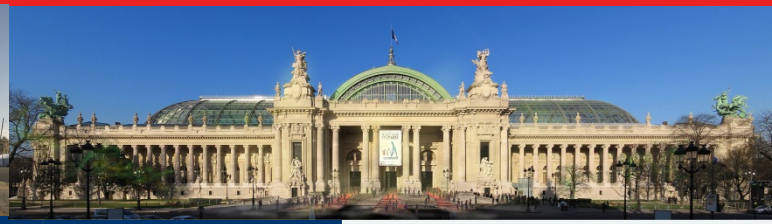
26th World Gas Conference

1 – 5 June 2015, Paris, France



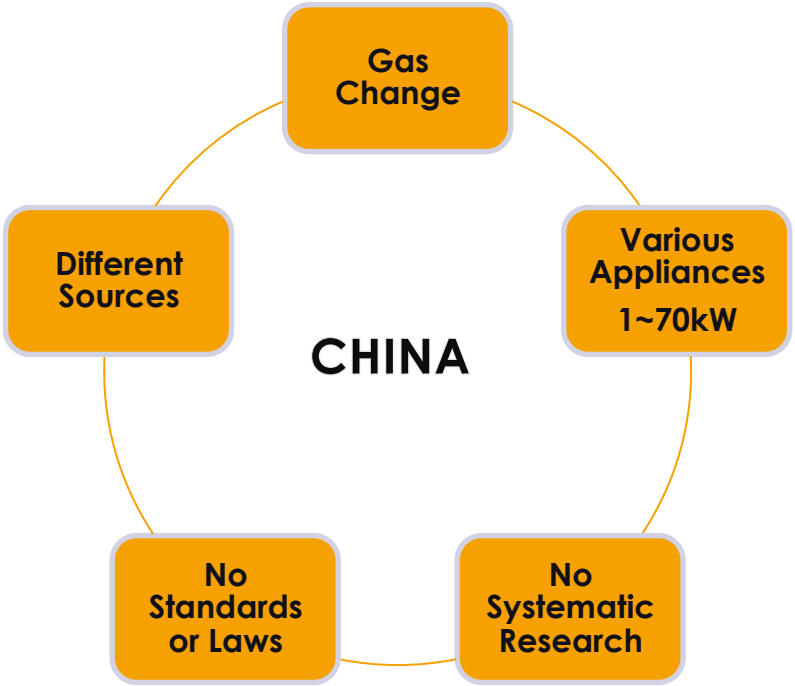



Research on influence of gas quality on domestic gas appliances in China

Prof. Dr. GAO Wenxue
1-China Gas Society;
2-North China Municipal Engineering Design & Research Institute CO., Ltd.

WGCPARIS2015
WORLD GAS CONFERENCE

Background



Combustion Index (CI)

- Evaluate the CO emission performance
- Intend to replace CP to classify gas group

Gas appliance adaptability

- Propose gas indexes combination characterizing the limit curves
- Determine the common adaptability range of Chinese major domestic gas appliances

Methods—Experiment system

Figure.2 Schematic diagram of gas combustion characteristic and gas appliance adaptability experiment system (GCTS)

$$CI = \frac{CO_{mix}}{CO_{CH_4}} = \frac{k_1C_1 + k_2C_2 + k_3C_3 + k_4C_4 + k_5H_2 + k_6N_2}{\sqrt{d_{mix}}} \quad (1)$$

Purity of gas component					
CH_4	C_2H_6	C_3H_8	i-C_4H_{10}	H_2	N_2
99.9%	99.5%	99.9%	99.2%	99.9%	99.9%

Results—Combustion Index about CO emission —CI

$$CI = \frac{CO_{mix}}{CO_{CH_4}} = \frac{0.74C_1 + 6.16C_2 + 9.31C_3 + 19.51C_4 - 1.96H_2 - 8.16N_2}{\sqrt{d_{mix}}} \quad (2)$$

Table.1 Experiment results of CO emission influence coefficient of ethane, propane and butane

CO_{mix}/CO_{CH4}	CH_4	C_2H_6	d	k_2	CO_{mix}/CO_{CH4}	CH_4	C_3H_8	d	k_3	CO_{mix}/CO_{CH4}	CH_4	C_4H_{10}	d	k_4
1.690	0.960	0.040	0.575	6.50	1.738	0.969	0.031	0.586	9.68	2.047	0.972	0.028	0.600	17.01
1.750	0.940	0.060	0.585	5.45	1.751	0.957	0.043	0.598	7.94	2.456	0.958	0.042	0.620	20.31
1.828	0.921	0.079	0.594	5.11	1.955	0.950	0.050	0.605	9.58	2.653	0.951	0.049	0.630	19.37
2.031	0.902	0.098	0.604	5.68	2.058	0.942	0.058	0.613	9.76	2.853	0.943	0.057	0.650	19.31
2.184	0.882	0.118	0.613	5.82	2.151	0.933	0.067	0.622	9.68	3.049	0.926	0.074	0.660	18.92
2.475	0.866	0.134	0.621	6.69	2.204	0.921	0.079	0.634	9.07	3.376	0.922	0.078	0.680	20.19
2.885	0.847	0.153	0.630	7.80	2.406	0.911	0.089	0.644	9.86	3.773	0.913	0.087	0.690	21.44
2.946	0.828	0.173	0.640	7.38	2.589	0.890	0.110	0.665	9.65					
2.951	0.808	0.192	0.650	6.87	2.607	0.883	0.117	0.672	9.37					
2.947	0.786	0.214	0.661	6.37	2.601	0.874	0.127	0.682	8.90					
2.273	0.766	0.234	0.671	4.09	2.682	0.863	0.137	0.692	8.89					
Mean				6.16	Mean				9.31	Mean				19.51
Variance				1.137	Variance				0.325	Variance				1.917
Standard Deviation				1.066	Standard Deviation				0.570	Standard Deviation				1.385

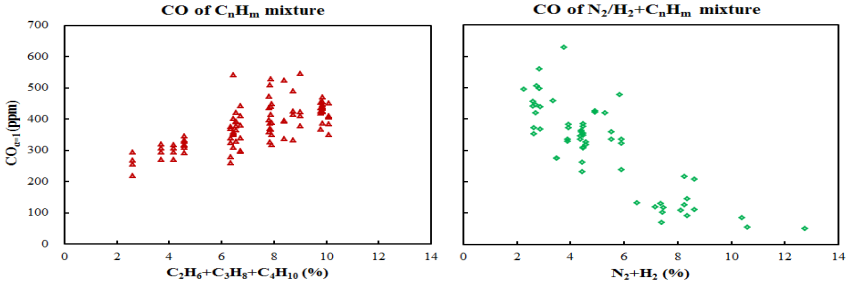


Figure.3 Eexperimental results of CO emission changing with gas components

Table.2 Experiment results of CO emission influence coefficient of hydrogen and nitrogen

CO_{mix}/CO_{CH4}	CH_4	H_2	d	k_5	CO_{mix}/CO_{CH4}	CH_4	N_2	d	k_6
1.163	0.952	0.048	0.532	-1.81	0.463	0.951	0.049	0.575	-8.88
0.553	0.873	0.128	0.493	-2.93	0.447	0.949	0.051	0.576	-8.70
0.613	0.865	0.135	0.489	-2.53	0.348	0.943	0.057	0.578	-8.66
0.508	0.830	0.170	0.472	-2.20	0.344	0.942	0.058	0.579	-8.54
0.455	0.794	0.206	0.455	-1.84	0.346	0.941	0.059	0.579	-8.52
0.317	0.789	0.212	0.452	-2.08	0.262	0.933	0.067	0.582	-8.05
0.250	0.748	0.252	0.433	-1.77	0.273	0.932	0.068	0.582	-7.96
0.400	0.745	0.255	0.431	-1.48	0.284	0.931	0.069	0.583	-7.59
0.309	0.710	0.290	0.414	-1.37	0.222	0.925	0.075	0.586	-7.35
0.137	0.707	0.293	0.413	-1.59	0.223	0.924	0.076	0.586	-7.34
Mean				-1.96	Mean				-8.16
Variance				0.235	Variance				0.337
Standard Deviation				0.485	Standard Deviation				0.581

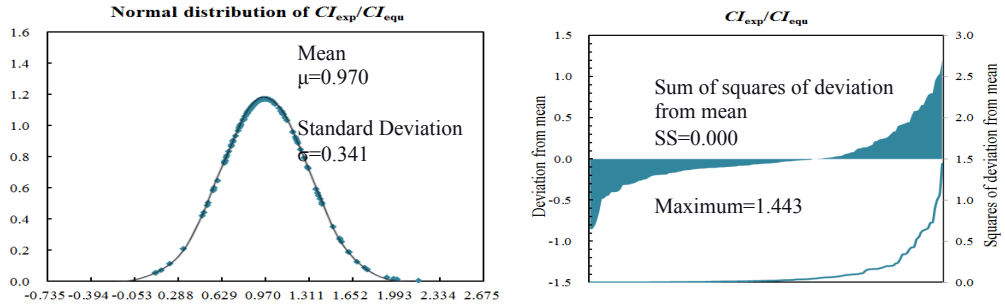


Figure.4 Mathematical statistical analysis of the specific value of CI_{exp}/CI_{equ}

Results—Combustion Index about CO emission —CI

Table.3 The correction of CO emission influence coefficient k_i of each gas component

CO emission influence coefficient		The first phase experiment	The second phase experiment
CH_4	k_1	0.74	0.74
C_2H_6	k_2	6.16	*5.1*
C_3H_8	k_3	9.31	*7.8*
C_4H_{10}	k_4	19.51	*16.3*
H_2	k_5	-1.96	*-1.9*
N_2	k_6	-8.16	*-7.6*

$$CI = \frac{0.74C_1 + 5.1C_2 + 7.8C_3 + 16.3C_4 - 1.9H_2 - 7.6N_2}{\sqrt{d_{mix}}} \quad (3)$$

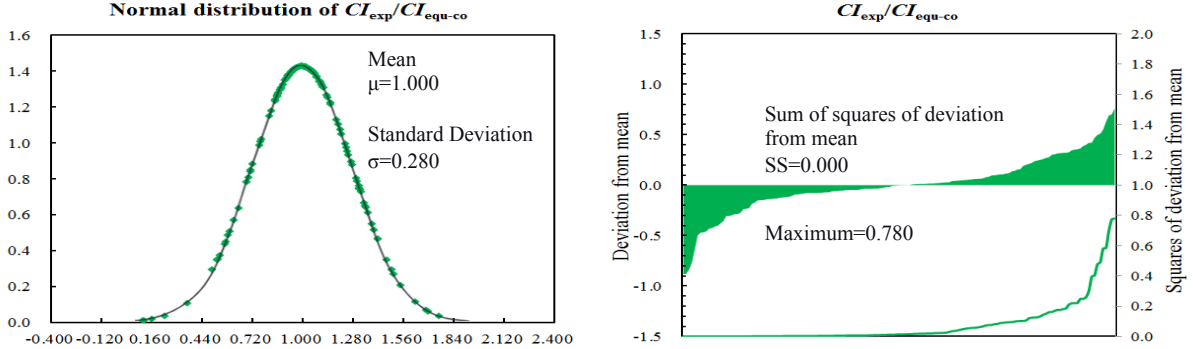


Figure.5 Mathematical statistical analysis of the specific value of $CI_{exp}/CI_{equ-corrected}$

$$CI = \frac{C_1 + 6.9C_2 + 10.4C_3 + 21.8C_4 - 2.6H_2 - 10.2N_2}{\sqrt{d_{mix}} / \sqrt{d_{CH_4}}} \quad (4)$$

Results— Gas appliance adaptability experiment

Hs, *d*, S_n, *WI*, *CP*, Yellow-tip ⇒ *WI* & S_n ⇒ H_s & *CP* ⇒ *WI* & *CP*

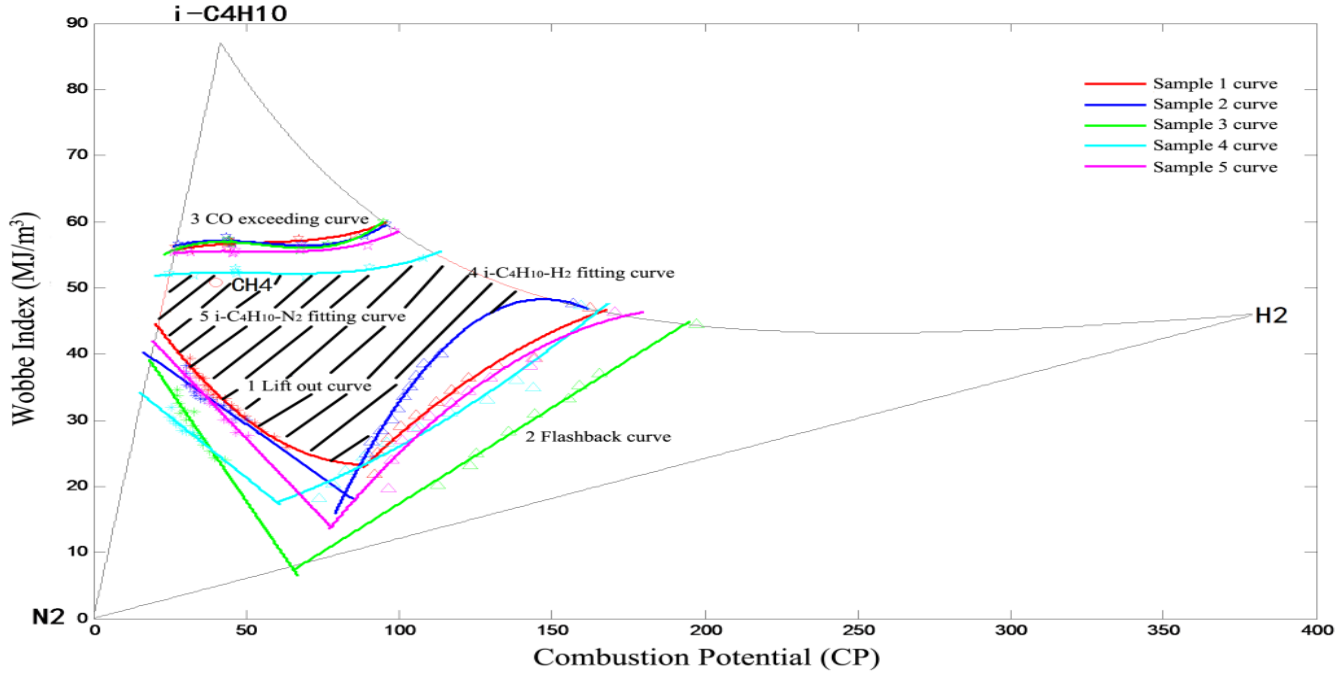


Figure.6 The common combustion adaptability area of different gas cooking samples

Results— Gas appliance adaptability experiment

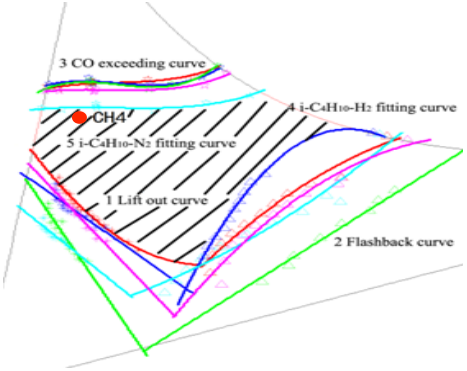


Table.4 The fitting curves of samples and the maximum allowable change of Wobbe Index

Number of appliances	The fitting curves		The maximum allowable change of Wobbe Index, % $=\frac{W_{lim,min}-W_{ref}}{W_{ref}}\times 100\%$
The common boundary line	i-C_4H_{10}-H_2	$y=97.5e^{-0.0144x}+32.27e^{0.00091x}$	--
	i-C_4H_{10}-N_2	$y=2.094x$	--
Sample 1	Lift out curve	$y=0.0045x^2-0.8011x+58.99$	--
	Flashback curve	$y=-0.0018x^2+0.7513x-29.6891$	--
	CO exceeding curve	$y=-0.0056x^2+0.3198x+50.5121$	9.5%
Sample 2	Lift out curve	$y=-0.3237x+45.6219$	--
	Flashback curve	$y=-0.0069x^2+2.0473x-102.5272$	--
	CO exceeding curve	$Y=-0.0001x^3-0.0108x^2+0.5588x+47.8411$	11.2%
Sample 3	Lift out curve	$y=-0.6731x+51.4152$	--
	Flashback curve	$y=0.2902x-11.7086$	--
	CO exceeding curve	$y=0.0001x^3-0.0151x^2+0.7875x+43.7402$	10.4%
Sample 4	Lift out curve	$y=-0.3694x+39.7986$	--
	Flashback curve	$y=0.0010x^2+0.0542x+10.7211$	--
	CO exceeding curve	$y=-0.0029x^2+0.1504x+49.7921$	1.9%
Sample 5	Lift out curve	$y=-0.4816x+51.2580$	--
	Flashback curve	$y=-0.0023x^2+0.9134x-43.1938$	--
	CO exceeding curve	$y=-0.0047x^2+0.2332x+51.7297$	8.6%

Conclusions

Gas-blending distribution boundary controlled by *WI* and *CP*

Combustion adjustability domain evaluated by *WI* and *CP*

$$CI = \frac{C_1 + 6.9C_2 + 10.4C_3 + 21.8C_4 - 2.6H_2 - 10.2N_2}{\sqrt{d_{mix}} / \sqrt{d_{CH_4}}}$$

Common adjustability domain manages the gas quality

Gas appliance adaptability
Urban gas interchangeability

Thanks For Your Attention