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INDONESIAN-GERMAN SEMINAR ON COAL TECHNOLOGY

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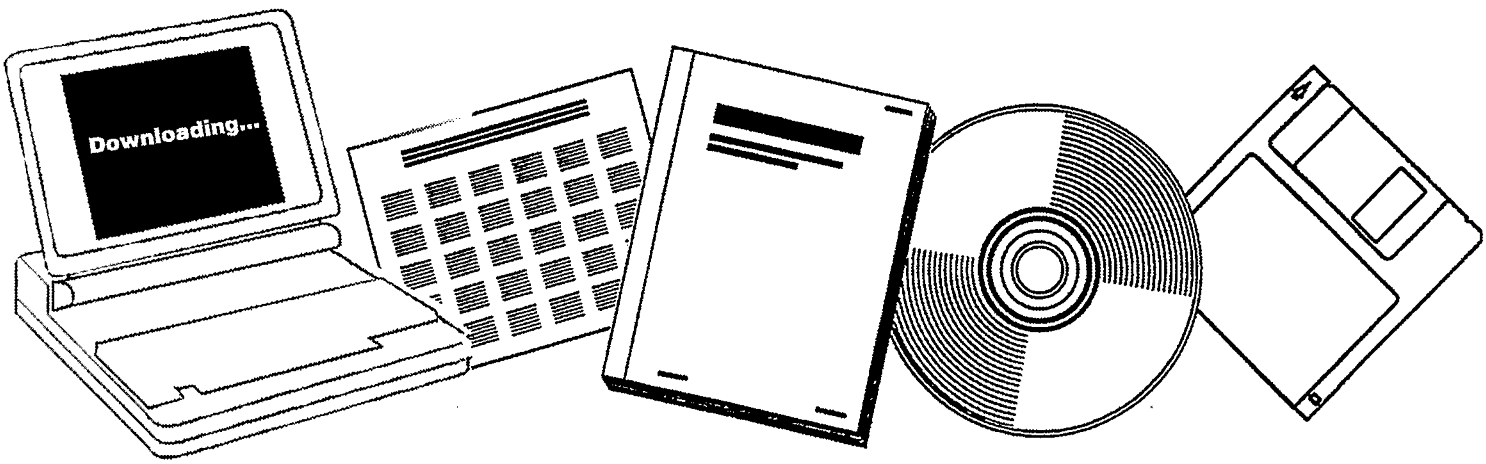

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Indonesian-German Seminar on Coal Technology

October 19th – 26th, 1980

Jakarta/Indonesia

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INDONESIAN-GERMAN SEMINAR
ON COAL TECHNOLOGY

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Overview of the Energy Research and Development Program of the Federal Republic of Germany with special Attention to Coal Utilisation Technology

Dr. R. Holighaus
Project Management for Energy Research (PLE)
Kernforschungsanlage Jülich

D: 8210040979

The program was started in 1974 with an annual budget of about 180 Million DM. Major target areas of the program are

- Efficient use of energy
- Coal and other fossil sources
- New sources of Energy

This first program was followed by the Energy Research and Energy Technologies Program covering the period from 1977 to 1980, which has now been extended until 1983. The financial scope has been significantly increased. Financial priority is given to the area "Coal and other fossil sources". This includes activities directed towards the improvement of the pollution of coal fired power stations. Most of the funds available for this part will be spent on large scale demonstration plants.

The paper briefly outlines the objectives, the content and the funding of the program.

The measures foreseen under the Energy Research and Energy Technologies Program, and harmonized with the Energy Program of the Federal Government, serve the following purposes:

- Guaranteeing the continuity of energy supply in the medium and long terms.
- Supplying energy at economically favorable costs in the long term.
- Due and timely consideration of the need for environmental protection and the protection of the public and the operators from hazzards arising
- Improving the technological performance capability of our energy technology to maintain its economic competitiveness.

The reason for Government funding lies especially in the fact that

- Research, development and commercialization of new energy technologies today require time in the order of decades. This is particularly true of new high risk developments, beyond periods of time which can be assessed in terms of industrial operation. This risk, and the exceptionally large investments required, often exceed the capabilities even of large industrial companies.
- The optimization of technologies in the light of industrial operation does not automatically satisfy goals of a higher order. This is true in particular of aspects of environmental protection, protection of the public, worker's protection and the reduction of the dependence of imports.

In its active participation in the program the Federal Government has adopted the cooperation between government and industry in suitable projects.

In the funding of the energy research various Federal Minister and Federal States cooperate but the distribution is rather complicated and of little interest here. By far the largest part is born by the Federal Ministry for Research and Technology, which is also responsible for the Federal Program.

The funds provided are high. To my knowledge the German expend tures for energy research and technologies are second largest in the world after the United States.

The total expenditures broken down into the main sections are shown in the following table (in Million DM). Figure 1

	1974-1977	1978	1979	1980	1981	1982	1983	1984	1985
Efficient Use of Energy	[illegible]	126	137	241	105	11	1	-	-
Coal and Other Fossil Sources	714	570	645	542	535	455	266	262	211
New Sources of Energy	[illegible]	52	189	87	58	17	4	-	-
Non Nuclear Total	1 263	748	971	870	929	483	271	262	[illegible]

About 50 % of the funds go into industry, 10 % to universities or government laboratories, which are funded 100 %.

The average percentage of government funding is about 60 %; the remaining costs are born by the industry.

The distribution of funding shows clearly the priority for "Coal and other fossil sources", which in fact means coal, our only large domestic energy source.

However, coal can only continue and extend to occupy an important position in our energy supply system, if non-pollution and economical conversion technologies are found in order to generate products which satisfy the need of the market for comfortable, easily handled and non-polluting sources of energy.

In order to open up these applications our development activities are divided into five sections:

1) Electricity generation from coal
2) Gas generation from coal
3) Liquefaction of coal
4) Coke production and direct combustion

The financial priority has been in accordance with this sequence up to now. Most of the money is spent on electricity generation.

But as far as the committed money is concerned coal gasification and coal liquefaction are of comparable importance.

The question may arise why the development of coal technologie is at the centre of our energy R+D program. It has already bee mentioned that coal, hard coal and lignite, is the only significant energy source in the Federal Republic. But besides the special situation in our country there are other important aspects valid world-wide, which ask for an increased consumpti of coal compared with oil. The availability of highly efficien coal conversion processes are a precondition for this.

1. There is a disparity between energy reserves and energy consumption which is illustrated in figure 2. The coal reserves are estimated to be about seven times as high as the oil and gas reserves together, but coal covers only 33 % of the energy demand. In the long term, however, the balance between reserves and consumption will have to be restored.
2. Coal is the only energy source which is able to substitute oil and gas in all respects. In figure 3 the four main fiel of energy demand are identified. Space heating, industrial fuels, transport fuels and non-energetic uses which means for example chemical raw materials. The graph shows too what process steps have to be undertaken to convert coal into a more usable type of fuel. Starting from the left side by applying coal hydrogenation an improvement contribution to al demands can be generated. Coal pyrolysis has the same broad spectrum of products, but by this process only a rather minc part is converted to valuable products. The yield in char ha to be used elsewhere.

Coal gasification with air delivers a gas which cannot be transported over long distances. Therefore the lean gas can only be used for power generation or for industrial heating. Most of the development in gasification, undertaken in Germany, can be operated with air.

Coal gasification with oxygen is, no doubt, the most flexible coal conversion step. By applying further process steps all requirements can be fulfilled. Therefore it is worthwhile paying special attention to all developments in this area.

It is also indicated in the sheet that coal can directly be used for power generation, which is today the main area of demand

Within this talk I will outline the development strategies which are applied in the individual fields of coal utilisation. The strategies are to some extent different in the main areas of interest "power generation", "gasification" and "liquefaction".

1. Power Generation from Coal

The Federal Republic has an installed electric capacity of 40GW based on hard coal and lignite. This makes clear that power generation from all types of coal is a well developed and proven technology.
However, the increasing demand for electricity from coal and the higher attention which is attributed to environmental protection required additional developments. Today it is expected that power is generated with low emissions with respect to SO_2, NO_x, particulates and CO_2 (as far as possible).

These developments concern modifications of conventional power plants and the addition of further process steps.
In Germany, and in other countries, at first particulate emission was limited (100-150 mg/Nm^3). This can be achieved by electrostatic precipators. Today new standards as low as 20 mg/Nm^3 are being discussed. But also this limit can be kept by preconditioning the flue gas before entering the precipitator or by applying cloth filters. Both technologies were developed and proved recently.
Sulfur emissions appeared then to be of highest concern. In Japan, US and Germany intensive development efforts were initiated. Now several processes for flue gas desulfurisation are available for commercial application. German companies offer three different processes which are converting sulfurdioxide to gipsum, ammonia sulfate and elementary sulfur.

NO_x-Emissions which are now under consideration turned out to be controllable by modification of the burners. It was demonstrated in one of our power plants (700 MW) that rather minor modifications to the burner design already produce a significant positive effect. In applying this advanced burner design even the very stringent US standard in NO_x emissions can be met easily.

All the previously mentioned means for environmental protection which can be considered to be commercially available, have a negative influence with respect to the efficiency of the power plant. The figure of 37 - 38 % which can be obtained by a modern designed conventional power plant is lowered to roughly 35 % and at the same time the investment costs go up by roughly [illegible] %.

The lower efficiency is contrary to the CO_2 emission aspect and to the requirement of saving the available energy reserves as well. Higher investment [illegible] are an obstacle to the widespread application of a technology in general. Therefore in 19[illegible] and earlier the development of new power plant concepts was initiated which promise to have

- higher efficiency
- lower specific investment costs and
- means for pollution control integrated in the process.

In Germany three different development lines were followed:

1) Gasification of the feed coal by air and use of the produced gas in a combined cycle. A prototype plant of 140 MW was operated successfully for several years. However the design data with respect to power plant efficiency could not be achieved.
2) Pyrolysis of the feed coal. Utilisation of the pyrolysis gas in a gas turbine and of the char in a steam boiler which also fired by the exhaust gas of the turbine. The critical steps of this concept were realised on a technical scale Now an integrated pilot plant is under consideration.
3) Pressurized fluidised combustion of coal with generation of steam in the fluidised bed and expansion of the hot exhaust gases in a gas turbine. The most critical units of this concept-fluidised combuster, hot gas cleaning - are now being investigated in a plant which is jointly funded and

operated by US, UK and Germany. This test plant with a capacity of 85 MW_{th} started operation a month ago. The results generated within the next 2 1/2 years will enable commercial plants of this type to be designed. Another activity concentrates on the question how such a combustor can be connected with the electricity generating units. Questions concerning the lifetime of the gas turbine, the part load behaviour, the load following characteristics etc. will be investigated by operating a pilot plant which consists of all the units of a later commercial plant.

Today it is impossible to give preference to one of these processes. Each of them has its own merits. Only on the results which will be generated within the next few years can reliable decision in this respect be taken.

Figure 4 indicates how we see the situation in the field of power generation today.

- Conventional power plants were in the course of their commercial application always further developed. This technology now represents an optimum with respect to efficiency and specific investment cost.
- The introduction of pollution control technologies had a negative influence regarding efficiency and investment cost. But due to the higher priority of environmental protection this burden was accepted for a limited period.

- The goal is to apply the advanced processes which promise favorable conditions in all respects but which are notgoing m ready until 1988.
- As an intermediate step atmospheric and fast fluidised bed boilers may enter the scene. This technology which is close to application will keep its merits later on too for special applicationssuch as small units (up to 200 MW_{th}) high ash high sulfur coals, heavy duty operation etc.

2. Coal gasification

Already in the 50's a series of gasification processes was available on an industrial scale. The list (fig. 5) indicates that we took these as a basis for our new developments. An exception in this respect is the Texaco Gasifier which is mainly based on the commercially proven Texaco-Oil-Gasifier. The Koppers-Totzek and the Rummel-Otto Generator are dust gasifiers, which are not sensitive with respect to the coal characteristics. The gas produced does not contain higher hydrocarbons and is therefore suitable for all kinds of synthesis.
The Winkler-Gasifier was invented as long ago as 1922. It requires a highly active coal because it has to be operated well below the sintering point of the ash in order to prevent clinkering. The gas with low hydrocarbon content can be used as feed stock for chemical processes.

The Lurgi-Gasifier is the only commercially available system operating under pressure. The gas, which is produced from lump coal or briquetted fine coal, contains an already relatively high amount of methane. This offers advantages for SNG production and for direct use via combustion as well.

Although all these processes were commercially available and still are today, it is in fact the development potential inherent in each of these processes, which suggest the need for intensive development work.

The development was initiated to fulfil the following general objectives (fig. 6).
- Increase in energy yield
- Reduction in plant costs
- Reduction in sensitivity with respect to the coal used
- Improvement in pollution control
- To increase the availability

One measure which promises to have a positive effect with regard to almost all objectives is the increase in gasification pressure. This means a significant alternation in the complete design for the Koppers-Totzek, Rummel-Otto and Winkler processes, which have up to now been operated under atmospheric conditions. In particular, systems for charging the coal into the reactor would be necessary.

Other measures for improvement are specific to the particular process and will be mentioned in the individual presentations.

Application possibilities of coal gasification

The single step of coal gasification enables oil and natural gas to be substituted in all fields of its present use. To come to the final purposes as listed in figure 7 it just needs the addition of technically proven processes. For the generation of SNG for the common supply, besides the clean-up of the raw gases, only a methanation unit is needed. Gasoline, methanol and chemical raw materials can be generated from synthesis gas by applying existing synthesis units. Direct reduction of iron needs only the mechanical clean-up of the raw-gases. Low BTU-gas produced by coal gasification has to be cleaned with respect to sulphur and particles before it can be used for power generation or industrial heat supply.

The fact that only one single step had to be developed to open the full spectrum of consumption to coal-derived products was the reason to put the highest priority on the development of this technology. All gasifiers which are available now because of this early decision are characterised by being closely related to already existing technology and areas simple and flexible as possible. Therefore we are convinced that the described gasifiers, known as the second generation, will be the only ones available commercially for some years as is now true for the first generation gasifiers Lurgi, Koppers-Totzek and Winkler.

The described advantages of coal gasification which are based on its high flexibility with regard to the coal characteristics and the product properties have to be confronted with a significant disadvantage as far as the production of liquid fuels is concerned. The yields in liquid products are always rather low. The methanol production reaches the best figure which still lies below 50 % energy-wise. The production of gasoline via F.T. Synthesis is characterised by a yield of only 40 %. Gasoline via methanol and Mobil conversion promises just 3 to 4 points in addition. Compared with this, the production of gasoline via coal hydrogenation looks attractive obtaining 55 % yield. Converting coal only to a syncrude type of product an efficiency of more than 65 % can be obtained.

Therefore coal hydrogenation for the production of liquid fuels is an option which has to be exploited carefully.

3) Coal hydrogenation

The development of coal hydrogenation always means the development of the whole process chain. The development of single units independently is not possible because of the high degree of interconnection. This makes the development most expensive and risky. Therefore the resources for the design and construction of a commercial plant have to be assessed carefully.

Again Germany is in a somehow unique position. Most of you may know that during the 2nd world war up to 4 000 000 t/a of synthetic gasoline was produced. The biggest plant at that time had a capacity of 400 000 t/a. The future commercial plants will have capacities of about 70 times as much per unit and it is obligatory that advantage has to be taken of the progress in this process development in particular, and in the process technology in general.

First I would like to show how closely related the former "IG-Farben" process (Bergius-Process) and the so-called "IG-new-process" are. First a flow sheet of the former process (fig. 8) is shown. The coal after being milled and mixed with a catalyst was pasted with recycled oil and then pumped into the reaction system. Hydrogen was added and the slurry heated up to 450 °C. The reaction took place at about this temperature and at a pressure of 700 bar. Afterwards gas and liquids were separated. While the gaseous products were condensed and separated into the fractions as indicated, the liquid product containing also the catalysts and the ash was treated by centrifuges. This separation delivered on the one side the oil for recycling and on the other hand a mixture of heavy hydrocarbons and solid residues. By coking this product in huge drums most of the hydrocarbons were recovered and fed into the recycle stream.

Another important feature of that process was the generation of hydrogen by gasification of coke under atmospheric conditions.

The hydrogen then had to be pressurised to more than 700 bar which was a most energy-consuming step.

The next figures show how these plants looked.

Figure 9 illustrates the I.G. new process. In going along the flow-sheet I will only point out the differences to the former process. <u>First</u>, which does not appear in the sheet, the reaction pressure is lowered to 300 bar, which lowers the investment costs considerably. This is reached by recycling a destillate and not an oil gained by mechanical separation. This is the <u>second</u> main difference.
<u>The third:</u> the residue separation is performed by means of a vacuum flash destillation.
<u>The fourth:</u> the residue is gasified in a pressurized Texaco to supply the necessary hydrogen for the reaction at an almost sufficient pressure level.

The advanced hydrogenation process was developed in a rather small continuously operating unit (10 kg/h). But now a pilot plant with 6 t/day is starting up and this will deliver mainly technical improvements (Figure). A demo plant with 200 t/day capacity is under construction and will start operation in 81.

In Figure 10 an attempt is made to illustrate the situation. The experience from the commercial operation of the I.G.-Farben plants is used directly and indirectly via the different development phases of I.G.-new. As is indicated too in the graph we also expect a significant contribution from the German participation in the SRC-II project of the U.S.

The flow sheet (fig. 11) shows how strongly related SRC-II is to the German processes. The main differences are:

1. No catalyst is added because the ash of the coal already contains enough of it
2. The bottom of the destillation containing the ash is recycled instead of a destillate.

We do not expect any process information because this process cannot be applied for German coals and probably not for most of the coals in the world. But the scale of the SRC plant is far beyond what we did in the 2nd World War in the commercial plants. It is the first time that hydrogenation reactors and other critical elements such as hot separation and vacuum separation will be designed and manufactured in a size which appears to be the most economic for the future. If and when the SRC-II plant is successfully put in operation we are very confident that the I.G.-new can be realised as a commercial plant without any further risk. We will do this first in Germany and later on hopefully in many other countries.

From what was said before you may have deducted that the FRG and especially myself favour the coal hydrogenation route as far as the production of liquid fuels is concerned. This is due to the fact that the product yield is significantly higher and the specific investment costs are significantly lower than for all indirect liquefaction routes (gasification plus synthesis).

Two critical aspects, however, should also be pointed out

1. Coal hydrogenation cannot be applied for low grade coals. The ash content of the feed coal should for example not be higher than 10 %.
2. Intermediate products of coal hydrogenation may be cancerogenic.

Up to now, contrary to the attitude in the U.S. we do not see the second point to be of relevance for commercial plants because these dangerous products will not normally leave the plant.

Planning with respect to commercial plants

The development technologies already described, which cost more than 1 Bill. DM up to completion is now, or in the very near future, ready for commercial application. This first commercial phase is, however, still connected with technical and economic risks: Technical risks because of the scale-up factor, economic risks because of the extremely high costs of the German coal, which prohibit a commercial operation in the near future.

In order to get the first commercial application realised, the German Government announced in 1979 a program "Coal conversion". Within this program the frame conditions will be determined which are needed from the industry to get things running. Up to now several proposals for commercial plants based on the technologies described above were prepared. The funds needed to realise all proposed projects total up to 13 Bill. DM. According to the proposals the plants for gasification will start operation in 84/85, that for coal liquefaction in 86/87. Until now the necessary funds for the program have not been committed. But our Chancellor confirmed two weeks ago that he is resolved to getting this program realised.

It should, however, be emphasised that the Federal Republic does not undertake all the above described efforts exclusively for commercial application in our own country. Considering our rather limited coal resources and the very difficult situation with regard to the mining conditions which makes our hard coal extremely costly, such an undertaking could hardly be justified.

We surely also undertook and will continue to undertake these activities in order to increase our attractivity as partners of joint ventures with countries owning large coal deposits.

There is always an incentive for these countries to apply the most economic and reliable technology to exploit their resources and an incentive for us to ensure our future energy supply.

But also the delivery of coal utilisation technology benefits from the rather advanced status of our developments and from the fact that several pilot plants are in full operation. In both cases we offer to perform feasibility studies which include test-runs with the respective coals in the most suitable pilot

plants, an engineering evaluation of the results, an economic assessment with respect to commercial plants and an analysis of the environmental impact. We attempt to perform this work jointly with the interested country in offering them the possibility of secondment to the German teams and vice versa. This helps both sides to get acquainted with the problems and the solutions proposed. It creates a firm and sound basis for decisions with respect to high investment.

Nowadays there are already two cooperations of this character running

1. Feasibility study on motor fuel from coal with Australia.
   Under the umbrella of a governmental agreement seven German companies supported by experts from Australia are performing this study which includes extensive investigations of Australian coals.

2. Feasibility study on the production and upgrading of Venezuelan heavy crudes.
   This study deals with heavy oil (which is from the point of upgrading very strongly related to coal conversion), it shows as a model how beneficial such a cooperation can be for both sides. In the course of this study careful investigations in our technical plants with raw materials from Venezuela were performed. Several Venezuelan engineers participate in the test runs as members of the operating team or observers.
   Also the evaluation of the results with respect to the economy and to the technology of a commercial plant was done by teams consisting of Venezuelan and German experts. Because of this

fact the results obtained and the conclusions drawn appreciate a high degree of confidence. The engineers engaged on both sides do not hesitate to identify themselves with the outcome of such a joint effort.

Another advantage of this kind of cooperation is that the seconded engineers get acquainted with the technology from the very beginning. In the case that a positive decision regarding the commercialisation of the technology is taken, the realisation of such a project is facilitated significantly by the fact that engineers of the relevant country are familiar with the technology and can act as the nucleus of working teams.

Generally it is our impression that this kind of cooperation is appreciated by our foreign partners as well as by our national industrial companies. And I can ensure you that the responsible Ministry within the German Government favours this model for bilateral cooperations too.

FIG. 1

	1974-1977	1978	1979	1980	1981	1982	1983	1984	1985	TOTAL
EFFICIENT USE OF ENERGY	259	116	137	241	105	11	1	-	-	870
COAL AND OTHER FOSSIL SOURCES	714	570	645	542	636	455	266	262	211	4 301
NEW SOURCES OF ENERGY	190	62	189	87	68	17	4	-	-	617
NON-NUCLEAR TOTAL	1 163	748	971	870	809	483	271	262	211	5 7[illegible]

Basic technologies in coal mining

Professor Dr.-Ing. R. Thar

1. Introduction

With the recent events on the oil markets coal recovers great importance. Therefore it is believed that coal mining will have a bright future. However, the expansion of coal production requires great efforts not only from the financial but also from the technical aspect.

Although coal mining is done in many countries, it is remarkable, that th. bulk of production is concentrated on a few countries. In 1979 world production of hard black coal amounted to 2 791,8 million t[1]. Only nine countries contribute 92,1% to the world production (Table 1).

Table 1. Production of hard black coal in 1979 (preliminary).

	Million t
China	663,2
USA	655,0
USSR	553,6
Poland	200,1
United Kingdom	120,6
India	109,0
Republic of South Africa	95,6
Federal Republic of Germany	93,3
Australia	83,6
Others	221,6
World	2 791,8

[1] In this contribution only metric tons are used.

Also the production of brown coal and lignite is concentrated on a few countries, especially in Europe. In 1979 world production totalled 951,7 million t. In this case 86,5% are produced by nine countries (Table 2).

Table 2. Production of brown coal and lignite in 1979 (preliminary).

	Million t
GDR	255,0
USSR	165,0
Federal Republic of Germany	130,6
CSSR	96,2
Yugoslavia	41,7
Poland	38,1
USA	37,2
Australia	31,8
Bulgaria	27,9
Others	128,2
World	951,7

Manifold methods are known in coal mining. This variety mainly depends on the geology of the coal deposits. Par example the following items are of importance: depth, seam thickness, dip, occurence of geological faults, folding, properties of the accompanying strata or overburden, distance between the seams and so on. Also the kind of coal varies from brown coal of low calorific value up to anthracite.

This article can deal only with modern basic technologies, which are of general importance. Therefore, main interest is given to technologies as they are in application in the industrialized countries.

2. The role of surface mining in the coal mining industry

Nowadays in brown coal and lignite mining throughout the world the percentage of production from open pits is at least 85%. Underground mining of brown coal and lignite takes place on a wider scale par example in the USSR and Yugoslavia. In the Federal Republic of Germany underground mining has only local importance, though there is still enough experience left from past decades with more underground mining.

In hard coal mining there is quite another picture. About 25% of world production are coming from open pits. According to the country there are great differences. In the United States the percentage of open-pit-mined hard coal rose to more than 50% in a very short time. It is estimated, that 90% of new capacity will be based on open pits, especially in the Western states, where enough suitable coal deposits are available. The percentage of open-pit-mined hard coal in other countries is as follows: USSR 20%, Australia 50%, Canada 85% and United Kingdom 10%. India and the Republic of South Africa have a percentage of about 25%. In both countries a rapid increase is expected for the near future. In India it is believed, that hard coal production from open pits will reach a percentage of 45% in 1988. On the other hand there are countries, which have no hard coal deposits suitable for surface mining, par example in the Federal Republic of Germany or in Poland.

It is clear that in several countries surface mining will be favoured in the next decade as long as suitable coal deposits near to the surface are available. The following advantages are connected with surface mining:

- Lower costs compared with underground mining, if the stripping ratio does not exceed an economical limit.
- High extraction rate
- Faster development of new capacities

- High productivity
- Better working conditions
- Easier mechanization of mining operations

Some disadvantages are mentioned:

- High capital charge
- Handling of large volumes of unusable material
- Dependence of climatic conditions
- Reclamation of mined-out areas

3. Technologies in surface mining

3.1 Surface mining on brown coal deposits

Brown coal deposits usually are characterized by an unconsolidated water-bearing overburden consisting of sand, gravel and clay. In the Federal Republic of Germany such deposits are mined in large operations. The technique, which is applied in these open pits, has reached a high standard. It can be stated, that this is an exemplary technique.

The most important district of brown coal mining in the Federal Republic of Germany is situated in the Rhineland. The yearly production of the five open pits amounts to 110 to 120 million t brown coal and 280 million m^3 overburden. The stripping ratio (m^3 overburden/t brown coal) varies between 2:1 and 3:1. In 1979 the largest open pit, which is also the largest brown coal open pit in the world, produced 48 million t of coal. The final depth of this mine will be roughly 300 m. At present a new open pit is under development since 1978. A yearly production of 50 million t is planned with a stripping ratio of 6,2:1. The final depth will be 470 m. First coal production is expected for 1983. In a first step this open pit is supposed to mine an area of 85 km^2.

Brown coal in this district has a low calorific value of about 8000 kJ/kg and 60% moisture. In the open pits several seams are mined which have a moderate dip and are cut by several geological faults. Therefore it may happen that on some benches there is not only coal but also overburden which requires selective mining.

Under this geological conditions bucket-wheel excavators (Fig. 1) are best suited for selective mining of coal and overburden. The largest units have a daily capacity of 240 000 m^3. Their weight is 13 000 t, the diameter of the bucket-wheel 21 m. From one level such an excavator can dig 100 m in height. These are the largest bucket-wheel excavators in the world. Because of the great depth of the open pits shiftable belt conveyors are in use for haulage of coal and overburden. All belt conveyors on the different working levels lead to a transfer point where by the aid of reversible conveyors coal is directed to the power station, whereas overburden is transferred to belt conveyors leading to the different levels of the refilling area (Fig. 2). Large spreaders with boom lengths up to 100 m take over the overburden from the shiftable belt conveyors and dump it into the mined-out area (Fig. 3). Refilling is following in a short distance to the lowest coal bench. The largest conveyors run 2,8 m wide belts with a speed of 7,5 m/s. Nowadays reclamation is integrated in the mining operation. After a short time the recultivated areas can be used again for agriculture or forestry.

Dewatering is of great importance, especially in respect to the stability of the slopes. For this purpose wells of several hundred metres depth have to been drilled. They are equipped with submersible pumps of high capacity. For each ton of mined coal 10 m^3 of water are pumped.

Continuous operation in excavating, haulage and refilling is characteristical for German brown coal open pits. The high mechanized mines in the Rhineland have a productivity of 100 t of coal per manshift on average with an outstanding productivity of 130 t per manshift in the best open pit.

This technology also is applied on smaller deposits at other places in the Federal Republic of Germany as it is demonstrated in Fig. 4. Throughout the world there are open pits which have adopted this system often using German equipment.

3.2 Surface mining on hard coal deposits

It is not astonishing that surface mining of hard coal is influenced by the American technique. Usually the country rock of hard coal seams consists of consolidated material. Very often drilling and blasting is required. Large blast-hole rotary drills for hole diameters up to 300 mm are in use. The holes are charged with ANFC, sometimes with slurries. Large draglines and shovels are predominant in overburden handling. In easy-digging overburden also dozers, scrapers, rippers and bucket-wheel excavators may work well. The coal itself is mined very often by shovels or front-end loaders and hauled with trucks. In the following some typical methods are discussed.

3.21 Strip mining

Strip mining is applied for mining a flat-lying seam under a not to thick cover. Generally it is to distinguish the contour strip mining and the area strip mining method. Strip mining may also be used to mine two or three underlying seams but mining operation is more difficult.

Contour strip mining is selected if the seam outcrops along a hillside (Fig. 5). Most popular equipment for overburden removal are dozers and front-end loaders which cast the overburden on the shortest way over the edge of the downslope. In doing so the coal is uncovered in a small cut along the hillside. Coal removal follows the stripping procedure. Successive cuts may be mined in the same manner until the stripping ratio (overburden thickness to coal thickness) becomes uneconomical. Stripping ratios up to 30:1 are reported.

In flat terrain the area strip mining method is practised. Also in this case the seam is uncovered in 20 up to 40 m wide successive cuts. The overburden is dumped into the preceding mined-out cut. In the case of seams lying within 15 m of the surface shovels with dipper sizes up to 130 m^3 are most in use (Fig. 6). Thicker overburden up to 45 m favours the application of draglines with bucket sizes up to 160 m^3 (Fig. 7). In strip mining overburden is moved only on a short distance. Therefore this method allows high stripping ratios.

Greater depths are not practicable with the simple strip mining method, because this is restricted by the dimensions of the draglines. In this case sometimes tandem operations, that means par example a shovel/dragline combination, are applied. There is also the possibility of combining a drag-line with a bucket-wheel excavator, if the upper part of the overburden consists of easy-digging material (Fig. 8). Some bucket-wheel excavators were sold from German manufacturers to such operations in the United States.

3.32 Open pit mining on dipping multiple seams

In the West of the United States more and more open pits are going on stream in which dipping multiple seams, sometimes of great thickness, are mined. Fig. 9 illustrates such a coal deposit. Similar conditions are also found in other countries par example in Canada, Australia and the USSR. Such deposits cannot be worked by strip mining as the main method. In this open pits a haulage system must be installed which moves the overburden to the spoil site.

The most used equipment is the shovel/truck combination. The shovels have a dipper size up to 12 m^2. Also hydraulic excavators of the same size are gaining more and more interest. Par example German hydraulic excavators are operating in Australian hard coal open pits. For haulage of overburden rear dump trucks with a capacity up to 120 t are in use. Commonly scrapers are integrated in overburden removal. Fig. 10 gives an idea of this method. It should be mentioned that train haulage still finds wider application in open pits in the USSR.

3.23 Further development in hard coal surface mining

Productivity in surface mining is by far higher than in underground mining. In the United States average productivity had reached a maximum of 33 t per manshift in 1973. Since that year it declined to 22,5 t per manshift in 1978. There are some reasons for this development which shall not discussed here. Nevertheless costs of surface-mined coal are remarkable lower than of coal from underground mines. Average productivity of the Australian hard coal surface mines was 30 t raw coal per manshift in 1977/78.

Depth and stripping ratio of hard coal surface mines will increase in future. Conventional strip mining technique reaches a limit with greater depth. Also truck haulage becomes more difficult and expensive with increasing depth. Therefore it is discussed, even in the United States, to find suitable and efficient techniques. Par example the German continuous haulage system with shiftable belt conveyors is in consideration if necessary with mobile crushers. Also the application of cross-pit conveyors is considered which are known from Germany.

Fig. 11 shows a new concept for the hard coal open pit Goonyella in Australia. The immediate overburden of the 6 to 10 m thick seam are consolidated permian rocks which are removed with a dragline according to the strip mining technique. The upper overburden consists of easy-digging tertiary strata. Removal of this material will be accomplished by the German continuous mining that means a combination of a bucket-wheel excavator, a spreader and a shiftable belt conveyor system. The equipment is delivered from Germany and is supposed to go in operation very soon.

4 Technologies in underground mining of hard coal seams

4.1 General

The methods of underground mining of hard coal seams are numerous because the geological conditions vary in a wide range. However there are to basic mining methods on which the bulk of production is based. The first method is room and pillar mining which is selected in the case of undisturbed flat-lying seams in shallow depth. The second method is longwall mining. Only these two most important methods should be discussed. Here it is not complied with the problems of mining of steep dipping or/and very thick seams though the German coal mining industry has a lot of experience concerning mining in steep formations.

4.2 Room and pillar mining

Typical countries with room and pillar mining on flat-lying seams in shallow depth are the United States, the Republic of South Africa and Australia. In room pillar mining only headings or rooms are driven in the seam leaving square or rectangular pillars. Good roof and floor conditions allow that the height of all workings does not need to exceed seam thickness even in the main entries. The main entries consist of 5 up to 10 parallel headings. Fig. 12 shows a plan of a mine in the United States which was operated by a German coal mining company, Fig. 13 another example from a South African mine. Important for the success of room and pillar mining is that roof bolting is sufficient to keep the roof in good condition. Roof bolting is easier to mechanize (Fig. 14) than other support.

Coal getting is done by two methods. There is the so-called conventional mining with a cycle of cutting, drilling, blasting, loading and roof bolting. The other method is continuous mining (Fig. 15). The trend is going to continuous mining. In the United States continuous mining has a share of 65%, in Australia 90%.

The maximum practical depth for room and pillar workings depends upon the strength of the pillars. In coal mining this depth generally is less than 300 or 400 m. Room and pillar mining normally allows a coal recovery of only 50 to 60%. To increase recovery numerous mines introduced pillar extraction.

Under favourable circumstances recovery rate may reach 80%. Generally in thick seams recovery rate is poor. As a precondition for pillar extraction immediate roof must cave properly. Fig. 16 shows some examples of procedures for pillar extraction.

Because of the low depth new mines are developped very easy and in a short time. If the seam outcrops at a hillside coal production starts immediately with driving the drifts in the seam. If the seam is lying under some cover slopes for coal haulage are usual often combined with shafts for man-riding, ventilation and material transport.

It must be mentioned that even in the United States, South Africa and Australia under special circumstances longwall mining, often with German equipment, is introduced as an alternative to room and pillar mining. The following advantages are seen with longwall mining: higher coal recovery, higher production rate in a panel and safer control of caving. Though there are a remarkable number of longwall faces operating in these countries, high investment costs are yet against a general introduction of this mining method.

Productivity of hard coal underground mines in the United States had reached a maximum of 14 t per manshift on average in 1969. In the following years productivity decreased to 7,4 t per manshift in 1978. Productivity in Australia was 12,1 t raw coal per manshift in 1977/78, in South Africa 6,3 t per manshift in 1978.

4.3 Longwall mining

Flat-lying or moderate dipping hard coal seams in depths from more than 400 oder 500 m generally are worked by the longwall mining method with total caving. Longwall mining also is applied in lower depth if geological conditions are not favourable enough for high mechanized room and pillar mining. Coal deposits with numerous seams close together usually are mined by longwall faces.

With modern equipment longwall faces are able to mine seams in a single lift up to a thickness of 5 m. Nowadays longwall mining with stowing is used rarely. Longwall mining with total caving contributes the main share to the world hard coal production from underground mines. Most important countries with longwall mining are the European countries, the USSR and China. Thicker seams may be mined with a multi-lift longwall system.

Concerning the development openings of a mine with longwall mining two general procedures can be distinguished. In the case of geological less disturbed seams which are succeeding in a greater distance in-the-seam mining is preferred, per example in the United Kingdom, whereas in the case of more geological unconformity expensive levels must be developped in the surrounding strata of the seams with interconnecting blind shafts or inclining roads. This method is called horizon mining.

The development of a mine in the United Kingdom is shown in Fig. 17. In a depth of 750 m a seam with a thickness of 2,7 m is mined by longwall faces. On behalf of ventilation three- or four-fold main roads are driven in the seam. Each mineable seam has to been developped in the same manner.

Hard coal mining in the Federal Republic of Germany is a typical example of horizon mining. Usually in a German mine coal seams are cut by several faults and thrusts. Folding of carboniferous strata caused all kind of inclination of the seams. Numerous seams are existing. A lot of development workings is necessary for obtaining a connection with all parts of the coal seams. There are at least two levels with main drifts and cross-cuts. Blind shafts or inclining roads connect the levels one another. Fig. 18 shows the main development workings of the largest German coal mine which winds 20 000 t of saleable coal daily in two winding shafts. Formerly three independent collieries are linked together by an underground computer-controlled belt conveyor system.

Standard mining method is longwall mining generally on the strike with total caving. In a few cases also longwall mining with pneumatic stowing finds application. In Germany longwall mining is feasible for inclinations up to 45°. The following average data are mentioned:

- length of face	224	m
- thickness of mined seams (inclusive dirt bands)	1,84	m
- thickness of mined seams (only clean coal)	1,51	m
- working depth	850	m

The deepest existing level is 1 400 m below surface. There is no deeper mine in the world. Fig. 19 shows a plan of a seam in a German colliery with planned longwall faces. Because of later convergence and ventilation gate roads must have a sufficient height. Therefore they have to been driven not only in coal but also in the surrounding rock. Yieldable steel arches are the standard support.

Longwall faces are equipped with self-advancing hydraulic support mainly of the shield and shield-chock type (Fig. 20). This support is available for a seam thickness of less than one metre up to five metres. Shearers (Fig. 20) and coal ploughs (Fig. 21) of different types are used as coal-getting machines. Shearers are selected in the case of hard coal and great seam thickness, whereas coal ploughs are operating in soft coal and thin or medium thick seams. The average daily output of a fully mechanized longwall face is 1 500 tons of saleable coal with best faces producing up to 5 000 tons of saleable coal.

In the gate roads belt conveyors transport the raw coal to the loading points. In main haulage locomotive haulage as well as belt conveyor haulage are usual. Trend is going to install more and more belt conveyor systems. There are also large locomotive haulage systems in planning including tubs with a capacity up to 28 m^3.

In headings more and more drifting machines are put in use. Boom-type heading machines are suitable for roads in the seam (Fig. 22). Several full-face tunneling machines (Fig. 23) with a diameter up to 6,1 m are driving long cross-cuts and drifts on new levels.

New shafts often must be sunk through a difficult water-bearing overburden. German contractors have developped sophisticated shaft-sinking techniques. For example moment a shaft-sinking operation takes place in whi upper 600 m must be sunk by the freezing shaft-sinkin

Since two decades the German coal mining industry also was engaged in the development of hydraulic mining. After sever successful pilot tests a whole mine was reconstructed for

hydraulic mining. But unfavourable geological conditions caused the closure of this operation next month t. ugh the technical equipment worked well.

Because of great depth German collieries have to encounter with several problems concerning rock pressure, ventilation, air conditioning and methane drainage. Despite of this difficulties the standard of safety is high. At present a lot of research and development projects are carried out for further improvement of mining techniques, safety and working conditions.

In the German hard coal mining industry average productivity underground is 4 tons of saleable coal per manshift. This is an outstanding figure in deep hard coal mining throughout the world. High mechanization and automation were necessary for this success. This is a remarkable development because 25 years ago in German collieries there still were hand-loading longwall faces with wooden roof support. German hard coal mining industry has passed all phases of technical evolution in .. very short time. Insofar there are still enough experiences concerning less developped coal mining techniques which may be of interest for coal mining in Indonesia.

5. Conclusion

With this contribution the attempt was made to give a short review concerning modern basic technologies in coal mining. Indonesia makes an effort to extend the coal mining industry. Manifold experiences of German coal mining industry and producers of mining equipment may be helpful for this purpose. This experiences are not only based on coal mining in the Federal Republic of Germany but also on many activities throughout the world. During recent years German hard coal mining enterprises have entered the international coal mining field. For example they are operating underground mines in the United States or are participitating in hard coal surface mines in Canada and Australia. Consulting divisions of coal mining companies are active in many countries. German mining equipment is installed in many coal mines all over the world.

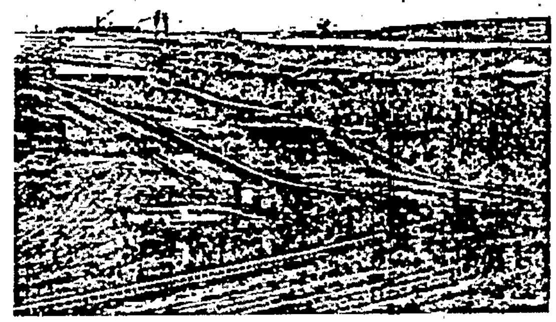


Fig. 1 - Large brown coal open pit with bucket-wheel excavators and shiftable belt conveyors in the Federal Republic of Germany

Fig. 2 - Belt conveyor transfer point

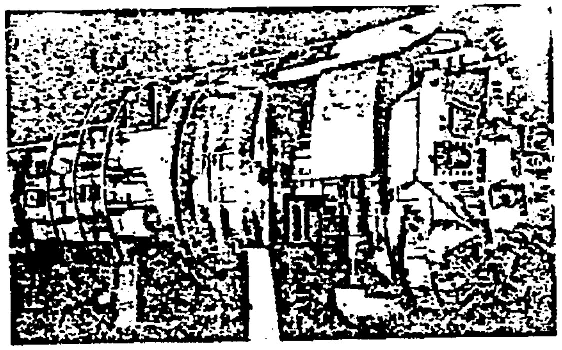


Fig. 23 - Full-face tunneling machine

Efficient use of modern coal preparation plant

Dipl.-Ing. F. Brinkmann

KHD Humboldt WEDAG AG, Bochum

Efficient use of modern coal preparation plant

By the time run-of mine coal has reached the surface, it has already been burdened with such costs that its total utilization has been an economic necessity.

Initially, almost all coal mining countries fired the run of mine coal as it was mined. But in the course of time, the percentage of impurities contained in the run of mine coal was steadily increasing, which was specifically caused by the increasing use of mechanical mining equipment. As transportation systems and ovens were loaded by the impurities, coal cleaning turned out to be mandatory. In the initial phase, the coal was only screened and crushed, and later on, only the rock material was sorted out until complete coal preparation processes were developed which finally allowed the most economical use of the coal.

To achieve this in Germany have, over the years developed a number of cleaning techniques which have become more or less standard practice in coal preparation technology.

This technology has gained ground not only in Europe, but also in the United States, Brazil and India, and I could imagine that it would meet the expectations of the Indonesian coal industry.

The trend of developments during the recent 10 years has been to build equipment with high throughput capacities, precise cut points and low operating cost.

The most important machines of the installations have so far been developed up to the following sizes:

1.	screens	up to a width of 5.5 m
2.	deducters	up to a diameter of 8 m and an output of 800 t/h
3.	jigs	up to jig bed widths of 7 m
4.	dense medium separators	with diameters up to 7 m
5.	disc filters	up to a filter area of 400 m^2
6.	drum filter	up to a filter area of 200 m^2
7.	flotation cells	up to 16 m^3 per agitator field

The installations were better arranged and could manage with fewer staff, running costs decreased accordingly.

Description of the Batac jig

A cross-sectional side view of the Batac jig, showing the air chambers below the screen plate and a diagrammatic air valve system, is illustrated in Figure 1. This shows a six-cell, three-compartment jig and is normally used in this form for treating fine sizes of approx. - 12 mm. A feldspar bed can be used in certain compartments.

By means of the air valve system, compressed air is intermittently fed into the air chambers. In this way water is desplaced out of the air chambers in a cyclic manner thereby causing a pulsating motion of the water.

The standard Baum jig uses either piston or rotary type air valves. The Batac jig uses a flat disc design valve, which gives a sharp cutoff to the air input and exhaust. These valves, both for inlet and exhaust of air, can be infinitely varied as to frequency and length of stroke. The ability to vary the cyclic characteristic of the dilation and compaction is of immense value in opening and closing of the bed to obtain efficient stratification in the bed as the raw coal characteristics change with regard to variations in size distribution and feed density changes.

The air valves are controlled by an electronic, solid-state circuit, in a cabinet, generally installed in the plant control center.

Photograph No. 1 shows the complete assembly of the air valve mechanism for a Batac jig. Photograph No. 2 shows a close-up of these air valves for a single cell. Photograph No. 3 shows the electronic cabinet for controlling the action of the valves in which the frequency is measured in milliseconds. These units are made in a modular, slide-in form and, if a malfunction does occur, they can easily be replaced in a few moments.

The lifting motion of the water causes the coal to stratify according to its density on the jigging bed and at the same time allows transport of the coal. The heavy gravity material in the coal discharges at the end of each compartment through shale ejectors. The finer sized heavy particles are separated in the artificial medium of the feldspar bed and pass through the openings in the screen plate.

In order to control the bed level of the stratified material in the jig, a number of floats are installed along the width of the jig in each compartment. These floats are automatically controlled by inductive coils which can be set to measure the various densities of separation. They trigger hydraulically operated refuse ejector valves which increase or decrease the bed level, as required. A diagram, illustrating this mechanism, is shown in Figure 2.

In the case of a plant stoppage or lack of feed to the jig, a float mechanism near the feed-end of the jig is used to bypass the jig qir used for pulsation. This prevents disturbance of the jig bed and avoids the usual misplaced material which would otherwise occur if the jig were operated without raw coal input.

Primary rejects or tailings can be discharged by the bucket elevator from either the first compartment alone or, depending upon the quantity of heavy tailings to be discarded, from both the first and second compartments.

Secondary rejects can discharged by the second bucket elevator, either from the second and third compartment or only from the third compartment. The secondary rejects may, if the character of the material warrants, either go to final tailings, be returned back to the jig feed for recirculation, or be classed as middlings or secondary product. The secondary rejects or washed overflow may also be recleaned in a heavy-media system.

This retratment, if required, only involves a relatively small tonnage of the total jig feed.

The Batac jig can be used to wash coarse as well as fine sizes of coal. In other words, it can handle any of the sizes now being washed in the various types of Baum jigs. However, as in any coal cleaning equipment, it can do a better job of cleaning the smaller sizes, if they are washed separately. This may sometimes be desirable as the finer sizes are generally cleaned at different densities of separation to the coarser sizes.

The jigs can be built up to almost any size. The largest size being built at present is 7 metres wide and 6.2 metres long, giving 42 square metres of jigging area. This jig will trat 600 tph of 10 mm x 0 raw coal. This tonnage would increase proportionately as the top size of the raw coal is increased.

Performance of the Batac jig

The performance of the Batac jig has been well oven. Over 50 installations have been completed, or are in the process of construction. It to date has replaces many of the installations of older jigs or heavy media processes.

As examples of the Batac jigs performances, Table 1 shows the separation results of two Batac jigs on the preparation plant Walsum.

1. Coarse grain jig, yield 500 t/h

density g/cm^3	yield	proportions in % by weight coal	middlings	tailings
- 1.45	30.6	99.4	26.4	-
1.45-1.8	9.3	0.6	55.0	1.2
+1.8	60.4	-	18.6	98.8

2. Fine grain jig, yield 500 t/h

density g/cm^3	yield	proportions in % by weight coal	middlings	tailings
- 1.5	66.3	98.7	19.3	0.2
1.5-1.8	5.6	1.1	54.3	1.5
+1.8	28.1	0.2	26.4	98.3

Furthermore, in the years to come, attempts will be made to use jigs increasingly for the preparation of minus 0.5 millimeter sizes. Equipment for smalls, which, until now, have been set to handle a mean particle diameter of 3 millimeters will be used, more and more, for the extremely fine sizes up to 0 millimeters in order to simplify the process further. When using jigs for 13 to 0 millimeter sizes, preliminary results have shown imperfections of 0.18 for the 0.5 to 0.1 millimeter size range.

Deduster

In order to save cost for the expensive dewatering of slurries -it-was developed a special coal deduster Figure 3. As far as is permitted by the moisture and ash contents of the dust, centrifugal deduster have been used to separate the - 0,5 mm fraction from the raw smalls.

These dedusters work according to the closed-circuit air principle whereby the material is separated with the aid of gravitation and additional centrifugal effect. The material fed through the hollow shaft in the rotating center of the unit is dispersed by the rotating distributor and centrifuged veillike and radially onward into the rising air-steam, where the fines are separated from the coarse material.

The fines taken along by the air stream drop into the space between outside mantle and in.side ring, accumulate on the bottom of the dust compartment and are then conveyed to the discharge by the rotating cleaning device.

Thanks to the considerably increased dust compartment volume the separation of air and dust is efficiently effected. This results in just a minor dust content in the air returning into the circuit via the impeller. The dedusted coarse material drops into the grit hopper and from there it is allowed to fall freely into the conveying means.

In order to avoid the formation of condensed water, a portion of the circulated air volume is permamently exchanged with fresh air.

This deduster has been developed in order to render possible the dedusting of run-of-mine coal which, due to the modern dust control regulation for underground mining, is getting to the preparation plants with a moisture content which is increasing all the time.

Even if very wet coal gets into the deduster at intervals, thus excluding the feasibility of dust collection, the separator keeps itself free and continues with dedusting as soon as th moisture in the feed drops back to the normal top limiting values. From the economical point of view each ton of coal gained in the dry process is of importance. Since it will not be subjected to expensive wet cleaning and losses.

Dewatering

In addition to the well-known drum and disc filters for the dewatering of coal slurries, a new double drum filter was developed which is characterized by a very high specific output of maximum 1,300 kg/m^{2}h. Figure 4. The material to be filtered is fed vertically downward into the gap between the two drums which rotate in parallel.

The double drum filter takes full advantage of the sedimentation of coarse solids in the feed trough: A layer of corser material is initially formed on the filter surface, serving as basic layer for the following fine grained filter layers.

Double drum filters are specifically suited for the dewatering of coarse coal slurries; they are insentitive to oversize material, if any.

Comparison of results obtained in commercial plants

	double drum filter	disc filter
feed		
percentage of solids g/l	553	468
percentage of ash %	9,5	9,1
filtrate		
percentage of solids g/l	19,3	2,0
percentage of ash %	16,5	13,2
filter cake		
filter discharge capacity (i.wf) kg/m^{2}h	1290,5	736,3
residual moisture %	20,1	21,6
percentage of ash %	9,5	9,7
recovery of solids	98,3	99,8

By means of the following figures I would like to explain which flow sheet we would suggest for your coal.

Aspects of Planning, Organisation and Management of Coal Mining Operations

Dipl.-Ing. Horst Friederichsen

Montan Consulting GmbH, Essen

Abstract

Aspects of Planning, Organisation and Management of Coal Mining Operations

The aim of planning and organisation in every coal mining operation is to achieve the "overall operational goal", which can be defined as the long-term assurance of an output both meeting the market's quantitative and qualitative requirements and representing the maximum and most cost-effective exploitation of deposits for the lowest possible outlay in capital spending.

The basis of all planning is a thorough knowledge of the deposit in terms of its geological makeup and raw materials. All available knowledge should be so documented as to be of practical use in planning the mining operation. Engineering planning itself extends over several distinct phases from the development of alternative concepts to their implementation. This is equally applicable for individual sections of an operation and entire new mines, whether underground or opencast. Modern planning in mining is thus a constantly self-regenerating process that involves thinking in terms of alternative concepts.

Planning formulates the alternative rules for running the mine on which management makes the decisions.

It is the task of Organisation to implement these decisions and to structure operations accordingly. In the German coal mining industry, for example, the line- and staff system has proved its worth, with Organisation retaining its responsibility for coordinating the various operational elements, i.e. for managing the mining operation.

This entails, above all, dealing with organisational and information tasks as well as solving such social problems as the selection and deployment of labour, with great importance being attached at all operational levels to standards of training.

Aspects of Planning, Organisation and Management of Coal Mining Operations

Every industrial operation involves the interaction of a series of factors which can only enable productive work and optimum results to be achieved when sensibly combined. A distinction must be made between what are known as the elemental factors manpower, plant, equipment and material - in mining the deposit - and management as the dispositive factor.

Planning and organisation are two factors deriving from management. Both focus on the "general aim of the operation" which can be defined for mining as ensuring long-term output that satisfies market demand in terms of quantity and quality - with minimum capital and operating costs and maximum exploitation of the deposit.

Planning formulates a number of alternative conceptual structures and rules for the mine as a whole so as to furnish a basis for the management's decisionmaking process. Organisation involves putting this chosen design and layout into effect - a two-fold activity:

- building up a sensible structure for the operation

- establishing efficient interaction of all operating units, i.e. managing the operation.

This short excursion into the basic concepts of industrial management seemed to be necessary to define the concepts "planning", "organisation", and "management" in the title of this paper and to show their interdependence.

Mine planning is an iterative process whereby preliminary judgements on mine design, production and economics are tested by subsequent analyses, which are supplemented if necessary by additional data derived from confirmatory studies of specific aspects, the procedure being repeated with an increasing level of accuracy as the degree of project definition increases.

Mine planning is based on the results of exploratory work which have to be evaluated and represented in map form. Determining the formation of the deposit in terms of stratigraphy and tectonics is the first stage. Separate maps are produced for the mineable seams and seam sections showing all the parameters important in mine planning, such as

- seam thicknesses
- partings in the seams
- data on coal characteristics
- nature of floor and roof strata of the seam
- tectonics
- thickness of the overlying strata
- hydrological features

These maps showing the results of exploration of the deposit form in turn the basis for

- delineation of workable seams
- alternative layouts of the panels or districts
- alternative locations for driving development openings.

On the basis of the alternative layouts the proven and mineable coal reserves can be estimated and information gained on possible additional reserves. Weak points and gaps in the exploratory work carried out will become apparent, indicating any further exploration needed in the areas already covered and permitting programs to be set up for exploratory work in areas adjoining the deposit.

The representation of the basic principles by which the geologist works out the basic design factors for the mining engineer engaged in planning the mine applies, of course, not only to the design and layout of completely new mines, but applies equally to each individual working of an existing mine. Thus, the same sort of investigations must essentially be carried out when, for instance, a new longwall face is to be planned in a deep-level mine. Traditional surface exploration methods, i.e. drilling and geophysical methods have been modified and advanced in recent years to provide a special type of underground exploration, namely forefield reconnaissance. Today, it is thus possible to drill horizontal boreholes up to 1000 m in length in the forefield of the workings and to investigate the structural geology using underground seismic methods. Mining itself furnishes new "exploration" results every day which, when carefully evaluated, lead to ever-increasing in-depth knowledge about the deposit.

It now becomes clear that planning in mining is an ongoing process because - in contrast to many other industrial processes - the elemental factor, namely, the material, i.e. the deposit, continually presents itself in different forms.

The technical and economic planning of a mining project - based on the evaluation and appraisal of the

deposit - is likewise a process proceeding in several phases. This can be seen by looking at the development of a new mine.

The first phase involves working out conceptual alternative approaches to the project. It contains as a first step a preliminary appraisal to clarify key parameters and identify obvious alternatives (including abandonment of the project). This allows a decision to be reached about whether or not to proceed to a more detailed examination. The result of this first step of the conceptual phase is often presented in the form of a pre-feasibility study. A basically satisfactory result ushers in the next step of the conceptual phase. This consists of a detailed examination and analysis of the situation, covering all significant practical aspects. Preliminary layouts are prepared and economic considerations embracing capital and operating costs, financial commitments and profitability are studied, including alternatives, of which the most appropriate are recommended. The conceptual phase is usually concluded with a feasibility study.

The second phase is the design phase. By the time project feasibility has been confirmed, the project should have become site-specific. Requirements for mine workings and equipment, infrastructure and relevant services, manpower and management organisation are specified in detail together with the associated capital and operating costs. Furthermore, project engineering is scheduled.

The <u>third</u> and last <u>phase</u> is the project engineering which initiates the phase of project implementation. It evolves naturally from the project design phase and evolves the substantial engineering design work necessary for the accurate assessment of capital costs, the preparation of tender documents, evaluation of tenders and supervision of construction and mine development.

Every mining scheme passes through the above phases, but, according to the size of the project, it is sometimes possible to merge one or more phases. This means that basically identical steps have to be carried out even when minor projects need to be carried out in an existing mine. In fact, detailed planning for a new longwall face in a modern German coal mine often begins more than a year before operations are scheduled to commence at the face. Plans must be adjusted to allow for any new geological and/or technical findings deriving from development work. The basic production and associated development plans are worked out at

least five years in advance and likewise continually adapted in the light of new findings and information.

As defined above, planning works out a number of alternatives in terms of mine layout and operating arrangements for decision by the management. Decisions in mining often involve a certain factor of uncertainty and thus entail risks. This means that decisions must be taken on the basis of incomplete information but on the assumption that most probably specific conditions and situations will ultimately be obtained.

The planning philosophy outlined above, i.e.

- thinking and planning in terms of a number of alternatives
- regarding planning as a process of continual revision rather than a task to be carried out once and for all

helps to increase the degree of probability that factors which have been allowed to influence a decision will actually prevail and hence minimises the risk involved.

The structure and rules proposed by planning and chosen by management must be translated into reality. This task is entrusted to those engaged in organizing the operation and involves the establishment of operational structures, i.e. levels on and between which the interplay of planning, decision-making and implementation takes place. Managerial organisation also involves the establishing of rules governing the interplay of the elemental factors of the operation - that is how the operation is run. The term "operation" must be seen in the widest possible context, encompassing a fully developed and operational mine at one extreme and a completely new project at the other. Organisational structure and rules are closely interrelated.

Organisational and management structures of mining operations are very strongly characterized by the historical background, the socio-economic system of the country concerned, standards of engineering, and the qualifications of managerial staff at all levels. Organisational forms vary in line with these manifold factors. It is thus very difficult to set up a uniform organisational structure ideally suited for all and any coal mining operations. It is worth looking instead at a few basic principles as exemplified in the form of organisation preferred in the German coal mining industry - the line and staff organisation.

In this type of organisation the production area, i.e. all those functions associated with coal mining in general and with authority and responsibility for management, flowing from the highest level of mine management down to the least significant working - represents the line. The line organisation is characterized by indivisibility in giving instructions and by clear-cut delegation of tasks, authority and responsibility. This entails unambiguous, well-defined and, where possible, comprehensive competency of supervisors vis-à-vis their subordinates and equally clear and comprehensive job descriptions, i.e. definition of duties, powers and responsibilities. Any line manager in German mining industry, for instance, has his area of activity defined in writing. A fundamental principle secured by the line organisation is that directives cannot be issued to operational divisions "from above" - the hierarchy cannot be bypassed. The actual entrepreneurial task left to corporate management above mine management level is the setting of guidelines for decisions relating to the enterprise as a whole.

A staff of specialists is assigned to the highest line function of an individual mine as a consulting body. This staff has no line function and therefore cannot issue directives to the managerial levels of the line and cannot intervene directly in operational matters. The duties of the staff functions assigned to mine managements are

- planning, and the engineering work necessary for its implementation
- assisting and advising line functions in making optimum use of equipment and manpower
- supervision of operations.

It becomes clear from the above description of the various duties that the staff function must be located close to the mine management to ensure flexibility and awareness of the problems at hand, thus giving life to the modern planning philosophy depicted earlier in the paper. There are many mining companies where the staff of specialists is not assigned in this way and where the mine itself is strictly engaged in production, while engineering matters - especially planning - are dealt with by engineering staffs assigned to headquarters. This results in rivalry between the staff function and the line functions, lack of insight on the part of the staff function into shop-floor requirements and unwillingness of the line functions to accept decisions in which they have not played a part. The avoidance of such conflicts is another basic principle embodied in

those types of organisation which are capable of functioning efficiently.

Finally, the controlling, i.e. operational management functions involved in organisation need to be looked at briefly. Coordination is the first and foremost consideration here. It involves integration of all the interlocking systems within the operation that arise from the combination of all the production factors. Every employee is faced with coordinative tasks; from the foreman of a face crew in allocating work, to the mine manager in coordinating line and staff functions, for instance. Purposeful and sensible coordination of all the operational elements to make full use of resources available is absolutely vital, especially in the case of large production units.

As the size of an operation increases, the number of possible links between individual decision-makers increases exponentially. This becomes particularly evident when one looks at the bandwith of the supervisory span of a group leader. With three people working under him there are 18 possible communicative paths, with 6 this increases to 222 and with 8 workers in a group there are 1080. In the German coal mining industry a supervision ratio of 1:6 to 1:8 has become established as best suited to operational needs. This is generally applicable - to the face crew underground and to an engineering team assigned to a staff department.

Repeated examination of supervision ratios helps in making adequate long-term coordination at all levels of line and staff functions possible. Where a supervisor has too many people working under him, an additional managerial level of management must be intercalated. A large number of people under the supervision of one individual is not a sign of particular personal managerial power but indicates rather the presence of an inefficient organisation.

Information is a further important element in the functions of the organisation. Comprehensive and reliable information dissemination is essential to enable managerial staff at all operational levels of a mine to make the right decisions. Enough of the right information must be available where needed and when needed. Any information which a decision-maker requires or requests must be made accessible to him as far as possible so that he can make the right decision. Such information should not be regarded in the negative sense as an instrument of control, but rather as a decision-making instrument, i.e. to initiate corrective

action when anything deviates from its planned path. On the technical side such information is given in the form of progress or present status reports which are collated in central control and instrument rooms.

A fundamental distinction has to be made between directory information transmitted via the managerial levels of the line and functional information passed along informal channels.

The former path has to be used for all operationally important messages. Such messages mostly have a standard form. The informal channels should, where possible, be left open for all other operational and personal messages.

Finally, the function of the organisation is to find solutions to questions arising from the selection and deployment of manpower. This applies in particular to all managerial levels of staff and line. The wellknown aim of personnel management of assigning the right person to the right place is one of the most important requirements. When this is not met conflicts will arise between the aims and potentialities of the employee and the needs of the operation. The training of suitable employees is becoming a special challenge to the mining industry. This is especially so when the industry is of recent origin and still in the development stage and the general training facilities available in the country are not yet sufficient to train the supervisors and management staff needed in mining. Recognizing the need for well-trained qualified manpower the German coal mining industry has built up training facilities of its own. Such training covers all levels - from the underground miner to top management. This approach to industrial training has achieved international recognition. Foreign coal mining countries already make frequent use of the opportunity to have skilled workers, managerial staff and supervisors trained on equipment in the training centres of the German coal mining industry. German instructors are also involved in instructing specialists for foreign companies or in setting up training centres for them.

The aspects of planning, organisation and management outlined above apply, of course, not only to coal mining, but to any mining activity. The basic principles have proven their worth in the German coal mining industry and have placed Germany among the world's leading coal mining countries in technological terms. The experience gained in all fields is available to the emerging coal-mining countries in developing their indigenous resources.

Abstract

Aspects of Planning, Organisation and Management of Coal Mining Operations

The aim of planning and organisation in every coal mining operation is to achieve the "overall operational goal", which can be defined as the long-term assurance of an output both meeting the market's quantitative and qualitative requirements and representing the maximum and most cost-effective exploitation of deposits for the lowest possible outlay in capital spending.

The basis of all planning is a thorough knowledge of the deposit in terms of its geological makeup and raw materials. All available knowledge should be so documented as to be of practical use in planning the mining operation. Engineering planning itself extends over several distinct phases from the development of alternative concepts to their implementation. This is equally applicable for individual sections of an operation and entire new mines, whether underground or opencast. Modern planning in mining is thus a constantly self-regenerating process that involves thinking in terms of alternative concepts.

Planning formulates the alternative rules for running the mine on which management makes the decisions.

It is the task of Organisation to implement these decisions and to structure operations accordingly. In the German coal mining industry, for example, the line- and staff system has proved its worth, with Organisation retaining its responsibility for coordinating the various operational elements, i.e. for managing the mining operation.

This entails, above all, dealing with organisational and information tasks as well as solving such social problems as the selection and deployment of labour, with great importance being attached at all operational levels to standards of training.

Dr.-Ing. Rudolf Gronebaum:

The technology of coal handling and conveying represented by actual examples

The questions which will be dealt with in my paper are based on the fact that the primary energy we need can in most cases not be found there anymore where it is utilized. This applies to coal as well. Therefore, the very simple model of coal transport from the deposit to the power plant (fig. 1) has changed into a complex transport system consisting of a variety of conveying equipment and intermediate stations (fig. 2).

This transport system allows a number of alternatives which I would like to introduce to you in the course of my speech.

The following is based on the assumption that the coal will be mined from open cast mines. A description of underground coal mining and transport would be a special, voluminous subject and could not possibly be given within the time limit I have to observe. For coal production in Indonesia underground mining is - to the best of my knowledge - of little significance anyway. Let me therefore concentrate on coal mining and transport in an open cast production.

In Europe due to the prevailing geological conditions it is mainly lignite (brown coal) that can be mined from open pits. To do this a certain technology has proved to give the optimum solution. For removing the overburden as well as mining the coal bucket wheel exsvators are being used. For the transport of both overburden and coal we employ conveyors (fig. 3). The belt widths of those conveyors are between 1200 and 3200 mm. The range of belt speeds reaches up to 7.5 m/s, thus giving transport capacities up to 30,000 t/h.

The single conveyor drive stations incorporate capacities up to 6 x 2000 kW with single conveyor sections reaching a maximum length of 2500 m. The belts are predominantly of steel-rope-type. The belt support structures are designed in such a way that the conveyors can be shifted in their entire length, thus following the advancing mining operation. fig. 4.

Belt conveyor systems of this size are only economical for very large open cast mines. For medium sized pits belt widths between 1200 - 1400 mm would be sufficient. Fig. 5 shows a conveyor system in such a medium size pit, feeding a power plant of 600 MW, beside a fertilizer and a briquette plant.

All these handling and conveyor systems are electrified so that the pit operation can be supplied with energy from its own power station.

There are other possibilities as alternatives for this European mining system, for example mining by dragline and transport by dump trucks. As we dispose of electric energy in unlimited quantities from the power stations erected right near the lignite open cast mines, we would not even consider to use diesel-driven vehicles for transporting the coal. We only do this in quarries where the conditions of energy supply are different.

As overburden and coal are stripped from different benches, we have to make sure that the different materials are distributed correctly by means of a collecting belt conveyor system; for example: overburden to the outer bank and later to the inner bank; coal to the railway car loading area or in case more coal is mined than can be immediately accomodated, intermediate storage of the coal and reclaiming at a later stage.
Figure 6 shows such a collecting belt conveyor system, figure 7 a railway car loading station. In most cases a ditch bin is used for intermediate storage of coal. This bin receives the coal from a stacker, and then the material is picked-up again by bucket wheels.

Now the coal is transported to the port of loading. I assume that transport by rail is the most appropriate means of transport for this purpose. Adequate cars, as they are used for this purpose in Europe, are shown on figures 8 and 9. These cars have a capacity of 55/28 tons resp. They are automatic hoppers which are emptied into a deep bin. The cars can be compiled to trains of up to 40/60 cars. The wagons shown here were built in large numbers for the German coal company Ruhr-Kohle AG and for the German Federal Railways. One can, of course, use simpler cars and discharge them in by using kick-back or circular tilting stations.

Rail transport, however, has a great disadvantage: the cars must return empty. In case of long distances to the port this increases the costs considerably. That is why alternatives have been searched for. The transport by belt conveyor systems would without doubt be such an alternative. Conveyor belts may reach single lengths of up to 10 km depending on the design, so that only few transfer points are necessary, provided, however, that the distance to the port of loading is reasonable and favourable geographic conditions prevail. Nevertheless, such belt conveyor systems have only been taken into consideration very rarely. A kind of transport which will be given more attention in future, is the transport of solids by pipelines. Figures 10 and 11.

Such pipelines are already in operation in North and South America as well as in Australia. One is being built in Europe, too, but this one is provided for ore. As we shall still hear a lecture on pipeline transport within the programme of this event, I do not want to go into details and now wish to turn to the next station, the shipment.

As the trains arrive in another sequence than the ships call at the port for loading, a larger coal stockyard is needed. The size of this stockyard also depends on the fact that in many cases different types of coal have to be stored. The coal is transported form the car dumping station to this yard by means of a belt conveyor. Piling and reclaiming is preferably done by combined machines, these are stackers equipped with a bucket wheel to reclaim the material. Combined with a tripper car this machine may pick-up coal at any position of the conveyor belt, figure 12. A coal stockpile of 40,000 tons corresponding to the loading capacity of a medium bulk carrier, has a floor space of 40 m x 180 m and a height of 12 m. The stockpiling capacity of such machines amounts to 2000 t/h and the reclaiming capacity to 1500 t/h. The reclaimed coal is transported to the ship loader via a belt conveyor, figure 13. The shown ship loader works in combination with a tripper car and may load the ship without having to warp it. The ship loader adapts itself to the different ship widths by slewing of the jib.

Other systems are equipped with stationary ship loaders, figure 14. In this case the ship must be warped when changing the hatch.

Most of the ships today are conventional bulk freighters. Figure 15 shows such a vessel of 40,000 tdw. It has a length of 182 m, a width of 30 m and a draft of 12 m. Toda vessels of this order have still their share in the coal transport at a rate of approx. 25%, while vessels of 50 - 100,000 tdw have already a share of 30%. The trend toward larger freighters will still increase in the next years, a the freight rate of a 100,000 tdw-freighter is only half a much as the rate of a 20,000 tdw-freighter. But larger carriers require corresponding unloading and storage capa- cities in the ports of arrival. At present, unloading wit clam shell-type unloading bridges is still the current system. Such an unloader with a 40 t grab as shown on figure 16 is capable of handling 1500 t of coal per hour. The capacity can be doubled by using 2 bridge unloaders o one vessel. This is practiced in normal cases. However, this kind of capacity increase is very costly so that one is looking for alternatives.

One of these alternatives is the automatic discharge bul freighter. In case of this freighter unloading is carrie out by means of a conveyor belt situated under the floor of the freigth space. This solution means a bad utilizati

of the ship's volume which, however, can be improved by using 2 belts. The unloading capacity can be raised to 8000 t/h. But then the vessel becomes accordingly ex- pensive. Another advantage of these vessels is that the equipment of the unloading port can be very simple, figure 17.

But in this case one is dependant on automatic discharge vessels. Conventional freighters cannot be unloaded in these ports. For this reason, another version being dis- cussed in Europe at present is the continuous ship un- loader , figure 18.

The continuous ship unloader - shown here - features a bucket wheel for reclaiming the coal. Form those corners of the loading space not accessible to the bucket wheel the coal is moved towards the reclaimer by means of scrapers. An elevator lifts the coal out of the boat and conveys it to a transport belt. This system is capable of increasing the unloading capacity to approximately 3500 t/h, that means to double it. The capital investment for such a system should not be considerably higher than for a clam shell unloader.

We are now turning to the last link in our transport chain, the storage facility and coal feeding system of the power plant. Here I would like to describe the relevant equipment of a modern coal power station of 720 MW situated on the German coast.

This discharge system mainly consisting of a 32 t clam shell-type bridge unloader is capable of unloading bulk carriers up to 60,000 tdw, fig. 19. The unloading capacity amounts to 1250 t/h. The distance between the pier and the storage area measures approx. 3 km, both connected by belt conveyors of 1400 mm width and a speed of 3.0 m/s. The stacker is adapted to this transport capacity and is capable of stacking 2 parallel piles of 600 m of length each by means of a tripper car, figs. 20.21.

The cross section of these piles is of trapezoid shape, the stacking of the coal is done according to the Windrow-method. Reclaiming is effected by bucket wheels with a capacity of 500 t/h each.

Due to the fact that the 2 bucket wheels do not simultaneously work on full capacity, the coal feeding belt connecting sampling station and boiler house does not require a transport capacity of more than 850 t/h. Within the boiler house the coal is being distributed to 5 bunkers situated above the coal mills. The components of the handling system only indicated in the ground plan are shown in the following fotographs:

- the clam shell-type bridge unloader, fig. 22
- the access bridge to the pier incorporating the conveyor belt, fig. 23.
- stacker and tripper car, fig. 24.
- the bucket wheel reclaimer with the boiler house in the background, fig. 25.

Coming to the end of my paper I would like to point out that there remains a large number of interesting details which I had to neglect because of the limited time available. Your Indonesian experts certainly will confirm this considering the tremendous work they have done and the expertise they have gained by elaborating the Bukit Asam project. I would be very glad, however, if I succeeded in giving you the idea that the German industry would be a reliable partner for the realization of this imminent project.

I do thank you very much for your kind attention.

COAL SLURRY PIPELINE TRANSPORT

by K.-H. Brachthäuser

of Friedrich Flick Industrieverwaltung KGaA

INTRODUCTION

When raising the question which integrated transportation system should in the future handle the protected world coal trade, one has to consider a system functioning similar to the transportation- and distribution system for crude oil and natural gas and offering, moreover, the same security supply while avoiding any increase of risks for the human being and his environment.

The world coal production has nearly to be tripled and the world coal trade with steam-coal for power stations has to be increased more than tenfold in order to obtain so much as a slight economical growth within the next 20 years. With regard to the extreme conditions in Japan, one even ought to consider a twentyfivefold increase of the coal trade. This was concluded by the experts who collaborated in the "WORLD COAL STUDY". It is expected that the coal has to take over at least half or even two thirds of the increase of the world energy consumption, since neither crude oil and natural gas nor nuclear power, solar energy, wind energy, biomass or rigorous economization of energy in some industrial countries so much as nearly can fill the arising energy gap. The main consumer of coal in the year 2000 will - as they are today - be the suppliers of electric power who are requiring about 70 % of the entire coal production. Even if the capacity of the nuclear power stations were to be extended to a large extent, the substitution of natural gas and fuel oil by coal would not decrease the overall coal consumption in electric power stations. This applies to industrial countries and certainly also to the developing countries.

If one yet includes the industrial heat supply systems, it will be necessary to develop the most economical integrated storage- and transportation system for about 70 % of the extended world coal trade. The coal trade in the entire world amounted in 1977 to approximately 200 million t/a and might by the year 2000 increase to about 1.000 million tons. The coal transportation could be achieved by a

"COAL SLURRY PIPELINE TRANSPORT SYSTEM",

primarily for the long-distance haulage work and certainly, though with restrictions, also for the local distribution. The integrated system, however, would have to be supplemented by special "coal tankers" which could utilize the infrastructures which ports have available for crude oil and other liquid hydrocarbons.

FUTURE COAL UTILIZATION

The short-term and long-term dependence on crude oil shall be decreased by an extended coal use, and the energy gap to be expected shall be filled by coal by the year 2000. It has to be considered in this connection that the coal will at least in the industry be used under economical aspects and without causing an additional charge to environment. Though in many mines worldwide coal can be exploited very easily and at low cost, the treatment and the transportation of coal will with respect to crude oil originate additional cost which in particular cases will rise up to 300 % for just transporting the coal from the mine to the consumer. The total cost in relation to the energy unit can only be reduced if the ash-, water- and, if possible, also the sulfur content can be strongly reduced by extending and improving the technologies of the coal treatment and the storage- and transportation systems. The introduction of new methods must be adjusted to the bulk transport of coal which is effected land-borne and seaborne.

It appears to me, Ladies and Gentlemen, that we are confronted with three interlocking nexuses of problems for which the most economical solutions for the respective use of coal will have to be found step by step.

The respective problem areas are as follows:

a) coal treatment
b) coal storage and handling
c) coal transportation

The targets "ECONOMIC EFFICIENCY OF THE ENTIRE SYSTEM" and the "WIDE USE OF STEAM COAL" are a combined function of the raw material coal and of the distances in transportation, i.e. of the geographical location of the mine and the geographical location and size of the coal consumer.

PROBLEM AREA A)

Consequently, a coal treatment facility which, in particular, would allow for a variable adjustment of the impurities content, must be designed to handle problem group A. I feel that for a transport of f.i. Indonesian coal to Germany or Japan, the ash content ought to be less than 5 %, if possible below 2 %, while the surface water content should be below 8 %, if possible between 1 % - 2 %. These values - as is well-known - can only be obtained for ordinary steam coal with a high impurities content on account of treatment cost above average. Such an extreme reduction of the impurities would probably not be economical in view of smaller distances of transportation and would thus not be required. A special solution will have to be found for each individual case of application.

In addition to the reduction of the impurities, a decrease of the sulfur content must also be considered. Not for reasons of transportation, but for reasons of environmental protection the sulfur content should not be more than 1.0 %.

In any case, the impurities and the sulfur content ought to be reduced to such an extent that the coal at the consumer will under imposed requirements for the protection of the environment be able to compete with petroleum derivates.

PROBLEM AREA B)

The nexus of problems under B) deals primarily with questions regarding storage, dust and drain water when handling coal. These include all activities that are required for the loading and unloading of transportation equipment respectively vehicles. Lump coal of all sizes with a surface

water content of about 3 % - 6 % can practically - without causing problems - be stored, reloaded and transported by trucks, conveyor belts, barges or train, however require large spaces and expensive loading facilities. In order to guarantee a quick and smooth loading of large coal freighters for lump coal, the necessary facilities still have to be installed at the seller as well as at the distributor of the coal. The largest dry bulk carriers available at present have a maximum capacity of 150.000 DMT. It is intended to have cargo ships for a capacity of 250.000 DMT built by 1990. An offshore-reloading from small cargo ships or barges to large ships and vice versa seems to be indispensable for many countries under present preconditions. Owing to this fact, additional expenditures and risks will arise for the environment. New deep water ports for the transportation of dry bulk material will be quite expensive and also require long construction periods. With the exception of Japan, this infrastructure is missing in nearly all industrial countries. Therefore, this transportation system does not appear to me to be the most economical one for the increasing coal consumption and transportation in the future.

The storage of the dewatered fine coals has in nearly all cases to be made in close bunkers or containers. This especially applies to cases when the dried coal fines or pulverized coal might ignite spontaneously. A storage in a protected atmosphere would then be indispensible. Coal slurry, however, can be stored in normal storage facilities. Fine coal offers the advantage of being conveyed to the transportation units in completely closed and continuously operating hauling equipment.

PROBLEM AREA C)

I now come to speak about the problem group C). I hold the opinion that Oil- or LNG-tanker terminals should be utilized for a special loading and transportation system of coal. This, however, is only possible if all types of coal are transported in a pumpable condition, that means as slurry by "COAL-TANKERS", as I call them, as a mixture of coal and oil, coal and water or even better of coal and methanol. Then available oil-tankers might - after having been slightly modified - also be used in future coal transportation. The coal slurry transportation of coal-oil-slurry and of coal-methanol-slurry offers the big advantage of only transporting a small amount of non-combustibles. In long-distance transportation, this leads to considerable cost reduction per energy unit.

For the extended use of coal in practically all countries of the world, the land-borne transportation, including storage and distribution of the coal, as far as to the consumer is a factor not to be underestimated. The hitherto used classical means of transportation, such as trucks, railroad and barges can by no means handle the future growth of coal transportation. In many countries the hitherto used means of transportation are not extensible in a sufficient way. In other countries the traditional transportation systems cannot be utilized due to the geographical location of the coal mines or can only be installed at high financial engagement. I, however, am of the opinion that the installation of slurry-pipelines seems to be possible everywhere. The experience gained in the worldwide construction and operation of oil pipelines, including all conditions of climate as well as geographical and geological problem areas, can be utilized.

Another factor not to be underestimated which applies to classical means of transportation only, is constituted by the principal environment disturbances, like dust, train noise, train or truck congestion and the risk of accident causing property damage risk to human life. These environmental problems are avoided by a pipeline.

Before I now come to speak about the technical details of slurry-pipeline, Ladies and Gentlemen, I want to speak in favour of the "COAL-METHANOL-SLURRY-TRANSPORT".

I think that the questions dealt with in the various problem areas, necessarily lead to the conclusion that a widely-spread and considerably extended coal trade and coal use cannot be realized, neither in a short-term attempt nor in a longer process up to the year 2000, unless coal will be handled as slurry in all large storage and transportation areas. Due to the factor that the oil price already is exorbitant and partially is accompanied by political risks, methanol ought to be used as "CARRIER" for the dried fine coal in which the ash content was removed in part.

I do not mention water as a carrier, since among other reasons many coal mines all over the world do not provide water in sufficient quantities for slurry pipelines. The recycling of water by pipeline from the consumer to the mine is, as was proved by hitherto made investigations, just as uneconomical as the high water content - or in other words impurities content - in the overseas slurry transport.

The high costs which are originated during the cleaning process of the slurry water which is separated from the coal have to be added yet. A not appropriate handling would in any case cause risks to environment.

Methanol as a carrier would avoid such problems. Methanol can easily be produced at any mine, partially from the middlings originated during coal treatment, by using well-known coal gasification technologies. Even lowest-grade coal could thus be transformed into a liquified product which can be widely utilized as fuel or as a chemical raw material. With the aid of methanol coal from the geographically most remote mining areas can be utilized. This utilization could yet be increased by using methanol also as a carrier for fine coals.

Owing to the fact that methanol is a highly pure fuel - the combustion results in H_2O and CO_2 only - the coal-methanol-mixture (usually 50 : 50) can be burnt directly and completely in power station boilers. The methanol content in relation to the total fuel quantity even brings about a reduction of the emissions per electrical energy unit.

The separation of coal and methanol can be realized at the consumer's end. While the coal is burnt as humid dust in power station boilers or furnaces, the cleaned methanol can be utilized in more important fields of application. It can be added to the motor gasoline, resulting in the mixture gasohol which is already being utilized in the United States. It can be utilized as a low emission fuel for gas turbines or special motors, primarily for motor-driven vehicles and heat-pumps. Along with an increasing supply, methanol will yet become a more interesting feedstock. Both components of the coal-methanol-slurry will, consequently, be utilized in the best possible way.

Taking into consideration all the possibilities I referred to above, I feel that the most different industrial enterprises might become interested in the utilization of coal-methanol-slurry as fuel or starting material. This would guarantee a wide utilization of lowest-grade coal and a continous demand.

DESIGN AND OPERATION OF COAL-SLURRY-PIPELINES

Pipeline systems for the transport of solid materials have been with us for some time. They were utilized in placer mining operations in the late 1850's, and a patent to move solid materials through pipes by pumping was granted in 1891. Already in 1914, coal was transported into the City of London by this method.

However, slurry pipelining - as it is known today - really began with the start-up of two systems in the United States in 1957; one of these was a coal-slurry pipeline. Thereafter, many pipelines for long-distance movement of large volumes of solids have gone into service.

Probably the best known slurry pipeline in the world is the Black Mesa coal pipeline in Arizona. This highly efficient system went on-stream in 1970 and delivers since that time approximately 600 tons of coal per hour and has an operation availability factor in excess of 99 %.

Therefore, the technology of modern slurry pipeline systems has been firmly established by the experiences with the Black Mesa pipeline.

The high level of confidence in the capability and economic practicability of solids pipelines is further evidenced by the planning of slurry pipelines currently under way in the United States, Europe, South and Central America and Africa, where large volumes of solid materials must be transported over long distances.

In the United States only eight major coal slurry pipeline projects are in the planning stage, two of these with methanol as slurry vehicle. All of these proposed systems will deliver thermal coal to electric power generation plants, and - with one exception - each of the pipeline distances will be in excess of 800 miles (1.287 km).

In Europe, slurry pipelines which would transport coal from the mines in Poland to markets in western Europe, are in the planning stage.

All of these proposed pipelines will transport coal which is ground to a maximum particle size of about 1.2 mm, with approximately 15 % - 20 % of it being smaller than 44 micron. This coal is then mixed with water at a mix ratio of almost one part coal to one part water (this may vary slightly from case to case), forming a slurry of concentration 45 : 50 percent solids by weight. This slurry is then pumped from the mine area through the pipeline to the generating plant where it is received into agitated holding tanks. From these tanks it is transferred to a dewatering facility where the coal and water are separated by centrifuges or a filter system. The coal may undergo some further drying, probably by thermal means, before being pulverized and fed to the burners. The water will be treated to remove all fines and impurities. The water can thereafter be released to the sewer-system or further used in the power plant, probably for cooling.

If there is no sufficient water available as slurry vehicle, methanol can be used as carrier. In this case the slurry, when it is supplied to the power station, can be fed without separation to the burner. Methanol is then part of the fuel. This can be a big advantage when using coal which is not very reactive.

In order to have an economic and reliable slurry pipeline system, special design requirements have to be taken into consideration. Tests over many years in a 4 inch pipeline testloop have demonstrated the aforementioned operating conditions.

The operating reliability is guaranteed if

- plugging by larger particles during operation of the slurry pipelines does not occur;
- the slurry pipeline can be restarted without problems, even after a shutdown of several days.

Therefore, the slurry which is introduced into the main line, is composed of solids which have undergone a carefully controlled crushing and grinding process. The particle size consistency and the slurry concentration must be maintained within rather narrow tolerances in order to ensure efficient operation of the system and start-up capability, should the system experience an unscheduled shutdown with slurry in the line. In the case of coal, this process begins when coal of an approximate size of 2 inches x 0 (50 mm x 0) is delivered into two bins which feed on impact crusher. From this crusher, the coal goes either to a rod mill or another crusher where it is ground to a top size of about 1.2 mm. This process provides the mesh spectrum which conforms to slurry specifications. This slurry is then stored in agitated tankage at a concentration slightly above pipeline requirements. Samples are taken periodically and they may be utilized for experimental purposes in the laboratory testloop which is part of the initiating station. If there is no problem found in screen analyses or other tests of samples, the material then is ready for the main line and will undergo densitometer-controlled dilution just prior to entering the main line pumps in order to bring it to pipeline concentration specification.

Associated with each particular slurry is some minimum flow velocity below which deposition of solids may occur in the pipeline. The minimum flow velocity found in long-term test runs was between 1.8 - 2.2 m/s. This minimum velocity is a function of vehicle density and viscosity, partically size consist and shape, solids density, and pipe diameter. The pipeline system must be designed for the ultimate solids throughput and must be operated at or very near design velocity even during build-up years when the throughput may be only one-third or one-half the design quantity. Unlike gas pipelines or conventional Newtonian liquid systems, build-up cannot generally be accomplished by addition of pump stations as throughput demand increases. This must be accomplished by pumping slugs of water between slurry batches or by operating the system only part of the time. The diameter of the slurry pipeline is therefore more closely defined by flow volume than are diameters of more conventional pipeline systems. Operations during build-up may be assisted somewhat by a small reduction in slurry concentration and/or a slightly lower flow rate, if it can be safely done, but seldom to the degree required to maintain full-time system operation.

The solids concentration of the slurry usually cannot be increased sufficiently to realize any appreciable gain in solids delivery because this results in slurry density and viscosity effects which require higher operating pressures and pump horsepowers than those for which the system was designed. If this system was efficiently engineered for the original design capacity, there simply will not be adequate pipe wall thickness to withstand the pressures required to move a high concentration slurry at the required velocity. Although, the pumps will not have been designed to operate at this new combination of pressure and flow rate.

The same problems will be encountered if throughput increase is attempted by maintaining slurry concentration, but raising the flow volume. This, of course, implies a higher slurry flow velocity, which also results in operating pressures beyond the design limits of the system. Additionally, if the new flow velocity is appreciably above that for good slurry pipeline design, abrasion of the pipe wall may occur, resulting in reduced project life or other operational difficulties.

In long-term test runs a pressure drop of 0.5 bar/1000 m was discovered by a flow velocity of 1.8 : 2.2 m/s. Under these conditions no plugging or abrasion did occur in the test facilities.

DEWATERING TECHNOLOGY, integral to most slurry pipeline transportation systems, is a highly specialized field within itself, and it is not possible to cover it in any detail in this brief presentation. It is mentioned here because a dewatering facility is an important component of most slurry pipeline systems. The common methods of dewatering include centrifuges or filtering systems. The surface water content of the coal will be reduced to 13 % - 15 % (by weight) by centrifuges and almost 20 % (by weight) by filtering systems. The following equipment is suitable for the solid/liquid separation:

- Suction Drum Filters for a particle size range from 0 to 0.5 mm.
- Disc Filters for a particle size range from 0 to 0.5 mm.
- Tumbler Centrifuges for a particle size range from 0.5 to 30 mm.
- Pusher Centrifuges for a particle size range from 0.1 to 3 mm.

In some cases, the slurry may be thickend prior to dewatering, and some thermal drying may be performed on the dewatered solids. This applies only for coal-water slurry.

In a coal-methanol slurry the separation of methanol from coal has in no case been done so far; thermal drying is not necessary at all. In view of this fact, the transportation of steam coal fines with methanol as slurry carrier is the most economic way I can think of.

However, a real economic comparison between coal-water-slurry and coal-methanol-slurry is not yet finalized. A study is under way in the United States. But all the facts mentioned before, make me believe that with raising oil prices and/or shortage of oil, methanol is the fuel and the chemical raw material of the near future. This huge quantity of methanol will then have to be produced from coal. By transporting the methanol favourably through a pipeline, it can at the same time carry coal fines. Can we think of a more economic system Can any other transport-system compete? I cannot think of anyone that could!

IV. SUMMARY AND CONCLUSION

Ladies and gentlemen,

to sum up, I would like to emphasize the following points:

1) Because of coal's abundance and its low cost per energy unit compared with oil and gas, national and international steam coal trade will increase dramatically in the near future.

2) Transportation and storage possibilities and cost are the major elements in national and internation coal trade.

3) Long-distance movement of large volumes of coal in a dependable, efficient and economical transportation system without causing disturbances for the environment, is only possible by slurry pipelines. Slurry coal can be used as feedstock

   . in electric power stations;
   . in coal gasification plants for the production of Low - and Medium BTU-Gas;
   . agglomerated to lumps in furnaces of all kinds.

4) Coal transport across oceans using special "SLURRY TANKERS" will reduce the transportation costs considerably, especially when using existing port facilities for large crude oil tankers.

. Methanol as carrier can significantly reduce the transportation and separation cost for coal slurry. When using methanol as carrier, coal can also be shipped from regions which are not provided with enough water. The methanol-coal slurry technology, however, will require testing before commercial operation.

. Methanol from the slurry can, after having carried the coal, be used for other applications. The total transportation cost will be reduced on account of this fact.

Attachment I:
Typical Slurry Pipeline Schematic

References:

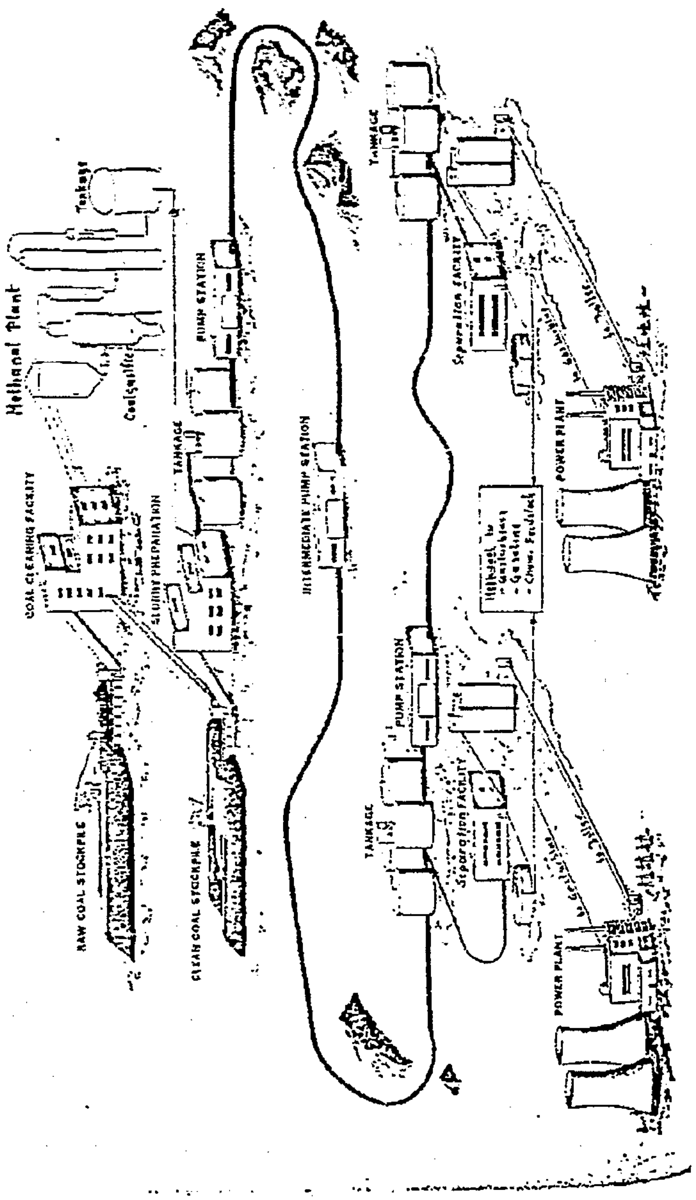
1) Ballinger Publishing Company, Cambridge, Ma.
   - Coal, bridge to the future -
   (World coal study)

2) Krauss-Maffei AG, Munich
   - Transport von Kohle in Pipelines -

3) Williams Brothers Engineering Company, Tulsa, Okl.
   - Solids pipelines, development and outlook -

Attachment: I

TYPICAL SLURRY PIPELINE SCHEMATIC



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Dipl.-Ing. Karl-Heinz Brachthäuser

The coal briquetting plant of Gewerkschaft Sophia-Jacoba with special regards to the production of briquettes binded by lignosulfonate

A. Contents

In connection with restructuring work for the purpose of increasing the capacity of the briquetting plant of Sophia-Jacoba at first the chemical engineering and operational equipment (installations) of coal briquetting using coaltar pitch as binder as well as the measures for the improvement of quality, such as the introduction of the emulsifying technique, will be described in detail.

For 13 years Sophia-Jacoba has also been working on the further development of a new briquetting technique for the production of coal briquettes, which are pure in smoke. Based on the proceedings developed by the German coal research institute, called "Bergbauforschung", the briquetting method using lignosulfonate as binder has been introduced and fully developed. Operational tests, the briquetting technique for the "Extracite production" and the second phase for an increase of the plant capacity to 50 t/h will be discussed in detail. At the time being plannig work is done for the design of the third serial-model modification which will provide an increase of capacity to 100 t/h.

The drawings and numerical tables to which in the course of this discourse will be referred, are attached at the end of this paper.

B. Description of the paper

In the preface of volume 3 of the encyclopaedia: Der deutsche Steinkohlenbergbau" (coal mining in Germany), the following has been written in 1952 under the headline "coal briquetting":

"The technique of coal briquetting as it has been developed during one century, in general is based on the experience gathered by operating big scale plants and only to a small extent on scientific research. Careful observations of the raw materials and of the operational proceedings together with intuition and correct conclusions have determined the hitherto development".

What has been written then is still valid today - about 20 years later - to a far extent for the briquetting procedure of coal with coaltar pitch as binder.

Only the development, testing and introduction of modern briquetting methods for the production of fairly low smoking coal briquettes has created a certain change. The development of coal briquetting done by Gewerkschaft Sophia-Jacoba, represents a typical example of this change.

Briquetting with coaltar pitch as binder

As first some details concerning the expansion of the conventional briquetting plant of Sophia-Jacoba:

The briquetting plant has been expanded from relatively small beginnings. Only since 1955 its capacity and its technical set-up have been improved and increased considerably by numerous rebuildings and enlargements.

In 1955 the plant equipment consisted only of:

1 rotary drying kiln with a capicity of 15 - 20 t/h

1 small suspension type drier with a capacity of 30 t/h

2 ovoid presses with a capacity of 20 t/h each,

1 small egg-shaped and 2 small nut-shaped presses (year of construction 1908), with a capacity of 7,5 t/h each.

The annual production was about 200.000 t in 1955.

During the following years the below mentioned equipment has been installed into the plant:

a) In may 1957 and in March 1963 2 efficient "Büttner" circulating driers with coal-dust firing and electro-static precipitators with a capacity of 60 t/h each. Due to an increasing mechanization and underground dust suppression, the yield of fine-coal and the humidity of raw coal had increased.

   Therefore the coal preparation plant, running until then with a dry technique to separate the coal fines, has been converted to wet practice with complete clearance from sludge and flotation during the years 1956 and 1957.

b) 3 modern nut-shaped presses of a capacity of 30 t/h each have been installed in December 1958, in July 1959 and in December 1961.

c) The capacity of the cooling conveyor facility has been increased in 1959.

d) The emulsifying method for the pretreatment of briquetting coal has been introduced during the summer of 1963.

e) A third cooling conveyor belt has been erected in 1964.

f) Installation of new loading plant with reversing device and platforms to be lifted and lowered for nut-briquettes and egg-shaped briquettes in 1968.

g) Extension of the 3 existing cooling conveyors by 50 m each in 1969.

h) In 1979 a research and development-project has been realized to substitute coaltar pitch as binder for the production of lower smoking briquettes in accordance with the Immission Act for the protection of environment

i) Restructuring of the old plant for the use of liquid hot bitumen as binder; new dosing and mixing devices; bitumen tanks; extension of cooling conveyors due to the deteriorated cooling behaviour of bitumen bound briquettes

The total capacity of the briquetting plant is at the time being 1 8 0 t/h concerning the drier facilities from which the capacity of one drier amounts to 60 t/h for the extracite production. The capacity of the presses for nut-briquettes (24 g) is 35 t/h and for egg-shaped briquettes (45 g) 40 t/h (After having restructured the machine equipment to meet the standards of modern technique, the efforts during recent years were fully concentrated on the improvement of the briquette quality. By special primary treatment of the wet briquetting coal which is a mixture of about 70 % of washed impact-pulverized fine-coal and of about 30 % of precipitator-dewatered flotation concentrate, the values for crushing strength and drum resistance of the produced briquettes could be increased considerably.)

...ile the standards for coal briquetting plant due to ... 22381 still indicate the following standards values

nut briquettes	crushing strength	50 kp,	drum resistence 55 %
egg-shaped briquettes	" "	70 kp,	" " 50 %,

...e values obtained at Sophia-Jacoba are considerably better already for years, i.e.:

...-nut briquettes	crushing strength	Ø > 120 kp,	drum resistance > 95%
...-egg-shaped briquettes	" "	Ø > 150 kp,	" " > 95%
...tracite 20	" "	Ø 120 kp,	" " > 96%
...tracite 40	" "	Ø 120 kp,	" " > 96%

The production of briquettes with such strength values is only possible by using a feedstock with an optimum grain structure and highest uniformity.

... indication for the grain structure you may refer to the characteristic factor of the surface; for years it has been more than 400 cm²/g for the coal feedstock to be used in the ...ith briquetting plant. In comparison to this code numbers of 200 - 250 cm²/g had been considered as sufficient before.

Of course, further factors for equally high quality features of the produced pitch briquettes besides of modern machinery equipment in accordance with the st...ds of technique, have been and are a regular and cur... operational supervision as well as careful laboratory exami...ns and quality control.

The result of our efforts is reflected in the development of the annual briquette production which still reaches a high output in spite of a decreasing market. The respective values can be taken from the attached tabular data: "Annual briquette production at Gewerkschaft Sophia-Jacoba".

Process engineering and installations

The two attached flow sheets showing the drier plant and the briquetting plant are showing the machinery equipment as well a s the operational conditions of the briquetting plant. The drier and the actual briquetting plant are housed in the same building, are however separate installations.

The briquetting plant is fed with wet coal from the washing plant. The briquetting coal is - as already mentioned - a mixture of washed, impact-pulverized fine-coal that is dewatered by centrifugal separators (about 70 %) and a dewatered flotation concentrate (about 30 %). The water content of the wet briquetting coal is between 10 - 12 percent by weight. The ash content is between 6 and 8 percent by weight (wf).

The wet briquetting coal is dried to a water content of 1.5 - 2 % in the drier plant which consists of 3 equal "Büttner" suspension type driers with downstream electrostatic filters. The hot flue gases for drying the coal flow are produced in separate furnaces which are fed by coal dust extracted from the electrostatic filters of the downstream vapor dustremoval installation. In order to improve rentability all 3 driers were equipped with vapor recycling in 1976.

The dry coal which is removed from the flue gas in cyclone separators, is subjected to a preparatory emulsifying treatment before be ing fed to the actual press plant.

The emulsifying technique is in operation after successful preliminary tests which have been carried out in July 1983. The quantity of the emulsion added amounts to an average of about 1.35 percent by weight in relation to the dry coal. The emulsion consists of about 0.25 % coaltar oil, 0,55 % lignosulfonate and about 0.55 % water. When using bitumen as binder, there is no adding of coaltar oil to the mixture.

The emulsion ready for use is added to the dry briquetting coal in a double mixing feed screw behind the circulation drying plant.

Lignosulfonate and tarpitch oil are stored in two heatable storage tanks outside the briquetting plant from where they are pumped to the daily storage basins of the plant according to the respective demand. The mixing of lye solution with water in the required proportion is realized in the daily storage basins. The quantity of the emulsion ready for use, which is produced in an emulsifying pump, is adjusted automatically to the coal quantity coming from the driers by means of a dosing machine. For this purpose a measuring conveyor belt connected in series with the mixing screw which gives via a potentiometer respective measuring impulses to the controllable direct-current motor of the precision dosing machine.

Due to the emulsion pretreatment of the dry briquetting coal, the binder contents of the briquettes could be reduced by absolutely 1 percent by weight. Simultaneously a considerable improvement of the briquette strengths, especially referring to the egg-shaped briquettes, and a reduction of the dispersion of strength values was obtained. After the introduction of the emulsion pretreatment, the annoyance caused by dust, moreover, was reduced considerably within the briquetting plant.

The pretreated dry coal reaches the actual briquetting plant via an ascending drag-link conveyor, the coaltar pitch which was crushed in two phases - first in a pan grinder and then in a desintegrator - by volumetric means respectively after feeding the hot (about 200 °C) liquid bitumen and an intimate mixing of dry coal, binder, and eventually also briquetting fines. In a fast running mixing screw, the finished briquetting material is transported via a bucket conveyor to the distributor screws above of the kneading machine.

A considerable improvement, i.e. constancy of the briquette quality, was caused by the steady dosing of the surplus dust from the vapors electrostatic filters and the elimination of the dry coal bin with its decomposition effects.

In the actual press plant 5 roll presses are installed for the briquette production in 2 systems, three presses which are of a capacity of 30 t/h each for the production of nut-shaped briquettes (24 g) and two presses of a capacity of 20 t/h for the production of egg-shaped briquettes (48 g).

As it is shown on the flow sheet attached to this paper, each press is connected in series with a kneading machine, in which the plastic briquetting substance is produced by means of steam supply and mechanical treatment of the material to be mixed, and an evaporation screw.

The steady distribution of the briquetting substance over the width of the roll tires is effected through the installed distributor bin with charging hoppers connected at the outlet side.

As it is known, the so called green briquettes which still have a temperature of 90 °C com ing out of the presses must be cooled before being loaded so far as they can meet the mechanical stress.

For this purpose 3 cooling conveyors consisting of wire tapes are connected in series with the loading plant. The cooling time of our plant amounts to 14 - 15 minutes after the rebuilding done in 1973.

2 modern loading plants facilitating a very gentle handling with regard to all possible types of railroad wag ons, are available for the loading of the 2 sizes.

During the loading process the briquettes are - if necessary - subjected to an antidust treatment by being sprayed with a calcium chloride solution.

Part 2

Production of smokeless coal briquettes using Lignosulfonate as binder

About 15 years ago when there did not yet exist any restrictions by the law concerning the use of pitch bound smoking briquettes as there exist today by means of the 8th implementing ordinance for the Immission Act of North Rhine Westphalia and the Federal Immission Law, the "Sophia-Jacoba" mine already reflected upon a possibility of producing briquettes, that burn smokeless or at least highly without smoke, from a high quality anthracite fine-coal.

Three different processes could be used for this purpose:

a) The oxidation of pitch bound briquettes, as it was already in use at that time in the countries of western Europe (France, Belgium, Holland).

   In this connection I would like to mention only the name of some products, such as Anthracine, Selgacine, and Syntraciet.

b) Briquetting without binder basing on the hot briquetting process of the Dutch State Mines. This technique has been acquired later on by the EBV and has been fully developed in the Ancite plant at Alsdorf.

c) The introduction of briquetting with lignosulfonate as binder based on the proceedings of "Bergbauforschung GmbH" in Essen.

The decision taken by Sophia-Jacoba favoured the proceedings of "Bergbauforschung". The following reasons were of decisive nature.

When applying the oxidation method, no deliveries could have been made to markets of the licensee.

When using hot briquetting, Sophia-Jacoba would have been forced to buy about 30 % of caking coal as a binder from other suppliers and consequently would have had to sell additionally an other 30 % of the production.

The briquetting with lignosulfonate as binder, however, could be realized by using 100 % of own coal input with about a 100 % yield of the finished product additionally; there were no sales restrictions by market embargos.

The first attempts to utilize the considerable adhesive strength of lye solutions, yielded as byproduct during the production of pulp, for briquetting purposes are dating back to the year 1900. E. Trainer applied for the first patents in this field in the years from 1900 to 1906. A utilization of the sulfur lyes for coal briquetting on a commercial scale, however, could not be realized.

Apart from other reasons, the water solubility of lignosulfonate, the lack of effective coke producers which are necessary for the cohesion of the carbon granules in the fire, small initial strength values of the briquettes after being discharged from the press and the luting of the roll moulds which quite frequently provocated shutdowns, hindered the application of lignosulfonates as binder for coal briquetting.

By applying the special process engineering which "Bergbauforschung GmbH" in Essen Kray developed for briquetting and by utilizing newly gained experience on the characteristics of lignosulfonates, it was possible to eliminate the basic difficulties in lignosulfonate-coal briquetting.

After the start-up of the extracite plant at Sophia-Jacoba in the fall of 1967, new disturbances of considerable extent occurred which led to a shutdown after an operation period of only 3 months. After very extensive and costly investigations for further development had been made, the plant could, restart its operations and one year later, i.e. in the fall of 1968, offer a good product quality for sale.
In the course of my further explanations, I shall still speak about the problems which occurred.

Before giving a description of the plant, I want to make some basic remarks on the lignosulfonates as binder and the special briquetting method to be utilized when applying these solutions.

The lignosulfonates

The lignosulfonates are, as is well-known, byproduct s of the pulp industry. While boiling the wood under pressure using bisulphides, about 50 % of the components of the wood are being solved. The bisulphides used are mainly lignine in form of lignosulphonic acid, small amounts of acetic acid and formic acid and among other carbohydrates in form of simple and combined sugars. The characteristics of lignosulfonates, however, are not only influenced by the chemical composition, but also by the further treatment of the so-called primary lignosulfonates which contain 10 %, of solid matter.

To this further treatment of the primary lignosulfonates in the pulp producing plants belongs besides the concentration by evaporation to a solids content of about 50 % to 60 %, also the *fermentation* of the hexose sugars to spirit as well as the binding of pentose sugars in the primary lignosulfonate.

In the Federal Republic of Germany the decompostion of wood is realized by adding calcium bisulphite so that calcium lignosulfonates will be available in the first place. Since especially abroad, wood is also treated with sodium sulphites, magnesium sulphites or with ammonium sulphites, lignosulfonates containing sodium (Na), magnesium (Mg) or ammonium (NH_4) are also traded though in less significant quantities. NH_4 lignosulfonate can also be produced from Ca-lignosulfonate by the adding of ammon. sulphite and precipitating calcium sulphite - a method which is in practise at "Sophia-Jacoba".

The NH_4-lignosulfonates differ from all the other lignosulfonates by a very low ash content and by a marked melting behaviour of the dried solid material during heating. Solid material from dried Ca-lignosulfonate when being heated up to 350 °C results in a powder; dried NH_4 lignosulfonate solids when being heated up to 250 °C in a melting pot fuses to a foamy coke-like substance.

During the heating of lignosulfonate solids, the ligno-sulphonic acids condensate in the first step and are being transformed to a substance which is not water-soluble. This process classified as hardening is realized with NH_4-lignosulfonate at 220 - 250 ° C and with Ca-lignosulfonate at 320 - 350 ° C.

During further heating a residual coke is produced through an increased spitting off of volatile components. This residual coke resulting from NH_4-lingnosulfonate, is a foamy substance with thin cell membranes and contains 4 % to 12 % ash depending on the ash content of the lignosulfonate.

Special process engineering regarding briquetting

The large adhesive power of lignosulfonates only becomes effective within a certain range of concentration. If the dilution is too extensive, the adhesive is too poor; if the drying process is not correct, for example in the briquetting material before being pressed, the adhesive power is lost.

In order to obtain a good distribution of the lignosulfonates on the coal surfaces only a not too strongly evaporated lignosulfonate can be used. If the lignosulfonates to be obtained on the market with solids of about 50 % are heated up to 50 ° C - 70 ° C, they have the right concentration and viscosity for the process, the adhesion of the lignosulfonate, however, is not sufficient for the production of briquettes of a satisfactory character; the lignosulfonates have still to be thickened during the process of mixing and distributing.

When trying to find out the reasons for the difficulties in connection with coal briquetting by means of lignosulfonates, "Bergbau-Forschung" stated in their pilot plant that through adding exterior heat to the lignosulfonate surfaces, these surfaces would exsiccate by producing non-adhesive, smooth and no longer dispersable skin structures. Under these skin layers on the coal surfaces of the briquetting material, there is not yet thickened lignosulfonate which would no longer be dispersable.
During the pressing process this lignosulfonate can be pressed out of the briquetting structure leading to the feared luting of the roll moulds (fried egg theory).

To avoid these difficulties, the special briquetting process patented by Bergbau-Forschung, provides the addition of the lignosulfonate heated up to 50 ° - 70 °C to the briquetting coal with a temperature of about 115 ° C in a closed, continuously operating high power mixer.
During the mixing process the binder is thickened only by the heat of the coal so that the adhesive power becomes efficient at the interfaces between the coal and lignosulfonate first in the interior of the mixture. By a dosed discharge of the vapors the thickening process of the lignosulfonate in the briquetting material can be controlled in such a way that the adhesive power of the lignosulfonate can be optimized while a good distribution of the binder within the coal is guaranteed and the undesired skin layer formation is avoided.
Thus one obtains a fluid briquetting material with a water content of 2 to 4 % which can easily be formed.
The obtainable strength values of the briquettes just after pressing, are sufficiently high to resist the strain they are subjected to in the later process.

In order to become resistent to water, the raw briquettes must subsequently be treated thermally.

This in done by a controlled heating up of the so-called "green briquettes" to the required hardening temperature that is about 250 - 270° C when utilizing ammonium lingosulfonate as binder.

In 1965 "Gewerkschaft Sophia-Jacoba" started to erect an industrial plant for the production of smokeless coal briquettes in accordance with the technology of Bergbau-Forschung.
The industrial plant was designed for a capacity of 25 t/h in the first step with a gradual increase with further plans of doubling the present capacity b realizing a complete second system in order to reach a final capacity of 100 t/h.

The plant was started in the autumn of 1967 with an hourly capacity of 25 t. The plant, however, had to be shut down again in December of 1967 due to considerable deficiencies in the quality of the finished product, showing imperfections as to the fire steadiness at temperatures from 450 to 500 °C, efflorescences occurring at the briquette surfaces during open air storage and a too high adsorption rate of H_2O.
Only after extensive and very costly investigations which were done by Isega, the central research institution of the pulp industry and the Battelle-Institut in Frankfurt and by others, and after completion of about 1000 industrial tests at a scale of 10 t, a product was obtained meeting all requirements after changing the process engineering and blending with different so-called additives to the coal charge and to the binder. Sophia-Jacoba secured the proprietary right for this technology.

As you gather from the table showing the annual briquette production, the production was continuously increased after the plant had been restarted in the autumn of 1968. In January 197[illegible] the second expansion phase was started, at which the hourly capacity of the plant was increased to 50 t.

Plant description

The plant for the production of smokeless lignosulfonate bound coal briquettes consists of two equal systems with a capacity of 25 t/h each. These systems are installed in an additional building south of the present briquetting plant.

The dry coal required for the briquetting is taken from the available central drier plant and is transported via an ascending drag chain conveyor to the dosing installation of the plant. The surplus coal ist conveyed via the empty belt of the drag-link conveyor to the conventional plant.

As opposed to the conventional briquetting, a coal charge of an essentially lower ash content is used for the extracite production, that means with an ash content of 6 - 7 % against 8 - 9 %. The reason is as follows:

The dosing conveyor belts transport the dry coal to subsequiently added fluidized beds where it is adjusted to the required temperature of 115 ° C and the humidity of 0,5 %.

The heating of the fluidized beds is affected by fuel oil EL. Flue gas and vapors are exhausted and are freed from dust in collecting funnels connected in series. Dry coal and dust are collected in warm conveyor screws and are conducted to jacket heated delay mixers.

The dosed quantity of the binder of ammonium lignosulfonate is added to the coal in the mixers.

Through devaporizing screws connected in series, the surplus humidity is eliminated from the material mixture. Via delay pans, exhaust screws and distributors the material mixture is conducted to the roll presses. The specific amount of pressure applied is 4 t/cm of roll width. The "green briquettes" are by means of wire tissue belts led to the hardening plant mounted in line.

All abrasion material is returned to the available drier plant.

The total "hardening plant" consists of 3 single processes connected in linie, i.e. the preheating process, the hardening furnace and the cooling process.

During the heating-up, the "green briquettes" are heated by the hot air produced by the cooling system. The resulting exhaust air is cleaned in a wet deduster.

The hardening furnace is subdivided into 6 zones each of which is equipped with an oil fired burner. In the various zones the briquettes are heated accordingly by circulating air which is required for the condensation of the binder. The briquettes thus become resistant to water and are hardened. The exhaust gas from the various zones is collected in a pipe and led to a chimney of a height of 90 m with a superimposed dry dedusting plant. The quantity of the exhaust gas which is deducted corresponds to the amount of combustion air which will be consumed in the burners.

Any dust and abrasion produced in the hardening plant will be returned to the drier plant.

The cooling conveyor provides the "hardened briquettes" with fresh air which is compulsorily blown trough the briquette bed in a countercurrent process, thus cooling them down to loading temperature. The heated up cooling air is then recycled to the preheating process.

After having passed the cooling system, the briquettes are led to an immersion-belt for anti-dust treatment.

The loading plant consists in general of a conveyor band which can be lifted and lowered and of rail scales.

Kohleaufbereitung für den Hausbrand

Für den Hausbrand werden in der BRD fast ausschließlich Anthrazit-Kohlen eingesetzt, die im Untertage-Bergbau aus Flözen von ca. 0,7 bis 1,5 m Mächtigkeit mechanisch gewonnen werden.
Die Förderkohle wird in einer sog. Bergevorabscheidung von den groben Bergen über ca. 40 mm Korngröße befreit und in einer Vergleichmäßigungsanlage über eine Zeitspanne von ca. 24 Std. vergleichmäßigt.
Die so vorbehandelte Rohwaschkohle wird in einer Vorklassierung trocken in die Korngrößen ca. 80 - 20 mm, 20 - 0 mm getrennt. In einer nachgeschalteten zweiten, aber nassen Vorklassierstufe wird die Körnung 20 - 0 mm in die Fraktionen 20 - 6 mm, 6 - 0,5 mm und - 0,5 mm zerlegt..
Die Nußkohlenfraktionen 80 - 20 mm und 20 - 6 mm werden in getrennten Schwertrübescheidern in Reinkohle, Mittelgut und Waschberge getrennt. Die Rein-Nußkohlen werden auf Nachklassiersieben in die verkaufbaren Sorten getrennt und verladen, das Mittelgut dient als Brennstoff für Kraftwerke, die Waschberge gehen auf die Bergehalde.
Die Fraktion 6 - 0,5 mm wird auf Setzmaschinen sortiert. Die gewaschenen Feinkohlen werden nach ihrer Entwässerung zusammen mit der gewaschenen Feinstkohle brikettiert, bzw. als Kraftwerks- oder Industriekohle verkauft. Mittelgut und Berge gehen die gleichen Wege wie bei der Fraktion 80 - 20 mm.
Das Rohfeinstkorn - 0,5 mm wird in einer Flotation in Konzentrat (gewaschene Feinstkohle) und Feinstberge getrennt. Die gewaschene Feinstkohle wird nach ihrer Entwässerung der gewaschenen Feinkohle zugemischt, die Flotationsberge gelangen nach ihrer Entwässerung zusammen mit den Bergen der Bergevorabscheidung und den übrigen Waschbergen auf die Bergehalde.

Jahr	Pech- und Bitumenbriketts t	Extrazit t	SJ-Gesamt t	Bundesrepublik gesamt Tsd. t	Anteil SJ an Erzeugung BRD %
1955	231 056	-	231 056		
1960	461 010	-	461 010	5 565	8,28
1965	469 917	-	469 917	4 570	10,28
1966	465 406	-	465 406	4 006	11,62
1967	461 228	7 322	468 550	3 578	13,10
1968	525 471	16 905	542 376	3 693	14,69
1969	555 868	103 444	659 312	3 907	16,88
1970	552 953	142 351	695 304	3 725	18,67
1971	417 844	155 724	573 568	2 716	21,12
1972	447 108	202 987	650 095	2 427	26,79
1973	527 463	209 630	737 093	2 271	32,46
1974	498 529	213 148	711 677	2 249	31,65
1975	329 310	150 167	479 477	1 697	28,25
1976	292 675	148 944	441 618	1 357	32,54
1977	248 950	176 106	425 136	1 306	32,58
1978	283 375	204 808	488 183	1 453	33,60
1979 Jan-Sep	182 617	152 239	334 856	1 230	27,22

While the standards for coal briquetting plant due to DIN 23061 still indicate the following standards values:

nut briquettes	crushing strength	50 kp,	drum resistance
egg-shaped briquettes	" "	70 kp,	" "

the values obtained at Sophia-Jacoba are considerably better already for years, i.e.:

RA-nut briquettes	crushing strength	Ø > 120 kp,	drum resist-
RA-egg-shaped briquettes	" "	Ø > 150 kp,	" "
extracite 20	" "	Ø 120 kp,	" "
extracite 40	" "	Ø 120 kp,	" "

The production of briquettes with such strength values is only possible by using a feedstock with an optimum grain structure and highest uniformity.

As indication for the grain structure you may refer to the characteristic factor of the surface; for years it has been more than 400 cm²/g for the coal feedstock to be used in the pitch briquetting plant. In comparison to this code numbers of 200 - 250 cm²/g had been considered as sufficient before.

Of course, further factors for equally high quality features of the produced pitch briquettes besides of modern machinery equipment in accordance with the standards of technique, have been and are a regular and current operational supervision as well as careful laboratory examinations and quality control.

The result of our efforts is reflected in the development of the annual briquette production which still reaches a high output in spite of a decreasing market. The respective values can be taken from the attached tabular data: "Annual briquette production at Gewerkschaft Sophia-Jacoba".

Modern Coal Combustion and Boiler Technology

Fluidized Bed Technology

by E. O. Braun, E. Wied, VKW - Düsseldorf

Introduction

During the last seven years coal as a fossile fuel has become more and more important.

The reasons for this are the rapid increase in oil prices and the dependence of energy supply on unstable political situations.

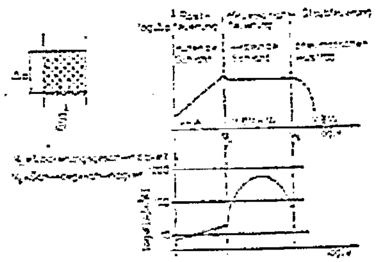
Therefore a worldwide effort is beeing made to use natural energy resources as much as possible and to become energywise independent.

In this respect coal does play an important role.

In addition to the well known coal combustion technologies such as grate firing systems and suspenstion fired system the new technology of fluidized bed combustion is offering an option with considerable advantages.

The Principle of Fluidised Bed Firing and its Advantages

The behaviour and properties of a fluidised bed firing system can be explained by the diagram in Fig. 1.



It is possible to establish different phases relative to the volume of gas as the flow is directed through a packed bed on a tuyere bottom. The bed remains firm and static in the range of blower stream velocities which are lower than the aerating velocity. This is the operational range of the grate firing system.

The densely packed bed is transformed into the some what looser state of the fluidised bed as the blower stream velocity rises above the aerating velocity. With the bed at a constant Δp (I) there is an increase in the proportion of cavities or gaps between the particles.

As the bed reaches fluidised state equilibrium is achieved between the entraining force of the gas flow and the gravity of the individual particles. The particles remain in contact with their surrounding counterparts with a pronounced exchange of momentum, resulting in a continuous positional interchange. This gives the fluidised bed characteristics which are similar to those of fluids.

This is the operational domain of the fluidised bed system.

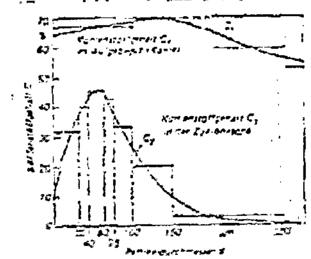
If the blower stream velocity continues to increase above the suspension velocity of the individual particles, pneumatic discharge will commence. This is the area within which the coal dust firing system operates. The heat transfer coefficients depicted in the lower graph in Fig.1 can be demonstrated relative to the blower stream velocity with firing systems in operation.

The sharp rise in heat transfer after the aerating velocity can be explained only through a change in state, i.e. from solid to fluidised bed.

The constant interchange of movement between the particles guarantees a constant and uniform combustion temperature throughout the entire fluidised bed, so that isolated hot spots cannot form in the bed. The combustion temperature is fixed by installation of surface heaters in the fluidised bed in conjunction with an appropriate air surplus. The conventional temperature range is between 800 and 900 °C.

The combustion rate depends very much upon the proportion of volatile constituents and the granular size of the fuel.

Fig. 2 (6)

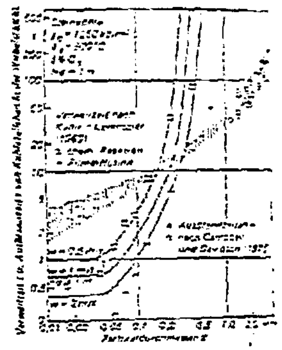


depicts a typical result of a fractionated carbon determination for a flue dust sample from a coal byproduct.

The residual carbon content is plotted relative to the particle size. One sees clearly a maximum in the grain size range from 0.03 to about 0.1 mm.

By estimating the dwell time of the fuel in the bed and the burn- times required, taking due account of the chemical reaction and diff... of the ash covering of the particle, it has been possible to compute ... graph (Fig.3) shown hereunder.

Fig.3: Estimate of dwell time and burnout time of coal particles in the fluidised bed for a selected test: comparison with test results



Within the range < 0.3 mm the dwell time is shorter than the burn... time required.

The greatest deviation can be seen at .03 to .05 mm. This computed result confirms the test result in determining fractionated carbon.

At temperatures below the ash softening point the alkaline ash constituents tend to be only slightly volatile. In consequence the like... of hazardous encrustation and erosion in the fluidised bed and booster heaters can be virtually disregarded.

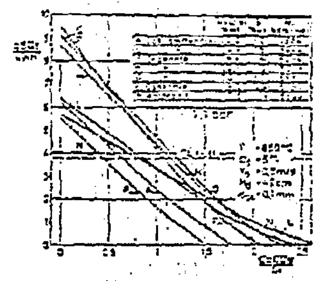
This situation permits fluidised bed firing systems to use fuels with ... high ash content, for example coal with a high inerts content, lignite, pitch sand, shale and fuels with a low reactivity as well as a very high proportion of inert constituents. Varying fuel conditions do not require ... structural modifications to the firing system and the steam generator, so that coal, lignite or even shale can fuel one and the same firing system.

Sulphur can be extracted from flue gases in the fluidised bed depending

... composition. In addition, suitable additives such as limestone ... can be used to bond sulphur in the fuel virtually totally in ... bed ash, thus ensuring that flue gas emissions comply with ... ations without any special treatment. The following relationship

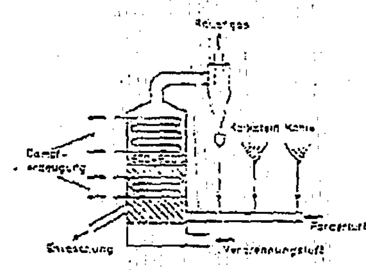
$$SO_2 + CaCO_3 + 1/2\ O_2 = CaSO_4 + CO_2$$

... (7): ... fic SO_2 emission ... various types of ... in relation to the ... stone/sulphur/mol ... at 1.1 bar



In addition the low combustion temperature also greatly reduces the ... ssion.

Fig. 5 ... shows a simple diagram of a fluidised bed firing system.

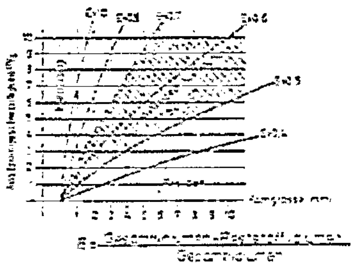


The combustion air flows over a distributor plate into the combustion chamber and swirls the bed material, consisting of carbon, ash and ... stone.

Thereby the carbon concentration is usually less than 1 %. Today a variety of methods are employed for introducing the fuel into the fluidised bed.

A constant bed height is sought in the firing bed during operation. This can be achieved, depending on the ash content of the fuel, by recycling the filtered ash or by extracting ash from the fluidised bed.

The major parameters for designing a fluidised bed firing system are shown in Fig. 6 (8).

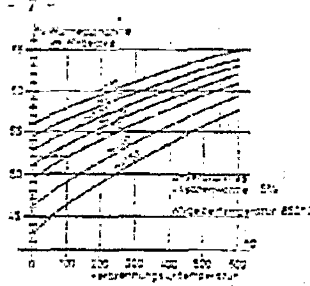


The blower stream velocity can be determined on the basis of a mean grain size in the fuel relative to the interstitial spacing. For design purposes interstitial spacing of between .5 and .7 is desirable. The blower stream velocity is deemed to be the empty tube velocity of the gas in actual operating state.

At a selected blower stream velocity it is then possible to read off the grain size area within which fluidised bed operation is possible. These flow relationships are normally depicted in accordance with the fluidised bed phase diagram from REH (8).

To achieve an economically efficient air surplus it is necessary for a large proportion of the heat to be taken up by surface heaters immersed in the fluidised bed. Appropriate layout of these surface heaters prevents the formation of larger air bubbles, i.e. the fluidised bed is stabilised and the fluidised solids are spread uniformly over the combustion chamber cross-section.

Fig. 7 (8)



...veys a general picture of heat absorption of surface heaters immersed ... the fluidised bed in relation to any air surplus and combustion air ...temperature.

Within the framework of the "Environmentally Approved Power Station" ...search and development programme the Federal Minister for Research and ...chnology is promoting a number of plants with which the prerequisites for ...ployment of this new process is to be drafted in the industrial sector ... for power generation in power stations.

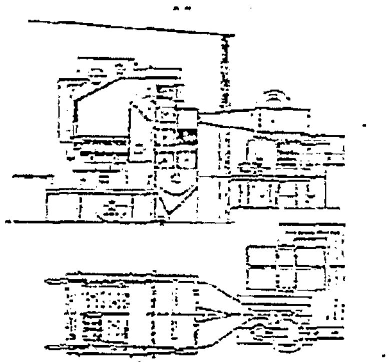
Vereinigte Kesselwerke AG, Düsseldorf, is playing a major role in the ...lowing installations:

Steam Generator with Atmospheric Fluidised Bed Firing:

Flingern, Ruhrkohle AG, Essen

In the Flingern power station of Düsseldorf Stadtwerke the travelling grate firing system has been removed from an existing steam generator and replaced by a fluidised bed firing system.

Fig. 5 (8)



The entire fluidised bed has been divided up into four equal cells separated by masonry walls. Each cell can be controlled independently from the fuel and air end. This simplifies starting and running of the system and it is possible to operate under partial load by shutting down individual cells.

The flow passes in forced circulation through the surface heaters in the fluidised bed.

The flue gases leaving the fluidised bed at 850 °C are cooled to about 130 °C by the heating surfaces of the steam generator. Flue gas cleaning is carried out in two phases:

1. Preliminary dust extraction in two parallel arranged cyclones;
2. final cleaning through a fabric filter.

In this temperature range the fabric filter is preferable to an electrical filter for cleaning the virtually sulphur-free waste gases.

The separated dust from the cyclones can be fed back into the bed with the fuel to improve burnout performance.

The ash is carried out of the fluidised bed through drain pipes arranged on the distributor plate . Specially designed ash coolers bring

the ash temperature down from 800 to about 200 °C and then carry it off into a collector bunker.

Fuel dressing must extend from middlings through to washed fine smalls. Crushing to a grain size of max. 6 mm is carried out with simultaneous drying to a residual moisture content of about 3 %. The fuel thus prepared is fed pneumatically together with the limestone and recycled fly ash from below into the bed.

This installation has been constructed by a consortium comprising Deutsche Babcock, Oberhausen, and its subsidiaries Vereinigte Kesselwerke AG, Düsseldorf, and Babcock-Büttner-Schilde-Haas AG, Krefeld. On completion of installation the commissioning work started on 20.4.1979, first with cold trials, then gas ignition firing and finally operation with coal alone. On 11.9.1979 performance and functioning were approved to contractual standards and the plant was handed over to the customer for final trials. The plant was formally commissioned on 12.11.1979 and, in the interim, had been in operation for well over 1,100 hours.

Afferde, EW Wesertal GmbH

As a logical further development of the demonstration plant at Ruhrkohle AG's Flingern Power Station a steam generator has been installed at the Afferde Power Station in Hameln with fluidised bed firing for a steam output of 140 tonnes/hr in conjunction with an extraction-condensation turbine of 35 MW electrical output. The steam is said to be at a pressure of 120 bar and a temperature of 530 °C. The extraction-condensation turbo set is designed to deliver 0 to 40 tonnes/hr extraction steam at 20 bar and up to 90 tonnes/hr extraction steam at 10 bars into the district steam heating network. The condensation section can accommodate steam at the rate of 10 to 40 tonnes/hr.

With this output from the condensation section the required load equalisation is achieved for assured operation, even where steam is being extracted for district heating at a rate lower than the minimum loading of the steam generator fired by fluidised bed.

Fig.9 shows the water-steam diagram of the system (7).

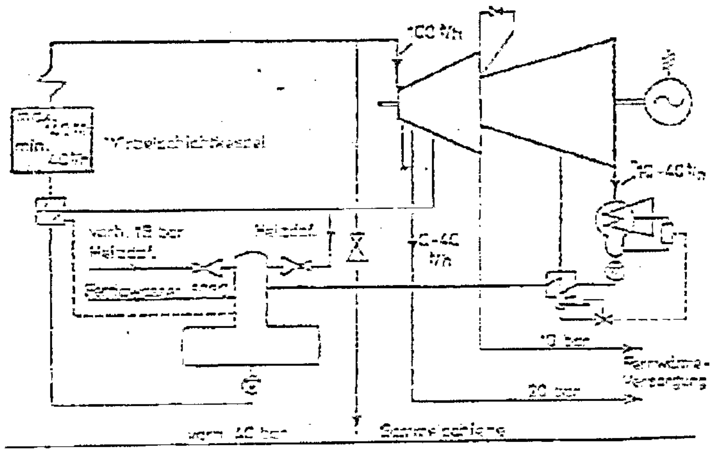
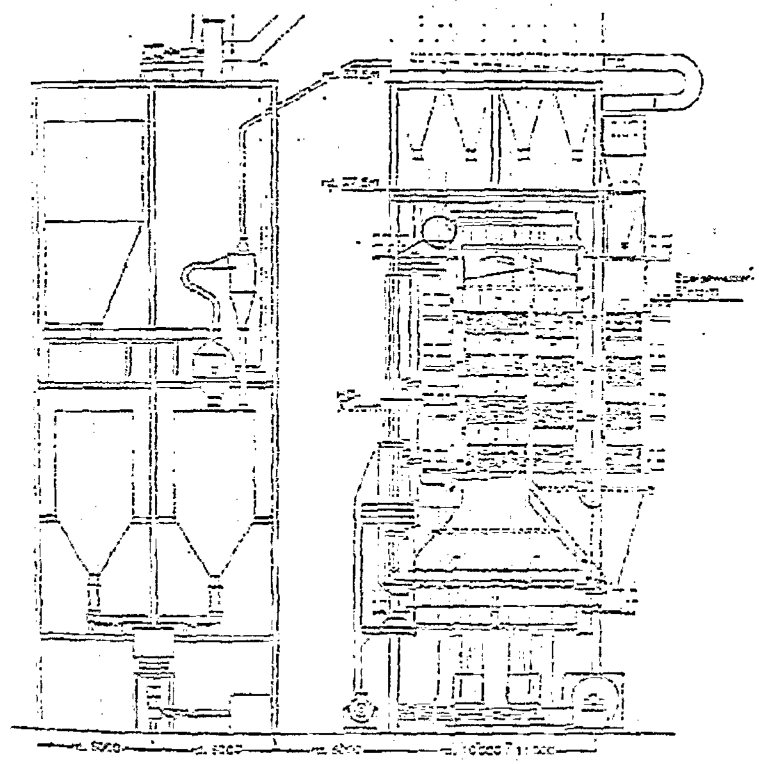


Fig.10 (7) depicts the conventional construction of the steam generator - three-flue design with fluidised bed firing.



This installation is to be operated with high ballast and high sulphur-con- [illegible]. The illustration shows that with fluidised bed firing no additional radiation space is necessary, but otherwise the steam generator can be built conventionally.

The entire boiler pressure section is suspended in the boiler frame and can expand freely downward.

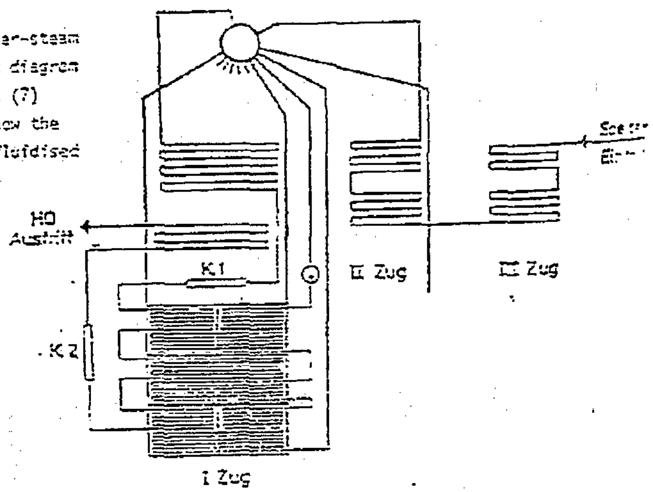
The distributor plate of the firing system is connected operatively with the wall surfaces of the pressure section and thus follows the expansion movements of the steam generator.

The containing walls of the furnace body and the 1st and 2nd flues are constructed of welded-flue gas-tight diaphragm pipe walls which serve as evaporator heating surfaces and channel the flow in natural circulation.

The pre and final superheater heating surfaces are located in the 1st waste gas flue and the feed water preheater heating surfaces in the 2nd and 3rd flues.

Additional steam generation heating surfaces, taking up about 50 % of the perceptible heat intake, form the immersion heating surfaces of the fluidised bed firing system.

The water-steam circuit diagram Fig. 11 (7) shows how the total fluidised bed



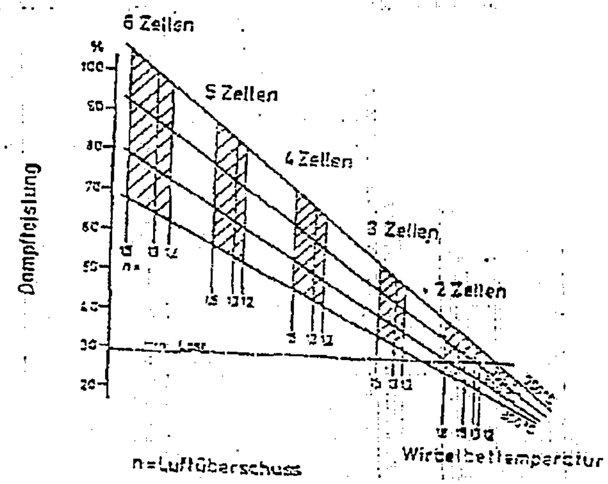
is divided into six compartments of equal size, each being controlled independently at the fuel and air end. This enables the partial load requirements of the user to be selected by bringing in or shutting off individual compartments. Of the six compartments in the fluidised bed firing system two are fitted only with evaporator and the remaining four with evaporator and medium superheater heating surfaces.

Flow is channelled in a positive cycle through the evaporator heating surfaces in the fluidised bed.

Those compartments fitted only with evaporator heating surfaces are the starting compartments and remain fully in operation under all load conditions. This is necessary to ensure that the mass flow of the superheater always remains sufficiently high as the cells fitted with combined evaporator and superheater heating surfaces are switched in, even at the high heat flow densities of the fluidised bed firing system.

The superheater delivery temperature of 530 °C is held constant by two injection coolers.

Fig.12 (7) depicts the steam output in relation to the fluidised bed temperature, the air surplus and the number of fluidised bed compartments in operation.

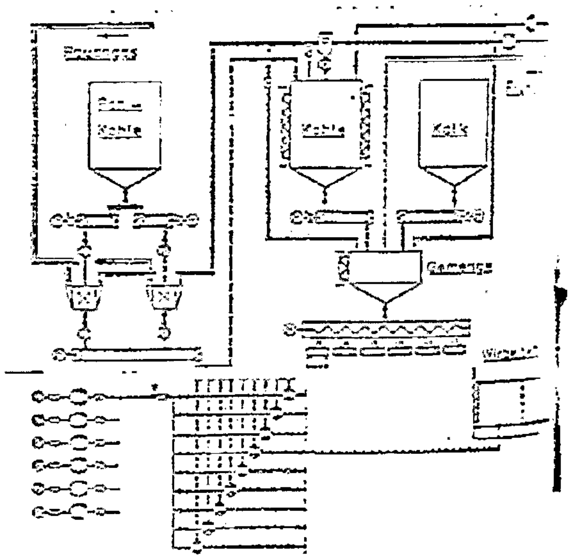


This diagram shows how a partial load of 75 % can be achieved already by lowering the fluidised bed temperature by 100 °C. Using this control ratio and by shutting off compartments the steam output can be regulated stepless down to the envisaged minimum load of the steam generator.

In order to exploit fully the influence of the immersed heating surfaces in the fluidised bed upon uniform distribution of air, fuel and limestone and thus to achieve high combustion and desulphurisation efficiency it is necessary to carry the fuel-limestone mixture into the fluidised bed from below. This can be achieved ideally by a pneumatic system.

With the supplementary fuel drying which, in addition to crushing, is essential for efficient fuel delivery, the flow relationships in the fluidised bed can be made largely independent of the amount of moisture in the fuel and, as the flow of flue gas required for drying is added to the waste gases at exhaust vapour temperature, an improvement is also achieved in the degree of efficiency.

Fig.13 (7) shows the envisaged crushing/drying process with pneumatic delivery into the fluidised bed.



The coal is fed from the raw coal bunker to two rebound crushers for reduction to about 6 mm grain size with simultaneous drying to a residual moisture content of about 3 %.

Flue gases taken from the steam generator gas flow are used as the drying medium.

The prepared fuel dropping onto the crusher outlet below is remixed in the coal bunker with the fine dust from the upper crusher outlet separated from the vapours in the cyclone separator.

The mixing bunker is fed in the required ratios by the coal bunker, limestone bunker and fly ash bunker.

From the mixing or batching bunker the charge is distributed to all batching channels and from there the prepared burden is carried uniformly and continuously by rotary piston blowers up into the fluidised bed from below.

The combustion air is fed at a controlled rate by two radial fans to the individual fluidised bed compartments. On leaving the fluidised bed the flue gases are cooled by the heating surfaces of the steam generator down to about 200 °C.

The high sulphur retention in the fluidised bed reduces the conductivity of the raw gas dust to the point where cleaning of these waste gases by electrical filtration is no longer practical.

The fly dust entrained in the flue gas flow is therefore separated in a fabric filter.

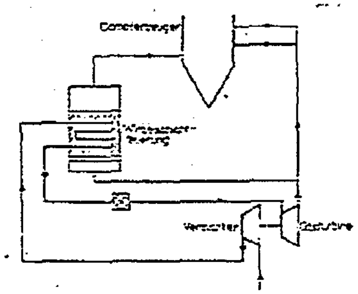
Where the coal has a high ash content the height of the fluidised bed is kept constant by drawing off bed material. This is achieved by exploiting gravity at the fluidised bed bottom. The hot ash is cooled to 200 °C by specially developed ash coolers

Völklingen Model Power Station of Saarbergwerke AG

The Völklingen Model Power Station of Saarbergwerke AG, Saarbrücken, represents an interesting concept in conjunction with a fluidised bed firing system.

Here, with the support of the Federal Minister for Research and Technology within the framework of the "Environmentally Approved Power Station" programme, a combination of fluidised bed firing and dust firing has been achieved for a gas-steam process.

The layout is shown in the simplified circuit diagram in Fig.14.



The compressor, driven by the gas turbine, draws in fresh air which it then compresses to 7.5 bar. The 240 °C hot compressed air is fed to the immersion heating surfaces of the fluidised bed firing system, heated up to 700 °C and then fed as a driving gas to the gas turbine.

Using this arrangement the gas turbine is driven by coal, as the fluidised bed firing system adopts indirectly the function of a combustion chamber of the gas turbine and is totally isolated from the water-steam circuit.

On emerging from the gas turbine the gas (air) is still at a temperature of 440 °C and serves as combustion air for both the fluidised bed firing and the dust firing systems.

The waste gases from the fluidised bed firing system, in which inerts are burnt, are channelled at about 800 °C below the coal dust burner into the combustion chamber of the steam generator. Here the greater proportion of the entrained uncombusted coal dust particles is burnt off.

The flue gases of the fluidised bed firing and coal dust firing systems then flow separately through the boiler flues and transfer their heat to the heating surfaces of the steam generator.

On emerging from the boiler the flue gases pass through electrofilters for dust extraction and a desulphurisation system and are then emitted together with the cooling air from the cooling tower.

The overall electrical output of the block will be about 220 MW, of which about 185 MW is attributed to the steam turbine and 35 MW to the gas turbine.

Steam Generator with Boosted Fluidised Bed Firing

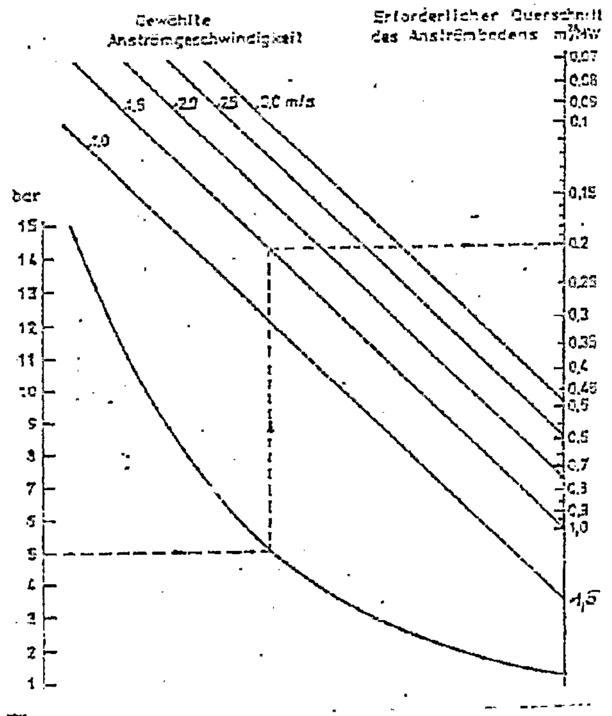
From numerous tests on laboratory scale and in pilot plants it has been shown that pressurised fluidised bed firing systems achieve an even better performance in respect of combustion, desulphurisation and NO_x content than their counterparts operated under normal atmospheric conditions.

Extensive operational experience with boosted or pressurised fluidised bed firing systems has been gained by the British Coal Utilisation Research Association (BCURA), which has been operating experimental plants in Leatherhead already since the middle 1960s the largest of which has a fluidised bed cross-section of .6 x 1.2 mtr and is operated at a service pressure of 6 bar.

The laboratory of Bergbauforschung GmbH in Essen has also been carrying out similar tests for years at a pressure of 4.5 bar.

Pressurised operation enables the structural sizes to be greatly reduced by comparison with the fluidised bed operated at atmospheric pressure.

Fig. 15 depicts the influence of pressure on the required cross-section of the blower stream bottom.



This leads to compact, largely prefabricated units. With an outer vessel diameter of 5 metres, which can still be fabricated within the confines of a workshop, and a service pressure of 10 bar, it is possible to achieve a thermal output of 150 - 200 MW.

In view of the relatively small cross-section in the blower stream

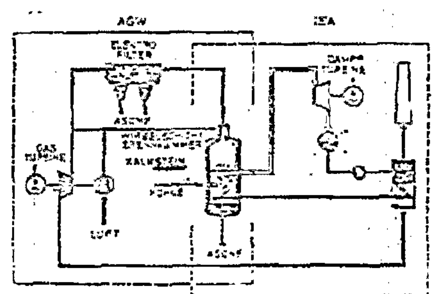
...m of the pressurised fluidised bed firing system, the heating area ...red to absorb the heat generated in that type of system can be ...ted only by appropriately raising the bed height.

...orizontal mixing in the fluidised bed, which is limited by comparison ... vertical mixing, therefore does not suggest any additional fuel ...tribution and combustion problems in the bed of pressurised fluidised ...ng systems, by contrast with the increase achieved in unit output of ...spheric fluidised firing systems where only the bed area is enlarged ...e retaining the bed height unchanged.

In return, however, with pressurised fluidised bed firing systems a ...siderably higher pressure loss must be anticipated than with their ...ospheric counterparts.

It is therefore advisable to use combined gas and steam processes for ...omic operation of fluidised bed firing systems of the pressurised or ...charged type.

Fig. 16 depicts the possibility for using a pressurised fluidised bed ...ring system in a combined gas-steam process.



The steam turbine process on the right-hand side reflects the state of the art and incorporates a high-quality thermo-dynamic version of intermediate superheating and multiple feed water preheating. The steam is generated in the heating surfaces immersed in the fluidised bed.

The gas turbine process can be seen on the left hand side.

Both processes are interconnected via the pressurised fluidised bed combustion chamber.

To reduce the development risks of such a combination process it would appear advisable to carry out the two parts of the process in two independent installations.

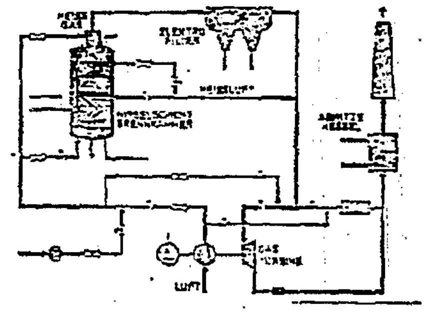
The two complementary installations, the AGW and IEA, which are considered to be important milestones in the development of fluidised bed firing for large-scale plants, are described in greater detail in the following pages.

The AGW Pilot Plant

The planning objectives of AGW (Working Party for Fluidised Bed Firing Systems), a joint venture by Bergbauforschung GmbH, Essen, and Vereinigte Kesselwerke AG, Düsseldorf (VKW), were to demonstrate the operational efficiency and reliability of a gas turbine process using a supercharged fluidised bed firing system in continuous operation.

With the assistance of the Federal Minister for Research and Technology (BMFT) a pilot plant for a thermal output of 25.3 MW is being erected on the site of the STEAG Power Station Zeche Haniel.

Fig.17 shows the circuit diagram of the AGW pilot plant.



The compressor compresses the indrawn air to a pressure of 4.5 bar, after which it flows in two streams into the fluidised bed combustion chamber. One stream serves as combustion air for the fluidised bed and the other is channelled through the heat exchanger immersed in the fluidised firing system.

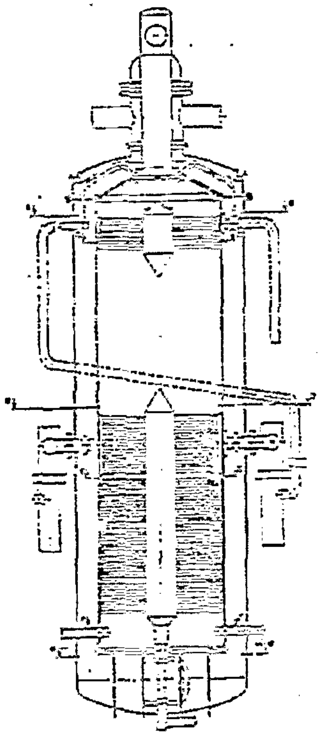
The combustion gas, at a temperature of 860 °C, is cleaned in pressurised dust extractors before entry into the gas turbine and then mixed with the hot air from the heat exchanger. The operating gas, which has a temperature of 800 °C at the design point, drops in the turbine to 475 °C and transfers part of its residual heat to the following waste heat exchangers.

Effective dust extraction from the flue gas is essential to avoid harmful erosion to the turbine blades and ensure reliable long-term operation. In view of the importance of this requirement the filter should be developed in a separate research project.

The project for developing a pressurised hot gas electrofilter, also promoted with BMFT resources and carried out by Babcock-BSH, Krefeld, is an alternative to the British and US solutions, which use cyclones or gravel filters.

It remains to be seen whether this filter will achieve the standard of flue gas cleaning required for reliable gas turbine operation at 860 °C and 4.5 bar.

Fig.13 shows the cross-section of the double-jacketed combustion chamber.



The separation of temperature and pressure stress is achieved by the double-jacket principle, the round vessel of 4 metre diameter being requ

withstand the full pressure of supercharging. The inn. vessel, with [illegible] diaphragm walls forming the gastight seal of the combustion chamber, required to withstand in terms of strength only the pressure differential between blower stream floor and fluidised bed firing system.

An untubed cavity is provided between the blower stream bottom and the heat exchanger tubes and the tubes for charging the coal-limestone mixture [illegible] into this cavity which is used to start up the firing system.

As the heat exchanger tubes are air-cooled and, owing to the discrepancy between inner and outer heat transfer coefficients, the tube wall temperature [illegible] almost as high as that of the fluidised bed, the heat exchanger tubes must be designed for the full bed temperature. A high-alloy chrome nickel steel is to be used for manufacturing these tubes.

A system of transfer channels brings the fuel into the bed and carries off the ash from the bed.

Experience gained with this pilot plant forms the basis for draft designs of a demonstration plant with an electrical output of 100 MW.

[illegible] IEA Grimethorpe Experimental Plant

A joint project promoted by the USA, Great Britain and the Federal Republic of Germany is being carried out within the framework of an agreement by the International Energy Agency (IEA) under the administrative control of the National Coal Board (NCB) in Grimethorpe, Yorkshire, UK.

The greater part of the experience gained by BCURA in the operation of supercharged fluidised bed firing systems is being channelled into this project.

The plant, constructed for a heat output of 85 MW at a maximum supercharge of 12 bar, serves mainly for research and testing of the behaviour of steam generator heating surfaces in the supercharged fluidised bed under variable operating parameters.

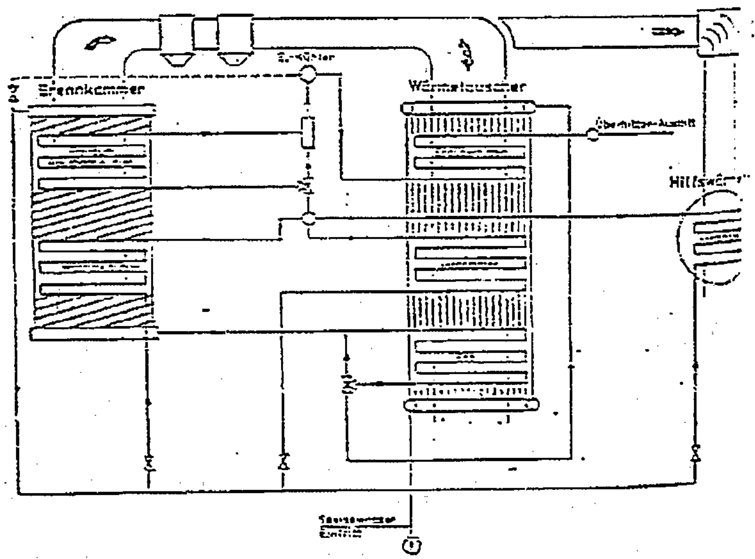
Supercharging is generated by a steam-operated compressor which can be controlled in a range of 7-31 kg/s air throughput at 5-12 bar.

In the interests of achieving reliable operation this initially bypass the problems of gas cleaning in conjunction with the operation of a gas turbine.

However, to ensure that it will be possible to instal a gas turbine later on, after successful testing of the components, the heat-absorbing heating surfaces are accommodated in separate pressure vessels.

The flue gases leaving the fluidised bed are cooled only nominally by the combustion chamber walls and fed at a temperature of 850 °C to the flue gas cleaning process, consisting of two cyclone stages coupled in series.

Further cooling of the flue gases takes place in the supercharged heat exchanger and ancillary heat exchanger, which cools off that part of the flue gas stream flowing to the turbine impeller test section.
The layout of the main system components for the water-steam circuit is shown in Fig.19.



The feed water delivered by the feed water pump flows initially through the walls and feed water preheater coils of the heat exchanger, with a two-directional valve enabling the feed water preheater to be bypassed when operating under partial load. After the feed water preheater of the heat exchanger, the stream passes through the tubes forming the walls of the combustion chamber.

These preceding heating surfaces bring the feed water up to a temperature clearly above vapor isation point. This ensures the subsequent distribution of the total quantity of water to the evaporators of the combustion chamber, heat exchanger and auxiliary heat exchanger by means of control devices in single-phase operation.

Choke controls are fitted at the inlet of the evaporator tubes for the combustion chamber in order to ensure uniform distribution of the water in the parallel tube coils during the starting process as well as to compensate marginal influences exerted by tube manufacturing tolerances.

The mass flow for the evaporator clusters of the combustion chamber is regulated to ensure superheating at the outlet in every operational state.

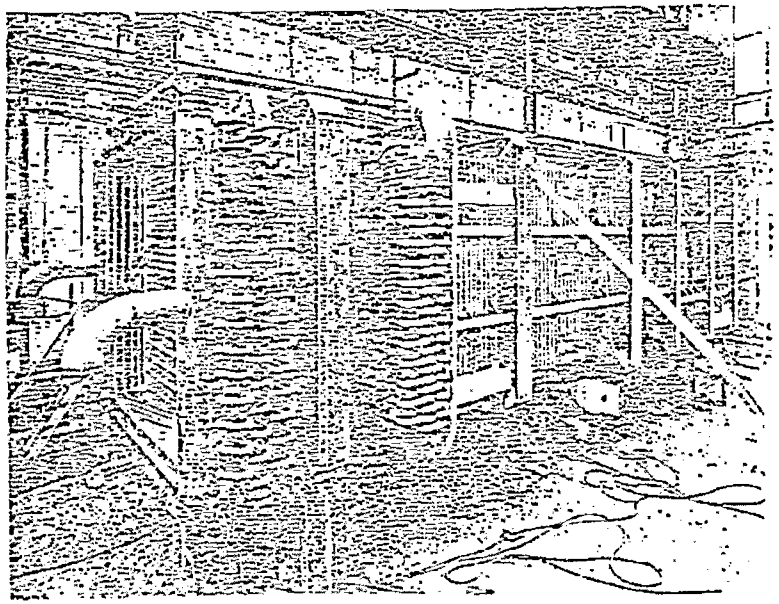
This ensures that the heat absorption of the evaporator is covered precisely, more particularly that of the immersed evaporator heating surfaces in the fluidised bed.

Balancing of the heat and material flows in the fluidised bed is thus rendered possible.

After the individual streams have been reunited a two-way valve regulates the partial flow rates required for the cooler heating surfaces to control the flue gas temperature in the cavity of the combustion chamber.

The final superheater in the heat exchanger generates the required hot steam emission temperature. Fluctuations in the fire control can be balanced off by the injection cooler interposed in front of the final superheater.

Workshop picture 20 shows the steam generator before installation in the pressure vessel.



The generated st[illegible] the design example 80 t/hr at 30 bar and 440 °C, is fed to the steam grid of the Grimethorpe Colliery Power Station for power generation.

...re Trends

In view of environmental requirements and structural dimensions, super-...arged steam generators with fluidised bed firing systems offer a particu-...ly favourable solution for use where high-performance units are required.

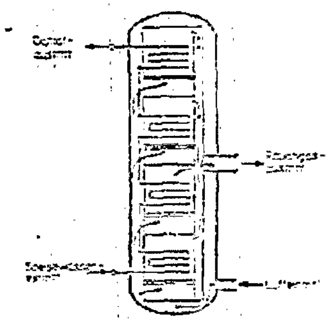
It is quite obvious that it will be possible to accumulate reliable back-...und knowledge for the future construction of largescale installations only ... the light of experience gained from the two projects mentioned above using ...ercharged fluidised bed firing systems.

The power station concept using the fluidised bed system stands or falls ... adequate dust extraction from the flue gas used for the gas turbine. ... a significant leap forward can be made in development work.

Cyclone separators, electrofilters, rotary dust extractors, ceramics filters and gravel filters are under discussion. Operating experience over the next few years will show which of these filters proves most suitable.

Irrespective of this there already exist today concepts based on steam ...eration units for an output of 600 MW_{el} with supercharged fluidised bed ...ring systems.

Based on a study by WESTINGHOUSE - Fig.21 -



...ereby for 635 MW four supercharged systems with 5.2 metres diameter and 18.5 metre height, each with four fluidised bed firing systems, are ...quired, approximately 18-21 % lower investment costs and 10-15 % lower