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USE OF POOR-COKING COALS IN THE IRON AND STEEL INDUSTRY

by

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Summary

While preserving the traditional technique of top charging moist coal, it is possible to manufacture a high-grade metallurgical coke by introducing up to 60% of poor-coking coal, provided that the coal is easily fusible. For this purpose it is necessary to crush the coke to a fairly fine size range, and to select a suitable make-up coal.

The technique employed at the Lorraine collieries, combining mixing with careful preparation of the blend (fine crushing, precise measurement of the constituents) and the addition of inert thinning-down materials, enables coals which are very difficult to fuse to be utilized; according to the characteristics of the latter, the proportion of make-up coal added can be reduced to a level of between 30 and 10 %.

Comparable results can be obtained with dry charging; it is often an advantage to combine this with systematic crushing of the coal.

1. INTRODUCTION

a) There exists a fairly wide range of techniques for the manufacture of metallurgical coke, that is, coke which can be utilized in the blast furnace, in which poor-coking coals are used alone, or blended with coals having complementary properties.

We will confine ourselves in this report to the principles underlying these techniques, referring to the literature for the technological details. On the other hand, we will attempt to specify the conditions of application and the possibilities offered by each, in order to guide users in the choice of technique best suited to their own particular problems.

b) The choice is governed by the following considerations:

i. The types of coal available. Under the name 'poor-coking coals' are included very variable qualities of coal, the utilization of which requires varying techniques. These techniques will be discussed on the basis of the Saar and Lorraine coals, with which our experience has been gained.

There are quite pronounced differences between the various types, which can illustrate clearly the spread of properties in the different categories of poor-coking or non-coking coals. Their laboratory characteristics, determined in accordance with international standards of classification, are shown in Table 1, as well as their classification number.

TABLE 1

Nomenclature	volatiles dry ash free	swelling index in the crucible	swelling index in the dilatometer	Roga index	International classification
Gras A	34 - 37	7.5 - 8.5	50 - 200		634
Gras B	36 - 38	6 - 7	15 - 25		633
Flambant gras A	37 - 39	3.5 - 6	0	40-60	632
Flambant gras B	38 - 40	2 - 3	0	20-40	721
Flambant sec	38 - 40	< 2	0	< 20	711

All these coals contain a high proportion of volatiles, but their plastic properties differ considerably. The gras A coals are very fusible and strongly swelling; if they are carbonized alone, by the traditional process, they give a well agglomerated but highly fissured coke, broken into small pieces and very 'frothy'. This coke can be used as a domestic fuel. The gras B coals are also readily fusible but are only slightly swelling; in the absence of special preparation they give a badly agglomerated and highly fissured coke. The flambants gras varieties are moderately fusible and swell either not at all or only slightly; it is impossible to charge them alone in a traditional coke oven, because it does not cake sufficiently to enable it to be discharged. The flambants sec are infusible under the thermal conditions of the coke oven.

ii. The quality of coke desired. This depends on the conditions under which the blast furnace is operated (nature of the ore, degree of preparation of the burden, configuration of the blast furnace) and varies greatly from one region to another. It is clear that the possibilities of using poor-coking coals increase with decreasing quality requirements.

We characterize the mechanical qualities of the coke, according to the normal French practice, by the two indices M 40 and M 10, as determined by the Micum drum test; the index M 40 represents the proportion over 40 mm after passing through the drum, and the M10 index the proportion under 10 mm. The following correspondence, in order of magnitude, can be assumed between the M 10 index and the 'hardness factor' (> 7 mm) determined by the tumbler test used in the U.S.A. :

M 10	hardness factor
6	72
8	67
10	62
12	58

It is agreed by most Lorraine metallurgists that the present limiting values are: M 40 > 78; M 10 < 8, but these limits vary widely from one region to another, depending on the blast furnace operating conditions; they are often less severe.

iii. The variety of coals available. The different techniques are adapted more or less satisfactorily to the variations in coal quality, which can impose fluctuations in conditions and operation.

iiii. The difference in price between the poor-coking coal and the make-up coal. The carbonisation processes for poor-coking coals often involve capital costs and, at times, manufacturing costs higher than those required for the conventional process. It could be tempting to compare two techniques by their capital and manufacturing costs. But these costs make up only a small fraction of the cost price of the coke, and the principal component of the cost price is always the price of the coal. The main factor to be taken into consideration when assessing the profitability of a carbonizing technique is therefore the proportion of poor-coking coal which can be used, and the difference in price between this coal and the make-up coal. If this difference is substantial, it could be an advantage to make use of a technique requiring a higher investment cost, if this enables a higher proportion of poor-coking coal to be used. If, on the other hand, the difference is small, then it would be necessary to restrict the choice to techniques, the cost of which is little more than that of the conventional process.

c) It is often of interest to combine a number of technical measures, in order to arrive at the optimum result. We will first examine individually the characteristics of different methods, after which we will give some examples of combinations utilized in Lorraine.

2. STAMP CHARGING

a) The ramming of the charge previous to loading it enables its density to be raised considerably; expressed in weight of dry coal per unit volume, the density can reach 950 kg/m^3, compared with a figure of the order of 700 kg/m^3 in the traditional process (top charging moist coal). Now the density of the charge exerts a great influence on the cohesion of the coke, which can be greatly improved by ramming, if the M 10 index is taken as a criterion of cohesion. This effect increases as the fusibility of the coal decreases. Thus ramming is especially useful when it is desired to use a high proportion of only moderately fusible coals, such as the flambant gras varieties.

Ramming has no direct effect on the size of the coke, except that it has a slight tendency to reduce it. But it enables a high proportion of the coke breeze to be added (see section 6) which greatly improves the M 40 index and the size of the coke (3).

To illustrate this statement we will give as an example the results obtained with a mixture of 70% flambants gras and gras à coke (Table II).

TABLE II

	M 10	M 40
Traditional process (10% moisture)	11.5	63
Ramming without coke breeze	6.2	60
Ramming + 10% coke breeze	6.6	40

By reducing the proportion of make-up coal to 10%, the M 10 index still remains at a suitable value of 7.5, but the M 40 index and the size range of the coke decrease considerably, and comparison with the traditional technique is no longer possible, because such a mixture would be only just dischargeable.

b) The technique of ramming is very old, but its field of application decreased considerably up to 1945, because it was thought to be too expensive. The result of the very great progress made in the technology of ramming under the stimulus of the Lorraine collieries is that this handicap has practically disappeared (4). The improvement obtained is based mainly on the following points:

1. The height of the oven unit has been taken up to 3.80 m. The ratio between the height and width of the oven is now about 9, although it was recently still considered imprudent to exceed 7.
2. The charge capacity of the battery, which can be served by a single ramming machine, exceeds 1500 tons.
3. The reliability of operation of the machines has been improved; breakdowns are very rare, and the risk of the rammed charge breaking is almost negligible. The coke ovens can now function satisfactorily without keeping a ramming machine in reserve.

These various improvements all have the effect of reducing investment and wages costs per ton of coke produced. The difference compared with the cost of the traditional process is now small.

c) In conclusion, stamp-charging can be strongly recommended when constructing a coke oven plant intended to operate permanently with poor-coking coals. On the other hand, it cannot be considered for a plant where the supply of high-volatile coals is not assured, and which, due to market fluctuations, may be led to charging a blend with a high content of true coking coal; because of the increased density of the charge the pressure on the furnace walls would certainly be dangerous.

3. DRY CHARGING

a) This technique, which consists of drying the coal before charging, has been thoroughly investigated since 1948 by the Station de Marienau on its experimental battery (3). It has been applied on the industrial scale since 1959 by the Hagondange coke oven plant.

The technology of the process (3) consists essentially of:

i. Drying and storing, which should be carried out in such a way that oxidation of the coal does not take place.

In the Hagondange plant the coal is dried in an oxidizing atmosphere, but it is cooled in the lower part of the drier and stored at a temperature below 40°C. Trials at the Station de Marienau (2) have shown that this cooling can be avoided and the temperature of the coal can be higher than 100°C, provided that neutral atmospheres are utilized for drying and preheating, and that certain precautions are taken in storing and maintenance. This procedure would simplify the drying equipment and improve the overall economic balance of the operation.

ii. Charging. In order to limit the ejection of pulverized material and prevent explosions, a special charging car has been designed, which has proved satisfactory.

b) Drying the coal greatly improves the coke quality; the improvement varies according to the nature of the coal, and is particularly marked with moderately fusible coals; it appears mainly as improved coke cohesion (the M 10 index). Two effects are obtained:

i. The density of the charge is increased; when the coal moisture is reduced from 7 to 2%, the density increases by about 1%.

ii. The temperature regime in the interior of the charge is modified. If the density of the charge is kept constant by an experimental device, it is found that a reduction in moisture content is still accompanied by an improvement in coke quality (1).

By way of example, the table below indicates the results obtained with three typical mixtures.

TABLE III

Gras A	70%					
Gras B			60%			
Flambant gras A					70%	
Gras à coke	30%		40%		30%	
	M 10	M 40	M 10	M 40	M 10	M 40
charge with normal moisture content (7%)	10.5	72	8.5	73	10.5	68
dry charging	8	73	6.5	74	7.5	66

The improvement in the M 10 index is little less than that permitted by stamp charging, especially where coals which are difficult to fuse are concerned, such as the flambants gras. On the other hand, the effect on the M 40 index is somewhat more favourable, but it is impossible to add equally large amounts of inert materials, such as coke breeze or semi-coke, without changing the M 10 index.

e) The reduction in the coal moisture content also has an important effect on the productive capacity of the battery and the consumption of underfiring gas. This arises simply from the fact that the amount of heat which must be supplied to the charge is less. A reduction of 1% in the water content of the coal increases the productive capacity by about 2.4%. If, for example, the water content is reduced by drying from 7 to 2%, productivity is raised by 14% (2) (6) (7). The drop in the consumption of heating gas is of the same order of magnitude. The resulting economy, both in capital and manufacturing costs, almost compensates for the costs of drying.

Preliminary drying has an additional advantage, in that it facilitates crushing: in particular it enables systematic crushing to be carried out without special screens, thus profiting from the advantages of this technique without large supplementary costs (see section 4a). It can readily be adapted, without considerable additional work, to an existing carbonization plant, and it is very easy to revert to 'wet' charging if the coke oven plant is obliged to utilize good coking coals, the pressure of which would be dangerous with a high charge density.

d) In conclusion, from the point of view of the grades of carbon which can be utilized, dry charging offers possibilities almost equal to those of stamp charging; but they are still somewhat inferior when very infusible coals have to be used (flambant gras). On the other hand, the investment and operating costs are a little less. There could thus be some difficulty in deciding between these two solutions, when it is a question of constructing a carbonizing plant in which it is intended to charge a high proportion of poor-coking coals on a permanent basis. On the other hand, dry charging is much preferable when an existing coke oven plant is to be modified, with the object of extending its range of operations, or when a new plant is to be constructed and it is intended to charge blends of various compositions.

4. CRUSHING AND SIZE GRADING OF THE COAL

The methods used can be divided into four categories.

a) Simple crushing involves passing the previously blended coke through a mill, or in some cases several mills in series; this is the method used in most coke oven plants. It is possible by using suitably dimensioned and well-maintained hammer mills to attain a fineness of 90% < 2 mm.

The usual aim is to crush to 80 to 85% < 2 mm. Beyond this, the gain in coke quality is less important. This depends on the density of the charge, however, and crushing should be finer for higher densities, as shown in the Table below.

TABLE IV

	Formulation			crushing 85% 2 mm		crushing 95% < 2 mm	
	make-up coal	gras A	gras B	M 10	M 40	M 10	M 40
'wet' charging	40	25	25	8.5	76.5	8.2	78.2
dry charging	30	35	35	7.3	73.5	6.9	79
stamp charged	15	73	12	8.1	60	6.5	72.5

There is a fineness limit which should not be exceeded with certain mixtures which are difficult to fuse, such as mixtures rich in flambant gras, but this limit is well below the values obtained in coke oven practice.

b) Systematic crushing consists in placing a screen above the mill, and only grinding the oversize; after passing through the crusher the coal is returned to the screen, so that all the material finally passes through the screen. This operation is readily carried out on a previously dried blend; it is also applicable to a moist blend if a heated screen is used. This technique, used in coke oven practice since 19[illegible]8, has recently benefited from considerable advances in screening technology; this progress has enabled screening capacity to be greatly increased, thus reducing the investment and manufacturing costs per ton of coke. A recent installation is treating 150 t/h, using 4 screens of 17 m^2 (moist coal crushed to 3mm).

Systematic crushing enables a more consistent mean particle size range to be obtained than is possible with simple crushing. All particles exceeding a certain size (for example 2 or 3 mm) can be eliminated with certainty, particles which are often the starting point of fissuring when they have a high fusion point, and at the same time the production of too large a proportion of fines, the present of which can be disastrous, is prevented.

The technique also guarantees a very consistent size distribution in the coke blend, in spite of fluctuations in the coal quality (in hardness and moisture) and in the amount of wear on the crusher; this results in more regular coke characteristics.

c) Differential crushing consists in submitting the constituents of the coke blend to simple or systematic crushing, previous to mixing, the crushing procedure varying with different constituents. As the parts played by the various constituents of a coke blend are not the same, it is conceivable that it could be an advantage to give them different crushing treatments. Generally speaking, it is better to crush finely the constituents which are readily fusible, and to crush less finely coals such as flambant gras or flambant sec, thus limiting the amount of very fine material; but the gain in coke quality is inconsiderable, and is closely dependent on the nature of the coal (1). Thus the technique is only economically justified in certain special cases.

c) Selective or petrographic crushing (9). By this term is meant all methods which consist in separating, by controlled crushing followed by screening, certain coals into several size ranges, having different compositions (ash content and petrographic composition) and hence possessing different coking characteristics. It is then possible either to eliminate some of these fractions by diverting them to other purposes, and only saving for carbonization the coals with the best coking characteristics; or to utilize all the fractions, after giving them a differential crushing treatment. Such treatments must conform strictly to the nature of the coal, and it is impossible to give general rules, apart from such simple rules as eliminating or crushing very finely the high-ash fractions.

5. **CHOICE OF THE COKE BLEND CONSTITUENTS**

a) For an existing coke-oven plant, with given equipment, the most effective means (in fact almost the only one) available of influencing the quality of the coke is the selection of coals charged and the choice of the proportions in which they are blended.

This problem often arises in the following way: the coke oven plant has available local supplies of poor-coking coal, to which it is obliged to add a certain proportion of make-up coal from another region. It wishes to reduce this proportion as far as possible, so it is a case of selecting the most suitable make-up coals for achieving this purpose.

b) There is no universal rule by means of which the coke quality can be predicted as an absolute value, in terms of the nature and proportions of the constituents; the quality of the coke is also dependent to a large extent on the characteristics of the coke oven plant. However, a systematic investigation in an experimental battery of large numbers of mixtures (10) (7), together with an analysis of the carbonizing mechanism based on laboratory studies (12) (13), has enabled us to predict how the coke quality varies when the characteristics and proportions are changed (11). The properties of the make-up coal which can appropriately be considered in this connexion are its swelling index in the dilatometer and its temperature of re-solidification (14). The latter varies as a rule in inverse proportion to the percentage of volatiles; the most characteristic properties of a poor-coking coal, on the other hand, are its coefficient of shrinkage on re-solidification and its swelling index in the crucible.

Without considering in detail the laws which have been established relating to the properties of the mixtures, they can be summarized as follows, as far as the choice of make-up coals is concerned:

i. When the base coal is a gras A, the best addition is a fusible coal, the re-solidification temperature of which may be as high as possible (corresponding roughly to a percentage of volatiles which is as low as possible). It should be fusible, but it is not necessary for it to be a swelling coal. These conditions lead to the selection of a carbon of the demi-gras type with 17-20% of volatiles (on a pure coal basis) (No.333).

i.i. When the base coal is a flambant gras, the make-up coal should be easily fusible and highly swelling; if this condition is met, its re-solidification temperature should be as high as possible. The combination of these two conditions leads to a gras type with 22-25% of volatiles (on a pure coal basis) (No.434).

i.i.i. The case of gras B lies between the two preceding examples.

c) These rules are a very useful guide, which is often sufficient for the purpose. But whenever possible, the best method of predicting the coke quality is to use an experimental oven, with a width equal to that of a carbonising oven, and with similar firing conditions. Ovens of this type, taking a charge of 300 to 400 kg of coke, have been used by various furnace builders or experimental stations (15). Suitably standardized and correctly operated, they supply very precise data, readily transposable to the operation of an industrial battery. However, their operation requires a highly experienced team, which can rarely be maintained by a single coke oven plant; such a unit can hardly be justified except for a fairly large group of coke oven plants.

6. ADDITION OF AN INERT MATERIAL

By this are meant infusible constituents such as: semi-coke, coke dust and lean coal, which are usually added in small amounts to the coke blend.

The action of an addition of this kind depends on the characteristics of the inert material, the nature and proportions of the coals to which it is added and the carbonising technique. The adoption of an inert material in a coke oven cannot therefore be decided without a study of each particular case, but in some instances it can lead to a considerable improvement in coke quality.

a) Coke dust

i. Whatever the coal mixture to which it is added, coke dust promotes an increase in the size of the coke and a rise in the M 40 index: this effect is considerable when the mixture naturally gives a highly fissuring coke (see Table II). The effect on the M 10 index is more complex; in small amounts of a few per cent, and when finely ground, the coke dust can produce a slight improvement in the index, reducing the 'frothy' parts of the coke. However, this effect is not always seen, because above a certain proportion of coke dust the action on the M 10 index becomes unfavourable, and there exists an optimum content, beyond which the improvement in the M 40 index is neutralized by the deterioration of the M 10 index.

i.i. An increase in the size of the coke dust particles exerts a favourable but weak influence on the M 40 index, and an unfavourable and very considerable influence on the M 10 index. This is why, in practice, a very finely crushed coke dust is added (of the order of 80% < 0.2 mm). The unfavourable effect on the M 10 index decreases with increasing charge density; for this reason the use of coke dust is particularly useful in stamp charging. It could also be effective in dry charging; but we have never found it to be an advantage, at any rate in Lorraine, in association with moist charging without ramming.

i.i.i. Up to the present, the coke dust has been obtained by drying and grinding the coke fines from the coke oven plant (0-10 mm). Until recent years this was a cheap by-product, but the development of iron ore sintering has led to a heavy demand and increased the price considerably. Allowing for the cost of grinding, which is relatively high, the cost of the price of the coke dust, at least in Lorraine, is comparable with that of make-up coals. Its use is still advantageous, however, because its effect on the M 40 index is much greater than that of the make-up coal (for a given content).

b) Semi-cokes

i. In contrast to coke dust, the effect of semi-coke is closely related to the nature of the carbon mixture to which it is added. When the mixture consists entirely of high-volatile coals, the anti-fissurant action of the semi-coke is considerable; it is less marked than that of coke dust, but it can be added to a mixture in a significantly higher proportion than coke dust without adversely affecting the cohesion of the coke. Thus a better final result can be achieved with semi-coke than with coke dust.

We have obtained the following results with the mixture 30% gras A - 70% gras B, charged dry:

TABLE V

% coke dust	% semi-coke	M 10	M 40
0	0	9.8	52
5	0	8.8	66
10	0	10.1	73
0	10	8.8	64
0	15	8.4	68

With a 10% addition, the antifissurant action (effect on the M 40 index) is greater with coke dust, but the M 10 index is unacceptable; the best compromise between M 10 and M 40 is obtained with 15% semi-coke.

If the quality of poor-coking coal which is available is taken into account, and it is found that the addition of semi-coke is insufficient to obtain the desired coke quality (this is the case in the example from Lorraine given above) it becomes necessary to add a certain proportion of make-up coal. But it is found that when the proportion of make-up coal is increased, the effect of the semi-coke diminishes; in other words, the effects of the make-up coal and semi-coke are not additive. The desired coke quality can be achieved by adding sufficient make-up coal, but the action of the semi-coke then becomes very slight, and it is then pointless to use it.

For example, we obtained the following results with the mixture of 30% make-up coal and 70% gras B, charged dry.

TABLE VI

% coke dust	% semi-coke	M10	M40
0	0	7	70
5	0	7	77
10	0	7.7	84
0	10	7.1	72
0	15	7.2	68

However, we have found that the effects of semi-coke and coke dust are to some extent additive, so that it is possible to obtain a better result by using coke dust and semi-coke simultaneously than by using either material separately (3). For example, using the mixture without make-up coal: 30% **gras A** - 70% **gras B**, it is possible by adding 5% coke dust and 10% semi-coke to obtain the indices M10 = 8.2 and M40 = 75.5.

ii. Another special feature of semi-cokes is that their effect is closely related to the conditions of manufacture, in particular the temperature at which they are produced (which governs the percentage of volatiles) (2) (3). It is thus very important to be able to control accurately the temperature of manufacture of semi-cokes. In this respect fluidizing processes are much better, because they enable a homogeneous semi-coke to be obtained at a temperature which can be regulated within a few degrees. The Marienau Experimental Station has developed a fluidized-bed coking process which can produce either a 'fluidization coke' which can be substituted for coke dust, or a true semi-coke, the temperature of manufacture of which can be controlled as required (16) (17).

It can be pointed out in conclusion that the size distribution of semi-coke has much less effect than that of coke dust; it is therefore unnecessary to grind it very finely, and in many cases it is sufficient to crush to the same fineness as the coal.

c) Lean coals

The action of lean coals with 8 to 12% volatiles is very similar to that of the semi-cokes: on the other hand the anthracites, containing very little volatile matter, have an effect approaching that of coke dust.

The different effects of adding the various types of inert substances, coke dust, semi-coke and lean coal, can be explained fairly satisfactorily by applying the mechanical theory of fissuring formulated by Foch (13) (3) (12). This enables the effectiveness of the addition of an inert material to be predicted in terms of the nature of the coal to which it is added, in accordance with the form of the shrinkage curve of the inert substance.

7. EXAMPLE OF RESULTS OBTAINED

a) To illustrate the above considerations we will conclude this report by reviewing the principal results which were obtained on the industrial scale in Lorraine by combining the various methods enumerated above. They can be classified into three groups:

i. Moist drying, not stamp-charged; fairly fine crushing (70 to 85% < 2 mm), with judicious choice of make-up coals and careful measurement of the constituents. This technique is used by the majority of coke ovens making metallurgical coke, and over 3 [illegible] 000 tons per annum are charged. The proportion of make-up coal can be reduced to 45-50%, the base coal containing a small proportion (generally less than 15%) of flambant gras (the remainder being gras A and gras B) (16). Some of these coke oven plants, operating with more accurate size grading, using the Cavaco technique, can reduce the proportion of make-up coal to 35%, while raising the proportion of flambant gras to 25%.

ii. Moist charging, combined with the addition of coke dust, very fine crushing of the coals (85 to 90% < 2 mm) a high carbonization temperature, and very precise measurement of the constituents (by means of load cells). This technique, put into operation by Houillères de Lorraine, is used for an annual production of 4 500 000 tons. It enables the proportion of make-up coal to be reduced to between 20 and 25% when the base mixture consists of equal parts of flambant gras and gras B. If the base carbon is a mixture of gras A and gras B, the proportion of make-up coal can be reduced to 10%.

iii. Dry charging, combined with systematic crushing. This is the solution adopted by the Hagondange coke oven plant (5). It enables the proportion of make-up coal to be limited to 30%, the base coal consisting entirely of flambant gras. If the base coal was made up of gras A and gras B, it would be possible to lower the proportion of make-up coal to 20%.

b) The figures given in section a) above relate to all the production of a coke, the quality level of which is that required at present by the Lorraine iron and steel industry (having an M 40 index between 75 and 80 and an M 10 index less than 8). If this level was lowered somewhat, it would be possible to dispense entirely with make-up coal, both for stamp charging and dry charging.

BIBLIOGRAPHY

1. R. LOISON and P. FOCH - 'Report on the activities of the Marienau Experimental Station in 1959' - Revue de l'Industrie Minerale (January 1961)

2. R. LOISON and P. FOCH - 'Report on the activities of the Marienau Experimental Station in 1960' - Revue de l'Industrie Minérale (September 1961)

3. R. LOISON and P. FOCH - 'Report on the activities of the Marienau Experimental Station in 1961' - Revue de l'Industrie Minerale (October 1962)

4. J. DURUELLE - 'Development of the Carling process in coking Lorraine coals'. - Revue de l'Industrie Minérale, Documentation Métallurgique (15 February 1956).

5. J. de MISCAULT, G. DAVID, P. FOCH and R. BUSSO - 'Application of the dry-charging process at the Hagondange coke-oven plant'. - Revue de l'Industrie Minérale (1961).

6. R. LOISON and P. FOCH - 'Production capacity factors of a coke-oven battery' - Revue génerale de Thermique (March 1962).

7. P. FOCH - 'Possibilities of using poor-coking coals offered by preliminary drying of the blend. Symposium on the carbonization of coal, Jealgora (India), March 1957' - Document Cerchar 1203 (November 1961 - text brought up-to-date)

8. R. LOISON - 'Coking of dry blends' - Revue dé l'Industrie Minérale, Document Sion Métallurgique, special number S.A. (1-15 February 1956).

9. E. BURSTLEIN - 'Selective preparation and petrography of coals for coking' - Chaleur et Industrie (December 1954).

10. P. FOCH and R. BUSSO - 'Choice of coal mixtures in the Lorraine metallurgical coke-oven plants' - Revue de l'Industrie Minérale (September 1958) - Technical note 4/58 of Charbonnages de France.

11. R. LOISON and P. FOCH - 'Choice of constituents of a coke blend' - (Proc.A.I.M.E. Blast Furnace, Coke Oven and Raw Materials Committee, Cleveland, 1958).

12. A. BOYER, LADAM and SOULE - 'The fissuring of coke' - Revue de l'Industrie Minérale (1953), Volume 34, No. 596, pp. 592-616)

13. A. BOYER, J. LAHOUSTE and R. MALZIEU - 'New studies on the coking of coal mixtures' - Revue de l'Industrie Minérale - pp. 232-256.

14. A. BOYER and J. LAHOUSTE - 'New laboratory tests for assessing the suitability of coals for coking' - Technical note No. 11/54 of Charbonnages de France.

15. P. FOCH and G. MEIMARAKIS - 'The use of 400-kg ovens in the study of carbonization' - 74th Congrés de l'Association Technique du Gaz (1957).

16. P. FOCH and J. GEOFFROY - 'Development of fluidization coking at the Marienau Experimental Station' - 31st International Congress of the Chemical Industry, Liège (1958).

17. J. GEOFFROY and P. CHAGNON - 'Production of cokes and semi-cokes from lignite in a fluidized bed' - Symposium 'The Iron and Steel Industry and Lignite' - Portoroz (Yugoslavia) (September 1960).

18. J. L. GOULE - 'Mechanical theory of the fissuring of coke' - Bulletin No. 17 of the Société Française des Mécaniciens.

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