Technology Study: Project Update

Low Emissions via Hydrogen Enrichment

Cost-Effectively Achievement of Compliance with SCAQMD Rule 1110.2 NO\textsubscript{x} Levels

without Catalytic After-treatment or Biogas Clean-up

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California Energy Commission PON 11-507
GTI Project: PIR-11-028
Project Team

- California Energy Commission – Project Sponsor
- Gas Technology Institute - Prime Contractor
- San Bernardino Municipal Water District – Host Site / co-funder
- AlturDyne Power Systems, Design and Construction of POGT
- Vronay Engineering Services Corp, Technical Lead and System Integrator
- Southern California Gas Company / Emissions Testing Support and Co-Funder
- SCAQMD – Co-funder
Introduction

> Challenges of POTW’s meeting Rule 1110.2 NO\textsubscript{x} Levels

> SCR can be technically effective but the technology is expensive and in the case of digester gas / landfill gas applications also requires considerable clean-up of the gas.

> Gas clean-up can be equal to or more expensive than the SCR system

> Gas clean-up also introduces new costs for carbon-like filter media renewal and/or electrical power for gas drying equipment

> Need an emissions reduction technology that can eliminate the need for gas clean-up, not require additional fuel or power, is simple and can be cost-effectively retrofitted to existing engines.
The Challenge of meeting 1110.2

> Rule 1110.2 Requires SI Internal Combustion Engines to maintain emissions levels of **11 PPM NO_x**, **250 PPMv CO** & **30 PPMv HC**

> Biogas fueled RICE engines produce low emissions of NO_x and CO by Operating Lean of Stoichiometric
  
  ─ Actual: NO_x 25-30 PPMv, CO ≤ 160-200 PPMv
  ─ Permit: NO_x 36 PPMv, CO ≤ 250 PPMv

> Engines already operate near the lean limit ≈ 8% exhaust O2, lambda ≈1.6-1.8

> Operating leaner produces dramatically lower NO_x emissions levels since the peak combustion temperature drops with leaner air/fuel ratios and NOx formation reduces exponentially with combustion temperatures

> If we could extend the lean limit, we could further reduce NO_x
Assisted Lean Operation (HALO)

> Wide body of research has shown dramatic reductions of NOₓ with the addition of 3-6% by mass with hydrogen

> Most of the work performed in the on-highway market where the technology did not gain commercial traction due to hydrogen storage issues and on-board hydrogen production costs, weight and safety issues

> A considerable amount of work on HALO has been conducted by the natural gas industry which has tested larger, natural gas engines as well as smaller, high-speed units for cogeneration applications

> Our project produces H2 Rich Gas in a balance of CH4 and Inserts using a Partial Oxidation Reactor and Energy Extracting Turbines to produce 100% of the engine fuel gas and additional electrical power.
This is a Good Fit for Biogas Engines

> Use of a POR reactor to produce a hydrogen rich gas
  – Does not introduce new requirements for gas clean-up
  – Does use biogas for hydrogen feedstock
  – Does produce additional electrical energy and heat, both of which are useful for waste water treatment facilities

> Component Technologies are already at mature stage of development (…well sort of- more on this later…)

> Unlike After-treatment / SCR, the system envisioned for this project will improve the overall efficiency of the process
  – Grams/BHP
Simplified Flow Diagram - Engine
Simplified Flow Diagram – POR+GT
Simplified Flow Diagram - Combined

CEC Ultra Low Emissions Biogas Fueled Engine Proposal

CEC Ultra Low Emissions Biogas Fueled Engine Project Status Update
Lambda at the limit of combustion stability was observed to be as follows:
1. 0% hydrogen: 1.86
2. 3% hydrogen: 2.00
3. 6% hydrogen: 2.13

At Exhaust O2 of 11%
NOx reduced to 5.5 PPMv corr
Example Performance - Efficiency

As the hydrogen fraction increases, BTE will increase. The results suggest BTE will reach a maximum at hydrogen fraction just above 6%.
Summary of Effects of HALO

- The addition of hydrogen significantly extends the lean limit of combustion stability under LB conditions.
  - Lean limit is increased from Lambda of 1.85 using pure natural gas to 2.15 with 6 mass % hydrogen blended with the natural gas.
  - Raw exhaust NOx is reduced from 50 Parts Per Million (ppm) to 10ppm, respectively.
  - Corrected NOx ≈ 6 PPMv.
- The addition of hydrogen significantly reduces raw exhaust hydrocarbons.
  - 6 mass % hydrogen blended with natural gas reduced raw exhaust hydrocarbons by 22.
A Little More Detail…

• HALO increases the burn velocity, with a laminar burning velocity of 2.9 m/s for hydrogen versus a laminar burning velocity of 0.38 m/s for methane.

• Improves cycle-by-cycle variations of lean-burn biogas gas engines.

• Hydrogen is characterized by a rapid combustion speed, a wider combustion limit and low ignition energy.

• These characteristics can reduce the exhaust emissions of the fuel, especially the methane and carbon monoxide emissions.

• The fuel economy and thermal efficiency can also be increased by the addition of hydrogen.
Project Status
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- POR / POGT Equipment Skid is in Final Stages of Assembly and Preparing for Testing at GTI in Chicago
- Testing of POR –GT System and GTI June 2014
- Installation of System and Integration into host site cogeneration system July 2014
- Field Test Program Commences August 2014
- Test Results Fall of 2014
- Final Report December 2014
Some Project Challenges

- POR / POGT Equipment Complexity Increased Dramatically During the Design Stage and has been the dominant activity.

- As POGT Complexity has had a cascading Effect of Infrastructure Requirements and Construction/Installation Costs

- A key project objective, can we produce H2 rich gas containing fuel and inserts by reforming biogas –AND
  - Can this fuel enable Compliance with the target 1110.2 Emissions targets remains to determined

- There is broad interest in POR combustion across many industries for emissions reductions
Completed Work

- Design of POGT
- Installation and integration drawings @ 90%
- Application Engineering and Engine Operating Modifications
- Completed baseline testing of engine (SCAQMD Funded)
- Completed modeling + simulation of POR and POR+GT System
- Identified and Developed engine and POR_GT control strategies for AFR, load control and fuel gas composition control – i.e. H2 content
Next Steps

> Completion of POR+GT Assembly and Hot Test at APS in San Diego
> Performance and Optimization Testing at GTI
> Installation of System at Host Site
> 30-day System Optimization Testing at Site
> 6-Month Long-Term Test at Host Site
Thank-you

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