Preliminary Selection of IGCC Candidate Coals in Korea for IGCC Applications

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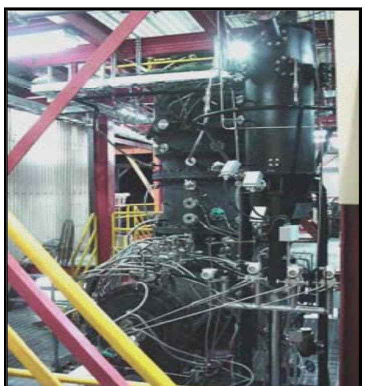
Yongseung Yun, Seok Woo Chung, Seung Jong Lee

Plant Engineering Center
Institute for Advanced Engineering
Korea
http://pec.iae.re.kr
http://www.coal.or.kr

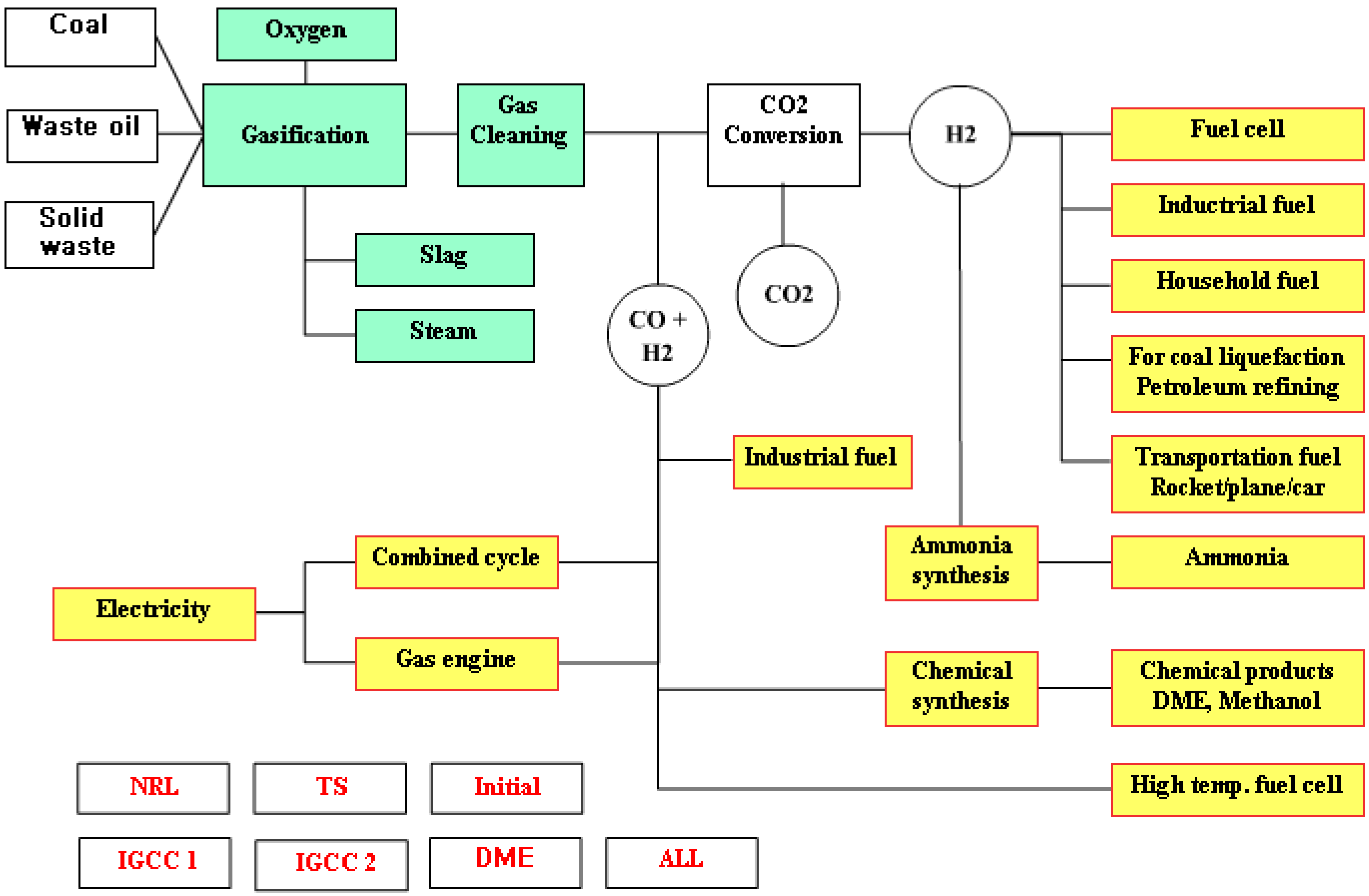
Background

- Korea imports 97% of total energy from abroad and thus must utilize the abundant worldwide coal resource to diversify the energy sources. For Korea, coal is an inevitable energy source to cover at least 30% of the necessary electricity. Unless a revolutionary method in energy generation is invented, IGCC should be one of the most suitable technology when utilizing coal for power generation.
- Korea is in great need to adjust into more fuel-diversified society and to adopt environmentally benign technologies in power generation sector with higher efficiency and with low CO_2 emission.
- Korea has a plan to build a 300 MW class clean coal technology (CCT) power plant by 2012 with imported technology.
- Small scale pilot plant for coal gasification has been operated from 1994 in Korea, with objectives of determining key coal selection parameters and verifying technical feasibility by local manufacturing skill.

Gasification/Melting Research in IAE



Coal, Wastes, Low grade fuel → **Gasification/melting** → **Clean fuel/Chemical Zero emission**



View of 3 Ton/Day-Scale Coal Gasification Pilot Plant

(Max. pressure: 28 bar,
Max. temperature: 1550^{o}C)

(Control Room)

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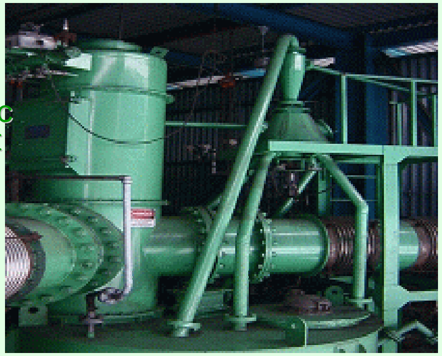
Process Flow of 3 T/D-Scale Coal Gasification System

Coal
(Bituminous, Subbituminous)

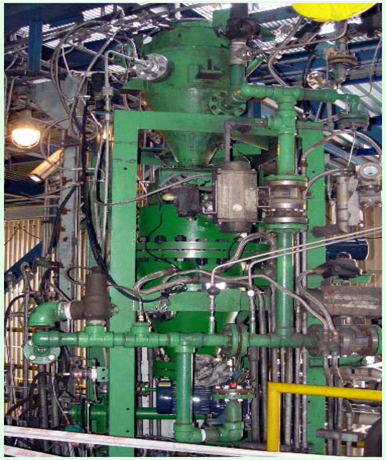
Drier/Pulverizer
(74㎛, moisture 2~4%)

Pneumatic transport



Hopper/Distribution hopper
(feeding to 4 lock hoppers)

Gravity transport



Lock-hopper Feeders

Pneumatic transport

Coal feeding nozzles

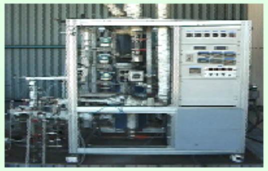
Coal Gasifier
(Gasification, Melting)

1200°C

Syngas Cooling
(Indirect Water Cooling)

550°C

Hot Gas Filtering
(Ceramic/Metal Filters)

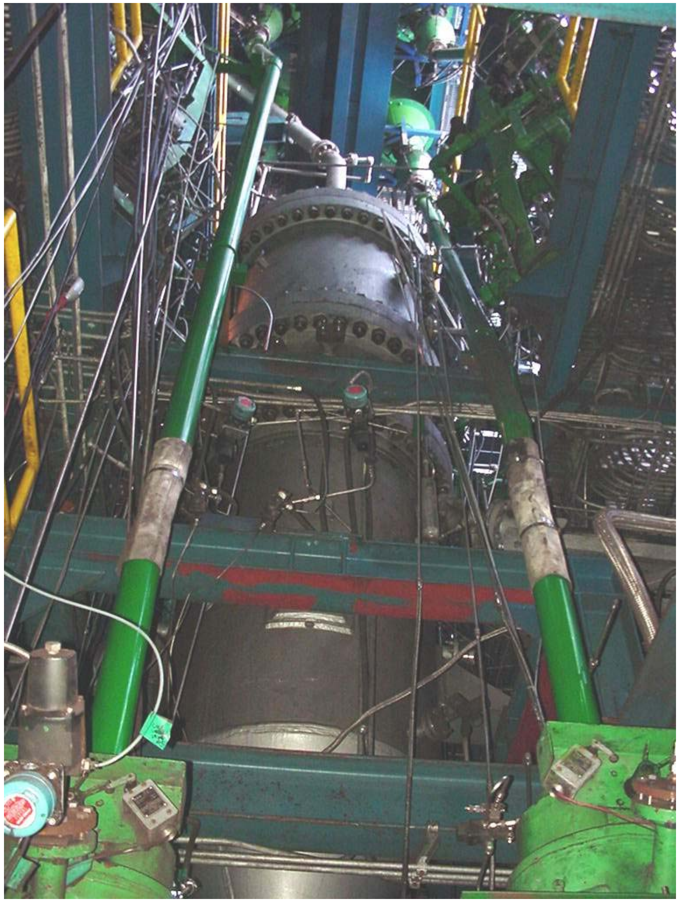


Hot Gas Desulfurization

Syngas combustor

Gas Engine System

Key Components of Pilot Plants



Coal Gasifier with Feeding System

High Temperature Filtering System

Low Temperature Desulfurization System

Slip-stream Hot Gas Cleanup System

Operation of Gasification System

Control Room

View of Gasification System

Particulates Concentration Measurement

High-Temperature Desulfurization

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Tested Coals

Property \ Coal		Indonesia			Austrailia		USA		China	Russia
		Baiduri	Adaro	Kideco	Curragh	Drayton	Usibell	Cyprus	Datong	Denisovsky
Proximate Analysis (as-rec'd, wt%)	Moisture	4.28	2.87	3.40	2.22	2.06	9.14	2.33	4.60	8.79
	Volatile Matter	42.99	45.32	43.07	26.91	34.93	44.11	40.97	32.64	20.08
	Ash	5.48	1.48	5.22	18.64	10.76	9.87	6.28	7.72	12.08
	Fixed Carbon	47.25	50.29	48.31	52.23	49.25	36.88	50.42	55.04	59.05
Ultimate Analysis (mf, wt%)	C	71.44	68.88	68.00	67.48	70.61	54.40	70.74	63.99	74.15
	H	6.42	5.04	4.61	3.36	4.94	4.55	4.94	4.11	4.68
	N	1.60	1.62	1.00	2.60	0.34	0.64	1.20	0.63	0.72
	S	0.84	0.10	0.16	0.43	0.90	0.17	0.33	0.57	0.34
	O	13.97	22.80	20.83	7.07	12.22	29.38	16.36	17.33	6.87
	Ash	5.73	1.56	5.40	19.06	10.99	10.86	6.43	7.72	13.24
Ash Fusion Temp. (Reduction, ^{o}C)	I.T.	1150	1250	1,160	1175	1260	1162	1155	1241	-
	S.T.	-	-	1,180	-	1580	1184	1165	1259	-
	H.T.	1250	1290	1,200	1300	1590	1224	1193	1285	-
	F.T.	1280	1340	1,220	1380	>1600	1257	1289	1343	1400
Inorganic Analysis (wt%)	SiO_2	30.30	37.0	35.11	44.22	63.30	42.73	59.80	56.80	54.59
	Al_2O_3	16.80	18.5	23.41	19.09	17.80	18.93	16.22	22.58	26.37
	TiO_2	0.68	0.84	0.88	0.80	1.09	0.74	0.89	1.10	0.99
	Fe_2O_3	10.14	15.8	13.32	8.74	4.96	6.00	6.91	3.59	8.29
	CaO	20.70	10.8	8.06	20.52	2.43	21.01	8.01	5.32	4.39
	MgO	5.02	2.59	2.79	2.58	0.72	3.13	2.07	1.33	1.89
	Na_2O	3.73	1.02	1.11	N.D.	0.21	0.93	10.6	1.39	0.44
	K_2O	1.07	1.38	1.41	1.12	0.21	1.27	1.06	0.87	1.69
	P_2O_5	-	-	0.28	1.66	0.33	0.33	0.34	0.27	1.16
	MnO	0.12	-	0.16	-	0.05	-	-	-	0.12
	SO_3	11.54	7.58	5.40	1.27	-	-	3.64	6.72	-
Gross Heating Value (kcal/kg)		6367	6748	6729	7008	6556	5304	6824	5240	7139

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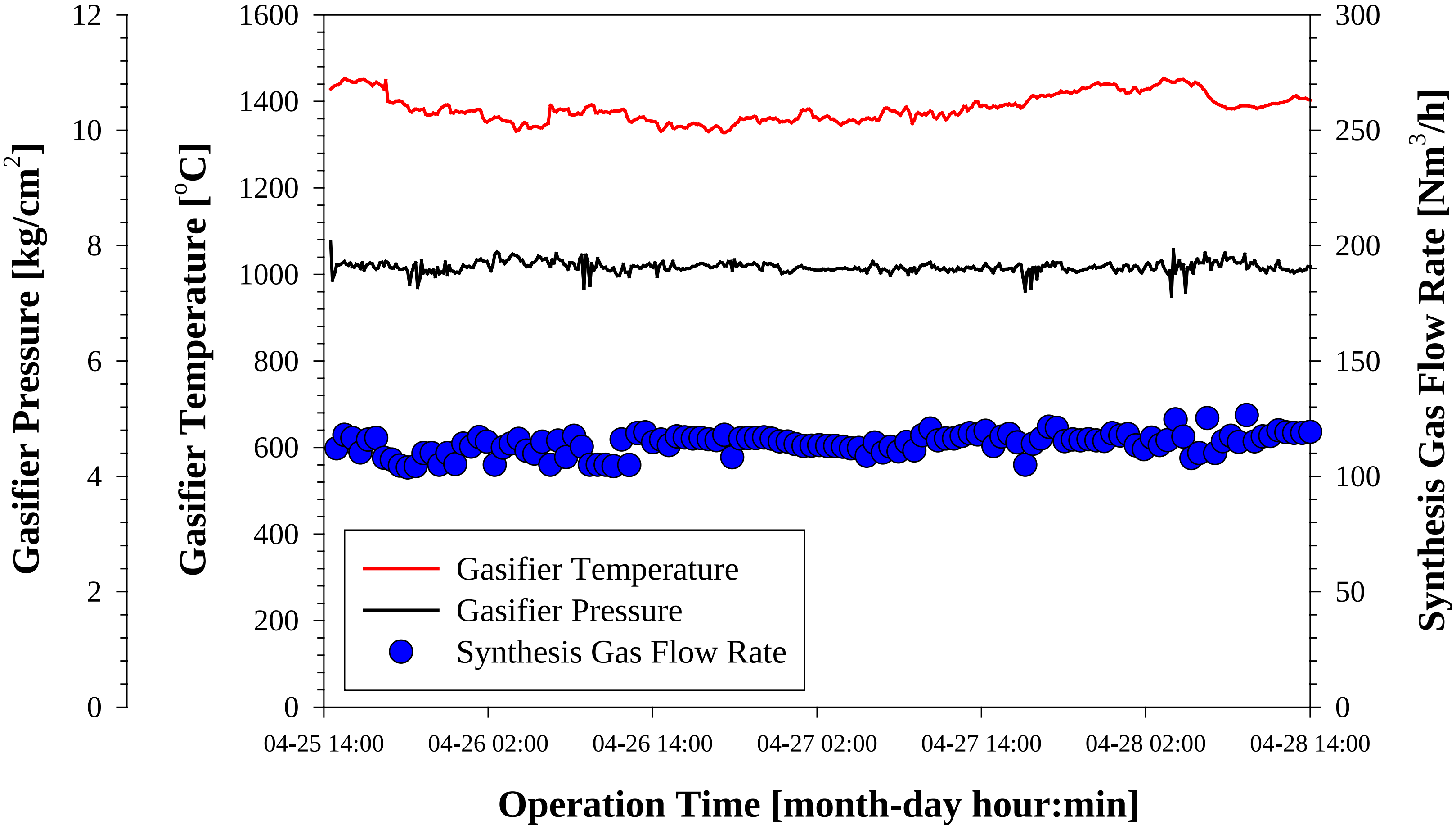
Temperature, Pressure and Flow Rate Profiles



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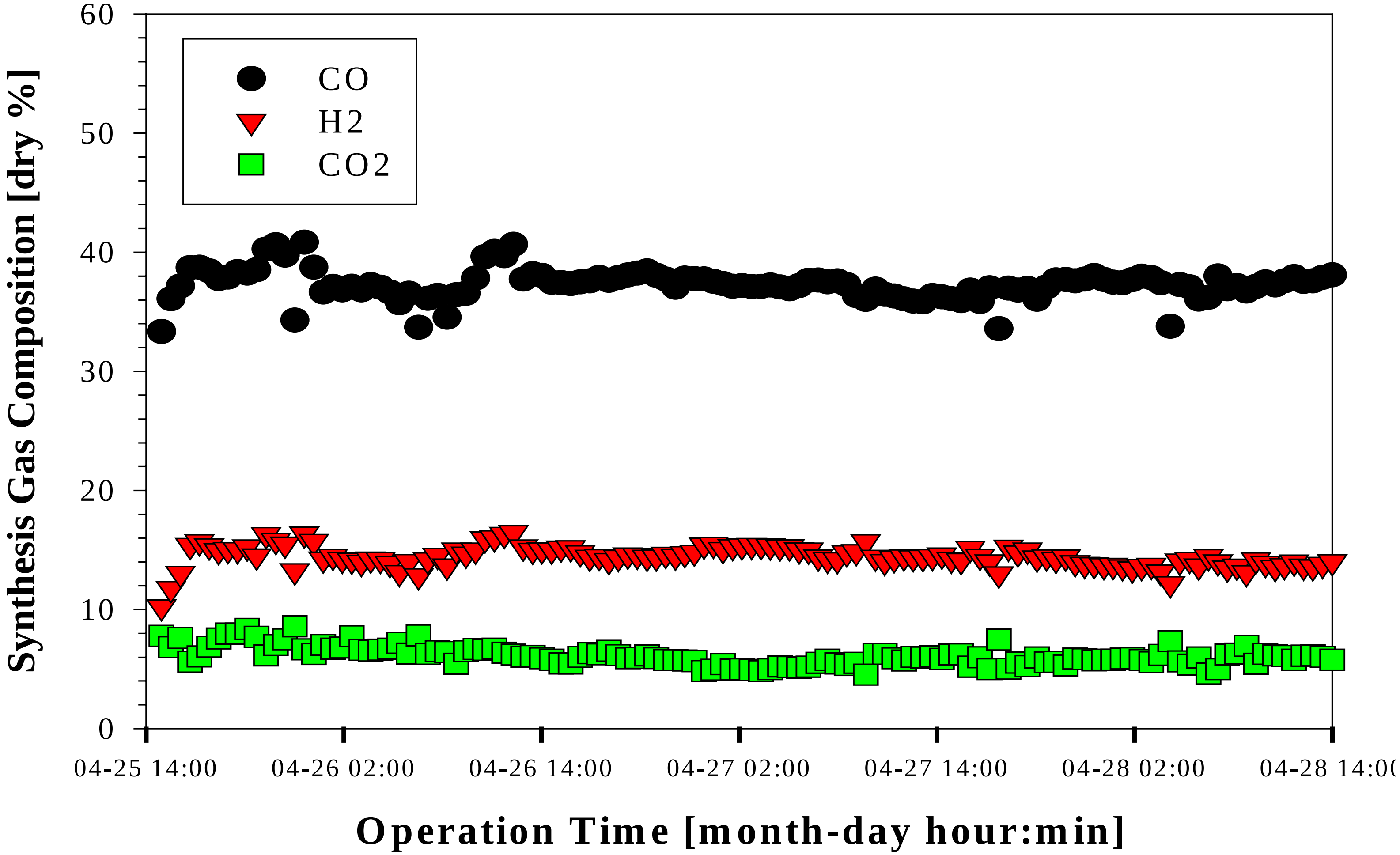
Syngas Composition (Indonesian Roto Middle Coal)



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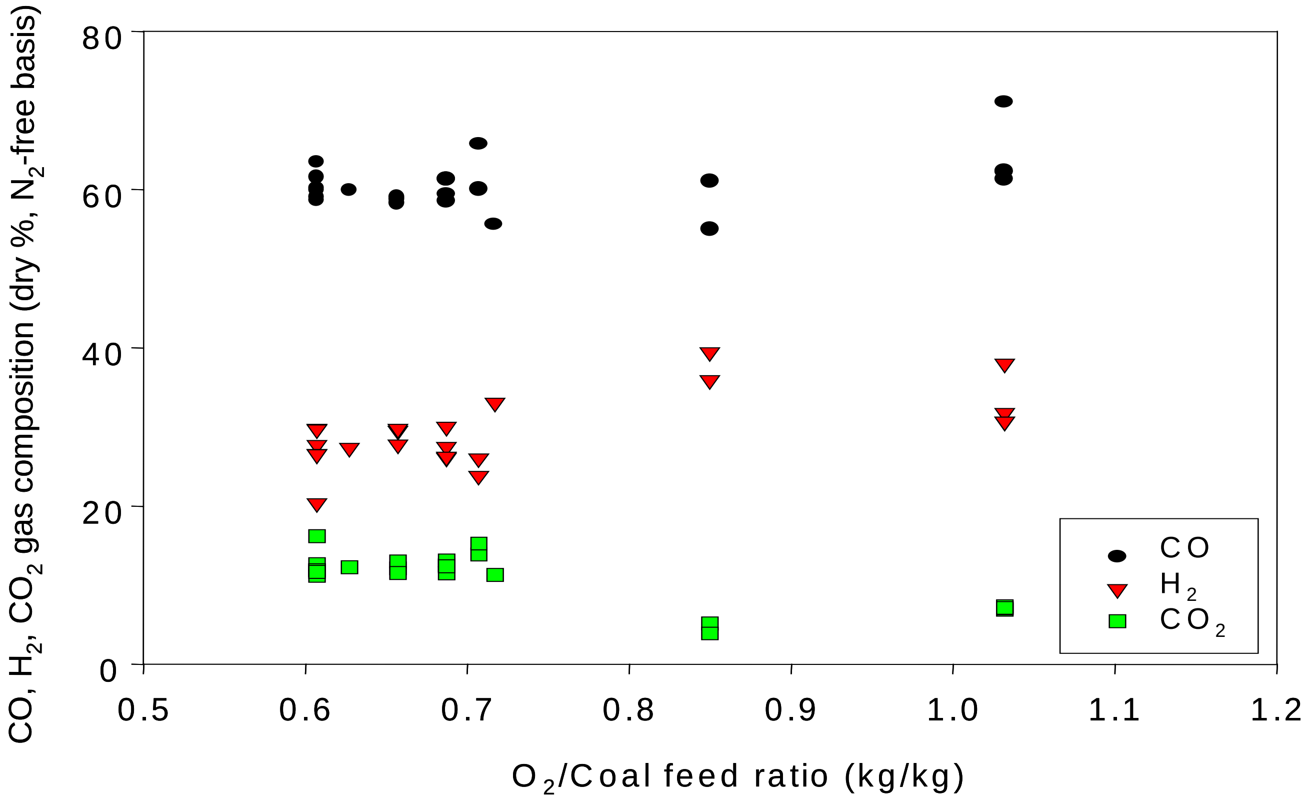
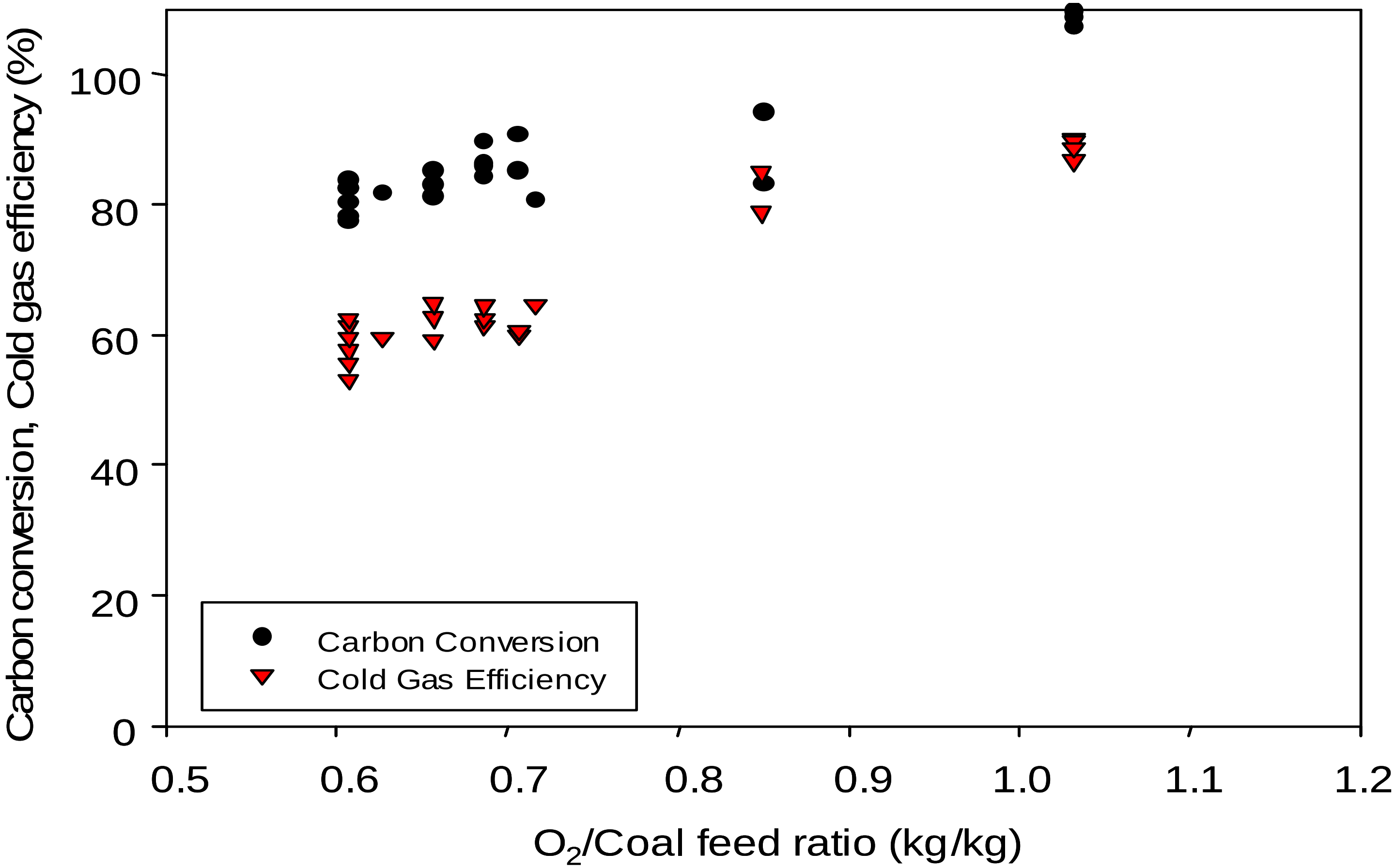
Syngas composition with oxygen/coal weight ratio



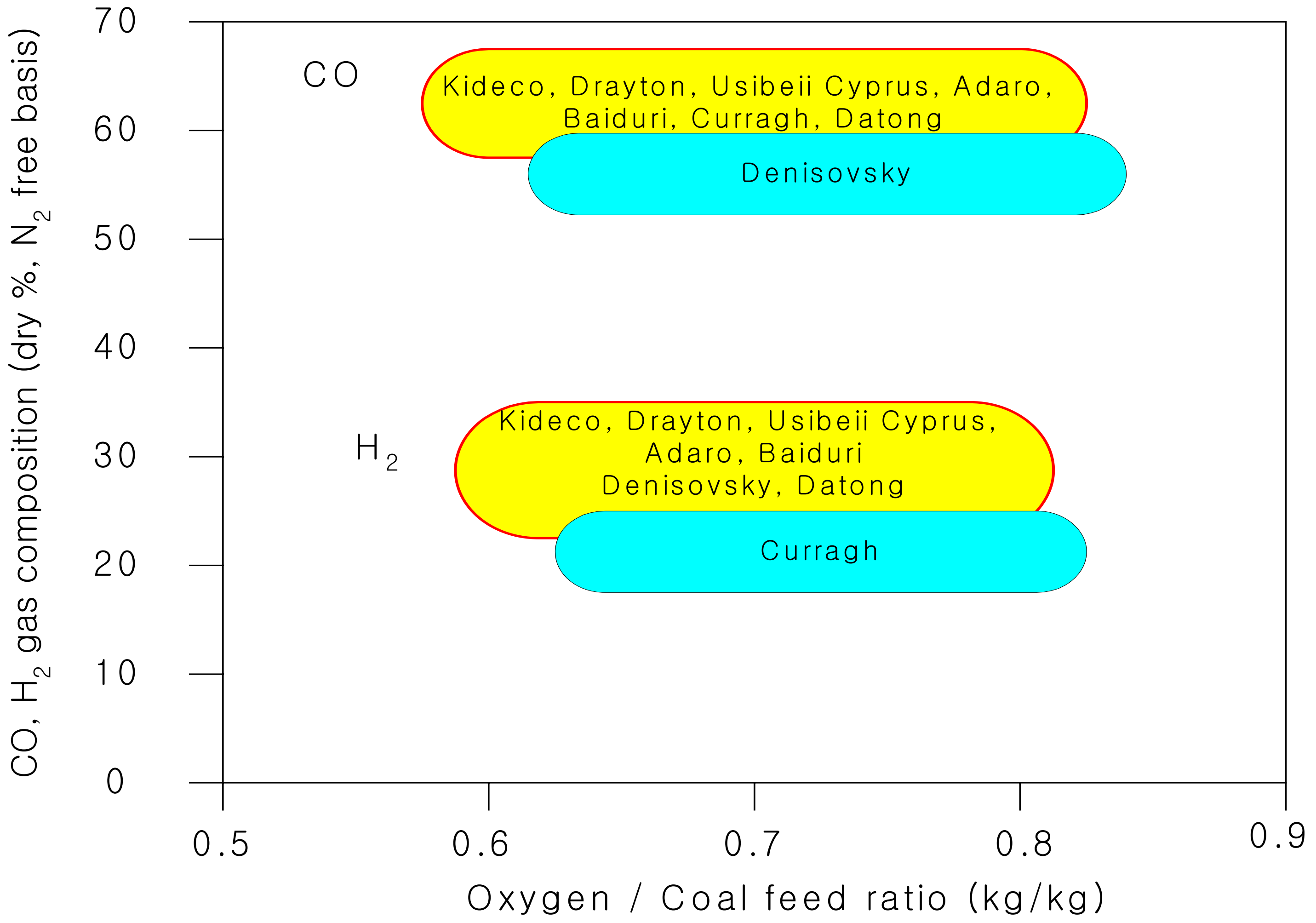
◆ Australian Drayton coal at 10-11 bar.

Gasification efficiencies with oxygen/coal weight ratio



- Australian Drayton coal at 10-11 bar.

Syngas composition of eight coals from pilot gasifier



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Coal Gasification – Slag, Syngas flame

(Unit: cm)

Produced slags after the gasification
(5-10 bar, 1450-1500°C)

Combustion flame of syngas

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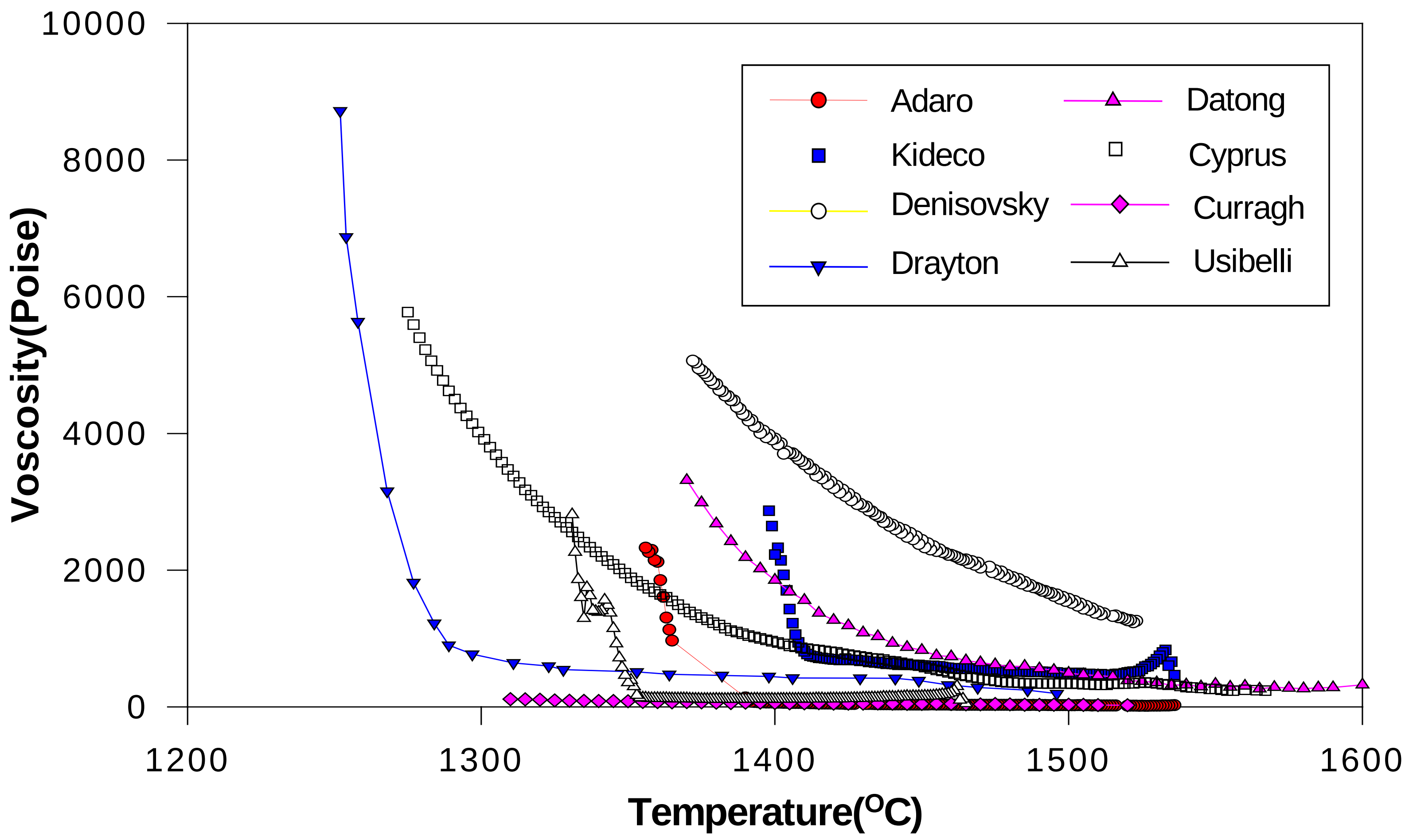
Elemental Analysis of Slags

Coal	Pressure (bar)	C (wt%)	H (wt%)	N (wt%)	S (wt%)
Datong	27.2	**0.08**	0.05	0.15	n.d.
Usibelli	26.6	**0.06**	0.03	0.11	n.d.
Cyprus	25.0	**0.18**	0.18	0.53	n.d.
	29.0	**0.13**	0.10	0.35	n.d.
Kideco	17.0	**0.03**	0.03	0.11	n.d.
Drayton	11.0	**0.11**	0.01	0.17	n.d.
	12.0	**0.01**	0.02	0.12	n.d.
	14.5	**0.03**	0.05	0.11	n.d.
Curragh	16-21	**0.03**	0.01	n.d.	n.d.
	26-29	**0.35**	0.07	0.29	0.02
Adaro	26.0	**0.52**	n.d.	n.d.	n.d.
Baiduri	16	**0.05**	n.d.	n.d.	n.d.
	25	**0.46**	0.04	n.d.	0.04
	25	**0.31**	0.06	n.d.	0.06
Denisovsky	26.0	**0.59**	n.d.	n.d.	0.01

- Not much differentiation in remaining carbon content in slags

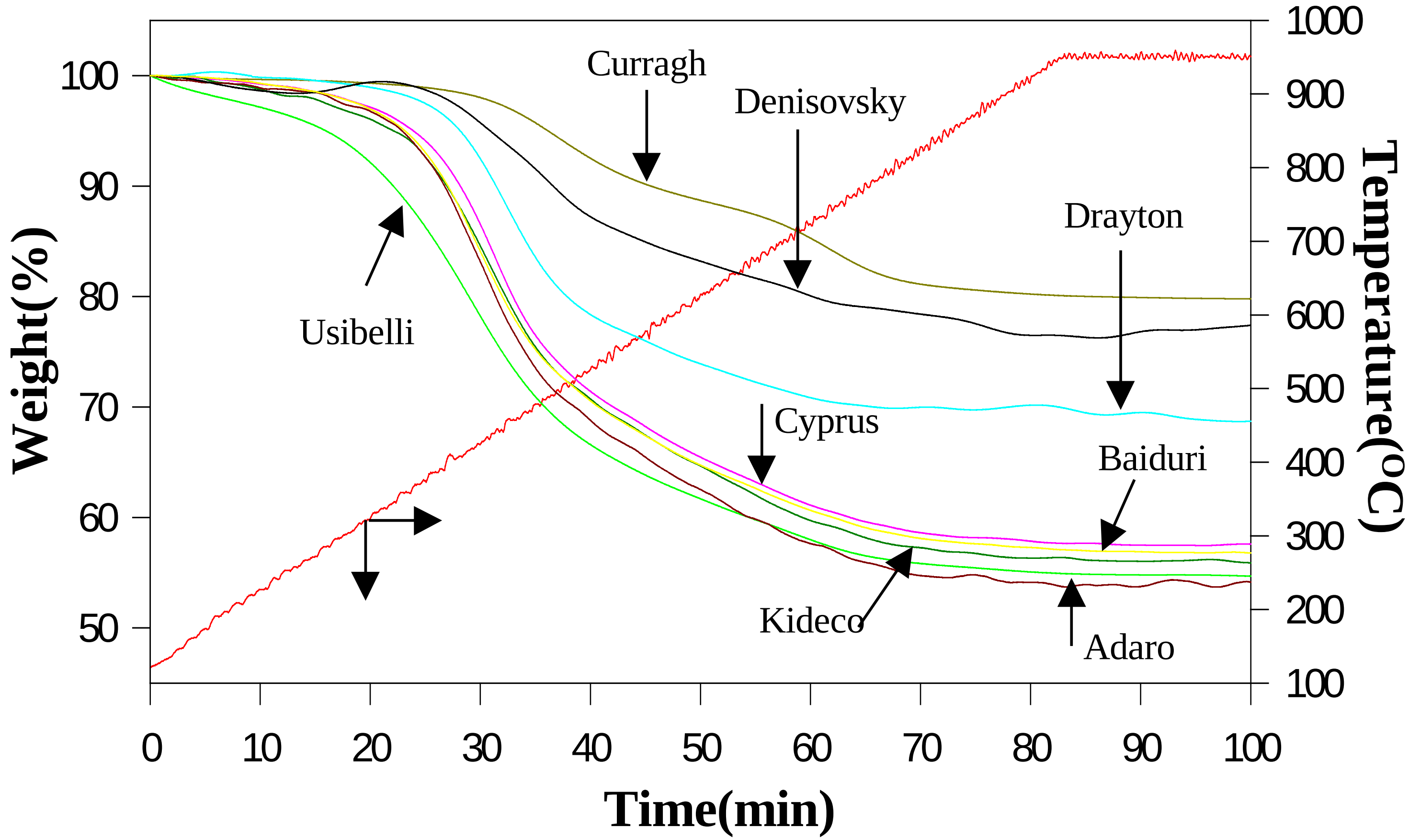
Viscosity Profile with Temperature for Slags



- Denisovsky coal shows high viscosity in melted slag → Not suitable for gasification
- Curragh coal needs a flux addition

Indirect estimation of coal reactivity by high pressure TGA

(1) 25 psig



- From reactivity point of view, Curragh and Denisovsky coals need a different gasifier design to account for longer reaction time.

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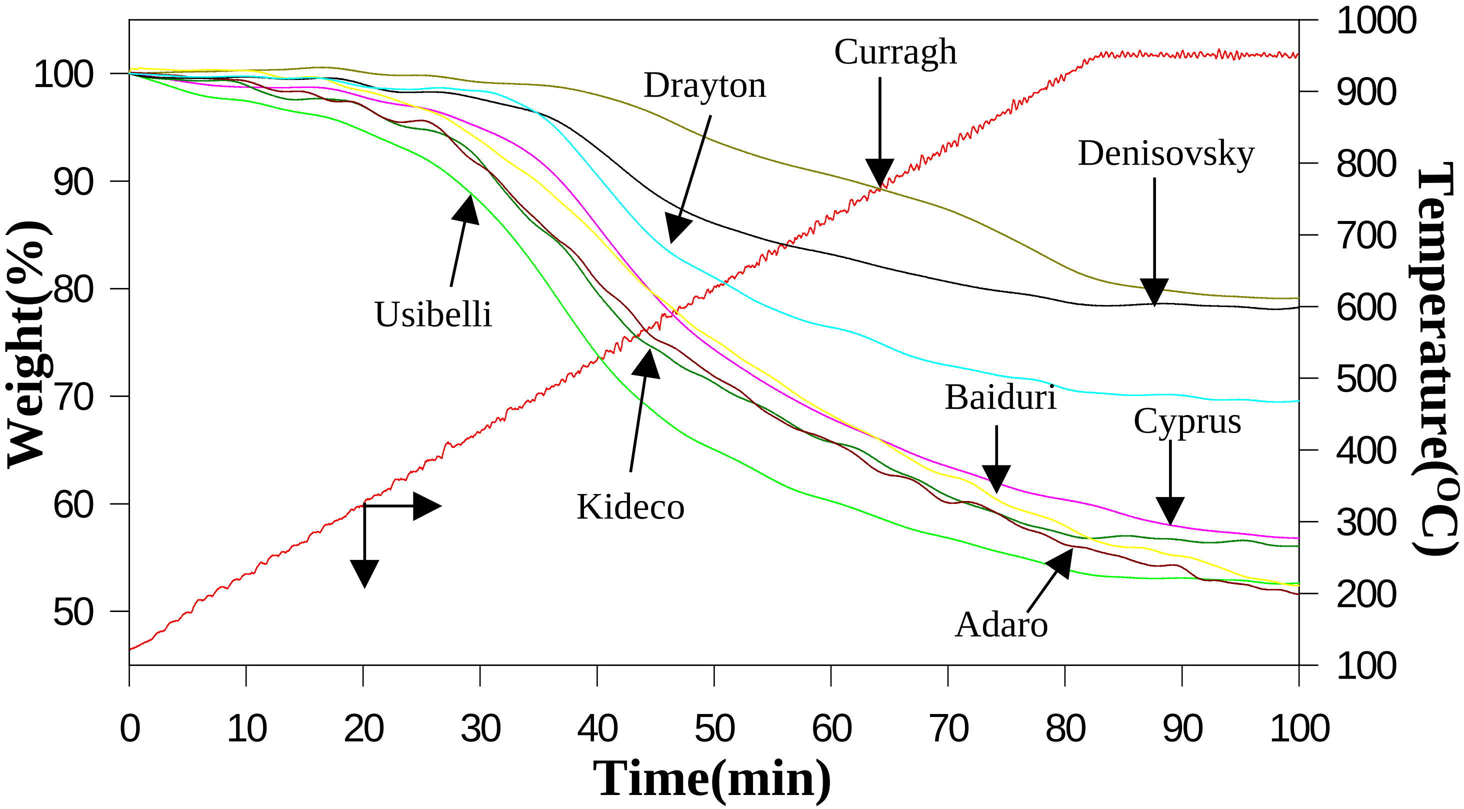
Indirect estimation of coal reactivity by high pressure TGA

(2) 500 psig



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Conclusions

- In commercial IGCC gasifiers that require long-term continuous operation, low ash containing coals might be a better candidate since they produce a minimal slag-plugging problem in addition to the minimal unburned carbon through fly-ash and slag.
- Most important indices for selecting suitable coal for IGCC applications are ash melting temperature, slag viscosity, ash content and the fuel ratio (or gasification reactivity).
- The suitable coal would contain the following properties.

  (1) ash melting temperature would be at the range of 1300-1400°C. If the ash melting temperature is below this temperature range, more precaution should be exercised to prevent the increased possibility in plugging by fly-slag. When the ash melting temperature is above 1,600°C, fluxing agent is required or the gasifier temperature should be increased with the anticipated problems in the refractory life.

  (2) low-enough slag viscosity at the gasifier operating temperature must be guaranteed where slag would flow freely along the gasifier inner wall.

  (3) ash content is better to be at the lowest level if possible, although a certain amount of ash protects the gasifier wall by thin-layer coating.

  (4) coals of low fuel ratio that means higher volatile content by which normally exhibits higher reactivity would be a better choice if the gasifier is run without the char-recycling process.
- To verify the suitable coal reactivity, high pressure TGA analysis under inert gas environment appears to be sufficient to differentiate the relative reactivity of candidate coals in selecting the coal for IGCC applications.

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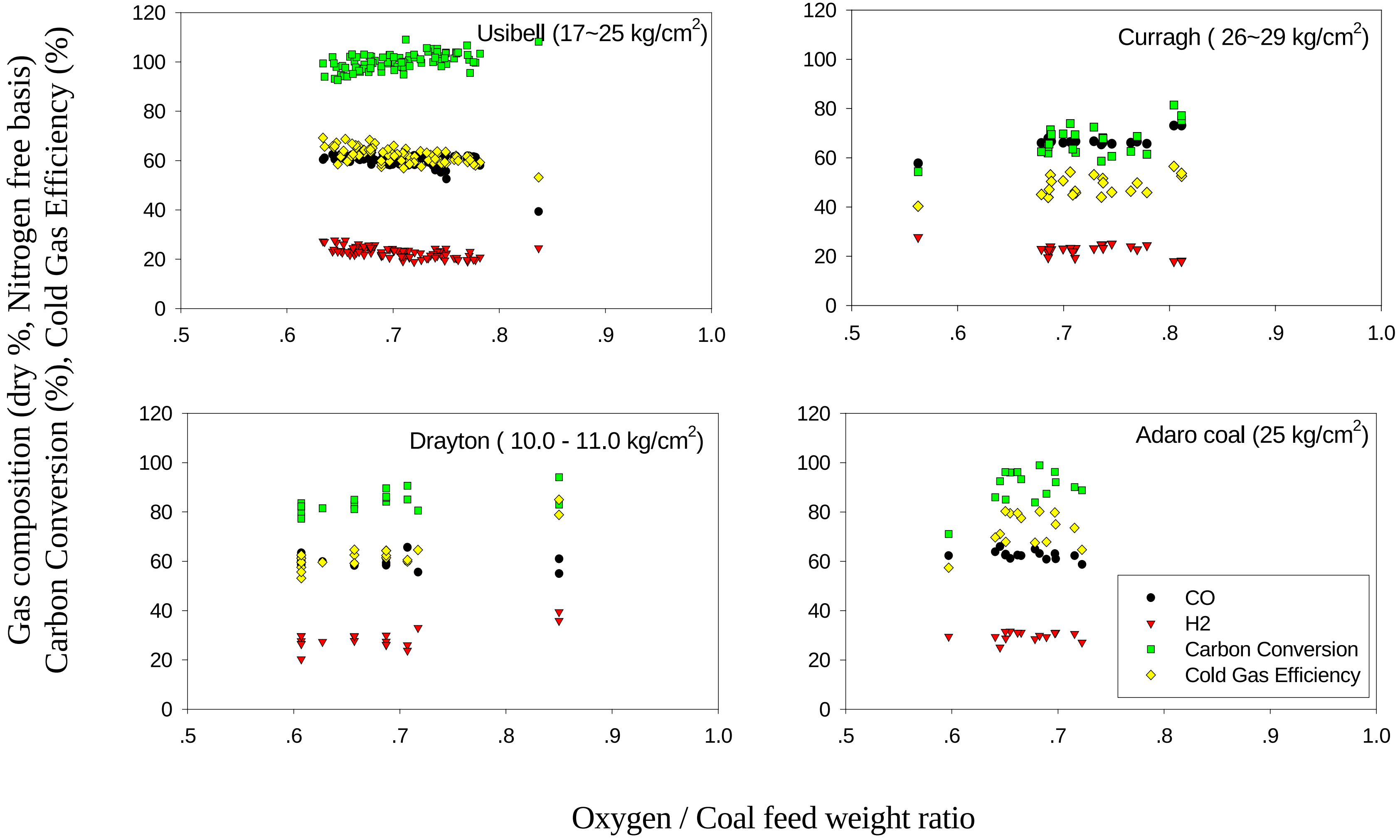
Syngas Composition and Conversion Efficiencies



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