A Study for the Gas Interchangeability of the Natural Gas Utilization Equipment Regarding the Variation of Heating Value

Hyunseok You

R&D Division
KOGAS

Contents

Background

- **A history of city gas trading unit in Korea**

  - **Volume flowrate : 1987. 2 ~ 2012. 6**

    - **Standard heating value : 10,400 kcal/Nm³**

  - **The 1st heating value : 2012. 7 ~ 2014. 12**

    - **The range of heating value : 10,100~10,600 kcal/Nm³**

    - **Raising the effect of HV change on the gas equipment performance in the residential/commercial, industry, power generation, etc..**

    - ⇒ **It is the background of this study**

  - **The 2nd heating value : 2015. 1 ~ ?**

   - **The range of heating value : 9,800~10,600 kcal/Nm³**

Methodology

- **The analysis of consumer's the present state**
  - The questionnaire survey analysis of 1,199 companies(sensitive & big consumer)

- **The decision and site visit on sensitive equipments and processes**
  - About 50 companies decided through the questionnaire and the site visit by experts

- **Demonstration experiments of sensitive equipments and processes by final decision**
  - Residential use: gas boilers, etc.
  - Commercial(gas engine) use : NGV, CHP, GHP
  - Industry use : the heating process like furnace, heat treatment process, IR dryer, direct fired processes in glass/steel
  - Power generation : gas turbine(not including the presentation)

Theoretical review

- **The effect of LNG HV on stoichiometric air/fuel ratio**
  - **The linear correlation between LNG HV and stoich. A/F ratio**

⇒ **The HV change provokes variation of A/F ratio in the operation of gas equipments.**
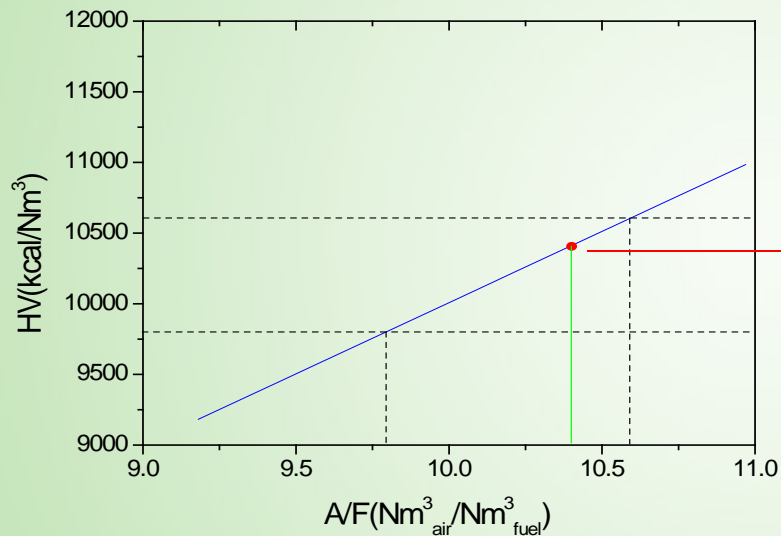

The correlation between HV and stoich. A/F ratio in LNG
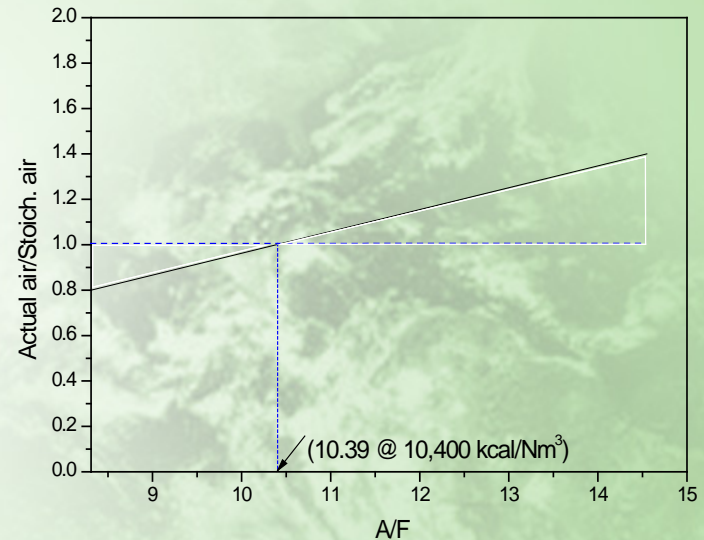
The conceptual diagram of the change of working A/F ratio according to the HV change in case of combustor tunned @ 10,400 kcal/Nm³

Theoretical review

- **The effect of A/F ratio on the flame temperature of natural gas**
  - The flame temperature is mainly affected by the variation of A/F ratio.
  - Only maintaining the constant A/F ratio minimizes the variation of the flame temperature because of the HV's weak effect.
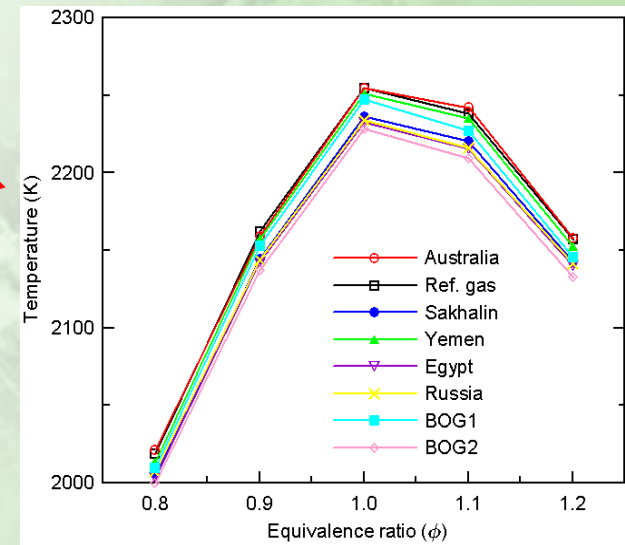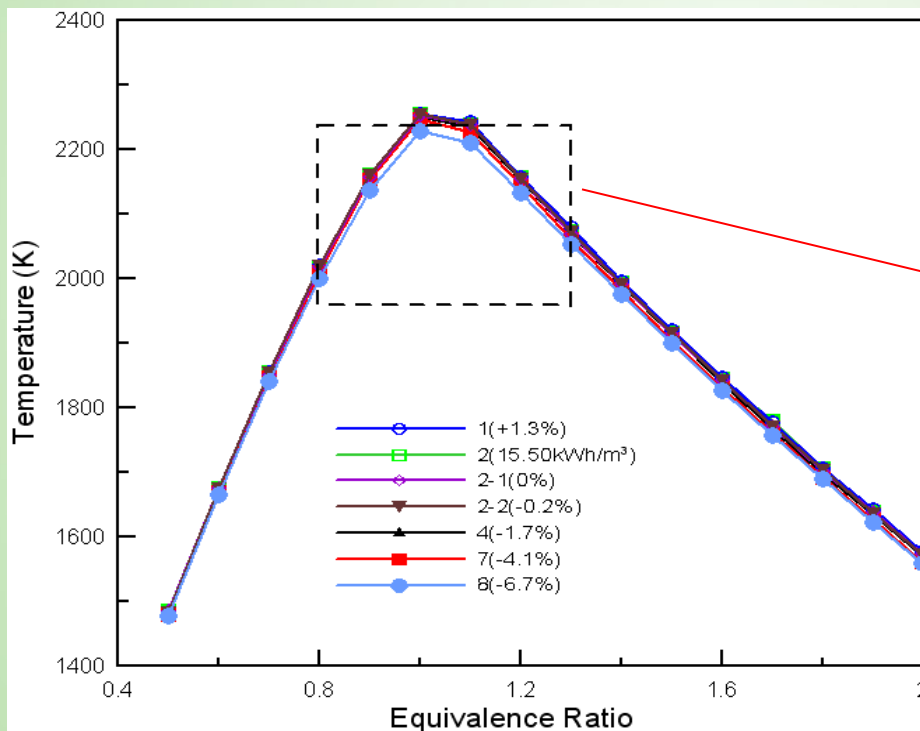
@ **The effect of A/F ratio on the thermal efficiency in the gas boiler**

- **In the exhaust gas point of view, the flowrate of excess air is another effect parameter on the thermal efficiency including the temperature.**
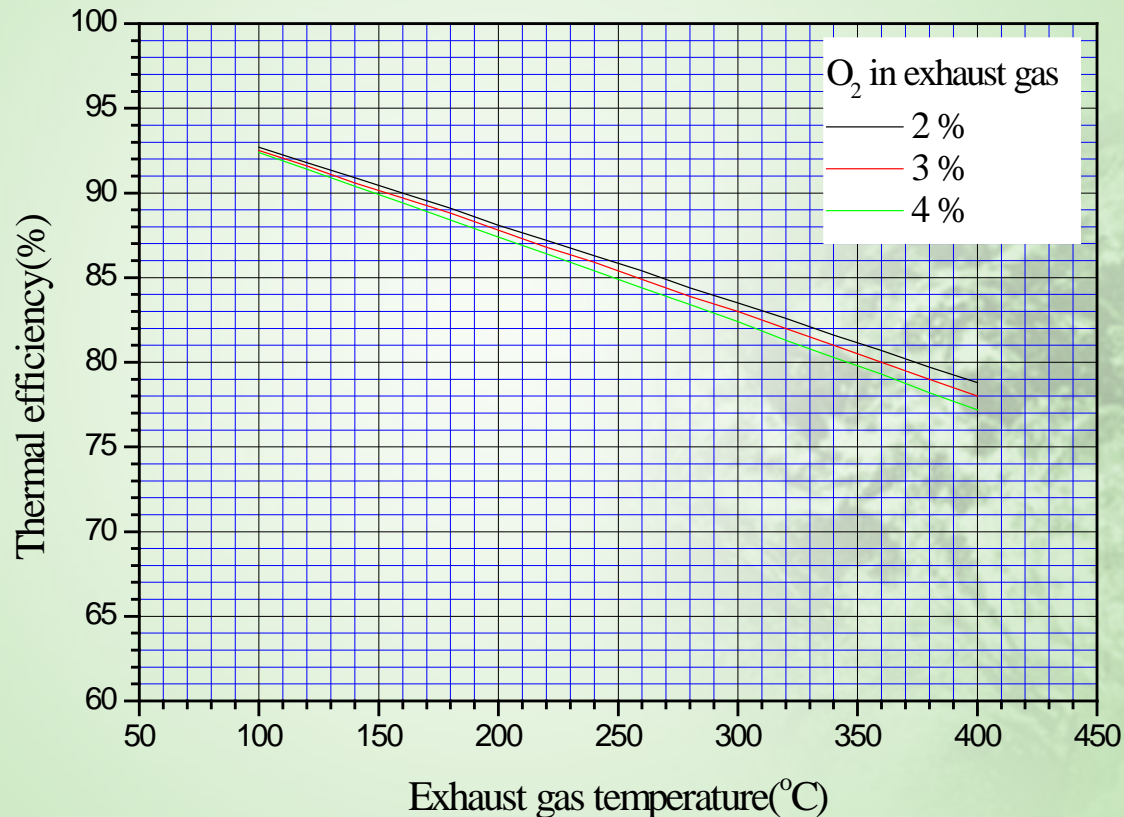
Demonstration experiment

Demonstrating the effect of natural gas based on producing location

No.	1	2*	3	4	5	6	7	8
Producing location	Australia	Ref. gas	Sakhalin	Yemen	Egypt	Russia	BOG1	BOG2
Higher heating value (kcal/Nm^3)	10,835	10,550	10,295	10,096	9,781	10,024	9,523	9,332
Wobbe index (kcal/Nm^3)	13,492	13,325	13,186	13,095	12,927	12,855	12,784	12,436
$[A/F]_{stoi.}$ (Nm^3/Nm^3)	10.8242	10.5415	10.2878	10.0891	9.7761	10.0046	9.5200	9.3296

* 2-1, 2-2 : the same heating value but different composition with No 2
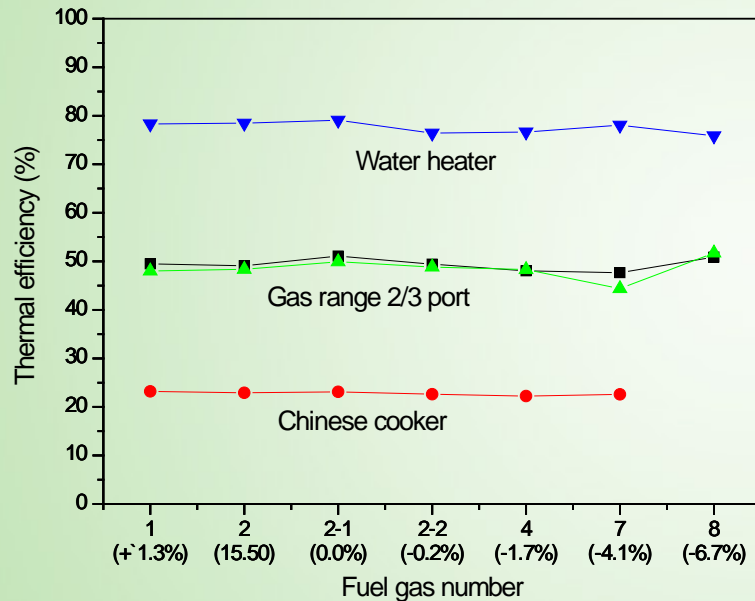
Demonstrating equipments

- **The residential : products**
- **The industry/engine : simulated devices**
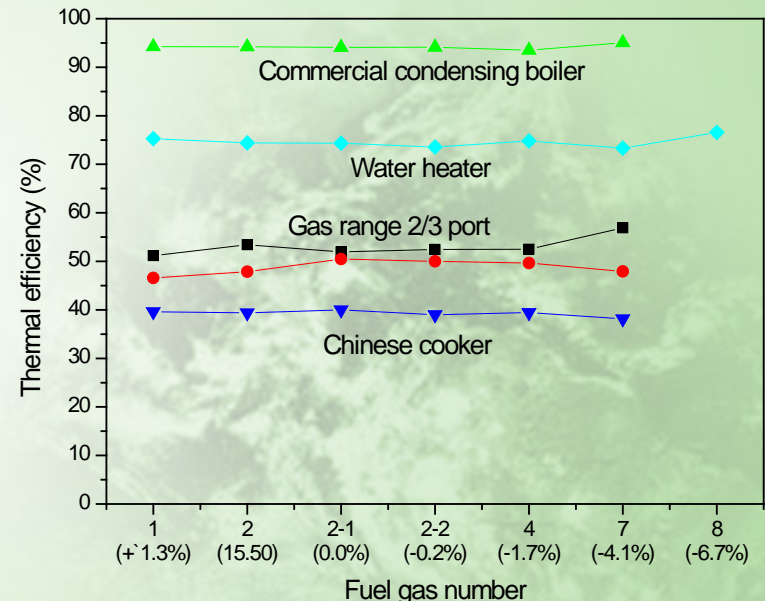
Demonstration result

⊙ **The residential/commercial**

- **The residential : gas range, water heater**
- **The commercial : condensing boiler, Chinese cooker**

⇒ **No serious effect of HV's variation on the residential and commercial**

(a) Max. load

(b) Min. load

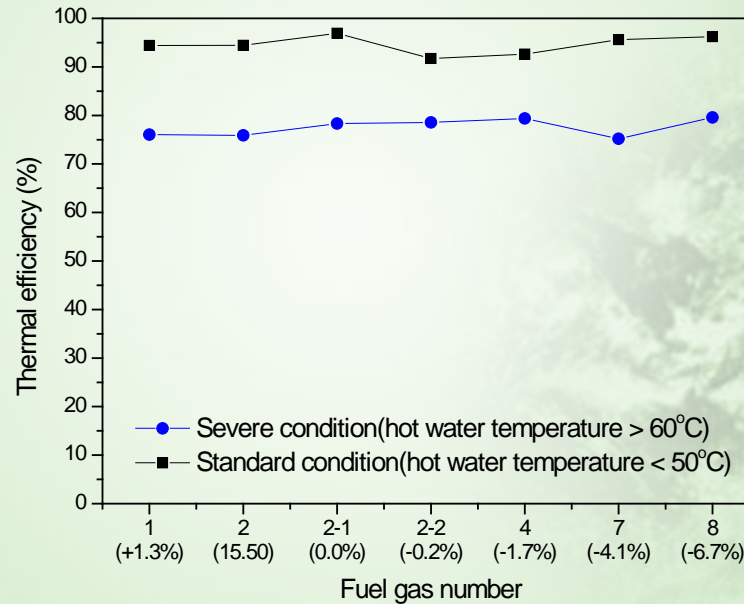**The change of thermal efficiency of various gas appliances according to HV's variation**

R&D Division
KOGAS

Demonstration result

⊙ **The residential : the condensing boiler**

⇒ **No serious effect of HV's variation on the condensing boiler**

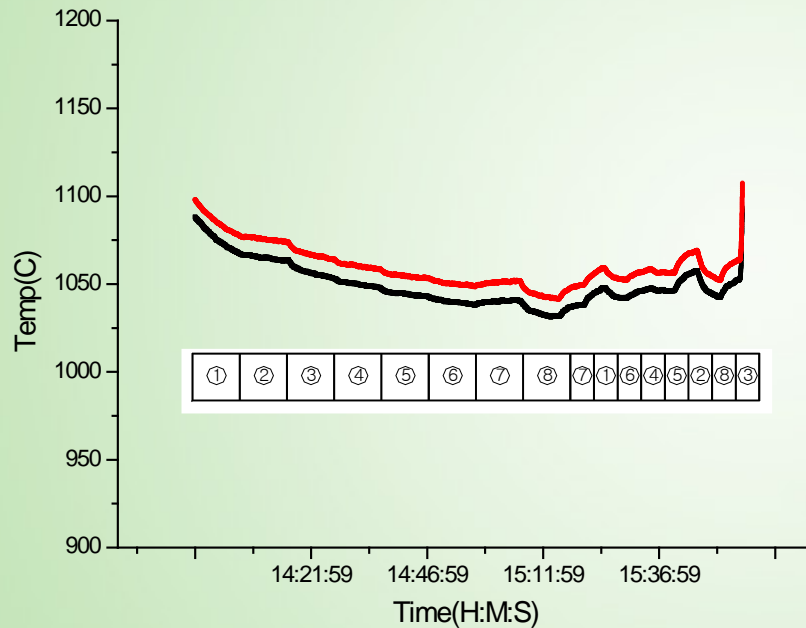⇒ **Post study* had made sure of this result.**

* "New Method for Estimating Gas Interchangeability for 13A Gas Appliances"
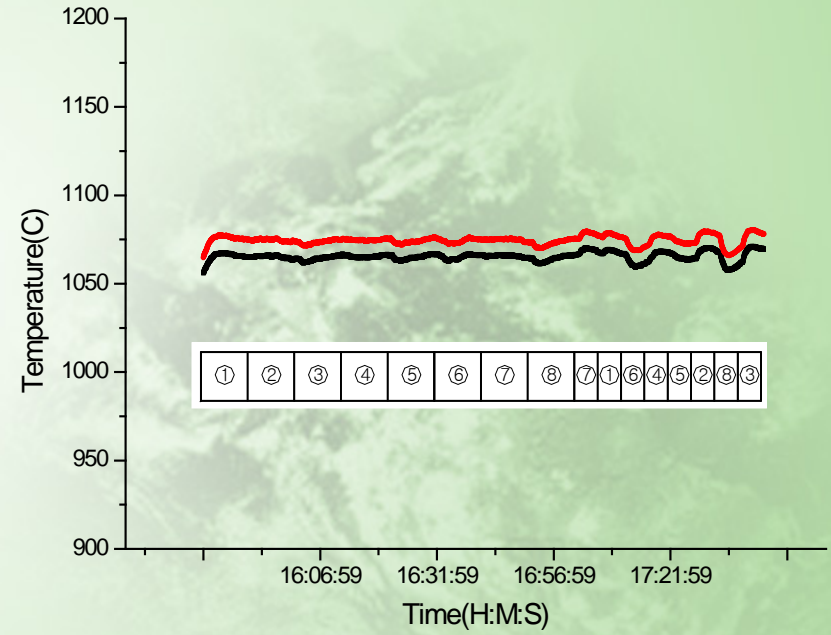

The change of thermal efficiency of the residential condensing boiler according to HV's variation

Demonstration result

⊚ **The industry : heating processes(steel/ceramics)**

⇒ **TIC can remove the effect of HV's variation on furnace temperature.**
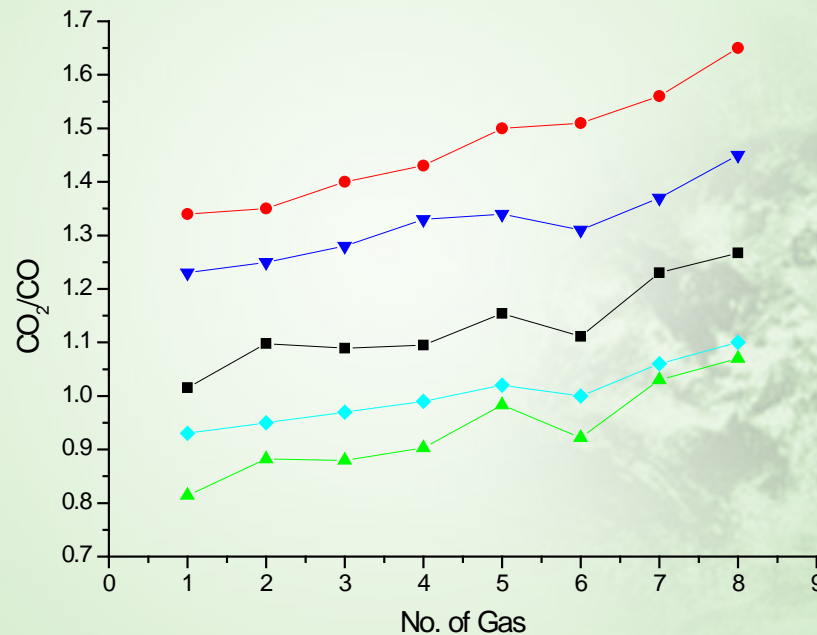

Uncontrolled temperature

Temperature controlled by TIC

The temperature profiles in the furnace according to HV's variation
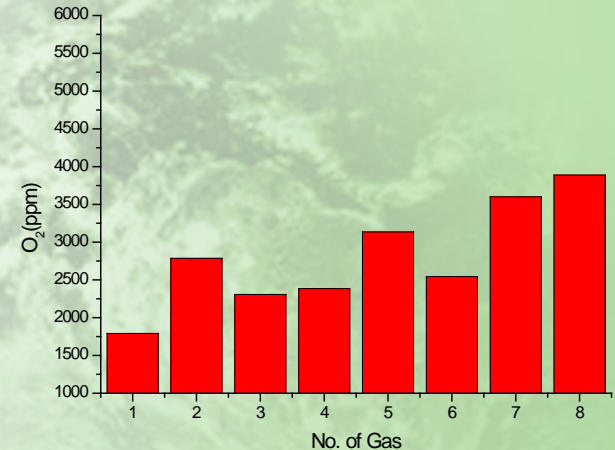
Demonstration result

⊚ **The industry : heat treatment processes(steel)**

- **The direct fired reducing furnace**

⇒ **The decrease of HV provokes the increase of the CO_2/CO ratio.**

(Chart: y-axis CO_2/CO from 0.7 to 1.7, x-axis No. of Gas from 0 to 9)

The change of CO_2/CO ratio in the reducing furnace according to HV's variation

Demonstration result

⊚ **The industry : heat treatment processes**

- **The DX gas annealing furnace**

⇒ **The decrease of HV provokes the decrease of the reducing gas.**
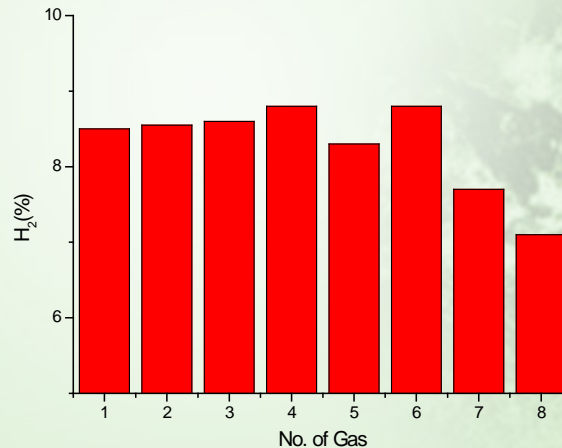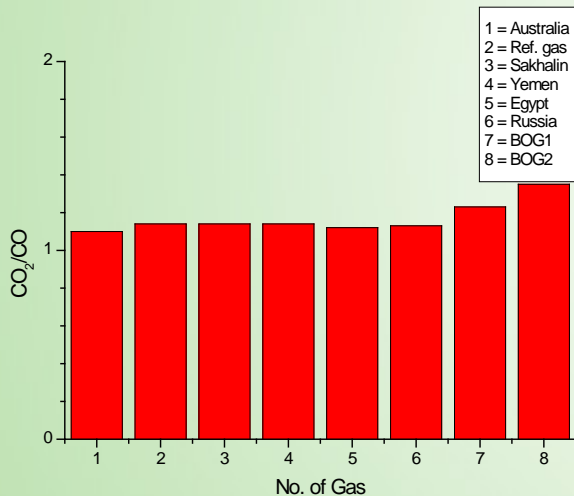
The change of DX gas in the annealing furnace according to HV's variation

Demonstration result

- The industry : heat treatment processes
  - The RX gas annealing/carburizing furnace
- ⇒ The decrease of HV makes the atmosphere of the reducing furnace oxidize.
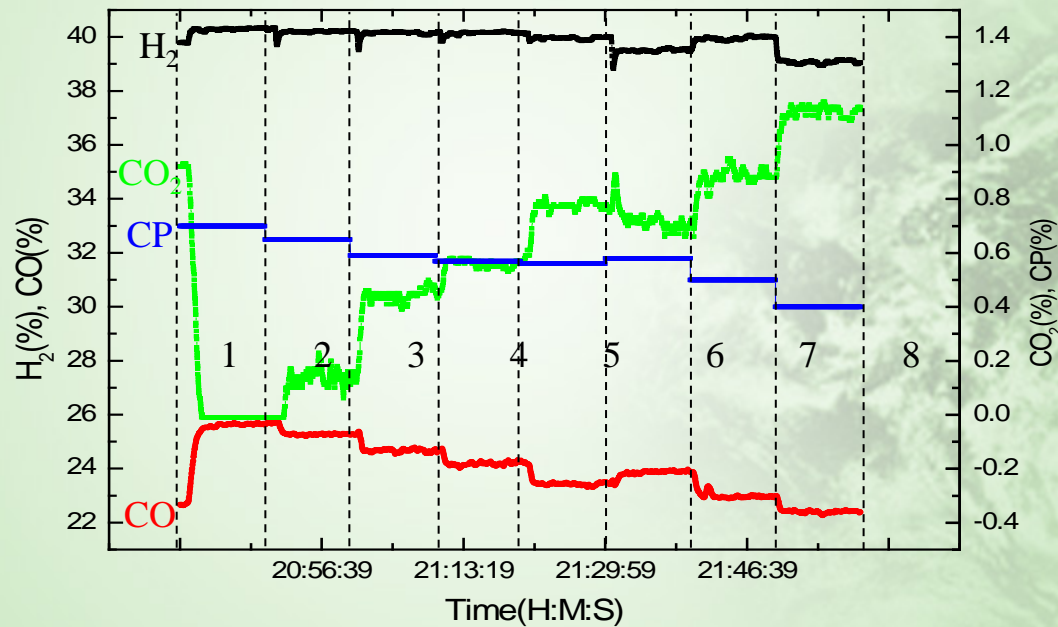
The RX gas profiles in the furnace according to HV's variation

Demonstration result

@ **The industry : direct fired process**

- **The steel cutting oxygen torch**

⇒ **No serious effect of HV's variation on the steel cutting process**

(mm/min)

300	A-1-1	A-2-1	A-3-1	A-4-1	A-5-1	A-6-1	A-7-1	A-8-1
375	A-1-2	A-2-2	A-3-2	A-4-2	A-5-2	A-6-2	A-7-2	A-8-2
450	A-1-3	A-2-3	A-3-3	A-4-3	A-5-3	A-6-3	A-7-3	A-8-3
No.	2	1	3	4	5	7	6	8
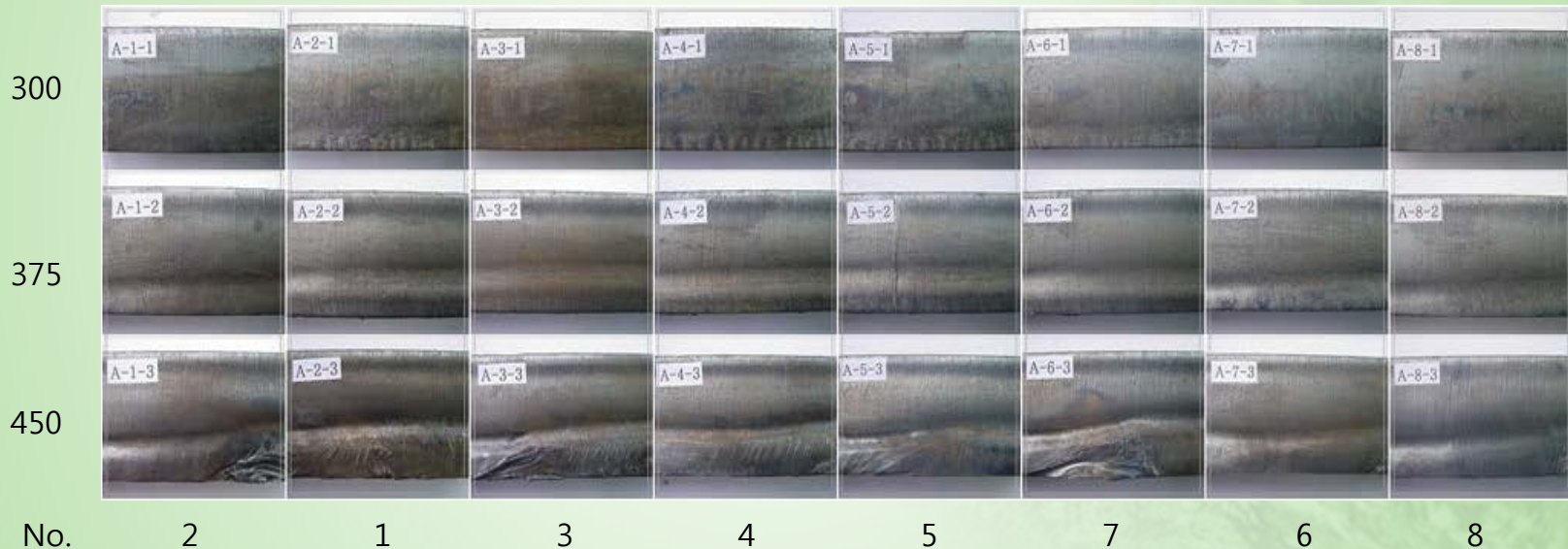
The photos of cutted steel surface by oxygen torch fuel by natural gas based on producing location

R&D Division KOGAS

Demonstration result

⊚ **The industry : direct fired process**

- **The class cutting and bending**

⇒ **No serious effect of HV's variation on the glass process**
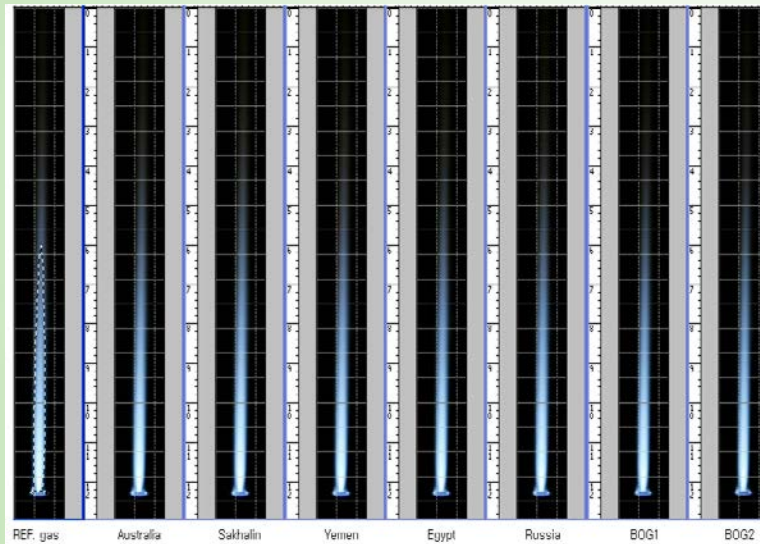
The change of the flame length in cutting flame according to HV's variation

Ref. gas — 14.63, Australia — 14.79, Sakhalin — 15.11, Yemen — 15.20, Egypt — 14.70, Russia — 14.19, BOG1 — 14.24, BOG2 — 14.19
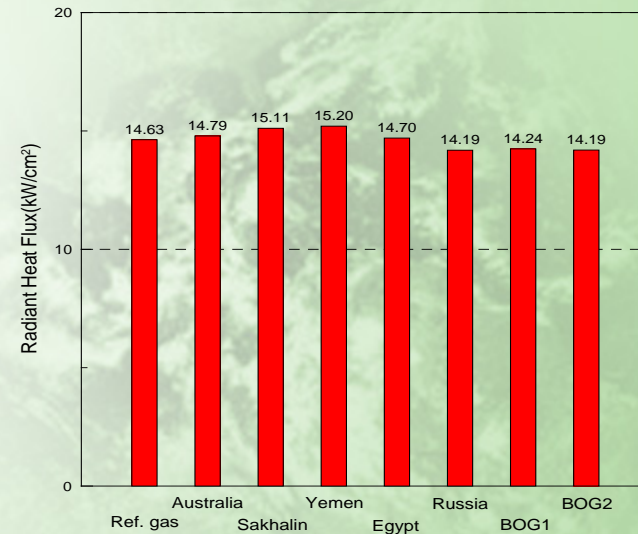
The change of the heat flux in cutting flame according to HV's variation

R&D Division KOGAS

Demonstration result

⊙ **The industry : direct fired process**

- **IR paper dryer**

⇒ **No serious effect of HV's variation on IR paper dryer**
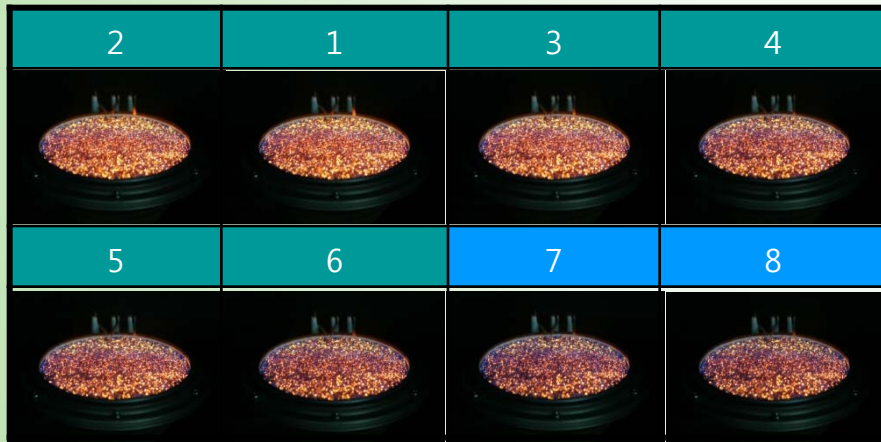
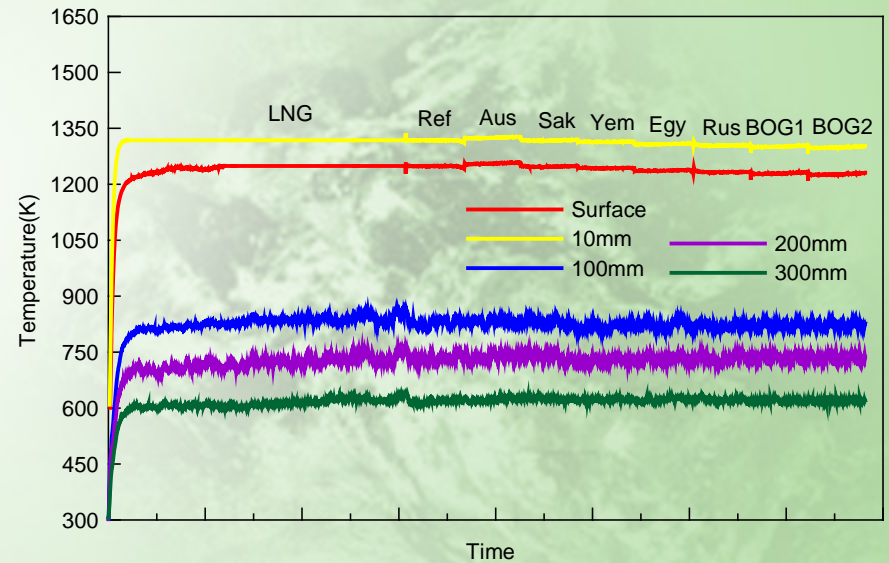The comparison of radiation intensity in the metal fiber burner according to HV's variation

The temperature profiles of each position in IR dryer according to HV's variation

R&D Division KOGAS

Demonstration result

The gas engine : NGV, CHP, GHP

- **Power**

λ control : ON(NGV, CHP)

rpm (WOT)	Power	Deviation(%)	
	10,450 kcal/Nm³	9800 kcal/Nm³	9500 kcal/N³
1000	57.8 kW	-3.7	-5.0
1500	97.6 kW	-2.6	-3.1
2000	131.3 kW	-3.2	-4.1
2500	158.4 kW	-3.3	-4.7
Average		-3.2	-4.2

λ control : OFF(CHP, GHP)

rpm (WOT)	Power	Deviation(%)	
	10450 kcal/Nm3	9800 kcal/Nm3	9500 kcal/N3
1000	58.9 kW	-3.7	-5.7
1500	99.3 kW	-4.4	-3.7
2000	131.3 kW	-5.3	-7.4

Demonstration result

- **The gas engine : NGV, CHP, GHP**
  - **Thermal efficiency**

λ control : ON(NGV, CHP)

rpm (WOT)	Thermal efficiency	Deviation(%)	
	10,450 kcal/Nm³	9,800 kcal/Nm³	9,500 kcal/Nm³
1000	34.9 %	-1.8	-2.3
1500	34.6 %	-1.1	-1.5
2000	33.3 %	-0.7	-1.1
2500	32.2 %	-0.8	-1.1
Average		-1.1	-1.5

λ control : OFF(CHP, GHP)

rpm (WOT)	Thermal efficiency	Deviation(%)	
	10,450 kcal/Nm³	9,800 kcal/Nm³	9,500 kcal/Nm³
1000	35.0	-1.8	-2.5
1500	34.7	-1.2	-1.7
2000	32.3	-1.5	-2.1

Conclusion

1) In the case of residential equipment, most performance factors did not show a problem including the thermal efficiency based on heating value change.

2) In the case of the industry, in glass processes, direct fired dryers and metal cutting processes, at the process where the flame makes a direct influence on the material, the heating value did not make a large influence on this process and it is considered that this is due to the fuel composed of the main component of methane with hydrocarbon series where the change of heat value has small influence on the flame characteristic.

3) Meanwhile, in the process like the furnace where the atmosphere temperature is maintained by the heating value, the variation of HV provokes the temperature fluctuation in furnace so an automatic temperature control device such as TIC is necessary.

Conclusion

4) It was confirmed that in the steel industry process such as the heat treatment process was very sensitive to the heating value where the natural gas is not used as the fuel but as the raw material. This change of heating value represents the change of stoichiometric ratio of natural gas/air and it is a phenomenon that is caused by the change of oxidation/reduction atmosphere gas components in this process.

5) In the case of NGV, the automobiles were all able to be driven under the basis of rules of the motor vehicle safety standard (performance parameter over -5%) in all types of the experiment gases because of λ control.

6) But in stationary engines like CHP, GHP, it was found that more than a 5% deviation of power change occurred in non λ control.

Thank you for your attention