Energy Engineering Research Laboratory

Brief Overview

Amidst the profound changes of the business environment for energy companies due to the deregulation of the energy/power market, worsening of global warming and lifestyle diversification, the Energy Engineering Research Laboratory aims at contributing to (i) the creation of a new highly efficient, clean and low cost power/energy supply system and (ii) the shift towards a recycling-based society while ensuring energy security. The Laboratory intends to achieve this by providing innovative fundamental technologies and presenting alternative energy sources.

In FY 2007, the Laboratory analyzed the combustibility, characterized the burnt gas and identified relating issues of various liquid fuels for gas turbines. Basic combustion characteristics of fuel droplets were also identified. The use of these fuels is expected to increase from the viewpoint of energy security as the supply of LNG is expected to become tight in the near future.

Moreover, the scope of the application of the DME dewatering technology which was developed as a upgrading technology for sub-bituminous coal was expanded to the removal of ice in cold regions and the removal of oil at normal temperature for the purpose of environmental conservation and the feasibility of these applications was confirmed. The development of a low cost technology to decompose volatile organic compounds (VOC) was advanced for the purpose of environmental conservation. Furthermore, a basic study and examination of the analysis methods were conducted to expand the application scope of fuel cells and heat pumps as highly efficient energy conversion devices. In regard to fuel cells, for performance prediction was expanded to several types of fuel cells. In regard to heat pumps, research was conducted to enhance the performance. The feasibility of an advanced humid air turbine (AHAT) system was also examined.

Achievements by Research Theme

Operation and maintenance technology in thermal power generation

[Objectives]

To understand the basic combustion characteristics of alternative or new type of liquid fuels, establish a fundamental technologies for combustion and develop an assessment tool for reliabilities of equipment using under a high temperature environment at existing thermal power plants, for the purpose of advancing the operation and maintenance technologies for thermal power generation

[Principal Results]

・The requirements for liquid fuel serving gas turbines were clarified. New types of fuels, including non-conventional fossil fuels, such as oil sand, etc., and biofuels, such as jatropha oil, etc., were evaluated based on the property analysis results and their applicability to gas turbines and the problems were investigated.

・To evaluate the applicability of palm methylester, a type of biomass fuel, to gas turbines, the evaporation characteristics of a single droplet under micro-gravity were investigated using a micro-gravity experiment facility.

Fuel reforming and environmental protection technology

[Objectives]

To develop base technologies relating to reforming of low grade fuels, coal ash utilization and decomposition of volatile trace substances for the purpose of contributing to the diversification of fuel and environmental protection

[Principal Results]

・With the DME dewatering technology, the feasibility of ice removal from frozen coal and wood was affirmed at the temperature below 0 ℃. Furthermore, the applicability of the DME extraction technology to oil removal was confirmed. Oil can be removed from oil absorbing sheets/oil sorbents having absorbed vacuum pump oil, and also from glass, wood, paper and metal to which insulation oil is attached.

・A VOC decomposing module using a ceria catalyst was developed and its performance for the decomposition of benzene, toluene and xylene was verified (Fig. 1). An design of a practical scale system revealed a low cost and compact system is achievable.

High efficiency energy conversion technology

[Objectives]

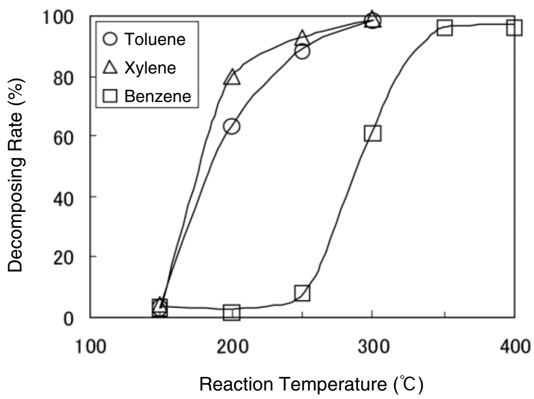
To develop fuel cell technologies, clean fuel technologies, heat transfer technologies of refrigerant for heat pumps, heat storage technologies and an evaluation technology for various energy systems, on the basis for highly efficient energy conversion technologies in the future

[Principal Results]

・In connection with a generating technology using fuel cells, performance models were developed for polymer electrolyte and solid oxide fuel cells. On a molten carbonate fuel cell, the dynamic characteristics were discussed and the dynamic model (Fig. 2) focusing on change of gas concentration in the cell was developed. The model clarified the characteristics of overload. Moreover, a new application of the molten carbonate fuel cells was proposed as a mitigating function of voltage sag.

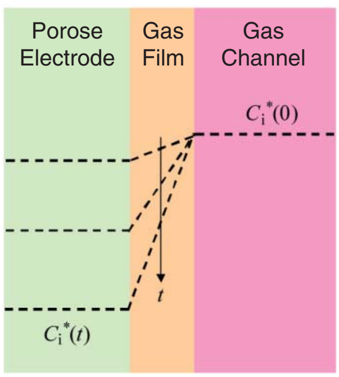
・A basic survey was conducted with a view to expanding the scope of applicability of the heat pump technology to agriculture. The evaluation of the basic characteristics of heat transfer was continued to enhance the performance of heat exchangers for CO_2 heat pumps.

・The feasibility of a AHAT system as a small to medium size, high efficiency power generation system was evaluated and the R&D issues were identified for commercial plant.



The decomposing rate is 98% or higher with toluene and xylene and 95% with benzene.

Fig.1 Reaction Test Results for VOC Decomposing Module



・Material balance equation for gas concentration

$$V^* \frac{dC_i^*(t)}{dt} = k_i\{C_i^*(0) - C_i^*(t)\} \pm \frac{A^* J_1}{nF}(1-e^{-t/\tau_{j\uparrow}}) \quad [\mathrm{mol/s}]$$

・Changes of gas concentration at the overload current

$$C_i^*(t) = C_i^*(0) \pm \frac{A^* J_1}{nFk_i}\left(1-\frac{\tau_g e^{-t/\tau_g} - \tau_{j\uparrow} e^{-t/\tau_{j\uparrow}}}{\tau_g - \tau_{j\uparrow}}\right)$$

C_i^*: Gas concentration [mol/cm³], V^*: Electrode volume [cm³], A^*: Electrode area [cm²]

J_1 : Overload current density [A/cm²], k_i: Volume transfer rate [cm³/s]

τ_g : Space time [s], $\tau_{j\uparrow}$: Time constant of internal current change [s]

Fig.2 Schematic diagram of dynamic model on gas concentration change