Section 3

THE PROGRAM ON NEW COAL CONVERSION TECHNOLOGIES OF THE FEDERAL REPUBLIC OF GERMANY

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INTRODUCTION

In the course of this Conference it will be reported on important German coal conversion development projects. Most of these projects are funded by the Federal Government. By way of introduction, I would like to give an overview of this field of technology development, especially those parts that are not presented to this Conference and also mention some of the conditions and constraints set by energy policy.

Hard coal and lignite are the only significant domestic energy sources of the Federal Republic of Germany. The hard coal deposits are unfavorable from a geological viewpoint so that mining costs are very high. The technically minable hard coal reserves are estimated at more than 20 billion tons. In addition, there are lignite reserves of 35 billion tons which are economically minable.

In 1955, coal accounted for 97% of the Federal Republic's energy supply; in 1975, however, its share had gone down to less than 30%.

In the Federal Government's energy program, coal was given priority over all other primary energy sources. The productive capacity of the mining industry was fixed at 90 million tons of hard coal per year. To maintain this capacity, extensive governmental support measures have been, and will be, required, which in the past few years amounted to about $3.3 billion U.S. each year. The 130 million tons of lignite per year are mined economically in open-cast pits.

The Federal Government's energy policy has strongly reduced the use of mineral oil for power generation. The large proportion of coal used as a primary energy source for electricity generation accounted for the fact that the Federal Republic's electricity supply was practically not affected by the oil crisis in 1973-1974.

Early this year, legislation was passed in order to increase the use of hard coal in power generation from the present 33 million tons per year to 45-50 million tons per year by 1995. Of the extracted lignite, 85% is used in power stations.

The Federal Government's outline program on energy research for 1974-1977 stimulated the broad-based development of advanced technologies for the utilization of coal. The program, which covers all nonnuclear energy research, was in essence a coal research program. About 60% of the program's funds were earmarked for coal technologies.

This emphasis on coal remained unchanged in the updated version of the program, now entitled "Energy Research and Energy Technologies Program 1977-1980," under which, in 1980, more than $300 million U.S. will be provided for nonnuclear energy research.

The year 1974 marked the beginning of the development of new technologies for coal conversion. In the Federal Republic, the production of gas and liquid products from coal was so unprofitable in the past years that the initiative of private companies did not suffice to develop and use these technologies. This is why the Federal Ministry for Research and Technology provided funds--so far amounting to about $350 million U.S.--for development work in the fields of coal gasification and coal liquefaction.

The resulting progress of new coal conversion technologies on the one hand and the most recent price escalations for mineral oil and natural gas on the other hand made it possible and necessary to launch the industrial demonstration and commercialization of technologies for the production of synthetic fuels. As a consequence, on 30 January 1980, the Federal Government presented a program for the large-scale demonstration of coal gasification and liquefaction technologies.

COAL GASIFICATION

The coal gasification projects promoted by the Federal Ministry for Research and Technology are based on conventional technologies. Their further development aims above all at:

- Increasing efficiency
- Operation under pressure

- Suitability of the technologies for as many coal grades as possible
- Reduction of the cost by 20% and more

The known processes are being improved by means of advanced engineering and adapted to present requirements of the energy-supplying industry.

The Federal Government supports four processes of conventional coal gasification:

- The Lurgi pressurized gasification (Ruhr 100)
- The Texaco Process
- The Saarberg-Otto Process
- The high-temperature Winkler process

Pilot plants for the first three processes were designed for the use of pit coal, and the Winkler-process pilot plant was designed for lignite. These plants are in operation. Coal throughput amounts to up to 10 tons per hour. Except in the case of the Lurgi gasifier, which produces a gas rich in methane, the end product is a synthesis gas.

The Shell-Koppers pilot plant for synthesis gas is the only pilot plant built and operated without governmental funds. A smaller pilot plant for the production of synthesis gas from anthracite or coal with a high ash content is funded by a state government.

Under the project called "Nuclear Process Heat Prototype Plant," two independent processes for coal gasification are being developed: hydrogasification and steam gasification. These two processes have been tested for several years on pilot plants with throughputs of 0.1 and 0.2 tons of coal per hour.

The firms participating in this project aim at combining a 500-MW_{th} high-temperature nuclear reactor with a coal gasification plant. The nuclear reactor will supply process heat of 900°C, a temperature high enough for the gasification reaction.

In the case of steam gasification, nuclear heat is directly transferred to the fluidized bed via an intermediate helium loop and a heat exchanger which is situated in the reactor. The resulting product is a synthesis gas.

In the case of hydrogasification, hydrogen is used at the gasification agent. SNG and residual coke are the resulting gasification product. The hydrogen required is produced by splitting some of the methane. Via methane splitting, nuclear heat is fed into the gasification process. The process can also be operated conventionally; hydrogen is then obtained by gasifying the residual coke. A pilot plant for a throughput of 15 t/h of lignite is under construction.

UNDERGROUND GASIFICATION

In order to be able to use the coal which cannot be mined, development work is under way for the underground gasification of coal. The coal seams to be gasified are made accessible from the ground by a number of drillings. Some drilling holes are used to inject the gasification agent, the others, to remove the product gas. Unlike efforts in the United States aiming at the exploitation of near-surface seams, European development activities aim at exploiting coal seams occurring at great depths, i.e., depths of more than 1500 m.

The development of this process is still in its initial stage. Autoclave experiments are carried out to investigate the prospects of pressure change gasification. The pressure with which the gasification agent is pressed down the drilling hole ranges from 30 to 60 bars. It is expected that a variation of the pressure applied will improve the flow of the gases and increase the gas yield. One important aim of the development work is to obtain a product gas with a maximum heating value. In the light of past experience, it is, however, probable that the heating value will be too low to justify transport of the gas. Hence, the gas will be used in a power plant near the exploited coal deposit.

Underground gasification development work is going on at several sites in the Federal Republic of Germany. For the execution of a field experiment, an agreement was concluded between the Federal Republic of Germany and Belgium. The first joint field experiment will be carried out at a coal deposit in Belgium. A German-Belgian project group took up work at Liege on 1 April 1979.

COAL LIQUEFACTION

There are two different ways of converting coal to liquid products: synthesis or direct hydrogenation. In the synthesization processes, coal is first broken down into its basic components, carbon monoxide and hydrogen, and this synthesis gas is then resynthesized into liquid hydrocarbons.

The most simple method is that of synthesizing methanol, which is an established technique without any technical problems. A large-scale experiment is at present under way in the Federal Republic in order to test a new motor car fuel, called M 15, under practical conditions. M 15 stands for a mixture of 85% gasoline and 15% methanol. If methanol is to be used as a motor car fuel, however, it is necessary to alter the filling stations.

Methanol can be converted to gasoline by means of the Mobil Process. The basic characteristics of the process are known. Installation of a pilot plant near Cologne under German-United States cooperation has just been started. The project is scheduled for a throughput of 0.5 t of methanol and will cost in all $35 million U.S.

In addition, efforts are being made to use zeolites in order to produce gasoline directly from synthesis gas. If experiments are successful, the intermediate step of producing methanol would no longer be required.

The Fischer-Tropsch Synthesis, in which a large number of complete hydrocarbons are synthesized, was applied in Germany on an industrial scale during the 1940s. Fuel production plants in South Africa still use this process today.

The end product of the synthesis is practically not affected by the properties of the feedstocks because they are completely converted by gasification. But the more complex equipment which is needed for synthesis probably involves higher costs and lower conversion efficiency as compared to direct hydrogenation. These are severe disadvantages in view of the high price of German coal.

Following initial detailed studies and laboratory work, activities to further develop the traditional Fischer-Tropsch Synthesis have meanwhile been limited to a small scale.

In direct hydrogenation, the coal molecules are split and hydrogen is added. The basic chemical structure of the coal used can partly be recognized in the products. The range of products can be influenced by varying the conditions of hydrogenation.

In 1943-1944, the capacity of all hydrogenation plants in Germany amounted to about 4 million tons of end products.

Today's hydrogenation processes have been developed from the IG Farben processes applied in these plants. The major advantage of the improved versions of this process is the removal of those components which are difficult to hydrogenate, but which can well be used to produce, in a pressurized gasifier, the hydrogen required. Since these components are removed, the reaction pressure can be reduced from 700 bars to 300 bars.

Two laboratory facilities for the hydrogenation of hard coal have been operated by Bergbau-Forschung in Essen and by Saarbergwerke for several years. On the basis of the results obtained in these facilities, Ruhrkohle and VEBA are building a pilot plant with a throughput of 200 t/d. Another smaller pilot plant with a throughput of 6 t/d built by the Saarbergwerke will be commissioned at the end of this year. The Rheinische Braunkohlenwerke operate a laboratory facility for the hydrogenation of lignite and are preparing a pilot plant project.

INTERNATIONAL COOPERATION

Since German coal is rather expensive, the Federal Republic of Germany made an early start on cooperation with countries where cheap coal deposits are available for liquefaction.

As early as 1974, a German group was offered an opportunity to participate in the preparatory work for the SRC-II demonstration plant of Gulf Oil Company in the United States. The process resembles that applied in German facilities.

Following the successful completion of preparatory activities, negotiations have led to a trilateral project for the construction and operation of the demonstration plant. The respective shares of the project partners are 50% for the United States and 25% each for the Federal Republic and Japan.

Another German industrial group cooperates with Australia in carrying out an engineering study for an industrial coal liquefaction plant. The financial cost is about $4.5 million U.S.

The liquefaction of coal on the site of the deposit itself offers a number of advantages. Oil produced from coal makes transport problems easier. If the liquefaction plant is built at a site where coal can be extracted at low cost, only the high-grade secondary energy has to be shipped. Ash and water of the raw coal need not be transported. The infrastructure for the oil transport is available; that for coal transport would, for the most part, have first to be provided and would in any case be more expensive.

It can be assumed that countries, especially the less-developed countries with large coal deposits, will be interested in liquefying their coal at home, thus achieving a higher GNP. Obviously, mutual benefit can be derived from international cooperation between countries which are in a position to export the sophisticated coal liquefaction technology and which, on the other hand, need feedstocks to produce energy, and countries which would find it difficult to exploit their coal deposits on their own.

THE FEDERAL REPUBLIC'S COAL CONVERSION PROGRAM

On 30 January 1980, the Federal Government submitted a program to continue the development of coal conversion technologies on an industrial scale. Industry has proposed 14 projects, which, according to present estimates, will require investments of about $7 billion U.S. during the period up to 1993. These include 2 projects for liquefying hard coal; one is for lignite liquefaction, and the other projects are gasification projects, mainly for synthesis gas. The program is open, and some additional proposals are expected.

The Federal Government supports design studies if funds are required and has earmarked $40 million U.S. for this purpose for the years 1980-1981. These studies serve to define the technical design and to determine the project schedule and cost, and they also investigate questions of siting, environmental protection and economics. The results will provide the basis for the decision on further work. For coal gasification, the most important results will probably be available at the end of 1980; for coal liquefaction, in 1981.

Today, coal conversion in the Federal Republic of Germany is not yet competitive. The production of synthesis gas from lignite is the only technology which will soon reach the profitability threshold. The price of liquid products and synthetic natural gas at present exceeds that of mineral oil products and natural gas by a factor of 2 to 4. But when the first large-scale plant will be commissioned in the mid-1980s or later, these factors will have changed in favor of coal.

The projects to be carried out under the coal conversion program will not do much to reduce the Federal Republic's dependence on energy imports. The program is above all a technology program intended to widen the range of technologies mastered and hence exported by German industry.

LOW-POLLUTION COAL-FIRED POWER STATIONS

In 1977, the Federal Ministry for Research and Technology considerably expanded its promotion of conventional power plant technology. This element of the program is aimed more than any other at harmonizing the requirements of environmental protection with the need for an economical and efficient energy supply. The development activities range from basic investigations to the testing of new technologies under commercial operating conditions. In all, 70 research projects will be carried out, and the funds available for the purpose amount to $55 million U.S. per year.

COMPONENTS DESIGNED FOR POLLUTION CONTROL

The majority of projects are designed to develop components and equipment which will reduce the emission of sulfur dioxide, nitrogen oxides, and fine dust and will help solve other related problems. After relatively short development and testing periods, these components are to be used in the construction of new power stations.

The largest single project is that of a pilot power station where a number of new technologies are being demonstrated. The desulfurization system is not housed in the cooling tower. No stack is necessary. The coal dust boiler combines dust firing and fluidized-bed firing under atmospheric pressure. This means that coal with very high ash content can also be fired. A hot-air turbine is fed with heat from the fluidized bed via a heat exchanger; it contributes 35 MW of the plant's total output of 230 MW. The efficiency of the pilot power station exceeds that of conventional power plants.

The power station combines heat and power generation. By means of a fluidized-bed heat exchanger, even the sensible heat of the flue gas is used for district heating. The flue gases need not be reheated because they are drawn upwards in the air lift of the cooling tower.

FLUIDIZED-BED FIRING

Fluidized-bed technology has been established as a development area in its own right. Fluidized-bed firing under atmospheric pressure has already reached the demonstration phase, whereas pressurized fluidized-bed firing still needs several years of development.

Fluidized-bed firing offers the advantage of relatively easy and low-cost desulfurization--even in small units--by the addition of limestone. Coal with a high ash content can be used. Fluidized-bed firing lends itself to low-pollution heat and power generation near residential areas or for industrial plants. It helps to directly replace mineral oil. Two facilities are presently being tested, and another four facilities are either being planned or are under construction.

Application and success of these advanced power station designs will depend to a very large extent on the results of gas cleaning and gas turbine development. Techniques to clean the flue and combustion gases at high temperatures and at high pressures are being developed. To remove the dust as far as possible, appropriate filters are being developed. The outlook seems to be good. The removal of sulfur and other pollutants at high pressures and high temperatures still presents numerous problems.

Efficiency losses and weaknesses in gas cleaning may be compensated by new gas turbines. For fluidized-bed firing, special attention is given to a gas turbine which is more resistant to dust. With a view to combining power stations with pressurized coal gasification plants, development activities are oriented towards high-capacity gas turbines for temperatures of 1300°C and more. Care is taken to test appropriate burners and operating modes so as to minimize the formation of nitrogen oxides.

CONCLUSIONS

Today's energy research will shape the power supply pattern we shall have in 20 or 30 year's time. Coal will gain in importance worldwide simply because there are large coal reserves. That is especially true for Germany. As its role becomes more significant, the demand for advanced technologies of coal utilization will grow. An increased use of coal involves environmental hazards, particularly in industrial conurbations. Coal must replace mineral oil and natural gas, but its adverse environmental effects must be minimized. The relevant technologies are available. During the next few years, it will be necessary to find the appropriate ways and means of achieving their commercialization.

ADVANCED SYSTEMS

One feature of advanced systems for the power generation from coal is the removal of sulfur during the power generation process itself. This means that the costly and technically complicated flue gas desulfurization is no longer necessary.

In addition, the advantages of the gas turbine can for the first time be exploited for coal-fired power stations. The efficiency achieved by the combined gas/steam turbine cycle exceeds 40%. The development lines pursued in the Federal Republic are power stations using

- Fluidized-bed firing under pressure
- Pressurized coal gasification
- VEW coal conversion process

In addition to its national activities, the Federal Republic also cooperates in a project carried out under the auspices of the International Energy Agency. The parties participating in the project are the United States of America, the United Kingdom, and the Federal Republic of Germany. The plant has a thermal output of 80 MW and is located at Grimethorpe, England.

The development of a power station combined with a pressurized coal gasification plant is of considerable importance. This combination using Lurgi gasifiers has already been tested in a 170-MW power station in Germany during the 1970s. The Federal Government's program on large-scale coal conversion again envisages two prototype power stations using the pressurized coal gasification technology. Their output will be about 600-MW. Some of the new coal gasification techniques which are at present being tested on pilot plants are well suited to be combined with a power station.

The VEW coal conversion process is designed first and foremost for a power station. Here the coal is degassed and partially gasified. The residual coke, which has a low sulfur content, is fired in the power plant.