

# **OPTIMIZING STEAM GENERATION...**

**A CALL TO CONSERVE FINITE RESOURCES AND REDUCE VALUABLE SPACE**

SFC  
August 2007

## **Prologue**

As a nation, the United States consumes vast amounts of energy on a daily basis; almost 25% of the world's supply with the Industrial sector alone consuming 24.7 quadrillion Btu's annually.

With this consumption comes consequences...A high degree of dependence on unpredictable foreign fuel supplies with imports exceeding 50%. A rapid depletion of known reserves, and with China expanding and consuming at an alarming rate, this only adds to the concern. We also have growing concerns surrounding clean air and global warming and the precipitous causes surrounding the burning of carbon based fuels.

We are at a crossroads, and as a nation we must act on various fronts in the energy conversion industry to curb this consumption, and clean our air while becoming more independent; lessening the threat to our present socio/economic state.

We in the boiler/burner industry have accepted our portion of the challenge, and are making significant strides. This paper is a brief synopsis of our direction and current accomplishments.

## **The Birth of the Super Boiler**

Steam is an important energy carrier in U.S. industry, but the current stock of industrial boilers is rapidly aging, and there is a clear need for advanced technologies to enable more efficient, cost effective, and environmentally clean steam generation. This was highlighted in the Industrial Combustion Technology roadmap that was drafted by industrial advisors and submitted to the DOE in 1999. It also pointed out that on balance, U.S. boiler manufacturers, although many in number, are mostly small businesses with limited ability to invest in R&D, so public-private alliances are required to pursue breakthrough technologies in steam generation. The "Super Boiler" project is the first step in that direction.

## **DOE Spearheads the Effort**

Following the review of the recommendations by the Industrial Advisors concerning optimal steam production needs, the Department of Energy's Industrial Technologies Program was initiated, reaching out to the public and private sectors for assistance in advancing the findings.

In 2000, the Gas Technology Institute (GTI) was selected as an allied partner by the DOE, and started conceptual development of a new "Super" boiler, combining a proven efficient packaged boiler system with a highly efficient combustor delivering ultra-low

Emissions and inordinately high fuel to steam efficiencies; all within an acceptably compressed footprint.

During this conceptual phase, other partners joined the effort as both sponsoring and performing entities and included the Gas Research Institute (GRI), Southern California Gas, Pacific NW Labs, Utilization Technology Development Company, GTI's Sustaining Membership Program, California Energy Commission, California Air Resources Board, and South Coast Air quality Management District (SCAQMD).

In 2002, Cleaver-Brooks Inc., a major U.S. manufacturer of packaged boilers, was added to the project team as a potential commercialization partner. The technology development focused on four (4) interrelated approaches:

- . Efficiency increase through extraction of both sensible and latent heat from stack gases with quantitative return of the extracted heat back to the boiler.
- . Emissions reduction through application of staged combustion with intensive interstage cooling, optimized fuel-air mixing, and engineered internal recirculation of the combustion gases.
- . Size reduction of the boiler through the use of extended convective surfaces which increase heat transfer and more uniformly distribute the radiative heat release in the furnace.
- . Application of state of the art controls to optimize boiler performance especially relating to combustion control.

### **Developments to Date**

With Cleaver-Brooks joining the alliance in 2002, work started on the building and testing of two (2) 80 horsepower high pressure steam boilers, one using a highly efficient single stage firing burner and the second a two (2) stage configuration. Both boilers used the extended convection surfaces and contained the latest advances in PLC based control technology.

The "Super Boilers" were tested using GTI's lab facility in Chicago, and were equipped with advanced external heat transfer equipment (two stack economizers, a transport membrane condenser and humidifying air heater) to raise fuel to steam efficiency beyond the boiler/burner packages' capability.

Following extensive testing and modification in the lab, the concept was extrapolated to a 300 horsepower configuration and placed in a beta test facility, *Specification Rubber*,

Alabaster, AL where it has been running with excellent results since July 2006. This is a single stage burner unit using advanced controls and a full heat recovery system. Results to date indicate NOx levels <9 PPM and fuel to steam efficiencies consistently in the 93-94% range.

The second beta test site is *Clement Pappas*, Ontario, CA who will be using a Cleaver-Brooks 300 horsepower “Super Boiler” with two stage firing, advanced controls and the complete compliment of heat recovery equipment being employed at Signature Rubber.

Startup of the system is expected in September 2007 and anticipated results are <9 PPM NOx, and 94% fuel to steam efficiency.

The third beta site is *Third Dimension*, West Jordan, UT. This site will include a standard Cleaver-Brooks 200 horsepower boiler, combination oil/gas fired, advanced controls, and a single economizer with provisions for the transport membrane condenser (TMC) to be added later.

Testing is scheduled for November 2007 with anticipated results of <9 PPM NOx, and >90% fuel to steam efficiency once the TMC is added. Without the TMC, an efficiency of approximately 88% is anticipated.

### **Market Potential & Requirements**

Considering US Industry today, and its consumption of approximately 24.7 quads annually, the Super Boiler with full heat recovery has the potential to save \$4 billion in fuel and facility costs while preventing >140,000 tons of NOx, and over 20 million tons of greenhouse gases.

Looking more closely at the US boiler market and restricting ourselves to firetube type boilers only in the 100 – 2000 horsepower high pressure steam range, we have over 210,000 units in operation. If we target those firetube boilers which are more than 25 years old, the number is a substantial 80,000 units, conservatively. These boilers are normally ranging in the 75% fuel to steam efficiency with NOx emissions when burning natural gas of approximately 120 PPM.

Additionally, we find the following drivers which dictate whether or not a customer will move to improve his fuel to steam efficiency and/or reduce his present emission levels.

- . **Energy savings;** substantially assisting in meeting required ROI. Generally speaking, this ROI is 3 – 5 years in the *Industrial* sector and 5 – 7 years in the *Institutional*.

- . **Safe/reliable** product
- . **Comparable footprint** or reduced if possible
- . **Operator friendly**; minimum complexity
- . **Fuel flexibility** including natural gas and #2 oil
- . **Environmental Compliance**, LEED/Green

Looking at the results to date with our lab testing and beta performance at Specification Rubber, it appears we are indeed hitting the targets regarding energy conservation and emission reduction. We are; however, coming up short with market demands as they pertain to complexity, footprint and fuel flexibility. The current design of economizers, humidifying air heater, and TMC are relatively large and cumbersome, exceeding the overall footprint requirement and adding to the complexity of the system.

The ROI requirements are also protracted when adding this equipment, though they are close to target, especially if the Southern California Gas rebate program (BEEP) is included in the rationalization.

### **Commercialization**

Considering the products developed to date, though in part still in the “refinement/development” stages as it relates to the heat recovery equipment, it appears prudent to begin launching the Super Boiler in stages, taking as much advantage of the significant energy and emission savings we can, as quickly as we can, without unacceptable corporate risk.

With this as a premise, we can separate the offerings into three (3) logical release *generations*, evolving to the optimum design (generation) once the packaging (footprint), firing (dual fuel) and complexity issues have been worked through.

The following release schedule and economic rationale is based on an 80,000 unit potential addressing the >25 year firetube population.

**Generation I:** Super Boiler with extended convection surfaces, single stage combustion, primary economizer and provisions for secondary economizer/TMC. This boiler will be offered with dual fuel option, and advanced control system.

Expected performance: <9 PPM NO<sub>x</sub>, 88% fuel to steam efficiency, 90% when TMC is added.

Annual Fuel Savings potential based on 40,000 units: \$2,395,202,000

Annual NOx Reduction potential based on 40,000 units: 67,000 Tons per year

Simple ROI: 3.6 years

Availability: Immediate

**Generation II:** Super Boiler with extended convection surfaces, dual fuel, single stage combustion, advanced controls with primary and secondary economizers/TMC and humidifying air heater (HAH).

Expected performance: <9 PPM NOx, 94% fuel to steam efficiency.

Annual Fuel Savings potential based on 20,000 units: \$1,222,042,000

Annual NOx Reduction potential based on 20,000 units: 33,659 Ton per year.

Simple ROI: 4.2 years

Availability: Summer 2008

**Generation III:** Super Boiler with extended convection surfaces, dual fuel, two stage combustion, advanced controls with primary and secondary economizers/TMC and humidifying air heater (HAH).

Expected performance: <9 PPM NOx, 96% fuel to steam efficiency

Annual Fuel Savings potential based on 20,000 units: \$1,543,632,000

Annual NOx Reduction potential based on 20,000 units: 34,782 Ton per year

Simple ROI: 5.4 years

Availability: Early 2010

## Summary

The Department of Energy and its allied partners have accomplished much since 1999 in forging a clear direction in the quest to reduce foreign oil dependence while conserving our finite resources of oil/gas and the air we breathe.

During this period, the global warming issue has become quite acute within the public's awareness, and though the debate continues as to its actual cause, reducing carbon based fuel consumption thus reducing the tons of carbon dioxide emitted to the atmosphere can only assist in the debate regardless of position.

With over 210,000 firetube boilers in the marketplace and 80,000 of these over 25 years old with an average fuel to steam efficiency of 75%, the time is right to begin the process of retrofitting these units or replacing them with new boilers which conserve significant amounts of energy (nominal 88% FTSE) while substantially reducing noxious pollutants emitted to the atmosphere.

The time is right to think globally, and act locally...

Foot notes:

- . Fuel saving and emission estimates are based on a 300 HP boiler operating at 50% (4000 hours), burning natural gas at \$12.00/million Btu's.
- . Southern California Gas Rebate program (BEEP) was figured into the ROI based on \$25,000 per applicant.