Low-Temperature Natural Gas Combustion for Micro-CHP

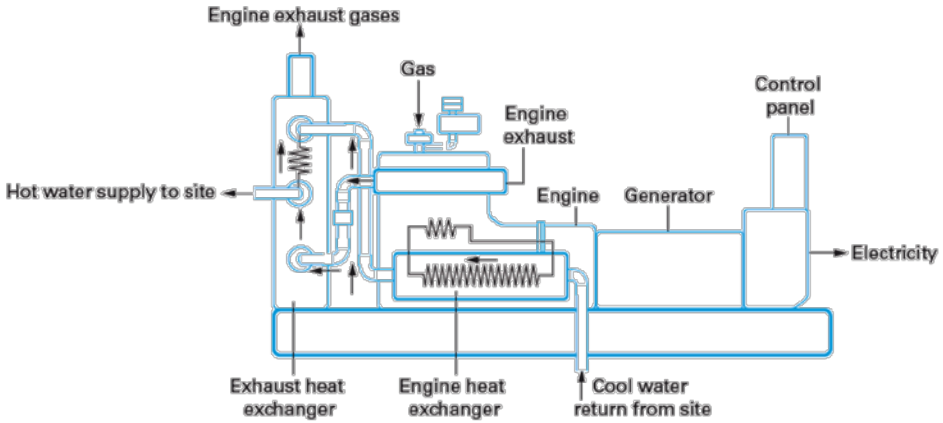
Sotirios Mamalis and Jon Longtin
Department of Mechanical Engineering
Stony Brook University

- Lean natural gas combustion
- Coupled with low-temperature building heating

Technical Details

- Prechamber spark-ignition (SI) single-cylinder engine
- Lean combustion: Air/Fuel > 30:1
- 3 – 50 kW range, scalable with number of cylinders
- Engine speed: 1200-1800 rev/min
- Single-cylinder engine weight < 35 kg
- Size: comparable to a small SI engine
- ~38% engine brake efficiency, > 40% CHP system efficiency
- Emissions: NOx < 10 ppm, no soot, low UHC
- Exhaust temperature: ~ 350°C for A/F = 30:1
- Ambient inlet temperature
- Durability similar to a SI engine
- Cost: comparable to a natural gas SI CHP system
- Low noise-low speed, low vibration, harshness

CHP system



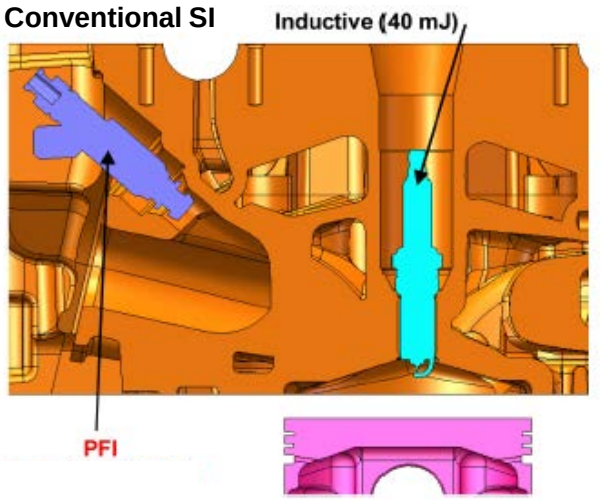
Schematic taken from carbontrust.com

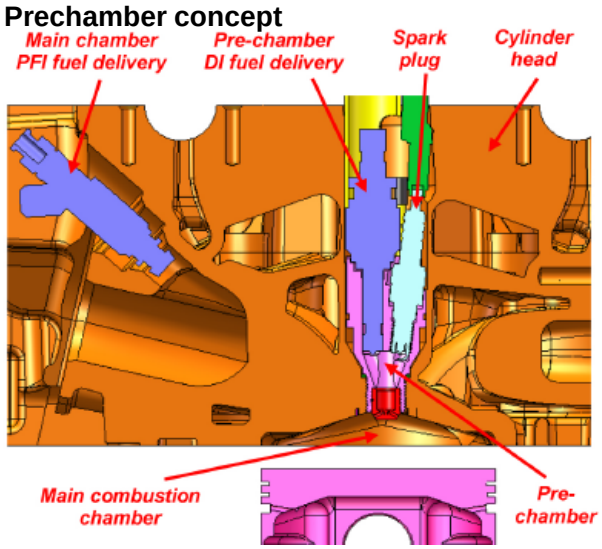
Low-Temperature Natural Gas Combustion for Micro-CHP

Sotirios Mamalis and Jon Longtin
Department of Mechanical Engineering
Stony Brook University

Development needs

- Prototype can be built and tested on engine dynamometer
- Higher efficiency by operating at more dilute (leaner) mixtures, higher intake pressure, compression ratio
- 10 years durability is expected with scheduled maintenance
- System cost reduced by eliminating the prechamber fuel injector (simpler system)
- Single-cylinder version in the 1-5 kW range
- Multi-cylinder versions up to 50-80 kW range
- Efficiency increases with size, but CHP system's heat/power ratio generally decreases with size
- Suitability for residential and light commercial use (homes, dormitories, sheltered accommodation, hospitals, hotels, leisure centers, schools, emergency services)
  - Challenge: Higher NOx around A/F ~ 20:1
- No current manufacturing of small prechamber engines, only larger units for power generation, marine propulsion
  - Similar manufacturing needs to SI production engines





Images taken from Attard et al. SAE 2012-01-0386

Low-Temperature Natural Gas Combustion for Micro-CHP

Sotirios Mamalis and Jon Longtin
Department of Mechanical Engineering
Stony Brook University

Notes

- Engine operation can be adjusted to avoid fixed thermal outlet
- Heat produced as hot water rather than steam, best suited to residential applications
- 1-2 units of heat produced for each unit of electricity
- Heat exchangers can be used to recover heat from:
  - Engine cooling circuit
  - Engine exhaust gas
  - Lubricating oil
  - Intercooler in the case of boosted engines
- Thermoelectrics can be additionally used for exhaust gas energy recuperation
- Engine can be modified to operate on propane, butane, LPG, or biogas from sewage/landfill waste
- Low-temperature combustion can be used in tandem with a low-temperature hydronic heating system: paradigm shift!

References

- "Introducing Combined Heat and Power," Carbon Trust, CTV044, September 2010, UK
- Attard, W. and Blaxill, H. "A Single Fuel Pre-Chamber Jet Ignition Powertrain Achieving High Load, High Efficiency and Near Zero NOx Emissions." *SAE International Journal of Engines* 5.3 (2012): 734-746
- Mamalis, S, "Simulation and Thermodynamic Analysis of High Pressure Lean Burn Engines," Ph.D. Dissertation, University of Michigan, 2012