Commission of the European Communities

technical coal research

Coal in the heat market

Proceedings of a symposium held in Berlin,
22 and 23 June 1987

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Proceedings of a symposium organized by the Commission of the European Communities, Directorate-General for Energy, held in Berlin (Federal Republic of Germany) on 22 and 23 June 1987.

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OPENING ADDRESS

N. MOSAR
Member of the Commission of the European Communities

Senator,
Ladies and gentlemen,

It is with great pleasure that I acceded to the request to open this Symposium on Coal in the Heat Market organised by the Commission of the European Communities. May I, therefore, welcome you all most warmly to Berlin and thank you for accepting our invitation.

There are several reasons why I was well pleased to come to Berlin. The first is that the Commission sets great store by being here in the year of the 750th anniversary of the City of Berlin.

I would like to convey to you, Mr Senator and through you to all inhabitants of Berlin the heartiest congratulations of the Commission on the occasion of the birthday of your fine City. You will be aware, I am sure, that the Commission accords Berlin a prime importance in the European Community and I trust that we will be able to strengthen the bonds between Berlin and the European Community even further; and this not merely because every one hundred and fiftieth EEC citizen is a Berliner.

The second reason for my gratification at coming here is because, for a variety of reasons Berlin has become a model for a careful and forward-looking energy policy. Before long we will be hearing more about this from qualified people, but it does seem to me that you have evolved solutions from your particular situation which have in some measure become pointers to the future for others.

Lastly - and here I come closer to the theme of this Symposium - I would mention the great role which coal has played in the history of your City and does to this day. I hope you will not take it amiss if I recall that Berlin partly survived a very bitter period thanks to coal.

Now let us return to today, a present which does look a good deal friendlier in general but still faces us with considerable energy policy problems. When I use the term "Energy Policy" I have to remind you that an actual Community energy policy has not existed for all that long, although two of the three EEC Treaties - the ECSC and Euratom - deal directly with energy aspects. We had to wait till the first oil crisis for the first overall Community energy objectives for 1985 to be passed in 1974. These were updated in 1980 to reach to 1990 and contained three major provisions:

- lowering total energy consumption by savings and rational energy utilisation;
- drastic lowering of the share oil has in energy consumption, especially through diversification of energy sources and
- raising the share of coal and nuclear power in electricity generation to 70-75%.

By 1984 it was already found that these objectives could certainly be achieved by 1990 or had already been reached at that time. This led to our devising even more ambitious objectives for 1995, which were to be finally passed by the Council of Ministers in September 1986. Let me outline the crucial contents in brief.

1. We want to improve the effectiveness of the end consumption of energy - or what is termed energy efficiency - by a further 20%.

Ladies and gentlemen, I regard this aim as very important as it is our belief that, despite the savings and the 20% efficiency improvement over 1973 already achieved, there is still considerable potential for further improvements. Should the Community not succeed in achieving the other 20% by 1995, then the other objectives would also be endangered, at least to some extent.

2. We wish to bring down oil consumption to about 40% of energy consumption by 1995 and so reduce oil imports to under one third of the total energy consumption of the Community.

I need hardly stress what challenges face us on this very point in view of current oil prices. Let me merely say that we want to avoid the events of 1973 and 1979 in the future and that substituting oil by other forms of energy emphatically retains its importance.

3. And now three objectives which I cannot deal with in detail for lack of time:

The 19% share of natural gas in the energy balance should be maintained, whereas the share of electricity generated from hydrocarbons should be reduced to below 15%. On the other hand, efforts are to be made to obtain an appreciably higher contribution from the new and renewable energy sources.

4. Without entering into detail I do have to raise one point which will be of decisive importance for the future role of solid fuels as well, namely the share of nuclear energy in electricity generation. At present none of our member states is prepared to give up the ongoing expansion programs and so the 38 GW nuclear capacity presently under construction would bring total Community capacity to 115 GW by the end of the century.

5. We now come to the energy form which is of particular interest to yourselves: the solid fuels, more especially bituminous coal, brown coal and peat. We are trying to raise their share in energy consumption, currently standing at 22%, and to improve the cost-effectiveness of the production capacities for these fuels.

I do not wish to anticipate Mr Sierra, who will explain more fully during the morning how the Commission visualises this development. All I will say now is that great efforts are needed on the part of coal producers, the coal trade, consumers, plant designers, researchers and developers, to bring about our aim for solid fuels.

This brings me to two overlapping themes of our new energy objectives which have great relevance for this Symposium as well:

One concerns questions of research, development and demonstration, which the Commission regards as very important. Especially on the heating market it will be a matter of urgency to develop all the options for promoting sales and finding new solutions if the share of solid fuels is to be stepped up in this market.

The second theme - and it is one that strikes me as particularly important - is the impact of environmental measures. You will know that the Community is presently preparing regulations concerning large-scale plants, and it seems important to me to take future developments into account already now.

Other speakers will deal with all this in greater depth so that I will limit myself here to a single recapitulation:

If we slacken in our search for new and better solutions, and if we do not manage to preserve our environment in doing so, without endangering our industry, we will never reach the goals we have set ourselves, and I do not mean only the energy policy objectives of the Community but the future of our society and our culture altogether.

Ladies and gentlemen, I am well aware that I have touched upon very weighty questions indeed and I hope that by the end of your Symposium you will have formulated further solutions to these problems.

Welcoming Address by Senator E WRONSKI
Senator for Transport and Services

I welcome you very warmly in the name of the Senate of Berlin.

My thanks go to the organiser who - on the 750th Anniversary of Berlin - has honoured this city with three international congresses.

In recent years Berlin has made itself into an important innovation centre of the European Community and is now deeply rooted in the consciousness of Europeans.

Berliners are known for their self-confidence when it matters, for their courage and most particularly for their openness towards one and all. These characteristics they have also exhibited in the renewal of the Economy of Berlin.

The political leadership of the city has achieved a noteworthy adjustment on the Berlin labour market. Since 1983 something like 35 000 additional jobs were created.

The good atmosphere in our city is also exemplified by the migration gain: 50 000 earners more than have moved away.

A new economic policy has released considerable dynamism and high growth in employment in Berlin.

The structural renewal strategies of the Berlin Senate have been pursued as a systematic policy. An important factor here is the great innovation potential of the city. In the long run innovations will have to replace subsidies. Only in this way will additional and lasting jobs be created.

Innovations in the form of microbic desulphurisation of coal with the help of isolated bacteria are just as promising for the future as innovations in biological effluent purification on a small scale and with small energy outlay.

Such processes protect the environment and create new, highly-skilled jobs. They are important pieces in the mosaic of future industries.

New, pathfinding technologies also give coal a new qualitative status.

Modern coal-firing technologies which take account of a high level of environmental compatability and cost-effectiveness - whether nitrogen or sulphur is removed - do represent an enormous high-tech potential.

New products and new technologies have, however, to be developed through laborious effort before they are ready for marketing.

It is here that Berlin's industry enjoys a great advantage in terms of location.

The close cooperation between science and industry - especially the research potential concentrated here with over 30 000 employees in 180 scientific establishments - effectively invites technology transfer from science to industry.

11% of the research and development capacity of the German Federal Republic is located in Berlin.

Production and services of many Berlin undertakings are directed beyond the confines of Berlin towards Europe. The spheres of activity of these firms broadly coincide with the key areas of future technical development in Europe.

Berlin is also a clearing house for many R & D contacts in Europe. The availability of these research results is something which benefits the European market in particular.

Berlin can only hold its own in the worldwide structure changes if it relies on its own initiative. And this is what we are committed to do.

A selective innovation and technology policy, a comprehensive campaign to promote qualifications and new growth and employment areas, especially in the service field - these are the key points of our economic policy.

Berlin is relying on new standards, which are recognised in Europe especially.

Historically it is Europe which has produced the greatest potential of spiritual, cultural and technical innovations.

The technological and economic challenge posed by many countries in the world raises the question of the position Europe will have in the world of tomorrow.

In the long run only an open Europe can stand up to competition with the United States and Japan.

Europe has embarked on the hard road - far removed from parochialism, subsidies and protection - of developing a new self-awareness based on creativity and a sense of achievement.

For this reason we, as Berliners welcome the internal market to be introduced from 1992 in the EEC.

In Europe every opportunity for discussion has to be seized, across national frontiers and especially in an East-West dialogue.

For this, Berlin is an ideal location, because our political, economic and cultural future is a European one.

May I wish you all every success in your Symposium.

Address by Herr Ralph-Michael WEBER
Board Member of VAUBEKA
Brenn- und Baustoff GmbH, Berlin

Mr President,
Senator Wronski,
Ladies and Getlemen

The Berlin coal trade greets the participants of the "Coal in the Heat Market" Symposium.

We are gratified that our city has this opportunity of providing the forum for such an important European meeting.

Everyone would surely agree that Berlin is a fascinating city and since Berlin is celebrating its birthday it has made a special effort to be attractive. So we have the best conditions for holding a meeting here.

Ladies and Gentlemen, you probably knew of the special significance of coal for this city when you chose Berlin, not to mention the fact that for decades coal was virtually the guarantee of survival in energy terms for Berlin.

But to stay with the present: even today almost all of the electricity in Berlin is generated from coal. On top of that, of more than a million apartments in the Western part of this city about 300 000 are still heated with solid fuels. These are statistics which need a little time to sink in properly.

You have also chosen a city for your meeting which lets coal compete with all other energies. Other energies are subsidised. Coal is not subsidised and yet it has maintained this considerable share in supply.

The Berlin coal trade is trying to play its part in enabling solid fuels to retain their position in households and in industry. That is why we are particularly concerned with problems of environmental protection, also to be discussed at your meeting.

From these few words you will undoubtedly appreciate the particular importance of your Symposium's theme for Berlin. We await the outcome of your Symposium with the closest attention.

Ladies and Gentlemen, on behalf of the Berlin coal trade I wish your important meeting in Berlin every success.

COAL IN THE BERLIN HEAT MARKET

Prof.Dr.Ing. L Muller
Chairman of the Board of the
Berliner Kraft und Licht (Bewag) Aktiengesellschaft

"Sales of German hard coal are still falling faster than production, only the electricity companies are burning more coal". This was a headline in the VDI Nachrichten newspaper dated 17.04.87. It highlights once again the situation that has been evident in German coal mining for some years.

In 1955 coal output reached its highest level at some 150 mt. Since then it has declined. In 1972 some 100 mt were extracted, today it is barely more than 80 mt. In spite of the fact that production was cut back by 20% during this period, stockpiles have continued to grow during the last 15 years. The conclusion to be drawn is that in spite of a significant decline in production, it has still not been possible to match output to demand.

The sharpest decline was to be seen in the heating market. Sales in this sector dropped by a full 5.8 mt, which is an insignificant proportion of total sales. In the opinion of the coal producers association the changed energy price situation brought about the reconversion from heating oil to coal which took place in the German heating market.

On the other hand sales of internal coal to the power stations had a stabilizing effect. The so-called hundred year agreement allowed mining companies to supply electricity generating companies with some 41 mt of coal in 1986.

These 41 mt, more than half of the domestic coal output, together with 5 mt of imported coal, produced almost one third of the electricity in our country (29%).

The stabilizing effect caused by the German electricity industry can clearly be seen in the structure of primary energy consumption in the Federal Republic of Germany (Fig. 1). After years of decline in coal's share of primary energy consumption a reversal of this trend has been apparent in recent years. Even an initial glance shows this. Thus it is to be expected that coal's share in primary energy consumption in the Federal Republic of Germany will remain at the current level of around 20%.

The diagram also shows however that coal will hardly contribute at all to a further reduction in the use of mineral oil. On the contrary, the substitution will be mainly through nuclear energy and natural gas.

Another development, and one that has benefits for coal, is noticeable for the individual primary energy carriers in West Berlin. In the future too, particularly because of the lack of nuclear energy and hydraulic power, the situation here will develop differently to that in other parts of the Federal Republic (Fig. 2). The amount of coal used, including lignite, has remained at a constant level and in the long term up to the year 2000 will even increase a little.

In 1960 3.4 mtce of coal as a primary energy carrier met over 85% of the total energy needs of West Berlin. In the rest of the Federal Republic this figure had already dropped to 75%. The far-reaching changes in the energy and overall economic situation since that time have made lasting changes to the structure of energy supply in Berlin too: the total consumption of primary energy for the year 1985 exceeded that for 1960 by almost 85%.

The highest consumption thus far was reached in 1979 with almost 8 mtce - including 1 mt fuel. The rising demand for energy since 1979 has been met, as we can see, mainly by oil. The increased use of this energy carrier was promoted particularly by conversion of town gas production from coal to oil (Fig. 3).

This negative substitution effect for coal was however compensated for by the increased use of coal in electricity and district heating supply. Use of this primary energy carrier by the Berliner Kraft und Licht (BEWAG) AG thus increased from 1 mtce in 1960 to 2.5 mtce in 1985. The proportion of coal burnt by BEWAG during this period thus increased from 30% to 85% of the total demand for coal in Berlin (Fig. 4).

This trend will continue, albeit at a lower level. To meet the rising demand for electricity and district heating we believe that the amount of coal used in primary energy consumption in Berlin will rise from today's figure of 40% to around 50% by the year 2000 (Fig. 5). This increase is thus entirely attributable to the expected development of electricity and district heating generation.

The expansion of district heating, like the use of natural gas which started in 1986, will mean a downturn in the use of the primary energy carrier oil. Among other things, town gas, which up to now has been produced using cracked petrol as a basis, will more and more be replaced by natural gas. Some of the electricity and district heating facilities operating on the basis of oil will also be replaced by natural gas when a 150 MW block in the Lichterfeld district heating power station is converted from heavy oil to natural gas in 1988.

It is to be expected that the increased use of coal and natural gas will depress consumption of oil from today's figure of around 60% to some 40% in the year 2000. This means that it will match the expected figure of 35% for the Federal Republic as a whole.

This trend fits in completely with the estimated figures produced by the heating supply plans of the Berlin Senate which were formulated in the "future energy policy" report by the Enquete Commission in 1983. These were based on a significant reduction of oil usage in the heating market by increased and explicit use of piped energy, particularly with regard to the environmental aspect.

Thus use of gas on the heating market is to be increased from today's level of around 13% to over 25% by the year 2000 (Fig. 6 and 7). It is further envisaged that the share of district heating in final energy consumption will rise from its current 15% to around 25% as well. This means that piped energy carriers are to cater for more than 50% of final energy consumption in the year 2000.

The table in Fig. 8 shows the substitution processes that are expected to occur in the domestic sphere. It shows clearly that the number of homes to be supplied via piped end energy will increase very sharply and that such energy should then meet far more than half of the demand for heating (62%).

This assumes that natural gas primarily replaces use of coal and oil in individual boilers, while district heating replaces oil-fired central heating in areas with high heating requirements. It would seem that today's heating facilities operated by local authorities on the basis of coal will also be converted to natural gas in the long term for environmental reasons. In spite of this district heating will expand further, mainly however as a related product of electricity generation.

This is a good opportunity and also the right point at which to make out a specific case for district heating from combined power and heat and with particular reference to the specific energy saving effects, but also to the opportunities which this presents for coal.

Berlin is one of the birthplaces of district heating systems supplied by power stations. In 1912 the city received its first district heating supplies and since 1926 they have been systematically built up. In addition to continuous expansion of district heating supply, BEWAG is currently undertaking a project entitled "main transport line" with a volume of investment of around DM 300 million - the largest district heating project on the continent - to transport district heating from two 300 MW blocks to a further 55000 homes at the main centres of consumption.

Fig. 9 shows the energy savings already currently made by district heating. On the left is the amount of district heating supplied from the power stations by BEWAG in the business year 1985-1986, about 15000 TJ per year, and on the right the amount of oil needed to provide the same amount of energy. The amount of fuel shown in the centre column is the actual amount needed for district heating supply. Value 1 gives the savings in primary energy and value 2 the oil substitution volume. The difference is the extra coal which has been utilized for district heating.

Expressed in figures this means that district heating supplied by the district heating power stations of BEWAG has saved 300000 tons of heating oil or allowed substitution of 410000 tons of heating oil. To generate the 15000 TJ of heat supplied by district heating, including distribution losses, an additional 155000 tce of coal were used.

The use of district heating based on combined power and heat thus has a significant energy-saving effect and also results in more coal being used. In addition to the BEWAG electricity generation power stations as large consumers, BEWAG district heating is thus another partner for coal. Thus coal is processed for the heating market and fed to the consumer via the district heating pipes.

After supply of coal by wire using electric storage radiators, supply of coal by pipeline represents a further application of coal on the heating market.

All of this, ie power and district heating from coal is, as you know, not without its problems. Environmental protection today demands far-reaching measures to keep emissions which occur when coal is burnt in power stations within acceptable limits. As part of modernisation, BEWAG's existing district heating power stations have been equipped with modern exhaust gas cleaning systems, a program requiring an investment of over DM 2.5 million. When this work is complete in 1990 the yearly emissions will be reduced as follows:

SO_2 - from 53000 t currently to around 39000 t

NO_x - from 34000 t currently to around 27000 t

Dust - from 5000 t currently to around 3000 t

With regard to emission, both in the middle of the heating period and under extreme meteorological loads, the district heating from our power stations will then almost be as good as natural gas-fired ystems and significantly better than modern oil-fired central heating systems. With regard to emissions - no exhaust at the consumer premises, dissipation of residual power station emissions via tall chimneys - district heating will be particularly good for the environment.

To conclude:

Electricity and district heating generation in Berlin are assuming a key role in the utilization of the energy carrier coal. They thereby fulfil the company objectives of "safe power supply" and "expansion of district heating" based on safe energy carriers.

They have encountered numerous problems. I have already mentioned the first one which is the large investment required for systems to clean exhaust gases.

A second problem is the solid residues. In exhaust gas cleaning, particularly in coal-fired heat power stations large volumes of residues occur (Table in Fig. 10). These must be removed, ie where possible an industrial application must be found for them in accordance with the recycling orders and they may only be dumped in special cases. The safety of power supply may of course not be adversely effected by this in any way. Extensive research into possible recycling processes is now being undertaken.

Another problem is that of fuel stockpiles, particularly here in Berlin. For a variety of reasons adequate stockpiles must be maintained to secure provision of power and district heating at any given time. Thus for our power stations alone with a yearly consumption of 2.5 mt coal at the start of the 1986/87 heating period there was a stockpile of over 400000 tons of coal. In addition to these BEWAG coal depots there are extensive stockpiles belonging to the Berlin Senate.

At current levels of consumption of something over 3 mt per year (1986) it is barely conceivable that this city made do with only 944000 t during the period of the blockage from 24.06.1948 to 12.05.1949, and this had to be airlifted into Berlin in sacks. BEWAG received 377000 tons for its power stations at that time to enable its 193 MW of installed power to maintain electricity supplies, albeit at a greatly reduced level.

To summarize I would like to make the following points:

- at that time, during the blockade, coal was the only source of energy available to the people and to industry,
- in the decades since then coal has significantly underpinned energy supply. Most of the demand has been met by BEWAG and its power stations for supply of electricity and heat,
- as a result of measures taken and those planned (new coal-fired power stations, expansion of district heating supply, implementation of environmental protection measures) coal continues to have a good chance of successfully beating off the challenge of its competitors, oil and natural gas.

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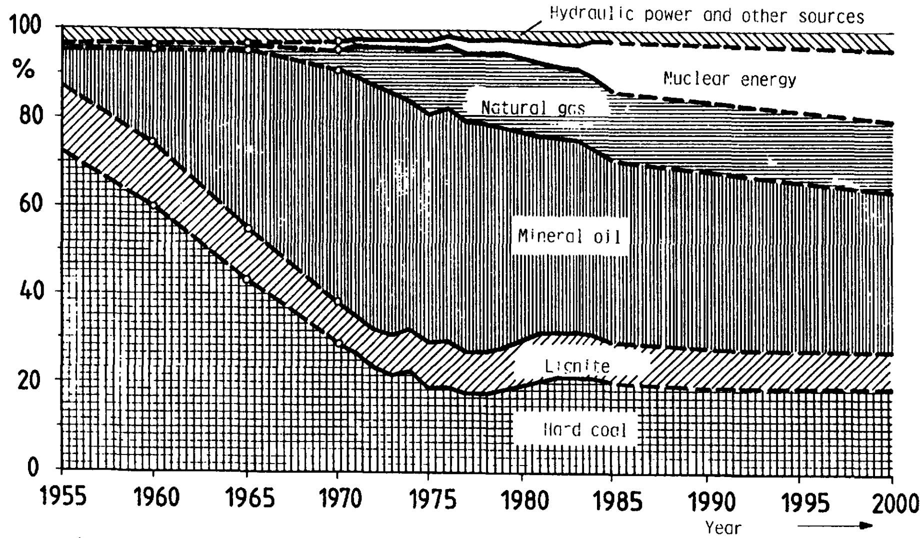
4. VDI Nachrichten No 16, dated 17 April 1987.



Source : VIK Energy Industry Statistics 1985/86; Forecast from 1985 onwards; German BP AG 1987

FIG. 1 - Shares of the various energy carriers in primary energy consumption in the Federal Republic of Germany

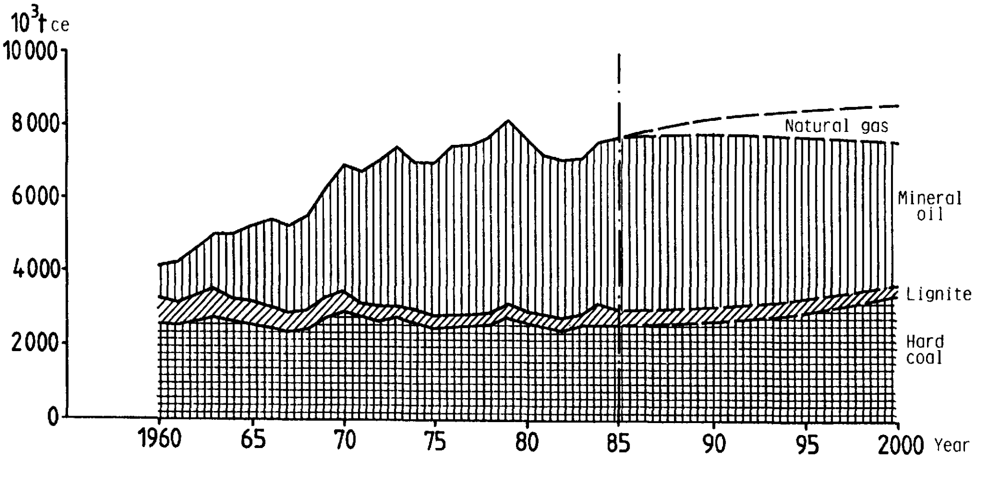


FIG. 2 - Development of primary energy consumption in West Berlin

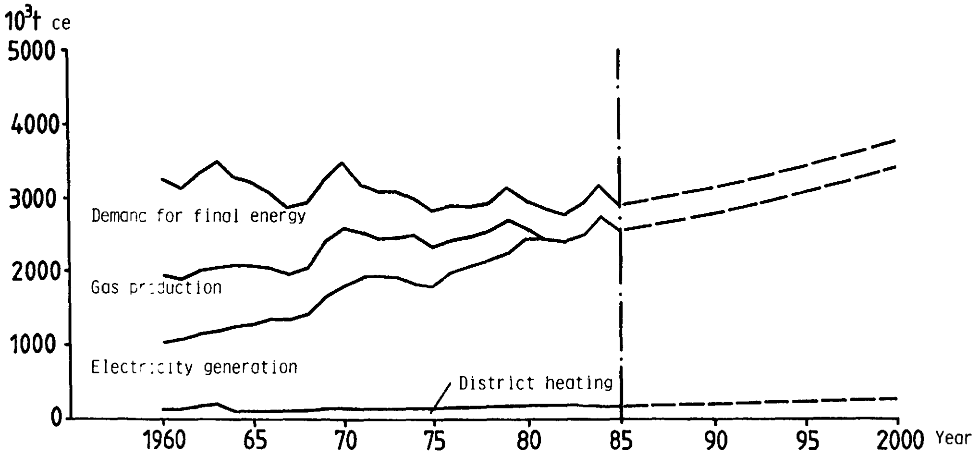


FIG. 3 - Development of coal usage in West Berlin

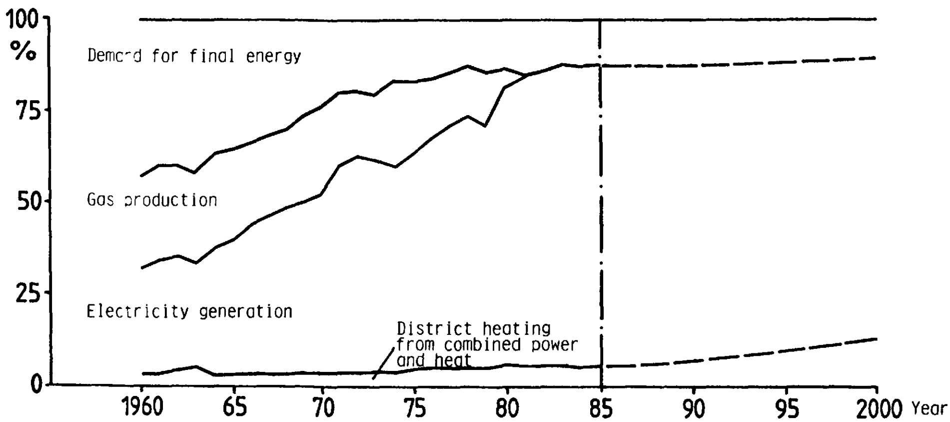


FIG. 4 - Proportion of West Berlin's coal taken by the various groups of consumers

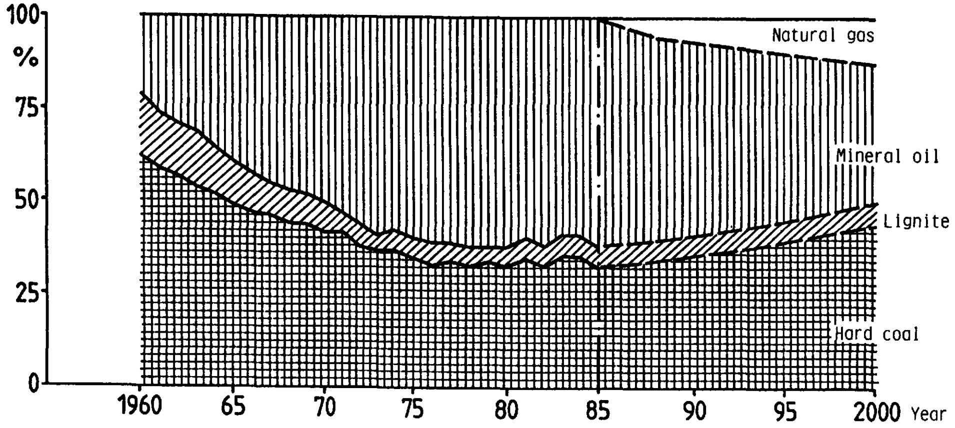


FIG. 5 - Proportion of primary energy supplied by the various energy carriers in West Berlin

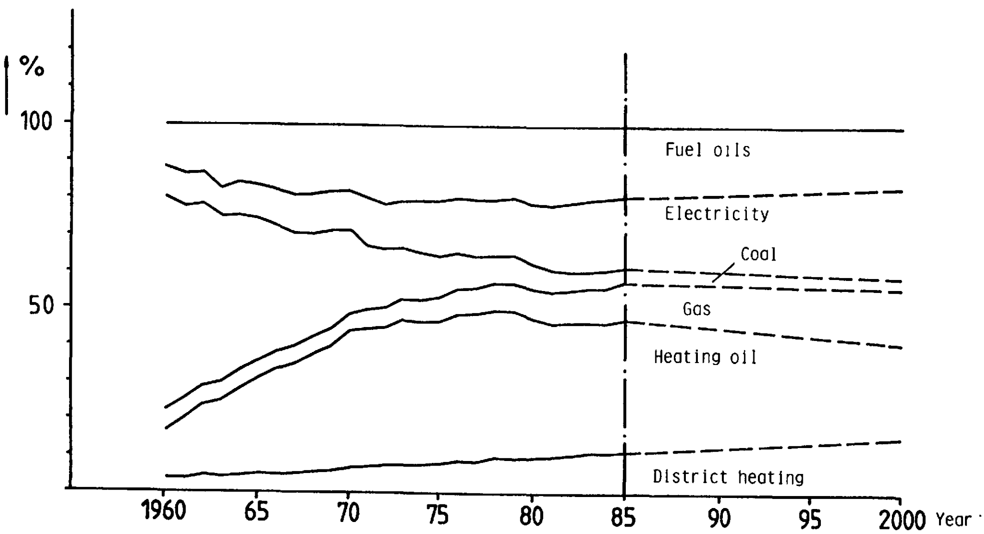


FIG. 6 - Shares in final energy consumption in West Berlin

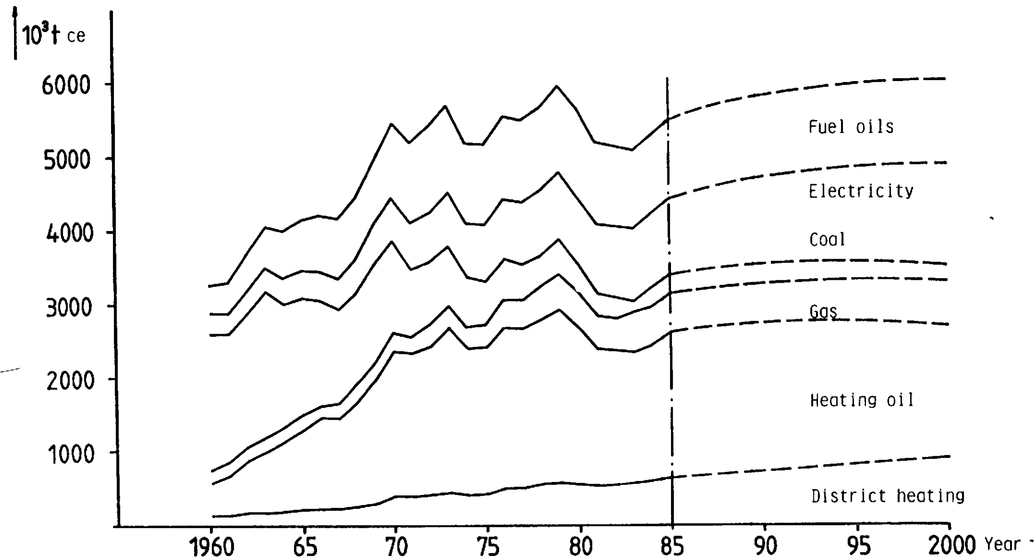


FIG. 7 - Development of final energy consumption in West Berlin

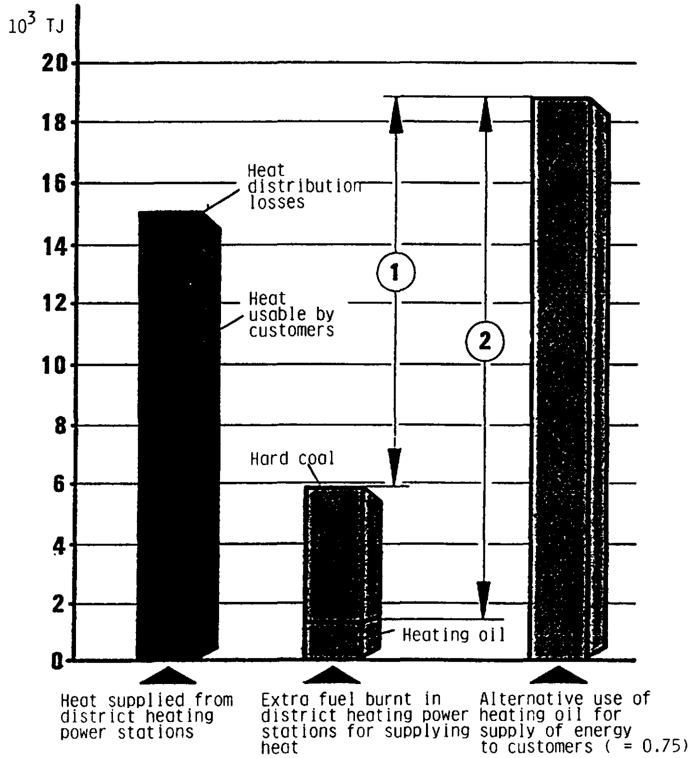
TABLE

Heating of homes Final energy carrier		Number of homes 1980	2000
Coal		305 000	92 000
Heating oil		439 000	260 000
Gas	(piped)	136 000	284 000
District heating	(piped)	150 000	219 000
Night storage heaters	(piped)	35 000	60 000
Number of homes heated :		1 065 000	915 000
percentage of piped supply		321 000	563 000
		= 30%	= 62%

Source : Report of the Enquete Commission "Future Energy Policy" Berlin Chamber of Deputies, document 9/1329 dated 07.10.1983

FIGURE 8

USE OF FUEL AND SAVINGS IN HEATING OIL BY COMBINED POWER AND HEAT IN THE BUSINESS YEAR 1985/1986



1 Savings in heating oil by combined power and heat = 300 000 t

2 Savings in heating oil incl. substitution = 410 000 t heating oil

FIGURE 9 – Fuel savings

TABLE : RESIDUES AND WASTE PRODUCTS FROM BEWAG FLUE GAS CLEANING SYSTEMS

Residues and waste products	Amount t/a
Rea gypsum	180 000
ZWS ash	40 000
Granulates	120 000
Fly dust	70 000
Waste water salts	30 000

FIGURE 10

ENERGY POLICY, COAL POLICY AND ENERGY R, D & D IN THE EUROPEAN COMMUNITY

J. SIERRA, DIRECTOR FOR COAL,
COMMISSION OF THE EUROPEAN COMMUNITIES

Ladies and Gentlemen,

It gives me great pleasure to represent the Commission of the European Communities at this Conference and to speak on the contribution the Communities are making to the present and future of coal in the heat market.

Before I do so, I would like to concentrate on the Community's solid fuels policy, within the framework of the general energy policy which has been pursued over the past few years. I hope to show you that within those policies there is a significant part for coal to play.

We all know that solid fuels occupy a very important part of the European energy mix, amounting to some 230 million tonnes of oil equivalent, of which 198 is bituminous coal and 32 million lignite and peat, that is to say, about 22% of our total EC energy requirements. Solid fuels are still the major indigenous source of primary energy and, consequently, constitute the major source of security of energy supply, a point worth emphasising.

In the energy balance of the Community, the importance of solid fuels - and coal in particular - took on a new significance following the oil crises of 1973 and 1979. This was of course true of the industrialised world as a whole, where internationally agreed energy policies were formulated aimed at palliating the effects of the oil shock. In the Community, the effects of these policies have included, since 1973, a halving of the amount of oil imported and a reduction in oil consumed by a quarter; a decline in the amount of energy used per unit of GDP by 20%; and an increase of nuclear capacity eightfold (from 10 to 80 Gigawatt), for the Community of Twelve.

In this picture we must include the stabilisation of solid fuels consumption, which had been in decline before 1973 and which now, as I have said, covers 22% of our total energy requirement. But here it has to be pointed out that this percentage is by no means assured for the future, and in fact already shows some signs of resuming a downward trend.

The Community's latest energy objectives, to which Commissioner MOSAR referred earlier this morning, set for realisation by 1995, were agreed at the September 1986 meeting of the Council of Ministers. As it has been said, they include : the further modification of the Community's energy mix so as to reduce the share of imported oil; the further reduction of the proportion of electricity generated from oil and gas; and, last but not least for our purposes, the increase of the share of solid fuels in energy consumption.

This last policy objective can and must be achieved even though, as I have said, the current situation for solid fuels is one of stagnation rather than expansion.

It is worth pausing for a moment to consider why this has come about.

Firstly, the dramatic price reductions provoked by the oil exporting countries may result in increased oil consumption, while, at the same time, they have compromised investments in other energy sources and led, to some extent, to an inappropriate policy of "wait-and-see" where coal is concerned.

Secondly, the value of the dollar has fallen drastically.

To add to the uncertainty, in the field of nuclear energy the rate and scope of further developments are seen as being conditioned by the Tchernobyl accident. There are also imponderables in the area of the environment, particularly the nature and stringency of future emissions standards.

All this is an unpromising background to increasing the consumption of coal in general and in industry in particular, where there has been no real increase of note since 1973, which had a level of consumption of 17 million tonnes compared with 20 million tonnes last year.

The fact is that this market appears to suffer from a multiplicity of obstacles to coal penetration, over and above the ones I have already mentioned, and some of them going a long way further back. I am thinking, above all, of the economic recession, which has for years put a question-mark over long-term investments in conversions from oil-firing to coal, the high cost of capital, and intense competition in some countries from natural gas.

These factors have combined to limit growth in the industrial heat market and to prevent any real breakthrough for coal, except in the case of cement, where energy costs loom so large proportionately that coal was clearly preferable to oil.

The overall picture, then, is that for coal in general, and in the industrial heat market in particular, we can have no grounds for complacency about future trends. We saw a decline in deliveries to industry in the early 1970s, which was only halted in 1976, when the trend moved upwards again from an all-time low of 17 million tonnes.

This slight increase in deliveries until 1980 accelerated afterwards, due to the second oil shock; this tendency was reversed only in 1986 as one of the results of the dramatic fall of oil prices.

Throughout the late 70's and early 80's there was awareness, both at Community level and in the Member States, of the need for positive measures in favour of coal.

Even before the Council agreed to two Community recommendations in favour of investment for the utilization of solid fuels in industry public buildings and district heating in May 1983, the governments of several Member States had taken legislative and administrative measures to encourage and promote the utilization of solid fuels in industries.

So far it has been difficult to evaluate the effect of these measures, but the accelerated growth between 1983 and 1985 suggests a certain, if modest, effect. The discordance in 1986, that is to say after the fall of the oil prices, on the other hand, is an indication of the impact of market forces on the complex sector of energy utilization industry.

I come now to the possibilities for aiding the supply of coal to the heat market under the aegis of the European Communities, and I have to say that they have up till now been somewhat limited. It is often possible for companies to benefit from interest-rate-subsidised loans under Article 54(2) of the ECSC Treaty if they burn Community coal; but there is no general scheme for encouraging conversions to coal in the heat market, although the Commission has in the past proposed to the Council of Ministers that such a scheme should be introduced. As a matter of fact, the Commission's programme for 1987 does include an undertaking to study and make proposals for the promotion of solid fuels consumption, and this is in progress.

The Community's activity in sponsoring coal use is centred rather on the technological side than on financial incentives. This is because research, development and demonstration are very important means of improving the role of solid fuels in all sectors of the market by rendering their use easier, cheaper and cleaner.

For a long time now, the European Communities have taken this into account when formulating their policy on solid fuels research, development and demonstration. As a result of these considerations, we are at present running four different programmes which I would like to present to you briefly, without going into too many details.

First of all, there is the **ECSC-Coal Research Programme** (European Coal and Steel Community) which has a long tradition. The major part of this programme concerns mining technology, and even if we are not dealing with mining today, we should recall that this is the origin of the feedstock for all subsequent processes, which should be produced as cheaply as possible.

The other part of the ECSC programme concerns the upgrading and utilisation of coal, covering some interesting items :

. There is for instance, coal preparation, the area between mining and utilisation.

Clearly, there are great advantages in removing as much ash and sulphur as possible from the product, but we have to ask ourselves what is a reasonable level of cleanness? Is it more cost effective to concentrate on eliminating pollutants at the point of use, rather than to opt for more intensive coal cleaning?

. Then, there is the area of coal upgrading. Will we be able to develop new processes for coal use and new products derived from coal? And, particularly, will it become possible to find outlets for the ever growing quantities of residues from coal mining and coal utilization?

. Finally, we have combustion and utilization of solid fuels, the topic in which you are most interested. This area was shifted to an EEC financed programme which is called the :

Non-Nuclear Energy Research Programme. In fact, this programme contains a subsector on the use of solid fuels, the main topics of which are

. Fluidised bed combustion in different variations,

. New improved burners,

. Coal-water-mixtures,

. Environmental protection techniques again, and the

. Transportation and handling of solid fuels.

My feeling is that the two last items have particular importance for the easy and clean use of solid fuels even in "small" markets. Particularly the transport and handling of coal have always caused problems, and these problems have not become any simpler as the proportion of fine coal produced has increased. We must continue to look for improvements in this difficult area.

Both our research programmes have produced very useful results, and have created the basis for the further demonstration projects which represent the last step before commercialisation.

This **EC Energy Demonstration Programme** was implemented in 1978, and today covers the rational use of energy, alternative energy sources such as geothermic, solar energy and wind as well as two branches related to solid fuels :

The first one is the subprogramme on **liquefaction and gasification of solid fuels** which includes liquefaction, underground gasification and some large gasification projects, which are all of less interest to you. Yet, should we not continue to develop smaller gasifiers which could be used in brickwork or ceramic factories as well as for local fuel gas production?

However, the second branch of our demonstration programme is much nearer to the heat market, because it concerns the **substitution of hydrocarbons by solid fuels**, which in practice means the combustion of solid fuels and all its related problems.

Of course, fluidised bed combustion is the most important technique, and the programme covers a number of projects of all sizes and all techniques. This means that the stationary fluidised bed is covered as well as the circulating and the pressurized types. Other promising solutions are proposed - staged combustions for example - but the question I would like to ask is this : can these increasingly complex technologies be made cheap enough for use on a reasonably small industrial scale? My feeling is that for the market we are interested in today, the somewhat conventional, stationary bed will still prevail for a certain time, because it is the easiest one to manage.

Another important item is the use of **Coal-Water-Mixtures.** For the time being, these are used only to retrofit oil-fired power stations, but why, in the longer term, could not CCWM become a new type of fuel presenting interest also for heat production?

Furthermore, we have a great number of projects dealing with the improvement of **Conventional Stoke-Fired Boilers** and new industrial boilers for the **Combustion of Pulverised Coal.** In this context, the development of low NOx-burners seems to me very urgent.

Finally, there are several projects under way aiming at the better **protection of the environment** by dedusting and desulphurisation of the flue gases as well as by treatment of the residues. This latter point will most probably become extremely important in future because of the growing quantities of gypsum, effluents or other residues.

Ladies and gentlemen, this was a very broad resume of our ongoing R, D & D activities, and at this point, I would like to give you at least an idea of the financial implications of all this work.

As an example, in 1986 we spent :

For the 2 research programmes	: 28.5 m Ecu or 63 m DM
For the 2 demonstration branches	: 33.6 m Ecu or 74 m DM.
That is in total	62.1 m Ecu or 137 m DM.

You will find more details in a brochure which is available on our stand in the exhibition.

I would like to emphasise that the Community's R, D & D programmes are far from neglecting the "smaller" markets such as general industry and heat production. A great many good solutions have already been developed, but a lot of problems remain still to be solved.

For the heat and industrial market, I think the following questions are the most urgent to be answered :

1. Is the handlability of the combustion processes for heat or heat/power generation sufficient? Or can we improve coal arrival at the site, bunkering, internal transport and feeding to the boiler? At the tail-end, do we not need improved or even automatic ash removal?

2. Do the combustion units have enough flexibility on the input side? Are they able to accept a broad range of coals without losses in efficiency?

3. Is the availability of such plants high enough and can it be guaranteed? Or should we develop better means of control and monitoring for fully-automated operation?

4. Do we have central gas, heat or heat/power generators for application in so-called industrial parks? Or do they have to be developed in order to reduce costs and emissions?

5. Are our combustion plants in line with current environmental legislation or, even better, do they anticipate future changes? In no case can we allow environmental protection measures to create new problems for the environment, or, in other words, to shift the problem from the air into the soil and the water.

I know that these problems are not easy to solve, but I hope that during your conference at least some of the questions will be answered. There is certainly an abundance of experience and expertise among the speakers, and it is up to us to listen to what they have to say and apply it to our individual and common circumstances as coal producers and users. I am sure, too, that the speeches will be complemented by informal contacts which will, as usual, be of great value in terms of problems set and solutions found.

Ladies and gentlemen, thank you for your attention.

THE PERSPECTIVES OF HEAT GENERATION

Dr. Peter Rohde
Member of the Board of Ruhrkohle AG

I

1 Around 300 B.C., the Greek Theophrastus, a follower of the philosopher Aristotle, published a tract entitled "On rocks" in which he described brittle rocks "which burn like charcoal when put on the fire ... smiths use them". This is no different to the use of bituminous coal in the heating section in a member state of the European Community.

For centuries - as Theophrastus stated - coal was used just for heat generation at atmospheric pressure and at low temperatures. With the start of the industrial revolution, three applications evolved by which we still classify the use of coal today:

- As a raw material, coal is used as a carbon carrier for chemical reactions. Examples of this are the reduction of iron oxide in blast furnaces or the production of quicklime with coke.
- Coal is used in a direct or linked process to generate process heat. The steam parameters range from the saturated steam temperature and 13 bar in breweries, for example, to 530°C superheated steam temperature and 110 bar operating pressure in chemical plants.
- In the space heating field, coal is used for the generation of heat and hot water with temperatures of approximately 90°C in single/multi-family dwellings and up to 180°C for the district heating supply.

2 As there are so many uses for coal in the heating market, it is not possible for there to be a standard definition of this market. Therefore, I would like to preface my remarks with a definition: I understand the heating market to be the total final energy consumption of a national economy (excluding motor fuels) except for that used in power stations and in the iron and steel industry. Expressed in terms of market sectors, I am talking about the domestic and small consumer market where some individuals only use a few tonnes of coal per year, and of the many fields of industry where consumption can range up to several hundred thousands of tonnes per year.

I would like to divide my remarks about the perspectives of coal in the heating market thus defined into four sections:

- Firstly, I will draw a picture of the development of the heating market in the EC.
- Secondly, I want to show the requirements that are made of plant engineering by the heating market today.
- Expanding on this, in a third section I would like to comment on the sale of coal in the heating market as a service.
- Finally, in a fourth section, the intention is to show how important coal is in the heating market by means of a review of the current situation in the international energy markets.

Now let me start with a summary of the development of the heating market.

II

1 Since 1950, the heating market in the 12 countries of the European community has grown continuously from 260 mtce to more than double by 1970, reaching a volume of 610 mtce. Although the growth fell with the first oil crisis in 1973/74, it had already more than returned to its former level by the time of the second oil crisis in 1979/80, with the result that the heating market had reached a volume of just about 660 mtce in 1980.

Since then, energy consumption in the heating market has fallen back to about the level of the Sixties - with some variations however. A decisive factor in this was that all consumers took measures to save energy in an attempt to keep the energy cost factor down even though the price had risen. Today, in the 12 member states of the European Community, we are talking about a market in the order of 600 mtce.

2 In contrast to the general development of the heating market, the consumption of bituminous coal and brown coal started falling as early as the middle of the Fifties, slowly at first, but more rapidly from 1960 onwards. This was the result of the great advance of fuel oil. Then, in the middle of the Sixties came natural gas and electricity as well. These line-supplied types of energy squeezed out not just coal, but also fuel oil.

Only from 1980 onwards has it been possible to stabilize coal consumption again. However, in the 12 member states of the EC, the level at which it has been stabilized now is only about 60 mtce. Thus, coal is used only for about 10% of the heating market. If the proportion of coal used indirectly in the form of gas, electricity or district heating to supply the market is calculated, then the total amount used in the 12 EC countries might be around 20% of the heating market.

3 In the Federal Republic of Germany, the heating market has developed almost in parallel to the EC. Today, the final energy consumption of the Federal Republic of Germany is approximately 260 mtce or about 68% of the primary energy consumption. The heating market accounts for around 65% or 170 mtce of the final energy consumption.

The development of coal, too, followed practically the same course in the Federal Republic of Germany as in the other EC countries. Today, however, the coal consumption figures are somewhat higher than the average: bituminous coal and brown coal together comprise about 23% of the heating market when both direct and indirect consumption are counted. Bituminous coal accounts for approximately 15%, made up of 6% direct and 9% indirect consumption.

4 In spite of the very different circumstances prevailing in the heating markets of the individual member states of the European Community, the competitive position of coal - and here I would specifically refer to bituminous coal - is characterized in all of them by being economic, being easy to use and by not polluting the environment. These three factors determine the requirements made by the heating market on heat generation plant today. I would now like to turn to these requirements using the example of the Federal Republic of Germany.

III

1 There are three main cost factors involved in determining how economic coal-fired plant is in the heating market: investment costs, operating costs and heat costs.

The investment and operating costs are characterized by the particular physical properties of bituminous coal:

- As a bulk material, coal requires special handling equipment.
- The non-combustible components of coal mean that special waste disposal devices are necessary.
- The relatively low energy density and the necessary processing components lead to large construction volumes.

Because of these properties of bituminous coal, investment costs today are approximately three times, and operating costs including waste disposal costs, about twice as high as the comparable costs for an oil or gas-fired plant. Coal-fired plants can only be economically viable in the heating market, therefore, if the unit price of heat from coal is lower than that from oil or gas. Then, the disadvantage of coal as regards investment and operating costs can be at least compensated by the benefit of the heat costs.

From this initial position resulting from the physical properties of the coal, our efforts must be directed towards reducing the disadvantage of the investment and operating costs as our room for manoeuvre with the heat costs is very limited. In my view, there are three conclusions to be drawn regarding technical development, as follows:

- The coal-fired plants must be constructed to be as simple and maintenance-free as possible. Modular construction should be aimed for to reduce building costs.
- Plants should permit closed-circuit operation in the low-pressure range and unsupervised operation in the high-pressure range.
- When building the plant, some thought should be given to ensuring that it fits in architecturally with the surrounding buildings and to using low-maintenance building materials.

2 With regard to ease of use, I would like to enumerate the following process steps in particular:

- fully automated fuel supply,
- fully automated de-ashing of the boiler, removal of filter dust and, if appropriate, flue gas cleaning residue,
- low-maintenance operation as a result of automatic cleaning,
- low-supervision operation in 24 h cycles,
- automatic and quick load turndown to as low as possible a partial load.

Over the last few years especially, great progress has been made in all the above areas by innovative design and improvements in instrumentation and control engineering. However, further technical improvements are required to increase the ease of use. I think the following points are particularly important:

- The availability of all bituminous coal-fired installations must be increased to over 99%.
- The range of partial load regime must be increased. Depending on the application, the partial load range must be extended from 1:4 to 1:8.
- Dry methods must be used for flue gas cleaning where the residue is then suitable for recycling. If recycling is not possible, it must be possible to dispose of the residue without any risk of polluting the environment.

3 With regard to coal-fired plant not polluting the environment, the main factors involved are the emission values for dust, carbon monoxide, sulphur dioxide and nitric oxide. Our efforts in this area to date have been very successful. Today, we have small fluidized-bed furnaces with emission values the same as those of a comparable oil-fired furnace.

However, this improved pollution situation has been brought about at considerable expense. For example, for a 5 MW_{th} grate combustion plant

- the cost of the filter equipment to ensure the maximum dust limit value of 50 mg/Nm^3 is adhered to is approximately 20% of that of the boiler (not including construction costs),
- the cost of a flue gas cleaning plant to reduce the SO_2 content by at least 50% to approximately 800 to 1000 mg/Nm^3 is approximately 60% of that of the boiler (not including construction costs).

Therefore, a double objective must be set for further technical development: firstly, the emission values for coal-fired plants will have to come down to the level of those of competing energy sources; secondly, the costs involved in this will have to be kept as low as possible. I think the following aspects in particular are important in order to achieve this double objective:

- Emissions can be reduced most simply by using as low-emission fuels as possible.
- Improving the efficiency of our plants would not only improve their economy, but would also reduce the emissions.
- Equipment to reduce emissions must be concentrated on primary measures, as these involve the lowest costs and are easiest to use.
- Secondary measures to reduce emissions should incorporate high efficiency and high availability to produce low costs for recyclable products or products which can be disposed of without polluting the environment.

IV

1 As indicated above, attempts are being made to improve coal's "hardware". However, this is also true of its "software", for in the heating market, the demand basically is not for the product coal, but for the supply of heat. Therefore, I think it is important that we sell coal in the heating market as a service to a certain extent and not only as a product.

The service must always be matched to the requirements of the individual customer. Thus, there is no standard recipe for developing "software" in the EC. It is not just the requirements of the customers which are different. There are different peripheral conditions which have to be met in the different countries such as legal requirements and official measures.

2 However, there are a few generally valid elements which make the sale of coal into a service. I count these as being the following:

Initially, it is a question of having a <u>consultation</u> to propose to the customer possible solutions to his problem (raw material, process heat, space heat). The consultation is generally accompanied by a draft project and a cost-effectiveness estimate.

A second step supplements the draft project with <u>planning</u> (basic and detailed engineering) together with a detailed calculation of cost-effectiveness.

As the boiler is generally an auxiliary plant in the heating market, the customers are not very willing to spend the necessary means for product investments on boilers. <u>Finance</u> must therefore be made available to the customer.

Management of the approval procedure, placing of the orders and <u>construction</u> of the plant right up to the turnkey handover may often be important to the customer as his engineering capacity is involved in the production.

In many cases, the customer leaves not only the construction but also the operation of the plant to a third party in order to remunerate only for the heat supplied. In this case, the third party is responsible in particular for supplying and waste removal from the plant.

Owner-operators, on the other hand, often expect continuous maintenance, including the necessary emission measurements.

3 The abovementioned elements are claimed by the customer individually or as a "service package". They have to be brought together in each case by the mining company in co-operation with the market participants in accordance with the specific requirements of the customer to form a service package.

In order to be able to offer the "software" service in the heating market, it is not just the marketing concept which is required. Continuous training of the employees is also involved as the legal regulations change just as quickly as the state of the art, eg in the field of environmental protection.

The trade and service companies co-operating with the mining company also have to be included in the training arrangements.

V

1 All efforts to improve the coal "hardware" and "software" in the heating market take place today against a background characterized by extremely low prices of the competititors, oil and gas. However, it is worth continuing with coal. The current competitive situation between coal on the one side, and oil and gas on the other, will not last very long; oil and gas prices will be rising.

This statement is made not just by the coal producers but also by the oil producers. The facts are clear to see:

- The fall in the price of oil - and as a result of gas - has not been due to technical innovation or rationalization measures. It was more the result of the politically induced imbalance between supply and demand in the world oil market because the OPEC cartel could not reach any agreement about production quotas.
- In contrast to this short-term situation, the long-term efforts of the oil-producing countries are aimed at stabilizing the price of oil and increasing it as soon as possible. This is because it is an increasingly costly business to find and win new oil reserves. In addition, all the oil-producing countries need higher income just to be able to maintain their living standards.

Even the Federal Government pointed out this situation in their statements on energy policy. Thus, the competitiveness of coal, compared to that of oil and gas, will increase in the future.

2 For the coal producers of the EC member states, the competitive situation not only with oil and gas, but also with coal from third countries, is of importance. As is the case with oil and gas, the very low price of coal from third countries cannot last too long. This is easy to see:

- The nominal prices of coking coal and boiler coal are at the level they were at in the first half of the Seventies. Many bituminous coal mining companies throughout the world are operating at a loss at present, or are just breaking even. There are reports of closures coming in from Australia, the largest cost-exporting country.
- With existing deposits, work is being concentrated on the least cost-intensive parts. Only limited work is being carried out on new deposits.

Investment is being limited to rationalization measures. Even international freight costs are now at such a level that it is impossible to cover costs.

The conclusion from this description of the market is obvious: capital depreciation through losses and the level of costs is exerting great pressure in the direction of higher prices. As soon as the growing world demand for coal allows, the price of coal from third countries will increase again. Then, the competitive position of EC coal will improve as well.

3 In Europe, we depend to a very large extent on the international energy markets as the 12 EC member states import just about 60% of their primary energy needs. Of particular importance in this regard is the fact that far-reaching price increases in the world energy market are generally quite unforeseen. We have experienced this several times in the past:

- Just think back to the oil crises in 1973/74 and 1979/80 which nobody foresaw. The effects of them are well known. But nobody would then have dared to forecast that the prices would soon drop greatly again either.
- Mention should be made here about the development of the exchange rates of the individual EC currencies against the US dollar. Since the high point of the dollar early in 1985, ie 3.40 DM/$, that is to say within two years, the cost of energy imported into the Federal Republic of Germany has almost halved with the drop of the US dollar against the D-Mark. Nobody foresaw that either.

These two examples show that particular importance is attached to the EC coal mining industry for ensuring that the 12 EC member states receive a regular and reliable supply of energy. With vitally important long-term investment, we cannot afford to think only about the short-term.

Our consumers of coal in the heating market are well aware of this situation too. Therefore, I am pleased that the CEC is reinforcing this view amongst the consumers by holding this symposium. As producers, we will do everything we can to maintain the positive perspective for EC coal in the heating market in the future.

VI

1 I would like to summarize the perspective of heat generation as follows:

- Since the beginning of the Eighties, the heating market in the 12 countries of the European Community has stabilized to the level of the Sixties. Coal makes up a 10% share of the market directly, 20% directly and indirectly.
- Considerable progress has been made in the efficiency, ease of use and non-polluting effect of combustion plant in the heating market. Further development work must be concentrated particularly on reducing costs and on flue gas cleaning with recyclable residue.
- The sale of coal in the heating market must in future involve the provision of a service.
- The current situation in the heating market of extremely low oil and gas prices will not continue. In view of the uncertainty in the energy markets, particular importance is attached to European coal for ensuring the supply of the EC countries.

2 The EC conference on coal in the heating market is taking place in Berlin which is celebrating its 750th anniversary this year. Therefore, let me end with a few words of Frederick the Great, the famous King of Prussia. In the 18th century he said: "I do not trust mining generally, but I have confidence in coal".

FIRST TECHNICAL SESSION

Rapporteur paper for first technical session - Grate firing for small installations (up to 20 MW)

Grate firing for large installations (20 to 200 MW)

Pulverized coal firing

RAPPORTEUR PAPER FOR FIRST TECHNICAL SESSION
GRATE FIRING FOR SMALL INSTALLATIONS (UP TO 20MW)

R.C. PAYNE
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1. INTRODUCTION

Grate firing for small installations (up to 20MW) in the first technical session comprises papers representing aspects of national programmes in five EEC member countries. The countries are Belgium, Denmark, France, Federal Republic of Germany and the United Kingdom.

A common theme which emerges from a review of the papers is that a significant revival of coal-fired stoker utilisation occurred during the latter seventies and early eighties following sharp increases in the price of oil. The resulting relatively high cost differential between coal and oil made coal use, to replace oil, attractive again following extensive oil utilisation during the sixties (when oil was low cost and readily available). This prompted the need to improve conventional stoker design in terms of the level achieved for automatic control and operation, combustion efficiency and environmental acceptability. Mechanical stoker fired designs were initially selected because of their proven reliability at acceptable cost.

Parallel improvements have also been made in developing automatic and clean, coal and ash handling ancillaries to match the improvements in stoker design. It was necessary to achieve these measures at acceptable cost in order to maintain a competitive technology. However, for specialised high energy consuming, competitive industries such as horticulture in Belgium, automatic operation of coal-fired plant was not considered essential, the payback on fuel savings against minimal capital investment being a primary consideration.

The papers describe a wide range of stoker/grate designs to burn a variety of coal types. Applications range from residential, commercial and group heating to industrial process plant. In France and United Kingdom the national coal-based industries launched major development programmes in collaboration with combustion equipment manufacturers and national agencies and with Community support to promote increased coal use. For the other countries it would appear that development has been through individual mining companies or district heating authorities.

Two countries, West Germany and U.K. have progressed the design of fully automatic coal-fired systems for the smaller size of installation based on the use of special graded coal. These fully comprehensive systems simulate oil-fired delivery schemes and involve the supply, reception and storage of coal at user sites and can include ash removal from the customer premises. Where fully automatic systems have been developed, conformation to stringent safety requirements regarding unattended operation has been stressed and demonstrated.

Since the collapse of world oil prices during 1986 the rate of technical development has been influenced by a significant reduction in the number of new coal-fired stoker installations. For Denmark no new coal-fired installations are planned at present.

The five papers will now be reviewed in greater detail before some general conclusions are drawn.

2. BELGIUM

Development of Coal Boilers for the Heating of Greenhouses and Large Buildings - J. Cerulus N.V. Kempense steentalenmijnen.

Interest in coal fired heating was revived in Belgium from 1982 particularly for the horticultural market sector and less so for heating large dwellings and commercial small premises. Reasons were the price differential between indigenous high volatile bituminous coal and heavy fuel oil for horticultural applications and for light fuel oil or natural gas for the heating of buildings. However, installations only proceeded where a two-year payback could be gained against the investment of the installed cost.

Initially, the requirement for manual attention in the operation of coal-fired plant was not an important consideration when set against the fuel cost savings achieved. The experience quoted in the paper is that for the smaller, horticultural boiler applications automatic ash removal was not found cost effective, particularly as the Belgian coal supplied has a low ash content. Also, the de-ashing systems available had proved unreliable and uneconomic

Campine Coalmines have marketed improved designs of underfeed stoker in competition with other small Belgian boiler manufacturers. The stokers form the basis for package boiler units with reliable internal cleaning arrangements for heat transfer surfaces such that high boiler efficiencies can be produced and maintained. It is claimed that the design provides good control of fuel/air ratios over a range of output to ensure high combustion efficiency particularly for the more highly swelling coals.

Attention has also been paid to the stringent requirements for particulate emissions from the boiler flue. This has led to the optional use of mechanical grit arrestors capable of limiting emissions to below 100 mg/Nm^3. To date some 150 installations have been supplied by Campine Coalmines out of a total of 1000. the Campine units appear to have met the performance targets required in terms of thermal efficiency (84% to 86%), high turndown to 1% of boiler capacity and particulate emission control (230 to 290 mg/Nm^3).

3. DENMARK

Grate Firing in Small Installations (<20MW)
Lars Jacobsen, dK - TEKNIK

Denmark has a long standing tradition for district heating schemes. Currently there are some 350 district heating networks and 40% of all residential heating is through such systems. For large towns these were initially in the form of combined heat and power plant based on coal firing. However, during the 1960's with the introduction of cheap oil, new district heating plant was based on oil. From the late 1970's with the increase in oil prices, the cost differential between oil and coal made coal use attractive again. Also, new coal-fired schemes were extended to include relatively small scale plant.

The choice of coal-fired plant was based initially on technology introduced from the U.K. where stoker development had been continued during the 1960's. Drop tube/static grate fired shell boilers were employed in two plants which were converted back from oil. However, these had the disadvantage of manual de-ashing and further new installations were in the form of fully automatic coal-fired plant designed to have high standards of environmental and aesthetic acceptability. This resulted in coal-fired plant which was as clean and convenient to operate as oil fired plant. New automatic coal-fired plant contained travelling and chain grate stokers with computerised combustion and load control facilities and included bag filters to give high standards of flue gas cleanliness (2 to $10mg/Nm^3$) rivalling those obtained for oil-fired plant.

Information is provided in the paper which shows the growth of such coal-fired schemes between 1980 - 1985 and in particular the rapid rate of growth from 1981 to 1983. From 1980 to 1985 a total of 67 coal-fired district heating schemes were installed incorporating 91 boilers and giving a total capacity of 532 MW. A typical installation (Ishoj Vamevaerk) is depicted and described comprising three boilers each of 12.5 MW capacity which replaced seventeen previous small oil-fired plants.

Following the extension of a natural gas network into Denmark, no new coal-fired installations are planned. Existing oil-fired plant is being converted to natural gas.

4. FRANCE

Grate Firing For Small Installations.
S. Delessard - C d F Energie (Groupe Charbonnages de France)

Since the late 1970's France has been committed to increasing coal use for industrial and community heating. Major research and development programmes were initiated by C d F in collaboration with manufacturers with support from EEC and several national agencies. This included design improvements to conventional coal-fired equipment to maintain its competitiveness.

The paper describes the range of stoker fired boiler equipment in use during the late 1970's (principally integrated furnace boilers and chain grate stokers with some ignifluid and travelling grate stoker installations). However, from 1982 the pattern of use changed with the introduction of vibrating grate stoker/boilers tending to replace chains. Integrated furnace boilers have maintained an important position in the residential and community heating sector. This is confirmed in information given showing the national pattern of stoker/boiler installations from 1983 to 1985 with overall capacities of 471.5 MW (1983), 392.7 MW (1984) and 231.2 MW (1985). New chain grate stoker installations have remained significant with regard to industrial hot gas generation.

Attention is drawn particularly to three designs of stoker.

Integrated furnace boiler units range from 0.25 to 3 MW capacity and are claimed to be particularly suitable for heating residential and commercial premises. Coal is fed from a hopper to a static grate by ram or screw action. The boiler is of package form and was designed for semi-anthracite although high volatile caking coals are also said to be suitable. Units are automatically load following with auto coal/ash handling.

The chain grate stoker boiler in shell or water tube form is applied to heating requirements over a range from 3 to 4 MW. Typical installations can provide steam, superheated water or hot water (less than 110°C). Attractions are its competitive cost and proven mechanical reliability. However, disadvantages are claimed in lack of response time to load change and the limited turndown in boiler output. Improvements are described which can give full automatic operation and a 1 MW demonstration plant has been installed by Cerchar incorporating safety features conforming to a Government directive for pressurised boilers operated without supervision. A 33 MW installation at Versailles is described which demonstrates fully automatic operation and environmental acceptability. The plant incorporates conventional coal and ash handling and full computer control and is fitted with electrostatic precipitators to meet stringent environmental requirements.

Vibrating grate stokers based on a German design have been used increasingly in France. Applications range from community heating to process plant with boiler capacities from 2 to 25 MW. The author describes the automatic operation of the water-cooled, tubular grate and the following advantages are claimed over the chain grate:

increased operating flexibility with a 5:1 turndown in boiler output;

ability to burn a wide range of coals (including caking types); with increased latitude regarding ash fusion characteristics and use of low ash coals;

comparable capital cost to chain grate but with reduced maintenance requirements.

5. FEDERAL REPUBLIC OF GERMANY

Latest Developments in the Field of Small Grate Furnaces.
Dr.-Ing. H. Guder - Preussag A.G. Kohle.

For coal-fired applications up to 20MW a range of stoker designs are available including static and mechanical grates. Five popular types of grate quoted which can burn a range of coals are of horizontal, double inclined, feeder, vibrating and travelling form. These designs have been developed to meet modern needs through optimisation of fuel/air ratio and improved grate coatings and control equipment. This has resulted in improved combustion efficiency and load change behaviour and reduced emissions. The paper draws attention in particular to three stoker developments which are described in detail and reviewed below.

The OMEGA coal boiler incorporates an anthracite gravity feed system to a water-cooled, double inclined grate. Developments include improved control and safety means, the boiler being suitable for automatic operation under the West German Technical Regulation for Steam Boilers, TRD 604. Its operational safety has been satisfactorily demonstrated regarding the production of explosive atmospheres, fuel burn-back to the hopper, continued burning of coal removed from the grate and excessive hot water temperature. Based on this experience 20 boiler plants have now been installed and represent the only high efficiency, fully automatic coal-fired plant in Germany.

The ram forced-feed grate is a new development of compact stoker which can be applied to various boiler designs including shell and watertube units. Features include an inclined grate with heatproof coatings. Movable rams, fitted in series down the grate, are located between grate bars and activated pneumatically by a programmable feeder unit. In a progressive stoking sequence the rams are programmed to clear sections of the grate for fuel fed from the rams above, the stoking sequence being adjustable for the type of fuel burned. The grate is claimed to combine high combustion efficiency with good emission control and to be suitable for a wide range of fuels ranging from bituminous coal and anthracite to lignite and wood/paper waste.

To cater for the space heating sector, which accounts for 70% of total heating requirement in F.R.G., a German mining company has developed and introduced a comprehensive coal fired heating service which comprises a fully-automatic heat generator backed by a fuel supply, ash disposal and maintenance facility. The service is similar to that provided by the oil companies and is based on an existing infrastructure for the distribution of small sized anthracite (5 to 20mm size is quoted).

The scheme features fuel reception from tipper lorry by screw elevator into horizontal silos of modular design. Coal is then transferred by mechanical screw to the appliance hopper and ash is screwed automatically from the appliance to refuse containers. Primary and secondary combustion air to the heating appliance is supplied via an induced draught fan whose operation (dependent on heat output) is controlled through a microprocessor. The plant which is fully automatic in operation is claimed to have high operating efficiency, flexible performance and acceptable levels of flue emission. The system has now been established on the market and been applied to local heating schemes ranging from 10 kW to 3 MW capacity.

6. UNITED KINGDOM

A Review of Stoker-Fired Developments in the United Kingdom Applied to Small Installations Below 20 MW capacity.
R.C. Payne - Coal Research Establishment, British Coal Corporation.

Since 1972, British Coal in collaboration with combustion equipment manufacturers and with EEC support has conducted a major development programme to make coal more attractive to the industrial user. Stoker designs account for a significant proportion of coal fired combustion equipment sold in the U.K. industrial market and cover a wide range of application. The principal fuel sold to this market is washed and graded high volatile bituminous coal. Generally, the larger units (travelling and spreader grate stokers) can accept a wide range of coal type and size (up to 30mm) whereas smaller installations (underfeed, static and reciprocating grate stokers) are more selective on fuel and require closely sized coal (singles) for satisfactory operation.

UK developments in coal-fired stoker plant (principally, below 20 MW capacity) are reviewed with reference to recent improvements in design and operational features which incorporate electrical ignition, automatic combustion control and self de-ashing.

For underfeed stokers (25 kW - 2 MW range), the need for manual de-ashing has been obviated by appropriate redesign of retort and air admission system which provides a shallow fire-bed with ready discharge of ash and clinker; a range of units (50 to 300 kW capacity) is being developed with automatic coal feeding and ash disposal facilities. These units can also burn 'Pearls' grade coal (6 - 12mm size) thereby permitting the incorporation of a low-cost pneumatic handling system. For side-grate de-ashing stokers (400 kW to 1.8 MW range), automatic ash removal can be effected by specially-designed reciprocating grate bars which also allow the introduction of undergrate air in order to complete the combustion of the coal. Both types of stoker can use electric hot air ignition for sequenced light up and shut down on demand.

For static grate stokers (normally used in low cost horizontal shell boilers), automatic de-ashing can be provided by the use of a dump grate or mechanical rake. Either system may be operated in sequence (by means of programmable logic controllers) to provide regulated tipping or raking. By these means, boiler output can be maintained with maximum control of steam output and smoke emission. Gas-fired automatic start-up is also available.

Improved commercial designs of reciprocating or coking stokers (up to 5 MW) incorporate programmed electrical ignition and are flexible with regard to coal quality. In particular, high intensity stokers (0.6 - 1.8 MW range) are now fully-automatic in relation to coal-feed rate, ignition and de-ashing; combustion intensities are similar to those achieved with oil or gas firing and continuous turn down of up to 5:1 can be attained.

Developments in moving grate stokers (up to 70 MW) have centred around the provision of automatic ignition (hot air at 650°C); during start-up, grate movement is sequenced according to the temperature of the ignition arch. Maximum boiler efficiency at a range of loads can be realised by full control of fuel to air ratios.

7. CONCLUSIONS

The following conclusions arise from consideration of the five papers.

During the 1970's and early 1980's, following substantial increases in the price of oil, there was a significant increase in coal fired stoker utilisation stemming either from national programmes or from authorities with specific interests in coal utilisation or heating.

To maintain a competitive technology, significant improvements have been made to a wide range of stoker designs (from small underfeed units to large moving grates) burning a range of coal types to provide fully automatic facilities with regard to coal feed, efficient combustion and load control, de-ashing arrangements and ignition, and also to control flue emissions to acceptable standards. Several examples of fully automatic installed plant are given. Operation of such plant has demonstrated that it can meet the stringent safety requirements imposed by National standards.

Current developments in stoker technology have been influenced by the recent fall in world oil prices, this leading to a reduction in the present level of activity.

GRATE FIRING FOR LARGE INSTALLATIONS (20 to 200MW)

Michel Philippe
Stein Industrie

Synoptic report of the national papers by:

Dipl.Ing. G. Schroth, E.V.T. (Germany)
Lars Kiorboe, dk-Teknik (Denmark)
R. W. Stockdale, Foster Wheeler Power Products Ltd (Great Britain)
Michel Philippe, Stein Industrie (France)

As from 1978-80 Europe has seen a revival in the marketing of large coal-fired boilers, once the oil crises had brought about a price rise in liquid and solid fuels. This emerges from a perusal of the national reports, except perhaps for the Danish report.

The report submitted by Great Britain gives the trend in prices of the different fuels between 1977 and 1983 and, in parallel with this, the trend in the number of enquiries for costed coal-fired boilers (Fig. 1). Some countries possessing national resources have also promoted this return to coal as a fuel, something true of France in particular.

Consequently, designers have sought to develop or improve equipment which will meet the needs of industry in terms of scale, flexibility of operation and adaptability to present day means of monitoring and control.

Among the coal combustion techniques which are within the range of capacities considered here, and bearing in mind the investment costs involved and the state of designer art, the equipment at present available is the spreader stoker and the travelling grate. The German report specifies that in Europe spreader stokers have been built for capacities up to 159 MW and even cites examples of boilers in the United States of 190 MW capacity.

I COMPARISON OF THE DIFFERENT TECHNIQUES

Without going into too much detail the various reports expound the characteristics of the main grate combustion techniques used at present, namely the travelling grate and the spreader stoker. The British report gives a detailed description of these systems.

1 Travelling grate (Fig. 2)

Charging is effected by a chute system of the gravity-feed type which will provide a bed of coal which is uniform and homogenous in product size across the full width of the grate.

The travelling grate has to resemble a mat which will allow a good distribution of air across the entire surface of the combustion zone (drying, ignition, combustion, extinction) and a form of bars which will prevent the finest particles from passing through.

The distribution of combustion air must be of a kind to enable the quantity of air being directed to different combustion zones to be regulated and to match the type of coal burned.

Primary air is distributed under the grate, secondary air to bring about combustion itself is distributed at great velocity in the combustion zone above the grate.

2 Spreader stoker (Fig. 3)

The coal is distributed by a feed mechanism which regulates the throughput and a spreader, usually with paddles, the object of which is to throw the coal onto the rear part of the grate.

The travelling grate is a return grate which moves from rear to front and has to have the characteristics described above.

Combustion air is split up into primary air, distributed under the grate and secondary air distributed (at high velocity) from the front and rear of the boiler at one or more levels. The quantity of this secondary air matters more than it does with a travelling grate in view of the fact that some of the combustion occurs in suspension.

3 Coal quality

In Europe many countries use a large proportion of imported coals. Denmark, for example, imports all its coal from South Africa, Poland, the United States, Great Britain and a significant share from France.

This makes it necessary for the grate combustion system to accept a wide range of coals. Limitations on suitability are these:

3.1 Moisture content

Moisture has to be less than 15% with the grate, according to the German report, 20% according to the British report and 15% according to the French.

In the case of brown coal, moisture may go up to 27% from the German report, 20-25% the French. Frequently this limitation originates in problems encountered in the feed (hopper clogging or coal drop impaired).

3.2 Ash content

The German report shows that the ash content has to be below 15%, the British report below 20% for on-grate combustion and 35% for spreader stoker combustion, while the French report has it below 25%.

This limitation does vary considerably from one report to another and may be explained by the fact that it can be linked to other coal characteristics: calorific value, V.M. content.

3.3 V.M. content

- the German report indicates a range of:
6 to 40% for on-grate combustion and
14 to 40% for combustion with spreader stoker.
- the British report has the same range for both types of combustion: 20 to 40%.
- the French report a V.M. content of over 15% for the spreader stoker.

The rapporteur of this paper is aware of installations in which coal with a V.M. content of 3 to 4% is burned on a travelling grate. The German report makes mention in its bibliography of a boiler in which anthracite with 8% V.M. is burned.

For spreader stokers the V.M. content has to be relatively high, say 14 to 15% since ignition and some of the combustion has to take place in suspension.

3.4 Swelling index

For coal combustion on a grate it is important for the swelling index to be less than 1 or 1½, while this index is not limited in the case of spreader stoker combustion.

This is explained by the fact that tar and V.M. combustion takes place in suspension with spreader stokers, while on travelling grates it takes place on the mat where the coal is liable to block the air passages because of its swelling.

3.5 Product size

For on-grate combustion the coal has to have a size range of 0 to 50 mm with a share of fines limited in the following manner:

- 30% of the weight of coal is made up of particles below 1 mm, according to the German report, 15 to 50% of particles below 3 mm, according to the British report.

For combustion in spreader stokers the coal has to be within the 0 to 30mm size range, according to the German and French reports with a fines share limited in the following way:

- 25 to 30% of particles below 3 mm, according to the British report,
- 40% of particles below 2 mm, according to the French report.

The size range is an essential factor for both types of combustion, but especially for the spreader stoker, in order to present:

- a significant quantity of unburnt residues remaining after the grate has been traversed and
- under-grate product containing a large quantity of entrained particles.

4 Comparison of the two types of combustion

Part of the combustion which takes place in spreader stokers occurs in suspension. This technique offers two advantages compared with the on-grate combustion method:

a) the calorific charge on the grate is larger. In the British report the ratio between the two is 1.5.

b) varying the charge is easier to achieve because a variation in the coal feed introduced into the combustion chamber is immediately converted into a variation in the heat released. With a grate boiler the response time is longer, as is explained in the British report.

These two reasons make the spreader stoker an important development of recent years for large plant and plant designed for industry, where variations of regime are a major choice criterion.

II IMPROVEMENTS MADE IN THE GRATE COMBUSTION SYSTEM

1 System of control

The boilers currently in service are mostly equipped with electronic control systems which enable the boiler plant to be run automatically without continual manual intervention (See British and French reports).

In the case of a boiler equipped with a spreader stoker this form of regulation makes for a good adaptation of the coal-fired boiler plant to the needs of the works it is to serve because the regulating system directly acts on coal feed and, in parallel, on the combustion air quantity supplied.

2 Re-injection of residues

With spreader stokers and small sizes in the charged coal the quantity of entrained particles can be significant; since these entrained particles contain a large quantity of carbon they can have an influence on combustion yield.

Large scale installations are normally equipped with a mechanical preliminary de-duster and the recovered residue is re-injected into the combustion chamber in order to burn the carbon it contains (See British and French reports).

The French report also tells us that for several years now large steam boilers with spreader stokers have been equipped with total re-injection systems (Fig. 4) which offer the following two advantages:

- increase in the combustion yield,
- evacuation of coal ash in the form of clinker, thereby avoiding having to stock and handle dry powdery products.

These installations are functioning in a satisfactory manner provided the whole system is scaled-up commensurately.

3 Automatic ignition

Modern boilers are generally fitted with a system which will ignite the coal without any manual actuation using igniters working on propane as a rule (see British report).

These igniters all have a remote control and safety system of a kind required for installation of this type.

III PROTECTION OF THE ENVIRONMENT

All reports emphasise the research done and the improvements made to grate installations which have helped to reduce waste released into the atmosphere.

1 Filtration

Modern installations are all equipped with efficient filtration systems, most often an electrostatic de-duster.

Legislation in the different European countries requires new plant to adhere to limits which range from 500 mg/Nm^3 to 50 mg/Nm^3 for plants with capacities from 20 to 100 MW. Stricter restrictions can be imposed for protected zones.

These values can be achieved with the equipment commercially available at present but it does raise the cost of investment in an appreciable way.

2 Nitrogen oxide

All the national reports draw attention to the fact that on-grate combustion takes place at a relatively low temperature. This temperature is even lower in boilers equipped with a spreader stoker in which combustion is split into two vertical zones:

- combustion in suspension
- combustion on the grate

The French report refers to measurements of NO_x contents within the 330 and 450 kg/Nm^3 band. The British report gives findings according to which the combustion temperature is reduced even further with recirculation of gas, while the NO_x content is lower than that recorded with fluidized bed combustion.

3 Sulphur oxide

The generation of sulphur oxides is clearly linked to the sulphur content in the fuel itself. A certain quantity of sulphur can combine with the coal ash and be evacuated in the form of clinker.

The French and German reports also inform us about tests which are in hand to inject lime into the combustion chamber.

The Danish report points out that legislation has required industry and district heating to use coal with a sulphur content of around 1.2%.

IV EXPERIENCE OF COAL COMBUSTION ON-GRATES IN THE DIFFERENT COUNTRIES

1 Germany

The report provides a list of the particulars of the main plants put into service in recent years.

It is noteworthy that the capacity of grate boilers varies between 30 and 100 t/h. The fuels burned are anthracite, bituminous coal and lignite briquettes.

The spreader stoker boilers, on the other hand, have capacities between 70 and 150 t/h, burning bituminous coal.

2 United Kingdom

The report informs us that, since the various oil crises, grate boilers have been frequently used for small installations. Also, that combustion in spreader stoker plants has not met with great success in the United Kingdom.

3 Denmark

The Danish paper reports that the technique of grate combustion has not been used at power stations except for two boiler plants which were commissioned in 1982.

This report does mention several installations which act as back-up power stations.

In industry several grate boiler plants have been installed since the last oil crises, all of them firing imported coal.

4 France

Since the early 80's a large number of coal-fired boilers have been installed in the lower end of the range up to 20 MW. Most of these are boilers with mechanical grates. For larger plant and throughputs up to 160 t/h (130 MW) the installations ordered have more often been equipped with spreader stokers, representing a total of 40 boilers.

V CONCLUSION

The experience in the different countries allows a certain number of conclusions to be drawn at this point in time.

The system involving combustion on a mechanical grate has been largely proven and the improvements introduced in the past few years have removed reservations which some clients still had. For industry, this mode of combustion presents the following advantages compared with other coal combustion technologies:

- low investment costs,
- equal thermal output
- low electric power consumption,
- good flexibility of functioning,
- ease of operating,
- reduced cost of operation.

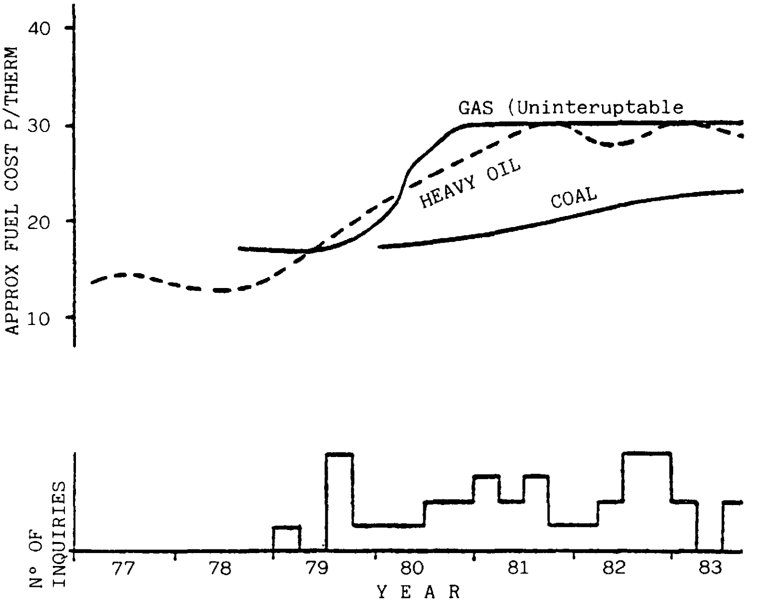


FIGURE 1 - FUEL COST V COAL FIRING INTEREST

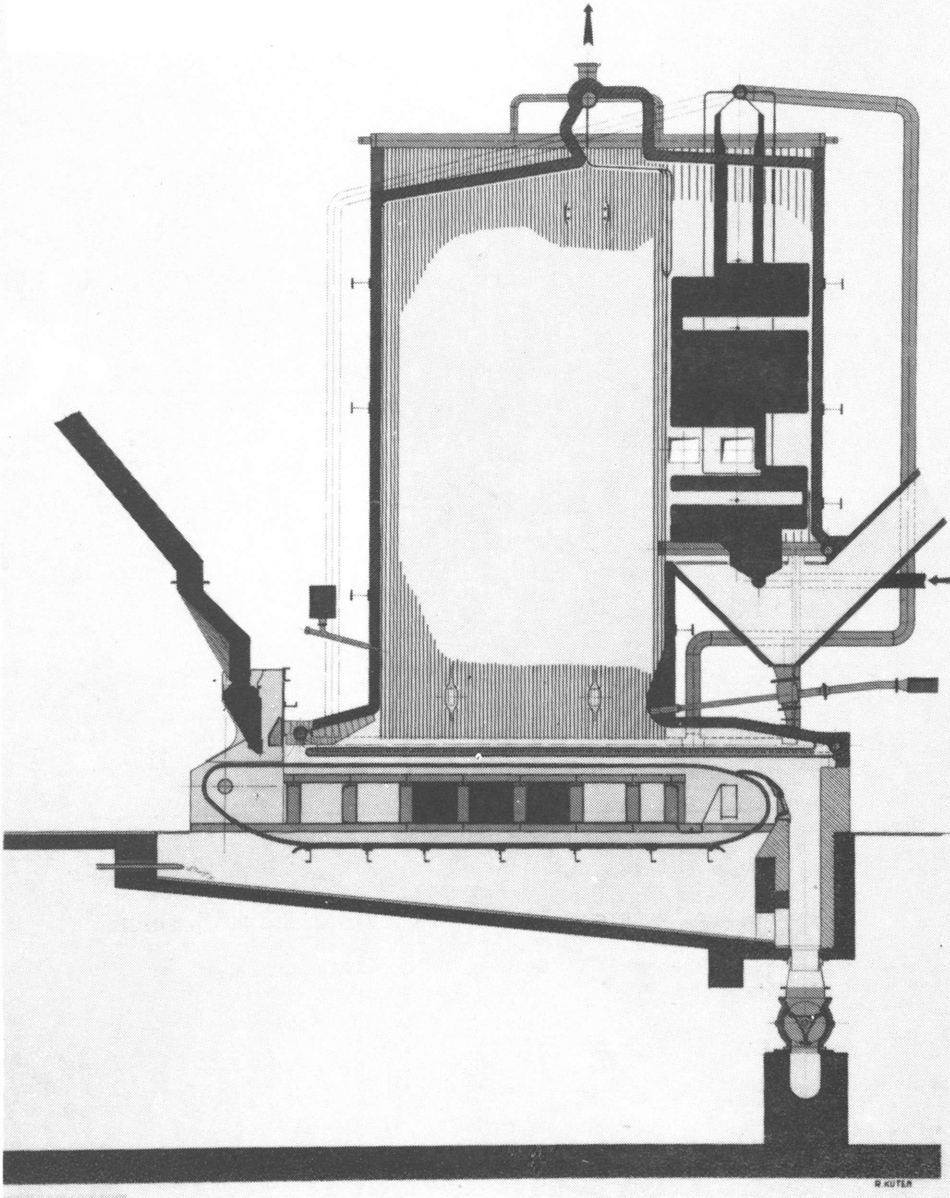


FIGURE 2

SUPERHEATED WATER BOILER WITH MECHANICAL GRATE

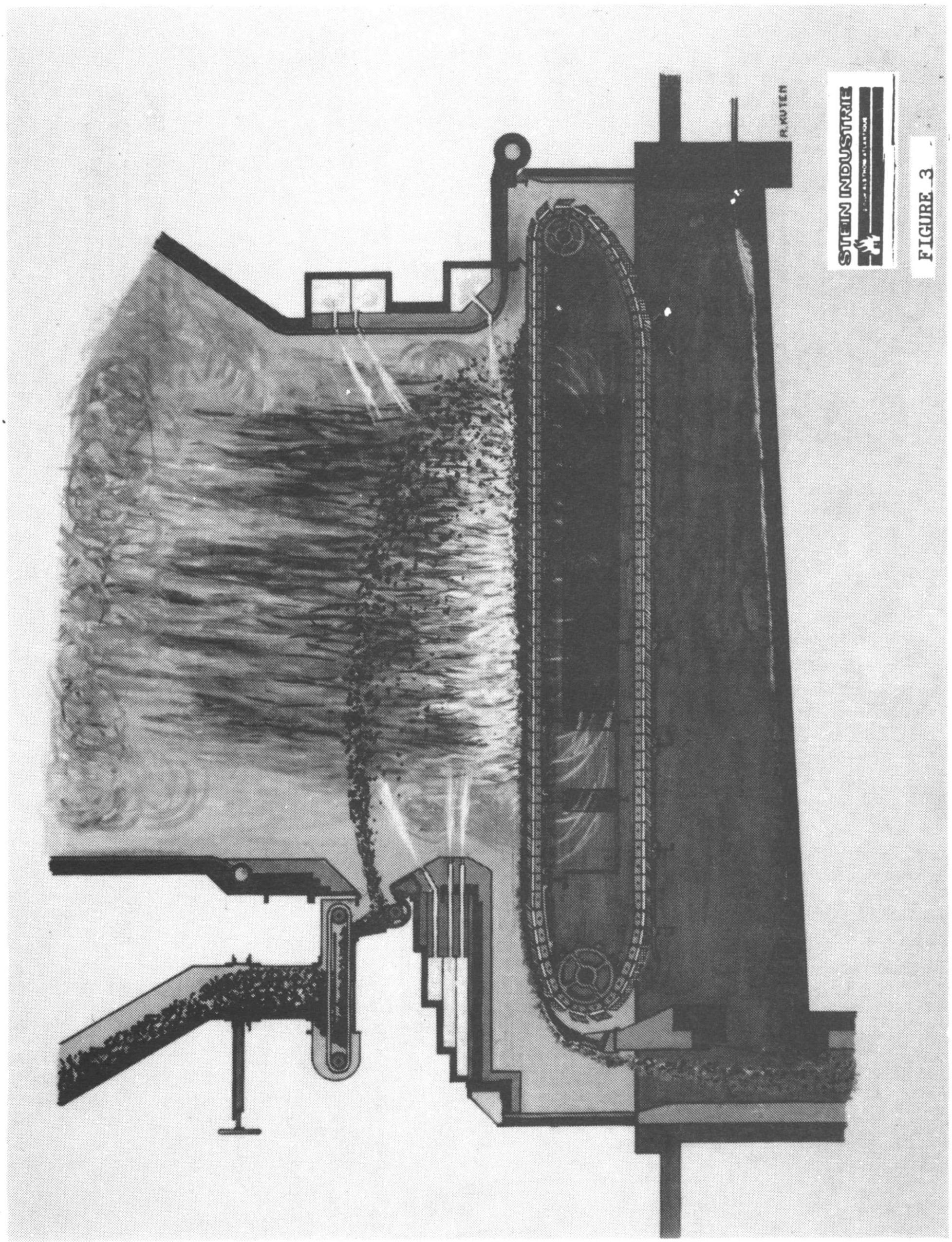
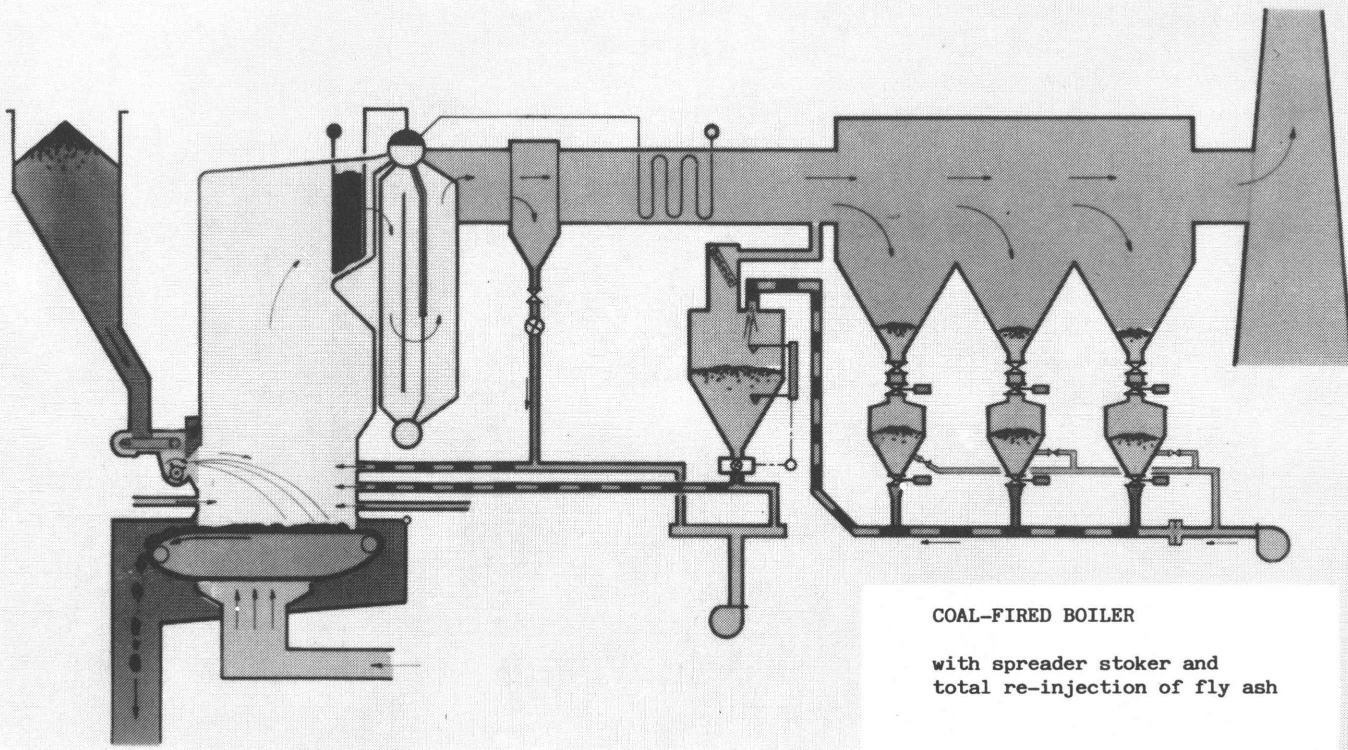


FIGURE 3



COAL-FIRED BOILER

with spreader stoker and
total re-injection of fly ash

STEIN INDUSTRIE
groupe ALSTHOM ATLANTIQUE

FIGURE 4

PULVERIZED COAL FIRING

Dipl.-Ing W. Reichert

Ruhrkohle AG, Essen

1. Introduction

Pulverized coal firing is one of the most wide-spread forms of coal utilisation in the EC. Most of the coal is used in large-scale power plants in which milling of the fines and combustion of the coal dust are closely connected. After the rise in oil prices in the 1970's consideration was given, for a variety of reasons, to extending coal firing to smaller firing plants on the heating market. One of the reasons was the dual prospect of the simple conversion of oil-fired systems and an easily automated and clean coal firing process with an efficiency rating almost equal to that of oil. Measures have been taken in various countries in the EC, and five reports have been submitted (References 1 to 5, see Appendix).

These reports are summarised below.

2. Technical principles

In small plants with, in most cases, narrow and restricted furnaces the success of dust firing depends largely on good ignition and a residence time sufficient for complete burn-out. The conditions are generally more favourable in drying plants and rotating tube boilers than in the furnaces with cooled walls that are found in boilers. As a rule, especially finely pulverised fuel from highly reactive coal is particularly suitable. For this reason, highly volatile coal is preferred for small coal-dust-fired plants.

In the individual firing plants on the heating market the installed capacity is in most cases too small to warrant a mill, so the pulverised fuel generally has to be produced in central mills and transported to the user in suitable facilities such as silo trucks or special containers. The necessary infrastructure varies greatly from region to region. The production and transport capacity for Rhenish brown coal, for example, is around 3 million tonnes per year.

In contrast to the large-scale power plants featuring coal-dust firing, the plants serving the heating market have, in most cases, only one burner. Only in rare cases are there more, which means that there are only two ways of adjusting thermal output in line with demand: either by operating the plant intermittently or by regulating the output of the firing process. Regulating the output calls for coal dust dosing equipment and burners with stable combustion over a wide operating range. Experiments and practical experience have shown that this can be done. Burners capable of virtually complete combustion of the pulverized coal are available.

At the same time as progress was being made in firing, development was under way on safety systems for handling coal dust. Today, these systems are highly sophisticated. Suitable facilities for fuel storing and handling, including inertization, are available.

3. Emissions, environmental protection

Reducing the level of emissions from coal combustion is a matter of increasing importance in the member countries of the EC, though there are differences from country to country. Operational data from coal dust firing plants show differences in the values for the various pollutants and this is due to differences between the various countries in specifications, measuring procedures and types of plant. Given the scope of this report, it is therefore not possible to analyse these values in any depth, but I shall mention some characteristic values from German plants:

Comparison between emission limit values according to the German Technical Regulations governing the Prevention of Air Pollution (TA Luft) and operational results based on boiler firing of Rhenish brown coal and Ruhr hard coal in mg/m^3 referred to 7% O_2.

"TA Luft 86" Regulations		Brown Coal	Hard Coal
SO_2	2000	Approx 650	< 2000
NO_x	500	< 500	> 850
CO	250	< 250	< 150

In view of the situation with emissions of nitrogen oxides, dust firing with hard coal in boiler plants for the heating market is not as yet feasible under the conditions in force in the Federal Republic of Germany. Development work has started with the aim of reducing the level of nitrogen oxides.

4. Current activities

The first major stage in the development of coal dust firing was the application of this technology in the furnaces of the quarry industry. Coal dust firing was then also used in drying plants and small boiler plants.

I should now like to summarise the major activities of the various countries of the EC:

4.1 Belgium (ref 1)

The Belgian report deals with the coal-dust-fired boiler plant at Winterslag colliery. The saturated steam output of the plant is 9 t/h. The pneumatic transport of the fuel (a highly volatile coal with a particle size of 10 to 15% greater than 75um) to the burner and transport of the residue to the ash container make the plant as easy to handle as an oil-fired plant. The plant has been in operation since the middle of 1986. At the start there were problems of instability in combustion but these were eliminated thanks to improvements in the air supply.

4.2 Denmark (ref 2)

The fact that Denmark is a coal-importing country means that it is particularly important for a plant to be flexible enough to handle coal of varying quality. Two plants are described by way of example.

To supply the Technical University of Lyngby, requirements of $5MW_e$ and $11MW_{th}$, a dust-fired plant was constructed and put into operation in 1985. The project was part-funded by the EC. Fuel is supplied from a power station located 50km away. The special containers manufactured for the purpose are also used for taking back the ash. The plant, which is equipped with one burner, is monitored from the power station. It is operated intermittently at rated load; a heat regenerator stores heat as a buffer between requirements and generation.

On the site of the Masnedo power station a coal-dust-fired plant with an output of 6.3 MW_{th} has been constructed which covers the summertime requirements of the district heating system. The plant is a prototype and features a vertical water tube boiler. It is equipped with one burner. This plant, too, is fully automatic.

4.3 France (ref 3)

In France, coal-dust firing is used in drying plants and boiler plants of medium output.

As far as the drying plants are concerned, the report mentions four asphalt mixing plants which are operated on coal dust and suitable burners with a quickly stabilisable flame. Rhenish brown coal is used in other plants. The report also refers to a number of coal-dust-fired hot gas generators which are used for drying feedstuffs, fertilisers, cement material and potash.

Two boiler plants with a steam output of 105 t/h each have been converted back to coal. Three further plants with outputs ranging from 50 to 150 t/h have been constructed since 1984.

CERCHAR is also conducting and R&D programme in which subjects such as burner adaptation, NO_x reduction and the potential of dust firing for large-scale boilers are being investigated. Two plants, a 10 t/h pilot plant and a 14 t/h industrial plant are in operation.

4.4 United Kingdom (ref 4)

Coal-dust firing is being used in drying, smelting and boiler firing plants. In addition, development work is being carried out by a number of universities and companies.

Most coal dust firing takes place in rotating tube boilers operated by cement works, brick works and the road materials industry. Here, coal dust firing is virtually state of the art.

There are also a few smelting furnaces for scrap and non-ferrous metals which feature coal dust firing.

There are some older coal-dust-fired heat generation plants with large-scale boilers in operation. This area of application is considered to have great potential provided ultra-fine pulverised fuel can be made available, and a new technique has been developed to produce this fuel.

Examples of current development work include theoretical studies into coal dust combustion and NO_x production, the properties of coal and the design and construction of suitable burners. Already a wide range of components has been made available for coal firing on a commercial scale.

4.5 The Federal Republic of Germany (ref 5)

On the heating market the principal application for dust firing is in the generation of process heat. Whereas hard coal dust is used primarily in the cement industry, the dust from brown coal is used in shaft lime kilns, smelting processes, gypsum production and in drying plants. Consequently, around 100 asphalt mixing plants alone have been converted to brown coal dust.

Coal dust firing is also gaining in importance on the heating market. Given the strict regulations in the Federal Republic of Germany governing emissions, the comparatively low level of emissions from brown coal firing gives this form of firing a natural advantage. Since 1984 a 40 t/h boiler converted to brown coal dust firing has been in operation in a paper factory. the project was backed by the EC.

All the burners functioned well and without the need for backup power with this boiler, which was originally designed for oil/gas firing. Boiler fouling could be controlled by simple means. The burn-out losses were between 1.4 and 5.3% at full load depending on the burner. The control response was similar to that for oil/gas burners.

The limit value for NO_x emissions laid down in the "TA Luft" regulations was exceeded by all the burners; the best value was 850 mg/m^3.

Resume and prospects

Experience gained from actual plants and from the many experiments carried out shows that the technical problems involved in using dust firing in small-scale plants for the heating market have largely been solved, or at least been contained within tolerable limits.

This means that the technology is basically available. As far as the burners are concerned, they can achieve good results in terms of burn-out, efficiency and control. Boiler fouling can be controlled and automation is a relatively simple matter. Thus, we can summarise by saying that even in the current output range coal dust firing is an interesting and clean alternative to the other types of firing.

In this respect, great importance is attached to a reliable dust dosing system. Experiments have shown that the choice is between low-cost, robust and relatively inaccurate systems and expensive but accurate systems. Selection is based on the application in question.

The disadvantage is that there does not seem to be any chance of observing all the limit values laid down in the "TA Luft" regulations of the Federal Republic of Germany solely through engineering improvements in the firing system itself. The problem area is the emission of NO_x. Experiments indicate the way to reduce NO_x is to feed reducing additives into the furnace. The simplicity and hence low cost of this method is an incentive to carry out further research and experiments in this direction.

In view of the high price of oil, the application of coal firing for the heating market was given a boost for economic reasons at the start of the 1980's. At present, because of the fall in the price of oil, this technology unfortunately is not quite as attractive as it was around a year ago, which has meant that the tempo of development for the heating market in the EC has slackened somewhat. Renewed interest is expected as soon as the economic climate changes.

References

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SECOND TECHNICAL SESSION

Atmospheric fluid bed combustors in Europe

Pressurized fluidized bed combustion

Coal - water mixtures

ATMOSPHERIC FLUID BED COMBUSTORS IN EUROPE

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INIEX (Belgium)

SUMMARY

The three families (Ignifluid, dense and circulating fluid beds) of commercial atmospheric fluid bed boilers are briefly presented and their status per EEC country is identified (number of units in operation, total installed power, maximum capacity ...).
In a second, more technical part, the major operating problems encountered with AFBC units are discussed.
A heuristic comparison between AFBC and CFBC is further done leading to the technico-economical justification of some promising new designs (circofluid, and other recirculating dense fluid beds).

1. INTRODUCTION

1.1. Technical presentation

Atmospheric fluid bed combustors (FBC) is a generic term recovering several configurations based on the principle of fluidization (Fig. 1).
By nature and achievable power range, FBC boilers are somewhere between small scale stoker boilers and large pulverized fuel boilers.
The first industrial applications have been done with the Ignifluid process, which may be briefly described as a 'fluidized stoker' boiler, operating on a moving grid at high temperature (1200°C) and generating fused ash as a residue. It is sometimes called 'hot fluid bed combustor' in France.
The other configurations may be seen as 'cold', operating between 800 and 900°C and generating dry ash. This temperature range leads to reduced NO_X emissions and allows in situ SO_X capture by limestone.
In the dense bed configuration (AFBC) exists a rather clear interface between the bed and the freeboard region above it. Classically, the bed depth is of about 50 cm to 1 m ; however, shallow beds, mainly developed in U.K., have a bed depth of about only 20 cm. On the other hand, in a circulating fluid bed (CFBC), injection of secondary air brings large quantities of solid in highly turbulent transport. This solid is then recycled. The recycling flow rate may be as high as 100 times the fuel feed rate.
A detailed comparison of the merits of the two systems would be made further in this paper.

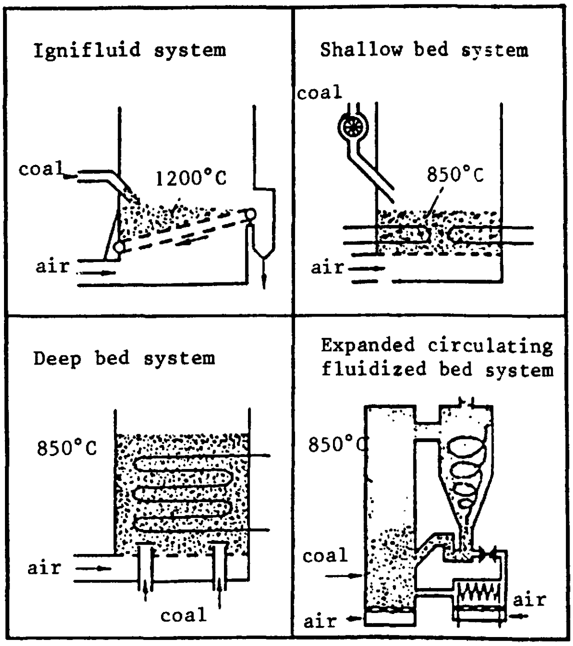


Fig. 1. Fluidized bed technology.

Table I. Status of FBC boilers and furnaces (in operation and ordered).

Country	Max. Power MW	Total FBC Power MW	Number of Units	Average Power/ Unit	Ignifluid AFBC (number ratio)	CFBC AFBC	Units in operation / Total nr	MW in operation / Installed MW
Belgium	80	243	23 (EEC = 2)	10.5	0	0	0.35	0.48
Denmark	11.6	32	4	8	0	0	0.5	0.49
France	168	1006.5	31	32.5	0.26	0.06	N.A.	N.A.
Germany	208	3500	44 (EEC = 4)	79.5	0	0.25	N.A.	N.A.
Italy		Under negotiation or early engineering phase. No construction agreement signed.						
Netherland	90	144.5	5	28.9	0	0	0.6	0.65
United Kingdom	40	1093	108	10.1	0	0	N.A.	N.A.
EEC (Σ)		6019	215					

1.2. Status of FBC in Europe

International status has been established in 1982 and 1985 by Power Magazine [1, 2] giving a detailed list of the most significant steps in FBC development.
Detailed descriptions of the several national programs are given in the specific reports further presented in the proceedings.
Table I summarizes some highlights, while Fig. 2 is a tentative time record of the maximum powers achieved per country.
From Table I, it may be concluded that :

1) Germany, France and U.K. appear as the leading countries as well for the installed FB power as for the existing number of FB units.
2) U.K. focuses mainly on small scale boilers, while Germany has more interest in large boilers. The last units (mainly CFBC) ordered have a power range well above 100 MW.
3) The Ignifluid technology is mainly localized in France.
4) Within EEC, circulating beds are developed up to now in Germany and France, although potential applications are under advanced discussion in Italy, United Kingdom and Belgium.
5) A rather high number of units are not further in activity in Belgium, Denmark and Netherland actually, for economical and (or) technical reasons.

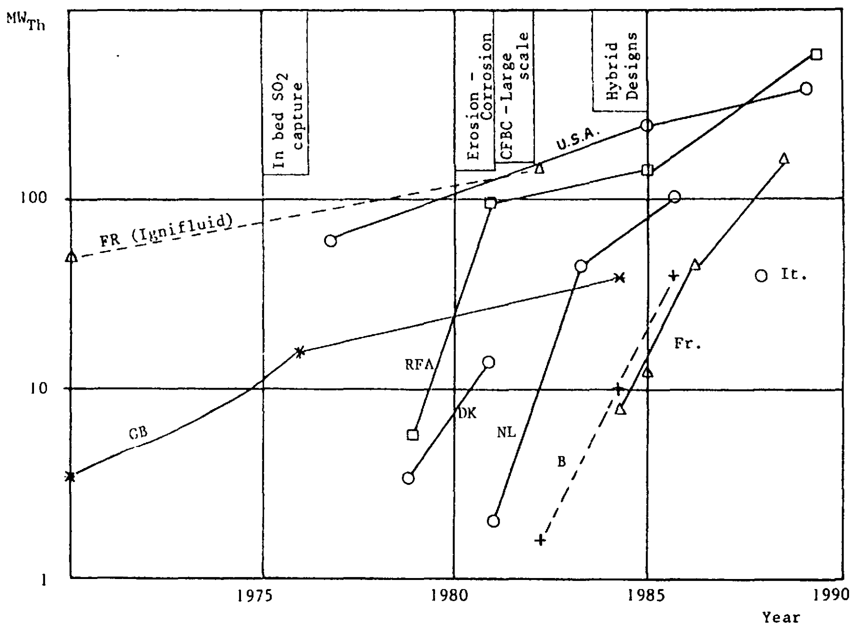


Fig. 2. Maximum powers of FBC units versus time.

From Fig. 2, it appears that :

1) Since the early seventies, Ignifluid boilers have been commercialized with a power range climbing from 60 to 130 MW (in 1982).
At this date, dense fluid beds have been developed in France, probably with a view towards future EEC depollution norms (SO_X, NO_X), difficult to respect when using an Ignifluid boiler, without further gas cleaning.
Actually in France, a 100 MW circulating fluid bed boiler has been ordered.

2) Fluidized bed combustors are in activity in the U.K. since the early seventies also, but the power range is always remained rather low and has never exceeded 40 MW, peak value achieved in 1984.

3) Germany has significantly started its development and demonstration program at the end of the seventies and the power range achievable has climbed since then very quickly.

4) Netherland and Belgium have started significantly in 1982 and reach also actually the 100 MW_{Th} level. In both countries, the market perspectives are not very favourable actually for further market extent.

5) The Danish market is also quite depressed actually, mainly due to competitive low price of oil.

2. ANALYSIS OF EXISTING PROBLEMS AND PROPOSED CONFIGURATIONS

The main steps in the development of a technique like FBC may be summarized as done in Table II.

Table II. Success criteria for FBC technology.

1) Bring confidence in system reliability (including the peripherals).
2) Certify a reasonable turn-down.
3) Meet in the same time the emission standards for Co, NO_X, SO_2 and dust.
4) Define clear technico-economical break even points on power range and fuel cost to switch over to FBC.
5) Demonstrate the extrapolability of the technique.

The next sections present a tentative to introduce the successive developments of AFBC, CFBC and of some recent hybrid developments on this basis in a heuristic way.

2.1. System reliability

An AFBC boiler is mainly a hot fluid bed equipped with an in-bed and a convective heat transfer section to make steam. A fuel feeding system and gas cleaning device must also be foreseen.
Most of the dense phase fluid bed systems have experienced operating problems. The mechanical problems concern mainly the reliability of the feeding system, the in-bed tube erosion and corrosion and burn-out of the bag filters.

2.1.1. Fuel feeding systems

In their earlier stage of development, fluid bed boilers have been presented as the most flexible kind of boiler available, accepting low grade, unexpensive fuels. It appears now that this statement must be slightly adapted due to limitations of the fuel feeding systems.
One may distinguish overbed gravity feeders and in-bed pneumatic feeding systems. With a view to reduce losses by unburned material and escape of volatiles, pneumatic feeding systems have received some preference in a first time. However, the sensitivity to fuel nature, grain size and humidity make their reliability questionable.
This solution was initially proposed for large scale boilers.
This part of the market seems now to be more and more reserved to circulating beds.
For small scale boilers, gravity (and spreader) feeders offer a more reliable and economical solution than pneumatic ones. The lower combustion efficiency achieved may eventually be compensated by improved configurations of the freeboard or by recycling of fines, as discussed further in this paper.

2.1.2. In-bed corrosion and erosion

In-bed corrosion is associated with the use of limestone for SO_2 capture. Deposits of CaO - CaS - $CaSO_4$ on heat exchange tubes are at the origin of the observed phenomena.
It is now clearly established that the in-bed tube corrosion may be described in terms of thermodynamical stability of the metal, its oxide and its sulphur, versus partial pressure of oxygen and sulphur. Critical conditions prevail in the 'plume of volatiles' around the fuel feeding point and in bubble poor regions, like near the walls. This statement has been checked using fast local solid state O_2 probes and also confirmed by operating experience. Low carbon austenitic steel appears as a reasonable solution as long as surface temperature remains below 650°C. Bundle hangers and other hot parts may be made of fecralloy or by cladding.
Erosion is mainly associated to high velocity systematic trajectories of the bed material grains.
The physical nature of the bed material (i.e. its hardness and roughness) is obviously also of importance. The fluidization velocity, more precisely the excess air above the minimum fluidization velocity (leading to bubbles), defines directly the in-bed velocities and the grain ejection velocity in the freeboard, in the so-called 'splashing zone' just above the bed.
At experience, the most critical localisations appear to be :

. the lower tube bank, in the vicinity of the gas distributor and its eventual associated high velocity gas jets ;

. the direct vicinity of pneumatic injection ports, generating also gas jets ;

. the bed wall region, on top of the bed, where the solid flows down, quite systematically ;

. heat exchange tubes being partly immerged in the bed and partly in the splashing zone, following the bed surface displacements.

2.1.3. Dust filtering

Dust is generally eliminated by a first stage cyclone or an inertial impact filter. A secondary step is done with an electrostatic or a bag filter.
Electrostatic filters used with FBC lead to some problems associated with low resistivity of the highly carbon loaded fly ash (10 to 50 % in some cases). On the other hand, glowing fine particles of carbon may destroy very rapidly the fabric filters. Furthermore acidic corrosion and clogging with partly hydrated calcium oxide and sulfate make, at times, their use problematic.

2.2. Turn-down ratio

Turn-down may be achieved by different ways :

. Modulation of bed temperature, but the CO content of the flue gases increases when the temperature drops and SO_2 removal is less efficient.

. Change of air excess ; but the efficiency of the boiler and the level of NO_x emissions are affected. The particulate emissions are directly related to air flow and the cyclone efficiency is also affected.

. Partial slumping of a part of the bed ; this solution leads at times to ash sintering on top of the slumped bed. As long as the bed temperature remains higher than 600°C, restarting without auxiliary fuel is possible.

. Partial recycling of flue gas to be mixed with combustion air.

. Critical localisation of the in-bed heat exchanger, in such a way that, under partial load (and reduced air flow), the bundle is only partly immerged in the bed.

But :
- the heat transfer coefficient remains high in the 'splashing zone' ;
- this 'splashing zone' is also a preferential localisation for bundle erosion, as discussed earlier.

None of these solutions is perfect. However, with the above drawbacks, a turn-down of about 3 to 1 is achievable with most of the existing AFBC boilers.

2.3. Pollution control

2.3.1. CO emissions (combustion efficiency)

For AFBC, combustion efficiency ($C \rightarrow CO_2$ conversion) ranges between 85 and 97 %, following how far the volatiles are burned, the CO emissions reduced and fines of carbon maintained in the fluid bed up to complete burn-out.
Significant improvements of combustion efficiency may be obtained with :

. optimum choice of fuel feeding points ;

. secondary air injection above the bed ;

. cyclone product recycling.

2.3.2. De-SO_x efficiency

Some difficulties have been reported

. when the fuel and sorbents feeding ports are poorly designed ;

. with very compact non-porous limestones.

It seems that each kind of limestone needs careful checking of its performances. For a Ca/S molar ratio of 3, the de-SO_X efficiency may range between 60 and 90 % for natural limestones. Slightly under stoechiometric combustion leads to comparable desulfuration efficiency ; the product being this time CaS instead of $CaSO_4$.
The disposal of the ash and partly sulfated limestone remains a problem. Search for a better use of de-SO_X sorbents is one of the priorities in FBC development.

2.3.3. De-NO_X

NO_X emissions in an AFBC depend mainly on the nitrogen content of the fuel, air excess and temperature. NO_X formation from air nitrogen is only merginal at the temperature of operation. The strong dependence on coal N_2 content leads to a large scattering of the results so far published. In about 50 % of the cases, an AFBC boiler would not reach the requested target : 200 mg/Nm^3 with 6 % O_2 in the flue gas.
This is probably the most critical pitfall of AFBC technology. Solutions to this problem could be found in :

- staged combustion ;
- recycling of fines and freeboard reactions between CO and NO_X ;
- high temperature catalytic reactions performed in the freeboard ;
- combination of staged combustion and catalytic CO/NO_X reactions in the splashing zone.

2.4. Possible actions to optimize the AFBC design

Possible improvements may be obtained, after a sensitivity analysis of the AFBC boiler performance versus adaptable parameters (Table III).
From this analysis, it may be concluded that :

1) Simultaneous control of CO, NO_X, SO_2 emissions, down the standards limits and without further gas cleaning, requires first of all to use deep beds and to maintain the bed temperature as close as possible to 850°C. This makes questionable the future of shallow beds and of Ignifluid boilers without improvements.

2) General improvement of combustion efficiency, SO_X and NO_X control is achieved by reducing the granulometry of both the fuel and the sorbent.

3) Increase of specific power (MW/m^2) may be achieved by increasing the pressure or the gas velocity. Only the second alternative is considered here, pressurized fluid beds being the object of another session.

2.5. Transition to CFBC systems

An extreme situation of possible action on solid granulometry and gas velocity to improve AFBC performances is the one where quite the whole bed is entrained by the gas stream. There is no further upper surface of the fluid bed. Solid circulates in a very turbulent way through the whole system. If solid is recycled from the cyclone, it is directly remixed with the suspended mass of solid and re-entrained. One has realized a circulating fluid bed (CFBC).
Fig. 3 gives a schematic view of a circulating fluid bed boiler (CFBC) together with its main characteristics.
It is worthwhile noticing that combustion and heat exchange are decoupled in such a fluid bed boiler (Lurgi design). Heat exchange happens in an

Table III. Parametric sensitivity of dense fluid beds to operating parameters [3].

Parameter	(Standard)	$\frac{MW}{m^2}$	% C-losses	$\frac{mg\ CO}{m^3}$	$\frac{mg\ SO_2}{m^3}$	$\frac{mg\ NO_2}{m^3}$
Pressure 1 → 4.5 bar	(1.1 bar)	↗	↘	↘	↘	↘
Temperature 750 → 950°C	(850°C)	→	↘	↘	↗	↗
Air excess 0.5 → 12 % O_2	(5 %)	↘	↘	→	↘	↷
Gas velocity 0.3 → 1.5 m/s	(1 m/s)	↗	↗	↗	↗	↘
Bed depth 0.2 → 1.2 m	(0.8 m)	→	↘	↘	↘	↗
Ca/S 0 → 3 mol/mol	(2)	→	→	→	↘	→
Fuel granulometry 0 → 2 mm	(0.1 - 1 mm)	→	↷	↘	→	→
Sorbent granulometry 0 → 2 mm	(0 - 0.1 mm)	→	→	→	↗ ↗	↗

auxiliary fluid bed heat exchanger operating at low temperature, in an oxidant atmosphere. These two measures limit the bundle erosion and corrosion.
Also of interest is the use of staged air injection, reducing NO_x emissions, as discussed previously, and eliminating the need to cool down the combustor chamber with an in-bed heat exchanger.

Other configurations of CFBC have appeared progressively on the market : AHLSTROM proposes the pyroflow process where the heat transfer is for a great part achieved by radiation to the membrane wall surrounding the bed. It is the dust load that defines the intensity of the heat transfer (Fig. 4).
BATTELLE has commercialized a multisolid fluid bed (Fig. 5), which may be described as a dense fluid bed of coarse particles through which flows a circulating bed of fines. The presence of the big particles is supposed to enhance greatly the turbulence at the bottom of the combustor.
The ultimate in simplification of CFBC seems actually to be the STUDSVIK design (Fig. 6), where the cyclone (which gives eventually some extrapolation problems) is replaced by an inerted impact filter (U beam particle separation - Venitian store) and where solid re-injection is done with a non-mechanical J valve, as just developed in the U.S. by the Institute of Gas Technology.
Fig. 7 summarizes the operating parameters of AFBC and CFBC as well as their performances.

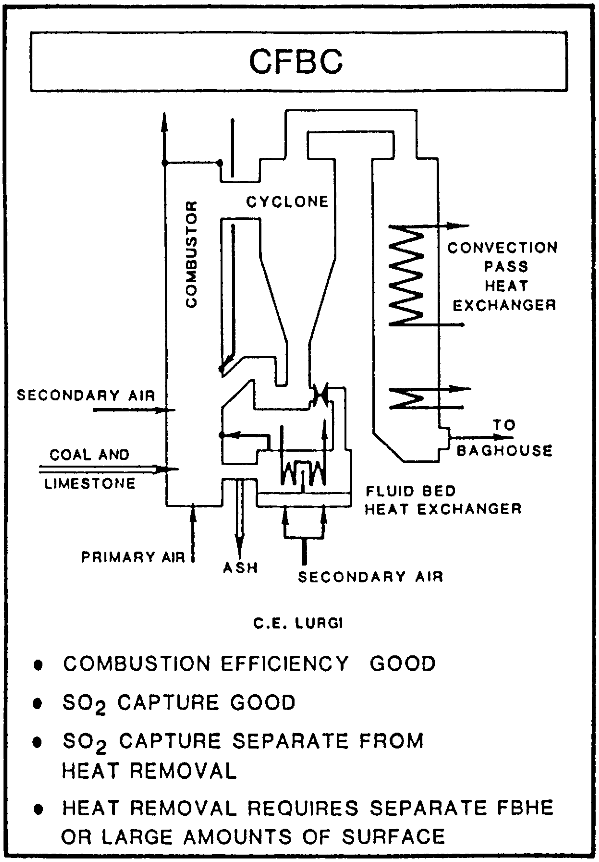


Fig. 3. [4].

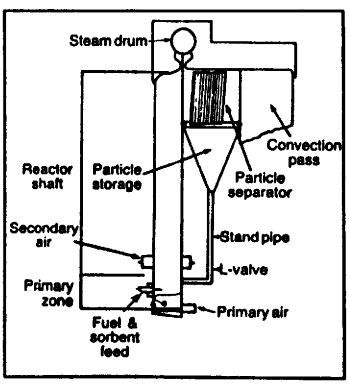


Fig. 6. STUDSVIK design.

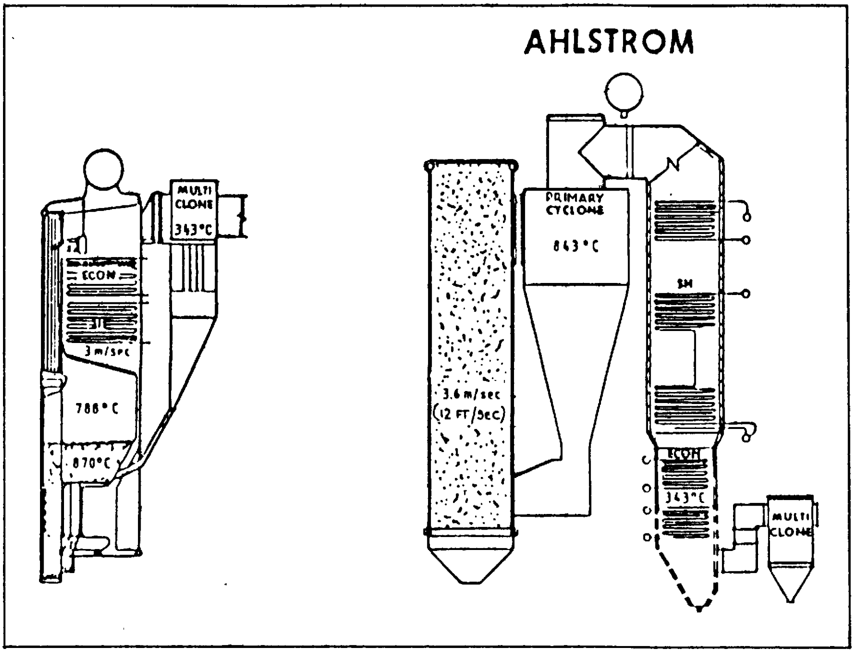

AHLSTROM
MULTI CLONE
343°C
ECON
SH
3 m/sec
788°C
870°C
PRIMARY CYCLONE
843°C
3.6 m/sec
(12 FT/SEC)
ECON
343°C
MULTI CLONE

Fig. 4.

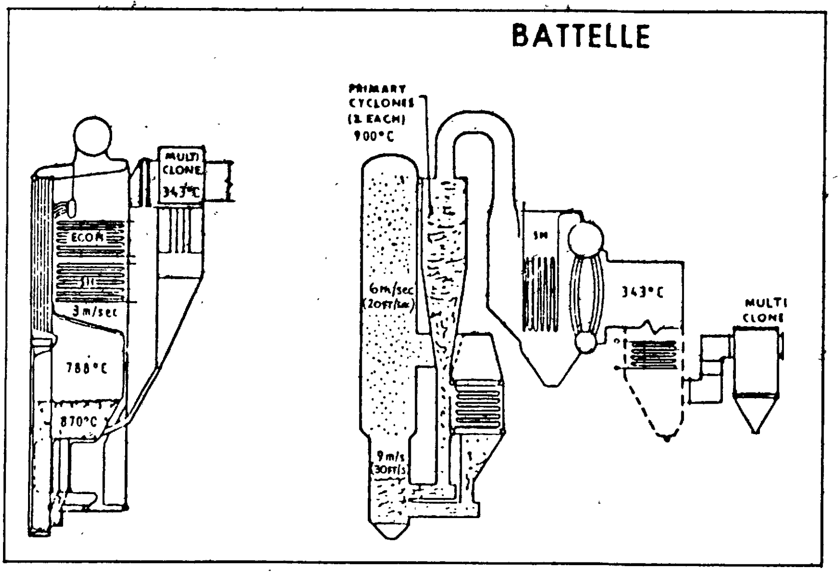

BATTELLE
MULTI CLONE
ECON
SH
3 m/sec
788°C
870°C
PRIMARY CYCLONES (2 EACH) 900°C
6 m/sec (20 FT/sec)
9 m/s (30 FT/s)
SH
343°C
MULTI CLONE

Fig. 5.

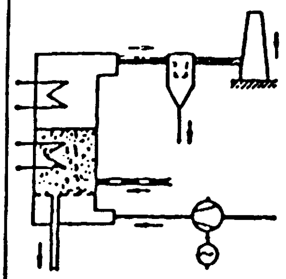
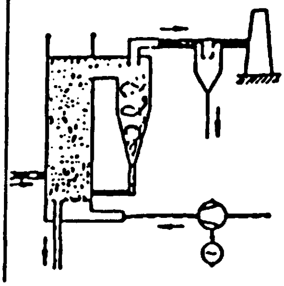
Fluidised Bed Type (atmospheric)	Slow Bed	Fast Bed
Fluidised-bed boiler diagrammatic representation		
Speed	up to 2.5 m/s	up to 7,0 m/s
Inert material grain size	0 - 6 mm	0 - 2 mm
Fuel grain size	2 - 3 mm	0,1 - 0,3 mm
Cross sectional thermal loading	1 - 2 MWth/m^2	4 - 6 MWth/m^2
Firing efficiency	Ø 90-95%	Ø 95-99%
NO in flue gas	Ø 200-400 ppm	Ø 100-300 ppm
Ca/S molar ratio (RS :)	Ø 2,5-3,5	Ø 1,5

Fig. 7. Characteristics of AFBC and CFBC [3].

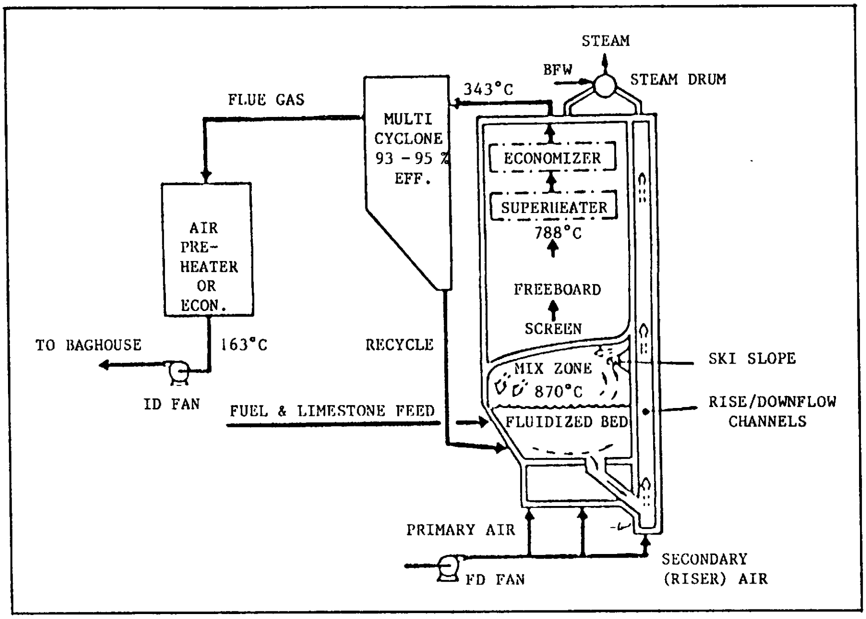


Fig. 8. Solids circulation boiler [6].

A further step in simplification may be obtained in making a fast bed comprising only one main package housed in a single casing, in which there is no dependence upon refractories for integrity of construction. This has been done by BABCOCK WILCOX, as shown on Fig. 8, with their solid circulation boiler (SCB).
Operating experience with circulating beds of different types has indicated a propensity to erode refractories, especially in the large cyclones, aggravated by differential expansion between packages.
The absence of any refractories and modest gas velocities in this configuration is supposed to ensure reliability.
Also, since there is no need for a separate fluid bed with immersed tubing as, for example, required by Battelle and Lurgi to control solids temperature, the potential problem of metal erosion has been eliminated.

Table IV compares the main characteristics of the circulating fluid beds described up to now. No detailed description of the Studsvik performances was available in due time for this review.

COMPARISON OF "*RECIRCULATING*" SYSTEMS

	SCB	AHLSTROM	BATTELLE	LURGI
• FLUID BED COMBUSTOR -FLUIDISED REGIME -HEAT RECOVERY	DENSE / LEAN (BUBBLING BED/RISER) INTEG. RISER/DOWNCR.	LEAN INTEG. W/COMB.TR	DENSE / LEAN (BASE/TOP COMB.) EXT. HT. EXCH.	LEAN EXT. HT. EXCH.
• GAS VELOCITY: (COMBUSTOR) -LEAN PHASE -DENSE PHASE • RESIDENCE TIME: -LEAN PHASE -DENSE PHASE	9·0 m/s 2·1 m/s (AVERAGE) 4·0 SEC MAX	3·65 m/s — 4·0 SEC —	6·0 m/s 9 0 m/s 2·0 SEC MIN	6·0 m/s — 2·5 SEC —
• BED MATERIAL • HEAT TRANSFER MEDIA	FUSED ALUMINA CONSTANT	SAND OR ASH VARIABLE	GRAVEL VARIABLE	SAND OR ASH VARIABLE
• MIXING ACTION	VERT / LATERAL	VERTICAL	VERTICAL	VERTICAL
• CONVECTION MECHANISM	SOLIDS AND GAS	GAS	GAS	GAS
• TURNDOWN CONTROL • TURNDOWN RATIO • LOAD FOLLOWING	SOLIDS 5:1 RAPID	GAS FLOW 3:1 RAPID	SOLIDS 4:1 SLOW	SOLIDS 4:1 SLOW
• CYCLONE -TYPE -INLET CYCLONE TEMPERATURE	MULTICLONE 343°C	PRIMARY/ MULTICLONE 845°C/343°C	PRIM/ MULTICLONE 900°C/343°C	PRIM/SEC/ MULTICLONE 900°C/900°C/343°C

Table IV. [6].

2.5. Technico-economical considerations

Economicity of fluid bed systems is a matter of discussion for several years.
As a rough guide line, the following statements may be advanced :

. The break even point between AFBC and CFBC lies around 80 MW_{Th}, CFBC being reserved to larger units.

. The lower limit of economic viability of an AFBC system depends on
- the number of annual operating hours ;
- the price difference between solid fuel and oil or gas (Ecus/GJ) ;
- the level of automation required ;
- local legislation concerning permanent presence of an operator or not.

For 6000 hours per year of operation, with permanent survey of the boiler, and an energy price difference of about 3 Ecus/GJ, the AFBC boiler must have at least a power of 10 MW_{Th} to lead to pay-back time of about 3 to 5 years. For lower power, the operator costs become prohibitive.

2.6. Extrapolation in size

Two aspects need to be considered :

. Simplification of CFBC leading to a market extent towards units smaller than 100 MW_{Th}. This way, one may expect to hold the intrinsec advantages of CFBC but at a more reasonable price.

. Comparison of AFBC and CFBC extrapolation potential towards very high power levels (300-500 MW_{Th}).

2.6.1. Hybrid designs between AFBC and CFBC

As it has been said previously, CFBC development has his origin in the need to increase gas velocity and to decrease solid granulometry to improve the performances of conventional AFBC units.
These actions lead to an increase in elutriated material that may eventually be recycled from the cyclone.
In CFBC systems, this recycling rate may be as high as 50 to 100 times the fuel feed rate.
Figg. 9 and 10 show some interesting results obtained by the Tennessee Valley Authority [4] in the early eighties. These figures give AFBC performances (combustion efficiency, de-SO_X, de-NO_X) as function of the recycling rate of an AFBC unit, operated at a rather higher velocity than normal.
As expected from principles, recycling of fines improve the performances. But the remarquable point lies in the fact that the curves present an asymptotic trend : nothing may be gained if the recirculation ratio becomes greater than 3. CFBC units seem thus to be overdesigned with respect to fines recirculation.
Deutsche Babcock has commercialized the circofluid process on this basis. It is mainly (Fig. 11) :

- a dense fluid bed with a high rate of elutriated bed material ;
- having a staged combustion
  - to reduce NO_X ;
  - to limit bed temperature by substoechiometric combustor ;
- having a recycling loop of the cyclone products. The recirculation rate is controlled by a non-mechanical valve.

A further tentative to develop a hybrid system between AFBC and CFBC has been made by STORK (NL). As in the previous case, cyclone products are recycled. But STORK proposes a system of interconnected concentric fluid beds (Fig. 12), presenting some similarities with a draught tube system.

- In the central part, fuel is fed and burned under slightly substoechiometric conditions, at an optimum temperature of 850°C.
- The heat exchange bundle is located in the annular region. This one is fluidized with air, at low velocity, to avoid erosion and corrosion. The temperatures never exceed 600°C in the heat exchange zone to avoid coupling between combustion and heat transfer.
- The heat exchange section air acts as secondary air and promotes staged combustion.
- Turn-down is defined by fuel feed rate and mainly by the solid flux between the cells.
- The solid flux is controlled by a non-mechanical (aerated) valve controlling the solid flow between cells through the immerged orifice.

Table V presents the claimed conceptual advantages of the STORK system.

2.6.2. Extrapolation of AFBC and CFBC units

The steps to be considered recover :

- the residence time of the fuel (mass of the bed / fuel flow rate) ;
- needed heat exchange surface and possible localization ;
- pressure drop (to avoid if possible costly compressors and to use only blowers) ;
- feed points for fuel and limestone ;
- turn-down methods and partial load operation ;
- dedusting devices and fines reinjection possibilities.

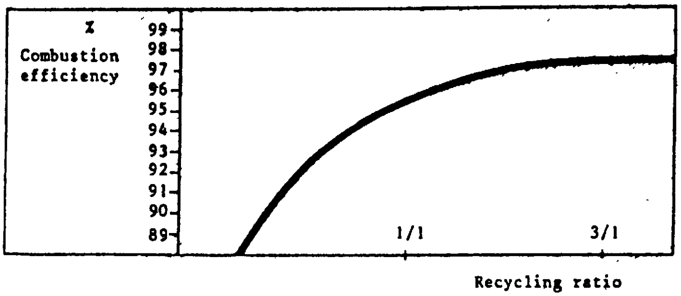


Fig. 9. Combustion efficiency.

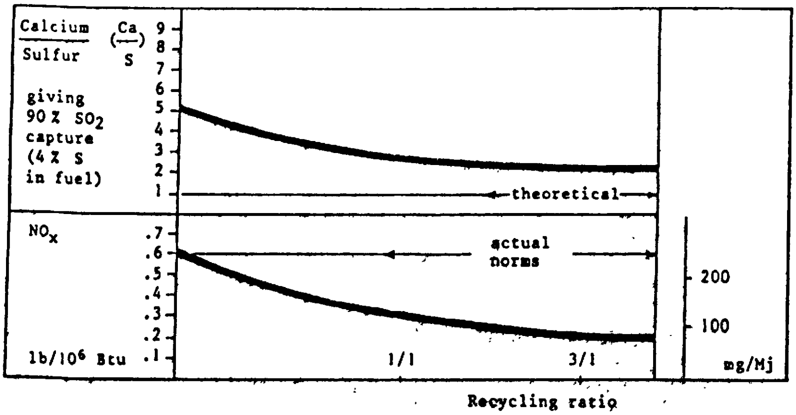


Fig. 10. Influence of the recycling ratio on the pollution control [4].

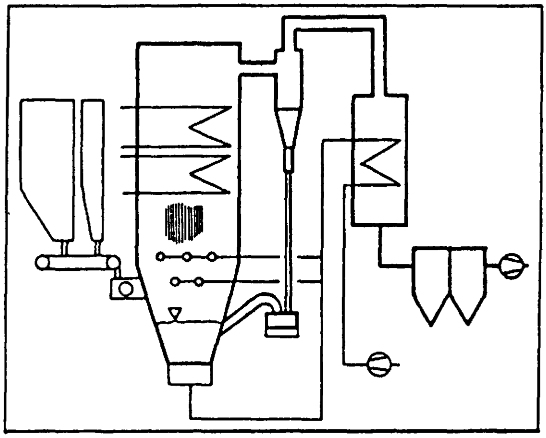


Fig. 11. Circofluid FBC by Babcock.

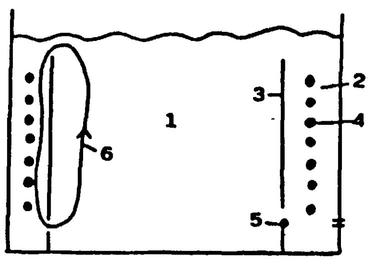


Fig. 12. Principle of the debording fluid bed combustor (DFBC) (STORK) [5].

Item	Comment	Response to problem
Tubes in bed erosion	$\propto U_g^{4.5}$	separated low velocity (0.7 m/sec 1.5 Umf) heat exchange cell
" " corrosion	dependent on p_{O_2} p_{S_2}	oxidant atmosphere (positive) very low (positive) : SO_2 escapes with volatiles - is fixed by limestone - in the combustion chamber
NO_x	. low in FBC (temperature) . may be reduced by staged combustion	fluidisation air of the heat exchange cell acts as secondary air
Volatiles	. burned in secondary combustion stage in the freeboard	done
Regulation	Interactions between combustion and in bed heat exchange in AFBC - CFBC (Lurgi design) have not this disadvantage	. decoupled as in CFBC (but with simpler more compact design and reduced cost) . heat exchange cell < 600°C and fed with char only : no combustion takes place
SO_2	. controlled by $CaCO_3$ injection ideally at 850°C in an oxidant atmosphere ($CaO + SO_2 + \frac{1}{2} O_2 \rightarrow CaSO_4$) . small size particles are very efficient → advantage of CFBC (recycle ratio 100) But a recycle ratio of 3 is enough	. combustion cell remains at 850°C whatever the turn-down . O_2 is present even at 90 % of stoechiometry in the combustion cell, locally, and instantaneously . cyclone products are recycled
Turn-down	Limited in AFBC and obtained by . air excess ↗ (η_{Th} ↘) . T° (CO and SO_2 control ↘) . partial bed slumping (risk of sintering on top of slumped bed of hot projected material)	Obtained by control with a non-mechanical valve of the solid flow between combustion and heat transfer cell (1/4 easily)
Thermal efficiency	. Optimum at 850°C (CO/CO_2) . increased by staged combustion with fine recycled (recycle ratio of 3 is enough) . staged combustion : ↗ flue gas temperature ↗ convective heat exchange performance	Combustion chamber always at 850°C done done
Fuel feeding	. reliability and performances depend on rapid dispersion of solid . volatiles may not reach the in-bed tube (p_{O_2} ↘)	Combustion chamber always > 2 U_{mf} whatever the turn-down No contact with heat exchange cell

Table V. Conceptual advantages of the 'internal circulation fluid bed' developed by STORK [5].

As the rule of similitude for fluid bed systems are poorly defined up to now, the only reasonable approach is to consider design features.
For dense bed systems there are two main bottlenecks : the needed place in the freeboard to localize the convective heat exchanger and in case of partial slumping of the bed, adequate communication between the active and inactive cells. This defines a size limitation in one direction : large AFBC would have a rectangular section divided in standardized modules.

For CFBC units, exist also some extrapolation problems, although they are claimed to be more adapted to large size units :
. Heat transfer happens through water walls (in the pyroflow system). When the size of the units increases, the surface/volume ratio decreases leading thus to higher beds to preserve enough heat exchange section. This increases the pressure drop through the system.
. Extrapolation in diameter is also limitated, due to the need for even repartition of secondary air. This secondary air is injected through annular injectors generating gas jets. These jets penetrate the fast fluid bed by no more than 60-80 cm.
. The cyclone size increases also with capacity. Large scale cyclones are not very efficient, leading to parallel batteries of smaller cyclones or hybrid solutions combining a cyclone and a concentric electrostatic filter. Both the options increase the specific cost of the operation. Finally, as the cyclones must be in geometrical similitude, their height could become taller than the one of the bed.

2.7. Reliability

Another point of comparison concerns the reliability of the systems. CFBC show very impressive figures ranging about 95 % of disponibility. AFBC range between 80 and 85 % in the best cases actually.

3. CONCLUSIONS

1) Due to actual low price of fuel and gas, commercialization of FBC units progress slowly for the moment, except of large units which were planned since several years. This situation gives time for reflexion.
2) On the other hand, extensive research and demonstration work have lead to deep understanding of the physico-chemical processes associated to fluid bed combustion as done in the early configurations of AFBC and CFBC units.
3) Throughfull analysis of these results have induced the apparition of new optimized and simplified concepts.
Their penetration on the market would depend greatly on how fast the European depollution norms become a reality.
4) In most of the latest designs, solid flow, recycled from the cyclone or flowing between adjacent fluid beds, is controlled through non-mechanical valves. The details of their operation are not yet fully documented neither understood.
There is a need for further R and D work in this field.

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PRESSURISED FLUIDIZED BED COMBUSTION

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1. Special features of fluidized bed combustion

The following are seen as particular advantages of fluidized bed combustion in an overall comparison with other methods of firing:

- The option of using a very wide range of fuelds, including lower quality products which cannot be used elsewhere and also
- The naturally lower level of pollutants released such as SO_2 or NO_x and the comparatively simple option of limiting the release of SO_2 to a large extent by adding dolomite or limestone.

In addition pressurised fluidized bed combustion provides the following benefits

- a further improvement in SO_2 retention or utilization of the added sorbent
- a lower level of NOx emission
- a significantly improved level of combustion
- considerably reduced volumetric flows for combustion air and flue gas so that compact vessels are produced and these are able to be fabricated in the workshop as modules of considerable size, thereby reducing construction costs and shortening installation times.
- The option of incorporating such systems into gas/steam turbine processes to achieve greater efficiency in electricity generation.

These arguments are also put forward, with differing emphasis to suit the circumstances obtaining in the particular country, by authors from Italy, the United Kingdom and the Federal Republic of Germany who have contributed nationally-based articles on this subject (1-3). These articles are an important source for this review.

The advantages of pressurisation in the process however are also set against a number of significant problems:

- The fuel and the sorbent have to be fed into the pressure vessel and the combustion residue has to be evacuated from it.
- Because of the higher rates of heat generation in the combustion chamber corresponding to the higher pressure, a correspondingly larger amount of heat has to be removed from the firing zone. For a bed heating surface this means increased bundle height and possibly smaller pipe spacing and thus greater fluidized bed height and greater loss of pressure as well as greater danger of erosion for the immersed heating sufaces.
- Incorporation into a combined gas/steam turbine process makes it necessary for the combustion gas to have the dust extracted from it in a hot state until it reaches a state where it will not impair the functioning of the machinery, since - other than with advance coal gasification processes - a flue gas with no combustion value will be present.
- Differing control characteristics of turbines and firing systems demand new types of control and part load schemes with some new parts.
- The corrosive/erosive load on the pipes, systems and machines carrying hot gas has thus far not been fully understood and requires detailed materials testing and possibly new materials.

To overcome these difficulties laboratory, research and pilot systems are being operated, demonstration and operational systems are planned and some have already been built and different types of process circuit have been investigated and their respective advantages for the various areas of application discussed.

2. Different designs of systems using fluidized bed firing

Fig. 1 shows a pressurised fluidized bed combustion chamber with air cooling. Only some of the air supplied by the gas turbine is used as combustion and fluidization air. It enters at the top of the pressure vessel and then flows through the distributor plate and the fluidized bed, cooling the internal combustion chamber. The flue gas is dedusted, mixed with the remainder of the compresor air which is heated to combustion temperature in the bed heater elements, and then decompressed in the gas turbine. An unfired (or post fired) gas turbine process can be employed to utilise the waste heat and thereby a combined gas/steam turbine process can be implemented. To make the diagram more simple it does not show the coal and limestone feed or the ash extraction systems.

The advantage of a sequence of this type is that a significant part of the gas turbine propellant is hot air which does not need to be cleaned. The gas turbine gas also contains a high proportion of oxygen so that it is particularly suitable to post-fired heating vessels. Air-cooled pressurised fluidized bed processes on the other hand require a particularly powerful

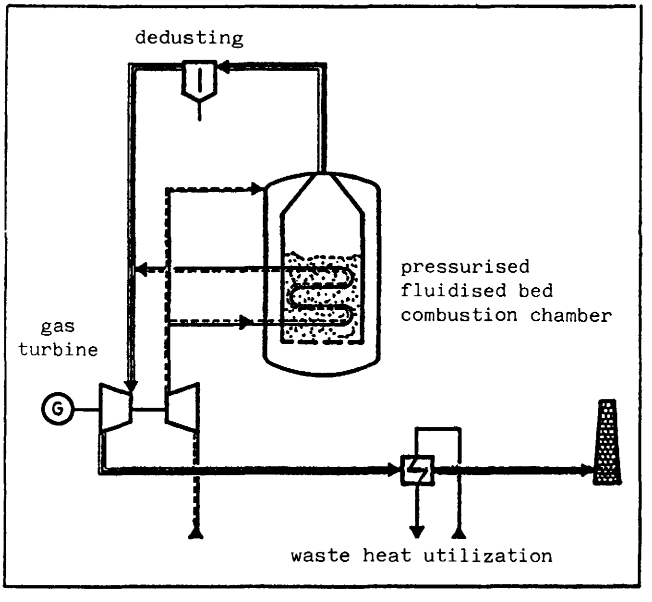

FIG. 1 - Gas turbine system with air-cooled pressurised fluidized bed combustion chamber

compressor relative to the volume of heat converted in order to attain the same level of efficiency as water/steam-cooled processes. They are therefore mainly planned for use in smaller systems. In the Italian article (1) air-cooled pressurised fluidized bed processes are particularly recommended for industrial power-heat coupling and for district heating supply. The high coefficient of power of 0.5 to 1.1 which is attainable in an industrial application with a system of this type is stressed particularly on account of its high load flexibility.

Snamprogetti has taken out a licence from the American Curtiss-Wright Corp. which has been operating an air-cooled pilot pressurised fluidized bed system and has built a demonstration plant (13 MW). A special feature of the Curtiss-Wright technology is the concentric finned tubes which run vertically in the fluidized bed and reduce the expansion problems and hinder fluidization less than the conventional horizontally-arranged bed heating surfaces. Snamprogetti is currently planning a demonstration plant in Northern Italy for supplying a coking plant with electricity and steam. Fuels will be coal, petroleum coke, coal preparation waste products and high-sulphur coals from the Sulcis field. Parallel to the pressurised fluidized bed chamber an air-cooled fluidized bed firing system of the same design is also operated in this system. A modified standard two-shaft system is provided as a gas turbine. 1989 is given as a start date for operation.

In Fig. 2 an integrated gas/steam turbine process with pressurised fluidized bed steam generator is illustrated. Fuel feed and ash extraction systems are again left out. Water/steam flows through the immersed heating

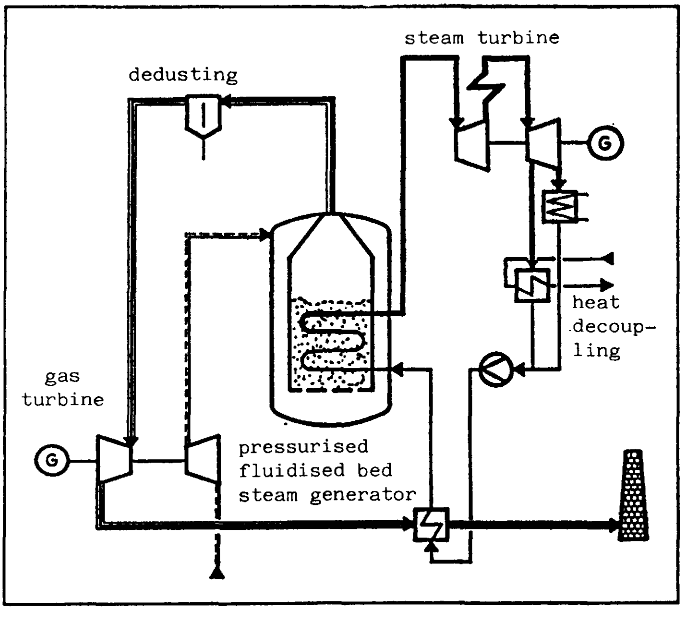

FIG. 2 - Combined gas/steam turbine process with pressurised fluidized bed steam generator

surfaces here and the membrane walls are water cooled as well.

The gas turbine in this sequence (for an identical overall heat output of the system) is smaller than in the air-cooled variant. The efficiency of this type of system can be as much as 42% and thus be much greater than that of conventional systems with flue gas desulphurization and catalytic nitrogen oxide reduction. The effective pressure of this type of system depends on the design of the gas turbine and, depending on the turbine, is between 10 and 16 bar.

3. Main Areas of Development

A particular problem for which there is not suitably developed technology yet available is the removal of dust from the heating gas. Currently cyclones are the only separation systems which have been tested under the conditions obtaining in these systems. However they have insufficient separation capacity to satisfy the demand of environmental protection so that a further dedusting system has to be installed at the cold end.

In a number of research systems studies have been performed with the objective of determining the erosion effect of residual dust on a gas turbine after cyclone cleaning. Namely the work at the large-scale research system in Grimethorpe, England, which was operated from 1980 to 1984 within the framework of the International Energy Agency (IEA) at the request of the United Kingdom, the United States, and the Federal Republic of Germany and since then has been operated by British Coal in conjunction with the Central Electricity Generating Board (CEGB) and work in the former Coal Utilisation Research Laboratory (CURL), the Swedish ASEA group and the American Curtiss-Wright Corp. These investigations, in which no effective expansion turbine has been able to be employed however, have shown that after a three-stage cyclone cleaning process the erosion load on a gas turbine appears to be acceptable. However in several projects, namely those in Grimethorpe, work is in progress on more effective hot gas dedusting facilities. In addition a gas turbine will be added in Grimethorpe in the next few years. In Livorno, Italy too a pilot system (10 MW_{th}) has been set up to investigate this problem and this will come into operation during 1987.

To get around the problem of removing dust from hot gas and by virtue of the better part load efficiency, pressurised fluidized bed firing systems with turbochargers, as illustrated in Fig. 3 have also been discussed. Here the exhaust gases from firing are cooled before dust removal to the point where high-power dedusting is again possible. The exhaust gas is then decompressed at 400° for example in a turbocharger which can still generate charge pressure but can no longer drive a generator. The efficiency of the turbocharger process is thus about 2% points lower (3). This process is implemented in the system in the Technische Hochschule Aachen in the Federal Republic of Germany (3.6 bar, 42MW_{th}). The system is currently undergoing trials. A metal mesh filter is employed.

In this system a new solution is also been tried for another problem. The increased pressure in the combustion chamber makes it necessary for fuel and combustion residue to be fed in and extracted from pressurised fluidized bed firing systems. The feed system uses dry, free-flowing coal, eg used on a large scale in the Lurgi pressurised gasification process and which has also been used in previous research systems. However this involves considerable effort in preparation of the wide range of fuels

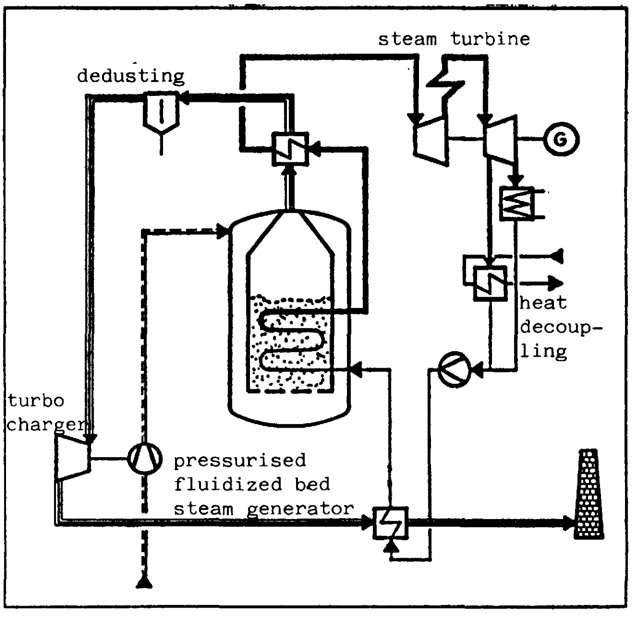

FIG. 3 - Pressurised fluidized bed steam generator system with turbocharger

which are to be used for pressurised fluidized bed firing. Both the British and the Germans thus suggested using coal-water suspensions which could greatly simplify fuel handling. The sorbent, limestone or dolomite could be mixed into this suspension or fed in separately. In the system in the Technische Hochschule Aachen this system has already been employed in actual operation. Fig. 4 shows a diagram of a fuel supply system of this type taken from a new planning study (3).

Because of the much greater thermal stress on the combustion chamber in pressurised operation multiple cooling surfaces have to be accommodated in the fluidized bed, which generally means that the bed is significantly deeper. Even though this has a beneficial effect on combustion and sulphur retention or use of the sorbent, it also entails an increase in pressure loss, makes it more difficult for bed material to mix and heightens the erosion problem for the immersed heater surfaces. In the large-scale experimental system at Grimethorpe this problem has been looked at more closely for the first time and initial solutions have been tried out.

British Coal is also currently operating a cold system in which the erosion patterns which have appeared at Grimethorpe can be reproduced and in which new configurations of pipe arrangements and other methods of extending the life of the pipes can be tried out.

A system developed by the Deutsche Babcok Werke AG completely avoids the immersed heating surfaces Fig. 5. By increasing the speed of fluidization to approx 5 m/s so much material is removed from the fluidized bed that a recirculating cyclone prior to the actual dust removal equipment becomes necessary. The dust fed back however is cooled to such an extent that the immersed heating surfaces can be dispensed with. The lower part of the combustion chamber has ceramic cladding so that air can be introduced gradually without corrosion damage occuring. The method achieves particularly low NO_x emission levels. This technology, called the "Circofluid System" by Babcock is currently incorporated into a number of atmospheric systems for district electricity and heat generation; an experimental system for pressurised operation is also being built.

Further reductions in NO_x emissions in pressurised fluidized bed firing are also the objective of the British-German program which is promoted by the EEC. It is expected that it will be possible to adhere to the particularly stringent German emission limits for pressurised fluidized

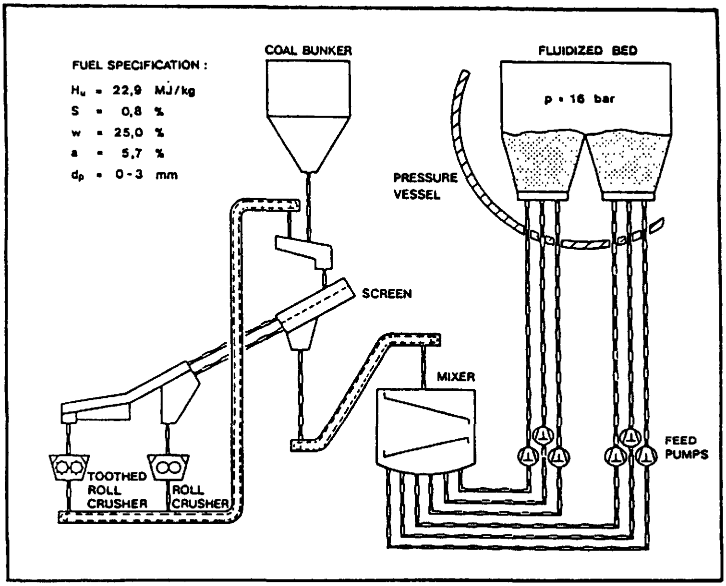

FIG. 4 - Fuel supply by means of coal/water suspension
(Source : Deutsche Babcock Werke AG /3/)

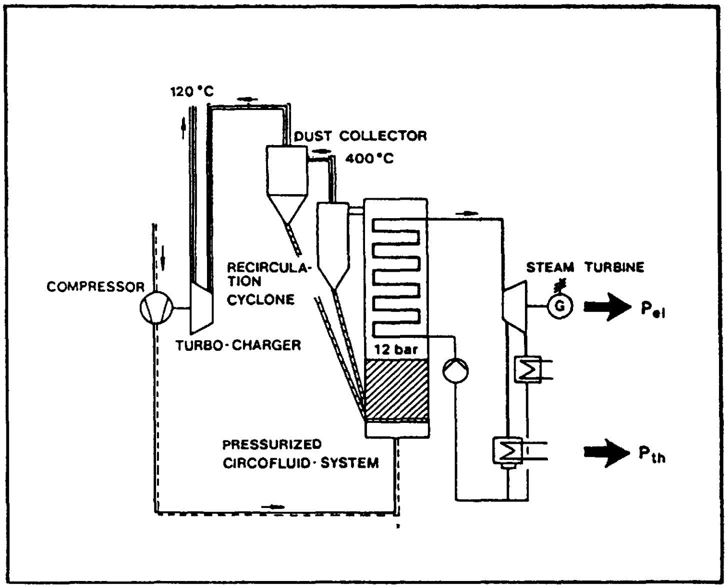

FIG. 5 - Pressurised fluidized bed steam generator without bed heating surfaces
(Source : Deutsche Babcock Werke AG /3/)

bed firing using primary methods but that the combination of effects is as yet not sufficiently known and has thus far not been technically or economically optimised.

4. Cost-efficiency and timetables for introduction

Studies in the USA above all have shown that pressurised fluidized bed firing systems should be able to reduce electricity costs by some 10% because of their extremely compact dimensions and improved efficiency. Although no such detailed studies are in existence for the European market, the authors of the articles mentioned here assume that there will be clear cost savings in their particular country. However there is still uncertainty about the optimum size of the systems. For small and medium-sized systems the combustion chamber could probably be completely fabricated in the works in which case transport considerations would dictate the maximum size. Deutsche Babcock Werke AG has also already formulated plans for a larger system (330 MW_e); this will produce considerable economies of scale.

Differing views have emerged in the three countries on the feasibility of implementing pressurised fluidized bed combustion.

- An air-cooled system based on the Curtiss-Wright design is already under construction in Italy, a small water-cooled pilot system will be manufactured soon
- In England the large-scale experimental system at Grimethorpe has been retrofitted with a gas turbine. Not until experience has been gained with this system will larger commercial systems start to be built. These could be in operation by the end of the century
- In the Federal Republic of Germany the thinking is that a system of this type is already technically feasible even though optimization is still needed with regard to the components and the operating conditions. The first large system could possibly be manufactured by the middle of the nineties.

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COAL-WATER MIXTURES

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INTRODUCTION

Coal Water Mixtures (CWM), a new coal-derived fuel of approximately 70% by weigth dry pulverized coal, 29% water and 1% chemicals, are a potential residual fuel oil (RFO) substitute in industrial and utility boilers and in other oil-fired industrial processes, and are an important way to reduce air pollution emissions (slurry can be processed by partially deashed and desulphurated coal).

R D & D has progressed rapidly since the 1970s and demonstraded the effectiveness of CWM in successful combustion and handling tests. In turn, burner designs have improved as the relationship between slurry properties, atomization behavior and combustion characteristics have been correlated. Slurry production plant capacity has increased up to 100,000 - 150,000 t/yr and demonstration projects based on the retrofitting of power plants and industrial boilers are being performed.

However, for the introduction of CWM on commercial full scale, other long term demonstration projects are required in order to:
- build up the economic analysis of CWM based on the examination of several individual elements namely, fuel price, cost of plant conversion, plant location, boiler size and

derating, equipment reliability, site specific reasons (space, distance from CWM production plants and slurry transportation systems);
- test and qualify different slurries in a combustion environment;
- gain confidence in the ability to handle and burn slurries continuosly;
- prove that values of air pollution emissions meet the levels of EEC environmental regulations.

In Europe, new demo-projects, partly financed by Commission of the European Communities, are running or under construction. In Italy, EEC is involved in the retrofitting of 75 MWe boiler of AEM-Cassano d'Adda power plant and in the combustion trials performed in a 12 MWt Enichem-Anic boiler to achieve data for burner development. Another project is the retrofit of 35 MWe S.Gilla boiler (oil designed) owned by Enel.

Recently, the present oil price decline has resulted in a research incentive to reduce CWM cost through the utilization of fine coal waste produced in washing plants, the optimization of characteristics and required quantities of chemical additives, and the application of advanced beneficiation processes of high sulphur and less economic value coal.

These studies are partly performed in the European universities and research centres with the support by the EEC and/or national Agencies. The up-to date results are very promising and encouraging.

Because availibility of low petroleum prices is considered a short term phenomenon, soon CWM should be competitive with oil once again.

Moreover, the interest on CWM is not limited to the RFO substitution. A strategic factor of relevant importance for those countries, who are main consumers of oil, as USA (80 Mt/yr), Japan (70 Mt/yr) and Italy (25 M/yr), are equaly focused replacing bulk transport of coal on a large scale with the slurry transfer via pipelines. The Soviet Union is appllying this new system in the construction of the Belovo-Novosibirsk coal slurry project (256 Km pipeline), having substantial advantages of lower investment and maintenance costs, minor energy consumption, and short implantation period for this system with respect to ground transportation.

Other possible oil-fired substitution of CWM include furnaces, kilns and process heaters in different industries, as well as the more ambitious applications in gas turbines and diesel engine, where problems with fuel atomization and engine wear are yet to be solved.

Another significant and important aspect of CWM is the integration of a preliminary coal beneficiation process into the coal-water slurry production plant. In fact, coal contaminants can often be removed more economically by coal-cleaning than post- combustion techniques.

Most coal-cleaning methods are based on differences in specific gravity between coal and its associated contaminants. However, fine coal particles, that are produced in conventional coal cleaning, are not effectively separated from the impurities on the basis of specific gravity, because the long settling time for fine particles and low efficiency in heavy media recovery. Instead, froth flotation and oil agglomeration techniques are being demonstrated as available and reliable commercial processes that can be integrated in the CWM preparation plants.

The next sections will describe in more detail the past, present and future activities that European countries are persuing to improve basic knowledge of CWM and bring this liquid coal over the threshold of commercialization. A few remarks on potential CWM market in Europe are also reported.

POTENTIAL MARKET FOR CWM IN EEC COUNTRIES

The existing market of RFO, in which CWM may replace heavy oil for the short term must be limited to the main end-users (i.e., electric utility, industry and wide residential/commercial sectors). This means the large scale and/or ash tollerant applications.

A reasonable starting point for consideration of this potential CWM market is the examination of EEC consumption of residual fuel oil that is given by country and sector in Table 1 (data of 1985). The main consumers by country are Italy (25 Mt/yr) followed by U.K.(17 Mt/yr), France (9 Mt/yr), FRG (9 Mt/yr) and Spain (7.5 Mt/yr), as it is shown in Figure 1.

Table 1 - RFO consumption (Mt/yr) in EEC countries (1985)

COUNTRY	SECTOR			
	ELECTRICITY	INDUSTRY	RESID./COMM.	TOTAL
Belgium	0.99	1.46	0.10	2.55
Denmark	0.36	0.79	0.93	2.08
FRG	2.66	5.13	1.03	8.82
France	1.69	4.82	2.44	8.95
Greece	1.71	1.15	0.15	3.01
Italy	16.98	6.31	1.70	24.99
Ireland	0.56	0.47	0.10	1.13
Luxemburgh	0.01	0.08	0.05	0.14
Portugal	1.58	1.55	0.08	3.21
Spain	2.06	5.18	0.28	7.52
TheNether.	0.99	0.17	0.01	1.17
U.K.	12.08	3.22	1.87	17.17

Refering to the utility sector, a significant number of boilers must be considered not convertible being the retrofit to CWM too expensive because of environmental, location or plant constraints. Furthermore, units with an useful residual life of less than 10 years are normally not considered to be conversion candidates. Additionally, in EEC countries the annual boiler load factor for oil-fired station is very low (for example, France 1.7 Mt/yr, FRG 2.7 Mt/yr and U.K. 12 Mt/yr) and the units are either placed in stand-by or used only to meet peak demand, because the main energy sources for these countries are nuclear, coal and hydroelectric.

Italy is the only exception, where for electric generation RFO consumption is about 17 Mt/yr. The Italian situation is unique worldwide with some similarities only in Japan. Italian Electric Generation Board (Enel), which produces 90% of country electricity, is carrying out a program (S. Gilla) aimed at demostrating the possibility of converting oil-design boilers to CWM. These units, partly already equiped with electrostatic precipitators (60%), may not be able to burn coal-mixtures without significant derating. To accept this derating, Enel is developing dual burners for CWM and fuel-oil which will allow switching from CWM to oil automaticaly in the period of maximum demand on the power system.

Without detailed techno-economic information from the S. Gilla long term test, a preliminary analysis on Enel boilers capacity to retrofit to CWM, based on the effect of fuels price on the electric power as function of:
- RFO-CWM price differential, ranging between: 0.1-2.5 $/GJ;
- boiler size: 300, 600 and 1000 MWe;
- boiler derating; 30%;
- retrofit capital cost: 140 $/KW (320 MWe size) and 120 $/KW (600-1000 MWe size);
- annual capital charge: 5%;
- combustion efficiency: 100%;
- boiler thermal efficiency: 90% oil, 85% CWM;

has been performed. It results that CWM use will be remunerative if RFO-CWM differential price is more than 0.6-0.7 $/GJ. Considering this analysis, the residual life of the Enel boilers (20 GWe x 0.7) and local problems gets an evaluation of 12-15% of total capacity, equivalent to a CWM consumption of about 4-5 Mt/yr.

<u>Refering to the industrial sector,</u> the amount of RFO burned for steam production is shared among the EEC countries in a more balanced degree (i.e., FRG 5 Mt/yr, France 5 Mt/yr, Greece 1 Mt/yr, Italy 6 Mt/yr, Portugal 1.5 Mt/yr, Spain 5 Mt/yr, U.K. 3 Mt/yr, see Table 1) than that consumed in the electricity sector.

The potential market for CWM as an alternative of fuel-oil in the industrial area has been investigated assuming as hypothesis:

- RFO-CWM price differential: 0.1-2.5 $/GJ;
- boiler size ranging between: 10-600 MW;
- boiler derating: 20%;
- boiler thermal efficiency: 90% oil, 85% CWM;
- combustion efficiency: 100%;
- retrofit capital cost: 70 $/KW (10 MWt size), 60 $/KW (100 MWt size), 75$/KW (over 100 MWt);
- payback time: 3 years.

Considering a standard industrial boiler population as shown in Figure 2, an analysis gives a conclusion that it may be economic to retrofit 15% of EEC oil-firing boilers with CWM (it is remunerative if RFO-CWM differential price is more than 1.5 $/GJ), corresponding to a CWM market in EEC countries of about 9 Mt/yr.

The CWM market for electric utilities and industrial applications could be 15 Mt/yr.

These few remarks on the potential market for CWM have to be considered an approximate evaluation, because it is necessary to confirm the above data with the results of the demonstration projects and to verify the current RFO consumptions and boiler population.

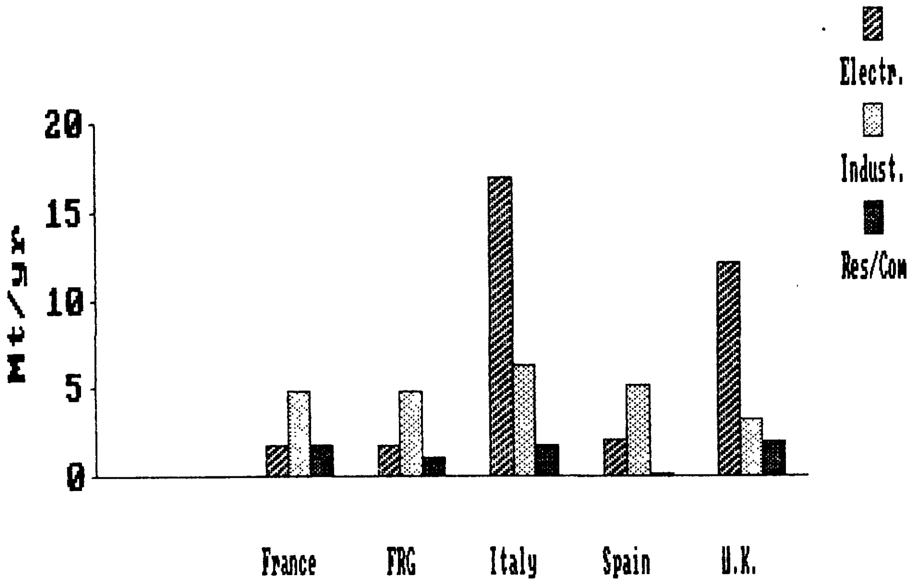

FIGURE 1 - MAIN RFO USERS

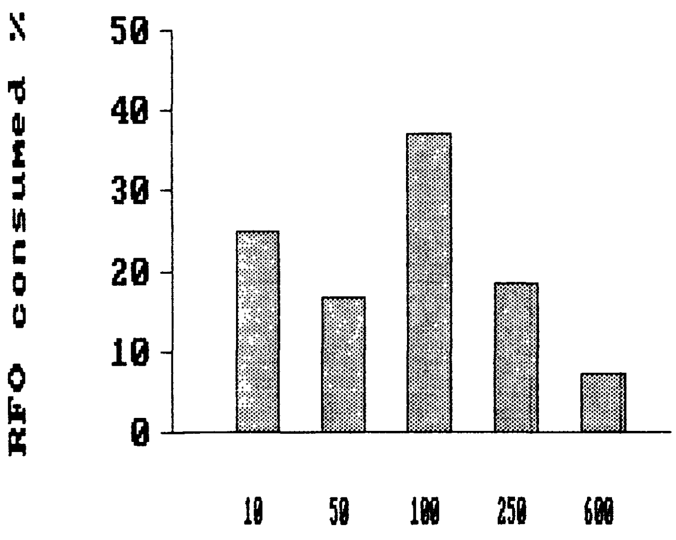

FIGURE 2 - BOILER SIZE MW

OUTLINE OF CWM RD & D ACTIVITIES IN EEC

Coal Water Mixtures to emerge as a viable alternative fuel to displace RFO in both the utility and industrial sectors requires a tremendous effort in all the research activities and demonstration projects of the world. The main RD & D activities have been and are focused on the principal topics, which are as follows:

- Coal Cleanup;
- Slurries Preparation;
- Slurries Transportation;
- Atomization, Combustion and Boiler Retrofit;
- Demonstration Projects;

developments of which, singular or in combination, are going to widen out the coal-slurry market.

The status of these topics will be presented individually reporting the progress and current activities in the European Communities countries.

The Commision of European Communities has financed part of the RD & D projects with a support of 19.4 M ECU subdivided as follows:

- European Economic Community Energy Demonstration Programme: 15.6 M ECU;
- European Economic Community Non-Nuclear Energy R & D Programme: 2.6 M ECU;
- European Coal and Steel Community Coal Research Programme: 1.2 M ECU.

COAL CLEANUP

Phisical Coal Cleanup technologies goals are on the reduction of inorganic sulphur and mineral matter levels and the increase of heating value of coal. Moreover, combustion characteristics indices show an improvement in slagging and fouling properties from raw- coal values. The coal-cleaning techniques can also be applied to coal fines with a significant heating value recovery, thereby affecting CWM economics.

In Europe two countries are involved in coal cleaning projects: France and Italy.

In France, Cherchar is developing a program on the utilization of fine coal from the Freyming (Lorraine) washing plant. The product is a slurry with a pulverized coal containing particules sizes less than 1 mm and an ash content of 20-25% by weight. The company in collaboration with Minemet Research has developed a treatment sequency comprising of screening under water at 300 microns and flotation of the fine fraction. The laboratory tests has been confirmed by pilot trials on site obtaining a final product with a mineral matter content below 10%.

The Technological University of Compiegne has undertaken studies on ash removal by selective oil agglomeration which produces coal fuel containing about 1% of ash. Because the operation uses a very fine coal (about 10 microns) the slurry fuel is prepared in a ternary form, coal - distillate fuel oil - water (54-16-30), with an acceptable viscosity and an heating value of 24,700 KJ/Kg. A continuous pilot plant is under construction with financial support of the French Agency for the Control of Energy.

In Italy, Eniricerche is performing in close cooperation with Snamprogetti (both companies of ENI group) experiments in a pilot plant project (100 Kg/hr of dry coal capacity) based on an oil agglomeration process that has been developped at Eniricerche laboratories. The pilot plant has been set up at Snamprogetti's Engineering Centre, Fano, in order to provide beneficiated coals for the CWM production facilities already available there. Furthermore, Eniricerche is developping a beneficiated process capable of producing coals with very low ash (1% max) and sulphur (0.2%) content. The project is sponsored by Agip Carbone (ENI group) and is aimed at producing high quality slurries for the retrofit of gas and oil fired units.

An important project, financed by the EEC, is ongoing at Department of Mining and Mineralurgical Engineering of University of Cagliari on the removal of organic and pyritic sulphur through bacteria. The above Department in collaboration with the Microbiology Institute of University of Rome has selected bacteria from Seruci Mine (Sulcis) and evaluated their adaption to organic sulphur extraction of Sulcis coal. Meanwhile, Thiobacillus ferrooxidans and Acidianus brierley have been studied with the aim to remove pyritic sulphur which is finely dispersed in the coal macerals. The obtained results are very encouraging.

SLURRY PREPARATION

CWM availibility is one of the most important factors for increasing the market growth because boilers will be retrofitted if production plants are running. Meanwhile, the cost of production and the reduction of additive quantities are certainly the main factors that can change the related economics of manufacturing coal-water slurries.

All these factors are taken in great consideration by producers and consumers, as well as government Agencies.

<u>In France</u>, at Cherchar a large number of laboratory tests have been carried out to define optimal particules size distibution and to identify additives presenting the best quality/cost ratio.

UTC-Creusot Loire worked out a ternary coal-water-air mixture with a density of 0.5-0.6 Kg/mc in form of a foam. This coal mixture presents several advantages such as:

- very high coal content (80% or more);
- low sensitivity to the nature of coal;
- cheap additives;
- self-atomization by air expansion at combustion.

The process is patented and a financial support from EEC was granted to build a continuos preparation pilot plant.

Elf Acquitaine has developed his own process named "Fluocarbelf". A project dealing with preparation of a CWM starting from coal wastes (slurries) and his combustion in a 5 MW steam generator is presently under way with the EEC support.

In Germany, CWM is not a potential substitute of RFO in the electric sector, because the oil burned for power generation is only 3% of total capacity. Instead, in the industrial sector oil substitution could reach a value 4 Mt CE/yr. This figure has activated several projects in the Federal Republic with funds from Federal Ministry of Research and Technology (BMFT). In one of these projects, Salzgitter AG in joint venture with Energie- und Versorgungstechnik, Stuttgart and BASF are working on the "Densecoal" project to study the technical and operational implementation of the entire chain from coal mine to combustion of the slurry in a pilot plant.

With the financial assistence from BMFT and North Rhine-Westphalian Ministry of Industry and Technology (MWMT), Ruhrchemie AG and Ruhrkole Oel und Gas Gmbh have developped a Coal-Water Mixture to load the Texaco gassifier in the "Holten coal pressure gassification" project. Since 1978, 70,000 ton of coal and 13,000 ton of solid liquefaction residues have been processed producing slurries for the gasifier.

In Germany CWM technology has been applied in other projects such as asphalt mixing plants (RAG/RoeG, Deutag Mischwerke GmbH and Teerbau Gesellshaft fur Strassenbau GmbH), financed by BMFT, and atmospheric fluidized bed combustor (Konig Ludwig AFBC plant demonstration project) supported by the European Communities, Directorate-General for Energy. Studies on formulation of new chemicals are performed too.

In Italy, Snamprogetti (ENI group) started the R & D activity on CWM to develop its own technology for the hydraulic transportation of coal by pipeline (it will be described in transporation section). The first result was the construction of a pilot plant (250 Kg/hr capacity) producing the slurry called "Reocarb".

The final result of this research was the design and construction of two demonstrative and industrial slurry production plants awarded to Snamprogetti by:
1. Industria Chimica Laviosa, 10 t/hr capacity (70% coal in water), at Leghorn (1984);
2. Enichem-Anic (Eni group), 10 t/hr capacity, at Porto Torres petrochemical complex (1985).

Both plants have to be considered the necessary technical background for the ongoing projects of 3 M t/yr, Belovo (Siberia) and of 0.5 Mt/yr, Porto Torres (Enichem-Anic).

Afterwords, Agip Carbone has commissioned to Snamprogetti the basic design for a slurry preparation plant of 120,000 t/yr of beneficiated CWM.

Nuova Italsider, Taranto Steelworks and CSM (Cemtro Sperimentale Metallurgico) (all companies of IRI group) have focused special attention to the CWM use into blast fornaces. After laboratory studies followed by blast furnace trials financed by ECSC and performed in collaboration with CSM, a 100,000 t/yr CWM plant was built at Taranto Steelworks. The plant will provide the CWM for injection into the tuyeres of the blast furnace # 3 which has an hot-metal capacity of 1.8 Mt/yr.

Other companies (Ecocarb and Scai) are analyzing, with the EEC support, the possibility to realize CWM producing plants using Swedish and American technologies, respectively.

CNR (National Research Council) and Enea (Government Energy Agency) have planed a National Energy project in which R & D on CWM are included. The project has been programmed to finance Italian bodies activities and universities studies. Related to slurry preparation, the Chemical Engineering Department of University of Rome and the Stazione Sperimentale dei Combustibili of Milan have been founds to study the influence of coal properties and chemical additives on the CWM stability.

In the Netherlands, Ankersmit Holding B.V., after small scale tests in the laboratory and trials in 2 t/hr plant, has completed a detailed design of a 10 t/hr plant to produce CWM with high quality characteristics (low price chemicals, high fineness coal particules size - 85% below 75 microns-, viscosity of 800-1000 mPa s at 100 rpm, high burn-out -95/98%-).

Meanwhile, Frans Swarttouw, who is the major dry mineral bulk stevedore in the Rotterdam port and has several facilities to screen, crush, and blend coal (about 1.5 M ton), started to research CWM in 1982. The activities are focused on the cooperation with Nycol (Sweden) and Sohio (USA) in order to combine know-how and excellent geographic position of Rotterdam port and on feasibility studies on the CWM application in the Netherlands country.

In U.K., there was a commercial attempt to build a preparation plant using froth flotation fines as raw material by a consortium involving Babckock Power, Elf Aquitaine, Claudius Peters and British Coal, that was overtaken by the fall in oil prices. British Coal did continue an investigation into the production of CWM from U.K. raw materials, with financial support of ECSC. As a result British Coal has a 1-2 t/hr pilot production plant in operation. The product has been fired in combustion test facilities.

In adition to the above reported work, further fundamental work has been continuing at Brunel University, Ecological Materials Research Institute in order to investigate a number of factors affecting the stabilization and particule size distribution of CWM. Other investigations on the basic physics of slurries using ultrasonic and shear wave techniques are currently in progress with the aid of European Community funds.

SLURRY TRANSPORTATION

Another aspect of developing a CWM market is the choice of the systems for slurry transporation in order to reduce its delivery cost and to solve logistic and environmental problems.

Slurry preparation processes aim to obtain a product with the two main characteristics, fluidity and static-dynamic stability, that behaves the in same manner as any liquid fuel.

Like petroleum fuels, therefore, it would be possible to use tank trucks and tank trains for transportation of limited quantities and short distances, while pipeline systems and marine transport are preferable for large quantities and long distances.

The improvements and optimazation of slurry fuel are based on basic integrated studies on rheology, equipment and materials and on engineering evaluation of the different adopted systems.

The first industrial experience in the design and construction of high solid content slurry is the Snamprogetti project for the pipeline from Belovo to Novosibirsk in USSR. The pipeline represents part of the Russian project that consists of an integrated system for production, transport by pipeline and direct combustion of CWM in a thermal power station. The main characteristics of the Belovo-Novosibirsk pipeline are: 20 in x 256 km tube, 3 pumping stations.

Salzgitter AG jointly with Energie-und Versor Gungstechnik, Stuggart and BASF are also involved in developing a transportation technology with a project for the technical and operational implementation of the entire CWM transport chain from coal mine to power plant.

ATOMIZATION, COMBUSTION AND BOILER RETROFIT

In recent years, studies on combustion performance of CWM have been carried out in burners ranging from laboratory to full scale size. It has been found that several factors, such as secondary air swirl, flame residence time, atomization quality of the spray and CWM characteristics, have specific effect on carbon burnout as well as on efficiency of the entire combustion system.

Extensive burner development work has been done to overcome problems related to flame stability, high carbon conversion efficiency and erosion process of burner tips associated with the CWM quality and chosen additives.

Several studies have been performed on boilers derating related to heat transfer efficiency, fouling and slagging phenomena and tube erosion process. Further important effects have been examined on water-wall and convective section deposits build up (rate, coverages, thickness and physical state) and susceptibility to sootblowing as well as chemical and thermal analysis of ash.

This research scenario is continuing in the EEC countries to prevent any retarding effect on CWM market growth.

In France, Cherchar has burnt the mixture prepared in its pilot plant in an experimental 1 MW furnace. The results are particularly interesting as far as concerns the flame stability and carbon burnout is concerned.

In Germany, Kali-Chemie AG has converted an industrial boiler (12 t/hr steam) to test the Salzgitter AG coal-water mixture, called "Densecoal". The target of this project is to acquire operating experience and collect data on combustion technology, flue gas treatmemnt and pollution control.

In Italy, electrical utilities and industrial bodies have been and are carrying out several experimental trials in the combustion field.

Electrical utilities

Enel, interested in a program aimed at demonstrating the possibility of utilizing coal-water mixtures in plant equipped with fuel oil designed boilers, has dedicated its research centre (CRTN) in Pisa to develop fondamental studies on CWM combustion and to design and construct its own multifuel burner that is actualy applied in S. Gilla 35 MWe boiler (see next section on demo-projects).

AEM-Milano, jointly, with Ansaldo is carrying out at Enichem-Anic boiler a combustion test on the prototype burner proposed for the demonstration project at Cassano d'Adda (see next section). On this occasion, several atomizing plates with mixing prechamber, of T-jet type and other shapes derived therefrom, are under investigation.

Industrial bodies

Enichem-Anic, Snamprogetti and Agip Carbone, with financial support from EEC, have converted a 22 t/hr boiler to verify the performance of several different burners using "Reocarb" mixture. The aim of the project has been the set up industrial burners, check wear of the atomizer tips, evaluate the main combustion parameters and assess the equipments performance.

Ansaldo and Franco Tosi, main Italian companies for power plant design and construction, are cooperating both with the aforesaid utilities and industrial bodies: in particular, Ansaldo with Cassano d'Adda consortium, Franco Tosi with Enel and Snamprogetti.

The Research Combustion Institute of University of Neaples has carried out studies on the diagnosis of CWM sprays under cold or combustion conditions. The study was financed by the National Energy Project of CNR-Enea.

An other interesting effort is the use of CWM in the heavy clay industry. Morando Impianti with an EEC founding has developed a project aimed to design and construct a new CWM fuel feeder that will be installed in a tunnel furnace.

In U.K., NEI-International Combustion Limited has carried out large combustion trials in its 88 MW test rig and participated in a 35 MW CWM burner firing demonstartion for the EPRI in the United States. Meanwhile, it has built an isothermal rig to study atomization problems and is continuing with European Community support.

Foster-Wheeler is carrying out a conversion test on a 70 MW water-tube boiler designed for burning oil. The experience should be completed by end of 1987. The EEC is supporting financially this project.

Peabody Holmes is very actively collaborating with ENI group in developing and installing six burners, rated at 5 t/hr mixture, on the 300 ton/hr steam power station in Porto Torres, Italy.

Atomization studies have been carried out by the Fuel Technology and Chemical Engineering Department of Sheffield University. A comprehensive study of CWM single droplet at the Department of Fuel and Energy of Leeds University demonstrated the mechanism of complete combustion process. The Mechanical Engineering Department of the Imperial College of Science and Technology is doing a combustion study to compare data from CWM burning with those produced by fuel oil and pulverized coal.

DEMONSTRATION PROJECTS

Since 1982 until now, about 15 industrial demonstrations have been undertaken in the world in small size boilers and/or with short term operation. The only exception is the Japaneese demo-project at Nakoso 75 MWe power unit, for one year operating, that is the largest CWM industrial test in the world for the moment. Nevertheless, experiences in Canada, USA, Japan, Sweden and China have led to a fast development of CWM fuel improving the knoweledge in operating and maintaining at full scale, and reducing the uncertainties and risks of a new technology.

The major CWM demo-projects planned in Europe are those of Enel, 35 MWe S. Gilla boiler, in operation, Enichem-Anic, 300 t/hr unit, partly operating and AEM-Cassano d'Adda Consortium, in which are involved seven bodies, that will enter full operation within two years with a 75 MWe boiler.

The target of the Italian projects have large differences between them.

Enel owns several thermal power plants (20 GWe overal capacity) of which it is possible to select those suitable for CWM firing conversion. In order to reach this objective, the demo-project is extended to all main aspects of coal-water mixture as characterization, preparation, handling of slurries and their combustion, boiler exploitation problems (fouling, slaging, erosion, heat transfer performance) and solid particulate collection from the flue gas.

Enichem-Anic will complete the transformation of the 300 t/hr boiler within 1986 to initiate its self CWM burning and collect data in order to evaluate the adopted technologies and achieve design parameters to retrofit other boilers of the same type and class.

AEM-Cassano d'Adda demonstration project is a consortium of seven bodies (electric energy municipal producers - AEM-Milano, ASM-Brescia, AEM-Torino, AGSM-Verona -, Ansaldo - IRI group, Agip Carbone and Enichem-Anic - both ENI group), promoted by the Italian Ministry of Industry and partly financed by EEC. The purpose of this project is the evaluation on industrial scale and on long period use of CWM in order to promote the industrial bodies to enter the commercial market and soon to reduce oil consumption that is about 60% of the overal primary energy sources.

Furthmore, success on application of this new fuel will allow conversion not only in Italy, but also in EEC which is supporting the Cassano d'Adda project with a consistent financing. In fact, positive results may promote this fuel in those countries such as Belgium that has made up its mind to wait and see having a large industrial sector oil burning, and such as the Netherlands that has two main companies ready to enter the commercial market. France, Germany and U.K. will be interested on results of AEM-Cassano d'Adda demo-project too.

CONCLUSION

The Coal Water Mixtures have been developed as a way to increase the efficient use of coal, either as substitute for residual fuel oil or in place of pulverized coal in those applications where there are environmental constraints.

Italy, being a main oil consumer, is particularly attracted by CWM, as it is demonstrated by the extensive activities in RD & D.

France, Germany and U.K. also have a significant interest to apply CWM in the industrial sector, and for this purpose are working in fundamental research as well in pilot plants.

Predictions of long term oil price trends have been notoriously poor. However, the expected oil price rise will open a minimum level of CWM market of about 2-3 M t/yr that is a reasonable figure to build producing plants at commercial scale. In fact, as it has been evaluated, the change from 250,000 to 1,000,000 t/yr production plant size will result in slurry cost that drops by 9-10%. However, as the plant size goes over 1,000,000 t/yr, the cost only reduces by an additional of 1-2%.

Beneficiated CWM presents enormous advantages as far environmental impact, and as far reduction of retrofitting cost.

The extent of commercial market penetration of CWM in Europe as a substitute for RFO has been evaluated equal to 15 M t/yr.

Other possible applications of CWM include a large potential markert for furnaces and kilns in the various mineral processing industry (e.g.) as the iron and steel production sector. No complete evaluation for these applications are available at moment.

Related to future R & D activities, particular attention should be focused on combustion characterization of highly benificiated coal water mixtures that present different burning behaviour, reduce boilers problemmes associated to the mineral matter and in future will be extensively used because environmental constraints.

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THIRD TECHNICAL SESSION

Synoptic report : Technical measures for the protection of the environment

Synoptic report : Economics and financing of coal-fired installations

SYNOPTIC REPORT

TECHNICAL MEASURES FOR THE PROTECTION OF THE ENVIRONMENT

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Nederlandse Energie Ontwikkelings Maatschappij
(NEOM)

1. Introduction

The national papers on this topic show rather different activities. In this synopsis an attempt is made to explain the differences. Besides the national papers several IEA-documents are consulted.

Whether or not a country is active in this field depends mainly on the size of present and future coal market, the need of small or larger boilers and on the emission regulations that are in force. Coal Information 1986 of OECD/IEA, Paris shows that the use of coal in the heat market (excluding the steel- and cementindustry) in all seven countries is limited to about 5% of the heat request. Oil and gas are the dominating fuels (in the Netherlands: gas only). The present use of coal varies from 4 to 6 million tonnes per year in Germany and the UK to less than 0.35 million tonnes/year in Denmark. The forcast for 1990 shows strong growth primarely in Italy and the UK. On the other hand no growth is predicted for Germany and the Netherlands. The average boiler size in all countries is rather small. Typical 5 MWth for all fuels. In case coal is used, grate-firing without systems to limit the emission of SO_2 or NO_x is dominating.
Especially in Germany and in the Netherlands a resonable share for larger boilers exists (about 15,000 MWth for boilers of 30 MWth and larger; all fuels. Source: IEA Coal Research, Economics of coal for steamraising in industry, April 1985). Stringent emission limits for SO_2 and NO_x for new boilers in the heat market are in force in Germany and the Netherlands. The progressive reduction clause in Germany may also affect existing coal boilers. In other countries the 'bubble concept' and local regulations or interests of equipment manufacturors may also bring about activities in technologies to limit the emissions.

It should be mentioned that only a few papers go into the topic of application possibilities of coal combustion by-products and desulphurization residue (gypsum). All the more so because contaminated combustion residues can not be disposed of in the environment without proper measures.

2. Measures to limit SO_2-emission

2.1 Grate firing and pulverized coal boilers

The emission of SO_2 can be limited by:

- the use of low sulphur coal;
- the addition of lime to the fuel (LIMB);
- by use of dry additive at the hot side of the boiler;
- by dry sorption at the cold side of the boiler;
- by spray absorption;
- wet scrubbing.

LIMB

Due to the 'bubble concept' adopted in Denmark low cost methods for SO_2-removal are of special interest in Denmark, in spite of moderate removal efficiencies.
Since 1981 Denmark has been participating in an IEA-project and in the current phase full-scale LIMB-tests are being performed.
In Germany trials with an additive briquette on a 30 MW travelling grate boiler are being performed.

Dry additive/hot side

With a relatively small investment a collection efficiency of 50-60% can be achieved. In Germany a test is done on a 12 MW traveling grate boiler. Some brief scoping experiments have been conducted on a 1 MW chain grate stoker at CRE, UK. Possible application of this technique is studied in France. Also in France promissing results were obtained during tests with ignifluid boilers and industrial plants should be commissioned in the near future.

Dry sorption/cold side

Also here with a relatively small investment collection efficiencies between 60% and 80% are reported. Test results are available from a 60 MW boiler in Denmark. Trial runs on a 7.5 MW vibrating grate boiler are being performed in Germany. A project to retrofit a 2.5 MW boiler is in study in the Netherlands.

Spraydrying

A collection efficiency in the 80-95% range can be achieved from large scale units at a greater investment.

In Italy a new multi fuel boiler (pulverized coal, heavy fuel oil and natural gas) of 145 MW will be equiped with a spray drier.
Desulphurization will be located between the electrostatic precipitator and the fabric filter.
A venturi-scrubber is beeing built downstream a 45 MW pulverized coal boiler in France. Although a high sulphur coal is used the high lime content of the coal ashes may permit to avoid the addition of sorbent.

A Belgian lime producer, in cooperation with a German producer, is developing a process to produce hydrated lime of large specific area (40 m^2/g). The facility has presently a capacity of 500 kg/hour.

Wet scrubbing

Only one case is known of wet scrubbing at small capacity. This 'high intensivity gas washing' project of 1 MW in Germany is supported by the EC. The slurry of a numer of such washers could be collected and treated in a gypsum recovery unit of a nearby powerstation.

2.2 Fluidized bed boiler

According to a report of IEA Coal Research (Atmospheric fluidized bed boilers for industry, November 1986) this boilertype is in use in all seven countries, ranging from 1 in Italy to 60 in the UK. Not indicated is wether the boilers are operated with or without lime/limestone. This aspect will probably be addressed in detail during the Second Technical Session under the topic 'fluidized bed combustion'. Judging from the national papers on the topic 'Technical measures for the protection of the environment' work on desulphurisation is performed mainly in the UK, France and the Netherlands. Although not reported under this topic also in Germany work is being carried out.

3. Measures to limit NO_x-emission

3.1 Grate firing

The basic design principles and operation of grate stokers encourage low NO_x-emission. Tests show that NO_x-emissions (expressed as NO_2) are in the range of 300-700 $mg/m^3{}_o$. There is potential to reduce emissions further with more careful control of combustion air. However, negative effects such as gaseous pollutants and carbon loss may be present.
The main drawback for grate stokers (and industrial boilers using pulversized coal) still is the cost of desulphurization.

A new series of boilers up to 2.5 MWth is developed in Germany based on secondary air injection and flue gas recirculation. The objective is to limit NO2 emission to 100-275 $mg/m^3{}_o$.

3.2 Small pulverized coal burners

The EC supports a project in Germany to burn anthracite dust. Burnertype: preburner and afterburner. Low NOx-emission by airstaging. In addition lime dust is supplied to the burner and in the afterburner ash and desulphurization products will be recovered. Size: 1 MWth - 8 MWth. It is not clear wether this concept will also be suitable for high volatile coals.

In France a small capacity low-NOx burner is being studied.

3.3 Large industrial pulverized coal burners

The methods used are pretty much the same as applied in the still larger powerstations. Former work in powerstations in Germany is well known.

In 1983 a 145 MWth boxertype furnace in the Netherlands, designed for a low burnerzone heat release, has been equiped with 4 double-register low-NOx burners. Early results were: NOx values of about 300 $mg/m^3{}_O$, but slightly higher carbon losses (from 0.3 to 1%).
As a result the fly ash will contain about 10% carbon, which limits the possibilities of reuse. So certain burner components have been modified recently. Test results of the modified burners are not avalable yet. Apart from airstaging in the burners in this project no airstaging (in the furnace) nor fuelstaging will be applied.

The new multi fuel boiler of 145 MWth in Italy, mentioned already in chapter 2.1, will also be equipped with low-NOx devices. Again a large boiler volume with low burnerzone heat release and 4 double register burners. It looks like airstaging (in the furnace) will be applied. The furnace-type is not known; it could be an arch-fired furnace.

3.4 Fluidized bed boilers

The low-NOx potential will probably be adressed in detail during the Second Technical Sesson under the topic 'fluidized bed combustion'. We are aware of activities in Germany, the UK and the Netherlands.

4. Measures to limit particulate emission

The emission of particulates can be limited by:
- traditional mechanical grit arrestors and multicyclones;
- bag houses;
- electrostatic precipitators.

4.1 Multicyclones

The attainable dust emissions with multicyclones (MC) depend on boiler type and coal characteristics (ash content and physical properties of the ash).

The French paper reports that, using high efficiency MC, emission values of 50-75 mg/Nm^3 (singles) and 70-100 mg/Nm^3 (small coals) have been obtained for travelling grate stoker boilers, and 100-150 mg/Nm^3 for spreader stoker boilers. This illustrates the use of relatively less expensive MC in grate stokers using singles and small coals. A design study of an electrostatic cyclone has been started in France.

In Great Britain an effort is underway for reduction of particulate emission by improved cyclone equipment. A novel cyclone design with vortex collector pockets (VCP) is now being demonstrated under an EC contract.

4.2 Bag houses

The requirement to keep below an emission limit of 50 mg/m^3 at all times can be satisfied by filter bag houses. For plants smaller than 30 MW, it is the only appropiate cleaning device to reach this emission limit, as the German paper states. Bag houses are also applied for installations larger than 30 MW, up to the nowadays largest fluid bed boilers. The Dutch paper reports about bag house filter applications in small plants between 1 and 10 MW, with both good and bad results.
The best results have been gained with Dralon T and Teflon. More problems occured with nomex and glass fibres. The reason for failures is however hard to trace, and much depends on specific circumstances. The reports from France and Belgium also mention some of these aspects. The Belgian paper mentions developments on filter design and materials with low pressure drop.

In the UK an ECSC supported programme is under way, studying methods for improving cost effectiveness of bag filtration (and electrostatic precipitation). Important is the investigation into the problems of collecting new, 'difficult' dusts being generated by combustion plants operating under low NOx and SO2 regimes.

As a general trend, bag house failures can be avoided by concervative design, bag house pre-heating and a by pass for off-regular operating conditions.

4.3 Electrostatic precipitators (ESP)

Electrostatic precipitators offer high system reliability combined with low operating costs, and are commonly applied for installations above say 100 MW.
According to the German contribution ESP can meet the particulate control limit of less than 50 mg/m^3 at all times. The French contribution makes some references to applications of ESP in newly commissioned plants from 10 to 20 MW and up. Outstanding results (10 to 20 mg/Nm^3) were obtained with stoker boilers. The results of pulverized or ignifluid boilers were not so good.

The Italian paper refers to a 145 MWth plant with an ESP for fly-ash removal, preceding the desulphurization unit which incorporates a bag house filter for absorber products.

In designing an ESP, one must consider the differences in flue gas conductivity caused by different coals, as the Danish paper mentions.

5. Coal combustion residues

Due to the various coal combustion techniques a range of combustion residues exists with a large variety in composition and quality. All ash-like residues are more or less contaminated with heavy metals which limits an unrestricted application. The Danish paper reports a growing resistance against disposal of fly ashes in the environment, which has triggered a massive programme aimed towards the utilization of ash for industrial applications. The paper does not give further details.

The Italian report mentions a study on the possibility of using desulphurization residue for the production of 'cefyll', a low grade cement material, as an alternative of 'controlled dumping'.

The Netherlands' contribution gives a comprehensive survey of past and future R & D and demonstration programmes to develop and promote utilization of ashes and gypsum (desulphurization residue) for industrial applications. In Holland environmental regulations do not allow combustion by-products to be used in unbound form and approve 'controlled dumping' only under stringent conditions. In Denmark fly ash (unbound form) is applied in road-building, whereas in Holland only fly ash-cement stabilization (bound form) is permitted.
The main features of the Demonstration & Implementation Programme in the Netherlands are the development of several fly ash applications in concrete products; fly ash stabilization in road-building (including development of a high capacity mixing plant); application of desulphurization gypsum in building blocks, plaster and floors and in gypsum-paper-fibreboard, to mention just a few. Also two Dutch demonstration projects for which EC subsidy has been granted should be mentioned. Both applications can accommodate all kinds of low-grade and high carbon containing fly ashes, bottom ashes and fluid bed ashes and hence offer excellent alternatives for 'controlled dumping'. The applications concern a production plant of cold-bound artificial gravel (Aardelite) and a calcining plant, producing a good quality fly ash-lime for the sand-lime bricks industry.

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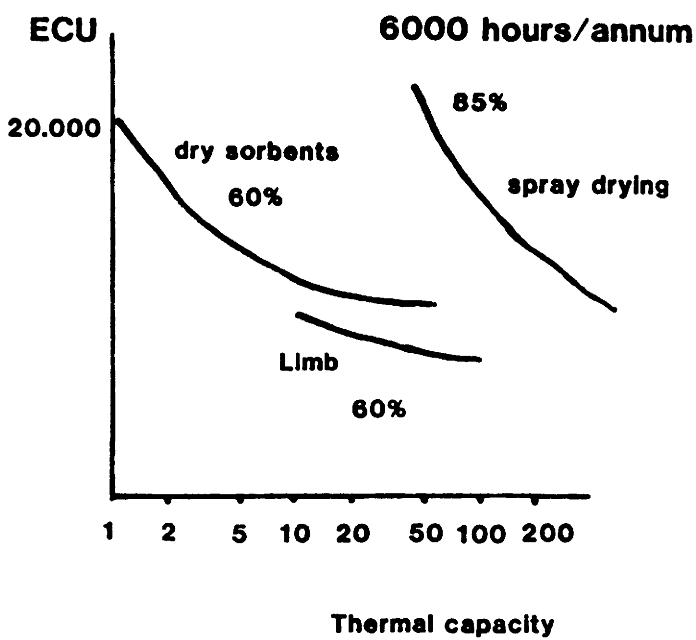
Relative operating costs
SO2 removal
per MW capacity



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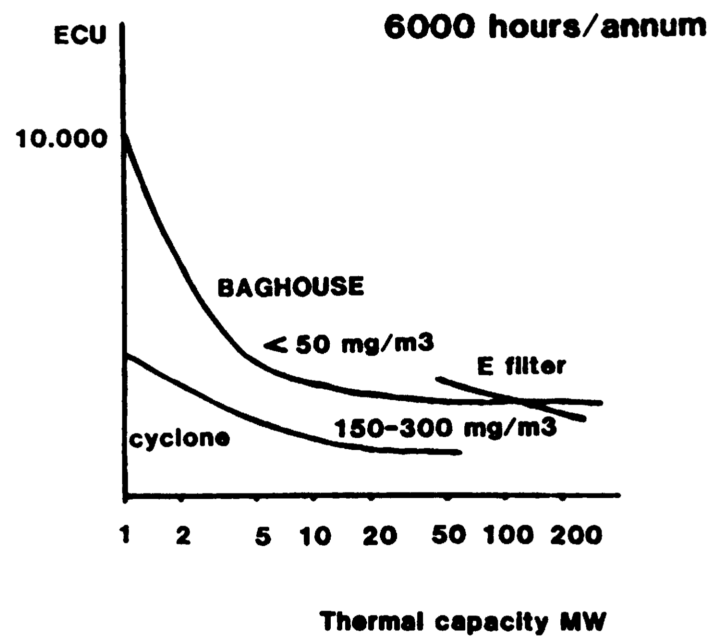
Relative operating costs
particulate removal
per MW capacity



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COAL RESIDUES

FIELDS OF FLYASH APPLICATION

CEMENT AND CONCRETE INDUSTRY

Flyash-portlandcement
Artificial gravel aardelite and lytag
Flyash - gas concrete (Gascon)
Flyash - foam concrete
Flyash - sand mixtures
Polysil concrete

CERAMICS INDUSTRY

Clay-flyash bricks for houses and road pavement

SAND-LIME BRICKS INDUSTRY

Flyash-lime mixtures as produced in limestone calcination plant

ROAD BUILDING AND INDUSTRY SITES

Flyash-asphalt fillers
Flyash-cement stabilization
Flyash-cement mixing plant

UPGRADING TECHNIQUES

Windsifting
Melting and grinding

STORAGE FACILITIES

Storage in salt domes
Storage in marlpits
Ecologically sound depot

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COAL RESIDUES

FIELDS OF FGD-GYPSUM APPLICATION

Dihydrate $CaSO_4 \cdot 2H_2O$
Hemihydrate $CaSO_4 \cdot 1/2H_2O$
Anhydrite $CaSO_4$

	Dihydrate	α-Hemihydrate	β-Hemihydrate	Anhydrite II
Binding agent cement industry	X			X
Self-levelling floors				X
Plaster			X	X
Building blocks			X	
Gas-concrete	X			
Gypsum-cardboard			X	
Gypsum-paper fibreboard			X	
Off-shore industry	X			
Mining		X		
Sugar industry	X			

ECONOMICS AND FINANCING OF COAL-FIRED INSTALLATIONS

Louis DOUAN du CHEF du BOS
Head of Marketing Service of the Charbonnages de France
Energy Division

SYNOPTIC REPORT

When I was requested to prepare this Synoptic Report I was at first somewhat uneasy since I was aware of the diversity of energy choices available in our countries in general and of coal policy in particular. I was afraid of having to present the succession of reports which would have been as different as our countries traditionally are.

The opposite proved to be the case: a perusal of the different reports shows that, beyond the detailed presentation of the situation, our analyses overlap a great deal on the basic problems and have resulted in solutions being worked out which are very much akin. Better mutual understanding can only help us to go forward in the knowledge of successful experiments and while analyzing why a given solution which succeeded well in one place has only had limited success in some other country. Often enough very little separates failure from success.

What all our analyses have in common is the structure of coal-based heat economy as compared with its competitors: this structure is made up of three major elements:

- Operating costs (labour, supplies etc. ..) which are generally higher than those of the competitors but ultimately a secondary factor in the overall balance.
- Cost of energy itself, which is fairly stable and often much lower than that of competitors, though the gap varies with fluctuations in hydrocarbon prices.
- Investment costs for constructing coal heating plant which are well above the competing investment costs (from 1.5 to 3 times), representing the main brake on the expansion of coal-based heating.

It is to remove this brake that a variety of solutions have been devised among which one can discern numerous similarities.

I will illustrate my contention with an example from France which does, however, illustrate well enough the situation in each of our countries if we transpose the prices of hydrocarbons. The example is of an industrial plant in 1983. The figures were still valid in 1986 when the price of oil had gone down, and will again apply the next time oil will go up, an eventuality which will certainly come, though I could not put a date on it. The other cost elements have hardly changed since 1983, either investment or coal costs.

The table of annual operation shows

- that although the running costs are higher with coal than with fuel oil they are still secondary compared with the cost of energy,
- that the difference between the solutions depends strictly on the price difference between fuel oil and coal. Depending on the period concerned, on the locations and the coals, this difference can be very marked or virtually nil, possibly even somewhat negative in certain cases. (See Table 1).

The table of investment costs shows

- that investments in coal can currently be twice those in fuel oil.

- that the different countries have to varying extents tried to reduce this handicap by a policy of subsidies or fiscal inducements. But these inducements are now being reduced or even eliminated in several countries. (See Table 2).

The table on the overall financial balance shows that the period of return on investments in coal-heat generation have been very attractive and is still so to this day in certain cases. (See Table 3).

Even so, the advance of coal-based heat has undoubtedly lagged behind the hopes in the period 1979 - 1986. This raises two questions:

- What can one predict about the future of the coal-fuel oil dichotomy which decides the profitability of a project?
- Who is best placed for investing in this section of the energy chain? This type of investment is not necessarily a priority for the users, although it can offer attractive prospects of profitability for other operators.

1. Operating costs often conceal false problems

- In his report with many Belgain examples M. Van RENTERGHEM raises this question of operating costs to stress that the annual subsidy to coal operating costs compared with fuel oil is less than a tenth of extra investment cost.

He singles out the KS and IGIEX company projects in the field of pulverised coal for small capacities, the very object of which is to obtain a coal utilisation which is comparable to that of oil, with the coal delivered in containers and the ash removed in the same way.

- In his analysis of the British situation, Mr. WILLIS examines the factors in detail which will favourably or unfavourably affect the decision of users for coal as an energy. Mr. WILLIS stresses that costs, when they do enter into the decision, can be regarded as somewhat subjective factors rather than objective. Undoubtedly coal is more expensive to transport and burn than oil and removing ash and clinker requires some effort. But Mr. WILLIS believes these costs to be often overestimated, especially by those who are looking for good reasons to do nothing. He typifies these factors as part of the general image of coal and underlines the considerable advances made in recent years in the construction, automation and handling of coal. While there is still some way to go for coal to be established in the 21st Century, it can be said that in many recent installations coal has truly become a push-button energy.

If efforts remain to be made it is perhaps in the field of making this known and for promoters of coal as an energy to use publicity and campaigning to project a young and modern image of this energy.

- There is one aspect among the utilisation problems which is not a false one: this is the question of consideration for the environment. Monsieur BOORSMA has touched on this in his description of the situation in the Netherlands. Although this country has natural gas under its feet and not coal, the government has sought to diversify energy sources and develop the burning of coal in industry and for electricity generation. But there are environmental constraints which are particularly stringent with regard to sulphur and nitrogen oxide. For this reason the Netherlands have concentrated on fluidized bed technology almost exclusively.

It has to be admitted that this is an entirely logical orientation for a country whose main energy is gas.

- The French report on the other hand notes that this move to protect the environment has to be made progressively and to avoid excessive constraints. If one actually penalised conversion to coal too severely this would perpetuate installations which burn heavy fuel oil which generally has a higher sulphur content than most types of coal. If it is at present normal to require desulphurisation in installations burning coal with a high sulphur content, it would be abnormal and contrary to the aim pursued throughout Europe to lower the level at which desulphurisation is mandatory to a level which make it necessary with all coals.

Today, coal figures in modern installations with the same degree of automation and no higher a pollutant effect than other energies.

Beyond this question of utilisation the factor deciding the cost effectiveness of coal-fired installations is that of the energy costs.

2. Stable coal costs versus fluctuating oil costs

Even though absolute figures may not be exactly the same as between one country and another, primarily because of transport costs and the tax systems, the curves which plot that trend in energy costs in our countries all have the same shape. Three deductions can be made from them (see Table 4).

- Coal prices are by far the most stable prices of all the fuels. While oil prices have frequently either doubled or halved, coal prices have only been multiplied by 1.3 or divided by that figure.

In his report on the concept of "Nahwarme" M. SCHMIEDEHAUSEN stressed that the cost of coal-based heat can be held stable for long periods simply because of the stability of coal prices themselves. In practice, this price is fairly independent of policy fluctuations and its stability is ensured by the fact that a large proportion of European coal consumption is indigenous in production. In the long term, the existence of proven reserves sufficient for centuries of consumption and spread all over this planet is the best guarantee of stability.

Clearly, when we say that the price of coal is a good deal more stable than that of other fuels we are not claiming that it stays constant. In his report Dr. WILLIS singled out two factors which accounted for the variations: first, the international coal market only involves a small proportion of world production, scarcely over 10%. This makes it a market of surpluses and very sensitive to variations in demand. As the coal chain has a certain inertia this can lead to fluctuations in prices. Thus the second oil crisis in 1979 increased the demand for coal and raised coal prices a little. The coal chain then reacted by expanding its production capacities. Today, however, this additional capacity is available at a time when demand has dived as a result of the oil events of 1986, hence a lower price level at the present time.

Dr. WILLIS also pointed out that the stability of coal prices in our countries is influenced by the dollar rate, which can sometimes wipe out the variations, but can equally make for an increase as has happened for the last two years.

Despite all the possible causes for coal price variations, the prices have still proved much more stable than those of hydrocarbons and there is every reason to expect such regularity to occur in the future. Utilisation of coal is the best guarantee for all those who wish to protect themselves from violent and destabilising variations in the price of oil.

- **Coal prices are generally lower than those of oil**

The curve representing energy costs for an industrialist in Paris had made this obvious since 1973. For about a decade or so before 1973 the price of oil had dropped below the coal price. Since 1973 three distinct periods may be distinguished:

- 1973- 1979: the price of coal was appreciably lower than the price of oil (20 to 30%).

This induced users of coal to stay with this form of energy, but the difference was not big enough for users with medium or modest capacities to embark on new investments in coal consumption.

- 1980 - 1986. The price of oil reached and sometimes exceeded double the coal price.

This period saw new investments in coal consumption for heat purposes, on varying scales depending on the country.

- Since 1986: the price of oil has plummeted and is now at a level close to that of coal, usually above it but sometimes even below in certain instances.

Even so, if one looks at imported energies at the European port of delivery, coal stands at about \$50/toe, while heavy fuel oil is around \$100/toe, or double. (See Table 5).

One can see that the uncertainty regarding the price difference between coal and oil is almost entirely due to the very unpredictable nature of the price of oil. Without attempting to predict the future price of oil, there are many who believe that actual prices are if anything low and that they are more likely to be higher than today in the coming twenty years. This is what emerges from the report of M. VAN RENTERGHEM when he states that many believe that the present price situation will not last, unfavourable as it is to coal.

The present shrinking of the price difference between coal and oil has put the brake on investments in coal. This decline in the profitability of coal and the uncertainty about the future give those who prefer to think in the short term plenty of reasons to wait and see. But M. VAN RENTERGHEM points out that, even in this situation there are cases where a decision to invest in coal is taken; these are generally:

- new installations
- installations in which the rates are high
- multivalent installations, coal and oil, or coal and gas.

This aspect makes it possible to obtain a high rate in the coal-based plant by utilising coal as a base, giving the operator a good chance of facing any energy price variations which may befall in good conditions.

- Operators who tend to think more in the long term rather than the short.

We observe this very situation in France. For example, we have recently noted the decision by the PECHINEY company to invest in what will involve a 160 000 t coal consumption at Gardanne, and also of a district heating plant in Paris to use an extra 300 000 t of coal.

In a more general sense, in as much as the main brake on decisions is the uncertainty about future energy prices, one has to recognise logically that suppliers of coal do take on some of this uncertainty upon themselves in return for a purchasing commitment over several years. It is something which the suppliers of natural gas do and is an important factor in the development of this energy.

This question has been raised by the report by M. VAN RENTERGHEM when he cited the promotional campaign by the KS company which is based on contracts to supply coal at a guaranteed price which is lower than the oil price by a given percentage.

The guarantee that coal will remain less expensive than oil for some time might not be too difficult to provide if it were not for the problem of financing the investments needed to consume coal. Such investment in coal is definitely higher than the investment needed for other energies, which is the very crux of the problem of promoting coal as an energy.

3. Solutions to counteract the braking effect of investment costs for the user

We have seen the cost of investment in coal to be definitely higher than the equivalent cost with oil or gas in general terms. As a result the coal option appears as a certain outlay at the beginning in exchange for future savings the level of which is vague because of the unpredictable nature of oil price fluctuations. To promote coal consumption we have to counteract the braking effect represented by the investment costs. Taking all the reports together, three main directions emerge:

- a technical one which aims to reduce investment costs of the user by simpler and more efficient processes,
- public incentives aiming to make the investment of the user easier through subsidies, reduced interest rates or fiscal benefits,
- provision of a service, in this case a specialised agency taking over the investment in coal from the user.

3.1 Technical advances to reduce the investment costs in coal

This aspect has been extensively covered by the other sessions of this Symposium. M. VAN RENTERGHEM in this context refers to the efforts made to build standardised equipment with the simplest possible controls.

He also mentioned the possibility of using oil or gas burning plants in the condition they are in now, but simply installing a coal gasification plant downstream. This type of solution would bring some drop in yield, but would make it possible to use cheap coal. Unfortunately, the recent oil crisis has broadly called a halt to research in this direction, which had not yet come up with solid findings.

Several reports also referred to the development of multivalent heating plants: the coal-fired boiler being the base unit here. This has the advantage of raising the utilisation rate of coal plant and so reducing the high investment handicap (see Table 6).

However desirable it remains for such technical advances and researches to be made to help reduce the handicap coal suffers because of investment costs, it does seem hardly likely that this handicap could be eliminated: simply because of its solid form and the resultant ash, coal will probably always have investment costs greater than those of its competitors, which are liquid or gaseous and leave no solid residues.

3.2 Public incentives to investment in coal

All the governments and the European Community itself have regarded the promotion of coal consumption to be an important factor in the diversification of energy sources which would contribute at the same time to keeping the balance of payments steady and to maintaining a European added value. This holds true when the coal used is produced in Europe. It is also true when the coal is imported, as the diagram shows (see Table 7).

Because of this every government has devised a variety of incentives for coal consumption and for the investments needed for it.

These are primarily

- fiscal benefits: lower VAT on coal as an example. Offsetting part of the coal investments against receipts or profits,
- subsidies to cover one part of the additional investment required by coal,

- grants to all research into new processes of using coal and particularly to all investments into new processes which could serve as guidelines,
- loans at reduced interest rates. Such reductions in the rates have in certain cases been financed by the governments but also by the European Community itself,
- introduction of a tax on imported hydrocarbons which improves the profitability of all investments in the use of energy forms other than gas or oil, which would provide the funds for subsidies to make energy more cost effective. The reports by WILLIS, VAN RENTERGHEM and myself specify the forms of public aid in Great Britain, Belgium and France. There is no doubt that these different aids have played an important part in launching the investments made between 1980 and 1986 in coal consumption in these three countries.

But these reports also indicate that the greatest part of these public incentives for investing in coal is now on its way out. while it is true that an energy constraint has set in since the recent oil events, it must not be forgotten that it is to a large extent the result of diversification policies in energy and in conservation policies in our countries. To abandon completely these policies today would mean disbanding the army with which one has won a battle. Several reports underline that such an attitude shows a short-sightedness and that our countries are in no way sheltered from further oil crises in the future.

Beyond these established solutions for counteracting the brake on investments (technical solution by reducing costs and financial solution by public incentives), it is interesting to see to what extent the reports agree on the setting up of financial services which aim to relieve the user of coal-based heat of the burden of investment.

3.3. "Heat-from-coal" services

This type of service is the sole subject of the report of M. SCHMIEDEHAUSEN who has developed the concept of "Nahwarme" in Germany primarily for the heating of premises in medium sized concentrations.

The "Nahwarme" service
- relieves clients of the responsibility for energy supply by transferring it to a specialised partner,
- absolves clients from investments and immobilising corresponding amounts of capital,
- guarantees a supply of heat at prices which remain stable over long periods.

The logic of this type of solution becomes evident as soon as one compares energy chains one with another in terms of the investments needed to produce the heat:

If one compares oil, gas, coal and electricity as generators of heat it is found that coal is the energy chain which is the cheapest in investments in overall terms. If investments in utilisation are higher for coal than for gas and oil, they are much reduced with regard to exploration because of the abundance of world coal reserves. In total, the coal energy chain is less costly than the oil energy chain. As to the gas energy chain, it is more expensive than the oil energy chain because of the high investments needed for the transport of gas. The electricity-nuclear energy chain for its part is much more expensive in investments than those of conventional fuels, which explains why this form of energy is not normally competitive in the supply of heat except in a marginal way. But this marginal stake could become significant when errors of forecasting have led to nuclear over-capacity.

If one considers who supports investments in the different energy chains one finds that the part played by the consumer is modest, except in the case of coal where almost half the total investment is borne by the consumers. This charge on the consumer of coal is all the more abnormal in view of the fact that this is the most economic energy chain in investment for the whole of the economy (see Table 8).

It is this which makes it seem rational to let the "energy supply" side take over a large proportion of the investments in the coal chain close to the user, and particularly the investment in heating plant (see Table 9).

This type of service linked to investment, together with all the other services such as the prior design of the most efficient installation and the subsequent running of the installation, as the report by M. SCHMIEDEHAUSEN shows, makes it possible to put forward a coal-based heat system which is no longer handicapped by investment compared with its competitors.

It is noteworthy that the same type of concept has been evolved at the same time by:

- the heat supply contracts of KS in Belgium
- the Sidec system in France
- heating companies in Great Britain, even though Mr WILLIS indicates that there have not been major developments so far in his country for reasons he analyses in his report.

At first sight this type of solution seems to do no more than shift the investment problem elsewhere and does not provide an answer which radically improves the competitiveness of coal-based heat.

In fact, the benefits of this type of solution is greater, and the reasons for this are expounded in the report by Mr. WILLIS: as soon as the energy costs do not represent a large proportion of the total costs borne by a user of heat, the latter will not accord a strategic priority to investments designed to lower these costs.

For this reason an industrialist will not agree to immobolise capital in a heat generating plant using coal if the return on this capital is going to exceed 3 years. But the same industrialist will agree to investments the return on which is going to be a good deal less immediate in areas he regards as strategic, such as the development of his products or opening up his markets, in other words, in areas which have a direct bearing on the future of his own business. If one excludes industrial risk, ie the risk that an activity will disappear in the coming years, one realises that managers are prepared to accept periods of return which are a good deal longer. This is the classic property situation: one would not build much if one always insisted on a 3 year return, and return periods of 8 years and more are common in this field as there is not much risk attached to inhabitation of a building in the 10 years subsequent to its construction.

If one, therefore, transfers the coal investment load from the user to another operator for whom the coal investment will become a strategic one, one can see that, beyond the accommodation bestowed by having recourse of a specialised operator, one obtains a longer time-scale for an operation to be profitable which opens the door to a wide range of projects.

What operators are likely to have a strategic interest in selling coal-based heat?

To my knowledge there are basically two kinds:

- service companies specially set up with this aim
- coal producers.

a) service companies

One needs to recall that the idea of a reasonable period of return as practised in industry today is only an imperfect reflection of profitability. It is an index of the rapidity of profitability rather than of its level. There are many very profitable activities which have return periods well in excess of the 3 years presently accepted as a maximum for investments in industry.

A service company, therefore, which makes it its business to invest in coal-fired boiler plants and supply heat to customers, can readily arrive at a profitability package which it can put to its shareholders. This is clearly the case with the heat supply companies quoted by Mr. WILLIS for Great Britain. In the French situation, when CHARBONNAGES DE FRANCE wished to set up Sidec in 1983, it easily found private investors to subscribe 45% of the capital for this company.

Since then, the results of Sidec have been sound and have remained so despite the collapse of oil product prices.

The features of coal-based heat supply contracts are generally these:

- exclusivity in heat supply during a period of 10 years. From the report of Mr. WILLIS one learns that in Great Britain the contracts are 5 years and this is undoubtedly one of the reasons for their poor acceptance.
- a constant heat price guaranteed over a long period (as with NAHWARME), or a guarantee of being cheaper than oil-based heat (as with Sidec).
- transfer of the plant to the user at the end of the contract.

Apart from these features the Sidec contracts contained two distinctive conditions:

- cover for industrial risk taken over by a fund specially set up for this purpose. If the risk of a paper mill, sugar refinery or chemical plant being closed at the end of 10 years is not negligible, the risk that all industries using heat will have disappeared after the same period is much less. This risk insurance makes it possible to reduce the cover margins entailed.
- a partnership to bear profits and losses liable to occur due to variations in the price of oil. In the event of oil prices being low, Sidec is penalised by a smaller return on its capital as a result of the price guarantees it has provided. Conversely, when oil prices are high the customer of Sidec shares the profits to be gained from this situation with Sidec.

It is worth noting that this partnership has brought Sidec considerable benefits in its first years of existence. Since the oil price slump the benefits have been lower but have still continued at a level attractive for the shareholders. Today, only a few contracts have seen the guarantee clause related to the oil price being invoked, and Sidec operations have not actually been in the red except for a few weeks in 1986 when the oil price fell to around $10/barrel. The shareholders of Sidec are counting on oil prices not falling often, nor to such low prices for long.

b) the coal producers

But there are not only the specialised service companies who could have a strategic interest in selling coal-based heat. There are the coal producers as well.

They are generally prepared to invest in coal winning with periods of return on capital which are well beyond the 3 year magic limit. And the profitability of these investments largely depends on the steady markets their products will find, regardless of the unpredictable oil price fluctuations. Coal producers, therefore, have a truly strategic interest in investing some of their capital in coal-based heat services. Not only will they benefit from the sure good returns the other shareholders enjoy, but they will consolidate the profitability of their investments in production by enabling new coal-consuming installations to be built and by acquiring exclusive delivery to these installations for 10 years.

This interest explains the creation of Sidec in France, Ruhrkohle Warme in Germany, the KS heat supply contracts in Belgium. In the case of KS the interest was even threefold since KS is also a manufacturer of boilers which are made available to clients. Clearly the progress of these service formulas for coal-based heat has also been held back by the oil price drop. Yet it is worth noting that such services still remain profitable today and attractive both for clients and for coal producers.

CONCLUSION

In concluding I would single out one of the points in the conclusion of Mr. WILLIS' report. He suggests that the diversification of energies consumed in the European Community remains an aim to pursue and that the promotion of coal in the heat market is one of the key elements in it, as the present symposium testifies.

But he also stresses that this promotion can only take place in a stable market. It strikes me that the development of coal-based heat services is a very valuable contribution to the stabilisation of a part of coal consumption, both in terms of quantity and price.

Coal producers should also, it seems to me, turn to good advantage the slowing down of new coal-fired installations we see today and which he believes to be temporary, by "tuning up their engines" in this area in taking proper account of everything that is relevant. Why should international trade in coal accept short-term contracts? Why should not producers and coal-heat service companies exchange longer supply contracts for a price guarantee in relation to oil as is done by the gas producers? This way of looking at things corresponds to the needs of the final client who wishes to buy heat which is free from all constraints, be they investment or any other. For the supplier this means devising a service which completely meets the expectations of his clients. This is something which has begun to happen, and I am convinced that if, instead of letting ourselves be dazzled by temporarily low oil prices, we continue along this path we could well witness an important development from the next crisis which is bound to activate hydrocarbon prices in the future.

Table 1

COAL UTILISATION BALANCE SHEET

ANNUAL OPERATION

Property group located in Paris region
Power supplied : 3 590 MWh
(of which for heating : 2 960 MWh, ECS 630 MWh)

Fuel	Oil	Coal
Quality	11 797 kW/t	8 278 kW/t
Boiler efficiency	84 %	82 %
Quantity required/a	362 t	529 t
Price per tonne (83)	3 066 F	949 F
OR (in thousand francs)		
Expenditure on fuel	1 111	502
Cost of piping and minor maintenance	48	104
Electricity (at 0.45 F/kWh)	4	7
Total annual expenditure	1 163	613

ANNUAL SAVING : 550 000 F
or 47 %
OF OIL UTILISATION COSTS

Table 2

C O A L U T I L I S A T I O N B A L A N C E S H E E T

INITIAL INVESTMENT

Heating plant for 200 apartments
Max. power requirement : 1 775 kW
Number and nominal rating of generators : 3 x 590 kW

In thousands of francs ('83)	Oil	Coal
Complete boiler plant, electrical switchgear, controls, recycling pump, flue fan		800
Complete boiler plant, electrical switchgear, controls, recycling pump, 2-stage burner	132	
Thermal and electrical equipment	150	170
Coal and clinker handling		175
Stocking and piping of fuel	80	
Civil engineering work on sunken bunker, boiler house and smoke stack		450
Civil engineering work and boiler plant and smoke stack	180	
Planning and study costs	90	175
Value Added Tax at 18.6 %	118	330
Total cost of works	750	2 100
Allowance for extra coal cost		- 92
Total investment	750	2 008

Table 3

C O A L   U T I L I S A T I O N   B A L A N C E   S H E E T

ECONOMIC BALANCE OF THE COAL SOLUTION

Extra investment cost	1 258 KF
Annual operation saving	550 KF
Period of return on investment	2.3 years

FIRST YEAR COST OF HEATING PLANT

Thousand of francs ('83)	Oil	Coal
Capital charges : 15 % (or a loan at 13 % over 15 years)	113	301
Fuel	1 111	502
Piping and minor maintenance	48	104
Other	4	7
Total	1 276	913

IN THE FIRST YEAR THE COAL SOLUTION PROVIDES :

A SAVING OF 363 KF

OR - 28.4 % COMPARED WITH

THE OIL SOLUTION

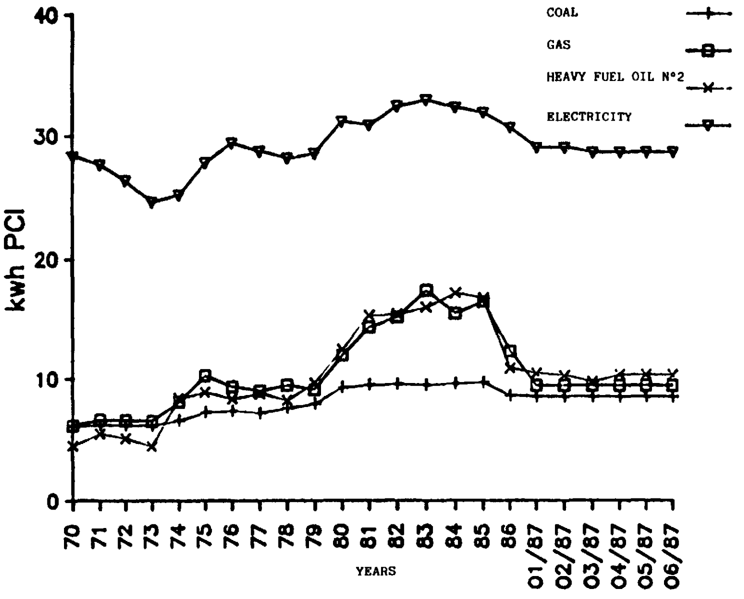

TABLE 4 - DELIVERED PRICE OF ENERGY TO INDUSTRY
Paris region - in constant units 86

COAL	50$/toe
GAS	80 to 100$/toe
Crude Oil	100$/toe

JUNE 87

TABLE 5 - COST OF ENERGIES DELIVERED TO EUROPEAN PORTS

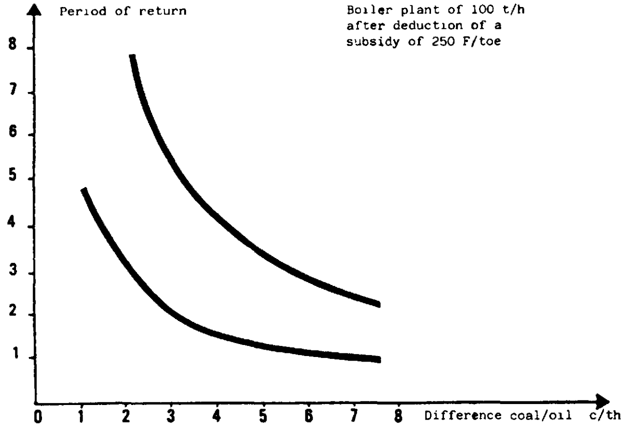

TABLE 6 - PROFITABILITY OF A COAL-BASED BOILER PLANT COMPARED WITH HEAVY FUEL OIL

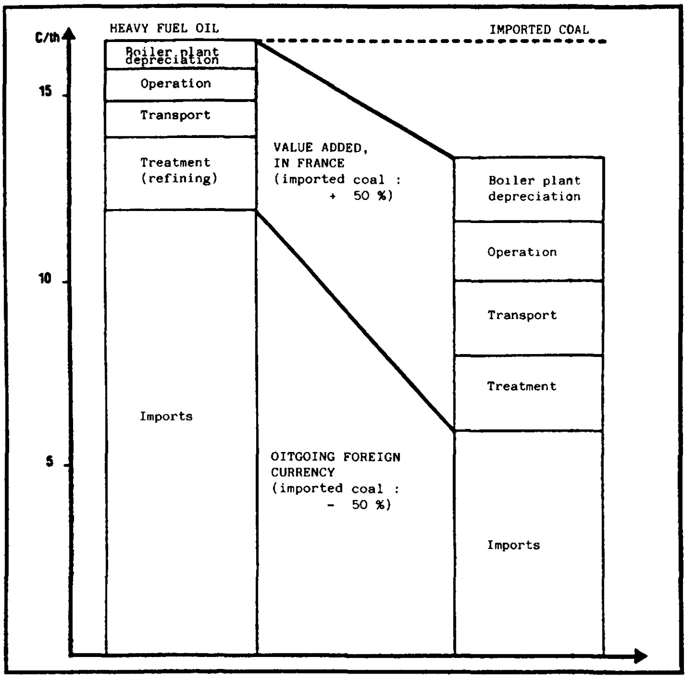

TABLE 7 - COST OF USEFUL ENERGY

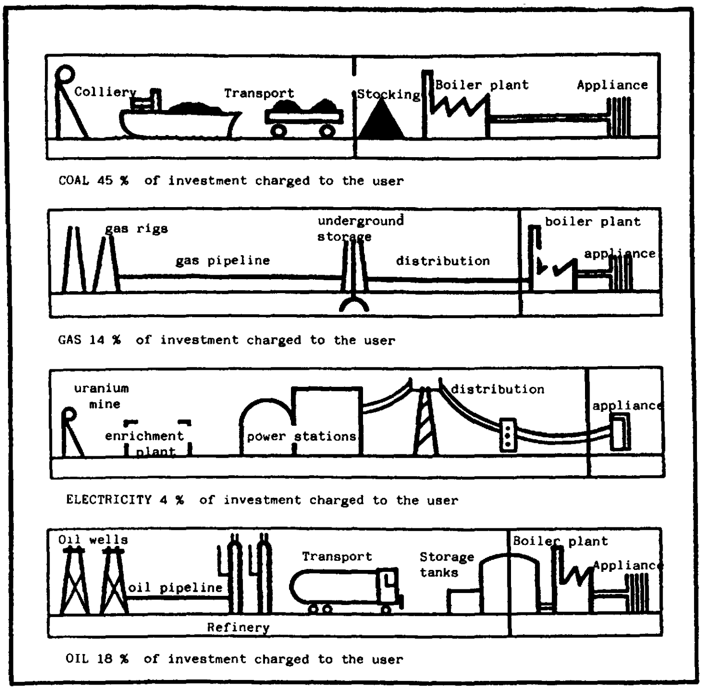

TABLE 8 - INVESTMENT IN ENERGY CHAINS

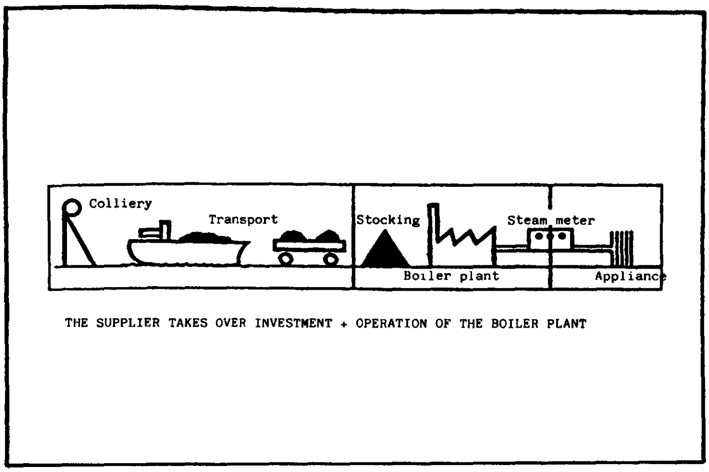

TABLE 9 - DISTRIBUTION OF COAL THERMS IN THE FORM OF STEAM

CLOSING ADDRESS

J.K. WILKINSON

Directorate-General for Energy
Commission of the European Communities

Ladies and Gentlemen,

We have now reached the end of our Conference on "Coal in the Heat Market". I believe that it has given us some encouragement by showing us a number of ways in which coal can be used cleanly and efficiently, but it has also served to indicate some directions in which further improvements can be made.

I hope that the European Community can continue to provide support for research, development and demonstration in the field of solid fuel utilization, not only to further the cause of science and technology and to contribute to the solution of our energy problems, but also to help accomplish the task of bringing the individual countries of our Community closer together. In the past two days, we have had an opportunity both to learn something and to meet old friends, as well as strike up new friendships and to establish new professional contacts.

I would like to end by thanking all those who have contributed to the conference - not only the speakers and chairmen, but also all the national contributors whose work has formed the basis of the papers that have been presented, the organizers in Berlin and my colleagues in Brussels who have helped with the planning of the conference, our interpreters and, last but certainly not least, the city of Berlin which has acted as our host, and in whose 750th anniversary celebrations we have been privileged to participate.

Finally, it is my duty to declare this conference closed. At the same time, I should like to wish you all a safe journey home, but I hope that before you set out on that journey, you will be able to participate in tomorrow morning's visit to the Berlin power and light company.

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For these reasons, the European Community symposium 'Coal in the heat market' was concerned with the technical possibilities and economic repercussions of the most up-to-date coal firing technologies and with their current and forseeable effects on the European heat market. In this context, the even more important question of environmental protection was brought to the forefront. Authoritative speakers from the coal industries, research institutes and national administrations of the European Community countries have reported on national research, development and demonstration activities in the European Community context and discussed current results.

The aim of the symposium was to open up, through this European exchange of experience, ways by which the most recent developments in coal firing technology can be transferred and most effectively applied in the future in the Community's Member States.

The present volume contains the full text of the papers presented during this symposium.

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