Selected Papers

A series of papers, articles and speeches prepared by Shell staff

The Shell Coal Gasification Process

by Maarten van der Burgt and Jaap van Klinken

Summary

The Shell Coal Gasification Process (SCGP) is a clean and efficient process for converting coal into synthesis gas. Synthesis gas is a versatile mixture of carbon monoxide and hydrogen that can be converted into many valuable products: electricity, synthetic natural gas, chemicals and liquid transportation fuels among them. SCGP is competitive for all applications because of its simple operation, its dry feed system and its generation of superheated steam in the syngas cooler which give excellent thermal efficiency.

NOVEMBER 1986

Fourth Advanced Coal Gasification Symposium, Su Zhou, China

THE SHELL COAL GASIFICATION PROCESS

Maarten van der Burgt and Jaap van Klinken

Maarten van der Burgt and Jaap van Klinken work in the Synfuels Development and Commercialisation Department of Shell Internationale Petroleum Maatschappij, The Hague, the Netherlands. Van Klinken is the head of the Department while van der Burgt is the group leader responsible for distillate synthesis and biomass upgrading. Both were previously at the Shell Amsterdam laboratory.

Published by Group Public Affairs

For further copies, telephone PA registry (Shell Centre 4918), or write to Shell International Petroleum Company Ltd (PAC/221), London, SE1 7NA

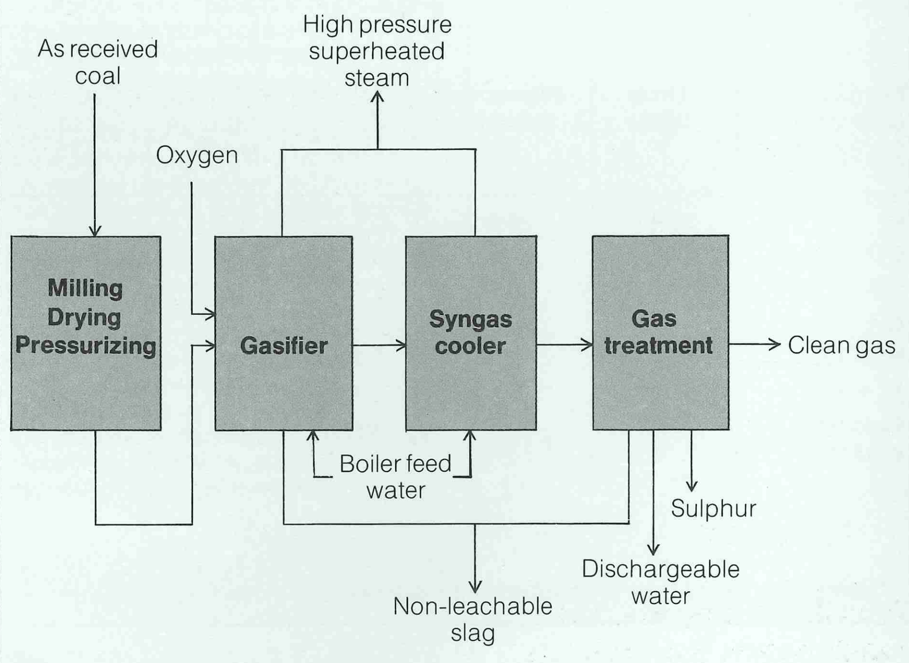
Background

SCGP has been under development since 1972. A 6 t/d experimental unit, which has run for over 12,000 hours, was started up in 1976 in the Shell laboratory in Amsterdam and this was followed by a 150 t/d pilot plant near Hamburg, which operated from 1978 to 1983 providing 6100 hours' experience on coal. Currently, a demonstration unit (SCGP-1) one-fifth the size of a commercial plant, is under construction near Houston, in the United States.

SCGP-1 differs substantially from the previous SCGP experimental and pilot units, as a result of continuing Shell research at Amsterdam and at Houston. These differences increase overall process efficiency and reliability, and reduce product gas cost.

Figure 1

Shell coal gasification process



SCGP process description

Dried, pulverised coal is fed pneumatically in a dense, fluidised phase to diametrically opposed burners in the gasifier. Oxygen needed for gasification and steam (if required) are also routed to the burners. The addition of coal, oxygen and, perhaps, steam controls the gasifier operating temperature (Figure 1).

The gasifier is built for an optimum pressure of 30-40 bar and a temperature of 1400-1700°C. The operating temperature is chosen so that the ash in the coal melts and drops to the bottom to be removed as slag. The slag, which is an inert, glass-like material that is essentially non-leachable, is quenched with water and the mixture depressurised to ambient conditions. The gasifier walls are protected from over-heating by a tube-wall that draws in heat to generate high-pressure steam.

The synthesis gas formed in the gasifier is cooled by a recycling process: some of the gas leaving the cooler is compressed and recycled to bring down the temperature of the product entering the cooler from the gasifier. This cooling also generates high quality superheated steam. Ash in the synthesis gas is solidified so that it will not stick to the walls of the cooler and is then removed. The final product gas can be readily treated to remove nitrogen (ammonia), sulphur compounds and hydrogen cyanide.

Complete conversion of any coal

SCGP can use any coal as feedstock and carbon conversions of over 98% are achieved in a single pass. The process is relatively insensitive to coal properties such as size (run of mine can be used), caking tendency, moisture, sulphur, oxygen and ash. SCGP can gasify efficiently low-rank coals such as lignites.

High unit capacity

SCGP has been developed with careful thought towards potential economies of scale. For further commercial plants it will be possible to design single trains which can run 2500 t/d of coal or more and still be small enough to be shop-fabricated and transported by rail or barge.

High thermal efficiency

Approximately 80-83% of the energy present in hard coals is recovered as synthesis gas and another 16-18% as superheated steam. The latter may be used to drive the air compressors in the oxygen plant, to generate electricity, or for other purposes.

Clean product gas

SCGP product gas is essentially all hydrogen and carbon monoxide, except for a small amount of carbon dioxide, nitrogen and argon (Figure 2). Only minute amounts of methane are present. Higher hydrocarbons, such as naphtha, phenols and tars, do not survive the gasifier.

Environmental acceptability

Sulphur compounds and ammonia are easily removed from the raw gas to yield a product than can be pipelined if desired.

Figure 2

SCGP performance
Effect of different feedstocks

Dry gas composition (% volume)	Texas lignite %	Rheinbraun brown coal %	Illinois No. 6 %	W. Virginia (Pittsburgh seam) %	Fluid coke (tar sands) %
H_2	32·4	28·6	30·5	31·7	22·3
CO	61·8	64·5	65·1	64·3	70·9
CO_2	4·6	6·1	2·0	2·0	3·7
CH_4	–	–	–	–	–
H_2S-COS	0·3	0·1	1·5	1·1	2·2
N_2 + A	0·9	0·7	0·9	1·0	0·9
Cold gas efficiency*	81	78	81	81	80

*Energy recovered from the coal in the synthesis gas

Most of the ash in the coal is transformed into a vitreous non-leachable solid which is suitable as a construction material. Process water can be readily cleaned and discharged.

Demonstration plant

The SCGP-1 demonstration plant in Houston will confirm equipment life and the scale-up information necessary for commercial design. Environmental design data for potential commercial feedstocks will also be acquired. SCGP-1 includes equipment for demonstrating several process optimisations. These will increase stream factor and system reliability, and reduce capital and operating costs.

A final objective for SCGP-1 is to move further along the experience curve, in part by developing an experienced operating team and extensive operating know-how, which will be readily transferable to the first commercial plant.

At approximately one-fifth the anticipated initial commercial module size, SCGP-1 is the most efficient route to commercialisation of the process. It is much less costly to construct and operate than a full-scale unit and provides the opportunity to test process optimisations more readily. The maximum scale-up factor of five for any given piece of equipment is well within Shell capabilities; the lower limit on size was actually set by a requirement to demonstrate equipment and configurations that would be employed commercially. Many of the components will require little or no scaling.

The unit will include coal receiving and preparation facilities, a high-pressure gasifier with high-temperature energy recovery, solids removal, and gas and water treating to provide both clean medium- BTU gas for power generation and high-value steam. The unit is scheduled for start-up in the first half of 1987.

SCGP-1 is designed to gasify feeds from lignites to bituminous coals. In principle, other feeds, such as petroleum coke, could also be gasified. Feeds will normally be received by train or truck and gasified at rates of about 250 t/d (as-received Illinois high sulphur coal) to 400 t/d (as-received lignite). The unit is capable of handling feedstocks with up to 35% moisture, 30% ash and 4% sulphur at design gas production rates.

Treated product gas will contain approximately 99% hydrogen and carbon monoxide (nitrogen-free basis), less than 160 ppm sulphur compounds, and other minor trace components. Actual nitrogen content in the product gas will depend on whether nitrogen or another gas such as recycled product gas or carbon monoxide is used as coal feed transport gas.

The Shell Deer Park Manufacturing Complex was chosen as the SCGP-1 location primarily because it can make use of the product gas. Also, some of the utility requirements can be met by existing facilities.

Oxygen and nitrogen will be purchased. Slag and fly slag produced will be used for road building and other applications, while acid gas will be sent to the Deer Park Complex sulphur plant. Stripped effluent and storm water will be sent to the Complex effluent treating system.

Slip stream units

The SCGP-1 acid gas removal system is designed to meet very strict environmental regulations. A gas treating slip stream unit will be installed and operated as part of the overall programme. Effluent water slip stream units will also be included. Properly designed slip stream units operating on SCGP-1 product streams are cost-effective methods of testing options and acquiring data necessary to design commercial plants with varying environmental constraints and product gas uses.

Participants

Combustion Engineering's subsidiary Lummus Crest and the Electric Power Research Institute (EPRI) are jointly participating with Shell companies in the design, construction and operation of SCGP-1. Lummus Crest will provide engineering design and procurement services. EPRI will provide an electric utility industry perspective. Shell Internationale Petroleum, Shell Internationale Research, Deutsche Shell, Shell Oil and Shell Development provided the process design and much of the engineering design information, and will operate and manage the unit and experimental programme.

Process applications

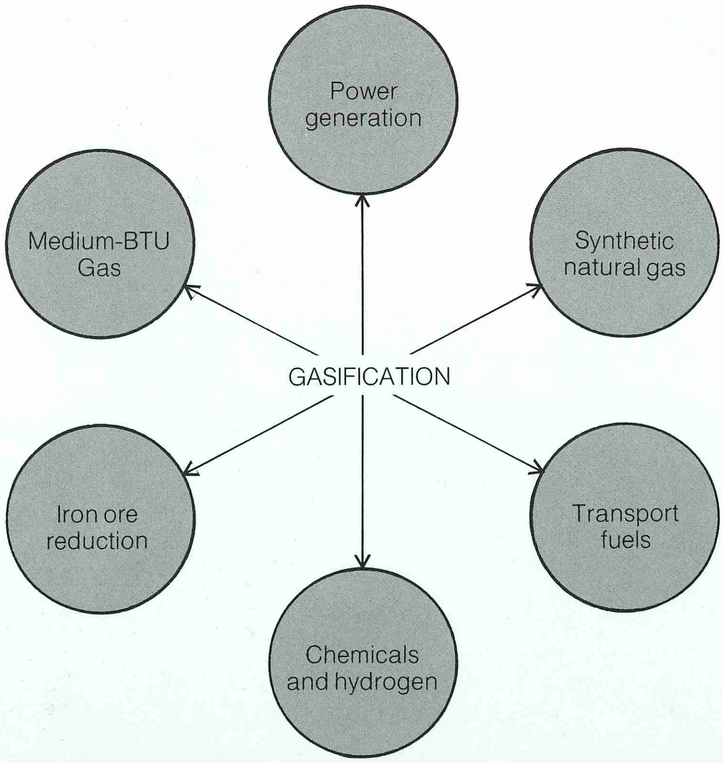
There are many applications for the gas produced in SCGP (Figure 3). The reason is that the gas is very pure and can be used to make liquid transportation fuels *via* Fischer-Tropsch synthesis; for the production of hydrogen and chemicals such as ammonia, methanol; and for synthetic natural gas (methane). Furthermore, the gas could be used for direct iron ore reduction and as medium-BTU fuel gas for industrial and domestic heating and for electricity generation.

Electricity can be generated with much higher efficiency in coal gasification, combined cycle power stations than conventional coal-fired ones. SCGP is also a very efficient process for the production of synthetic natural gas. Waste heat from the methanation step allows the co-production of electricity. Thus SCGP is competitive with processes where large amounts of methane are generated in the gasifier itself.

While not limiting the scope of the first few commercial ventures, we believe initial applications for electric power generation are most likely. To this end, Shell companies have become involved in a number of venture feasibility studies with utilities. Full-scale designs would be finalised after SCGP-1 operation on the commercial venture coals, with construction possible soon thereafter. This could lead to commercial operation in the early- to mid-1990s. SCGP-1 is expected to continue operating to confirm commercial design for various applications and commercial coal types. From there on, a broad commercial application of SCGP is expected.

Figure 3

Markets for coal gasification



Printed in England by Well Hall Press 09763/2m/11.87