1.6 United Kingdom

The United Kingdom of Great Britain and Northern Ireland-or Britain as it is also known- is an island nation. The land area is small - only some 230,000 km^2 (90,000 sq mi) - but it is densely populated with some 61 million people. Per capita energy use is about 145 GJ/year (137 x 10^6 Btu/yr).

Britain's immediate need for liquid hydrocarbon fuels from coal is nonexistent because of the now ample oil being produced by the off-shore oil platforms in the British Sector of the North Sea. In 1978 there were 11 producing fields with another eight scheduled to be in production by 1981. Production during the 1980's is expected to be in the range of 100-150 Mt/year (110-165 x 10^6 tons/yr = 730-1100 x 10^6 barrels/yr). Proven reserves are 1,405 Mt (1545 x 10^6 tons = 10 x 10^9 barrels) and total reserves are estimated at 4,200 Mt (4620 x 10^6 tons = 30 x 10^9 barrels). Some onshore fields exist but their production is very small.[47]

In 1977 inland deliveries of petroleum products were 83.2 Mt (91.5 x 10^6 tons = 610 x 10^6 barrels) which was down some 30% from the peak consumption in 1973/74. Although Britain's 20 refineries had a gross capacity of 142.7 Mt (157 x 10^6 tons = 1 x 10^9 barrels) in 1978, the 1977 throughput of crude and process oils was 93.6 Mt (103 x 10^6 tons = 686 x 10^6 barrels). These refineries have been or are being upgraded to meet the changing pattern of demand.[47]

The government interest in oil is through the British National Oil Company which has significant interests in all phases of production, processing and distribution.

Britain has large coal reserves and before the advent of oil and natural gas as more convenient fuels, the country was energy self-sufficient. It wasn't until the discovery of gas in the British sector of the North Sea in the mid-1960's, and of oil in the early 1970's, that the country started back on the road towards energy self-sufficiency. During the 1980's Britain is expected to be a net exporter of energy.[47]

Coal is Britain's most abundant energy resource. Table 1.9 shows its extent. Estimates of the total reserve indicate that some 190 Gt (209 x 109 tons) exist of which 45 Gt (5 x 109 tons) are recoverable using existing mining technology. The latter is sufficient for 300 years at the present extraction rate. A national exploration program by the National Coal Board (NCB) is proving fresh reserves of recoverable coal at the rate of about 500 Mt/year (550 x 10^6 tons/yr), which is four times the annual consumption of coal.[47]

The NCB was set up in 1946 and nationalized all the coal mines in 1947. Private operators can mine coal under licenses granted by the NCB. Of the 121 Mt (133 x 10^6 tons) mined in the 1977-78 production year, 86.5% was from NCB's underground operations, 11.0% from surface mines and 2.5% from privately operated mines. The areas where coal is found are shown in Figure 1.5. Also shown in the figure are the locations of British experimental and pilot plants for coal liquefaction and gasification.

The NBC's Coal Research Establishment at Stoke Orchard in Gloucestershire is concerned with the combustion and utilization of coal. Major projects are being undertaken to convert coal to liquid fuels including gasoline and to produce chemical feedstocks from coal.

Table 1.9 British energy resources, production and consumption (Petajoules)*

	Known Reserves			Production		Consumption
	Proven/ Measured	Probable/ Indicated	Total Resource	1967	1977	1977
Non-renewable						
Coal	1,150,000	3,650,000	4,800,000	4,325	3,201	3,005
Oil	62,000	123,000	185,000	0	1,644	3,346
Gas	30,000	30,000	60,000	54	1,604	1,538
Uranium	-	-	-	-	-	350
Total	1,242,000	3,803,000	5,045,000	4,379	6,449	8,239
Renewable						
Hydro				10	12	12
Total				10	12	12

*Petajoule = 10^{15} Joules = 0.9478×10^{12} Btu.

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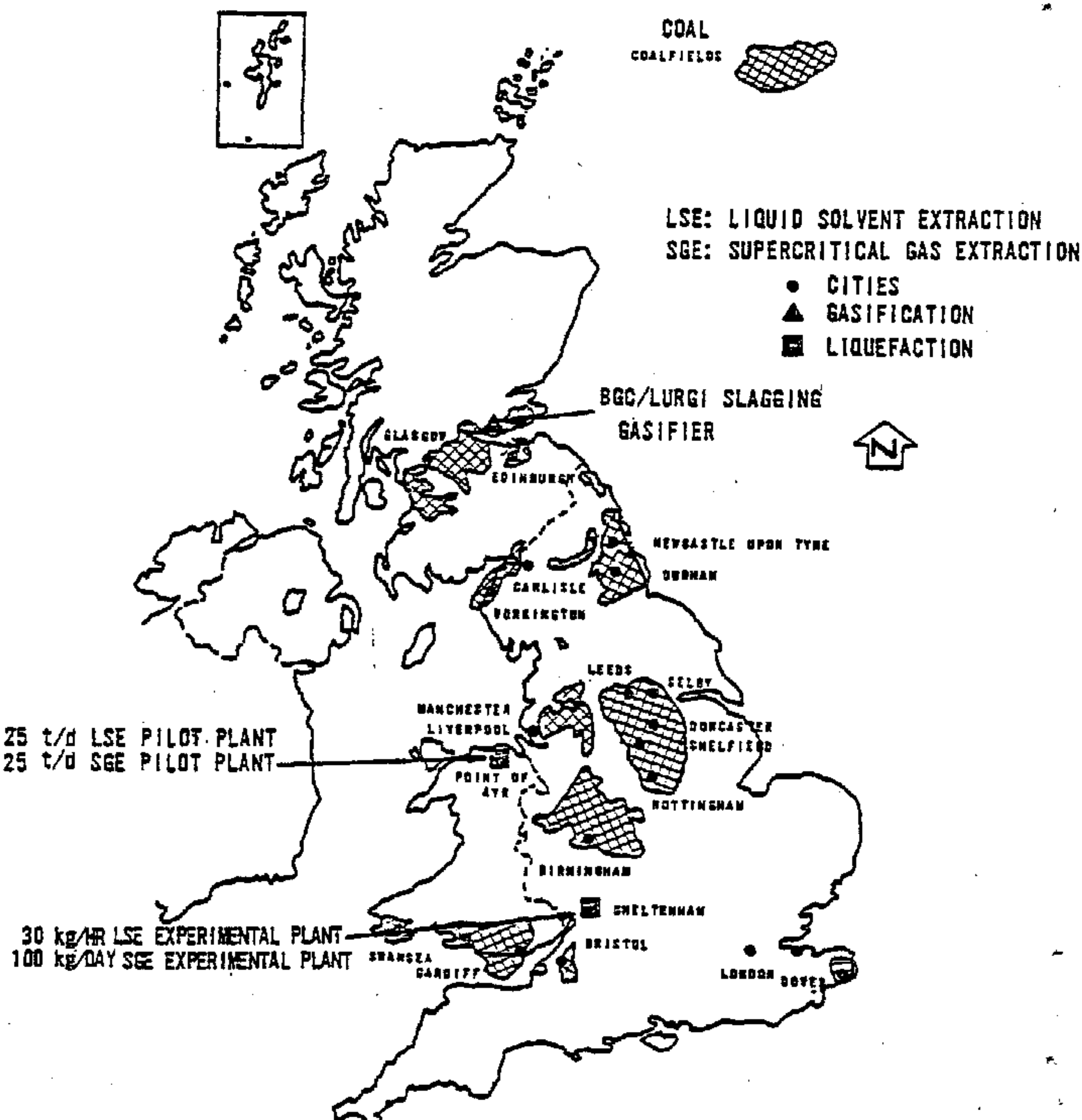

FIGURE 1.5

COAL GASIFICATION AND LIQUEFACTION PILOT PLANTS IN THE UNITED KINGDOM

In early 1979 it was announced[48] that the NCB, assisted by British Petroleum Ltd., had started engineering and design studies for two oil-from-coal plants. Each plant was to have a feed rate of 25 t/d of coal. The two processes to be used are liquid solvent extraction (LSE) which is similar to several U.S. technologies, and supercritical gas extraction (SGE). Plans were later changed to a single pilot plant that could be operated in either the LSE or SGE mode to be built at the Ayr Colliery in North Wales.[49] Construction was to begin in mid-1980 at a cost of $60 million overall. The British government agreed to contribute 5 million pounds (about $9 million) to the project.

Construction of the pilot plant was expected to start soon, but it is not certain whether building will begin this year. The plant would take three years to complete. The NCB is looking for sponsors to invest in the pilot plant and is apparently also soliciting funding from the members of the European Economic Community and from private companies. A

Laboratory testing of the processes has shown that the technology is much more efficient than coal liquefaction technologies under development in the U.S., it is claimed. The pilot plant also looks promising economically, it was added.

The liquid-solvent process will yield some 13 t/d of useful fuels. Crushed coal is slurried with anthracene oil and pumped to a dissolver operating at 370 to 450°C (700 to 840°F), where up to 85% of the coal dissolves. After filtering and solvent-stripping, the resultant liquid is hydrogenated over a cobalt-molybdenum catalyst.[48]

Some 8 t/d of aromatics such as benzene, toluene and xylene will be yielded in the SGE process. Here a supercritical fluid (typically one of the process products) at 20 to 27 MPa (2900 to 3900 psi) and 300 to 400°C (570-750°F) is passed into a heated bed of coal in an extraction vessel. Coal constituents are transferred into the fluid, leaving a residue of char and ash. The enriched fluid enters a separator operating at atmospheric pressure and the coal-extracts precipitate.[48]

Commercial interest in SGE surfaced when Shell Coal International Ltd. awarded Badger, Ltd. (the British subsidiary of The Badger Company) a short duration contract to design a plant with an output of 8,000 t/d of liquid hydrocarbons.[50] The European Economic Community (EEC) has offered financial assistance for the design and construction of the SGE plant and will enter into a contract with NCB.[49] (For ECC gasification R&D projects, see Table 1.10.)

Table 1.10 EEC gasification R&D projects in the UK[54]

Project	Operator/Sponsor	Main object	Status
British gas/ Lurgi slagging gasifier	British Gas, Lurgi and U.S. companies	SNG	Tests on coals and component development 300-400 t/d on UK and US coal
Composite gasifier	British Gas (EEC) under consideration)	SNG from run-of-mine coals	20 t/d plant being designed
Fluid bed gasifier	NCB-ECSC	Low-Btu gas for power generation	Small pilot plant tested. Demonstration plant with CEGB under discussion
Synthesis gas from COGAS process	NCB-COGAS	Design data for SNG and oil from coal demonstration plant	2 t/hr gasifier operating
Fluid bed gasifier	Esso Petroleum	Low Btu gas for boilers	American coals tested in pilot plant

Up until the 1960's Britain had a gas distribution system that was fed with town gas manufactured from coal. At that time the switch was made to oil-based feedstocks. Soon afterwards natural gas was discovered in the North Sea and now the gas supply system has been completely modified to use natural gas.[47] Only in Northern Ireland does a town gas system still exist and this is oil-based.[51] The gas is distributed by the British Gas Corporation (BGC), a nationalized entity which came into operation in 1973, replacing the former Gas Council. Exploration and production is done under license by the private sector.

Natural gas is supplied from seven gas fields in the British sector of the North Sea. The indigenous sources supplied 88% of the gas to the national distribution system. This proportion had been declining because of gas being supplied from the Norwegian sector of the Frigg field. Having reached a low of about 80% in 1979 this proportion is expected to rise with the coming on stream in 1980 of gas supplies associated with the Brent and Tartan oilfields. A small proportion of the gas distributed is imported as liquefied natural gas (LNG) from Algeria.[51]

Although the supplies of natural gas are expected to last until at least 2000, a major research and development program for the manufacture of substitute natural gas (SNG) is underway. British Gas Corporation is anticipating spending about $600 million (1979 dollars) over the next 20 years so that processes to produce SNG are available to augment natural gas supplies when this becomes necessary. The Midlands Research Station at Solihull has pioneered several SNG production processes such as the catalytic rich gas and fluidized bed hydrogenation processes which use light and middle distillates, and heavy oils as feedstocks.[52]

Work on the methanation of "lean" gas produced at the Corporation's Westfield Development Center in Fife enabled the world's first SNG from coal to be supplied to consumers in parts of Scotland in 1974.[51]

Tests were coordinated in 1978 by Conoco Coal Development Corporation for a test program funded and sponsored by 15 U.S. gas pipeline and oil companies on British Gas' slagging Lurgi gasifier at Westfield. Some 15 tests were run which culminated in June 1978 with tests using sized Pittsburgh No. 8 coal to which progressively more fines were added. The fines ranged in size from dust particles up to 12 mm (0.5 in) while the sized coal was up to 50 mm (2 in) in diameter. During the last 24 hours of the five days of testing the fines constituted 25% of the feed and did not impair the process. However, long test periods will be required to make a firm conclusion regarding the use of fines. There was no pretreatment of the coal other than routine washing and screening.[53]

1.6.1 British Gas 20 Year Plan for SNG Development [B]

British Gas commenced in 1978 a program planned to last 20 years dedicated entirely to the development and demonstration of a range of processes to produce SNG. The current cost of this program in 1980 dollars is estimated to be $630 million. A significant part of this program continues to be the development of the Slagging Gasifier, leading to a second generation process - the Composite Gasifier. This program is currently under review and may be further enlarged to include full scale commercial demonstration during the 20-year program. This may well increase the cost by a factor of three. The program will involve continued operation of the 6-ft diameter shaft Westfield gasifier and construction, commissioning and operation of a 8-ft diameter shaft prototype commercial slagging gasifier. Aspects of this program are: (1) performance testing of the slagging gasifier on a range of British coals; (2) development of fine coal injection systems into the Slagging Gasifier; (3) a long (three month) demonstration run on the Slagging Gasifier; and (4) the production and distribution of SNG from the Slagging Gasifier, via British Gas Corportion's HCM process.

1.6.2 Plan for Commercialization[B]

In March 1975 British Gas entered into an agreement with Lurgi for the development of the British Gas/Lurgi Slagging Gasifier, and this has recently been updated. Under these agreements British Gas is the licensor of the process and also provides the detailed engineering and procurement of its proprietary equipment relating to the bottom half of the gasifier. Lurgi is responsible for the detailed engineering and procurement of its proprietary equipment relating to the top of the gasifier, but British Gas puts together and supplies the complete package.

An ERDA contract signed in May 1977 included a license to Conoco granted by British Gas. Phase I of this contract, the design of the demonstration plant, was estimated to last 22 months and included the Technical Support Program at Westfield to gasify Pittsburgh 8 and Ohio 9 coals.

Unfortunately the project has been subject to various slowdowns and delays so that Phase I will not be completed before June 1981, and the U.S. Department of Energy has still not selected the process to enable the construction phase to proceed in 1981 despite the successful completion of the Technical Support Program in 1978. Thus it remains uncertain whether the plant will be built because of the various political, environmental, regulatory, and financing problems which face all coal gasification projects in the USA at the present time.

British Gas policy is to have ready a fully developed and proven process for the manufacture of SNG from coal for the time when natural gas from the North Sea is no longer sufficient to match the reuqirement for natuural gas in the premium market. The uncertainty in the prospects for the Conoco project meant that British Gas decided that it must itself carry the project forward and it is now in the middle of a program at Westfield which will include the construction of a larger gasifier of 8 ft nominal diameter which will gasify 600-800 tons/day, and the carrying out of a three month run during which the gas will be treated by the HCM route to make SNG. This program should be completed in 1982 and will confirm the commercial status of gasifiers of this size, which are smaller than that proposed for the Conoco demonstration plant which will gasify 1000 tons/day. British Gas is now prepared to grant licenses for plants utilizing slagging gasifiers of sizes up to 8 ft diameter and will provide full commercial guarantees.

1.6.3 Future programs[C]

As the demand for coal increases it will become increasingly desirable for any coal conversion process to utilize total mine output, i.e., the whole size range from lump to fines. While the slagging gasifier has in large measure the ability to handle fines either or both in the feed and by injection with the steam and oxygen through the tuyeres, there is still expected to be a surplus of fines which cannot be handled. Rather than adopt an entrained process which requires the total feed to be pulverized and which has a low efficiency in an SNG manufacturing role, it is proposed to develop the slagging gasification process along lines which will enable the proportion of fines which can be efficiently gasified to be maximized while preserving the inherent advantages of fixed-bed operation. Thus, an experimental gasifier is now being designed which will enable the ability to inject fines with the steam and oxygen through the tuyeres to be developed further by providing, below the fixed-bed and coupled in series with it, an entrained gasification zone.

This arrangement has become known as the Composite Gasifier. It is not, however, the only method which will be tested. Ways of introducing fines with the top feed will also be studied, including the use of briquetts and extrudates - different coals will require different treatments. This experimental unit which is expected to lead to a new generation of slagging gasifiers, is to be built at Westfield and is expected to be ready for commissioning in 1983.

The slagging gasifier or a second generation development of it is expected to meet the needs of British Gas at least into the next century. There will, however, be increasing incentives to raise thermal efficiencies and, with the likelihood of an escalation in the proportion of fine coal in the mine product due not just to more mechanization but also perhaps to the introduction of remote mining methods, it will be necessary to turn to powdered coal processes based on fluidized-bed technology. Thus, the British gas SNG program incorporates in the longer term the development of a fluidized-bed coal hydrogenation (FBH) and gasification process following on, as previously indicated, the development and demonstration of the FBH process applied to heavy fuel oil. This will be a logical sequence of development if such processes are not by then already available. If they are, British Gas would be in the position of an informed buyer. Much engineering development will be needed, however, before fluidized-bed technology can realize the potentially higher thermal efficiencies it holds in prospect for SNG manufacture. In the meantime, British Gas believes that this long term SNG program will enable them to approach the next century confident that they can meet the demand for gas as the supply of natural gas declines.

British Gas has awarded a contract to Worley Engineering Ltd., for the design, engineering and project management for a new experimental coal gasification facility at the Westfield Development Center. The facility will include a 170 t/d composite gasifier under development by BGC,[52] which would use run-of-mine coal including fines. The product gas could be upgraded to SNG. The project has two phases: design and engineering to be completed by late 1980, and then project management of the construction. Total cost of the facility is estimated at $33 million.[54,55]

1.6.4 NCB Low-Btu Gasification Process [54]

The National Coal Board, Coal Research Establishment (CRE), is developing a fluidized gasifier for the production of low Btu-gas for power generation in a combined cycle. The process enables sulfur emission control to be achieved by limestone or dolomite addition and the high volatile coals currently used in the UK for power generation can be successfully gasified. The approach is that of the gasification of coal with steam and air at relatively low temperatures to minimize the vaporization of mineral matter which would adversely affect the gas turbine. The residual char is then burned in a fluid-bed combustor to supply heat to the boiler of the steam cycle.

The process has been evaluated in conjunction with the Central Electricity Generating Board and it is proposed that a pilot plant should be built to demonstrate the gasifier, gas cleaning plant and turbine life.

1.6.5 NCB COGAS Work [54]

The Leatherhead laboratories of the NCB (CURL) have assisted in the development of the COGAS process on behalf of a U.S. consortium. Char from the pyrolysis process has been gasified and combusted in a 50 t/d steam/air-blown pilot plant developed by the laboratories.

An agreement between the U.S. consortium developing the COGAS process and the NCB provides for further studies of the char gasification stage in support of the proposed plant for Perry County, Illinois.

1.6.6 Esso Chemically Active Fluid Bed Gasification Process [54]

Esso Petroleum Co., Ltd. at the Abingdon (UK) Research Centre, has been developing a chemically-active fluid-bed gasifier since 1970 using limestone for sulfur retention. Initially the work was on heavy fuel oil but from 1976 U.S. coals and lignite have been treated in a 0.9 meter (3 ft) shallow bed, with a modified coal feed treated in a 0.9 meter (3 ft) shallow bed, with a modified coal feed system. The results showed that some 87% carbon utilization could be achieved together with good removal of sulfur by limestone in the bed. A 20 MW(e) boiler demonstration in the U.S. is planned based on the work done in the UK.

1.6.7 Use of Slagging Gasifier for Electric Power Generation [B]

During the first phase of the BGC slagging gasifier program, a three month interruption was made to accommodate a short but highly significant program at Westfield, sponsored by EPRI. This three-month program was aimed at demonstrating the potential of the Slagging Gasifier for electric power generation in a combined-cycle plant using Pittsburgh 8 coal. The program greatly increased EPRI's confidence in the slagging gasification process and its use in the above mode, as the EPRI Press release at the end of the project in December 1979 indicated.

British Gas is supporting Florida Power Corporation in a feasibility study for the integration of a slagging gasifier with combustion turbines and exhaust heat recovery steam generators to repower existing condensing steam turbine generators at the Higgins Plant in Pinellas County, Florida. This study will last twelve months and is expected to be followed by detailed engineering and construction of the facility.

A number of other feasibility studies are under consideration and these should lead to the construction of additional gasifiers. British Gas considers that, in view of the results obtained at Westfield and the ongoing program, there is no technical objection to ordering plants at the present time based on 8-ft diameter gasifiers.

1.6.8 Underground Gasification[54]

An experimental program was undertaken in 1949 by the NBC on underground gasification using holes drilled from existing workings and from the surface in seams 400-500 ft deep. Some success was achieved, but by 1960 the process appeared to have little prospect of becoming economic and the test was terminated. No further experimental work has been done in the UK and a recent survey has confirmed that the prospects are not encouraging at the present state of knowledge. However, it is estimated that 90% of Central European coal reserves are deeper than can be worked by conventional means, hence there is a considerable incentive to develop techniques for their exploitation.

1.6.9 HCM Process H

British Gas has a proprietary direct methane synthesis route incorporating the High Carbon Monoxide or HCM process which has been specifically designed to exploit the features of the slagging gasifier already outlined, especially its low process steam requirement.

In this route purified synthesis gas is processed by the HCM stage, one configuration of which is illustrated in Fig. 1.5. Feed gas first enters a saturator in which it is contacted with a countercurrent flow of water that has been heated by indirect heat exchange with gas streams within the HCM process stage and also the crude gas cooling system. This arrangemment utilizes otherwise unusable low grade heat for provision of process steam and makes a substantial contribution to the efficiency of the HCM route to SNG. Saturated feed gas then undergoes direct methane synthesis in a series of catalytic reactors, the outlet temperatures of which are controlled by recycle of cooled product gas. The heat released from the highly exothermic synthesis reaction is used to generate high pressure steam for export to other process stages. Final methanation, gas cooling, carbon dioxide removal and drying yield an SNG containing less than 3% hydrogen and 0.1% carbon monoxide.

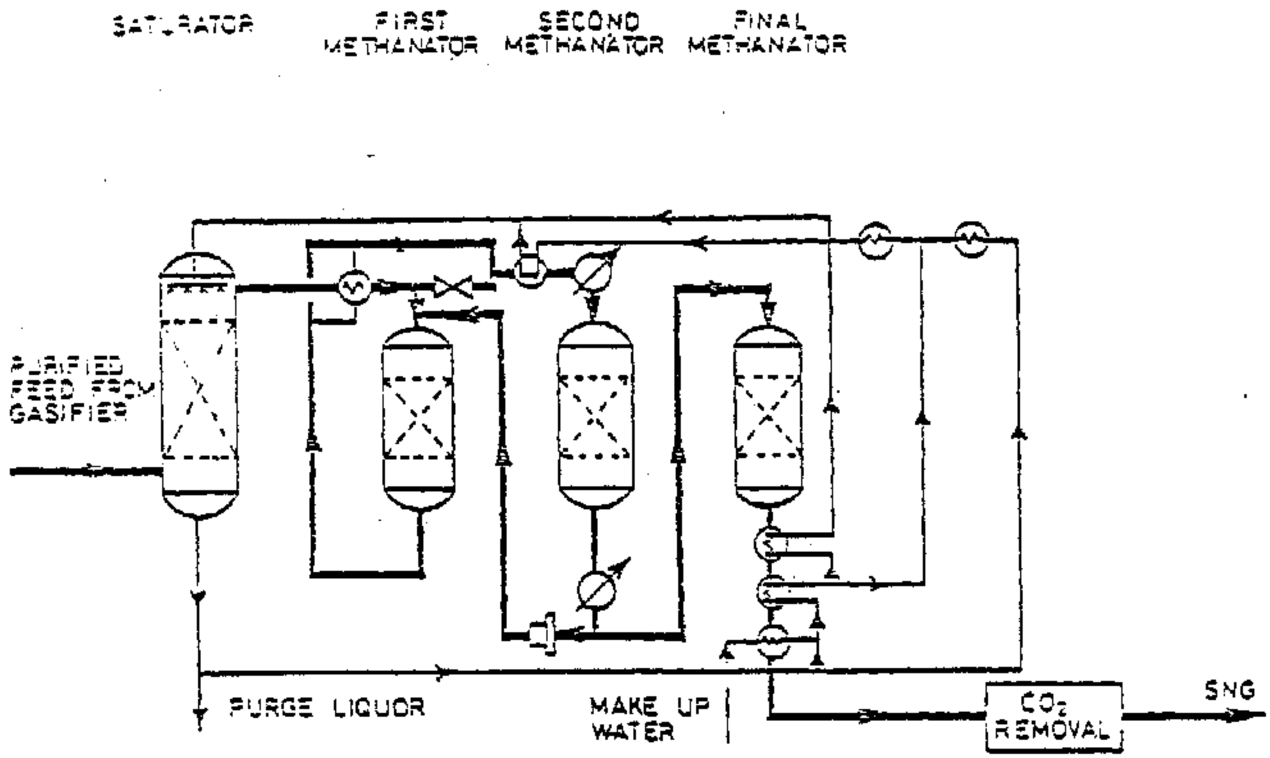

Fig. 1.6 The HCM process[H]

The HCM route offers the following advantages over the alternative indirect methane synthesis route:

1. It has a significantly lower net process steam requirement and a resultant reduction in low grade latent heat of condensation released from gas cooling trains.
2. It is possible to generate a major part of the process steam requirement for methane synthesis by using the otherwise difficult-to-recover low grade heat (by means of a saturator).
3. The need for a separate CO—shift stage with all its ancillary equipment is obviated and there is also a consequent reduction in the volume of phenolic liquor produced.
4 Gas purification costs are lower owing to a lower volumetric throughput and a lower CO_2 feed concentration, which favors the production of a H_2S rich sidestream.
5. The volume of CO_2 removed is much the same but the volume of gas from which it is removed is substantially lower.

The overall process thermal efficiency of the HCM route, for the conversion of a bituminous coal to SNG, is about 71%. This route also has a low capital cost compared with other schemes, and will allow SNG manufacture at a cost unlikely to be bettered by other local gasification processes at a similar stage of development.

Process conditions chosen for the HCM possess have been validated by laboratory and pilot plant scale tests.

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