Basic Technology Subjects

Energy Engineering Research Laboratory

Brief Overview

The Energy Engineering Research Laboratory is aiming to achieve security, as well as construct power and energy supply and demand systems, through the R&D of clean and high efficiency thermal power generation technologies and advanced heat utilization systems.

Achievements by Research Theme

High Efficiency Power Generation

To secure the reliability and decrease the operation and maintenance costs of thermal power plants, the rationalization of maintenance and management for the boiler tube and the gas turbine hot gas path parts, as well as evaluation technology of applicability of non-conventional liquid fuel to the thermal power plant are under development. In order to improve efficiency and reduce carbon emissions, we aim to support the smooth introduction of IGCC commercial plants and to evaluate a next-generation coal-based thermal power plant system.

- The creep damage of boiler tubes was evaluated to be negligible by the results of a creep test and metal temperature analysis of boiler tubes in pulverized coal fired power plant boilers which adopted Combined Water Treatment. These tests also suggested that the extension of chemical cleaning interval of boilers was possible.
- The applicability of the eddy current testing method, which is a form of nondestructive testing for a base metal surface cracking of thermal barrier coatings of gas turbine blades, was revealed. Furthermore, the nondestructive testing methods, including the eddy current testing, which contribute to determination of the extension of TBC recoating interval, were established by devising an effective testing flow for multiple damages and degradations such as cracking and recession of TBC blades (M14006).
- The deterioration behaviors of biomass liquid fuel in storage, which is one of the solutions to reduce CO_2 emissions intensity, was evaluated. Molecular weight spectrum was suggested as an indicator for deterioration such as the increase in viscosity and precipitation of solid matter, which could not be evaluated by conventional indicators (M14005).
- CRIEPI has developed a high-efficiency Oxy-fuel IGCC system, anticipated as one of future technologies to reduce CO_2 emission. In 2014, a heat and mass balance analysis was executed and the results showed that the system can maintain efficiency at over 43% even with CO_2 capturing, supposing three different brands of imported coal, namely, Indonesian coal, Chinese coal and Australian coal*1.

Advanced Fuel Utilization

For the diversification of energy resources and the improvement of environmental friendliness of coal-fired power plants, combustion enhancement methods of a low combustibility coal, countermeasures for the spontaneous ignition of solid fuels, dewatering methods of brown coal, measurement methods for trace elements, countermeasures for clinker in boilers, manufacturing methods of fly ash solidification material and the evaluation method for coal utilization are under development.

- TIn order to clarify the issues surrounding coal ignition in mills, we interviewed pulverized coal-fired power plant staff about recent accidents, their causes and the related preventive measures. The results showed that ignition in mills was mainly caused by self-heating of locally deposited pulverized coal. In addition, the factors influencing ignition in mills and explosion of suspended pulverized coal were investigated on the basis of literature research.
- To increase the utilization amount of coal fly ash (FA), the production condition of FA-shell solidification material without the use of cement and heat treatment was clarified. In the production process, FA, unburned pulverized shell, gypsum and lime as raw materials were mixed with kneading water and casted with vibrating to obtain high compressive strength with depressing large pore. A solidification material which has the same material strength to the granular solidification material that has already been in practical use, was produced by adjusting the frequency of vibration and the suitable proportion of FA and shell. Furthermore, it was confirmed that the trace elements leaching from the material of 1-2 mm in diameter was lower than the environmental standards at an age of 28-days.

Heat Pump and Thermal Storage

For developing high-efficiency heat pumps and expanding their application areas, we seek and evaluate innovative technologies. To assist in proposing energy-saving solutions to customers, we develop a simulation tool for analyzing their energy consumption.

- Regarding the proposed frost-free air-source heat pump system, we experimentally investigated the heat and mass transfer characteristics of the solid desiccant coated heat exchanger (SDCHE), and carried out a trial design to determine the layout and dimensions of the heat pump unit. The results revealed that it is possible to productize the proposed system at almost the same sizes as existing Eco-cutes, when the SDCHE

and the evaporator are laid out in the upper and down sides of one case (Fig. 1) (M14004).

■We improved the customer energy consumption analysis tool to evaluate the load leveling effect for a large number of customers. By analyzing the actual load data of the heat storage system, we quantitatively demonstrated the effect of maximum power reduction and power load leveling.

Energy Conversion Engineering

Basic technologies that relate to the evaluation of thermal efficiency and fuel cells, and environmental analysis, etc., will be developed to improve operability and thermal efficiency of the thermal power plants and geothermal power plants.

■Improving the efficiency of oxygen production facilities should bring about high thermal efficiency and reduction of CO_2 emission in coal-based power generation such as Integrated coal Gasification Combined Cycle (IGCC) power generation and pulverized coal oxy-fuel combustion power generation. Research into the development trend of high efficient oxygen production technology revealed that the cryogenic distillation method with heat integrated distillation column and the high temperature oxygen transport membrane method are highly applicable to coal-based power generation (M14010).

■Load-variation tests that involve a periodic current fluctuation test for 0.02-60 sec to a bench-scale Solid Oxide Fuel Cell (SOFC) have been carried out to explore the possibility of SOFC power systems toward dynamic operation for compensating power fluctuations of renewable energy sources such as photovoltaic and wind power generation. The results show that power response of SOFC is able to increase up to 125% in 2 seconds without increasing the amount of fuel fed into the cell (M14007).

■An electrode polarization model has been developed to evaluate SOFC cell performance under the pressurized conditions simulated SOFC triple-combined cycle system and the distribution performance of gas flow within the SOFC cell. Thus, an efficient performance improvement in SOFC gas channel can be expected (M14009).

Innovative Numerical Simulation Technology

A comprehensive numerical simulation tool is being developed by integrating multi-scale and multi-physical numerical schemes and models in order to solve issues taking place in thermal power generation plants by accurately evaluating performance and optimizing the operating conditions of thermal equipment, such as pulverized coal combustion boilers, coal gasifiers, and gas turbines.

■Towards the establishment of a combustion characteristics evaluation method for coal-fired boilers, a determination method of swirling flow condition for each burner based on plant operation data and local numerical simulation of a burner was developed. Moreover, in order to improve the accuracy of radiant heat transfer in the numerical analysis of pulverized coal combustion, a soot prediction model with high-accuracy and low-computational cost was developed by reducing enormous chemical species and reaction paths using the reaction reduction method.

*1 This work was commissioned by NEDO (New Energy and Industrial Technology Development Organization).

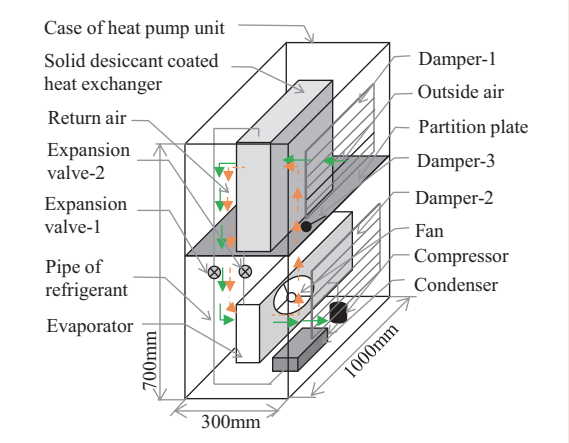

Fig. 1: Structure of a frost-free heat pump unit

●When in adsorption mode, expansion valves -1, 2 are throttled, dampers -1, 2 are opened and damper -3 is closed. Frosting of the evaporator can be suppressed because the outside air is dehumidified at the SDCHE. Hot water is produced at the condenser.

●When in desorption mode, expansion valve-1 is opened and expansion valve-2 throttled, damper-3 is opened and dampers-1, 2 are closed. The condensation heat of the refrigerant is used to produce hot water and regenerate the desiccant. A high system performance is obtained due to the recycling air flow between the SDCHE and the evaporator.