The Way to High Efficiency Boilers for Power Plant Led by Ni-Based Alloy

From 600°C-class Ultra-Super Critical (USC) boilers to 700°C-class Advanced Ultra-Super Critical (A-USC) boilers

As an economical solution for reducing CO_2 emissions from boilers for coal-fired power plant, IHI is conducting verification tests of a system that achieves high power generation efficiency by generating steam with temperatures over 700°C.

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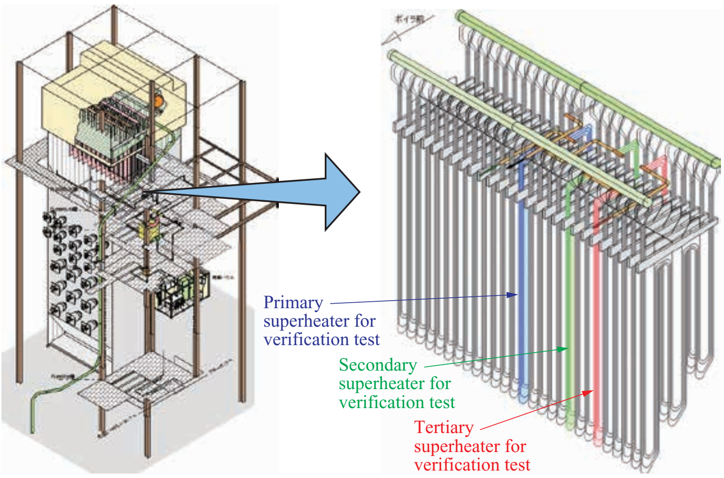


Left: Bird's-eye view of existing boiler and equipment for boiler component testing
Right: Configuration of heating surface for boiler component testing

A view inside furnace of 700°C-class superheater

A-USC boilers effective in global environmental load reduction

After the Great East Japan Earthquake, coal-fired power plant is being rediscovered as a reliable and economic source of power that meets Japan's energy needs (e.g., diversified energy source), because coal can be procured with limited geopolitical risks.

Coal emits more CO_2 than other fossil fuel during power generation. CCS (Carbon dioxide Capture and Storage), as well as mixed-firing of biomass, are examples of various efforts being made to reduce the environmental load (i.e., green-house gas emissions reduction). Improvement of thermal efficiency (to obtain the same amount of power from less thermal energy) is recognized as an effective and economic way to reduce CO_2 emissions.

It is necessary to raise the turbine inlet steam temperature and pressure condition more in order to improve the efficiency of existing coal-fired power plants. It is able to improve roughly 10% of the net thermal efficiency by raising the turbine inlet steam temperature from 600 to 700°C class. This improvement corresponds to roughly 10% reduction of CO_2 emissions.

Pursuit of higher efficiency by raising the steam temperature can be accomplished by extending conventional technologies. From a practical application standpoint, this option requires less development tasks compared to other approaches to reduce CO_2 emissions. As in conventional boilers, such a solution can accommodate wide range fuel properties, and there is a feature which has less restriction of fuel.

Verification test

Against this background, looking to the long term, preparation for boiler component testing (a de facto verification test) is already underway with a 700°C-class verification test loop (demonstration plant) having been installed in a commercially operated boiler with the intention of making a system that can be used when Japanese power companies install new plants or replace old ones at existing coal-fired power plants. Given the huge scale of the developmental efforts involved, this initiative was launched in 2008 as a national project, and is being led by manufacturers of boilers, turbines, and materials both from Japan and abroad. Since 2014, electric utilities have also been participating in the development platform as advisors.

In December 2014, a demonstration plant was installed at the Mikawa Power Plant of Sigma Power Ariake with a coal-fired boiler supplied by IHI. This plant in Fukuoka Prefecture was selected by members of the national project. After the trial run, the boiler component testing started in May 2015.

Necessary development tasks to realize a 700°C-class coal-fired boiler

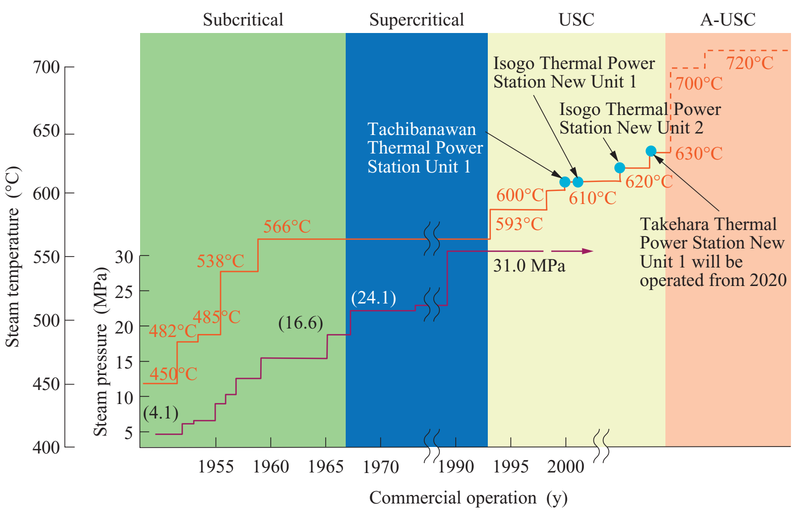
The first necessary step for building a 700°C-class coal-fired boiler is the development of high-temperature materials that resist temperatures over 700°C and still have the allowable tensile stress of the materials proven to work with 600°C-class boilers. Conventional 600°C-class boilers were built by developing 9Cr steel. No such conventional boilers have ever been upgraded to 700°C-class boilers before. For this reason, to resist the high temperature and high pressure, we must develop a Ni-based alloy material that has never been used before.

The use of a Ni-based alloy also requires studies on the structure, development of manufacturing and processing technologies, and operational maintenance and management. The issues that need to be examined and the measures to be taken for the development tasks have been clarified. Material evaluation and other fundamental element tests are being conducted under the national projects. The remaining development tasks are handled independently by each company.

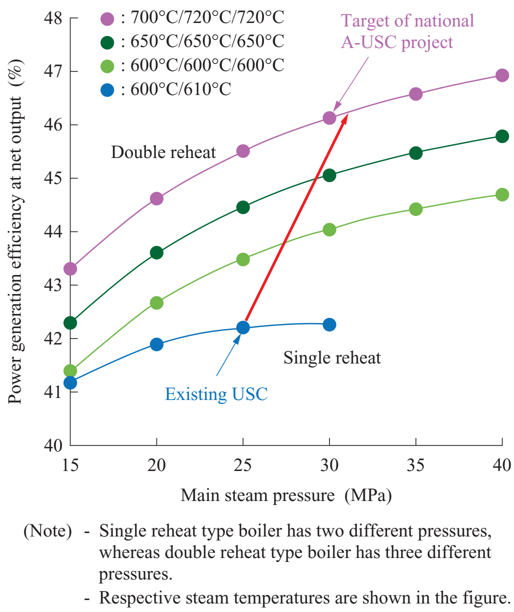
Material testing is conducted with candidate boiler materials made of Ni-based alloys while taking into account the strength, ductility, workability, and other characteristics. Given that Ni-based alloys are very expensive, the key is to use the material sparingly in as few places as possible and choose the right materials in order to remain cost competitive.

The challenges of Ni-based alloy include:

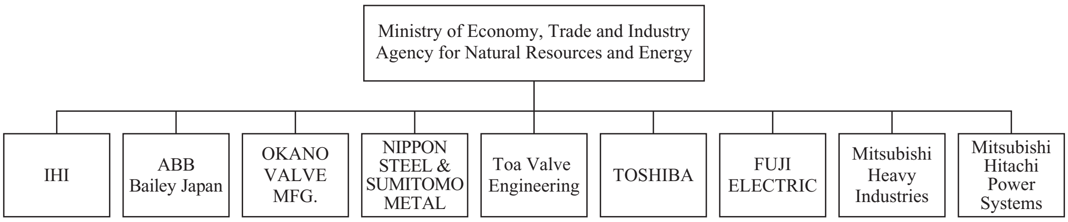
- The material is so hard that tends to cause cracks at weld
- The coefficient of thermal expansion is large, therefore careful design of thermal stress is necessary
- Very expensive materials are required



Progress of steam conditions

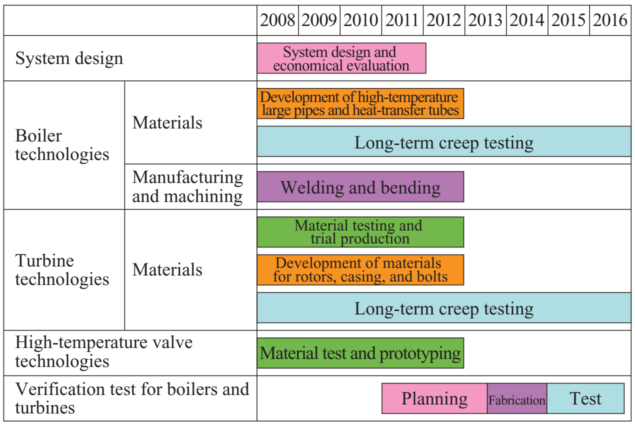


Power generation efficiency at net output under different steam conditions

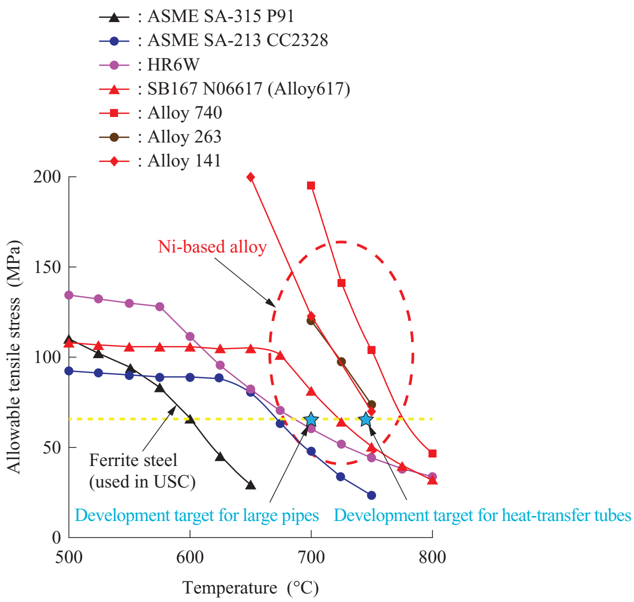


(Note) Electric power utilities (CHUBU Electric Power Company and J-POWER) participate in the initiative as advisors

National project organization for verification test of 700°C-class boilers



Schedule of national project



Comparison of allowable tensile stress of various materials

New processing and welding technologies are required to manufacture the pressure part of a boiler using a Ni-based alloy. IHI verifies the soundness of each candidate boiler material by:

- Providing the workability of machining
- Obtaining heat treatment condition data

Regarding welding techniques, soundness is verified by:

- Weldability between pieces of the same material and between different materials
- Obtaining heat treatment condition data
- The mechanical properties of the weld zone
- The creep strength of the welded part

Toward practical application through validation of the demonstration plant

As mentioned above, boiler component testing with a steam temperature of over 700°C has been going on at the demonstration plant since May 2015 aiming to reach 10 000 h of operating time at 700°C.

Many challenges must be overcome to realize 700°C-class boilers for power generation. In addition to accommodating customer needs, material test for 100 000 h will be required. Therefore, it takes time before all test results gather, and it is the fact that the distance until realization is not short.

Fortunately, solutions to the key challenges almost come in sight, and new findings will no doubt be gained in the ongoing process, solutions that will lead to the development of new materials. The on-site installation of the demonstration plant

A Ni-based alloy pipe made by high-frequency bending

Ni-based alloy superheater header

Ni-based alloy reheater header

The 700°C-class verification test loop welded at the IHI Aioi Works

The facility for 700°C-class boiler verification test at the Mikawa Power Plant of Sigma Power Ariake

Installation of a 700°C-class verification test loop

made with new materials was carried out by the IHI Group, as the existing boiler had been made by IHI. In this way, the corporate group's technical capability is mobilized to support boiler component testing.

Practical application of 700°C-class boilers is being attempted in Europe, the United States, China, India, and other countries that have major boiler and/or turbine manufacturers. But no successful case has been reported anywhere in the world. We proudly believe that Japan is leading the way with IHI's ongoing demonstration.

In addition, coal-fired power plants in Japan are also aging. The high-temperature steam of 700°C-class toward next-generation coal-fired thermal power plants is expected to be adopted to replace existing coal-fired thermal power plants.

IHI continues to make the development efforts to achieve practical application of a 700°C-class A-USC boiler for power generation.

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