RDP25b - 7

# Development of a biodiesel reformer-burner unit as part of a membrane reformer system for APU applications

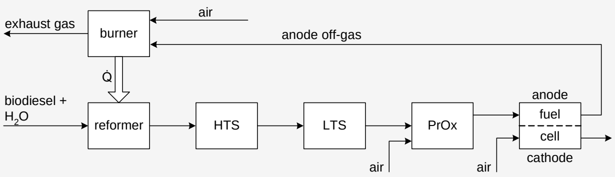

**H. Beyer***, A. Heinzel*, C. Matthias**, T. Melin**, M. Steffen*

** Zentrum für BrennstoffzellenTechnik (ZBT) gGmbH, Duisburg, Germany*
*h.beyer@zbt-duisburg.de*

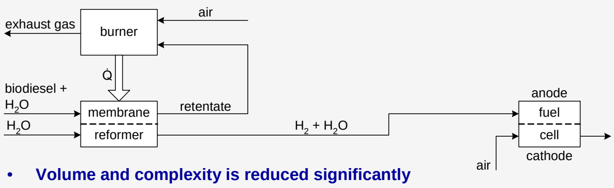
***AVT - Chemical Process Engineering, RWTH Aachen University, Germany*


## 1. Background

*Conventional steam reformer fuel cell system*




*Membrane based steam reformer fuel cell system*

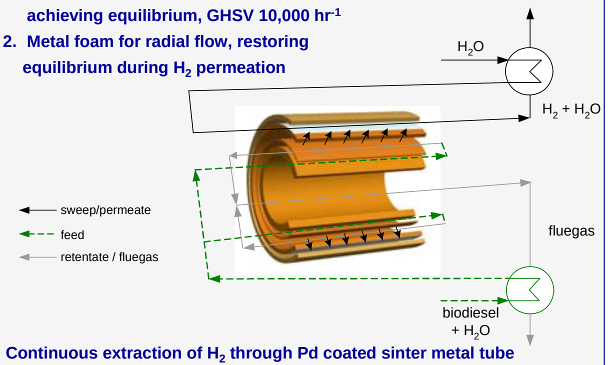



- Volume and complexity is reduced significantly
- Pure hydrogen

## 2. Reactor design

*Burner*
- Catalytic combustion, metallic structures, GHSV 50,000 $hr^{-1}$
  - → Low peak temperatures
  - → Low emission levels in the exhaust gas
  - → High fuel tolerance and high fuel utilization

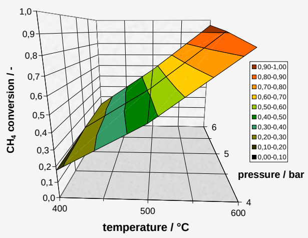
*Reformer*
- Two reactor stages:
  1. Metallic structures, decomposition of long chain HC, achieving equilibrium, GHSV 10,000 $hr^{-1}$
  2. Metal foam for radial flow, restoring equilibrium during $H_2$ permeation

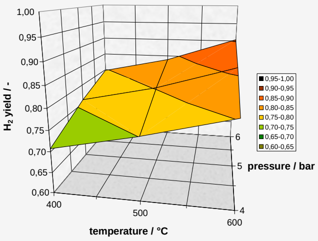



*Membrane*
- Continuous extraction of $H_2$ through Pd coated sinter metal tube
  - → Shift of thermodynamic equilibrium composition
  - → Reaction temperature can be lowered, decrease of the material stress
- Retentate supplies burner for an even heat balance
- Water vapor as sweep gas to lower partial pressure of $H_2$ on permeate side

## 3. Simulation results

*Membrane-reformer*
- $CH_4$ conversion rate and $H_2$ yield increase with increasing pressure and increasing temperature
- Shifts the equilibrium composition towards the product side

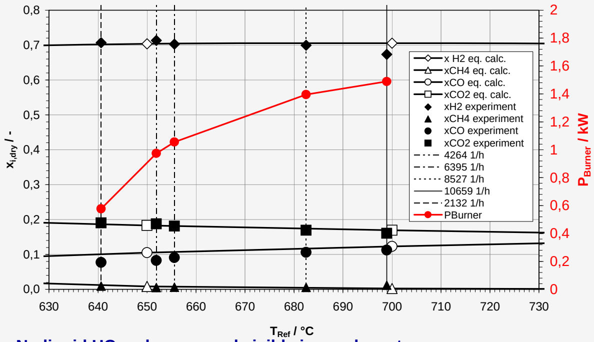



## 4. Experimental results of reformer burner unit

*Reactor performance*
- Biodiesel steam reforming var. GHSV, synthetic retentate as burner feed
- Ambient pressure
- S/C = 3.5

**Calculated equilibrium composition and experimental results**

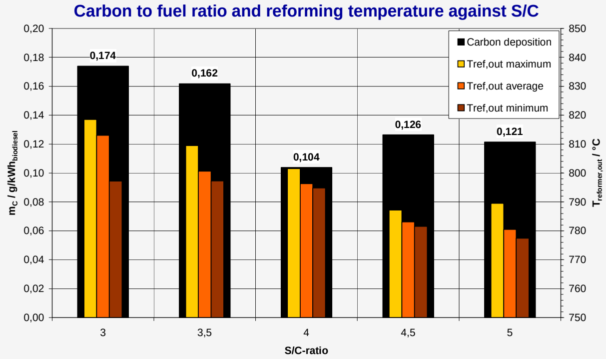



- No liquid HC and no aerosol visible in condensate
- Good analogy to equilibrium calculations
- Increasing GHSV leads to decreasing $H_2$ yield
- GHSV 10,659 $h^{-1}$: Analysed product adds up to only 95.8 %
  - → non-detectable gaseous HC existent
  - → higher reforming temperature is essential

*C-formation*
- Decreasing C-deposition with increasing temperature and S/C expected
- Detectable by supplying air at reforming temperatures
- Deposited carbon to fuel ratio as expedient characteristic number to compare carbon formation at different operating conditions

$$\frac{m_C}{H_{L,BD}} = \frac{\int_{t_{0,ox}}^{t_{1,ox}} x_{CO_2}(t)\cdot\frac{\dot{V}_{prod}(t)}{V_{n,m,CO_2}}\cdot M_C\,dt + \int_{t_{0,ox}}^{t_{1,ox}} x_{CO}(t)\cdot\frac{\dot{V}_{prod}(t)}{V_{n,m,CO}}\cdot M_C\,dt}{\int_{t_{0,ref}}^{t_{1,ref}} \dot{m}_{BD}(t)\cdot LHV_{BD}\,dt} \quad \left[\frac{g_C}{kWh_{th,BD}}\right].$$

**Carbon to fuel ratio and reforming temperature against S/C**




- Carbon to fuel ratio decreases with increasing S/C although temperature decreases (low C-Value for S/C=4 originates from still high temperature)
- Equal average temperatures at S/C variation not achieved

## 5. Conclusion

- A compact biodiesel reformer with an integrated metal membrane was designed
- Volume and complexity was reduced significantly
- Similar overall efficiencies to conventional reformer systems
- Simulations confirmed operability in principle and provided design data
- Biodiesel reforming with a synthetic retentate burner feed was demonstrated under various operating conditions
- After complete characterization of reformer-burner unit and membrane the coupling of both will be investigated

## Acknowledgments


This research project (218 ZN) of the research association DECHEMA was financed in the program for the promotion of the “common industrial research” (IGF) by the Federal Ministry of Economics and Technology of Germany over the AiF.