



## INDUSTRIAL TECHNOLOGIES PROGRAM

### Super Boiler

#### First Generation, Ultra-High Efficiency Firetube Boiler

The U.S. manufacturing sector uses more energy for steam generation than for any other single purpose. In 2002, steam accounted for 31% of total U.S. manufacturing energy consumption. This high energy demand in part reflects the reliance on an aging U.S. industrial boiler population employing designs that conceptually vary little from those used at the end of the 19th century. As such, new developments are limited and have offered only incremental gains in operational efficiency. The U.S. manufacturing sector utilizes more than 33,000 boilers with capacities greater than 10 million Btu/hr. Of these, more than 80%

were purchased prior to 1978, with the largest share purchased in the 1960's. However, an important window of opportunity to reduce steam generation energy use will open to U.S. manufacturers as they begin to replace their aging stock of existing industrial boilers nearing retirement.

Researchers are working to develop new, breakthrough steam generation technologies that could potentially save U.S. industry billions of dollars per year in operating costs and substantially lower associated environmental impacts.



Fig. 1 Two-stage design Super Boiler at Cleaver-Brooks Thomasville Plant.



#### Benefits for Our Industry and Our Nation

By utilizing a unique boiler geometry incorporating a two-stage firetube design and heat recovery system that are both compact and highly efficient (>94% HHV efficiency), First Generation Super Boilers will offer up to 25% increases in steam generation efficiency and occupy substantially reduced footprints relative to their conventional counterparts. Efficiency gains alone could result in total U.S. manufacturing energy cost savings of approximately \$6 billion per year. Reduced footprints also enable new opportunities for boiler modularization. In addition, the First Generation Super Boilers will integrate several novel technologies to achieve extraordinarily low emissions ( $\text{NO}_x < 5$  ppmv), aiding in compliance with stringent emissions regulations.

#### Applications in Our Nation's Industry

Steam is used in almost every manufacturing industry to provide process heat, electricity, and space heating. The largest industrial steam users include the forest products, chemicals, petroleum refining, and food and beverage industries.

## Project Description

The goal of this project is to develop and demonstrate a first-generation ultra-high-efficiency, ultra-low emissions, compact gas-fired package boiler (Super Boiler), and formulate a long-range RD&D plan for advanced boiler technology out to the year 2020.

## Barriers

Major Barriers to overcome include:

- Complete R&D for dual-fuel capabilities
- Improve manufacturability of the heat and energy recovery component.
- Laboratory testing confirmed the potential of a microchannel heat exchanger for use as an ultra-compact economizer. Future work could improve the commercial potential of the microchannel heat exchanger.

## Pathways

Key innovations include a transport membrane condenser (TMC) and compact humidifying air heater (HAH) to extract sensible and latent heat from the flue gas, for increased energy efficiency; compact convective zones with intensive heat transfer; and a staged/intercooled combustion system for ultra-low emissions.

The Super Boiler project will ascertain whether the individual advanced technologies meet specifications and perform well in a systems environment. Researchers will integrate and demonstrate several of the unique, advanced combustion concepts into a technically and economically feasible boiler design.

## Progress and Milestones

- Super Boiler Program Definition (Complete)
- Laboratory Boiler Testing and Evaluation (Complete)
- Two 80-horsepower laboratory firetube boilers—single-stage and two-stage—were designed, built, and tested up to four million Btu/h; confirming 94% fuel-to-steam efficiency (Complete)
- The single-stage Super Boiler system was scaled up to 300 horsepower for field demonstration at Specification Rubber Products in Alabaster, Alabama; the boiler operated for >5000 hours and is now providing all steam to the plant (Completed)
- The two-stage Super Boiler system was scaled up to 300 horsepower for field demonstration at Clement Pappas & Company in Ontario, California. The boiler was built and pre-tested at Cleaver-Brooks' Thomasville, Georgia plant in January-March 2007, and will be installed at the host site for long-term testing.

## Commercialization

Project partners are exploring other possible Super Boiler demonstrations at Federal and privately operated commercial facilities.

An improved pre-commercial TMC design for retrofit to existing boilers is being developed, and will be field-tested on a 200-horsepower boiler at Third Dimension Inc. in West Jordan, Utah. Project partners have developed a commercial introduction scenario and projection for the TMC as a new or retrofit product manufactured and sold under license.

## Project Partners

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Cleaver-Brooks Inc.

Pacific Northwest National Laboratory

Southern California Gas Company

Utilization Technology Development NFP

California Energy Commission

South Coast Air Quality Management District

California Air Resources Board

Specification Rubber Products

Clement Pappas & Company

## A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.



**U.S. Department of Energy**  
**Energy Efficiency**  
**and Renewable Energy**

Bringing you a prosperous future where energy  
is clean, abundant, reliable, and affordable

June 2007