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RESEARCH ON THE COAL BENEATH THE NETHERLANDS

IV – NEW PRODUCTION METHODS

1. UNDERGROUND GASIFICATION OF COAL, PAST AND PRESENT[1]

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ABSTRACT

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The history of underground coal gasification and the achievements in the USSR and the USA are briefly reviewed. The different conditions under which coal occurs in Western Europe and The Netherlands are indicated and field tests in Belgium and France are mentioned. In The Netherlands research is mainly undertaken by the Delft University of Technology.

BACKGROUND AND EARLY HISTORY

For several centuries coal has been used as a solid fuel and mined above as well as underground in Europe. In 1784, however, a Dutchman, Jan Pieter Minckelers (born 1748 in Maastricht), then professor in Leuven, successfully gasified coal and even illuminated his classroom using the gas. Eight years later Murdoch in Cornwall invented the process anew, which led in England to an industrial application. From there gasworks were introduced into continental Europe around 1825.

More than a century ago men asked themselves already if the trouble of digging coal, carrying it to the surface and transporting it to gasworks could be avoided by gasifying it underground and piping the gas to its destination above ground. In 1868 Sir William Siemens put a proposal to this effect before the Chemical Society in London. In 1912 another chemist Sir William Ramsey started field tests in County Durham in the N of England. The war of 1914 put an end to this activity and Ramsey died in 1916.

Lenin, living at that time in Switzerland, was apparently aware of Ramsey's efforts, which were considered encouraging. He published an article in Pravda, visualizing a bright future for in-situ coal gasification under a socialist regime. He predicted not only the liberation of 'millions of miners' from their unhealthy labour, but also shortening of working hours and a lowering of the cost of electricity to one fifth or one tenth of the current level. Lenin died in 1924, but his article is believed to have led the Russians to undertake research on the subject from 1930 onward under the auspices of the Russian Academy of Sciences.

RUSSIAN WORK AND RESULTS

The idea seemed simple. A gallery or drift in a coalseam was closed off by a wall on two sides, except for an air inlet on one end and a gas outlet at the other end (Fig. 1). While air was blown in on one side the coal in the gallery was ignited. The resultant gas appeared incombustible. The coal had burned completely forming carbon dioxide ($C + O_2 = CO_2$) and the hydrogen-bearing components in the coal had produced water ($H_2 + O = H_2O$). The amount of oxygen had been clearly too abundant in relation to the exposed surface of coal. Smaller reaction chambers, such as boreholes gave better results, because after free oxygen was exhausted the hot gases could react further with coal, forming carbon monoxide and hydrogen, both combustible gases ($CO_2 + C = 2\,CO$; $H_2O + C = H_2 + CO$).

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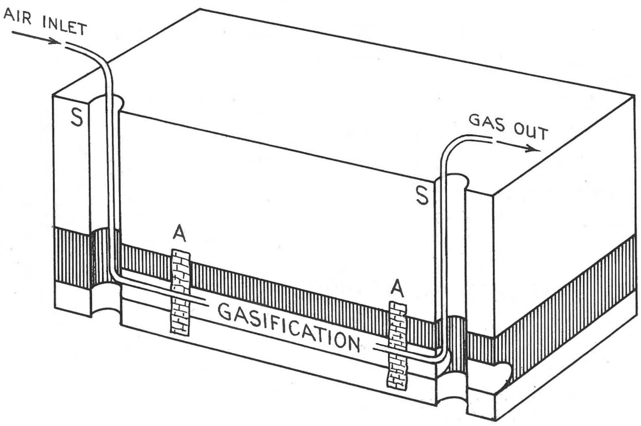

Fig. 1
Principle of gasification of a coal seam in a closed off galery. A, closing wall; S, shaft.

Thus two critical aspects already became apparent: (1) the shape of the reaction chamber, and (2) the control of the chemical processes to optimise the quality of the gas. The Russians, after switching from drifts to boreholes, drilled the latter at first from galleries in the seam, but discovered later that drilling could be performed from the surface into dipping coal beds. This led to drilling vertically down even into flat seams. In 1940 they linked successfully two vertical holes 25 m apart by blowing air through the somewhat permeable brown coal layer, igniting the coal in the receiving hole and burning an airpassage open by 'reverse combustion'. Thus when the second world war broke out the Russians had already developed a method to gasify rather flat coalseams not only with deviated, but also with vertical boreholes. Figure 2, a schematic drawing of a small section of a prewar project illustrates the advanced nature of developments at that time. The basic principles of present procedures had been established by the Russians: vertically drilled holes and linking those by retrocombustion.

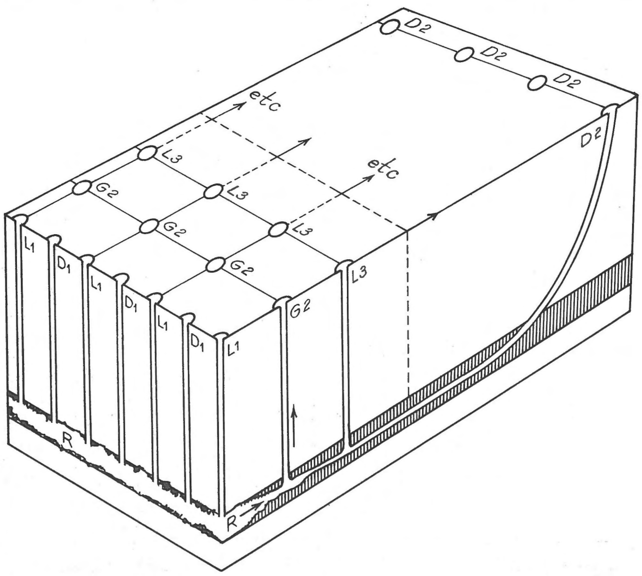

Fig. 2
Schematic sketch of part of a Russian prewar project at Kholmogorsk
L1 Borings for air inlet.
D1 Supplementary borings for initiating linkage in the first row.
D2 Deviated borings to obtain air-passage in the direction of the progression of the reaction front.
G2 Boring for gas production.
L3 Air injection for improving air passage towards G2.
R Reaction chamber.

The work was taken up again after the war. Difficulties with groundwater, subsidence, leakage, poor quality of the gas etc. were more or less solved. During the sixties work slackened to be speeded up again after 1973.

At the moment coal is being exploited by Underground Coal Gasification (UCG) at a few localities. As an example we may mention Angrensk near Tashkent. A lignite seam 2 to 15 m thick, between 40 and 200 m deep produces 7.2 milliard m^3 gas per year with a caloric value of 3-4 MJ/m^3. Two thirds of the coal are being gasified and the energy content of the gas represents about 65% of that of the consumed coal, so that the overall efficiency is approximately 40 to 45%, which compares with about 30% for primary oil recovery. The gas is being used for power generation.

ACHIEVEMENTS IN THE U.S.A.

After the second world war the demand for energy rapidly increased. This caused much interest a.o. in the possibility of UCG, known to have been a prewar research topic in Russia. The Bureau of Mines, later the Department of Energy (DOE) promoted and carried out research in the fifties with the same results as the Russians. However, they introduced a technique derived from the oil industry. Linking was brought about in practically impermeable coal-seams by applying 'hydraulic fracturing' or 'sandfracking'. A high pressure is applied to the liquid in a vertical borehole opposite a seam. The increased horizontal stress causes in principle fine radial cracks and opens existing ones. The fluid, a suspension of fine sand, is pressed into the cracks, which are kept open by the sand grains left behind after the pressure is reduced to normal. By applying this technique in consecutive borings the cracks of one may reach those of the next. Thus sufficient permeability can be created to allow air passage for initiating a primary channel by retro-combustion. Unfortunately the range of fracking is limited and thus wellspacing restricted accordingly to roughly 40-50 m.

After an interruption from 1959 onward, research was reactivated again in 1972. All in all 17 fieldtests have been conducted in W.Virginia and Wyoming, 12 under the auspices of DOE, and 5 by industry. Different types of coal have been tested, swelling and non-swelling bituminous coals, coals with different ash and sulphur contents and of different rank. There were no failures. Seams were in general thick and shallow: 7 to 10 m and not deeper than 100 m. The thinnest and deepest coal-layer gasified was 2 m thick at a depth of 275 m in Princetown (W.Va.).

In total about 30,000 tons of coal have been gasified. The average duration of each gasification amounted to 45 days, the longest to 197 and the shortest to one day only. Various gasifiers were tried giving different qualities of product gas with the following approximate caloric values:

air	3 MJ/m^3
oxygen	7 MJ/m^3
oxygen and steam	10 MJ/m^3

These figures for caloric value compare with a figure of 35 MJ/m^3 for Slochteren natural gas.

The cost of the product gas is expected to be comparable to other energy carriers with potential for improvement towards a competitive cost level. Reportedly ARCO is planning to initiate a pilot test using oxygen as gasifier in the Powder River Basin (Wyo.) in the hope of establishing commerciality by 1990. They believe UCG-gas to have certain advantages over other kinds of SNG (Substitute Natural Gas). With present coal demand it seems more attractive to produce 100% of a thick coal layer at say 100 m depth by opencast mining than to convert 40% of it into a low or medium energy gas. Thus interest in the USA to further develop UCG is waning and being restricted towards application under special conditions.

CONCLUSIONS REGARDING USSR AND USA RESULTS

Experience in the USSR and the USA shows the technical feasibility of UCG on thick, relatively shallow seams. The distance between vertical boreholes is limited to approximately 40-50 m. The quality of the product gas depends on the thickness of the seam and the composition of the gasifier. At best a low to middle caloric gas is obtained. A sizeable surface area is needed to accomodate the shifting network of borings. Advantages are the scale independance of the method and the much reduced environmental impact as compared to other mining methods, the borings being removed after a limited time and all ash remaining underground.

WESTERN EUROPE

Except for certain lignite or brown coal fields, coal occurs under essentially different conditions in Europe as compared to the USA. A fair to good coal seam measures not more than 1 to 2 m, and in unmined area's they occur at least at a depth of 800 m to 1000 m, deeper coals being in principle available to UCG. In some instances these conditions may have a positive effect, e.g.: (1) with increased depth a higher gas pressure will apply, ensuring greater density and better contact with the coal, resulting probably in an improved quality of the gas; (2) because the bedrock is denser losses into adjacent formations might be reduced.

Tthe following unfavourable conditions may be mentioned: (1) the reduced thickness of the seams adversily affects the gas quality; (2) thin seams cause a considerable reduction of the quantity of coal gasified per vertical well on the basis of the US well spacing; (3) since the drilling depth is roughly 10 times larger than in the USA, a vertical drilling pattern becomes economically prohibitive under European conditions; (4) the mechanical behaviour of cavities and reaction chambers at depth under high temperatures and stresses is insufficiently known.

Consequently it will be clear that USSR and USA results cannot be applied directly to W.European conditions. A viable technology still has to be worked out, while the question of its possible commercialisation is still academic.

After initial experiments in the U.K., Belgium, and France (Morocco) in the fifties, research including field tests has been taken up again in the seventies in Belgium, Germany, and France. Activities in the U.K. are presently limited to theoretical studies.

The Belgians spurred by their lack of sufficient primary energy resources are most active. In 1976 they combined their efforts by treaty with those of the Federal Republic of Germany. After much preparatory work involving some 12 institutions and universities a field test lasting several years is being undertaken, at a budgetted cost of some DM 100 million. The EEC bears 40% of the costs, Belgium and Germany 30% each. At Thulin, W of Mons in Belgium, 4 vertical holes, 35 m apart have been drilled to a depth of 860 m. The thickest seam measures 1.70 m. After having studied the in-situ permeability of the coal, tests were carried out to effect linking by hydraulic fracking. The extremely low permeability improved at pressures close to the lithostatic pressure. At present tests with ignited coal for creating a channel from one hole to the next by retro-combustion are underway. In France three major institutions combined their efforts in 1977: Charbonnages de France, Gaz de France, and the Institut Français du Pétrole (IFP). Later the Bureau de Recherche Géologique et Minière (BRGM) joined this club. After preparatory studies they carried out experiments in a closed and abandoned coal mine near Bruay en Artois. From the deepest level, 1000 m below the surface, they drilled two holes 65 m apart to a 1.20 m thick seam at -1170 m. Fracking appeared possible at pressures ranging between 300 and 500 bar, about lithostatic pressure, and so was linking. They experienced difficulties with auto-combustion of the coal using normal air. With a mixture containing only 5% oxygen they succeeded in linking the wells by retro-combustion. Gasification was brought about. The field experiments are continuing in Lorraine with a different type of coal, also in an abandoned mine. After that they plan a test drilled entirely from the surface. An initial phase of the work, up to 1980 involved an expenditure of FF 30 million; the present phase will cost some FF 125 million. EEG again bears 40% of the expenditure.

DIFFERENCES IN PRIORITY

Differences in policy adopted vis à vis this type of long term research in various countries can be explained easily. The potentialities of USA domestic oil and gas production have improved since the end of domestic crude price control. There is no dearth of coal reserves and the economy of recovering shallow coal in the midwest by open-cast mining lessens the inclination to invest into research for UCG. The priority of this type of research has thus been lowered since 1980. Still the DOE apparently plans to support an industrial interest directed to special conditions. The UK's energy needs are entirely covered by domestic resources till the end of the Century. Understandably this country does not give a high priority to UCG research. Belgium, however, imports all its energy carriers and hopes to cover only 11% of its requirements from its own coal resources by the beginning of next century. At that time the Federal Republic of Germany, hoping to increase domestic coal production from 120 to 150 MTCE/year (Million Ton Coal Equivalent/year) expects to import an additional 40 MTCE/year of coal, while the amount of unproducible coal is estimated at 20 000 to 100 000 million tons. France, having very limited coal resources foresees at the end of the century a production of 10 million tons/year. They expect an import of between 26 and 100 million tons/year. 2000 million tons of coal cannot be extracted conventionally. If gasified, this would represent a quantity equal to twice the present gas reserves of the country. It is clear that the three last mentioned countries adopt a positive attitude towards long term research aimed at achieving UCG.

THE NETHERLANDS POSITION

The need for coal in The Netherlands, possibly some 30 million tons annually by the year 2000, will have to be covered by imports. The size of our unminable resources is comparable to that of Germany. Depending on imports by the end of the Century for roughly two thirds of its total energy requirements, the Dutch situation is comparable to that of Belgium, Germany and France. Thus it is in the Dutch national interest to join with these countries in a sustained long term effort, searching for ways and means to extract the energy content, especially of thin and deep coal seams.

The positive attitude adopted by the Netherlands government in 1980/81 towards such research opens that possibility. A serious backlog exists, however, in comparison with neighbouring countries. Present work must be stimulated and new projects initiated, while trying to avoid duplicating results obtained elsewhere. After gaining enough experience and knowledge The Netherlands will one day become an accepted partner in a W.European working community, able to participate actively in joint projects. In the absence of operating collieries and their research institutions in The Netherlands the Mining Faculty of the Delft University of Technology should develop towards a future centre of expert knowledge of coal and its extraction.