Inconel® Alloy 740/740H Code Case Approval is Major Step for Advanced Ultrasupercritical Power Plants

A consortium funded by the U.S. Department of Energy (DOE) Office of Fossil Energy and the Ohio Coal Development Office (OCDO) has successfully gained American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (B&PVC) approval for use of Inconel® Alloy 740/740H in power boilers. This is a major step by the U.S. Department of Energy in the development of high-temperature materials needed for Advanced Ultrasupercritical (A-USC) steam cycles. These materials enable steam temperatures up to 760° C (1400° F), which can dramatically improve efficiency and reduce emission of all effluents (including carbon dioxide [CO_2]) by about 30% over the current U.S. coal-fired power generating fleet.

The long-term research necessary to gain approval was conducted by the U.S. DOE/OCDO A-USC Steam Boiler Consortium made up of the U.S. Boiler Manufacturers (ALSTOM Power, Babcock & Wilcox Power Generation Group, Inc., Babcock Power, and Foster Wheeler) led by the Energy Industries of Ohio (EIO), the Electric Power Research Institute (EPRI), and the National Energy Technology Laboratory (NETL), with support from Oak Ridge National Laboratory (ORNL). The program has recorded a number of major accomplishments, and ASME B&PV Code approval of Inconel® Alloy 740/740H is one of the most critical steps needed before an A-USC demonstration power plant can be constructed.

The U.S. DOE/OCDO A-USC Consortium

In 2001, the U.S. DOE challenged the U.S. boiler and steam turbine suppliers to develop a pre-competitive R&D program which would lead to higher-efficiency coal-fired power plants with reduced emissions. The goal of the program is to develop materials technologies necessary to build and operate an A-USC boiler with steam temperatures up to 760°C (1400°F). Studies show the cost for reducing CO_2 by moving from conventional supercritical to A-USC designs is far lower than that of any other CO_2 capture and storage systems. Higher-efficiency generation also requires less coal, less cooling water, smaller environmental control systems, and less coal mined and transported.

The major barrier to realizing A-USC technology is the materials which could withstand the higher steam temperatures and pressures. The boiler team developed a comprehensive program with research primarily focused on a group of nickel-based alloys, including research into

Hot extrusion of an Inconel® Alloy 740H (ASME Code Case 2702) Pipe at Wyman-Gordon Pipe and Fittings, Houston, Texas. The 15,000-pound ingot was cast by Special Metals Corporation, Huntington, West Virginia. The alloy is the prime candidate for advanced ultrasuper-critical steam boilers. (Photo courtesy of Wyman-Gordon Pipe and Fittings)

"The approval of Code Case 2702 will help enable future power steam boilers to operate with very high efficiencies, beyond today's technology, significantly reducing CO_2 emissions from coal-fired power plants."

~ John Shingledecker, EPRI Senior Project Manager and A-USC Steam Boiler and Turbine Consortia Technical Lead

long-term material strength (single test lasting beyond 5 years in some cases), weldability and weld performance; fabrication processes; steam oxidation, and fireside corrosion (including in-plant testing). Some work, such as a steam corrosion loop operating in an actual boiler, weld repair studies, and very-long term tests to evaluate component life, still is ongoing. The initial research identified Inconel® Alloy 740 as the best candidate alloy for the highest-temperature boiler components, leading to the program's extensive work to gain approval for its use by the ASME B&PV Code.

Inconel® Alloy 740/740H

Inconel® Alloy 740 is an age-hardenable nickel-based alloy developed by Special Metals Corporation (Huntington, West Virginia) for use as superheater and reheater tubing in A-USC power plants. Due to its excellent high-temperature (creep) strength and corrosion resistance, the consortium also evaluated its use in thicker components such as boiler piping and headers. This involved numerous welding and fabrication trials combined with long-term testing. Initial challenges were encountered when welding the alloy in thicker sections up to 75mm (3") in thickness. The consortium worked closely with the alloy designers and other research institutions to refine the alloy and weld metal composition. The result was the 740H composition, specifically targeted for improved weldability in thick section components. Revolutionary progress was made, and the alloy now is considered weldable after numerous successful welded joints were produced. Fabrication of steam loops, tube bends, and demonstration articles all showed typical boiler fabrication procedures could be used with this new material.

Development of Code Case 2702

Materials used in the construction of power boilers must be approved for use by the ASME B&PV Code. While some materials are allowed for Section I construction at 760°C (1400°F), they did not have the requisite strength (allowable stresses) needed to design and build an A-USC boiler. The program developed a comprehensive data package which included test data on multiple material heats and product forms containing long-term data beyond 20,000 hours (more than two years of testing). Babcock & Wilcox Power Generation Group, Inc. championed the case with supporting data from the other project members. ORNL conducted the long-term testing and EPRI conducted the stress analysis. The robust data package was accepted on the first ballot and did not result in any negative votes. The approved Section I code case, Code Case 2702, covers the 740 and 740H compositional refinements and contains fabrication rules, welding specifications (including weld strength reduction factors), allowable stresses, and other key requirements. Users now can design and specify the alloy for use in Section I construction to a maximum use temperature of 800°C (1472°F).

Worldwide interest in the use of Inconel® Alloy 740 is high, and in 2011, PCC Energy Group (using its internal resources), produced the world's largest Alloy 740H pipe, 381mm (15") outer diameter by 10.4m (34.5ft) long with a 89mm (3.5-inch) wall thickeness. A-USC programs in Europe, India, and China are evaluating and planning use of the U.S.-produced material.

What's Next

A concurrent ballot item to approve Inconel® Alloy 740/740H for use in the ASME B31.1 piping code now is progressing. Additional test data also are being generated to extend the maximum temperature range for the alloy and validate the long-term strength projections. The consortium work also continues on other aspects of the program, including operating a steam-cooled corrosion loop in an existing boiler. A parallel A-USC steam turbine program is progressing, with research reaching the point of full-scale rotor disc forging production and scale-up of nickel-based casting for casings and valve bodies.

In 2001, A-USC technology was a challenge. Successful materials research supported by the industry, including the ASME B&PV code acceptance of a key alloy, Code Case 2702, is paving the way to make it a reality with the construction of a full-size demonstration plant by as early as 2015.

For More Information

U.S. Department of Energy and Ohio Coal Development Office Advanced Ultra-Supercritical Materials Project for Boilers and Steam Turbines. EPRI, Palo Alto, CA: 2011. 1022770.

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