NETL

the ENERGY lab

PROGRAM FACTS

Advanced Research Materials

Advanced Research Materials Program

Description

The Advanced Research (AR) Materials Program addresses materials requirements for all fossil energy systems, including materials for advanced power generation and coal fuels technologies. Examples of these technologies include coal gasification, heat engines such as turbines, combustion systems, fuel cells, hydrogen production, and carbon capture technologies. 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 advanced power generation systems being pursued by DOE-FE. These systems include advanced ultra-supercritical combustion systems (AUSC), Integrated Gasification Combined Cycle (IGCC), fuel cells, gas turbines, and carbon capture and storage (CCS) technology developed to fulfill the DOE's mission to achieve near-zero emissions for power generation. The foundation of this technology, centered in high-temperature materials research, includes the development of new materials that have the potential to improve the performance and/or reduce the cost of existing fossil fuel technologies; development of materials for new systems and capabilities; development of a technology base in the synthesis processing life cycle analysis; and performance characterization of advanced materials.

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.

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

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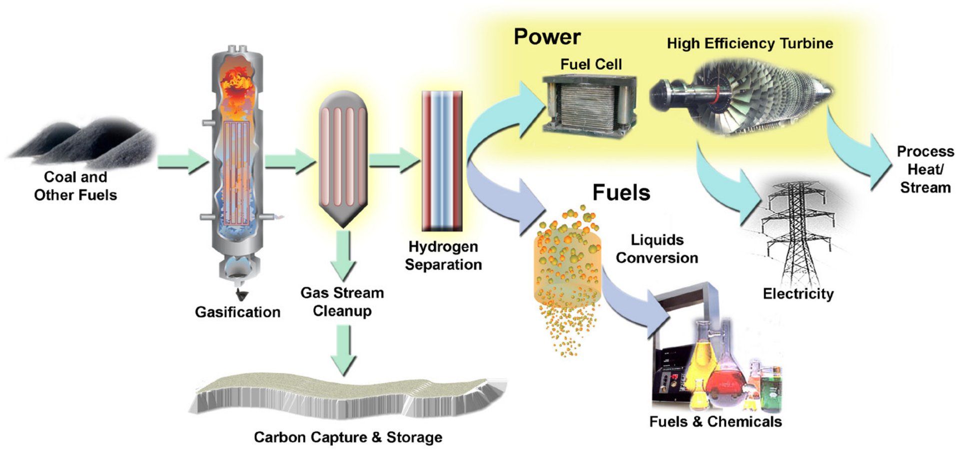
Goals

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 through 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 fall under these areas, known as clusters:

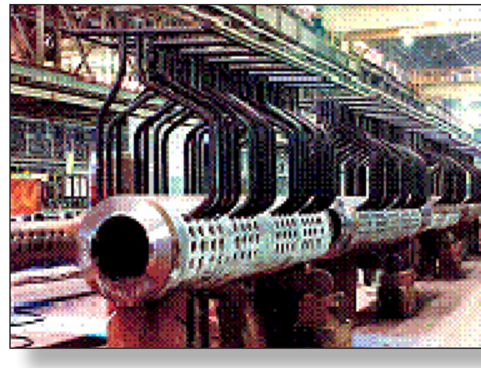
- Development of new alloys that offer improved corrosion and erosion resistance, and have unique mechanical properties.
- Development of materials for use under Advanced Ultra-Supercritical (AUSC) conditions of 760 degrees Celsius (°C) and 350 bar pressure (500 pounds per square inch)
- Development 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 that serve a unique purpose, such as energy storage.
- Pursuit of breakthrough concepts, based on mechanistic understanding from any discipline, for routes to the development of materials with capabilities beyond those currently available. Computational design of materials has the potential to provide major breakthroughs.



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

Program Successes

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

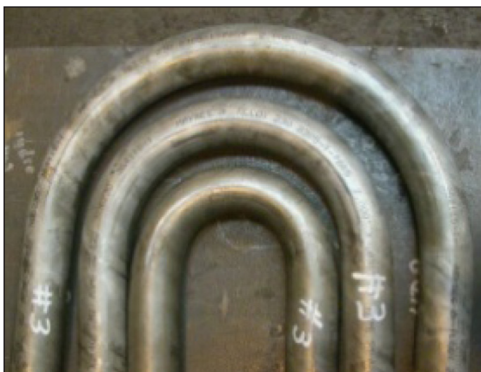


Fabrication of headers for steam systems.

- Inconel 740 has been submitted to the ASME for pressure vessel code case approval.
- NETL has successfully casted nickel alloys that previously were used in wrought form only. These alloys have the potential to be used as cast casings for AUSC steam turbines.
- 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.
- Completed development of welding procedures on advanced alloys for both thick and thin section product forms in AUSC boiler applications.
- 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 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.

Benefits

Materials and process technologies developed under projects sponsored by the DOE NETL's Advanced Research Materials program will be used to solve problems associated with high-temperature operation in current power generation systems. Advances in ultra-supercritical coal combustion systems could increase efficiencies in coal-fired power plants to 50 percent and decrease carbon dioxide emissions by 30 percent. In addition, AUSC systems provide more complete combustion of coal, contributing to fuel conservation and reductions in cost of electricity. Improvements in the use of integrated gasification combined cycle plants will allow capture and sequestration of carbon dioxide as well as reduction in other emissions resulting from the use of coal for generating power. Advanced materials will also be used to develop hybrid cycles incorporating partial gasification and fluid bed combustion. Improved and new materials able to perform well in the high-temperature, high-pressure, and corrosive environments found in power plants will enable increases in efficiency and reduction in emissions critical to providing energy security for the U.S. as well as improved environmental management.



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

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