

COAL GASIFICATION TECHNOLOGIES: PAST EXPERIENCE AND FUTURE DIRECTION IN KOREA

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ABSTRACT

Korea has a long-term plan to construct and operate IGCC plants of 300 MW scale after 2012. The plan in installing CCT plants has been rescheduled twice from three plants of 300 MW by 2007, 2013, 2014 to one IGCC plant in 2009 according to the schedule published in 2002. Technological and economical obstacles should be cleared before wide acceptance of IGCC. Although many obstacles and uncertainties in economic and technical aspects are present, it appears imperative to utilize IGCC in Korea because Korea imports 97% of energy and minimum 28-32% of electricity should come from imported coal. To understand the technical details in IGCC, a pilot scale coal gasification system has been operated from 1994. Past experience, current status, and future direction of IGCC in Korea are described, with emphasis on the possibility of the 300 MW IGCC plant in Korea and the gasification experience from a pilot-scale plant.

1. INTRODUCTION

Coal gasification has revived recently because of current high oil price and high probability of oil production peak that can reach in 20-50 years. Gasification is a better conversion technology than combustion in terms of pollutants generation and energy carrier. While combustion converts S and N-containing compounds into SO_x and NO_x and hot flue gas of CO₂, gasification produces instead the H₂S and NH₃ that are more cleanly removable and the syngas of H₂ and CO that can be basic components for the C1 chemistry. Moreover, syngas can be a energy source to the gas turbine and thus make possible to apply more efficient combined cycle system. But, CO₂ from the combustion only make possible to use steam turbine.

As widely known, coal can support the world energy system for the next 200 to 250 years at the current energy consumption rate. Furthermore, environmental concerns and recent issue on climate change mainly by CO₂ prompt the development of clean coal technology, especially since the year 2000. Among the many clean coal technologies, IGCC (Integrated Gasification Combined Cycle) is the most promising one. Advantages of IGCC are high environmental performance in that SO_x and NO_x can be reduced more than 80-90% compared to the conventional pulverized coal power plant as well as the tendency of producing high CO₂ concentration in the flue gas.

Korea possesses low-grade anthracite only as a domestic energy source and thus imports 97% of energy. With diversification strategy of energy source that is inevitable in Korea's situation, coal should remain as a key player in the energy sector through the 21st century although there are many technological and economical barriers in the future coal usage. Main barrier resides in environmental concerns when fossil fuels including coal are utilized. Among technologies to cope with the ever-stringent environmental regulations, IGCC and PFBC (Pressurized Fluidized Bed Combustion) are known to be the most prominent choices. Korean government had decided to employ clean coal technology (CCT) in the future coal-utilizing power plants and included CCT power plants in the long-term electricity forecast plan from 1998. Although the final CCT technology that will be employed in Korea has not decided officially between IGCC and PFBC, IGCC appears to be a better position to be chosen.

Environmental advantages of IGCC have been widely accepted, even by the people in power industry in Korea. Essence of gasification technology in IGCC is that dirty feeds containing high level of sulfur and ash such as coal, petroleum residues, and even municipal wastes can be utilized as a clean energy source with higher efficiency than conventional methods. Examples of final syngas application are fuel cell, ammonia production, and fertilizer.

If current concerns for the environment and energy get more severe, technology shift from the combustion-based to gasification-based processes appears to be a natural trend in the long run. However, since the gasification-based process deals with explosive and toxic syngas, complexity of equipments cannot be avoided. Thus, most important deciding factor in commercialization would

be how the process could be designed and constructed safely and reliably, which is the key factor to be solved if IGCC is to be widely accepted.

Gasification/melting technology that has developed as a core part of IGCC technology can be applied not only coal but also wastes and asphalt that were not considered as an energy source until recently. In situation of Korea that 97% of nation's energy is imported, every available energy source has to be utilized with suitable technology. Among the available technologies, IGCC is the one of the best options. Korean government sets a goal of replacing 5% of total electricity with new and renewable energy till 2011. With many technologies of solar power and wind power, etc. that are inherently not suitable for big scale power generation and also produce electricity with very high price, it's not enough to cope with the ever-increasing pressure to increase a portion of new and renewable energy with only these technologies. Even after the actual introduction of a commercial-scale 300 MW IGCC plant in Korea being delayed to the year after 2009, it seems imperative to build IGCC plants in Korea to meet the national need in energy diversification and the goal for new and renewable energy.

An example of the technology pushed change can be found in transition case of coal utilizing power generation technology during the 1920's from the stoker-type to the pulverized combustion type at a relatively fast rate. The IGCC technology is expected to change the paradigm regarding the coal-based power plants, petroleum industry, and the waste treating plants in the 21st century.

It appears imperative to utilize IGCC technology in Korea because Korea imports 97% of energy with the requirement of energy diversification and minimum 28-32% of electricity should come from imported coal. However, there exist many obstacles in introducing CCT into Korea such as serious concerns for the commercial status of the technology itself and the reported low availability performance from the earlier demonstration plants. Moreover, NGO's continuous insistence have caught people's ears in that energy policy should be switched into encouraging the energy system based upon renewables that replace fossil based energy infrastructure.

Korea has a plan to build a 300 MW class CCT power plant around the year 2012, although CCT construction plan has been postponed twice already. Among CCT technologies of IGCC and PFBC, IGCC appears to be a better position because coal gasification is classified as a new energy that allows government incentives. Since Korea cannot afford the cost in demonstration steps in IGCC technology, a pilot-scale gasification system of maximum 3 ton/day (T/D) capacity has been constructed and operated from 1994 with objectives of identifying key coal selection parameters as well as verifying technical feasibility by local manufacturing skill.

2. COAL AS A KEY SOURCE FOR ELECTRICITY IN KOREA

As well known, world coal reserve can meet the future world energy demand at least 250 years, and importantly the coal deposits are distributed in many countries which indicate less possibility in coal shortage and embargo. With Korea's energy situation of importing 97% of total energy, sustained supply as an energy source and less susceptibility in political situation are critical factors. Therefore, coal should remain as a key ingredient of energy source in Korea.

Coal sustains as an important energy source in Korea as demonstrated in Table 1. Of the primary energy consumed in 2001, coal comprises 23.3% after oil that represents 52.6%. Since it's reported that the peak of oil production would reach around the year 2040 even with the optimistic view [3], coal should remain as the more important ingredient in the Korea's energy mix.

Table 1 Primary Energy Consumption of Korea in 2001 [1]

Energy Source	Primary Energy Consumption (MM TOE)	%
Oil	103.1	52.6
Natural Gas	20.8	10.6
Coal	45.7	23.3
Nuclear Energy	25.4	13.0
Hydro-Electricity	0.9	0.5
Total	195.9	100.0

Table 2 summarizes the percentage of each energy sector in Korea's electricity production market till 2010 projected based on the current electricity generation statistics. For the electricity production in Korea, two key sources are nuclear and coal with a supplementary role by LNG. Table 2 demonstrates the key role of coal for electricity generation in Korea.

Table 2 Projected Electricity Generation Amount and Percentage with Different Feedstock in Korea (unit: GWh, %) [2]

Year	Nuclear	Coal	Domestic Coal	LNG	Petroleum	Hydro	etc.	Total
2002	122,764 (40.5)	110,945 (36.6)	7,001 (2.3)	29,684 (9.8)	26,666 (8.8)	5,982 (2.0)	-	303,042 (100)
2005	134,083 (38.8)	127,153 (36.8)	5,502 (1.6)	45,638 (13.2)	24,807 (7.2)	6,656 (2.0)	1,377 (0.4)	345,216 (100.0)
2008	138,870 (36.7)	156,448 (41.4)	6,098 (1.6)	43,073 (11.4)	23,995 (6.3)	8,300 (2.2)	1,302 (0.3)	378,086 (100.0)
2010	166,720 (42.1)	169,087 (42.7)	6,098 (1.5)	26,480 (6.7)	17,889 (4.5)	8,542 (2.1)	996 (0.3)	395,812 (100.0)

Table 3 illustrates the sharp increase in the total electricity demand volume and reserve rate is steadily decreasing after 1998. Table 3 also shows the trend in electricity price. Current exchange rate of Won to dollar is 970 to 1.

Table 3 Recent Electricity Demand and Power Generating Capacity in Korea

Item / Year	1980	1990	1995	1997	1998	1999	2000	2001
Max. Demand(MW)	5,457	17,252	29,878	35,851	32,996	37,293	41,007	43,125
Electricity Generating Capacity(MW)	9,391	21,021	32,184	41,042	43,406	46,978	48,451	50,859
Capacity Reserve Rate(%)	72.1	21.8	6.4	13.1	31.1	19.1	16.8	15.1
Electricity Price(Won/kWh)	50.88	52.94	61.28	65.26	72.08	71.59	74.65	77.06

To meet the ever-increasing electricity demand, more power plants are scheduled to build and Table 4 exhibits the construction plan for power plants till 2015. Comparison of plan summarized in 2000 with the plan adjusted in 2002 shows the increased portion by LNG while a sharp decrease in petroleum based power generation, and still emphasizing the key position of coal and nuclear.

Table 5 demonstrates the long-term electricity generating capacity with each energy sector. Comparing Table 2 and 5 clearly indicates the importance of coal as a base load feedstock in electricity generation in Korea. Electricity generation capacities of coal and LNG in Table 5 are comparable as 30.7% and 25.9% in 2010, but actual electricity generation in Table 2 mainly relies on coal instead of expensive LNG as values are widely different by 42.7% and 6.7%. LNG mostly provides electricity for the peak load period while coal supply electricity as a base load.

Table 4 Power Plant Construction Plan till 2015 in Korea

Item	Nuclear	Coal	LNG	Petroleum	Hydro/etc.	Total
Plan till 2015 in 2000 (MW)	13,600 (12 units)	9,000 (15 units)	6,870 (20 units)	5,150 (12 units)	3,060 (23 units)	37,680 (82 units)
Power Companies Construction Plan till 2015 in 2002(MW)	13,600 (12 units)	8,900 (16 units)	7,570 (20 units)	150 (2 units)	2,520 (21 units)	32,740 (71 units)

Table 5 Long-term Electricity Generation Capacity by Energy Sector in Korea

Year / Energy Source	Nuclear	Coal	LNG	Petroleum	Hydro	Total
2010 (MW, %)	23,116 (29.2)	24,265 (30.7)	20,437 (25.9)	4,817 (6.1)	6,385 (8.1)	79,019 (100)
2015 (MW, %)	26,637 (34.6)	22,240 (28.8)	19,550 (25.4)	2,212 (2.9)	6,385 (8.3)	77,023 (100)

Since separate power companies are competing each other for cheap electricity, power companies are becoming more concerned with mature and proven technology as well as cheap feedstock. Private companies are also able to participate in the electricity market in Korea after the deregulation in 2001. Currently, separated five fossil fuel based power companies prefer coal as a basic feedstock of base load for electricity generation with natural gas power plants as a backup for load changing market while the private companies favor natural gas for power generation. Considering the increased role of coal in power generation and the requirement of cleaner utilization of coal, IGCC should play a key role in Korea.

3. POSITION OF CCT IN KOREA

In Korea, among clean coal technologies, IGCC has been selected as the next generation technology for coal power plants. Most likely, a commercial-scale 300 MW IGCC plant would start to operate after 2012. PFBC (Pressurized Fluidized Bed Combustion) technology might be the next option that can be tried in Korea when the commercial-scale plant is fully operational.

Clean coal technology power plant was first noted in the Korea's long-term power plant construction plan of 1993 as an item for the technology development item. Construction plan for CCT in Korea has postponed continuously after the first CCT construction plan was included in the long-term construction schedule of power plants in 1998, in that CCT of 300 MW scale was scheduled to be finished by 2005. Technology for the CCT at that time was supposed to be chosen from IGCC or PFBC.

The CCT plan was rescheduled in 2000 from the plan building three CCT plants of 300 MW by 2007, 2013, and 2014. Again, according to long-term power plant construction schedule from MOCIE that published in August, 2002, only one 300MW-size CCT plant is included to start operation by 2009 and possibly postponed to 2011. Current status is in the feasibility planning stage to build one coal-based IGCC plant by 2012 and operates the plant as a demonstration plant to decide the direction that can provide information on wider applicability for the future coal-utilizing power plants in Korea.

More stringent environmental regulation might increase the momentum for the IGCC power plants in Korea. New coal-based power plants that would build from 2005 in Korea must meet the NO_x level of 80 ppm. When this stricter environmental regulation becomes effective, environmental advantages of IGCC technology would be more eminent. For comparison, Donghae circulating fluidized bed combustion plant of 200 MW using domestic anthracite can meet the NO_x level of 150 ppm at best with current technology. Thus, IGCC technology is probably the only available option before 2010 to deal with newly enforced regulations. Even with this background, power companies in Korea still prefer installing additional de-NO_x facilities instead of venturing into new technology like IGCC.

4. OBSTACLES AND FUTURE DIRECTION FOR IGCC

Power companies interested in CCT in Korea are considering mainly IGCC among many available CCT options. Main reason is that many developed countries like USA, Japan, Germany, Holland reached the demonstration level of commercial-scale IGCC plants while PFBC technology has a limited demonstration plant performance of 300 MW scale.

However, many technological barriers are still exist in IGCC such that coal powder injection, erosion of refractory, plugging of heat exchangers by fly-slag, etc. and more long-

term operational experience is still required. Probably 5-10 years of time would be required to solve all the technological barriers and particularly in developing the hot gas cleanup technology to improve the energy recovering efficiency. Appearance of high efficiency gas turbines utilizing the hot gas more than 1,500°C probably in the next 5 years would yield 52-53% IGCC plant efficiency that is much higher than the conventional 36-38%. If IGCC system is connected to fuel cell technology, the efficiency can reach even 55-70%. However, all these fancy possibilities need to be proven in a commercial scale with high technical reliability.

Most critical obstacle for commercialization of IGCC is capital cost. It has been reported that construction cost of coal IGCC plant after 2010 would drop to less than US\$1,200/kW, but still remains in the range of US\$1,400-1,600/kW or sometimes even much higher.

To be commercialized in Korea, many factors exist to consider, but eventual construction of a commercial plant of 300 MW appears to be realized after 2012. First, KEPCO has been divided into several competing companies and the companies prefer LNG plants that are cheap to construct and easy to operate. Second, uncertain return on investment in Korean market on the high capital cost for construction delayed the time schedule. Third, timing for applying emission credit trading according to the Kyoto protocol has been delayed in enforcement.

To promote the construction of coal-based IGCC plants in Korea, many aspects have to be considered and several suggestions are possible as follows:

- Environmental regulation level is still not stringent enough to give leverage to IGCC plants. Current conventional facilities are still usable with small modification to meet the environmental standards. Thus, incentives are still not present to overcome the high risk in construction and operation.
- Deregulated power companies prefer natural gas power plants for their short-term profit. Therefore, government support like many foreign countries should be considered. Best examples are available from cases of Italy and USA in that incentives for electricity price are given.
- Engineering capability of local heavy industry is not sufficient in IGCC plant area, although manufacturing ability has an international competitiveness. With local manufacturing of key IGCC components, total investment amount can be lowered and government subsidy, if there's any, might be justified.

Government incentives appear to be essential to make a best use of CCT technology that can generate minimal pollutants in dirty fuels and can reduce 15-25% of CO₂ to the conventional power generation plants. If the identical electricity price can be applied as solar power or wind power, there will be an immediate construction of CCT plants in Korea, particularly IGCC plants. Even much smaller incentive in electricity price can push the inertia for the early CCT introduction in Korea.

Korea includes electricity from coal and petroleum residues gasification as a new energy, which means that IGCC is entitled for incentives in electricity price. PFBC that bases on combustion is not classified as a new energy category. However, NGO's persistent push to delete any energy from fossil fuels from the list of new energy category even with clear environmental advantages by CCT can influence the actual implementation, which is another cause of uncertainty for major investment in CCT plants.

All in all, deregulation of power companies, high technological and economical risks by low availability and reliability in operating CCT plants, people's perception on coal as dirty reinforced by the notion as a main culprit for CO₂ emission by coal are key obstacles in pursuing CCT. For the wide acceptance of CCT in Korea requires more wide distribution of information on the current technology and cost status of CCT as well as the role of coal as an inevitable energy source for the future while coal can be utilized as clean as natural gas.

5. PAST EXPERIENCE WITH A POLOT-SCALE GASIFICATION FACILITY [4-6]

A dry-feeding type gasifier facility, that is located at Ajou University in Suwon, Korea and can treat 3 ton/day at maximum 30 bar, 1550°C has been built in April 1995. The facility (8 m x 17 m x 20 m) located in 30 m x 50 m space. Main target feeds are subbituminous and bituminous coals, but petroleum coke is also possible to gasify. Coal feed is identical size with that of conventional power plants using pulverized coal, as 80-90% passing -200 mesh. Pulverized coal is pneumatically conveyed with nitrogen gas in dense-phase into the feeding nozzle system, where 99%-purity

oxygen and steam are mixed with the coal powder. Steam is injected separately from the oxygen and coal powder, but the current study doesn't use any steam but only oxygen was employed to control the temperature and the degree of conversion.

Normal operation consists of the preheating, pressurization, transient operation, normal gasification operation, and the shutdown steps. LPG burner at the bottom of the gasifier did preheating of the gasifier at least for 20 hours. Then, nitrogen is introduced to pressurize the gasifier till the operating pressure range in less than 30 min, after this step, oxygen as well as coal powder are being fed into the gasifier. Coal supply is first started at the low feeding range in order not to cause any sudden pressure buildup in the gasifier and thus causing any back pressurization into the coal feeding lines. This step takes normally less than one hour. Normal hot test operation step for obtaining gasification data is maintained at the steady state for at least 4 hours to provide enough gas, slag, and other process data.

The coal was dried during the drying/pulverization step to less than 4% moisture content and this dried coal powder was used for gasification. From the former studies using the pilot-scale dry-feeding coal gasification system, Indonesian subbituminous coals were chosen as the best candidate coal for IGCC in Korea. Another subbituminous coal from Alaska, USA yielded a poor performance in the pilot gasifier, mainly by clogging in the syngas cooler inlet. Low ash fusion temperature in the Alaskan Usibelli coal induced the fly-slag clogging in the pipe just after the gasifier.

Typical gasifier operating profiles are illustrated in Figure 1, in that gasifier pressure was controlled at the constant 7.8 kg/cm² while the gasifier temperature was maintained above 1,350°C that is required to melt the ash into molten slag. Temperature shown in the figure represents the actual temperature in the gasification zone just beside the coal feeding ports and thus exhibiting some fluctuation according to the reacting coal powder and oxygen. In the commercial gasifiers, this temperature is not directly measured. Instead, refractory temperature slightly away from the real hot gas temperature is typically measured. Syngas flow rate was maintained around 120 Nm³/hr.

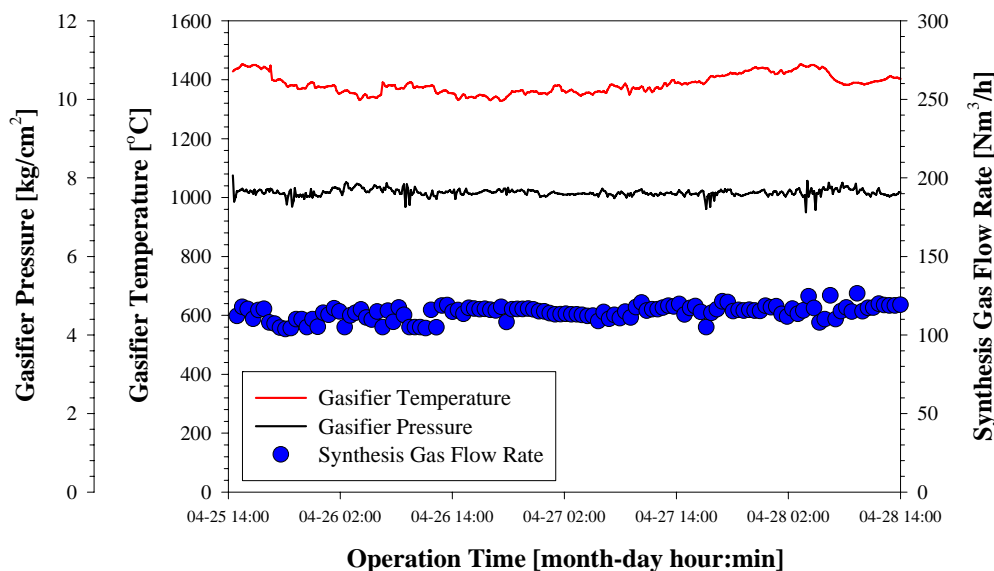


Figure 1 Gasification temperature, pressure and flow rate of produced syngas.

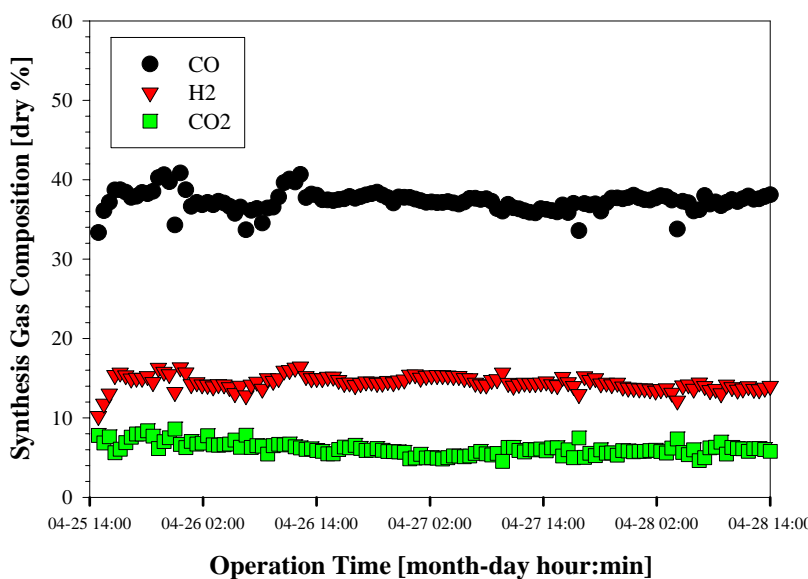


Figure 2 Profiles of coal syngas composition for the Roto Middle coal.

The coal syngas produced in Figure 2 exhibits about 36-38% CO, 14-16% H₂ and around 5-8% CO₂ concentrations (dry basis). Normally in the pilot-scale dry-feeding gasifier, nitrogen that was used for pneumatic coal conveying into the gasifier exists in the coal syngas. The necessary nitrogen amount for pneumatic feeding depends upon the size of feeding nozzle that is obviously bigger in the larger-scale gasifier. Because there's a tendency of particle blockage in the smaller-scale reactors that have a smaller feed-lance diameter, higher transport velocity for particle feeding is employed in the smaller-scale gasifier than the larger dry-feeding gasifier. Also, in a large-scale gasifier, nitrogen concentration will drop through more dense phase particle feeding and also sometimes by replacing the nitrogen transport gas with the product coal-gas.

Figure 3 exhibits the coal gas composition from the gasification test of the 1 ton-coal/day (T/D) pilot scale unit operated at the 10-11 bar pressure. Syngas comprises mainly CO and hydrogen at about 60% and 38% in dry-nitrogen-free basis, respectively in the region of O₂/coal ratio about 0.85.

Conversion efficiencies based upon the syngas composition shown in Figure 3 are illustrated in Figure 4. At the O₂/coal ratio of 0.85-1.05, carbon conversion reaches nearly 100% and the cold gas efficiency exhibits about 78% at LHV basis. The carbon conversion of above 100% at the O₂/coal ratio 1.05 occurred due to the possible instrumental errors incorporated in the measurement of syngas volume and the amount of coal fed used in gasification. Particularly, since the amount of coal fed was estimated indirectly from the rotation speed of screw feeder, there was an inherent measurement uncertainty involved.

Comparison of the pilot scale results in Figures 3-4 with the data from bigger scale gasification systems [7] on the same Drayton coal is summarized in Tables 6 and 7. Gas concentrations are scaled to the nitrogen-free basis. At the 1 T/D gasifier test, nitrogen is utilized for pneumatically transporting coal powder into the gasifier. Typical nitrogen concentration at the 1 T/D pilot system was 15-30% for the wide range of gasifier operating conditions.

For the 1 T/D scale gasifier system, CO concentration was 62% compared to the 67-70% at the bigger scale gasifiers. In contrast, hydrogen concentration was comparable with the bigger scale systems. The higher CO₂ concentration of 7% is shown for the 1 T/D system while the concentrations at the bigger systems are nearly identical values of 1.6-1.7%. Increase of CO₂ concentration at the 1 T/D system compared to the bigger scale gasifiers succinctly illustrates that the bigger heat loss at the small gasifier system yields higher CO₂ value, mainly due to the increased reactor surface area per reactor volume. The result in Table 6 shows that CO concentration tends to be more sensitive to the change in reactor size compared to the hydrogen concentration.

The necessary O₂/coal ratio increases with the smaller reactor size in Table 7, which is probably the effect of heat loss with the reactor size. Even with drastically different gasification reactor size

as in Table 7, carbon conversion values are all high enough to be above 98-99%. Cold gas efficiencies were different only less than 1% from 77.7% to 78.6%. Note that the carbon conversion value for the 1 T/D gasifier system is from single pass through the reactor. For the bigger scale gasifiers, captured fines that contain carbon are recycled to the reactor in order to increase the conversion efficiency. The carbon conversion value in the commercial scale 1,890 T/D gasifier improves after the fines recycling from 98% to above 99.5%.

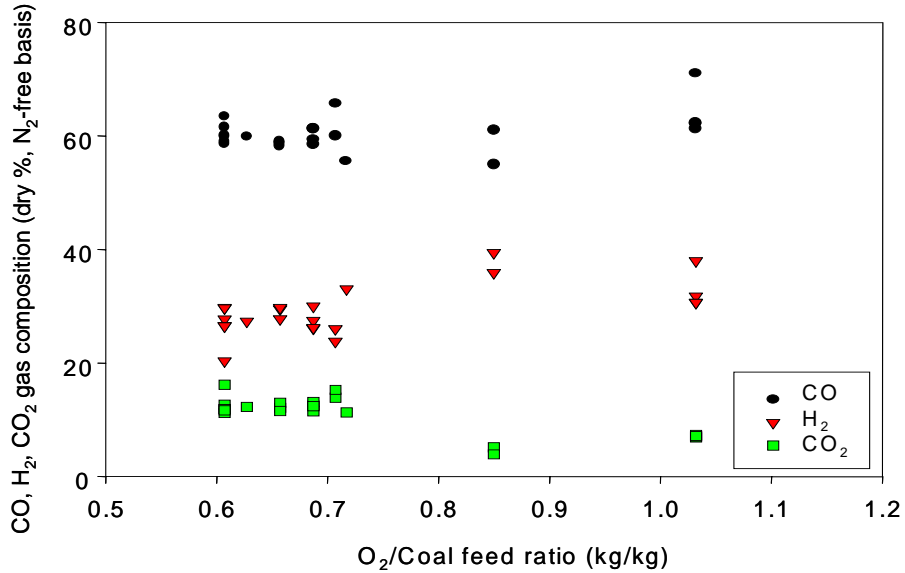


Figure 3 Syngas composition with oxygen/coal weight ratio from the 1 T/D gasifier for Drayton coal at 10-11 bar.

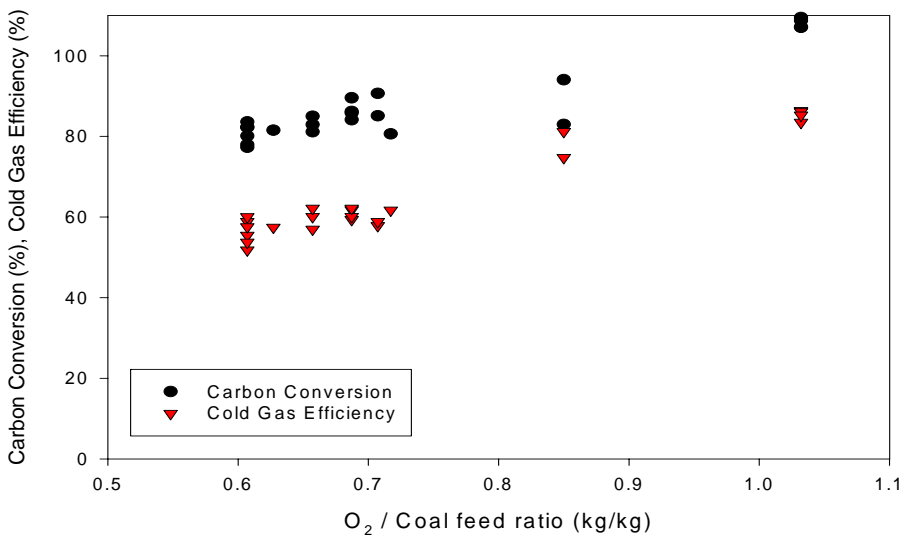


Figure 4 Conversion efficiencies with oxygen/coal weight ratio from the 1 T/D gasifier for Drayton coal at 10-11 bar.

Table 6 Syngas compositions in N₂-free basis from different scale gasifiers

Gas composition \ Gasifier scale	1 T/D	150 T/D	1,890 T/D
CO	62	69.8	67.6
H ₂	31	28.0	30.3
CO ₂	7	1.7	1.6
Others	-	0.5	0.5

Table 7 Gasification data and conversion efficiencies for different scale gasifiers

Data \ Gasifier scale	1 T/D	150 T/D	1,890 T/D
O ₂ /Coal weight ratio	0.95-1.05	0.93	0.88
Steam/O ₂ weight ratio	0	0	0.08
Cold gas efficiency (% LHV)	77.7	78.0	78.6
Carbon conversion (%)	~ 99*	> 99.5**	> 98*, > 99.5**
Slag recovery efficiency***	> 90	60	75

Note) * single pass, ** after fines recycle, *** approximate value

In addition, slag recovering efficiency of the inorganic components in coal was estimated above 90% at the 1 T/D gasifier in contrast to the 60% and 75%, which can be expected from the fact that slag forming in the gasifier occurs mainly on the inner surface of the hot gasifier wall and the surface area of wall at the smaller size reactor is bigger to the wall surfaces of bigger systems. The slag recovery efficiency at the 1 T/D was estimated after deducting ash amount captured after the gasifier system from the inlet ash amount because a certain volume of slag resides coated at the inner gasifier wall and not exits to the slag hopper.

The above results demonstrate that coal gasification performance can be realistically estimated even with the far smaller gasification system when the gasification reaction can be maintained at the high temperature and pressure.

Particulates contained in syngas are in a half melted state or in a char shape and contain about 35-65% unburned carbon. From the mass balance point of view, the amount of unburned carbon is normally less than 0.5% of the total coal that is gasified. To employ the syngas for the electricity generation or to use as a feedstock in manufacturing chemicals, syngas should be cleaned to the level that typical clean syngas should contain particulates in concentration of less than 10 mg/Nm³. The experimental results show that the particulate concentration before the filtering system which is located after the gasifier and the gas cooling pipes was in the range of 2,500-3,000 mg/Nm³. After the hot gas filtering system, the particulate concentration drops below 4-5 mg/Nm³ which is difficult to identify visually in the timble surface that is used for capturing the particulates.

In the gasification test with Roto Middle coal, particulate concentration at the filter inlet was measured as 2,883 mg/Nm³ average after 5 measurements, whereas the outlet particulate concentration was 4 mg/Nm³. From these results, particulate removal efficiency was 99.86%.

6. CONCLUSIONS

Construction of a CCT plant, especially IGCC plant of 300 MW scale, in Korea after 2012 appears to be realistic if similar Asian economic crisis in 1997 does not happen again. Accumulation of core IGCC technologies would be very essential then, especially considering the problems in design and operation at the demonstration IGCC plants till now. With limited domestic energy reserve and ever-increasing environmental regulation level on pollutants and CO₂, the gasification-based IGCC process seems like only the option when using coal for electricity generation in Korea.

Although many obstacles and uncertainties in economic and technical aspects are present, it appears imperative to utilize CCT in Korea because Korea imports 97% of energy and minimum

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28-32% of electricity should come from imported coal.

Indonesian coals of subbituminous rank were selected as one of the most suitable coals gasification for IGCC applications among the tested coals of bituminous and subbituminous ranks in the 3 ton/day-size pilot gasification plant. Produced syngas composition was 36-38% CO, 14-16% H₂ and around 5-8% CO₂ concentrations (dry basis) and particulate removal efficiency was above 99.5%.

The pilot-scale plant results demonstrate that coal gasification performance can be realistically estimated even with the far smaller scale system when the gasification reaction can be maintained at the high temperature and pressure. Therefore, the pilot scale dry-feeding coal gasifier can be utilized effectively as the versatile pre-operational equipment in examining the gasification behavior of the commercial-scale gasifier. Moreover, the pilot system might provide the ability for technology evaluation when IGCC plant is imported in the near future in Korea.

Since Korea expects that at least 30% of the electricity generation would come from coal during the early 21st century, development of environmentally acceptable technology such as IGCC is timely and an inevitable choice of future technology. Through the operation and development of the pilot plant, key technical barriers have been evaluated before the actual introduction of the commercial scale IGCC plants in Korea.

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- AIChE、KIChE、ACS会員