Quality of Blast-Furnace Coke Produced in Wide Oven Chambers

by

Dr. G. Juranek
Dr. E. Falk

Ruhrkohle AG, Essen

Read at the 1st International Meeting on
Coal and Coke Applied to Iron Making Conference
Rio de Janeiro, August 1987

Short Abstract

Since 1985, Ruhrkohle AG has been operating coke ovens with a chamber width of 590 mm. The operational experiences revealed that a high coal charge bulk density and coking times which are shorter than previously supposed made it possible to virtually setoff the loss of performance associated with wide oven chambers. The wide oven chamber allows for producing good blast-furnace coke from charge coal blends containing 50 % and more of marginal coking coals (high-volatile and low-volatile coal). An aspect deserving special emphasis is the easy oven push even if the charge coals contain just 23.5 % (wf) volatile matters.

In contrast with previous expectations, wharf coke from wide oven chambers is not greater in grain size than coke from standard width chambers. It bears the result that the coke grade pattern of such a coking plant does not differ from the coke grade pattern of coking plants operating ovens with a commonly usual chamber width.

In the Federal Republic of Germany, the theoretical bases for the design and construction of large high-capacity coke ovens have been established (1,2)* within the scope of the advanced development and modernization of cokemaking technology. The first projects have been realized and put on stream (Table 1).

Operational experience substantiated results of tests run in the 70s and it revealed that the loss of performance entailed by a wider oven chamber was judged much too unfavourably (the exponent n in conversion of coking times ranges at 1.20 rather than at 1.5 as supposed previously).

Along with the findings that the charge bulk density in wide oven chambers increases, it leads to an economic setoff in the relation between performance loss and productivity rise in coke production in wide oven chambers.

Generally, oven pushes are considered easier on account of the greater shrinkage of coal charge, a feature which certainly will bear positively on coke oven service life.

As a result of the substantially reduced number of coke ovens at the same given capacity, a remarkable decrease in environmental pollution could be noticed around these wide oven batteries.

*) Figures in brackets refer to reference list attached.

Apart from these positive experiences, the question arises whether and how the quality of coke produced in high-capacity wide coke ovens in the long run differs from the quality of coke produced in standard-width coke ovens.

As Ruhrkohle AG operates coke ovens being between 410 mm and 590 mm wide, there were sufficient data available to draw the desired comparison. The reference point for this comparison should be the results from previous tests for carbonization in wide oven chambers as well as physical coke properties (grain size range, strength) which were determined on operation at RAG coking plants.

1. Carbonization Tests to Determine the Raw-Material Basis for the New Prosper Coke Plant Construction

Bergbauforschung GmbH made a lot of experiments and tests at bench scale level and on their test coke plant with the objective to investigate how chamber width influences performance rate, oven pushes and coke quality. The results of these tests were reported on recently in certain papers (2).
Parallel to these studies, selective tests were run from 1981 till 1983 on coals forming the raw-material basis for the new Prosper coke plant which led to the following findings in comparison with a carbonization in standard-width coke oven chambers:

- Charge bulk density increases with chamber width.
- A charge coal blend for wide coke ovens may contain abt. 15 % high-volatile (gas flame) coals and just limited portions

of low-volatile coal (10 %) and/or coke breeze (3 %).

- Charge coal shrinkage is abt. 4 % (abs.) greater, ovens are easier to push.

- Following the stabilization which is common practice in screening facilities, coke contains abt. 25 % of the fraction > 80 mm, and abt. 5 % of the fraction 25 - 40 mm. (Fig. 1) The coke strength index M 40 is abt. 2 percentage points higher than it is for coke produced in standard-width coke ovens. Coke abrasion is not affected by chamber width.

2. Range of Coals for RAG Coke Plants

Cokemaking characteristics of charge coal blends from RAG coking plants are summarized on Table 2 which makes possible to classify coke plants into two groups:

a) Coke plants with charge coal blends featuring good coking properties (coke plant 2,4,5,6).

b) Coke plants the charge coal blends of which feature excessive coking property (coke plants 1,3 and 7 thru 10).

The Prosper coke oven plant where high-capacity large-volume coke ovens are in operation, belongs to group (a). The comparison to be presented below will cover this group of coke oven plants when it matters to rule out and disregard the influence of raw-material basis on coke properties. The comparison will also include for group (b) coke plants when it matters to highlight the influence of charge coal properties on coke quality.

3. Charge Coal Blends of Prosper Coke Oven Plant

The charge coal blend of the new Prosper coke oven plant normally comprises 4 components, the properties of which are summarized on Table 3. The components are equally distributed and spread in layers on the coal homogenization stockyard with a capacity of abt. 55,000 tons adequate to meet 1 week's demand each (Fig. 2).

On reclaiming the entire stockyard cross-section, a charge coal blend is obtained which can be considered very uniform (7). Standard deviations for the most significant properties of the charge coal blend range within the following orders of magnitude:

	Pts
Water	± 0.25 up to 0.4
Ash	± 0.15 up to 0.25
Volatile Matters	± 0.25 up to 0.4
Grain Size < 2 mm	± 1 up to 2
< 0.5 mm	± 1 up to 2

Upon reaching the intended operation time, it could be found that the charge shrinkage accounted for abt. 10 % with the achieved high bulk density amounting to approx. 890 kg/m³. With oven pushes giving no cause for concern as reported previously by other authors (5,6), the decision was taken to gradually increase the portion of low-volatile coals in the charge coal blend (Fig. 3). Presently, as shown on Fig. 4, a charge coal blend is used which contains abt. 18 % high-volatile coal and 35 % low-volatile coal, and hence is far away from the desirable optimum if conventional criteria are taken as yardstick. This blend does not come within the range of charge coal blends which is considered optimal by Miyazu and Simonis.

This measure has led to the unexpected finding that oven pushes and coke quality remain invariable if charge coal blends containing extremely high portions of low-volatile coals are used and if charge shrinkage decreases to 7 %. This feature can be considered the result of a higher charge bulk density and a lesser mean coking rate. The reduced content of volatile matters in the charge coal blend and the high charge bulk density bear a positive influence on productivity of coke ovens.

4. Wharf Coke

Planning of the Prosper coke plant was based on the understanding that coke from wide oven chambers would be coarser in grain size than coke from narrow oven chambers. For this reason, the screening plant was equipped with primary screens and spiked roller crushers of a bigger than normal capacity (Fig. 5).

The testing of wharf coke made upon commissioning of Prosper coke plant brought two significant findings:

a) Coke from wide oven chambers showed no evidence of the interdependence between heating flue temperature and coke grain size range (coke strength characteristics) during heating-up phase which was found to notoriously occur on plants with a lesser chamber width (Fig. 6).

b) The grain size of wharf coke from wide oven chambers hardly differs from the grain size range of wharf coke from other RAG coke plants with standard-width coke oven chambers (Fig. 7).

5. Blast-Furnace Coke

Wharf coke is handled differently on every coke oven plant. The number of conveyor belt transfer points, heights of fall, type and intensity of screenings, separation and crushing of oversize grains bear an influence on:

- grain size range of blast-furnace coke and yield of coke smalls 0-25 mm
- coke strength.

Comparative evaluations of coke quality from coke plant to coke plant therefore must be established with consideration for local, prevailing conditions in screening plants and even then, the results cannot be utilized or adopted without reservation.

5.1 Grain Size Range of Blast-Furnace Coke from Prosper Coking Plant

The grain size range of blast-furnace coke from the Prosper coking plant shown on Fig. 8 covering 2 time periods (January - June 1986 abt. 15 % low-volatile coal; October 1986 - February 1987 abt. 30 % low-volatile coal) is summarized to one average value each.
Fig. 8 shows that the doubling of the low-volatile coal portion in carbonization in wide oven chambers merely involved a slight

variation in the grain size range of blast-furnace coke. This proves to be in perfect compliance with the results of previous tests run by Bergbauforschung (Fig. 1).
The grain size range of blast-furnace coke does not differ from the grain size range of No. 5 coke plant coke (494 mm chamber width) where oversize grains + 80 mm are crushed as well. Blast-furnace coke from No. 7 coke plant is coarser in size with a similar raw-material basis despite a chamber width of just 450 mm, because the grain size + 80 mm is not crushed there.

5.2 Blast-Furnace Coke Yield

The careful crushing of the fraction + 80 mm yields coke 25 - 80 mm but also 0 - 25 mm coke smalls. Hence it is quite interesting to draw a comparison between coke grades obtained on various RAG coke plants (Fig. 9).
On the basis of balancing computations to vary the portions of various grain size fractions, it is possible to verify the crushing effect of spiked roller crushers on two coke plants of ours (Fig. 10). It does not reveal either any difference in coke grades obtained on crushing of coke produced in differently wide coke oven chambers.
Despite a crushing of oversize coke grains + 80 mm, the Prosper coke oven plant does not produce more grains sized 0 - 25 mm than other RAG coking works.

5.3 Coke Strength

As there obviously exists a correlation between M 40 index and grain size range of the coke sample put into a drum (8,9), RAG

in co-operation with German metallurgical works in 1984 decided to apply the following method for blast-furnace coke quality determinations:
50 kg of coke with the grain size range supplied to the metallurgical works will be put into the Micum test drum. After 100 revolutions, the screen analysis of coke is carried out (Fig. 11).
By drawing a comparison between the portion of various fractions before and after the drum test, the tendency to decompose of single fractions is then evaluated (degree of stabilization).
The degree of stabilization of coke from the Prosper coking works will be compared in Table 4 with the degree of stabilization of blast-furnace coke from other RAG coking plants.
These figures indicate that upon 100 revolutions which in fact are made to simulate the mechanical stresses during coke passage through a blast-furnace

approx. 84 % of the grain size > 40 mm (N 40/V 40 x 100)

approx. 93 % of the grain size > 25 mm (N 25/V 25 x 100)

remain unchanged.

Under mechanical stress, little grain size 25 - 40 mm (7.2 %) is obtained and the coke features unusually low N 10 abrasion indices (5.6 %). Hence, the coke from the Prosper plant, despite its unusual coal blends, judged by its strength indices can be considered equal to the coke from those RAG coking plants which use coals with excessive coking property (coke plant 7 thru 10 (Table 2)).

6. Summary

The evaluation of operational results from the Prosper coke plant judged by its physical coke properties indicates that a wide oven chamber with the same specific performance offers unexpected opportunities to broaden the range of coals for carbonization.

The maximum portion of low-volatile coal accounting for 10 % as determined in previous tests could be stepped up to 35 % without involving any deterioration for oven operation or coke properties. The coal charge blend carbonized in wide oven chambers therefore can contain approx. 50 % marginal coking coals (35 % low-volatile and 18 % high-volatile coals) which is considered as being a special flexibility for coal carbonization viewed from the raw-material basis. It is safe to assume that those notorious problems with heavy pushes known from narrow oven chambers will not occur in a wide oven chamber as a result of the higher shrinkage of the coal charge.
Wharf coke from wide oven chambers is not greater in grain size than coke from standard-width coke ovens. This is probably attributable to the evolutionary mechanism of cross fissures and cracks in coke cake. Blast-furnace coke loaded for transportation upon being stabilized shows a narrow grain size range and is characterised with a very good strength index (little tendency to decompose). An aspect deserving special emphasis is the very high structural strength of coke (low abrasion index N 10) obtained from this charge coal blend (30 % and more low-volatile coal). Future studies will have to clarify whether it is caused by a secondary conditioning effect involved by a greater bulk density and the somewhat lesser coking rates.

Reference List

1. G. Nashan — Considerations and Developments to a New Design of Coking System. Paper read at: Annual Convention Association of Iron and Steel Engineers, Chicago 1986

2. W. Rohde, D. Habermehl, K. G. Beck — Cokemaking in 18, 24 and 30 Inches Wide Oven Chambers. Comparison of Throughput, Coke Quality, and Battery Operation, Fifth International Iron and Steel Congress, April 1986

3. K. Leibrock, H. Groß, H. Petak, E. Harion — Experience and Developments of the Saarberg Stamping Technology for Coking in Large Chamber Ovens. 41st Ironmaking Conference, Pittsburgh, March 1982

4. R. Beckmann, H. Bonnekamp, G. Winzer, H. Dürselen, D. Heese, G. Meyer — Design, Commissioning and Operation of the World's Largest Coke Oven Battery at Mannesmannröhren-Werke AG 45th Ironmaking Conference, Washington, April 1986

5. W. Holz, F. Schönmuth, D. Stahlhern, F. Wackerbarth — The Modernisation of the Prosper Coke Oven Plant 45th Ironmaking Conference, Washington, April 1986

6. K. D. Mielke, U. Stewen — Quality of Coke from Wide Oven Chambers with Special Regard to Suitability for Blast Furnace Process. 4th Nippon Steel-RAG Techn. Meeting, April 1987

7. W. Stewen
F. Schönmuth

Conception of Plants Units for Conditioning of Charge Coals with the Scope of the Pad-up Rebuild of the Coke Oven Sector on Prosper Plant
4th Nippon Steel-RAG Techn. Meeting, April 1987

8. A. Scholz
H. Sporbeck

The Strength of Blast Furnace Coke
Glückauf-Forschungshefte 42 (1981), Vol. 4, P 2 - 8

9. A. Scholz
K. Eppels

A New Way to Describe the Strength of Blast Furnace Coke
Paper read at the "Deutscher Kokereiausschuß und Hochofenausschuß", 1984, Manuscript

Coke Plants in the Federal Republic of Germany

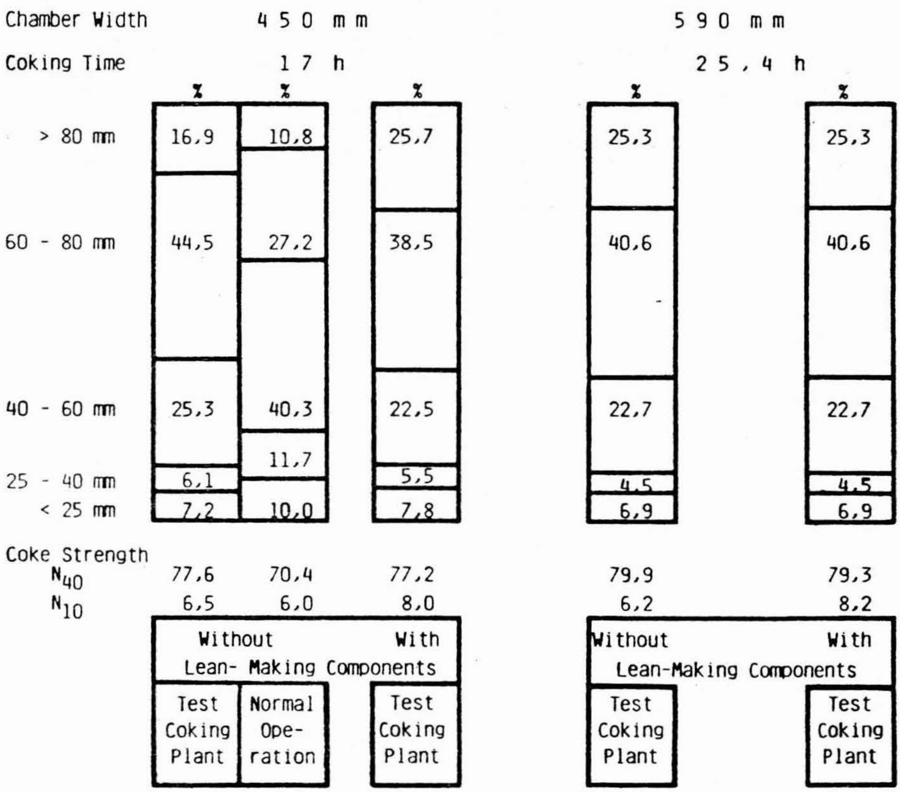
where Large-Scale High-Capacity Coke Ovens are in Operation

		Coke Plant (3, 4, 5)		
		Mannesmann Huckingen	R A G Prosper/Bottrop	Zentralkokerei Saar Dillingen
Commissioning		Jan. 1985	September 1985	April 1984
Number of Ovens		140	100 (150)	90
Oven Dimensions (hot)				
Length	mm	18.000	16.600	16.500
Heigth	mm	7.850	7.100	6.250
Width	mm	550	590	480
Effective Volume	m^3	70	62,3	43,6
Coal Bulk Density (wet)	kg/m^3	856	860	1.130
Coking Time	h	22,4	24,5	19,6

Tab. 1

Fig. 1

Grain Size Range and Strength of Coke from Test Carbonizations



Coking Properties of Coal Blends from RAG Coking Plants

Reference Figures	Coke Oven Plants									
	1	2	3	4	5	6	7	8	9	10
Volatiles (d) %	27,0	23,5	25,0	25,0	26,0	23,0	25,0	24,0	25,0	25,0
Volatiles (daf) %	29,0	25,2	27,0	27,0	28,0	25,0	27,0	26,0	27,0	27,0
Swelling Index	8 ½	7	8	7 ½	7	7 ½	8 ½	8 ½	8 ½	8 ½
Dilatation %	100	31	85	34	15	43	205	144	158	195
G-Index	1,069	1,009	1,060	1,015	0,975	1,026	1,087	1,075	1,071	1,083
max.Fluidity DDPM	900	200	590	325	36	94	690	400	463	650
Maceral Group Analysis										
Vitrinite %	74	69	71	67	64	78	75	77	73	74
Exinite %	5	5	3	5	7	5	5	2	5	5
Inertinite %	15	21	21	23	21	12	14	14	17	18
Minerals %	6	5	5	5	8	5	6	7	5	3
Mean random Reflectance %	1,10	1,32	1,26	1,21	1,21	1,32	1,16	1,25	1,19	1,21
± 2 S %	0,35	0,64	0,45	0,56	0,68	0,52	0,11	0,21	0,18	0,11

Tab. 2

Components of Coal Blend from Prosper Coking Coal

	Volatiles (daf)	Dilatation %	max.Fluidity DDPM	Rm ± Stand.Dev. %
Gas Coal (KK I)	35 - 36	30 - 40	200	0,87 ± 0,17
Low volatile Coal	16 - 17	- 9	2	1,6 ± 0,42
Medium volatile Coal (KK III)	25 - 26	135	1.100	1,2 ± 0,17
Medium volatile Coal (KK II)	27 - 28	170	1.700	1,15 ± 0,23

Tab. 3

Fig. 2

Coking Coal Transportation to the Blending Stockyard

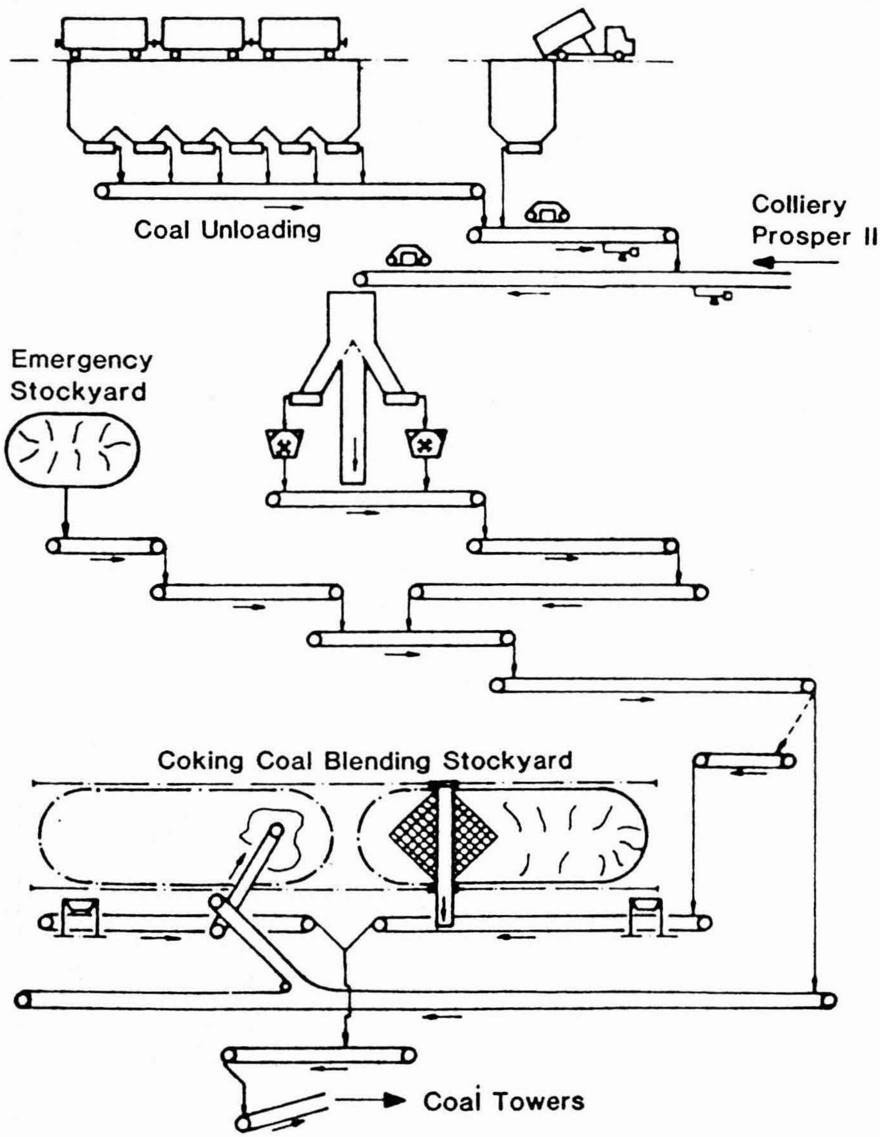


Fig. 3

Charge Coal Blends on Prosper Coking Plant

Chronological Trend 1986/1987

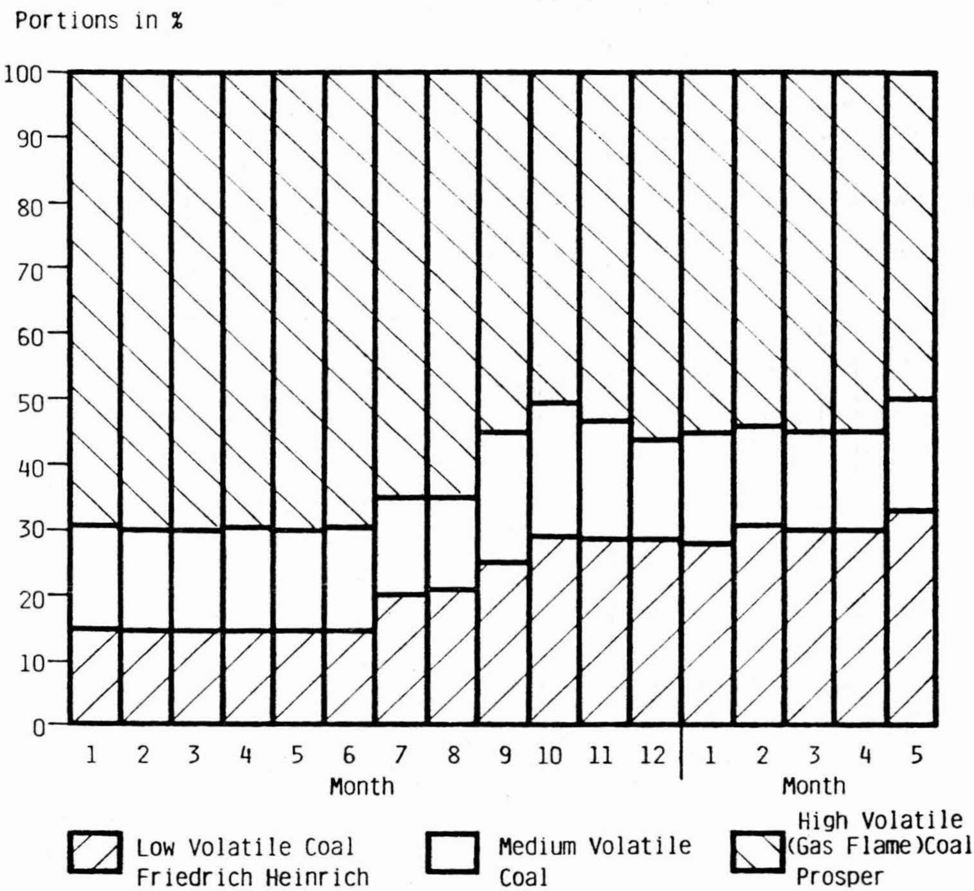


Fig. 4a

COKING PROPERTIES OF COAL BLEND
COKING PLANT PROSPER

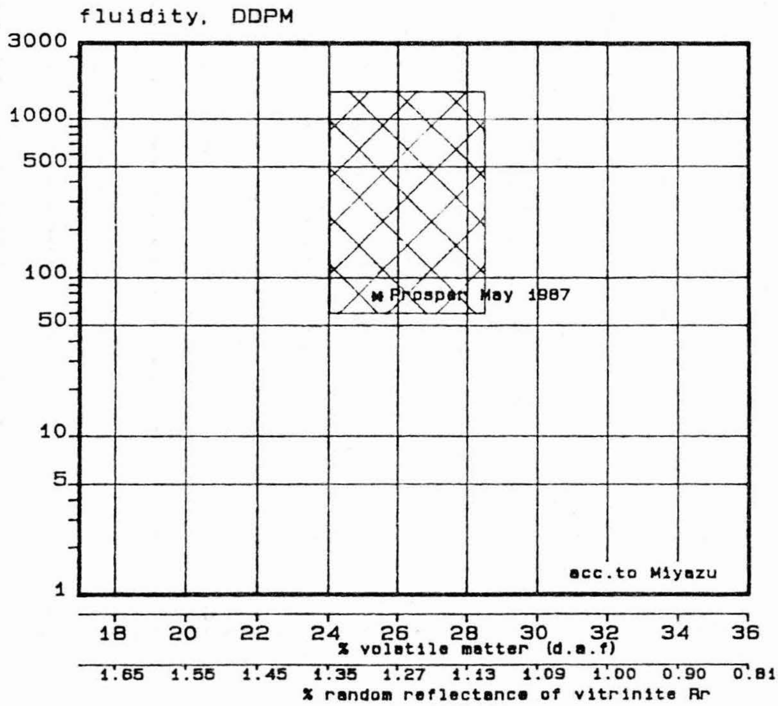


Fig. 4b

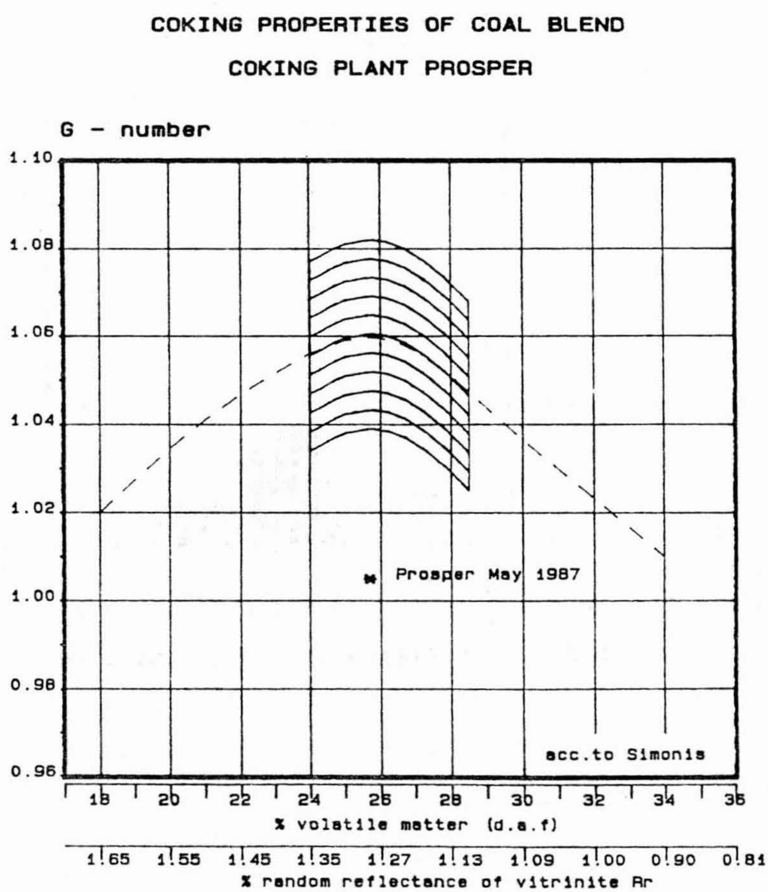

COKING PROPERTIES OF COAL BLEND
COKING PLANT PROSPER
G - number
1.10
1.08
1.06
1.04
1.02
1.00
0.98
0.96
Prosper May 1987
acc.to Simonis
18
20
22
24
26
28
30
32
34
36
% volatile matter (d.a.f)
1.65
1.55
1.45
1.35
1.27
1.13
1.09
1.00
0.90
0.81
% random reflectance of vitrinite Rr

Fig. 4c

COKING PROPERTIES OF COAL BLEND

COKING PLANT PROSPER

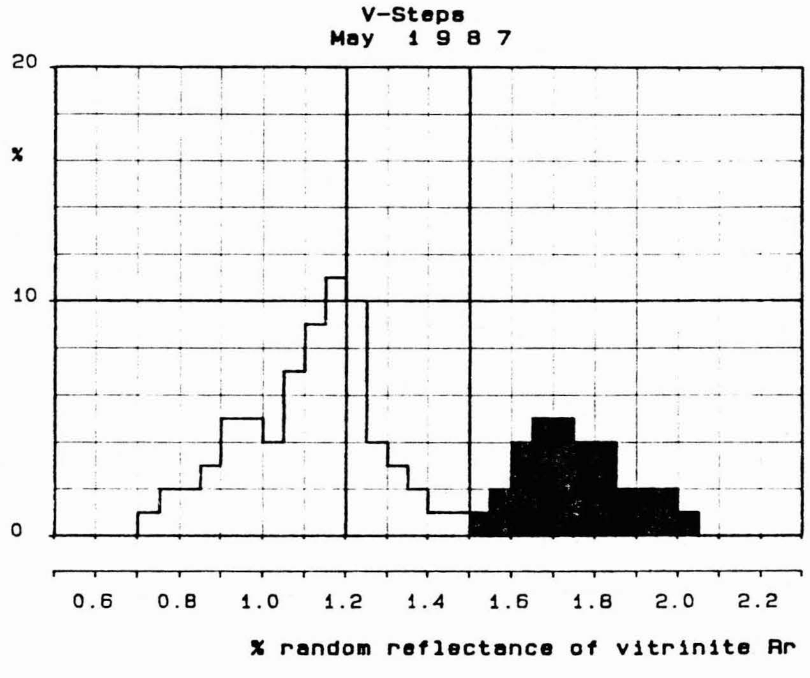


Fig. 5

Coke Screening Plant

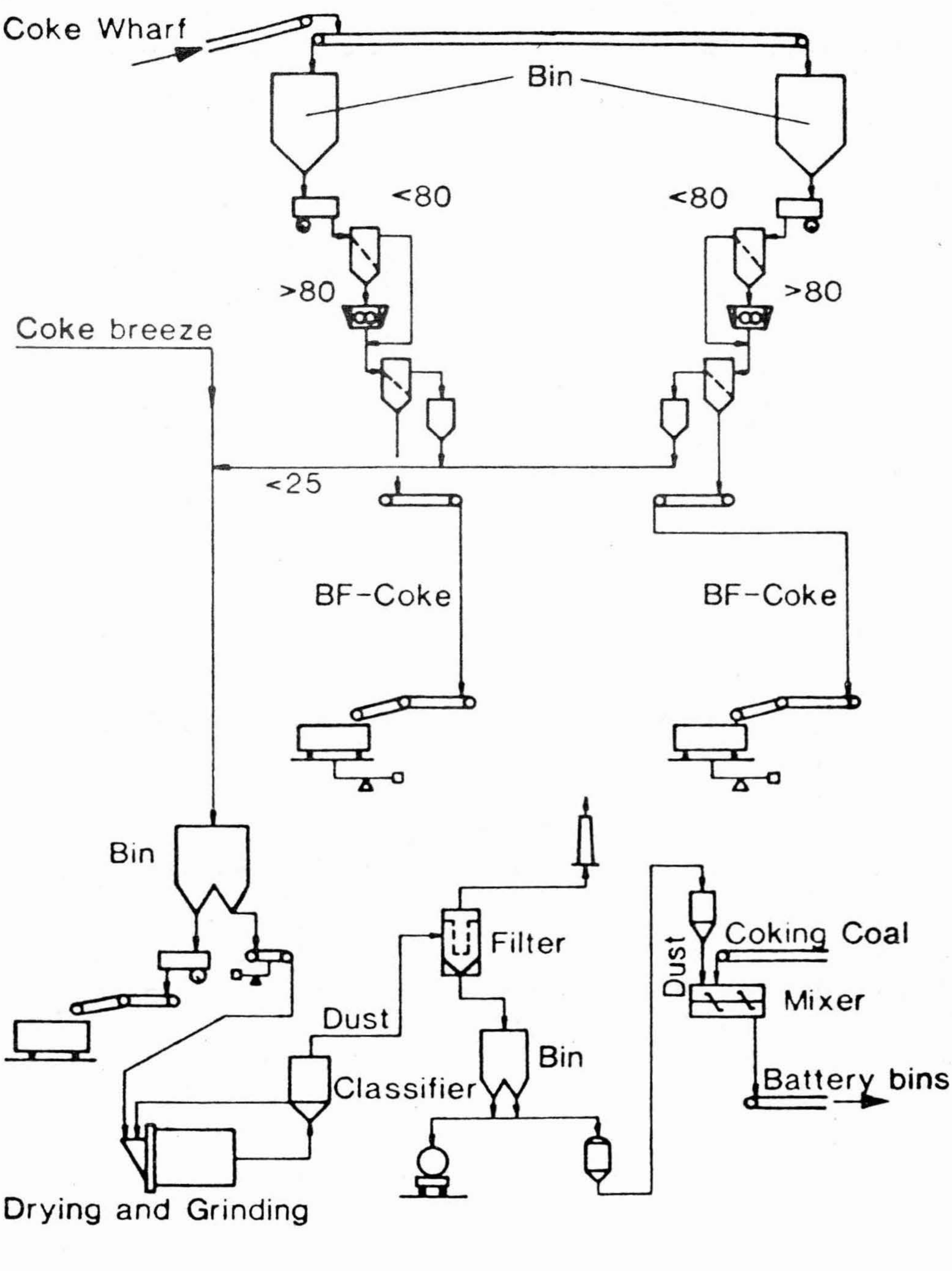
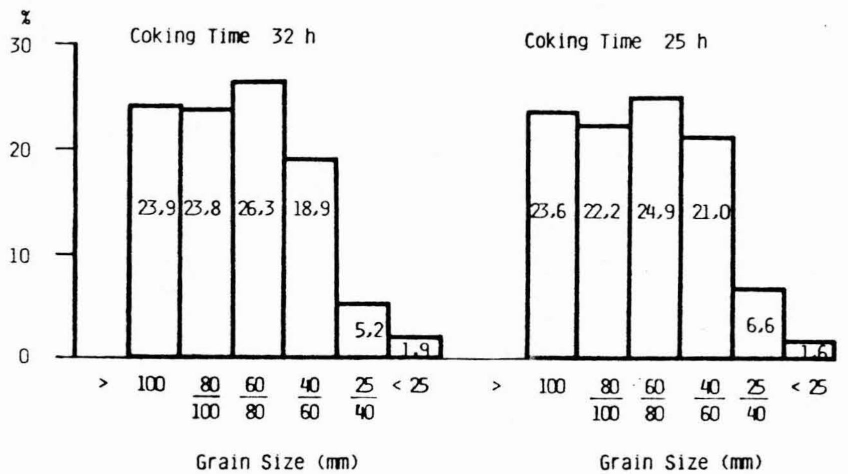


Fig. 6

Interdependence of Wharf Coke Size and Operation Time (Heating Flure Temperature)



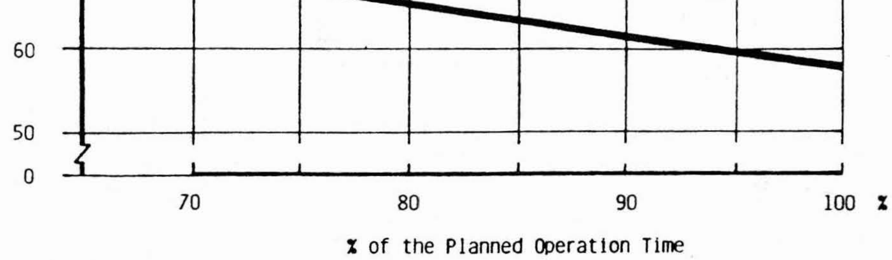


Fig. 7

Grain Size Range of Wharf Coke for Coke Oven Batteries with Different Chamber Widths

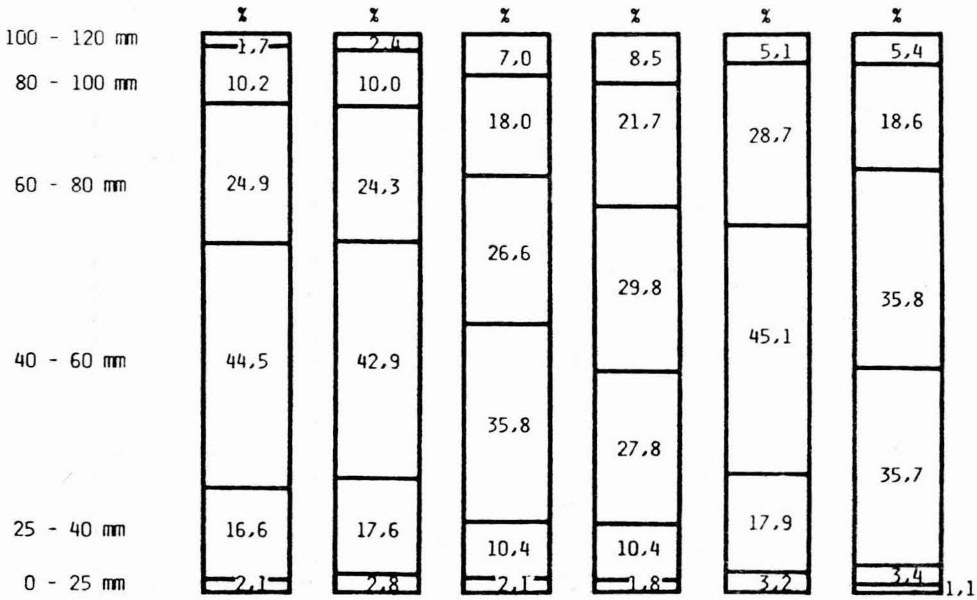
Coke Plant	6	Prosper
Chamber Width mm	447	590
Coking Rate mm/h	11,5	12,0
Grain Size Fraction:		
> 100 mm	18,1%	24,6%
100 - 80 mm	24,4%	21,8%
80 - 60 mm	28,1%	24,7%
60 - 40 mm	20,8%	21,4%
40 - 25 mm	4,6%	5,6%
< 25 mm	4,0%	1,9%

Fig. 8

Grain Size Composition of B. F. Coke from Various RAG Coke Oven Plants

Coke Plant	Prosper		4	5	5*	6
Chamber Width mm	590	590	444	494	494*	447
Coking Rate mm/h	12,0	12,0	12,5	10,5	10,5	11,5

Grain Size:



*) Edged by Crushing the Fraction > 80 mm

Fig. 9

Coke Grades on Various RAG Coke Plants

Coke Plant	Prosper	1	3	4	5	8	6	9
Chamber Width mm	590	437	450	444	494	410	447	391
Coking Rate mm/h	12,0	12,2	11,7	12,5	10,5	10,9	11,5	10,5

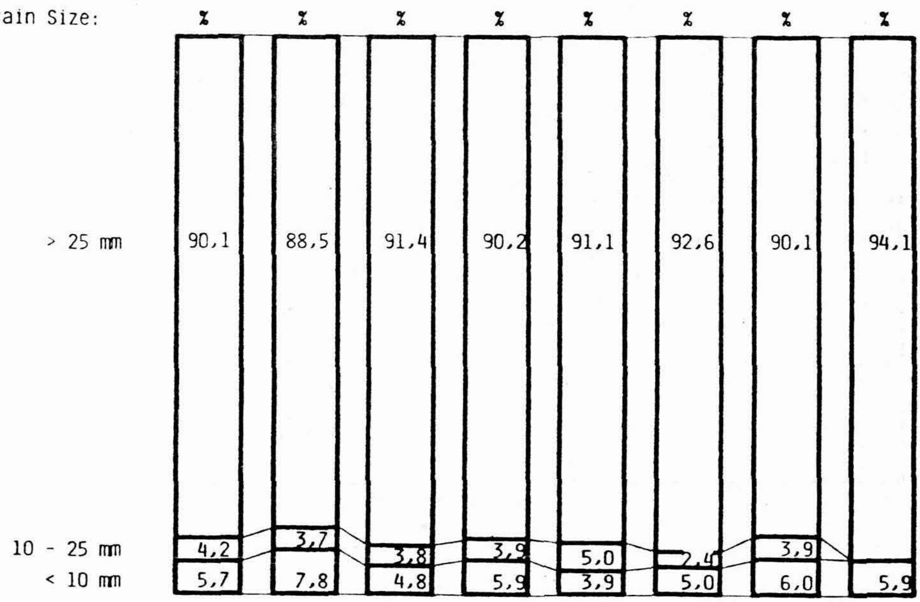
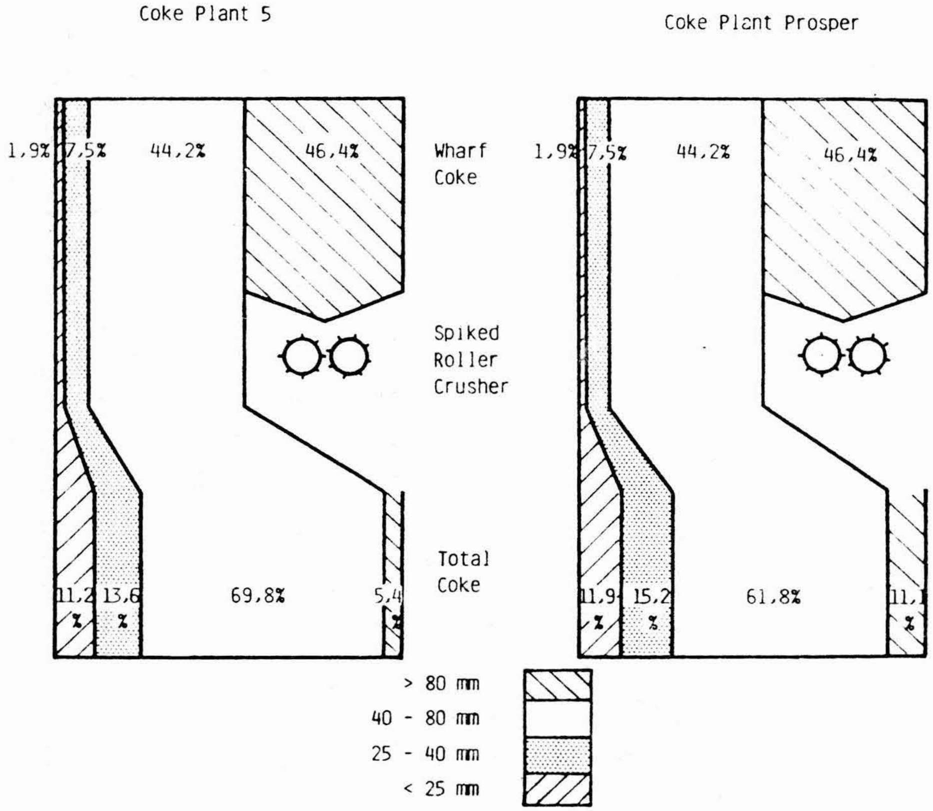


Fig. 10

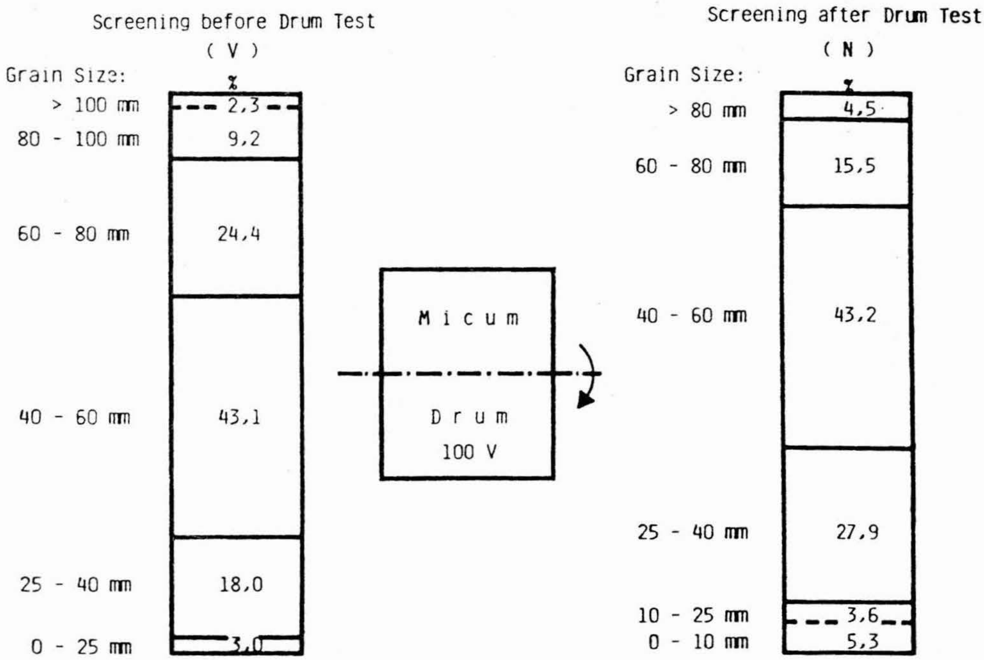
Crushing of Coke > 80 mm in Spiked Roller Crushers



Crushing of 1 000 kg Wharf Coke > 80 mm Yields:
- 470 kg Coke 40 - 80 mm
- 290 kg Coke 25 - 40 mm
- 240 kg Coke > 25 mm

Fig. 11

Method Applied by R A G for Description of Coke Strength



$\frac{N\ 40}{V\ 40} \times 100 = 80{,}1\%$ $\quad$ $N\ 25\text{-}40 - V\ 25\text{-}40 = 9{,}9\%$

$N\ 10 = 5{,}3\%$

Tab. 4

Strength Characteristics of B.F. Coke produced on RÄG Plants

January - June 1986

		Prosper*	1	3	4	5	5*	8	6	9
		%								
Before Drum Test	V 40	81,0	85,0	84,4	86,9	84,2	79,0	93,9	95,6	92,4
	V 25 - 40	16,9	12,9	13,6	10,9	14,0	17,8	4,8	3,4	6,1
	V 25	97,9	97,9	98,0	97,8	98,2	96,8	98.7	99,0	98,5
After Drum Test	N 40	67,2	66,2	60,1	63,3	62,1	61,2	77,8	80,2	77,2
	N 25 - 40	24,1	24,2	29,6	25,2	26,5	28,3	14,1	11,5	14,8
	N 25	91,3	90,4	89,7	88,5	88,6	89,5	91,9	91,7	92,0
	N 10	5,6	5,7	5,5	6,2	6,5	6,3	5,5	5,5	6,4
	N 40 / V 40 x 100	82,9	77,9	71,2	72,8	73,7	77,5	82,8	83,8	83,5
	N 25 / V 25 x 100	93,2	92,3	91,5	90,5	90,2	92,4	93,1	84,6	84,7
	N 25-40/V 25-40 x 100	7,2	11,3	16,0	14,3	12,5	10,5	9,3	8,1	8,7
	N 10	5,6	5,7	5,5	6,2	6,5	6,3	5,5	5,5	6,4

*) not greater than 80 mm