Multi-Staged Printed Circuit Boiler for Industrial Applications

Innovative Industrial Steam Generation

The importance of steam in various industrial applications is far-reaching. Approximately one third of the total industrial energy consumption is used to generate steam, with 60% of the boilers in use involved in steam-intensive industries. New boilers usually have efficiencies of 75% at full load and 70% at low loads. However, considering that a 100,000 lb/hr boiler is typically sized at about 3 m wide, 3.7 m tall, and 9 m long, and that an estimated 80% of industrial boilers were installed prior to 1978, an innovative boiler design stands to improve upon all aspects of existing boiler constraints.

Based on the already commercialized printed circuit heat exchanger (PCHE), the printed circuit multi-staged industrial boiler (PCMB) offers a highly compact, highly integrated design. Taking the form of stackable plates in which fine (~ 1 mm) fluid passages are chemically etched, a PCMB plate is about 600 mm long, 100 mm wide, and 1 mm thick. Intense process integration of heat transfer and heat release can realize high efficiencies that can be maintained over a wide load range, and the multi-staging of fuel can provide a close control of temperature of combustion to levels that can eliminate pollutant formation. The elimination of the radiant furnace section of the boiler due to the increased convective heat transfer coefficients in the millimeter-size fluid passages permits a significant reduction in boiler weight and footprint. Furthermore, dividing the boiler into modules presents the ability to change the materials of construction between different sections. Smaller wall thicknesses and fluid passage sizes allow for operation at high pressures and the elimination of explosion hazards.

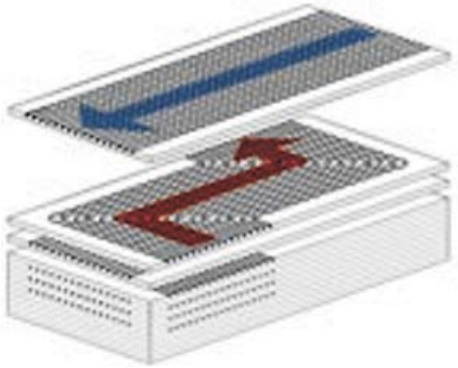


Figure 1. Showing Meggitt-Heatric's printed circuit heat exchanger (PCHE) plates stacked and diffusion bonded.

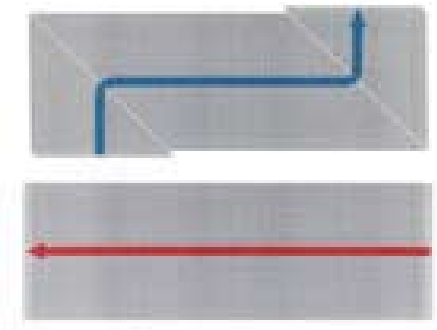
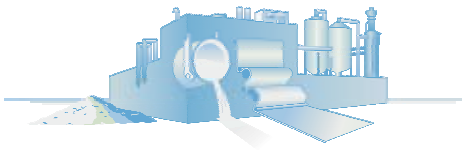


Figure 2. PCHE Plates showing chemically etched channels



Benefits for Our Industry and Our Nation

The printed circuit multi-staged industrial boiler (PCMB) promises to produce high pressure and temperature steam (1500 psig/ 1500ºF) at a thermal efficiency greater than 94%. The boiler design eliminates the furnace section found in conventional boilers, reduces tube wall thickness, and increases heat transfer area per unit volume, which enables the boiler to have a 50% smaller footprint and weight compared to comparable conventional boilers. Furthermore, the PCMB utilizes catalytic combustion and premixing for highly uniform combustion, which produces ultra-low NO_X, CO, and VOC emissions. Once commercialized, this technology has the potential to save over 120 trillion Btu per year in energy.

Applications in Our Nation's Industry

The design will improve efficiency and scalability of boilers used in steam-intensive industries, such as the paper, chemicals, food, and primary metals industries.

Project Description

By drawing upon advanced manufacturing techniques, the overall objective of the project is to commercialize the PCMB by establishing its technical feasibility. The multiple adiabiatic bed (MAB) approach will be the basis for the combustion and heat transfer sections of the PCMB, in which the major flow stream is air to which fuel is added in stages and reacted in adiabatic catalytic beds, with interstage preheating/cooling. The sections will be comprised by the grouping of plates. Such an approach minimizes the technical risk in going from a demonstration plant to a full-scale plant as the plate scalings are purely multiplicative.

Barriers

Major barriers to be overcome include:

- Achieving a fuel-to-steam efficiency greater than 94%;
- Reducing combustion emissions to: NO_x emissions below 2 ppmv, CO emissions below 2 ppmv, and VOC emissions below 1 ppmv;
- Incorporating the capability to operate on multiple fuels;
- Producing high pressure and high temperature steam greater than 1500°F and 1500 psig; and
- Reducing the boiler system weight and footprint by 50% of currently available boilers.

Pathways

The project involves two phases. In the first phase, the project team will test critical components of the PCMB, develop the conceptual design, evaluate its performance, and compare the PCMB with conventional boiler designs. If the PCMB is proven to be technically feasible, the project team will pursue the second phase by negotiating a host site, completing the detailed mechanical and process design for demonstration, fabricating the PCMB, testing the developed module for load variation and the ability to operate on multiple fuels, installing, and field testing the PCMB at the host site.

Progress and Milestones

- Test the critical components of the PCMB including the vaporizer, catalytic preoxidizer, stage-wise reforming and combustion, heat exchange and boiling, and flue gas cooling through feed pre-heat and water condensation
- Develop an integrated system design and performance expectations
- Develop detailed mechanical and process designs for an industrially relevant sized PCMB
- Fabricate the PCMB and test it for load variation and the ability to operate on multiple fuels
- Install and conduct field testing of PCMB

Commercialization

The project team has various partners that will participate in developing, demonstrating, and commercializing the PCMB technology. REI will lead the research effort and provide technical services. Heatric, a wholly-owned subsidiary of Meggitt and developer of the printed circuit heat exchanger technology, will provide PCMB modules for testing at the University of Sydney and University of Utah. Heatric will also develop the preliminary demonstration PCMB design and controls. Meggitt will provide marketing and management resources for the commercialization of the PCMB technology.

PROJECT PARTNERS

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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

July 2007