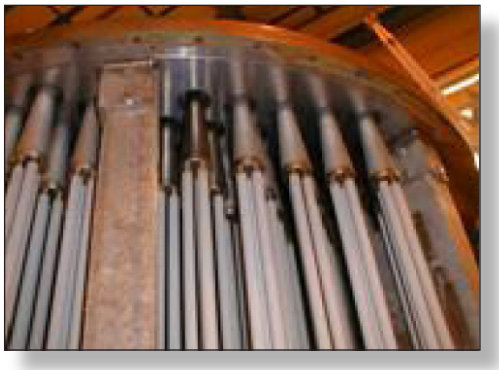


Fabrication of headers for steam systems



Hot gas filtration system

Tube bend typical of those needed for USC systems, after high-temperature steam exposure

Creep failure of a tube bend as a result of cold work (strain hardening)