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GASIFICATION OF COAL

(Address to the Ottawa Chapter of the Canadian Institute of Energy, Rideau Club, Ottawa, January 31, 1979)

by

D.A. Reeve

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by

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GASIFICATION OF COAL

The Gasification of Coal! - after a few martinis and a good lunch in such pleasant surroundings such a title seems a good recipe for a snooze. However, I perceive that I am addressing a keen bunch, and I shall attribute any snores to my style rather than the content of my remarks. To set you at ease a little further, I intend to take some poetic license with title of my talk because of Canada's fortunate position of having a continued availability of natural gas at acceptable prices. A catalogue of developed and developing coal gasification processes with a discussion of kinetic and thermodynamic considerations I think would be inappropriate today but perhaps I could take one minute to outline CANMET's role in the development of coal conversion technology in Canada and I would thank you for this opportunity to address an Ottawa group in an area in which I am very interested.

CANMET, the Canada Centre for Mineral and Energy Technology, is one of the R & D arms of the Science and Technology Sector of the Department of Energy, Mines and Resources. It is a large Branch by present-day standards, split very roughly 50/50 into Minerals and Energy Research Programs. Resources for the latter, for which I am responsible, are 334 person years in 1979/80 and $15.5 million. On the Energy side, our R & D projects fall into the general commodity areas of oil and gas (heavy oils and tar sands, rather than conventional), coal, nuclear, renewables energy sources, transportation, and energy conservation. Following the Arab oil embargo of late 1973 and consistent with the government's contracting-out policy, a significant energy R & D contracting-out program was established in CANMET and just over $1 million of these funds was earmarked for coal conversion.

Thus our 50 percent shared-with-industry coal conversion program was launched to participate with Canadian companies in investigating the potential for implementing established and emerging coal conversion technologies within their operations. For our part, these studies have been useful in defining our own in-house R & D program, in providing comparative fuel cost data to assist the Energy Policy Sector of EMR in preparing energy supply strategies to meet new demands, and in giving us a sound base for proposing a possible multi-million dollar demonstration program in coal utilization.

Included in the term "coal utilization" are the technologies of gasification, liquefaction and combustion but gasification runs like a thread through the latter two. If one disregards (as one really can't) developments in the United States to develop substitute natural gas producing processes, it is true to make the general statement that coal gasification technology has been developed, with the exception of such things as lock-hopper feeding of caking coals, some of which are the subject of R & D agreements between nations participating in the International Energy Agency.

Now that I have homed in on coal gasification technology per se, let me become technical for a few minutes before spreading out again to examine where this technology fits into the Canadian context.

Coal gasification involves the reaction of coal with gasifying media to yield a gaseous product that can be used either as a clean source of energy or as a raw material for chemical synthesis. Gasification processes can be classified by the gasifying medium (oxygen or air, steam, hydrogen, carbon dioxide), by the method of contacting reactants (fixed bed, fluidized bed, entrained bed), by the flow of reactants (cocurrent, countercurrent), by the operating pressure (normal or elevated), by the condition of residue removed (dry ash, slagging), and by the method of supplying the heat (internal or external).

When an air-steam mixture is used to gasify the coal, the heating value of the product gas is rather low, 130-190 Btu/ft^3 (1.2 - 1.7 million calories/m^3), because of the diluting effect of the nitrogen in the air. This low-Btu gas is suitable for use as an energy source only near its point of production because its low heat content makes it uneconomical to transmit long distances. However, as I shall return to later, this is Canada's most attractive option as it can be utilized in a combined-cycle power plant to generate electricity at higher efficiency than today's conventional coal-fired systems, or as an industrial energy source for process heat and steam raising.

If oxygen is used rather than air in the gasification step, the fuel value of the gas is increased to 290-400 Btu/ft^3 (2.6 - 3.6 million calories/m^3) because of eliminating the nitrogen. Such gas can be used to advantage as an alternative to low-Btu gas within a distance of, say, 40 km from the gasification plant itself. Medium-Btu gas can be upgraded to SNG at 1000 Btu/ft^3 (9 million calories/m^3) in a catalytic methanation step.

Returning to the classification of gasification processes, I shall mention a few recent developments according to the method of contacting reactants.

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Fixed bed processes offer the advantages of high thermal efficiency and carbon conversion with the disadvantages of requiring non-caking (agglomerating) and uniformly-sized coals. The best-known example of this type is the Lurgi gasifier.

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which operates under a pressure of 360 psi (2500 k Pa). A system has been developed to enable gasification of strongly-caking coals in the fixed-bed gasifier and a slagging Lurgi gasifier has been under development, with assistance from U.S. D.O.E. funding, by the British Gas Council at Westfield, Scotland. This process route is currently the number one strategy for the D.O.E., with COGAS (which also produces liquids) coming next. The slagging gasifier operates at higher temperatures (1400-1500^{o}C) and increases the gasifier capacity about four times. Construction of a small commercial plant for supplying gas to the West Midland distribution grid is underway at Solihull, Warwickshire, U.K.

In entrained or dilute-phase systems, reactants flow concurrently and fuel is gasified while suspended in the gas stream. The principal advantage of fully-entrained gasification processes is the ability to use highly-swelling and caking coals whilst disadvantages include a low fuel inventory in the reaction zone and high exit gas temperature. The best-known example of this system is the Koppers-Totzek gasifier, which operates at atmospheric pressure. Experience gained from development of the Koppers-Totzek system has been combined with the expertise of Shell (Shell Internationale Research Mij.) in high-pressure gasification of oil to commercialize the Shell-Koppers entrained-gasification process which operates under pressure. A 150 ton per day prototype plant has been constructed at the Harburg refinery of Deutsche Shell A.G., near Hamburg, W. Germany.

TRANSPARENCY NO. 3

The third gasification process type, fluidized bed, is intermediate between fixed bed and entrainment type processes. The principal advantages of fluidized bed gasification processes are the ability to tolerate variations in the quality of fuel during operation and high rates of heat transfer. Disadvantages include the limitation of fuel range by caking properties, reactivity and ash-fusion temperature. The best known example of this type is the Winkler gasifier, taking 0-10 mm coal feed and operating at normal pressure.

Rheinische Braunkohlenwerke A.G. of West Germany have extended the concept to the so-called "High-Temperature-Winkler" coal gasification process in which coal is gasified with oxygen and steam or air in a fluidized bed under pressure (up to 11 bar) and at increased temperatures (up to 1100^{o}C). A test plant (25 ton per day) has been erected and is in the start-up phase near Cologne to gasify brown coal to produce a low-Btu gas.

TRANSPARENCY NO. 4

As an extension to this, since 1975 Rheinbraun has been developing a process for hydrogasification of coal in a fluidized bed in a test plant near Bonn to produce a synthetic natural gas.

Having now put you into the picture about gasification process options, or refreshed the memories of those of you who are close to the technology, let me now turn my attention to the situation as it seems to exist today in Canada. The comment has been made to me recently, more than once, that because of the predicted availability of frontier gas for a long time to come, not to mention the extensive newly-discovered "tight" gas reserves of the western Cordilliera, coal gasification is passé. This view of course arises from the simplistic approach that coal gasification is only good for making pipeline-quality gas (1000 Btu/ft^3), although comparative fuel costs will always be necessary to ascertain if frontier natural gas supplies at southern markets retain a cost advantage over gas from local coal. Nevertheless, the coal resources available at locations where water and other factors are favourable suggest that up to about one trillion normal cubic metres of SNG could be produced, a quantity essentially the same as the present established reserves of natural gas in the Mackenzie Delta and other frontier regions. It is the technology of coal gasification to a low-Btu gas which is the black thread running through those technologies of highest priority in the now-accepted EMR Coal Utilization Strategy.

Before following this black thread, let us take a quick glimpse at the supply and anticipated demand side. The EMR coal resources and reserves estimates for 1976 show total resources of immediate interest (measured, indicated and inferred) to be 228,047 millions of short tons of coal in place. Current policy studies suggest the need for thermal coal for electrical power production to grow from 22.5 million (metric) tons in 1977 to about 95 million tons in 2000. Together with increased demands for coking coals both for home and abroad and an expected major diversification of coal into the production of synthetic fluid fuels, the total anticipated demand in the year 2000 may exceed 160 million tons, the current production being around 30.

Coupled with this increase in demand must not be forgotten the requirement to develop new technologies to extract the coal from its seam and put it in the feed hopper of the coal gasification plant. Whilst about 90 percent of low-rank and bituminous coals may be mined by established open-pit techniques, development of long-wall mining systems suited to the geological conditions of the Prairies is required. These low-rank coals may contain up to 50 percent of undesirable mineral matter, not to mention water, and coal preparation techniques developed for metallurgical coals may have to be modified. In spite of Canada's coal resources, only ten sites have been identified where sufficient coal is available (and not allocated to other uses) to support SNG plants generating about 8 million cubic metres of gas per day and requiring at least 5 million tons of bituminous coal equivalent per year (more for low-rank coal) for 30 years.

Returning now to the black thread, as just mentioned, significantly greater quantities of coal will be required for electrical power production, especially in western Canada.

At present, electricity is generated from thermal coals using steam turbines, the steam being raised from the combustion of pulverized coal. Some coals high in sulphur content may result in atmospheric emissions of greater than 1.2 lb SO_2/million Btu, probably requiring expensive flue gas desulphurization add-ons (FGD's). As well as obviating the sulphur dioxide problem, higher thermal efficiencies can be achieved by combined-cycle power generation. In the low-Btu coal gasification case, the gas is expanded in a gas turbine and waste heat used to generate steam for a steam turbine.

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Saskatchewan Power Corporation, with CANMET help, is investigating the feasibility of various low-Btu gasification processes (in the examples already mentioned) for a 150 MW generating station at Shaunavon. Since 1972, STEAG at Lünen, West Germany, has been operating a 170 MW combined-cycle plant using five Lurgi gasifiers operating at 20 bar pressure and a 96 MW steam turbine and 74 MW gas turbine.

In passing I should mention that as well as the low-Btu coal gasification combined-cycle case, B.C. Hydro is contemplating a 67 MW pressurized fluidized-bed combustion combined-cycle generating plant at Hat Creek, B.C., where a very large low-rank coal deposit has been found. A proposal has also been prepared (which is dependent upon provincial power utility company backing) for a techno-economic feasibility study of low-Btu gasification combined-cycle power generation in New Brunswick and Nova Scotia. However, a sequential series of atmospheric fluidized-bed combustion coal-to-electricity plants is planned for eastern Canada as well as interfuel substitution effected by coal-oil slurry combustion to raise steam for electricity generation.

Let us now follow the black thread to liquid fuels from coal. Interest in processes which produce liquids from coal has grown recently because of the perceived need to ensure the supply of energy in a form suitable for transportation across Canada and because under the special circumstances of western Canada, there are indications that liquids produced from coal could be competitive with oil sands extraction processes. Our program at CANMET in this area is expanding rapidly and Alberta is expected to mount a major effort soon with funding through the Alberta-Canada Energy Resources Research Fund (ACERRF).

The conversion of coal into liquid products involves increasing the proportion of hydrogen to carbon either by synthesis or degradation. In the synthesis route, yielding paraffinic-type products, the first process step is low-Btu coal gasification (Lurgi) followed by conversion of the synthesis gas by the Fischer-Tropsch catalytic process into a wide range of products such as hydrocarbons, as well as alcohols and aldehydes. The coal liquefaction plant built in 1955 in South Africa at Sasolburg using gasification of high-ash coal and Fischer-Tropsch synthesis has been well-documented. Schematically, the process route is shown in the next transparency.

TRANSPARENCY NO. 6

side-by-side with the degradation route, which produces mainly coal liquids with molecular ring structures (aromatic). A new SASOL oil-from-coal plant is now under construction in the Transvaal, the Lurgi gasifier being seen on the left in the next transparency. However, the economic viability of coal liquefaction in Canada may rest on a supply of hydrogen from reforming of the natural gas available at acceptable prices.

TRANSPARENCY NO. 7

I want to finish my talk by referring again to the gasification aspects of the CANMET 50 percent shared-with-industry coal conversion program as well as the in-house program, but before that I should like to complete the catalogue of coal gasification in Canada.

Underground coal gasification, which I myself prefer to regard as an extrapolation of automated underground mining, has been looked into through a series of cooperative industry/government trials (under ACERRF) managed by the Research Council of Alberta and cooperation with U.S. efforts in Wyoming has been established. Consideration has also been given to methane drainage (really coal seam degasification) possibilities in Alberta and Nova Scotia.

Finally in the catalogue must be mentioned the carbonization of metallurgical cokes to make iron blast-furnace grade coke. Coking is essentially a gasification process in which secondary cracking reactions are allowed to occur yielding a major portion of complex condensed ring structures, solid coke. In the context of iron and steel

TRANSPARENCY NO. 8

making should be mentioned the use of reducing gases from the gasification of coal applied to the direct reduction of iron ores although such an application seems unlikely in Canada's booming steel industry (in comparison with elsewhere).

Our contracting out program (50 percent shared with industry) has included engineering studies of processes that produce medium-energy content gases from Canadian coals for a number of purposes and for application at several sites. In cooperation with the Department of Energy and Natural Resources (ENR) of the Province of Alberta, we have shared in a program with the Shell/Pan Canadian group of companies to assess the production of fuel gas from coal in the Edmonton/Fort Saskatchewan region of Alberta for a number of industrial applications in that region. Trials of local coals in the Lurgi slagging gasifier demonstration plant at Westfield, Scotland, are in course of negotiation. The Pan Canadian group, in cooperation with the Province of Alberta, is also conducting similar studies applicable to the Medicine Hat area.

Somewhat similar studies directed towards the synthesis of such related products as ammonia and methanol have also been conducted in cooperation with Algas Resources Ltd. Of the 21 coal conversion processes studied, none indicated a positive discounted cash flow for SNG at current prices but the production of liquids appeared somewhat more attractive.

The Algas, Shell/Pan Canadian, and Saskatchewan Power Corporation (mentioned previously) studies have all provided the capital costs for plant associated with gasifying coal; data* are tabulated in the Appendix to my written text but I do not intend to confuse you with a bunch of cost figures at this stage. Suffice it to say, the manufacture of low-Btu fuel gas was generally attractive for: (i) the provision of heat energy to increase yield in oil recovery and refining, (ii) the provision of heat energy for recovery and upgrading of heavy crudes and (iii) provision of heat energy for separation and upgrading of oil sand bitumens. Processes resulting in hydrogen production were relatively expensive, underlining again the Canadian advantage of cheap hydrogen from natural gas.

Within CANMET and in support of the study of low- and medium-Btu gasification processes, experimental facilities are

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* Read, P.J., "The Canadian Coal Conversion Program, The First Year", Symposium on Coal Refining, Edmonton, Alberta, Proceedings p. 273; Alberta Research Council Information Series 85, 1978.

being established to evaluate Canadian coals in a fixed-bed reactor (25 mm ID), a high-pressure thermobalance reactor (20 g.), and a continuous gasifier (100 mm ID). Construction of a fixed-bed reactor is also being funded at Carleton University for similar evaluation studies and a study of the gasification of western Canadian caking coals is being funded at the University of British Columbia using a spouted-bed reactor (300 mm ID). Finally, funding has been provided to the B.C. Research Council for studying the gasification of coal washery plant middlings in a fluidized-bed gasification process of their design. The study is directed towards providing hot gases for drying coal after wet preparation operations.

In conclusion, whilst at present prices the gasification of coal does not seem to be attractive for SNG production, it is an important process step in new energy technologies which will be required to reduce Canada's dependence on imported oil, including low-Btu gasification-combined cycle electricity generation and possibly coal liquefaction via the synthesis route. The EMR (CANMET) shared-cost contracting-out program, now about to start year four, has identified capital and fuel costs necessary for policy decisions, helped to shape an in-house program including more academic but process-oriented contracted-out spin-off studies and, perhaps most importantly, has provided the basis for a proposed multi-million dollar coal utilization demonstration-plant program.

The role which fuels from coal will play in Canada's total interfuel substitution picture and with respect to such other alternate-to-oil energy sources as nuclear and renewables awaits further Energy Policy developments, but the future for coal gasification technologies in Canada does appear to be hopeful.

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(29th January, 1979)

APPENDIX

TABLE III COMPARISON OF CAPITAL COSTS (IN 1985 $) FOR CONVERSION PLANTS

PROCESS	FUEL TYPE	HHV (MJ/kg or /M³)	QUANTITY/DAY (10^6XM³ or TONNES)	ENERGY/DAY TJ	PLANT (CAPITAL(X10^6$)	COST/POWER ($M/TJ/day)	$/GJ
FISCHER-TROPSCH-KELLOGG	SYNCRUDE	51	1 300	66	1 274	19,22	6.41
LURGI	SNG	38	0,8	32	414	12,95	4.32
LURGI	SNG	38	1,7	64	816	12,75	4 25
SYNTHANE	SNG	38	3,4	129	1 587	12,32	4.11
KOPPERS-TOTZEK	METHANOL	23	907	21	251	12,18	4.06
LURGI	SNG	38	3,4	128	1 471	11,49	3.83
LURGI	METHANOL	23	2 000	45	518	11,42	3.81
KOPPERS-TOTZEK	FUEL GAS	11	2,8	32	363	11,37	3.79
LURGI	FUEL GAS	12	2,6	32	361	11,28	3.76
KOPPERS TOTZEK	FUEL GAS	11	5,7	64	696	10,87	3.62
KOPPERS-TOTZEK	FUEL GAS	12	5,2	64	690	10,78	3.59
KOPPERS-TOTZEK	HYDROGEN	13	2,2	28	298	10,72	3.57
LURGI	FUEL GAS	18	1,8	32	330	10,30	3.43
WINKLER (PRESSURIZED)	METHANOL	23	2 000	45	465	10,25	3.42
LURGI	FUEL GAS	18	3,6	64	646	10,10	3.37
IGT STEAM-IRON	HYDROGEN	12	2,1	26	256	10,01	3.34
KOPPERS-TOTZEK	FUEL GAS	11	11,1	128	1 277	9,98	3.33
KOPPERS TOTZEK	FUEL GAS	12	10,4	128	1 266	9,90	3.30
KOPPERS TOTZEK	FUEL GAS	12	2,6	32	311	9,71	3.24
SYNTHANE	SNG	38	6,8	257	2 499	9,71	3.23
LURGI	FUEL GAS	12	5,3	64	608	9,51	3.17
LURGI	FUEL GAS	18	7,2	128	1 157	9,04	3.01
LURGI	SNG	37	3,4	124	1 090	8,77	2.92
BIGAS	SNG	37	3,4	125	1 091	8,70	2.90
LURGI	FUEL GAS	12	10,6	128	1 092	8,53	2.84
CO_2 ACCEPTOR	SNG	37	3,4	126	1 008	8,00	2.67
COGAS	SNG	38	6,2	237	1 794	7,56	2.52
HYGAS	SNG	37	3,4	125	908	7,24	2.41
LURGI-RUHRGAS	FUEL GAS	5	15,0	78	558	7,14	2.38
BIGAS	SNG	37	6,7	250	1 742	6,96	2 32
LURGI	SNG	37	6,7	249	1 730	6,96	2.32
KOPPERS-TOTZEK	METHANOL	23	1 905	43	274	6,34	2.11
LURGI BGC	SNG	37	6,7	249	1 571	6,32	2.11
CO_2 ACCEPTOR	SNG	37	6,9	252	1 592	6,31	2.10
KOPPERS TOTZEK	METHANOL	23	15 000	340	2 125	6,26	2.09
KOPPERS TOTZEK	METHANOL	23	4 500	103	627	6,09	2.03
HYDRANE	SNG	38	3,4	129	[illegible]	6,00	2.00
LURGI RUHR-100	SNG	37	3,4	124	[illegible]	5,89	1.96
HYGAS	SNG	37	6,7	251	1 448	5,76	1.92
H-COAL	FUEL OIL	45	6 800	309	1 757	[illegible]	1.89
LURGI	METHANOL	23	10 200	230	1 212	5,25	1.75
SYNTHOIL	FUEL OIL	40	8 300	332	1 698	5,11	1.70
WINKLER	METHANOL	23	4 500	103	524	5,09	1.70
HYDRANE	SNG	38	6,8	257	1 259	4,89	1.63
GULF	SRC II	40	7 400	339*	1 654	4,88	1.63
LURGI-RUHR-100	SNG	37	6,7	249	1 186	4,77	1.59
LUMMUS CFFC	FUEL OIL	39	8 900	349*	1 588	4,55	1.52
STEAG-IGF	SYNCRUDE	51	7 300	373	1 605	4,30	1.43
COMBUSTION ENGINEERING	FUEL GAS	5	3,1	16	66	4,18	1.39
LURGI	FUEL GAS	16	10,0	159	504	3,18	1.06
IGT U-GAS	FUEL GAS	5	11,5	60	127	2,10	0.70
WELLMAN-GALUSHA	FUEL GAS	6	2,3	14	26	1,88	0.62

* INCLUDES SALEABLE BY-PRODUCT FUELS INCLUDING SNG