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Current status of commercialization for small scale stationary fuel cell systems in Korea

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Contents

Government policies related with new & renewable energy in Korea

New Renewable Energy Feed-in Tariff (FIT*)	· Cost difference of electric power generation for fuel cell is supported since Oct. 2006 · The cost difference support is decreasing the amount 3% every year compared to the previous year for 15 years, since 2008 · Scheduled to be replaced with the RPS system in 2012
Renewable Portfolio Standards (RPS**)	· 10% of total power generation is planned to be supplied as new & renewable energy from 2012 to 2020 · The government selects some mandatory subjects (500 MW and above), and the mandatory subject must complete the goal in a specified time. The goal is to be progressively increased from 2% in 2012 to 10% in 2020. · Mandatory subject can operate the obligations by investing in the new renewable energy field directly or by trading the REC (Renewable Energy Certificate).
1 Million Green Home Supply Business	· Until 2020, new & renewable energy equipment installation cost will be partially supported and a million green homes are planning to be supplied · In the case of fuel cells, 80% of the current installation cost is supported by the government

*Feed-in Tariff : The system where electricity produced with new renewable energy has a price set by the government and the power providers are obligated to purchase this energy.

** Renewable Portfolio Standard : A system that obligates a specified size or larger power provider to make their total produced energy provided with new renewable energy for a specified ratio and above. Detailed enforcement decree is currently under review.

Government policies related with new & renewable energy in Korea

Obligation of New Renewable Energy use for Public Buildings	· After 2011, all public buildings over Gross Floor Area of 3,000㎡ built by a public institution must cover 10% or above of the total energy usage with new & renewable energy. (previously it was 5% based on the construction cost) · The obligation ratio is increased from 10% in 2011 to 20% in 2020 and the gross floor area of subject building was adjusted to 1000㎡ or above in 2012
5 kW-class Building Fuel Cell Demonstration Business	· For two years from Dec. 2009 to Nov. 2011, the 5kW-class fuel cell demonstration project for building was proceeded as a new & renewable energy development business · 5 kW fuel cell system for building were installed and operated as demonstration in the different site for daytime and for nighttime energy consumption · Established commercialization technology basis through acquiring durability and reliability during this project

Domestic Fuel Cell market trend in Korea

- Fuel cell is suitable to cope with RPS(Renewable Portfolio Standard)
- Government decided to introduce 660MW of fuel cell power plant until 2024 as national electric power supply plan, and Seoul city decided to install fuel cell systems on 700MW(47.6% of total new & renewable energy of Seoul) scale as distributed generation
- Government is under consideration for fuel cell system to be able to substitute for emergency generator(75MW/yr.)
- In the domestic power market, fuel cell applicable potential households are 16.4 million, and it is expected to be expanded to 2 million houses and above by 2020

Domestic Fuel Cell development trend in Korea

- POSCO power built stack factory at 2011, is expected to manufacture the stack in the 10MW to 100MW class
- KEPRI(Korea Electric Power Research Institute) undertook the 250kW-class cogeneration MCFC system development research and MCFC stack mass production research
- Doosan Heavy Industries have produced and operated 25 kW-class internal reforming MCFC stack in 2006 and are currently developing the 300 kW-class interior reforming MCFC system
- KOGAS installed and operated 210 fuel cell systems for demonstration research with various fuel cell production companies since 2006 as ‘residential fuel cell monitoring business’ for 5 years until 2011

Strategy roadmap for Fuel Cell development in KOGAS

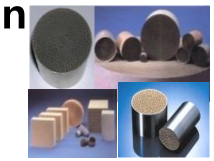
Project

- Hydrogen Production and Utilization under $50Nm^3$

Final Target

- Development of $50Nm^3$ Reformer and Hydrogen Utilization
  - Commercialization of Steam reformer (PEMFC, SOFC)
  - Commercialization of SMR, WGS Catalyst and Desulfurizer

  → Heat Efficiency 75% (Reformer), Durability 40,000hrs Catalyst



Period

- 1^{st} Stage ('11.9~'14.12, 40 months) : $10Nm^3$ Hydrogen Production
- 2^{nd} Stage ('15.1~'17.12, 3years) : $30Nm^3$ Hydrogen Production
- 3^{rd} Stage ('18.1~'20.12, 3years) : $50Nm^3$ Hydrogen Production

Particular Object

- 1^{st} Stage : Heat Eff. 75%, Sulfur conc.<50ppb, Durability 5,000hr
- 2^{nd} Stage : Heat Eff. 77%, Sulfur conc. <10ppb, Durability 10,000hr
- 3^{rd} Stage : Commercialization of $50Nm^3$ Reformer

Research Plan for Fuel cell in KOGAS

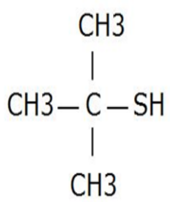
- 1ST Stage : Development of PEMFC System and Evaluation ('15)
- 2nd Stage : Core component improvement and Cost down ('17)
- 3rd Stage : Domestic market entry of 5-50kW System ('18) 및 Overseas Market ('20)

	11	12	13	14	15	16	17	18~
National Roadmap & National Project	100,000 dissemination of fuel cell for buildings, Obligation for Public buildings							
	Development of PEMFC Core part ('11 ~ '15)			Commercial System				
5-10kW Reformer	5-10kW SMR Reformer			Demonstration, Cost down		Domestic Market		Export
Catalyst (SMR , WGS Desulfurizer)	Devlopment of SMR,WGS, Desulfurizer			Improvement & Cost down		Commercialization & Export		
Hot Water Utilization	Hot water reservoir		Drier	System Integration & Commercialization			Export	

Desulfurization

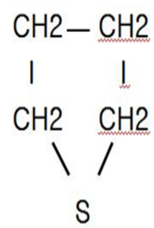
Types of Ordorant(sulfur compound)

Tertiary-buthyl mercaptan(TBM)



$C_4H_{10}S$

Tetra-hydro-thiophene(THT)

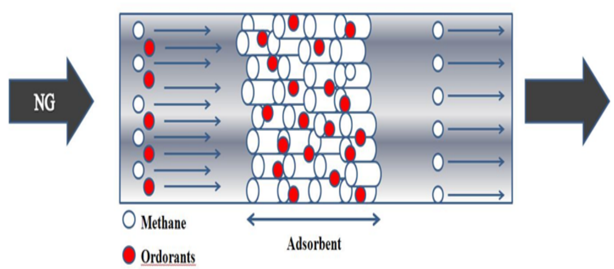


C_4H_8S

Concentration of Sulfur Compound

- Total Concentration : 3.8ppm
- THT : TBM = 70% : 30%

Role of Desulfurizer

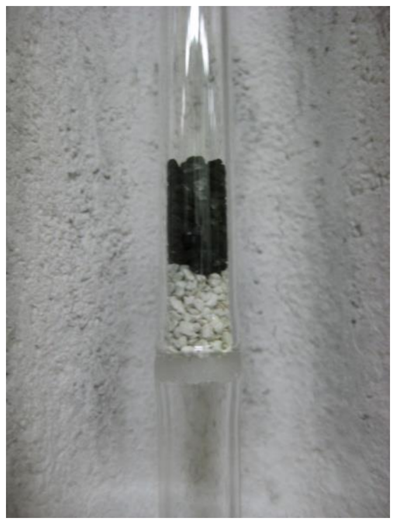


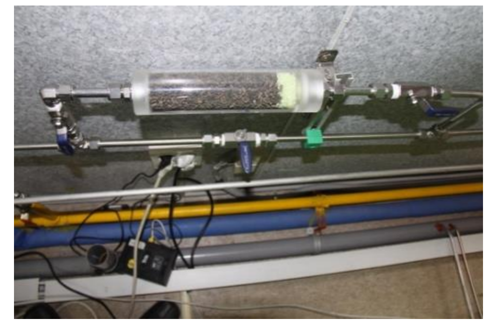
- Natural gas used as City gas in Korea contains organic sulfur compound (3-4ppm) such as tertiary-butyl mercaptan(TBM) and tetra hydro thiophene(THT) as odorants to make it easy to detect leakage of the gas.

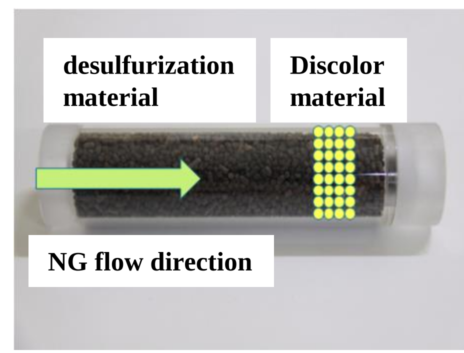
- However, sulfur compounds easily poisoned steam reforming catalysts containing Ni. Therefore, sulfur components have to decrease to ppb level in fuel cell system.

Desulfurization

- **Evaluation of desulfurization material for Power plant MCFC (Posco Power)**
- **Evaluation of desulfurization material for Residential fuel cell**

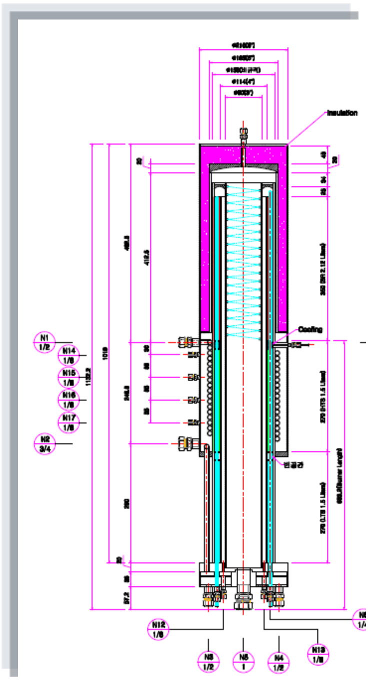


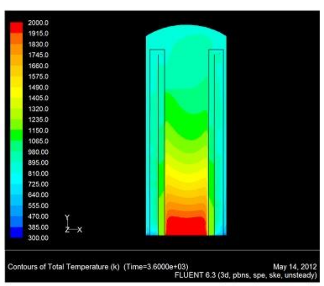


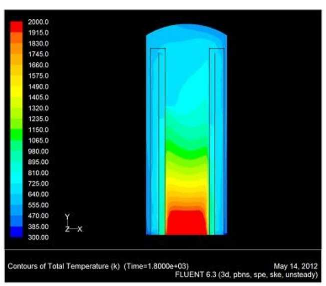


Desulfurization for Molten Carbonate fuel Cell

Basic experiment for simulation of PEM reformer







Chemical modeling in SR region

- **Steam Reforming**

$$CH_4 + H_2O \rightarrow CO + 3H_2 \qquad \Delta H = -206.1 \ {}^{kJ}/_{mol}$$

$$r_1 = \frac{k_1}{p_{H_2}^{2.5}}\left(p_{CH_4} p_{H_2O} - \frac{p_{H_2}^3 p_{CO}}{K_1}\right)/(DEN)^2$$

- **Water Gas Shift**

$$CO + H_2O \rightarrow CO_2 + H_2 \qquad \Delta H = +41.15 \ {}^{kJ}/_{mol}$$

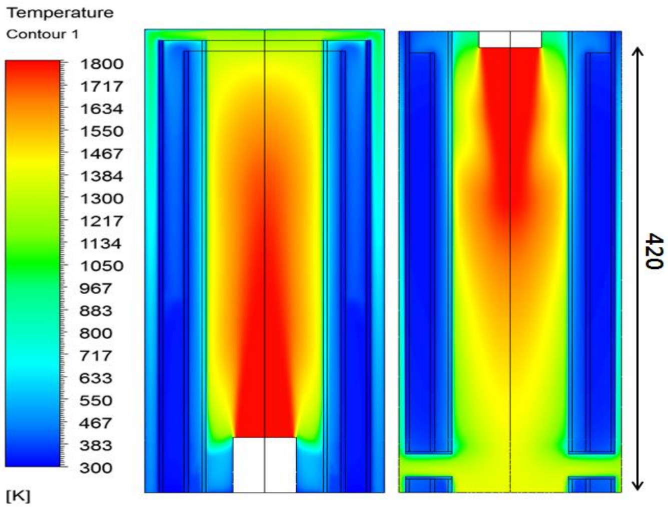
$$r_2 = \frac{k_2}{p_{H_2}}\left(p_{CO} p_{H_2O} - \frac{p_{H_2} p_{CO2}}{K_2}\right)/(DEN)^2$$

- **Direct Steam Reforming**

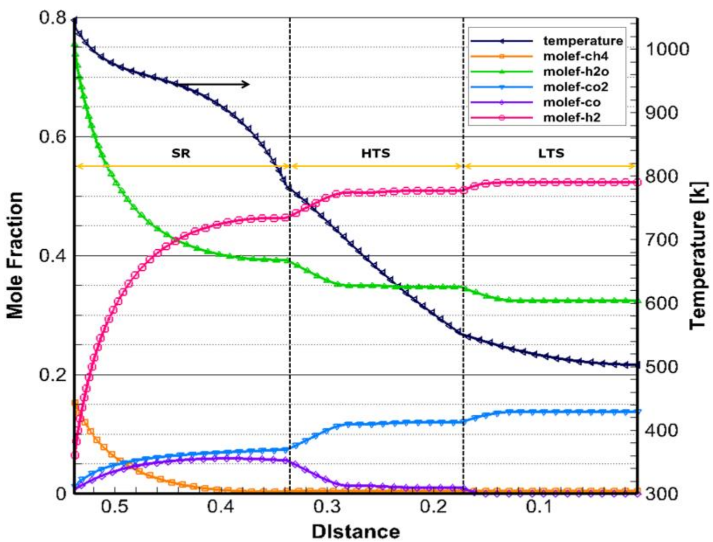
$$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2 \qquad \Delta H = -165 \ {}^{kJ}/_{mol}$$

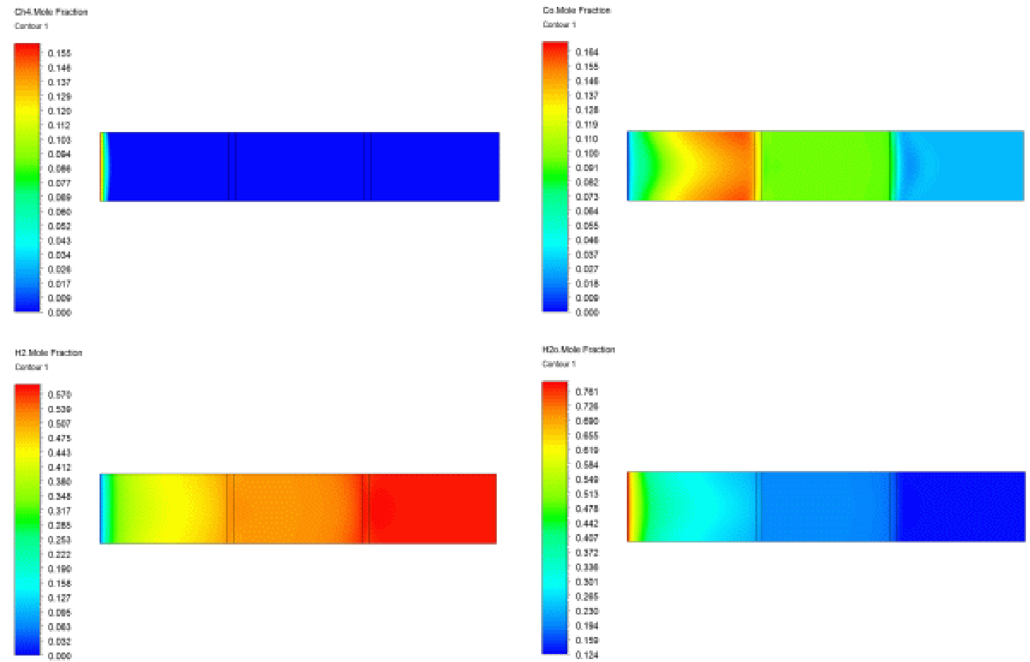
$$r_3 = \frac{k_3}{p_{H_2}^{3.5}}\left(p_{CH_4} p_{H_2O}^2 - \frac{p_{H_2}^4 p_{CO_2}}{K_3}\right)/(DEN)^2$$

Results of simulation



Temperature contour





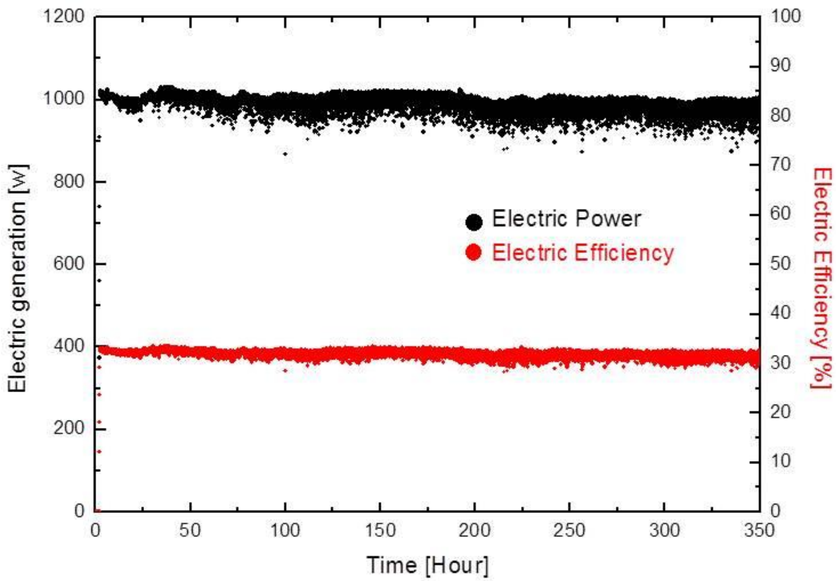
Concentration contour

Species	Simulation	Experiment
CH_4	0.56%	2.43%
H_2	77.33%	77.16%
CO	0%	0.32%
CO_2	20.29%	18.86%

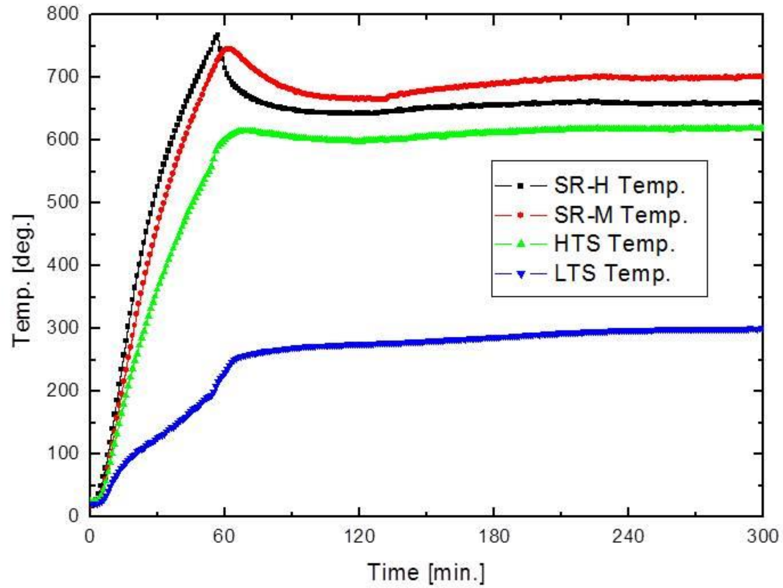
Comparison between simulation data and experiment data

Reformer for 1kW PEMFC System

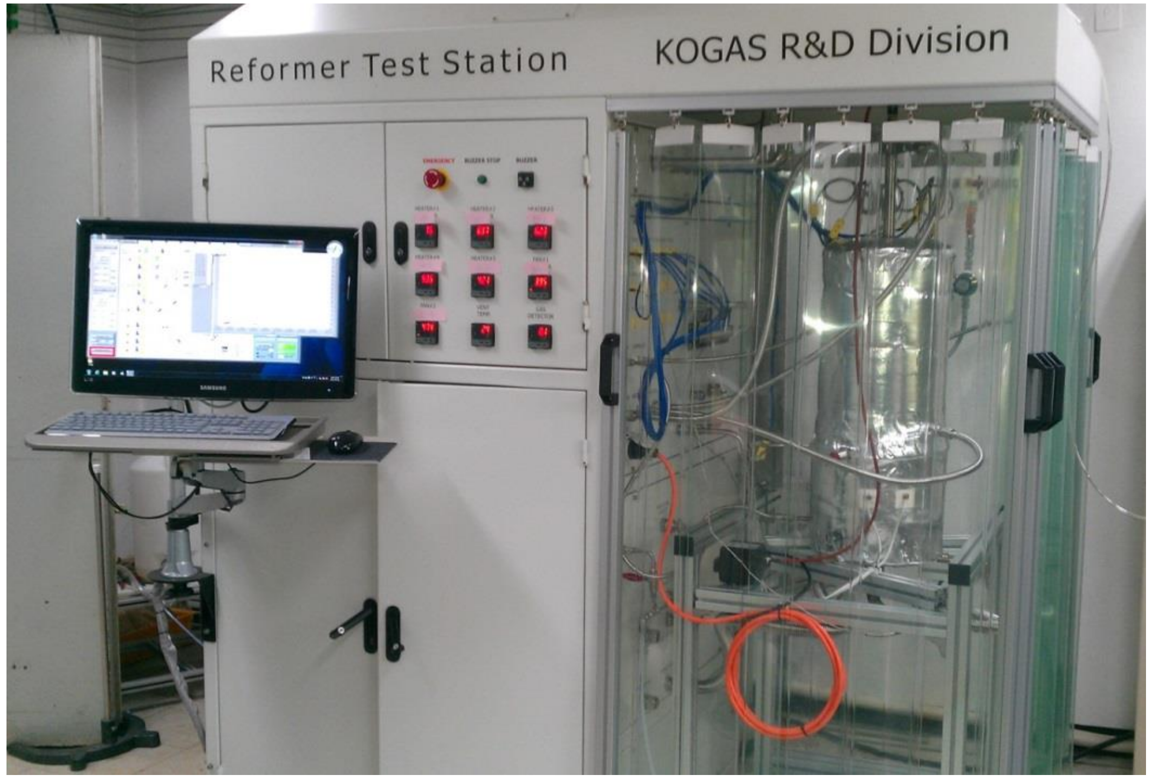
Performance Test



Temp. of Reformer

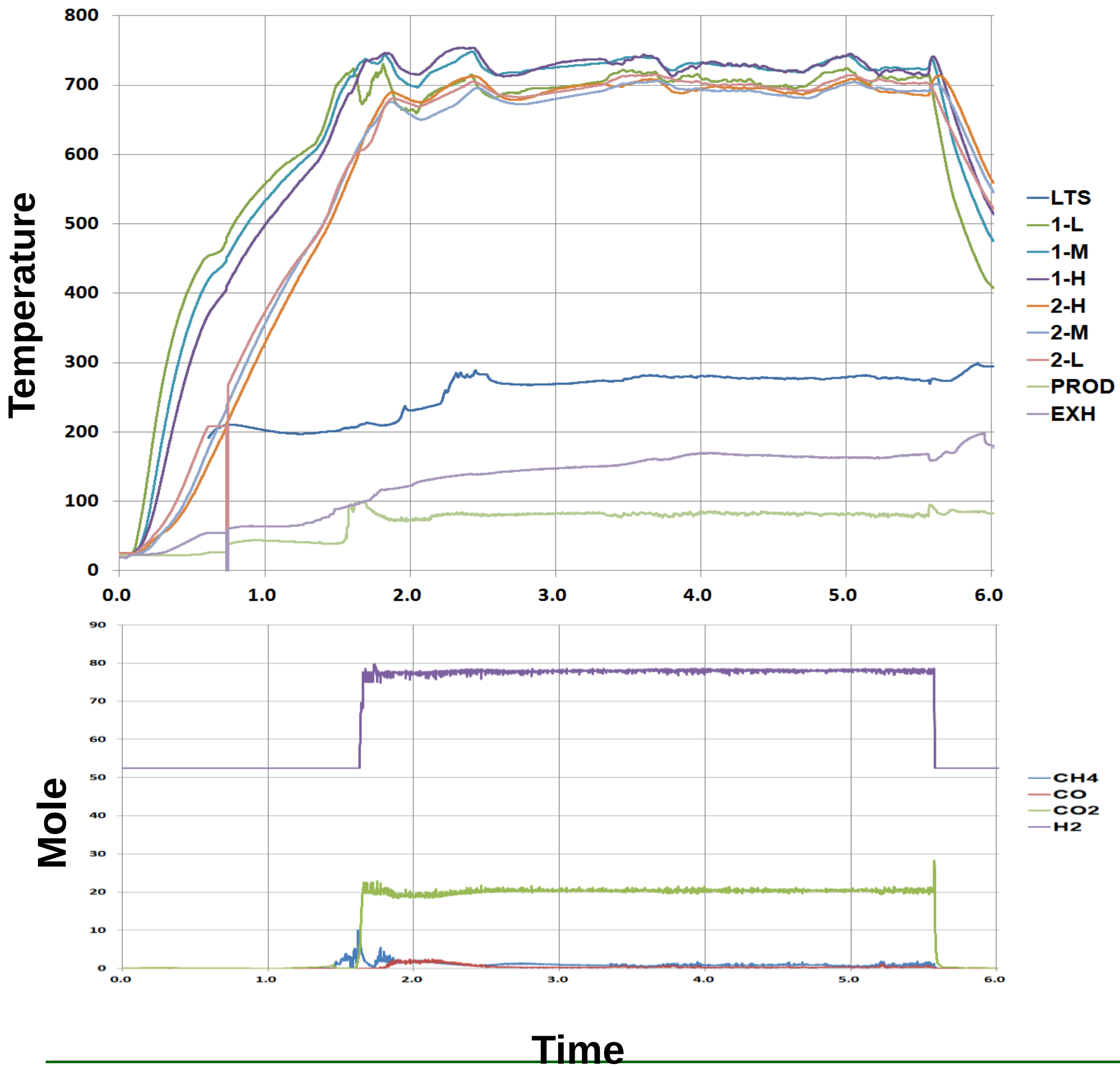


Reformer for 5kW HT-PEMFC developed by KOGAS



Developed compact reformer for 5kW HT-PEMFC

Results of performance test for 5kW-class reformer



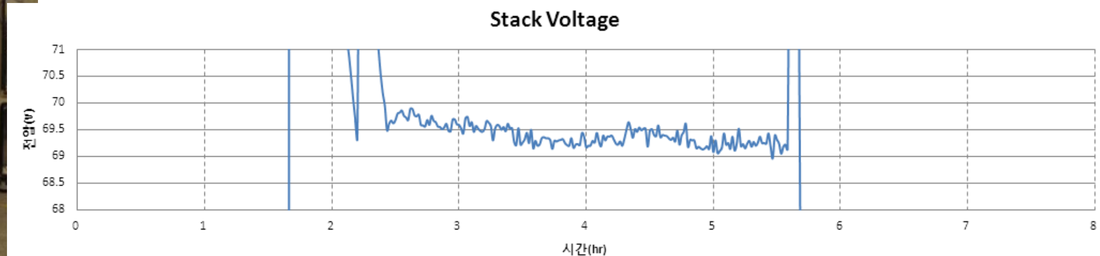
name	input data	Volumetric flow
	[-]	[l/min]
nat. gas reformer	(Natural gas)	20.000
nat. gas burner	(AOG)	45.44
A/F-burner	1.1	
S/C-Reformer	3.000	

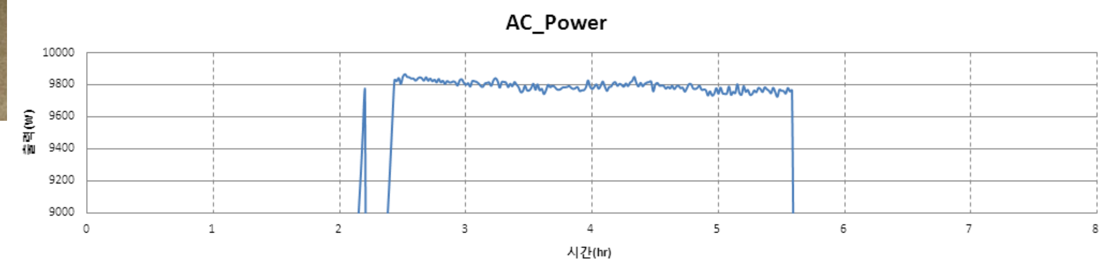
name	symbol	fraction x_i (dry)
	[-]	[mol %]
methane	CH_4	0.64
hydrogen	H_2	79.1
carbon monoxide	CO	0.25
carbon dioxide	CO_2	20.01
nitrogen	N_2	0.00
water	H_2O	0

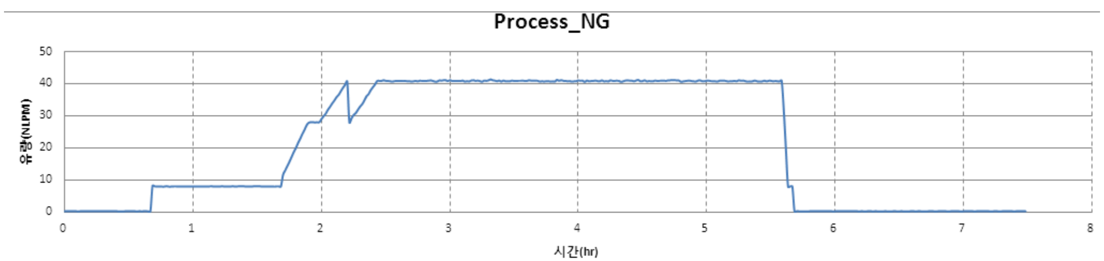
name	Efficiency(LHV)
standard (behind shift)	77.66

Reformer for 10kW for PEMFC

Application of developed 10kW-reformer to fuel cell system

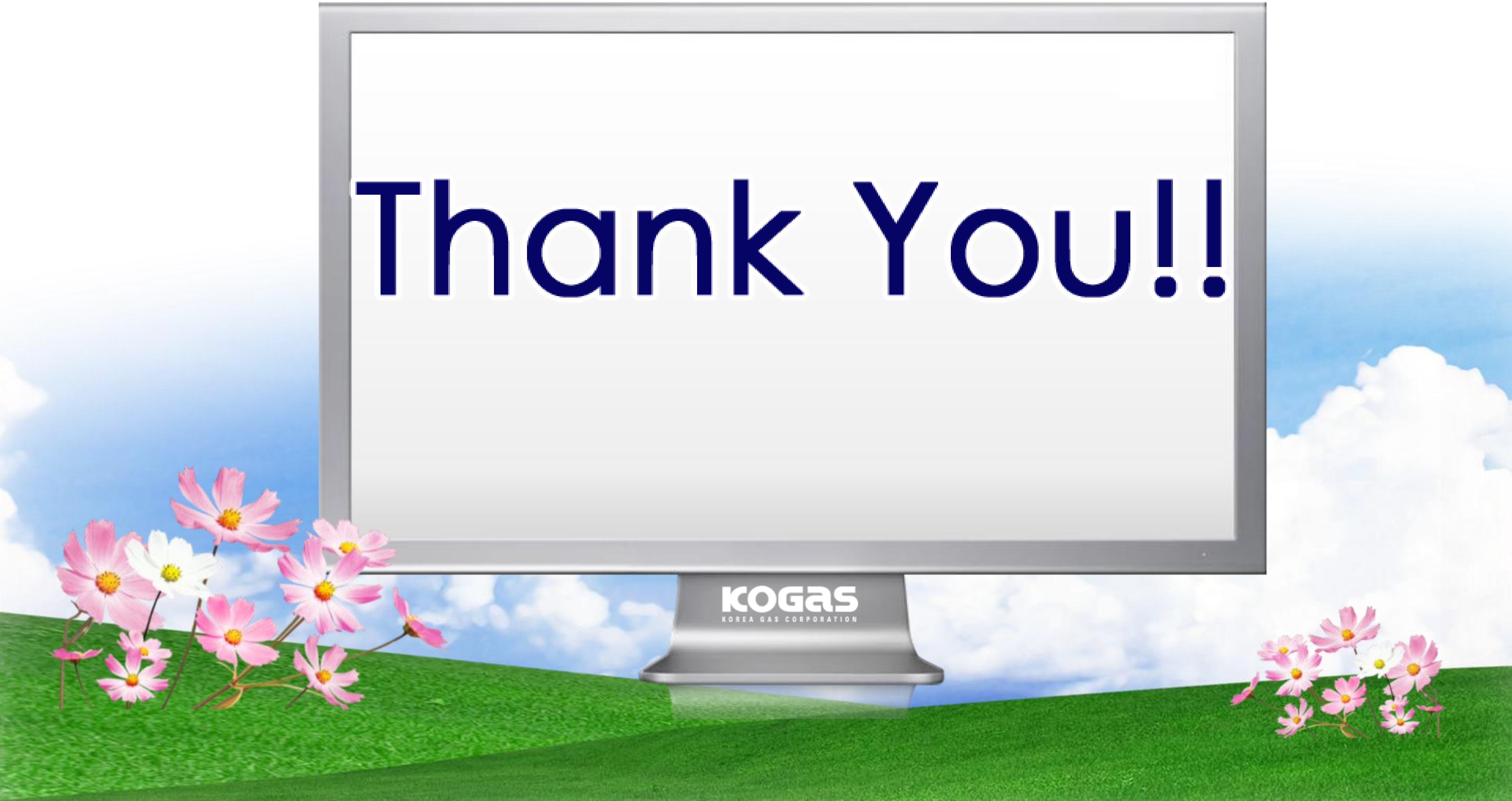






Conclusion

- The demand for new renewable energy is becoming stronger and in the current situation the government also is forcing the process by creating legislations.
- The domestic fuel cell market is currently being largely expanded and technology development is actively in progress.
- In accordance to this, KOGAS has developed many sizes of reformers (1~10kW-class) and displayed the highest level of performance.
- Furthermore, KOGAS has specific strategy for Fuel Cell development and plan to develop under 50kW-class reformers according to this strategy.
- Through development and commercialization of reliable reformers, KOGAS will lead in the supply of fuel cell systems in Korea.


Thank You!!
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Application to Gas Supply station

Heating 1.22ton/hr of natural gas with heat generated from 10kW fuel cell

Gas heater

- Reduce the pressure of gas in pipe line in order to supply desired gas pressure to city gas companies or power plants at the gas supply station .

- use gas heater usually to prevent pipe line, gauges and metering facilities from low temperature gas flow caused by pressure drop

- 5 or 10kW fuel cell system can be used as auxiliary heat supplier to heat natural gas during reducing gas pressure

Prototype burners for 5kW HT-PEMFC

Type A
Nozzle burner

Type B
Surface combustion
(Cylindrical)

Type B
Surface combustion
(Round flat)

Nozzle shape

Flame pattern1

Flame pattern2

Fuel : NG (7.3kW)

Fuel : Offgas (5.9kW)

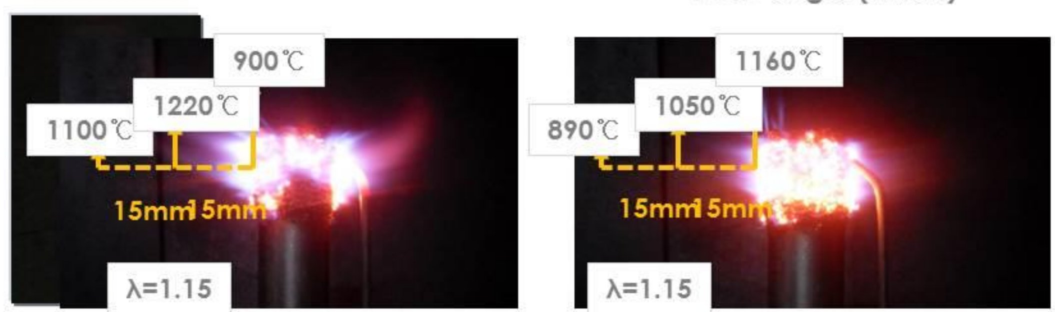

Figure temperature profile of flame according to fuel