Process Performance of the SCGP at Buggenum IGCC

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Abstract

In 1994 Demkolec BV started-up the 250 MWe, fully integrated, IGCC facility with combined the Gasification and Gas Treating technologies from Shell (Shell Coal Gasification Process, Shell HCN/COS conversion technology and Shell Sulfinol-M Acid Gas Removal) with the Combined Cycle technology from Siemens (Siemens 94.2 gas turbine) and the Air Separation technology from Air Products.

Since the "humming" problems of the gasturbine, which plagued initial operations of the Demkolec IGCC have been resolved some three years ago, a review of the SCGP performance in the past three years seemed justified.

Since this review concentrates on gasification performance as function of coal properties and operating conditions and on the comparison of test results of the Demkolec facility with those of the SCGP demo/pilot plants, a short presentation on the basic principles of the SCGP and on the relevance of coal properties for SCGP will be included.

The performance of support systems as coal feeding, syngas scrubbing and desulphurization, and waste water treatment are reviewed briefly, since a reliable operation of these proved, in some cases, more challenging than the gasification as such.

The comparison between the three facilities, Harburg, Houston and Demkolec, showed a stepwise improvement of energy efficiency, due to design modifications, when going from the pilot to the demonstration and to the commercial scale.

The overall performance of the Demkolec facility, confirmed the high expectations: environmental friendliness, high efficiency (43 % LHV basis) and large coal flexibility.

Based on the actual operating results and experiences, ways to improve availability, especially in the initial years, and to reduce investment and operating costs for future units could be developed.

Introduction

Demkolec facility

In 1988 Demkolec BV started to evaluate the options (process line-up, plant capital and operating cost, etc.) for building a “demo” IGCC facility in the Netherlands. The “demo” aspect being: “Proving that IGCC is a technical and economical viable technology for electricity production in The Netherlands”([1], [2]). In 1989 the three main “building blocks” (Air Separation unit, Gasification Facilities and Combined Cycle - mainly Gasturbine -were selected) and in 1990 the investment decision was taken. In 1994 the 250 MWe fully integrated “demo” IGCC facility in Buggenum the Netherlands was started-up.

Figure 1 shows the integration concept of the Demkolec IGCC facility.

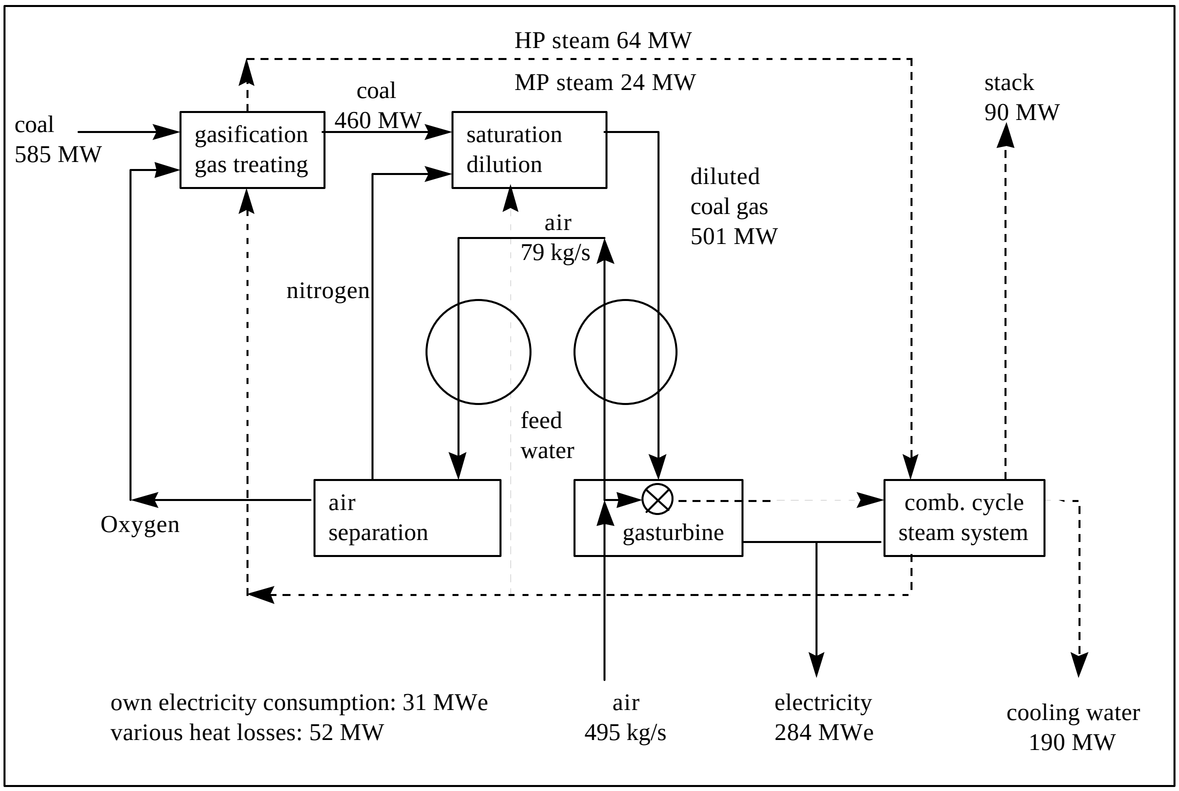

Figure 1: Integration concept Demkolec IGCC

Coal, 585 MWth, is supplied to the, coal milling and drying unit of the, Shell Coal Gasification Process (SCGP) where it is gasified with oxygen (95 % purity) and steam producing syngas, which is cooled in a syngas cooler (SGC) to some 250 degree C. In this process slightly superheated HP and MP steam (some 88 MW for export to the steam systems of the Combined Cycle), saturated LP steam, slag and fly ash are co-produced.

The oxygen is supplied from an Air Separation Unit (ASU; Air Products technology) which operates on bleed air, some 79 kg/s, from the gasturbine (GT).

The crude syngas is treated and leaves, after deduction of internal consumption, some 460 MWth of clean syngas for combustion in the Siemens 94.2 gasturbine.

As BFW and LP steam some 32 MW are imported from the Combined Cycle for SCGP and gastreating units.

This clean syngas is diluted with nitrogen, and saturated at some 110 - 130 degree C with “clean process water” prior to being introduced into the gasturbine where it is combusted with 417 kg/s of air. Gas- and steam-turbine combined produce hereby 284 MWe, of which 31 MWe is internally used, leaving a net production of 253 MWe. Heat losses from the system are: 190 MW with the cooling water of the condenser, 90 MW with the Heat Recovery Steam Generator (HRSG) stack-gas and some 52 MW distributed over various streams. The overall net efficiency being 43 %.

SCGP process

General

In the early 70’s Shell decided to start the development of a coal gasification process building upon the technology base of pressurised oil gasification. Against the background of the potential applications (power production, chemicals, town gas, synthetic natural gas and transportation fuels) and the environmental requirements, the basic concepts for this process were selected to be:

- Slagging, Membrane wall gasifier (high temperatures allowable because of insulation/protection of wall by solid slag layer; inert solid waste),
- Pressurised (compact equipment),
- Entrained flow (compact gasifier),
- Oxygen blown (compact equipment; high gasification efficiencies),
- Multiple, opposed burners (high carbon conversion due to good mixing of coal and blast; large turndown; “easy” scale-up),
- Dry feed of pulverised coal (high gasification efficiency; size/moisture content/caking properties of coal no issue).

These concepts were developed via a 6 t/d pilot plant at Shell’s Amsterdam (The Netherlands) laboratories, a 150 t/d test unit, KVA, at Shell’s Harburg (Germany) refinery and a “250 t/d” demonstration plant, SCGP-1, at Shell Oil’s Deer Park Manufacturing complex (Houston). This latter facility was designed to validate “lessons learned” from the Harburg facility for a number of coals with a large variation in properties. It was designed to gasify from 250 t/d of high sulphur bituminous coals up to 400 t/d of high moisture, high ash lignite’s. Its operating results, which have been reported earlier ([3]) confirmed during some 15,000 operating hours, including a 1500 hour continuous run, the expectations of reliability, coal flexibility and environmental performance of the SCGP and provided information for fine tuning of SCGP design rules, to be applied in the design of the Demkolec SCGP facility (including gas- and waste water-treating plants).

Demkolec facility

Figure 2 shows the flow scheme for the Demkolec gasification, gas- and water-treating facilities, which is a typical SCGP-scheme.

Raw coal, plus recycled sludge, is fed to a pulveriser, a conventional roller mill, which grinds the coal to the size suitable for efficient gasification. As the coal is ground it is simultaneously dried utilising a heated inert recycle gas stream that carries the evaporated water from the system as it sweeps the pulverised coal through an internal, rotating, classifier to collection in a baghouse. The majority of the gas is recycled via the inert gas generator, where it is reheated by in-line combustion of treated syngas, to the coal mill. Excess gas is vented on pressure control.

Milled and dried coal from the milling and drying system is collected in a silo from where it is pneumatically transported to the coal pressurisation and feeding system (two lockhopper systems). From each system coal is supplied to two opposite burners, which feed the gasifier gasification chamber, in which the gasification reaction takes place, with pulverised coal, oxygen and, in most cases, some steam.

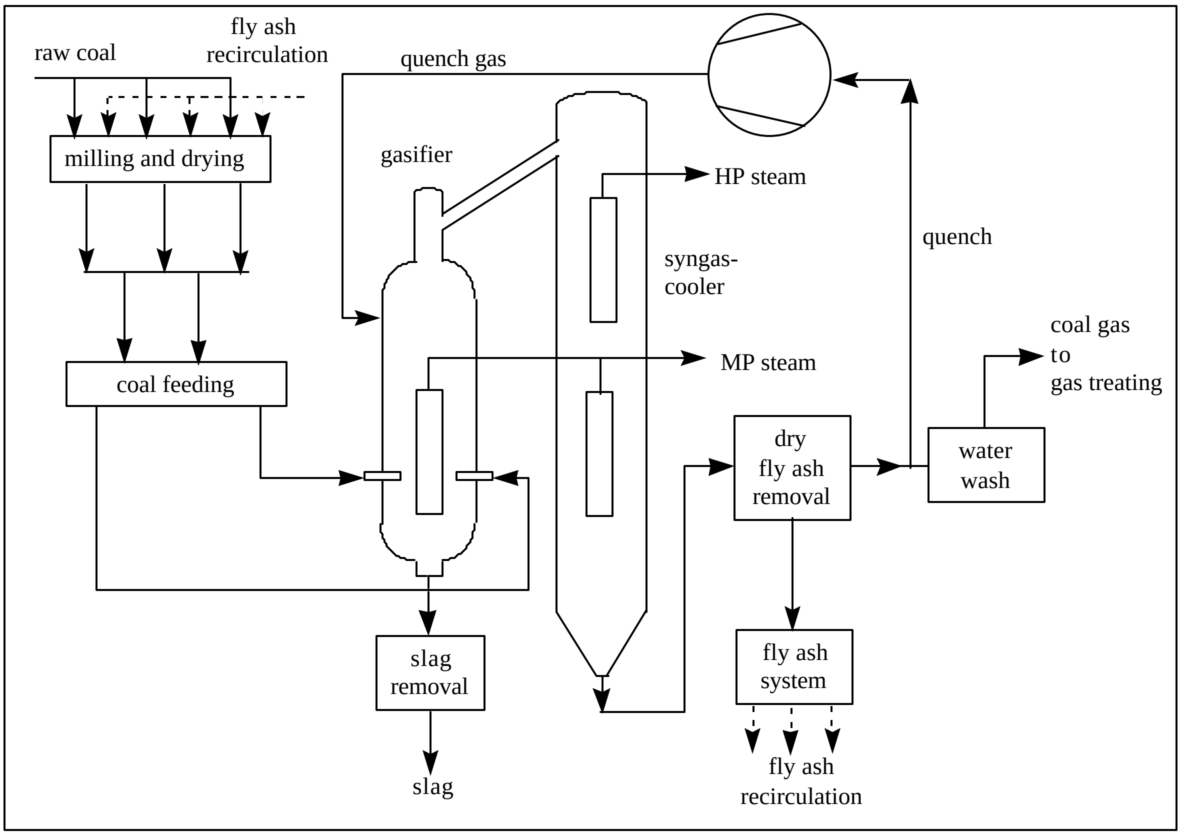

Figure 2: SCGP systems of Demkolec ICGCC

The gasifier consists of a pressure vessel with a gasification chamber inside and operates at some 26 barg. The inner gasifier wall temperature is controlled by circulating water through the membrane wall to generate MP (some 45 barg) steam. The membrane wall encloses the gasification zone from which two outlets are provided.

The outlet at the bottom of the gasifier is used for removal of slag. The outlet at the top allows hot gas with entrained fly slag to enter the quench zone, where the hot gas is quenched with cold (some 250 degree C) dust-free recycled gas to avoid fouling problems by molten or sticky fly slag particles entrained in the raw syngas.

Most of the mineral content of the coal leaves the gasification zone in the form of molten slag. The high gasification temperature ensures that the molten slag flows freely down the membrane wall via the slagtap, into a water-filled compartment at the bottom of the gasifier. As the molten slag contacts the water bath, it solidifies into dense, glassy granulates, which are removed from the system via a lockhopper system in which they are also washed. After dewatering they are transported to off-site to be used in road construction.

The high gasification temperature (1400 - 1700 degree C) ensures that high carbon conversions are obtained and that no hydrocarbons other than traces of methane are present in the raw syngas. The insulation provided by the slag layer in the gasifier minimises heat losses such that cold gas efficiencies are high and CO_2 levels in the syngas low. Recycling of fly slag can enhance efficiencies for low ash coals. Flux will be added to high ash melting point coals to promote the appropriate slag flow from the gasifier at the preferred operating temperature.

The fly slag is removed from the syngas in two stages, the first one a cyclone and the second one a high pressure, high temperature ceramic candle filter. The ash is discharged via lockhopper systems and can, if so desired, be recycled via the coal milling and drying system.

The “solids free” (< 5 mg/Nm3) syngas is partially recycled for quenching; the main stream is cleaned via water scrubbing (deep halide and trace solid removal) and thereafter treated in a catalytic COS/HCN conversion unit, cooled (ammonia removal) and sent to the Acid Gas Removal unit.

The Acid Gas Removal unit uses Sulfinol-M as selective solvent to reduce sulphur components in syngas to < 20 mg/Nm3 with minimum co-absorption of CO_2.

Water discharged from the slag removal, wet scrubbing, HCN/COS conversion and acid gas removal units is stripped and clarified (where required). Part of it is directly reused, the remainder is further treated, before being reused, in an Effluent Water Treatment facility, with as final step evaporation/condensation, producing condensate and salt.

The acid gas from the Acid Gas Removal system and the strippers is fed to a Sulphur Recovery Unit, consisting of an, oxygen-blown, Claus and a Shell Claus Off-gas Treater, where > 99 % of the sulphur is recovered as liquid sulphur. The off-gases are incinerated.

Coal properties relevant for SCGP; design and operation

Relevance of coal properties

Coal “reactivity”

SCGP-1 operations already showed ([3],[4]) that the composition/properties of the inorganic components of the coal are, for most coals, more relevant than the organic components, with the exception of sulphur, since the SCGP allows high gasification temperatures and thereby ensures high conversions for coals of all ages or ranks.

Ash content

The ash content of a coal impacts the performance of the slag tap, the slag handling systems, but also to a certain extent the gasification performance, since molten ash in the form of slag on the wall of the gasifier forms part of the “insulation” which prevents excessive heat loss during the gasification reaction. For low ash (< 8 % wt) coals fly ash recycle is therefore in most cases recommended; at the high ash content side, operating costs will slightly increase from some 15 % ash in coal onwards.

Ash melting point/slag viscosity

SCGP is a slagging process, it is obvious that this requires a “specific slag behaviour”. Models have been developed ([5]) and validated to predict this behaviour for a large variety of coal compositions and are used as design/operation guidance tool. As a first approach the phase diagram ([6]) SiO2-Al2O3-FeO-CaO can be used for a large number of coal ashes. This also implies that for a large number of coals, “fluxing” (in most cases CaCO3 addition), is recommended to strike a good balance between slag-viscosity and gasification temperature.

Ash fouling characteristics

Most existing fouling indices are based on experiences with pulverised coal boilers. However, it has been established that coals that have a reputation as “foulers” can be a challenge in gasification, too. Elements like Cl, F, Pb, K, Na, and P are elements to be taken into account since they are vaporised during gasification ([7]) and can form “condensates” in the syngas cooling operating range (900 - 230, more specifically 900 - 600, degree C; see figure 3), i.e., the can form the “glue” between the ash particles causing fouling. Actual operating experiences have shown that more than average fouling can be predicted and that due to the syngas cooler design the build-up of a non-stabilising or non-reversible fouling can be prevented by taking the appropriate countermeasures (design and operation). If it occurs unexpected (changes in coal parameters) the required quench gas flow and the resulting syngas outlet temperature will be somewhat higher (but well within the design margin).

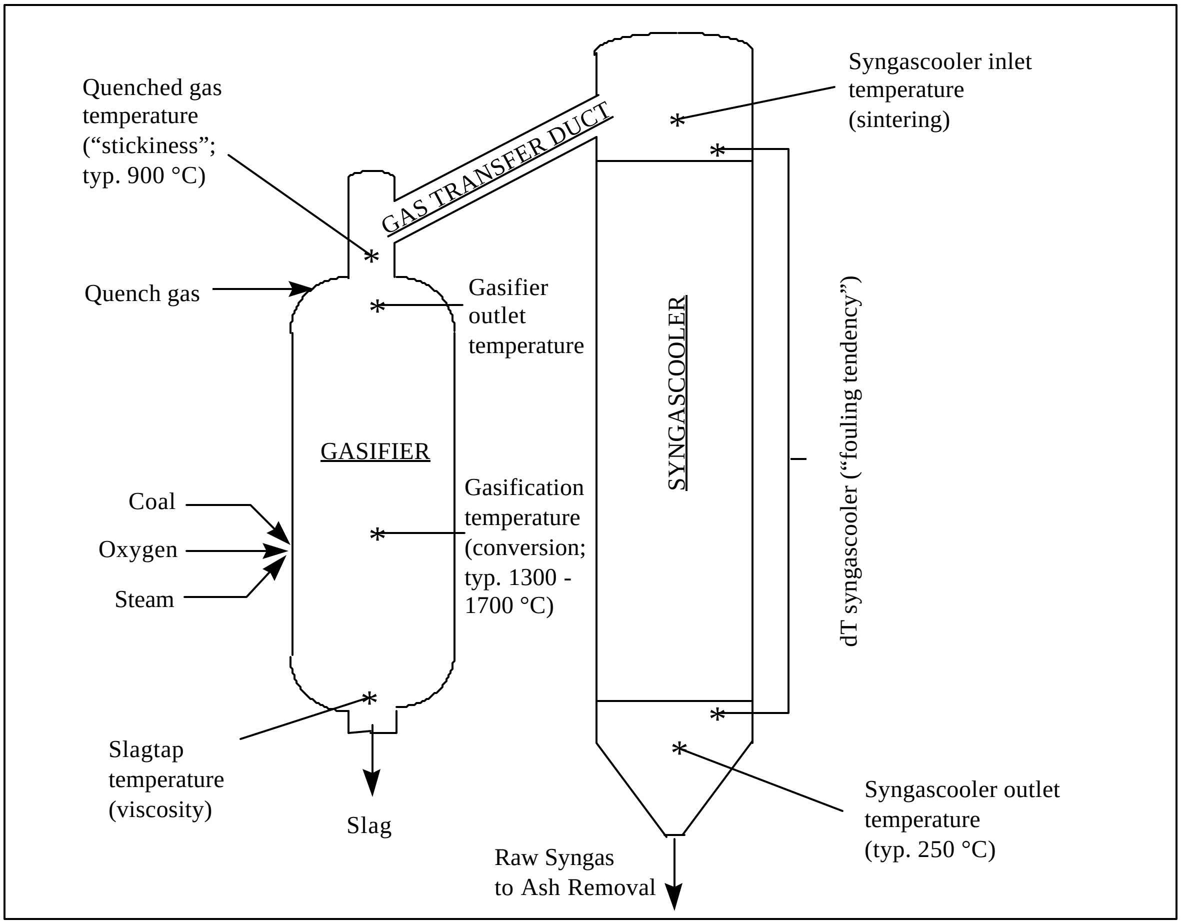

Figure 3: Relevant temperatures in gasification and syngas cooling

Halides

Chlorine and fluorine levels affect corrosion rates, mainly in downstream equipment. They can play a role in fouling and affect to a large extent the cost of waste water treating facilities

Sulphur

Sulphur levels effect corrosion rates, and thereby equipment costs, and have a major impact on the cost of sulphur removal and recovery facilities.

Trace elements

Trace elements can effect fouling; they will affect the complexity and cost of waste water treatment facilities.

Consequences for design and operation

Above mentioned effects don’t present any special challenge for the design if the design has to be based on a specific coal, since models have been developed to take the various aspects into account. It might become more of a challenge if the facility, like Demkolec, has to be designed for a large range of coals with varying properties. In this case optimisation studies, in consultation with client, are required. Large variations in coal sulphur content have, in general, the largest impact, followed by variations in coal moisture content and coal ash content.

Like the designer, the operator has a challenge too, if coals with large variations in properties (sometimes even outside the specified range) have too be processed. Switching of coals is therefore normally done “on the fly” since this allows plant operations to adjust operating conditions based, not only on predictions, but also on plant performance indicators, like:

. gasifier outlet temperature,

. syngas cooler inlet temperature,

. syngas cooler outlet temperature,

. syngas composition,

. heat loss (steam production) via membrane wall, and

. slag and fly slag production rates and “appearance”.

Process performance of SCGP and related systems

Coals tested at Harburg, SCGP-1 and Demkolec

Harburg

At Harburg, four bituminous coals were extensively tested: Griesborn Duhamel (Germany), Goetelborn (Germany), West Virginia(USA) and Illinois # 5 (USA). The latter being the design coal for SCGP-1.

SCGP-1

At SCGP-1 a large number of coals were gasified, of which the most relevant ones are given in table 1, while table 3 indicates the range of coal properties explored.

Demkolec

At Demkolec again a large number of coals were gasified; the majority of them as blend, however. The background for this being that the coals being gasified at Demkolec are not specifically selected for gasification, but are blended for lowest possible costs and general use in the Dutch power stations, i.e., for combustion in pulverised ("dry bottom") boilers, and have therefore, automatically, not the preferred ash compositions for gasification; i.e. fluxing is virtually always required. Table 2 gives the most relevant ones, while table 3 indicates the range of the coal or blend properties encountered. It should be realised, however, that sometimes the changes within a specific coal are about as large as between coals; as is shown in table 3 (example: Drayton), too.

Gasification performance in SCGP-1 and Demkolec

SCGP-1

Table 4 summarises the most relevant gasification data from the SCGP-1 facility for some of the coals gasified From these data the following main conclusions have been drawn:

- A large variety of coals can be gasified, all with carbon conversions of 99 % or more,
- Bituminous coals will require, in most cases, steam injection and oxygen/MAF (moisture and ash free) coal ratio's from 0.95 - 1.05, producing syngas with 1 - 3 % CO2,
- Subbituminous coals and lignite's normally don't require steam injection and can be operated with oxygen/MAF coal ratio's between 0.8 and 0.85, producing syngas with some 3 - 5 % CO2,
- Cold gas efficiency are strongly coal dependent; range: 75 - 83 %,
- Total energy (syngas + steam) recovered from coal is coal dependent; range: 93 - 97 % (LHV)

Demkolec

Table 5 summarises the most relevant gasification data from the Demkolec unit. Table 6 the coals used in the various blends From these data and taking into account that the same name doesn't represents the same coal, it can be concluded that they, in general, fit within the SCGP-1 data.

Comparison of Harburg, SCGP-1 and Demkolec performance

Table 7 compares gasification data from all SCGP facilities by comparing test results on Illinois # 5 coal for Harburg vs. SCGP-1 and for Drayton coal for SCGP-1 vs. Demkolec, realising that although the coals have the same name their properties weren't fully identical (as is shown in table 3 for coals gasified by Demkolec).

From this table and taking into account the differences between the various facilities, following conclusions can be drawn:

- Data are well in-line with each other,
- Larger plants improve Cold-Gas Efficiency by having a lower "heat loss" (MP steam production) via the gasifier membrane wall,
- Steam can efficiently be used to replace part of the oxygen (with as result a.o. a larger H2-content in the syngas) in larger facilities,
- Improved syngas cooler design (SCGP-1/Demkolec vs. Harburg) raised total energy recovery by some 6 - 7 %.

Process performance of the other, related, systems

Coal Milling and Drying

The Coal Milling and Drying unit produced, in general, pulverised coal at specification, within the guaranteed power and fuel consumption, allowable O2-content of circulating gas and dust content in vent gas. However, once in awhile some problems are encountered with maintaining the product specification, if: or, a blend contains coals with large differences in hardgrove index between the coals, or, at very frequent changes in coals/blends.

Coal Pressurisation and Feeding

The coal pressurisation and feeding unit provided the desired coal feed with the design nitrogen consumption and with a lower than allowed dust content in the vent gas. The capacity of the system proved to be exactly its design capacity. If capacity problems are encountered they are, normally, related with off-spec pulverised coal (particle size or moisture content).

Slag removal

Two process related problems were encountered

- Excessive build-up of slagfines; was resolved by adjusting (fine tuning of) the operating conditions and a modification of the fines recovery and recycle system (allowing larger amounts to be processed),
- Slag outlet valves blockage by slaglumps. The actual Demkolec operating mode (frequent load and "coal" changes; which is related with its concept of following the grid -no base load station-, and gasifying the coals as being imported for all power stations) seem to result in insufficient time to adjust operating conditions sufficiently to avoid this, incidental, slaglump formation. For future units having to operate on a this large variety of coals, reintroduction of a slag-crusher (as installed in the Harburg facility) is recommended.

Ash removal

Ash content in syngas downstream high pressure, high temperature filter (typical 1 - 2 mg/Nm3) was well below specification (< 20 mg/Nm3). Ash discharge systems proved to have spare capacity.

Wet Scrubbing

Halide and dust removal efficiencies were met.

Slurry and Water Stripping

Stripping efficiencies of acid gases and ammonia were met.

HCN/COS conversion, Acid Gas Removal and Sulphur Recovery

HCN/COS conversions were above target and no deterioration of catalyst activity has been noticed, so far. Acid gas removal targets (< 20 ppmv “S” in syngas) were met, as were minimum sulphur recovery efficiencies (> 98.5 %).

Solvent losses were somewhat higher than anticipated, due to solvent losses during FeS removal (filtration) and solvent degradation (Heat Stable Salts formation, etc.) rates, requiring more frequent (on-line) solvent reclaiming. Due to a planned, minor, modification this latter effect is expected to be reduced in the future.

Effluent Water Treatment

Despite the fact that the zero-discharge concept has been fully proven, the overall process performance is still not optimal, partially due to a borderline capacity of the various units. Some modifications had to be made and further modifications (addition of treatment steps) are still being considered to achieve the final target of producing a “saleable” salt as by-product.

Performance of equipment

Coal Milling and Drying

The Coal Milling and Drying unit is a “standard stand-alone” coal milling and drying facility designed and constructed by Loesche Gmbh. Problems encountered were related with some specific features and were to the largest extent corrected in the initial operating period. Moreover, a spare unit is installed to allow maintenance activities to be carried out while the IGCC is in operation.

Coal pressurisation and feeding

Two problems were encountered. The first one: “Damage to one of the bagfilters due to a faulty interlock system” was encountered during initial testing and easily resolved. The second one: “Low life time of nitrogen injection device” was a more basic one and required a.o. a redesign of this device.

Gasification and syngas cooling

Within the main gasification hardware (gasifier/syngas cooler) some problems were encountered, with pressure equalisation over the membrane wall in the duct, This problem has been adequately solved (modifications during scheduled shutdowns) without any effect on the performance.

The coal burners have in the mean time passed their expected life time (> 8000 hours); a doubling of this lifetime expectancy (> 16000 hours) is realistic.

Slag systems

Two problems were experienced in this part of the unit, being:

- Failure of a refractory lined heat skirt below the slagtap (note: will be redesigned for future units to allow cooling by a membrane wall),
- Higher than expected erosion at a few specific points. This problem is tackled by slightly adjusted operating conditions and, at most critical points, installation of more erosion resistant materials, which proved very effective.

Fly ash systems

Initially one major problem was experienced in this system, being: "Failure of the ceramic candles in the high pressure, high temperature filter". Once the cause was traced, this was adequately resolved by a minor modification. Since then the candles have passed their, originally, expected life time (> 8000 hours) and, at least, a doubling of this lifetime expectancy (> 16000 hours) is realistic.

Wet Scrubbing and slurry- and water-stripping units

The wet scrubbing and sour slurry and sour water stripping systems encountered some corrosion problems, which could be completely explained by failures to detect/recognise, in time, due to instrument (pH probe) failures, that pH's of circulation loops were outside the allowed limits.

HCN/COS conversion, acid gas removal and sulphur recovery

Nothing to report.

Effluent water treatment

Nothing to report

Conclusions

Based on Demkolec (and SCGP-1) operations following can be concluded:

- Technical feasible of IGCC using SCGP is proven,
- The SCGP has a large flexibility with respect to coal and coal ash properties,
- Scale-up from SCGP-1 to Demkolec size (250 - 2000 t/d of coal) has been successful; scale-up to single units of some 5000 t/d is feasible,
- Models developed for prediction of coal and coal ash behaviour and SCGP scale-up are accurate,
- Further improvements in availability (mainly slag systems) and costs (mainly coal feeding, gasification and ash removal systems) are possible.

Table 1: Coals gasified in SCGP-1

Name	Type	Origin
Illinois # 5 (*)	Bituminous	USA; Illinois
Maple Creek	Bituminous	USA; Pennsylvania
Drayton	Bituminous	Australia
Buckskin	Subbituminous	USA; Powder River
Blacksville # 2	Bituminous	USA; West Virginia
Pyro # 9	Bituminous	USA; Western Kentucky
SUFco	Bituminous	USA; Utah-Uinta
Texas Lignite	Lignite	USA; Texas-Wilcox
Pike County (washed)	Bituminous	USA; Eastern Kentucky
Pike County (ROM)	Bituminous	USA; Eastern Kentucky
Dotiki	Bituminous	USA; Western Kentucky
Newlands	Bituminous	Australia
El Cerrejon	Bituminous	Colombia
Skyline	Bituminous	USA; Eastern Kentucky
Robinson Creek	Bituminous	USA; Eastern Kentucky
R & F	Bituminous	USA; Ohio
Pocahantas # 3	Bituminous	USA; Virginia
Petroleum Coke	Coke	Refinery

(*) Design and start-up coal

Table 2: Some of the coals, all bituminous, gasified in Demkolec

(between brackets in blends, only)

Origin	**Coals**
Australia	Drayton (*), (Yarabbe), (Noble Queensland)
Columbia	El Cerrejon (**), (Prodeco Glencor), (Drummond)
Indonesia	(Kaltim Prima), (Enviro)
Poland	(Poland 55)
South Africa	Douglas Premium # 2, (Enerco), (Economy), (Kroonfontein), (Middelburg), (Anker), (Johannesburg-O)
USA	(Evergreen), (Baileys)

(*) Design coal

(**) Start-up coal

Table 3: Range of key properties of SCGP-1/Demkolec feedstocks

Property	SCGP-1 range (*)	Demkolec range (**)	
Moisture (AR), %	4.5 - 30.7	6.2 - 18.3	9.1 - 12.6
Ash (MF), %	5.7 - 35.0 (0.5)	9.1-16.8	9.7 - 12.7
Oxygen (MF), %	5.3 - 16.3 (0.1)	3.8 - 12.4	6.0 - 9.8
Sulphur (MF), %	0.3 - 5.2	0.3 - 0.9	0.4 - 0.9
Chlorine (MF), %	0.01 - 0.4	0.01 - 0.1	0.01 - 0.04
Na2O (% ash)	0.1 - 3.1	0.1 -1.4	0.1 - 1.4
K2O (% ash)	0.1 - 3.3	0.3 - 2.3	0.3 - 1.8
CaO (% ash)	1.2 -23.7 (0.8)	0.7 - 7.9	1.4 - 7.5
Fe2O3 (% ash)	5.9 - 27.8	3.0 - 16.7	5.9 - 16.7
SiO2 (% ash)	20.9 - 58.9 (6.8)	47.9 - 67.7	47.3 - 67.7
Al2O3 (% ash)	9.5 - 32.6 (1.9)	17.2 - 32.1	21.1 - 30.0
MJ/kg	22.8 - 33.1 (35.6) (HHV-MF)	22.2 - 26.8 (LHV-AR)	24.9-26.5 (LHV-AR)

(*) Values between brackets Petroleum Coke

(**) First column: between coals; second column: within a coal

Table 4: SCGP-1 test results

Coal	Conditions			Results	
	O2/MAF coal kg/kg	Steam/O2 kg/kg	CO2 %v	Carbon conv. %	Cold gas eff. %
Illinois # 5 (*) (**)	0.92	0	1.6	98.8	76.1
Maple Creek (**)	1.05	0.11	4.0	98.9	75.6
Drayton	0.98	0	1.4	99.4	77.5
Blacksville #2	0.97	0.16	2.6	99.9	80.0
Pyro # 9	0.98	0.16	3.8	99.7	77.6
Pike County	0.96	0.16	2.6	99.5	80.0
SUFco	0.87	0.11	2.9	99.5	81.0
R & F	0.92	0.05	1.2	99.5	79.6
El Cerrejon	0.97	0.08	2.0	99.9	83.4
Skyline	0.97	0.08	1.0	99.8	82.4
Buckskin	0.83	0	4.0	99.7	78.1
Alcoa lignite	0.81	0	4.0	99.5	81.0
Texas Lignite	0.82	0	4.0	99.7	80.3
Petr. Coke	1.03	0.23	2.2	99.1	78.9

(*) Design coal

(**) Prior to plant optimisation tests

Table 5: Demkolec test results

Coal	Conditions			Results	
	O2/MAF coal kg/kg	Steam/O2 kg/kg	CO2 %v	Carbon conv. %	Cold gas eff. %
El Cerrejon (*) (***)	1.03	0.10	4.0	> 99.5 (*****)	76.4
Drayton (**) (***)	1.06	0.06	2.2	> 99.5	77.5
El Cerrejon (*) (****)	1.00	0.05	1.9	>99.5	78.6
Drayton (**) (****)	1.03	0.09	1.5	> 99.5	78.6
DGP-2	0.93	0.07	1.8	> 99.5	78.1
Blend 1	1.06	0.09	3.8	> 99.5	76.9
Blend 2	1.01	0.05	2.1	> 99.5	78.1
Blend 3	1.00	0.05	2.0	> 99.5	78.3
Blend 4	0.98	0.05	0.9	> 99.5	79.9
Blend 5	1.00	0.08	1.6	> 99.5	79.8
Blend 6	0.88	0.07	2.0	> 99.5	78.9
Blend 7	0.87	0.08	2.1	> 99.5	78.8
Blend 8	0.84	0.10	2.2	> 99.5	78.9
Blend 9	0.94	0.10	2.2	> 99.5	78.3
Blend 10	0.87	0.08	2.6	> 99.5	77.8
Blend 11	0.88	0.10	1.9	> 99.5	80.5
Blend 12	0.86	0.08	2.4	> 99.5	79.4

(*) Start-up coal

(**) Design coal

(***) Prior to optimisation studies

(****) After optimisation studies

(*****) Not actually measured anymore, since: fly ash: 0.1 - 2 % C; slag: < 1 % C;

slag fines: recycled

Table 6 Composition of Demkolec coal blends

Blend #	Coals	
	Name	**%**
1	Douglas Premium 2/El Cerrejon	25/75
2	Drayton/El Cerrejon	25/75
3	Enerco/El Cerrejon	50/50
4	Enerco/Koornfontein	50/50
5	Enerco/Koornfontein	25/75
6	Enerco/Middelburg	50/50
7	Enerco/Douglas Premium 2	50/50
8	Yarabbe/Anker/Middelburg/Enerco	12/41/42/5
9	Enviro/Anker/Noble Queensland	11/39/50
10	Anker/Yarabbe/Kaltim Prima	36/33/31
11	Johannesburg-O/Enviro/Noble Queensland/Anker/Baileys	29/14/25/16/16
12	Noble Queensland/Johannesburg-O Anker/Kaltim Prima/Enviro	31/23/21/13/12

Table 7: Comparison of Harburg, SCGP-1 and Demkolec gasification results

	Harburg		SCGP-1		Demkolec
Coal type	**Goetelborn**	**Illinois # 5**	**Illinois # 5**	**Drayton**	**Drayton**
Coal data (*)					
Moisture, %w	0.6	2.2	2.1	1.5	2.0
Ash, % w	9.1	14.2	10.6	12.3	12.2
LHV, MJ/kg	28.4	26.4	27.4	27.8	27.7
Gasification data					
Pressure, barg	25	20	24	24	27
Coal, t/h	4.4	4.1	7.2	6.3	78.7
O2/coal, t/t	0.85	0.84	0.84	0.93	0.88
Steam/O2, t/t	0.15	0	0	0	0.08
CGE, % LHV	77.3	75.5	77.2	78.0	78.6
Steam , %LHV	10.6	12.2	19.0	18.8	18.2
C conv., %	> 98.5 (***)	> 99 (***)	> 98.5 (***)	> 99.5 (****)	> 98 (***) > 99.5 (****)
Gas composition (% v, dry)					
CO	62.8	62.7	64.1	65.3	63.4
H2	27.6	25.5	26.6	26.2	28.4
CO2	3.3	2.2	1.6	1.6	1.5
N2	6.1	8.8	6.5	6.5	6.2
others	0.2	0.8	1.2	0.4	0.5
Slag. Eff., % (**)	50	50	60	60	75

(*) After coal milling and drying

(**) Approximately

(***) Single pass

(****) After fines recycle

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