Plasma Fuel Reformer

Integrated Microplasmatron Fuel Converter-Exhaust Catalyst System for Diesel Emission Reduction

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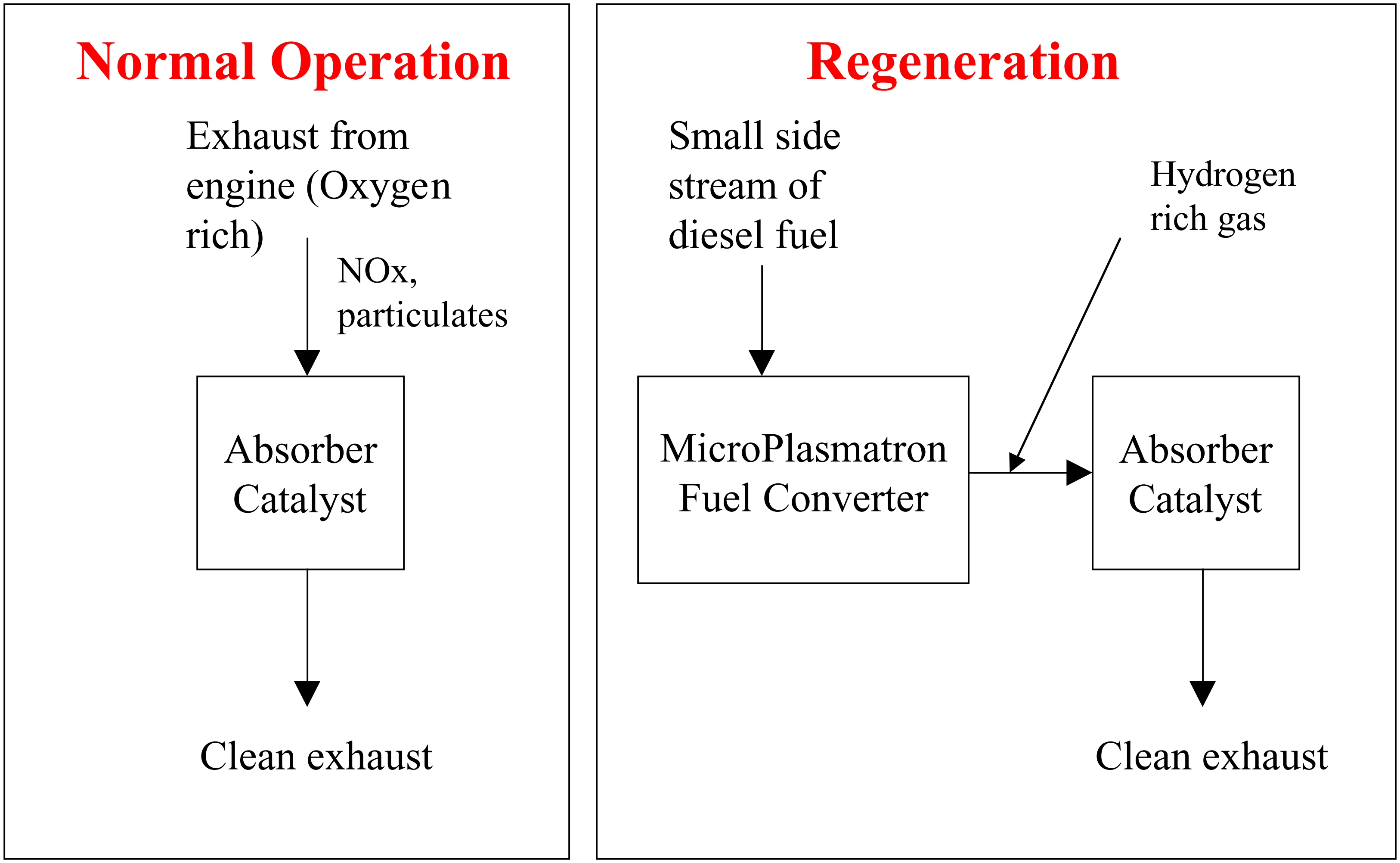
Microplasmatron fuel converter

- Rapid response compact device for conversion of hydrocarbon fuels into hydrogen rich gas
- Suitable for onboard vehicular use
  - Size
  - Cost
- Hydrogen rich gas enables a wide range of environment-quality improvements in vehicles

Concept


Normal Operation
Exhaust from engine (Oxygen rich)
NOx, particulates
Absorber Catalyst
Clean exhaust
Regeneration
Small side stream of diesel fuel
Hydrogen rich gas
MicroPlasmatron Fuel Converter
Absorber Catalyst
Clean exhaust

Plasma Enhanced Hydrogen Generation

- Plasma boosts partial oxidation reactions
- Partial oxidation produces hydrogen-rich gas from hydrocarbon fuels
    - (stoichiometric partial oxidation)

$$C_mH_n + \frac{m}{2}\left(O_2 + 3.8N_2\right) \rightarrow mCO + \frac{n}{2}H_2 + 1.9N_2$$

- for iso-octane (representative of gasoline)

$$C_8H_{18} + 4\left(O_2 + 3.8N_2\right) \rightarrow 8CO + 9H_2 + 15.2N_2$$

- 15% of energy is released in partial oxidation of gasoline

Low power plasmatron fuel converter

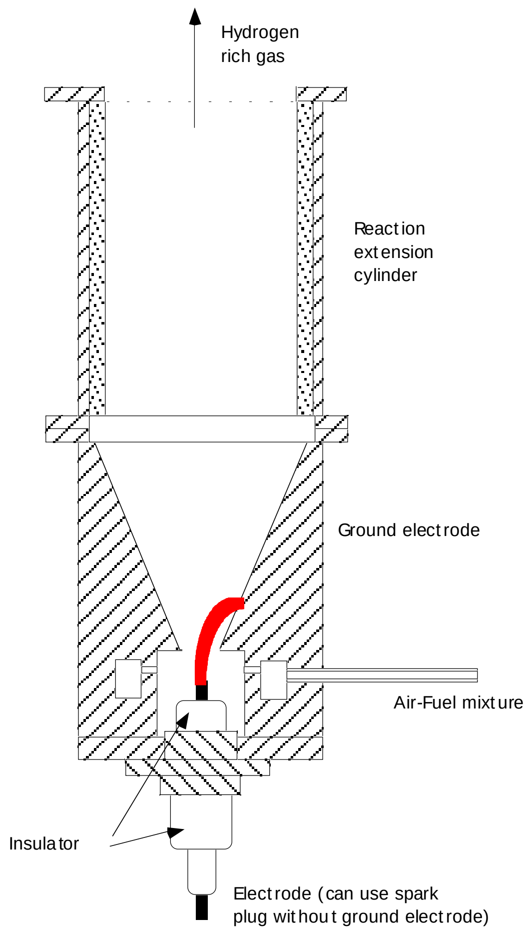


Figure 1 High voltage, low current discharge plasma fuel converter

MIT Microplasmatron Reformer*
*sponsored by USDOE

Microplasmatron
with
reaction extension
cylinder

Conventional
automobile
catalyst

Spark ignition engine:
emissions reduction (cold start, complete driving cycle)

Compression ignition engine:
emissions reduction (catalyst performance improvement; engine emission reduction; trucks; buses)

Natural gas vehicles:
(emissions reduction; trucks; buses)

Microplasmatron fuel converter

Spark ignition engine hybrids:
(emissions reduction, efficiency improvement)

Turbine engines:
emissions reduction

Fuel Cell vehicles:
(rapid response; small size reformer)

Biofuels:
(greenhouse gas reduction; reduced dependence on foreign oil)

Microplasmatron for studies at MIT and for preliminary engine tests at ORNL

With fuel

No fuel

Plasma Enhanced Partial Oxidation
Plasma Enhanced Combustion

- Plasma source facilitates partial oxidation by
  - continuous ignition of incoming fuel
  - generation of reactive species
  - mixing of fuel and air (turbulent flow)
  - Increased temperature

- Plasma boosting particularly important for
  - reformer startup
  - changes in throughput

Advantages of Plasma Enhanced Partial Oxidation

- Hydrogen rich gas can be produced in very compact devices
- Rapid response (<1 second)
- Elimination of need for catalyst
  - removal of problem of catalyst deterioration
  - removal of impediment to conversion of high sulfur fuel
- Capability for processing a very wide range of fuel (including diesel, biomass derived fuels, heavy oils)

Plasmatron fuel converter
Experimental results with diesel fuel

Plasmatron electrical power, W	220
Diesel Flowrate, g/s	0.31
H2 Yield	0.94
Hydrogen flow rate (liter/min)	26
Energy Consumption (MJ/kg H2)	6.2
Product Gas Composition, Vol.%	
H2	18.2
CO	19.8
CO2	3.8
N2	58
CH4	0.3

Potential Benefits for Diesel Engines

- Pretreatment of fuel into hydrogen rich gas prior to engine:
  - Speculative (in contrast to benefits for spark ignition engines)
  - Use of hydrogen-rich gas in engine to reduce particulate emissions
    - 90% reduction in small particulate generation (0.1–1_mµ)
    - requires high fraction of engine fuel is hydrogen rich gas (e.g. 75%)
    - need to significantly improve fuel converter efficiency in order to prevent decrease in overall fuel economy

- Use in engine exhaust treatment
  - NOx/particulate absorption catalyst regeneration

Possibility for Improved Performance of NOx Trap Catalyst

- Hydrogen rich gas can be used to regenerate particulate/NO_x absorption catalysts
  - H_2 and CO are powerful reducing agents
- Hydrogen rich gas can provide advantages of
  - reduced amount of fuel for catalyst regeneration and lower catalyst temperature requirement (in comparison to use of hydrocarbon fuel)
  - increased temperature provided by hot reformate (700 C)
  - less sensitivity to sulfur poisoning (?)
  - modest hydrogen regeneration requirements