Table 2.23. Distribution of particle sizes of separated dust in the Saarberg-Otto gasifier

Particle sizes μm (micron)	Cyclone wt %	Waste heat boiler wt %	Fibrous filters wt %
>100	12.4	10.7	
100–90	2.6	1.2	
90–80	4.8	2.3	
80–70	21.3	5.1	
70–60	5.4	3.1	
60–45	12.6	4.6	
45–30	15.4	7.8	
30–25	1.4	1.4	
25–20	3.6	3.9	
20–15	1.7	1.5	
15–10	3.2	4.9	
10–5	0.7	1.7	
<5	14.9	51.8	
>3			8.6
3–2			17.4
2–1			30.4
1–0.5			17.4
<0.5			26.2

2.3.5 British Gas/Slagging Lurgi process

The British Gas/Slagging Lurgi gasifier is a development resulting from the traditional fixed-bed high-pressure Lurgi dry-ash gasifier. The slagging gasifier operates with a higher temperature in the ash removal area so that the ash melts and is removed as a molten slag. The BG/Slagging gasifier operates under slagging conditions, which greatly extend its capability to gasify a wider range of coals at higher efficiencies and greatly increased outputs.

2.3.5.1 History and Status

Lurgi, after recognizing the advantages of the slagging mode of operation, first experimented with a pilot unit in early 1950's. Further development was done at the British Gas Council's pilot plant at British Gas Midlands Research Station (MRS) at Solihull during the period 1955-1964. The work was suspended at a stage at which British Gas considered further useful development could only be continued on a larger scale under conditions which allowed continuous operation of several months rather than several days duration.[47]

At that time, in 1963/64, Westfield had been mentioned as a possible site but any chance of following this up was overtaken by the discovery of natural gas under the North Sea. Research and development programs on coal were terminated and eventually the MRS pilot plant was dismantled. Also operated was British Coal Utilization Research Association's pilot plant at Leatherhead in late 1950's.

The evolutionary development of the Lurgi gasifier at Westfield resumed when U.S. interest in coal gasification increased. A consortium of U.S. gas, oil and pipeline companies led by the Continental Oil Company used the facility to demonstrate the production of SNG from coal-based synthesis gas, and the American Gas Association tested the gasification of a series of U.S. coals in the Westfield Lurgi gasifier. The successful completion of these two programs coincided with the conversion of the local district to natural gas and the termination of town gas production at Westfield. On the initiative of the Continental Oil Company (now Conoco) and with the full support of British Gas, who recognized the potential international value of the Westfield plant as a gasification development and demonstration center, a program for the development of the slagging gasifier to commercial status was put up for sponsorship. As a result, a project to convert one of the Westfield gasifiers to slagging operation and undertake its development according to a three-year program was initiated under the sponsorship of the fifteen American companies listed in Table 2.24. In addition, by agreements signed with British Gas, the Lurgi company joined the project and collaborated fully in the development work. A gasifier incorporating British Gas and Lurgi technology will be known as the British Gas/Lurgi slagging gasifier, and will be licensed by British Gas on behalf of the sponsors who will receive a share in the license fees.[47]

Table 2. 24 United States companies sponsoring the Westfield slagging gasifier project

Cities Service Gas Company/Northern Natural Gas
Continental Oil (now Conoco)
El Paso Natural Gas
Gulf Energy and Minerals
Michigan Wisconsin Pipe Line
Natural Gas Pipeline
Panhandle Eastern Pipe Line
Standard Oil of Indiana
Southern Natural Gas
Sun Oil
Texas Eastern Transmission
Tennessee Gas Pipeline
Transcontinental Gas Pipeline
Electric Power Research Institute

The three-year program was proclaimed successful. The program included a 23-day continuous test of the gasifier that confirmed its readiness for commercial demonstration. At present, the British Gas program has started to obtain performance data on typical British coals and to explore further improvements in the technology. Also planned is an investigation of the feasibility of injecting coal fines through the tuyeres [48,49] as ell as tar reinjection.

2.3.5.2 Plant Location

The Westfield Development Center, which occupies a site of 45 acres, is situated on the borders of Fife and Kinross-shire in Scotland and is served by the Edinburgh airport. The center is sufficiently remote from residential areas to minimize environmental problems. It is adjacent to a strip mine supplying low-swelling, non-caking bituminous coal. A rail line serves the center, and the port of Leith, which is 30 miles away, can receive and handle ocean-going vessels carrying coal.[50]

2.3.5.3 British Gas/Slagging Lurgi Process Flow

The Gas Council's original slagging Lurgi gasifier at Midland Research Station (MRS) was a vertical, cylindrical, water-jacketed vessel operating at about 500 kPa (73 psi). Coal was fed downward from a lockhopper on the top of the gasifier. Steam and oxygen were mixed and then fed through tuyeres in the gasifier wall. Slag was intermittently tapped from the side of the gasifier near the base to a slag quench vessel. The gasifier was 6.0 m (20 ft) high and had a 1.14 m (3.74 ft) internal diameter. The modified version (1962) operated at about 2.6 MPa (377 psi) and had intermittent slag tapping from the bottom.

The BCURA gasifier at Leatherhead, similar in design, operated at 300 kPa (44 psi). The gasifier was 6.7 m (22 ft) high and had a 1.83 m (6 ft) diameter. The slag was continuously tapped from the bottom.

The gasifier currently operating in Westfield was modified from one of the Lurgi dry-ash units to make it similar to the 1962 version of the MRS gasifier (see Figure 2.31). The gasifier has an internal diameter of 2.82 m (9.25 ft) an outside diameter of 3.05 m (10 ft), and is 5.8 m (19 ft) tall.

In all cases, a burner was provided at the slag tap to maintain a free flow of slag.[51]

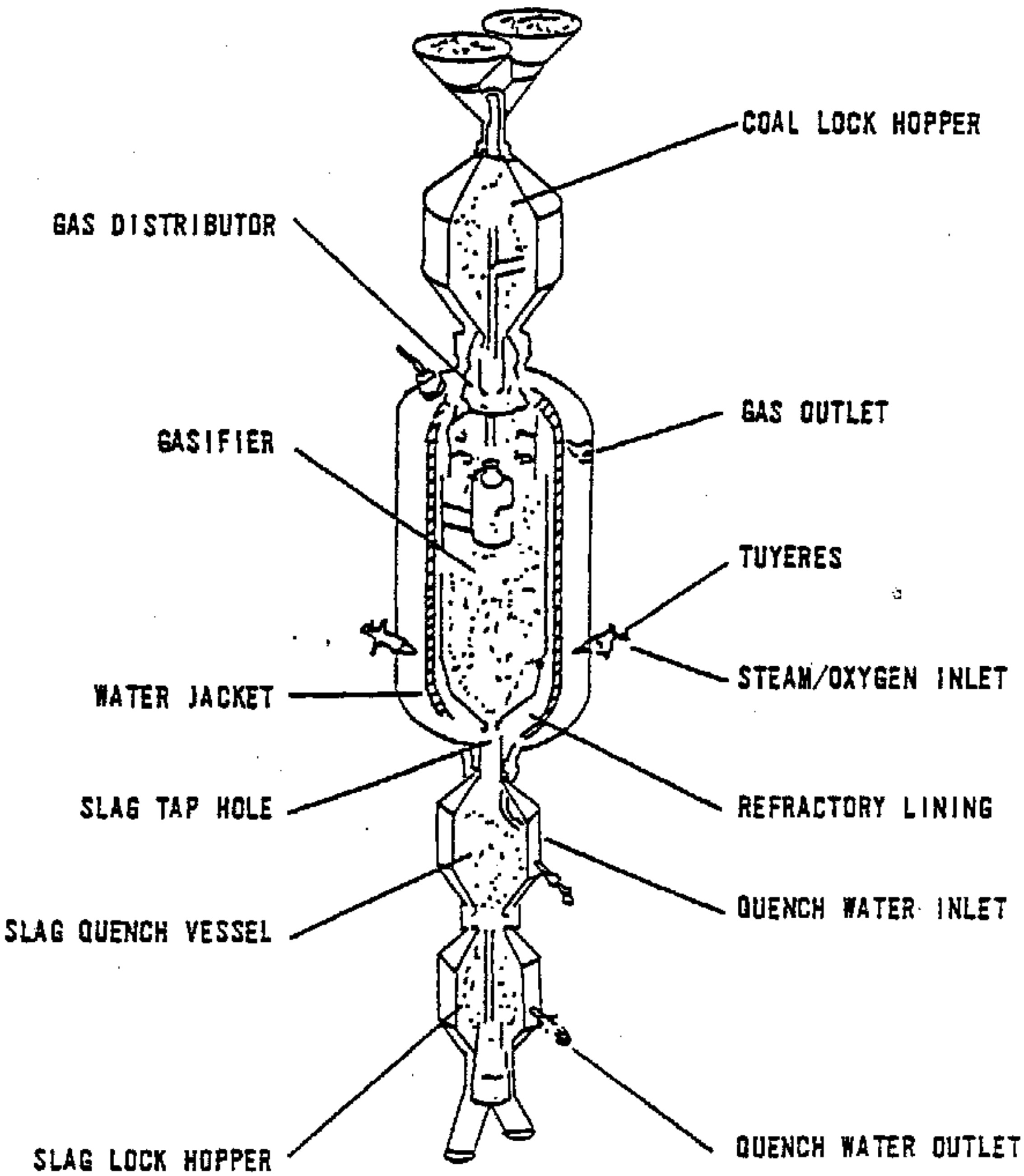

Figure 2.31
BRITISH GAS/LURGI SLAGGING GASIFIER

About 50% of the raw gas from the gasifier is passed through a shift conversion unit to adjust the H_2/CO ratio. All of the gas is then cooled, and the liquid condensate is sent to an effluent treatment system where coal tar, tar oil, ammonia, and phenols are removed from the water. The product gas is sent to purification where naphtha, H_2S, and CO_2 are removed. The H_2S and CO_2 are removed by the Lurgi Rectisol process and sent to a Stretford unit where elemental sulfur is produced from H_2S. The clean gas is then sent to the methanation and compression steps.[51,52]

A portion of the coal from the coal preparation unit is burned in a utility plant for steam and electricity production.

2.3.5.4 Feed Requirements

The coal is crushed and screened to remove the coal fines smaller than 20 mm (0.8 in) diameter.

The BG/Lurgi slagging gasifier can handle caking coals with no more than 15% by weight refractory ash (i.e., ash with a very high fusion point) and no more than 20% by weight moisture. Refractory ash can be accommodated by adding fluxes. Coal fines can be used by injecting them with the steam and oxygen feed. Recent tests on two British coals used feeds with up to 35% of the particles smaller than 6 mm (0.24 in).

2.3.5.5 Performance Data

Table 2.25 provides a summary of the results that have been obtained on various coals using the BG/Lurgi slagging gasifier. For comparison the same results on a dry-ash Lurgi gasifier are also shown.

Table 2.25 Performance data for British Gas/Lurgi slagging and Lurgi dry-ash gasifiers at Westfield

Gasifier type	Slagging				Dry ash
Coal	Frances	Rossington	Ohio 9	Pittsburgh 8	Pittsburgh 8
Origin	Scotland	England	USA	USA	USA
Size (mm)	6-25	6-25	6-25	3-30	3-30
(in)	(0.24-1)	(0.24-1)	(0.24-1)	(0.12-1.2)	(0.12-1.2)
Proximate analysis, wt %					
Moisture	8.7	9.5	6.1	4.2	4.8
Ash	4.4	4.6	18.9	7.2	7.9
Volatile matter	32.9	31.2	33.6	35.4	37.4
Fixed carbon	54.0	54.7	41.4	53.2	50.3
Ultimate analysis, wt %					
Carbon	83.0	83.5	79.6	82.4	84.9
Hydrogen	5.5	4.9	6.1	5.3	5.8
Oxygen	9.2	7.7	7.4	9.1	5.0
Nitrogen	1.4	1.7	1.2	1.5	1.6
Sulfur	0.5	1.7	5.6	1.6	2.6
Chlorine	0.4	0.5	0.1	0.1	0
B.S. swelling no.	1½	1½	4½	7½	7½
Cake index (Gray King)	B	E	G	G8	G8
Operating conditions					
Gasifier pressure, MPa (psi)	2.4 (348)	2.4 (348)	2.4 (348)	2.4 (348)	2.4 (348)
Steam/oxygen ratio, v/v	1.3	1.3	1.3	1.3	9.0
Outlet gas temperature, °C (°F)	480 (900)	480 (900)	410 (770)	510 (950)	660 (1220)
Crude gas composition, vol %					
H_2	28.6	27.2	28.7	28.9	38.8
CO	57.5	58.1	53.2	54.9	17.9
CH_4	6.7	6.8	6.9	7.1	8.4
C_2H_6	0.4	0.5	0.3	0.6	0.7
C_2H_4	0.2	0.2	0.2	0.2	0.3
N_2	4.2	3.9	4.0	4.4	2.4
CO_2	2.3	2.9	5.5	3.4	30.8
H_2S	0.1	0.4	1.2	0.5	0.7
HHV, MJ/m^3 (Btu/ft^3)	15.0 (403)	15.0 (403)	14.5 (389)	15.0 (403)	11.9 (319)

Table 2.25 (continued)

Gasifier type	Slagging				Dry ash
Coal	Frances	Rossington	Ohio 9	Pittsburgh 8	Pittsburgh 8
Origin	Scotland	England	USA	USA	USA
Size (mm)	6–25	6–25	6–25	3–30	3–30
(in)	(0.24–1)	(0.24–1)	(0.24–1)	(0.12–1.2)	(0.12–1.2)
Derived data					
Coal gasification rate, kg/(m^2hr) (lb/ft^2-hr)	4160 (850)	4140 (846)	3240 (662)	3250 (664)	684 (140)
Steam consumption, kg/kg coal (lb/lb coal)	0.405	0.398	0.390	0.407	3.54
Oxygen consumption, kg/kg coal (lb/lb coal)	0.539	0.549	0.555	0.547	0.70
Liquor production, kg/kg coal (lb/lb coal)	0.20	0.21	0.16	0.21	2.24
Gasifier thermal output, GJ/(m^2hr) (10^6 Btu/hr-ft^2)	120 (10.6)	120 (10.6)	89 (7.8)	94 (8.3)	19 (1.7)
Gasifier thermal efficiency,[a] %	83.4	82.1	82.3	79.9	62.3
Coal expressed "moisture and ash free"					

[a] Defined as total product gas thermal output (based on HHV, including tar, oil, and naphtha) divided by the corresponding thermal input of coal feedstock and the fuel equivalent of the steam and oxygen used.

2.3.5.6 Environmental Aspects

The crude gas contains tars, oils, phenols and ammonia. This gas is scrubbed with water at the exit of the gasifier to remove these components. The water is then treated to remove the tar and oil phenol, and ammonia. It is also treated by biological oxidation for the removal of organics. Tars, oils and phenols could be recycled back to the gasifier.

2.3.5.7 Equipment Design of Demonstration Plant with Key Problems and Points of Emphasis for Development

The potential problem areas identified for the Lurgi slagging ash process are presented in this section.[51]

Crushing and sizing of coal are required and fines smaller than 20 mm (0.8 in) are removed. This is an energy expense, and, if the fines are not injected into the gasifier with the steam and oxygen, then the fines must be briquetted or otherwise used to gain process credit.

Coals with high ash fusion temperatures can only be handled by increasing the bed temperature, thereby increasing the oxygen demand which represents an economic penalty.

Viscosity of the slag must be controlled for ease of flow. Potential problems exist here, in that burners are used at the slag taps to keep the slag flowing freely. Lock hoppers on the slag remove system could also be points of high wear. In general, the entire area of slag removal needs additional attention, especially materials and mechanical reliability.

Lock hoppers to feed coal are costly from the standpoint of hopper repressurization, mechanical wear, and leakage under pressure operations.

The higher temperatures required in the slagging bottom gasifier impose refractory maintenance problems not found with the dry bottom gasifier.

2.3.5.8 Composite Gasifier EK

All Lurgi units have difficulty in operating with more than about 25% fines in the feed coal without excessive solids carry over or throughput restrictions. This is a considerable disadvantage as mechanical mining methods tend to increase the proportion of fines in coal beyond this level. One approach to this problem being developed by British Gas is to use an entrained gasifier beneath a fixed-bed slagging Lurgi unit. Hot product gases from the entrained section flow into the bottom of the fixed-bed slagging gasifier section. The combined product gases then flow counter-current through the lump coal, heating it in the process. The entrained section can also gasify oils or tars if necessary. This concept has been termed the British Gas Composite Gasifier.[54]

Although the slagging gasifier has a somewhat increased tolerance to fines in the coal feed compared with the basic Lurgi gasifier, owing to the potential ability to inject some fines through the tuyeres into the slagging zone, and further fines may be used as plant fuel in pulverized-coal boilers in an overall coal-based gasification scheme, the maximum fines content acceptable in the coal input is in the range 20-40 wt %. While many British coal mines currently meet this criterion, the future spread of advanced mechanized mining techniques may increase the fines content to as much as 60%. This is of some concern since SNG production plants in the future may be so large as to consume the entire output of at least one large mine; for exmaple, the Westfield town gas plant had a dedicated open-cast (i.e., strip) mine. In such circumstances, the ability of the gasification complex to consume the entire "run-of-mine" coal output is of some economic importance. While this could be achieved by some combination of smaller gasification units each suited to a particular fraction of the coal feed, such a combination is likely to have increased costs and a lower efficiency. A more elegant approach is to develop a combination gasifier which can directly accept coal of various size ranges.

British Gas is now initiating the development of such a process, called the Composite Gasifier, as a logical extension of the slagging gasifier. The reactor consists essentially of a pressurized entrained-flow slagging gasifier for coal fines coupled in a proprietary manner in series with a lump coal slagging gasifier. This utilizes the large sensible heat content of the hot gas leaving the entrained stage in a highly efficient manner to support the endothermic gasification reactions in the lump coal section, while minimizing the overall oxygen consumption of the two stages. The result would be a gasifier capable of handling a greatly increased content of fines in the feed coal at only a very small penalty in efficiency and process costs; incremental costs are likely to be lower than the costs of the alternatives of marketing surplus coal fines or of crushing all the coal and gasifying it in a conventional single-stage entrained-flow process.

The R&D Working Party of the Coal Industry Tripartite Group examined a number of proposals for new coal-based processes and recommended in 1978 that the composite gasifier was worthy of support. Since then British Gas has carried out a comparative evaluation of several conceptual schemes for producing SNG from run-of-mine coal, with the conclusion that the Composite Gsifier was a cost-effective option. A major design study of a large facility which will allow experimental data on the composite and other gasifier systems to be obtained was completed in 1979.

2.3.5.9 The HCM Process [EL]

Owing to the high temperature and high steam decompositions achieved in the British Gas/Lurgi Slagging gasifier coupled with the low steam content in the slagging gasifier gasification zone, gasifier product gases contain very high levels of carbon monoxide, and low levels of carbon dioxide.

Rather than employ separate crude gas shift and methanation stages as in the conventional Lurgi route, direct steam-consuming methane synthesis may be carried out in a single reactor. This concept has been developed by British Gas into a proprietary methane synthesis process known as the HCM (high carbon monoxide) process, specifically designed to exploit the characteristics of slagging gasifier gas.

In the HCM methane synthesis step purified synthesis gas flows up through a packed bed saturator and picks up water vapor from a downward flowing stream of hot water. The recirculating water stream is heated by heat exchange with hot gas streams in the methanation stage, and perhaps in the crude gas cooling system on the outlet of the slagging gasifier. Thus, the necessary net process steam for team-consuming methane synthesis:

$$4CO + 2H_2O = CH_4 + 3CO_2$$

is generated from low grade process heat, which is one of the main reasons for the high efficiency of the HCM route to SNG. The saturated gas then enters a series of adiabatic methane synthesis stages, in which reaction temperatrures are controlled by cooling and recirculating product gas, and by by-passing part of the feed gas around the first stage. Methanation is completed in a third reactor. The product gas is cooled and subjected to carbon dioxide removal and drying, to yield an SNG with H_2 and CO content of less than 2 and 0.1%, respectively. Although the HCM process has not been commercially demonstrated, laboratory tests, large-scale CRG plant experience and the results of earlier trials on the synthesis of methane from CO-rich gases using steam addition to control carbon deposition give ample confidence in its successful application. A commercial scale demonstration is being planned by British Gas.

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