Behavior of Coal Particles in Entrained-Bed Gasifier

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Note: Main content of this presentation had been presented earlier at 5th Int. Conference on CCT (2011/5), and at 7th Int. Symposium on Novel Carbon Resource Sciences (2011/6).

Introduction

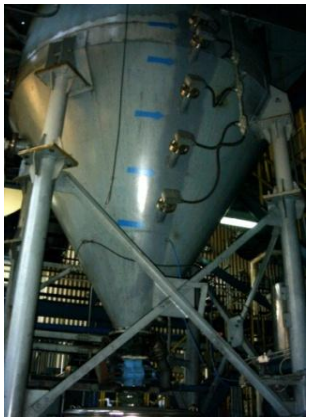
- Almost all coal gasifiers that are currently employed at commercial scale are slagging type in that coal ash is melted and re-solidified as slag. Two prominent weaknesses in processes using gasifier have been known as higher construction cost and a relatively low process reliability compared to the long-proven coal power plant based upon the pulverized coal combustion. For the wider usage of coal gasifiers to IGCC or chemical production, a much cheaper version of gasifier is required with much higher operational reliability.
- Although some coal gasifier vendors claim that their gasifiers can last for more than ten years and most reported troubles on gasifiers are related to the auxiliary parts rather than the gasifier itself, there still exists a room for the cheaper version of coal gasifier. Fluidized-bed type like KBR, or fixed-bed type like Lurgi might be improved to fill the gap, but the advantages of entrained-bed type is still clear in terms of size reduction by smaller residence time in gasifier and less moving parts for greater reliability.

Scope of the Study

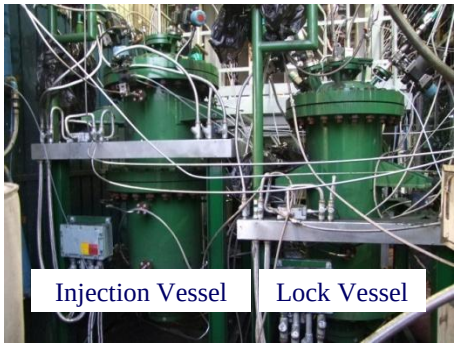
- Non-slagging/Partial slagging entrained-bed coal gasifier was built in a pliot scale to verify the practicability as a reliable coal gasifier. In particular, morphology of produced fines as well as the trend in fouling were studied.
- Earlier tests in the non-slagging/Partial slagging, entrained coal gasifier for the subbituminous coals demonstrated the carbon conversion of more than 91% in a single cycle, which means that recycling of captured fines would produce the final carbon conversion higher than 99%.
- Coal gasifier of non-slagging/partial slagging type was operated with two coals of different ash melting temperature. Two coals were Indonesian subbituminous coal and Australian bituminous coal. Indonesian coal exhibited the ash fluid temperature of 1,190^{o}C while the Australian coal showed the fluid temperature above 1,650^{o}C. Typical Australian bituminous coal possesses a characteristics in ash melting above 1,600^{o}C, which is mostly unsuitable for gasification of slagging mode.

Pilot-scale (2 ton/day) Entrained-Bed Coal Gasification Process

Coal Pulverizer/Dryer



Pulverized Coal Hopper



Coal Feeding System

On-line Analyzers

Feeding Nozzle

Coal Gasifier

Syngas Cooling

High Temperature Metal Filters

Flare Stack

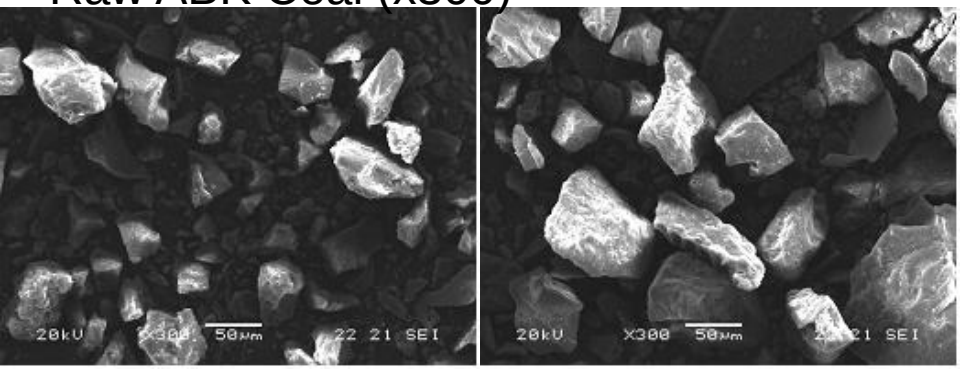
Analysis Data of Feed Coals

Coal		Indonesian Subbituminous ABK	Australian Bituminous BA
Proximate analysis [wt. %][1)]	Moisture	9.33	4.72
	Volatile matter	39.71	33.71
	Fixed carbon	44.33	48.10
	Ash	6.63	13.47
Ultimate analysis [wt.%][2)]	C	61.79	60.86
	H	5.90	3,57
	O	23.10	19.78
	N	1.36	1.28
	S	0.53	0.37
Ash fusion temperature [℃]	IDT	1160	>1,600
	ST	1170	–
	HT	1180	–
	FT	1190	>1,650
Higher heating value [kcal/kg][2)]		5,841	5,787

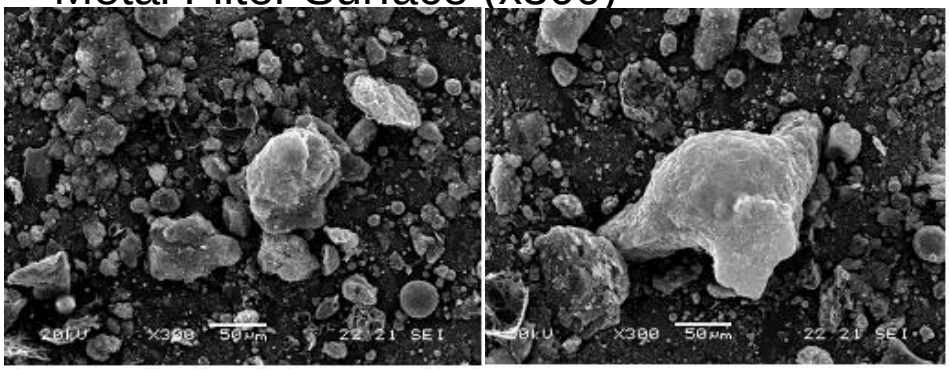
1) air-dried, 2) dry basis

Changes of Particles through Gasifier–Filters
(Indonesian ABK coal, Up-flow / Slagging, *ca.* 1450°C)

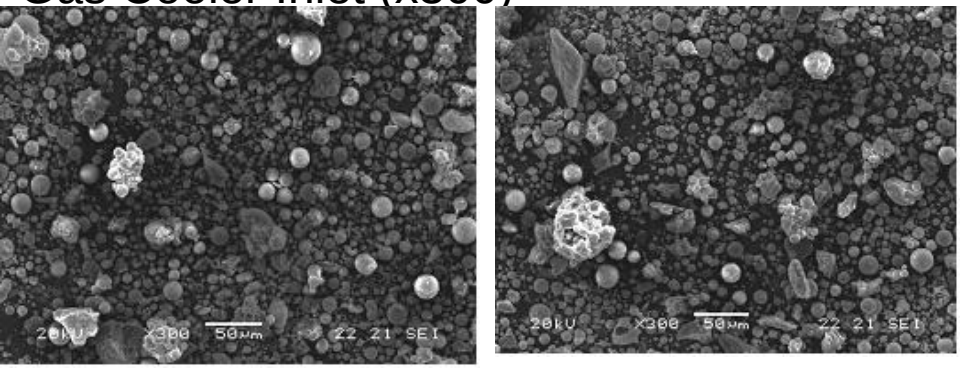
Raw ABK Coal (x300)



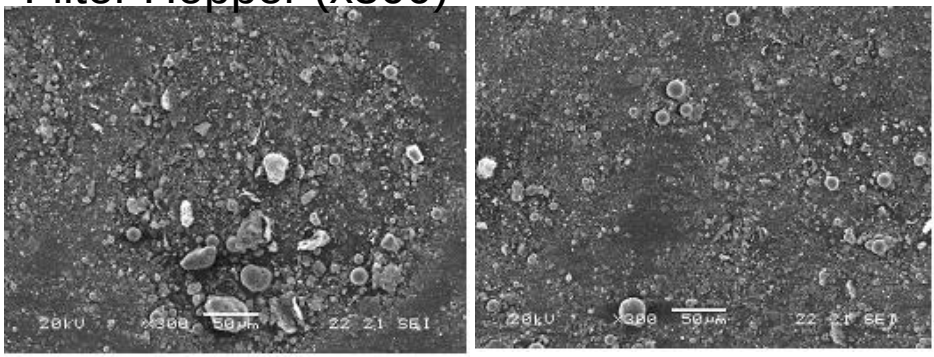
Metal Filter Surface (x300)



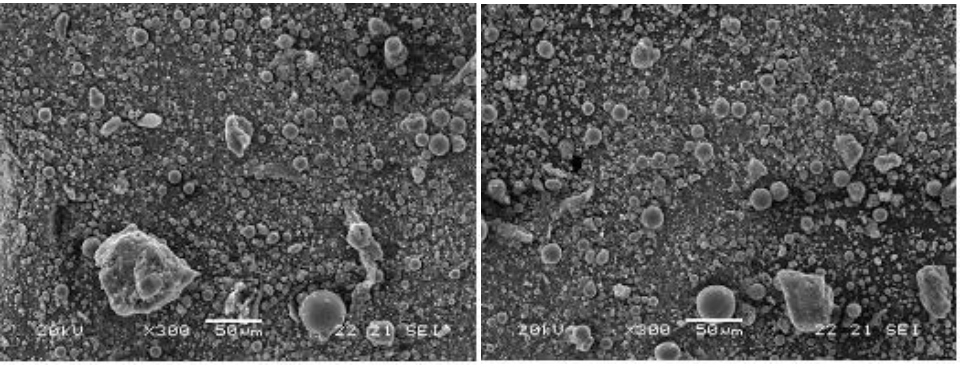
Gas Cooler Inlet (x300)

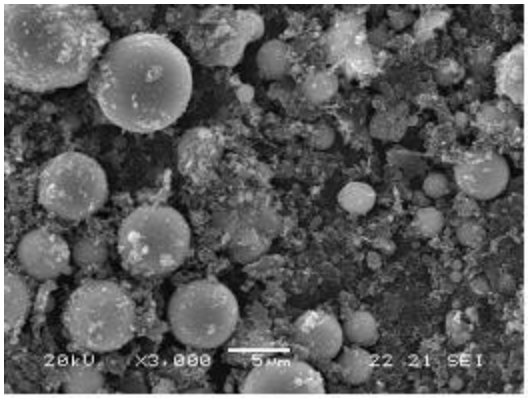


Filter Hopper (x300)



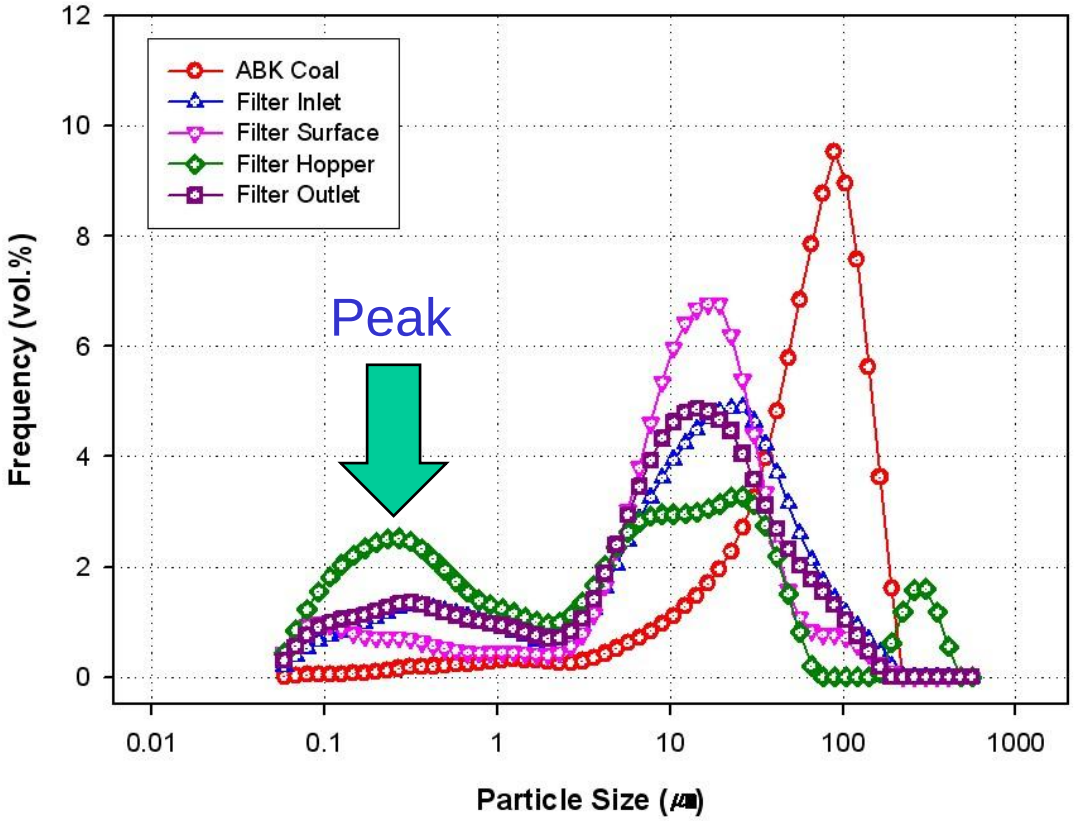
Inlet Pipe for Filters (x300)





(Inlet Pipe for Filters (x3,000)

Particle Size Distribution of Raw Coal, Captured Fines (Indonesian ABK coal, Up-flow / Slagging, *ca.* 1450°C)

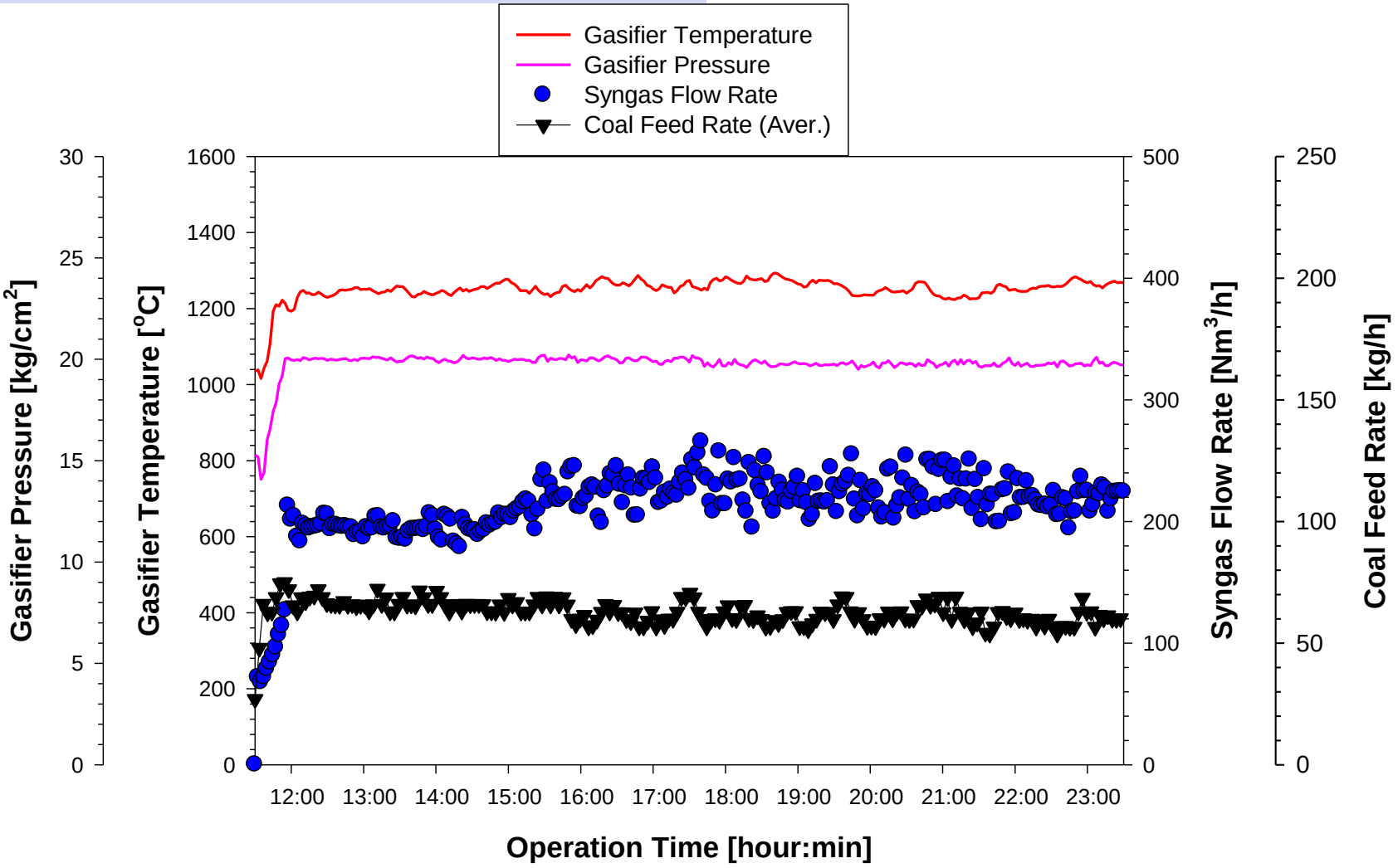


- Fines exhibited two humps of smaller sizes in particle distribution pattern while raw coal showed one sharp peak.
- Captured fines frequently showed a loose-packed aggregate pattern which would cause a different characteristic in recycling into coal gasifier.

Gasification of Indonesian Subbituminous coal at *ca.* 1,250°C

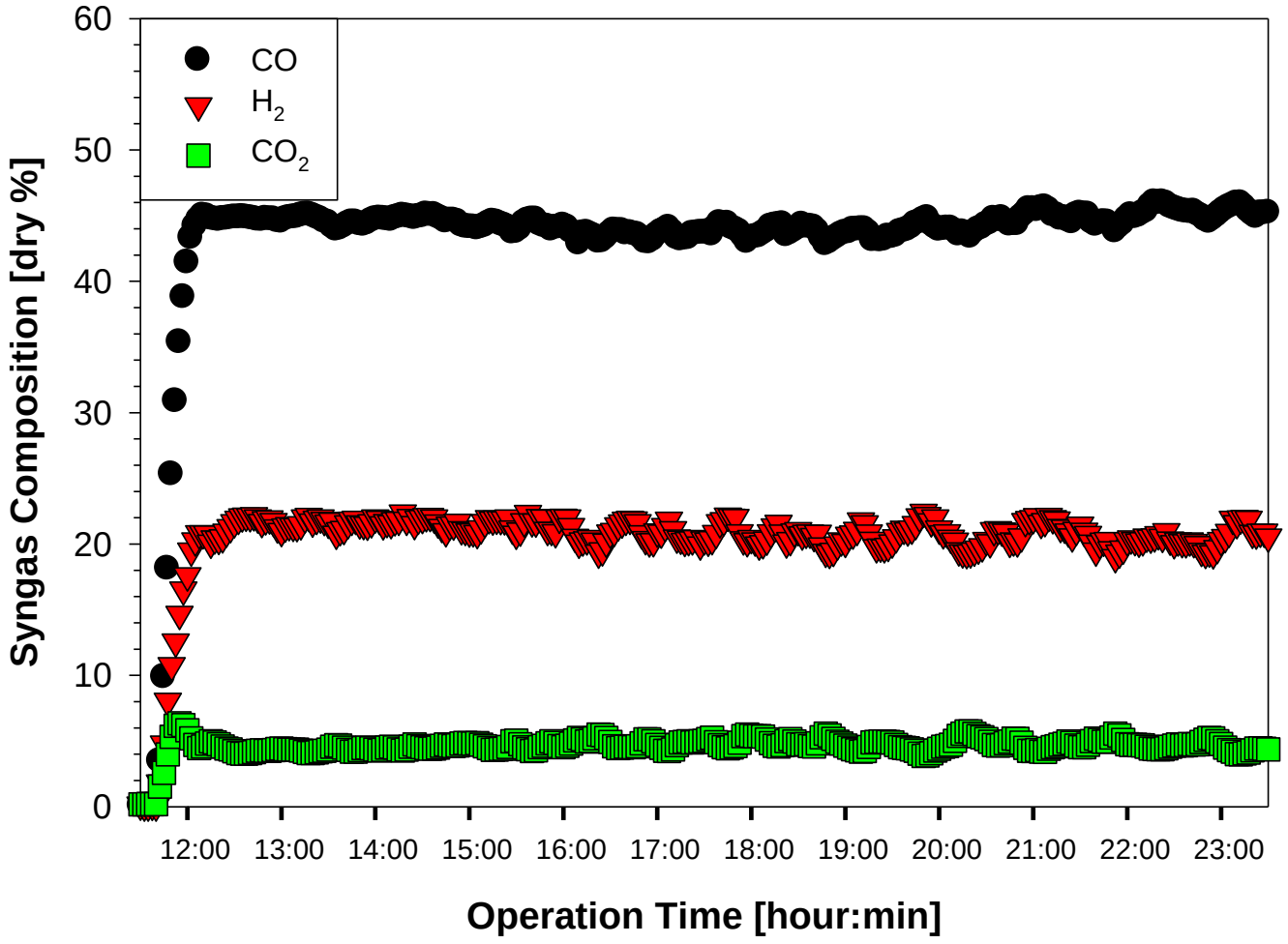
Profiles of Key Operation Parameters ((Indonesian ABK coal)

Gasifier Temperature : *ca.* 1,250°C



Syngas Composition (Indonesian ABK coal)

Gasifier Temperature : *ca.* 1,250°C



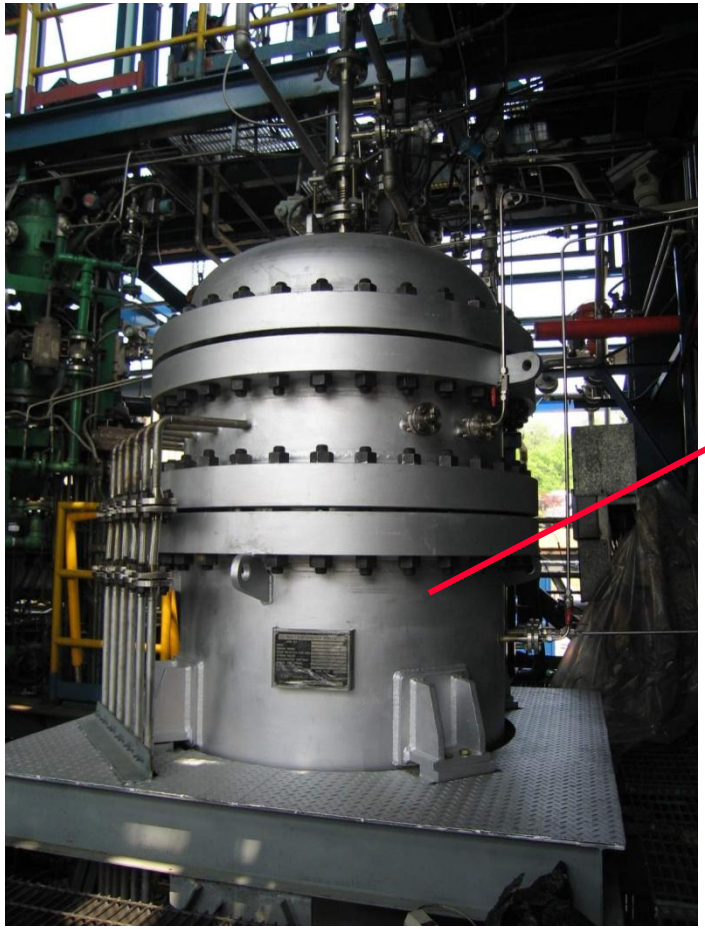
Analysis Data of Raw Coal / Fines (Indonesian ABK coal)

Gasifier Temperature : *ca.* 1,250°C

Sampling Point		Raw Feeding Coal	Gasifier		Cyclone	Metal Filters
			Upper section	Lower section		
Proximate Analysis (dry basis, wt.%)	Volatiles	43.36	2.04	1.35	3.16	4.37
	Ash	7.42	35.47	70.13	42.92	42.44
	Fixed Carbon	49.22	62.49	28.52	53.92	53.19
Ultimate Analysis (dry basis, wt.%)	C	69.00	62.70	29.15	55.43	54.47
	H	5.02	0.30	0.21	0.35	0.62
	N	1.34	0.34	0.06	0.39	0.15
	S	0.48	0.44	0.45	0.90	1.10
	O (by-difference)	16.74	0.75	0.00	0.00	1.23
	Ash	7.42	35.47	70.13	42.92	42.44
Heating Value (dry basis, kcal/kg)		6325.5	4984.3	1475.8	4642.8	4237.2

Metal Filters after Gasification Test

(ABK Coal, Down-flow / Non-Slagging, 1250ºC)

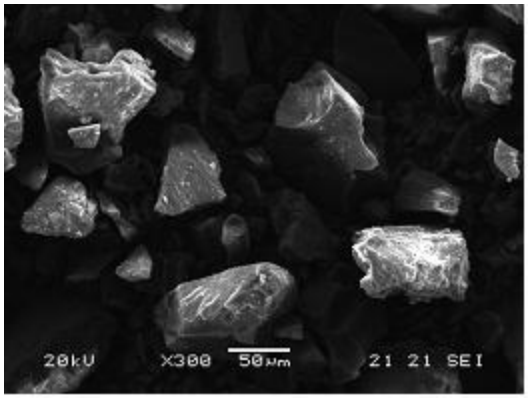


(High Temp. Metal Filter System)

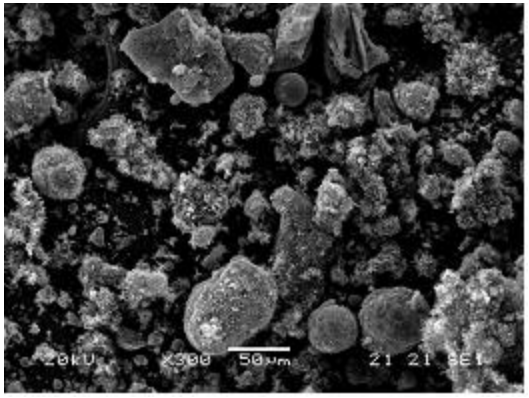
Changes of Particles through Gasifier–Filters

(ABK coal, 1250°C, x300 magnification)

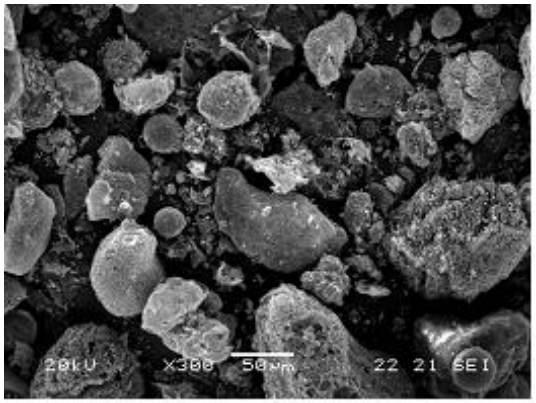
Raw ABK Coal



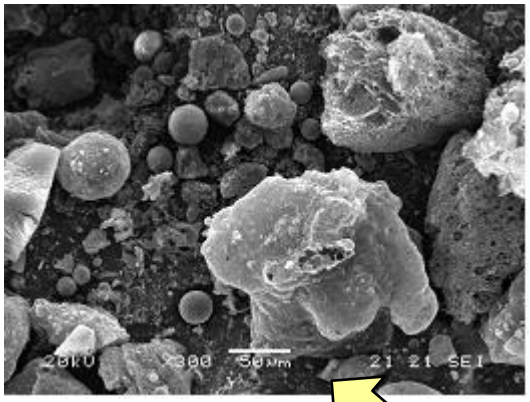
Gasifier
– Upper section



Gasifier
– Lower section

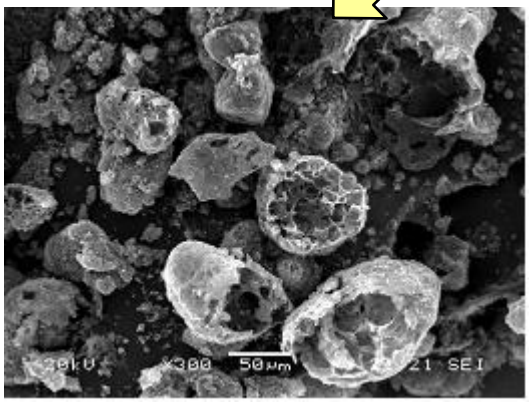


Cyclone



Main Target for Usage

Metal Filters



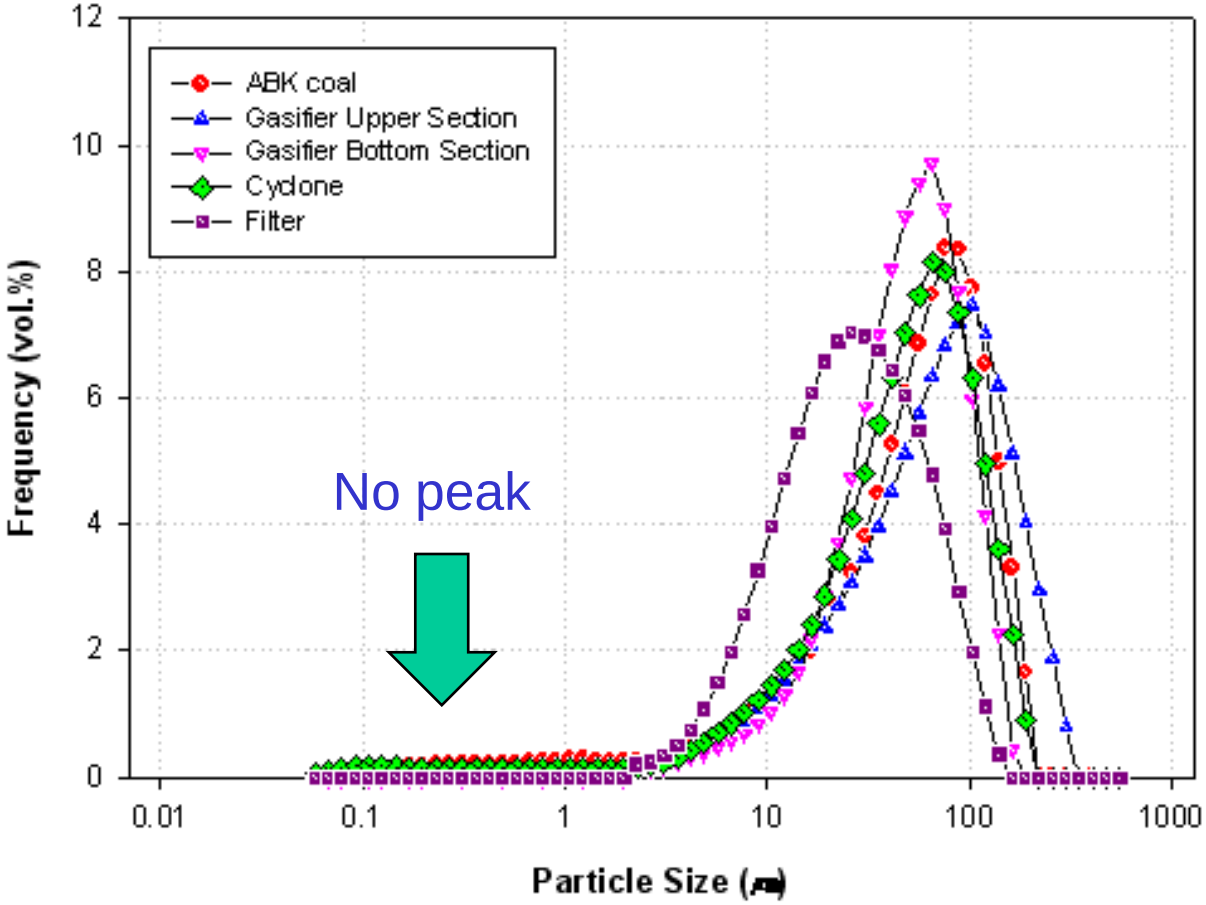
Heavy Metal Content & Leaching of Coal / Fines

(Indonesian ABK coal, 1250°C Gasification)

Heavy Metal	Content of Heavy Metal (mg/kg)					Leaching of Heavy Metal (mg/L)				
	Pulverized Raw Coal (ABK)	Gasifier-Upper	Gasifier-Lower	Cyclone	Metal Filters	Pulverized Raw Coal (ABK)	Gasifier-Upper	Gasifier-Lower	Cyclone	Metal Filters
Hg	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Pb	n.d.	n.d.	n.d.	n.d.	11.9	n.d.	n.d.	n.d.	n.d.	n.d.
Cd	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cr	n.d.	72.61	411.27	178.2	945.86	n.d.	n.d.	n.d.	n.d.	n.d.
Cu	n.d.	10.76	33.34	22.33	28.54	n.d.	n.d.	n.d.	n.d.	n.d.
Fe	5172.97	23073.16	39992.1	28983.48	29755.9	0.47	n.d.	n.d.	n.d.	n.d.
Al	2956.23	6924.81	6557.13	10413.99	2860.7	**1**	0.62	n.d.	**10.98**	0.05
Zn	0.87	14.38	9.54	3.8	76.57	n.d.	n.d.	n.d.	n.d.	n.d.
As	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Sb	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ti	205.5	1095.78	2183.78	1414.42	1473.09	n.d.	n.d.	n.d.	n.d.	n.d.
Ba	104.89	409.22	692.98	587.81	566.01	0.02	0.14	0.09	0.63	0.08
K	273.12	1430.34	2973.87	1943.68	2011.23	1.41	1.42	0.92	1.89	4.03
Ca	4108.1	6499.76	8883.22	15224.18	6910.11	**8.18**	116.63	24.95	**73.38**	**59.21**
Na	410.59	1694.77	3594.83	2608	2910.28	24.08	17.13	3.16	5.58	10.5
Mg	318.01	298.49	489.47	974.67	377.25	**5.96**	0.06	0.16	0.22	**12.09**
Cr^{+6}	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.006	0.007
CN^-	n.d.	0.008	0.004	0.013	n.d.	n.d.	0.021	0.006	0.005	0.034

n.d. : not detected

Particle Size Distribution of Raw Coal, Captured Fines (Indonesian ABK coal, 1250°C Gasification)

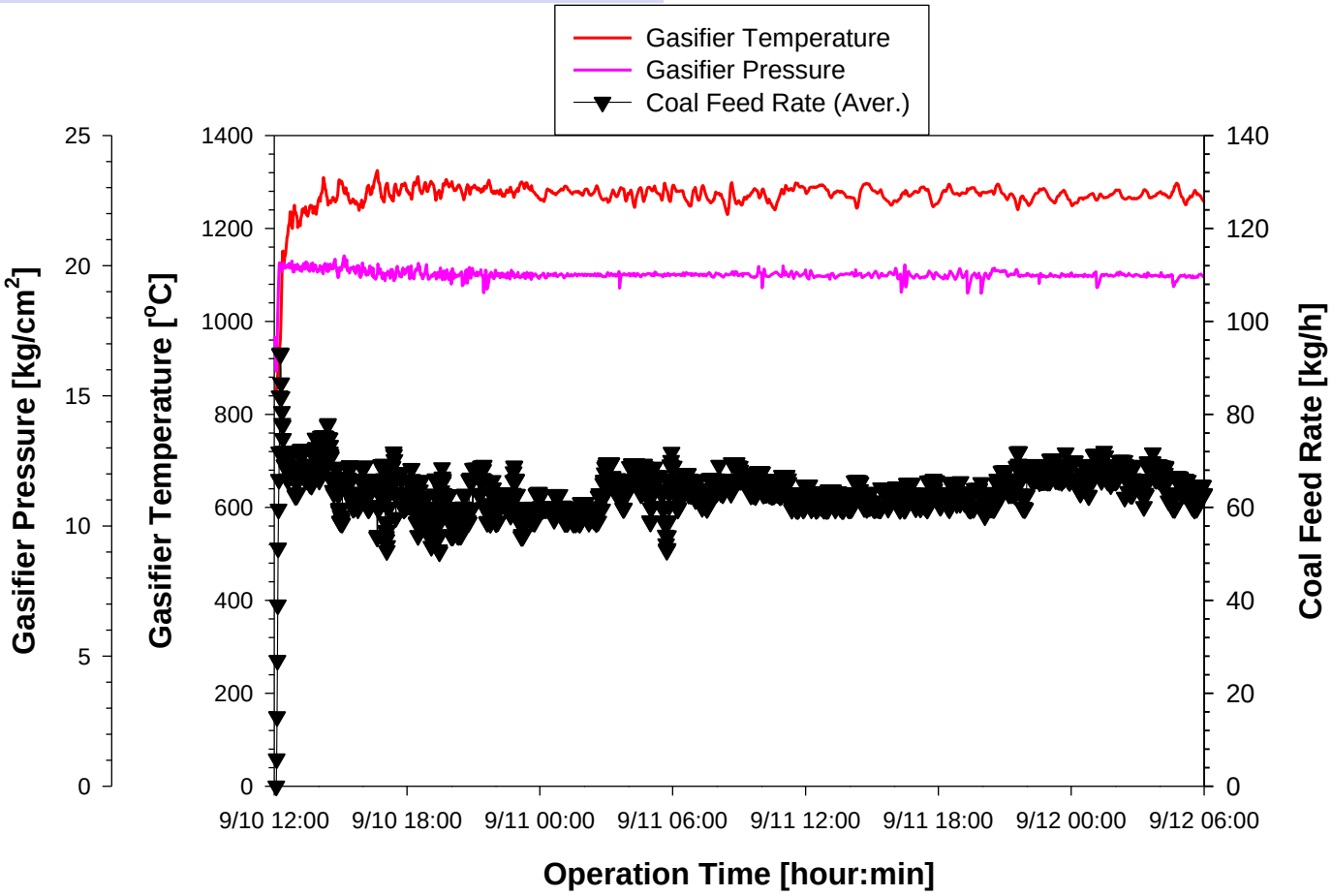


- Fines exhibited one hump in particle distribution pattern.
- Captured fines frequently showed a loose-packed aggregate pattern which would cause a different characteristic in recycling into coal gasifier.

Gasification of Indonesian Subbituminous coal at *ca.* 1,300°C

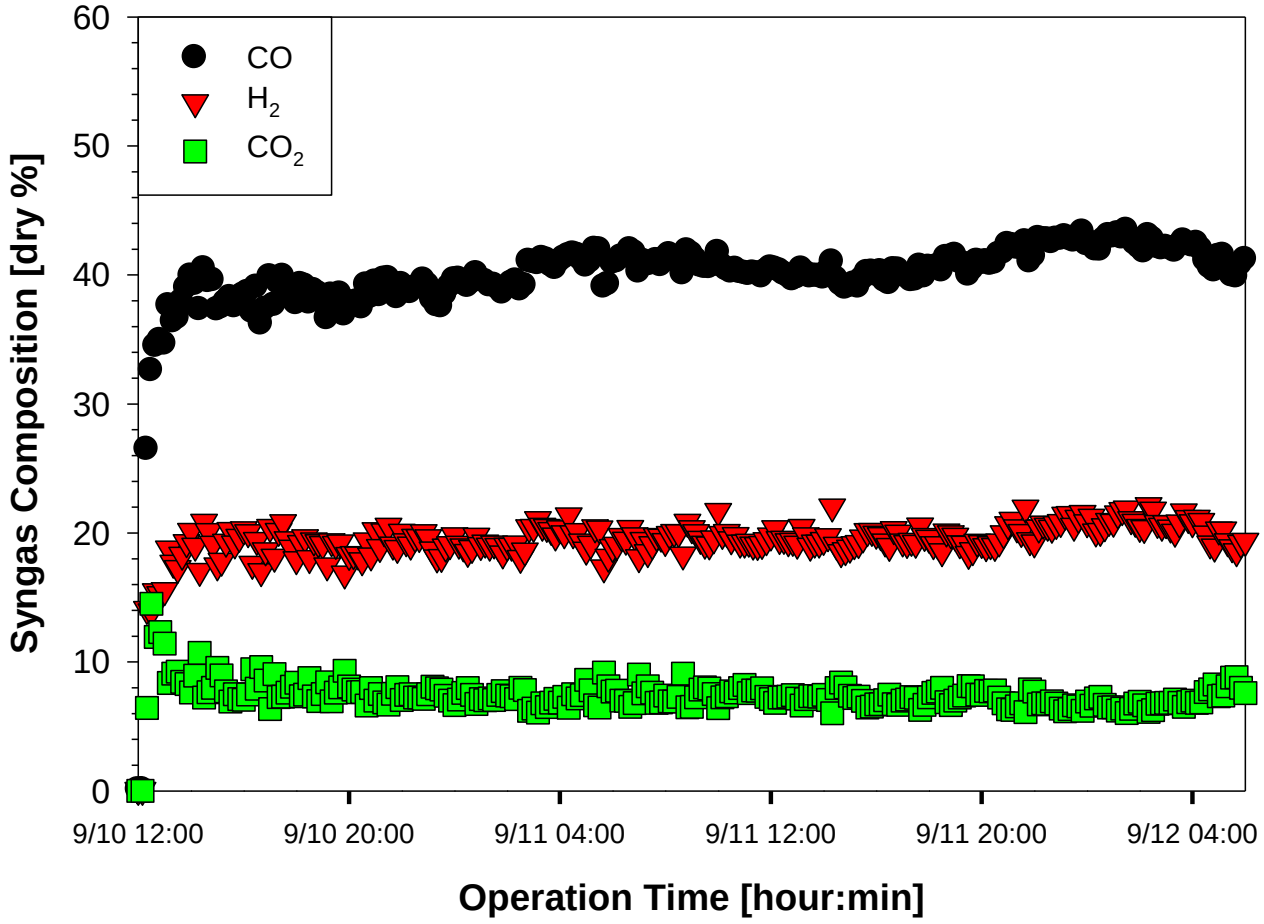
Profiles of Key Operation Parameters (Indonesian ABK coal)

Gasifier Temperature : *ca.* 1,300°C



Syngas Composition (Indonesian ABK coal)

Gasifier Temperature : *ca.* 1,300°C

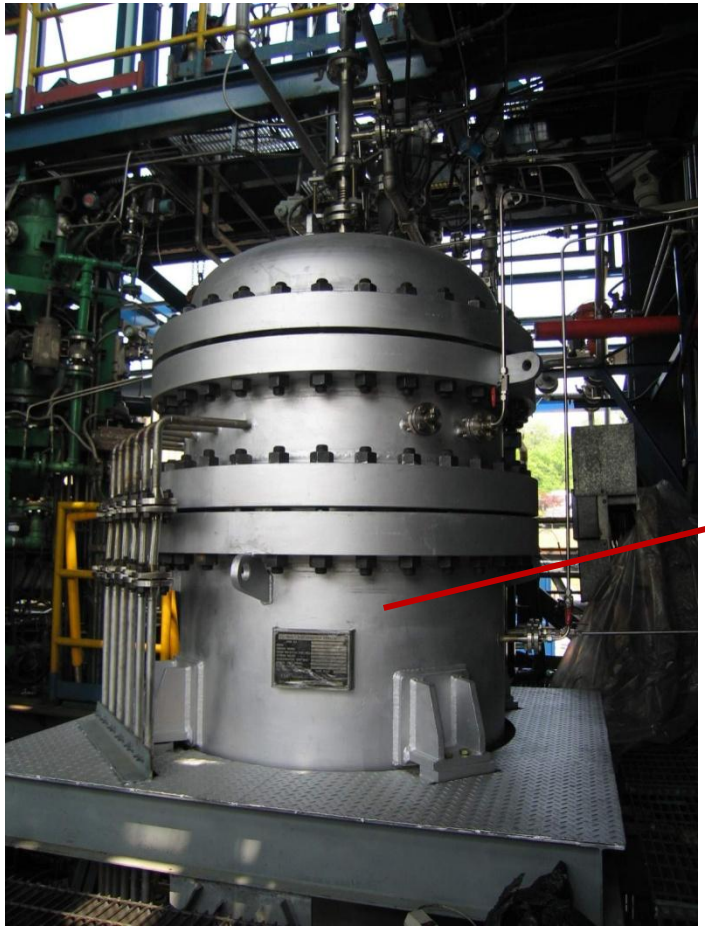


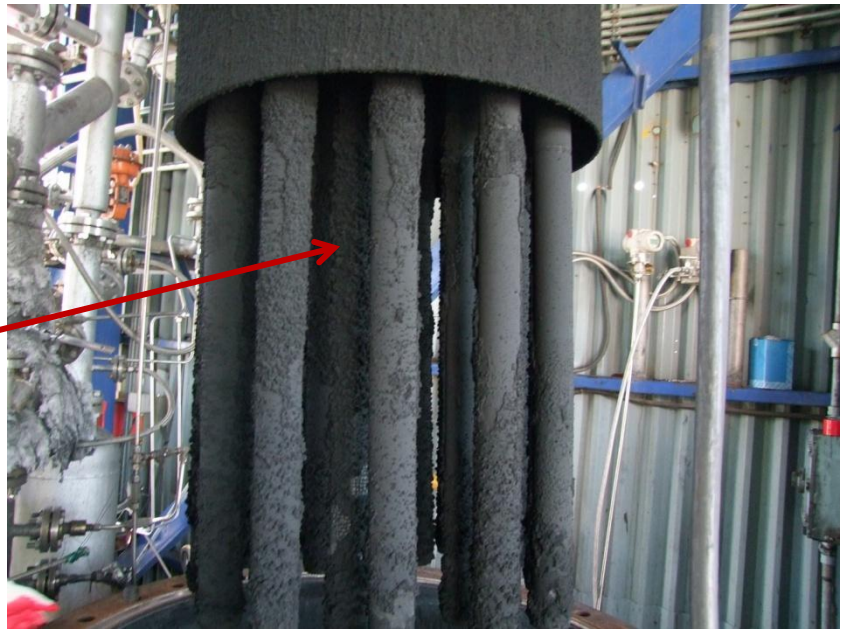
Analysis Data of Raw Coal / Fines (Indonesian ABK coal)

Gasifier Temperature : *ca.* 1,300°C

Sampling Point		Raw Feeding Coal	Gasifier		Cyclone	Metal Filters
			Upper section	Lower section		
Proximate Analysis (dry basis, wt.%)	Volatiles	43.80	2.45	0.35	1.23	6.01
	Ash	7.31	29.30	86.43	86.70	52.47
	Fixed Carbon	48.89	68.25	13.22	12.08	41.52
Ultimate Analysis (dry basis, wt.%)	C	61.79	65.51	29.70	13.95	36.17
	H	5.9	0.46	n.d.	0.81	2.06
	N	1.36	0.79	0.37	0.32	0.62
	S	0.53	0.33	0.20	0.20	2.06
	O (by-difference)	23.10	3.60	0.00	0.00	6.61
	Ash	7.31	29.30	86.43	86.70	52.47
Heating Value (dry basis, kcal/kg)		5,841	5,249	1164	1,008	2,921

Metal Filters after Gasification Test
(Indonesian ABK coal, 1300°C)



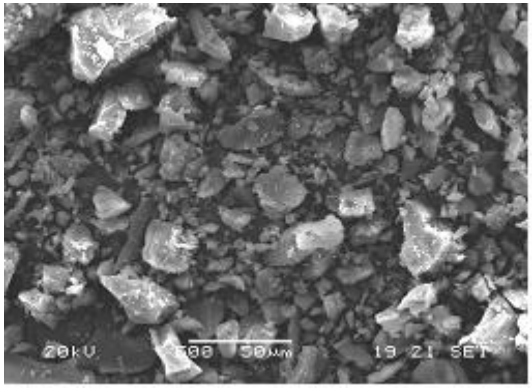


(High Temp. Metal Filter System)

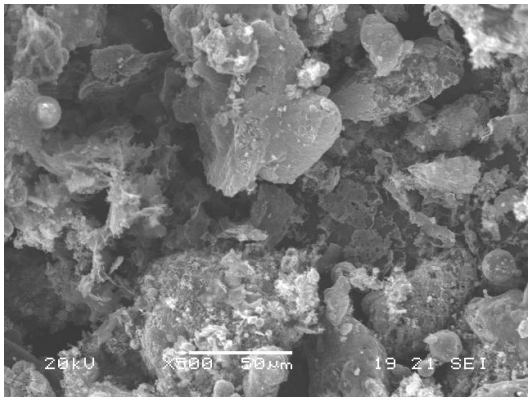
Changes of Particles through Gasifier–Filters

(ABK coal, 1300°C, x500 magnification)

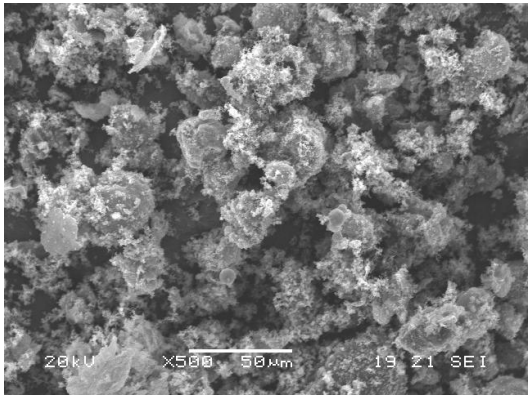
Raw ABK Coal



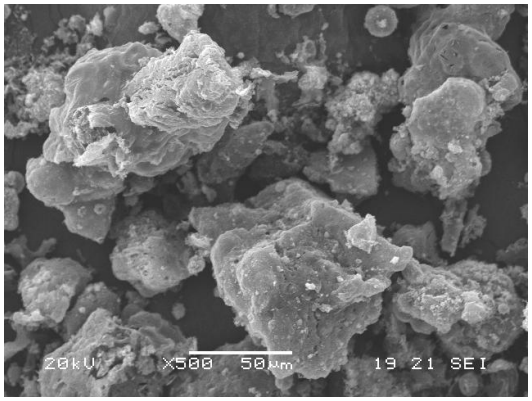
Cyclone



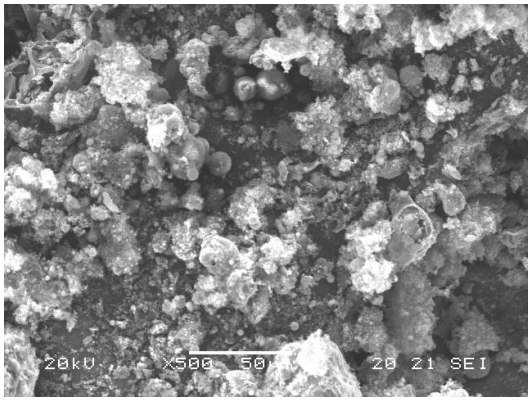
Gasifier
– Upper section



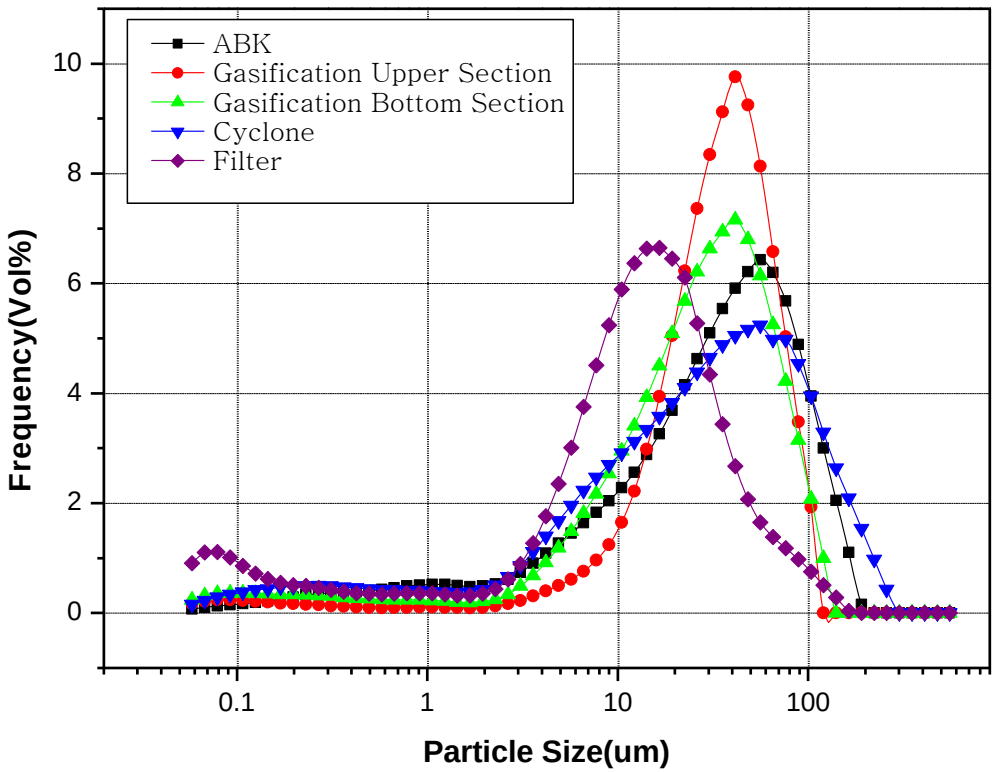
Gasifier
– Lower section



Metal Filters



Particle Size Distribution of Raw Coal, Captured Fines (Indonesian ABK coal, 1300°C Gasification)

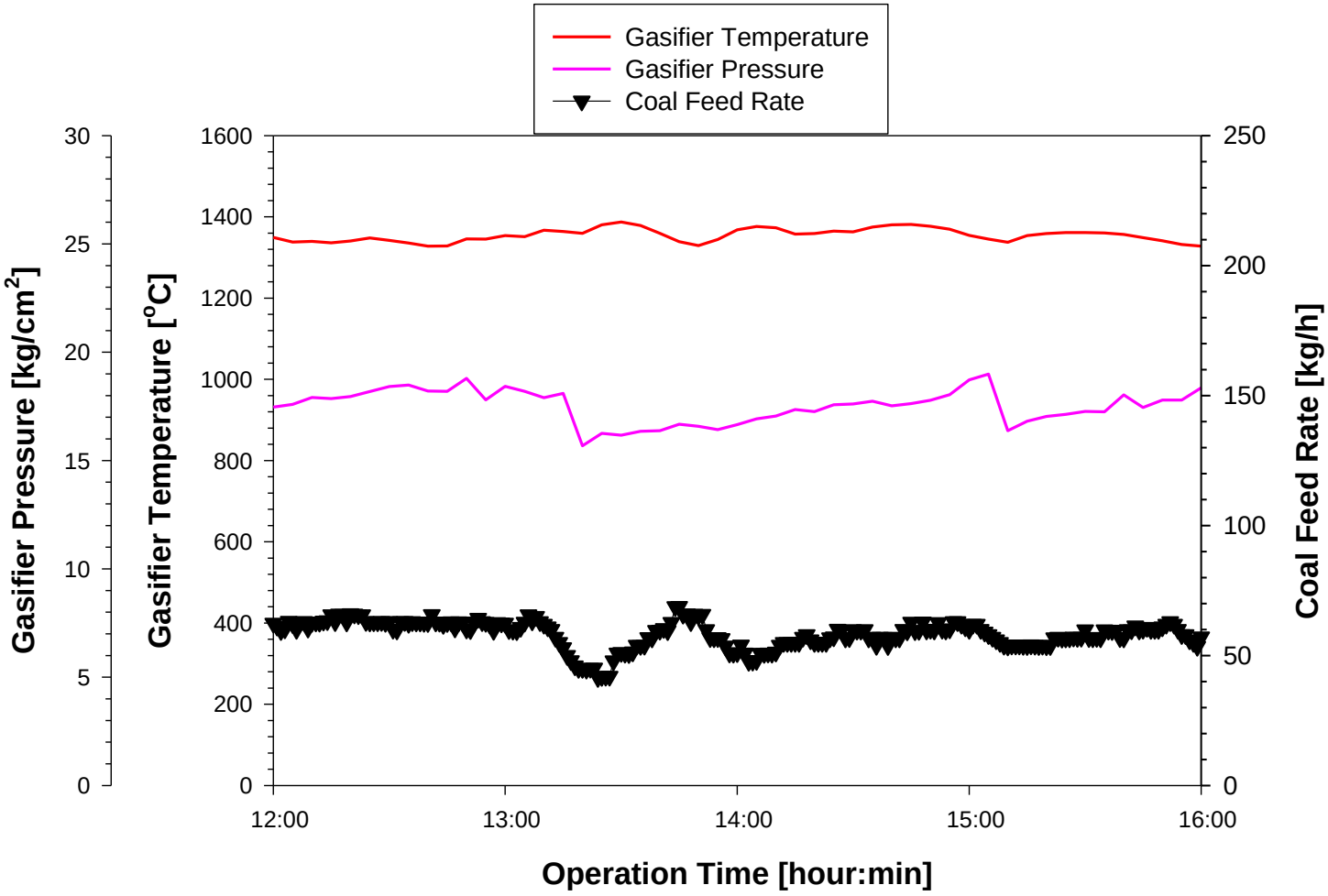


- Fines captured by metal filters showed a small hump of less than 0.1 microns in particle distribution pattern while raw coal showed one sharp peak.

Gasification of Australian Bituminous coal at *ca.* 1,350°C

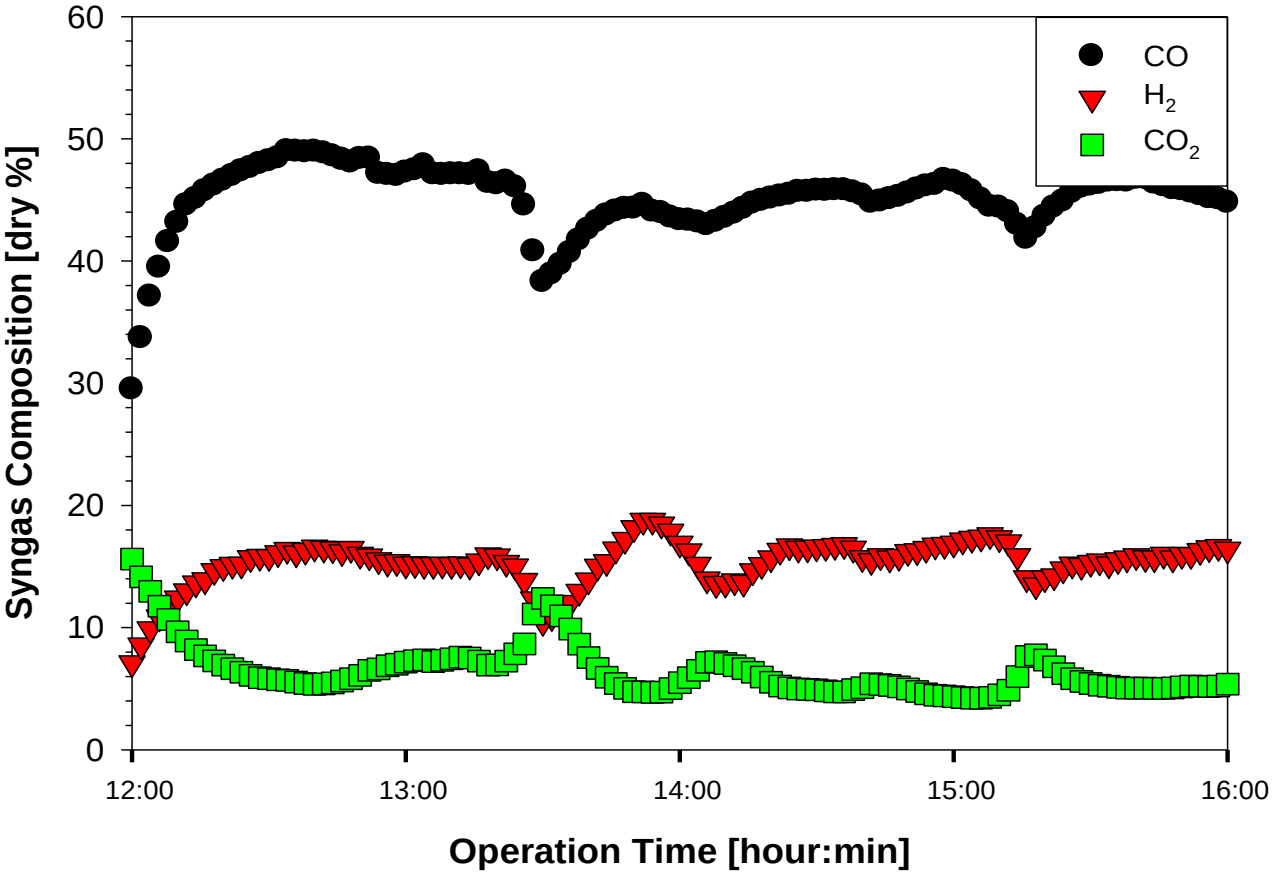
Profiles of Key Operation Parameters (Australian BA coal)

Gasifier Temperature : *ca.* 1,350°C



Syngas Composition (Australian BA coal)

Gasifier Temperature : *ca.* 1,350°C



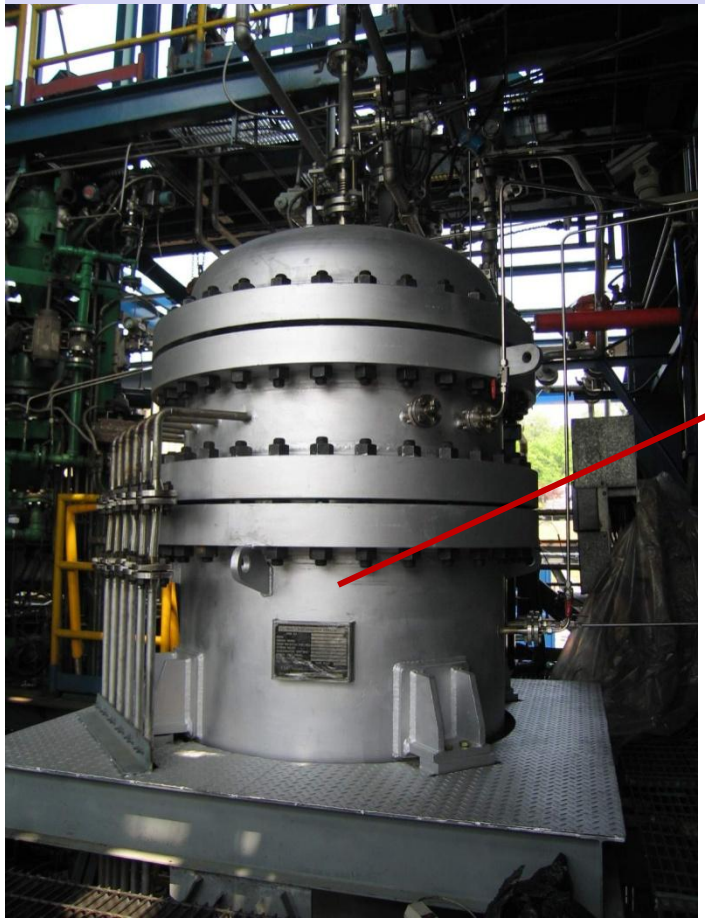
Analysis Data of Raw Coal / Fines (Australian BA coal)

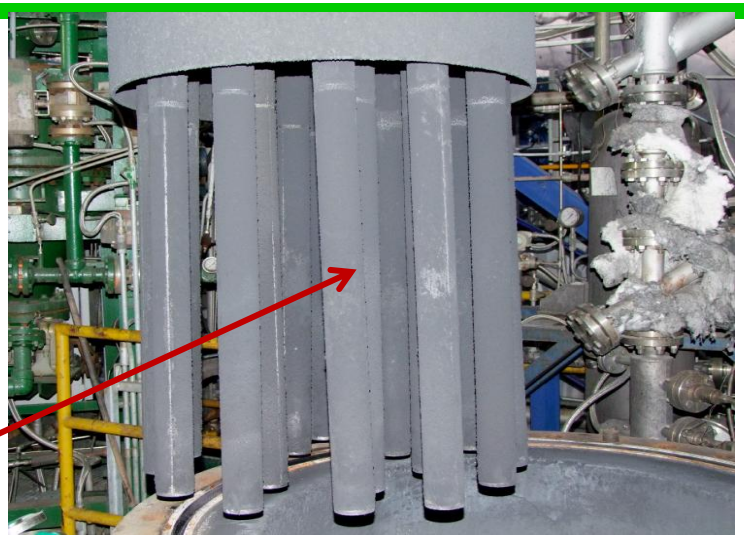
Gasifier Temperature : *ca.* 1,350°C

Sampling Point		Raw Feeding Coal	Gasifier		Cyclone	Metal Filters
			Upper section	Lower section		
Proximate Analysis (dry basis, wt.%)	Volatiles	35.38	0.00	1.52	1.30	2.19
	Ash	14.14	99.96	51.07	55.56	52.69
	Fixed Carbon	50.48	0.04	47.40	43.14	45.11
Ultimate Analysis (dry basis, wt.%)	C	60.86	0.42	48.25	43.44	43.37
	H	3.57	N.D	N.D	N.D	N.D
	N	1.28	0.2	0.77	0.67	0.63
	S	0.37	N.D	0.39	0.34	0.5
	O (by-difference)	19.78	0	0	0	2.86
	Ash	14.14	99.96	51.07	55.56	52.69
Heating Value (dry basis, kcal/kg)		5,787	-	3,861	3,357	3,454

Metal Filters after Gasification Test (Australian BA coal)

Gasifier Temperature : *ca.* 1,350°C



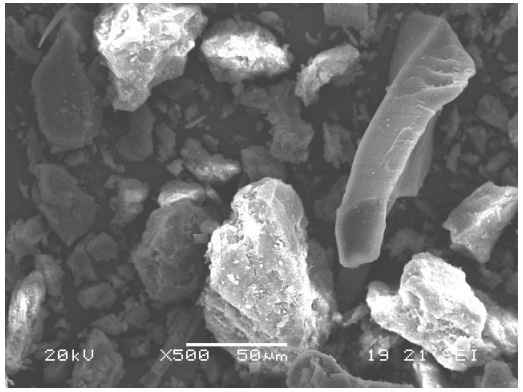


(Enlarged)

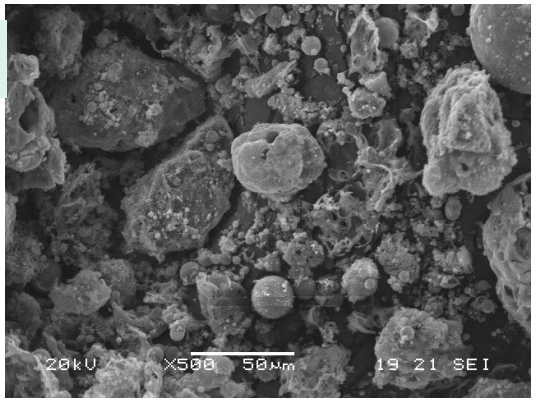
Changes of Particles through Gasifier–Filters

(Australian BA coal, 1350°C, x500 magnification)

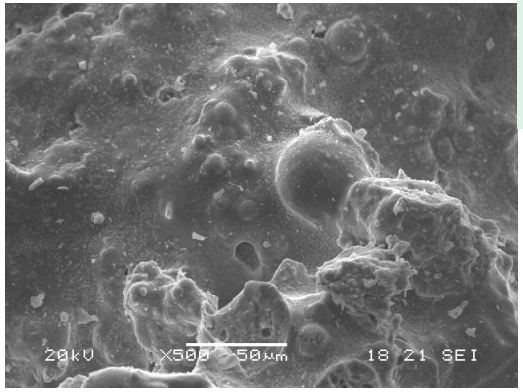
Raw ABK Coal



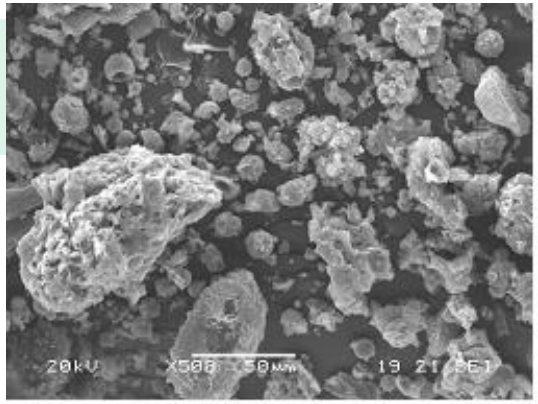
Cyclone



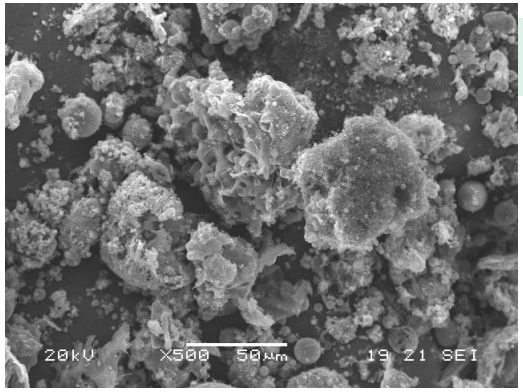
Gasifier
– Upper section



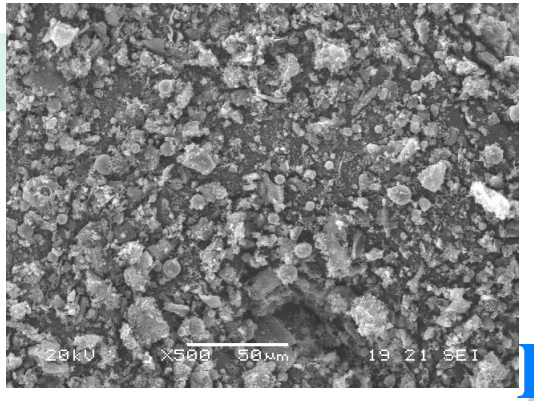
Cyclone to Filters



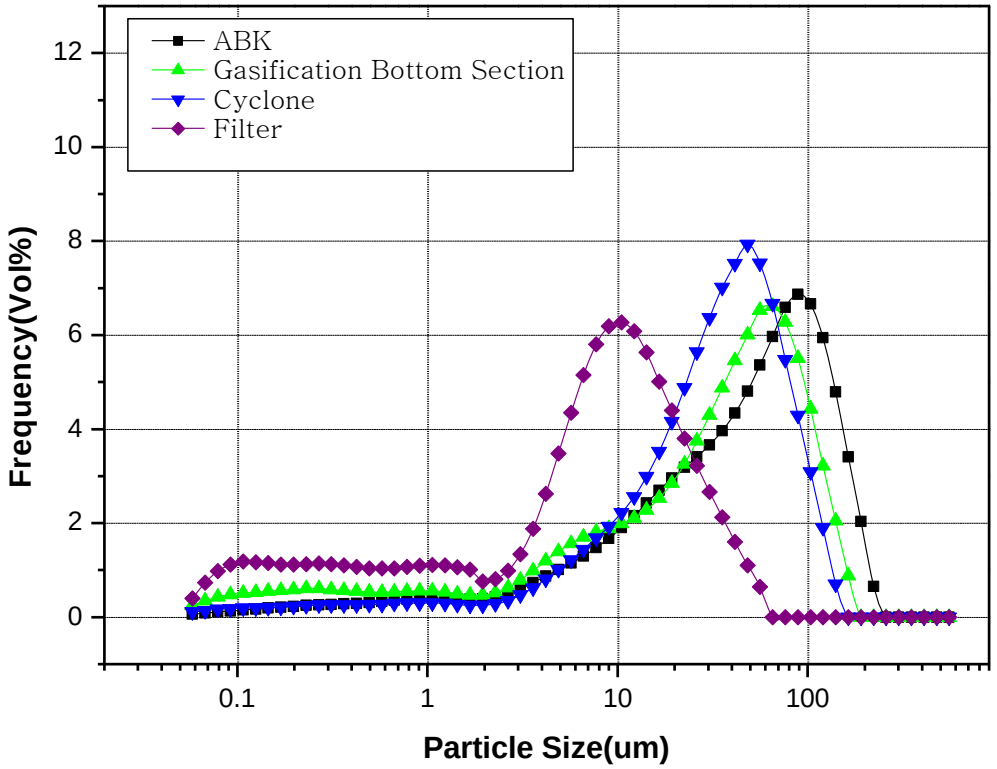
Gasifier
– Lower section



Metal Filters



Particle Size Distribution of Raw Coal, Captured Fines (Australian bituminous BA coal, *ca.* 1350°C)



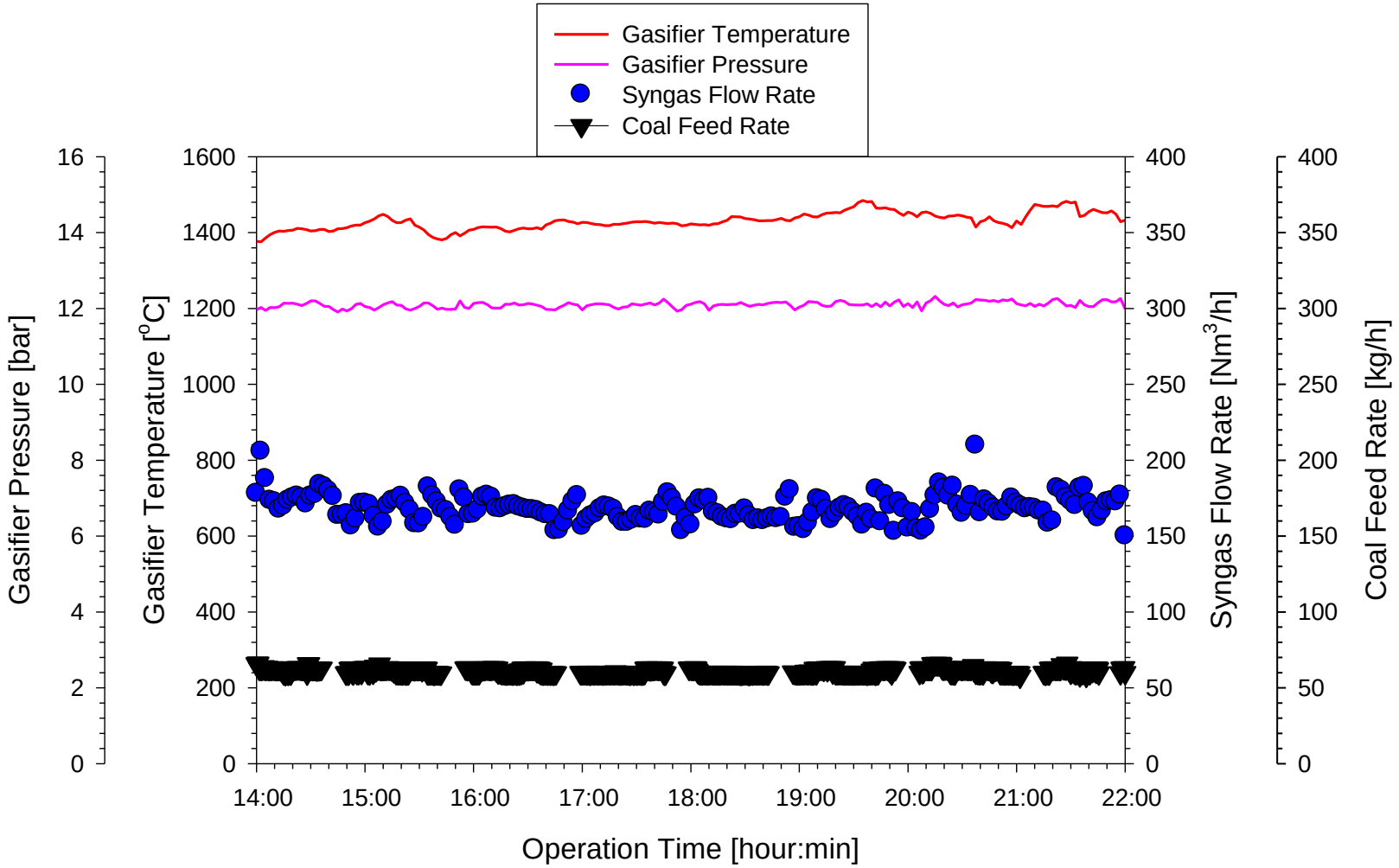
- Fines at metal filters exhibited a wide range of small particle size at 0.1-2 microns.

Gasification of Indonesian Subbituminous coal at *ca.* 1,420°C

(Partial Slagging Condition)

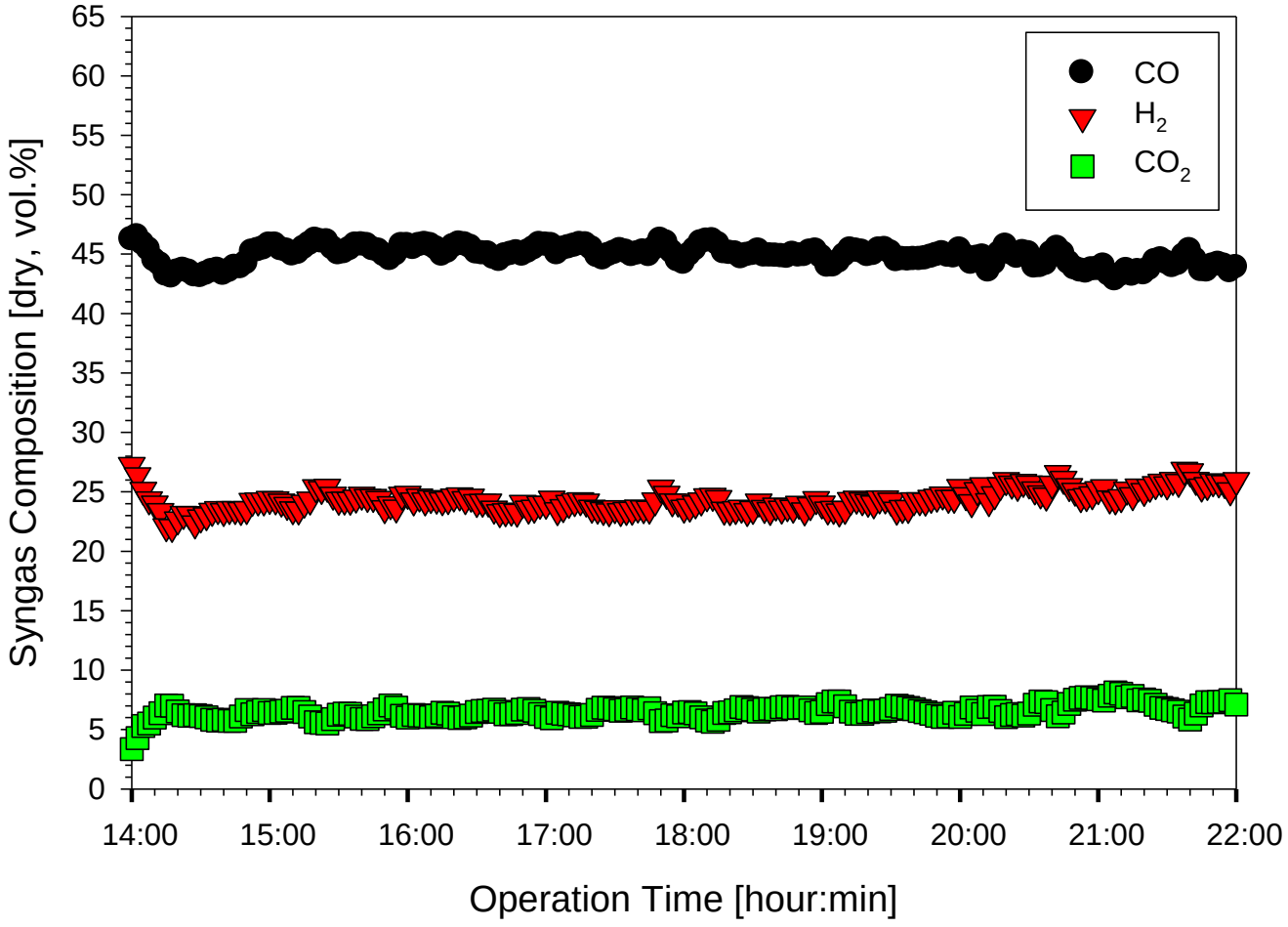
Profiles of Key Operation Parameters (Indonesian subbituminous coal)

Gasifier Temperature : *ca.* 1,420°C



Syngas Composition (Indonesian subbituminous coal)

Gasifier Temperature : *ca.* 1,420°C



Sample Pictures of Slag / Fines (Indonesian ABK coal)

Gasifier Temperature : *ca.* 1,420°C

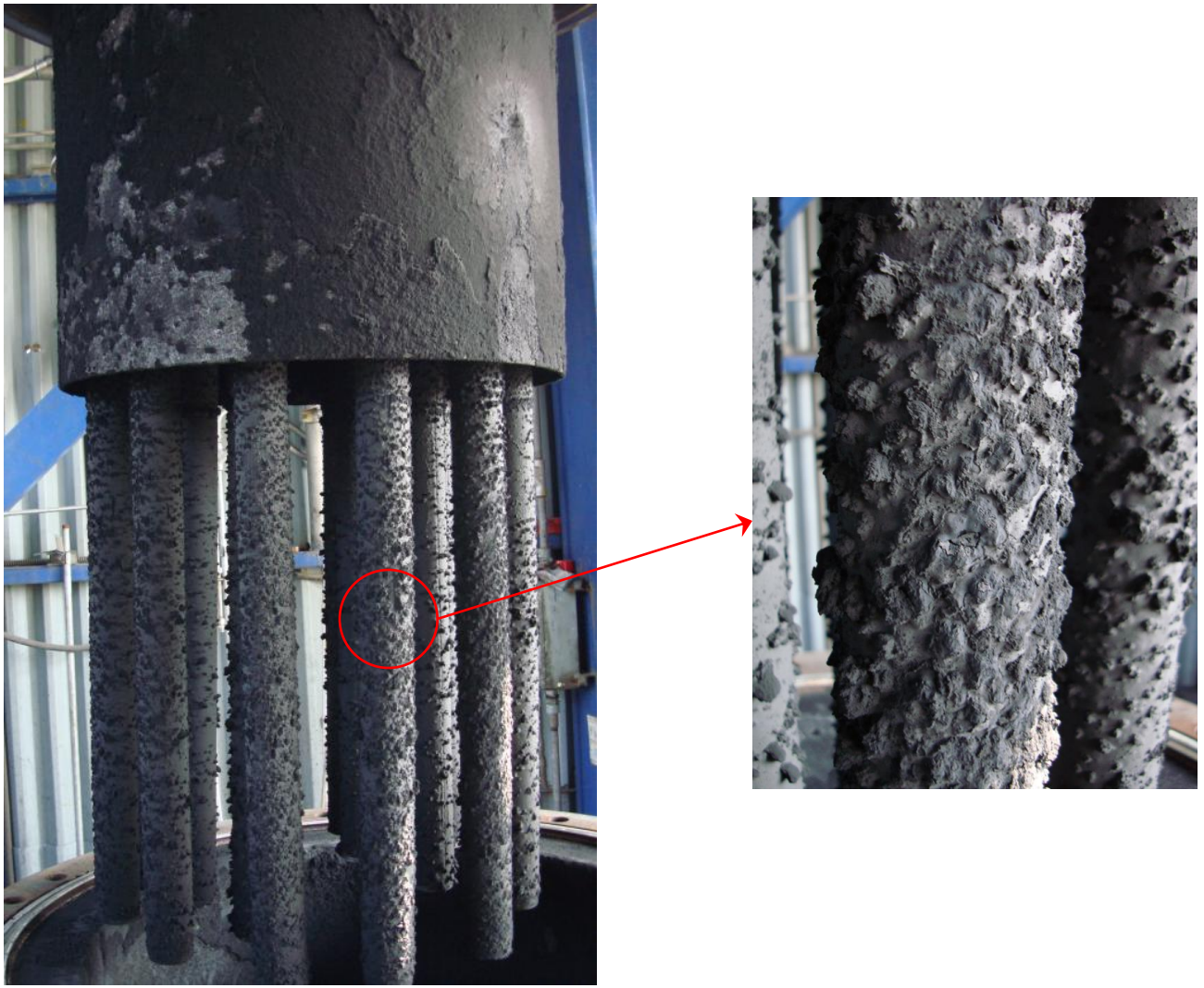
(0.4% of feed coal)

(5.7% of feed coal)

Recycled or Use as low-grade fuel

Metal Filters after Gasification Test

(Indonesian subbituminous coal, 1,420°C)



Conclusions

- Non-slagging/Partial slagging coal gasifier can be developed to ensure the lower construction cost and to reduce the operational problems related to slagging. But, there exist a lot of challenges for high ash content coals, especially while the fines are transported to the filtering system.
- For typical Indonesian subbituminous coal of reasonable ash content, a non-slagging gasifier might become a good replacement for slagging gasifiers. Fines can be used as a feedstock for other purpose or simply recycled into the gasifier for higher carbon conversion.
- Fines obtained from non-slagging gasifier exhibit a different particle size pattern at less than 1 micron compared to the cases of slagging gasification. Analyses of particle size distribution and SEM for the captured fines provide a valuable information regarding the performance of gasifier.

IAE

Thank you

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