

EUROPEAN COMMUNITY FOR COAL AND STEEL

COMMISSION

NEW METHODS AND DEVELOPMENTS  
IN THE FIELD OF COKE PRODUCTION

Seminar  
Luxembourg, April 23-24, 1970











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Published by  
the General Directorate Dissemination of Information  
CID - Centre for Information and Documentation  
Luxembourg, January 1971

PARL. EU
N.C./L
CL EUR 4520 d,f,e

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Price : B.Fr. 700.— DM 51.20 F.Fr. 77.60 It.Lire 8 740 Fl. 50.50 US \$ 10.40 £ 6



## I N T R O D U C T I O N

Following the changes in the pattern of coal sales, these are becoming increasingly concentrated on three fields, namely, coking plants, power stations and the domestic heating market, with coking plants assuming special importance. Not only are they now the biggest consumers of coal, but there will be no substitute for coke for a long time to come in major areas, particularly in blast furnaces.

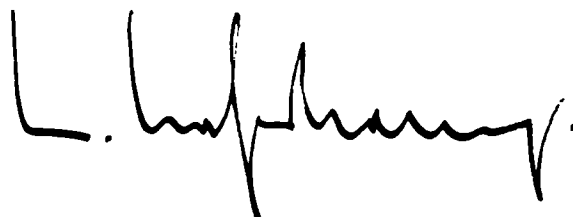
Like the former High Authority of the European Coal and Steel Community, the Commission of the European Communities is aware of the Community's need for a secure and cheap supply of coking coal and coke. This is reflected in, amongst other things, the Community Regulations aimed at facilitating the production and marketing of coking coal and coke, support for investment projects in these fields and the encouragement of research into coking plant technology.

The Commission attaches special importance to the research sponsored by it aimed at improving the technical capabilities and economics of the coking industry. It is doing its utmost to disseminate the results of this research as widely as possible to the interested parties, thereby making a further contribution to the solution of technical and economic problems in the coking business and the closely related problems of a Community coking coal and plant policy.

With this in view the Commission held a seminar in Luxembourg on 23 and 24 April 1970 on "Technology and Trends in Hard-Coal Coking", at which papers were read on the latest technical advances in this field.

The Proceedings of the seminar are herewith published for the information of interested parties.

Brussels, July 1970.

A handwritten signature in black ink, appearing to be 'L. Hafkamp', written in a cursive style.



## Introduction

As required by Article 55 of the ECSC Treaty, the High Authority and its successor the Commission have aided technical, economic and safety research in the coal and steel industries - research on coal valorization by coking being a major beneficiary.

The seminar on new methods and developments in the field of coke production that the Commission organized in Luxembourg on 23 and 24 April 1970 examined the results of several coking research programmes which have received Community support.

In the absence of Mr. Wilhelm Haferkamp, member of the Commission, the meeting was opened by Mr. F. Spaak, the Commission's Director-General for Energy. Mr. Eugène Schaus, Deputy Prime Minister of Luxembourg, welcomed participants on behalf of the host country and commented on the hopes aroused by the common energy policy of the Commission. Mr. O. Schumm, Head of the Coal Directorate in the Directorate-General for Energy, outlined the basic problems facing a common policy as regards coking coal and coking plants.

At three technical sessions - chaired respectively by Mr. K.H. Hawner, member of the Ruhrkohle AG Managing Committee, Mr. R. Cheradame, General Manager of Cerchar, and Mr. J. Ligny, General Manager of Charbonnages Monceau-Fontaine - German, French, Belgian and Italian experts submitted eleven papers on three subjects:

- (a) Increase of throughput of coke-oven plants;
- (b) Recent developments in the field of coke production;
- (c) Selection of coals of different rank for carbonization.

The papers were followed by lively discussion, rounded off by contributions based on practical and research experience.

The meeting was attended by more than 400 experts from 17 countries - coking technicians, coking-coal producers, coke consumers, equipment makers and representatives of universities, trade associations and governments.

Scientific and technical preparations for the seminar were in the hands of a drafting committee, chaired by Mr. G. Wonneerth of the Directorate-General for Energy and comprising six members of the Community's expert Coal Valorization Committee.

The material details of the seminar, including the printing of conference documents, were entrusted to a secretariat headed by Mr. L. Emringer and backed by the relevant departments of the Directorates-General for Personnel and Administration and for Information. The conference received valuable support from four national research associations, which assumed responsibility for translating the reports and discussions: Steinkohlenbergbauverein, Essen, Centre d'Etudes et de Recherches des Charbonnages de France (Cerchar), Paris, Institut National des Industries Extractives (Iniex), Liège, and the British Coke Research Association, Chesterfield.

It was not only the specialists and the Commission who attached importance to this meeting and its highly topical theme: a great deal of interest was displayed by the Luxembourg Government too. Special mention should be made of the hospitable welcome the meeting and all taking part received from the City of Luxembourg and its Mayor, Miss Colette Flesch.

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OPENING SESSION

Welcoming Speech of Mr F. SPAAK, Director-General for Energy,  
Commission of the European Communities

Speech by Mr E. SCHAUS, Deputy Prime Minister and Minister of the  
Interior of Luxembourg

Report of Mr F. SPAAK:

The Commission's energy policy and encouragement of coking technique  
research in the Community

Introductory report of Mr O. SCHUMI, Director Coal  
Directorate-General for Energy, Commission of the European Communities

Problems of a common ECSC policy in the field of coke and coking coal



Welcoming speech by Mr. Fernand Spaak, Director-General for Energy,  
Commission of the European Communities

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It gives me great pleasure to welcome you, on behalf of the Commission of the European Communities, to Luxembourg for our seminar on new methods and developments in the field of coke production.

I am particularly pleased that Mr. Schaus, Deputy Prime Minister of Luxembourg, is with us. His presence bears witness to the interest shown by the Grand Duchy of Luxembourg in the future of the Community coal industry, whose representatives have had their headquarters in Luxembourg for as long as eighteen years, enjoying a hospitality for which we are indebted to the Government of the Grand Duchy and to the City of Luxembourg.

To begin with, I have to express the regrets of Mr. Haferkamp, member of the Commission, who was prevented from attending this meeting at the last moment and has instructed me to transmit his message.

I am happy to greet the representatives of the Community's Coal Research Committee, the members of the International Commission for Coal Valorization and all the specialists from European and other countries who are present here today.

I am pleased to see so many representatives of the Community's mining and steel industries, and of the unions and trade associations.

Let me also welcome the scientists, teachers and technicians from the Grandes Ecoles, technical colleges and universities.

The presence at our meeting of so many representatives from firms making coke ovens prompts me to look forward to a useful discussion between research workers, business leaders and manufacturers of coking equipment.

I also take the opportunity to greet the gentlemen of the trade press.

I extend a particular welcome to our research workers and scientists who are going to describe, today, their research findings. I trust that these will be discussed in detail during our seminar. In this way we shall help to provide hard facts and figures for Community firms, their representatives and our young scientists and technologists, who will perhaps find they inspire new ideas.

Our two-day seminar on new methods and developments in the field of coke production is being held at a particularly propitious juncture. For several months the coking coal and coke market has been under pressure as a result of the steel industry boom. The Commission is convinced that the research undertaken on coking techniques, sometimes with its support, will soon help to mitigate these world-wide stresses.

I trust that the papers to be read today and tomorrow and the ensuing discussions will ensure that due importance is attached to the results of this research and that they receive the industrial-scale development they deserve. In the meantime, and with this hope, I formally open the seminar on new methods and developments in the field of coke production. I now have the honour of asking the Deputy Prime Minister of Luxembourg, Mr. Schaus, to address you.

Speech by Mr. Eugène Schaus,  
Deputy Prime Minister  
and Minister of the Interior of Luxembourg

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Mr. Spaak, Ladies and Gentlemen,

The Commission of the European Communities felt that a representative of the Luxembourg Government should say a few words at this opening ceremony. In the absence of the Minister of the National Economy and Power, Mr. Marcel Mart - who would have been the appropriate person - the honour of making these introductory remarks falls to me.

I shall endeavour to steer clear of economic and technical complexities. I just want to review certain general and specific aspects, to make one observation of a more or less philosophical nature and to wind up with some words of welcome.

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Your proceedings are concerned with the throughput of coke-oven plants, recent developments in the field of coke production and the selection of coking coals.

So valorization of the relevant scientific and economic achievements, with its implications for our economies, is certainly the keystone.

The terms of the problem have been clearly stated in the context of the Community of the Six.

Need I recall, in this connection, the stance adopted in the European Parliament by Mr. Haferkamp, member of the Commission, the deliberations in the European Parliament and in the ECSC Consultative Committee, the Commission's report on coking coal and coke for steelmaking and, finally, the work on launching and implementing Decision No. 1/70 of 19 December 1969, following up and amending Decision No. 1/67 of 21 February 1967.

Our economies, and more especially our iron and steel industries, require a reliable supply basis. Coking capacities have been cut back severely and are being utilized to the full. Hence the urgent call for cooperation between research workers and technicians with a view to optimum utilization of existing capacities, increasing throughput and valorizing lower-grade coals.

Despite some upward price adjustments the demand/supply situation is still in disequilibrium. The Brussels Commission singles out several major factors from among the underlying causes:

- (a) Inelasticity of supply and inadequate production reserves in the coking plants;
- (b) World-wide shortage and hence inelastic supply in non-member countries;
- (c) Hesitation in some sectors of consumption;
- (d) Inadequate supply on the labour market;
- (e) Sharp advance by iron and steel production.

As regards the remedies, this is a matter for the people in the market-place - businessmen in the main - and those with responsibilities for energy policy.

Now valuable assistance here can be furnished by the experts and economists, this being a problem of orientation, of optimum utilization of capacities and broadening the supply basis.

Your proceedings in Luxembourg - in the best ECSC tradition - are thus of special importance.

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From the Luxembourg point of view - and I readily agree to this approach being adopted - the main problem as regards metallurgical coke is the delivery of a raw material which is vital to our iron and steel industry.

I shall refer briefly to some of the relevant points.

First of all, there was Eschweiler Bergwerksverein's acquisition of the Westfalen mine in the Ruhr - a clear-cut pointer to the pattern of reinforced trading relations and supplies for ARBED.

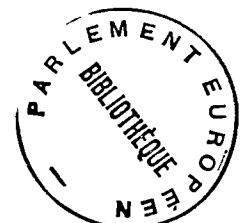
Secondly, I would mention the enormous importance attached by my country to the Community's Decision No. 1/70 of 19 December 1969 and the recent Commission communication laying down target prices for supplies from non-member countries.

It must be reiterated that legal, economic and technical factors have played a crucial role in the search for and implementation of a Community solution giving appropriate weight to the interests of the Community and to mutual rights and duties - all with due regard to the principles underlying the Paris Treaty or, if you will, the fundamental ground rules which must prevail in an integration venture.

The special location and economic situation of Luxembourg obviously force it to keep pace with all productivity advances. Transport costs - metallurgical coke inwards (over three and a half million tons in 1969) and iron and steel products outwards - are, of course, high; our coke rate is still 150 kg above the Community average; and competition is keen, given all the cost factors.

Furthermore, it is far from proved that the sellers' market is here to stay.

Then there is a technical point that will require all the attention we can give it. A month ago, the trade press featured the headline "Steel has no coke and no blast furnaces". Direct reduction is in the forefront of attention. Now that this development has begun, the problem will be restated in new terms once the process can be used on an industrial scale.



Ladies and Gentlemen,

Your seminar is sure to be marked by two features which regularly occur in high-level discussion groups. Contacts are easily established between specialists who know and appreciate each other, and free, open discussion produces the vital spark.

I hope that the capital city of Luxembourg, your host, will provide a propitious atmosphere for your proceedings, and that these will be very helpful.

Finally, there is a real likelihood that any discussion on productivity and technology - apart from revealing the close links if not kinship between the two fields - will raise the question of a postulated opposition between man and machine. Now, it is man who is at the centre of experience. Jean Rostand, discussing in 1964 a point made by Louis Armand, added: "If you do not hesitate Sir, to give voice to a resounding 'Hurrah for technology', it is because you take it for granted that human intelligence will be able to dominate the tool and ensure that it is properly used."

I am convinced that your seminar will provide further evidence of the truth of this and that your proceedings will offer guidance for the future.



Report by Mr. Fernand Spaak,  
Director-General for Energy,  
Commission of the European Communities

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The Commission's energy policy and encouragement  
of coking technique research in the Community

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Mr. Schaus, Ladies and Gentlemen,

Let me first thank the Deputy Prime Minister of Luxembourg for the remarks we have just heard. He has lent distinction to our meeting by his presence and given an excellent introduction to the matters we are to discuss, presenting them in very concrete terms. I thank him in particular for having stressed the contribution the Community can make to resolving the problems we shall be touching upon today and tomorrow.

Before introducing the major subjects of our two-day seminar, I should like to set the question of the Community's coking-coal and coke supply in the context of a common energy policy. For many years the High Authority of the European Coal and Steel Community addressed itself to improving the terms on which coal competes with other energy sources and keeping the output of Community coking coal at a satisfactory level as measured by the supply requirements of the iron and steel industry. This concern is shared by the Commission of the European Communities, which took over responsibility for formulating and implementing a common energy policy when the Executives merged in 1967. My first task here will be to discuss the reasons behind this common energy policy, its objectives and the measures involved. I shall then introduce the subjects to be discussed in this seminar.

The first question which may be asked is why a common energy policy is necessary. To answer this, we should begin by taking stock of the stage of integration reached by our economies. We find that now the common market has been achieved, not only for coal and steel but also for all our industrial and agricultural products, the next stage is establishment of an economic and

monetary union. Such an advance is hardly conceivable without a policy on energy, since ensuring that all energy users are on a comparable footing as to the utilization of energy sources and access to them is fundamental to an economic union.

Secondly, when we talk about economic union we are bound to take note of the fact that energy plays a very important role in the economy as a whole. I need hardly remind you that energy accounts for 12% of the Community's industrial investments and 18% of its import bill. In other words, energy is one of the most important segments of the economy and requires a common course of action if it is to grow.

Finally, the Six, like many other countries, are faced by acute problems of energy source substitution. Recent years have seen very rapid changes in the Community.

We import much more fuel than we export at the moment. Solid fuels have given ground - and this process is continuing - to liquid or gas fuels. And we can see the day, not too far distant, when nuclear energy will be making a fundamental contribution to our energy supply. These problems of substitution, of shifts from one form of energy to another, raise difficulties which, in an economic union, we must consider and remedy together.

On the other hand, our dependence on outside sources raises a problem of security of supply requiring an approach by the Six as a group differing from that which would have been adopted by each of our countries acting in isolation. The scale of the Community as an energy consumer introduces a new aspect as regards the security of its supply, and the existence of the common market itself has some implications for risk-spreading in the Community as a whole.

Now let me sketch out for you the objectives of the Community's energy policy.

The Commission's first memorandum suggesting guidelines for a Community energy policy was submitted to the Council at the end of 1968 and approved by the latter, at least in broad outline, at the end of 1969. In this memorandum

we set ourselves the basic objective of satisfying the interests of the consumer; in other words, we seek to reconcile, within the same approach, the requirements of assured supplies and of supply at minimum prices.

We believe that these two ideas, these two requirements of an energy policy, can be reconciled for the better satisfaction of the consumer, despite the fact that the opposition between them is stressed so often.

In reality there is no such thing as reliable supply at low cost or a low-cost supply which is reliable. Any approach that fails to recognize this will sacrifice one or other of the two advantages.

The prime objective of our policy is accordingly to find some way of reconciling reliability and low cost in the interests of the consumer. But, of course, we cannot disregard certain specific problems posed by the substitution of energy sources. I am thinking, in particular, of the coal industry, which has been changing very rapidly for several years and requires that the Commission, the entire Community, should temper the application of energy policy principles by social or regional considerations, substituting one fuel for another at an appropriately gradual pace.

And what instruments do we have to implement a common energy policy? The Community relies mainly on competition; this is only logical, for I have already said that the main objective is to serve the interests of the consumer. The Community wants to make competition the regulator in the energy field - competition not only between the various sources of energy but also within each of them, competition between enterprises and competition between the countries of the Community.

Having made this point, I must again say that energy is not completely comparable with other branches of industry. To a very large extent the fuel and power industry is akin to a public service, with all its obligations and all its constraints, in particular the constraint of reliability of supply justifying certain measures that might not perhaps be easily reconciled with the purely competitive approach. One of the Commission's concerns, for instance, is to ensure that conceivable interruptions in the supply chain can

be met without difficulty by coordinated measures at both national and Community level.

Finally, the various energy sources we count on for the future, and also at the moment, are manifestly at different stages of development, each source posing specific problems requiring public action.

I have mentioned coal, but this is also true of oil and gas - relatively new industries in the Community whose terms of competition with non-Community firms have still not gelled completely. Similarly, nuclear energy is an infant industry. It faces the problem of financing research which, we know, will eventually yield industrial developments of vital importance to us. All these specific problems, due to the different stages of development reached by our energy sources, call for a Community capability to intervene in the energy sector. The nature of the measures involved can differ very substantially, depending on how wide a range of instruments we possess. The more instruments we can use, the more substantial our means of action, the less drastic each of our measures taken in isolation. The Commission accordingly makes a point of only taking action, generally speaking, in the form of surveillance, information, encounters and discussions between Community or national authorities, between public authorities and the private sector - such as the discussions we shall be having in this seminar.

The Community would only have to resort to the traditional type of intervention in these industries where this indirect approach, this exertion of influence, this engaging in discussion between the public authorities and the interested parties, does not have the desired effect.

Such, in outline, is the common energy policy as we see it. I would now like to indicate, very briefly, the major measures which are currently being worked out, have already been the subject of decisions or are to be submitted very shortly to the decision-making bodies of the Community. I would add, if I may, that we are faced with three types of problem. The first is that of providing information on supply and demand prospects, as a guide for action by public authorities and industrialists. In this connection, I would stress the advantage to the Commission of ascertaining, as accurately as possible, the advances in technology, the developments in research, which are liable to affect

the place of the various energy sources in the overall picture we are trying to establish in view of the decisions to be taken by governments and firms.

As part of this activity, which is of vital importance for us, we also envisage studies on the reliability of supplies in order to learn more about the value to the Community of each energy source available to us, with a view to their separate development.

The second type of problem we are going to tackle relates to the establishment of the common market in general and concerns all the areas where integration must be completed if the Community is to operate effectively in the energy field. Briefly, they are the free movement of goods, the right of establishment in the Community, rules governing competition, and direct and indirect taxation.

The third facet of our activities relates to the establishment of a policy of reliable supplies at low prices. Measures here impinge on the common commercial policy. I have referred to our increasing reliance on energy imports and their role in the Community's general policy on non-member countries. We who are responsible for studying the Community's energy problems will henceforward have to address ourselves to incorporating these energy considerations into the Community's commercial policy - which became a joint responsibility on 1 January of this year and is no longer left to the discretion of the Member Governments.

Investments are the second sector in which we must act. You know the scale of investment required in this industry; you know the importance of the choices which have to be made; you know how long it takes for investment projects to mature; you know the risk of misplaced investments in this field. The Commission therefore plans to keep track of investments in all the energy sectors for which it has responsibility, so that it will be able, once again, using the most flexible possible procedure, to initiate and maintain a dialogue with those responsible for deciding on and carrying out energy investment projects, in order to familiarize them with all the decisions brought to our knowledge which are not without relevance for each of you.

The final problem is posed by the structure of the Community industry, the expansion and maintenance of certain production capacities. This is the area

I referred to just now when I discussed the rate of contraction, which had to be kept from going too fast. Here, we must concern ourselves with strengthening the supply situation in certain industries so as to maintain the competition between Community firms and their counterparts elsewhere which is among the prerequisites for our obtaining supplies at low cost. More specifically, in the coal industry the aim is to ensure adequate coordination between the steps taken to protect coal production or consumption at both national and Community level.

As you know, at the end of last year the Commission submitted to the Council a draft decision on support for production of coking coal to be coked for the iron and steel industry and on aid arrangements for intra-Community trade.

This is the type of action which can be devised at Community level. It helps maintain a degree of security of coal supplies and requires a coordination of Community and national measures if it is to have really full effect.

We are currently faced with the matter of renewing a coal-industry decision taken by the ECSC High Authority in 1965, a decision authorizing the system of subsidies granted by Member Governments to their domestic coal industries and giving them a Community character. We are studying the renewal of the decision, which expires at the end of the year. For the Commission, for the Community and for all of us, this will provide an opportunity for a fresh review of the facts governing the operation of the coal industry and coal market conditions. It will inevitably lead us to hold discussions, which we trust will be exhaustive, with the trades concerned. This area of interest is very close to us, and we are sure that today's and tomorrow's discussions will throw a very useful light on it.

So much, ladies and gentlemen, for the energy policy - the framework within which the Commission acts in matters concerning research.

Research is the subject of the last section (though it is anything but the least important) of the Commission's memorandum on energy policy. For the Commission considers that making competition the basic regulator in the energy field means that firms will have to adopt a resolutely progressive attitude with

regard to technology and that this compulsion will become stronger and stronger. The Commission considers that it is duty bound to help here, more particularly by the instruments afforded it by the Euratom Treaty for the nuclear industry and by the ECSC Treaty for coal and steel. The steps undertaken in this sector have already had some success, as our meetings will show. The Commission intends to carry on in the same vein and has four main targets:

1. Improvement of cooperation between the Community research centres, in particular by personal contacts between those with research responsibilities and research workers themselves;
2. The guidance and coordination of research by establishing medium-term programmes covering all research activities in the Community;
3. Within the framework of these medium-term programmes, financial assistance for research of special value to the Community; the Commission attaches very special importance to the potential industrial value of these projects and the extent of their contribution to attaining the objectives of the common energy policy;
4. Access of all interested parties to findings obtained with Community financial support - in other words, the widest and most effective possible dissemination of such new knowledge.

These principles have been adhered to by the European Coal and Steel Community since its establishment in 1952. This Community has, in fact, encouraged technological research - mainly by granting financial assistance, which has already exceeded an aggregate sum of \$112 million. More than \$34.5 million of this went to coal research, as against \$45.5 million for steel and ore research and \$32 million for social research.

Coal valorization has received very special attention from the High Authority and subsequently from the Commission of the European Communities. Assistance totalling 7.75 million u.a. has been provided for the implementation of five research programmes in this field.

1. To begin with, the European Coal and Steel Community helped the Centre d'études et de recherches des Charbonnages de France (Cerchar) and Klöckner,

Humboldt & Deutz with their research on the preheating of coking blends. The latter worked on developing a cyclone heat-exchanger, the former on the horizontal chamber oven. The Cerchar research, carried out on a semi-industrial scale and in the laboratory, showed that improved utilization of coke ovens reduced the cost of coke and that it was also possible to make coke from weakly caking grades. The findings should be corroborated by full-scale tests under way in twenty industrial ovens in the Hagondange (Lorraine) coking plant. The work in question is to be discussed by Mr. Foch this afternoon.

2. The second research programme on coking techniques to be backed financially by the Community was carried out by the Steinkohlenbergbauverein in Essen. This research lasted six years. Hitherto, coking technique had been developed mainly thanks to the pragmatic methods of enterprises and research in laboratories and technical institutes, the latter yielding results which are not always easy to reproduce on an industrial scale. Several thousand tons of coal were coked and all the fundamental operational, technological and raw material parameters, together with their interrelationships and interactions, were analysed and evaluated scientifically for the first time in a large number of industrial-scale experiments under the Steinkohlenbergbauverein programme. The findings are of general validity; their technical and economic importance has been acknowledged and confirmed by the mathematical description developed for the coking process. For the first time, this mathematical description makes it possible to control the coking process directly, i.e. to adjust coking conditions to the properties of the coal used and the grade of coke desired; it also makes it possible, again for the first time, to optimize the coking blend with due regard for the requirements of economy - in other words, to employ "less good" cokes with complete safety. The results have now been incorporated extensively into the coking technique, so we can confine ourselves at this meeting to clarifying some specific operating problems, to be described by Mr. Juranek tomorrow afternoon.

3. A third research programme, also carried out with ECSC aid in close cooperation with the Steinkohlenbergbauverein and Cerchar, concerns high-temperature coking. This new technique is expected to increase considerably the productivity of conventional coke-oven plants and improve their return on capital. The work is to be described by Mr. Weskamp and Mr. Beck this



afternoon. Their explanations will be amplified by Mr. Guhr's paper on the experience and industrial development of the Eschweiler Bergwerksverein.

4. The fourth group of research assignments receiving Community assistance is being carried out by the Oziol company of Saint-Etienne and by the Deutscher Braunkohlenindustrieverein of Cologne. It concerns the production of special cokes and also covers the study of raw materials and briquetting.

5. The last item here is the fundamental research being carried out, also with assistance from the European Coal and Steel Community, into the physical and chemical structure of coal and coke - the scientific basis of coking and coal chemistry applications. We cannot discuss the findings of this very wide-ranging research in our seminar, which we have had to restrict to a few main subjects with a special emphasis on practical problems.

Tomorrow morning Mr. Beck will outline future research on traditional coking technique, its objectives and the ways in which technical and economic efficiency can be increased still further.

Apart from these five Community-backed programmes Mr. Ledent, Mr. Peters and Mr. Soubrier will discuss other coking developments in their organizations. These developments are already of such importance for the mines as coal producers and for the iron and steel industry as a coke consumer that we included them readily in our agenda.

This is also true of the papers to be read by Mr. Tognana and Mr. Meltzheim, who will broach the topical question of broadening the range of coking coals used and the technical problems raised by the various imported coals.

Ladies and Gentlemen, with these brief comments I have sought to outline the Community's endeavours to promote research into coking technique and introduce you to the subject of our technical seminar. I now have to thank, on behalf of the Commission, all who have helped with the organization of this seminar. Firstly, our research workers and rapporteurs who have been prepared to summarize the outcome of their protracted research in very succinct papers;

let me refer you here to the many publications in the specialist press, on which you will find particulars in the bibliography you have been supplied with.

I would also express my special thanks to Mr. Hawner, Mr. Cheradame and Mr. Ligny, who have agreed to take the chair in our three working meetings. The responsibilities they carry in their organizations, and the reputation they have acquired beyond the frontiers of the Community, guarantee that they will preside over our discussions with authority.

Finally, I thank those who have said they will contribute to the discussions and those who will contribute spontaneously; they will be able to supplement our rapporteurs' papers by suggestions and perhaps criticism based on their own experience.

You will forgive me if I do not assess the technical papers and the speakers separately. I am sure that I can leave this to the chairmen of the technical meetings, who have all the necessary qualifications.

Ladies and Gentlemen, that is all I wished to say by way of introduction. I give the platform to Mr. Schumm, Head of the Coal Directorate in the Commission of the European Communities, who is to read the introductory paper on the Communities' coking-coal and coke supply.

Introductory report of Mister Oskar SCHUMM,  
Director "Coal" Directorate General Energy of the  
European Communities

Problems of a common ECSC policy in the field of coke and  
coking coal

Coke and coking coal are a topic of world-wide debate, and it is for this reason, among others, that the Commission has convened the present information meeting on coking techniques and trends. I am here today to give you an account of the problems of a common policy on coking coal and coking capacity from the Commission's angle. I propose first to outline the existing position in the matter, and then to indicate the elements, aims and problems of a possible common policy. As you know, the Commission and its predecessor the High Authority have devoted special attention in their coal and energy policy to these two particular items, coking coal and coke.

As Mr. Spaak mentioned just now, Decision No. 1/67 was issued by the High Authority three years ago with the primary object of enabling the coal industry, amid the then prevailing glut, to bring its prices into line with the lower prices ruling in the world market. The Decision was extended for a year at the end of 1968 by the Commission, with the unanimous consent of the Council, and expired on 31 December 1969. The Commission meantime, in the spring of 1969, submitted to the Council a study on coking coal and coke for the Community iron and steel industry, which it subsequently published for the information of the industry; the document was well received everywhere, and in the Commission's view it abundantly fulfilled its purpose of making the situation known. After lengthy negotiations in the Council, the Commission finally, on 19 December 1969, issued a further three-year decision on coking coal and coke, which I shall deal with in some detail in the course of my remarks.

You will understand if I concentrate particularly on the subject of coke for the steel industry, for coke is irreplaceable in the blast-furnace process - at present anyhow - and the amount of it that is produced depends on the coking capacity currently existing. In the blast furnace, coke is not merely a fuel: it is simultaneously a reducing agent and a sort of refractory ingredient in the burden. It is by reason of this latter property that it is so indispensable to the steel industry and offers only very limited openings for substitution.

Now to produce coke you need coking coal. As the Commission was able to show in its study, there are sufficient reserves of coking coal physically present in the world: the trouble is, they are not readily available. They have to be opened up - and coking coal is everywhere more expensive to mine than, say, steam coal. This is a very real problem, which has now become apparent to all as a result of the world-wide shortage of coking coal.

I propose to deal first with the question of coke, since in this regard the difficulties are the same whether the coal that is used to make it is indigenous or imported.

Analysis of the present state of affairs shows that nowhere in the world is there the coking capacity to supply more coke to the world market. In the whole world there is only one exporter of coke on any scale to speak of - Germany, which sells some ten million tons a year to the rest of the Community and to non-Community countries.

The Community's aggregate coking capacity today is approximately 70 million tons. This is not enough to meet present demand. The shortfall is at least two million tons, and probably more like four million: the exact figure is uncertain, since quite a number of consumers receive no coke at all and have to use substitute fuels, so that there is no way of ascertaining what the real requirements are. In the last two years the Community was so fortunate as to have substantial coking-plant stocks available: in 1968 2.9 million and in 1969 1.5 million tons were lifted from stock. Today it is living from hand to mouth.

The coke shortage is giving rise to concern in a great many quarters, and as usually happens in such cases people are asking who is to blame.

Well, fundamentally the answer is simple enough. There had been a glut since 1958, and with the benefit of hindsight we can see now that our projection methods are still not sophisticated enough for us to be able to predict coming turnrounds and accurately estimate their extent.

We had come to take the glut for granted, and to take for granted it was there to stay. As a result, the coking plants scaled down capacity from 84 million tons in 1961 to 78 million in 1966 and 70 million in 1970. This made perfectly good sense in the circumstances. Plants were closed in the first instance for economic reasons, because, quite simply, coke was not fetching a sufficient price to cover production costs and the servicing and amortization of capital investment: the owners, like good businessmen, acted accordingly and got rid of the loss-making items - that is to say, they closed the plants. Then over and above these purely economic closures there was the case of those mine-owned plants which, when the colliery concerned closed and so deprived them of their coal, naturally closed too. It is worth noting that in fact only mine-owned coking plants did close: steelworks-owned ones did not, for the steel industry realized that a steady flow of coke must be assured, glut or no glut. In any event the steelworks-owned plants are "steelworks-integrated" - that is, integral to the steel production cycle.

Regrettably, even when the market upswing and the steel boom were beginning to loom on the horizon, coking-plant closure programmes still went ahead regardless. Had some flexibility been shown then by those responsible for decision-making, had they deferred the scheduled closure of viable coking plants, we should not be facing such a difficult problem now. But they did not: for purely operational or national reasons closures once settled were duly carried out, resulting in this short- and medium-term undercapacity.

To make matters worse, while more and more mine-owned coking plants were closing, so too were more and more gasworks, which were no longer paying their way in face of the upsurge of competition from natural gas. In many cases coal-gas works have been replaced by cracking installations, which has meant that the contracting capacity of the mine-owned coking plants is called upon to meet an additional demand, that of the household sector, hitherto supplied with gas coke.

What with all these factors, in conjunction with the general market buoyancy and the boom in steel, coke is now a scarce commodity - scarce not only in the Community but everywhere. What is so extraordinary is the way the world steel boom has turned a world surplus of coking coal in a mere two years into a world shortage.

The shortage has borne less heavily on the Community steel industry than on the other coke consumers. I hope no one will mind my pointing out that so far, by and large, the steel industry's coke requirements have been met, and it is invariably the other consumer groups, and in particular private households, that have had to do without. This is especially noteworthy inasmuch as these other sectors, and in particular the household sector, have paid in the past and are prepared to go on paying a good deal more for their coke. So the coal industry has turned away customers offering it high returns and obliged them to go over to substitute fuels, and has instead given priority to supplying the steel industry even though this means lower returns. This is very much to its credit and deserves due appreciation.

There are a number of conclusions to be drawn from developments in the last three years.

First, coking must be made a paying proposition by appropriate pricing. And since secondary earnings will go on falling, that means coke prices will have to go on rising. As we showed in the report on coking coal, and as you all know, the coal/coke price ratio in the Community was until recently 1:1.3 - tonnage-wise, that is - whereas in Britain it has long been 1:1.7 and in the United States 1:1.9. That gives us a rough indication of how things will develop in Europe if the advance of natural gas continues, and gas has in effect to be aligned on the natural-gas price, and secondary earnings on the other products fall still further.

A second conclusion is this. The present coking capacity of 70 million tons is not enough to meet demand now - but all the Commission's forecasts indicate that from about 1975 onwards 70 million would be just about right for supply and demand to balance. It would not be at all desirable, therefore, to embark on any long-term expansion of coking capacity. A short-term spurt would be fine, and I shall be going on to suggest how it could be managed. But long-term capital schemes for a permanent increase would prove a misinvestment.

In 1975, according to our estimates, the Community steel industry will be consuming about 55 million tons of coke. The 1969 consumption of the other sectors came to 16.5 million tons in all - private households nine million, industry other than iron and steel 5.6 million, sundry consumers around two million. Now these other consumers have been treated downright shabbily in the last two years, by being left to go short, and in the years ahead they will react accordingly: wherever they can go over to other fuels they will, and consequently their coke requirements will, we calculate, decline steeply down to 1975. In consideration of these various factors, we reckon that from 1975 on a capacity of 70 million tons will be sufficient. All the same, this does not mean we can afford to go below 70 million. If we did, in response to some future downturn in demand, this would mean that in the event of business picking up again the Community would have no spare capacity at all to meet increased demand from the steel industry.

This brings me to the third point suggested by recent developments - namely, that every effort must be made to ensure that sound and sufficient capacity is maintained even when demand is slack. Since the steel industry will be the main consumer of coke, it will be up to the steel industry to see that coke prices fully cover the capacity costs even if the capacity is

underutilized. If it is not prepared to do this, more mine-owned coking plants will close, and the next time boom conditions set in the coke it needs simply will not be there. In other words, coke must be priced, irrespective of the degree of capacity utilization, at a level that enables the producers to recoup their costs and maintain adequate standby capacity.

The further point then arises that the extra cost of underutilization ought not to be borne entirely by the mine-owned plants. Some system will need to be arranged whereby when demand is low the extra cost of underutilization of capacity will be shared between them and the steelworks-owned plants. Why I am putting such emphasis on this is that the Commission considers the matter of vital importance for the future and is exceedingly anxious for the Community to continue in possession of a good-sized and satisfactorily operating coking economy. For one thing, all the forecasts indicate that the coke-based blast-furnace process will still be the way to produce pig-iron even in the 1980s. This was one reason why the Commission wrote into its Decision No. 70/1, which I mentioned just now, the proviso that coke must not be sold below cost, even in sales by alignment.

The view that coke will still be a major item in pig-iron production in the 1980s is obviously shared by the steel industry, for it is planning to install some seven million tons' capacity of its own by 1975. Now these seven million tons of steelworks-owned capacity ought of course to swell the total. But given the age pattern on the mine-owned side, at least another seven million tons' capacity would normally be taken out of service by reason of ageing. In addition, equally large or larger capital expenditure on renewals and replacements in the mine-owned plants will be needed to keep aggregate Community capacity up around 70 million tons at all. I said just now we should have to look for ways to achieve a short-term rise in capacity: well, here is a possibility that should be carefully gone into. For if the aggregate capacity really were increased, by building new steelworks-owned installations on the one hand and deferring the closure of obsolescent mine-owned plants for a couple of years on the other, that would be a real achievement - provided of course that the latter could be made to operate efficiently, for if they ran at a loss the collieries owning them would not



be prepared to keep them going, and would simply close them of their own accord, as was done in the past.

It is worth noting that the seven million tons of new steelworks-owned capacity is going to alter the pattern of Community coke production. The breakdown today is approximately 65% mine-owned and 30% steelworks-owned: in 1975, according to the plans, it will be 54% and 40% - that is, steelworks-owned capacity up and mine-owned capacity down.

This shift in balance is important in two ways. In the first place, the steelworks-owned plants enjoy flexibility of procurement: a steelworks-owned plant can switch coal suppliers much more easily than can a plant tied to a particular colliery. In the second place, practically all the coke consumed by the "other sectors" is furnished by the mine-owned side. This means that flexibility of supply will diminish, since as the mine-owned side contracts there will be less scope for varying production by varying the degree of capacity utilization.

The extensions on the steelworks-owned side show the importance the steel industry attaches to coke. New coking plants, in consequence of the higher capital costs, operate with higher servicing charges and higher depreciation rates: that is to say, new plants have higher conversion costs than older ones where depreciation is already well advanced or which were built at a time when capital goods and capital itself were cheaper.

Building new coking capacity is astronomically expensive, and finding the money is a problem. It is a problem the Commission is well aware of, which is why some little time ago it took the decision, in accordance with Article 54 of the ECSC Treaty (concerning the financing of investment), to grant interest subsidies - subsidies enabling capital loans to be made at reduced interest - in favour of projects for the installation of coking plants. A far-reaching decision, ladies and gentlemen, and one which clearly demonstrates how much the Commission has the Community's coke supplies at heart. For to grant interest subsidies on behalf of a specific industry raises complications as to competition, which the Commission had no wish to do.

There is one more thing I would like to say on this matter of financing. I do not address it directly to the coal industry, nor to the steel industry either. It is this: from all I have seen of the two industries' balance sheets I personally consider it very much easier for the steel industry to find the money to build coking plants than for the coal industry. I will say no more on this count. Just you read the company reports and you will certainly feel the same as I do.

The Commission regards it as important that future coking plants should be steelworks-integrated. Wherever coal and steel are produced in proximity, this is no problem: it is just a matter of organization. According to press accounts they have already realized this in the Saar and are trying to work out new arrangements for cooperation or joint running of coking plants. To my mind this approach offers real openings for achieving optimum utilization of by-products.

One last observation on depreciation periods. Reference was made in the report on coking coal to the difficulties arising out of the fact that coking plants were not paying their way, and that it was hard to plan any extensions when there was no knowing whether the installations would ever be fully amortized. To this I would add that what counts is where the coking plant is installed: for a steelworks-integrated plant with the advantage of flexibility in the procurement of its coal the position is very different from that of a plant integrated with a particular colliery.

To sum up my remarks on the coking-capacity aspect, we need coking plants at whatever cost. Incidentally, if the researchers manage to get the coking time down, that will be a great thing in itself; the Commission has been, and will go on, giving the coking sector priority for research grants.

I now turn to the subject of coking coal.

With regard to coking coal the situation is not so pressing. We stated in our report on the subject that there were sufficient reserves of coking coal in the world, and came in for a certain amount of criticism for saying so. But I think it is still a fact nevertheless. Only the coal is not get-at-able: it needs to be opened up, and that takes time. For years to come, supply will not match demand. One important factor here is the huge demand from Japan, which has started a race for coking coal in the world market. And the Community will need to consider how it can enter the race too, and where it lies among the runners.

I think the implications of the coking-coal position today require to be very carefully considered. It must be frankly admitted that mistakes were made in the past. As I say, we assumed far too readily that the glut which had prevailed since 1958 would prevail for ever. As late as 1967 it was still with us, and the High Authority's Decision No. 1/67 was intended first and foremost to enable the coal industry, saddled as it was with ever-growing pithead stocks, to bring its prices down to the ruling world-market level, as it had no choice but to do if it was to continue selling to the steel industry at all. This had the effect of freezing prices, and perhaps - another point that needs to be made today - perhaps in view of the glut Decision No. 1/67 did not give the steel industry pause for thought as it ought to have done; perhaps in view of the glut the steelmakers did not recognize that they would do well even so to conclude long-term contracts with Community as well as with non-Community producers. By the same token, by 1968 if not earlier the subsidized Community coal was cheaper, thanks to the price freeze, than the coal that could have been procured in the world market by new contracts. This too may have contributed to the steel industry's failure to look sufficiently far ahead.

It was a good thing we had those pithead stocks in 1967. Since then, more than thirty million tons coal equivalent of coal and coke have been taken from stock. If the stocks had not been there, the steel that is in such demand in the market could not have been produced. And the moral of that is that the Community ought to mine sufficient coking coal of its own, for unless it does there will not - given the pattern of coke production - be enough coke for the steel industry to meet its export demand. And here too of course the same old question is being asked, Whose fault is it that so many collieries have been closed? For practically throughout the press it is now being contended that far too many collieries have closed.

Well, ladies and gentlemen, we have got to be realistic about this. In a free-market economy, where supply and demand, and business efficiency,

are the deciding factors for every firm, there is no place for those that sell poorly and keep on running up losses. In the coal industry things are basically not so very different. Sooner or later pits that get left with unsold coal and are constantly in the red are doomed; they can carry on so long as the Treasury helps out with subsidies, but when the burden becomes too great the decision is taken to discontinue the subsidy, and that means closure.

So as regards who is to blame, the fact of the matter is that, what with the low price coal was fetching in the world market and the high production costs of Community coal, to say nothing of the glut as a result of which pit-head stocks were mounting by several million tons a year, economically speaking there was nothing for it but to close the collieries. We are paying today for any lack of foresight we may have shown, for now the demand for coking coal can barely be met by indigenous production and imports together.

Actually a good deal of coking coal is mined in the Community. Most of it is produced at a loss. It was for this reason that the Commission issued Decision No. 70/1, to maintain an adequate level of indigenous production. The Decision, as you know, permits the payment of production subsidies for three years; it also provides for degressive sales aids in respect of long-distance and intra-Community shipments, to be jointly financed by the countries of destination and by ECSC contributions out of its own funds.

The great point about the Decision, as the Commission sees it, is contained in its preamble. While the Decision itself has to do with the details of subsidization, the primary purpose in issuing it was to make it easier for the producers and consumers concerned to take the necessary steps during those three years to get things organized so that the iron and steel industry should bear the cost involved in keeping it supplied with coke, either

- (a) by buying Community coal at a price sufficient to pay for the maintenance of production at the necessary level (in effect, paying a "security premium"), or
- (b) by having increased recourse to the world market for so long as the system of aids was in force (which would mean enterprises replanning their procurement policy).

The Decision does not mince matters: the steel industry is the biggest consumer of coking coal and coke and has a responsibility as such. The Decision sets out to face the steel industry squarely with its problems; at the same time it contains a message for the coal industry as well.

For alas, coal is not behaving in accordance with rational market considerations either. From the way price bargaining is going in all the Community countries it is obvious that the coal side ought to be taking a much robuster line and not granting any and every rebate it is asked for. It needs to be told bluntly that there is no possible object in trying to hold on to untenable positions by making uneconomic price concessions: that way lies disaster.

At the same time the Governments need also to be told, equally bluntly, that they have no business to arrogate to themselves pricing powers which the ECSC Treaty denies them. Any market intervention for the purpose of tinkering with the market price - and the market price for coking coal today is quite manifestly the price charged under long-term contracts in the world market - results in distortion and in discriminations between consumer and consumer. The object of Decision No. 70/1 is to prevent discrimination between the different steel industries in the Community. And that requires that the true world-market prices should be paid in every Community country.

The proper play of supply and demand, in the Commission's view, requires two things. First, the steel industry must be able to import freely, without restrictions of any kind; only so can the Governments avoid the charge that had it not been for their import restrictions the steel industry would have chosen to act differently. Secondly, no price concessions must be made that are not justified by the state of the market. There will be less danger of this if the steel industry's procurements are a combination of indigenous and imported coal, and if the true price of non-Community coal can be determined on the spot on the basis of fresh long-term contracts.

Now to determine the true price you have to have objective quality criteria. As you are aware, Decision No. 70/1 empowers the Commission to issue quality criteria. These are currently being discussed with the experts; strenuous objections are being raised by both the coal and the steel sector to the idea of uniform guidelines, and in particular to assessment of the coking properties of coal.

Frankly, I do not see why. Practically all the import contracts I know contain particulars as to the coke button or the swelling index; at any rate the quality of the coal is clearly specified in pretty well every contract. The fact that coal of poorer quality than that contracted for is now being delivered, and prices altered, is neither here nor there: nobody has yet got me to believe that uniform quality guidelines are a new departure. The whole thing is as old as the hills. The Commission intends to pursue the matter further.

Next, the question of security of supply. Given the present pattern of coke production, the Commission's studies indicate that should the Community fail to produce an annual 50-60 million tons of coking coal in the coming years it will not be possible to make up the deficiency from the world market. So obviously we have simply got to mine our own, cost what it may: those 50-60 million tons are an essential part of the steel industry's supply. Never mind the fact that as more collieries close - and they are still scheduled to go on closing in all the Community countries except Germany - the proportion of imported coal will go up. Those seven million tons of new steelworks-owned coking capacity I mentioned just now - well, if we take it these plants are going to operate with imported coal (mind you, coal is not just conjured up overnight in the world market: it is a long and probably costly business getting hold of it), then I suppose the share of imported coking coal would increase by the amount of their input, say ten million tons.

I do not think this poses any problem for the Community coal industry: after all, world-market prices at present, unlike Community prices, are governed by supply and demand. Extra demand would in all probability have a stabilizing effect on them, and a stabilizing of world-market prices would almost certainly benefit Community coal too.

One important aspect of the security question is how far consumers are able to assess for themselves the extent of their own security risk. On this I have a special point to make to the steel industry.

I think the steel industry is the only big coal consumer that is able to form a really accurate assessment of its security problem. I think this by reason, more especially, of the way it has acted in the matter of its ore supply. It has coped superbly, undertaking capital projects on its own account in all parts of the world, and pursuing a vigorous storage and stockpiling policy. There could be no better example of how an industry ought to go about tackling security of supply. And I cannot see why it should be any different with the supply of coal. I do feel that the steel industry, influenced like all the rest of us by the glut in the past, has not taken the necessary steps to safeguard the flow of coal as well as the flow of ore. But I am very hopeful, for I have the impression it has been rethinking the matter, and it really does look as though before long we shall be seeing some new and constructive action taken. I realize it will take the combined efforts of all concerned - coal as well as steel - to get this business of the steel industry's security of supply properly settled.

Mr. Schaus in his very interesting speech referred to the Eschweiler Bergwerksverein - that is, the ARBED group. It is worth noting that there is one big steel concern in Europe today that has fixed itself up with a supply of Community coal and no other. A particularly striking point about

this is that the steel plants in question are the ones with the highest specific consumption of coke, because they use ore with a very low iron content; also, the collieries and coking plants are a very long way from the blast furnaces and steelworks, so that the products have to be carried a great distance to the coast. To my mind this is confirmation that there are quite a number of top steel men who are thinking hard about this whole problem, and I really do have great hopes that quite soon it will have been fully overcome. The Commission for its part will do all in its power to help.

Two further points. First, still on this question of security of supply, it seems to me important that the steel industry should not confine itself to signing long-term contracts with non-Community suppliers: it should conclude similar contracts with Community suppliers too, allowing the possibility of adjusting prices just as is the normal practice today in the world market. It was with this in mind, incidentally, that the Commission made its authorization of Ruhrkohle AG conditional on Ruhrkohle's undertaking for a period of two years to give all steel companies wishing to conclude long-term contracts with it the option of doing so.

Secondly, and self-evidently, long-term contracts are pretty pointless unless they fix definite tonnages. In this respect I think the steel industry has a good deal to make amends for, and the coal industry a good deal to learn from past mistakes. A contract that allows huge margins above and below the figure actually referred to obliges the supplier to furnish any tonnage up to the upper limit, but does not oblige the purchaser to take anything over the lower limit. But without fixed tonnages to calculate from, the coal industry cannot do any proper production and sales planning. What is more, the whole brunt of business fluctuations, and the whole risk of them, has to be borne by the coal industry alone. So the coal industry should make it a rule to



contract for specified tonnages only, thereby settling the question of buyer's as well as seller's obligation.

The further problem remains of how in future we are to ensure flexibility of response to fluctuations in demand, and how the impact of these can be cushioned.

As is quite obvious from the present state of affairs, it is no use thinking the cushioning can be done by importing. No world-market exporter is prepared nowadays to supply coal unless he is offered a long-term contract: to look to the world market for coverage of peak requirements is hopeless. Nor is exporting the answer. Sad to state, the Community coal industry has done itself a disservice by failing to honour export orders, which will pretty certainly lose it some customers if and when business does take a turn for the better. So there is no prospect of achieving flexibility by simply, in the event of an upturn in demand, leaving exports unmet and cutting down that way. In effect, then, all that is left as a means to flexibility is stock variation. That is not to say, though, that the stocks must be piled and held by the coal industry and nobody else. What is needed is that the steel industry too should pursue a judicious stockpiling policy enabling it to take the initial impact of demand fluctuations itself. It would repay study, and I dare say we shall be making such a study some time, to see how this aspect is being handled in the case of ore, and what the average level of buffer stocks of ore may be. This would provide pointers as to what stocks of coal and coke the steel industry might reasonably be expected to maintain.

Well, ladies and gentlemen, that brings me to the end of my remarks. As I have told you, the High Authority and the Commission have done quite a number of things. First came Decision No. 1/67, aimed at enabling the coal industry as far as possible to go on selling to the steel industry in the teeth of the glut and the outrageously low prices in the world market. Next, the Commission set out to brief the business circles concerned on world developments, by publishing its study on coking coal and coke for the iron and steel industry. After that, it issued Decision No. 70/1, a set of financial provisions which was at the same time a plea to the coal and steel industries to rethink their supply

arrangements: that, as I see it, was the great point and value of the Decision, whose implications went far beyond the field of finance. And lastly, invoking Article 54 of the ECSC Treaty, the Commission decided to grant interest subsidies to encourage the installation of coking capacity - a most unusual measure, the importance of which cannot be sufficiently emphasized.

In addition, coking has been and will be given priority rating in the Commission's research spending. That is a matter for further discussion on its own account.

The Commission plans to continue working to keep the industries concerned better posted on what is going on. It will be systematically assembling all relevant particulars and publishing them at intervals. The coal and steel enterprises represented here today are urged to forward information in their possession to the Commission, so as to ensure that the intelligence the Commission in its turn provides is as comprehensive as possible.

One last word. There are quite a string of things I have begged that the steel industry will do about its supply arrangements. Now I would like to beg that the coal industry will do everything it possibly can to make itself more economic.

The crucial element for the future of coal, it seems to me, is pricing and the security premium. The question is who is to pay that premium. Unless it is paid, there can be no possibility, even with world-market prices at their present level, of mining sufficient coking coal within the Community. I repeat, this is crucial.

Much will also hinge on the Governments' willingness, in accordance with a common energy and coal policy, to engage on coal's behalf, along with the Commission - taking due account of the interests of the consumers, more especially the iron and steel industry - in some kind of concerted push to get the business circles concerned to work out carefully what steps need to be taken, and then take them with vigour, in order to deal with these pressing problems, to my mind so vital to the good of the Community.

Discussion  
Mr. S. Bobbio

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Mr. Chairman, Ladies and Gentlemen,

First of all I should like to thank Mr. Schumm who, with authority and skill, has given us a fully detailed picture of the situation of the coal and coke market.

A number of comments could be made concerning what Mr. Schumm has told us, but the time available is very short and therefore I shall confine my remarks, those of an old cokeman profoundly interested in his profession, to a single point: the future role of coke and to what extent there are justified grounds for all cokeworkers to look forward with confidence to the future in each particular case; in other words, can we still, today, believe in the future of coke?

The discussion in our meetings mainly relates to the use of coke in the iron and steel industry, inasmuch as this is undoubtedly its largest user.

As we all know, the preparation of charges, preheating the blast to higher temperatures, its enrichment with oxygen, and the use of auxiliary fuels (natural gas, fuel oil) have within recent years allowed the specific consumption of blast furnace coke to be greatly reduced.

It therefore seems necessary to revise the traditional concepts of the role of coke in the blast furnace process and to consider it largely as a chemical reducing agent, to the extent that the thermal energy needed for the process can, in the limiting case, be supplied wholly by other combustible materials.

What will the influence of this fall in the specific coke consumption be on the future of coke in the iron and steel industry?

At the moment the world production of pig iron is estimated at around 390 tons/year.

Assuming an average consumption of 600 kg of coke per ton of pig iron,

the blast furnace coke requirement thus works out at about 234 million tons per annum.

By 1980 the average specific coke consumption is expected to fall to 470-510 kg, but at the same time the world production of pig iron will go up to 580-600 million tons. If we postulate a probable average coke consumption of 490 kg, the blast furnace coke requirement comes out at 285-295 million tons per year, a 22-26% increase on today's figure.

For the next ten years at least, it does not look as though the direct reduction of iron ore will have any appreciable repercussions on steel production in competition with the blast furnace, since the process does not yield pig iron and steel but only sponge iron which then has to be remelted in electric furnaces or used for enriching blast furnace charges, in similar fashion to the use of ordinary scrap. A reliable estimate puts the contribution of direct reduction at only 3.5% of the steel production forecast for 1980.

The conclusion, therefore, is that at least in the field of iron- and steelmaking, even though coke is progressively relinquishing its role as the energy medium and assuming more the specific role of a reducing agent, there is no immediate cause for concern as regards the sale of coke. Hence cokeworks should pay great attention to current research designed to improve productivity, in order to be able to face up to the greater task in store for them.

Moreover, they should not disregard those processes that enable coals of low grade and poor coking properties to be used, those for example that can be used for producing preformed coke.

The problem of the future of coke is much more complicated for the independent cokeworks, not directly associated with the iron and steel industry or other important coke-consuming industrial sectors and not part of the iron and steel industry itself.

Not much is said about the independent cokeworks because, compared with those in the coal and iron and steel industries they count for relatively little in the overall world economy. But they nevertheless remain a far from negligible work force and have their own clearly defined and important role in the development of many industries which rely on the output from the independent cokeworks for their coke requirements.

Independent cokeworks, even more than those in the iron and steel industry, should keep clearly in mind that coke can no longer be considered as a fuel but as a raw material indispensable in certain industrial processes because of its chemical and physical properties.

Their development or survival programmes should therefore no longer count on the use of coke for domestic heating or on those industrial uses where coke has largely a thermal role, as in cement works for example, reverberatory furnaces, etc. The cost of coke is too high compared with that of other fuels, and it is therefore natural that modern technologies should tend to do without coke as far as possible.

There are, in any case, many sectors of industry where coke has a special role that makes or will make it indispensable at least for a good number of years.

The first of these is the melting of pig iron in the cupola furnace, where the coke, apart from its mainly thermal role, also performs tasks of a mechanical, physical and chemical nature to which the progress of the process is linked.

Attempts have been made for many years to replace coke in whole or in part by other fuels in iron foundries, but with little success.

According to a reliable American journal 80% of the castings produced in the United States in 1980 will still come from traditional coke cupolas, and the problem is not so much whether cupola furnaces will use coke but whether the cokeworks specialized in producing cupola coke will be in a position to supply all the coke that the U.S.A. foundries will require.

This quantity will reach no less than 4 million tons per annum to produce 21 million tons of finished castings, an increase of about 25% over 1968.

In 1968 the production of cast iron in Western European countries exceeded 13 million tons. Applying the same increase as that forecast for the United States this figure could go up to 16 million tons in 1980, calling for an annual cupola coke consumption of over 3 million tons.

Higher increases still may be realized in Eastern countries and in developing countries, and overall there is no risk whatever in forecasting a world demand for cupola coke of well above 10 million tons in 1980.

In view of the special lump and mechanical strength characteristics that this coke has to satisfy, it can only be produced by specialized cokerworks with the right sort of plant and not subject to other production restraints as to quantity and quality.

It is clear that cupola coke can, in practice, only be produced by independent cokerworks.

Another field in which the prospects for the use of coke seem favorable is that of non-ferrous metals (lead, zinc, copper, etc.). These metals are partly obtained by electrolytic methods (particularly copper and zinc) and partly by thermal methods. The most important thermal processes use coke, generally in 60-80 mm lumps. Large quantities of coke fines are also required for briquetting.

Unfortunately, no reliable statistical data are available in this field because of the alternation of the processes used. In the single case of lead, largely obtained by thermal means, the 3 million tons produced in 1968 by ore reduction correspond to about 750,000 tons of 60-80 mm coke consumed. If the growth in output over the next ten years is the same as that over the last decade, the lead produced in 1980 by thermal ore reduction is going to reach 4 million tons, equivalent to a consumption of about 1 million tons of 60-80 mm coke.

It is improbable, to say the least, that iron and steel cokeworks will be able to make any coke available to the non-ferrous metal industries in the next few years. It will remain, therefore, the task of the independent coke works to supply these needs.

The third very important industrial sector with excellent coke consumption prospects is that of iron alloys. This sector is in full development and has grown considerably in recent years. Practically all alloying processes take place in electrical furnaces, where the power required can be introduced from the outside in the form of electrical energy, carbon being used as the reducing agent. In practice, this carbon is introduced into the furnace in the form of coal or coke, which must, however, satisfy certain purity, reactivity, and electrical conductivity specifications.

The ideal raw material for this process is undoubtedly wood charcoal, but this product is becoming more and more rare and costly. For this reason iron alloy manufacturers have tried for some time to replace it by gasworks coke, but this in turn began to disappear from the market. This chain of events has obliged the iron alloy industry to fall back on the independent cokeworks for their carbon requirements, and some of these have managed to produce special types of coke that are perfectly suited to the purpose.

Here again reliable statistical data are not available because of the varieties of carbon that are used, although it is certain that this is a strongly developing sector likely to lean more and more towards the use of coke.

It would be a safe guess, therefore, to expect the demand for coke for the electrometallurgical industry to reach a few million tons per annum in the next few years.

Lastly, appreciable quantities of coke are required by many other industrial sectors.

Let me just mention the chemical industry (production of calcium carbide, lime, dolomite, phosphorus, carbon dioxide), the refractories and electrodes

industry (artificial graphite), many metal engineering and building sectors, etc.

In 1967 about 25% of the world's production of coke was sold outside the iron and steel industry.

In the years to come this percentage is going to fall, because coke will be up against the competition of other fuels in the industry itself, but it should be borne in mind that in the meantime many important sectors where coke will continue to be used will develop considerably.

What is more, gas coke production will stop completely and the iron and steel industry will no longer have any surplus coke even in small sizes, inasmuch as the 10-40 mm will be used in the blast furnace and the 0-10 mm fines will be used in briquetting plant.

It should not be forgotten that the iron and steel industry itself might, under certain circumstances, fall back on the independent cokeworks to make up their coke needs.

It would seem reasonable to conclude, therefore, that there are no justified grounds for anxiety, even for the independent cokeworks, as regards the future prospects of selling the coke produced. But there are some important factors that independent cokeworks should bear in mind, in particular the following:

- the need to specialize in the production of quality coke;
- the suitability of the plant for receiving the coal and making, preparing, and despatching the coke;
- reaching an optimum capacity, covering production costs;
- close study of geographic relationships both as regards the sources of coal supplies and the centres of coke consumption.

It would thus be wise for the independent cokeworks too not to lose sight of modern coking processes, as they may find themselves faced with increasing difficulties in securing supplies of good coal suitable for coking by the traditional method in vertical coke ovens.



K. Heller

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I believe that no general analysis of the coke situation can be made today without mentioning the problem of environmental hygiene and working conditions. This problem will influence coke-oven technique and economics to an increasing degree in the next few years, possibly to such an extent that the present-day coking process will not even be defensible any longer. The development of alternative coking processes such as are being discussed today and tomorrow therefore has an urgency which unfortunately is still too little comprehended in the industry - else the problem would have been mentioned in the opening session at least.

I would therefore like to put this problem most urgently before the industry and the Commission once again here. Much more must be done in this field in the next few years and a lot of money is required!

M. Peeters

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I would like to thank M. Spaak and M. Schumm cordially for the very clear accounts they have presented, with which I am entirely in agreement.

The coverage of energy needs in the course of the next few years is a problem of primordial importance, as M. Spaak has emphasised. According to the information published by the Commission the demand will reach the equivalent of 1100 million tonnes of coal by 1980. How is this demand going to be satisfied? It is vital to fix from now on the production level that must be maintained in the Community.

M. Schumm has brought to the fore the problem of supplying the steel industry with coking coal and its seriousness. The Commission has allowed a three-year delay to interested parties in order for them to agree on the amounts to be supplied. The speaker estimates that this delay is far too long and that the users, particularly the steel industry, will have to take up a position in the shortest possible time if they still want to obtain Community coal.

The regression in coal production is caused not only by the setting in motion of a shut-down scheme formulated by the governments but also by other reasons.

In certain coalfields the average age of the workers is 40 and recruitment is forbidden. These mines have only a short time left.

More than that, the governments refuse to continue to pay important subsidies.

Under these conditions, as M. Schumm has said, the steel industry must declare that it is willing to pay a price substantial enough to cover the cost price.

The main objective of the speaker's contribution is to draw attention to the seriousness of the problem and the need for taking up a position without delay. The producers are willing to pull out all the stops in order to assure supply under the best conditions. They are waiting for a precise reply.

M. Guillon

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I would like to thank and congratulate M. Spaak and M. Schumm for their brilliant reports so perfectly documented, and I would like to call attention to a particular aspect of the American coal consumption.

As a result of the application in the U.S.A. of air-pollution measures, the majority of the American power stations and coal-using industries are having to use coals with a sulphur content of less than 1%. However, the production of coal in this category represents only 38% of the national production. From around 500 million tonnes, the available production is thus reduced to 180 millions, of which an important part corresponds to the coals used so far by the coking plants, which seriously modifies the designs one may have on American coking coals, this situation necessarily leading to a certain restriction on the amount available for export.

M. Spiers

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From the article published in "Business Week" on April 18, 1970 under the title "Why coal users are turning gray" it is obvious that the present and temporary dearth of American coals is due principally to a halt to investment in new operations in the years 66/67, this being due to the optimistic predictions of the producers of electricity concerning the coming into operation of nuclear power stations.

Unfortunately the forecasts were not realised and the electricity producers have to fall back "in confusion" on coal.

Since then strong pressure, has been put upon the authorities in general and the White House in particular, in order to obtain a ban on exports.

And according to Alex Radin, Secretary General to the APPA - American Public Power Association - the presidency would have reacted positively.

On the other hand, the APPA is now concerned with the subject of existing and unexploited coal deposits and considers that in view of the important holdings of the petroleum companies in the coal-producing firms these could retard if not arrest exploitation.

On the same subject, the Department of Justice has been asked if the policy followed by these same petroleum groups, leading to control first of prices and then of exploitation, is not likely to violate the famous "anti-trust" law.

M. Demain

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1. What is the significance of the measure taken by the Community to fix the target prices?
2. What are the means available for fixing these target prices?
3. How does the Community intend to proceed in order to maintain realistic target prices?
4. To what degree does the Community intend to respect them?

M. Schumm

I would like to reply to Mr DEMAIN as follows:

1. The Commission has not so far notified any target price.
2. Article 47 of the Treaty allows the Commission to collect all necessary information. For this purpose and in pursuance of Article 47 the Commission has addressed a request to all enterprises in the steel and mining industries to supply the Commission with full details of current import contracts.
3. By the supply of regular information to the Commission about contracts that are concluded.
4. The Treaty provides the Commission with every facility for ensuring that the Commission's notifications and decisions are respected.

For greater clarity I would like to add the following comments to the answer to this question.

The problem of a target cif price is, as you know, an extremely sensitive question. For this reason the Commission began by building up a picture of terms and conditions in which the steel industry is supplied with imported coal at the present time.

On the basis of this information the Commission then issued a notification to the mining enterprises couched in the following terms:

"At the moment coking coal is supplied to the Community's steel industry from free trading countries, i.e. excluding countries whose trade is a government function, at terms working out at an average cif price ARA\* ports of \$ 17.50 per metric ton for coking coal of average quality for the Community as a whole. There are upward and downward variations on this figure, depending on the date of signing of the import contract. Secondly, member countries use different import systems for the import of coking coal from other countries, so that the steel industry's supply conditions vary in individual countries within the Community. Given these facts and in view of the uncertainties currently clouding future long-term coking coal supply conditions on the world market, the Commission regards a price of \$ 17.00 per ton cif ARA ports for contracts lasting at least two years as a lower limit. Any undercutting of this price in the guise of a pretended "alignment" will be regarded by the Commission as a breach of Article 3 of Decision No. 70/1".

The notification also gives details of the quality to which this minimum price of \$ 17.00 applies. This is followed by a section that unfortunately has not been read or insufficiently absorbed by those receiving the notification. It reads as follows: "The Commission wishes to make it absolutely clear that this price of \$ 17.00 per ton is intended neither to fix nor to recommend a price level for alignment deals in accordance with Article 3 of Decision No. 70/1. On the contrary, it is up to the mining enterprises to agree higher alignment prices as the market situation and prevailing trading conditions require".

In other words, this means that the mining enterprises remain completely free to grant alignment discounts for the steel industry only insofar as the market situation in the individual cases demands it.

Ladies and gentlemen, the Commission's notification does not say that a target cif price has been laid down. On the contrary, it gives an impression of how the community's steel industry was buying supplies at the moment of the publication of this notification. The Commission intends to amend this notification at regular intervals on the basis of information on new contracts.

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\* Translator's note: Abbreviation unfamiliar



FIRST WORKING SESSION

A. PRODUCTIVITY INCREASE OF THE COKE OVENS

Chairman: Mr K.H. HAWNER

Member of the Board of Directors of Ruhrkohle A.G. Essen  
Chairman of the Board of Directors of Steinkohlen-  
bergbauverein, Essen

1. Mr P. FOCH

"Preheating of Coke Blends"

Graduate of the Ecole Polytechnique  
at first: Engineer with the Compagnie Générale de  
Construction de Fours;  
later, Manager of the Expérimental Station of Marienau  
and, since 1966, Chief Engineer, Laboratoire de  
Verneuil-en-Halatte du CERCHAR

2. Messrs W. WESKAMP and K.G. BECK

"Productivity Increase of the Coke Oven Batteries"

Mr W. WESKAMP: Engineer Metallurgist (Doctor Engineer)  
Since 1957, Manager of the Experimental Coke Ovens  
of Steinkohlenbergbauverein, Essen

3. Mr G. GUHR

"Operational Experiences in the Field of Productivity Increase  
of the Coke Ovens by Means of Increased Temperatures"

Qualified Engineer, Metallurgy of Ferrous Metals  
Since 1957, Manager of the Cokery Anna of the  
"Eschweiler Bergwerksverein"

4. Mr W. SIMONIS

"High Temperature Carbonization of Loose Charges in the  
Conventional Oven with Regard to Reaction Dependent on  
Temperature and Time"

Chemistry Graduate, Doctor ès Natural Sciences  
Since 1965, Section Chief<sup>1</sup> Control of Quality and  
Output, Steinkohlenbergbauverein  
and Charged with Lecturing on Technics of Preparation  
and Valorization at the Technical University of Berlin





M. Hawner

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Ladies and gentlemen,

This afternoon's papers fall under the heading "Increasing the output of cokeworks". For many reasons this subject has today a very special significance. To begin with, the capacity of existing plant is hardly adequate to cover the coke requirements in full, and secondly, the continual increase in operating and building costs forces us to consider how improvements can be made to productivity both in the existing batteries and especially, of course, where the inevitable new buildings and basic repairs are concerned.

It was only a short while ago that the development of the coking technique seemed to have come to a halt, at least to a certain extent and the coking of pit coal seemed condemned to a technologically stagnant sub-area of processing technique.

Happily, all this has completely changed in the last few years. Suggestions from the coking concerns, theoretical research, and practical development work by various institutes in European and other countries have all combined to open up new ways of improving the efficiency of horizontal coke ovens.

From a large number of research and development projects the following principal ways of increasing production have crystallized out:

1. Predrying and preheating the coking coal.
2. The use of higher operating temperatures.
3. The use of compressed silica material.
4. Reducing the wall thickness of coke ovens.
5. The use of refractories with better heat conductivity.

Some of these possibilities can be used in combination. The increases in output possible, at least in theory, with these methods are so astonishing that continuation of these successful development projects is to be earnestly desired, in order to make the results usable in practice as quickly as possible

In this, and taking the conventional coking technique as an example, it is clear how important is the collaboration between the cokeworks, the engineering firms, and research in order to solve problems, in which all concerned are equally interested, in a spirit of real cooperation. We are happy to be able to say at this point how unreservedly the European Communities Commission has supported these developments in every aspect right from the start, and to point to the positive results to which this involvement has already led -- and, by the looks of the present situation -- will lead in the near future.

Now for the papers themselves.

In the first paper Monsieur Foch will be giving us an account of "The preheating of coking coal". Up to 1966 Monsieur Foch was the Director of the Marienau Test Centre operated jointly by the Centre d'Etudes et Recherches des Charbonnages de France (CERCHAR) and the Institut des Recherches de la Sidérurgie (IRSID), and is now the Chief Engineer at CERCHAR. As you know, he has worked for a number of years on the preheating of coking coal and has already published part of the results he has obtained. One publication that is surely known to all of us is the summary of the results on the charging of coke ovens with preheated coal, which appeared in 1965 in the research journal of the Hohe Behörd.

I would now like to ask Monsieur Foch to present his paper.

PREHEATING OF COKE BLENDS

P. Foch, Research Centre, Charbonnages de France

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I propose to describe to you the present state of French research on the charging of coke ovens with coal which has previously been dried or preheated. This seems to me particularly opportune in these two days devoted to the current development of the carbonisation industry, for 3 reasons:

Firstly, we know that the production capacity of coking plants in the Community is beginning to be insufficient because many old batteries have been closed down without reconstruction having been undertaken on a sufficient scale. We will see that a preheated charge enables the quantity of coal charged to be increased considerably, sometimes by more than 40%. For an existing battery, the type of installation which I will tell you about can almost always be installed more easily and at less cost than the reconstruction of additional ovens. In the case of a new coking plant the design is obviously easier: the economic effect is generally advantageous.

Secondly, we are all aware of the difficulties of supply of good coking coals. A dry or preheated charge makes it possible to use on a large scale high percentages of coal which are reputed to be non-coking. I will quote the experience which we have had in the Hagondange coking plant where more than a million tons of coke with high mechanical properties has been produced with 70% of Lorraine bituminous flame coal. This type of coal is much more widespread in the world than the good coking coals which we are used to in most of the basins of the Community. It is also often less expensive. This therefore makes it possible to enlarge considerably the quantities of coking coals available. This aspect of the question was discussed in the paper of M. Meltzheim.

Thirdly, part of the research work which I am going to tell you about, the study of charging preheated coal, has been financed by the Community. This is one more reason to speak of it today.

Definition of dry charging and preheating

Before describing the results obtained I must define the terms used.

The blend of coals charged in a coking plant usually contains between 7 and 10% moisture. Dry charging, which I will call sometimes dry charging, first type, to distinguish it from simplified dry charging which I will define later, consists of carrying out preliminary drying by normal industrial methods. In this way moisture is reduced to about 1% with coking coals and 2% with high volatile coals. This residual moisture escapes only if the temperature of the coal is raised well above 100° C whereas 60 to 80° C is barely exceeded in a normal industrial dryer. The coal, which is more or less cooled after drying, is charged at a little above the ambient temperature, at about 40° C.

In preheating of the charge, an attempt is made to raise the coal to as high a temperature as possible but without reaching the thermal decomposition threshold which is about 350° C. The aim therefore is a preheating temperature of the order of 250° C which leaves some margin. We shall also mention a variant consisting of limiting the preheating to 100° C; this allows certain technological simplifications, obviously at the expense of a smaller increase in production. This is what we call simplified dry charging because this process is planned to replace dry charging such as we introduced in 1960. Of course, economic or other considerations of opportunity may lead to the choice of an intermediate temperature between these two values.

#### Difficulties to be resolved

How are these processes developing?

A first difficulty to be resolved is the risk of oxidising the coal during drying or preheating. It is hardly possible to avoid bringing the coal to be treated into contact with hot flue gases which are oxidising to some extent.

In the case of dry charging, first type, we used flue gases at about 600° C, resulting from combustion carried out without any particular precautions and consequently containing a considerable excess of air. Oxidation of the coal was avoided by keeping the time of contact very short (less than 1 minute) and by cooling the coal after drying. A preliminary study had shown in fact that dry coal, reduced to 40° C, could be kept for at least 48 hours without deterioration of its coking properties. In use, this precaution was however found to be rather excessive, since much longer stocking periods did not cause any difficulty.

In the case of preheating, the coal can obviously not be re-cooled. Oxidation is then avoided by maintaining in the flue gases an oxygen content of less than 2%, which requires recycling of the flue gases to the combustion chamber of the preheater. This content of 2% is not difficult to maintain if the fuel (generally coke oven gas) is of uniform composition.

Safety raises a second problem. A certain amount of dry or preheated coal must be kept in reserve, equivalent to a few hours of operation, so that it is necessary to have a hot-coal service bunker in which it is inevitable that fine dust is more or less in suspension. There would be a risk of explosion if it was filled with air. A simple precaution consists of taking from the flue of the preheater a small quantity of flue gases, washing them immediately and then injecting them into this service bunker.

Finally, consideration must be given to the actual charging operation which, in all coking plants, involves the emission of dust which is harmful to the workers. In the case of dry charging, the emission is more intense but shorter. In the case of a preheated charge, it appears to be less intense, which may be explained by the fact that a large part of the gases which are emitted at the moment of charging is constituted by the moisture in the coal which suddenly evaporates. There still remains a certain moisture (1 to 2%) in the case of dry charging but not with the preheated charge so that less dust should be expected. But, bearing in mind the increasingly strict requirements of the regulations with regard to atmospheric pollution, considerable attention should be paid to this problem.

For some years there has been a development of charging cars equipped to suck in the gases around the charging holes. These gases are washed with water before being emitted into the atmosphere. Such installations can obviously be suitable for the charging of dry or preheated coal by means of fixtures which will be installed during the large-scale experiments planned at Hagondange for the current year.

Another solution is at present being studied by the American firm Wilputte. There is no charging car. The ovens are charged by a pneumatic operation directly from the service bunker. Experiments with this method are to be carried out during this year at the coking plant at Ironton (Ohio). The coal will be prepared by a preheater of our design.

## Successive developments

These preliminary considerations are justified by the arrangements adopted for the sequence of developments which I will describe to you now.

The first two are very old: carmolithe and carbolux, developed in France about 1935, the second having been used till last year. These are domestic cokes but observations made have suggested that they might be used for the production of blast furnace coke. This work was carried out by the Marienau Experimental Centre, a research centre financed by CERCHAR, IRSID and Houillères de Lorraine (Lorraine Coal Mines). The research was carried out in experimental battery comprising 4 ovens of industrial size and also experimental ovens called "400 kg ovens". The first industrial application was in the Hagondange works which now belongs to the Wendel-Sideler group.

The arrangements adopted show how dry charging was introduced into an existing coking plant (Figure 1). The plant consists of 120 ovens grouped in 4 batteries of 30 served by a central service bunker which has always been used to supply the 2 batteries on the left with a wet blend, in the usual conditions. The dry blend for the two batteries on the right crosses the central service bunker, passes through an intermediate bunker of 700 tons then into the building housing the dryers and crushers before being stocked in a special bunker which appears on the right of the battery.

The dryer is an apparatus (Conreur Ledent model with rolls) in which flue gases circulate upwards as coal descends (Figure 2). In the lower part of the dryer the coal is cooled by means of cold air in order to avoid oxidation during stocking, in accordance with what was stated previously.

Systematic crushing consists of controlling by a screen the particle size of dry coal and of recycling the residue to the crusher. The normal grain size for charging is of the order of  $95\% < 2 \text{ mm}$  which is made necessary by the requirement for a high MICUM 40. Figure 3 shows the building housing the dryers and closed-circuit crushing.

The lower part of the service bunker is equipped with conveyors feeding at fixed intervals a charging car designed to limit the emission of dust (Figure 4).

This installation has operated on 30 ovens and then on 60 ovens from 1960 to 1968. More than a million tons of coke have been produced with excellent mechanical properties.

MICUM 40 = 80

MICUM 10 = 7

from a blend containing 70% of Lorraine "flambant gras" (bituminous flame coal) with the following characteristics:

Ash	5 - 6
Volatile matter (dry)	37
After expansion	4 - 5

Charged in the normal conditions, such a blend would certainly not have given better than:

MICUM 40 = 70

MICUM 10 = 9 to 10

which is far from sufficient for our requirements.

This encouraging result suggested that we should go further by pre-heating the coal blend.

To preheat the coal our first idea had been to use a normal fluidised bed (Figure 5). We had seen in this the advantage of controlling the temperature of the bed very accurately at all its points. But it was difficult to avoid a small fraction of the particles near the grate being raised to the threshold temperature of thermal decomposition leading to some deterioration of the coking properties and sometimes even to sticking on the grate (Figure 6). We then turned towards a slightly different scheme (Figure 7) in which the coal is introduced wet into a current of hot flue gases. The fluidised bed is formed in the upper part of the installation as a result of a widening of the cross-section which reduces the speed of flow of the gases. The very hot flue gases are therefore in contact only with the wet coal and the preheating temperature is controlled in the fluidised bed. We have therefore been able to attack the coal with flue gases at 800 and even 1000° C whereas, in the previous project, difficulties began at 600° C which was a serious problem because we had to envisage a considerably larger and therefore

more expensive installation. In the fluidised bed we rotate a movable crusher which reduces the coal to a suitable particle size. The finest particles are carried away by the flow of gas, while the others fall on to the crusher wheel so that partially closed-circuit crushing is carried out. Finally the installation is fed with coal in the form of wet 0-10 mm fines. The coal leaves dried, preheated and crushed. It is also transported pneumatically to the service bunker which allows completely clean handling.

Figure 8 shows the pilot plant installed at Marienau on a scale of 2 ton/hour. The plant is, as you can see, very small and very compact. Figure 9 represents the project carried out at Marienau with this pilot plant. The same elements are found in it as in the coking plant which we will talk about in a minute.

A larger unit has been installed at Thiers (Figure 10), This was only for drying without preheating. The capacity envisaged was 10 ton/hour but it was raised to 15 ton/hour.

At present two units with a capacity of 35 ton/hour are under construction, one in France at the Hagondange coking plant for preheating to 100° C (simplified dry charging) and the other at the coking plant at Ironton (Ohio) belonging to the Wilputte Company of the Allied Chemical Group, with preheating to 250° C (actual preheated charge). These two units will be put into operation next summer.

Crusher-preheaters can be installed in different ways on a coke-oven battery. The most reasonable solution is that shown in outline in Figure 11. The wet-coal service bunker has been kept in its traditional place which enables wet charging to be resumed if necessary, for example if the coking plant is supplied with good coking coal. The crusher-preheaters are situated on the side of the battery and fed by conveyors. The preheated coal is transported pneumatically into the hot-coal service bunker from which the ovens are fed by the charging car.

Now that you have seen what the installations are like, I will give you details of the improvement in productivity which can be expected from such processes and of the possibilities with regard to coke quality.



### Improvement in productivity

In the case of dry charging of the first type (as it was designed following the initial studies at the Marienau Experimental Centre and installed at Hagondange, 10 years ago), the improvement in productivity compared with a blend with 7% moisture was 18%. By this I mean that the quantity of coal, less moisture, carbonised in an oven per unit of time was increased by 18%. Of course the quantity of coke produced is also increased by 18% if the comparison is made with the same blend of coals. There is obviously a correction to be made if the blends, wet and dry, do not have the same yield of coke.

The case of the blend with 7% moisture constitutes a particularly interesting case because the increase in bulk density of the charge between the wet blend and the dry blend is about 18% so that the increase in production is obtained without modifying the charging schedule, which is convenient for the organisation of work.

With regard to a blend with 10% moisture, the increase in production is 24%.

In the case which we have called simplified dry charging, i.e. preheating to 100° C, the increases in production become respectively 26 and 35%.

Finally in the case of an actual preheated charge, with a preheating temperature of 250° C, the increases in production rise to 34 and 43% respectively, which is considerable.

It should be added that these values are conservative because I have indicated fairly systematically the lower limit of the range of variation. In practice, slightly higher increases in production will often be found.

### Effect on coke quality

Let us move on to the coke quality.

Experience shows that dry charging improves appreciably the mechanical properties of coke (especially MICUM 40 and MICUM 10). Preheated charging increases the improvement further.

This is due firstly to the increase in the density of the charge which tends to increase the cohesion of the coke, i.e. to improve the MICUM 10 but not MICUM 40. But this does not explain everything; the absence of water in the charge modifies the transmission of heat and, consequently, the heating regime which improves both the MICUM 10 and the MICUM 40. Very precise measurements have shown that these two varying factors had a comparable importance. As they act in the same way for MICUM 10, the improvement of this characteristic is always very marked. With regard to MICUM 40 the two factors often act in the opposite way so that the improvement is less. This again is true only with equal particle size but the control of the particle size of the blend which is achieved by closed-circuit crushing in the various projects considered leads to a further improvement in MICUM 40 which could not be obtained simply in a traditional wet charge.

If the lump size of coke is considered, it is found that the percentage of coke above 40 mm varies little or increases slightly but the proportion of very large coke is reduced which is a step in the direction of a restricted size range.

The preheated charge accentuates these trends if only because it causes a further increase (not clearly explained but definite) in the bulk density of the charge.

Finally dry or preheated charging makes it possible to produce a coke more resistant to abrasion and with a more restricted particle size which is in line with the development of blast furnace techniques.

Moreover in practice attempts will rarely be made to improve an existing coke but rather to obtain a comparable quality with coals which are less expensive because they are less suitable for coking. The example which I gave just now is evidence of this since it has been possible to make, on an industrial scale and over a period of several years, a coke of excellent mechanical properties from a blend which traditionally could give only a very inadequate quality which no blast furnace man in the Community would accept. The possibility of making good coke with poor quality coals widens the range of coking coals which contributes to security of supplies in normal circumstances.

Economic aspects

I have up to now spoken only of technical matters. Reference must be made to the economic aspects of the problem. I will not go into many details, since the figures have been published elsewhere, and will restrict myself to the main conclusions.

The problem does not necessarily arise in the same way in the construction of a new coking plant as in the possible modification of an existing coking plant.

We will start by considering the first case. A modern coking plant is designed on the basis of the number of ovens which can be served by one group of machines. If it is assumed for example that such a group can guarantee 140 discharges per day, a rate which is still rarely attained but is quite conceivable in a new coking plant, the ovens carbonising in 17 hours a blend with 10% moisture, the carbonisation unit will comprise

$140 \times \frac{17}{24} = 99$  ovens. With modern ovens of a capacity of, say, 20 tons of wet coal, the charge will be:

$20 \times 140 = 2800$  tons of coal per day,  
i.e. 2520 tons of dry coal equivalent.

If the unit is designed for preheating to  $250^{\circ}$ , the increase in production per oven consists of an increase in the density of the charge of about 25% and a reduction of the carbonisation period by 15% to 14.5 hours. The basic unit of the coking plant will then be:

$140 \times \frac{14.5}{24} = 85$  ovens.

It will carbonise:

$(20 \times 0.90) \times 1.25 \times 140 = 3150$  tons of dry coal per day.

More coal is therefore carbonised with fewer ovens.

From these basic data, the two coking plants can be designed. Capital expenditure, in relation to a ton of coal charged, is 5 to 10% lower in the case of the coking plant working on a preheated charge. With regard to production costs comprising depreciation, wages, maintenance, heating and

power, i.e. all the costs except the price of coal, there is a saving of the order of 1 F per ton of coal charged in the case of a small coking plant and 2 F in the case of a large plant. This is not negligible but the price of coal used can make the difference much larger. We find again here the main advantage of the process which, by widening the range of coking coals, at the same time extends the possibilities of choice and assists the search for the most advantageous sources of supply. The second case to consider is introducing preheated charging in an existing coking plant. It is difficult to formulate a general conclusion because the economic result of the operation depends on the initial conditions. If, for example, the group of machines is used to the maximum, it may be difficult to guarantee a greater number of discharges than would otherwise have to be guaranteed in any case if new ovens were built. But conversely an increase in capacity by the addition of new ovens is not always possible for lack of space at the end of the battery, whereas a preheater occupies much less space and it is much simpler to install. In general the operation will be advantageous from the point of view of capital expenditure and production costs, with the obvious reservation that this would have to be checked in each particular case. The increased freedom of choice of coals will obviously remain the main advantage.

The search for the economic optimum suggests moreover that one should examine the preheating temperature, which can be fixed at will between 100 and 250°C or slightly more. Between these two temperatures, the size of the preheater varies considerably (the cross-section is approximately doubled) which obviously affects the cost. Conversely the number of ovens necessary to guarantee a determined output will be less for preheating at high temperature. We have tried to draw up a balance sheet of the advantages and disadvantages of these extreme solutions but have not found any significant difference. We therefore assume provisionally that the preheating temperature has little influence on the production costs. But we will re-examine this problem when, having built and seen these two types of installation in operation - which will be the case at the end of the current year - we shall have more accurate data to work on than now.

### Conclusion

To conclude, I will restrict myself to reviewing the main points developed in this paper.

I have described several projects:

- dry charging which I call "first type". It was developed at the Hagondange coking plant 10 years ago and has for several years furnished proof that excellent blast furnace coke can be produced industrially by dry charging. This stage was essential in the development of this type of process;
- actual preheated charging, characterised firstly by the fact that the coal is raised to a temperature of the order of 250° C and secondly by the use of the installation called a crusher-preheater which constitutes an improved solution because it is simpler, cleaner and more economic;
- simplified dry charging which is identical in outline to the above but in which the preheating is limited to about 100° C.

Only the last two solutions will be retained for the future. We have seen that they produced an increase in production of between 25 and over 40% depending on the conditions, with an equal number of ovens. In addition they widen appreciably the range of coking coals which assists the research for the most advantageous sources of supply, a problem which is particularly relevant at present.

Let me remind you that two plants on the scale of 35 ton/hour are at present under construction - one in the United States for preheating to 250° (actual preheated charging) and the other in France for preheating to 100° C (simplified dry charging).

Finally I would like to thank:

- firstly the management and staff of the Hagondange works of the Wendel Sideler Group where the first dry charging plant was operated on an industrial scale, a stage which was fundamental in the development of the processes described. It is also at Hagondange that simplified dry charging is to be tried from this year;
- secondly the Community, which has subsidised the research into the preheated charge.

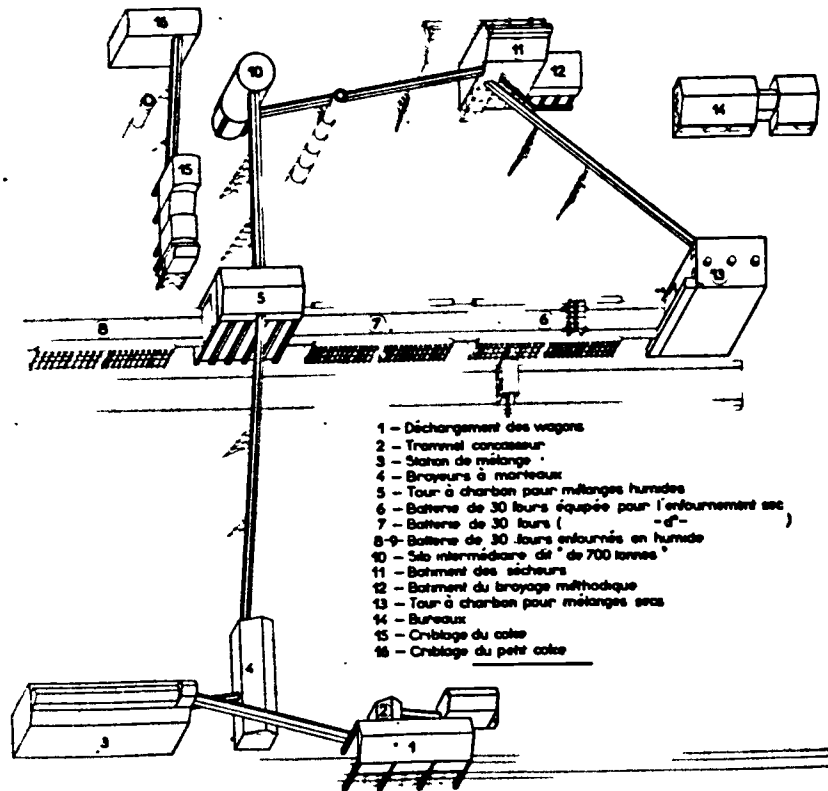


Figure 1 Layout of dry charging system in the coking plant at Hagondange

- 1 Unloading of wagons
- 2 Drum crusher
- 3 Blending plant
- 4 Hammer crusher
- 5 Service bunker for wet blends
- 6,7 Battery of 30 ovens equipped for dry charging
- 8,9 Battery of 30 ovens wet charged
- 10 Intermediate "700-ton" bunker
- 11 Dryer building
- 12 Systematic crusher building
- 13 Service bunker for dry blends
- 14 Offices
- 15 Screening of coke
- 16 Screening of small coke

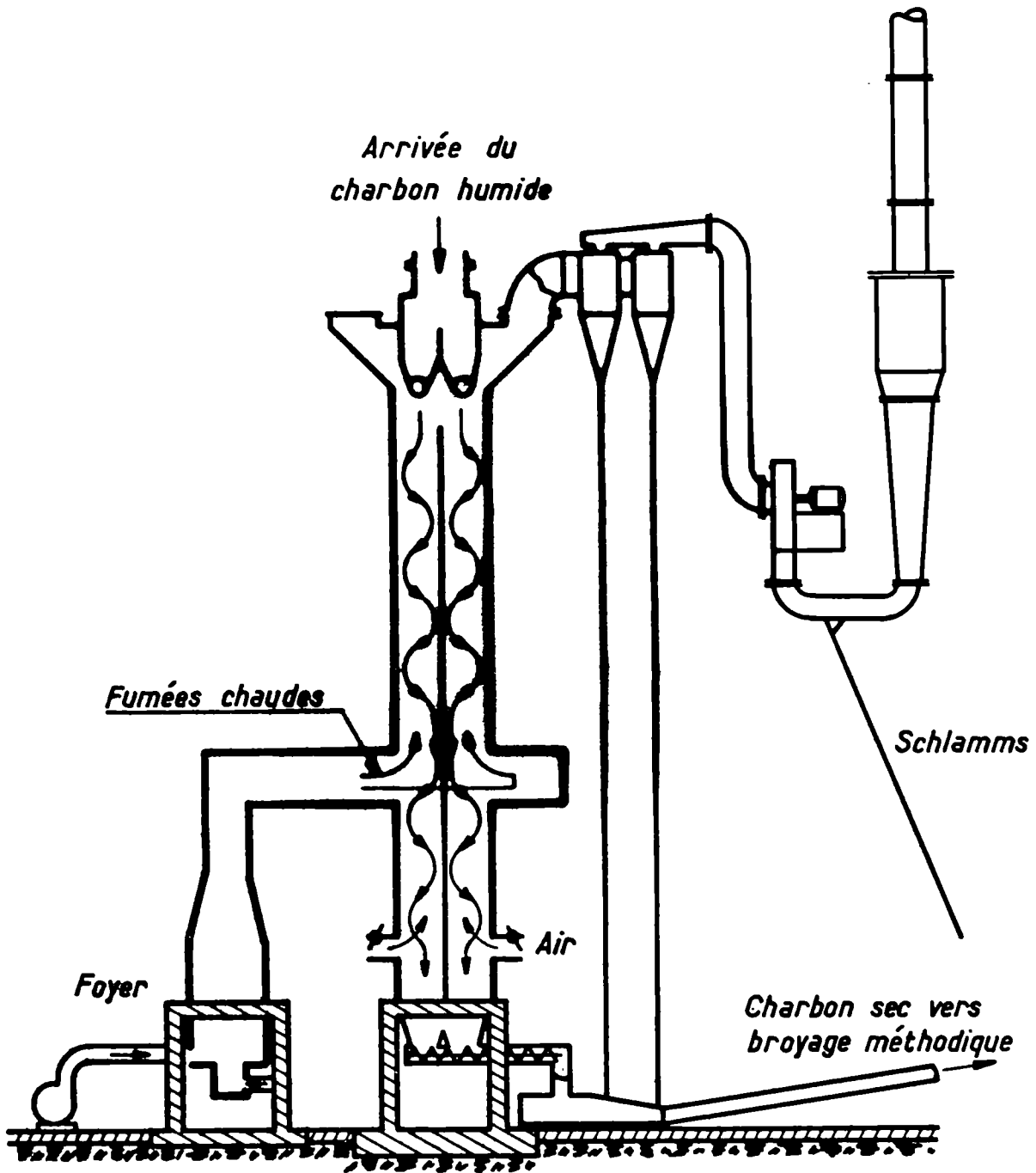


Figure 2 Coking plant at Hagondange - Diagramm of a dryer

Arrivée du charbon humide

Arrival of wet coal

Foyer

Combustion chamber

Fumées chaudes

Hot flue gases

Charbon sec vers broyage méthodique

Dry coal to closed-circuit crushing

Schlamms

Slurry

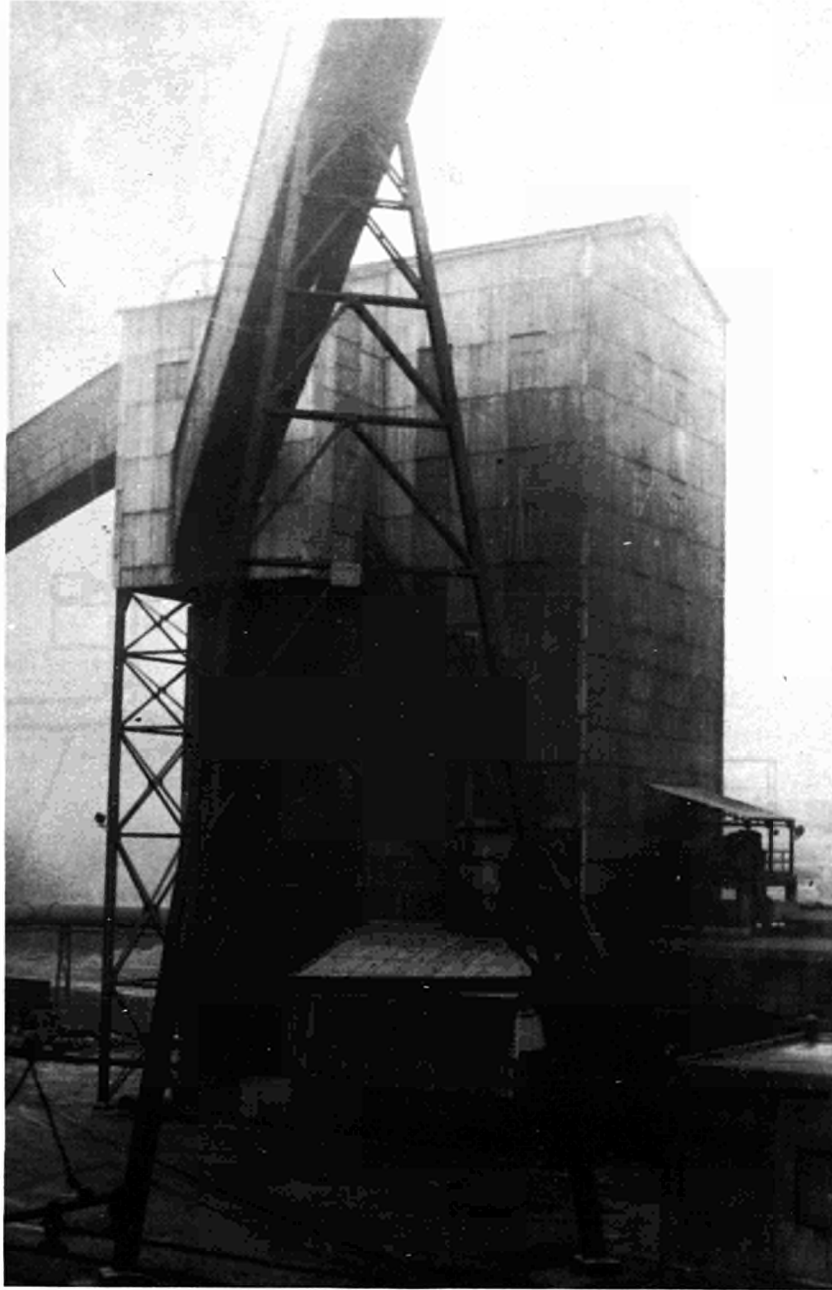


Figure 3 Dryer building at Hagondange



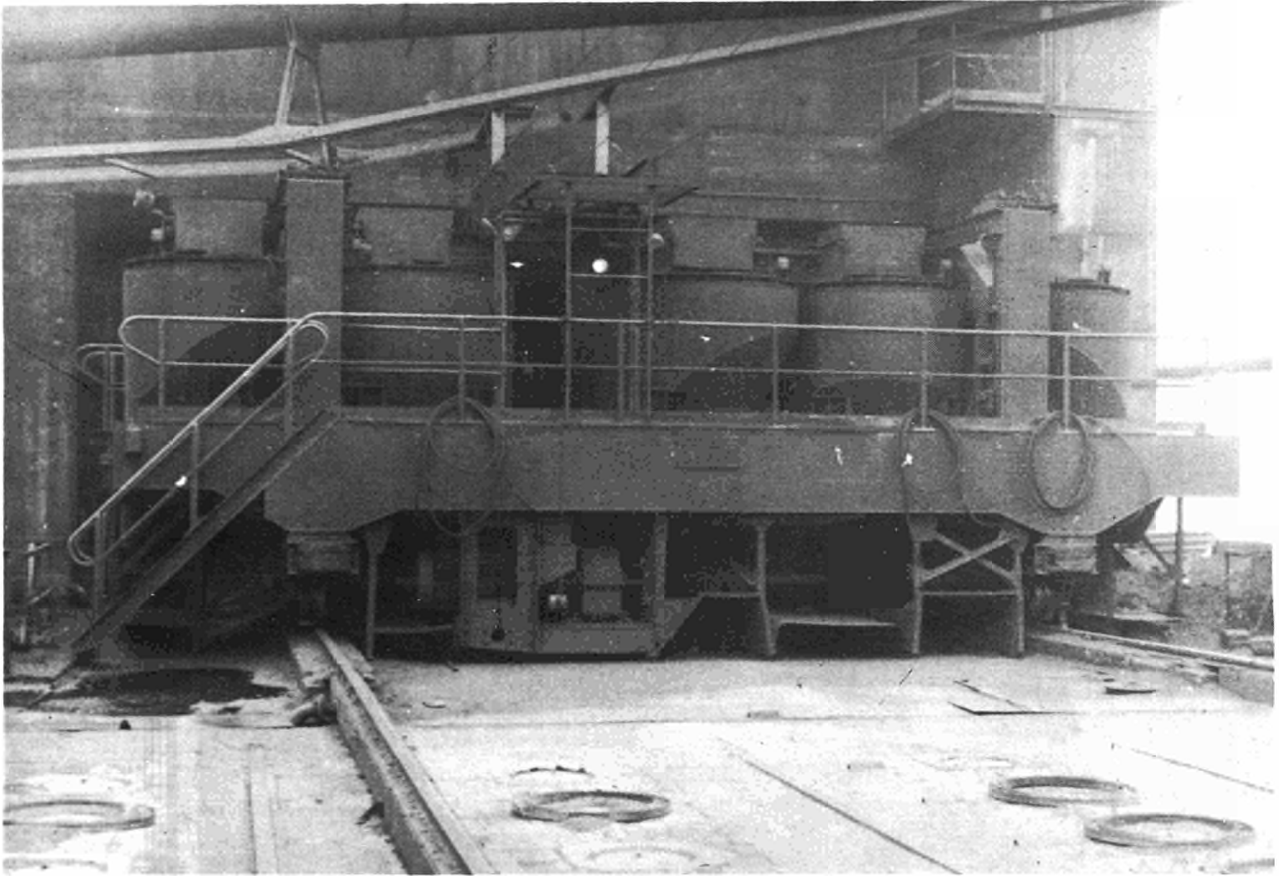


Figure 4 View of charging car

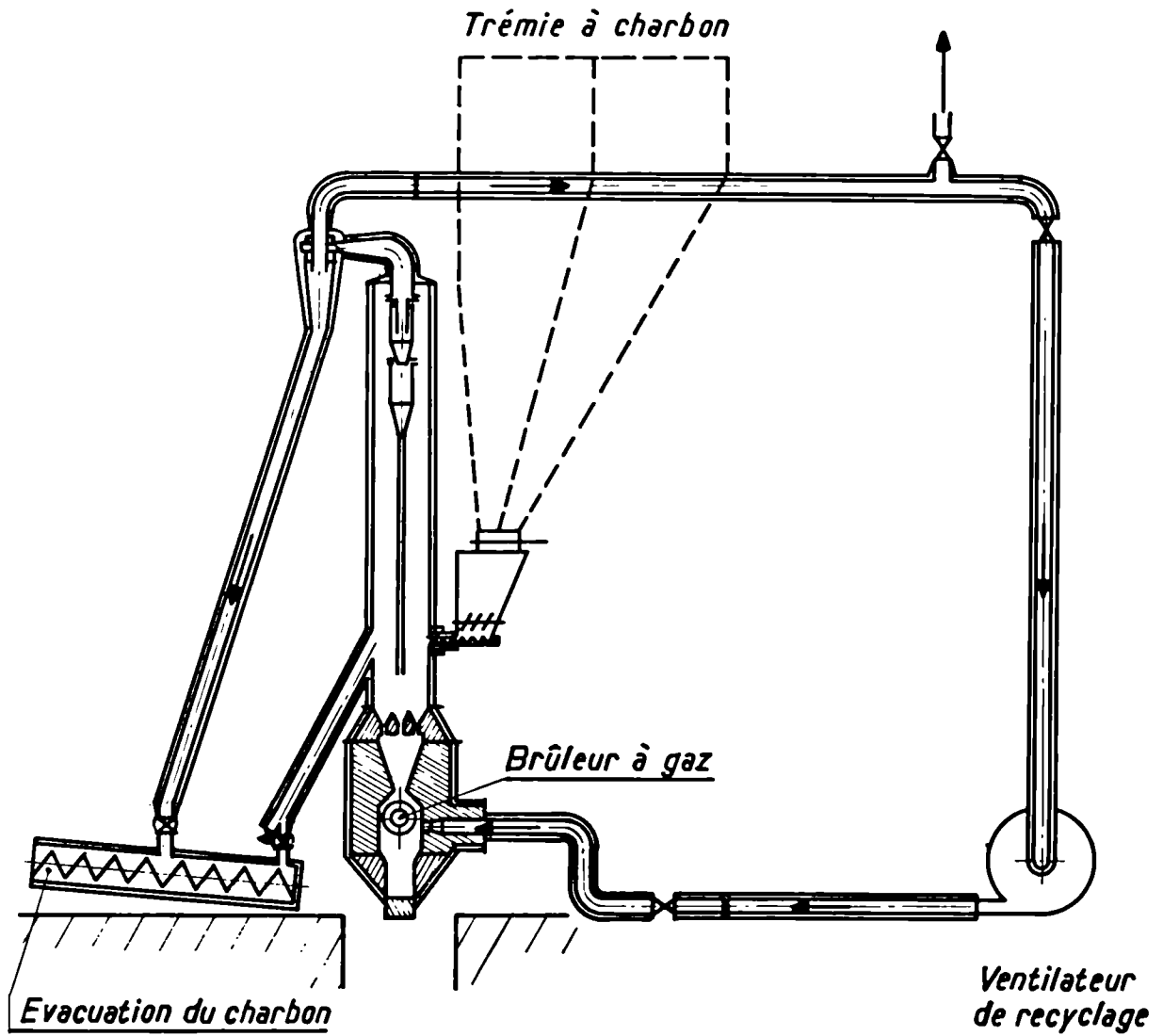


Figure 5 Diagram of first preheater (simple fluidised bed)

Trémie à charbon

Coal hopper

Brûleur à gaz

Gas burner

Evacuation du Charbon

Discharge of coal

Ventilateur de recyclage

Recycling blower

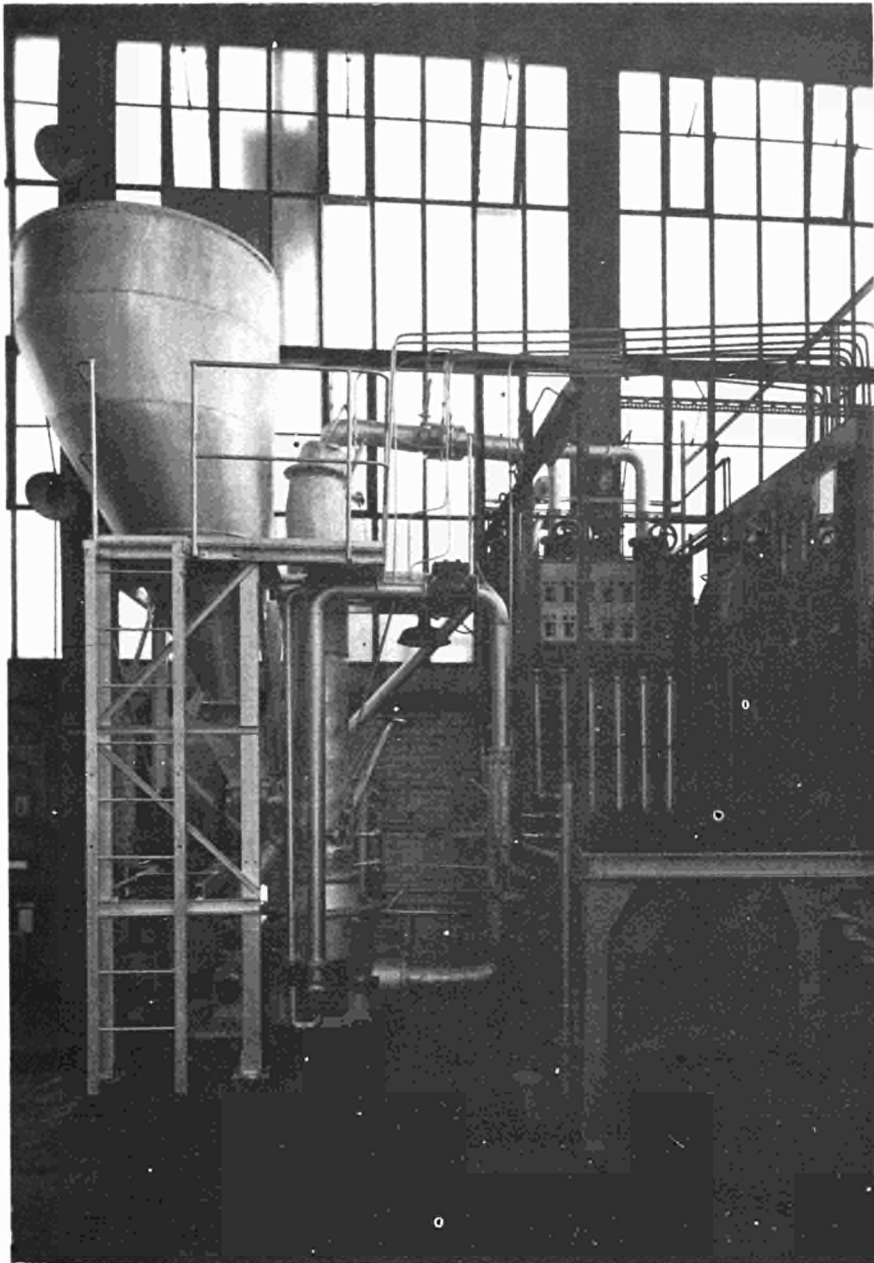


Figure 6 First preheater (simple fluidised bed)



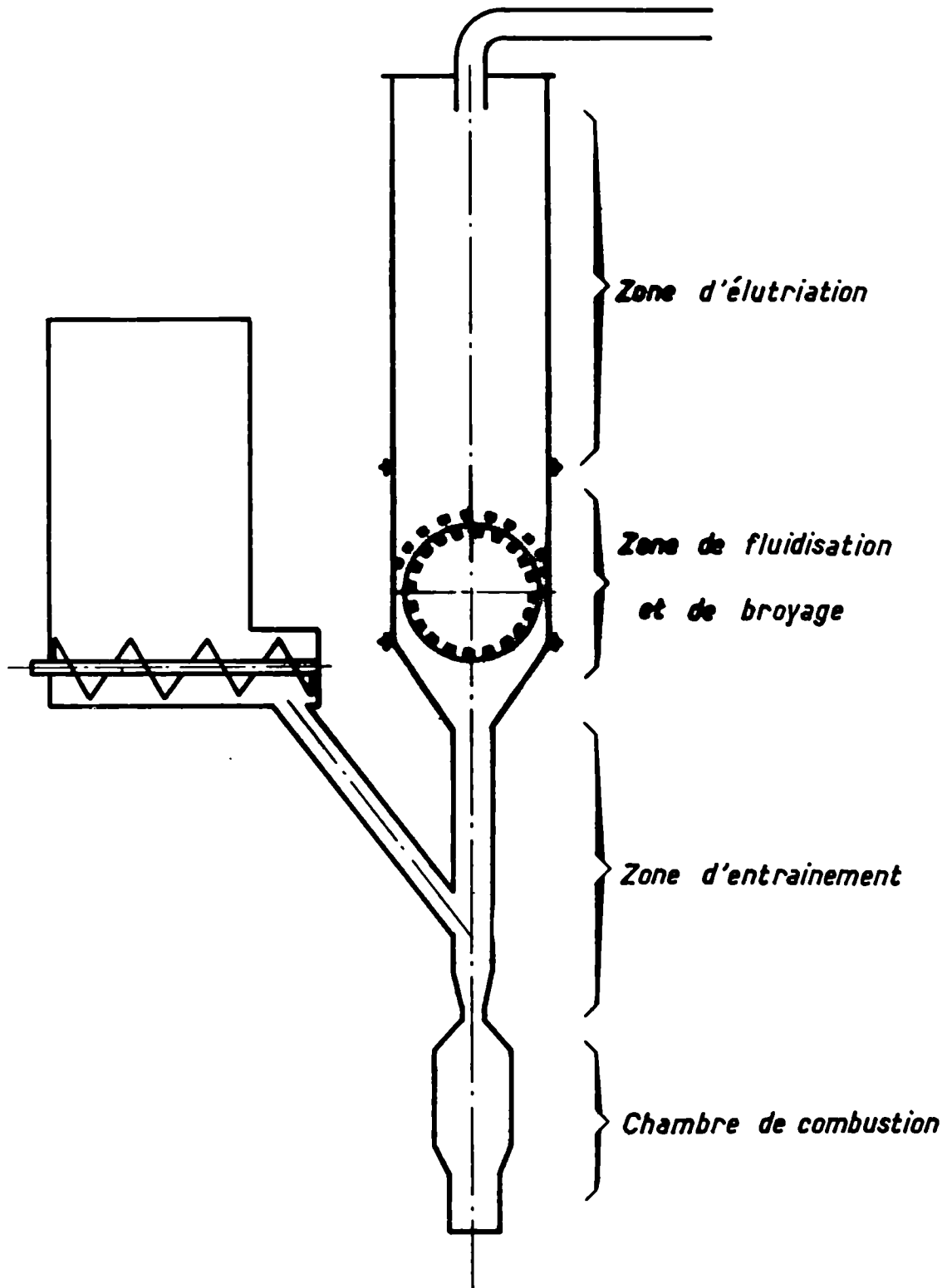


Figure 7 Diagram of crusher-preheater at Marienau

Zone d'élutriation

Elutriation zone

Zone de fluidisation et de broyage

Fluidisation and crushing zone

Zone d'entraînement

Removal zone

Chambre de combustion

Combustion chamber

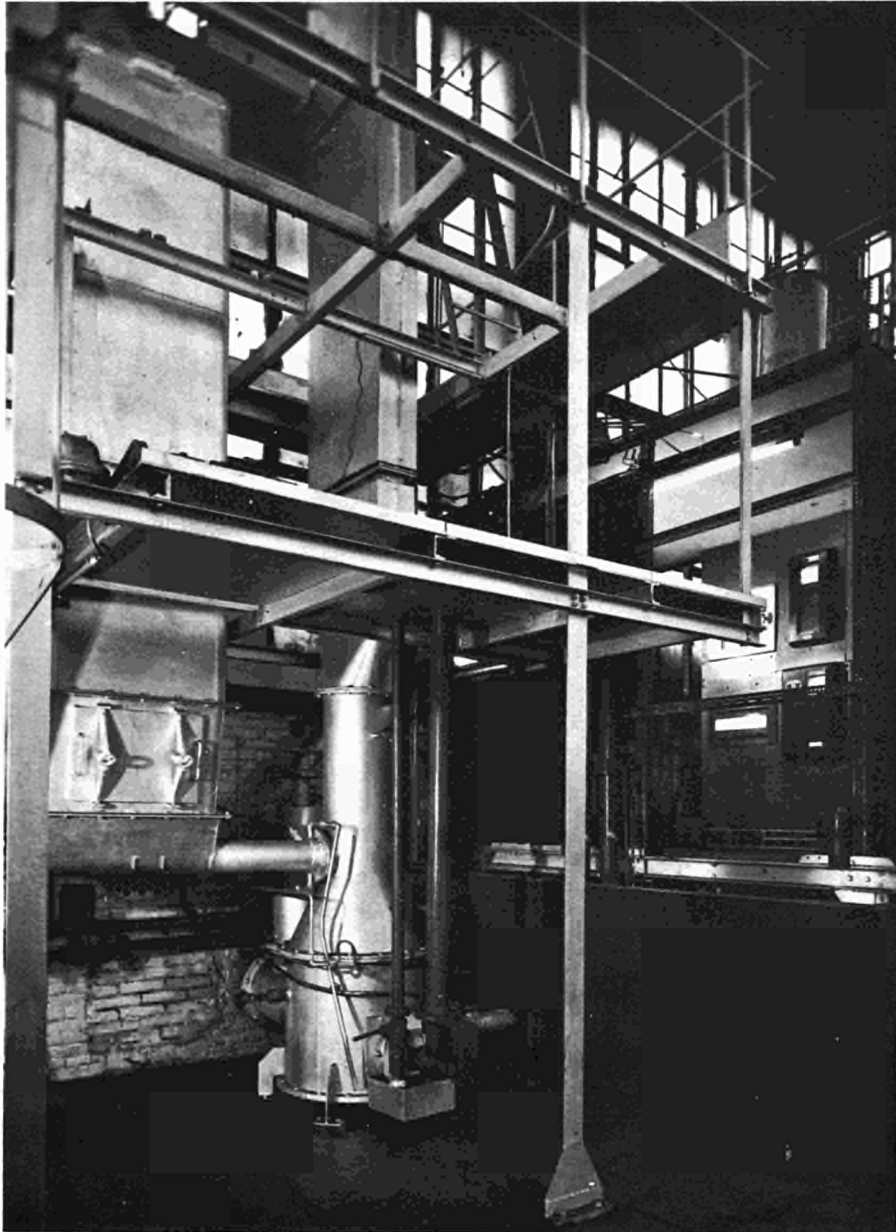


Figure 8      Crusher-preheater, 1.5-2 ton/hour at Marienau

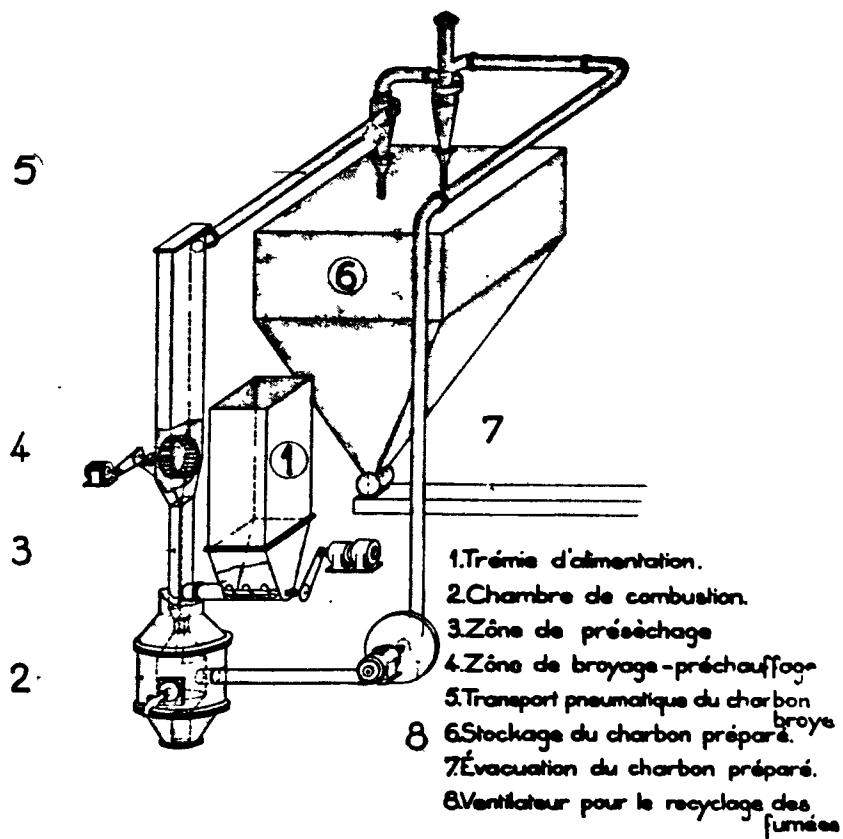


Figure 9 Flow diagram of the crusher-preheater at Marienau

- 1 Supply hopper
- 2 Combustion chamber
- 3 Pre-drying zone
- 4 Crushing-preheating zone
- 5 Pneumatic transport of crushed coal
- 6 Stocking of prepared coal
- 7 Delivery for recycling of flue gases
- 8 Blower for recycling of flue gases

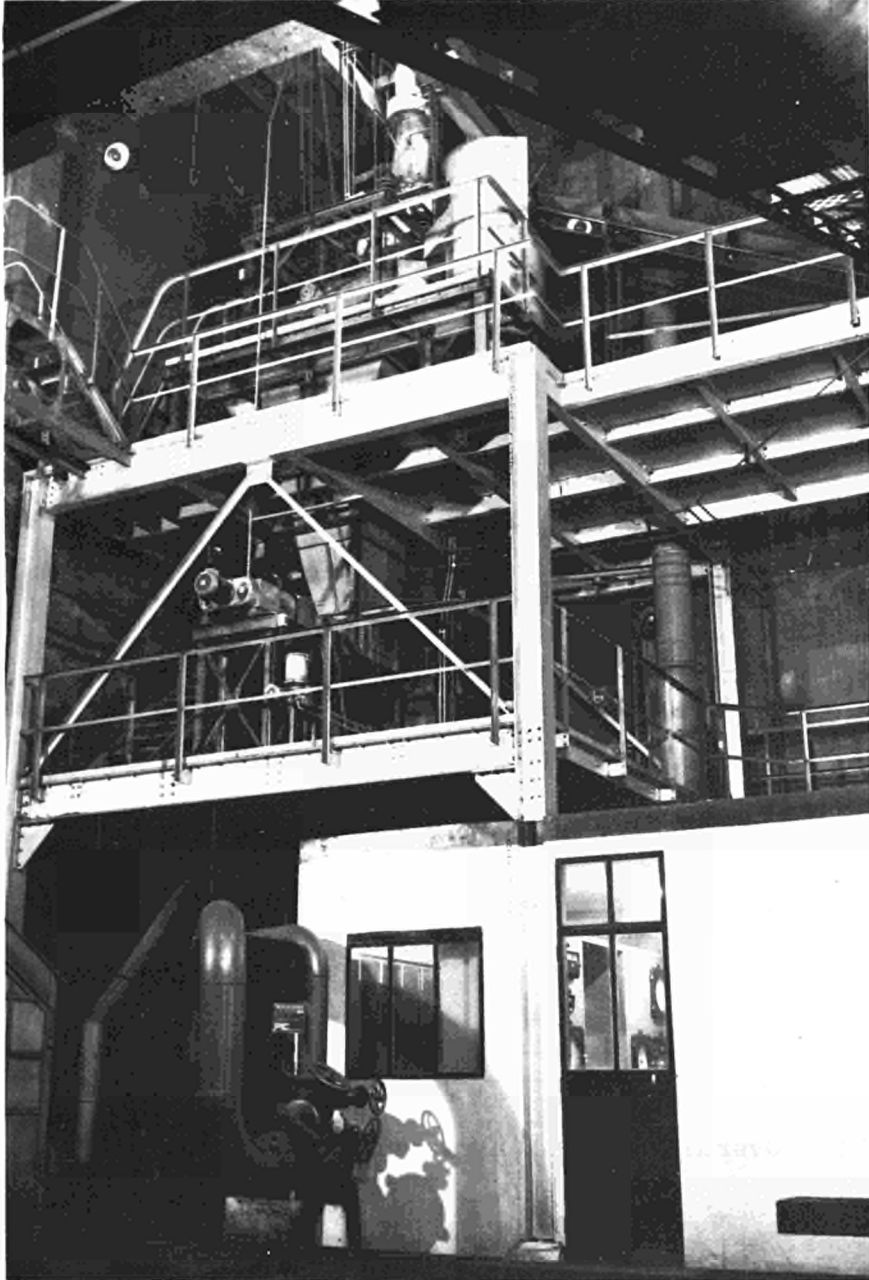


Figure 10 Dryer crusher at Thiers (10-15 ton/hour)

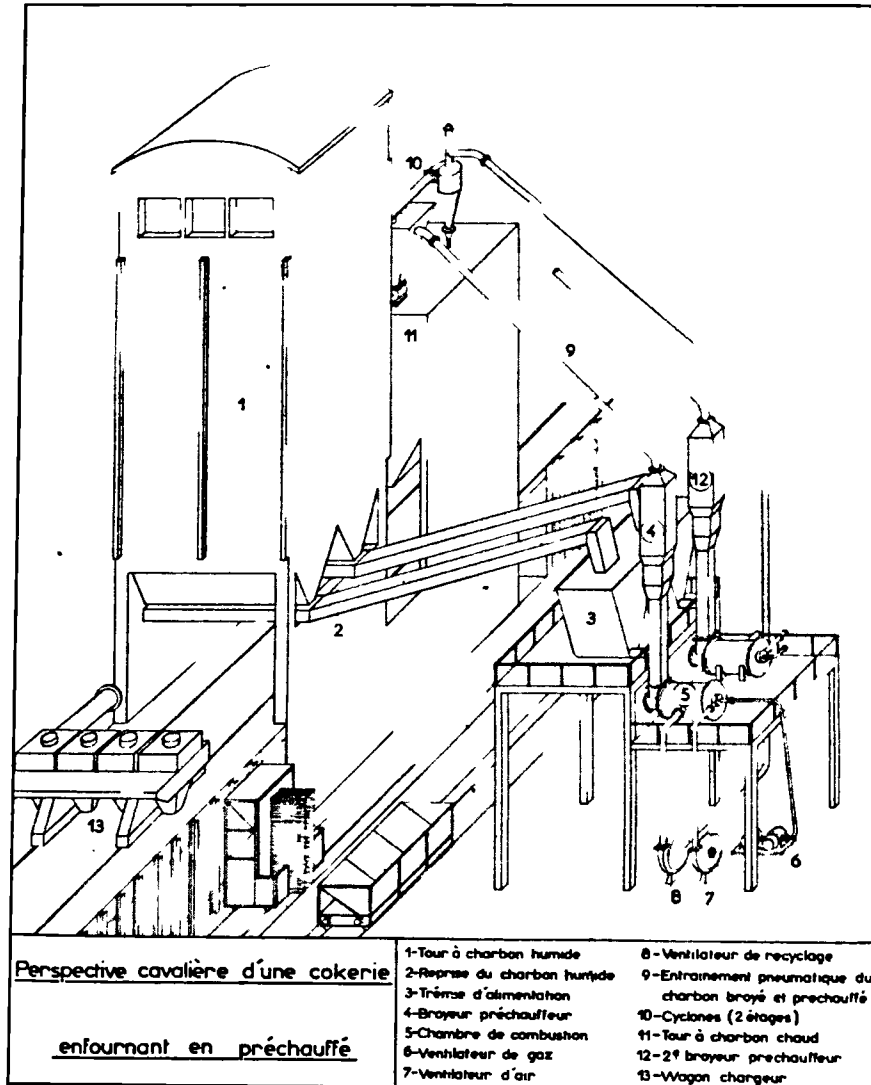


Figure 11 Overall view of a coking plant with preheated charging

- 1 Wet-coal service bunker
- 2 Reclaiming of wet coal
- 3 Supply hopper
- 4 Crusher-preheater
- 5 Combustion chamber
- 6 Gas blower
- 7 Air blower
- 8 Recycling blower
- 9 Pneumatic transport of crushed and preheated coal
- 10 Cyclones (2 stages)
- 11 Hot coal service bunker
- 12 Second crusher-preheater
- 13 Charging car



Discussion

K. H. Hawner

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Preheating of coal promises a considerable increase (25-40%) in coke-oven throughput.

As a result of systematic investigations at the Marienau Experimental Station the stage of commercial testing has now been reached. The first experiences will be at hand in the next year, so that extensive introduction into commercial practice will then be possible.

The British Coke Research Association has likewise been concerned intensively with this development. Mr. Graham has presented a contribution to the discussion about the English work.

J.P. Graham

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The thermal pre-treatment of coal prior to carbonisation in coke ovens formed part of The British Coke Research Association's practical research activities for at least the last decade. Initially, work on this subject was concerned with drying; this led to the study of preheating which, in simple terms, may be defined as coal drying without subsequent cooling of the material, although the range of final coal temperature is somewhat different in these two treatments.

The Association's work on preheating was initiated on a small-scale experimental basis which confirmed that preheating significantly increased the throughput of the ovens, the extent of the improvement being related to the degree of preheating. The small-scale work was combined with a survey of the information already available, which confirmed that the main advantage of preheating would lie in the increase in coal throughput. It was also apparent that there should be no deterioration in coke quality and indeed in some instances it would be reasonable to expect some improvement in coke quality. The survey revealed little information concerning the effects of preheating on the yields and qualities of the by-products or on the overall economics of the process.

It was clear that further data with regard to the effects of preheating on charge bulk density, throughput and coke quality using British coals, together with facts about the yields and qualities of by-products, were desirable to enable assessments to be made of the potential importance of preheating in relation to coke manufacture in the United Kingdom.

As a result of these considerations, the Association, with the support of the Ministry of Technology, decided to proceed with the erection of a preheating unit for use with the 10-tons capacity test oven which had been in continuous operation at the Coke Research Centre since 1957. Preheating of the coal by a pneumatic entrainment method was chosen from the very limited number of approaches available in 1966.

A pneumatic type of preheater at the Coke Research Centre was designed by Rosin Engineering Ltd., in co-operation with the Association and Simon Carves; Rosin Engineering also supplied the preheater and Simon-Carves the ancillary equipment, the latter firm acting as the main contractor. The erection of the preheater began in May, 1967, commissioning of the plant started four months later in September of the same year and, following the commissioning trials, a systematic programme of testing was commenced in April, 1968.

Figure 1 shows a schematic flow diagram of the two-stage Rosin preheater designed to preheat 5-tons of wet coal per hour, evaporation of the surface moisture and partial preheating taking place in stage one and preheating of the coal to the maximum final temperature of over 250° C in stage 2, this temperature being considered sufficiently high for the type of investigation in process. The diagram shows how the stages are interconnected and indicates the method of re-circulation of some  $\frac{3}{4}$  of the heating gases and the measurements taken to provide the required control and the operating data.

Figure 2 gives the general view of the preheater and its location in relation to the 10-tons oven.

Concurrently with the development of the preheater the Association has also undertaken development work on the charging car which would facilitate charging of the preheated coal by gravity to the oven. It should be added, however, that out of the total of 125 preheated charges carbonised to date more than half were charged using a slightly modified gravity car of simple design. The car used at present is basically of Hartung-Kuhn type and comprises 2 coal hoppers each with a telescopic chute and a hood over the charging holes, together with the appropriate ducting, to transfer the gases evolved during charging into a wet separator where the gases are cooled down, washed and discharged to the atmosphere.

Figure 3 shows the 10-tons oven during charging the preheated coal. This photograph shows the conditions on the top of the oven and the plume of steam discharged from the washer.

The commissioning trials and the subsequent work on systematic surveys of British coals, on the comparison of wet, dried and preheated coals, as well as the work on commercial blends (mainly of British coals, but some also of foreign coals), have all shown the same trends, which can be summarised as follows.

- (a) There was no evidence that preheating the coal to temperatures of the order of  $250^{\circ}$  C resulted in any significant change in coal properties.
- (b) Preheating the coal charge resulted in changes in the nature of the porous structure of the coke.
- (c) A tentative relation was established between the abrasion resistance (M<sub>10</sub>) of the coke, the distribution of pores and the loss of volatile matter within the plastic range.
- (d) It appears that changes in these properties are a consequence of (a) the accelerated rate of carbonisation of preheated charges compared with the corresponding rate for wet charges, and (b) an increased bulk density of the charge in the oven.
- (e) Handling and charging by gravity of thermally-treated coal was found to be practicable; because of the flow characteristics of the treated coal, mechanical levelling of the charge in the oven was found to be unnecessary. This is illustrated in Figure 4, which gives a comparison of the contours of the cokes pushed from the wet and mechanically-levelled charge (top contour), from the dried but unlevelled charge (middle contour) and from the preheated and also unlevelled charge (bottom contour). This tendency of preheated coal to self-levelling has been confirmed throughout the last two years.
- (f) Thermal pre-treatment of coal led to significant increases in the bulk density and decreases in the carbonising time, resulting in a substantial increase in the oven throughput, the final value depending on the rank of coal and on the final temperature of the coal charged.

Figure 5 shows an example of the changes in the carbonising conditions due to drying and preheating five representative British coals. For drying, the increase in throughput ranged from 5 to 16 per cent, depending on the coal rank; corresponding increases after preheating to about  $180^{\circ}$  C were as high as 52 per cent.

- (g) Figure 6 summarises the effect of thermal pre-treatment on the resultant quality of the coke obtained, again from five representative British coals. It should be stressed that the effects as recorded with other coals or blends were similar, although the degree of change varied with different coals. Although the mean size of the coke was changed only slightly, the proportion of large coke was in general decreased without increasing the yield of breeze. The impact-strength indices, only slightly affected by drying, were in most cases improved by preheating. The resistance to abrasion was always improved by thermal pre-treatment, the preheating giving larger improvements than drying. Figure 7 shows the proportional improvements in the M10 microm indices, recorded with various preheated commercial blends, which were greater for the cokes of poorer initial resistance to abrasion.
- (h) As shown in Figure 8, the changes in the yields of the products were generally small. The difference in the gas flow rate at "on main" was found to be much greater when the coal was preheated.
- The yield of crude liquor from the preheated charges was decreased considerably; it appears from the laboratory studies that preheating is not likely to affect detrimentally the treatability of the liquor, although this must be confirmed by practical tests. It appears that the preheated charges produce crude benzole of higher purity and tar which is easier to process.

One potential advantage of the application of preheating on a commercial plant is the control of the coal throughput by charging the preheating temperature, rather than by changing the flue temperature.

The necessity of providing a precisely defined and closely observed "start-up" and "shut-down" procedure must be appreciated, because these are necessary for the safe operation of this type of equipment. Similarly, close attention must be paid to maintenance procedures, which must be of a preventive nature. The automation of preheating equipment, the elimination of levelling and the practical possibility of more consistent operation and better-quality products should help in making this process commercially attractive.

The technique of preheating has certainly reached the stage when the next step of translation to commercial practice must be undertaken, particularly at the present time when reconstruction in the coking industry in the United Kingdom is of such critical importance.

It is, therefore, gratifying to report that following the work carried out at the Coke Research Centre complete installations, one in England and in South Africa, will shortly be erected and put into operation by the end of this year or early next year.

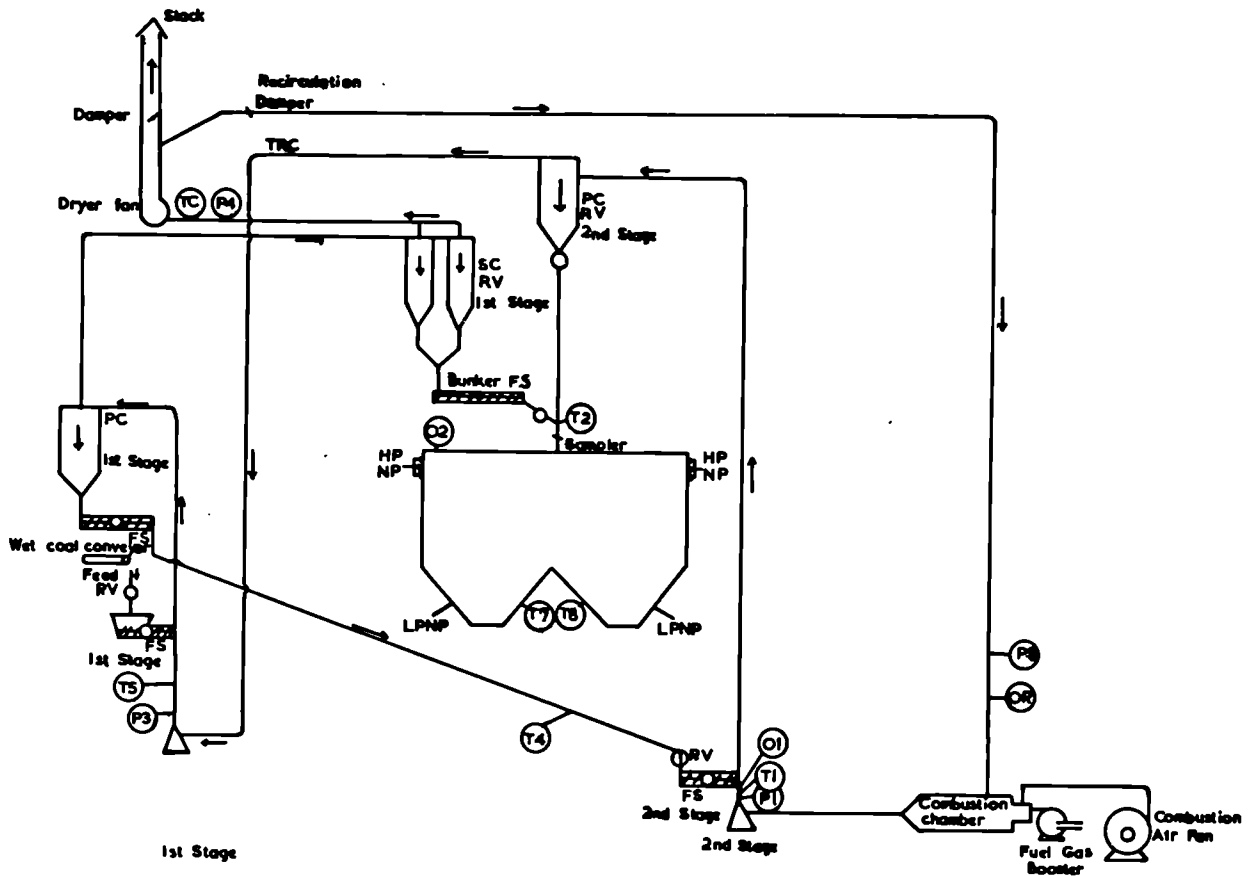


Figure 1 - Schematic flow diagram of the two-stage Rosin preheater

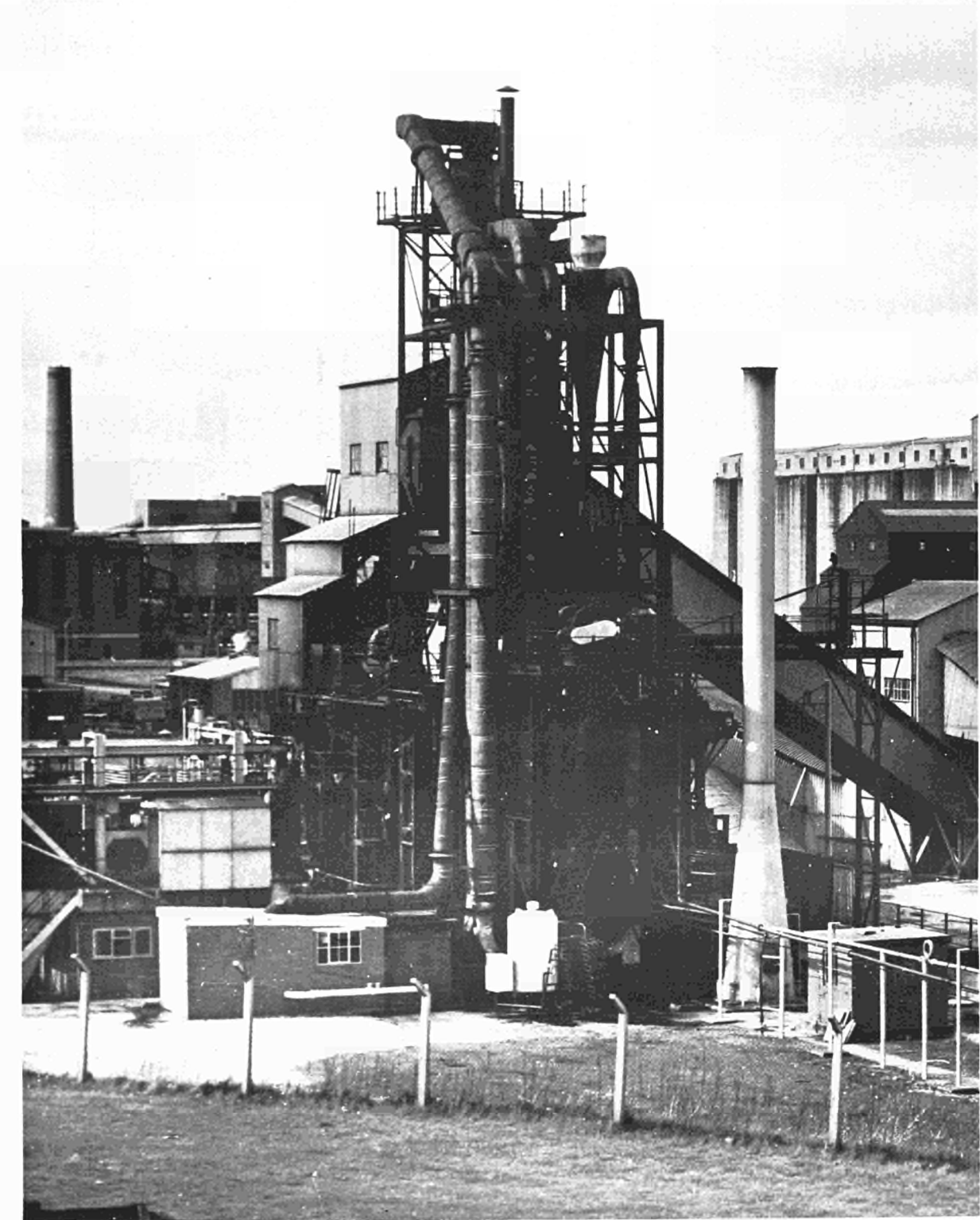


Figure 2 - General view of the preheater and its location in relation to the 10-tons oven

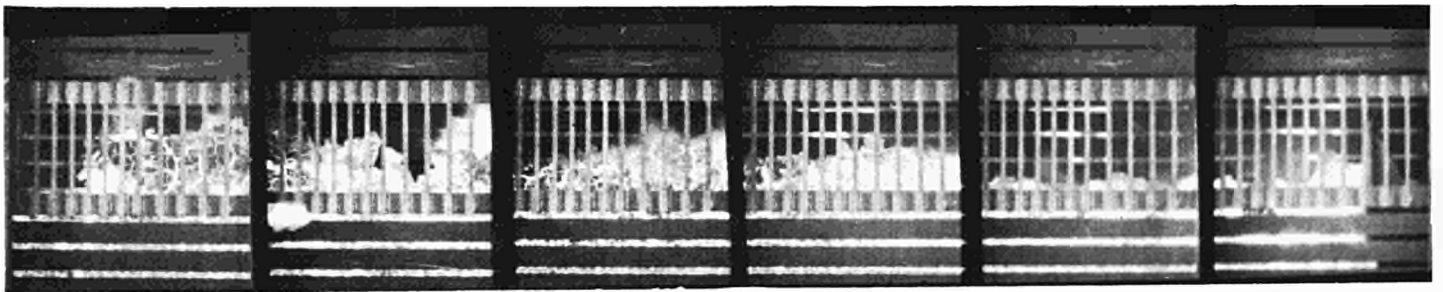


Figure 3 - 10-Tons oven during charging the preheated coal





a) from the wet and mechanically-levelled charge (top contour)



b) from the dried but unlevelled charge (middle contour)



c) and from the preheated and also unlevelled charge (bottom contour)

Figure 4 - Comparison of the contours of the cokes pushed

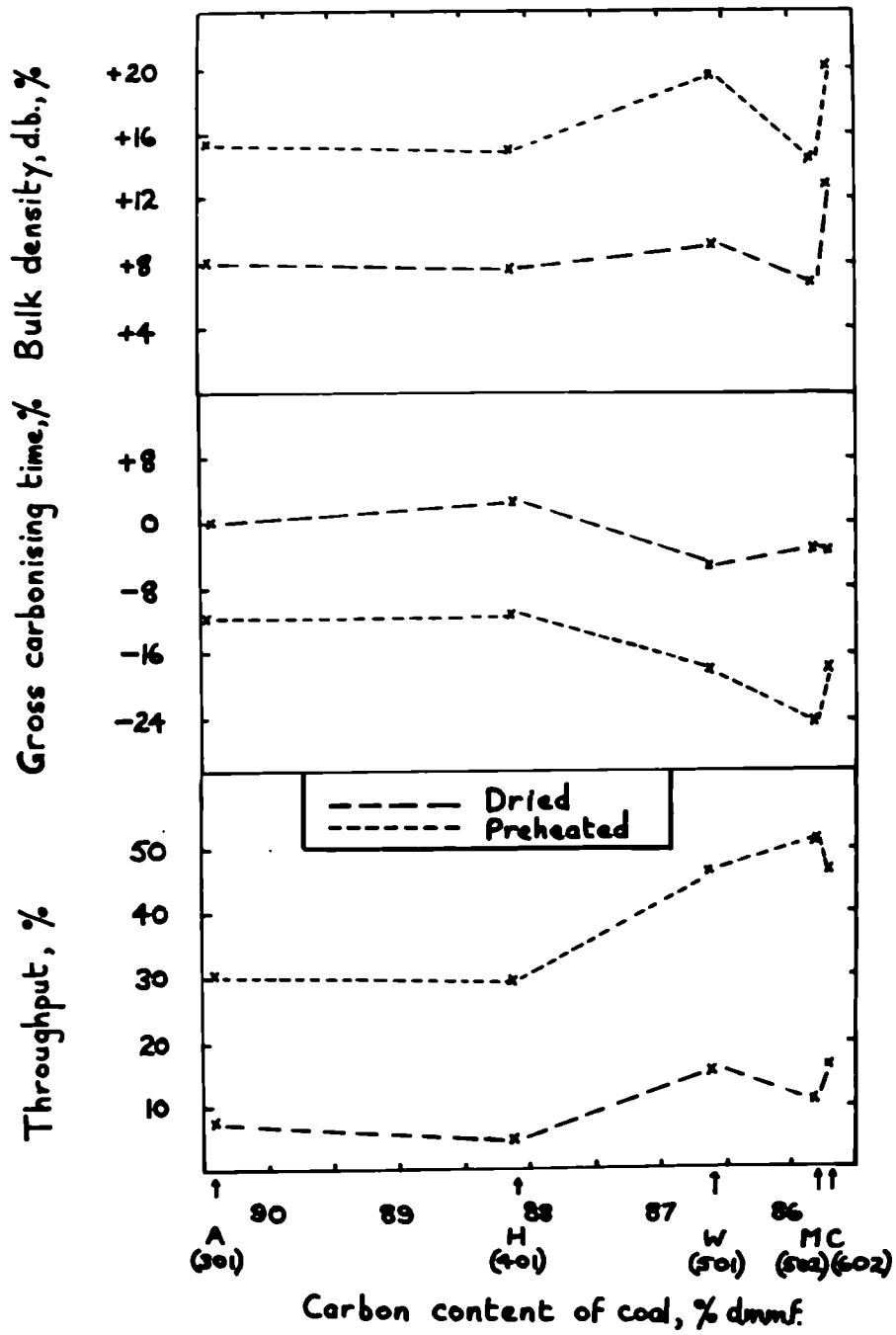


Figure 5 - Changes in the carbonising conditions due to drying and preheating five representative British coals

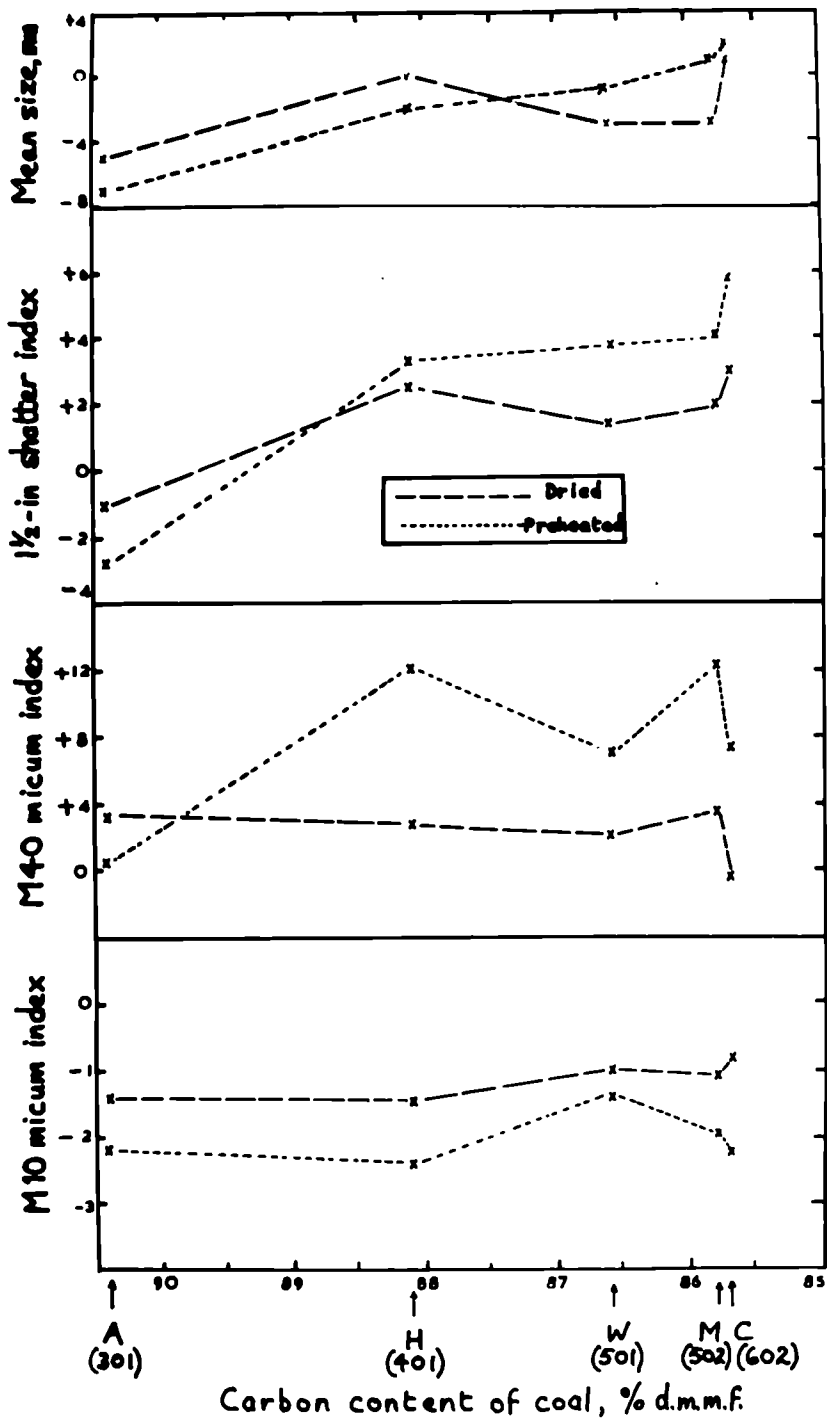


Figure 6 - Effect of thermal pre-treatment on the resultant quality of the coke obtained

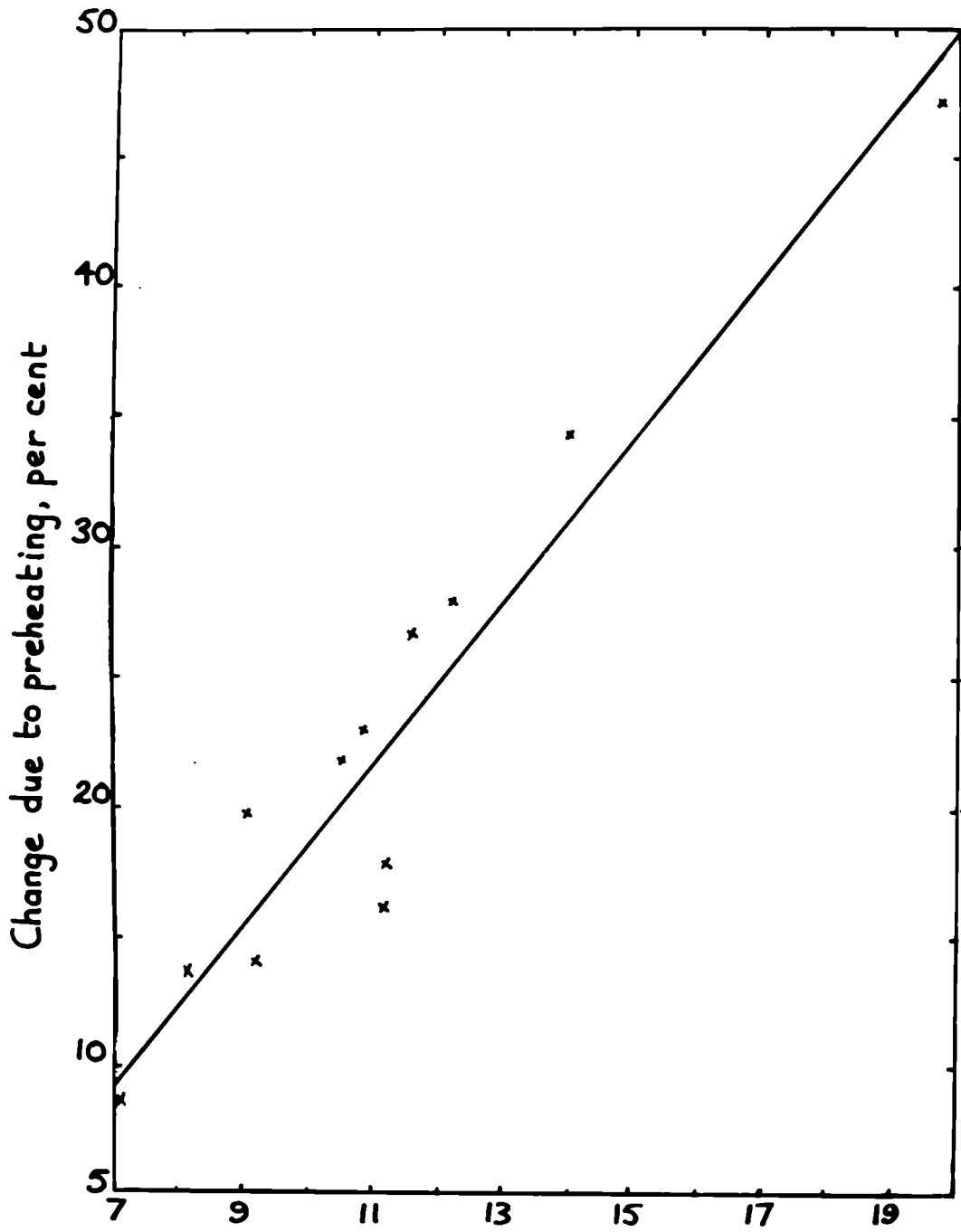


Figure 7 - Proportional improvements in the Mlo micum indices

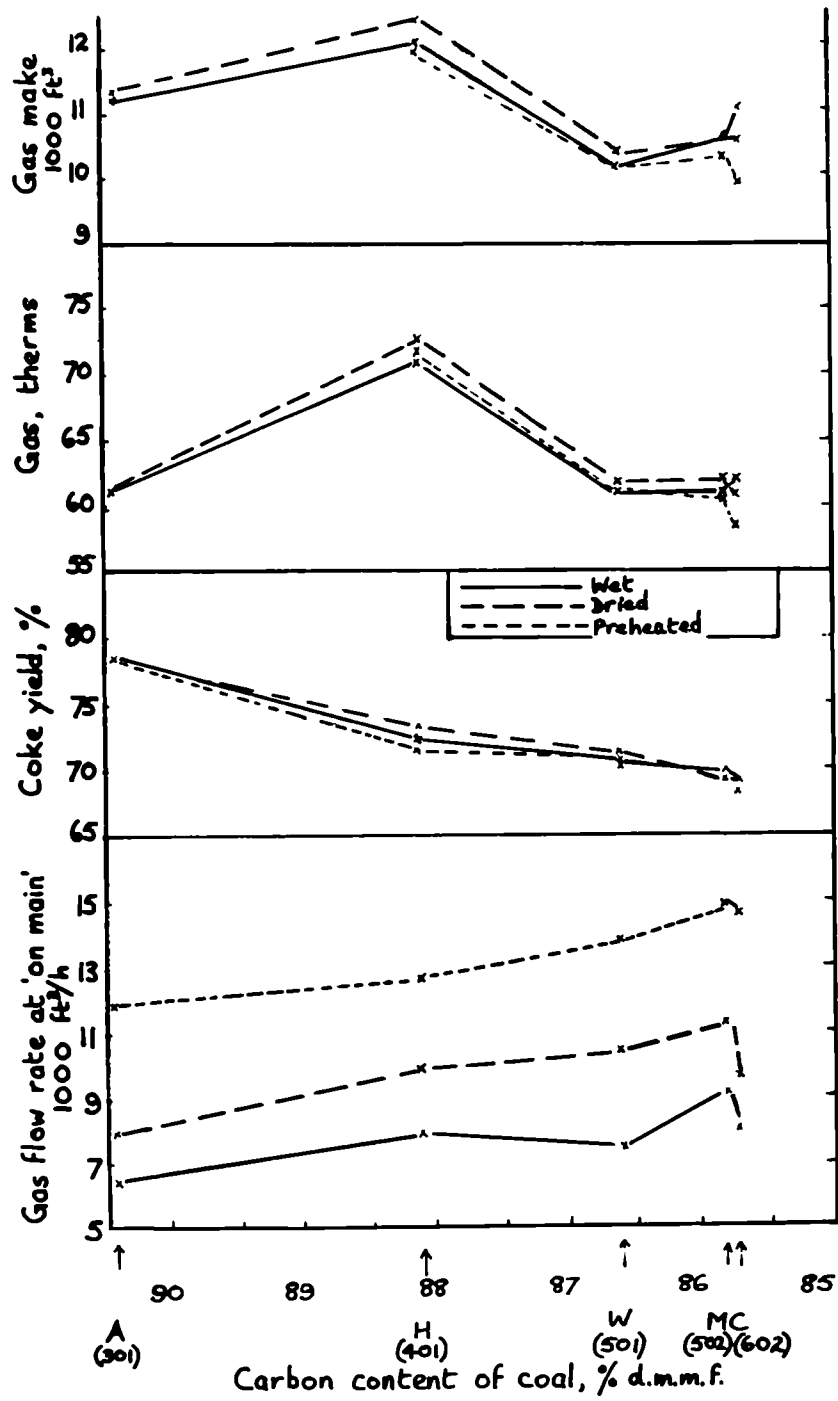


Figure 8 - Changes in the yields of the products

MM. Gudenau and Wenzel

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Up to now the method of producing uniform size coke, in other words coke as far as possible of the same lump size, on the basis of the coke oven process, consists of introducing a breaking and screening process after coking. The use of this method for producing e.g. coke of optimum blast furnace lump size, 40-60 mm, has the disadvantage apart from the high cost of breaking and screening, that it produces large quantities of under-size coke for which other uses must be found. In comparison, the moulded coke methods have obviously the advantage of being capable of producing the required lump size for the most part during the actual coking process.

Tests at the Aachen Ironmaking Institute have led to the surprising result that, with the use of a suitable processing technique, coke of uniform size can also be produced directly by the coke oven method. This type of uniform size coke, which has the shape of relatively equal-sized polyhedra, is closer in its particle shape to the product of the well-known moulded coke process than the crushed coke from normal coke oven product.

The basis of this new coking technique is the fact, known for a long time, that the caking ability of coking coals is completely neutralized by the addition of haematite ore. This phenomenon is used for the production of polyhedral coke in coking ovens by the following processing sequence:

Fine coking coal is first converted into lump form by one of the well-known methods. Pelletizing is particularly suitable for this purpose, with the proviso that the raw coal be reduced to a particle size of something less than 1 mm. A coal of this kind can be easily pelletized by the addition of water, so that large-scale production of coal pellets with a pellet diameter of about 40 to 50 mm should present no difficulty.

These coal pellets are then coated with a shell of haematite ore or a mixture of fine haematite ore and coal fines. These shells have a high adhesive power, so that even when dropped from a height of several metres no spalling is observed.

The coal pellets with their haematite shell are charged into ordinary coking ovens and coked in the usual way. This produces a cohesive coke cake due to the fact that during the coking process the spherical pellets soften and fuse into one another thus filling all the vacant spaces. This results in the polyhedral shape of the coke removed from the oven.

The fusion of the coal pellets together into polyhedral shape occurs only if the haematite coating is kept below a critical amount; if larger amounts are used the spherical pellet shape is retained. However, in this case such a large amount of the caking bitumen in the charged coking coal is destroyed by the haematite ore that only a comparatively small core of the charged pellets remains as solid coke. This method of coating with large quantities of haematite ore is also impractical in normal coking ovens for another reason, and that is that the oven content does not have sufficient consistency after coking for normal equipment to be able to push the coke out of the oven. Only the formation of the polyhedral shape ensures sufficient interlock and adhesion between the coke lumps.

Fig. 1 shows the formation of polyhedral coke in the coking oven. Fig. 1a is a section through part of the charge in an oven consisting of coal pellets with a haematite shell. Fig. 1b shows the charge after coking, in diagrammatic form. The pellets have fused into one another, filled out the interstices, and in this way formed polyhedron shaped bodies. The boundary area between individual polyhedra has been converted by the haematite ore, during the coking process, into a fine-particle coke which prevents adhesion of neighboring polyhedra.

Fig. 2 presents photographs of materials before and after practical coking tests. The coal pellets in Fig. 2a about 45 mm in diameter and have haematite shells. If certain processing parameters are observed during the production of these coke pellets they have adequate strength for charging into coke ovens. For example, drop tests from a height of over 6 m have given satisfactory results. Fig 2b shows a sample of polyhedral coke made from the pellets shown in Fig. 2a. The small pile of coke fines in this illustration is the fine particle coke produced during coking between the polyhedra due to the action of the haematite ore. This coke breeze (smaller than 30 mm) is screened out from the lump

coke and amounts to some 12% of the polyhedral coke removed from the oven.

The tests were carried out in an oven having an internal width of 38 cm. Low coking times proved possible in this polyhedra production process without any loss of coke strength or reduction in lump size. This is probably due to the fact that each polyhedron forms a self-contained field of stress, much less prone to crack formation than that observed with normal coke oven processing because of the approximation to the spherical shape and the relatively small dimensions.

Table 1 lists some of the test data of importance in evaluating the polyhedra coking process.

Test data for polyhedral coke production in coke ovens

Coking time	12 h
Average oven temperature	1010°C
Pellet size	40-45 mm
Iron ore content in pellet	2.5%

Screen analysis of coke produced

0 - 5 mm	10.1%
5 - 10 mm	0.4%
10 - 30 mm	1.2%
30 - 60 mm	68.5%
over 60 mm	20.2%

Drum test strength

(M. 40 at 100 rpm)	88.4%
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Drum tests on a normal oven coke made from the same coking coal with a coking time of 16.5 h gave about 84%.

Of the haematite ore coating the coal pellets, about 75% is found in the form of sponge iron in the coke breeze below 5 mm removed from the oven



and can be recovered by magnetic separation. In the production of blast furnace coke this low iron content in the coke represents an improvement that can profitably be represented as a credit.

For a definitive evaluation of the new coking process comprehensive trials on industrial scale would be necessary, with particular reference to the facilities required for charging the coal pellets into the coke ovens. For this apparently difficult task there are a number of simple and reliable solutions. The operational procedure and the choice of suitable charging techniques depend on whether existing coke oven plant is to be worked by the new method or whether plant is to be built or converted from the start with special modifications, compared with the normal method, designed for the new method.

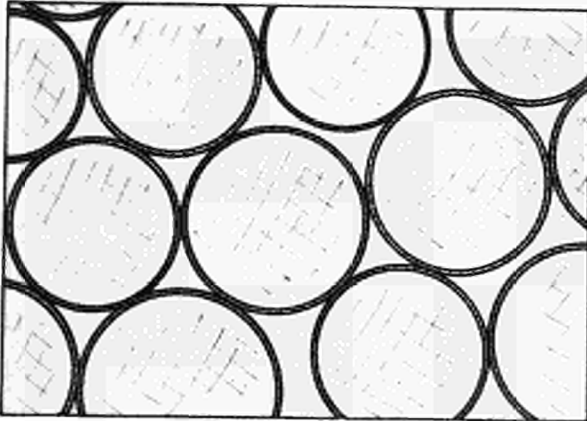


Figure 1 a

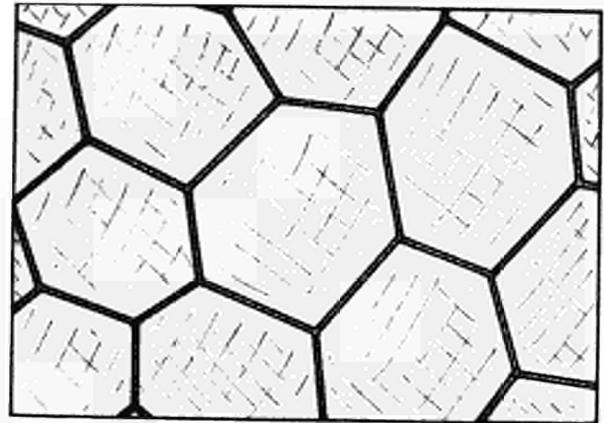


Figure 1 b



Figure 2 a



Figure 2 b

K. H. Hawner

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The two papers which now follow are concerned with the use of increased operating temperatures as a means of raising the throughput of coke ovens. In the first paper Dr. Weskamp will report on systematic investigations into raising the flue temperature and the limits found to this. Dr. Weskamp is Director of the Experimental Coking Plant of the Steinkohlenbergbauverein.

His paper is supplemented in significant manner by the succeeding statements of Dipl.-Ing. Guhr who reports on "Practical experiences with increasing the throughput of coke ovens by the use of higher temperatures". Herr Guhr is Manager of the Anna coking plant of the Eschweiler Bergwerksverein, at which, as is known, a high-throughput battery was erected some time ago.

Since the two papers are closely allied, I hope that you will agree if I propose a common discussion at the conclusion of both papers.

May I now ask Dr. Weskamp first to present his paper.

INCREASING THE PRODUCTIVITY OF COKE OVEN GROUPS

by

K.G. Beck and W. Weskamp

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The object of the first research at the Test Plant was the investigation of the influence of the most important raw material and operational parameters on oven throughput, heat consumption and products of carbonisation. For this purpose, the heating flue temperatures selected were representative of those in common use in the Ruhr area. The results of these investigations yielded basic data for optimisation of coke oven operation and starting points for the planning and construction of coke oven plants.

In the last few years, discussion of possible means of increasing coke oven throughput, to improve the economics of coke production, has assumed increasing urgency and importance. The subject of the investigations to be described is one of the many possible ways of increasing output, the reduction of carbonising time by increasing carbonising temperatures. In 1960 we investigated the influence of flue temperatures over the range  $1100^{\circ}$  to  $1350^{\circ}\text{C}$  using a Ruhr coal with approx. 25% V.M. (Ref. 1). The investigation planned for 1968 was to be with an average flue temperature of  $1400^{\circ}\text{C}$  and if possible  $1425^{\circ}$  or over. The principal emphasis was less on the exact determination of a heat balance than on finding the limits of increased capacity from increased temperature and the operational consequences for our plant. In view of the importance of the investigations, tests were to be carried out with several coals with different V.M. content, so that the results might have the widest possible useful application.

Before starting the investigation, an attempt was made to enable the temperature gradient in the ovens to be better observed during the 'forced operation'; the means chosen were additional temperature measurements in the upper part of the ovens and the building-in of thermocouples in the region of the regenerators. These measurements, which have already been reported in 'Glückauf' (Ref. 2), set the limits for temperature increase on the Test Plant ovens. Like almost all coke ovens in operation at present, the lower part of those on the Test Plant are built of silicious material.

Fig. 1 shows that with an average flue temperature of  $1,350^{\circ}\text{C}$  measured on the nozzle blocks, the hottest part of the regenerators above the filling was  $1,260^{\circ}\text{C}$  (Point a in Fig. 1), whilst the temperature at the silica/fire-clay boundary was about  $1,200^{\circ}\text{C}$ . If the average flue temperature was raised to  $1400^{\circ}\text{C}$  (which entails  $1430$  to  $1450^{\circ}$  on the coke side), the corresponding temperatures were  $1320^{\circ}$  and  $1220^{\circ}\text{C}$ .

Hence, on the ovens under consideration an average flue temperature of  $1350^{\circ}\text{C}$  was permissible for protracted operation, but an increase to  $1400^{\circ}$  could only be tolerated for short test periods, and under very strict supervision. On safety grounds, an increase beyond  $1400^{\circ}$  could not be allowed.

Fortunately, the construction of the new, high capacity battery on the Anna coke oven plant made a considerable extension of our investigations possible. The design and construction of this battery enabled temperatures to be raised well above  $1400^{\circ}\text{C}$  (Ref. 3).

In addition, interesting results were anticipated from the difference in chamber width, that on the Test Plant being 450 mm. and on the Anna battery 400 mm.

Fig. 2 gives the programme of the investigations.

On the Test Plant four coals, having V.M. content between 22 and 30% daf were carbonised at flue temperatures of  $1350$  and  $1400^{\circ}\text{C}$ , the coal with 22% V.M. corresponding to that used at Anna. In order to enable comparison of the results from the various coals at each temperature, operating conditions were kept as constant as possible, using the specific heating value, K.

On the Test Plant the average temperature on the nozzle blocks were laid down, whilst on the Anna plant the investigations were based on the operating time, according to the builders' Guarantees. Three tests were carried out with coal of about 21.6% V.M., with carbonising times of 14, 12.5, and 11 hours. The corresponding average nozzle block temperatures were  $1343, 1413$  and  $1490^{\circ}\text{C}$ . Finally, two further tests were carried out, with coal of 25.9 and 29.6% V.M. daf and 11 hours carbonising time and nozzle block temperature of approximately  $1490^{\circ}\text{C}$ . For operational reasons, only a few chambers

could be charged with the high volatile coals, so no figures for heat consumption could be obtained.

The principal details of the coals used on the Test Plant and at Anna are given in Fig. 3. Variations from the average values given here were only small, and can be regarded as normal for works conditions. Every endeavour was made to crush the coals so that 75 to 80% was below 2 mm. and 40 to 45% less than 0.5 mm. to avoid any great difference in charge density. Except in one instance, this was achieved.

The most important consequence of operating with higher nozzle block temperatures is the effect on the economics of the plant due to alternation of carbonising time and hence throughput. Fig. 4 shows carbonising times and throughput per 24 hrs., calculated for coal with 10% moisture and a charge density of  $800 \text{ kg/m}^3$ , plotted against nozzle block temperatures for the 450 and 400 mm. chambers.

For the sake of completeness, the results obtained at lower nozzle block temperatures on the 450 mm. chambers are included. By increasing the temperature to  $1400^\circ\text{C}$ , carbonising time on these ovens was reduced to 15 hrs., and the throughput increased to more than 26 tonnes per 24 hrs. On the Anna plant, with 400 mm. chambers, the increase in temperature from  $1350$  to  $1490^\circ\text{C}$  reduced carbonising time from 14 to 11 hrs., and increased the throughput from 24.7 to 31.5 tonnes per 24 hrs., corresponding to an increase in throughput of 27.5%.

From this point of view, chamber width has only a little influence on throughput, if as a pre-requisite for the comparison comparable nozzle block temperatures are selected. We hope soon to be able to verify the influence of chamber width on throughput, by tests planned at Oviedo on ovens with chamber widths of from 350 to 500 mm. at equivalent heating wall temperatures and over the range to be expected on the works. (Ref. 4).

In the paper presented to this Conference by Simonis (Ref. 5) it is shown that a prerequisite for the proper comparison of carbonisation processes is equivalent time/temperature alteration, i.e. equivalent specific heating factors, K. If this condition is satisfied equivalent carbonising

conditions are assured, and hence for a given raw material the yield and quality of the products of carbonisation should be the same. If the results of our investigations are looked at in this way, it is clear that under equivalent carbonising conditions throughput varies as the square of the chamber width, as chamber width squared enters into the formula for the value of K. This comparison shows that for different chamber widths different wall temperatures (and hence different nozzle block temperatures) must be used to achieve equivalent values of K.

Fig. 5 shows the heat consumption at 1350 and 1400°C for the various coals, as measured on the Test Plant. The curve for 1250°C is included for comparison. The curve for 1350° shows a definite relationship between heat consumption and V.M. in the coal. Heat consumption increases from about 520 K.cal/kg for coal with about 20% V.M. to some 570 k.cal/kg for coal with about 30% V.M. This curve, just as the curve for 1250°, can be accepted as accurate, since the necessary data for deriving the heat balance of coke oven, such as waste gas temperature, waste gas analysis, excess air, heat loss in waste gas and oven surface, as well as underfiring efficiency, correspond to values obtained during the tests. The values for 1400° on the other hand, were quite different, and are shown in Fig. 5 as dots.

Investigations into the influence of glue temperature on the Test Plant have shown quite clearly that the ovens can best be operated in the temperature range 1250 - 1300°C. The regenerators are designed for this range. As the operating temperature is increased the efficiency falls in increasing measure. Even at the start of the tests at 1400° it was clear that the thermal data recorded for calculating underfiring efficiency were only comparable to a limited extent with those recorded for the lower temperatures. Complete combustion, even loading of the regenerators and hence undisturbed flow conditions, are essential for optimum oven operation. These conditions could not be properly fulfilled at 1400°, because the cross-sectional area for gas flow could not be altered. Certainly, it was possible to achieve an average nozzle block temperature of 1400°, and to regulate the temperature gradient across the oven to correspond with the oven taper, and so get evenly burnt-off charges; however, to do this we were compelled to reduce the heat supply to the ram side of our half-divided ovens. The reason for this was as follows; the relatively large volume of hot combustion gases originating on the coke side of our half-divided ovens gave up part

of their heat to the heating flues on the ram side as they flowed through. The regenerators on the ram side were abnormally highly loaded. For this reason, the air for combustion could not remove enough heat from the ram side regenerators, and became abnormally hot. This led to an unusually high difference in heat supplied to ram and coke side, so the temperature of waste gases entering the ram side regenerators was about  $100^{\circ}$  above that on the coke side. The result of this was that the temperature of the waste gas in the waste heat boxes was about  $200^{\circ}$  higher on the ram side than on the coke side. This asymmetrical heat distribution disturbed the normal stability of the system throughout the test period.

The high rate of gas supply to the coke side already referred to had the further consequence that the excess air needed for satisfactory combustion could not be supplied, because there was no more capacity in either air inlet or chimney pull. As a result there was insufficient excess air in the waste gas on the ram side.

Fig. 6 illustrates the heat balance at Anna, for coal with 21.5% V.M. Underfiring consumption varies practically as a straight line with carbonising time; the figures were 522 k.cal/kg for 14 hrs., 542 k.cal/kg for 12.5 hrs. and 558 k.cal/kg for 11 hrs. These figures correspond to an increase of approx. 7%.

No heating difficulties arose for 11 hrs. C.T.; the cross-sectional area of air inlets and waste gas flues had been adequately designed.

Heat loss in waste gas is proportionately high, and increases from 15.4% for 14 hrs. to 16.7% for 11 hrs. The reason for this is to be sought in the decision to give up any idea of designing regenerators with an optimum height. Herr Guhr will speak on this point later.

The surface heat loss shows an increase from 8.5 to 9.8% with reduction in C.T.; this was to be expected. The oven efficiency fell from 76.1% at 14 hrs. C.T. to 73.5% for 11 hrs. C.T. in consequence.

The values marked with small circles on Fig. 6 give the results for carbonisation of coal with 25.9% V.M. daf, at 11 hrs. C.T. and about  $1490^{\circ}\text{C}$ .

Heat consumption for this coal was 588 k.cal/kg., an increase of 30 k.cal/kg compared with that for coal with 22% V.M.

These results agree very well with the increase in underfiring observed on the Test Plant for coals of this type. Heat loss in waste gas and from the surface show practically no difference from those observed in other tests. The increase in heat consumption is due to the increase in the heat required for coking.

The temperature in the free space above the charge is of particular interest at the higher carbonising temperatures. Fig. 7 shows the variation of free space temperature with time for the carbonisation of the three coals tested, at 1490°C at the nozzle blocks.

The mean temperature for the coal with 21.6% V.M. was 814°. Of special interest is the increase in mean temperature for the coals with 25.9 and 29.6% V.M., 869 and 914° respectively. At the end of the carbonising period the temperature reached 950° and just below 1000° for these two coals. Carbonisation of the coal with 21.6% V.M. did not result in carbon formation, whilst the coal with 25.9% V.M. gave roof carbon, especially round the roof arch. The carbon grew steadily during the two weeks of the test, especially near the charge holes.

By taking appropriate action, such as admitting air to the free space before pushing, no special difficulty is to be anticipated in carbonising this type of coal continually. The shortness of the test period of only a few days did not enable any firm judgement to be formed as to carbon formation from coal with 30% V.M. when carbonised at 1490°. However, we can refer to our experience on the Test Plant, working at temperatures of 1400°. The mean free space temperature for coal with 30% V.M. was 850° and at the end of the carbonising period the temperature rose to 950°. Thus on the whole the temperature of the free space on the Test Plant was lower than that recorded at Anna for this coal. Nevertheless, we experienced considerable carbon formation in the roof arch, specially near the charge holes. It was only possible to keep to regular working by routine air admission and continually knocking off the carbon through the charge holes.



If coking coal is to be carbonised at high temperatures, and hence short carbonising time, the determination of the shrinkage is important for trouble free operation. The investigations on 400 and 450 mm. chambers showed the expected picture, that shrinkage decreased with increasing V.M., but at the same time it revealed the considerable influence of temperature on shrinkage.

Fig. 8 shows the shrinkage curves for coal with 21.6% V.M. in the 400 mm. chambers, for 14, 12.5 and 11 hrs. C.T.: increased temperature and shorter C.T. reduced the total shrinkage from 3.6 to 2.7%.

At the same time the amperage during pushing rose correspondingly. Similar results were observed on the Test Plant with the 450 mm. chambers.

For coal with 30% V.M. and coal with 22% V.M. an increase of nozzle block temperature from 1350 to 1400 resulted in a decrease of the total shrinkage.

These operational results lead to the conclusion that any measure for increasing throughput should only be considered if account is taken of the actual coal to be carbonised.

The effect of increase in carbonising temperature on the size grading and mechanical strength of coke produced is of special importance.

Fig. 10 shows the size grading of coke from 450 mm. chambers for the various coals for nozzle block temperatures of 1350 and 1400°. Taking the coke produced at 1350°, coke above 80 mm. falls with increasing V.M. from about 51% to 40%, most of the increase in the fraction under 80 mm. appearing in the grade 80-60 mm. whilst the proportions of the other grades alters little. The same holds good for a temperature of 1400°.

If we now consider the size distribution of coke from coal of one V.M. content, we see that for the highly coalified coals there is only an inconsiderable change in size distribution with change in C.T. On the other hand, the less coalified coals show a greater decrease in coke over 80 mm., with corresponding increase in the fractions 80/60 and 60/40 mm. The yield

of blast furnace coke + 40 mm from 450 mm chambers is practically independent of the type of coal and the nozzle block temperature.

Fig. 11 shows the size grading for coke from the 400 mm chambers at 1490° for the three coals tested. As V.M. increases, the fraction + 60 mm. decreases sharply, so that smaller, but more uniform coke results. However, the blast furnace fraction of + 40 mm falls from about 72% to 61%.

Table 1 gives the figures for coke strength and abrasion for coke produced at the higher temperatures, determined according to ISO methods.

For coke from the 450 mm chambers at 1350°, coke strength and abrasion indices are good except for the high volatile coal. Increase of temperature to 1400° results in a more or less serious fall in coke strength.

For coke from the 400 mm chambers at 1490°, the M40 index is below 70% for all three coals. The abrasion index increases as the V.M. content increases.

The reduction in coke strength at high operating temperatures is in the main due to increased fissuring, whilst the actual material strength is improved by the high temperatures. This has been clearly shown by the researches of Echterhoff (Ref. 6) and by observations at the Anna plant on coke produced under extreme operating conditions.

The best way of overcoming the increased fissuring of the coke is by stabilisation. On the Test Plant we handled the coke from coal with 30% V.M. mechanically, and obtained an improvement in coke strength from 65.5 to 72.5, an increase of 7 points, as can be seen in Table 1. At the same time the abrasion index fell from 8.1 to 6.9%. Fig. 12 shows coke before and after stabilisation.

The photograph of the untreated coke shows clearly the uneven sizes of the pieces, the high incidence of fissures, and the stick-like shape of some of them. The picture of the coke after treatment is quite different. Individual pieces show no fissures, the sharp corners are rounded off, and the individual pieces are almost cubical in shape. The fraction above 40 mm consists in general of equal sized lumps. This can also be seen

from the two right hand columns in Fig. 10, which shows the make-up by the various size grades. The yield of + 80 mm. coke is much reduced by mechanical handling from 33 to about 8%. The 80/60 grade is nearly the same for both untreated and treated samples, and the 40/60 grade increases from 22 to 38%; this gives almost equal amounts of the 80/60 and 40/60 grades in the treated sample. The fraction under 40 mm increases from 9 to about 20% with the greater part of this fraction in the range 40/20.

Thus the inclusion of a stabilisation stage makes it possible to produce a coke suitable for blast furnace use, even at high coking temperatures.

The by-products collected on the Test Plant were examined, and the results showed the well-known relationships with temperature and V.M. in the coal. Even at 1400°C no noticeable alteration in composition of tar and benzole was observed.

At Anna it was not possible to separate the by-products from the high capacity ovens, so the investigation was confined to the crude gas after the collecting main. Benzole samples were collected using active carbon cartridges from tests at 14 and 11 hrs. Table 2 shows the analyses of crude gas for various coals and temperatures. Only a small variation with increasing temperature is to be seen.

The decrease in methane and higher hydrocarbons goes hand-in-hand with an increase in the pyrolytic breakdown products, Carbon monoxide and Hydrogen. The amounts of Nitrogen, Carbon Dioxide and Oxygen remain practically constant, showing that the ovens were tight.

The analysis of the crude benzole, shown in Table 3, is of greater interest. The benzole content increases by some 8%, whilst the toluol content falls by about 9%. At the same time the xylol is reduced to half. The considerable increase in naphthalene and non-aromatic content is specially noteworthy. These changes are due in the main to the high temperature in the oven free space. It is especially important when designing ovens which are to be worked at temperatures of up to 1500° to ensure that the top of the hairpin flues is in the correct place, with reference to the known shrinkage of the coals to be carbonised; this is to avoid extremes of temperature in the free space, and the consequent

formation of naphthalene and all the difficulties which this can entail.

The work here reported was carried out in the course of a research programme which was largely supported financially by the European Association for Coal and Steel, to whom our thanks are due. We are also very grateful to the Management of the Eschweiler Bergwerks Verein for their support for the work at Anna.

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T A B L E 1

COKE STRENGTH ISO METHOD

BWV  
1970

VK  
283

450 mm. Chambers

Nozzle Block Temp <sup>o</sup> C	1350				1400					
V.M. %	22.3	25.0	27.7	30.2	22.0	25.5	27.9	Norm <sup>301</sup> Stab		
M40 index %	74.7	76.8	76.5	68.4	68.1	76.5	72.5	65.5	72.5	
M10 index (abrasion) %	7.1	7.4	6.5	6.4	8.0	6.8	7.9	8.1	6.9	
<u>400 mm. Chambers</u>										
Nozzle Block Temp <sup>o</sup> C	1490		1488		1486					
V.M. %	21.7		25.9		29.6					
M40 index %	69.5		65.1		66.2					
M10 index (abrasion) %	6.7		7.1		7.8					

T A B L E 2

ANALYSIS OF CRUDE GAS

BWV  
1970

VK  
285

400 mm. Chambers

V.M. (daf)		21.5	21.6	21.7	25.9
Nozzle Block Temp.		1343	1413	1490	1488
Hydrogen	H <sub>2</sub> %	63.7	63.7	64.4	63.0
Methane	CH <sub>4</sub> %	24.0	23.4	23.0	24.4
Carbon Monoxide	CO %	4.9	5.4	5.7	5.6
Higher Hydrocarbons	C <sub>m</sub> H <sub>n</sub> %	2.2	2.1	1.9	2.1
Nitrogen	N <sub>2</sub> %	3.4	3.6	3.2	3.2
Carbon Dioxide	CO <sub>2</sub> %	1.6	1.5	1.5	1.4
Oxygen	O <sub>2</sub> %	0.2	0.2	0.3	0.3

T A B L E 3

ANALYSIS OF CRUDE BENZOLE

400 mm. Chambers

Nozzle Block Temp.	°C	1343	1490
Benzol	%	67.4	75.5
Toluol	%	21.6	12.5
m.p.-Xylol and Athybenzol	%	6.3	3.2
O-Xylol	%	0.8	0.5
Styrol	%	0.9	0.9
High boiling factor	%	1.3	1.9
Naphthalin	%	0.3	1.9
Non-aromatic	%	1.4	3.6

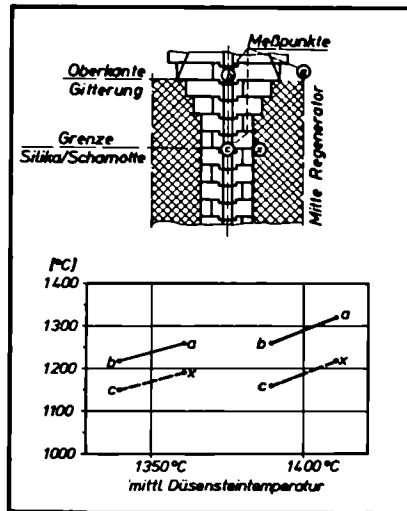


Figure 1 Temperatures in the regenerator and regenerator dividing wall

Abscissa: mean nozzle-block temperature  
 Legend : measuring points  
           upper level of checkerwork  
           silica/firebrick boundary  
           regenerator centre

<i>Kammerbreite 450 mm</i>								
Düsensteintemperatur °C	1350				1400			
Garungszeit h	16,4	16,2	16,4	16,4	15,0	15,0	14,9	15,4
Spez. Aufheizgröße K g/cmh	245	242	244	239	264	255	260	25,8
Flücht. Bestandteile (Lwat) %	223	250	277	30,2	220	255	279	30,1

<i>Kammerbreite 400 mm</i>					
Düsensteintemperatur °C	1343	1413	1490	1488	1486
Garungszeit h	14,0	125	11,0	11,0	11,0
Spez. Aufheizgröße K g/cm h	220	249	280	283	—
Flücht. Bestandteile (Lwat) %	215	216	217	259	296

Figure 2 Test programme

Legend : oven width  
           nozzle-block temperature  
           carbonising time  
           specific heating value K  
           volatile matter (dafb)



Flüchtige Bestandteile (waf)	%	450mm Kammer				400mm Kammer		
		22,2	25,2	27,8	30,2	21,7	25,9	29,6
Aschegehalt (wt)	%	6,8	6,8	6,5	6,0	6,8	7,1	7,6
Wassergehalt	%	10,1	9,6	10,1	10,6	9,3	9,3	8,0
<b>Kernungsaufbau</b>								
> 315 mm	%	11,0	9,5	12,5	16,2	9,0	11,0	7,0
< 20 mm	%	78,3	81,6	77,5	71,2	82,0	80,0	85,0
< 0,5 mm	%	38,2	43,6	38,7	31,0	42,0	39,0	45,0
Summenabweichung $M_s$	± %	15,0	19,0	17,1	16,4	16,9	15,9	17,9
Dilatation	%	20	155	206	178	37	56	112
Koksbildungsvermögen G		100	107	109	108	101	104	106

Figure 3 Characteristics of the coking coals

Legend : chamber  
 volatile matter (dafb)  
 ash (db)  
 moisture content  
 size composition  
 sum deviation  $M_s$   
 dilatation  
 coke-forming capacity G

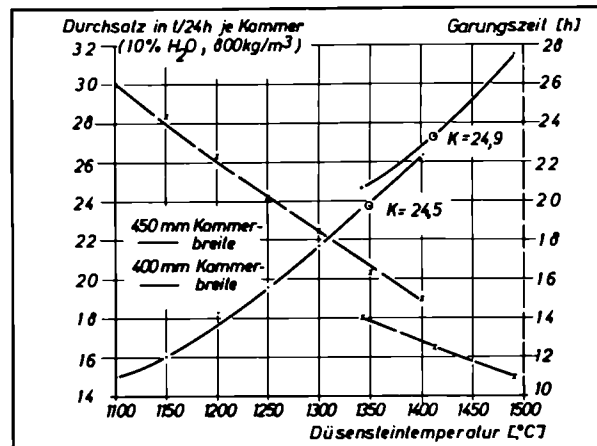


Figure 4 Throughput

Ordinates: throughput in t/24 h per oven; carbonising time  
 Abscissa: nozzle-block temperature  
 Legend : chamber width

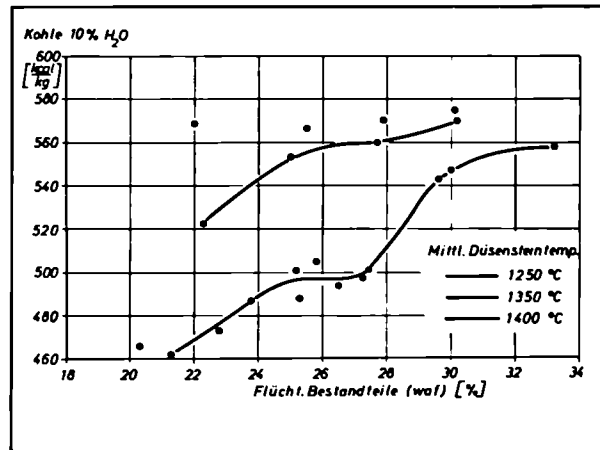


Figure 5 Heat consumption

Abscissa: volatile matter (daf)

Legend : coal

mean nozzle-block temperature

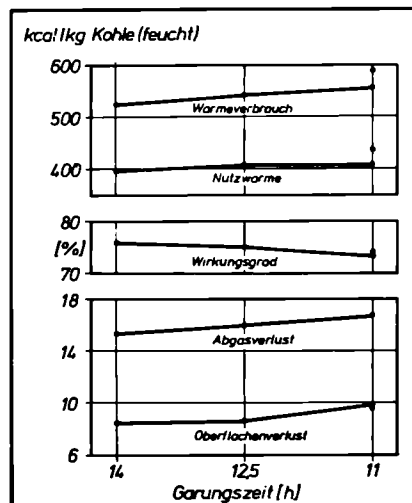


Figure 6 Heat balance

Ordinate: kcal/kg coal (wet)

Abscissa: carbonising time

Legend : heat consumption

useful heat

efficiency

waste-gas loss

surface loss

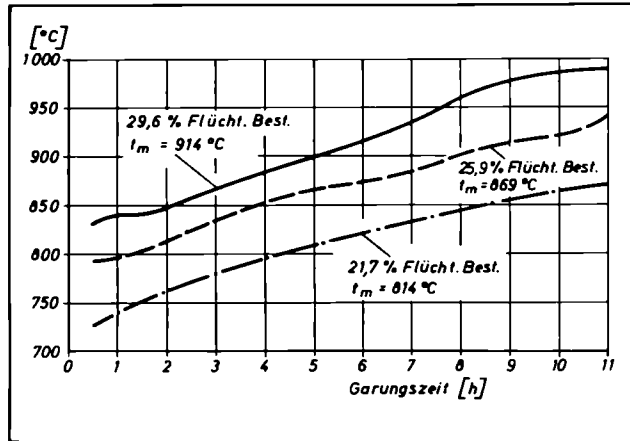


Figure 7 Free-space temperatures (mean nozzle-block temperature 1490°C)

Abscissa: carbonising time

Legend : volatile matter

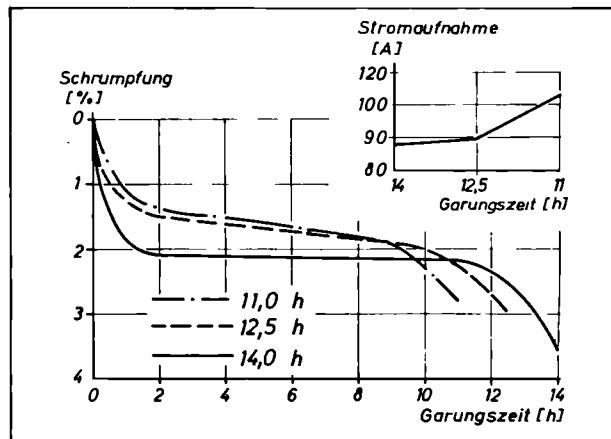


Figure 8 Shrinkage and current consumption

Ordinates: shrinkage; current consumption

Abscissa: carbonising time

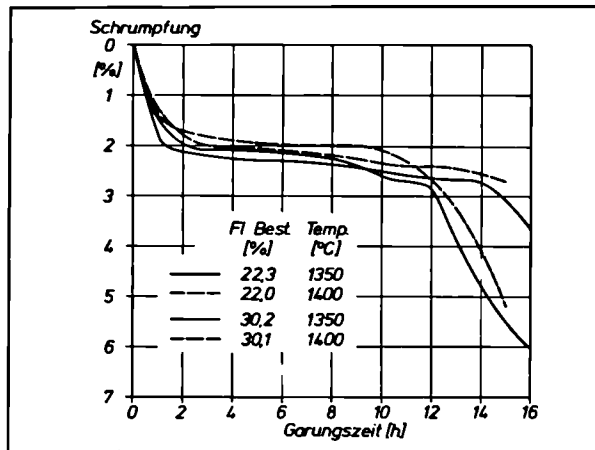


Figure 9 Shrinkage

Ordinate: shrinkage  
 Abscissa: carbonising time  
 Legend : volatile matter temperature

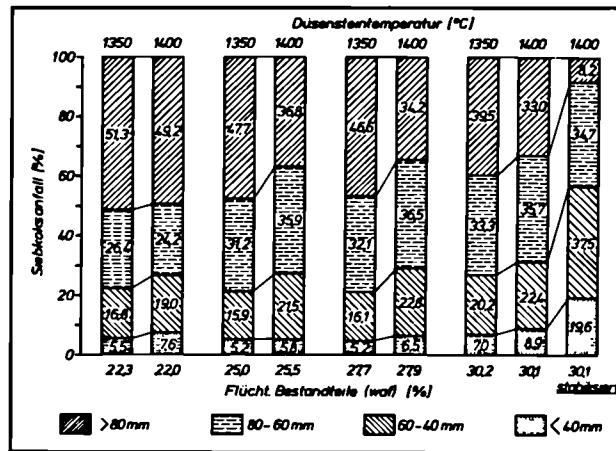


Figure 10 Size composition of the screened coke. Oven width 450 mm

Ordinate: proportion of screened coke  
 Legend : nozzle-block temperature  
 volatile matter (dafb)  
 stabilised

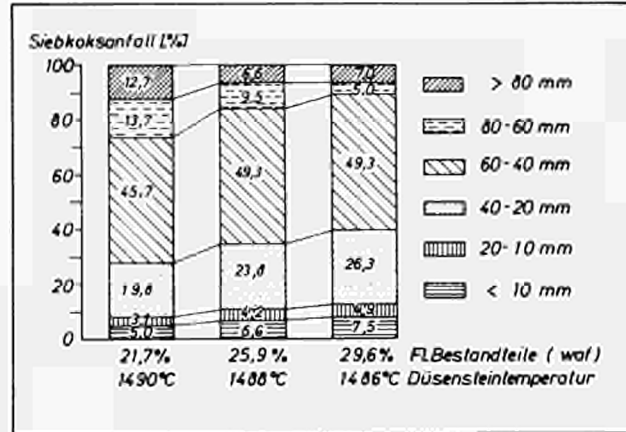


Figure 11 Size composition of the screened coke. Oven width 400 mm

Ordinate: proportion of screened coke

Legend : volatile matter (daf)

nozzle-block temperature

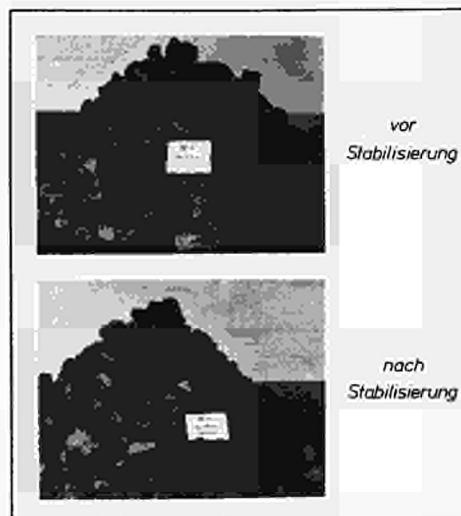


Figure 12 Influence of stabilisation.

Legend : before stabilisation

after stabilisation

K. H. Hawner

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And now may I ask Herr Guhr to tell us about his practical experiences with high-throughput ovens.

OPERATIONAL EXPERIENCES DURING A PERIOD OF  
INCREASED OVEN THROUGHPUT BY MEANS OF  
INCREASED FLUE TEMPERATURES

by  
G. GUHR

About ten years ago the Coking Industry in general had come to the conclusion that the classical coking process had reached the peak of its development and no further improvement in its economics could be looked for.

Unsatisfactory results, especially due to the high cost of new construction and the expense of manning which discontinuous processes bring in their train led to a search for improvement in the direction of continuously operating systems.

Since then, it has become clear that these new processes, interesting and important as they may be in the future, need a relatively long period of development before they become operational, and even then they might not immediately show the hoped-for reduction in the cost of coke production. It is therefore understandable that a fresh look should have been given to the normal coking process, to see whether there was any possible means of improvement.

In the last few years very good progress has been made in mechanisation and part automation of coke oven machines and coal preparation and coke handling plants (Ref. 1) which have led to not unimportant reductions in the cost of manning. A further step forward then became necessary, an examination of oven throughput, to see if a reduction in carbonising time could lead to a lower capital expenditure per ton of coke. Soon very valuable preliminary work was done, both by theoretical calculations and by practical work on the Test Plant of the Bergbau-Forschung GmbH at Emil C.O.P., Essen-Kray. The basic and very successful work carried out there has recently been published (Ref. 2 & 3). The results of these tests was everywhere received with the greatest interest, and all were anxious to see how far these ideas could be put into practice in long term working on a coke oven plant.

The Anna Coke Oven Plant of the Eschweiler Bergwerks-Verein at Alsdorf seemed to be not unfavourably placed for such a trial on a large scale.

The close commercial connection with one large user of blast furnace coke had favoured good use of the coking capacity of the plant, even in the crisis years. In 1967 it became necessary to let down a battery which was nearly thirty years old. This posed the problem of covering the shortfall in coke production whilst the new battery was being built, as far as possible or even in full, by increasing the production of the remaining batteries. It goes without saying that the new battery was to be of the most modern design and to be capable of the highest possible production.

#### Increasing the throughput of the existing batteries

Excluding the new battery, there are nine batteries on the Anna plant, averaging thirty ovens each. Of these nine one is a special case, not least because of its considerable age, so it is not included in this report. The remaining eight batteries range from 8 to 17 years in age, four being gas-gun and four underjet ovens. Chamber width is 400 mm, taper 60 to 80 mm, and wall thickness 120 mm. this last is an unfavourable feature when trying to reduce carbonising time by increasing flue temperatures.

This report is concerned only with the work done at Anna. It cannot deal with ovens of other design or dimensions, and with one exception it is confined to the coal used on the Anna plant.

The eight batteries mentioned were built of excellent refractory material and had been very carefully heated up, ten weeks being taken, and were in good condition throughout. Furthermore, they had been regularly operated under a very even load, even if this had been at the upper limit previously considered permissible.

Apart from the thickness of the oven wall bricks, conditions were favourable for a reduction of the carbonising time. Fortunately the Brohltal A.G. of Urmitz, suppliers of the refractories, and the firms of Koppers, Essen and Dr. Otto of Bochum who built the ovens, were in agreement.

In consultation with these firms, it was concluded that after a number of years operation at relatively high temperatures the quartz conversion of the silica in the heating flues must be complete, and so no fear of further growth of the bricks need be entertained. There was no question of exceeding the  $t_a$  value of the silica.



Higher flue temperatures mean that the temperature of the waste gas entering the regenerators will be higher. In discussing the permissible temperature at this point, the design and material of the lower part of the ovens must be taken into consideration.

The various oven types at Anna are compared in Fig. 1. Top left is the Otto Underjet Oven, top right the Koppers Underjet. Bottom left is the Koppers Gas Gun oven, and bottom right the design of the new oven. It will be seen that the ovens in the first group have only the upper part of the regenerator walls of silica, the remainder and also the checker work being of fireclay. The second group have all walls of silica, but the checker work is of fireclay, as is the case in the Koppers Gas Gun ovens. The most recent design has not only all walls, but also the upper part of the checker work made of silica, to suit the higher temperatures. An oven is the better suited to high temperature operation the more the lower part of the structure is built of silica.

The fireclay material used in the regenerators had a  $t_a$  value of  $1370^{\circ}\text{C}$ . If it is decided on safety grounds that the waste gas temperature at inlet regenerators must be  $100^{\circ}$  below the  $t_a$  value, and assuming from previous experience that the difference between flue temperature and regenerator inlet temperature is  $150^{\circ}$ , then a maximum temperature of  $1420^{\circ}$  in the flues should be perfectly safe. The results of temperature measurements on the various types of oven showed that fears of dangerously high regenerator inlet temperatures were generally unfounded, but that underjet ovens required more careful supervision than the gas gun ovens.

Figure 2 shows how the temperature at the inlet to the regenerator depends on the flue temperature in the two types of oven.

The regenerator inlet temperature on the gas gun oven was taken with a Pyropto on the 'Scissors' (Translator's note: The Germans use this term for the point in the middle on the oven block where the inlets to ram and coke side regenerators cross one another), while on the underjet ovens it was measured at the top of the filling at the third cell in from the stopping. The difference between inlet regenerator temperature and flue temperature five minutes after change-over is  $25^{\circ}$  less than the usually accepted figure of  $150^{\circ}$ , on the underjet ovens, and  $25^{\circ}$  greater on the gas gun ovens.

This difference in the behaviour of the two different types of oven no doubt has its origin in the protective effect of the horizontal flues leading to the 'scissors' which are between the upper and lower parts of the Koppers gas gun oven. The curves show that, contrary to original opinions, the ovens have further reserve capacity, which would certainly have allowed a further increase in flue temperatures.

Next, a further difficulty appeared to be the greatly increased volumes of gas, air and waste gas which would have to be forced or drawn through the flues and fittings of the ovens, which had all been designed for the former coal throughput. Increased production would have to be achieved without any alteration in construction. In fact, these considerations seemed to limit the possibility of increase, until, based on results of previous performance, the draught relationships on the ovens was altered; for example, flue pressure at oven deck level was reduced from + 3 mm. to + 0.7 mm. The higher waste gas temperatures also intensified the draught relationships. Without going into details of the intermediate stages, Table 1 shows the results obtained on the existing batteries.

In 1958 the ovens were operated at 17 hrs. carbonising time, which seemed to be full utilisation of the capacity, taking into account the thickness of the wall bricks, 120 mm. The average flue temperature was 1310°C, and the average daily coke production over the year was 3945 tonnes for the eight batteries. Over the next ten years various small alterations, mostly in organisation, enabled the carbonising time to be reduced to 16 hrs., with an average flue temperature of 1321°C and a coke production of 4200 tonnes per day. In 1967 intensive efforts to increase production began, with the result that today the ovens are operating at a carbonising time of 13.9 hrs. The average flue temperature is 1350°C, with an average of 1404°C and a peak temperature of 1420°C on the coke side. Coke production for these batteries amounts to 4650 tonnes per day. Compared with operating results for 1958, the increase is 18%.

Increased throughput is not obtained just by increasing flue temperatures; organisational measures also play an important part. The whole operation of the plant must be carefully supervised and generally tightened

up. Control of heating is so important that it pays to employ highly qualified staff on this duty. Pushing schedules must be strictly kept to, including change of shift, hold-ups in pushing must be avoided and so on. It must be emphasized once more that these operational measures contribute in a great degree to the full utilisation of available capacity.

#### Operating Conditions and Capacity of a New Coke Oven Battery

Although the increased throughput achieved by the existing batteries is considerable, and helped considerably to cover the loss of coke production, it was expected that a new battery of up-to-date design and the most modern refractories would give considerably better results.

In mid-1965 new developments in the refractory field became known (References 4, 5 and 6) by which it was hoped to obtain greatly increased throughputs from batteries in the U.S.A. Two different means of advance were proposed; good results were expected from using silica of higher density, and from the inclusion of metallic oxides in the silica bricks. When the Eschweiler Bergwerks-Verein decided in early 1967 to build a new battery, these ideas were seriously considered. However, since up to the beginning of 1967 no results worth mentioning had been obtained from trials with metallic oxide addition, this proposal was abandoned and instead silica wall bricks of special quality were decided upon. This quality can only be produced by the Refractory Industry by the use of the best quality raw material and the most rigorous control of manufacture and firing.

Table 2 gives the principal details of the specification of the silica chosen for the wall bricks of the new battery, compared with the Specification DIN 1089 for lime-bound silica coke oven bricks, valid until then, and the proposed new DIN 1089 Specification.

It will be seen that the specification chosen by the Eschweiler Bergwerks-Verein is even stricter than the new DIN 1089. The gravity, reduced in the DIN specification from 2.38 to 2.35 g/cm<sup>3</sup>, must for the new bricks average 2.33 g/cm<sup>3</sup>, with no value over 2.35. Porosity, formerly specified as 70% less than 27, is now 90% equal to or less than 22, with no value over 24. Compressive strength and refractoriness under load are correspondingly increased, the former from 200 kp/cm<sup>2</sup> to an average of 450, with no value less than 350, and the latter from + 1580°C to + 1660°C.

It must be noted here that the Specification must not be set too high. Wall bricks with very low porosity can suffer damage due to change of temperature, and one knows the considerable stresses set up by charging the ovens with damp coal and by spraying the walls. The experts of the Refractory Industry consider that porosity should not be less than 20%.

Figure 3 gives the conductivity curves for silica bricks of the former KO quality and for the KOD quality used in the new battery at Anna.

The difference is considerable, especially at the higher temperatures which are worked for short carbonising times.

The new battery was put to work on 1st October 1968. Heating took ten weeks, and further heating was carried out slowly and with care, and the dates for the tests at 14, 12.5 and 11 hrs. carbonising time were agreed as the second half of January, the second half of March and the second half of June, 1969. The tests were undertaken by the Bergwerksverband GmbH of Essen Kray.

Table 3 gives details of the coals used during the tests. For all three, a comparatively lean coal, with only 21.6% V.M. (daf) was used, such as was normally carbonised at Anna. This coal is a blend of widely differing coals, whose V.M. content varies from 14 to 32%.

Only for the first test, in January 1969, was the coal finer than normal, at 86% under 2 mm. Deviation was 16 and 16.9%, expansion ranged from 53 to 37%, coking index G 1.04 to 1.01, and swelling index 8 for all three.

If a coking coal with such a low V.M. content is carbonised very fast and with very high temperature, difficulties are to be expected from insufficient shrinkage (Reference 7). On the other hand no trouble from excessive carbon formation is to be anticipated.

Table 4 gives details of throughput. Battery III during the three test runs carbonised 773, 847 and 979 tonnes per day, and thereby achieved 1.37, 1.50 and 1.74 tonnes per m<sup>3</sup> of oven volume (excluding free space) per day.

The percentage increase for 11 hrs. carbonising time was 153% based on 17 hrs. as normal. As already explained, this figure had been accepted as a limit for ovens 400 mm. mean width, at least for 120 mm. thick wall bricks. The wall bricks in the new battery were reduced to a thickness of 108 mm. As was expected, the specific heat consumption increased appreciably, since an increase in the size of regenerators had been decided against.

Waste gas figures were normal, as Table 5 shows. Even at 11 hrs. carbonising time the combustion in the flues was satisfactory, though the waste gas temperature rose to 308°, 318° and 336°C. Average flue temperatures were 1347° for 14 hr., 1413° for 12.5 hr., and 1490°C for 11 hr. carbonising time. Since in the circumstances the highest flue temperatures are of interest, and not only the average figures, it should be added that for 11 hr. carbonising time average flue temperatures of 1542° on the coke side, with a highest value of 1560°C were recorded. The Brohtal A.G. put the  $t_a$  figure for the silica at 1680°C. The satisfactory performance of the material was guaranteed at 1640°C, which has regarded as the highest temperature to which the material was to be subjected, and a figure not to be exceeded. With this in mind, a safety margin of 70°C was added to the actual temperature of the nozzle blocks five minutes after reversal, optically measured. This was made up as follows:

For inaccuracy in observation	20°C
For temperature drop during the five minutes between reversal and observation	50°C

Hence the highest permissible figure for the flue temperature five minutes after reversal was set at 1570°C. A further margin of 30°C was allowed for the difference between freshly charged ovens and those burnt off and as a safety margin for breakdowns, so the average flue temperature on the coke side five minutes after reversal' was set at 1540°C.

Thus the average flue temperatures on the coke side and also the highest temperatures were set within the range which the refractory manufacturers gave as permissible.

Oven wall temperatures were measured 300 mm. above oven sole level

and 300 mm. below the level of the top of the charge. At the lower level, temperatures of  $1100^{\circ}$  for 14 hr. work,  $1150^{\circ}$  for 12.5 hr. work, and  $1182^{\circ}\text{C}$  for 11 hr. work were recorded. The corresponding figures for the upper level were  $1077^{\circ}$ ,  $1120^{\circ}$  and  $1157^{\circ}\text{C}$ . The difference between upper and lower wall temperatures for the three carbonising times was about  $25^{\circ}\text{C}$ , so even at the shortest carbonising time the heat distribution in a vertical direction was satisfactory.

A critical examination of the burnt-off charges, which in general were very satisfactory, showed a little incomplete carbonisation localised in the upper part of the charges and on the coke side. This showed the need for more heat in the upper part of the walls, and for this very short carbonising time an increase in the temperature difference in a horizontal direction from ram to coke side. Contrary to the usual practice, this difference had to be a greater number of degrees Centigrade than the taper of the ovens in millimetres. As is well known, the temperature in the free space above the charge is of great importance, because of roof carbon formation. It reached  $789^{\circ}\text{C}$  for 14 hr. work, and only  $814^{\circ}$  for 11 hrs., though  $840^{\circ}$  had been expected. Since on the one hand there was no sign of roof carbon formation, and on the other the tops of the charges were not completely burnt off, more intense heating of the upper part of the oven chambers can be allowed, which would bring in its train a further reduction in carbonising time.

The drawings of the various oven systems in Figure 1 show that the new ovens have not only the regenerator walls, but also the upper half of the regenerator filling made of silica. Thus there is no need for fears of the waste gas temperature being too high. However, it is interesting to see how this temperature varied with the flue temperature for 11 hr. work. Five minutes after reversal, there was a temperature difference of  $120^{\circ}\text{C}$  between flue and inlet regenerator on the coke side. The latter rose to  $1415^{\circ}\text{C}$  at the end of the reversal period. Thus it will be seen that fireclay bricks, with their  $t_a$  value of  $1370^{\circ}\text{C}$  could not have been used. Figure 6 shows the temperature curves in the centre of the charge during the final hours of the carbonising period, for the various carbonising times. Here too, it will be seen that the upper part of the ovens should have had more heat for all three carbonising times. It ought not to be

difficult to make the necessary correction, which is all the more permissible since the temperature in the free space is low, only 814°C.

It the amount of heat supplied to the upper part of the oven is increased, it should be possible - as can be seen from the curves for 11 hr. work - to push the ovens after 10½ or even 10 hrs., since the temperatures in the centre of the charge are above 1000°C.

The Effect of Increased Coking Temperatures on the Properties of the Blast Furnace Coke

The use of extremely high temperatures naturally result in coking conditions which are not without influence on the properties of the coke produced (Ref. 8).

Of more importance is the alteration in the coke which results from shortening of the carbonising time. There are numerous references in the literature to the fact that the size of the coke is reduced as carbonising time is shortened and higher temperatures are employed (Ref. 9, 10, 11 and 12). These deductions and observations were confirmed.

The proportion of coke above 80 mm. fell from 27.7% for 14 hr. work to 23.4% for 12.5 hr. and 12.7% for 11 hr. work. The 60 - 80 mm. fraction was 21.9%, 11.3% and 13.7%. The fraction 40 - 60 mm. increased from 34.3% to 41.4% and 45.7%, and the fraction 20 - 40 mm. from 9.8% to 16.4% and 19.8%. Fortunately the total amount suitable for blast furnace use remained about the same.

On grounds which will be presented when the question of coke strength is discussed, stabilisation of coke produced by very short carbonising time is desirable. The size spectrum of stabilised coke naturally depends on the degree of stabilisation to which it is subjected; a moderate degree resulted in the alteration below:

Under 80 mm	.....	5.9%
60 - 80 mm	.....	6.9%
40 - 60 mm	.....	52.9%
20 - 40 mm	.....	24.3%

and an unimportant increase of the fraction under 20 mm from 8.1 to 10%.

The reduction in the fraction above 80 mm because of short carbonising time and stabilisation is an advantage, all things considered, because the blast furnace coke which results complies with the present day requirements of blast furnace operators for coke with a narrow size spectrum and small size. There is no need for coke cutting plant.

Stabilisation of the coke appears to be indispensable, since Micum tests of the material appear to indicate a reduction in the coke strength.

Table 6 shows how greatly the Micum Index is changed by reduction in the carbonising time; the  $M_{40}$  Index falls from 86.3% for 24 hr. work to 73.5% for 11 hr. work. When the 11 hr. test run was carried out the ISO Test had been adopted at Anna, and this gave a value of 69.5; it was known from a long series of tests that for coke from Anna an ISO figure of 69.5 corresponds to a Micum Index of 73.5%. After stabilisation the  $M_{40}$  Index increased to 77.5%.

Examination of the  $M_{10}$  Index, which is equally good for all carbonising times, gave rise to the suggestion that the actual strength of the coke was perfectly satisfactory. Very short carbonising time results in a pattern of large fissures in the coke, and hence when the normal test procedures and trommeling are employed there is a falling off of the large pieces which results in a poor  $M_{40}$  Index.

In order to test the suggestion that the coke strength was considerably better than the  $M_{40}$  values indicated, the resistance to grinding (literally, grinding-hardness) and the strength under compression were compared for coke from 11 hr work and coke from a neighbouring battery working at 14 hrs.

The resistance to grinding was 3567 mkp/kp for 11 hr coke compared with 3120 for 14 hr coke, and the compressive strength for a cube of defined base area was 117.9 kp/cm<sup>2</sup> for 11 hrs and 100.3 kp/cm<sup>2</sup> for 14 hrs. These figures show that actual coke strength increases with reduction in carbonising time.



Of course, the need to make the methods of investigation of carbonisation under extreme conditions suit the special features of rapid carbonisation was not neglected.

Now a few general observations on the effect of short carbonising time and the associated high oven temperatures have on operation:

Under the conditions formerly regarded as normal, if there was a stop to pushing it was not a disaster. The coke stayed somewhat longer in the oven chamber, but could still be pushed out, even after a long stoppage, without trouble. The flue temperatures were fairly low, and overheating because the gas supply was reduced too late and insufficiently did not cause damage.

On a battery operating at very high temperature, the whole thing is much more sensitive. The coke, which is already small in size, must not be allowed to become smaller from overheating, or else pushing will become very difficult; the gas supply for underfiring must be very quickly reduced at the first sign of an interruption in pushing; all in all, the whole operation of the battery needs much more supervision and quick action by the supervisory staff.

Since stoppages can have more unpleasant, or even dangerous results than formerly, naturally it is logical to make all parts which can give rise to stoppages perfectly safe. There must be greater reserve capacity of oven machines, and the electric power supply must be safeguarded; even the coal blending plant and coke handling and loading must not have machines, plant or transport units out of action at the wrong time.

In the description of the operating conditions for the various carbonising times, oven temperatures were given which are of interest from the technical point of view. In contrast with earlier records for such 'forced working', the temperatures on the oven surfaces which are of interest were recorded.

The data in Table 7 can only be compared with caution, because the 14 hr test was carried out in January, the next in March and the third

in June, that is all three were held in quite different weather.

Nevertheless, it can be seen that the surface temperatures rise sharply for very short carbonising times. On the oven top the temperatures range from  $130^{\circ}$  to  $150^{\circ}\text{C}$ , and on the charge holes from  $300^{\circ}$  to  $370^{\circ}\text{C}$ . Temperature on the doors was  $160^{\circ}$ , on the ascension pipes  $235^{\circ}$ , and on the ascension pipe heat shields  $146^{\circ}\text{C}$ .

Under such unusual working conditions the oven crew is faced with a hard task. The installation of highly mechanised and automated plant, formerly desirable as saving manpower, now becomes an operational necessity. Continuous operation at short carbonising time is unthinkable without modern oven machines and mechanical door cleaning. Naturally the coke oven construction firms will in the future have to give much more attention to heat insulation than in the past.

The new battery which has been described in this paper is not the ideal type for short carbonising time. It is a compromise, insofar that the aim was to achieve an 11 hr carbonising time with the least possible expenditure. With the prospect of poor returns from the sale of gas in the future, higher heat consumption figures come into the picture.

On this hypothesis, better quality refractories and certain small alterations in details of construction would only require a small additional financial outlay, compared with a battery of equal size of the usual type.

If heat consumption figures similar to those achieved by batteries operating at present normal carbonising times are required, the regenerators must be made 700 or 800 mm bigger. This will add appreciably to the extra cost; but even in this case the increased production obtained from the reduced carbonising time will only be burdened with a small increase in capital cost.

Naturally, a battery should remain in service longer than the time needed to write off the capital cost, so the question of the expectation of life of the new type of battery is of interest. First, it should be

said that the basis should not be a set number of years, but the greatest possible output of coke from the battery. To make an extreme comparison, even if a new battery only lasted fifteen years instead of the usual thirty, there would be no objection if, in that time, the coke produced was double the former expectation, for a unit of time. It would even have the advantage that new developments could be adopted after fifteen years, instead of waiting for thirty years.

On the question of expectation of life of a high-capacity battery, one can only say that it must be a matter of experience. However, if such a battery is properly looked after, and - what is most important - has a steady work load and is not perpetually up and down in production, there is no reason to suppose that its life will not be such as to produce a greater total amount of coke than a conventional battery would do in thirty years. The increase in production of 18% on the old batteries and 53% for a battery of new design depends solely on the adoption of higher working temperatures. When further possibilities such as pre-drying of the coal and the use of thinner wall bricks (Ref. 13) are considered, one can say with every confidence that the classical coking process still has a notable future.

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T A B L E 1

OPERATING FIGURES FROM EIGHT BATTERIES AT ANNA C.O.P.

	1958	1967	1969
Carbonising Time, hrs. Std.	17.0	16.0	13.9
" %	100	94	82
Flue Temp. average coke side and ram side °C	1310	1321	1350
Flue Temp. average coke side °C		1377	1404
Peak temp coke side °C			1420
Coke production t.p.d.	3945	4200	4650
Increase in throughput %	100	106	118

T A B L E 2

PRINCIPAL PROPERTIES OF OVEN WALL BRICKS,  
DIN AND EBV SPECIFICATIONS

	DIN 1089 (old)	DIN 1089 (new)	EBV Battery IIIa 1968
1. Density or gravity g/cm <sup>3</sup>	95%=2.38 no value 2.40	95%=2.35 no value 2.36	Av. value 2.33 No value > 2.35
2. Total porosity %	70%<27 No value >28	Av. value ≤ 22 No value >25	90% ≤ 22 No value > 24
3. Crushing strength kg/cm <sup>2</sup>	≥200	90%>300	Av. value 450 No value <350
4. Hot strength (t <sub>a</sub> ) °C	>1580	No value <1620	> 1660

T A B L E 3

PROPERTIES OF COKING COAL

Carbonising Time hrs		14	12.5	11
V.M. (d.a.f.)	%	21.5	21.6	21.7
Ash (dry basis)	%	7.0	7.4	6.8
Moisture	%	10.7	10.1	9.3
Size Grading:				
> 3.15 mm.	%	7	10	9
< 0.5 mm.	%	43	39	42
< 2.0 mm.	%	86	81	82
Summated deviation + -	%	16	16.9	16.9
Expansion	%	53	43	37
Coking Index G		1.04	1.02	1.01
Swelling Index		8	8	8

T A B L E 4

THROUGHPUT AND HEAT CONSUMPTION, BATTERY IIIa

Carbonising time	h.	(17)	14	12.5	11
Throughput	t.p.d.	(640)	773	847	979
	%	(100)	121	132	153
t.p.d. per m <sup>3</sup> oven vol.			1.37	1.50	1.74
Heat consumption k.cal/kg (10% Wasser)			522	542	588

T A B L E 5

WASTE GAS DATA

Carbonising Time	h.	14	12.5	11
Analysis				
CO <sub>2</sub>	%	7.0	7.1	7.0
O <sub>2</sub>	%	4.3	3.8	4.2
Excess air	%	20.4	17.2	18.1
Temperature	°C	308	318	336





T A B L E 7

EXTERIOR TEMPERATURES ON OVENS

Carbonising time	h.	14	12.5	11
Surface			°C	
Oven top				
above oven		80	93	131
above heating flue		99	120	154
Charge hole lid		304	359	368
Charge hole frame		279	284	305
Heating flue plug		165	200	220
Door and frame		127	126	162
Ascension pipe				235
Heat shield				146

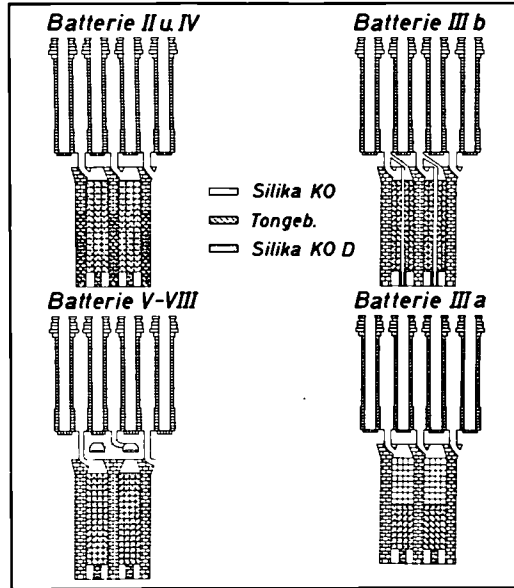


Figure 1 Construction of the substructure of the different oven types at the Anna coking plant

Legend : silica  
fireclay

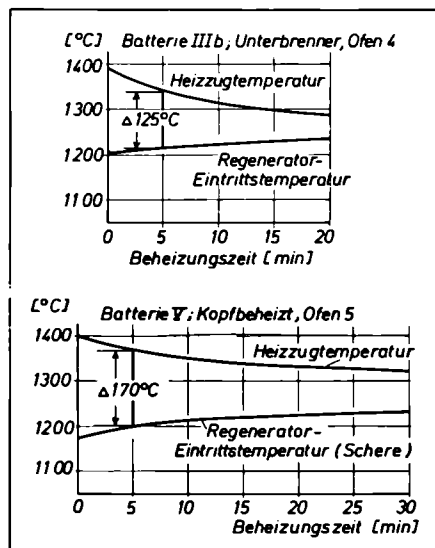


Figure 2 Regenerator entry temperature and flue temperature at 14 h carbonising time

Abscissa : heating time  
Legend : battery IIIb, underjet, oven 4  
flue temperature  
regenerator entry temperature  
battery V, gas gun, oven 5  
flue temperature  
regenerator entry temperature ("scissors")

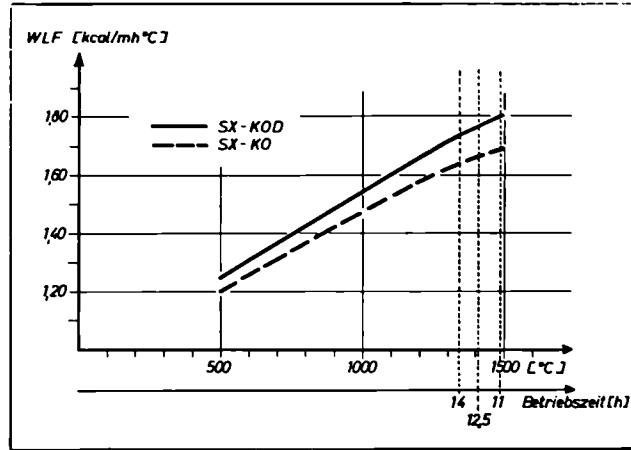


Figure 3 Thermal conductivity of silica bricks

Ordinate : thermal conductivity

Abscissa : carbonising time

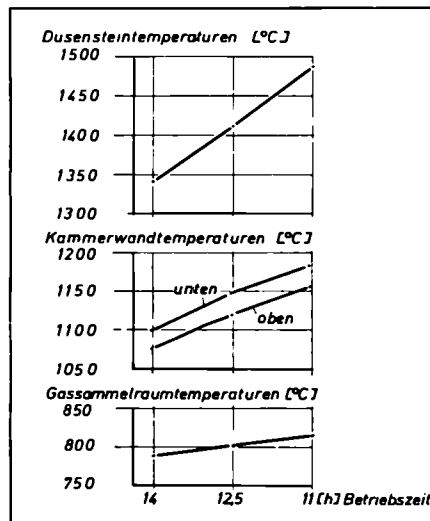


Figure 4 Flue and oven-chamber temperatures

Ordinates: nozzle-block temperature; chamber wall temperature; free-space temperature

Abscissa : carbonising time

Legend : bottom

top

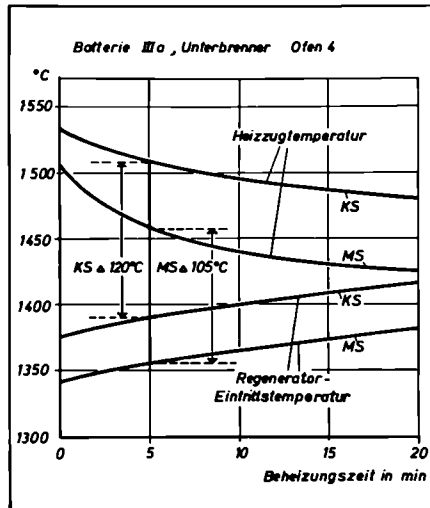


Figure 5 Regenerator entry temperature and flue temperature at 11 h carbonising time

Abscissa : carbonising time

Legend : battery IIIa, underjet, oven 4  
 flue temperature  
 coke side (KS)  
 pusher side (MS)  
 regenerator entry temperature

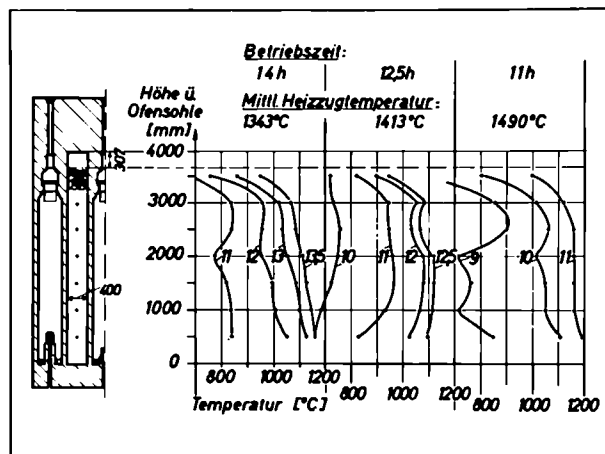


Figure 6 Temperature progression at the oven centre

Ordinate: height above oven sole

Abscissa: temperature

Legend : carbonising time  
 mean flue temperature

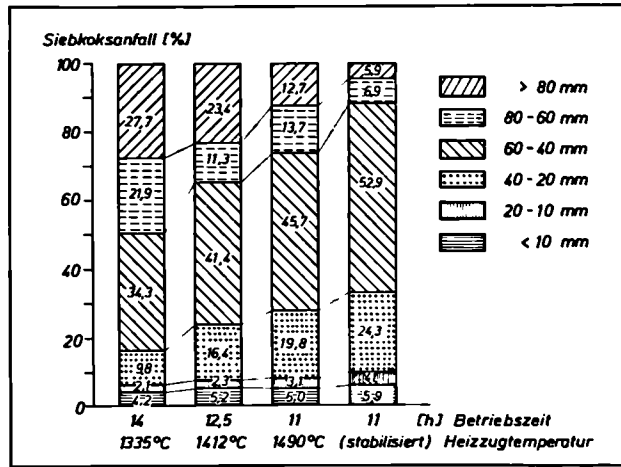


Figure 7 Size composition of the screened coke

Ordinate : proportion of screened coke

Legend : carbonising time

stabilised

flue temperature

DISCUSSION

K. H. Hawner

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The results reported by Messrs. Weskamp and Guhr are of great value for the construction of the replacement capacity which will be necessary in the next few years. What has been established about the requirements of coke-oven practice under these forced operating conditions is of significance, as well as the circumstance that the properties of the coke produced approach the requirements of blast-furnace plants for a smaller and more uniformly sized coke.

Weskamp's evidence however is of significance for the commercial coking plants which for the most part have been in operation for very many years already. The investigations show emphatically that an increase in coke production at these plants makes necessary intensified measurements on the coke ovens. Only in this way can safe oven operation and adequate oven life be ensured. Herr Guhr has likewise indicated emphatically that with these operating conditions the introduction of modern coke-oven machines and extensive automation of the plant processes becomes an operational necessity.

W. J. Pater

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Could authors give the final coke temperatures at different flue temperatures and in the case of Drs. Beck and Weskamp's paper were these final temperatures similar in case of coals of different volatile matter?

With adoption of higher flue temperatures was the operation of the battery changed e.g. was the reversal time shortened?

Were there any variations in coke sulphur observed with increased flue temperature, if so, was this related to the final coke temperature?

Finally, what would be considered as a significant change in coke quality parameters in the series described?

W. Weskamp

The final coke temperatures at the various flue temperatures and with the coals of different volatile matter are shown in the following Table;

Flue temperature °C	Volatile matter (d.a.f.) %	Final centre-of-charge temperature °C
<u>Oven width 450 mm</u>		
1348	22.3	1103
1345	25.0	1122
1353	27.7	1127
1360	30.2	1144
1398	22.0	1173
1393	25.5	1137
1403	27.9	1143
1395	30.1	1144
<u>Oven width 400 mm</u>		
1343	21.5	1105
1413	21.6	1143
1490	21.7	1189
1480	25.9	1145

No change was intended in the method of running the battery at the extra-high flue temperatures. The oven schedule was merely maintained exactly to the minute, in order to avoid unnecessary soaking of the carbonised coke charge. The reversal time at the Anna coking plant was 30 or 20 minutes. A reversal time of 20 minutes was chosen for the new high-throughput battery. It appears to be more favourable on the basis of our own investigation to shorten the reversal time when extra-high flue temperatures are used, because the temperature fluctuations at the nozzle block and therefore in the flue are thereby reduced.



No changes occurred in the sulphur content of the coke at the higher flue temperatures.

The smaller lump size and the apparently lower strength can be regarded as the important changes in the properties of the coke as a result of the reduction in operating time. The smaller size meets the desire of the blast-furnace operator for a closely graded coke. This coke has proved best in the blast furnace. The fall in coke strength is not to be regarded as absolute. Herr Guhr also expressed an opinion on this. He indicated that the fall in strength is to be attributed to the greater degree of fissuring of the coke. The true strength of the coke substance increases, as the values of microhardness and compressive strength show. It is therefore urgently necessary to attune the testing methods to the extreme coking conditions.

Meltzheim

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1. I would like first of all to confirm that in the study of high-temperature carbonisation which we are carrying out at the moment at Marienau, with the financial help of the ECSC, we also have noticed that the coke charges showed less shrinkage at very high rates of carbonisation. In particular, even on the scale of the 400-kg oven, we have noted difficulties in pushing. Do you not think that this may lead to operating difficulties?

2. During tests carried out at the Anna coking plant at 1400°C, did anyone notice with a blend of 21% v.m. any swelling phenomena causing for example deformation of certain heating walls?

V. Meskamp

To question (1). I have indicated in my paper that the total shrinkage of the coking coals used decreases as the operating time decreases and the temperature increases. I mentioned furthermore that, as a result of the decrease in total shrinkage at high temperatures, the current requirement for pushing the coke increases, i.e. that the coke recedes from the oven wall less than was the case previously at lower temperatures. The shrinkage was still always adequate, so there were no difficulties in practical operation.

To question (2). No coking pressure could be established with the coal of about 22 per cent volatile matter at the Anna coking plant. There was no deformation of the heating walls.

K.H. Hawner

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In the last paper of today's programme Dr. Simonis will tell us about new results of his theoretical work on carbonisation.

Dr. Simonis is Deputy Director of the Coal Processing Department of the Steinkohlenbergbauverein and at the same time honorary lecturer at Berlin Technical University. He is no doubt known to you through his basic work on the mathematical relationships between the properties of the raw material and products on the one hand and the carbonisation conditions on the other. In his paper today he will report on a definition of coking time and on the incongruence on the time scale between heat supply and heat requirement in the course of carbonisation in the coke oven. Here we are dealing with matters which recently have been more often discussed under the catchword "programmed heating".

May I now ask Dr. Simonis to present his paper.

W. Simonis  
( Steinkohlenbergbauverein )

HIGH-TEMPERATURE CARBONISATION IN TOP-CHARGED  
CONVENTIONAL OVENS CONSIDERED AS A TEMPERATURE-  
AND TIME-DEPENDENT REACTION.

Experience has shown that increasing the temperature of the flues shortens the coking time and raises the final temperature of the coke. The completion of carbonisation is determined industrially by different criteria. The most widely known method relies on the evaluation of the colour of the gas flames at the ascension pipe at the end of coking. Other criteria, like the quantity and quality of the products of carbonisation, indicate, after several years' practical experience, the relation between the flue temperature and the coking time.

This report proposes to indicate a generally valid function for the temperature- and time-dependent reaction according to the raw material, the dimensions and the operating conditions of the coke oven. This is only possible if the phenomena of heat transfer in the oven are amenable to a mathematical description like that one would expect to find in the Fourier differential equation; but Rohde has shown in a previous paper<sup>1</sup> that it is not, in its simple form, applicable to the coking reaction.

One can however describe the heat-transfer phenomena thanks to an extended form of the Fourier equation (Figure 1) in which these phenomena are related to the variation in the temperature field as a function of time, itself a function of the density of the charge, of the specific heat, of the thermal conductivity and, as a derived value, of the thermal diffusivity. The values indicated are therefore functions of the temperature and, partly, of the variation of the density of the charge. The extended Fourier differential equation assumes, in its present form, that the parameters cited enter as physical values, even if in the work mentioned above<sup>1</sup> they were treated as purely arithmetical values which thus contained heats of reaction.

The temperature field is measured in a plane of the oven perpendicular to the wall as far as the middle of the chamber. A certain number of determinations are necessary to that end, according to the heterogeneity of charging the chamber. In the calculation of the temperature field it can therefore by the same principle only be a question of a statistical picture. Figure 1 shows the results obtained at the first, tenth and sixteenth hours of coking.

The problem consists in finding the time- and temperature-dependent reaction applicable to the coking of coal in a given reactor, in terms of the properties of the raw material and of the operating conditions. The difficulty lies in the diversity of the heat-transfer phenomena which develop in the course of

coking at a different temperature level at each instant and at every point in the charge in the chamber. It is necessary therefore to find out if a knowledge of the modification of the temperature field in the oven enables one to deduce the coking time and in consequence the coking heat.

The heat transfer in the heating wall takes place by conduction. The heat supplied to the charge is determined by the temperature gradient in the heating wall, which depends on the thermal conductivity of the material of construction. The contents of the reactor absorb the heat differently according to their degree of carbonisation. The result is that the variation in the characteristics of the constituents during carbonisation must be known in order to be able to deduce from the modification of the temperature field during carbonisation, information about the heat-transfer phenomena.

After charging, the temperature of the charge climbs rapidly to 100°C and remains there until complete evaporation of the moisture; it is necessary therefore to supply during this period the latent heat of vaporisation of water. One would expect in principle a discontinuity in the curve to appear in the interior of the plastic zone. This is not however normally the case when the measuring device we had available is used, and also partly because of the value of the heat of reaction. Heat is transmitted mostly to the solid and plastic substance by conduction across the wall, but also by radiation and by convection in the gases produced.

The differential equation is solved numerically on a computer by the Schmidt difference method<sup>2</sup>. The limiting conditions are imposed by the temperature of the heating walls and the temperatures at the internal wall surface and at the centre of the chamber. Applied in the absence of heat sinks and sources, the equation leads to no agreement between the measured and calculated temperature fields. One must therefore introduce such sinks and sources in order to establish a coincidence of the two fields. The summation provides a check on the choice of the sinks and sources, which correspond respectively to an endothermic and an exothermic reaction. Comparison with a thermo dynamic treatment or with the calculation of the heat of reaction effected from actual measurements by subtracting the sensible heat of the carbonisation products from the coking heat permits us to verify whether the iteration as regards the choice of heat sinks and sources has been correctly conducted.

The specific value "charge density of the solid substance" depends on the temperature during carbonisation. From practical measurements and from consideration of the relation between the density of the charge and the size distribution of the coal, it follows that it is necessary to rely at 100°C on a charge density in the region of 830 kg/m<sup>3</sup>, which remains constant right from the start, to diminish afterwards by liberation of gas and increase afresh at the moment of semicoke formation. The final point of the function describing the charge density of the coke can be calculated according to the coke yield as a function of the volatile matter and of the specific heating value K. It is necessary in this connection to point out that the coke yield, like the yields of the other products of carbonisation, is thus contained in the extended Fourier differential equation. The course of the variation in charge density with temperature cross-checks the results of the tests carried out at B.C.R.A.<sup>3</sup>.

An equation proposed by Fritz and Moser<sup>4</sup> allows the determination of the variation of the specific heat  $C_p$  with temperature up to 250°C. The course of this function at higher temperatures can be calculated from the variation of the specific heat of graphite; the alteration is hardly perceptible above 800°C. Between 250 and 800°C, the influence of temperature can be deduced by analogy, the work of Richter<sup>5</sup> being of decisive importance in this connection.

The coefficient of thermal conductivity of the charge as a function of the temperature has been determined from the previous work cited above<sup>1</sup> and from Wicke<sup>6</sup>.

The coefficient of thermal diffusivity is a derived value, equal to the coefficient of thermal conductivity divided by the product of the charge density and the specific heat. Compared with previous work, the types of functions represented in Figure 2 are therefore no longer to be considered as arithmetical values, but as values with a physical significance.

The scrutiny of a number of carbonisation trials on the industrial scale has shown that, independent of the flue temperature in the range 1100-1500°C, carbonisation is ended when the thermal gradient is equal to 40 degC/m on statistical average. This numerical value is a result of the division of the temperature difference between the wall and the chamber centre by the half-width. Owing to the measuring technique, this value can be understood only statistically. the precision of the thermocouples being  $\pm 20$  degC at these temperatures. It must be added that the median plane does not coincide with

the geometric centre of the coke oven on account of the difference between the degrees of carbonisation attained by neighbouring ovens. The heterogeneity of the oven charge is yet another parameter. It is necessary to expect that, for a homogeneous charge, the end of carbonisation will correspond to a thermal gradient around 50 degC/m, which represents a reduction in the coking time of about half an hour. The thermal gradient of 40 degC, therefore, makes allowance for the length of time imposed by the heterogeneity of the charge.

Knowledge of this state of affairs allows one to calculate, with the help of the extended Fourier differential equation shown in Figure 1, the heat supplied to the charge per unit of time and per square metre of wall. This heat corresponds to the coking heat defined as the heat necessary to transform 1 kg of wet coal into its carbonisation products at their temperature of formation. One has thus for the first time the possibility of calculating beforehand the coking heats as functions of the properties of the raw material, of the characteristics of the oven structure and of the operating conditions. One can measure the quantity of underfiring gas and can therefore determine directly the thermal efficiency of the coke oven.

It is apparent that the heat supplied does not correspond to the optimum possible consumption. The heat consumption is much greater at the beginning of carbonisation than it is towards the end. As a result the heat input can be adapted to the consumption, a process possible only with the help of programmed heating like that discussed by Beck<sup>7</sup>. It is necessary however to point out now that such programming involves not only a reduction in the heat consumption necessary for carbonisation but also, accompanying a fall in the final temperature of the coke, a shortening of the coking time which corresponds to a certain increase in throughput. Programmed heating also permits the flue temperature to be raised up to the limit imposed by the properties of the structural material and the ash-fusion point of the coal charged.

The extended Fourier differential equation brings in, besides the volatile matter of the coal treated, a specific heating value  $K$  equal to the product of the average charge density by the square of the average half-width of the chamber and by the coking time. This equation therefore allows the yields of coke, gas, crude tar and crude benzole to be determined<sup>8</sup>.

The influence of the structural characteristics of the oven, such as the resistance of the bricks, their coefficients of thermal conductivity and thermal diffusivity and the width of the chamber, provides some indication of the optimum operating conditions and shows where the theoretical limits for these parameters of the coking process lie.

I have given here, by design, a simple qualitative outline of the results provided by the research carried out in the last few years.

As for future prospects, let us say that present research has as its object the search for a function which describes the conditions prevailing in a Pieper calorimeter, in an experimental 300-kg oven and in an industrial oven. We are also trying to formulate mathematically the heterogeneity of the charge in the chamber and to introduce it into the extended Fourier differential equation.

We would like to thank the European Coal and Steel Community for the encouragement it has given to the realisation of this research work.

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Variation of temperature field with time

Legend : Flue

Stretcher brick

Chamber

Centre of chamber

Quantity

Symbol

Unit

Temperature

Time

Bulk density

Specific heat

Thermal conductivity

Thermal diffusivity

Heat of reaction

Volatile matter

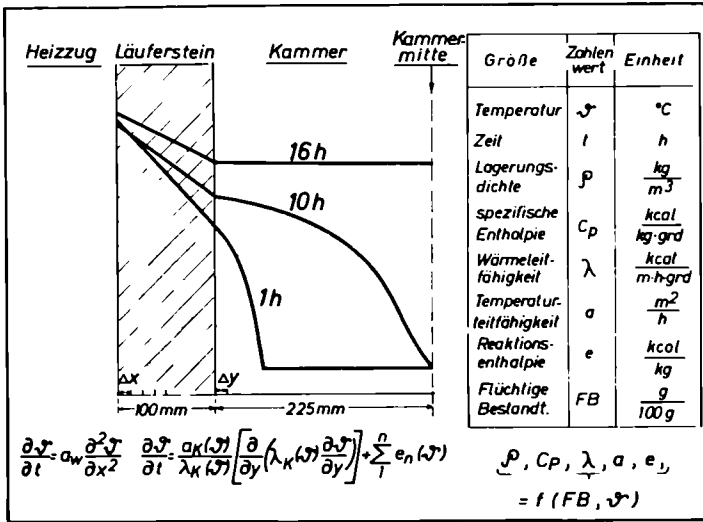


Figure 1

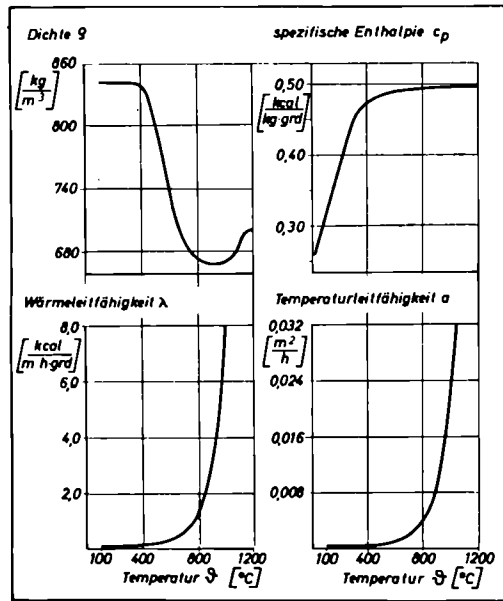


Figure 2

Variation of properties of coal and its pyrolysis products with temperature

Ordinates : Density; Specific heat; Thermal conductivity; Thermal diffusivity

Abscissa : Temperature

DISCUSSION

K.H. Hawner

The scientific studies of E. Simonis hold out the prospect of important applications in coke-oven practice: on the one hand the programmed heating already mentioned, and on the other hand the prediction of the heat of carbonisation for different coals and different operating conditions, which is of great interest to the coke-oven constructor as well as the coke-oven operator.

M. Parodi

A topic frequently discussed today is the possibility of increasing the productivity of coke ovens to really high rates and at the same time using mixtures containing up to 70% of coal of low coking power. The aim is obviously to reduce the level of investment and, simultaneously, to bring down the unit costs of coke processing. However, to my mind this policy calls for some qualifications which are necessary if it is to have a more general value, especially on the community level.

- For example, in the first place a policy of this nature does not seem applicable, for productivity purposes, to cokeworks with a large number of ovens fed by the same charging machine and operating already at low coking times, under 18-17 h;

- It has less immediate interest for cokeworks that are working with coals with less than 6% moisture when charged;

- The improvement in the coke quality is dependent on the initial condition of the coal used and on the safety limits applying to the coke oven refractory structures.

Obviously these comments cannot have any absolute value. All they are intended to do is to emphasize the fact that whilst these techniques are highly interesting when applied to the use of local resources, transposed to the more general level they involve a considerable commitment on the part of the coal producers. I am talking of the quality of what is called "good coking coal" with particular relation to its coking properties. These special techniques can affect the market in different ways, and not only towards the use of coals with low coking potential; they should also prompt efforts to increase the quality grade of that part of high coking coal that has to be used, though in smaller quantities than before, possibly for specially prepared e.g. pre-heated charges, but also as base coals to be used in coal mix preparation techniques that are becoming more and more vital mainly because of market and quality conditions.

M. Hawner

Ladies and gentlemen,

I would like your leave to say a few concluding words. From these highly interesting papers we have heard that a number of developments have been initiated in the field of coking technology that right from their beginnings have led to highly positive results. We can therefore hope that notable advantages in practice may be expected from the continuation of this work. I think that the European Communities Commission can observe with satisfaction how valuable the results of the development projects it has financed are for coking practice, and therefore for the economic influence of this important branch of coal processing industry. I should like to express the hope that the successes we have heard of today will be taken as confirmation of good collaboration, backed by the Commission, within the framework of the European Communities, and at the same time as a stimulus towards further intensification of this cooperation in the future.

This afternoon's papers have shown how valuable the results of the work described in the conventional coking technology sector are for coking practice. The programme, originally planned as systematic research into the basic principles of coke oven coking, has revealed the possibility of firstly broadening the range of coals usable for coking and secondly achieving a considerable increase in output from horizontal coke ovens.

Both are eminently important for countries in the European Community at this time and obviously in the future as well. Herr Spaak and Herr Schumm made the reasons for this very clear this morning.

The coke requirements of the steel industry and other coke users in the community cannot at present be met completely from the existing cokework capacity. This makes all the more welcome every step that helps to expand the volume of coking coal supplies and to raise the production capacity of existing and future cokeworks.

This is where the real opportunities lie for successfully backing up the Commission's efforts to secure the supplies of coking coal and coke.

We have heard from Herr Foch how the introduction of the technology of preheating coking coal permits not only an increase in output but also a broadening of the range of usable coals.

Herr Weskamp and Herr Guhr have shown to what limits the output of existing ovens and new ones built with improved refractories can be raised.

This information answers the request of Herr Schumm, who said this morning that rapid expansion to the limits of efficiency is particularly desirable.

Finally, Herr Simonis described on a theoretical basis another way of reducing coking times, which requires the introduction of programmed coke oven heating.

It remains to be wished and hoped that the results described today will be applied as quickly as possible to coking practice to the benefit of users and producers in the Community.

The fact that this morning's audience paid us the honour of returning almost to a man this afternoon says much not only for the topicality of the subjects being discussed but also for the high technical quality of the papers given and indeed also for your own keen interest.

I would like to conclude by offering my warm thanks to the gentlemen who have presented papers and those who have contributed to the discussion, as well as to our interpreters and translators. At the same time, I declare today series of paper over.

SECOND WORKING SESSION

B. RECENT DEVELOPMENTS IN COKE PRODUCTION

Chairman: Mr R. CHERADAME

Technical General Manager, Centres d'Etudes et de  
Recherches des Charbonnages de France, Paris

5. Messrs P. LEDENT, G. BURTON and M. MARCOURT

"The Development of the INIEX Process for the Production  
of Formed Coke"

Mr P. LEDENT: Civil Mining Engineer and  
Electrical Engineer

Since July 1968, Manager of the Institut National  
des Industries Extractives, Liège

6. Messrs W. PETERS, E. AHLAND and J. LANGHOFF

"Development of a Continuous Formed Coke Production Process  
by Bergbauforschung GmbH"

Prof. Dr. W. PETERS: Studies of Physics and Mathematics

Since 1966, Assistant Manager, Bergbauforschung  
(Institute of Mining Research) GmbH

Since 1961, Lecturer at the Technical High School  
of Aix-La-Chapelle

7. Mr L. SOUBRIER

"Formed Coke: Research and Tests Made by the Houillères du  
Bassin du Nord et du Pas-de-Calais and the FUVU Company  
- Economical Aspects"

Engineer of the Ecole Polytechnique de Paris

Since 1953, Manager at H.B.N.P.C., Department of  
Carbonization, Gas and Agglomeration-Anthracine

8. Mr K.G. BECK

"Programme for Carbonization Technics Improvement in the  
Conventional Coke Oven"

Graduate in Chemistry (Doctor)

Since 1957, Department Chief, Office for Thermic and  
Chemical Valorization of Coal, Steinkohlenbergbauverein



M. Cheradame

These two sessions devoted to the present day development of carbonization technique would have been incomplete if some time had not been given to the question of moulded cokes and whether these might replace coke produced by the conventional process, which itself has undergone a fair amount of improvement. This problem, including competition with the conventional process, constitutes the theme of this morning's meeting.

For moulded cokes agglomerates must be made and carbonized. There are many ways of doing this. Agglomeration may be:

Conventional: using a moulding wheel press and a binder of tar (or bitumen or even products such as sulphite liquor).

Hot: The binder is a fusible coal, the rest of the mixture being in general infusible, possibly a lean coal.

Pelletization: The moulding wheel press is replaced by a dish or a drum.

Carbonization can be effected:

In a chamber, i.e. by means of an apparatus analogous to the wellknown gas or coke ovens;

In a kiln, i.e. in a cylindrical space where the agglomerates are heated by hot gases (gaseous heating medium).

By means of sand otherwise heated (Solid heating medium).

Variants can be introduced. For example, some coals can be semicarbonized before agglomeration, or the agglomerates can be semicarbonized between briquetting and final carbonization. An actual operation can include considerable technological variations.

With all these possibilities, a whole range of routes to the final product can be imagined. Some will not stand up to examination, while others merit testing. At the moment three such experiments are in progress in the Community, these being based on very different schemes. All are at the pilot stage and have already provided batches of several hundreds of tons (and even thousands of tons in one case). The products have been tested in the experimental blast furnace at Liège.

These three experiments are of great value and we are very pleased that the authors have come to stress this today before us.

Mr. Beck's paper, which will end the session, appears at first sight to deal with a different subject. It primarily concerns raising the productivity of coke ovens by raising the temperature and improving heat transfer across the side-wall bricks. More exactly, Mr. Beck will tell us of the problems this poses for the designers of ovens and for coke users. He will also tell us how he proposes to deal with this problem. All this is of interest because to assess the value of moulded cokes, one should not relate them to the coking plants that we know but to the ones that we shall build in the future. This is the only way to make objective assessments when it is necessary to take decisions concerning the future.



THE DEVELOPMENT OF THE "INIEX" PROCESS  
FOR THE PRODUCTION OF FORMED COKE

by

P. Ledent, G. Burton and M. Marcourt

1. The basic principles of the INIEX process

The research which has been in progress over the last 10 years at the INICHAR Research Establishment (recently integrated into the new National Institute of Extractive Industries) has led to a technique for the thermal treatment of coal briquettes by immersing them in a fluidised sand bed which is used both as a heat carrier and as a dense medium. The fluidised sand flows in a closed circuit in a complex of air lifts and air channels; the briquettes to be treated float freely in the upper part of the bed, like chips in hot fat in a deep frying pan.

By varying the temperature of the sand bed, this technique can be applied to the drying of briquettes made with water-soluble binders, to the polymerisation of briquettes made with binders capable of being hardened by heat, to the de-smoking of pitch-bound briquettes by oxidation and to low-temperature or medium-temperature carbonisation of briquettes produced from blends containing high-volatile coal.

The principle of the sand bed carbonisation method is illustrated in Fig.1. Treatment is carried out in a covered-in enclosure whose lower wall consists of grates with appropriate air distribution. These grates support a sand bed whose thickness may reach 80 to 90 cm and which is intermittently fluidised by blowing gas or steam. The plant also includes a screen to separate sand from briquettes, a re-cycling and re-heating circuit for the sand, and inlets and outlets for the briquettes.

When the sand has been pre-heated to the required temperature the feeding-in of the green briquettes commences. The briquettes mix with the sand during each fluidisation period, and this mixing proceeds by gravity from the feed-in point towards the outflow point at the other end of the channel. Between two periods of fluidisation, the distillation process continues in the static sandbed.

The fluidising agent can be steam, re-cycled gas or inert gases. The operating cycle usually consists of 4 or 5 seconds of fluidisation for every 80 to 90 seconds of steady state; because of this, the volume of fluidisation gases remains small in comparison to the volume of distillation products.

In this simple form, the fluidised sand bed carbonisation oven is only suitable for the semi-carbonisation of briquettes which are capable of supporting a rapid heating programme.

To carry out more extended treatment we have to distribute the heat input by introducing part of the hot sand at the beginning of the oven and by a progressive re-heating of the sand bed by additional feed at points along the treatment channel.

The fluidised sand bed oven, as it is, allows semi-carbonisation treatments up to final temperatures of the order of 550°.

When the semi-coke briquettes have reached this stage they have a good mechanical strength, but their volatile matter is still too high, and their thermal-impact resistance insufficient for them to be charged to a blast furnace.

A progressive increase of temperature beyond 800° is required to give the pre-formed coke its definitive characteristics.

The sand bed oven is not the most appropriate means for this last stage of treatment and in the pilot plant which was built at Seraing on the grounds of Colard colliery we decided to carry out this last stage in a vertical oven with hot flue gases in countercurrent.

## 2. The Colard Pilot plant (Figs. 2 and 3)

The pilot plant for the production of formed coke at Colard colliery was constructed in 1968; it was financed jointly by S.A. Cockerill-Ougrée-Providence and S.A.B. Stein et Roubaix, and with a subsidy from the Prototype-Development Fund of the Ministry of Economic Affairs.

It is operated by D.F.C. ("Division Four de Carbonisation" = Coke-oven Division) with the participation of S.A. Cockerill-Ougrée-Providence, S.A.B. Stein et Roubaix and the National Institute of Extractive Industries.

The general layout of the carbonisation ovens is outlined in Fig. 4. The elevation shows first of all the horizontal fluidised sand bed carbonisation oven and the vertical re-treatment oven.

The sand bed oven, which has an overall length of 14 metres, is subdivided into two sections as follows: a pre-heating zone in which the briquettes to be treated are rapidly heated by mixing with a current of 5-6 times their volume of hot sand from air lift No.1; and a carbonisation zone in which the ratio between sand and briquettes is reduced to 2 or 3 to 1.

The sand temperature in this second zone of the oven is regulated by a progressive addition of hot sand from air lift No. 1, distributed by a distributor channel running along the axis of the oven. An equivalent amount of partially-cooled sand can be withdrawn by two lateral channels on either side of the treatment channels.

The sand and briquettes are separated on two screens at the end of the oven, and all the sand removed is returned towards the re-heating air lifts by means of a continuously fluidised return channel.

Pulsating fluidisation of the treatment channels and continuous fluidisation of the distribution and sand-recovery channels is carried out by a mixture of steam and inert gases.

The bottom of the air lifts and the sand-return channel are continuously fluidised with hot air.

Syphoning-off of sand at the recovery point below the screens and at the point where the sand is withdrawn ensures a complete seal between the atmosphere of the treatment chamber and of the return channel towards the air lifts.

In the vertical secondary carbonisation oven there are 3 super-imposed zones: a heating zone in which the briquettes circulate in countercurrent to the hot gases injected through 3 distributor flues, a zone in which the briquettes are maintained at high temperature and in which they circulate co-currently with the hot gases and, finally, a cooling zone in which the briquettes descend in countercurrent to a mixture of gases and steam injected at the bottom of the oven at a temperature around 100 °.

Three gas burners are provided to heat the plant. Burners Nos. 1 and 2 provide the hot gases which feed the two sand-re-heating air lifts, whereas burner No.3 produces the inert gases to heat the vertical oven.

Coke-oven gas provides the necessary heat for the ovens.

In view of the experimental nature of the plant, no provision has been made for the recovery of by-products, and the tar-loaded unscrubbed gas from the sand bed oven is burned in a combustion chamber at the foot of the chimney.

The mixture of flue gas and distillation gas omitted from the vertical oven is recycled to burner No.3.

The sensible heat of the flue gases omitted from the air lifts is recovered to heat the combustion air, the mixture of steam and flue gases used for the fluidisation of the treatment channels and the fluidisation air of the return channel and of the bottom of the air lifts.

The dimensions of the fluidised sand bed oven at the Colard pilot plant were reduced in order to keep the capital charges low. The total surface area of the fluidised channels is of the order of 30 square metres and their maximum treatment capacity is 5 to 6 tonnes per hour.

For the industrial development of the process, the objective would be to design ovens with a treatment capacity of the order of 30 to 40 tonnes per hour, so that one single oven can replace a battery of coke ovens.

### 3. The question of heating programmes

The advantage of associating a fluidised sand bed oven and a vertical oven in which hot gases circulate is the result of a certain number of basic facts concerning the carbonisation of coal and, in particular, of pitch-bound briquettes.

The various stages of the thermal treatment of a briquette can be studied in the laboratory by means of thermo-balances and dilatometers.

The results depend on the type of coal utilised; qualitatively, however, the progress of the various carbonisation phases remains very similar for all types of coking coal and, generally speaking, this progress can be represented by the various phases shown in Table 1.

Between 0 and 380° the coals heat without changing their structure to a marked extent and without losing weight (with the exception of the surface moisture of the particles).

The phenomenon of transitory plasticity occurs between 380 and 500°; it is accompanied by a very high emission of volatile matter (gas and liquid by-products) and may cause considerable dilation by the creation of a structure of bubbles when this volatile matter is emitted during a particularly viscous liquid phase.

Between 500 and 600° there is a stage of rapid consolidation of the solid products; devolatilisation becomes slower and the composition of the volatile matter evolves towards lighter products (gaseous, rather than liquid, by-products).

Between 600 and 1000° the structure of the solid product evolves from the vitreous state towards a crystalline stage; this graphitisation causes a reduction in volume and an increase in cohesion; it is accompanied by a

slight emission of volatile matter in the shape of gas with a high hydrogen content which no longer contains any condensable by-product.

It is possible, on the basis of these theoretical data, to visualise an "ideal" heating programme which would make it possible to carbonise a pitch-bound briquette in a minimum period of time and in conditions likely to produce minimum deterioration.

Between 0 and 380° the aim will be very rapid heating whilst avoiding any compressive stress on the charge; the point is that, during this period, the coal particles remain inert and the briquette behaves like a pasty mass because of the plasticity of the pitch which is utilised as a binder.

It is between 380 and 500° that the charge requires the most care as regards mechanical stresses and heating speeds. The tricky stage of carbonisation ends at around 550°. Beyond that temperature the briquettes can be stacked and are capable of withstanding considerable mechanical stresses; nevertheless, their heating must be slow and sufficiently regular to avoid internal fissuring as a result of excessive thermal stresses.

It is this "ideal" heating programme which is the aim of Colard pilot plant in which the briquettes proceed through the following 5 successive zones of treatment (Fig.5):

- A rapid pre-heating zone by immersing the briquettes in pre-heated sand.
- A slow heating zone by progressive addition of hot sand along the carbonisation channels where transitory plasticity occurs.
- A zone of more rapid heating countercurrent to hot gases.
- A steady temperature zone at around 850 °.
- A cooling zone in the presence of a countercurrent flow of steam and cooled gases.

The following two parameters are of crucial importance in the thermal process which we have just described:

- The temperature of the sand bed at the end of the preheating zone.
- The temperature of the bed at the end of the horizontal oven.

The first of these two temperatures determines the blends of coal which can be utilised to prepare the briquettes. A value of 500° is acceptable for low-volatile briquettes based on lean coal, whereas the value may not exceed 420° for briquettes which contain a high proportion of high-volatile coal

The temperature which is reached at the end of the horizontal oven determines the mechanical strength of the briquettes at the point in time when they are transferred to the vertical oven. A value equal or superior to 530° is desirable, and a value of 500° must be considered the minimum limit.

The preliminary studies for the Colard pilot plant were made on the assumption that sand could be re-heated by about 100° along the length of the treatment channels.

In practice, the temperature increase had to be limited to around 50 to 60° to avoid too irregular a temperature distribution across the width of the oven.

This limitation is to a large extent due to the fact that the pilot plant is too small, and it is quite clear that a temperature increase of 100° would be possible in a longer oven by placing end-to-end two treatment zones like those in the ovens at Colard.

With these data in mind, the first carbonisation projects were carried out with briquettes made from lean coal at temperatures which were usually between 480 and 500° at the end of the pre-heating zone, and of the order of 530 to 550° at the outlet of the sand bed oven.

#### 4. The first carbonisation trials

The commissioning of the Colard pilot plant began in January 1969. Approximately 3,000 tonnes of semi-carbonised or re-carbonised briquettes were produced over the whole year; 5 to 10-day operating periods were alternated with periods of stoppage for modifications and adjustments. During the first six months, work was concentrated on the semi-carbonisation treatment. During that period 1,200 tonnes of lean-coal briquettes, carbonised at around 600°C, were produced; they were marketed under the name of "Colcite".

These small, cushion-shaped briquettes measure 30 x 30 x 20 mm and have an average weight of 12 to 13 g; they are characterised by high strength

(of the order of 150 kg), by their low volatile matter ( $\pm 6\%$ ) and by a total absence of smoke. They represent a top-quality domestic fuel which can replace 20/30-mm anthracites.

Another trial of low-temperature carbonisation was carried out on a 150-tonne batch of pitch-bound briquettes made from anthracitic coals from the German Federal Republic. During these trials the temperature of the gases introduced into the vertical oven was maintained at between 600 and 650°.

The average results which were obtained may be summarised as follows:

	<u>Green briquettes</u>	<u>Carbonised briquettes</u>
Average weight dry (g)	23.2	20.2
Specific weight (g/cm <sup>3</sup> )	1.23	1.18
Crushing strength (kg)	105	197
<u>Proximate Analysis</u>		
Moisture (%)	1.1	1.9
Ash dry (%)	8.0	9.0
VM dry (%)	13.8	3.9

The first second-stage carbonisation trials with a view to producing formed coke were launched in September.

These trials were made with larger (43 x 41 x 29 mm) pitch-bound briquettes produced from a blend of 90% lean coal and 10% type B high-volatile coal\*). The carbonised briquettes have an average dry weight of 26g and a crushing strength of the order of 300 kg.

The following average results were obtained from Micum tests on samples taken every 2 hours during one week's production;

- After 100 revolutions of the drum
  - fraction > 20 mm ( $M_{20}$ ) = 93.6%
  - fraction < 10 mm ( $M_{10}$ ) = 5.7%
- After 500 revolutions of the drum
  - fraction > 20 mm ( $I_{20}$ ) = 74.7%
  - fraction < 10 mm ( $I_{10}$ ) = 23.6%

\* ) Translators Note: roughly 33 - 38% VM.



The volatile matter of this formed coke is slightly higher than that of metallurgical coke (the difference is of the order of 1% to 2%). Its ultimate analysis (dry ash free) is as follows:

C = 95.31%  
H = 1.06%  
N = 1.26%  
S = 0.89%  
O = 1.48%

An 800-tonne batch was produced during November with a view to a trial to be made by AIRBO (International Association for Basic Research at the Ougrée Blast Furnace).

#### 5. Trials in the experimental furnace at Ougrée

The experimental furnace at Ougrée is a small furnace with a cupola diameter of 1.40 metres and an effectictive capacity of 8.64 cubic metres. A counter-pressure of the order of 1.40 kg per square cm is maintained at the throat so as to reduce the upward gas velocity and to obtain operating conditions more comparable to those of a blast furnace. The apparatus is fitted with sensors and thermocouples which make it possible to study the distribution of the temperature and the composition of the gases at various levels.

Because of its reduced scale, the experimental furnace can be used for fuels of smaller sizes than those normally used in a blast furnace; the reference coke is a crushed coke of between 20 and 25 mm.

Fuels of larger sizes can, however, be used in the furnace, and excellent results have been obtained with 30 - 40 mm cokes and with 45 x40 x25 mm formed coke produced in the German Federal Republic.

Trials with the D.F.C.'s carbonised briquettes produced at the Colard pilot plant began in the middle of December 1969 and ended on 5th January 1970.

During the trials the burden consisted entirely of agglomerated ore with a lime/silica ratio of 1.1 to 1.2.

The performance of the furnace began to deteriorate 8 hours after the first charge of formed coke; this deterioration was marked by a progressive rise of the combustion zone, together with a temperature increase at the throat, by a deterioration in the  $\text{CO}_2/\text{Co}$  ratio and by an increase in the coke rate.

The trials had to be interrupted after 67 hours of operation because of the appearance of considerable scaffolding, which had to be eliminated after the furnace was emptied.

A second trial - in which the unitary weights of the charges of ore agglomerate and formed coke were doubled - had no greater success; it was necessary to surrender to the force of the evidence and to accept that the tendency of the combustion zone to rise was the result of insufficient gas/coke exchange surface in the reaction zone.

A comparison of the characteristics of the formed coke produced by DFC, of metallurgical cokes and of the formed coke previously tested in the furnace at Ougrée does show that their basic difference is in the external specific surfaces, which themselves are determined by the factors of shape and density (Table II).

This difference in specific surface appears to be the cause of the insufficient gas/coke exchanges observed in the case of formed DFC coke.

In order to verify this hypothesis it was decided to increase the briquettes' exchange surface artificially by crushing and screening to 12 mm.

The crushed products included a certain percentage of whole briquettes, the balance being made up by briquettes which had been split into two or three (Table III).

The furnace was fed for four days with this crushed coke. It operated satisfactorily with the following characteristics:

Coke throughput : 20 tonnes per day

Coke rate (raw coke) : 660 kg per tonne of pig iron

i.e. 645 kg of coke at 85% C per tonne of pig iron

Good quality pig iron, well carburized and well de-sulphurised.

The coke rate and the  $\text{CO}_2/\text{CO}$  ratio were not as good as those obtained with 20/25 mm coke, but this may have been due to the fact that, in spite of having been crushed, the average size of the DFC coke was still slightly higher than that of the 20/25 mm coke.

A discussion of the results of this experiment is of considerable interest because it highlights the interdependence of density, of size consist and of the shape of the fuels intended for blast furnaces. In order to meet the requirements of steel making, blast furnace coke must comply as closely as possible with the following three conditions:

- it must have a high mechanical strength and, in particular, a good abrasive strength (Micum and IRSID indices);
- there must be sufficient channels between the lumps of coke to allow passage for the currents of gas and liquid which have to work their way through the "coke grate" at the level of the boshes (size, density and voidage);
- it must present a specific surface which is sufficient to allow the heat and mass transfers between the gas and the solid to occur with the required speed in the reaction zone (size consist, density and shape). These three conditions appear contradictory from the start.

The rounded shapes of formed coke are favourable so far as strength is concerned, but, compared to a well-sized conventional coke, they reduce the voidage and the specific surface of the pieces.

The increase in particle size increases the size of the gaps in the "coke grate", but reduces the surface area for exchange between gas and solid.

The reduction in density increases the surface area, but may entail a reduction in crushing strength and abrasive strength.

The traditional type of coke produces an acceptable compromise between these various exigencies, and its qualities may be further improved to a considerable extent by appropriate crushing and sizing.

The success or failure of processes for the production of formed coke may to a large extent depend on the capacity of these processes to achieve an equally satisfactory compromise between these contradictory requirements.

## 6. New programmes

The new target set for the tests which will be undertaken during the months to come at the Colard pilot plant will be to produce a formed coke with mechanical and chemical characteristics comparable to those of the first batch of DFC coke, but whose apparent density will approach that of metallurgical cokes.

There are three possible ways of obtaining an appreciable reduction in density:

- by replacing lean coal with semi-coke of lower density;
- by increasing the proportion of high-volatile coal;
- by changing the method of agglomeration.

Bearing in mind the material available for processing at the Colard pilot plant, and the heating curves which are at present feasible, the next experiment will probably be carried out on pitchbound briquettes made from a blend of 25% type B high-volatile coal and 75% semi-coke.

Other blends under consideration are three-component mixtures of high-volatile coal, gas coal and semi-coke.

Consideration might also be given to using binders other than pitch, because this would allow a big increase in the proportion of medium- or high-volatile coal without requiring any modification of the heating programmes.

Finally, it is intended to use the Colard pilot plant for the carbonisation of blends of coals briquetted by pelletisation, because this briquetting technique is liable to reduce considerably the density of green briquettes.

Trials are also envisaged with a view to producing a formed foundry coke, since the cupola can cope with high-density fuels.

## 7. Conclusions

We have attempted within the framework of this paper to give the salient points of the state of progress of our research into the production of formed coke by carbonisation in a fluidised sand bed.

The low-temperature carbonisation trials have made it possible to finalise the technological aspects of the fluidised sand bed oven and have shown that it is possible to use it for the production of high-quality smokeless domestic fuels.

The first production scheme for formed coke made from pitchbound briquettes containing 90% of lean coal and 10% of type B high-volatile coal have confirmed the advantage of associating a sand bed oven and a vertical oven heated by countercurrent hot gases, and has made it possible to obtain formed cokes which are satisfactory as regards both their chemical composition and their mechanical qualities.

These results show that a big step forward has been taken.

The aim of later developments will be to reduce the apparent density of the products and to increase as much as possible the proportion of high-volatile coals.

At this present stage of our work we are convinced that it will be possible to achieve successful results, provided that the research teams continue to be supplied with sufficient material and finance.

Table I. Various stages in the thermal treatment of a pitch-bound briquette

Temperature intervals	Changes	Volatile matter released
0 - 380°	Drying - melting of the pitch	Steam
380 - 500°	Coal passes through plastic zone Considerable loss of weight Contraction or dilation depending on the coal and on the heating curve	Considerable production of tars and of gas of high calorific value
500 - 600°	Contraction of the semi-coke Reduction in the rate of weight loss.	End of tar emission. Slowing of the rate of gas evolution.
600 - 800 °	Contraction and solidification Slight loss of weight	Evolution of gas of low calorific value.
800 - 1000°	Slight contraction. Very slight loss of weight.	Very slight evolution of gas of low calorific value.

Table 2. Comparison of the characteristics of formed DFC coke and of various cokes tested in the Ougrée furnace

Characteristics	D.F.C.	Coke 20 - 25 mm	Coke 30 - 40 mm	German formed coke
Average weight (g)	26.32	6.07	18.10	22.41
Apparent density ( $d_a$ )	1.254	0.981	0.987	0.784
Bulk density ( $d_v$ )	0.73	0.52	0.50	0.47
Voidage (%) ( $1 - d_v/d_a$ )	41.8	47.0	49.4	40.1
Average volume ( $\text{cm}^3$ )	21.0	6.19	18.3	28.6
External surface ( $\text{cm}^2$ )	36.8*	20.3**	41.6**	45.2*
Specific external surface ( $\text{cm}^2/\text{g}$ )	1.40*	3.34**	2.30**	2.01*
<u>Proximate analysis</u>				
Moisture % (Azeotropic method)	1.45	1.0	0.8	2.4
Ash dry (%)	6.8	8.3	9.6	8.6

\* calculated for an equivalent sphere.

\*\* calculated for an equivalent cube.

Table 3. Size consist of the crushed DFC coke tested in the Ougrée furnace

Groups (round mesh)	Fraction (%)
30 - 40 mm	20.1
20 - 30 mm	57.8
10 - 20 mm	20.9
5 - 10 mm	0.4
0 - 5 mm	0.8
Average diameter (mm)	24.7
Standard deviation from average dia- meter (mm)	6.8

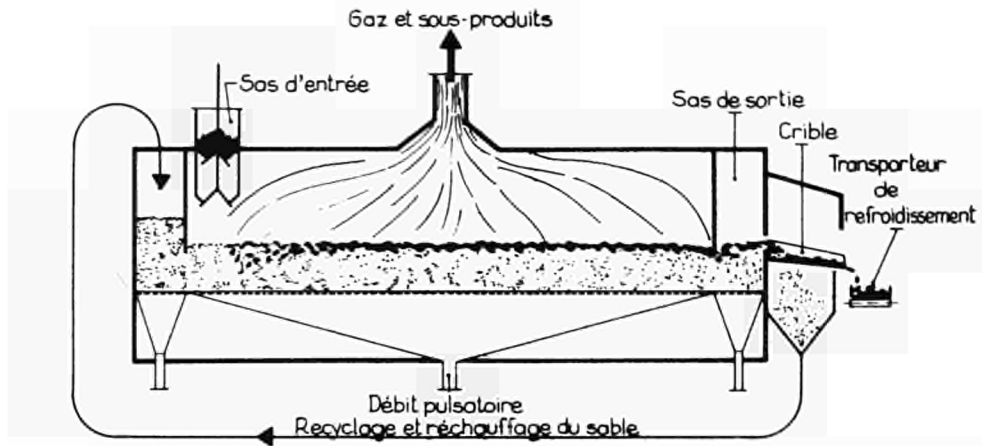


Figure 1 Schematic diagram of a fluidised sand bed carbonisation oven

Legend : gas and by-products  
feed  
discharge  
screen  
cooling conveyor  
fluidising point  
sand recycling and reheating

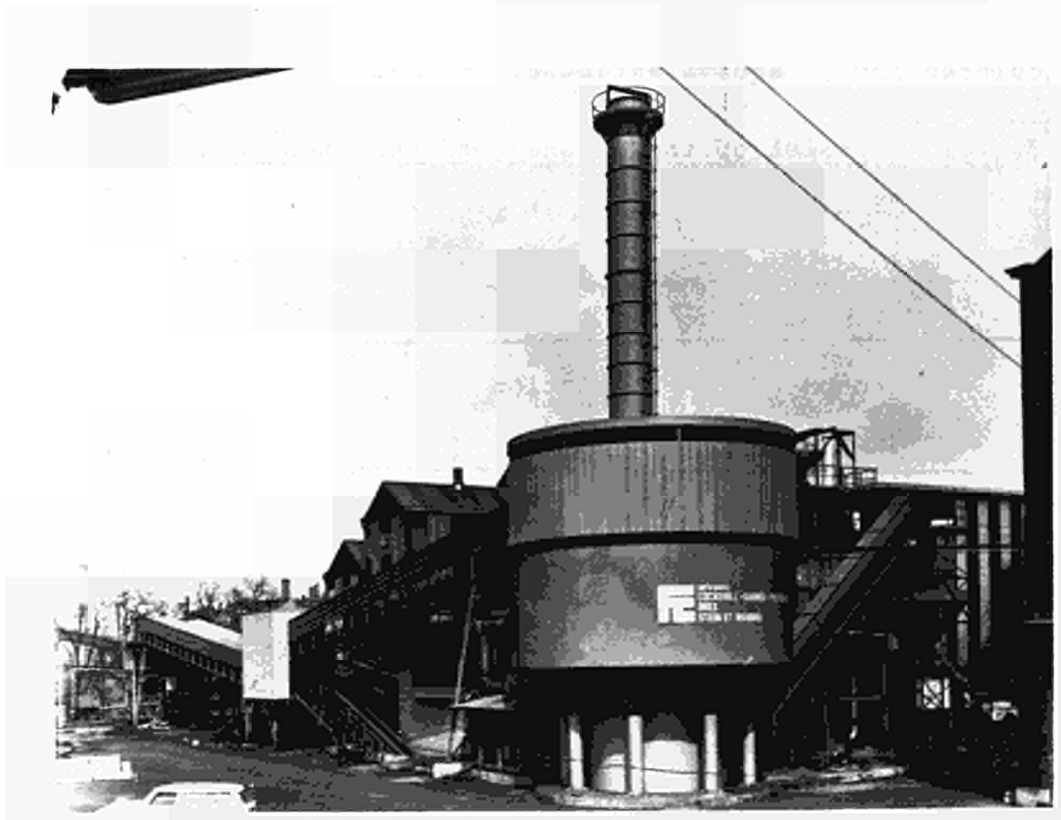


Figure 2

Overall view of the pilot plant at Colard colliery



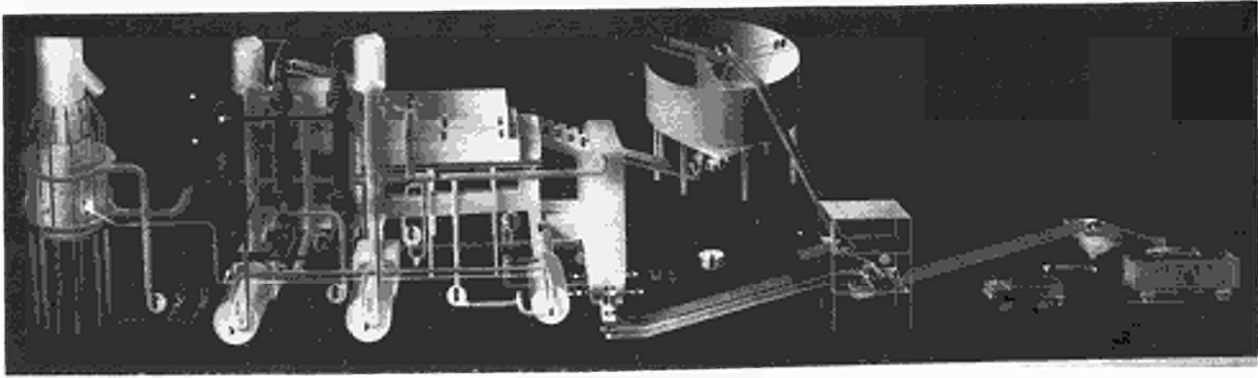
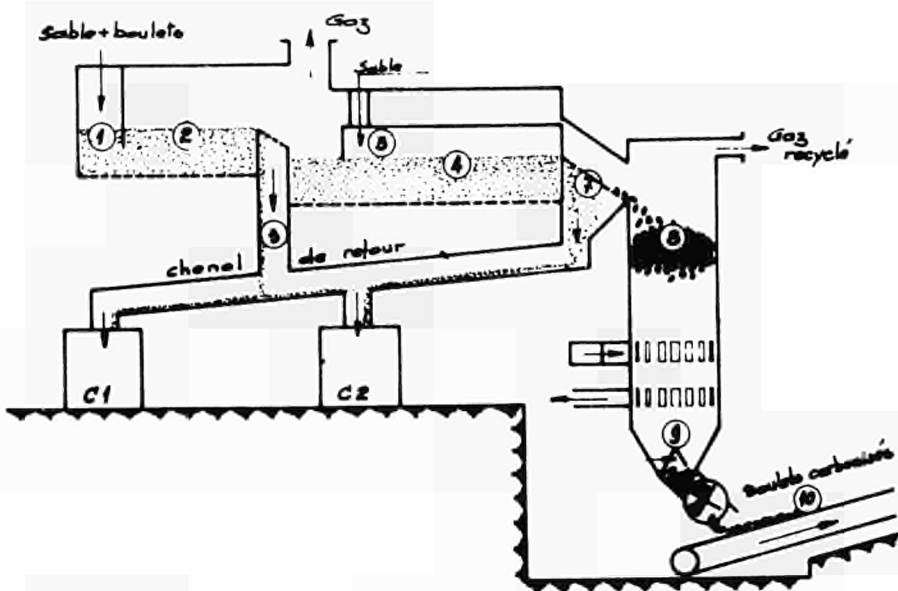


Figure 3

Mimic panel in the control room at the Colard pilot plant



Legend :

- sand + briquettes
- gas
- sand
- recycled gas
- return channel
- carbonised briquettes
- briquettes
- (1) inlet door
- (2) preheating zone
- (3) sand withdrawal
- (4) carbonisation zone
- (5) sand distribution channel
- (6) sand recovery channels
- (7) screens
- (8) vertical oven
- (9) cooling zone
- (10) cooling conveyor
- (AL<sub>1</sub>) (AL<sub>2</sub>) heating air-lifts
- (C<sub>1</sub>) (C<sub>2</sub>) (C<sub>3</sub>) combustion chambers

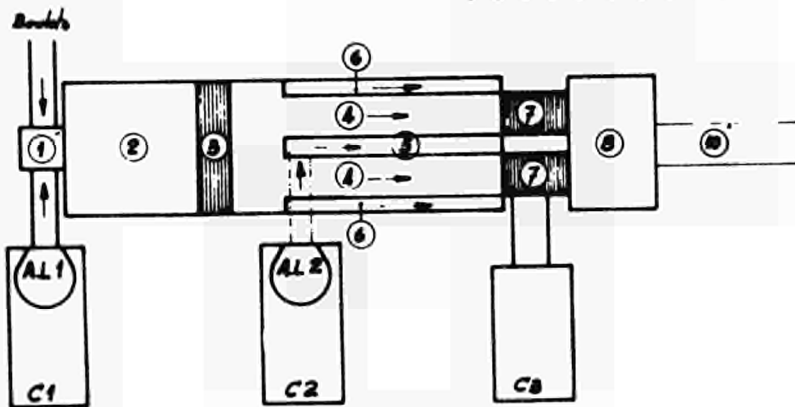


Figure 4

Diagram of the carbonisation ovens at the Colard pilot plant

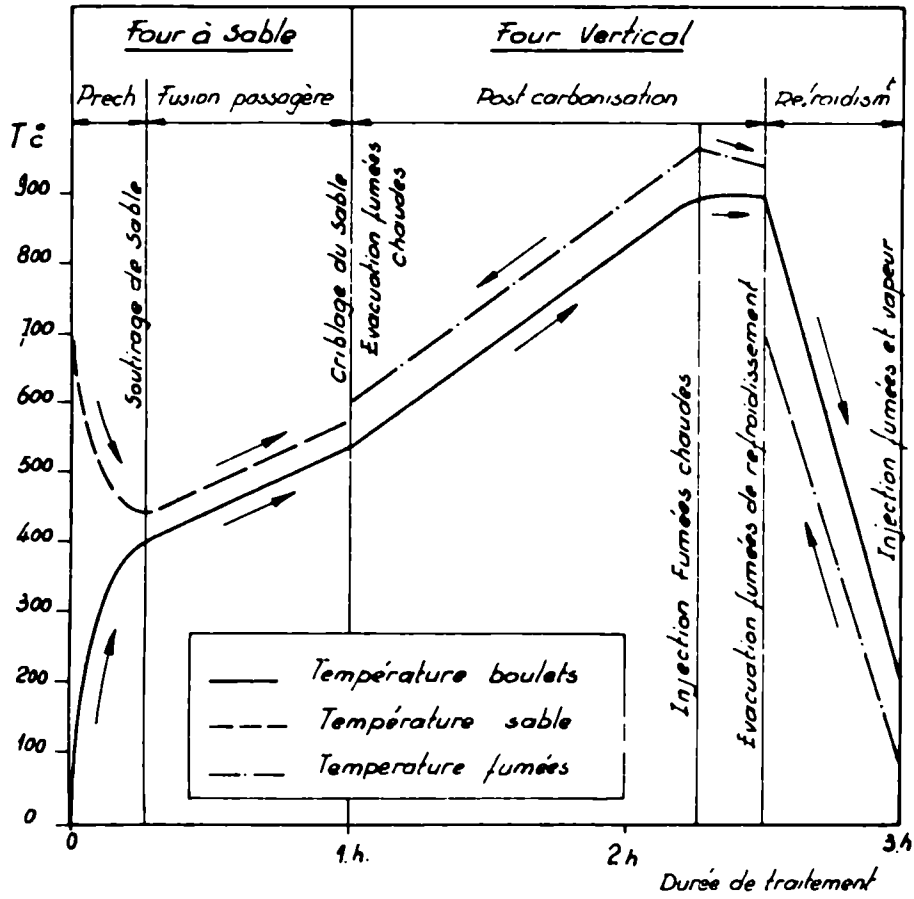


Figure 5

Heating curves produced in the sand oven and in the vertical carbonisation oven

Abscissa : residence time

Legend : sand oven

Vertical oven

Preheating

Plastic zone

Carbonisation

Cooling

Withdrawal of sand

Sand screening

Evacuation of hot flue gases

Injection of hot flue gases

Evacuation of cooling flue gases

Injection of flue gases and steam

Briquette temperature

Sand temperature

Flue gas temperature

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DEVELOPMENT OF A CONTINUOUS PROCESS FOR THE PRODUCTION OF  
FORMED COKE BY THE BERGBAU-FORSCHUNG G.m.b.H.

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Essen

INTRODUCTION:

In 1962 the first basic research work was commenced by Bergbau Forschung for the development of a continuous coking process. The "Two Components Hot Briquette Process" was considered very promising as a technical solution for the Ruhr Area. The initial experiments were confined first of all to determining the bitumen content of various kinds of coal as being one of the more important factors of influence in hot briquette manufacture, but the basic principle of this process, which works without the addition of binding agents, is to make use of the bitumen released by the thermal treatment of the coal for the binding of the briquette mixture of coal and coke.

From these first beginnings in the laboratory an extensive research and development programme developed very quickly which led to further material and technical tests in the laboratory until experimental trials could be carried out on a semi-industrial scale. The programme, the execution of which was shared by LURGI-GESELLSCHAFT FUR WARME UND CHEMOTECHNIK MBH and Institute of Chemical and Fuel Technology of the University of Clausthal, was thankfully subsidised in a generous manner by the Minister for Transport, Economics and Social Security of the District of North Rhine-Westfalia and the Volkswagen Trust. In 1964 work was begun with the construction of large experimental plants having a capacity of 5 metric tons per hour, which went into operation in 1965 and 1966. After several years development work the question of whether the expectations in respect of this plant would be fulfilled has now been satisfactorily answered. Before starting to deal with this question it is best first of all to look into the basic requirements <sup>1)</sup> imposed prior to commencing the development of the process.

Following recent trends, and the requirements of modern process technology, the first basic requirement listed in Fig. 1 was to endow the coking process with the advantages of continuous operation <sup>2, 3)</sup>.

Ideal features of a coal upgrading process

Legend : Continuous

Brief heating-up and cooling-down

Short residence time and high output

Extensive heat utilisation

Avoidance of dust emission

Broad coal basis

Good product quality

Large units with favourable scale-up characteristics

Fig. 1

The explanation of the process in Fig. 2 clearly indicates to what extent this requirement was able to be fulfilled: in a multistage formed coke process for producing hot briquettes coal is dried in a continuous drier and brought to the requisite size in a crushing and screening plant to  $< 3$  mm for "low temperature coking coal components" and  $< 1$  mm for the "bituminous coal components". The prepared fine coal is fed pneumatically to the hot briquetting plant. Here the coal to be carbonised at low temperature, which constitutes about 70% of the entire charge, is carbonised in a fluidized bed reactor or by some other low-temperature process, for example the LURGI-RURHGAS process, to a temperature of from 700 to 800°C. The hot fine coke is then thoroughly mixed in a mixing plant with the bituminous coal, which represents the other 30% of the charge. The briquette mixture has a temperature of from 450 to 500°C. - a temperature range in which the bituminous coal, which must be a coal having good coking properties, softens. The pseudoplastic briquette mixture is briquetted whilst hot in a roll press.

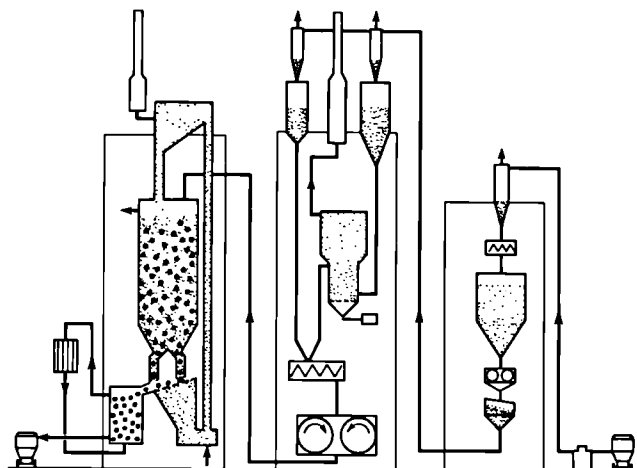


Diagram of the hot-briquetting formed-coke process

Fig. 2

In a second stage in the process the hot briquettes are delivered without cooling to the Research Station design of (BF) sand-coker illustrated on the left of the Fig. 2 and completely coked with sand introduced into the circulation with direct transfer of the heat. On removing the heat carrier the formed coke is drycooled with inert gas and conveyed to the loading point. This diagram of the process shows how the flow of material, starting from the delivered coal to the intermediate products of low-temperature coke and hot briquettes to the finished formed coke, is continuous throughout the plant. The total treatment time amounts to only 1 to 1.5 hours.

The BF coker is the basis of two other process variants, which differ only in the method of forming the agglomerates. In the one process the conventional briquetting technique is employed, in the other the pelletizing technique is used. The coking conditions used - especially the coking temperature - depend naturally on the type of coal charged. If high final coking temperatures are required, then normally the caking properties of the charge are reduced or carbonising is carried out in several stages. Just recently, however, the use of lower coking or cracking temperatures seem to offer attractive possibilities. The products obtained by carbonising at a low temperature in the sand coker, pitch-bound anthracite briquettes or coal pellets have approximately the same, or at least adequate, strength properties

as those of high-temperature formed coke. They differ from each other only in the content of volatile matter. A relatively high value for blast furnace fuels can sometimes be considered an advantage.

Apart from one or two constructional elements the process has no special requirements for the equipment of the plant. The crushing and screening installations correspond with standard construction. The brickwork for the hot parts of the plant, such as the fluidized bed carbonizer, mixing plant, sand coker and combustion chambers, consists of standard-type hard fireclay refractory materials. As was found from several years experimental operation, it was necessary to make some parts of the sand coker more resistant to erosion. This, however, has no effect on the rapid heating and cooling times often tested during the experimental operation. The experience gained justifies the view that much larger plant can be rapidly heated and cooled, whereby the second basic requirements of the process is fulfilled.

A reference has already been made to the short treatment time of 1.5 hours max. It is therefore obvious that such short treatment times can lead to large specific capacities. Thus in the 5 t/h experimental plant a specific capacity of approximately 400 kg/m<sup>3</sup>/ hour has been achieved, which is about 10 times greater than that of conventional chamber ovens.

The amount of under-firing needed is determined, both in respect of the continuous as well as the conventional coking process, mainly by the final coking temperature required, and lies between 450 and 500 kcal/kg of moist coal. However, due to the dry coke cooling in the formed coke process a high utilization of heat is achieved.

If the formed coke produced at 850°C. were cooled to an economically suitable temperature of 300°C. then 75% of the sensible heat of the coke can be utilized; this is equivalent to about 35% of the under-firing requirement. Also the sensible heat of the gaseous products should be utilized.



Since the entire process of manufacturing formed coke takes place in completely closed apparatus much consideration is also being given to the ever increasing need of avoiding dust emission during the coking of pit coal.

Next to the technical development of the process the testing of various kinds of coal for the hot briquette process has been given much space in the development programme. A large number of domestic and foreign coals have been investigated in research and industrial laboratories as to their suitability. Among the things found out was that not only the "classical" coking coals are to be considered as bituminous coal components, but also higher volatile coals may be suitable. Hot briquetting experiments on some foreign types of coal whose content of volatile matter was in the region of 36% daf, gave surprisingly good results. This was a result of the very good petrographic composition of the coals in question. Even when reliable forecasts on the suitability of a coal as a "bituminous coal component" for the hot briquetting process cannot be made using the analytical data of the coal in question due to its uncertainty, the present results nevertheless clearly indicate that wider basis has been given to bituminous coal than was originally thought. However, even if this coal component is still subject to certain limitations regarding the degree of coalification one is completely free in the choice of the "low-temperature carbonisation coal components", which, at 70%, represents the predominant part of the coal charge. Not only on a small scale but also by means of short and long-duration experiments with the 5 t/h plant it has been proved that coals of any degree of coalification can be used as low-temperature coal components and final products having satisfactory qualities can be obtained.

The qualitative characteristics determined in the laboratory in respect of products manufactured by various modifications to the process are illustrated in Fig. 3. The weights and geometric sizes are optional within certain limits, at least in the case of shaping by means of briquetting, can be adapted to the intended use. The content of volatile components depends largely on the final temperature attained. Uncoked hot briquettes, often termed "green", have a volatile matter content of approximately 6 to 7%. As they are practically free of tar, they have

Formed-coke properties

Legend : Hot-briquettes

Pitch briquettes

Pellets

green

coked

semicarbonised

Dimensions

Lump mass

Ash (d.b.)

V.m. (d.a.f.b.)

Sulphur (d.b.)

Porosity

Calorific value, gross

Compressive strength (kgf)

Abrasion resistance

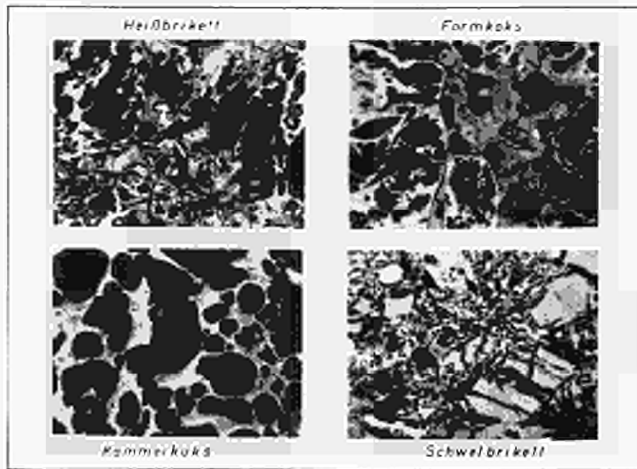
Bulk density

		Heißbriketts		Pechbriketts	Pellets
		grün	verkokt	geschw.	geschw.
Abmessungen (b-l-h)	mm	48-61-35	47-60-35	33-43-24	30 <sup>6</sup>
Stückgewicht	g	48	44	19,5	130
Asche (wf)	%	6,7	7,8	7,8	7,4
Fl Best (wf)	%	6,5	1,0	6,4	6,4
Schwefel (wf)	%	0,85	0,80	1,08	0,87
Porosität	%	49,0	58,6	23,0	38,0
Heizwert H <sub>g</sub>	kcal/kg	7461	7154	8070	7320
Bruchfestigkeit	kp	185	260	205	210
Abriebfestigkeit(-10mm)	%	7,8	7,1	10,0	9,2
Schüttgewicht	t/m <sup>3</sup>	0,508	0,495	0,656	0,490

Fig. 3

proved themselves to be particularly suitable for domestic consumption on account of their smokeless burning qualities. By coking the hot briquettes the volatile matter content of the formed coke can be reduced to 1%, as for blast furnace coke. The ash and sulphur content of the products is independent of the manner of coking; both values are determined by the quality of the coal used in the charge. Further experiments carried out on a smaller scale justify the view that a considerable reduction in the content of sulphur in the formed coke can be achieved by including an additional process stage<sup>4)</sup>. The strength properties that can be obtained with hot briquettes and formed coke comply with the requirements of the various consumers. It is also thought that the abrasion resistance, which in Fig. 3 is shown to be between 7 and 8% in M<sub>10</sub> values, can be further improved. The so-called "structural" data, in particular porosity, only show small differences between hot briquettes and the formed coke made on the one hand and oven coke on the other. In actual fact there are noticeable differences in the formation of the porous system - as may be seen visually in Fig. 4 - which are even more evident by quantitatively determining the distribution of pore radii. A comparison of the polished sections shown in Fig. 4 and the degree of porosity of only 23% make it clear how much pitch-bound anthracite briquettes carbonised at low-temperature differ in their grain structure from the three other products. It seems justifiable in assuming that the

different grain structure can be a cause of a different reaction behaviour.



Sections of different types of coke

Legend : Hot briquette

Formed coke

Oven coke

Briquette semicarbonised

Fig. 4

There is no doubt that quality characteristics determined in the laboratory have only a limited value. Far more important is the assessment of a product by the consumer himself. This state of affairs was also taken into consideration when designing the large experimental plant. Besides the primary task, namely the actual development of the process, products were to be produced in sufficient quantities which enabled an assessment by the consumer. In the meantime several such consumer tests have been carried out.

The first experiment consisting of 500 metric tons of formed coke manufactured by the hot briquette process was made in September/October, 1967 in the experimental blast furnace of AIRBO in Ougrée/Liege<sup>5)</sup>. The oven coke having a grain size of 5 to 20 mm previously used was replaced by 100% pillow-shaped briquettes weighing 21 g. It was shown that the capacity of the blast furnace could be increased by almost 70%, the capacity limit not being reached due to lack of coke. Another kind of formed coke, which originally was used as high-quality smokeless fuel, resulted in lesser increase in capacity. Subsequent experiments very precisely carried out with closely graded 30/40 mm chamber coke, which was very similar to a formed coke from the point of view of geometric size and shape, gave almost as good a result as the BF formed coke. Just recently the experiments have been continued

using other types of formed coke. The results are summarised in Fig. 5. It is surprising to note the difference in the productive capacity in terms of pig iron when charging BF formed coke made by hot briquetting and the other three formed cokes produced by the cold briquetting process. As far as we know the causes of this different behaviour have not yet been clarified. It may well be a complex interaction between coke properties and oven conditions. The similarity in porosity of oven coke 30/40 and BF formed coke, the two cokes which give the greatest increase in capacity, gives rise to one or two suppositions. It is conceivable that the combustibility of the coke in front of the blast tuyeres has a functional relationship with the apparent density or bulk weight.

Legend : Test

Oven coke

Formed coke

Coke

Consumption

Throughput

Pig iron

Output

Coke properties

Porosity

Bulk density

Reactivity

Standard

On lumps

a = normal driving

b = output test

\* = output limit not reached

x = calculated

Versuch	Kammerkoks						Formkoks							
	5-25 mm		10-20 mm		30-40 mm		Carmonaux		ERIM		DFC		BF	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b
<b>Koks</b>														
Verbrauch kg/IRE	608	651	595	620	660	670	639	669	645	640	645	654	663	
Durchsatz t/24h	21,6	31,4	21,5	30,2	19,5	49,0	18,3	41,1	18,5	29,0	20,2	19,9	56,2	
<b>Reaktion</b>														
Produktion t/h	1,48	2,01	1,53	2,01	1,22	3,02	1,28	2,56	1,19	1,89	1,3	1,27	3,53	
t/m <sup>3</sup> 24h	4,21	5,60	4,29	5,60	3,40	8,45	3,49	7,10	3,32	5,25	3,6	3,52	9,80	
CO <sub>2</sub> /CO	0,62	0,56	0,62	0,51	0,54	0,43	0,63	0,51	0,59	0,55	0,59	0,55	0,44	
<b>Kokseigenschaften</b>														
Porosität %	—	—	—	—	47,8	—	25,6	—	19,4	—	27,5	—	53,9	
Schulfgewicht kg/l	—	—	—	—	0,50	—	0,76	—	0,84	—	0,73	—	0,47	
<b>Reaktivitätskoeffizient</b>														
Standard [cm <sup>3</sup> /g s]	0,104	—	0,202	—	0,187	—	0,531	—	—	—	—	—	0,581	
Stück [cm <sup>3</sup> /g s]	0,150	—	0,360	—	0,270	—	0,150	—	0,360	—	—	—	0,329	
	a = normale Gestellbelastung						a = Leistungsgrenze nicht erreicht							
	b = Leistungsveruch						x = errechnet							

Test results with different coke types in the experimental blast furnace of AIRBO in Liege

Fig. 5

By reason of the favourable results obtained with BF formed coke in the experimental oven at Ougrée, about 1,400 metric tons of formed coke now having a lump weight of approx. 50 g. were tested in a second stage for the first time in April, 1969, in a 9.5 m. works blast furnace belonging to HOESCH AG HUTTENWERKE. The normal blast furnace coke was 100% replaced by the formed coke. So far as this short-duration preliminary experiment, which lasted for more than 24 hours, can be regarded as a guide it was found that the formed coke withstood well the mechanical loading during delivery, unloading on to the stockpile and charging of the blast furnace. During unloading

into the bunker drop heights of up to 10 m. occurred. The abrasion measured by HOESCH was only 1% greater compared to oven coke. The first formed coke could be recognised in front of all blast tuyeres about 8 hours after charging. Samples of formed coke taken from the blast tuyeres still showed clearly the briquette form. The formed coke was certainly lighter and smaller due to the gasification or partial abrasion, but it was in no way disintegrated. The air blast to the furnace remained practically unchanged. The amount of flue dust had not increased to any appreciable extent. The smoothness or unevenness of furnace operation corresponded with the previous working period. On account of the short duration of the experiment the consumption of coke per ton of pig iron could not be calculated. The quality of the pig iron thus manufactured showed no differences over normal operation. When all the formed coke was used up reversion to normal blast furnace coke was carried out without any difficulty.

A test with 500 metric tons of uncoked hot briquettes was carried out in short-duration experiments at the end of 1969 in a 6.8 m. works blast furnace belonging to RHEINSTAHL HUTTENWERKE AG. The briquettes likewise replaced 100% of the blast furnace coke. Furnace trouble, the causes of which could have been traced to the charging with hot briquettes, did not occur. A similar favourable result was obtained by a second experiment carried out under the same conditions (February, 1970) with approximately 2,700 metric tons of uncoked hot briquettes, which functioned properly for 72 hours. As compared with normal furnace operation there was an expected increase in the calorific value of the gas as a result of the released volatile matter of the hot briquettes. The specific consumption of coke increased accordingly. The dust content in the top gas rose slightly, but remained within the value usually applicable for the Ruhr Area. The pig iron production remained unchanged.

The blast furnace trials made so far naturally showed only provisional results. The significance is undoubtedly limited and will have to be supplemented and checked by longer-duration experiments. A trial with approximately 7,000 metric tons of formed coke is scheduled to take place shortly, probably before the conference, at the works of RHEINSTAHL HUTTENWERKE AG, WERK RUHRSTAHL HEINRICHSHUTTE. (The test in fact lasted 11 days).

Notwithstanding the need for reservations, it can be accepted that formed coke made from hot briquettes and to all appearances also uncoked hot briquettes, are suitable for blast furnaces. To what extent an operational improvement in the blast furnace can be achieved as compared to standard oven coke can only be ascertained by appropriate long-term experiments, a task which is beyond the production capacity of the 5 t/h experimental plant.

It has been a wish of long standing to achieve uniform products where solid fuels are used. Even though it may never be a "universal" fuel there are nevertheless distinct possibilities of manufacturing in continuous coking plant suitable products which have a greater range of use. It is known that a considerable amount of pit coal coke is being used in electric reduction furnaces. For testing the suitability of formed coke in this sector a test of several days with approximately 400 metric tons of coked hot briquettes was carried out in the middle of 1969 in a silicon-chrome furnace belonging to GESELLSCHAFT FUR ELEKTROMETALLURGIE MBH. In order to reduce to a minimum the possibility of a stoppage in production the gas coke serving as a reduction medium was first of all replaced by only 45% of formed coke. As the operation of the furnace was completely normal and the top gas temperature and dust quantity remained constant compared with the usual method, the result of this experiment can also be taken to be successful. On the other hand the use of uncoked hot briquettes must be excluded for the time being due to the results obtained from a short-duration preliminary experiment. The volatile contents of the hot briquette cause too much above-grate firing. However, provision has been made for a further experiment at the beginning of May of this year with 800 metric tons of formed coke, in which the gas coke will be replaced by 100% formed coke.

At the moment there is a lively interest in the Federal Republic in the production of smokeless domestic fuels. It is thus reckoned that in future only smokeless, solid fuels will be allowed for domestic consumption in North Rhine - Westfalia. This measure involves among others pitch-bound

anthracite briquettes, which represent a considerable market for the coal industry. Fortified by previous experiments in pilot furnaces, the Mining Research has therefore used the BF sand coker principle for the low-temperature carbonisation of such pitch-bound anthracite and lean coal briquettes. Approximately 1,200 metric tons of low-temperature briquettes have been produced over several months operation in the 5 t/h experimental plant for a consumer test. The products have an excellent quality, as may be seen from Fig. 3. The volatile matter content of the low-temperature briquettes is about 6% and can be carried to a certain extent by means of the adjustable heat-carrier temperature. The breaking strength amounts to 205 kg. As experiments in smoke testing apparatus have shown, the product burns absolutely free of smoke. The setting up of a larger sand coker plant for low-temperature carbonisation of pitch-bound anthracite briquettes is being considered.

As already mentioned, the hot briquettes produced in the intermediate stage of the formed coke process with 7% volatile matter constitute a clean smokeless fuel. The combustion characteristics of such hot briquettes manufactured by B.F. have been investigated several times by RUHRKOHLLEN-BERATUNG GMBH in various types of furnaces. The firing strength was shown to be particularly good. Compared with pitch briquettes and graded anthracite the loss in combustibles at the grate was much less. As with low-temperature carbonised pitch briquettes the hot briquettes have good strength properties. The breaking strength amounted to 185 kg while the abrasion of 10 mm determined in the drum test fell far below the usual values for pitch-bound products. It should be stressed that an important advantage in the manufacture of smokeless domestic fuel by the hot briquette process is in the possibility of using various kinds of coal.

The present level of development can be judged by the fact that the continuous form coke process developed by B.F. has been successfully tried out in large experimental plant 6, 7, 8 ).

Fig. 6 shows the experimental plant for hot briquetting and pelletising and also the BF sand coker on the experimental site "Queen Elizabeth" of B.F.; the capacity of the plant is 5 t/h.



Fig. 6

Experimental Plant for continuous coking having an hourly capacity of 5 metric tons

The increased size of the next unit will be 25 to 30 t/h. This is equivalent to an increase in capacity from 5 to 6 times with the minimum possible incumbent risk.

For the manufacture of blast furnace coke such plants are, however, too small, as planning work has proved. Guaranteed offers have been given by Messrs. LURGI GESELLSCHAFT FUR WARME - UND CHEMOTECHNIK MBH for a formed coke plant and for the BF sand coker. Thus it follows that these processes have been developed to the production stage. Fig. 7 shows a model of a formed coke plant for 600 tons per day. It is thought that this or a similar plant will be ordered sometime this year.



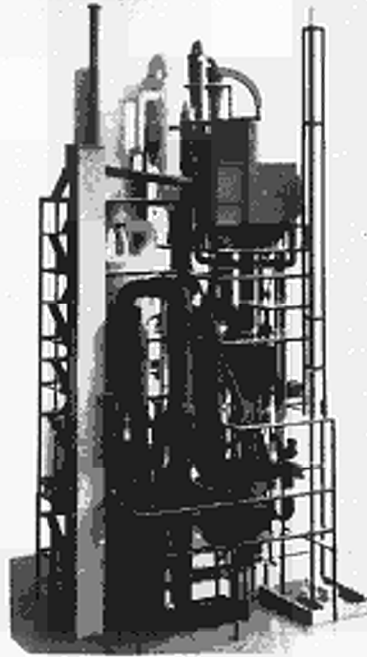


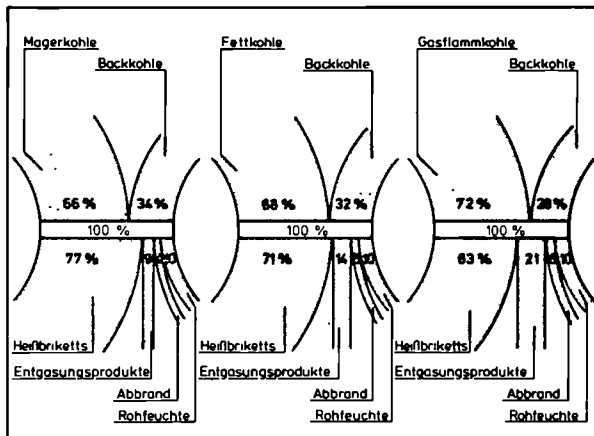
Figure 7

Model of a 600-t/d plant producing formed coke  
(Lurgi)

All this clearly shows to what extent the requirements imposed at the beginning of development have been achieved by the work carried out over the last few years. In the final analysis, however, it is the economics of a new process which will determine whether or not it will be used in practice. Therefore during the course of this development work consideration was taken of the profitability of a formed coke process, bearing in mind the level of development so far achieved. The cost of coke is influenced considerably by the cost price of the coal and the profits realised for the by-products and heat recovery independent of the carbonisation process. The disposal of by-products, whether it is gas, tar or waste heat, is becoming more and more difficult. The tendency is to burn these products in the power station or to supply neighbouring industries with these in a partially gaseous condition.

This results in a situation totally opposing that of 20 years ago. Then it was proposed to degasify the coal at the boiler before burning it, in order to obtain valuable gas for the gas industry. Appropriate methods have been developed for this. In the situation existing today, however, one would have to impose the opposite requirement, namely to "de-coke" the coal at the boiler house prior to its burning. The continuous formed coke process would be suitable for this, particularly when MHD principle is employed for the energy conversion<sup>9)</sup>.

Taking everything into consideration one can assume that, with regard to heat content, the by-products are valued less than the coke product. This in turn means that the coal most suitable for coke manufacture is that which guarantees a high coke yield. To what extent the yield of the final product depends on the type of low-temperature coal used in hot briquetting is shown in Fig. 8. According to whether one uses steam coal caking or high volatile gas coal as low-temperature components the yield of hot briquettes is 77, 71 or 63%, based on a moist coal charge having 10% of water, corresponding to 85, 79 or 70%, based on dry coal. The above figures are based on measurements carried out in the 5 t/h experimental plant of Mining Research. Because of the high output the use of low-volatile coals should therefore be preferred, if the present prices for coal in the Ruhr remain at their present level.



Legend : Lean coal  
 Fat coal  
 Gas-flame coal  
 Caking coal  
 Hot-briquettes  
 Volatile products  
 Burn-off  
 Moisture in raw material

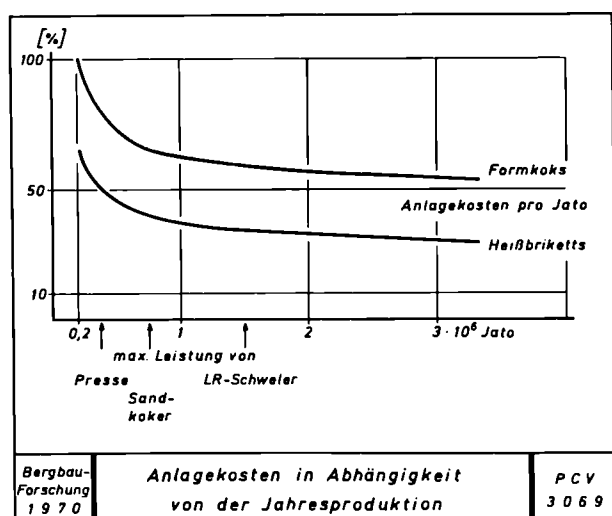
Figure 8

Material balances of hot-briquetting

As already mentioned, the investment costs in respect of production plant in the region of 200, 000 tons a year can be given with some certainty and accuracy. However, the question is raised as to how the investment costs are changed in the case of a further extension of plant capacity. In principle there are two possibilities of cutting down costs when the productive capacity is increased:

1. By enlarging the machines and apparatus - the saving is considerable.
2. By installing a number of machines and apparatus of the same size - the saving is not so great.

If one wishes to predict how the costs will rise when the plant is enlarged one must first of all make some assumptions regarding the maximum unit capacity of the individual apparatus. These assumptions are plotted in Fig. 10, from which it can be seen that one can reckon with a maximum capacity of approximately 50 t/h per unit for the hot briquetting press, from 90 to 100 t/h for the sand coker and 270 t/h for the low-temperature coal carboniser. Accordingly, a plant having 3 million tons a year would consist of 2 parallel low-temperature carbonisers, 4 sand cokers and 8 presses.



Abscissa : tonnes per annum

Legend : Formed coke

Plant costs per t/a

Hot-briquettes

Maximum output of  
Press

Sand carboniser

Low-temperature carboniser

Fig. 10

Plant costs as a function of annual output

The curve plotted in Fig. 10 in respect of investment costs per year drops sharply in the case of the small capacities, as the cutting down of costs takes place here by enlarging the units. The curve becomes straighter when the capacity increases, since the saving is not so great when the plant consists of units of the same size. For the set range of from 0.2 to 3 million tons a year the specific investment costs drop from 100 to 55% in respect of formed coke plant, and for hot briquetting plant from 65 to 30%.

Thorough examination of the costs of formed coke production in large units leads to the conclusion that distinct advantages are above alloffered when:

1. Low-volatile coals are available or
2. Cheap high-volatile coals are available or
3. Volatile matter to the extent of 6.5 can be permitted in the coke.

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FORMED COKE:  
RESEARCH AND TESTS MADE BY THE HOUILLÈRES DU  
BASSIN DU NORD ET DU PAS-DE-CALAIS AND THE FUVU COMPANY  
- ECONOMIC ASPECTS

by

L. Soubrier

The H.B.N.P.C. has for some years been concerned with the manufacture of formed coke, as much for the general reasons that have influenced all those concerned with this problem as for reasons peculiar to their own interests. Among the former are the need to supply the steel industry with a sized coke which will give smoother furnace operation as well as greater productivity, and the need for a continuous process of coke manufacture, giving increased productivity in this operation also.

There were also a number of special considerations peculiar to H.B.N.P.C. In the first place, the area had developed some fifteen years ago a process for producing smokeless briquettes for production of an artificial anthracite, Anthracine 54. This had enabled them to gain some important experience on problems of treating coal, either the original lean coal to which the process was first applied, or the high-volatile coal to which it was later extended.

Another factor was the nature of the seams in the area, including both high volatile coal of good quality, suitable for the standard methods of coke manufacture, and lean coal. Production plans, laid down some years ago, called for a much more rapid reduction in output of high volatile coals than lean coals. It was important therefore to maintain the maximum carbonisation capacity of the area using its own coals, while at the same time ensuring sales of the lean coals, which was likely to prove more difficult now that consumption of this type as domestic fuel was decreasing. With this in mind, development was pushed ahead of a method which would enable formed coke to be produced with a relatively low percentage of volatile coal and using a certain amount of lean coal.

Finally, the fall in domestic consumption makes it likely that, on a medium-term basis, the area will have under-employed briquetting capacity, which could probably be used.

#### 1. Research by H.B.N.P.C.

We first decided to work on coal briquettes, made with the traditional binders, pitch or oil bitumen. Research was carried out on blends and on methods concurrently, and it was directed towards obtaining good quality coke, since we judged that it was important, particularly with the prospects of the increase in size of modern furnaces, to place at the disposal of the steel works a coke with good mechanical properties.

##### 1.1. Blends

As regards blends, our main concern was first to manufacture good formed coke using as varied a range of coal as possible.

Generally speaking, we considered it important to use, in addition to a certain quantity of coking coal and lean coal, coal with a higher volatile matter, available in larger quantities on the world market and therefore less subject to the price increases that result from increased demand for coking coal.

Results proved conclusive, as we succeeded in producing formed coke with good mechanical properties from high-volatile coals and even from lignites. Naturally, as experts in this field know, there is no prospect of making formed coke from highly-swelling coking coal alone.

## 1.2. Method

Here we obviously had a difficult choice to make. Indirect heating was out of the question for productivity reasons, and we had therefore to choose between a solid heat-carrier such as sand or coke dust, and a gaseous heat-carrier. We finally decided to continue along the lines with which we had gained experience in making smokeless fuels. In any case, this approach appeared to have certain advantages, chiefly in offering an easier method of cooling the briquettes, which should not only give a good thermal balance but simplify the difficult problem of removing the briquettes from the carbonisation oven.

For this reason H.B.N.P.C. joined forces with the Société Fusion et Volatilisation (FUVO) of Saint-Etienne, which had experience with the ERIM oven, and came to an agreement with them in which H.B.N.P.C. was responsible for development of a joint process.

At the present moment, these two organisations have two test ovens:

- 1) a pilot oven in a H.B.N.P.C. plant, used for studying problems connected with direct heating by flue gases produced outside the oven. (See Figs. 1, 2 and 3).
- 2) the oven at the firm of OZIOL, Saint Etienne, under licence from FUVO, which has been in full commercial operation for several years.

At present they are considering a unit of four larger ovens, with an output approaching 130 - 150 tonnes/day, which can easily be expanded to 220 - 250 tonnes/day.

I shall now give some details of the manufacture of formed coke as we see it. It involves basically two stages of manufacture.

- 1) agglomeration of coal into briquettes,
- 2) treatment of the briquettes in a carbonisation oven with its ancillary equipment.

### 1.2.1. Briquetting

Briquetting itself is carried out in standard presses with standard binders, either pitch or bitumen. The briquettes may for example have a weight of 40 to 50 gms. and the largest size is about 60 mm. Particular attention should however be paid to the size of the coal, which is relatively important for the final result. Broadly speaking, fine coal should be used.

The methods used by FUVVO may be quoted as an example. By using a special pugging mill and a certain percentage of tar, it is possible to produce briquettes with a relatively low percentage of binder.

But although the briquetting method is practically identical in all cases, the preparation of the blend varies appreciably according to the type of coal. Apart from the binder, three types of blend can be quoted here, each with individual characteristics:-

#### Mixture 1:

This has a relatively high percentage of up to 90% of low-volatile coal (100 - 200 - 300 in the international classification). The remainder is coking coal.

#### Mixture 2:

The percentage of low-volatile coal is lower, although still relatively high, while the coking coal is replaced by weakly coking coal, with an AFNOR swelling index possibly only 3, e.g. class 621 of the Lorraine type fat coal B.

#### Mixture 3:

In this third mixture the base consists of a high-volatile coal of the type "flambant sec", that is with a swelling index of 1, class 811. This coal is quite unsuitable for coking, but is previously converted by low-temperature carbonisation to a semi-coke of about 15 to 16% volatile matter. The rest of the mixture then consists of a coking type coal.

#### 1.2.2. Treatment of briquettes

The plant includes the carbonisation oven itself, with a certain amount of by-product plant for removal of tar.

Fig. 4 shows the flow sheet for the first two mixtures and Fig. 5 a more complete flow sheet covering all types, and including the whole process for mixture 3.

As regards the carbonisation furnace itself, I shall say something about the single-stage ERIM oven of Messrs. OZIOL, which was used to treat the briquettes in the tests of formed coke, and which proved entirely suitable for this type of product. It is a shaft furnace with vertical walls in heat-resistant steel. The section is 2 m X 0.5 m, the height 4 m. The briquettes travel by gravity in counter-current to the rising gases. There are three distinct zones:



- 1) The upper zone in which the briquettes are heated while cooling the gases,
- 2) the middle carbonisation zone,
- 3) The lower zone for cooling the briquettes.

In the upper zone, the freshly charged raw briquettes are progressively heated while the hot gases which have been used for carbonising the briquette in the middle zone, give up their heat. Since the exit temperature of the gases is in the region of 100 to 120°, the loss as sensible heat is relatively low.

In the middle zone, the briquettes are progressively raised to a temperature in the region of 900°, but possibly reaching 950°, by the introduction of air which makes it possible for some of the gas passing through the zone to be burned on the spot.

In the lower zone, the carbonised briquettes gradually lose their heat to the recycled gases admitted at the bottom of the furnace. They leave the furnace at a temperature of about 100°.

The overall heat losses, in the form of sensible heat are extremely low, so that the furnace economy is good. It is also a furnace in which the operation is relatively simple, and which lends itself especially to intermittent operation.

A diagram of the ERIM four-oven unit is given in Fig. 6.

## 2. Tests with formed coke

An oven of this type, at Messrs. OZIOL, was used to manufacture formed coke which, by the courtesy of IRSID, was afterwards tested on the blast furnace at the International Association for Fundamental Research on Blast Furnaces at Ougrée (A.I.R. B.O). This was a special product, representing probably the limit of what can be achieved in producing a fuel of maximum weight and maximum percentage of low-volatile coal. The tests were valuable although the results were not directly applicable to blast-furnace working.

After preparation using the FUVVO process and with the special FUVVO pugging-mill, the green briquettes consisted of a mixture of coals comprising: 90% anthracitic coals of about 5% V.M. and 9% ash content, as the main constituents.

10% coking coals of 24% V.M. and 9.5% ash content. briquetted with a binder composed of 5% pitch and 2% tar.

Because the press normally manufactures domestic fuel, the products are of relatively small size (24 g) well suited for that specific use, as they have a low voidage, for that same reason they are badly suited to blast furnace purposes.

Table I gives analyses and properties of the carbonised product, determined in the H.B.N.P.C. laboratories and by A.I.R.B.O. respectively. As was expected, this is a very dense product, in which the prosioty of each briquette and the voidage, which is associated also with the shape of the briquettes, are particularly low.

This coke was used at A.I.R.B.O. with pellets having an iron content of 56 to 57%, a basicity of 1.1 to 1.2, and size 100% <22.6 mm the blast temperature was 1,020°.

The object of the tests was to study the coke's behaviour and dertermine the maximum productivity. The following conclusions were drawn.

#### Normal working

At normal rates of working, corresponding to a coke consumption (at 85% carbon) of 18.5 tonnes/day and an iron output of 1.19 tonnes/hour, the results were:

- 1) Coke rate (85% carbon, according to ash determination) of 645 kgs per ton of iron,
- 2) good distribution of gas in the shaft with the fire zone not exceeding the permitted height of 2.5 metres above the tuyères,
- 3) loss of charge slightly above normal.

So far as iron production was concerned, operation was relatively stable, but, with a normal silica content, the iron had a relatively low percentage of carbon (3.8%) and a high sulphur content (0.08%)

### Intermediate working

On intermediate working, corresponding to a coke consumption of 23.8 tonnes/day and an output of 1.45 tonnes/hour, the coke rate was slightly increased, to 685 kg per tonne of iron. The operation of the furnace remained stable and the fire zone normal. The quality of the iron improved, reaching 4% carbon, 0.76% silica and 0.065% sulphur.

### Rapid working

With a coke consumption of 29 tonnes/day and an output of 1.89 tonnes/hour a rate at which blockages occurred - the coke rate was 640 kgs per ton of iron; the fire zone remained less than 2.5 metres above the tuyères, the top gas temperature remained steady at 300°C, the iron was better carburised (4.18%) sulphur was low (0.036%) but silica content was slightly higher (1.08%), characteristic of high metal temperature.

Altogether, the conclusions which may be drawn from this test seem particularly interesting.

This type of coke was poorly suited to slow working. Measurements made of the loss of charge confirm the importance of the shape of briquettes in influencing voidage; but this is a characteristic which is easy to change. It is clear that, should it prove possible to use briquettes made by some such method as this in a standard blast furnace, it would be preferable to aim at products with an apparent density and bulk density nearer to those of conventional coke.

### 3. Economic aspects

We now propose to examine the costs of manufacture of formed coke in relation to those of conventional coke.

If it is difficult to speak in absolute terms of the cost of manufacturing conventional coke, it is even more difficult in the case of formed coke, since it is possible to produce it from very different types of coal.

There is no question of making these calculations in a way that will be generally applicable, and it is obvious that the optimum solution is to determine each individual case as a function of the possible supply of coal, the coal price, the availability of pitch or bitumen. Finally, the cost - as in a conventional coking plant - cannot fail to be influenced by the quality of product required.

As practical examples we shall examine the case of the three typical mixtures described above. At present our research is much more advanced on the first two types, which we have studied in detail.

We will take the case of a coking plant producing a total of 1 million tons per year.

### 3.1. Plant

#### 3.1.1. Formed coke plant

For mixtures 1 and 2, with a high percentage of lean coals, the system is that shown in Fig. 4, while for mixture 3, the system in Fig. 5 can be used.

We have envisaged plants on the generous side in order to obtain a more reliable judgment on this question.

The plant comprises the briquetting plant with its driers in the form on independent feed lines each with a capacity of 40 to 50 tons per hour. We have assumed that, according to requirements, 4 or 5 streams would be in use. We have added an additional reserve stream to allow for continuous working while reducing the capacity of the intermediate storage bunkers which always lead to waste.

We have assumed fifteen carbonisers, one of which is essentially stand-by to cover maintenance periods.

For coke screening, in view of the high percentage of coke utilisation in modern plants, we have allowed for an installation equal in size to that of a conventional coking plant, which is certainly excessive.

Finally as regards the treatment of gas, we took into account the special problems associated with making formed coke in a furnace with internal heating using gaseous heat carriers. These include:

- 1) As regards volume of gas, the need to treat a gas consisting of
  - a) distillation gas, b) flue gases used for heating and
  - c) recycled gas, amounting in all to practically five times as much gas as in a conventional coking plant.
  
- 2) As regards quality of gas, the presence of a large quantity of heavy tar. This is because on the one hand, the temperature

of the volatiles never rises above that at which they are formed, and on the other hand, particularly where the briquettes contain much low-volatile coal, the tar comes mainly from the pitch binder and is therefore heavy and very viscous at the ambient temperature. Finally these gases contain a relatively large amount of dust.

We therefore chose to adopt primary condensation in direct condensers with practically no packing, and with fresh water provided by sprays. Each condenser has a nominal capacity of 80,000 m<sup>3</sup>/h so that if four are provided, one can be in reserve. The condensers each have their own settling tank for condensate. This arrangement avoids transporting the condensate.

The following leave the settling tanks:-

- a) hardened tars which are mechanically removed as in conventional coke manufacture,
- b) water and pitch which undergo a further decantation before being either stocked for tar distillation or - in the case of water - removed in water/water exchangers.

The cooled washing water is then returned to the washers while the cooling water goes to a hyperbolic cooler.

On leaving the washers, the gas passes through mechanical tar-removers in order to protect the four extractors (of capacity 80,000 m<sup>3</sup>/h), and then to the three electrostatic tar removers of the same capacity. It contains practically no ammonia and no naphthalene, owing to the method by which it was produced and treated. Its gross calorific value is approximately 2,000 kcal/m<sup>3</sup>.

The gas stream is then split: one stream goes to the carbonisers to maintain the necessary heat input and recycle make-up; the other is discharged either to a gas-holder or to atmosphere.

We shall not examine here how the gas can be used in the industrial complex of a steelworks; for example, in the furnaces or for power generation. Within our chosen limits of a coking plant of one million tons output per annum, there would only be an output of 80MW, which would seem rather low to allow the optimum utilisation of the thermal value of gas; a thermal power station can however be only partially based on gas. On the other hand, an output of 3 million tons would doubtless make this an attractive solution.

The use of mixture 3 would present the same problems, and in addition those arising from manufacture of semi-coke by low-temperature fluid-bed carbonisation and the necessary plant for the condensation and separation of the one or the two types of tar produced.

For the sake of illustration, Fig. 7 represents a perspective drawing of a unit capable of producing 1 million tons per annum, so far as it can be visualised in the light of our assumptions. Obviously, other schemes could also be devised. It is clear that the area required is appreciably smaller than in the case of a conventional-type coking plant.

### 3.1.2. Conventional coking plant

We have produced a simplified scheme similar to those drawn up by the H.B.N.P.C. at the time of the construction of the Dunkirk coking plant including:

Coal preparation; batteries of ovens; primary condenser with cooling circuit for water and clarification; elimination of the necessary ammonia and naphthalene, at least in special circumstances, because of the total quantity as well as the concentration; extractor; discharge.

This scheme is shown on Fig. 8. It is characterised by non-recovery of benzol, which makes it possible to dispense with the usual stage of final condensation, as the whole circuit operates at negative pressure.

### 3.2. Capital Investment

Table II shows figures for the traditional type coking plant and the formed coke plant, in the case of mixtures 1 and 2. Although we have no detailed breakdowns of prices, we think that these figures are consistent and I emphasise that as regards formed coke our evaluation has been more than adequate.

In fact, as I have said, briquetting could be simplified. The cost of screening the coke has risen since the number of sizes will probably be smaller than in a conventional plant. Furthermore, the cost per m<sup>3</sup> for the carbonisers, to which we have added a margin over the estimates made by the specialists, is higher than that of conventional type batteries, although their equipment is much simpler.

Finally, we set aside 20% for expenses such as engineering, promoters expenses, etc and not 15% as in the case of the conventional coking plant, since we considered that the new process did not have the same know-how based on past experience as the traditional method, and would require, at least at first, a larger amount of research.

### 3.3. Cost of blast furnace coke with 10.5% ash

Some hypotheses are necessary at the outset if valid calculations as to cost are to be made.

Comparing cokes made from coals of very different volatile matter, it is necessary, to get an exact idea of their value, to take into account the ash content of the products, which will be different in different cases even when the original coals have the same ash content.

The necessary adjustment to make valid comparisons was carried out by taking an ash premium at a rate of 2.5% ad valorem. The balance by weight for the manufacture of conventional coke and formed coke also gives rise to a problem.

In order to ensure uniformity, all calculations were based on theoretical figures presented by Messrs. BOYER and LAHOUSTE to the 1961 Congress of the Association Technique du Gaz en France.

Table III gives the balance by weight related to a tonne of total coke.

Although we have not wished to change these figures, the tables which we have drawn up, based on practical results, particularly regarding mixture no. 1, show that yields of tar, for example, are probably exaggerated.

This deviation is incidentally unimportant, in view of the price stated for tar and for the thermal value of the gas, i.e. 70 francs per tonne of tar and 8 francs per 1,000 thermies (whether gas or benzole, since the latter is not removed from the gas).

### 3.3.1. Raw materials

The relative costs were calculated from the weight balance of Table III and expressed per tonne of blast-furnace coke, making the required correction, as described earlier, to relate to coke with 10.5% ash.

Starting with coals of rather special characteristics which we had used in a sample study, we end with rather complicated figures, which however we have not modified, and these are given in Table IV.

Assuming on the other hand that we are dealing with a coastal coking plant, the base prices for coals all at 5.66% ash and 6.47% moisture, have been taken as CIF costs, as follows:-

- P<sub>1</sub>: price of low-volatile coal
- P<sub>2</sub>: price of high-volatile coking coal
- P<sub>3</sub>: price of a high-volatile coal of poorer coking quality
- P<sub>4</sub>: price of pitch of 2% moisture

### 3.3.2. Operating expenses

These comprise all the labour and supply expenses, including unloading of coal and stocking, also including general plant and site costs.

Table IV shows that overall the operating expenses, if briquetting is included, are appreciably higher than for a conventional coking plant.

### 3.3.3. Depreciation charges

These have been calculated as a constant annual rate equivalent to a depreciation period of 20g at an interest rate of 7%.

### 3.3.4. Receipts to deduct

These refer to small coke, tar, gas and benzol.

### 3.3.5. Formulae of costs

Finally, the resulting formulae for costs which are reached are given in Table IV. The calculations were made with coal of precisely specified properties, the volatile matter being respectively 10.1% for the low-volatile coal, 24.3% for the coking coal, 36.1% for the weakly-coking high-volatile coal.



4. Cost of Blend No. 3

Although we were able to obtain with this type of mixture a formed coke of good quality, we were unwilling to place the cost on the same footing as the others, because, so far as the low-temperature carbonisation is concerned, the H.B.N.P.C. did not have such full information on which to base their calculations.

But we consulted the Marienau experimental station, where they have been studying problems of low-temperature carbonisation for many years, so that they have the knowledge to build or commission suitable plant of large capacity and are in a position to examine under normal conditions the problems connected with condensation and separation of low-temperature tars.

The information which they supplied made it possible for us, on the basis of a less complete calculation than the previous ones, to arrive at a cost which can be represented with a fair approximation by a formula, which this time includes the CIF price,  $P_5$ , of the non-coking coal of class 611, having the same moisture and ash as the other coals, but with volatile matter taken as 38%.

The price of tar,  $P_6$ , a certain quantity of which is required for manufacture, is also included in this formula. Obviously the tar produced is included under receipts.

5. Summary of the formulae for cost and sample calculations

The formulae for costs are set out below:

Conventional coke	$1.37078 P_2$	+ 14.77
Formed coke blend 1	$1.00217 P_1 + 0.17684 P_2 + 0.11343 P_4$	+ 14.77
Formed coke blend 2	$0.86878 P_1 + 0.37229 P_3 + 0.11937 P_4$	+ 13.50
Formed coke blend 3	$0.3506 P_2 + 1.049 P_5 + 0.1229 P_4$ $+ 0.0615 P_6$	+ 12.77

In order to arrive at some figures which are certainly interesting it is necessary to establish the differences of price between the various coals. The following appear reasonable:

Between coking coals and low-volatile coals, or  $P_2 - P_1$  1 ¢

Between coking coals and weakly coking coals, or  $P_2 - P_3$  2 ¢ and 2.5 ¢

Between coking coals and non-coking coals, or  $P_2 - P_5$  3.5 ¢ and 4 ¢

The results are given in Table V, for two values of  $P_2$  of 17 and 18 ¢ (1 ¢ = 5.6 francs) and a pitch price of 130 francs/tonne.

In this connection, attention should be drawn to the fact that the blend assumed for the conventional coking plant, with 24.3% V.M. is extremely favourable and, for the same coal price, the cost of coke with 10.5% ash would increase by:

1.25 francs/tonne for 1 point of V.M. above 24.3%

4.40 francs/tonne for 1 point of ash " 6.5%

Keeping to Table V itself we find that mixtures 1 and 2 are definitely competitive, and mixture 3 gives a cost which, according to the basis adopted, is lower or slightly higher than that of conventional coke.

It seems proper to stress that the H.B.N.P.C. engineers have made these calculations with an objectivity that some would consider excessive. In fact, in calculating the cost of conventional coke, a subject with which they are familiar, they have been very conservative.

In contrast, the basic considerations adopted in the case of formed coke are in its disfavour, for example

1) in capital investments

a) in the briquetting plant, where an additional stream was allowed;

b) in screening, which has been taken on the same basis for a conventional coking plant;

c) in the gas supply system, where allowance has been made for the increase in output but not for the reduction in length of transport lines;

2) in operating expenses, which allow for

a) a very high consumption, of heating gas (250 th/tonne of briquettes) for the process;

- b) a high percentage of waste in briquetting;
- c) a high consumption of binder, on which it might be possible to save 0.50 to 1 franc per tonne of coke;
- d) a rather lower yield of furnace coke than in a conventional coking plant, with direct repercussions on the cost.

On the other hand, it should be said that we have assumed the same value per therm of gas, whether it is standard coke oven gas or of calorific value 2,000 kcal/ m<sup>3</sup>.

Finally, we must take into account the advantage for furnace operation of using a sized and dry coke, and the elimination of air pollution.

## 6. Conclusion

After reporting on our work, I have examined the economic aspects of manufacturing formed coke using three possible blends as examples. A choice would have to be made. But, faced with a particular problem, the choice itself must be an individual one, governed by the coals available, their price and the requirements of the furnace operator.

The best solution has a good chance of using several of the categories of coal which occur in each of the examples described and of leading to a cost intermediate between the various formulae.

The choice should in every case be based on a special study and only the existence of a method of treatment having the required flexibility can allow advantages to be taken of the economic conditions of the market.

Overall, if we care to make a wise choice, the least we can say is that the time has come to ask ourselves if formed coke does not show favourable prospects for development, in many parts of the world, and in all probability throughout the world.

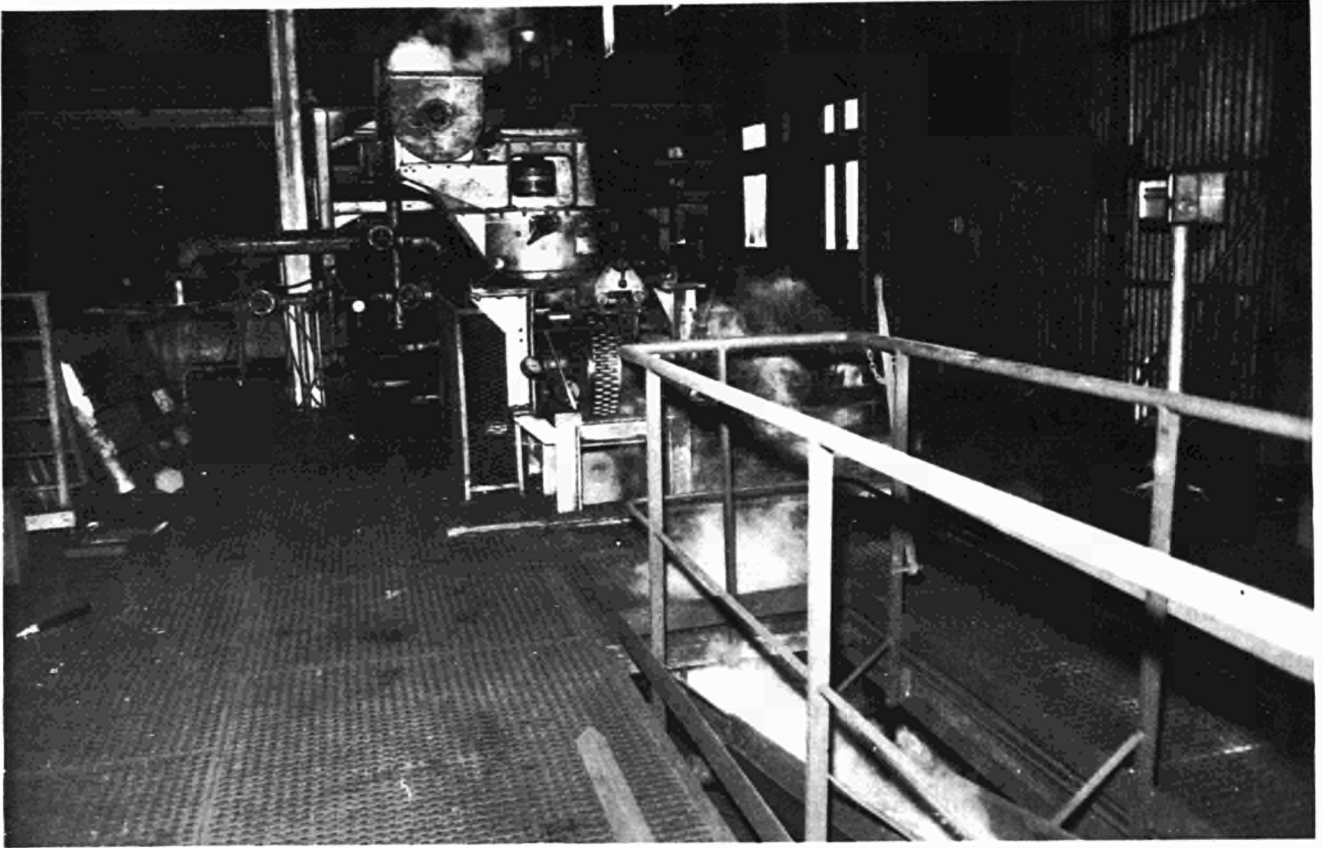


Figure 1 - Press in briquetting department



Figure 2 - View of the pilot oven.

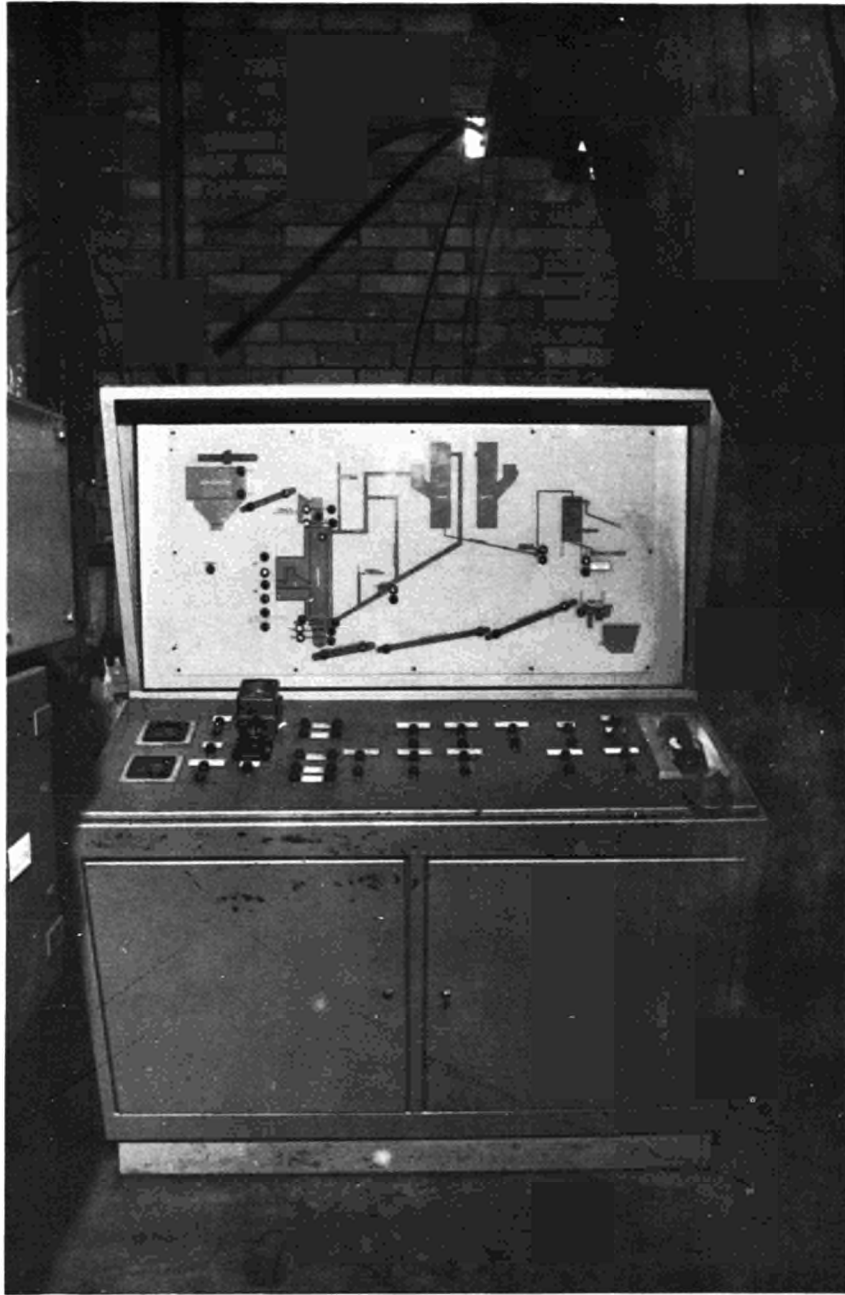


Figure 3 - Viewing and Control Panel for the pilot oven.

MANUFACTURE OF FORMED COKE

Blends 1 and 2

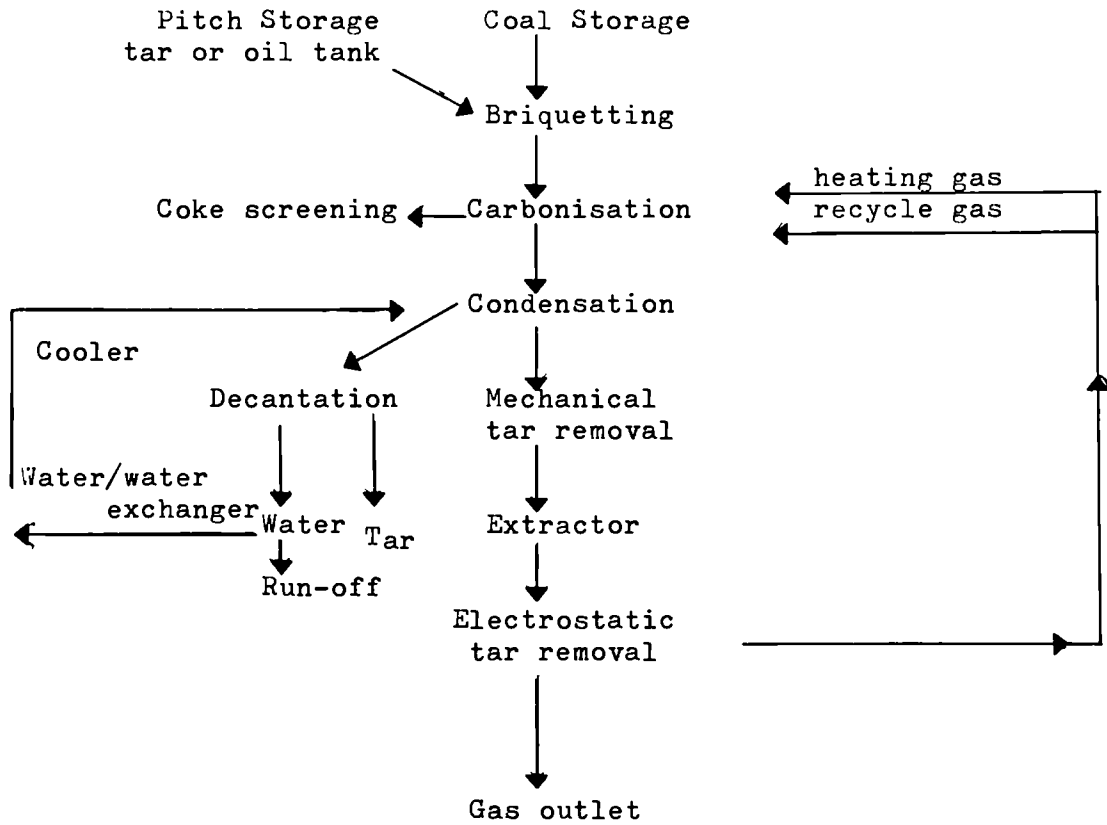


Figure 4

MANUFACTURE OF FORMED COKE

Possibility of treating coals of the kinds considered in mixtures 1, 2 and 3

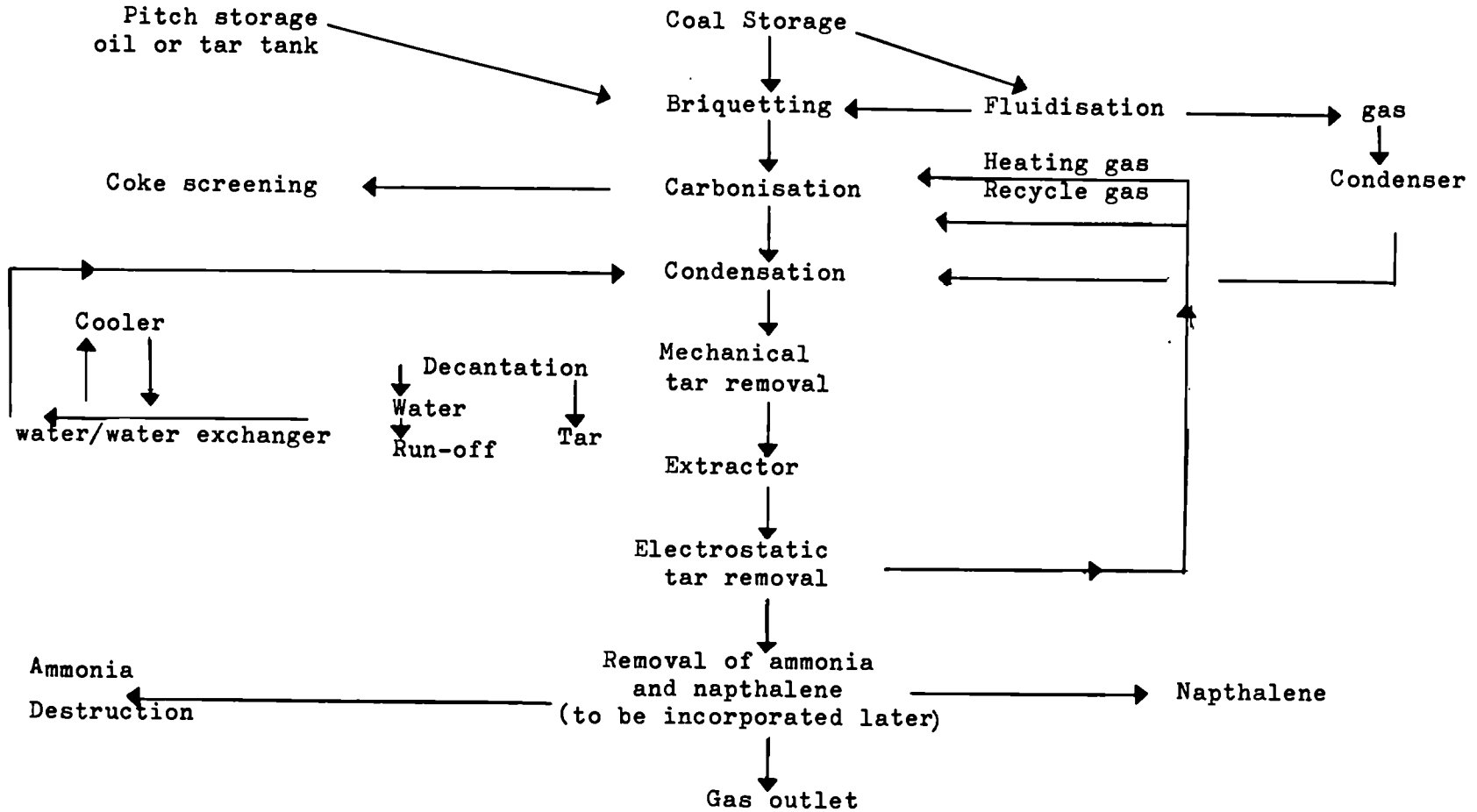


Figure 5



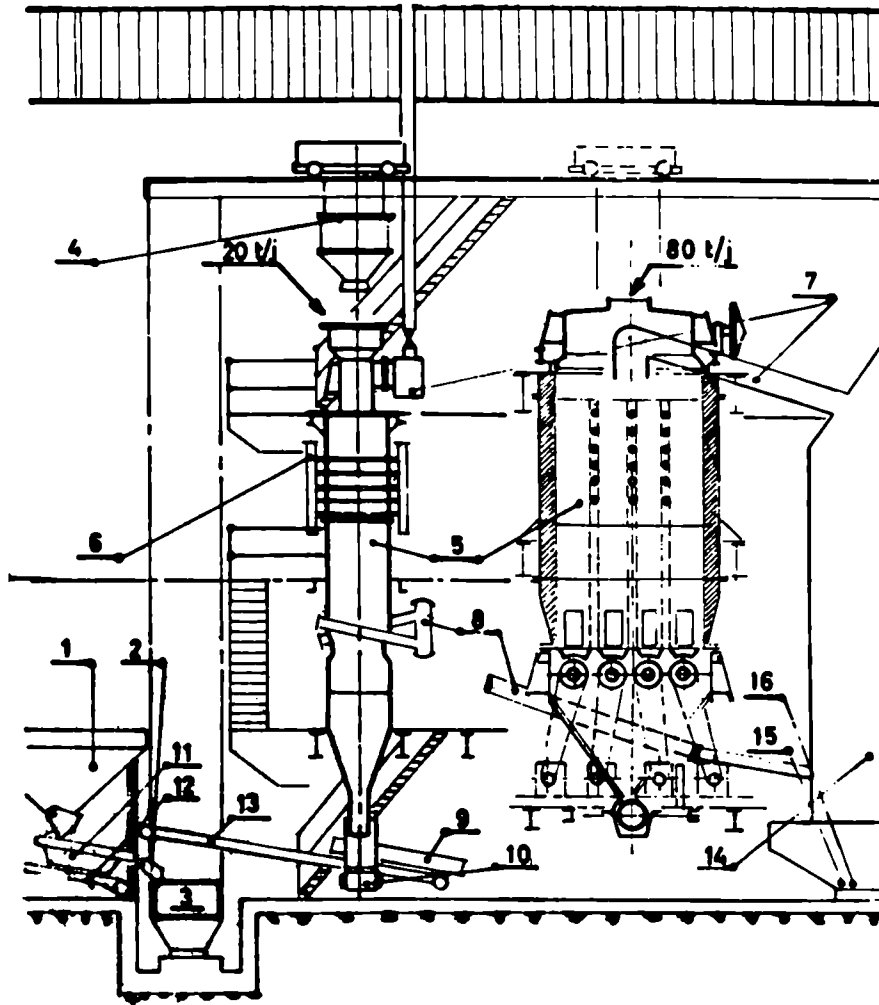


Fig. 6 - Main features of the Erim oven

1. Bunker for green briquettes ( $8 \text{ m}^3$ )
2. Screen for green briquettes
3. Charging bin (lower)
4. Charging bin (upper)
5. Erim oven
6. Air injection
7. Gas inlet points
8. Feed point for recycled gas
9. Screen for carbonised briquettes
10. Conveyor for carbonised briquettes
11. Take-off for crude reject
12. Conveyor for crude reject
13. Conveyor for carbonised reject
14. Tar removal plant
15. Pump for condensed tar
16. Pump for gas-cleaning water

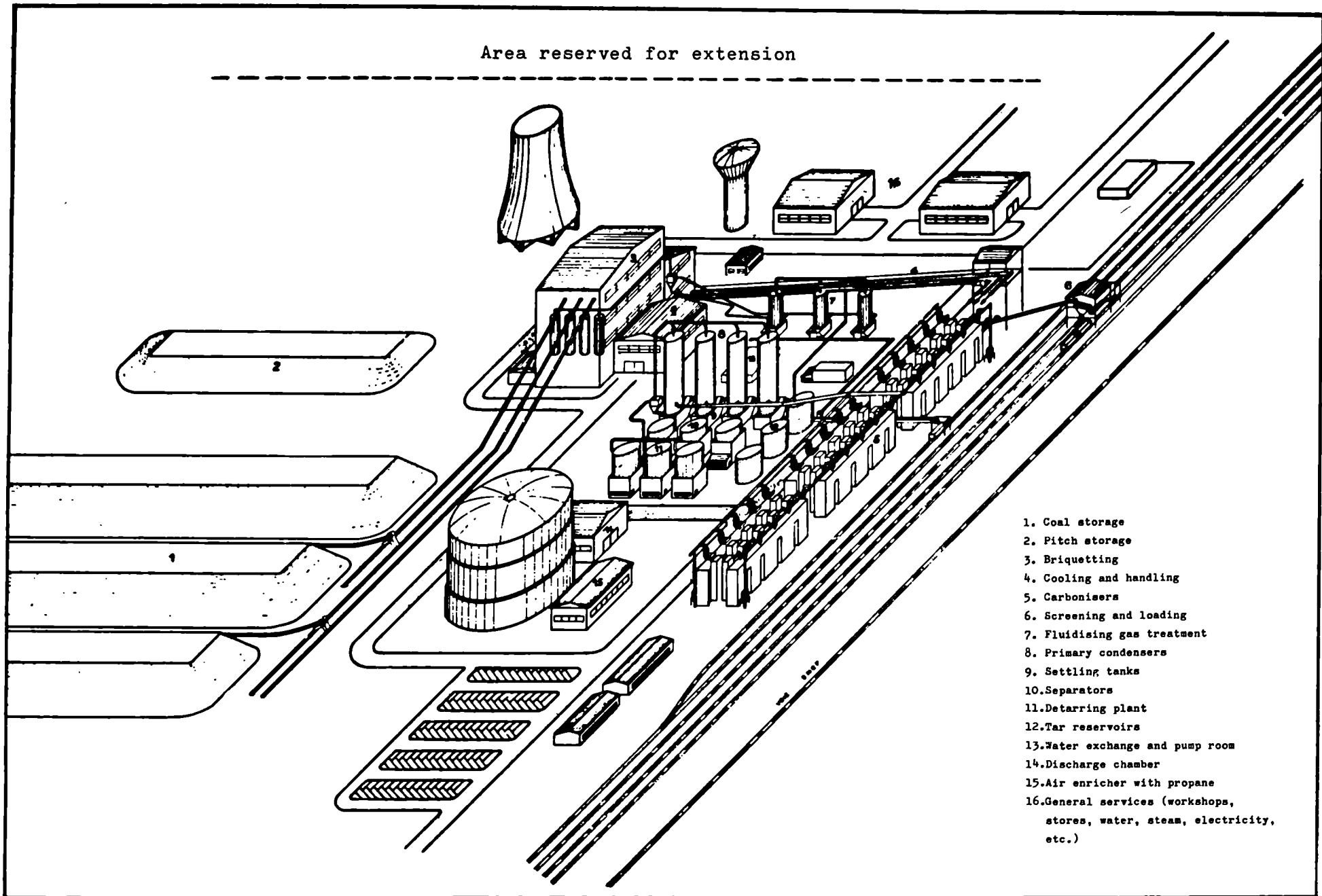


Figure 7

CONVENTIONAL COKING PLANT

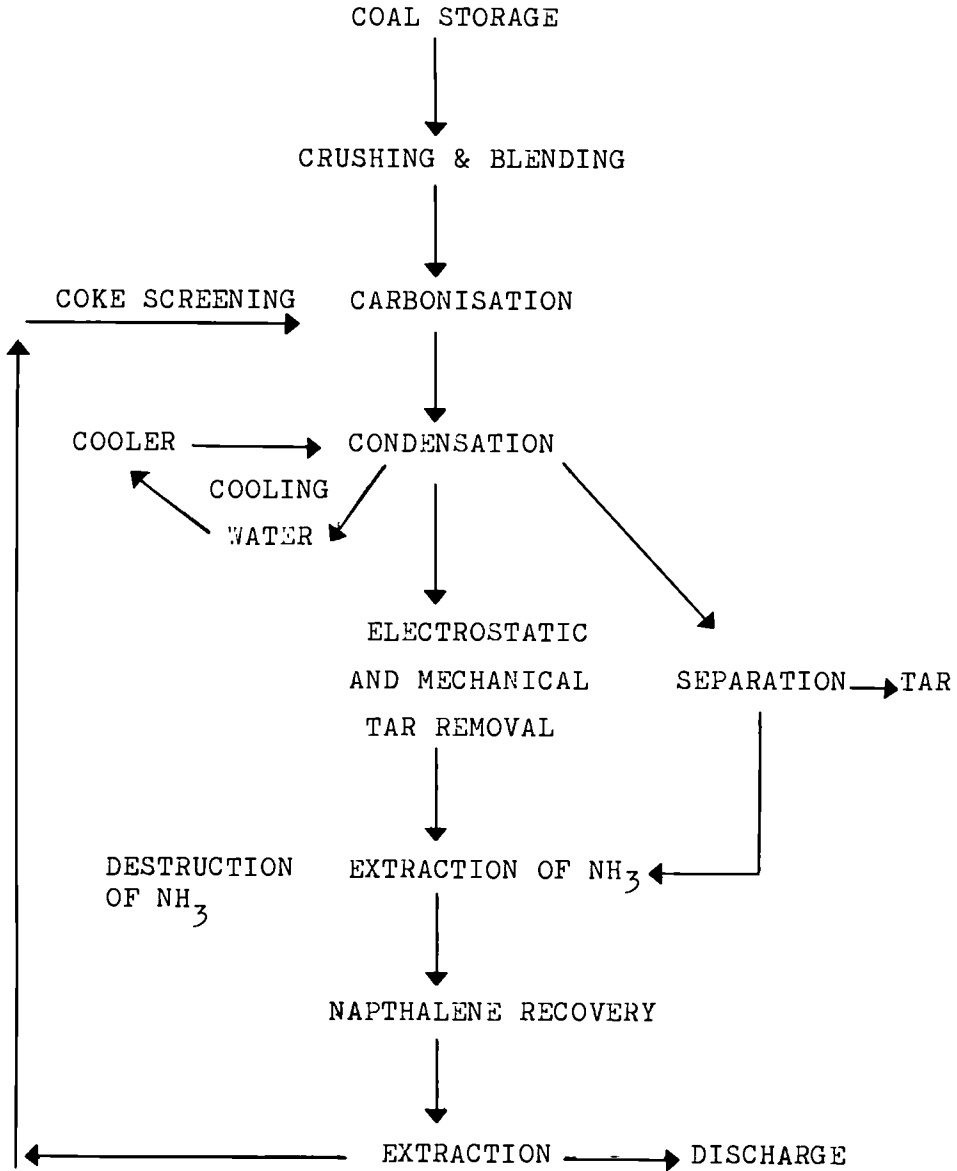


FIGURE 8

FORMED COKE, H.B.N. -FUVO, TESTED AT AIRBO

PROPERTIES

	<u>H.B.N.P.C. Results</u>	<u>AIRBO Results</u>
<u>Analyses:-</u>		
Ash Content	9.0%	9.28%
Moisture Content	3.5%	
V.M. Content	3.7%	3.45%
Bulk density	0.745	0.842
Tone density	1.697	1.68
Porosity	26.3%	19.4%
Apparent density	1.250	1.355
Average weight	21.5 g	21.38g
Average crushing strength	>230 kg	
Total Sulphur content	0.925%	
M <sub>20</sub>	92.5	91.9
M <sub>10</sub>	7	7.7
I <sub>20</sub>	76.3	70.2
I <sub>10</sub>	22.8	27.8

TABLE I

CAPITAL INVESTMENT

	<u>Conventional</u>	<u>Formed coke plant</u>	
	<u>Coking Plant</u>	<u>Blend 1</u>	<u>Blend 2</u>
Miscellaneous	38,675	42,242	42,242
Stockpile	5,950	5,950	5,950
Silos		5,950	5,950
Coal preparation	11,900		
Coal handling	5,432		
Briquetting		16,740	20,137
Carbonisation & associated equipment	65,720	24,000	26,000
Coke treatment	7,497	7,497	7,497
Gas treatment & discharge	<u>28,323</u>	<u>36,693</u>	<u>36,693</u>
	163,497	139,072	144,519
Increase 15%	24,525		
20%		27,814	28,904
	<u>188,022</u>	<u>166,886</u>	<u>173,423</u>
Interest	10,792	9,579	9,954
	<u>193,814</u>	<u>176,465</u>	<u>183,377</u>

TABLE II

WEIGHT BALANCE IN KILOGRAMS

	<u>Standard</u>	<u>Formed coke plant</u>	
	<u>Coking Plant</u>	<u>Blend 1</u>	<u>Blend 2</u>
Total coke	1,000	1,000	1,000
Blast furnace coke (2% moisture)	903.8	889.8	889.8
Small coke (12% moisture)	96.2	110.2	110.2
Briquettes made		1,360.7	1,423.3
Briquettes used in blast furnace		1,224.5	1,280.9
<u>Fuel</u>			
Lean 5.66% ash, 6.47% water		977.022	841.643
High Volatile " " " "	1,324.8	172.400	
" " B " " " "			360.655
Pitch		108.85	113.858
Tar	37.7	86.30	101.08
Gas & Benzol (gross calorific value) thermies	1,952.2	1,370.2	1,602

TABLE III

COST IN FRANCS PER TON OF BLAST FURNACE FUEL

	<u>Standard</u>	<u>Formed Coke Plant</u>	
	<u>Coking Plant</u>	<u>Blend 1</u>	<u>Blend 2</u>
1) Fuel	1·37078 P <sub>2</sub>	1·00217 P <sub>1</sub> +0·17684 P <sub>2</sub> 0·11343 P <sub>4</sub>	0·86878 P <sub>1</sub> + 0·37229 P <sub>3</sub> + 0·11937 P <sub>4</sub>
2) Operating costs	15·74	20·39	21·18
3) Depreciation & Interest	19·19	16·94	17·59
4) Costs recovered			
small coke	7·08	7·83	7·83
tar	2·70	6·35	7·24
gas & benzole	10·68	8·38	10·20
Total	20·46	22·56	25·27
5) Realisation			
Standard coking plant	1·37078 P <sub>2</sub> + 14·47		
Formed coke			
Blend 1 Formed coke	1·00217 P <sub>1</sub> +	0·17684 P <sub>2</sub> + 0·11343 P <sub>4</sub> + 14·77	
Blend 2	0·86878 P <sub>1</sub> +	0·37229 P <sub>3</sub> + 0·11937 P <sub>4</sub> + 13·50	

TABLE IV

COST IN FRANCS PER TON OF BLAST FURNACE COKE WITH 10.5%  
ASH CONTENT IN FRANCS/TON

	<u>C.I.F. PRICE OF COKING COALS</u>	
	<u>17 ¢ per ton</u>	<u>18 ¢ per ton</u>
<u>Standard coke</u>	145.00	152.65
<u>Blend 1</u>		
$P_2 - P_1 = 1 \text{ ¢}$	136.15	142.75
<u>Blend 2</u>		
$P_2 - P_1 = 1 \text{ ¢}$		
$P_2 - P_3 = 2 \text{ ¢}$	138.15	140.10
$P_2 - P_3 = 2.5 \text{ ¢}$	137.10	144.05
<u>Blend 3</u>		
$P_2 - P_5 = 3.5 \text{ ¢}$	145.75	153.60
$P_2 - P_5 = 4 \text{ ¢}$	142.80	150.65

TABLE V

DISCUSSION

S. Henkel and K.D. Haverkamp (Rheinstahl  
Huttenwerke AG Henrichshutt Works)

To supplement the Bergbau-Forschung work we would like to report briefly on the first tests with "Hot-briquettes" and formed coke in a commercial blast furnace at the Henrichshutte Works of the Rheinstahl Huttenwerke AG at Hattingen.

As may be known to you from the technical literature, the Bergbau-Forschung has endeavoured to develop a formed coke which would be suitable for use in shaft furnaces, e.g. blast furnaces.

The idea of charging the intermediate product of formed coke, namely the so-called "Hot-briquettes", into the blast furnace came to us about 1 year ago during a conversation with Bergbau-Forschung representatives, in the course of which we were informed about the different physical and chemical properties of hot-briquettes and formed coke.

Since the available quantities of hot-briquettes were strictly limited, we could not consider a stepwise increase in the proportion in the fuel charge. We were therefore compelled to replace the coke 100 per cent with hot-briquettes straight away. To avoid excessive operating risk the hot-briquette charge was limited in preliminary tests first to 1 hour, later to 4 hours and finally to 12 hours. As there were no operating difficulties, a 3-days'test was carried out in February this year. The results of this test as well as a test of several days with formed coke are briefly reported as follows.

Blast-furnace characteristics

The tests were carried out in furnace no. III of our blast-furnace plant. The furnace has a hearth diameter of 6.8 m, a height of 25.2 m and a useful volume of 764 m<sup>3</sup>. The furnace is operated with an oxygen-enriched blast with controlled humidity and heavy-oil injection. The furnace output lies between 1250 and 1350 t steelmaking pig iron per day.



### Hot-briquette test

The test with hot-briquettes lasted for 72 hours from 16 to 19.2.70. About 2700 t of hot-briquettes were used altogether. All the individual values cannot be examined here, owing to the lack of time. The furnace operation was completely normal during the test and the output remained unchanged at about 1350 t/d. The furnace pressure did rise from 0.9 to 1.07 atm, but hanging did not occur. The top-gas temperature fell from 224 to 107°C. This is to be attributed to the high moisture content of the hot-briquettes, 13.5 per cent, as well as to the devolatilisation reactions in the upper part of the furnace. The calorific value of the top gas rose from 1016 to 1111 kcal/m<sup>3</sup>n.t.p., owing to an increase in hydrogen content. This phenomenon may be desirable in most cases, from the point of view of the utilisation of the blast-furnace gas. There were no difficulties in the fine purification of the gas (in a Beth filter plant) due to tarry constituents. A negative aspect compared with operation on normal blast-furnace coke was a certain increase in the dust separated from the top gas: during our test it rose from 23 to 49 kg/t pig iron. At the same time the carbon content of the dust increased from 26.2 to 34.6 per cent. This corresponds to a 2 per cent increase in fuel loss. Further investigations will be needed to determine to what extent this phenomenon can be avoided by improvements in the quality of the hot-briquettes.

The consumption of hot-briquettes was about 672 kg/t pig iron, about 18 per cent higher than the crude coke requirement in the comparison period. It must be observed however that the moisture content was much higher, 13.5 instead of 6.3 per cent, the volatile matter was higher, 7.1 against 1.0 per cent, and the oil consumption was lower, 61 instead of 70 kg/t pig iron, in the hot-briquette test. If the fuel consumption is corrected for these differences, it is seen that the effective increase in consumption in the hot-briquette test is only about 1 per cent. It is therefore lower than was to be expected from the increased dust loss. It must be pointed out all the same in considering these values that no final and exact conclusions can be made, especially about the fuel consumption, so the accuracy of the present data should not be overrated. The test has shown clearly however that the uncoked hot-briquettes are equal to the demands of a commercial blast furnace.

### Formed-coke test

On the basis of the positive results of the hot-briquette test it was resolved to carry out the long-planned testing of the Bergbau-Forschung

formed coke in the same blast furnace. This test took place from 3 to 13.4.1970 when about 7000 t of formed coke altogether were used.

Basically it can be stated that the test has confirmed the utility of the formed coke investigated. In contrast to the hot-briquette tests, the furnace output did fall by about 7 per cent compared with normal operation, since without doubt the excessive fluctuations in the moisture content of the formed coke had a detrimental effect. It must be taken into consideration that this had partly had to be stored in the open for more than a year. The determined moisture contents fluctuated between 12 and 23 per cent, with an average of 17.4 per cent. It can easily be imagined that trouble-free and optimum furnace operation is impossible with such a range of variation. It would therefore be untrue to conclude from the operating results that the charging of formed coke instead of normal coke or even hot-briquettes leads to a drop in output. Apart from these effects to the non-uniform moisture content of the formed coke the furnace working was normal. As in the hot-briquette test, the pressure increased to 1.07 atm. The dust separated, 59 kg/t pig iron, was again higher than during operation with normal coke. Here also it remains to study how far an improvement can be made by altering the coal blend. As for the fuel consumption, the same explanation holds as in the case of the hot-briquette test. The formed-coke consumption was 652 kg/t pig iron, 18 per cent above the normal coke consumption. Considering the higher moisture content, 17.4 versus 6.4 per cent, higher volatile matter, 1.7 versus 1.0 per cent, and the smaller amount of oil injected, 47 versus 57 kg/t pig iron, the corrected fuel consumption is 582 compared with 571 kg/t pig iron for normal coke. This slightly greater consumption is explained by the higher dust loss as well as the very high moisture fluctuations.

The tests described have shown that both the Bergbau-Forschung formed coke and hot-briquettes are suitable as full-value substitutes for blast-furnace coke. It is to be expected that the somewhat higher amount of dust can be avoided by improvements in quality. Final conclusions can of course be drawn only after lengthier testing. From the point of view of the blast-furnace operator commercial use will consequently depend solely on the price of these fuels. The hot-briquettes thus inevitably acquire a greater significance.

M. Schmalfeld

Ladies and Gentlemen,

You have heard in the address of Prof. Peters, details of the development of processes for the production of formed cokes, particularly the hot briquetting process. You learned also that formed cokes have already been tried in a blast furnace. Dr. Henkel can inform you about the major results of charges of uncoked and coked hot briquettes in the blast furnace. Thereby the development is brought to a final conclusion, but there is still the gap between plant construction and operation to complete.

It is our view that the step in the construction of plants for the production of about 700 (metric) tons of hot briquettes or about 600 (metric) tons of coked hot briquettes per day is bound to be overcome. Lurgi secured an order for the completion of such a plant. You see in the photograph the layout of a model of this plant.

The red plant produces hot coke fines (breeze) in the Lurgi-Ruhrgas process. The green plant is the heart of the installation. There is the blending plant for the hot coke fines and the dried caking coal and the double roll press. The yellow plant comprises the "BF Sandkoker" (plant for producing fine coke) and its circulation system. The plant for dry coke cooling is shown in blue. You see that the circulation system is built overhead, the highest part of the plant being about 55 metres from the ground. You see further, that so important an item of plant, by which costs can be saved, allows uncoked hot briquettes for the charge to fall direct into the blast furnace, and thereby eliminates the need for the yellow and blue plants.

The bottleneck in the scale-up of the plant as a whole is to be seen in the double roller press. Of prime importance are the difficulties associated with the increase in width of the rollers and the uniform distribution at high temperatures of the plastic material to be briquetted by those rollers. We must await sound results from the existing press handling 700 (metric) tons of hot briquettes daily, the design of which was obtained by scaling up earlier experimental results, before we can prepare a design for a press to handle 1500 (metric) tons of hot briquettes per day.

We can produce hot coke fines (breeze) by the Lurgi-Ruhr gas process, also a rich fuel gas of high calorific value. Alternatively we can install the simple fluidised bed process in which a portion of the fuel is burned, from which we get a lean fuel gas, which is suitable in its hot state to be burned under adjacent steam-raising boilers. Lurgi-Ruhr gas units for producing 4-5000 (metric) tons of hot briquettes per day have been built, and fluidised bed units with outputs of 2-2500 (metric) tons of hot briquettes per day.

Plants for 3 million (metric) tons of hot briquettes, corresponding to 9000 (metric) tons per day, consist of 2 Lurgi-Ruhr gas units or 4 fluidised bed units in association with 7-10 presses with one in reserve. We await to see whether such plants can be built more cheaply than classical coke oven plants with their improvements, to report on which is the object of this meeting.

70% of the coal charge of non- or weakly-caking coals involves the use of coals possibly cheaper and frequently of local origin, lower in ash and sulphur contents or carrying lower transport charges, needing smaller coal stocks, economising in the use of good coking coals or the reduced demand for such coals. Besides, the continuous process of operation avoids the need for plant to deal with atmospheric pollution.

What possibilities lie now on the side of the blast furnace charge from the use of briquettes? As a first approximation it can be stated that for the same charge of hot briquettes as against oven coke, the amount of volatile constituents which appear in larger quantity and unburned in the blast furnace gas is greater. It has been established that these volatile constituents take part in the pre-reduction of ores in the upper part of the blast furnace; the calorific value of the blast furnace gas is increased; the carbon in the blast furnace dust is advantageous to the sintering of that dust. The chance increase in consumption of hot briquettes is advantageous to the blast furnace gas and the sintering plant. On the other hand it is possible in the production of hot briquettes that many coals low in ash and sulphur may be used to reduce the sulphur content of the coke fines (breeze).

It is also possible to use a coke low in ash and sulphur in the blast furnace, which leads directly to the use of less limestone flux and reduces slag production. The performance of a blast furnace depends primarily on the air blast, which in turn determines the number of compressors required. From research work to date, the use of briquettes requires fewer compressors, because briquettes are not so angular and serrated, and the structure of which is not so easily changed. Furthermore, from research work to date it was found that the maximum air blast required for briquettes was the same as that for oven coke. It is to be expected that when the correct size, form and porosity of hot briquettes are established, that the performance of a blast furnace will be about 10% better than that with a prepared and very good oven coke, and about 20% better than with an average classical oven coke.

These are the big attractions of the technical and economic aspects of the use of formed cokes in general and hot briquettes in particular in the blast furnace. The stimulus to build hot briquette production plants is very great indeed. The building of the first technical plants for the production of formed cokes must be pursued by the great industrial countries as they contain areas which suffer a scarcity of good coking coals. Accordingly we are handling the construction of demonstration plants for the production of 700 (metric) tons of hot briquettes or alternatively 600 (metric) tons of coked hot briquettes per day in Germany, Japan, England and the U.S.A. With the first plants, hot briquettes may be made in larger quantities, produced during long experimental runs and with variations of ore burden. In this way, coals of different origin can be tested and the production of hot briquettes optimised with reference to their size and shape.

When the first demonstration units have been proved successful and when long series of tests of hot briquettes in the blast furnace have been done and when the blast furnace manager had been convinced, further plants of the same or greater output can be built in a wider field, including the smaller industrial and also the developing countries.

M. de Miscault

M. Soubrier, you indicated that you had worked with several standard blends.

You have therefore probably obtained formed cokes with characteristics that differed according to the blends. Now you have above all laid stress on the blend based on low-volatile coals, which departs the furthest from conventional coke and which moreover did not give the best results during its use at AIRBO.

Could you give us the characteristics of formed cokes obtained with other types of blend and tell us why you emphasise blends based on low-volatile coals?

M. Soubrier

As I mentioned in my paper, one of our main aims is to obtain moulded coke with good mechanical characteristics. We have been guided in this by the requirement of the blast furnace. We have obtained this result with the three mixture types that I have examined. The mixture with the highest percentage of lean coal, however, has given the best results, with an M10 of the order of 6 - 6.5 .

With mixtures based on semi-coke, the M10 was less favourable, being of the order of 8 - 8.5.

We therefore decided to keep to mixture no. 1. Moreover, some iron smelters said they were not averse to using less reactive coke; they even preferred it.

This type of coke was chosen by AIRBO, so we now have had more experience with it.

The characteristics of coke obtained with other mixtures are effectively very different.

In this connection, we have the results of some analyses made by CERCHAR in June 1969 and ones made recently, also by CERCHAR, which wished on the occasion of the AIRBO trials to carry out a certain amount of work, the results of which we had telephoned to us at the beginning of the week.

There follows a report on the main values for these moulded cokes and for those we have obtained with mixture types 1 and 3 for two variants, semi-carbonization of a coal of class 811 and semi-carbonization of a lignite.

	Conven- tional coke	Mix- ture no.1	Lignite mixture	No.3 class 811	B.B.F.	D.F.C.	H.B.N. F.U.V.O Carmonoix	
Apparent sp. gravity	0.911	1.07	0.963	0.930	0.740	1.19	1.353	1.253
Porosity %	51.8	45.9	50.3	52.8	61.8	34.5	28	39
Bulk density (per m <sup>3</sup> )	0.550 *	0.760	0.562	0.546				

\*Coke 40/60

You will see therefore that coke with various characteristics can be obtained.

I should like now to return to my first remarks. Concern about the mechanical qualities was a determining factor for us in choosing the lean coal, but there were other reasons.

The first was that preliminary cost price calculations showed that the cost price was clearly more favourable.

Secondly, HBNDNC had just this type of coal.

Finally, in view of all the foregoing, there are clearly two problems:

- 1) To what extent can we directly apply the results obtained with the Ougrée furnace in assessing the coke?
- 2) Insofar as a dense coke would be effectively less appropriate for use in the blast furnace, but bearing in mind the fact that a dense coke has effectively given a smelted product conforming to an already high production rate, where does the economic choice lie among :
  - the mechanical properties of the coke;
  - the productivity of the furnace;
  - the regularity advantage of moulded coke, since it is dry and graded.

Producers have various possibilities. As always, but even more in times when cost prices are continually increasing, it is the users' privilege to choose.

M. Cypres

I would like to draw the attention of the assembly to the fact that in the processes of formed-coke manufacture which have just been explained to us, the volatile matter produced is different in composition and quantity from that produced in coke ovens. One in fact passes through carbonisation up to about 550 C, which produces a primary tar. Its quantity may reach 8%, depending on the coals treated. It is characterised in chemical composition by a high content of heavy phenols.

The research carried out in my laboratory, at the University of Brussels within the framework of a programme set up in collaboration with our national research institute, INIEX, and subsidised by the Commission of the European Communities, whom I would like to thank most warmly here, has shown that by controlled cracking one can upgrade the heavy phenols by transforming them mainly into cresols.

In a communication presented in September 1969 to the International Congress of Industrial Chemistry we proposed, on the basis of the results of our research, a scheme of upgrading of low-temperature tars, based on fractional condensation of the volatile matter and controlled cracking at about 750 C of the fractions not condensed.

It will be necessary, when an economic assessment of the new processes studied on a semi-industrial scale is to be carried out by comparing them with the conventional coking process, to take into account this possibility which is specific to them.

The upgrading of the low-temperature tar, the inevitable product of manufacture, may contribute a positive and not negligible element to the economic balance sheet of the processes of formed-coke manufacture that does not exist in conventional coking.



J. L. Bryson

Imperial Smelting Corporation are deeply interested in formed coke for use in their zinc blast furnace - the Imperial Smelting Furnace. Already 11 furnaces are in operation around the world, and three more are in course of construction. Some of these, and others under consideration, are in areas where coke and coking coal is not readily available. Thus for some time we have been examining formed coke processes as a means of providing for our furnace a reducing agent made from materials other than prime coking coal.

The process calls for metallurgical coke of high quality. It should have high strength and resistance to abrasion, as required by iron blast furnaces, and a narrow size range, ideally about 60-80 mm. In addition, low reactivity with respect to carbon dioxide is essential.

To us, formed coke appears to have the ideal characteristics for use in blast furnaces.

The Imperial Smelting process differs from other blast furnace processes in that it is necessary to charge coke to the furnace at a temperature of 800°C. If a formed coke plant could be integrated with the zinc blast furnace, there would seem to be scope for transferring hot briquettes direct to the furnace without a preheating stage, as is necessary with coke obtained from an independent coke oven plant.

M. Ledent

The fact that coke must be charged to the furnaces at a temperature of the order of 800°C certainly gives additional interest to the use of formed coke in zinc smelting furnaces.

It is expedient however to emphasise that the formed cokes produced so far have a rather high reactivity to CO<sub>2</sub> in the temperature region below 1000°C and that this could be inconvenient.



Programme for the Improvement of Carbonisation  
in Normal Coke Ovens

Dr.rer.nat. K.G. Beck, Steinkohlenbergverein, Essen

For decades the development of coke production in horizontal chamber ovens has been achieved mainly by remarkable engineering skills, intuition and empirical knowledge. Milestones in this development were the combination coke oven with its special importance for the integrated iron and steel works due to the choice of heating with coke oven gas or with blast furnace gas, the transition from fireclay to silica as refractory material with consequent increase in operating temperature and throughput of coal, and the development of extra large ovens and hence economies of coke production. The last-named stage in the development took place more than 40 years ago and a quarter of a century had to pass before a second plant followed the first coke plant having 6 m. high coke ovens. Not until today has the large capacity oven become a standard modern coking technique due to the worldwide need to replace and extend coke oven capacity.

Fig. 1 shows the average coal throughput per oven in metric tons per 24 hours for a coke plant operated in the Ruhr District around 1930 compared with the throughput of the first 6 m. high oven, and next to this comparable information for 1970, showing actual present-day large capacity oven and the biggest coke oven ever projected, with a height of 8 m. The average coal throughput of working plants has been doubled, namely from 9 metric tons per oven per day to 18 metric tons per oven per day; however even in 1970 it has not reached the throughput of 30 metric tons per day reached by a 6 m. oven in 1930. This in turn seems quite modest compared to the present-day throughput of 45 metric tons per day in a 6 m. coke oven or 72.5 metric tons a day for an 8 m. coke oven. This diagram is based on information disclosed at the First Carbonisation Science Lecture given in London in November of last year by Professor Reerink<sup>1)</sup>.

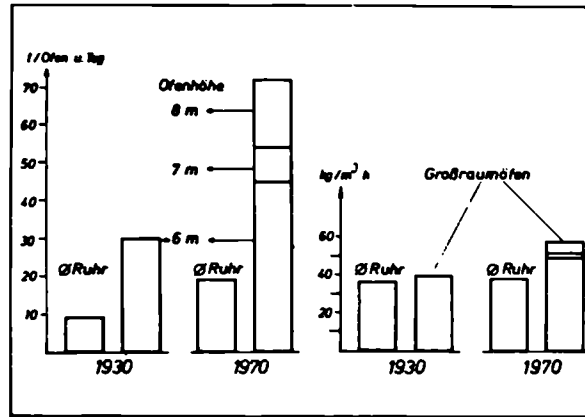


Figure 1 Development of coke-oven coal throughput (d.b.)

Ordinates : t/oven day;  $\text{kg/m}^3\text{h}$

Legend : Oven height

Large-capacity ovens

The picture, however, changes somewhat when one looks at it from another angle and sees the specific coal throughput per cubic metre per hour. This information is shown in the right-hand part of the figure and indicates a more modest development. The conclusion of this introductory retrospective observation are: the development of the horizontal chamber oven over the last four decades shows the concentration of coke production in a lesser number of coking plants having a much higher capacity, in parallel with increasing the coal throughput per coke oven or operating unit, but does not show any appreciable advance in the specific throughput. If the maximum possible daily coal throughput of an 8 m. high coke oven in 1970 is eight times as much as the average daily throughput of all coke ovens operated in the Ruhr District in 1930, then the specific throughput for each cubic metre per hour of the 8 m. oven has risen only by 60% compared with the average oven of 1930. Thus the increase of daily throughput, obtained mainly by making the oven bigger, is five times greater than the increase in the specific throughput.

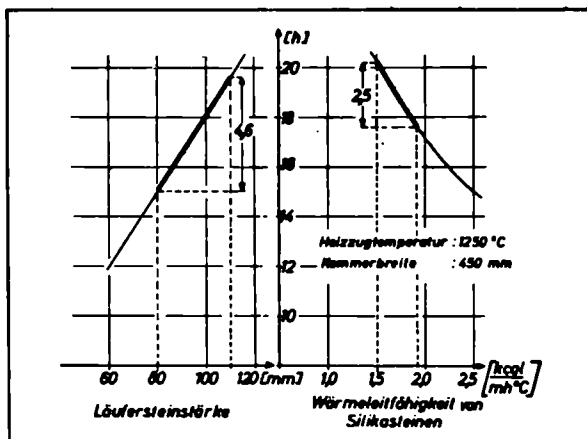
The object of my report is therefore the discussion of possible future developments of the horizontal chamber oven and trying them out under industrial conditions, which will be our task in the coming years within the framework of a technical development programme for coke ovens. I would like to mention here that the main impulse and preparatory work for this development work was provided as the result of research financially sponsored over the last decade by the Board of Management of Montan-Union and the Commission of European Communities. In this connection I would like to mention in particular yesterday's lecture by Mr. Simonis, when he made known to us his own results

of a basic research programme into the physics and chemistry of coal and coke, which can be regarded as a classical example of how results of research can be drawn from a purely scientific problem, which can procure the conditions and start the impulse for a subsequent large-scale development.

The use of preheated coal represents the first important contribution to increasing the specific throughput of the horizontal chamber oven, the main aim of future development work, this having been tried out for the first time during a systematic experimental programme carried out at the Marienau experimental station. A report on this subject was given yesterday by r. Foch. The increase of throughput is not really the most important and primary aim of this work, the latter no doubt being the possibility of a considerable extension in the range of coking coals. From an economic standpoint it should also be taken into account that the maximum increase in throughput of coke ovens necessitates the operation of an adjoining plant for preheating the coal, which involves additional investment and operating costs. Moreover the plant costs for a preheating plant are according to our calculations some 30 to 50% less than the investments for comparable extension of the coke oven. Finally it should be borne in mind that preheating of the coal reduces the amount of silica bricks needed as the result of the rise in throughput achieved in the coke oven, which is of some importance in view of the present difficult situation in the refractory material sector. It is thus understandable that the preheating of coking coal is now receiving increasing attention not only in the countries and districts where the extension of the range of coking coal is a pressing problem. The first technical plants in France and Great Britain are very shortly to be completed and put into operation. At about the same time we hope to be able to start with the operation of a large experimental plant at the experimental coking plant in Essen, when we wish to look into the possibility of transporting preheated coal and charging it smokelessly into the coke ovens using a "Redler" coal feeder as proposed by D. #agener<sup>2)</sup>.

Further possibilities of increasing the throughput of horizontal chamber ovens are offered by resorting to higher operating temperatures and improving the flow of heat through the oven walls, i.e. by using thinner panel bricks with a higher thermal conductivity.

The use of higher operating temperatures was the subject of the research programme about which Mr. Weskamp and Mr. Guhr spoke yesterday. Attempts have been made by various American firms to increase thermal conductivity through the oven walls by adding metal oxides to the silica material in order to increase the heat transfer. If these attempts have not met with much success, the development of improved silica bricks having a lower porosity, i.e. greater density, has been accelerated, so that the thermal conductivity of the material is likewise improved. Since we now know that the possibilities of increasing the throughput of horizontal chamber ovens are limited, the compacted silica bricks will facilitate the task of constructing thinner oven walls, from which we can expect an important contribution to increasing the throughput of the coke oven.



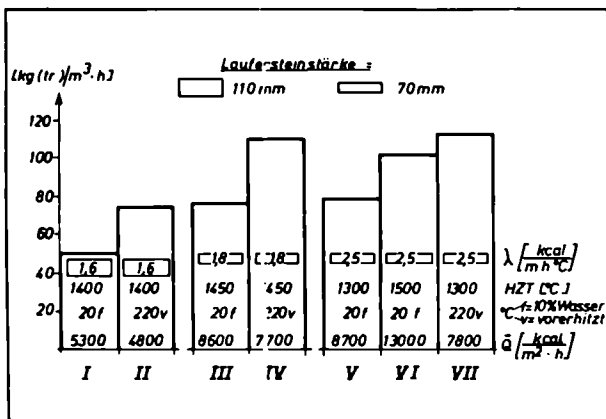
Heating-up time  
 Abscissae; Stretcher-brick thickness; Thermal conductivity of silica brick  
 Legend ; Flue temperature  
 Oven width

Figure 2

Figure 2 shows results of calculations made by W. Rohde<sup>3)</sup>; plotted is the heating time required for reaching 1100°C. in the coke charge in relation firstly to the oven wall thickness and secondly to the thermal conductivity of the refractory material. The reduction of heating time that can be obtained by using thinner walls can amount to 4.6. hours in the example chosen of a coke oven having a chamber width of 450 mm. and a flue temperature of 1250 C., if the wall thickness is reduced from the present 110 mm. to 80 mm. On the other hand by improving the thermal conductivity of the silica bricks a reduction in the coking time is restricted to a maximum of 2.5 hours; a further lowering of the heating time and hence the operating time, or a corresponding increase in the oven throughput can only be expected when some other brick material having a greater thermal conductivity is used in the coke oven.

The study of heat transfer in the horizontal chamber oven which is the basis of this calculation allows us to make certain preliminary calculations regarding the possible coal throughput as a consequence of constructive changes in the coke oven and therefore affords us the possibility of a comparative assessment, i.e. of initiating and concentrating efforts further to develop the horizontal chamber oven where the greatest useful effect can be achieved.

Figure 3 shows a more advanced calculation by J. Kasperczyk <sup>4)</sup> of the theoretical possibilities in coking development for the horizontal chamber oven:



Ordinate : kg (d.b.)/m<sup>3</sup>h  
 Legend : Stretcher-brick thickness  
 Flue temperature  
 10% moisture  
 preheated

Figure 3

Possibilities for increasing coke-oven throughput

Column I gives the specific throughput of a silica oven having a panel brick thickness of 110 mm., which corresponds to the throughput of our coke ovens in the experimental plant, which, at a heating temperature of 1400°C., is already 30% greater than the average value shown in the first figure for coke ovens being used at the present time in the Ruhr District.

If these ovens are charged with preheated coal then their output should be increased according to Column II. The next two columns III and IV relate to silica coke ovens having a panel brick thickness of only 70 mm with a charge of moist and likewise preheated coal. If these operating conditions can be realised the specific throughput compared of Column I should increase by 50 or 120%.

In Columns V to VII a refractory material having a thermal conductivity of 2.5 Kcal/m h deg. is supposed; in Column V an oven wall temperature of

1300°C.; in Column VI the same at 1500°C. and in Column VII again the use of preheated coal at an oven wall temperature of 1300°C. The increase in the specific oven throughput thus made possible is calculated at 125% with reference to Column I.

Shown in each column is the requisite average heat flow through the wall of the oven, which at the present time must be increased from 5300 Kcal/m<sup>2</sup>h in Column I to 7700 and even 8700 Kcal/m<sup>2</sup>h for Columns III to V, and in the extreme case VI even to 13000 Kcal/m<sup>2</sup>h. This important increase in heat flow must be taken into consideration when designing the coke oven, particularly in respect of the flue cross-section and the layout of the regenerators. I will deal with this point later on. Since capital expenditure must necessarily rise for the coke ovens a special reference will be made here to the combination of the discussed changes to the horizontal chamber oven using preheated coal. As a considerable proportion of the entire heat requirement is used up beforehand in the adjoining plant for preheating the coking coal the average heat flow is somewhat reduced - as can be seen in Fig. 2 - if we compare Column II with Column I, or Column IV with Column III and Column VII with Column V, while on the other hand the specific throughput of coking coal is higher. Therefore the use of preheated coal should be investigated in combination with the new experimental ovens inside the framework of the technical development programme.

The realisation of these possibilities implies on the one hand a close cooperation between experienced coke oven designers and on the other hand industrial tests in large-scale experimental plant. In this connection the Steinkohlenbergbauverein has encouraged cooperation with the coke oven construction companies and concluded an agreement two years ago with the firms Didier, Koppers, Dr. C. Otto and Still. The first results of this Coke Study Group are reflected in the projects for extending the experimental coking plant and supplementary experimental equipment. I have already mentioned the experimental plant for preheating and transporting the coal. The next project will be a group of experimental ovens having 70 mm. thick walls made of high-quality dense silica refractory material. The testing of brick material having improved heat conductivity is now being carried out in preliminary experiments on a semitechnical scale, which have already furnished good results, both in respect of the effects of extremely rapid coking speeds on the



technical behaviour of coking coal and also on the behaviour of refractory material. The investigations have also shown that cokes produced under such conditions comply in every respect with the requirements of the market as to strength properties and meet with the recently changed ideas of blast furnace manufacturers as regards their particle size<sup>5)</sup>. The coke is becoming smaller in size but more uniform in its grading, so that from this point of view there will be no objection to the desired technical development of coke production in horizontal chamber ovens<sup>6)</sup>.

This work previously carried out by H. Echterhoff in the laboratory has also brought to light an important fact that represents a heavy obstacle to our efforts in this direction if solutions for overcoming these difficulties are not found. With the desired high throughput of coking coal and the increased heat flow required for this in the oven walls the latter can reach temperatures during the last hours of coking at which the ash in the coal is melted. Considerable damage can thus be occasioned to the oven walls. In addition, with the usual kind of heating the coke ovens of today with constant heat flow throughout the entire coking time the coke charge can be excessively overheated, which can cause much deterioration in the coke quality and serious cracking of the crude gas components so that the graphite deposits on the oven walls, in the gas collecting space and in the gas exhaust pipes can no longer be controlled.

In Fig. 4 are shown the temperature curves in the charge in the centre of the chamber and against the oven walls during the coking operation:

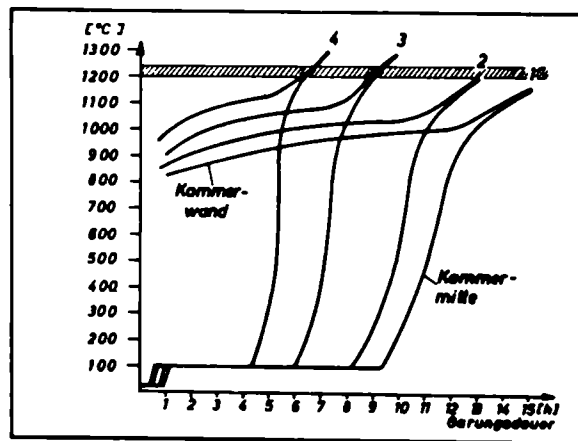


Figure 4 Temperature curves at the centre of the charge and at the oven wall

Abscissa : Carbonising time

Legend : Oven wall

Oven centre

1) in respect of the usual type of coke oven operation used today;  
 2) in respect of new plant with fast coking, as described by Mr. Guhr;  
 3) and 4) in respect of operating conditions which exist in the case of a coke oven having thin silica walls and a flue temperature of 1450°C. or even higher in the case of a coke oven having 70 mm. walls made of refractory material having a thermal conductivity of 2.5 kcal/ m h deg. For continuous operation of coke ovens the temperature range indicated by shaded lines above the 1200 C. mark should not be reached in the chamber charge nor on the oven walls. Thus while case 2 can evidently be admitted, considerable difficulties must be reckoned with in cases 3 and 4, which could possibly jeopardise their technical realisation.

We see a solution to this problem in the programme controlled heating of a coke oven already discussed two years ago and tested in the first preliminary experiments at the experimental coke plant, i.e. the adjustment of the heat flow to the varying heat requirement as the process progresses. This is made clear in Fig. 5.

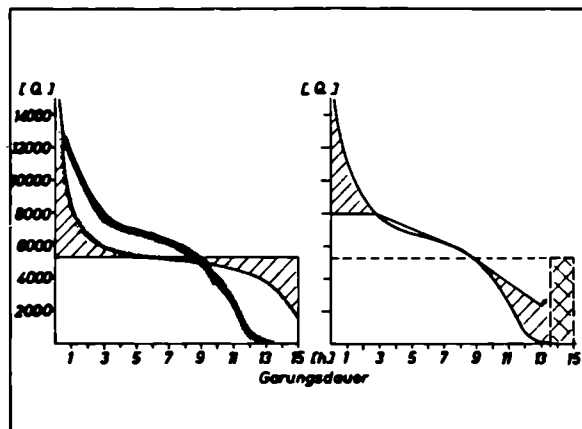
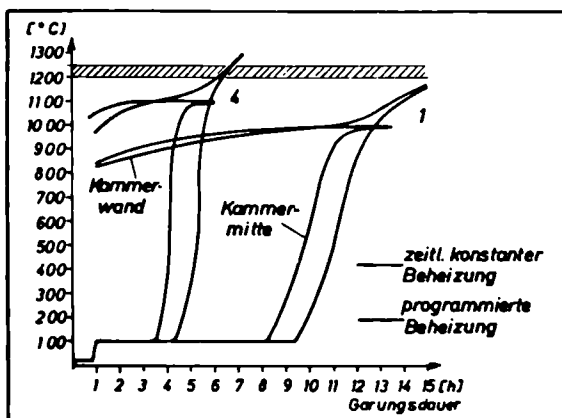


Figure 5 Heat supply and uptake with constant and programme-controlled coke-oven heating  
 Abscissa : Carbonising time

An even supply of heat is fed to the flues over the entire coking time, in the example chosen on the left-hand side of the diagram it is 5300 kcal/m<sup>2</sup>h. The green curve indicates the heat take-off from the coke oven walls; it changes considerably during the course of coking the chamber charge. The heat requirement for coking the charge is indicated by the red curve, however the constant supply of flue gas does not meet the heat requirement for about two thirds of the entire coking time. When there is a shortage of heat it is extracted from the oven wall, as indicated by the shaded part

in the left-hand part of the diagram. Conversely, the supply of heat during the last third of the coking time is much higher than the heat requirement - a part of the surplus heat is once more stored in the oven wall, a part however flowing unnecessarily into the charge and thus causing an increase in temperature of the coke. These conditions become even worse for the desired operation, whereby a greater throughput of coal is intended. The expected effects of a programme-controlled coke oven heating, i.e. the adjustment of the supply of heat to the relevant heat requirement, are to be seen in the right-hand part of the diagram. At the commencement of coking the supply of heat is increased, but after the first three hours the supply of heat can be gradually diminished. Even then a certain amount of heat in the oven walls is stored or extracted, as an appropriate designing of the coke oven to meet the enormous heat requirement of the first two coking hours would not be justifiable. By adjusting the supply of heat to the relevant heat requirement the following results are obtained:

1. The coking time is shortened from 15 to 13.5 hours, i.e. by 10%;
2. In all less heat is consumed. The saving in heat is indicated by the double shaded part at the extreme right of the diagram. This saving in heat is the result of preventing the flow of unnecessary heat quantities into the charge, which is also reflected in a corresponding lowering of the final coke temperature, as shown in Fig. 6.



Abscissa : Carbonising time  
Legend : Oven wall  
Oven centre  
constant heating  
programmed heating

Figure 6

Temperature curves with constant and programme-controlled coke-oven heating

Plotted here are the temperature curves for chamber wall and chamber centre for cases 1 and 4 of the previously mentioned Fig. 4, first of all in respect of heating usual today, then in respect of programmed heating. The charge is completely coked, even under programmed heating - the temperatures at the chamber wall and in the chamber centre coincide, corresponding to practically no transfer of heat taking place. In Column 1 the coking time is shortened, as already indicated in Fig. 5, from 15 to 13.5 h, and correspondingly in Column 4 from 7.2 to 6. Above all, however, the final coke temperatures in both columns and the chamber wall temperatures at the end of the coking time are far below the critical temperature range - and thus the means have been achieved for a trouble free continuous operation, while in addition the throughput could easily be further increased by raising the temperature level, i.e. the oven wall temperatures.

Programme-controlled heating implies moreover a change in the pushing sequence, as neighbouring coke ovens must be in more or less the same coking condition. That this stipulation can be industrially solved has already been proved two years ago at the experimental coke plant. Further conditions for successful use of programme-controlled heating reside not only in the time-controlled regulation of gas inflow but also the regulation of the air amounts that are required. Proposals regarding this have already been made and these will be tested in the planned new experimental equipment.

A necessary consequence of an increased throughput of the coke ovens is a corresponding increase in the amount of gas and air required and hence a much higher regenerator loading. From the present studies, in which it has been shown that in the case of B (Fig. 7) the throughput as compared with A is 65% greater and in the case of C as compared with A 150% greater for the same volume of the oven chamber, it has been shown that the effective regenerator space would have to be enlarged, in the case of B by approx. 50% or in the case of C by approx. 110% as compared with A. Thus the ratio of useful chamber height to height of the regenerator space is changed from a present 1.5 : 1 to 0.7 : 1. In other words if approx. 50% of the entire height of the coke oven is useful height - without taking into consideration the oven roof - this proportion is diminished in the case of C to about one thir

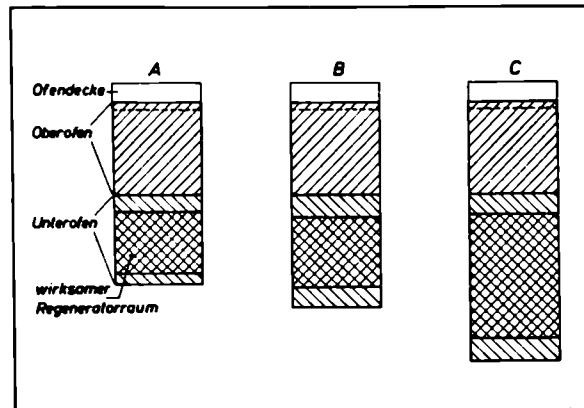


Figure 7

Oven chamber and substructure for increased coal throughput

Legend : Oven roof  
Superstructure  
Substructure  
effective regenerator space

The conclusion is: either the regenerator space is increased to the requisite size - and thereby a not inconsiderable amount in the desired reduction of investment costs for new coke oven groups is once more sacrificed - or one accepts a less efficient oven with an admittedly smaller regenerator, i.e. a greater requirement for underfiring. Moreover technical limits are very quickly reached for the increase of the waste gas temperature, and similarly with the reduced gas profits of the future the point of intersection will quickly be reached between reduced capital costs for the smaller regenerator on the one hand and the higher under-firing costs on the other.

Thus the only alternative is to achieve an increase in the throughput of the coke oven side by side with an increase in the specific heat exchange.

Therefore within the framework of the technical development programme for coke production promising projects for the technical improvement of the regenerator ought to find consideration and sponsoring. A proposal regarding this has now been made.

A technical development programme for coke ovens which has as its object important advances in the specific throughput of the horizontal chamber oven should not ignore two further fields which are important requisites for the continuous operation of new coke ovens. Mr. Guhr in his report has pointed out that automation of the coke oven operations

when fast coking conditions exist is an absolute necessity. It is also to be noted that with the desired higher specific throughput the pollution from the coke plant does not increase. New ways are also to be found here, in particular in respect of combatting dust when pushing the coke, and existing methods of dust emission prevention improved where possible. The space allocated for this report does not allow this important subject to be dealt with, but I felt I had to mention it, and I should add that proposals and studies have already been presented to the Coke Study Group.

The various projects of the above-mentioned development programme in respect of the horizontal chamber oven necessitate the testing and economic assessment of the construction and operation of large experimental plant on an industrial scale, only then can the risk when going over to commercial use be kept to manageable limits. It must be shown by the operation of this experimental plant whether the possibilities of a future development of the horizontal chamber oven which can be seen to have a scientific basis can be fully realised or whether unforeseeable difficulties may yet arise, and I am thinking especially of the technical behaviour of various kinds of coking coal, for example their swelling and shrinking properties, which can have an effect on the operation of the oven. The construction and operation of this experimental plant will give rise in the next few years to investments and research costs to the order of approximately 4 million calculation units, which at first seem quite considerable, but on the other hand hardly make up for 0.5% of the investments required in this decade, when one takes as a basis the statement of the Commission of European Communities that "by 1980 there will be a shortage of coke producing capacity of around 30 million metric tons a year due to a pronounced aging of plant at present in use and which will have to be replaced by new plant in order to secure the coke requirement for the production of pig iron." Since a successful outcome of all these possibilities in coke development is of decisive interest for all coke consumers and manufacturers in the Community - in mining as well as in the steelmaking industry, in Italy and in the Netherlands as also in the Ruhr District - the most decisive action of the Commission will no doubt be the granting of research help.

We now have at our disposal the scientific principles and from the Coke Study Group the technical means of solution in order to bring about a new phase in coke development. It may well be that the question of the most suitable coke quality for operating these new coke plants will be differently framed and solved than was the case in the past, so that in the last analysis when other process techniques are developed with the same degree of success, about which we have already heard in three earlier lectures, the coking coal in question will determine which process will be resorted to for the production of coke. When making this commercial decision, when all the pros and cons relating to the relevant process will have to be considered, the underlying principle should be that - irrespective as to which decision is made - in every case a modern process technology should be chosen which takes account of all the possibilities of modern technological development.

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DISCUSSION

K. Heller & P. Hoekstra

In connection with my remarks yesterday may I now ask the following:

If the results of the various tests, on the coking side as well as charging into the blast furnace, have up to now given no strong economic motive, the question arises as to which group has sufficient interest in the development of these processes to bring them through the phase of inadequate profitability. We have heard yesterday from Herr Schumm that the steel industry and its coke suppliers have need of a great deal of money in the near future to maintain their production capacity. It seems to me that little is to be expected from the producers of domestic fuel in a period of increasing use of natural gas.

Surely the rapid further development of these processes, which have great advantages as regards environmental hygiene and improvement of working conditions, would be very important before a very large expansion of production capacity on a conventional basis has taken place.

Hence my question to all three speakers: from what quarter do you expect continuing vigorous support for your work: from the coke producers, from the users or does it rest with the authorities and organisations such as the KSG ?

M. Ledent

In the particular case of the pilot installation built at the Colard mine, the necessary funds were supplied by an oven constructor (S.A. Belge STEIN & ROUBAIX), a coke user (S.A. Cockerill-Ougree-Providence) and a Belgian state contribution.



M. Peters

I agree with your view that the new methods are of primary importance as regards environmental hygiene and improved working conditions. As I explained in my paper, in the case of continuous coking, this comes from the prevention of any uncontrolled emission of dust and fumes and the scrubbing of any toxic ingredients out of the waste gases in accordance with prevailing regulations.

However, I cannot agree that the new methods do not correspond to any powerful economic motives. Because of the small proportion of conversion costs in the total costs, the final coke production costs cannot be reduced to any considerable extent by technological processing improvements, as I made clear in my paper. A much more effective possibility, depending on geographical location, may be to use coals below coking grade, at least up to the extent of 70% for coke production. The more important advantages, from the economic viewpoint, seem to me those that I have listed; the possibility of shutting a plant down, rapid re-starting, matching the gas quality to possible gas consumers, lower personnel requirements, and so on.

As regards domestic consumption, I should like to contradict what you have said. In the very long view users may be expected to change over to natural gas, but in the Federal Republic we have found that in recent years the sales of solid fuel for home burning have been very steady, and from this we infer that we shall be able to continue to sell solid fuel for domestic consumption in the foreseeable future; this market seems to us extremely attractive.

For these reasons and from the many expressions of interest reaching us from both Germany and other countries we are in no anxiety about support for our work. As regards development work on mining research, we think that the following development is likely.

In the Ruhr district a contract for the erection of a prototype plant with a daily output of 600 tons will shortly be awarded. Possibly the same plant will have to be constructed in Japan and the United States. If we have enough experience with this prototype plant 1972/73 it will be

possible to give contracts for the supply of plant with an output of 1 million tons per annum, for which constructional drawings, ready for work to begin, will be available.

For the erection of the 600 t/day prototype plant we need the financial backing of the authorities and possibly also the ECSC. The main load however, will be borne by the plant operators. There is a commercial benefit in the transposition of the process to the industrial scale whereby the operator will be able to cash in on the economic advantages it brings. These ideas are based on the present state of development, but in my view there is absolutely no doubt that further development of the process, which is as yet in its infancy, will produce farreaching economic improvements.

M. Soubrier

The development of work on formed coke poses problems of finance, of course.

Their acuteness depends largely on the level of expenditure to be provided for, itself associated with particular conditions such as the presence on the spot of part of the necessary plant and the coals of the desired quality.

On the other hand one cannot exclude the possibility of envisaging a certain profitability, even for installations of relatively small dimensions - producing of the order of 7 to 10 t/h - but lending themselves to further extensions.

These questions are at present being studied by the HBNPC and will probably be undertaken by the European Community in the very near future.

The remarks of Messrs K. Heller and P. Hoekstra seem to encourage taking the following line of action, which seems to us altogether cogent:

In the present period, while waiting for the questions which arise concerning formed coke to be clarified, it would be prudent, depending on the availability of sufficient quantities of coke, to enforce the slowing-down of the construction of conventional coke ovens and therefore the maintenance of the maximum possible number of existing coke ovens in working order.

M. Philippon

The tests carried out in the experimental blast furnace at Ougree with the ERIM-HBN briquettes have allowed us to examine the behaviour of the briquettes manufactured almost entirely from anthracitic coals.

The shape of the briquettes used has been one of the causes of the limitation of the furnace output.

The nature of the coal, giving a high density to the briquette, might have had an effect on the heat transfer in the furnace and on the height of the combustion zone.

Do you not think that it would be desirable for the specialist research organisations to incline towards the physical properties of this type of briquette, particularly its thermal conductivity, reactivity, etc.

All the dense cokes used have given results sometimes difficult to explain, everything happening as if a specific property had not been sufficiently brought to light.

It would be illogical in our opinion, being given the definite economic interest of the use of fuel of low volatile matter for the manufacture of formed coke, not to seek to draw all the information possible from the remarkable work carried out at Ougree.

We hope to have the opinion of Messrs Peters and Ledent on this question.

M. Ledent

The tendency for the combustion height to rise, observed in the experimental furnace at Ougree during the passage of the formed cokes of high density, seemed to us to be caused by the low specific surface of these briquettes, which reduces the surface of contact between the gas and the solid. In fact, three factors may limit the rate of reaction between a gas and a solid porous phase:

- external diffusion from the gas towards the gas-solid interface;
- internal diffusion from the gas to the interior of the pores of the solid;
- the chemical reaction between the gas and the solid at the entire surface of internal and external contact.

Any one of these three processes may control the overall reaction rate if its rate is sufficiently low compared with that of the other two.

Reactivity tests carried out at a temperature of 950°C on the various formed cokes tested at the Ougree blast furnace showed that in this temperature region, where the chemical reaction rate is the deciding factor, all the formed cokes had a reactivity distinctly greater than that of the conventional cokes.

In contrast, at the very high temperatures which prevail in the elaboration zone of the blast furnace, the chemical reaction rate becomes much greater and from then on it is the external diffusion which limits the overall reaction rate. This external diffusion depends on the extent of the gas-solid interface, which is itself a function of the size, shape and density of the briquettes.

A satisfactory reaction rate has been observed with the formed cokes of large size and very low density.

The rate remains acceptable with formed cokes of high density and small size; it becomes insufficient with formed coke of high density and large size.

W. Peters

The tests in the AIRBO experimental blast furnace at Ougree with different grades of coke, reduced to a common denominator, have the following result: all cokes were sufficiently strong; the tests with the screened coke-oven cokes have shown that the lump sizes chosen for the formed cokes were optimum. If nevertheless there are considerable differences in the output figures, only the different densities of the cokes can be responsible, as has been stated by M. Ledent.

Valuable hints on the optimum properties of coke for blast furnaces can be drawn from the tests. We take the view however that not too great a significance should be attached to these results; for it is still not established with certainty whether the same correlations between the density of the coke charged and the furnace output are obtained in commercial blast furnaces. Our opinion is therefore that tests in the AIRBO experimental blast furnace have supplied only so many results as were practicable, and that the facts of the case can be clarified only by commercial tests with larger quantities of formed coke.

M. Soubrier

The interest of the tests carried out at Ougree on the **formed** cokes with an anthracitic coal base is precisely in having **made evident** a rather special mode of behaviour of these products.

It would therefore be effectively most interesting to **draw the maximum** information from these tests and it is good that this is **what** the specialist organisations are going to be forced to do; but it **seems** to us above all that, being given the economic interest of the **use of low-volatile** or anthracitic coals, it would be important to **test the behaviour** on this type of coke in a blast furnace, if necessary **after having reduced** the density of the product by making the briquettes under **conditions** different from the usual ones.



THIRD WORKING SESSION

C. POSSIBILITIES OF CHOICE OF COAL UTILIZABLE FOR CARBONIZATION

Chairman: Mr J. LIGNY

Administrator Director-Manager of the S.A. Charbonnages de  
Monceaufontaine

President of the Association Charbonnière de  
Charleroi et de la Basse Sambre

9. Mr A. TOGNANA

"Problems Concerning Coking Coal Used in Italy"

Engineer, Electrotechnical Industry

Manager of VETROCOKE of Porto Marghera

10. Mr C. MELTZHEIM

"The Extension of the Range of Coking Coals"

Engineer, Graduate of the Ecole Supérieure de Chimie  
Industrielle, Licentiate ès Sciences

Chief of the Carbonization Department at the  
Experimental Station of Marienau

11. Mr G. JURANEK

"Optimization of Coking Coal Blends Based on the Mathematical  
Pattern of Carbonization in the Conventional Coke Ovens"

Doctor ès Natural Sciences (Geology and Mineralogy)

Chief of the Department "Office de qualité" with  
the General Management of Ruhrkohle A.G.





M. Ligny

The subject which will be discussed during this last working session is of much immediate importance. In fact, whereas for a good number of years one has had the impression of an abundance of coking coal, the market conditions have changed profoundly during the last year and there has been an abrupt change from plenty to a shortage. The problem of the supply of coking coal has become a major concern of coking plant workers and we all believe that the papers that they will hear will provide answers to some of their questions.

During this session, the scope for choosing coal for coke making will be examined from different points of view.

M. Tognana will tell us of the problems encountered by the buyer who must guarantee supply to a coking plant a long way away from the coal production centres. We believe that the parts of his paper dealing with the source and quality considerations will be of great value to many users who traditionally have enjoyed coal of a constant quality produced nearby and who, lately, have had to have recourse to extensive imports of foreign coals. M. Tognana will be speaking about Italian coke producers who have long known the necessity of importing their fines from various countries particularly the USA, Germany, Poland and Russia.

M. Meltzheim's paper will be devoted to the problem of extending the range of coking coals and, more particularly, to the problem of the use of the growing quantities of coals containing large proportions of volatiles, which are allegedly deficient in coking qualities. In 1966, when the International Congress devoted to coke in iron smelting was held at Charleroi, M. Meltzheim, in collaboration with one of his colleagues, had already, in a very good paper, answered the question of how to approach a coking problem with a new type of coal. Four years ago M. Meltzheim foresaw the adjustment that is currently demanded of the coke industry.

M. Juranek's paper will give us the point of view of a user in a large coal concern on the important problem of optimization (technically profitable) of coke pastes taking account not only of the restrictions of traditional coal use but also of the scope for the ration lization of coal

working due to the existence of a large company, the Ruhrkohle A.G. (52 mines and 29 coking plants). This optimization implies a recognition of the quantities of the seam and of the reserves that it contains; optimization leads to the rational establishment of exploitation projects, the most appropriate choice of methods of preparation, and, perhaps, to optimization of the conditions for transport of coal with a view to supplying coking plants with the mixtures best adapted to their needs and to the requirements of modern iron smelting.

PROBLEMS OF COKING COALS USED IN ITALY

A. Tognana

Italy is a country completely lacking in coal suitable for the production of coke either for the steel industry or for foundries.

This particular sector of Italian industry is therefore obliged to import all the necessary raw materials from various producers, of which the most important are U.S.A., Germany, Poland and Russia.

As in general for the production of coke, blends of two, three or more different coals are used in order to obtain a basic raw material with such characteristics that they can guarantee an end-product (coke) likely to satisfy specific characteristics, the first major problem arises immediately. This problem, of supplies and stocking, does not arise or only on a very small scale in coking plants operating near the pithead.

It is well known that, given the tonnage required, the geographical position of the producer in relation to the consumer, the relatively large distances to be covered, the transport of coal for Italian industry can only be by ship.

The following factors have an effect, often unforeseen, on the time necessary for this transport:

- (a) waiting in the port of embarkation due to congestion of ships, because coal has to be loaded in certain ports, unfortunately with a lot of traffic, and this congestion is becoming more and more serious (recently the case has been reported of ships whose loading date has been unexpectedly delayed by more than two months);
- (b) bad weather conditions which ships may encounter on their routes and which may increase the duration of the voyage beyond normal expectations (12 days for ships from Baltic and North Sea ports, 15 days for those from American ports travelling to Venice);
- (c) bad winter weather, with snow and ice, which may delay transport to ports of embarkation; this particularly affects the Baltic region since Polish coal for example must be transported by rail across the country.

The coal mining basins are in fact situated in Upper Silesia and consequently in the south of the country, while the ports are in the north and there are no navigable canals linking these two extremities of the country.

To the factors mentioned above, which can cause considerable delays in the arrival of coal, we should add:

- the necessity to have, on the arrival of the ship, sufficient space in the stockyard for the rapid discharge of the 25,000 or 30,000 tons transported,
- the necessity to separate the various types of coal so that one can be sure of putting the determined quality of coal in the blend,
- the absolute necessity to maintain separately, arrival by arrival, even the coals of the same type, to permit not only the control and the determination of the physical properties by analyses which require much more time than unloading, but also some rotation of stocks to avoid the deterioration of the quality which may go as far as spontaneous combustion.

It is then seen clearly that the Italian coking plants are obliged to maintain large capacity coal stockyards which are completely equipped and efficient.

For example a coking plant which carbonises 2,500 tons per day of a blend comprising only three types of coal, in order to have a minimum guarantee of security in the carbonisation system, needs a coal stockyard with a capacity of at least 130,000 tons, corresponding to over 50 days of self-sufficiency.

This factor has a considerable economic effect on the cost of coke, because, apart from the installation, maintenance and operating costs, capital is tied up. Consequently the cost in cash is appreciable, because of the necessity for stocking a much greater quantity of raw material would be necessary if supplies were easy to obtain, as in the case of coking plants located in coal mining areas.

The quantities of coal carbonised in Italy during the last five years for coking plants are as follows, in figures rounded to the nearest hundred tons: 6,017,300 metric tons in 1964; 7,377,800 tons in 1965; 7,999,500 tons in 1966; 7,987,700 tons in 1967; 8,188,400 tons in 1968; 8,455,000 tons in 1969.

With regard to the distributions of these tonnages, there has been a sharp drop in American deliveries, which have declined steadily from 94.4% in 1965 to 37% in 1969, while Polish supplies particularly are increasing, rising from 1% in 1965 to 17.5% in 1969, and Russian deliveries have risen over the period 1964 to 1969 from 2.7% to 13% of the total quantity carbonised.

The independent coking plants, i.e. those not belonging to the Italsider iron and steel group (whose production goes in a closed circuit to the iron and steel plants of Cornigliano, Bagnoli, Piombino, Trieste Servola and Tarante), today use about 36% of the imports reported above. Their choice of coals is governed by the market demand for metallurgical coke and foundry coke.

Limiting the examination of coals of various blends to only the independent coking plants, we will consider separately the raw materials used for the production of coke for foundries and those used to produce metallurgical coke.

#### Coke for foundries

For this type of coke strictly selected coals are generally used, for which the market offers either various prepared mixtures or "pure coals", the latter term signifying coals of homogeneous composition.

The main American embarkation points are now equipped to prepare on conveyor belts blends with a high degree of precision and good uniformity of composition; the coking plant technicians, however, prefer to have individual coals which are not blended so that they can process them individually and use them in the most opportune way to obtain a coke which satisfies the requirements of the market.

American coals are classified by their content of volatile matter-medium, low and high. The American medium volatile coals which arrive in Italy under the name "New River" come almost entirely from the Jewell and Sewell deposits. Generally this is a well-defined and uniform coal and it is rare that any appreciable heterogeneity is encountered; the difference

from corresponding European medium volatile coal is that it has a higher fluidity.

The characteristics of Jewell coal can be summarised as follows: average humidity 6.27% (with variations from the average of between 5.30 and 7.03); average content of volatile matter 22.5% (with maximum 23.4% and minimum 22.2%); average ash content 3.56% (with maximum 3.9%); average sulphur 0.6% (with maximum 0.7%); coke button 9; average grain size + 3mm = 28%, 3 to 0.5 mm = 41%.

The characteristics of coal from the Sewell deposit are slightly different and can be summarised as follows; humidity 5.56%; average content of volatile matter 25.20%, varying between a maximum of 26.04% and a minimum of 24.55%; average ash content 5.98% with a maximum of 6.76%; average sulphur 0.83% with a maximum of 0.85%; coke button 9; grain size + 3mm = 47%; + 0.5mm = 81%; - 0.5mm = 19%.

It should be remembered that these coals, especially if their content of volatile matter is less than 24%, may have a slight tendency to swell and must therefore be used with some care.

The values reported are the averages of all the shipments received in 1968 and 1969 in one of the independent Italian coking plants.

American low volatile coals imported into Italy come on the other hand almost entirely from the Pocahontas deposits and represent a much appreciated typical American coking coal whose physical and chemical qualities are difficult to find in other parts of the world.

Generally the extraction and preparation of this coal are carried out very carefully and it is possible to obtain, even over a long period, coals from a single source with excellent and uniform characteristics.

Obviously there are also small mines, less well equipped, which send their production to central preparation plants which supply the market with American low volatile coals which are not well defined and not so uniform and satisfactory.

The average analysis of these coals, again for arrivals in 1968 and 1969 in one of the Italian coking plants, gave the following results: Humidity 5.60%; content of volatile matter 17.89% with a maximum of 18.10% and a minimum of 17.66%; ash 4.93% with a maximum of 5.45%; sulphur 0.70% with a maximum of 0.73%, grain size + 3mm = 33%, + 0.5mm = 74%, -0.3mm = 26%.

The predominant characteristic of Pocahontas coals is their excellent coking properties, despite the low content of volatile matter; they exert a considerable pressure on the pillars and consequently are not carbonised as such but are blended with other coals with a high content of volatile matter.

The latter constitute the widest range and quantitatively the most important of the American coking coals for export. They come from many deposits, some large and well defined, but others marginal and with more uncertain characteristics.

American coals with a "high content of volatile matter" are not always uniform and constant because sometimes coals from different sources are loaded on the same ship; the heterogeneity, however, is almost always within acceptable limits for normal coal uses.

It is however possible to find pure coals, from a reliable source, with good chemical and coking properties uniform and constant.

Analysis carried out on an American high volatile coal known as Green Mountain have given the following results: average humidity 5.06%; content of volatile matter 33.36% with fluctuations between a maximum of 33.60% and a minimum of 33.05%; average ash content 4.83% with a maximum equal to 5.14%; average sulphur content 0.71% with a maximum of 0.77%; average grain size + 3mm = 54% (with a maximum up to 72%), + 0.5mm = 84% (with corresponding maximum up to 92%), - 0.3mm = 16%.

The average composition of the ash contained in American coals can be summarised as follows:

$\text{SiO}_2 = 49-52\%$ ,  $\text{Fe}_2\text{O}_3 = 11-15\%$ ,  $\text{Al}_2\text{O}_3 = 28-32\%$ ;  $\text{CaO} = 2-2.5\%$ ;

$\text{MgO} = 1.5-2\%$ ; melting point  $1450^\circ\text{C}$ .

In conclusion, American coals, suitably selected among the different types available on the market, processed and blended together or even with other types of coal, can be used in coking plants to obtain coke with chemical and physical properties suitable for the most rigid conditions in use, namely for foundries.

For example the blends normally used for this purpose are the binary type Moss 40 to 60% + Jewell 60 to 40% or Green Mountain 60% + Procahontas 40%.

To improve the compactness of foundry coke, some coking plants usually add to the coal mixture a certain quantity of coke breeze, petroleum coke or anthracite fines.

An excellent European coal, which can be used either blended or alone for the production of coke, is the German coal known as Ruhr washed fines.

For these coals we will give only brief details since they are a well known raw material among European coal users. In the past this coal has presented very uniform characteristics, but in the analysis in 1968 and 1969 of a quantity of about 200,000 tons, it was noticed that these characteristics tended to show some variation.

Referring to the weighted percentages on the quantities stated, it was found that: the humidity has remained almost constant (about 8%); the ash has increased from 6.16 to 6.5%; the volatile matter from 22.65 to 23.44%, while the sulphur has remained practically unchanged at 0.99%.

In recent times, particularly, the volatile matter has tended to increase up 25%.

The grain size of this coal is fairly stable and shows little variation from the following averages: + 10mm = 0.5%; 5 to 10mm = 8.9%; 3 to 5mm = 8.5%; 1 to 3mm = 30.4%; 0.5 to 1mm = 17.5%; 0.2 to 0.5 mm = 20.5%; -0.2mm = 15.7%.

This coal is used in a blend to produce foundry coke and some coking plants use it sometimes 100% for this purpose.



In this case, a product is obtained with an M<sub>40</sub> of about 90-91 and an M<sub>10</sub> of about 6-6.2; an ash content of 7.6%; a sulphur content of about 0.88%, analyses made on + 80.

The product discharged from the ovens contains a percentage of foundry coke + 80 which is around 53% and a percentage of foundry coke + 120 which is around 38%.

For the production of metallurgical coke, this coal can be blended very well with Polish coal and a product is obtained which fully satisfies the requirements of our market.

### Metallurgical coke

The blends used for the production of metallurgical coke (for blast furnaces, reheating, chemical uses) are those made with coals from Russian and Polish sources; these blends are fairly new for our coking plants.

Russian coal, from the Donetz mining basin, is of two qualities; the first, Donetz K, has a lower content of volatile matter while the second, Donetz M 2 has a medium content of volatile matter.

Donetz K has an average humidity of 7.6% rising to 9.3% during the winter, probably because of the presence of ice and snow on stocks in the country of origin. The ash content is an average 6.95% with variations which are not excessive in relation to the average (from 6.12% to 7.32%).

This ash has the following composition:

$\text{Fe}_2\text{O}_3 = 16.14\%$ ;  $\text{TiO}_2 = 1.14\%$ ;  $\text{Al}_2\text{O}_3 = 25.48\%$ ;

$\text{CaO} = 3.60\%$ ;  $\text{MgO} = 1.80\%$ ;  $\text{SiO}_2 = 44.30\%$   $\text{SO}_3 = 1.93\%$ ;

$\text{P}_2\text{O}_5 = 0.70\%$ .

Comparing these analyses with those of other coals with a comparable content of volatile matter (for example Ruhr coal), we find that they stand out from the latter only for the contents of  $\text{Fe}_2\text{O}_3$  and  $\text{Al}_2\text{O}_3$ , while for the other constituents the contents fluctuate within very narrow limits.

The ash of Russian coals is richer  $\text{Fe}_2\text{O}_3$  and less rich in  $\text{Al}_2\text{O}_3$  .

Analyses of ashes of certain coals

Constituents	Moss 3	Polish 1st May 1st May	Coals		
			Ruhr	Russian Donetz K	Clintwood
$\text{Fe}_2\text{O}_3$	7.10	6.00	9.63	16.14	10.20
TiO <sub>2</sub>	1.10	1.00	0.97	1.14	1.20
$\text{Al}_2\text{O}_3$	31.20	36.60	31.82	25.48	30.24
CaO	6.40	2.50	3.36	3.60	2.20
MgO	1.80	1.20	1.66	1.80	1.50
SiO <sub>2</sub>	40.40	46.30	44.30	43.77	49.00
SO <sub>3</sub>	4.90	1.50	2.72	1.93	1.95
P <sub>2</sub> O <sub>5</sub>	0.86	1.26	0.89	0.70	0.58
P in carbon	0.035	0.052	0.036	0.037	0.029
Alkali	0.84	0.64	0.95	0.74	0.83
Melting point	1500	1580	1440	1490	1490

The analyses carried out on 193,000 tons which arrived in 1969 at the Porto Marghera coking plant indicated a weighted average content of volatile matter of 22.58% with values which tended to decrease in the course of the year and were constant for groups of ships, giving the impression that the coal came from different mines and was loaded without any blending of coal from different sources. At any rate, if this impression is correct, it should be pointed out that this characteristic is sufficiently constant in the products of different mines and does not call for any significant comment.

A weak point of this coal is the sulphur content which can even reach 1.73% while the weighted average is 1.55%, the former value having been found in a whole cargo of 17,000 tons.

These values limit the use of this coal because it is necessary to make blends which give a final sulphur constant in the coke not exceeding 1%.

Furthermore, Russian coal is supplied with an extremely variable grain size index (ratio between + 1mm and - 1mm) and which varied during last year from 0.88 to 1.51.

We give below the two analyses relative to these limits:

+ 20	20-10	10-5	5-3	3-1	1-0.5	0.5-0.2	-0.2	Index
0.0	5.4	6.6	6.0	28.8	18.0	21.0	14.2	0.88
13.6	7.6	7.4	6.2	25.4	16.8	15.6	7.4	1.51

These variations in grain size cause difficulties, firstly during unloading, because part of the coal, with the finest grain size, adheres to the walls of the holds and requires difficult and dangerous action by the personnel who must get the part stuck to the walls to fall to the bottom of the hold. Moreover this work increases the unloading time considerably (it has been found that the rate of unloading may be 25% less than the normal rate for Polish coals). Secondly the crushing operation must be modified to give this coal a grain size which is as close as possible to that of the coal with which it is blended.

From this point of view, it would be desirable for the grain sizes of different coals to be standardised at the source, so that coking plants receive raw materials which have similar grain sizes to one another.

This would lead to uniform treatment for all the coals used and it would be easier to obtain a more constant and homogeneous blend, simplifying the work of preparing the blend itself.

Improvement of the grain size composition of the blend would also produce indirect advantages for the coking plant by stabilising better the density of the charge in the coke ovens and permitting a more uniform distribution of the humidity in the mass of the blend.

Polish coal comes from Upper Silesia from the Ribnyk and Katowice area where many mines have been opened. The most important is the mine called "1st May" which has given its name to the type of coal.

This is a long flame coal with a high content of volatile matter, the weighted average of which in 820,000 tons in the above-mentioned coking plant, during the period from 1.1.1968 to 31.12.1969 was 29.1%, with a variation from this average of 1%, but with a satisfactory uniformity on average.

It should be taken into account that the averages reported above are in their turn the averages of systematic analyses carried out on the whole cargo of coal carriers whose capacity varies between 13,000 and 20,000 tons.

The "1st May" coal has a weighted average humidity of 6.10% with considerable fluctuations from 8.80% during the winter season to 4.40% in the summer season, probably for the same reasons as we indicated for Russian coal.

On this subject it would be desirable to have some standardisation of this humidity at the source because coking plants pay fairly high freight charges to transport water: for example in 1969 the Porto Marghera coking plant, for the transport of 800,000 tons of coal received, had a proportion of water of at least 52,800 tons, which is equivalent to the complete cargos of three ships.

The average ash content, again weighted, is 6.53% (still in relation to the quantity received in 1968-1969, and on this subject it should be mentioned that the same figure applies exactly if the arrivals in 1968 or 1969 are taken separately) with insignificant variations from this value, except for a single cargo which unexpectedly gave 8.62% but which was not repeated.

The analysis of the ash is in line with that of coals of the same category; the various constituents are:

$\text{Fe}_2\text{O}_3 = 6.00\%$ ;  $\text{TiO}_2 = 1.00\%$ ;  $\text{Al}_2\text{O}_3 = 36.60\%$ ;  $\text{CaO} = 2.50\%$ ;

$\text{MgO} = 1.20\%$ ;  $\text{SiO}_2 = 46.30\%$ ;  $\text{SO}_3 = 1.50\%$ ;  $\text{P}_2\text{O}_5 = 1.26\%$ ;

P in carbon = 0.52%; melting point 1580°C.

Sulphur present in this coal averages 0.91%, and this is very stable since only rarely does some mine slightly exceed 1%. The coke button is between 7.0 and 8.0.

The grain size is fairly constant, the maximum variations found being as follows:

+ 20	20-10	10-5	5-3	3-1	1-0.5	0.5-0.2	-0.2	+1/-1
0.00	5.5	10.0	9.5	34.2	18.2	14.8	7.8	1.45
4.20	8.8	15.1	10.4	32.0	14.3	11.5	3.7	2.38

It should be noted that in these two cases the humidity was almost the same, 5.00% in the first ship and 5.20% in the second ship, which both arrived during the summer season on 7th August and 22nd September 1969 respectively.

As can be seen, this coal is very stable in its characteristics and is very suitable for blending with Russian coal because it limits the high sulphur content of the latter and the variations in its ash content.

As we have already said before, the Porto Marghera coking plant has been using, since the middle of 1967, for the production of metallurgical coke, mixtures of Russian coal and Polish coal in the ratio of 25-30% of the former to 75-70% of the latter, in order to obtain a raw material for its coke ovens with the following characteristics:

Volatile matter + 27%; ash + 67%; sulphur 1.1%; humidity obtained 9%; grain size + 10mm = 0.6%; 10+5 mm = 8.8%; 5 + 3mm = 8.3%; 3 + 2mm = 9.5%; 2 + 1mm = 24.1%; -1mm = 48.7%; grain size index + 1/-1 = 1.175.

The coking plant in question produces coke in ovens with average dimensions of 13,590 x 4,000 x 450, at a temperature of + 1330° and with a coking time of 17 hours 40 minutes. In these operating conditions, it has not been possible to raise the ratio of Russian coal to Polish coal above 30/70% because if the Russian is increased stresses begin to appear during discharging and at 35% it is no longer possible to discharge the ovens. With the blend described, a good metallurgical coke is obtained which, on the cooling bank, has the following grain size:

0+5 = 4.9%; 5+10 = 1.5%; 10+10 = 4.2%  
20+40 = 13.8%; 40+60 = 41.2%; +60 = 34.4%;

these values have been determined without taking into account the breeze which is recovered by settling of the water used for quenching.

This grain size changes during the transport of the coke to the place of utilisation because of the breakup of its stabilisation and because of various falls to which it is subjected (bunkers, hoppers, bins). Following this, at the moment of loading either on to lorries or on to railway wagons, its distribution between the different sizes, distribution of stabilisation, becomes as follows:

0+5mm = 6.6%; 5+10mm = 2.0%; 10+20mm = 6.5%;

20+40mm = 21.4%; 40+60mm = 57.5%; +60mm = 6.0%;

again excluding breeze from the settling basins.

The 40+90 fraction formed by the 40+60 and the 60+90 fractions, has the following average characteristics:

ash 8.50% with maximum 8.65% and minimum 8.11%; volatile matter 0.725% with maximum equal to 0.92% and minimum equal to 0.50%; sulphur 0.89% with maximum equal to 0.95% and minimum equal to 0.81%. Micum M40 has an average value of 87.5 with variations from 88.6 to 86.1, while the abrasion index M10 has an average value of 4.50 with variations from 3.9 to 5.0.

It should be pointed out that the values given above were determined in the following way:

- volatile matter: reheating in a muffle furnace to a temperature of 925°C for 7 minutes in a quartz crucible after moistening with two drops of benzole (unichim 1-2 - Manuel 15);
- sulphur: combustion in a flow of oxygen at 1100°C in the Seuthe apparatus with reception of the fumes from combustion in neutral 1% oxygenated water and titration with NaOH N/20.

When the blend of 30% Russian and 70% Polish coal is distilled, we notice a very variable yield of tar, although the coking temperature, the coking time and the humidity of the blend are kept constant. At the same time as this variation in yield, we also find a wide fluctuation in the carbon which is not soluble in anthracene oil, Cl, and this variation causes many difficulties in the treatment of tar for the production of pitch for the manufacture of electrodes used in the aluminium industry, because it modifies considerably the ratio between certain elements which must be maintained within certain limits.

Despite the tests and the studies carried out, and certainly because the laboratory equipment possessed by the coking plant is necessarily limited, we have not yet succeeded in fully explaining this phenomenon, nor in accounting exactly for its causes.

It may be that the deterioration encountered arises directly from the raw material and escapes the routine chemical control which is normally carried out on arrival of the coal.





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THE EXTENSION OF THE RANGE OF COKING COALS

## 1. Introduction

In the last few years, two new facts, although anticipated for some time, have begun to assume more and more importance in the field of coking of coals. They show that the coking industry must adapt itself to economic conditions very different from those we have encountered up to now.

In the first place, it has become evident that the world reserves of good coking coals are limited; it is therefore going to be necessary to use for coking to a larger and larger extent, coals of a quality to which most of the coking plants of the Community are unaccustomed. These will be, essentially, coals of high volatile matter similar to the Saar-Lorraine coals; they have, in fact, the advantage of being available in large quantities and, further, they are easy to mine. Unfortunately their coking properties are poorer and in consequence they are less suited than the classic medium-volatile coking coals to the manufacture of blast-furnace coke.

The second fact is connected with the quality of the coke destined for the blast-furnace. A clear trend towards a new quality from that traditionally demanded to date has been apparent for several years. In fact, as a result of the modifications in the operating conditions of the blast furnace, related principally to the progress made in productivity, people have turned to using a coke smaller than usual but well graded (between 30 and 80 mm for example). This coke should maintain, on the contrary, a hardness and resistance to abrasion comparable with those formerly used, but it will not then be possible to characterise it by the M10 index of the micum test because this test can be applied only to cokes larger than 63mm. It will be necessary to substitute the IRSID test (I10 and I20 indices), specially adapted to small cokes. An M10 index which one hopes to keep generally below  $7\frac{1}{2}$ -8 will correspond to an I10 index of about 20-21 or approximately to an I20 index of 76-77.

As a result of these considerations, it appears useful to see how the coke makers are going to be able to adapt themselves to this new situation whilst keeping their cost returns as low as possible. The Marienau Experimental Station has been encouraged for the last twenty years to carry out,

on a semi-industrial scale, important research into the utilisation in coking plants of coals with a high volatile matter, because France has in Lorraine important reserves of this type of coal. This research, conducted in close liaison with the operators, allowed us to acquire a deep knowledge of the laws governing the carbonisation of coals and thus has made possible the incorporation of large proportions of weakly coking coals of high volatile matter in coke-oven blends.

Putting this experience to use, we are going to examine how in the future the problem of the manufacture of metallurgical coke can be envisaged, taking into account the observations made above. \*

First of all we will review the means available to the coke maker for controlling the quality of his coke. We shall then see how they can be combined to regulate coke manufacture in the best possible way.

## II. Means available to the coke maker for controlling the quality of the coke.

Our intention here is not to give a detailed account of the laws, frequently empirical and qualitative, governing the coking of coals. We want only to review some of the principal ideas which we believe should be kept in mind each time one has to resolve a problem in coking manufacture, We will consider successively the parameters on which coke quality depends putting particular emphasis on those which are likely to be employed in response to the demands of the moment.

### 1. Quality of the coals

This factor plays a most important part in the manufacture of coke. It is known that the problem of the relation existing between the quality of the coal and that of the coke is complex; it has already been the subject of a number of publications within the Community. We will content ourselves here with emphasising the necessity of being aware of rational associations between coals of different qualities. Let us add that the ideas we are going to develop can find their full application only if one has previously characterised the coals in the laboratory carefully. On this point, the increasing importance assumed by petrographic control must be

\* We shall not discuss here the problem of the manufacture of formed coke, which is the subject of several articles elsewhere.

mentioned; for example, thanks to the establishment of the reflectogram , we have gained the very important notion of homogeneous coal and thus can adduce very useful supplementary information in the characterisation of coal of uncertain origin. A blend can lead to a coke of sufficient cohesion only if the coals constituting it are sufficiently fusible and swelling; but it is necessary also to ensure that the whole does not possess excessive fusibility because that can be disastrous on account of the excessive formation of fragile "sponge", leading to the generation of breeze. It is necessary also to be certain that the fusion zones of the different coals of a blend intersect freely; if this is not so, some coals can play the part of a diluent although by themselves they have important swelling properties. This observation has a particular importance moreover in the case of coals of high volatile matter; in fact their plastic fusion generally ends very early (approaching 460-470°C) and it is necessary therefore that the medium-volatile coking coal with which they are associated has maximum fluidity at a temperature below this level.

The problem of the fissuring of coke and, in consequence, of its resistance to breakage must be also approached rationally; in this field, a highly elaborate theory has been proposed by CERCHAR; it is necessary above all to mention here that thanks to some simple tests (measurement of the resolidification temperature of the coals in particular) it allows one to predict adequately the extent of fissuring of a coke-oven charge and in consequence to choose a coal or blend suiting the desired size composition of the coke.

Finally, it can be said that the blend composition leading to a given coke quality cannot be determined by solely theoretical reasoning. One must in most cases rely on known blends which one modifies gradually, by applying the simple rules of the type we have just described.

## 2. Preparation and method of charging of the coal

Let us recall first of all the interest in the careful control of the various stages of coke manufacture, and primarily of the preparation of the coals. In fact, a precise and well-controlled preparation of the constituents of a blend means that the coke is uniform and thus allows us to increase the proportion of weakly caking coals that we use, without risking uncertainty concerning the quality of the coke.

The importance of the influence of the coal size on the coke quality is well known. Without repeating in detail the study of this factor, which has already been the subject of several publications, we will say that the crushing must be adapted to the nature of the coals and to the method of charging. The cost of the operation must also be taken into account when choosing the ideal size distribution.

The most common method of crushing is simple crushing which, let us recall, consists in passing the whole blend, once, through the crusher. Figure 1 shows, in Rosin-Rammler coordinates, industrial size distributions corresponding to this type of crushing. For formal wet charging, a size distribution producing around 80-85 per cent of particles below 2 mm seems to us most appropriate. Sometimes also the crushing method in which the coal is screened beforehand is recommended so that only particles above a certain size are crushed and in controlled manner; an example of size distribution obtained under these conditions is given in the same Fig.1. It is seen that this allows the proportion of large particles to be reduced in the most efficacious manner without causing an over-crushing of the fine fractions. This method of crushing also has the advantage of achieving most surely a well controlled and therefore regular and durable size distribution; but it has the disadvantage of being expensive. For this reason, one often hesitates to make use of it.

With the special charging techniques whose interest we shall point out later, crushing takes on greater importance than it does with normal techniques. Experience has in fact shown that the size distribution of the coals has all the more importance, as far as coke quality is concerned, as the density of the charge is increased. It is necessary therefore in this case to attend particularly to the crushing. It is not unreasonable to aim at a fineness of around 90-95 per cent <2mm; controlled crushing can then be better justified.

The density of the coal charge in the oven is another parameter with a large influence on the coke quality. Under this heading, it is known that stamping, owing to an increase in density of around 30 per cent in comparison with wet charging by gravity, has allowed a considerable increase in the possibilities of using weakly caking Lorraine coals. The collieries of the Lorraine Basin have acquired great mastery of the process

which provides them with the possibility, through judicious use of coke breeze, of putting to best use significant tonnages of the coals of the Basin in the manufacture of metallurgical coke. This process unfortunately has the disadvantage of necessitating a complicated technology and in consequence being more expensive than the usual process.

Dry charging also has great possibilities as regards the use of weakly coking coals. We shall not go over in detail the particulars of this technique; they are in fact elaborated by M. Foch in another paper. Let us remember that this process has a favourable influence on coke quality through the increase in density and that the suppression of moisture in the blend also has a beneficial effect on the coke. Moreover it leads to an increase in oven throughput. These various advantages have been confirmed industrially at the Hagondange coking plant of the Wendel-Sideler Group. This Group has encouraged the Marienau Station to perfect this technique, by studying, with the financial help of the Community, the charging of preheated coals. It is going to be tested, remember, at the 35-t/h scale at the same Hagondange coking plant. Another installation is moreover in the course of being erected in the United States, at the Iron-ton coking plant.

### 3. Carbonisation conditions

The quality of the coke equally depends on the thermal carbonisation conditions of the coals. These operate under the influence of three factors: the width of the chamber, the flue temperature and the temperature of the coke at the end of carbonisation.

The width of the chamber is obviously a parameter which one decides on, once and for all, at the time of the construction of a coke oven. Actually, in the Community, the tendency is nearly always to build 450-mm ovens because they permit the better utilisation of the set of battery machines. In the future, in the perspective of coke of the future, one may be tempted to return to a smaller width (400 to 420 mm) because it produces a slightly smaller coke and facilitates the caking of weakly coking coals; this is, for example, what they are beginning to do in Russia. In our opinion however the importance of this effect must not be exaggerated; according to tests carried out at the Marienau Station it

remains in fact rather moderate within the limits of width which can be envisaged in practice.

The effect of the temperature of the heating walls is worth examining with particular attention. At the present time one is forced, in order to increase the output of the ovens, to reduce more and more the coking time. Now this is found to harmonize well with the operating conditions of the future. In fact, coking at high rates of carbonisation favours the caking of coals which are poorly coking because they are hardly fusible, and also reduces the dimension of the lumps of coke. Let us note in passing that this effect is moreover comparable with that resulting from a reduction in width, but it is much more important. The curves represented in Fig.2 provide a very convincing example of the importance of the variations. It is seen for example that when the temperature of the heating wall is  $1250^{\circ}\text{C}$  - which is actually fairly normal - the coke is still large (40 to 60 per cent of the pieces being over 80 mm) and hardly fissured (M40 of 75 to 80); with the medium-volatile coking coal alone its resistance to abrasion indicated by the Ilo index is good. On the contrary, it is very mediocre with the mixture containing high-volatile coal. If one operates at  $1350 - 1400^{\circ}\text{C}$ , i.e. at a much higher thermal level, the proportion of large coke is reduced by half at least; there is therefore a reduction in the size range, particularly interesting with coke from the high-volatile coal. The two cokes are naturally more fissured, but this is not inconvenient in the future outlook. On the contrary, with the high-volatile coal the Ilo index, now mediocre, becomes acceptable. All these effects are therefore well in favour of the new tendencies in the matter of coke quality. This shows that the present effort of the constructors in proposing increasingly productive ovens must be followed with great interest.

It is well finally to remember that it is important to attend to discharging the coke from the oven after suitable thermal stabilisation - that is to say, when it reaches a sufficient temperature level, generally between  $900$  and  $1000^{\circ}\text{C}$ . The productivity of the coking plant evidently influences the choice of this level; it is necessary therefore finally to reach an acceptable compromise. Closely allied to this there is room

to mention the effect of certain constructors in proposing ovens of increased height, giving a much more uniform vertical temperature distribution at the end of carbonisation than has been realised in the past.

#### 4. Mechanical treatment of the coke

When it leaves the coke oven, the coke has already been subjected to mechanical treatment throughout the various processes which preceded screening; it has therefore undergone a certain mechanical stabilisation. The latter not always being particularly intensive, it may be interesting to accentuate it by submitting this coke to new mechanical treatments. They may for example consist of effecting repeated drops with passage through a bunker or treatment in a rotating tube. To give an idea of the order of magnitude let us say that one may hope thus to improve the M40 index by 3 to 8 points and the M10 index by 0.5 to 2 points, but there is simultaneously a supplementary production of coke breeze of 2 to 4 per cent and a 5 to 15 per cent reduction in the proportion of large coke (+ 80 mm); moreover the effect varies considerably from one type of coke to another and depends in particular on the initial quality. Finally it appears logical to us to foresee a place for the installation of stabilisation devices in new coking plants.

Although the effect of mechanical stabilisation is interesting in itself, it is generally insufficient when one wishes to obtain a well graded coke, devoid of large lumps; it must then be completed or replaced by crushing. This operation has in fact the advantage of allowing much higher reduction ratios and of resulting in a more regular grading of the coke. Actually we have in progress at Marienau a systematic study of the possibilities of this method of fragmentation, which will be carried out more and more in the future. It rests principally on the choice and the control of the crusher and the definition of the cokes best adapted to the treatment. The factors of reduction ratio and production of breeze are also naturally taken into consideration. The cost of obtaining a graded coke is in fact bound up with the control of the whole of these parameters.

#### III. How can these various means be combined to best effect for coke manufacture?

In order to make this paragraph at the same time more convincing and



more concrete, we shall discuss the manufacture of two types of coke chosen as reasonably representative of the present and future requirements:

-a coke A of good quality and quite large, which is used generally in the blast furnace in the form of + 40 or + 50 mm. Its mechanical characteristics, taking into account its size, must be defined by the micum test (M40 78-80, M10 7.5 - 8). This quality is still currently achieved in the Community; nevertheless certain industrial countries outside Europe consider this needlessly high and aim at a lower level.

-a coke B which maintains a high hardness and resistance to abrasion but which is of a smaller size because it has been decided that it should be sized between 30 and 80 mm. It must be characterised by the IRSID test, adapted to small cokes but which remains strongly based on the micum test. One can aim at an I10 <20-21 or approximately the same, an I20 <76-77. This is near enough equivalent to an M10 of 7.5-8. It is to this sort of coke quality that certain countries (Japan, Italy, United States) are already systematically oriented; we have seen that this will be increasingly demanded in the future.

To illustrate the possibilities, we shall base our discussions on the relatively simple case in which only two coals are available for manufacturing these cokes:

- high-volatile caking coal which one would, hypothetically, seek to use in maximum proportion. It is in fact supposed to represent one of the coals of high volatile matter which would be easily marketable in the future. Let it be observed that we have voluntarily chosen, amongst these, the high-volatile caking coal which is not one of the easiest to coke.

- a good medium-volatile coking coal which, playing the role of make-up coal is supposed to be well adapted to the high-volatile coal. We shall also assume that it is not made up of a mixture of several qualities, that is to say that it is homogeneous.

To establish these ideas we present in Table 1 the essential characteristics of these two coals.

TABLE 1

Coal	Volatile matter d.b.	Swelling index	Dilatation
High-volatile caking	36 to 38 %	4 to 5	- 20 to - 10
Medium-volatile coking	22 to 25 %	8 to 9	+ 70 to + 100

We are going to see how under these conditions, from the considerations in the previous paragraph, one can propose blends corresponding to the defined objectives. We shall analyse successively the possibilities of three charging techniques - usual wet charging, stamp-charging and dry (or preheated) charging. Let us add that the tables of values on which we are going to depend are based on the results obtained in a 400-kg oven, some of which have been verified in a coking plant.

1. Normal wet charging by gravity

This technique of charging has limited possibilities but it can be perfected by judiciously combining the parameters enumerated previously. It is a question principally of blending and crushing the coals well. One can envisage oiling of the blend, which raises the density by 5 to 8 per cent. In Table II we have assembled the formulae that one may put forward under such conditions.

TABLE II

Treatment undergone by coke	Coke A		Coke B
	Normal handling	Intensive mechanical stabilisation	Crushing
<sup>+</sup> Flue temperature	1 250°C	1 250°C	1 350°
High-volatile caking	25 %	35 %	40 %
Medium-volatile coking	75 %	65 %	60 %

We assume that the two temperature levels indicated correspond on average to coking times of about 18 and 15-16 hours in a 450-mm chamber

It is seen that we have made the flue temperature appear in this table. This parameter in fact plays an important part in obtaining the coke quality aimed at in this method as well as in the others. For coke A it is not necessary to carbonise at too high a temperature because we are seeking, let it be remembered, a coke of fairly large lumps and consequently little fissured as it is necessary on the other hand to facilitate the fusion of the high-volatile coal, we think that 1250°C corresponds finally to the best compromise to allow the use of 25 per cent of coal of high volatile matter. Mechanical stabilisation allows a supplementary incorporation of around 10 per cent of this coal. On the other hand a slight reduction in the size of the coke and extra production of coke breeze must evidently be assumed. These are not truthfully disadvantages, because on the one hand this is in line with the search for a graded coke and on the other hand the requirements for breeze in ore sintering are increasing.

With coke B the possibilities become even more interesting; there is, in fact every interest in turning deliberately towards a much higher rate of carbonisation: it facilitates the introduction of the weakly caking high-volatile coal; moreover it leads to a more fissured and therefore smaller coke, it will thus necessitate crushing operations. Let us observe finally that the elevation of the flue temperature moves in the direction of research into increased throughput of the coking plant; this corresponds, in fact, to a production gain of the order of 20 per cent.

Note: It is seen that after all, for the manufacture of a coke of type B, graded and smaller in size a blend based uniquely on good coking coals is not only no longer of interest but is even to be advised against. It would produce in fact a much larger coke than with the blend with high-volatile coal and would thus lead to higher crushing costs.

## 2. Stamp-charging

This technique considerably increases the possibilities of using

weakly coking coals, but we have already said that it has a more complicated technology, which increases the investment and production costs. Let us add that it seems difficult to adapt to ovens over 4 metres high.

In Table III we present the formulae envisaged under the best conditions.

TABLE III

Treatment undergone by coke	Coke A		Coke B
	Normal handling	Intensive mechanical stabilisation	Mechanical stabilisation or crushing
Flue temperature	1350°	1350°	1350°
High-volatile coking	60 %	63 %	85 %
Medium-volatile coking	33 %	30 %	15 %
Coke breeze	7 %	7 %	-

To obtain coke A, note that we have provided for the use of fine coke breeze which has the effect of reducing the fissuring of coke. The presence of this product is indispensable in making the most of the advantages which stamping offers. The possibilities for the utilisation of high-volatile coal then become much more important than in the usual technique; on the other hand there is no longer any limitation on the flue temperature, thanks to the presence of the breeze.

With coke B, it is possible to make use of yet greater quantities of high-volatile coal; the technique in fact is particularly suitable and there is no limitation on the flue temperature. In this case moreover it is possible for the coke to be sufficiently closely graded for simple mechanical stabilisation of the remaining large pieces to be substituted for crushing.

### 3. Dry (or preheated) charging

The possibilities of this technique are also very important and it has,

unlike stamping, the great advantage of according with the present concern for lowering the cost price and increasing productivity. Further, it can be easily adapted to a coking plant already built and practising conventional wet charging.

Table IV indicates the formulae of the blends envisaged under optimum conditions.

TABLE IV

Treatment undergone by the coke	Coke A		Coke B
	Normal handling	Intensive mechanical stabilisation	Mechanical stabilisation or crushing
Flue temperature	1 250°	1 250°	≥1 350°
High-volatile coking	65 %	70 %	80 %
Medium volatile coking	35 %	30 %	20 %

With coke A one can go up to 65-70 per cent of high-volatile coal but, as in conventional wet charging, the flue temperature must be limited to 1250°C because this coke has to be little fissured in order to conform with the demands on the M40 Index (78 to 80). Naturally one could add some fine coke breeze to the blend, which would allow the temperature to be raised by 50 to 100 deg<sub>C</sub>. In fact the presence of this product not being indispensable as it is with the stamping method, we thin that this would needlessly complicate the preparation of the blend.

With coke B we found, as with stamping, extremely interesting possibilities since one could go up to 80 per cent of high-volatile coal. As we said previously, it is not even certain that crushing is still indispensable - simple mechanical stabilisation can lead directly to the graded coke desired.

#### IV. Conclusion

What must we finally draw from these conclusions? We saw that coking was going to find itself in the presence of a new situation due on one hand to the lack of good coking coals and on the other to the orientation of ferrous metallurgy towards a new coke quality. The coking plant proves itself well equipped for keeping pace. It can stand, without fundamental modifications in its scheme of manufacture, an increased range of coking coals and turn itself particularly towards the utilisation of coals of high volatile matter. Moreover, these assist in obtaining the smaller and graded coke towards which we are turning. The solutions are varied. The simplest is to maintain the conventional method of wet charging by gravity by ensuring very good control of some of the factors of manufacture (blending, crushing, flue temperature particularly). The possibilities of this technique remaining limited however, it is more advantageous to turn to other charging techniques: stamping and above all the drying and preheating of the coals. They assist considerably the utilisation of weakly coking coals and are better adapted to the production of a coke of close size range. Dry (or preheated) charging also presents the supplementary advantage of conforming to the present concern for increasing the throughput of coking plants.

One finally sees therefore that there is no room for pessimism about the future, as regards raw material for coking. The conventional coking plant is perfectly equipped to adapt itself to the new economic and technical demands.

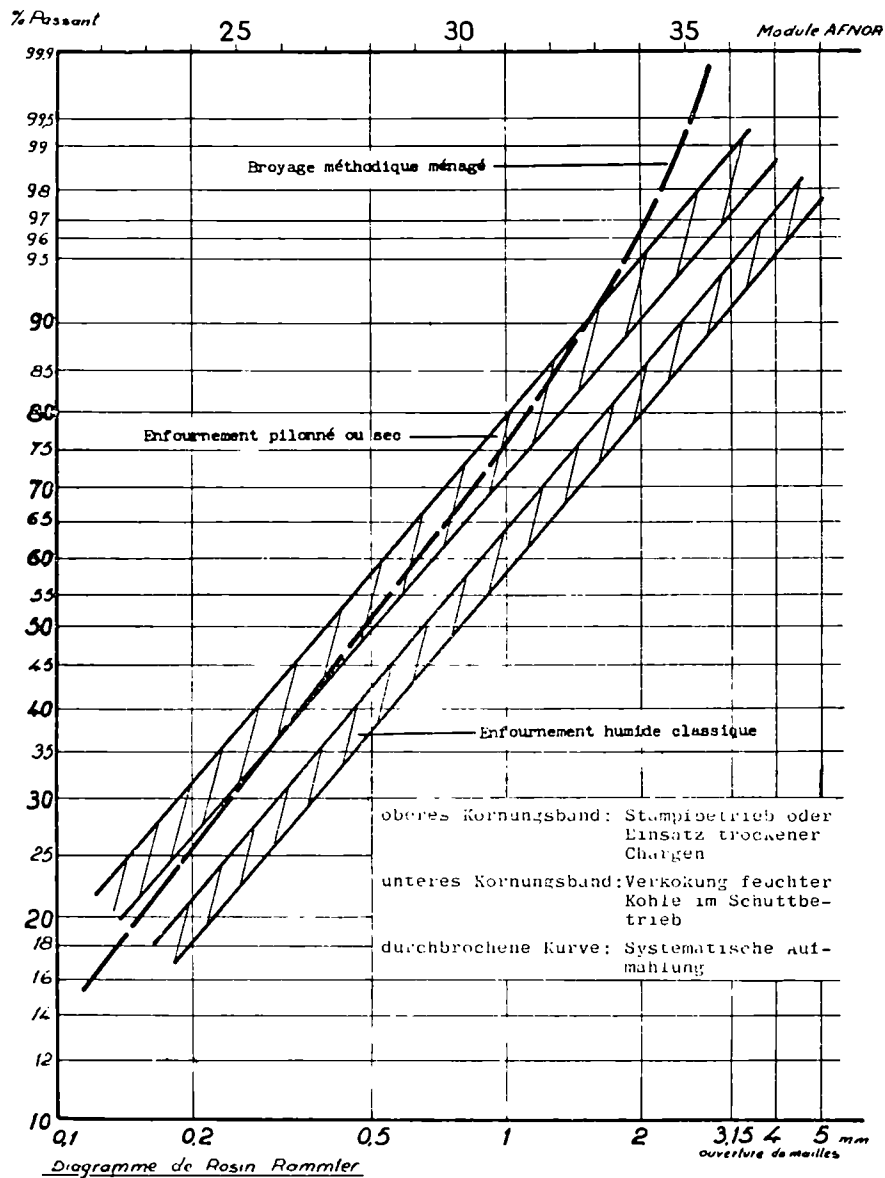


Figure 1

Size distributions recommended for different charging techniques

Ordinate : % undersize

Abscissa : (top) AFNOR modulus

(bottom) mesh opening

Legend : Controlled systematic crushing

Stamped or dry charging

Conventional wet charging

Enfournement humide par gravité.

——— 100 % Fettkohle  
 - - - - 50 % Fettkohle, 50 % Gasflammkohle

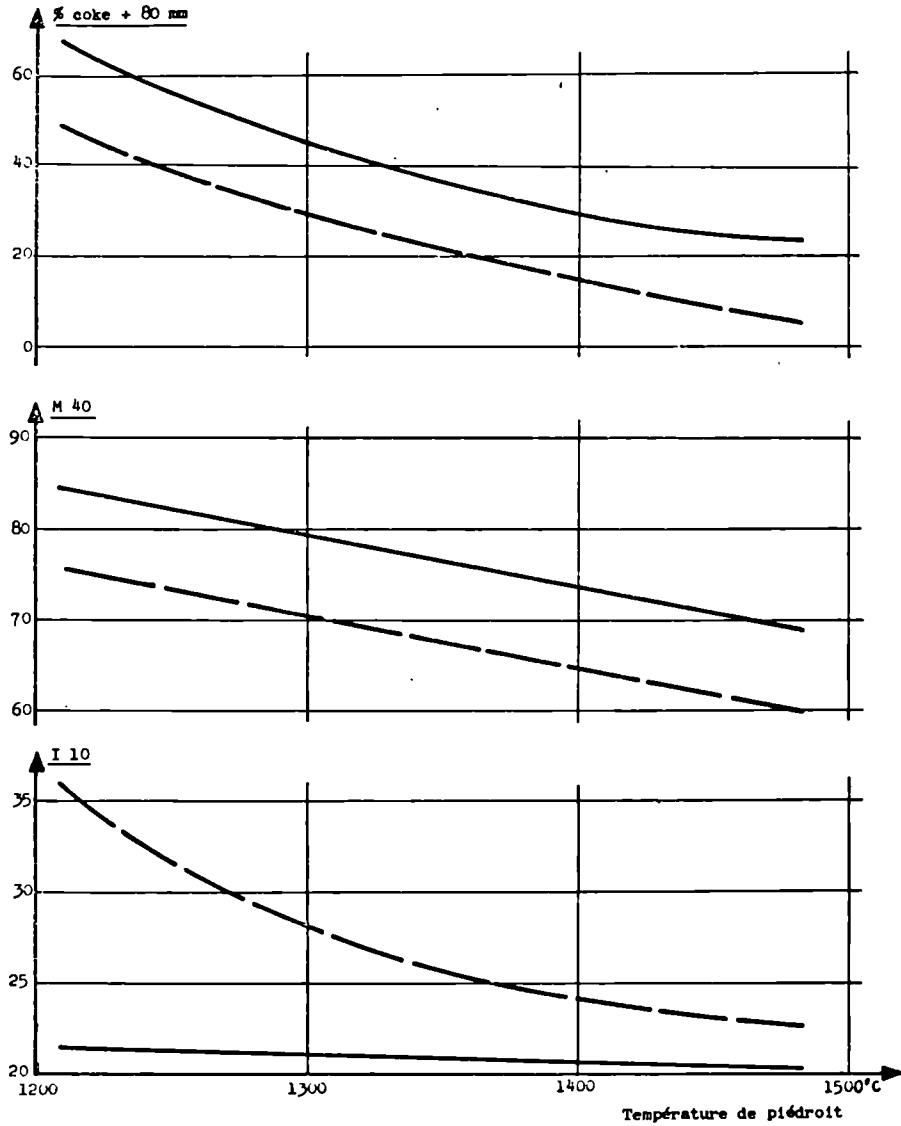


Figure 2

Effect of a rise in flue temperature on the mechanical properties of the coke

Abscissa : Flue temperature

Legend : Wet top-charging

100% fat coking coal

50% fat coking + 50% fat flame coal



DISCUSSION

J. P. Graham & W. J. Pater

It is generally agreed that the most important single factor influencing the quality of oven coke is the quality of the coal charged to the oven. In addition, the extent to which the plant manager can alter the carbonising conditions is limited by the physical characteristics of the material from which the plant is constructed. These also have an important bearing on the additives which may be put into the charge. Thus, when the pattern of the multi-variable studies was initially established by the British Coke Research Association it was limited by these considerations and it was clear that the effort would require to be concentrated largely on the means of altering or modifying the charge conditions. Inevitably, certain variables were included for examination about which some knowledge was already in existence. However, such variables were re-examined in order to quantify the effects they produced and to define accurately with the facilities available at the Coke Research Centre those details of technique which could ensure a confident and consistent application.

In order to give some target at which to aim, the improvement which was sought was defined as an increase in the M40 micum index of the coke obtained from a poorer than hitherto used medium-caking coal at least 20 points as compared with that from the unmodified coal.

Many variables were considered and those selected were first examined using small ovens to establish trends and to select those worthy of investigation with the 10-ton oven. The variables may be classified under three headings: charge-preparation; additives; carbonising conditions. The plan of the main investigation was divided into two sections. In the first, the effects of the variables were studied singly. In the second, the purpose was to examine the effects of certain chosen variables acting together, the objective being to determine the conditions necessary to achieve an optimum economic result.

Thus, a complete and systematic investigation of the production of metallurgical coke from a blend based upon a medium-coking coal (n.C.B. coal rank coke number 600, International Coal Classification number 633) was carried out by the Association between 1958 and 1967 with the 10-ton test oven and associated facilities permitting carbonisation research on a scale directly comparable with full-scale commercial practice. The successful conclusion reached in the investigation meant that not only was a threat to the future availability of adequate supplies of the required quality of metallurgical coke alleviated but that there now existed the possibility of securing immediate and significant improvements in the economy of production of metallurgical coke. Subsequent application of the general method of approach to particular problems at various plants has further shown how in this context the dependence of the coking industry upon supplies of very good coking coal can practically be eliminated, with medium-rank coals playing a part not hitherto considered possible. The general implementation of the Association's recommendations will, in fact, in both branches of the manufacture of metallurgical coke (i.e. for blast-furnaces and for foundries), permit acceptance of lower-rank coals as currently dictated by the changing pattern of coal supplies.

Statistical analysis of the results of the multi-variable experiments carried out at the Coke Research Centre enabled the independent effects of the variables used in combination to be established, but it was also necessary to study the interdependent effects which theoretically were expected to exist. A computer-based multiple-regression analysis of all the data available showed that the independent effects accounted in general for at least 80 per cent of the observed changes. A further 10 per cent be attributed to interdependent effects, which were thus shown to be of secondary importance. The total variability accounted for by these two sources was usually about 90-95 per cent. It was thus shown to be permissible for practical purposes to consider the independent effects of each variable, even when dealing with the general case of several variables applied together.

The outstanding practical conclusion arising from this work was that, under the optimum technical conditions which could be chosen on the basis

of the results, a really substantial improvement could be secured on the strength of the coke produced from a medium-rank coal. For example, by carbonising under precise conditions a blend based on a 633-type coal and containing additives, the M40 index was increased from 40 to 75 and the M10 micum index was decreased from 10.0 to 8.7, these strength parameters being determined on coke sampled at the wharf. Moreover, this improvement could be brought about without adverse effects on the bulk density, ash or sulphur content of the coke. The improvements obtained with blends based on a 634-type coal with additives included over 30 points in the M40 micum index without any detrimental effect on the resistance to abrasion; the size of this coke, intended for the foundry industry, also increased substantially, giving a higher yield of the required grade.

Using additional data on oven throughput and yields and qualities of gas and by-products obtained from the 10-ton oven and test plant, it was possible to estimate the costs of production of blast-furnace coke from blends based on a medium-caking coal and to compare these costs with those for the type of blend currently used in British coke-making practice. It was found that, principally because of the saving in the cost of the charge material per unit weight of blast-furnace coke obtained when basing the blend on the medium-caking coal, there was a significant reduction in the estimated cost of production at a given level of the strength index.

The actual saving which would be obtained in practice would depend upon the location of the plant, upon local factors and upon the quality of the coke produced, but should generally be of the order of several shillings per ton of blast-furnace coke. Even at the very modest rate of five shillings per ton, the sort of improvement which has already been obtained in practice at one plant (Graham, J.P. and Jenkins, D., "34th Blast Furnace Conference", B.I.S.R.A. 1967, pp. 7-15), the total saving to the British blast-furnace coke-making industry would be over £ 2½ million per year. In this context it is important to note that, in the practical application mentioned above, it is understood that, in addition to the saving achieved in the charges for coal, even bigger economic advantages arose from the improvement of blast-furnace operation resulting from better coke quality, consistency and uniformity.

Development of the approach has therefore reached a stage at which technical certainty has been achieved and economic viability demonstrated, at least as regards plants where the recommendations can be put into effect without capital expenditure on new plant. The Association is now undertaking further investigations on behalf of Members with the objective of defining the blends corresponding to the best overall economy whilst meeting their requirements concerning coke quality. The studies so far completed have been concerned with application of the method to commercial blends based on medium-rank coals and from the results it has proved possible to define modified charge-preparation conditions and the compositions of the blends of base coals and additives which would yield good blast-furnace coke under the particular production conditions at the plants concerned.

The rigorous application of the Association's method to medium-rank coal demands first the selection of the particular coal (or coals) to be used, secondly the experimental investigation of this coal as the basic component of the blend, thirdly the statistical examination of the data to derive equations for the effects of the variables on coke, gas and by-product yields and characteristics, and finally the statistical optimisation of the blend composition and the rate of carbonisation to achieve the minimum net cost of coke of defined quality at the required rate of production. Using the results already obtained with the reference coal as a guide, the length of the experimental investigation need be only a fraction of that of the work carried out on the reference coal: the useful variables have been identified and the approximate ranges of interest defined.

M. Burstlein

In his masterly introduction Mr. Schumm has expressed the anxiety that has recently been felt by European, Japanese, and other iron smelting circles because of supply difficulties with respect to coking coal in world markets, difficulties which, moreover, may rapidly become worse in the very near future. It is feared, in fact, that this shortage may endanger expansion programmes and that the production prices of coke and of steel may undergo excessive increases in comparison, for example, with those in the USA. The USA cannot appreciably increase their exports of bituminous coals with low and medium volatile values and perhaps in future years will not be able even to meet their long-term supply contracts with the large European countries or Japan (see John K. McHugh - Blast Furnace & Steel Plant. Dec. 1969).

However, I feel that there is really no reason to be concerned for the future of the European, Japanese, or other iron and steel industries that have to import their coking coal.

In fact, they can, as shown on curve II of Fig. 2, reduce their present consumption of coking coal by between 40 and 70% (average 55%) by increasing, by the same quantity, the amounts of subbituminous coals, which are less expensive and are available on national or world markets. At the same time they produce a better and more regular coke.

This conversion can be brought about in the brief space of only a few months, thanks to a very recent invention which I have pleasure in announcing at this Session of the European Communities Commission.

This invention is a new high-efficiency screening process which, with minimal investments, allows the introduction into existing coking plants of a well-known and long tested procedure, namely selective, economical crushing, which I also devised.

For example, it is sufficient to complement the standard crushing section of an existing coking plant with a throughput of 5000 t/day of coal with a single screening apparatus with an area of about 60 m<sup>2</sup>, as compared with at least 140 m<sup>2</sup> before.

The time has therefore come to make a fundamental change in our views on the subject of the preparation of coal for coking.

It is absolutely essential to take account of the following;

- a) The coke industry should treat its primary materials with at least as much care as other sectors of industry, as the times are definitely over when the necessary efforts did not pay because coking coal was practically the same price as subbituminous or inert coal.
- b) The main feedstock for coking will no longer be coking coal but subbituminous or inert coal.
- c) Coking coal should be considered as valuable making-up coal to be used sparingly since it provides the indispensable binder for subbituminous or inert coal and is much less expensive than tar for example.
- d) To reduce the consumption of this binder to a minimum, subbituminous coals should be subjected to efficient crushing so as to give them a minimum specific surface for a given total granulometric composition.
- e) In comparison with the conventional crushing procedures the Burstlein procedures permit the specific surface to be reduced by a factor of 3-6 (e.g. from 70 to 15 m<sup>2</sup>/kg), and a ton of subbituminous coal to be bound with between 3 and 6 times less coking coal.

The following is an example of the application of this method at a coking plant processing 5000 t of coal per day, of which 70% (3500 t/day) is bituminous and only 30% (1500 t/day) is subbituminous.

Figure 1 shows that the Burstlein methods give a coke of at least equal quality with a mixture of 36% (1800 t/day) of bituminous and 64% (3200 t/day) of subbituminous coal.

Figure 2 shows a saving in bituminous coal of 34% (or 1700 t/day) in relation to the total mixture treated (curve I), or 48.5% (1700 t/day) referred to the 3500 t/day of bituminous coal consumed previously by the coking plant when the coal was prepared by conventional coarse crushing procedures (curve II).

In order to meet the scarcity of coking coal and the sharp increase in its price, the Commission of the European Community is looking for a procedure with the following characteristics:

- a) proved on the industrial scale;
- b) capable of being introduced into coking plants in less than one year;
- c) requiring low investments;
- d) possessing high profitability.

The method of selective coal preparation exactly meets these aims.

In fact, this procedure and the equipment I have devised have proved themselves since 1950 in a dozen French and foreign coking plants as well as in several ore crushing works (with a view to integral agglomeration).

They can be incorporated in less than one year since it is sufficient to augment the existing equipment at a coking plant with one or two screening machines according to whether simple or differential economical crushing is desired, as well as with some conveyors connecting with existing crushers and mixers.

The investments are relatively small as the necessary screening surfaces are reduced by more than 50% on account of the high efficiency of the screens with increasing layer heights which have been referred to above.

The cost of selective crushing (including amortization) is currently in the order of \$ 0.30 per ton of mixture treated, for example, in a 5000 t/day coking plant.

On the credit side is a figure of \$ 3.00 per ton for the reduction in the consumption of coking coal from 60% to 30% for example.

The net result is currently \$ 2.70 per ton in the chosen example. This value will increase if the gap between the current prices of bituminous and subbituminous coal (\$10/ton) increase in the future, which is probable, if not certain.

Profitability is therefore absolutely assured.

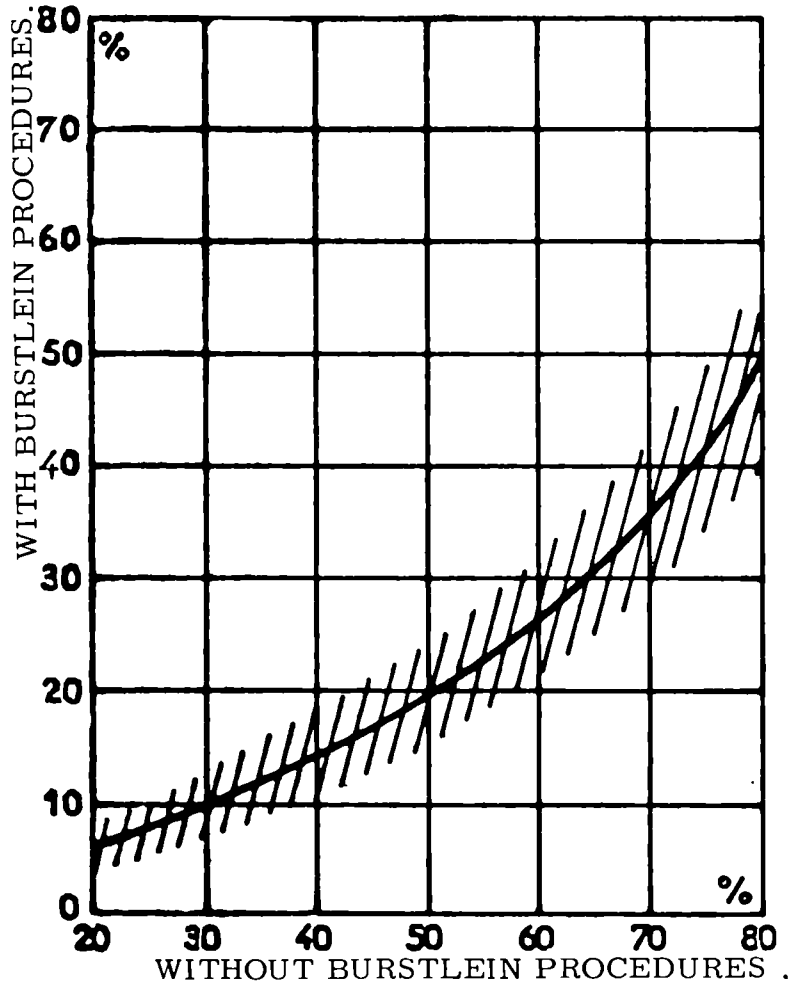


FIG . 1 :

Percentage of coking coal in the mixture with and without Burstlein procedures.

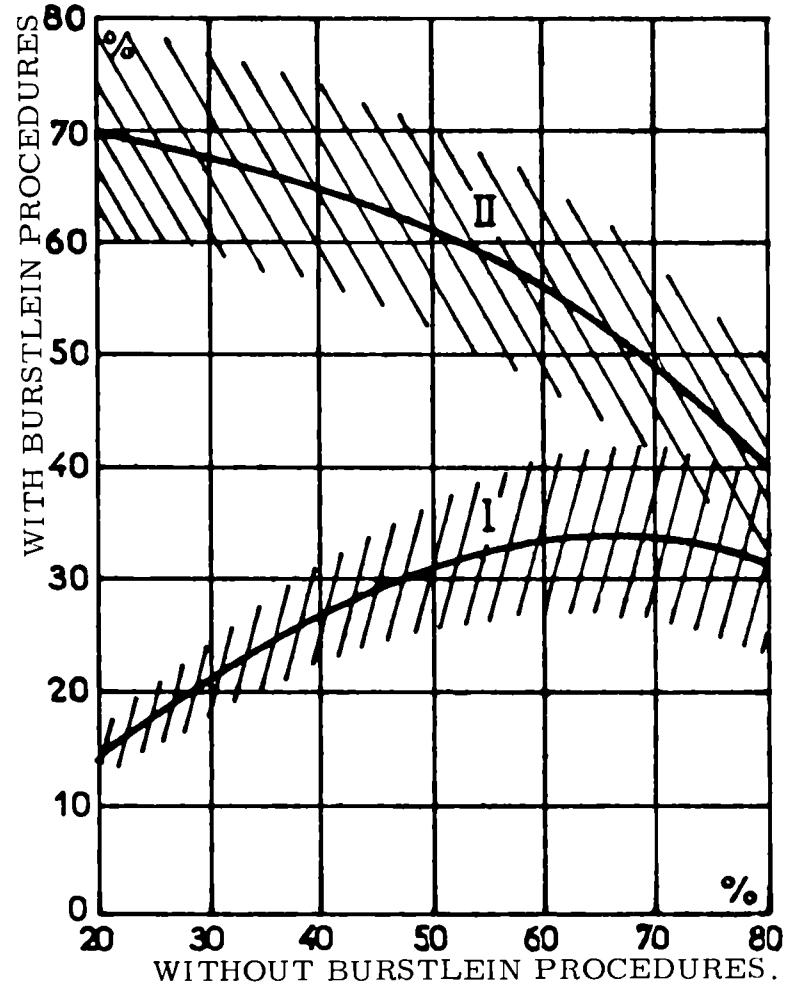


FIG. 2 :

Percentage of coking coal saved by the Burstlein procedures related to :

I : total mixture.

II : coking coal alone.



M. Meitzheim

The supplementary information supplied by H. Burstlein is most interesting. In particular, the details given concerning a wholly new technique of screening coals show that the cost of systematic crushing of cok oven charges can be reduced and that as a result the process remains one of the interesting solutions for resolving in a certain number of cases the problem of upgrading weakly coking coals at coking plants.



G. Juranek

( Ruhrkohle AG, Essen )

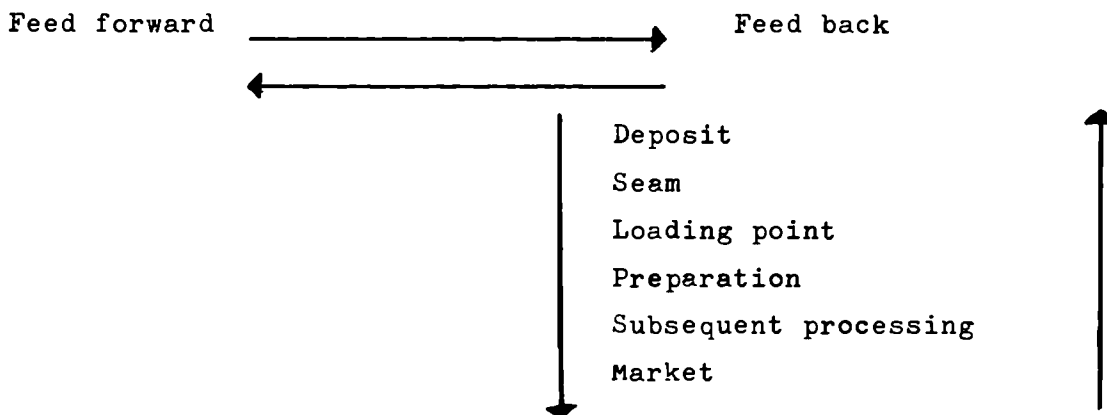
OPTIMISATION OF COKING COAL BLENDS BASED ON THE  
MATHEMATICAL MODEL OF CARBONIZATION  
IN SLOT-TYPE RECOVERY OVENS

The purpose of this report is to demonstrate how to apply a technically feasible method of optimising blends of coking coal. This optimisation should be based on quality, quantity and profitability, and should be adapted in the full sense of the term to the mining firm's overall model. The quality, quantity and profitability of mining the coking coal are influenced to a great extent by the requirements the products of coking have to meet, and therefore quite simply by the properties of the coking coal, the carbonizing reactor, and the coking conditions. This relationship makes it necessary, when discussing the properties of the coking coal that are allowed by the selection of carbonization conditions, to take account of the acceptable size of the variants. "Properties of the coal" refer to water content, ash content, volatile content, sulphur content, coking capacity, and swelling and shrinking behaviour. Some of these properties may have either a positive or a negative influence on optimising carbonization conditions. For quantity, when this refers to the quantity of blast furnace coke required, which is the case dealt with here, this depends upon market requirements. In addition to the technical optimisation required for the results from the points of view of quality and quantity, economic data play an essential part. These are clearly provided by the deposit, the mining method, and the preparation plant.

Optimisation systems

In principle, technically feasible optimisation based on two market control systems is necessary (Fig. 1).

Fig. 1: Feed forward and feed back market control systems



Using the feed forward control system based on production price, optimisation of the results proceeds from the coal deposit, via the loading point and preparation, to the coal market. The market is sub-divided into the main coal purchasers: coking plants, electric power stations, and other consumers. As long as the coal market can be considered from all angles, the second control system, that of feed back, which is based on income and proceeds from the market via preparation and the loading point to mining from the seam, is superfluous. Today however, as a result of developments over the last few years in the metallurgical industry, use of the feed back control system based on income is an absolute necessity, as this is the only means of taking account of purchaser's wishes. It follows from this that the technical and economic optimum is obtained from a combination of the two systems of control.

For the feed forward control system, the constitution of the deposit, the quantities and the properties of the coal seems should be known. It can be judged from short, medium and long-term planning of the mining which seams should be mined separately and which together. The nature of the preparation process and the facilities of the processing plant must also be decided. The desired optimisation of coking coal blends should therefore begin with mining the coal, at the face, and should make itself felt right up to preparation; in these circumstances, it is also an important factor in influencing the type of mining chosen for the with a view to obtaining the minimum expenditure on producing and preparing the coal.

Whereas the coking coal's properties, water content, mineral content, sulphur content and volatile content, have a mainly additive effect and can easily be taken into account, cokeability and the behaviour of a coking coal in coal in carbonization must be considered in a rather different way. As the result of research by the Steinkohlenbergbauverein (1) in Essen, with financial support from the Commission of the European Communities, it has been possible to determine quantitatively the coking capacity of a coking coal, irrespective of the number of its components. Other research has made it possible to formulate mathematically the carbonization process. This states the properties as to quality and the quantities of primary product as a function of the carbonizing reactor, the reaction conditions, and the qualities and quantities of the products of carbonization. Subjects for future research and development work are the mathe-

mational description of particle size distribution in coke, and swelling and shrinking behaviour of coking coal.

In the feed back control system, the properties of the coking coal inside the coking plant are naturally dependent on the criteria demanded of blast furnace coke by the blast furnace operator. These criteria can be divided into physical properties such as the particle size of the coke, hardness properties\* and reactivity.

The chemical properties are predominantly determined by the coal seam. The request by customers for the lowest possible level of inert material can be met in principle, but in practice only within reasonable economic limits on account of the production price of the process. The physical properties such as particle size distribution and the hardness properties\* of the coke can be influenced only within set limits for the given primary products because of the reaction conditions. For optimisation of the results, it is desirable that in each case the standards imposed on a metallurgical coke should be established precisely; in this way optimisation of coking coal blends could be undertaken in a reasonable manner. To date the objective of optimisation can frequently be established only empirically for the properties of blast furnace coke.

#### Ruhrkohle A.G.'s coal and coke

To give an idea of the need for considering optimisation and for optimisation calculations, Fig. 2 (not reproduced in translation) shows the sites of Ruhrkohle A.G.'s 52 mines and 29 coking plants. Each year these 52 mines now extract from around 380 workings approximately 86 million tons of coal, which are washed in the same number of preparation plants as there are mines. The types of coal mined range from anthracite to long-flame bituminous coal (charbon flambant à gaz). There is a preponderance (over 60%) of coking coal which easily carbonizes; this situation favours the Ruhr Coalfield and the Community.

Composition according to categories is as follows:

Coking coal	62%
Sized coal	20%
Power station coal	12%
Lean coal, anthracite	6%

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\* or crush resistance

Ruhrkohle A.G.'s 29 coking plants produce around 26 million tons of coke annually, consisting of:

Blast furnace	62%
Crushed coke	28%
Foundry coke and special cokes	4%
Coke dust	6%

These figures show clearly the importance of coking coal and coke from the Ruhr from the economic point of view.

Delivery alone of coking coal to coking plants involves several million DM per year in transport costs. But optimisation of transport costs from the point of view of quantity alone, not considering quality, is impossible.

After this brief survey, optimisation of coking coal blends will now be considered in general and with the help of examples.

#### Optimum coking capacity

With regard to inert material, sulphur content and volatile content, optimisation of the product raises no problems concerning the additive effect of these properties, as had already been stated. But as a result of the mathematical description of high temperature coking, which includes optimising coal blends, it is now also possible to integrate quantitatively the coking capacity at the same time as the volatile content as factors influencing the hardness and abrasion resistance of the high temperature coke produced from coking coal. (2)

The term coking capacity refers to an index representing the overall expansion rate in the Ruhr dilatometer. The coking capacity G is given by the product of two quotients. The first contains the temperatures of the plastic range of the coal, and the second contains the volume variation of the coal briquette in relation to the temperature:

$$G = \frac{E + V}{2} \cdot \frac{k + d}{kV + dE}$$

where E = plastification temperature in °C;

V = resolidification temperature in °C;

k = contraction in %;

d = expansion in %.

A statistical estimate revealed that for every value of volatile content there is an optimum coking capacity, which means that, for a given volatile content and a given numerical value for the coking capacity, maximum values can be obtained for coke hardness at the time of carbonization of this coal. Coking capacity, in terms of volatile content, is shown in Figure 3.

The curve in Figure 3 represents the optimum coking capacity mentioned above. Any variation above or below the curve indicates a decrease in the coke's hardness properties. Coal with co-ordinates (coking capacity G, volatile matter) above the curve has excessive coking capacity. Coal with co-ordinates below the curve has poor coking capacity. In the area between  $G = 0.95$  and  $G = 1.10$ , the index G has an additive effect.

#### Coking coal blends

Work on optimising coking coal blends should now be concerned with the fact that once the blend has been made the various components are situated either as close as possible to the optimum coking capacity curve, or on the curve itself. (3). For coal with excessive coking capacity, this optimum can be obtained by blending it with coal with poor coking capacity or by adding inert additives (to reduce coking capacity) such as lean coal, anthracite, petroleum coke, coke dust. It should be pointed out in this respect that the optimum coking capacity for "maximum coke hardness" depends solely on the volatile content of each of the samples considered, in other words the absolute coke hardness properties develop along the optimum coking capacity curve. Figure 3 shows that the majority of Ruhr coking coal (represented by black dots in the diagram) has excessive coking capacity or is clustered around the optimum coking capacity curve. This advantage which Ruhr coking coal has over other coking coal from non-member countries (represented by black triangles in the diagram) is obvious, as the latter is most of the time substantially below the optimum capacity curve. The example of adding the coal known as "improving coal" is well-known. This produces only an increase in coking capacity in the other types of coal available, bringing them nearer to the optimum coking capacity curve. In this way American coal with a relatively high volatile content, which also has quite a low G index, has its coking capacity improved by the addition of Pocahontas coal, in other words the co-ordinates of the coking coal blend



produced in this way are moved towards the area of the optimum coking capacity curve. As can be seen in Figure 3, this Pocahontas coal can be replaced, for example, by coal with a lower volatile content, giving the same effect.

A coal with co-ordinates outside the given area must be approximated to the curve by means of a blend with a coal within this area. Even a component with a coking capacity of  $G = 0$  has when blended a value which should be determined by expansion tests. Extrapolation to  $G = 0.95$  of the curve established in this case for coking capacity  $G$  makes it possible subsequently to deal with coking capacity  $G$  in an additive way.

#### Particle size of coking coal

The above assumes (when various coal blends are compared) that the carbonizing conditions used are constant. It should also be pointed out that a coking coal blend should be carried out in such a way that it is homogeneous from the point of view of the quantitative distribution of the various compounds. However, homogeneous distribution of the properties can only be obtained if the various compounds are pulverised in such a way that their surfaces are equal. This means that the lower the concentration of a component, the more finely it should be pulverised. In general, it should be said however that the particle size distribution of the final blend to be made corresponds to the optimum particle size distribution. This should be obtainable in practice, as has been shown by experience in the last few years, with indices  $M_s = 10$  to  $20$  for particle size distribution. (4).  $M_s$  is the overall divergence and shows the sum of the positive (and, when they occur, the negative) divergences of a given particle size distribution from the optimum particle size distribution in the technical screening ranges of: above 3.15, 3.15 to 2, 2 to 1, 1 to 0.5 and below 0.5 mm.  $M_s = 0$  represents an optimum particle size distribution. Data on equal surface pulverisation, in blends with several compounds, can be obtained by using the Rosin - Rammler - Bennett diagram.

Coking coal blends can therefore be optimised quantitatively according to criteria imposed for coke hardness properties. In this case, however, the particle size distribution of the pieces of coke in relation to the primary product and the behaviour of coking coals during carbonization have

not yet been taken into consideration. The swelling and shrinking behaviour of the coal during heating is also of practical interest. These factors, which have a fundamental influence on the coking process, have not to date been open to quantitative understanding. At present one is limited in this field to practical experience.

### Practical experience

#### Hardness

Practical experience has been confirmed at pilot-plant level by carbonization tests with seam coal of varying categories. (5). (Figure 4).

These showed that the optimum values for coke hardness could be found in coal with 24 to 26% volatile matter without water or ash. The hardness values decreased with earlier and later stages of coal formation. No hard coke can be produced from seam coal with less than 17.5% volatile matter without water or ash in the carbonization conditions adopted. The divergences from the various values of the hardness curve should be compared with the various values of G.

#### Shrinking behaviour

Shrinking is so bad when seam coal with less than 20% volatile matter is carbonized that it is impossible to push the coke from the oven. Even carbonization of coal with up to 25% volatile matter without water or ash leads to bad performance of the oven. With an increasing volatile content, there is a distinct improvement in shrinking behaviour. The curve in Figure 4 shows the behaviour of coal with rather coarse particle size, in other words coal in which only 75% of the particles are under 3 mm. Shrinking behaviour generally improves when the particles of the coal used are increasingly fine.

#### Swelling behaviour

Measurement of swelling behaviour has given the highest values with a pressure of over 400 kp for coal with up to 20% volatile matter without water or ash. With increasing volatile content, swelling decreases to 0

for seam coal with 28% volatile matter without water or ash. Here too the curve is applicable to coal with rather coarse particle size, and swelling decreases considerably with increasing fineness of particles. This is shown in the bottom curve in Figure 4.

The danger arising from swelling is reduced by carbonization at a lower temperature. The two factors, fine pulverization and a lower flue temperature, however, mean a reduction in the charging capacity and are therefore in conflict with the present purpose of attempting to increase the yield. It is to be hoped that these rather empirical considerations on the swelling and shrinking behaviour of coal soon lead to their being expressed quantitatively as a result of research in this field. Adding coal which swells but shrinks badly to coal which does not swell but shrinks well could, taking account of the optimum coking capacity, lead to more certain operating results.

#### Coking conditions

The coking conditions can be expressed in terms of a specific heating characteristic  $K$ , which is the product of the overall density, the speed of carbonization and half the average width of the coking chamber

$$K = p \frac{B}{h} \cdot B$$

where  $p$  = overall density in  $\text{kg/m}^3$ ,

$B$  = half the average width of the chamber in cm,

$h$  = coking time in hours.

This specific heating characteristics is the reciprocal of Fourier's index.

Present operating conditions in the Ruhr are on average between  $K = 18$  and  $K = 24$ . The mathematical description of high temperature coking is limited to these operating conditions. But in future, and already in new and replacement constructions, values of  $K$  over 24 must be reckoned with, and this means that the mathematical description must be extended to this range.

Once the mathematical description of the primary product and of the coking conditions has been obtained, it is possible to formulate the quantitative relationship between these factors and the coke hardness properties. (6) With coke hardness  $M_{40}$ , this is expressed as:

$$M_{40} = a^1 K + b + M_s \cdot a^1$$

where:  $a^1$  is a specific coke hardness coefficient, showing the variation of coke hardness  $M_{40}$  in relation to the coking conditions  $K$ .  $a^1$  is a function dependent on the volatile matter and the coking capacity  $G$ . This factor  $a^1$  may also be obtained through the reflecting power and through analysis by groups of macerals. (7). This factor has the same importance as an operator as it can be expressed by a coefficient proportional to the atomic number.

$b$  is the coke hardness extrapolated to the specific heating characteristics  $K = 0$ , as the hardness varies linearly in relation to the specific heating characteristic  $K$  in the area between  $K = 18$  and  $K = 24$ .

$a^1$  shows the variation of coke hardness in relation to the particle size distribution index  $M_s$ .

An equation to obtain coke abrasion loss  $M_{10}$  is formed according to similar principles. (8). Coke hardness  $M_{40}$  and abrasion loss  $M_{10}$  are however based on the coke hardness test, which used to be operated in accordance with Standard DIN 51712. For more than a year now, however, Standard DIN 51717 has been binding in accordance with Recommendation ISO 556. This means that the conversion must be made, and this is done on the basis of a regression calculation. Account should be taken of the fact the hardness properties shown here refer essentially to coke hardnesses resulting from a particle size distribution of coke with a lower screening limit of 60 mm. Continually advancing blast furnace techniques make it possible however to use small and medium grades of sized coke. Because of these facts, a vast enquiry has been undertaken in the coking plants in the Ruhr; this should enable the range of validity of the mathematical description of high temperature coking to be extended.

This is also the reason why, in the criteria for comparing and evaluating the various qualities of coking coal and coke, coke hardness properties

have in the main been considered only as results of calculations. (9). Yield in coking products has been formulated by means of regression equations as a function of the primary product and the coking conditions according to the laws of mathematical statistics. These are the conditions in which it is possible to optimise yield, taking account also of the processing capacity and the potential output of the various products of carbonization.

The fact of taking the mathematical description of high temperature coking as a basis for optimising coking coal blends presupposes that the properties of coking coals and the coking conditions have been accurately determined. It is obvious that this should be expected, as especially in the operation of coke ovens - and even for very varied reasons connected with operation - there are relationships which cannot always be observed; this is the case, for example, with flue temperatures and heating time for a given wall thickness. The resulting errors can however be revealed immediately by programming the numerical value of  $a^1$ . It should also be assumed in principle that as long as it is not possible to undertake an extensive kinetic analysis of the carbonizing reaction, this reaction can only be dealt with by a statistical mathematical method. Another improvement to the analysis concerning the reaction rate is given by knowledge of the carbonizing reaction, considered as a function of the temperatures and the time.

At first sight the relationships mentioned here may seem manifold and very complex to the operating technician. But this is by no means the case as all the equations systems programmed in practice show themselves suitable for processing by electronic data processing equipment.

In the past optimisation of coking coal blends, taking into account coking plant operating requirements and mining planning, which was conditioned by the former structure of the mining companies, could only be carried out for a single company or even a single colliery. As a result of the merger of the mining companies in the Ruhrkohle A.G., optimisation is now in the forefront and can be carried out with better economic success. Indeed, in addition to the economic, technical and qualitative points of view mentioned, it is now possible to quantify all the factors which have an

influence, including transport. As a result of the research done by Mr. Simonis and his colleagues from the Steinkohlenbergbauverein with financial support from the ECSC, the preliminary data for practical applications are now available.

In this paper I have set out, from the point of view of those dealing with the raw material, the basic tasks incumbent upon the Ruhrkohle A.G. in the future and upon the Community's mines.

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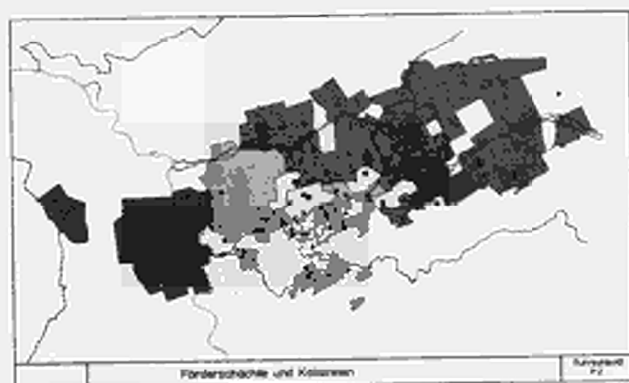


Figure 2

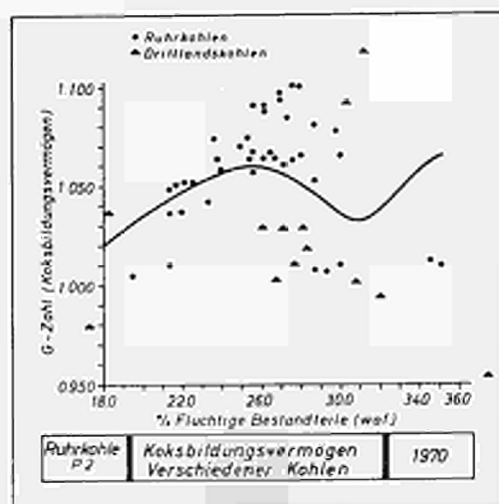


Figure 3

Coking capacity of different coals

Ordinate : G number (coking capacity)

Abscissa : Volatile matter, % d.a.f.b.

Legend : Ruhr coals

Foreign coals



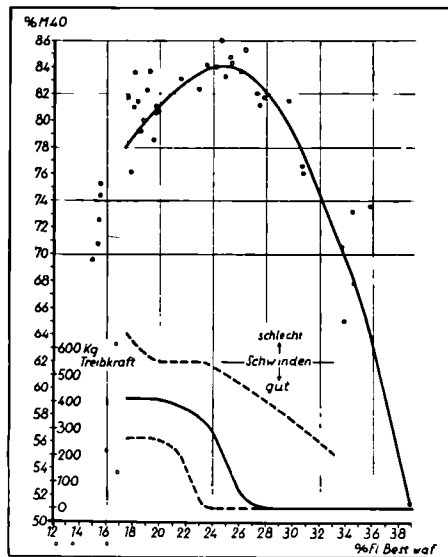


Figure 4

Coking characteristics as a function of  
volatile matter

Ordinates: M40 index; kg swelling pressure

Abscissa : Volatile matter, % d.a.f.b.

Legend : poor

Shrinkage

good

DISCUSSION

MM. Szpilewicz et Krupinski

Pit coal continues to be the backbone of Poland's energy balance and an important Polish export.

Geological and mineworking stocks are high, extraction and transport conditions favourable, the transportation costs low on the average, and the coal mining on the whole profitable.

Conversion costs in cokeworks are practically fully covered by sales of gas and by-products.

The domestic market for coke and other products' is secure for a very long time, since substitution by other energy media in the heating market can only take place to a limited extent.

Organization:

All cokeworks are nationalized, centrally run to a uniform plan, and subordinate to the Iron and Steel Industrial Association. This applies both to purely "smelting works" and to juridically autonomous "cokeworks".

Coking coal facts:

Low-carbon low and high gas coals still largely predominate.

Sub-bituminous coals are still imported to some extent.

Lower Solesian semibituminous coals are available in sufficient quantities. Highly bituminous coals - thanks to the new pits in the Rybnik district - are showing rapid growth. These have recently come to form an element in the equilibrium between supply and demand. They have also become a factor in Poland's increased exports of coking coal. The overriding directive at the moment is still to use sub-bituminous coals sparingly, satisfy metallurgical needs with the best possible quality, strictly differentiate coal mixtures and match them to the coke type concerned, and regard transportation questions as a subsidiary factor.

Technology:

The principle of differential grinding in relation to constituents is used practically everywhere.

Stamping is the prevailing modus operandi. Coking parameters in newly built oven blocks during the last 20 years at nozzle brick temperatures of 1330-1350°C.

Coke categories are individually tailored to the intended use. For blast furnace purposes, this is usually the over 30 mm fraction but for high-efficiency furnaces 30-50 and over 50 mm fractions are separated.

Up to 3/4 of existing coke oven batteries are largely standardized by chamber dimensions.

Coke economics:

Broad, multi-functional range of application.

The following facts can be quoted for 1969:

- a third of the total output, i.e. approx. 5 million tons, used for blast furnaces (sintering coke not included);
- another third goes to other industrial users (chemical, refractories, non-ferrous metal industries, etc.);
- the remainder is used for domestic purposes, goes to the trade, or is exported.

Specific coke rates (wet) at the moment (1969):

National average: 728 kg for a net burden weight of 2330 kg/ton of pig iron. For high-efficiency furnaces: 634 kg for a net burden weight of 2250 kg/ton pig iron.

We are counting on a continuing and practically linear increase of the coke demand in the next 10-15 years.

This expectation arises firstly from the national energy model and secondly from the growing importance of the role of Polish coke and coking coal within the overall pattern of the European steel industry.

As things stand at present, we expect for 1975 a coal production figure of 160 million tons and a cokeworks capacity of 18 million tons to be real and necessary.

The growth in coal production will largely come from bituminous coal.

These are favourable prospects for a broad-based cokeworks programme on which the equivalent of approximately 240 million U.S. dollars have already been invested in the past 20 years.

In our opinion, the model cokeworks of the sixties should have featured the following elements:

- large-capacity ovens combined with predrying and preheating of the coal together with dry coke cooling;
- far-reaching internal and external standardization of constructional elements in the refractories and engineering fields combined with light constructional principles;
- simplification of gas treatment.

The time has come for decisions.

Growth is our destiny.

Considerable resources and imaginative powers will be required for structural renovation and the reshaping of our existing cokeworks capacity.

We regard this task as part of the awaited overall European programme designed to secure fuel supplies for Europe's steel industry.

In this sense we regard closer technical and economical collaboration between the countries involved as useful and desirable.

M. Ligny

The task I have performed in presiding over the session on work devoted to "possibilities for choosing coal suitable for coking" has honoured me extremely: if I have been aware of this honour, I am now confused at having to speak after the notable accounts you have listened to this afternoon with such attention.

I will limit myself to giving thanks and expressing wishes.

The thanks: first of all to the Commission of the European Communities and in particular to the Director General, Energy, Monsieur F. Spaak, and to his collaborators who have organised the symposium whose success is uncontested and moreover incontestable. It was time, you were all aware, to deal with this problem of great urgency: the technique and development of coking.

Thanks go also to the speakers - experts or research workers - and to all those who participated in the discussions.

My wishes are directed to all the listeners, who I hope will find in this afternoon's exchanges of opinion a large complex of new knowledge in the field of coke production from primary materials of very varied origin and characteristics.

If my wishes are realised; this afternoon's session will constitute a means of safeguarding certain coal reserves whose economic role has sometimes been placed in doubt.

May the two days we have spent together in a community with a definite objective form the starting point of a new stage of progress and cooperation.

M. Schumm

Ladies and gentlemen,

Kindly allow me to say a few words at the close of this conference.

In the first place, I should like to say that I have been extremely impressed by the quality and high standard of the papers given on both days. As Coal Director I would like to take this opportunity to express once more to those who have given papers both my own regard and the thanks of the Commission for the unselfish efforts they have made in the preparation of their work and its presentation to us here.

I would also like to take this opportunity to repeat our special thanks to the city of Luxembourg for giving us the use of these magnificent rooms and for yesterday's reception, and to all departments of the Commission concerned for the tremendous work done on technical preparation and the exemplary organization of the conference. Our special thanks are also due to the translators.

I think I can say that not only the standard of the papers but also the general atmosphere and the spirit we have found here have contributed considerably to the success of the conference.

The fact that the hall is still full is proof that this conference was remarkable not only for its high standard but also for the fact that it took place at the right time, on the right subject, and at the right place. Ladies and gentlemen, bringing all these three factors into agreement is an art.

The two days have yielded a wealth of information.

- General Director Herr Spaak has presented a broad outline of the Community's energy policy:
- Minister Schaus, Vice-President of the Luxembourg government, has shown most impressively how the Luxembourg steel industry has solved the problem of securing its coking coal and coke suppliers on the basis of production within the Community;

- I was privileged to present, from the Commission's point of view the problems of a Community policy in the field of coking coal and coke;
- Finally, we have not been merely informed verbally about the latest developments in the field of coking; this information has also been provided in written form for us to take back and study carefully.

Ladies and gentlemen, I am a coal technologist. I regard myself - if you will - as a coal politician. Today's conference has shown that there are close relationships between coal policy and coal technology.

As a coal politician I am particularly interested at this moment, for example, in the problem of evaluating various coking coal qualities in relation to their coking properties, and in this context I followed the talk given by Herr Tognana with special interest. His remarks about the special problems of coking coal used in Italy will strengthen me in my efforts to do my utmost to have standard quality rules instituted within the Community.

I should also like to take the liberty at this point of throwing out a suggestion: In the Community we have test cokeworks. It would be a great step forward if the Community could take the necessary measures to see that coking coal imported from all areas of the world was coked under identical conditions. In this way it would not be long before the coking properties of these different coals and coal mixes were established objectively. May I invite you to think over the ways in which this simple task can be found a practical solution. With a little good will it surely must be possible to find quickly an answer to the problem.

Ladies and gentlemen, I must bring our proceedings to a close. Here we are setting directions for the future. The problems facing us tomorrow will depend on how we act today. Today, coolly, thoughtfully, and without emotion or wishful thinking, we have to take the right decisions. If this conference has contributed towards progress in the clarification of present technical and economic problems, then, from the Commission's viewpoint, I would like to say that it can be regarded as a complete success.

I thank everyone who has taken part in the conference, and in particular all those ladies and gentlemen who have contributed to its success, and I hereby declare the conference closed.





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