Case Study: University of California, Irvine

UCI School of Engineering Implements SNAP PAC System for Research Exploring Green Energy Sources

Introduction

At the University of California, Irvine (UCI), within the Lasers, Flames, and Aerosols Laboratory at the Henry Samueli School of Engineering, researchers are seeking to create greener energy sources. UCI Professor Derek Dunn-Rankin and Associate Specialist Dr. John Garman, are leading a project with the goal of discovering ways to burn coal more completely and with fewer emissions. More specifically, Professor Dunn-Rankin's research team[1] focuses on converting this coal into energy more efficiently, controlling the residual particulate matter, and in the process collecting naturally released toxins such as mercury, so that they do not adversely impact the environment.

University of California, Irvine

Understanding coal combustion is more important than ever, even today when oil and natural gas consumption is more prevalent and other "greener" energy sources, like wind and solar, are becoming increasingly popular.

According to Garman, forty percent of the rail cars in the U.S. are transporting coal used to generate electricity. Over one billion short tons of coal were consumed in 2005, ninety percent of which was used for electricity production. Furthermore, coal consumption for residential use, after hitting a low of 258,000 tons in 2006, is now on the rise, growing 9% in 2007 and another 10% for the first eight months of 2008, according to the Energy Information Administration.[2]

Project Scope

Dunn-Rankin and his team, in a project partially funded by General Electric and the University of California's Industry-University Cooperative Research Program (IUCRP), are seeking to understand the fundamental processes that occur during the final stages of burnout when burning coal, biomass fuel, or a combination of the two.

"Part of what we're doing is examining the process of char burnout and investigating what processes affect the small percentage of unburned carbon remaining after combustion," says Garman.

The project also seeks to better understand and potentially minimize mercury emissions, as mercury emissions from coal-fired power plants account for forty percent of all such emissions resulting from human-related activities.[3]

Additionally, one byproduct of coal combustion is fly ash. Due to certain characteristics of its shape, size, and chemical composition, fly ash is used as an important ingredient in concrete, to both improve its durability and increase its strength. Fly ash is also considered a green building material because it replaces a portion of cement and the emissions associated with its production. Thus, if Dunn-Rankin and his team can discover ways to burn coal so that less than 5% carbon remains in the ash, not only will coal combustion become more efficient, but the residual waste from this process can potentially be recycled.

With this and other goals in mind, Dunn-Rankin's team is varying the residence time, temperature, oxygen concentration, and other variables related to burning coal particles in order to observe and understand how they interact during the combustion process. The condensation of ammonium bisulfate and the use of fly ash as a sorbent to capture mercury are also being studied.

1. The research team includes Mohammad Kebria, De Ly, Shawn Maghzi, Jennifer Menesha, Feng Jiang, and Kyung Man Kim

2. "Burning Coal at Home Is Making a Comeback", Tom Zeller Jr. and Stefan Milkowski, 2008

3. Fact Sheet on Power Plant Emissions of Mercury in Virginia, Rodney Sobin, Office of Air Permit Programs, Virginia DEQ, 2004

UCI's research makes use of pulverized coal

An OptoGreen Grant

Garman had used products from Opto 22 in various automation and control projects he had been involved in over the years. Through a colleague who was visiting UCI to see Opto 22 hardware being used for oil-water emulsions research taking place at the university, Garman discovered that his project qualified for an OptoGreen Grant.

"These grants are donations of automation hardware, software, and engineering services to companies, research organizations, educational institutions, and government agencies involved in projects, products, machines, or services related to alternative or renewable energy, energy conservation, or environmental responsibility," explains Arun Sinha, Director of Business Development at Opto 22.

UCI's SNAP PAC System hardware was obtained courtesy of an OptoGreen grant

After a very brief application submission and review, Garman was awarded a grant of Opto 22's flagship SNAP PAC System hardware and software, including a rack-mounted programmable automation controller and a mix of analog input, analog output, and serial modules. Garman's system includes a 0–10v analog output module, used to control the coal feed rate into the reactor (typically 0.5–10 grams per minute). An 8-channel thermocouple module monitors a series of thermocouples that aggregate process control data to help maintain the proper temperature within the reactor, while analog input modules interface to an oxygen monitor to help the team keep the O_2 at the three percent level used for testing.

How the Process Works

"We're utilizing sophisticated CFD (computational fluid dynamics) software from Fluent Inc. that uses algorithms to simulate, solve, and analyze the flow and the interaction of fluids and gases as we burn the coal and biomass," explains Garman.

On the hardware side, the team uses instrumentation from Fossil Energy Research Corporation (FERCo), an engineering services and R&D company specializing in combustion and emissions control, to measure remaining residual carbon content on captured ash particles.

"For our research, we burn very small amounts of pulverized coal (2–5 grams minimum), which we feed into our drop tube furnace, also known as an entrained flow reactor (EFR)," says Garman.

UCI's entrained flow reactor

This nearly 15-foot-tall, column-shaped furnace is designed to produce the very high-temperature reaction environments needed for investigation of coal and biomass combustion. Various sample feeding and residence rates are established for the furnace so that the proper environment can be reproduced for experimentation. Through a combination of propane and electric heat, the furnace is raised to a temperature of more than 1200 °C, a process that takes more than 24 hours. A sample of pulverized coal is carried by a small air stream and fed into the furnace. As the coal is burned, lasers are used to measure particle sizes and temperatures over the length of the EFR, and emissions are carefully monitored and recorded.

Emissions monitor

Findings

The coal research facility at UCI is currently conducting preliminary measurements to initiate the new SNAP PAC hardware and ensure safe operation. Experimental results from the reactor tests are compared to data from CFD simulations to validate predictive computer models.

These models will then be applied to full scale coal burning utility burners used by companies like GE to predict how small changes in design or operation of these burners can be used to reduce emissions and otherwise improve efficiency.

About Opto 22

Opto 22 develops and manufactures hardware and software for applications involving industrial automation and control, remote monitoring, and data acquisition. Opto 22 products use standard, commercially available networking and computer technologies and have an established reputation worldwide for ease-of-use, innovation, quality, and reliability. Opto 22 products are used by automation end-users, OEMs, and information technology and operations personnel. The company was founded in 1974 and is privately held in Temecula, California, USA. Opto 22 products are available through a worldwide network of distributors and system integrators. For more information, contact Opto 22 headquarters at +1-951-695-3000 or visit www.opto22.com.

About the OptoGreen Grant Program

The OptoGreen Grant program recognizes the efforts of organizations and individuals involved in research, or the development of new products and services in fields such as energy management, alternative fuels, and recycling. OptoGreen grants are donations of automation hardware, software, and engineering services to companies, research organizations, educational institutions, and government agencies conducting research or developing products, machines, or services that promote alternative or renewable energy, energy conservation, or environmental responsibility.