Advanced Materials for Ultra Supercritical Boiler Systems

CONTACTS

Robert R. Romanosky
Technology Manager
Advanced Research
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4721
robert.romanosky@netl.doe.gov

Patricia A. Rawls
Project Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-5882
patricia.rawls@netl.doe.gov

Robert M. Purgert
Prime Contractor and Administrator
Energy Industries of Ohio
6100 Oak Tree Boulevard, Suite 200
Independence, OH 44131-6914
216-643-2952
purgert@msn.com

Description

A consortium led by the U.S. Department of Energy (DOE) Office of Fossil Energy (FE) has conducted the first phase of a multiyear program to develop materials technology for use in advanced ultra supercritical (USC) coal-fired power plants. The advanced materials developed in this project are essential for construction of coal-fired boilers with advanced steam cycles involving much higher temperatures and pressures than those presently used in conventional pulverized coal (PC) power plants. These higher operating conditions will enable the achievement of much higher efficiencies with the added advantage of reducing emission of carbon dioxide and other effluents as well as solid waste products.

As part of the first project phase, lasting five years, new high-temperature, corrosion-resistant alloys capable of operating at temperatures as high as 1400 ºF have been selected, evaluated, fabricated, and tested in corrosive environments simulating the boiler conditions. A second phase has been initiated with a duration of three years to include development of a USC boiler design that would allow for the firing of coal with oxygen and recycled flue gas — commonly known as OXY fuel — instead of air.

Funded by DOE with co-funding by the Ohio Coal Development Office (OCDO) and the consortium partners, the project is managed by the National Energy Technology Laboratory (NETL) Advanced Research (AR) Program. Other consortium participants include Energy Industries of Ohio (the prime contractor), the Electric Power Research Institute (EPRI), Oak Ridge National Laboratory (ORNL), and four major U.S. boiler manufacturers: Babcock & Wilcox Company (B&W), Foster Wheeler, Riley Power (a Babcock Power, Inc. company), and Alstom Power.

Goals

The goals of this research are to identify improved alloys, fabrication processes, and coating methods that allow boilers to operate at 1400 ºF; lay the groundwork for code approval by the American Society of Mechanical Engineers (ASME); explore and define issues affecting the design and operation of USC plants operating at even higher temperatures, up to 1,600 ºF; and — working with alloy makers, equipment vendors, and utilities — aim to develop cost targets and promote commercialization of alloys and processes expected to emerge from this effort.

Technical Approach and Accomplishments

Following an initial conceptual design phase, six alloys were selected based on creep strength (the ability to resist strain under constant load over time): two austenitic steels specifically for superheater/reheater tubes, two ferritic alloys for waterwall tubing, and two nickel (Ni) based alloys for heavy wall piping. Mechanical testing of these alloys was done to determine their strength. Steam side corrosion susceptibility was evaluated in autoclaves. Fireside corrosion tests were conducted

CONSORTIUM PARTICIPANTS

Alstom Power
Windsor, CT
Babcock & Wilcox Company
Barberton, OH
Electric Power Research Institute
Palo Alto, CA
Energy Industries of Ohio
Independence, OH
Foster Wheeler
Clinton, NJ
National Energy Technology Laboratory
Morgantown, WV
Oak Ridge National Laboratory
Oak Ridge, TN
Ohio Coal Development Office
Columbus, OH
Riley Power, Inc.
Worcester, MA
Assisted by Oak Ridge National

PROJECT DURATION

09/30/01 to 12/31/09

COST

Total Project Value
$33,179,639

DOE/Non-DOE Share
$24,432,672 / $8,746,966

ADDRESS

National Energy Technology Laboratory

1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

2175 University Avenue South
Suite 201
Fairbanks, AK 99709
907-452-2559

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

One West Third Street,
Suite 1400
Tulsa, OK 74103-3519
918-699-2000

CUSTOMER SERVICE

1-800-553-7681

WEBSITE

www.netl.doe.gov

both in the lab and in actual boilers by inserting test loops made up of several candidate alloys and coatings. Various fabrication operations typical of component manufacture were carried out. Weldability of the alloys was studied using a variety of techniques. Diffusion coatings as well as overlay coatings were tested in steam and in simulated fireside environments.

As a result of these activities, the materials and processes required for successful operation at 1400 ºF were identified, and the capability to perform many different fabrication techniques was demonstrated. Creep rupture tests showed that Inconel 740 is the strongest alloy capable of operating at 1400 ºF, followed by Haynes 230 and CCA 617. Oxidation rates of the various alloys in steam environment and the spalling susceptibility of the oxides were determined; Ni-based alloys containing the highest level of chromium were found to be the least susceptible to corrosion. Chromium diffusion coatings and high chromium overlay coatings were found to have excellent resistance to both steam side and fireside corrosion. The effect of the sulfur level in the fuel on fireside corrosion rates was determined. Welding processes and filler metals for successful welding of each alloy were identified. The limits to which tubing of each alloy can be cold bent without damage were established. Coatings and claddings capable of withstanding corrosive conditions at 1400 ºF were identified. Robust stress analysis methods for determining the effect of plant cycling on damage to headers were successfully demonstrated. Based on this work, less conservative approaches for stress calculation of cylindrical components were adopted through changes to ASME codes.

Completion of both phases of this project will enable selection of appropriate alloys and coatings required for economical construction and operation of coal-fired power plants capable of operating under varying steam conditions and using coals containing different levels of sulfur. Optimal methods for fabricating and welding these alloys will become available. The cycling studies performed will eventually enable optimization of operational and maintenance practices in power plants. Knowledge gained as to the creep strength and corrosion rates of alloys will enable appropriate inspection intervals to be defined and the remaining life of operating components to be estimated. In the continuing second phase, the potential for combining the USC technology with OXY fuel combustion technology will be explored. It is hoped that this will be a major step towards capturing and reducing carbon dioxide emissions.

Benefits

The advanced materials technology being developed in this collaborative project will enable construction of very high efficiency USC plants with greatly reduced emissions. Efficiency gains of at least 8–10 percentage points are anticipated, resulting in substantially reduced releases of carbon dioxide and other fuel-related pollutants and greenhouse gases by nearly 30 percent. The advances developed here will, at the same time, keep the cost of electricity competitive even with respect to natural gas turbine combined-cycle plants, and will also be applicable to retrofitting of existing coal-fired plants.

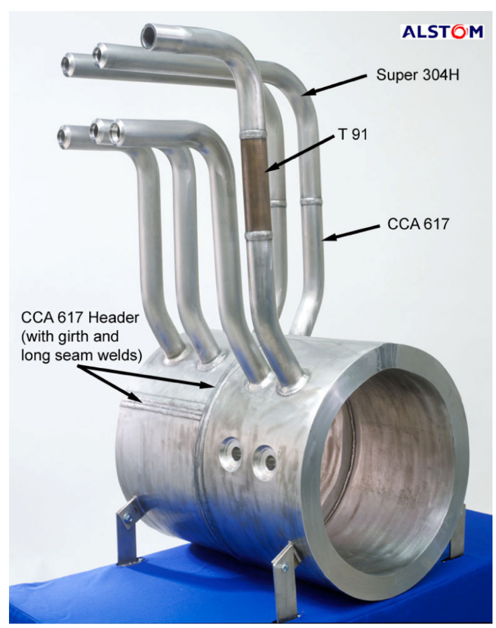

Figure 1. Demonstration header used in alloy testing