Rept Bk No 39-61

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Deutz Plant and Equipment (Australia)
Pty. Ltd.,
Attention: Herrn Dr. E.R. Pohl

504 Bridge Road,
RICHMOND MELBOURNE VICTORIA

Australia

Dühsburg
Dusseldorfer Str. 352

Ref: Dr.R/1

8th March 1955

Low Shaft Furnace Process for Nairne Pyrites Ltd.

Department of Mines Adelaide Inquiry DM 1518/52

Dear Mr. Pohl,

During the pre-tests carried through with the raw material supplied by the Department of Mines we obtained the following results:

Analyses

	Nairne pyrites	Newcastle Coal	Leigh Ck. Coal	Angaston.
Fe	55.38%	6.81%	3.29	1.66
Mn	0.17	0.32	0.28	0.40
P	0.06	0.02	0.66	0.22
S	1.00	not det.	not det	traces.
Cao	0.55	1.83	7.95	54.60
Mgo	0.36	0.34	1.70	traces
Sio	10.85	54.25	46.80	0.22
Al_2O_3	2.98	28.99	34.50	traces
C fix	-	50.40	31.46	-
CO_2/loss due to burning	2.02	-	-	42.79
vol	-	34.65	44.95	-
H_2O	-	3.80	13.50	-
ashes	-	14.95	23.95	-

The coal analyses of line 1-8 were taken from the coal ashes

REPORT ON THE BRIQUETTING TESTS WITH AUSTRALIAN RAW MATERIAL

In the appendixes we have summarized the detailed statements about all pre-tests and briquetting tests with Australian raw material placed at our disposal i.e.

10 kgs of Newcastle Coal
10 " of Leigh Creek Coal
10 " of Nairne Pyrites
10 " of Angaston Marble (Limestone)

All details can be seen from our appendixes.

The pre-tests have proved that the use of only Leigh Creek coal or big parts of it as mixing components would not be favourable. Carbonization tests with Leigh-Creek coal briquetts without ore and fluxes components but with the addition of binders up to 8% have proved to be unfavourable. When using pitch as well as petroleum bitumen as binder, there were always powdery remains from the carbonization. On the other hand, the carbonization tests with poor baking Newcastle proved to be favourable. Even the addition of about 10% Leigh Creek Coal resulted a surprising improvement of the briquette's qualities provided the fluxes to be added were marble. More better results were reached by the addition of limestone instead of marble. On this reason we propose, to use - if possible - limestone as fluxes for the planned low shaft furnace plant. As the Leigh Creek coal is being produced with a pit moisture if about 31 - 36% a higher use of this coal should not be advisable owing to the higher costs of transport and drying. With reference the above mentioned reasons we have carried through most of our tests with Newcastle coal, which we suppose to be sufficiently at disposal.

It can be seen from the enclosed burden calculation that owing to the proportionally high Sio_2 - and low $_Ca?$- contents of the Nairne pyrites higher amounts of limestone have to be charged as well. Consequently it would be advisable to use limestone hydrate ($ca(OH)_2$) if there are sufficient quantities at disposal and the ways of transport and freight charges are favourable. If marble is to be used as fluxes, special care has to be taken on the briquettes mixture grain structure in order to get resistance and, nevertheless porous combined ore coal briquettes. As can be seen from the enclosed appendixes, point B, the briquetting tests No 7 8, 11, 12, 13, 14, 15, 17, 19 20 and 23 can be considered as 'good'. The tests No 15 and 18 can even be considered as 'excellent'. For the both last mentioned test series marble was used as fluxes for No 15 and limestone for N 18 Furthermore it was proved, that too high an amount of marble as fluxes did not result the required resistibility of the combined ore-coal-briquette. A ration of 6-8% pitch or petroleum bitumen proved to be a favourable ration for the binder

Appendix C shows briquetting tests with higher consumption of material on rolling presses proving good results under No 1 Also in this case it is proved that a ratio of coal of 50% Newcastle coal or 40% Newcastle coal and 10 per cent Leigh Creek coal will result resistant combined ore-coal-briquettes which have proportionally big pores and become good carbonization coke even in a respectivelly cocking temperture of up to 1000OC and only small amounts became 'liquid coke'.

In accordance with the test results we are of the opinion that the Australian raw material sent to us is absolutely suitable for our process. The sense of the Statements about the use of marble can be applied hereto as well.

We have to remark, that we have carried through our pretests with the Newcastle pit coal, as we think that this coal with its higher contents of volatiles will be more economical than the Leigh Creek coal you have sent to us as well. Some months ago we have carried through long-time tests with American open burning coal which in its analyses is quite similar to a German open burning coal and gained a good success

The output of tar condensates of about 450 kg pure tar/t PI from the top furnace gas produced is just so excellent that the whole amount of binders necessary for the briquetting was covered by this production. Furthermore, there was still a remarkable abundance of tar for other purposes. We suppose that also in Australia tar will be welcomed for carburizing purposes in the Siemens Martin stove or for chemical purposes as well as for street building as tar macadam.

As to our experience won during our various long time tests with similar raw material and sorts of coal there will be no difficulties for the production of steel pig iron as well as foundry pig iron from raw material of the kind and constitution you have sent to us. Enclosed we are sending a burden calculation for haematite pig iron and foundry pig iron each. For the last mentioned sort of pig iron possibly a phosphor containing material would have to be added to the foundry pig iron burden in order to reach a phosphor contents in correspondence with the various sorts of pig iron for foundries. (o,8-1,8%) Accordingly for the production of steel pig iron a manganese-containing material would have to be added to the haematite burden.

We should like to call your attention to the fact, that it will be absolutely possible to produce a special foundry pig iron ~~xx~~of the supplied Australia raw material (Nairne pyrites New castle coal and Angaston marble (limestone), which meets the demands of the ahpero cast ie. with low Mn and P contents as well as with a silicium contents what ever required. In accordance with the test the pig iron produced from the American raw material which in the test report of the German Max-Planck-Institute for Iron Investigation in Duesseldorf was stated to be similar and of the same value as the special sorts of pig iron the special suitability of the low shaft furnace pig iron for steel casting purposes (chill casting among others) was proved in a well-known German

Sphero-
idale
Graphite
Gast Iron

rolls producing foundry.

As Herr Dr. Pohl has informed us on occasion of his visit some time ago, the State South Australia is interested in the erection of a centrifugal casting foundry for the production of spun iron pipes. The low shaft furnace pig iron, which is being produced as foundry pig iron, could be used for this purpose as well. In this case it would be useful to charge the liquid pig iron into a gas-heated mixer, and to produce spun iron pipes in a direct process by overheating and use of the respective carbon-contents and the respective analysis, hereby evading the cupola furnace. Moreover, we like to call your attention to the fact, that the heating of the mixer can be carried through with the high-valuable has produced during our low shaft furnace process.

In this case in question it would be practicable as to our experiences to use a flat-hearth type mixer, as is operated by the Halberger Huette in Brebach Saar for their spun iron pipes and centrifugal casting foundry as well. (see for "Stahl und Eisen" 1935, No. 6, Report No. 143 of the Hochofenausschuss (Board of Blast Furnace Experts).
We found out, that the use of the Newcastle pit-coal, samples of which you have supplied to us, will guarantee in the low shaft furnace process the favour of an essential gas and tar production. As to our experiences with similar American pit coal the gas will have a calorific value of 1400 - 1450 calories (157 - 163 BTU/cb.ft.). With regard to the gas volume there will be 10% more gas than in the respective blast furnace process, consequently the gas credit will be a 60% better one - by the 50% higher calorific value and the increased volume - than in the conventional blast furnace process.

Moreover, the blast supply for the low shaft furnace plant is less expensive - because of the smaller pressures required - than the conventional blast furnace with its essentially higher charging shaft.

In case, in the planned low shaft furnace plant there are not sufficient consumers for the gas produced, for instance it could be used for the heating of a moulding or core-drying stove in a foundry connected to this low shaft furnace plant. Moreover, it could be used as additional heating in a steam boiler plant in power stations, or in forging plants and rolling mills.

The quality of the marble you sent to us is excellent, but it is only conditionally suitable for the production of combined ore-coal briquettes based on your raw material.

It was proved by the pre-tests that there will be a slag volume of about 1250 kgs/t PI. This slag can be granulated or foamed, accordingly it is suitable for the cement production as well as for the production of slag bricks or pumice slag.

In this case in question the fuel consumption of coke with 85% C amounts to 1450 - 1550 kgs/t PI, and it is expected that it will be a better one in a big plant.

The performance of further tests is necessary for a reliable detailed calculation of ecomomy. We propose 3 tests in the water jacket furnace in our plant in Koeln-Kalk; for this purpose we will need about the following raw material:

15 t Nairne Calcines
20 t Newcastle Coal

We are of the opinion, that the supply of limestone is not necessary in this case. We would carry through these tests with a German limestone of a similar constitution. We would perform 3 tests with a charge of 5 t briquettes for each. The calculation of burden would be based on the sorts of pig iron required by you; this is haematite iron as we suppose. The costs for these tests would amount to about DM 12.000, provided, that you will deliver the required material free of any freoght charges to our plant in Koeln-Kalk.

Based on these tests, we would be able to let you have the following technical data:

1. Raw material Balance.
2. Production sheet with statements of the PI-

Slag-, Dust- and Gas-Analysis.
3. Results of a Pre-Test for the Tar-Output.
4. Calculation of Economy.
5. A draft plan for a low shaft furnace plant with 2 furnaces with a daily capacity of 100 t each.

If you are of the opinion, that beside of the water-jacket furnace tests we should perform a long-time-test, our low shaft furnace pilot plant with a daily capacity of 12 tons in Koeln-Kalk will be at your disposal for this purpose. In this case we propose the performance of tests with a smelting period of 4 days, for which the following raw material is required:

150 t Nairne Calcines
200 t Newcastle pit coal.

Also in this case we would operate with German limestone, for to keep the costs of these tests as low as possible. The cost for the big test would amount to about DM 120.000.— to 150.000. In this connection we should like to remark, that at the present time we are completing the plans for low shaft furnace plans for other foreign customers, for instance in Spain and then in Italy, which are based on the results of water-jacket-furnace tests only.

We have completed a report about the long-time-tests with American raw material in the beginning of 1954; as soon as this report will be printed - in the middle of 1955 - we will send it to you for your information. As the coal of the American raw material is similar to that in Australia, the water-jacket-furnace tests proposed by us can be used for comparison purposes resp. their results can be considered transferable foraa big plant.

We would like you to study our information and data, and we look forward to a soon reply.

Sincerely yours,

DEMAG-HUMBOLDT NIEDERSCHACHTOFEN GmbH.

(Encl.) (Sgd.) Dr.,H. Reinfeld Dr. A. Reichmann

DEMAG - .HUMBOLDT
NIEDERSCHACHTOFEN GMBH

Herrn Dr. E.R. Pohl, Deutz Plant, Australia

Dr. R./L. 8-3-1955

Low Shaft Furnace Process, Nairne Pyrites Ltd.

Briquetting Tests with Australian Raw Material.

REPORT

Supply:

About	10 kgs Coal "Newcastle"	
	10 kgs " "Leigh Creek"	
	10 kgs pyrites "Nairne"	
and	10 kgs marble (limestone) Angaston (lumpy).	

The analysis of the bituminous "Newcastle" coal supplied proved the following constitution:

Fe	Mn	P	SiO_2	Al_2O_3	CaO	MgO	SO_3	water	ashes	vol	C fix	S
6,81	0,32	0,22	54,25	28,99	1,83	0.34	0,69	3,80	14,95	34,65	50,4	1,4

The "Leigh Creek" coal is a sub-bituminous coal, like about the boehmische hard brown coal,

Analysis of "Leigh Creek" coal.

Fe	Mn	P	SiO_2	Al_2O_3	CaO	MgO	SO_3	water	ashes	vol	C fix	s
3,29	0,28	0,66	46,80	34,50	7,95	1,70	0,90	13,50	23,59	44,95	31,46	0,4

Both sorts of coal were supplied in a corn-mixture up to 2 mm.

The calcined pyrite "Nairne" had the following screen analysis and constitution:

Screen-Analysis:

2	mm	8,51%
2- 1	mm	3,83
1- 0,5	mm	3,83
0,5- 0,3	mm	3,83
0,3- 0,2	mm	3,40
0,2- 0,12	mm	8,94
0,12	mm	67,66

Constitution:

Fe	Mn	P	S	SiO_2	Al_2O_3	CaO	MgO	loss due to burning.
55,38	0,17	0,06	1,00	10,85	2,98	0,55	0,36	2,02

The marble "Angaston" was supplied in a lumpy condition as the fluxes planned; it had the following constitution:

Fe	Mn	P	S	SiO_2	Al_2O_3	CaO	MgO	Loss due to burning.
1,66	0,40	0,02	traces	0,22	traces	54,60	traces	42,79

Deutz Plant & Equipment (Aust.) Pty. Ltd.,
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CALCULATION OF BURDEN FOR SOUTH AUSTRALIAN RAW MATERIALS.

Burden No. A.

	%	Kg	Fe	Mn	P	S	CaO	MgO	SiO_2	Al_2O_3	C_{fix}	CO_2	Volatile
Ore N x)	30.3	100	55.38	0.17	0.06	1.00	0.55	0.76	10.85	2.98	-	2.02	-
Coal NC x)	39.3	130	1,33	0.07	0.08	-	0.35	0.07	10.54	5.55	65.52	-	45.04
Coal L x)	9.2	30	0.23	0.02	0.05	-	0.56	0.12	3.31	2.44	9.43	-	13.48
Limestone	21.2	70	0.48	0.07	0.01	-	37.84	0.41	0.80	0.15	-	29.75	-
total in P.I.	100.0	330	56.42	0.22	0.16	1.00	-	-	-2.14	-	74.95	31.77	58.52
in slag			1.00	0.11	-		39.30	1.36	23.36	11.12			

Analysis of Pig Iron

Fe approx.	93 %
C	4.50
Si	1,50
Mn	0.36
P	0.26
S	0 .050

Quantity of Slag approx. 1250 kg/ton P.I.

Coke Rate Approx. 1460 kg/ton P.I.

$P_1 = \frac{CaO}{SiO_2}$ approx. 1.65

$P_2 = \frac{CaO+MgO}{SiO_2+Al_2O_3}$ approx. 1.18

x) N = Nairne Calcines
x) NC= Newcastle Coal
x) L = Leigh Creek coal.

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Appx. 1B

CALCULATION OF BURDEN FOR SOUTH AUSTRALIAN RAW MATERIALS.

Burden No. B.

	%	kg	Fe	Mn	P	S	CaO	MgO	SiO_2	Al_2O_3	C_{fix}	CO_2	Volatile
Ore N x)	30.3	100	55.38	0.17	0.06	1.00	0.55	0.76	10.85	2.98	-	2.02	-
Coal NC x)	48.5	160	1.63	0.08	0.05	-	0.43	0.08	12.98	6.83	80.64	-	55.44
Marble	21.2	70	1.16	0.28	0.01	-	38.22	-	0.15	-	-	29.95	-
Total in P.I.	100.0	330	57.17	0.36	0.12				1.58		80.64	31.97	55.44
In slag			1.00	0.17		1.00	39.20	0.84	22.40	9.81			

Quantity of Pig Iron = 61.5 kg

Coke rate = 1545 kg/ton P.I.

Quantity of slag = 1215 kg/ton P.I.

Analysis of Pig Iron

Fe	93.50 %
C	4.50
Si	1.20
Mn	0.59
P	0.18
S	0.030

Analysis of Slag

CaO	37.94 kg (CaO=39.20kg)	50,76 % (51.11%)
MgO	0.84	1.12
SiO_2	22.40	29.98
Al_2O_3	9.81	13.13
FeO	1.29	1.71
MnO	0.22	0.29
CaS	2.24	2.99
	74.74	100.00

$$P_1 = \frac{(CaO)}{(SiO_2)} = \underline{1.75}$$

$$P_2 = \frac{(CaO)+(MgO)}{(SiO_2)+(Al_2O_3)} = \underline{1.24}$$

x) N = Nairne Calcines
x) NC = Newcastle coal.

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BRIQUETTING TESTS WITH SOUTH AUSTRALIAN RAW MATERIALS.

No.	Coal NC	Coal L	Ore N	Binder	Carbonization Temp. (Cooking Temp.)	Remarks / Conditions found
				A. Pre - Tests.		
1	20 g	-	-	-	1000°C	baked
2	-	20 g	-	-	1000°C	powdery
3	10 g	10 g	-	-	1000°C	baked - powdery
4	10 g	5 g	5 g	-	1000°C	powdery
5	15 g	-	5 g	-	1000°C	slightly sintered - powdery
6	15 g	5 g	-	-	1000°C	slightly sintered
7	15 g	-	5 g	-	1000°C	slightly baked
8	15 g	5 g	-	-	1000°C	slightly baked
				B. Briquetting Tests (hydr. Press)		
				Softening point (Fusing point)		
1	60 g	-	40 g	Pitch 6%	600 - 800°C	'liquid coke', slight cracks
2	30 g	30 g	40 g	" 6%	600 - 800°C	very porous) no 'liquid coke'
3	30 g	30 g	40 g	" 8%	600 - 800°C	porous)
4	60 g	-	40 g	" 8%	600 - 800°C	firm coke, slight cracks
5	40 g	20 g	40 g	" 6%	600 - 800°C	no 'liquid coke', very porous
6	40 g	20 g	40 g	" 8%	600 - 800°C	good, coke production
7	50 g	10 g	40 g	" 6%	600 - 800°C	good, firm coke, few big cracks
8	50 g	10 g	40 g	" 8%	600 - 800°C	good firm coke, few big cracks

No.	Coal. NC	Coal L	Ore N	Fluxes	Binder	Carbonization Temp. (Coking Temp.)	Remarks / Conditions fould
9) 10)	100 g	-	30 g	21 g marble 2 mm	pitch 8%	600 - 1000°C	powdery, easily powderable, no deliquescing of bitumen.
11	40 g	10 g	30 g	20 g marble	'Strabag' bitumen 8%	600 - 800°C	firm, good coke production deliquesced bitumen.
12	40 g	10 g	30 g	20 g marble 0.5 mm	'Strabag' bitumen 7%	600 - 600°C	firm, good coke production, deliquesced bitumen.
13	40 g	10 g	30 g	29 g marble 2 mm	'Strabag' butimen 6%	600 - 800°C	rather firm, good coke production, deliquesced bitumen.
14	40 g	10 g	30 g	20 g marble 0.5 mm	'Strabag' bitumen 6%	600 - 800°C	rather firm, good coke production, deliquesced bitumen.
15	100 g	-	30 g	21 g marble 0.5 mm	'Strabag' bitumen 6%	600 - 1000°C	very firm, very good coke production, deliquesced bitumen.
16	100 g fine		60 g	40 g mable 0.5 mm	pitch 6%	600 - 1000°C	powdery
17	100 g fime		60 g	20 g marble 0.5 mm	pitch 6%	600 - 1000°C	good, firm coke, deliquesced bitumen.
18	100 g		60 g	40 g lime-stone hydrate	pitch 6%	600 - 1000°C	very good, firm, 'liquid coke'
19	100 g		60 g	40 g sand	pitch 6%	600 - 1000°C	good, firm, 'liquid coke'.
20	100 g		60 g	40 g marble 1 mm	pitch 6%	600 - 1000°C	rather good, no 'liquid coke'.
21	100 g		60 g	40 g marble 0.5 mm	pitch 6%	600 -,1000°C	good, firm, slightly 'liquid coke'.
22	70 g	30 g carbonized 1mm	60 g	40 g marble 0.5 mm	pitch 6%	600 - 1000°C	rather firm, no 'liquid coke'.
23	70 g	30 g	60 g	40 g marble 0.5 mm	pitch 6%	600 - 1000°C	good, rather firm, slightly 'liquid coke'.

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No.	Coal NC	Coal L	Ore N	Fluxes Marble	Binder	Carbonization Temp. (Coking Temp.)	Remarks - Conditions found

C. Briquetting Tests (Rolling Press)

No.	Coal NC	Coal L	Ore N	Fluxes Marble	Binder	Carbonization Temp. (Coking Temp.)	Remarks - Conditions found
1	40 %	10 %	30 %	20 %	6 %	600 - 800°C	Strenght in cold condition 25-30kg, after one day's storage.
						heated up to 1000°C in the retort.	no sticking together The briquettes have sufficient strength, and are relatively very porous; there were only small amounts of 'liquid coke' to be found.
2	50 %	-	30 %	20%	6 %		

The Present State of Development of the DEMAG-HUMBOLDT- Low-Shaft-Furnace Process after the completion of the Long-Time-Test with American Raw Material in the beginning of 1954.

GENERAL REMARKS

Owing to the rapid development in the pig iron and steel production of all countries during the last 50 years, it has been taken into consideration which amount of the necessary raw material - especially of coal stocks - is still at disposal for the next decades. The classic smelting process for the pig iron prodiction is the reduction of iron ore in the blast furnace with the use of lumpy, abrasion-proof coke. A modern blast furnace is also being charged with burden material which has been prepared in order to reach the optimum of charging capacity. The preparation of the burden material consists of the sintering of coarse grained ore, which is screened and the grain-sizes suitable for the blast furnace process - 40 - 80 mm. - are thereby seaprated from the fine ore. Thereafter the fine ore is being charged into the blast furnace, partly sintered, i.e. agglomerated, and partly as fine material. The shaft height if the blast furnaces amounts to 15-30 m. and the necessary period for the throughput of their burden ← material and the coke will take 7 - 10 hrs., that depend on the reduction capacity of the ore.

CONDITIONS OF CAKING COAL

As to the present general opinion bituminous coal (coking coal) is the most suitable one for the purpose of coking; the most important dates of this coal are:

19 - 28% volatiles
less than 7% ash contents
87 - 89% C-contents, with reference to pure coal
4.6 - 5.2% H_2-contents, " " " " "
3.3- 5.0% O_2-contents. " " " " "
1.1% S-contents, " " " " "
1.5% N_2-contents, " " " " "

more than 80% of grains under 3 mm if the coal mixture free of mud and free of swelling nature

BLAST FURNACE COKE

The coke produced from such coal in a coking plant has the following chemical constitution;

With reference to pure coal	With reference to dry coke
97 % C	86 - 88
0.4 % H_2	1.8 % $H_2 + O_2 + N_2$
0.6 % O_2	1.0 % S^2
1.0 % N_2	10.0 % Ashes
1.0 % S^2	

DEPOSITS) OF COKABLE COAL LIMITED

Bulk density about 430 - 570 kbs/m^3.

By the increasing inquiries for cokable coal the deposits still at the disposal have been called in question. As is will known the coal reserves in the European and North American countries are not inexhaustible. Many countries do not have any cokable coal deposits at all; consequently since 20 years there have been made investigations for smelting processes allowing the use of anthrazite coal or coal of a high gas content for metallurgical purposes. By this, those countries having at their disposal rich iron ore deposits, but no suitable coal deposits, have to import cokable pit coal or lumpy resistable coke for metallurgical purposes.

INCREASING WINNING OF FINE ORE

Furthermore, it is will known, that during the iron ore winning in all countries the amount of fine ore has considerably increased during the last decades. Owing to technical and economical reasons it is advisable to prepare the fine ore before charging it into metallurgical furnaces; now there is the question of building of ore-preparing plants in order to meet the increased demand of ore, as there is sufficient lumpy ore at disposal.

Further METALLURGICAL PROCESSES

Therefore it is obvious that investigations were made in order to find a way out of the difficulties which may arise sooner or later in the supply of suitable charging material. Several smelting processes had been developed or are still being developed in order to overcome this narrow pass. The use of charcoal is possible in well-wooded countries - like Sweden - only, and only for small types of furnaces. The use of electric power is only economic for those countries.

where electricity is being produced by water-power or the production of 6 kilowatt hours is less expensive than 1 kg of coal. The pig iron production in the revolving tubular kiln can be carried through economically under certain suppositions only, which are not granted in most cases in fuel wanting countries.

LOW-SHAFT FURNACE PROCESS

The low-shaft furnace process gives the possibility of smelting of ore together with non-cokable or nearly non-cokable sorts of coal. In the meantime several parties have tried to solve the problem of smelting of ore in a shaft furnace with other fuel but coke. In most cases, as a consequence of the arising difficulties, coal as the reduction and heating material put aside again and the smelting was carried through with small-sized ore and small-sized coke or anthrazite. It has to be remarked that thereby the problem of the narrow pass in the coking coal supply was not really solved and the question of the smelting of the fine ore had to be postponed, as by this partly solution there was the possibility for the production of sponge iron or iron containing balls.

LOW TEMPERATURE CARBONIZATION PROCESS

The low temperature carbonaization process, which has been developed by the Demag-Humboldt-Niederschachtofen-Gesellschaft in testing-and investigations-work during logg years, for the time being as single stage process, allows the carbonization (coking) together with the reduction and smelting work with combined ore-coal-briquettes, which have been combined suitably for the bruden. The raw briquettes will be combined of the necessary components of ore, fuel and fluxes for a special slag analysis with regard to the sort of pig iron to be produced. For the combined ore-coal-briquettes it is important to find a compensation in the physical activity of the single components by varying the grain sizes and binders as to the baking capacity of the coal at disposal, which will alloe the production of briquettes - under consideration of the reduction degree of the ore - remaining resistable during the through-put in the furnace and having sufficient porosity. In case, the briquettes will meet these demands, a correct operation of the furnace is guaranteed and the amount of dust keeps within normal limits.

<u>BRIQUETTING AND BINDERS</u>

The destination methods for values of resistibility of combined ore-coal-briquettes in cold condition which have been usual until now, do not frant a clear view on the behavior of the briquettes during their throughput in the furnace. When being charged into the top of the furnace they will be exposed to a temperature interval from outside-temperature to 380° - 400°C whithin a very short time; by this they shall neither burst nor soften to such a degree that during the throughput in the furnace under the temperature of 400°C - 800°C, that means in the end of the carbonization they can be crushed by the weight of the burden. When the carbonization is completed there will be a coke-framing in the briquette improving the values of resistibility and keeping the stability of forms. The time interval during which the briquettes will pass the temperature zones between 400 and 800°C in the furnace, will take the average of 25 - 30 minutes only - in the total throughput period of only 2½ - 3 hours - in the low shaft furnace. It turned out necessary to develop a check-apparatus for the combined ore-coal-briquettes, by which the values of resistibility can be controlled in order to correspond most possible with the requirements of the furnaces. This check apparatus had been built; as to this it os possible now, to check the various briquettes samples before they are being charged in the low shaft furnace on the same conditions they will be exposed to during their throughput in the upper part of carbonization in the low shaft furnace. Hereby the briquetting of the burden components can be regulated as to the actual conditions, varying the grain sizes as well as the adding of binders.

The binder is of a considerble influence on the stability of the briquettes in the furnace. It is turned out, that a suitable binder will always have to be used in accordance with the fuel at disposal. During a test series binders were developed, which correspond with the above mentioned requirements of resistibility of briquettes in the furnace, in accordance with the fuel to be combined in these briquettes. For coal containing a high amount of gas, the binders can be recovered from the own tar-production, whilst in case of anthrazite coal, containing a low amount of gas, as far as possible those binders should be used, which are produced in the own country and cheap at the price. Also in this regard the Demag-Humboldt-Niederchachtofen-Gesellschaft (D.H.N.) has carried through fundamental development work, which will be extended to the brown-coal-section in future.

LOW SHAFT FURNACE KOELN-KALK

Fig. (1)

The low shaft furnace of the D.H.N. in Koeln-Kalk, in which the various long-time tests have been carried through, has a hearth diameter of 1.0 x 1.3 m, a hearth area of 1,04 m^2 and an effective capacity of the furnace of 5.1 m^3. The furnace is operated with 4 tuyeres of 100 mm nose end diameter and has an oval square section. The height of the furnace from the bottom to the top amounts to 4.1 m, 3 m thereof present the effective height of the furnace shaft from the tuyeres to the top of the furnace. The top has a double bell and hopper arrangement; the top furnace gas produced will be cleaned and purified and is used - among other purposes - for the pre-heating of the blast, which is carried through via a recuperator for the time being. In a Theisen type disintergrator the tar products of the carbonization of coal of a high gas contents can be separated from the top furnace gas, consequently the top furnace gas can reach the cleaning degrees of normal blast furnaces. The possible pig iron production in this furnace amounts to 12 - 15 tons/24 hr. The slag produced is of the same constitution as blast furnace slat and is granulated in water in order to grant a cheap transport. The pig iron is casted into sand pig beds, and after having been weighed it will be stored each cast separately. A most possible technical measuring of the plant guarantees the careful and correct finding and stating of all necessary data of operation.

FORMER TESTS IN COLOGNE

Since the low shaft pilot furnace had been erected in Cologne, it has been operated on various sorts of ore and fuel. During this time the plant has been often altered and completed for reason of technical development. The general oversight drawings (2) and (3) show clearly the alterations in the building. The 6 weeks long-time-test in November/December 1952 proved the possibilities of the single stage low shaft furnace process by smelting of several charging materials. Former Tests in 1948 to 1951 had been carried through in order to prove the suitability of the low shaft furnace for the low temperature carbonisation process. Hereat it has to be stressed that the low temperature carbonisation is not carried through with oxygen-enriched blast.

WWATER JACKET FURNACE TESTS

During the course of the test series it turned out, that it is not always necessary to operate the big pilot furnace in order to find out the suitability of the briquette sorts. For this purpose, there was often used a water-jacket-furnace of about 0.5 m^2 hearth area (fig. 4), located also on the area of the pilot plant, in which the behaviour of various sorts of combined ore-coal-briquettes were studied during smelting tests with about 3 tons of charging material. The same furnace had also been used for pre-tests with combined ore-coal-briquettes based on American raw materials, in the end of 1953. The ore placed at disposal, the iron contents of which were 50% and nearly pure iron oxide (Fe_2O_3), was briquetted together with high-baking and swelling coal of more than 30% vol. and fluxes (limestone) and addes binders on tar-pirch-basis.

CHECK APPARATUS FOR BRIQUETTES

By the above mentioned check apparatus for the determination of the stability of the briquettes in warm conditions, i.e. in the temperature interval between 400 – 800°C, it was found out that the most practical stability value of the briquettes amounts to 30-35kg. which is reached without any difficulties by the use of 6% of binders of the total weight of the briquettes and a moisture contents of 6 – 8% in the mixture. These values of stability have proved to be practical for the above mentioned American raw material. They may change in case of other charing material, especially for the coal of another analysis. The check apparatus can determine the degree of compression of the briquettes when being heated up to 400 - 800°C, under the simultaneous loading of a constant weight, for example of 4 kg, on the sample briquettes in coresspondence with the maximum pressure on one briquette caused by the charge. As to the experiences of the Demag-Humboldt-Niederschachtofen GmbH the compression of about 3 mm is absolutely possible and favorable, as in the proceeding carbonization the values of stability in the briquettes are increasing and may reach more than the double values of their cold condition.

LONG TIME TESTS

The long time test which have been carried through in the meantime have proved, that by the intimate mixture of the fine-grained components of ore, coal and fluxes in the combined ore-coal-briquettes there will be really rapid carbonization and reduction of the iron and metallic oxides in the low shaft furnace which compared with the classic smelting process in the blast furnace is shortening the throughput period of the charge 2 -3 fold. The tests have proved that the former opinion, as to which reduction degree of the low shaft furnace was only a small one, had been an error. The low shaft furnace can reach a reduction degree of more than 70%, whilst part of the reduction of the iron - and metallic - oxides takes place in the hydrogen phase. Owing to the short period of the throughput the shaft height of the low shaft furnace is a considerable smaller one that the shaft height of the blast furnace. As the burden is not being prepared in the shaft of the furnace, the height of this part of the shaft is considerably smaller and amounts to 3 - 5 m. Moreover, the necessary blast pressures are considerably lower than in the blast furnace with its high charge shaft; thereby there are lower expenses for the blast. When a low shaft furnace is operated with small-sized charging material only, the shaft of the furnace will be somewhat higher, but it will not reach the height of a blast furnace. When new plants are being planned, it is necessary to find out by pre-tests the specific conditions of the charging material, and in accordance with this result to build the profile of the low shaft furnace with regard to the height of the shaft, the hearth, and the bosh-and shaft angel. By the long time test we won valuable knowledge in this concern, which will be favourable for the future planning works.

LONG TIME TEST WITH AMERICAN RAW MATERIAL.

When some water jacket furnace tests in the end of 1953 had proved that the briquettes of the American raw material combined with a special binder of the tar pitch basis were just suitable for the low temperature-carbonization in the low shaft furnace and had a good stability of forms down to the tuyeres as well as a good porosity with regard to the gas diffusing, and excellent values of combustibility, a long time test with about 600 tons of combined ore-coal-briquettes was carried through in the low shaft furnace in Cologne in the beginning of 1954. The test lasted 11 days, during this time about 120 tons of pig iron and 95 tons of slag were produced. Fig. (3) shows the arrangement of the total plant including the gas cleaning plant and the tar condensating plant in a schematic drawing.

TOP FURNACE GAS AND TAR PRODUCTION.

In order to prevent the separation of the tar from the top furnace gas before its proper time, during the continuous running of the furnace it will be operated with a shaft height of 2.8 m only; thereby a constant temperature in the top furnace of 380-400°C will be kept up. The charging will be carried through via the conveyor belts, the weighing machine, trap-bucket and slide into the charging arrangement with valve, Parry-cone and cover. In this way the raw briquettes are carefully charged into the furnace. The top furnace gas will be discharged through gas takes at the side and transferred to a djust catcher for dry dust separation. Then the gas is being transferred to a pre-cooler, driven by direct current, into which hot water of about 90–100°C is being injected under pressure, The t ar separation is carried through in a Theisen-desintergrator with an increase of the pressure up to 350 mm column of water, and in addition thereto a drop-catcher with Raschig-rings and a tube-cooler for the catching oil. By this single stage gas cleaning plant a cleaning degree of less than 0.06 g/Nm^3 is reached. The cleaned top furnace gas has a calorific value on the average of 1400 - 1450 kcal/Nm^3 and can be used for the preheating of the blast, the heating of steel-work and rolling-millpfurnace as well as for the production of steam. If there is a double stage cleaning degree of 0.02 g dust/Nm^3, so that gas can be used as machine gas. In this case in question the pre-cleaned gas had been used for the preheating of the blast in a recuperator on the average of 450°C whilst most of it was burned at the surplus gas burner.

1. TEST SECTION

Owing to operational reasons it had been proved necessary to carry through the long-time-test in two sections first of which took six full days. Hereat the pig iron production amounted to 73.5 tons during 144 hours, i.e. 508 kgs of pig iron per hour. The slag production of 50.5 tons means a slag amount of 690 kgs per t on of pig iron. The first section of the test came to an end by an unforeseeable coldness which required additional insulations of pipes and the building of steam pipes in the tar and mud-offset basins, in the meantime the furnace has been kept fired with a normal slag burden.

2ND TEST SECTIONS

For the second part of the test the basic slag practice had been increased in order to keep constantly a slag ratio of $p = \frac{CaO}{SiO_2} = 1.33$. For this purpose additional samll-sized fluxes had been operated together with the briquette burden i.e. about 10% of the total charge. By this measure there were lower Si-contents in the pig iron, consequently at a pig iron production of 47.5 tons during 101 hours, i.e. 468 kg of pig iron per hour, there was an average analysis of;

carbon	C	=	4.30%
silicium	Si	=	1.49%
manganese	Mn	=	1.05%
phospherus	P	=	0,13%
sulphur	S	=	0.05%

During this part of the test the slag production amounted to 44 tons, i.e. 930 kgs of slag per ton of pig iron. The average analysis for the flush-slag and cast-slag were:

	Flush Slag			Cast-Slag		
iron	Fe	=	0.78 %	Fe	=	1.11 %
manganese	Mn	=	0.64 %	Mn	=	0.61 %
phospherorus	P	=	-	P	=	0.01 %
Sulphur	S	=	1.53 %	S	=	1.52 %
lime	CaO	=	44,75 %	CaO	=	44.67 %
magnesia	MgO	=	6.82 %	MgO	=	6.64 %
silicic acid	SiO_2	=	34.04 %	SiO_2	=	34.10,%
alumina	Al_2O_3	=	11.13 %	Al_2O_3	=	10.37 %

GENERAL DATA OF THE OPERATION

The above mentioned operational data shall be completed by further data; they prove in a convincable way, that the single stage low shaft furnace process of the Demag-Humboldt-Niederschachtofengesellschaft can produce a technical unobjectionable pig iron of nearly all analysis wanted, from combined ore-coal-briquettes using non-cokable coal of a high gas-contents. The amount of fuel consumption, which were determined during the long-time-tests, correspond with the amounts of coke consumption of blast furnaces producing the same sorts of pig iron. When calculating the fuel consumption for a low shaft furnace it has to be taken into consideration, that all the coking heat has to be produced, which in case of the classic smelting process is produced separately from the blast furnace. It has to be considered as favourable that at the single stage low shaft furnace process this heat is for the benefit of the process. Moreover it should be remarked, that a certain amount of heat is required for the sintering of the amount of fine ore for the briquettes, in the blast furnace process this heat is also being produced separately from the system, whilst the sintering in the low shaft furnace takes this heat during the carbonization and smelting process. For the use of non-cokable coal with a high gas contents it is necessary to keep up temperatures of about 400°C at the furnace top in order to avoid the separation of carbon from the tar products contained in the gas. As is well known, each 100°C higher top furnace temperature means an additional coke consumption of about 7% ; there fore it is suitable to calculate each further 150 - 200°C top furnace temperature as an additional coke consumption of 10%. During this long time test the reached blast temperature in the recuperator was on the average of 450°C, that was 250°C less than in the Cowper-plant. In accordance with the usual operational data in smelting processes each 100°C higher blast temperature means a coke saving of 5%, consequently further 10 - 12% coke consumption had been saved in the case in question. Accordingly, the respective coke consumption (coke containing 85% C), considering the essential higher wall - and cooling-water-losses in a small furnac amounted only to 1050 (- max 1100) kg per ton of pig iron produced during the long time test with American raw material This value is really favourable for the Bessemer-pig-iron produced and corresponds with the conditions in a well-operated blast furnace plant. It can be taken for granted, that in case of bigger types of furnaces there will be smaller losses through the wall and by cooling water and still more favourable fuel consumptions and operational data.

BENEFITS

The expected benefits of top furnace gas and slags are considerably high. The gas produced during the operation with coal of a high gas contents has a higher calorific power than blast furnace gas and amounts to the average of 1400 - 1450 kcal/Nm^3; consequently, under consideration of a 10% higher production, there is a higher gas benefit of 65%. Gas with a lower calorific power H_u of about 1450 kcal/Nm^3 corresponds with a very good producer gas and can be used successfully in furnaces of steelworks and rolling mills as well as in other heating furnaces. The chemical constitution of the slags produced is quite equivalent to normal blast furnace slags and can be used like this as granulated slag (in brick - or cement factories).

BALANCES OF MATERIAL AND EQUILIBRIUM IN THE FURNACE.

After the conclusion of the long time test, by careful determination of all operational data balances of material were made up, which showed a remarkable result. The low shaft furnace had been operated with a hearth area loading of 700 - 800 kgs of coke per m^2 and hour, with reference to the whole hearth area; this value is alike the one of a well-operated blast furnace. The dust produced amounts to about 6% of the total charge, whilst in a bigger plant this amount is a considerably smaller one owing to the extensive mechanisong of the raw material and briquettes-transport and the careful treating connected therewith. Nevertheless, even this amount of 6% is not unusual for a blast furnace plant. The blast balance shows, that 5000 Nm^3 of blast will be necessary per ton of pig iron produced, that means, that 7400 Nm^3 top furnace gas per ton of pig iron will arise. It can be seen from the manganese balance, that in thw low shaft furnace a manganese reduction of more than 60% can be reached, this corresponds with the values of a well-operated blast furnace.

There is another good corresponding of the sulphur balance with regard to the sulphur charged in the burden and the output of sulphur in the pig iron and slag.
The well-known publications of T.H. Kootz and W. Oelsen (Arch. f. d. Ehw., Book 3/4, 1954 (21)), is dealing with the conditions of equilibrium in a blast furnace. By monograms and characteristics the above mentioned investigators have stated the conditions of equilibrium, proved by calculations, which can be reached during the continuous running of a well operated blast furnace. If these values will be compared with those of the manganese reduction, the sulphur redu tion and the dependence of the C-contents on the slag ration determined in the low shaft furnace, it will be obvious, tha the values of equilibrium of the low shaft furnace do quite agree with those of the blast furnace, and may be even highe

REDUCTION CONDITIONS IN THE LOW SHAFT FURNACE

As has been mentioned already above, reduction degrees of more than 70% were reached in the low shaft furnace. For reasons of systematic determination of these operational values most important for a metallurgical process, after the conclusion of the smelting tests the low shaft furnace in Cologne was stopped with its full charge in it which was cooled by passing nytrogen. There-after layers of 20 cm height were removed, beginning from the top, and 17 samples for analysing purposes were taken equally from each layer. By this it was possible, to examine the stage of oxidatio n of the iron in thw wall-, middle- and centre zones of each layer, and to determine the reduction degree. From the lots of samples a reduction degree was determined for each layer, which represents clearly the progressing of the iron oxide reduction from the top to the hearth of the furnace. The charge layer before the tuyeres which was most important for a summarized judgment, showed a reduction degree of more than 70% on the average, these are figures meaning optimum fo the blast furnace process. They are originating from the eas

Reducibility and combustibility of the carbonization coke i the upper part of the shaft, which reacts considerably better than normal high temperature coke.

<u>SUMMARY</u> The present state of development of the single stage low shaft furnace process is represented by the working results of the long time tests carried through in the 12 tons low shaft furnace of the Demag-Humboldt-Niederschachtofen GmbH with ore and non-cokable coal of this country and from abroad during the last years. By the experiences won during the examinations including the usual determination of all necessary working dates as well as the scientific clearance and comparison with the classic smelting processes in the blast furnace known until now, it may be stated that the process may be considered as <u>fit for the start</u>, especially with regard to the results of the tests with the American raw material. In comparison with the requirements of a blast furnace plant, especially with regard to the ore preparation and the quality of the coke to be charged, it has been pointed out, that the smelting of fine ore is possible now together with the use of non-coking coal in form of combined ore-coal-briquettes, containing all burden components in an equal and well-distributed way. By the unusual high reducibility of the iron- and metal-oxides, originating from the above mentioned distribution, as well as by the quick carbonization of the coal to a well-combustible and-reactive coke the low shaft furnace process will be most importnat factor of the iron producing industry. It has been stated herewith, that by this process all pig iron sorts on the market can be produced, whilst the slags produced have all conditions of the blast furnace slag and can be used for the same purposes as these; the top furnace gas produced will have an essential benefit as its calorific power is about 50% higher - if non-cokable coal of a high gas contents is used and the total amount is higher one too. These statements refer also to the economy of this process, which - as to the present determinations of investment capital and continuous

expneses for the operation - will be an obvious favour of this process, if there will be the same basis for the classic furnace process as well as the low shaft furnace process:

Raw material basis = fine ore + coking coal on one side;
fine ore + non-coking coal on the other side.

This is not to say, that the blast furnace process is being relieved by the low shaft furnace process. The use of these processes depends in each case on the raw material conditions in question. The low shaft furnace process shall and will fill the vacancy in the smelting processes known until now, this vacancy has existed in the series of classic smelting processes owing to the altered raw material situation, caused in some countries by their specific methods of operation.