
VERSATILE FUEL PROCESSOR

- for oxidative steam reforming and (catalytic partial) oxidation



Dr. Thomas Aicher
Fraunhofer-Institut für
Solare Energiesysteme ISE

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Electric power supply by mobile fuel cell systems: Liquid fuels are used for various reasons.

application	benefit
auxiliary power (APU), campers	high energy density, simple logistics
yachts	high safety (compared to gaseous fuels)
portable/mobile power supply	high energy density, commercially available
back-up power (telecom)	renewable (e.g. ethanol)
μ -CHP in homes	traditional

Mixture preparation for liquid fuels is a challenge.

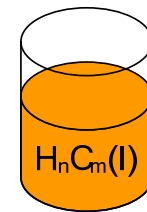
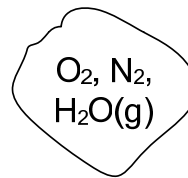
■ thermodynamics

- composition of product gas
- formation of soot

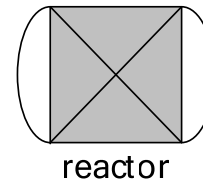
■ operating parameters

- O/C
- S/C
- reactor temperature

gaseous phase
large volume



liquid phase
small volume



■ mixture preparation upstream of reactor

- fast
- thorough
- on micro scale
- risk: soot formation

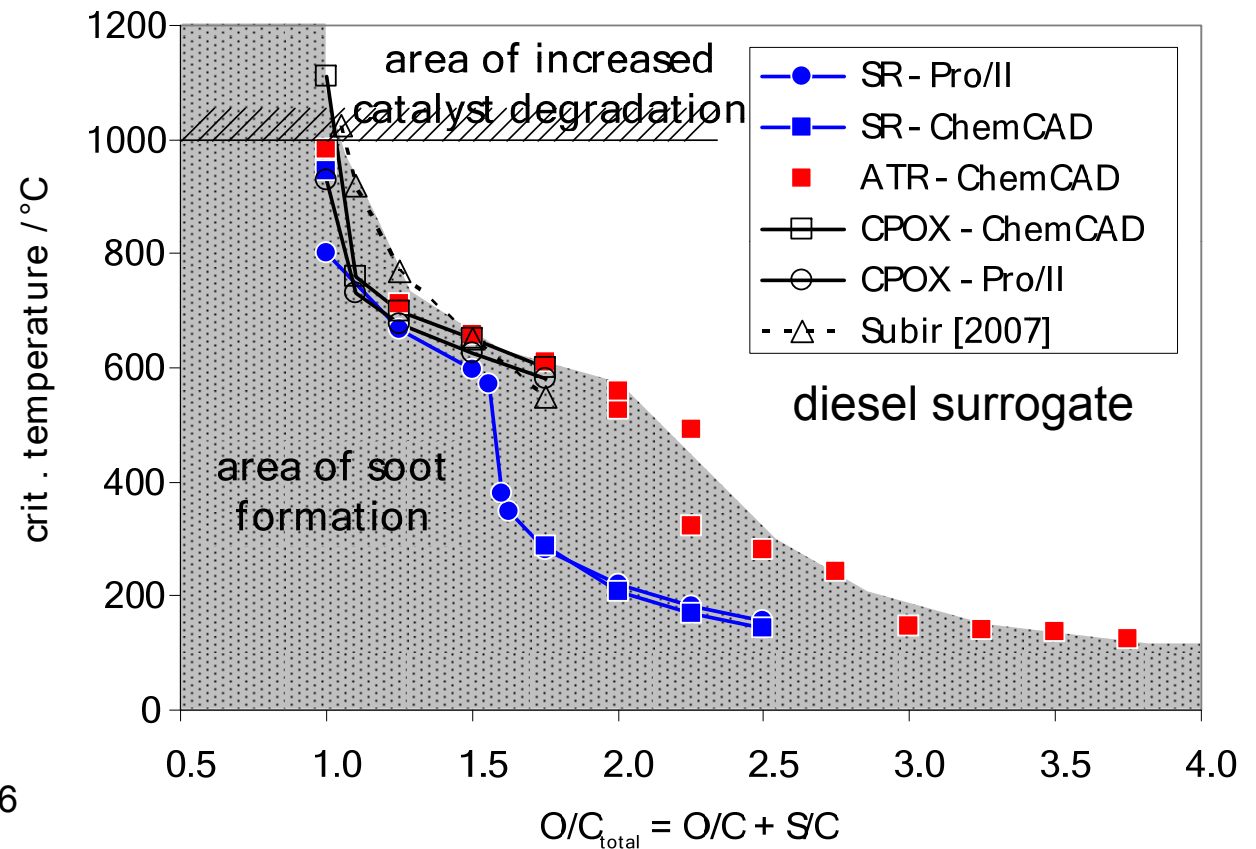
-> reactor design

-> process design

Thermodynamics warn us against soot formation.


- thermodynamic equilibrium
- minimize Gibbs Energy
- variables
 - temperature
 - O/C, S/C
 - aromatics and sulfur*

*e.g. Shekhawat et al.,
Appl. Cat. A 311 (2006) 8-16



Let's have a closer look at mixing - differences between gaseous and liquid fuels ...

	gaseous	liquid
autoignition temperature*	natural gas 580-600 °C LPG 450-470 °C	ethanol 425 °C gasoline 200-450 °C diesel 220-280 °C kerosene 210-220 °C
ignition delay (T↑ or p↑ -> delay ↓)	10-100 fold longer than for liquid fuels	1 to 10 ms

- 
1. low autoignition temperature
 2. short ignition delay
- > in case of feed preheating:
fast, homogeneous
mixture preparation important

Autoignition temperature:

The lowest temperature at which a fuel will spontaneously ignite in a normal atmosphere without an external source of ignition.

“Catalytic” evaporation solves problem of mixture preparation for liquid fuels.

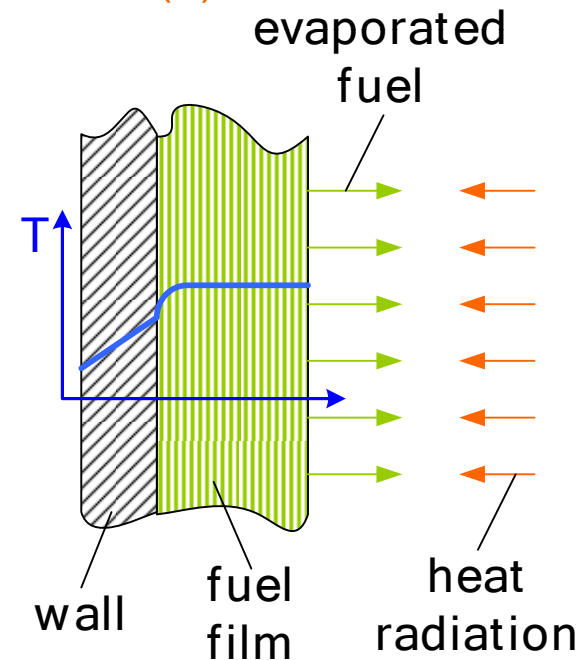
- conventional way of evaporation...



... or nozzles

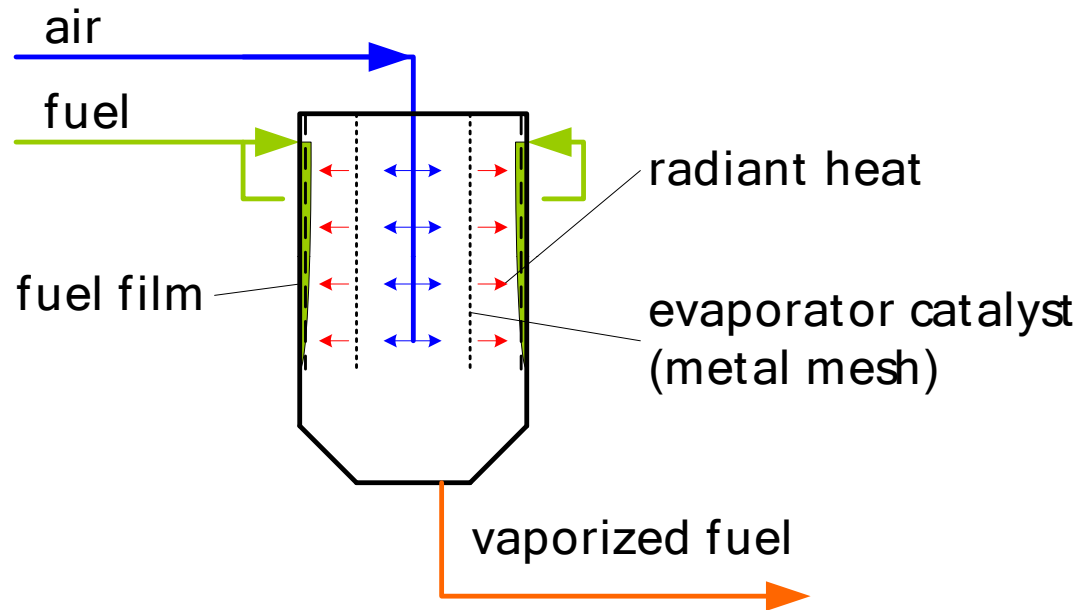


- novel, proprietary evaporation process
 - radiative heat transfer to fuel film
 - no residues (!!)



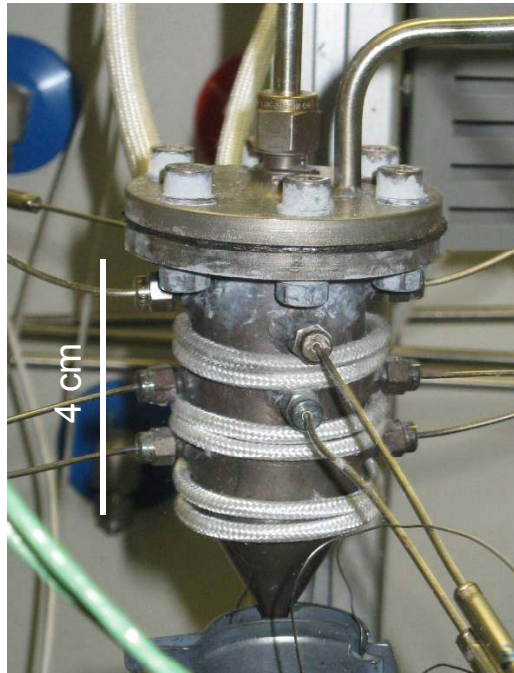
Translation of principle into apparatus

- vertical design
- metal mesh with catalyst
- partial oxidation of fuel -> enthalpy of vaporization



Status quo of development

- tested with diesel, kerosene, ethanol, gasoline, glycerol
- current system capacity: 0.5 to 25 kW_{th}
- turn down ratio 1:10
- several patents pending

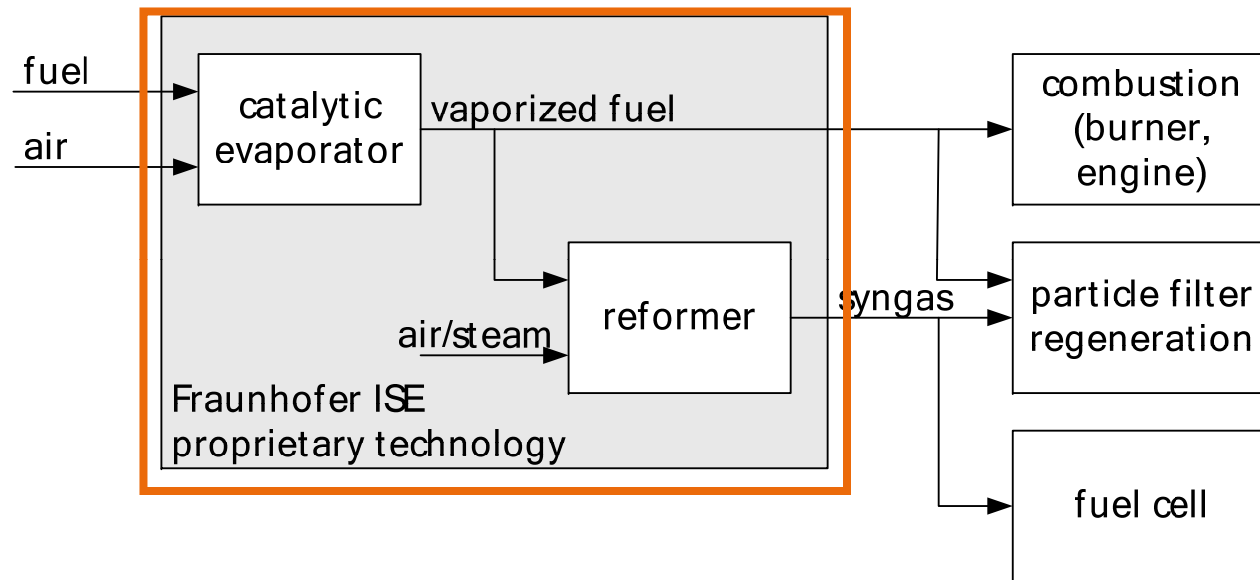


vertical evaporator (5 kW),
ISE 2009



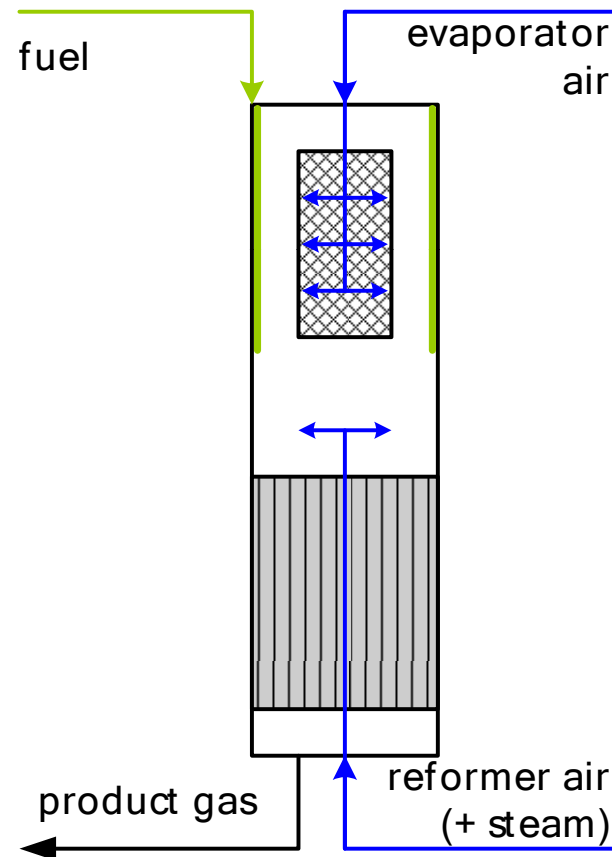
vertical evaporator (25 kW), ISE
2007

Various, attractive applications of evaporator technology

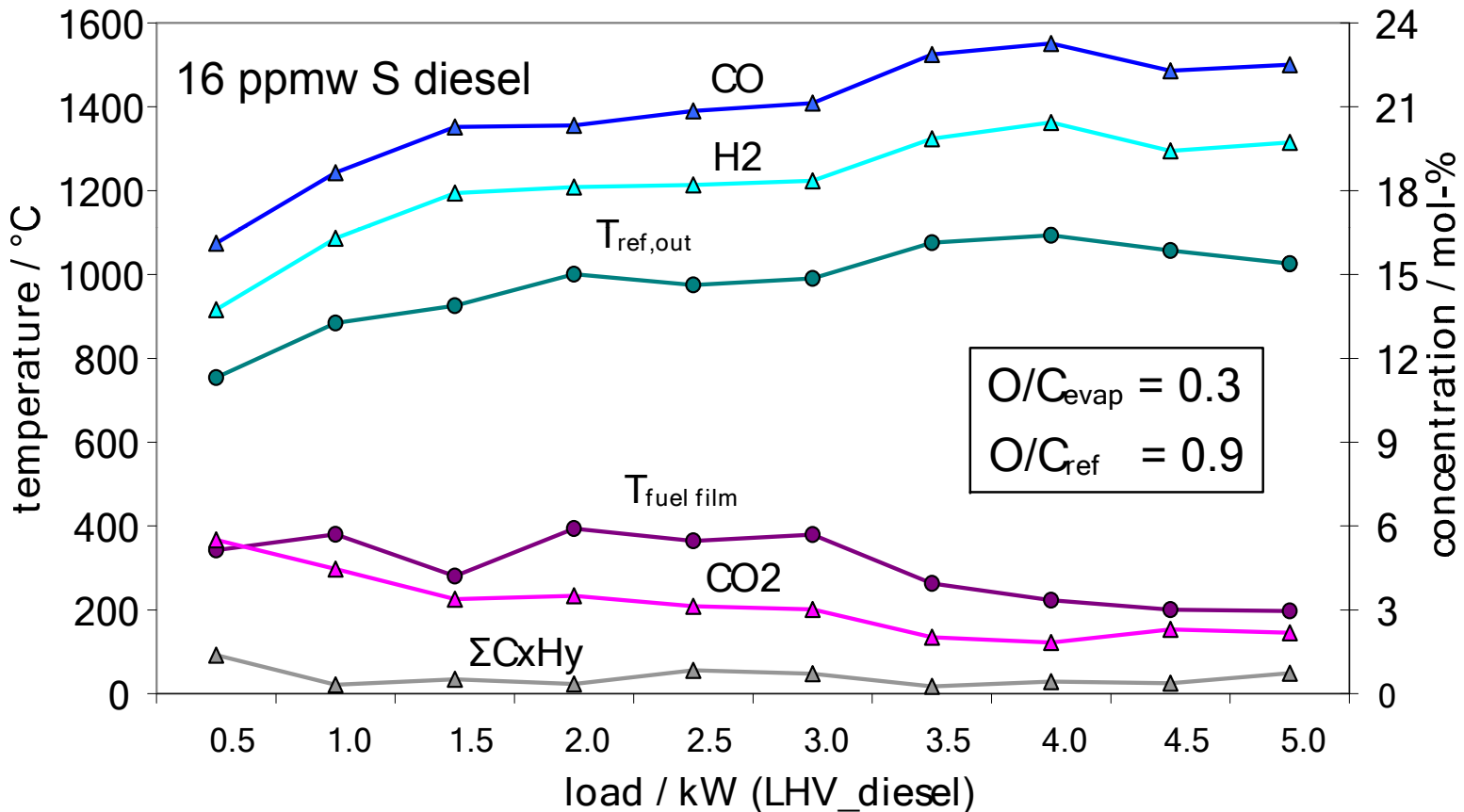


Integration of evaporator with reformer

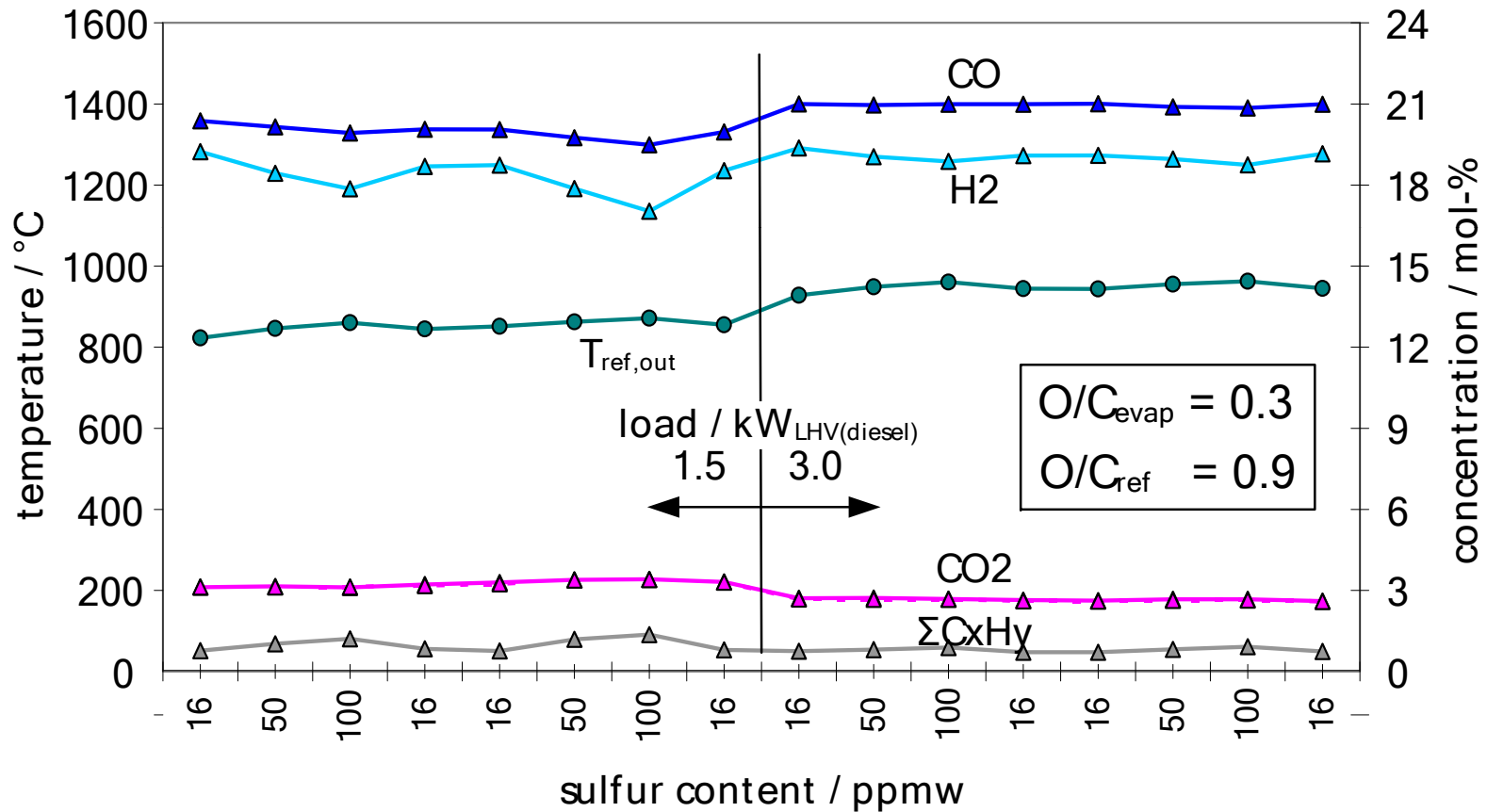
- commercial catalyst monolith
- second air supply (reformer)
- multi-fuel
- easy start-up, easy control
- CPOX/ATR mode



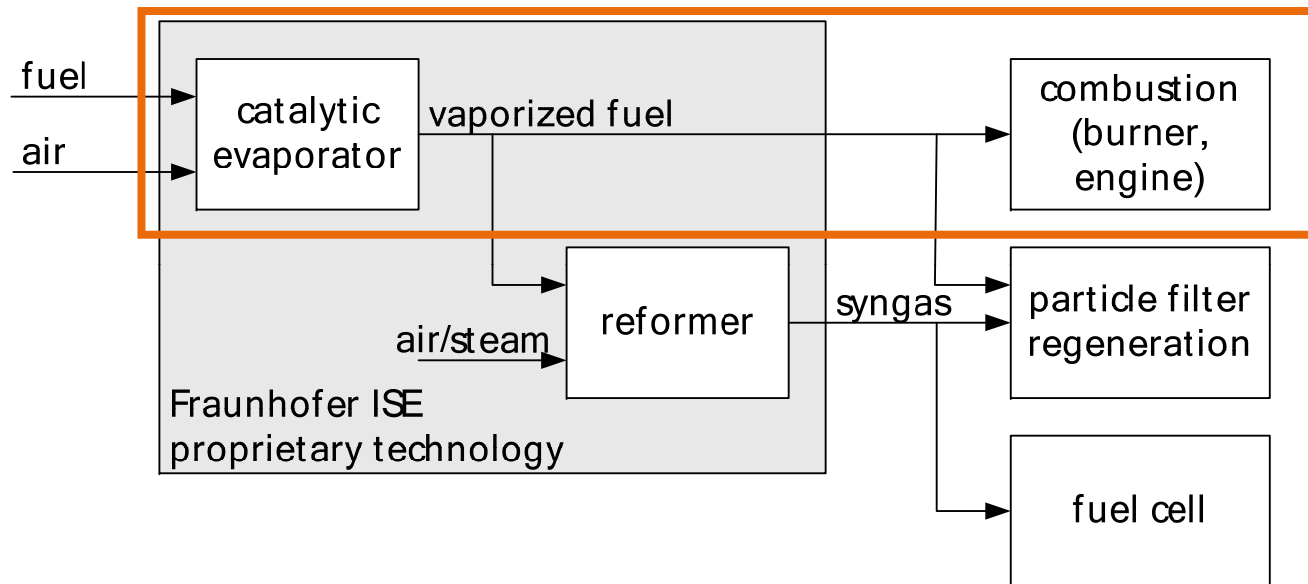
Diesel CPOX: performance over wide load range



Diesel CPOX: impact of sulfur

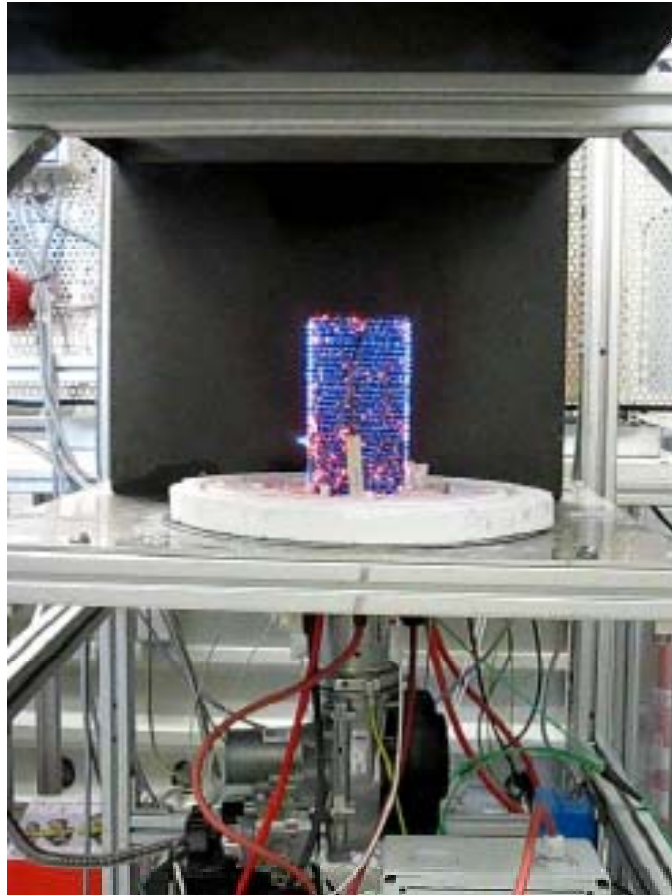


Combination of evaporator with a burner

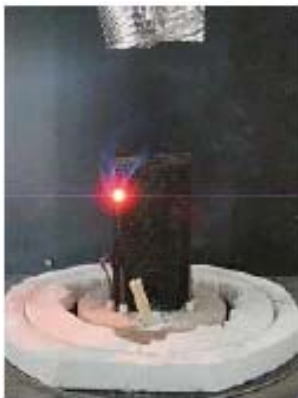


Operating a gas burner with vaporized heating oil

- commercial gas burner
- minor modifications
 - replace gas feed line with oil vapor line



Start-up is no problem...



t = 0 sec



t = 1 sec



t = 1,5 sec



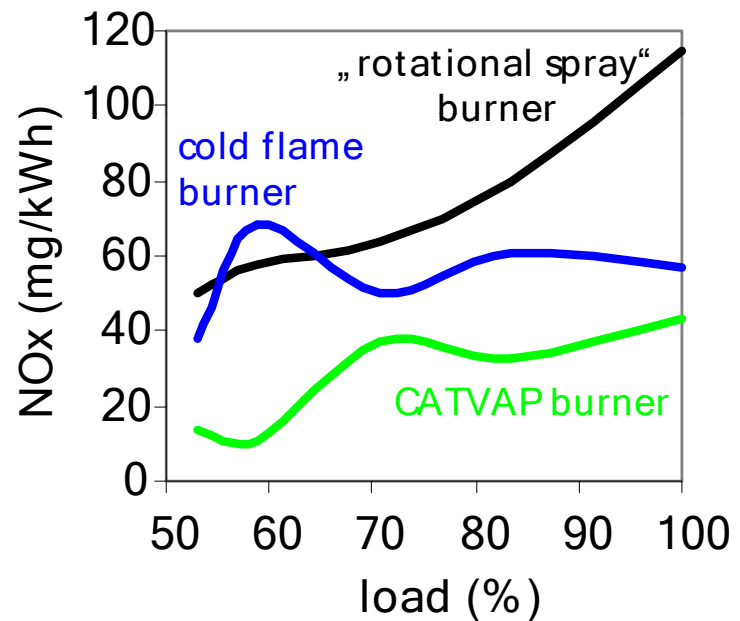
t = 2 sec



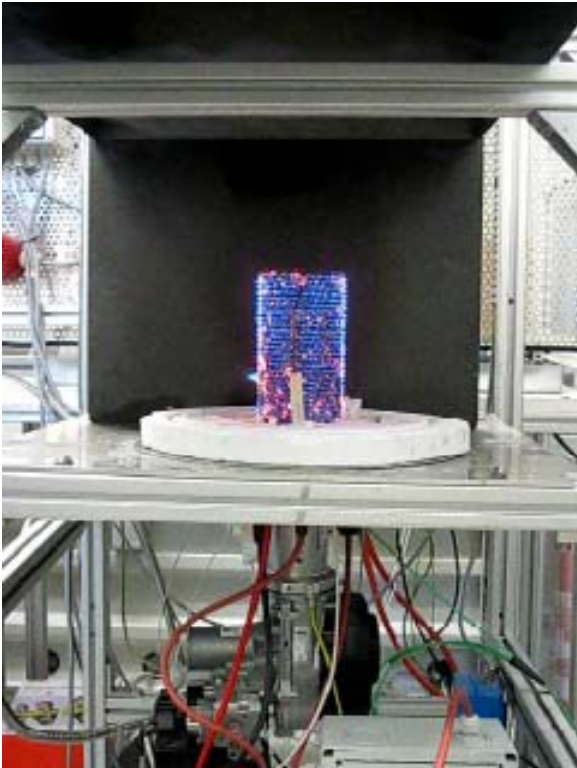
t = 3 sec

Various advantages...

- wide range of operation
 - 4-18 kW_{th}
- low emissions
- simple revamp



Summary



evaporator + gas burner, ISE, 2008

- proprietary evaporation process
 - radiative heat transfer
- various liquid fuels
- application in reformers
 - demonstrated for CPOX/ATR
- gas burner



Thank you for your
attention!