Hydrogen production by dry reforming of kerosene using microwave plasma

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MOTIVATION

- The greenhouse effect from CO_2 emissions exhorts searching of new energy sources meeting the requirements of being environment-friendly.
- Hydrogen is a promising future energy carrier.
- Alternative plasma technologies are very promising for hydrogen production using hydrocarbons conversions [1].
- The rotational temperature of heavy species (assumed to be close to gas temperature) was up to 5500 K (for plasma without additios).
- High temperature of microwave plasma in carbon dioxide [2] and stable operation of the microwave plasma source encouraged us for performing tests of the hydrogen production via conversion of heavier liquid hydrocarbons.

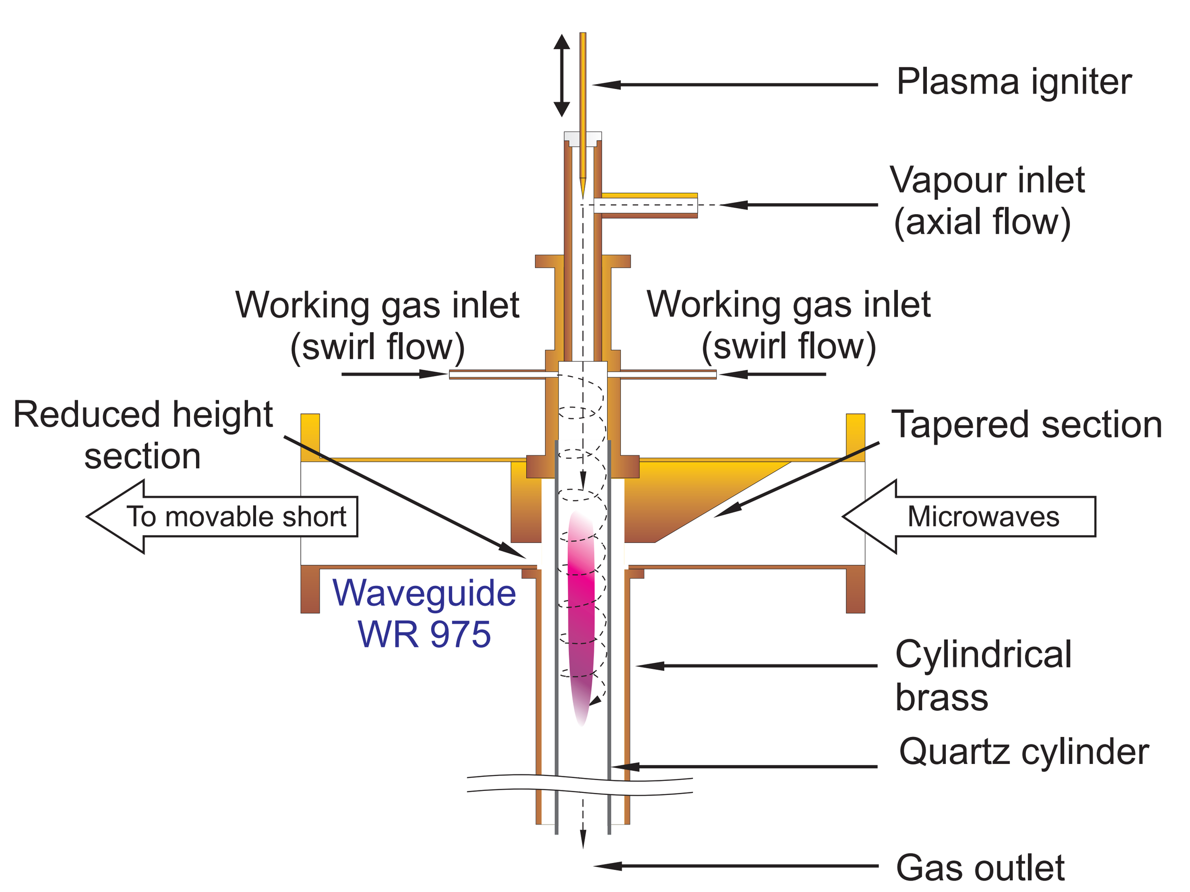
MICROWAVE PLASMA SOURCE (MPS)

TECHNOLOGY
Waveguide-suplied
Nozzleless
Cylindrical type

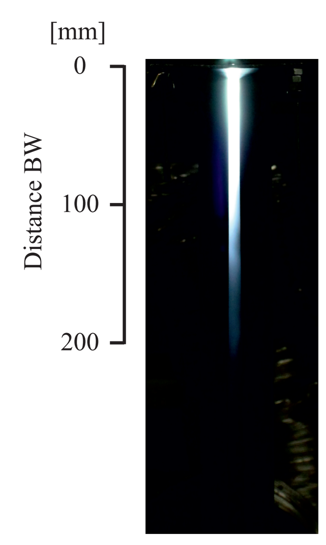
MICROWAVES
Frequency: 915 MHz
Powers: 4000 - 6000 W

GAS FLOW
CO_2 swirl flow rate: 2700 NL/h

Kerosene vapour
axial flow rate: 0.2-1.2 kg/h

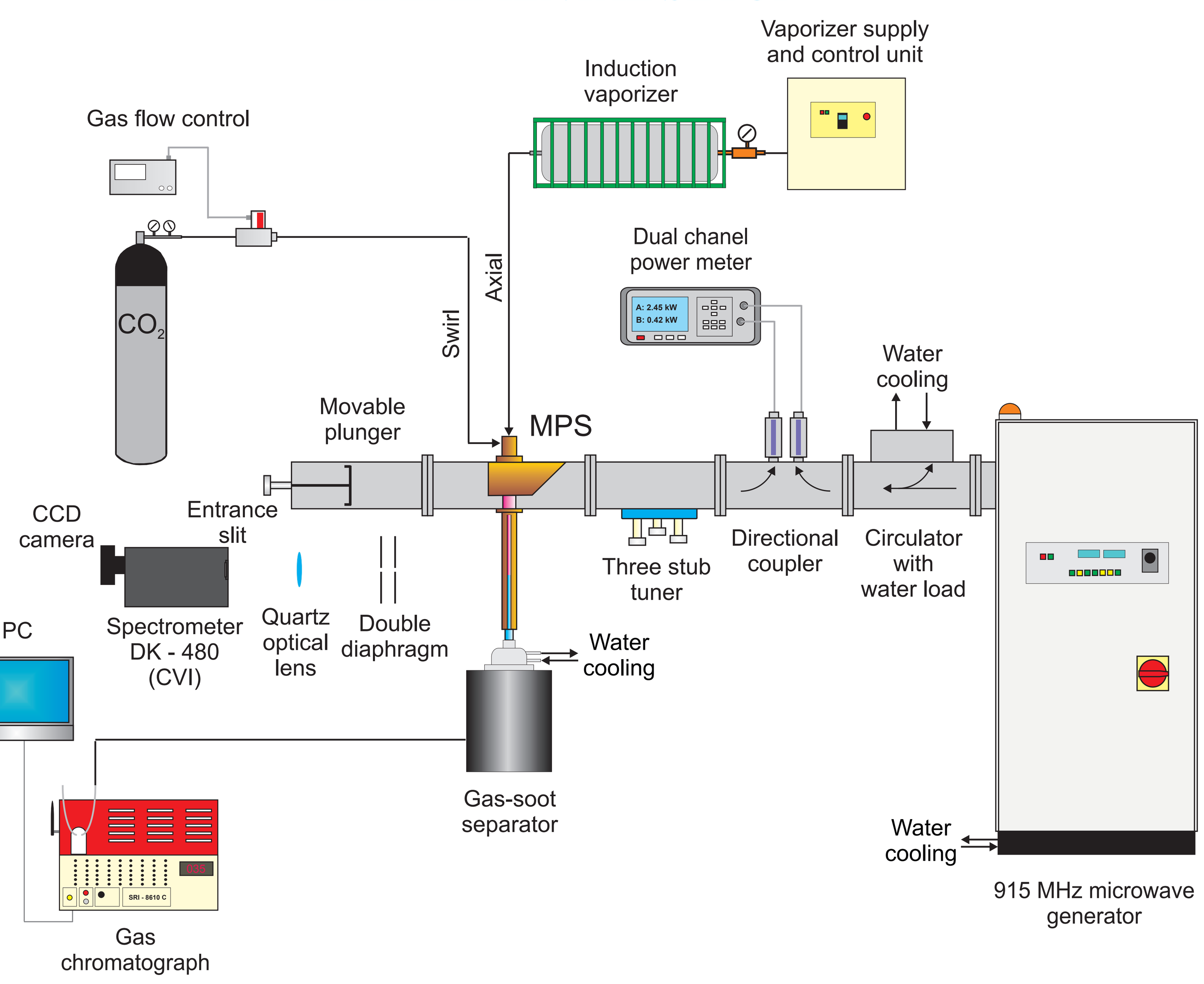


The sketch of MPS



Microwave plasma

EXPERIMENTAL SETUP



The experimental setup for study of hydrogen production by dry reforming of kerosene using microwave plasma

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[6] B. Hrycak, D. Czylkowski, R. Miotk, et al. *Int. J. Hydrogen Energy* **39** (2014) 14184
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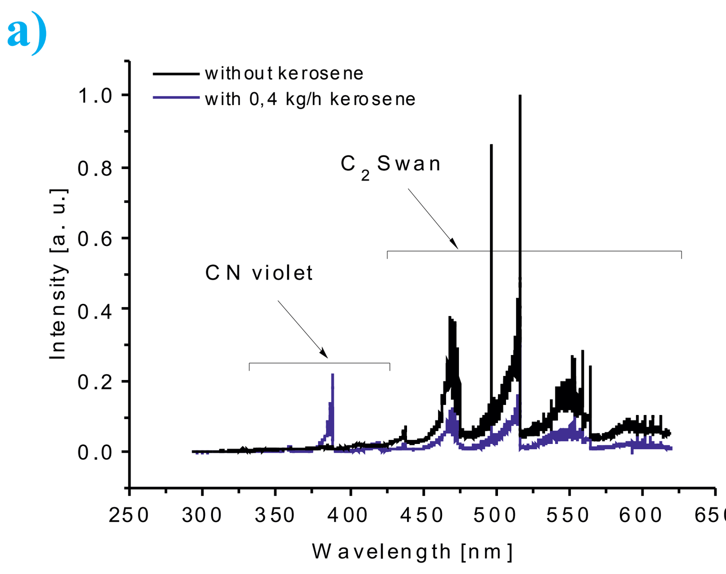
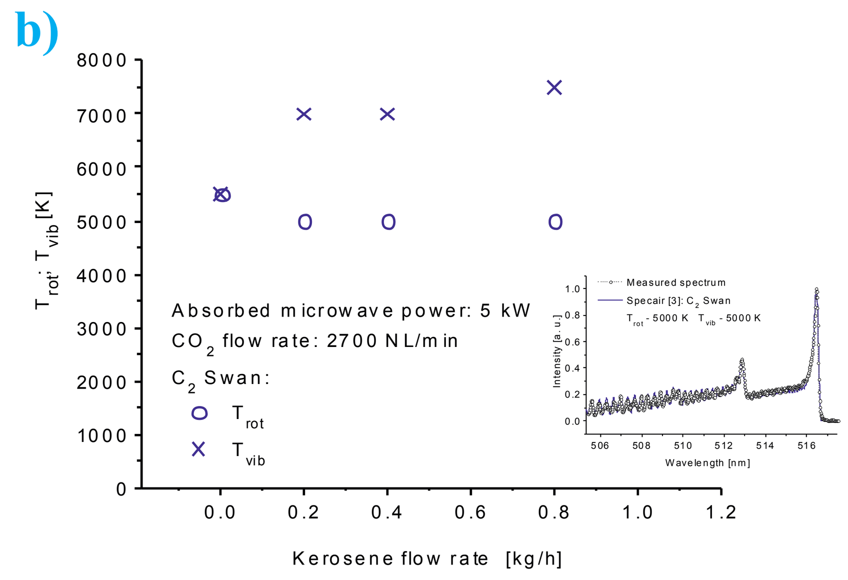
RESULTS

a)

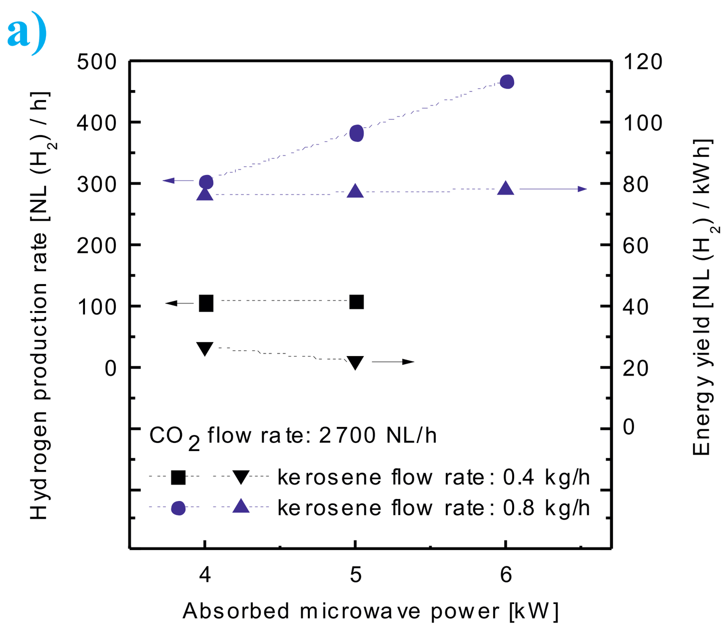


b)

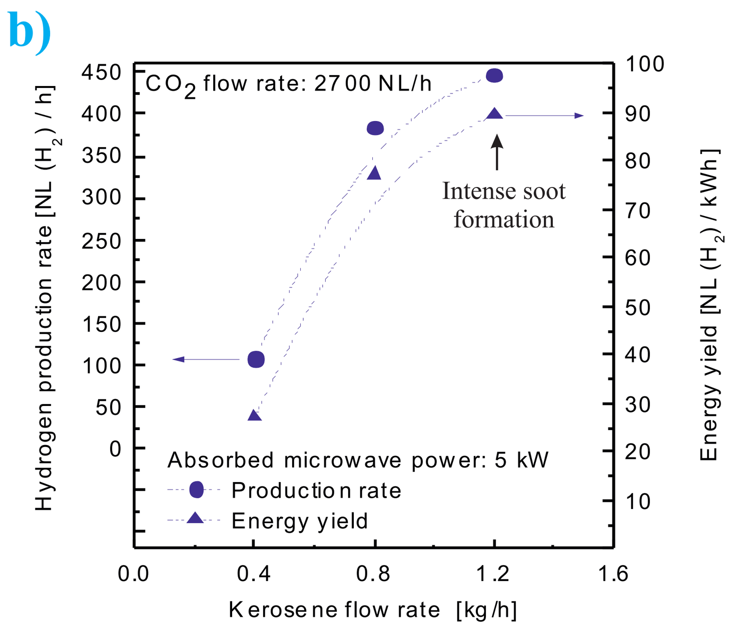


Measured emission spectra of CO_2 plasma without and with addition of kerosene vapour (a) and the rotational and vibrational temperatures of the C_2 molecule as a function of kerosene flow rate (b) (P_A – 5 kW, CO_2 flow rate - 2700 NL/h, 10 mm below the waveguide).

a)



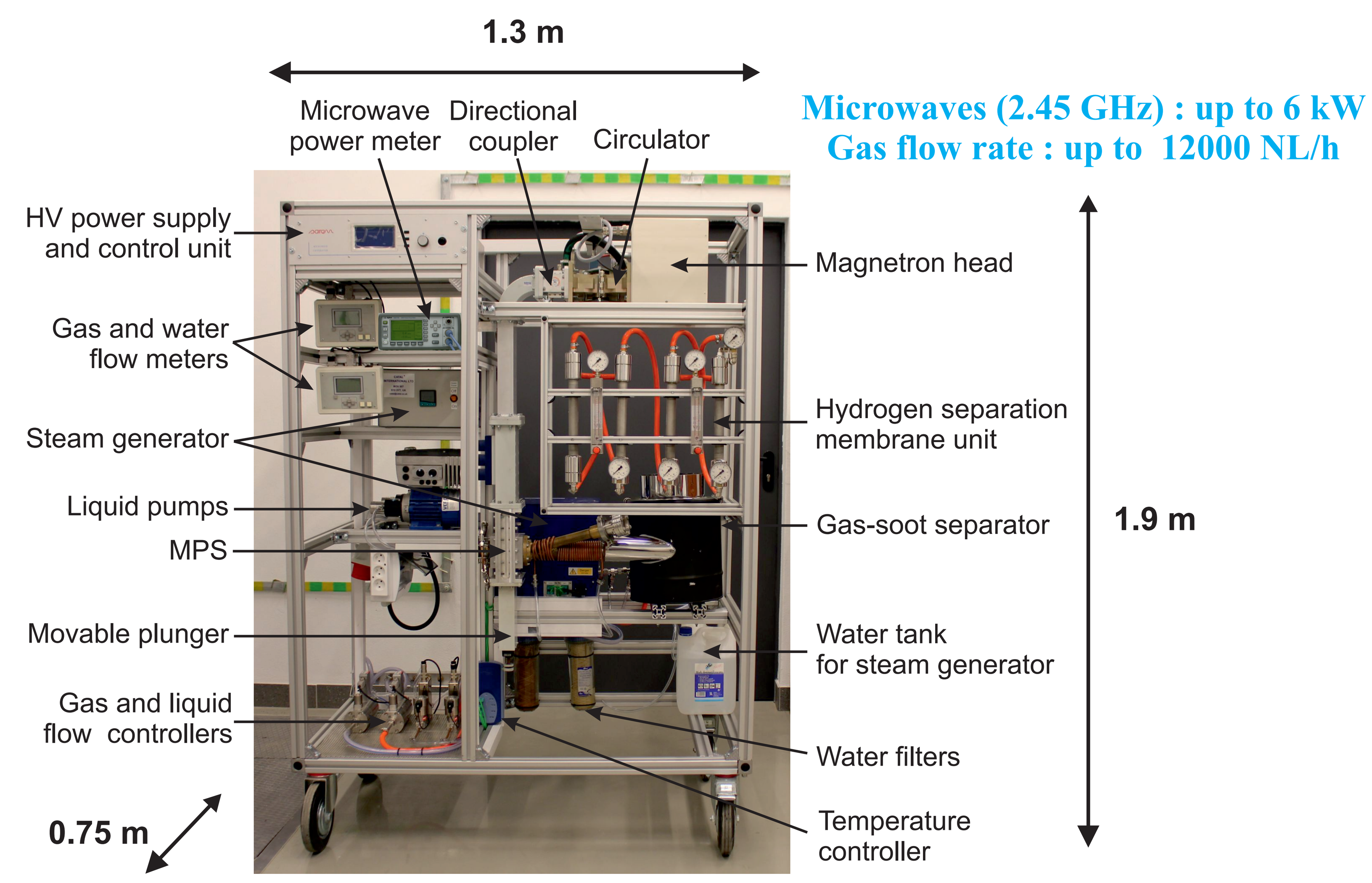
b)



Hydrogen production rate and energy yield of hydrogen production as a function of absorbed microwave power at CO_2 flow rate – 2700 NL/h (a) and as a function of kerosene flow rate at CO_2 flow rate – 2700 NL/h and absorbed microwave power P_A – 5kW (b).

PROTOTYPE OF MICROWAVE PLASMA MODULE FOR HYDROGEN PRODUCTION FROM HYDROCARBONS

Microwaves (2.45 GHz) : up to 6 kW
Gas flow rate : up to 12000 NL/h



Microwave plasma method	Hydrogen production rate NL(H_2)/h [g(H_2)/h]	Energy yield NL(H_2)/kWh [g(H_2)/kWh]
$CO_2 + H_2O + CH_4$ (combined steam reforming)	2300 [192]	515 [42.9]
$N_2 + C_2H_5OH$ (thermal decomposition)	1150 [95.7]	267 [22.2]
$CO_2 + C_3H_7OH$ (dry reforming)	1116 [92.9]	223 [18.6]

SUMMARY

- The rotational temperature of heavy species (assumed to be close to gas temperature) was up to 5500 K (for plasma without kerosene). Addition of kerosene caused the slight decrease of the rotational temperature (about 500 K).
- The hydrogen production rate was up to 470 NL[H_2]/h and the energy efficiency was 89.5 NL[H_2] per kWh of absorbed microwave energy.
- The investigated nozzleless, waveguide-supplied, cylindrical type MPS works very stable with various working gases. The high gas temperature makes it attractive tool for different gas processing at high flow rates [4, 5].
- The microwave plasma reforming methods can be also used for effective hydrogen production from alcohols [6, 7] and different other liquid fuels [present work].

This research was supported by The National Science Centre (NCN) under the programme DEC-2012/05/B/ST8/02789