U. S. BUREAU OF MINES
HYDRO. DEMON. PLANT DIV.

T-387

KCBraun
6/20/47

Hydrogenation of Bituminous Coal to Aviation Gasoline with Hydrogenation of the Tar Obtained

I. G. Ludwigshafen, 10 May 1943

Case I. (above title).

H_2-Production: Hy-gas splitting and Winkler generator with O_2.

A) Production from Hydrogenation of Coal and Tar.

100000 t av. gas	+	18100 t av. gas	=	118100 t av. gas	=	72.4%
32000 t C_3+C_4	+	4500 t C_3+C_4	=	36500 t C_3+C_4	=	22.4%
7850 t C_2	+	750 t C_2	=	8600 t C_2	=	5.2%
139850 t	+	23350 t	=	163200 t	=	100 %

B) Low Temp. Carboniz. (Lurgi-Spülgasschwelung)

L.T.C. coal, 204800 t (4% ash, 8% H_2O, 7000 Kcal, nut coal)
Power coal for L.T.C., 2600 t (7000 Kcal/kg)
L.T.C. coke, 143000 t (70.2%/L.T.C. coal, 5% H_2O, 7000 Kcal, gasification in Winkler generator with O_2, because the L.T.C. coke from nut coal L.T.C. from the flushing gas L.T.C. oven can not be gasified in revolving grate generator).

C) Hydrogenation of Coal and Tar.

H_2 req'd for coal (3200 m^3/t av. gas)	40000 m^3/h
H_2 req'd for tar (1900 m^3/t av. gas)	4300 m^3/h
	44300 m^3/h

Hy-gas yield (95%) for coal,	98.5 x 10^6 Kcal/h
for tar,	10.7 x 10^6 Kcal/h
	109.2 x 10^6 Kcal/h

less C_2 (80% of balance figures) for coal,	11.1 x 10^6 Kcal/h
for tar,	0.8 x 10^6 Kcal/h
	-11.9 x 10^6 Kcal/h

less C_3+C_4 (80% of bal. figures) for coal,	44 x 10^6 Kcal/h
for tar,	5 x 10^6 Kcal/h
	-49 x 10^6 Kcal/h

H_2-produced by hy-gas splitting (from 49 x 10^6 Kcal/h),	20400 m^3/h
H_2-produced from L.T.C. coke,	23900 m^3/h
	44300 m^3/h

L.T.C. coke req'd. for H_2-production, 143000 t/ann
Hydr. coal req'd. (4% ash, 8% H_2O, 7000 Kcal) 205000 t/ann
= 181000 t pure coal)

Power req'd. (power coal 7000 Kcal/kg) for hydrogenation, incl. C_2, C_3 & C_4 recovery for hy-gas splitting, for H_2 from coke and for auxiliary plants,

for coal hydr.,	234000 t/ann
for tar hydr.,	24000 t/ann

Fuel gas req'd.

for coal hydr.,	58×10^6 Kcal/h
for coal hydr.,	6.6×10^6 Kcal/h
	64.6×10^6 Kcal/h

Use of surplus gas from L.T.C. for heating

	102×10^9 Kcal/ann	$= 12.8 \times 10^6$ Kcal/h
Fuel gas req'd.	516×10^9 Kcal/ann	$= 64.6 \times 10^6$ Kcal/h
Resid. fuel gas req'd.,	414×10^9 Kcal/ann	$= 51.8 \times 10^6$ Kcal/h

Coal req'd. for fuel gas production,
83000 t/ann = 10.4 t/h

8% tar credit in fuel gas production,	6650 t/ann
Tar yield in Lurgi-L.T.C. Plant,	18950 t/ann
Total tar yield	25600 t/ann

, will give an av. gas. production of 18100 t @ 70.8% yield.

D) Coal Input.

L.T.C. coal		204000 t/ann
(Power coal for L.T.C.,	2600 t	
" hydr.,	258200 t	
" fuel gas,	83000 t	343800 t/ann
Hydrogenation coal		205000 t/ann
		752800 t/ann

E) Coal Consumption/t Product = 4.6 t
" " /t Av. Gas. = 6.4 t

728600 t coal	X 7000 Kcal	$= 51 \times 10^{11}$ Kcal		
118100 t av. gas.	X 10500 Kcal	$= 12.4 \times 10^{11}$ Kcal	= 71.4%	(71.0%)
36500 t $C_3 + C_4$	X 11000 Kcal	$= 4.00 \times 10^{11}$ Kcal	= 23.1%	(23.0%)
8600 t C_2	X 11300 Kcal	$= 0.95 \times 10^{11}$ Kcal	= 5.5%	(5.4%)
		17.35×10^{11} Kcal	=100%	
1112 t phenols	X 7800 Kcal	$= 0.09 \times 10^{11}$ Kcal		(0.5%)
164320 t		17.44×10^{11} Kcal		99.9%

From the coal with 100×10^{11} Kcal are produced:

Av. gas,	24.3×10^{11} Kcal
$C_3 + C_4$,	7.8×10^{11} Kcal
C_2,	1.86×10^{11} Kcal
Phenols from waste water,	0.18 10^{11} Kcal

From the coal, 100000 t are produced:

Av. gas,	16200 t
$C_3 + C_4$	5010 t
C_2	1180 t
Phenol from waste water	154 t

At Maximum Phenol Recovery:

728600 t coal	X 7000 Kcal =	51 X 10^{11} Kcal
109000 t av. gas.	X 10500 Kcal =	11.50 X 10^{11} Kcal
36500 t $C_3 + C_4$	X 11000 Kcal =	4.00 X 10^{11} Kcal
8600 t C_2	X 11300 Kcal =	0.95 X 10^{11} Kcal
1120 t phenols from waste water	7800Kcal =	0.09 X 10^{11} Kcal
11800 t phenols from M-Oil	7800Kcal =	0.92 X 10^{11} Kcal
		17.46 X 10^{11} Kcal

From coal with 100 X 10^{11} Kcal are produced:

av. gas.,	22.5 X 10^{11} Kcal
$C_3 + C_4$,	7.80 X 10^{11} Kcal
C_2,	1.86 X 10^{11} Kcal
phenols fr. waste water	0.18 X 10^{11} Kcal
phenols fr. M-Oil,	1.80 X 10^{11} Kcal

From coal, 100000 t are produced:

av. gas	15000 t
$C_3 + C_4$	5020 t
C_2	1190 t
phenols from waste water	154 t
phenols from M-Oil	1620 t

F) Iron Requirement:

for coal gas. hydrog.	63400 t	for 100000 t Min. Oil =
for tar " "	6700 t	(av. gas, $C_3 + C_4$, C_2)
for L.T.C.	2250 t	
	72500 t	

Aviation Gasoline from Ruhr Coal.

100000 t/a av. gas. from 22.6 t/h pure coal
553 kg. av. gas/t pure coal.

Hy-gas yield:

Liq. Phase,	71.5 X 10^6 Kcal/h	(100% accord. to balance)
Vap. Phase,	32.0 X 10^6 "	(" " " ")
	103.5 X 10^6 Kcal/h	(" " " ")
	98.5 X 10^6 Kcal/h	(95% " " ")

H_2 in hy-gas yield:

Liq. Phase	6250 m^3/h	(276 m^3 X 22.6 t/h pure coal)
Vap. Phase,	875 m^3/h	(70 m^3 X 12.5 t/h av. gas.)
	7125 m^3/h	

Yield in Recovery:
80% 5700 m 3/h, heat value = 13.5 X 10^6 Kcal/h

C_2 in hy-gas yield:

170 X 22.6 X 0.24 X 1.25 = 1150 Kg/h
31 X 12.5 X 0.12 X 1.25 = 58 kg/h
147 X 12.5 X 0.01 X 1.25 = 23 kg/h
1231 kg/h

Yield in Recovery:
80% 985 kg/h, heat value = 11.1 X 10^6 kcal/h

$C_3 + C_4$ in hy-gas yield:

170 X 22.6 X 0.52 X 1.22 = 2440 kg/h
31 X 12.5 X 0.74 X 1.22 = 350 kg/h
147 X 12.5 X 0.98 X 1.22 = 2200 kg/h
4990 kg/h (65% C_4)

Yield in Recovery:

80% 4000 kg/h, heat value = 44.0 X 10^6 Kcal/h

Hy-gas yield,	98.5 X 10^6 Kcal/h
Recovery of C_2, C_3, & C_4	55.1 X " "
Residual Hy-gas,	43.4 X 10^6 Kcal/h

This hy-gas goes to hy-gas splitting and supplies $H_2 = \frac{43.4 \times 10^6}{2.4 \times 10^3} = 18000\ m^3/h$

Total H_2 Reqmt:	40000 m^3/h
H_2 from hy-gas splitting,	18000 m^3/h
H_2 from Winkler coke.	22000 m^3/h

L.T.C. Coke req'd for this, 22 X 0.75 = 16.5 t/h = 132000 t/ann

Power Req'd.	H.P. Steam t	L.P. Steam t	Gas, Kcal	Current KW	Water, m^3
Hydr. incl C_2, C_3, & C_4 Recovery fr. 12.5 t/h	8	36	37.5 X 10^6	14000	2500
H_2 fr. Hygas (18000 m^3/h)	0	13.2	20.0 X 10^6	10000	2400
H_2 fr. coke (22000 m^3/h)	-15	30	0	18500	3500
Auxil. plants (10%)	0	8	0	4200	500
Water works	0	0	0	2500	---
	- 7	87.-	58.0 X 10^6	49200	9000
		+ 80			

L.P. steam, 80 X 1.45 = 116 t/6.9 = -16800 KW
+49200 KW current reqmt.
+ 4900 KW power pl. consumpt.
37300 KW

37300 X 4.2 = steam: = 157t
Total Steam 273t

Power coal for power plant,

$\frac{273 \times 600}{1000 \times 0.8} = 29.2$ t/h = 2.34 t/t av. gas.

Case II. Bit. Coal Hydrogenation to Aviation Gasoline and Fuel Oil with Hydrogenation of the Tar obtained to Aviation Gasoline.

A). Production from Hydrog. of coal & Tar.

av. gas,	52000 t	+ 14500 t	= 66500 t	=	41.8%
fuel oil,	60500 t	+ -----	= 60500 t	=	38.1%
C_3+C_4,	20400 t	+ 3620 t	= 24020 t	=	15.1%
C_2,	7400 t	+ 570 t	= 7970 t	=	5.0%
	140300 t	+ 18690 t	= 158990 t	=	100 %

B) L.T.C. (Lurgi-Spülgasschwelung).

L.T.C. coal (8% H_2O)	158000 t	
Power coal for L.T.C.	2040 t	
L.T.C. coke	111000 t	(70% to 8.5% H_2O)
L.T.C. tar	14200 t	(9.3% to 8% H_2O)

L.T.C. gas surplus, 79 X 10^9 Kcal/ann = 9.9 X 10^6 Kcal/h

C). Hydrogenation of Coal and Tar.

H_2-reqm't. for coal (2380 m^3/t prod.)	33600 m^3/h	
H_2-reqm't. for tar (1900 m^3/t av. gas)	3450 m^3/h	
	37050 m^3/h	

Hy-gas yield (95%) for coal,	79.0×10^6 Kcal/h		
" " " for tar,	$8.6 \times$ " "	=	87.6×10^6 Kcal/h
less C_2 (80% of balance figures) for coal	10.5×10^6 Kcal/h		
for tar	$0.6 \times$ " "	=	11.1×10^6 Kcal/h
less $C_3 + C_4$ (80% of balance figures) for coal	28.0×10^6 Kcal/h		
for tar	4.0×10^6 Kcal/h	=	-32.0×10^6 Kcal/h
			-43.1×10^6 Kcal/h

H_2 prod. by hy-gas splitting (fr. 44.5×10^6 Kcal/h)	18500 m^3/h
H_2 prod. fr. L.T.C. coke in Winkler generator with O_2	18550 m^3/h
	37050 m^3/h

L.T.C. coke req'd. for H_2-production	111000 t
Coal req'd. for hydrogenation	205000 t
" " " power (energy coal with 7000 Kcal) for hydrog. incl. C_2, C_3 & C_4-recovery, for H_2 prod. and auxil. plants, for coal hydrog.	184000 t
" tar "	19400 t
	203400 t

Fuel gas req'd. for coal hydrog.,	51.0×10^6 Kcal/h		
" tar "	$5.3 \times$ " "	=	56.3×10^6 Kcal/h
Use of surplus gas fr. L.T.C. for heating,			$- 9.9 \times$ " "
Residual fuel gas req'd.			46.4×10^6 Kcal/h

Coal req'd. for fuel gas production, 9.3 t/h	=	74000 t/ann
Credit for tar in fuel gas production		5900 "
Tar yield in Lurgi-L.T.C. plant		14700 "
Total tar yield (Gesamtteeranfall)		20600 t/ann
will give an av. gas. prod. of @ 70.8% yield.		1500 t/ann

D). Coal Input.

L.T.C. coal		158000 t
Power coal for L.T.C.	2040 t	
" hydrog.	203400 t	
" fuel gas	74000 t	279440 t
Hydrogenation Coal		205000 t
Total coal consumption		642440 t

E). Coal Consumption/t Product

" " /t av. gas. + fuel oil	4.04 t
	5.20 t

642440 t coal x 7000 Kcal = $45. \times 10^{11}$ Kcal

66500 t av. gas	x 10500 Kcal	=	7.0 x 10^{11} Kcal	=	43.4%
60500 t fuel oil	x 9100 "	=	7.5 x " "	=	34.1%
24020 t C_3 + C_4	x 11000 "	=	2.65 x " "	=	16.4%
7970 t C_2	11300 "	=	0.9 x " "	=	5.6%
158990 t			16.05 x 10^{11} Kcal	=	99.5%
150 t phenols from L.T.C. waste water x 7800 Kcal					
950 t " " hydrog. " " , or					
1100 t		=	0.09 x 10^{11} Kcal	=	0.5%
160090 t		=	16.14 x 10^{11} Kcal	=	100%

From coal with 100 x 10^{11} Kcal are produced:		From coal 100000 t are produced:
av. gas.	15.6 x 10^{11} Kcal	10300 t
fuel oil,	12.25 x " "	9400 t
C_3 + C_4	5.9 x " "	3740 t
C_2	2.0 x " "	1245 t
phenols fr. waste water	0.2 x " "	171 t

E) Iron Requirement:

for coal hydrogenation,	70500 t
for tarhydrogenation	8700 t
for L. T. C.	2850 t
	82050 t
for 100000 t mineral oils	52000 t

Aviation Gasoline + Fuel Oil from Bit. Coal.

52000 t/ann av. gas. = 6.55 t/h
60500 t/ann fuel oil = 7.56 t/h
112500 t/ann av. gas. + fuel oil = 14.11 t/h product

Hy-gas Yield

Liq. phase,	68 x 10^6 Kcal/h	(100% accord. to balance)
Vap. phase,	15 x 10^6 Kcal/h	(100% " " ")
	83 x 10^6 Kcal/h	(100% " " ")
	79 x 10^6 Kcal/h	(95% " " ")

C_2 in Hy-gas yield

166 x 22.6 x 0.24 x 1.25 = 1120 kg/h
31 x 6.5 x 0.12 x 1.25 = 30 "
117 x 6.5 x 0.01 x 1.25 = 10 "
1160 kg/h

Yield in recovery 80% = 927 " (heat value 10.5 x 10^6 Kcal/h)

C_3 + C_4 in Hy-gas Yield

166 x 22.6 x 0.52 x 1.22 = 2380 kg/h
31 x 6.5 x 0.74 x 1.22 = 18 "
117 x 6.5 x 0.98 x 1.22 = 910 "
3308 kg/h

Yield in recovery 80% 2646 " (heat value 28.8 x 10^6 Kcal/h + 39.3 x 10^6 Kcal/h)

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Hy-gas yield,	79.0×10^6 Kcal/h
Recovery of C_2, C_3, & C_4	-39.3×10^6 Kcal/h
	39.7×10^6 Kcal/h

These go to hy-gas splitting and supply $\frac{39.7 \times 10^6}{2400}$ = 16600 m^3/h H_2

Total H_2 Requirement =	33600 m^3/h
H_2 from hy-gas splitting,	-16600 m^3/h
H_2 from Winkler coke	17000 m^3/h

L. T. C. coke req'd. for this = 12.5 t/h = 100000 t/ann.

Power Req'd. (for 14.1 t/h prod)	H.P. Steam; t	L.P. Steam; t	Gas Kcal	Current KW	Water m^3
Hydrogenation	8.5	26.0	32.6×10^6	10500	2000
H_2 fr. hygas (16600 m^3/h)	----	12.5	18.5×10^6	9300	2000
H_2 fr. coke (17000 m^3/h)	-11.5	22.5	----	14000	3000
Auxil. plants	----	6.0	----	3200	500
Water works				2000	
Power plant				4000	
	- 3.0	67.0	51.1×10^6	43000	7500
		-64			

L.P. Steam, 64 X 1.45 = 93t/6.9 = -13500 KW
+43000 KW
29500 KW

Steam, 29500 X 4.2 = 124t
Total Steam = 217t

$\frac{217 \times 600}{7000 \times 0.8}$ = 23 t/h power coal = 1.63 t/t prod.
= 184000 t/ann.

Fuel Gas Production:

$\frac{51 \times 10^6}{5 \times 10^6}$ = 10.2 t/h fuel gas coal = 0.72 t/t prod.

8% tar credit/t fuel gas coal

Case III. Bit Coal L.T.C. & Hydrogenation of L.T.C. Tar.

A). Production from L.T.C. Tar Hydrogenation.

100000	t/ann. av. gas	= 77.6%	From 142000 t/ann L.T.C. tar (1000 Kg tar yield 708 Kg av. gas.)
25000	" C_3 & C_4	= 19.4%	
3900	" C_2	= 3.0%	
128900 t/ann		100%	

B). L.T.C. (Lurgi Flushing Gas)

L.T.C. coal	1520000 t	(4% ash, 8% H_2O, nut coal, 7000 Kcal)
Power coal for L.T.C.	19600 t	(heat value - 7000 Kcal/h)
L.T.C. coke	1065000 t	(70%/dry coal - 8% water, 5% H_2O, 7000 Kcal)
L.T.C. tar & gasol,	142000 t	(9.3%/dry coal - 8% water)
L.T.C. gas surplus,	760×10^9 Kcal/ann.	

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C). L.T.C. Tar Hydrogenation.

H_2 Reqm't. (1900 m^3/t av. gas.)	23800 m^3/h
Hygas yield (95%)	59 X 10^6 Kcal/h
less C_2 (80% of balance figures)	- 4.4 X " "
less C_3 + C_4 (80% of balance figures)	-27.5 X " "
	27.1 X 10^6 Kcal/h

H_2 Production by hygas splitting,	11300
H_2 Production from L.T.C. coke	12500 *)
	23800t

*) Gasification with O_2 in Winkler generator.

L.T.C. coke req'd. for H_2 production,	75000 t
Power coal reqm't. (7000 Kcal/kg)	
for hydrog. incl. C_2 + C_3 + C_4 recovery,	
for H_2 from hygas splitting,	
for H_2 from coke in Winkler generator	
for auxil. plants,	134000 t
1). For fuel gas prod. (36.5 X 10^6 Kcal/h)	58500 t
	192000
8% tar credit in fuel gas prod.	4700 t

~~2). Without fuel gas production, use of surplus~~ from L.T.C. for heating.

L.T.C. surplus gas	760 X 10^9 Kcal/ann
Fuel gas reqm't.	290 X " "
	470 X 10^9 Kcal/ann

~~Surplus gas as coal @ 7000 Kcal,~~ 67000 t/ann

D). Coal Input.

L.T.C. Coal			1520000 t	
Power coal for L.T.C.	19600 t			
" " " Hydr.	192500 t	(134000)		
	212100 t			
Credit for surplus gas	- 109000 t	(- 67000)	163100 t	(86600)
			1623100 t	(1606600)
L.T.C. coke credit,	1065000 t			
	75000 t			
	990000 t		990000 t *)	
			633100 t ‡)	(616000)

*) Added to coal economy in form of coke.

‡) Taken from coal economy.

E). Coal Consumption.

$$\frac{633100\ t}{128900 + 4700} = 4.74 \text{ t/t product.}$$

$$\frac{616600\ t}{128900} = 4.79 \text{ t/t product.}$$

Coal,	1606000 t x 7000 Kcal	= 112.5 x 10^{11} Kcal			
Coke	990000 t x 7000 "	= 69.2 x 10^{11} Kcal	= 83.5%		
Gasol.,	100000 t x 10500 "	= 10.5 x 10^{11} Kcal	= 12.7%	(10.5)	77.1%
C_3 + C_4	25000 t x 11000 "	= 2.75 x 10^{11} Kcal	= 3.3%	(2.75)	20.0%
C_2	3900 t x 11300 "	= 0.44 x 10^{11} Kcal	= 0.5%	(0.44)	3.0%
	1118900 t	= 82.89 x 10^{11} Kcal	= 100%	(13.69)	100%

Phenols from L.T.C. waste waters:
0.7% based on tar
1000 t x 7800 Kcal = 0.08 x 10^{11} Kcal

Phenols from hydrog. waste waters:
0.65% based on av. gas.
650 t x 7800 Kcal = 0.05 x 10^{11} Kcal
1120550 t = 83.02 x 10^{11} Kcal

From coal with 100 x 10^{11} Kcal are produced:		From coal are produced	100000 t
coke	61.6 x 10^{11} Kcal	coke	61600 t
av. gas.	9.35 x "	av. gas.	6240 t
C_3 + C_4	2.44 x "	C_3 + C_4	1550 t
C_2	0.39 x "	C_2	243 t
Phenols fr. waste water	0.115 x "	Phenols from waste water	103 t

F). Iron Requirement:

for hydr., 48800 t for 100000 t Min. Oil (= av. gas, C_3 + C_4 + C_2)

for L.T.C. 21800 t " 100000 t Min. Oil " " "
70600 t
71000 t

Av. Gasol. from Lurgi Flushing Gas Tar.

100000 t/ann. av. gas. from 17.7 t/h tar.
708 kg. av. gas/t tar.

Hy-gas Yield

	1)		2)		3)				
Liq. Phase,	72	x	17.7	x	15600	=	19.9	x	10^6 Kcal/h
	112	x	17.7	x	2360	=	4.7	x	10^6 Kcal/h
Vap. Phase,	30	x	17.7	x	13800	=	7.3	x	10^6 Kcal/h
	112	x	17.7	x	13800	=	28.0	x	10^6 Kcal/h
	50	x	17.7	x	2360	=	2.1	x	10^6 Kcal/h
							62.0	x	10^6 Kcal/h (100% acc. bal.)
							59.0	x	" " (95% acc. bal.)

C_2 in Hy-gas Yield.

			4)		5)		
72	x	17.7	x 0.24	x	1.25	=	380 kg/h
30	x	17.7	x 0.12	x	1.25	=	80 kg/h
119	x	17.7	x 0.01	x	1.25	=	26 kg/h
							486 kg/h

Yield in recovery 80%. 390 kg/h (4.4 x 10^6 Kcal/h = Heat Value)

(NOTE: - See Page 10 for explanation of figures 1) 2) 3) 4) 5)

$C_3 + C_4$ in Hygas Yield

	4)	5)	
72 x 17.7	x 0.52	x 1.22 =	1030 kg/h
30 x 17.7	x 0.74	x 1.22 =	340 kg/h
119 x 17.7	x 0.98	x 1.22 =	1780 kg/h
			3150 kg/h
Yield in recovery 80%			2500 kg/h

Heat Value = 27.5 x 10^6 Kcal/h

31.9 x 10^6 Kcal/h

Hygas Yield	59 x 10^6 Kcal/h
Recovered from $C_2 + C_3 + C_4$	31.9 x 10^6 Kcal/h
Residual hygas	27.1 x 10^6 Kcal/h

These go to hygas splitting and supply:

$$\frac{27.1 \times 10^6}{2400} = 113000 \ m^3/h \ H_2$$

(Note: - See note at bottom of page 9)

1) kg C gasified/1000 kg tar.
2) tar processed in t/h
3) heat value of gasified hydro-carbons in Kcal/kg C.
4) % content of the corresp. hydro-carbons in total gasification.
5) conversion factor for kg C into kg hydro-carbon.

Total H_2 Reqm't.: 23800 m^3/h (1900 m^3/t av. gas.)

H_2 from hygas splitting 11300 m^3/h

H_2 from Winkler coke 12500 m^3/h

L.T.C. coke req'd. for this 9.4 t/h = 75200 t/ann.

Power Reqm't.	t-HP Steam	t-LP Steam	Kcal Gas	KW Current	m^3 Water
Hydrog. incl. C_2, C_3, C_4	3.5	30.0	24 x 10^6	6500	1500
H_2 fr. hygas (11300 m^3/h)	-3.4	11.3	12.5 x 10^6	6300	1500
" " coke (12500 m^3/h)	-8.5	17.0	----------	10500	2000
Ancil. plants	----	5.7	----------	2300	500
Water Works	----	----	----------	1400	----
	-8.4	64.0	36.5 x 10^6	27000	5500
		+ 55.6			

L.P. Steam, 55.6 x 1.45 = 81 t/6.9 = - 11800 KW

+ 270000 "

power plant use + 2700 "

+ 18000 KW

18000 x 4.2 = 76 t Steam

157 t

Total Steam:

$$\frac{157 \times 600}{7000 \times 0.8} = 16.8 \text{ t/h power coal} = 1.34 \text{ t/t av. gas.}$$

Fuel Gas Production:

$$\frac{36.5 \times 10^6}{5 \times 10^6} = 7.3 \text{ t/h fuel gas coal} = 0.58 \text{ t/t av. gas.}$$

8% tar credit/t fuel gas coal.

Case IV. Bit. Coal L.T.C. (Heating Surface and Tar Decomposition by Byk Gulden

A). Production:

74300t	fuel oil	74300t
7200t	phenols	
820t	phenols from waste waters	
15000t	pitch	
7900t	light ends	7900t
6100t	L.F.G.	6100t
111720t		88300t min. oil.

B). L.T.C. (Heating Surface Process, [illegible])

L.T.C. coal	1208000t
Power coal for Lean gas prod.	112000t (abt. [illegible])
Power coal for Elec. & Steam	14500t ([illegible])
L.T.C. coke,	875000t
Generator tar,	8150t
L.T.C. tar,	94000t
	8800t (L.T.C. [illegible])
	6100t (C_3 + C_4)
	117050t

L.T.C. gas, 90 X 10^6 Nm^3/ann ([illegible])

=580 X 10^9 Kcal/ann, corres[illegible] to 80000t coal, heat value [illegible]

All L.T.C. gas is used for pip[illegible]. The fuel requirement is covered by lean gas.

C). L.T.C. Tar Decomposition.

L.T.C. tar yield,	117050t
of which L.F.G.	[illegible]
" " light ends (95% auto gas.)	7[illegible]
of which tar for decomp.	102[illegible]
	11[illegible]

Tar Decomposition supplies:

fuel oil,	7[illegible]
phenols,	[illegible] ([illegible] phenols & tar with [illegible] - 240° end point)
pitch,	1[illegible]
losses,	57[illegible]
	102[illegible]

Distribution (by Dr. [illegible]).

61000t	fuel oil,	60%	[illegible] fuel oil
20500t	phenols, (total phen)	20%	7[illegible] phenols [illegible]
15400t	pitch,	15%	1[illegible] pitch
5750t	5% loss.	5%	57[illegible] loss
102650t		100%	10[illegible]

Power coal for tar decomposition, 36200t

Properties of the product:

fuel oil, spec. grav =	1.035/20°C
heat value =	9490 Kcal/Ltr.
(Stockpunkt) pour point,	2-8°C
viscosity,	30°E/20°C

Pipe Line gas (Ferngas):

CH_4	41.3%	($1000\ Nm^3 = 6.2 \times 10^6$ Kcal)
H_2	18.9%	
CO_2	10.7%	
CO	9.3%	
CnHm	5.4%	(C_2H_4)
C_2H_6	6.5%	
N_2	8.3%	
O_2	0.6%	

D). Coal Input:

L.T.C. Coal		1208000t
Power Coal for lean gas prod.	112000t	
Same for tar decomp.	36200t	148200t
		1356200t
L.T.C. coke credit	875000t	
Power coal for L.T.C.	- 14500t	- 860500t
		495700t

E). Coal Consumption:

$\frac{495700}{88300}$ = 5.61 t/t mineral oil

	1356200 coal	X 7000 Kcal	=	95.0	X 10^{11} Kcal.		
	860500t coke	X " "	=	60.2	X " "	=	79.3%
88300t {	7900 t gasol.	X 10500 "	=	0.83	X " "	=	1.1%
	6100t L.F.G.	X 11000 "	=	0.67	X " "	=	0.9%
	74300t benzol	X 9100 "	=	6.70	X " "	=	8.8%
	8020t phenol	X 7800 "	=	0.62	X " "	=	0.8%
	15400t pitch	X 8600 "	=	1.32	X " "	=	1.7%
	90 X 10^6 Nm^3 pipe line gas/ann. X 6200	Kcal	=	5.60	X " "	=	7.3%
				75.94	X 10^{11} Kcal	=	99.9%

8900t gasol.	X 10500 Kcal	=	0.935	X 10^{11} Kcal	=	10 % gas.
6900t L.F.G.	X 11000 "	=	0.760	X " "	=	8.1% $C_3 + C_4$
84200t benzol.	X 9150 "	=	7.690	X " "	=	81.9% fuel oil
100000t mineral oil		=	9.385	X 10^{11} Kcal	=	100%

F.) Iron Reqm't.

for BT -L.T.C. incl. power plant, fuel gas prod, & C_3+C_4 recovery,	33100t
for tar processing	4830t
	37930t

$\frac{37930}{88300}$ X 100000 = 43000t iron.

From coal with 100 X 10^{11} Kcal are produced:				From Coal 1000000t are produced:
coke	63.3 X	"	"	635000t
gasol.	0.88 X	"	"	5830t
L.F.G.	0.71 X	"	"	4500t
fuel oil	7.05 X	"	"	54800t
phenols	0.65			5910t
oitch	1.39 X	"	"	11350t
P.L. Gas	5.90 X	"	"	413 X 10^9 Kcal

Heat value of pipe line gas = 6200 Kcal/Nm^3 without gas oil = 0.9 kg/Nm^3

Case V. Coking and Tar Decomposition for Upper Silesia

A). Production:
- 18800t oils
- 24500t high temp. pitch
- 9200t light oil & benzol
- 400t phenols fr. waste water
- 52900t

294 X 10^6 Nm^3 coke oven gas (4400 Kcal) = 1290 X 10^9 Kcal/ann.

B). Coke Plant (365 Operating Days)

coking coal,	1000000t	(8% H_2O, 7000 Kcal/kg.)
high temp. coke,	687000t	
generator tar,	10600t	
crude tar,	370000t	
light oil & benzol,	9200t	

coke oven gas, 294 X 10^6 Nm^3 (4400 Kcal) = 1290 X 10^9 Kcal/ann.
All coke oven gas is shipped out. The fuel gas requ't. is covered by lean gas.

Power coal for lean gas prod:	130000t/ann.
" " " elect. & steam:	20000t/ann.

for which fine coke can be used.

C). Tar Decomposition (365 operating days).

crude tar, 370000t (with H_2O)
will give after blisters are broken up:

21700t	pitch
12200t	oils
3100t	losses

generator tar, 10500t
will give after distillation:

2800t	pitch
6600t	oils
1100t	losses

Power coal for elect. & steam contained in above.
" " " lean gas production, 1600 t

D). Coal Input

Coking Coal		1000000t
Power Coal for tar distill.	1600t	
Power Coal for coke plant	130000t	131600
		1131600t
High Temp. Coke Credit	687000t	
Fine Coke Reqm't.	- 20000t	- 667000t
		464600t

E). Coal Consumption:

t/t mineral oil = 16.5t

Coal,	1131600t X 7000 Kcal	= 79.2 X 10^{11} Kcal		
Coke,	667000t X " "	= 46.6 X "	= 72.4 %	
Oil,	18800t X 9300 "	= 1.7 X "	= 2.69%	28000t (Oil, Light Oil, + Benzol)
Light Oil,				
+ Benzol,	9200t X 9600 "	= 0.88 X "	= 1.37%	
Pitch,	24500t X 8600 "	= 2.10 X "	= 3.25%	
Phenols,	400t X 7800 "	= 0.03 X "	= 0.05%	
Coke Oven Gas,		= 12.9 X "	= 19.95%	
		64.25 X 10^{11} Kcal	= 99.71%	

Oil,	67300t X 9300 Kcal	= 6.25 X 10^{11} Kcal	= 66.5% fuel oil
Gasol + Light Oil	32700t X 9600 Kcal	= 3.14 X "	= 33.5% Gasol + Light Oil
	100000t min. oil	= 9.39 X 10^{11} Kcal	= 100%

From coal with 100 X 10^{11} Kcal are produced:			From coal are produced: 1000000t
Coke,	58.7 X	"	590000t
Oil,	2.19 X	"	16600t
Benzol + Light Oil,	1.11 X	"	8130t
Pitch,	2.65 X	"	21600t
Phenols,	0.04 X	"	3500t
Coke Oven Gas,	16.3 X	"	11.4 X 10^{11} Kcal

F). Iron Reqm't.

For coke plant, incl. auxil. plants,	23600t
For tar decomposition,	990t
	24590t

For 100000t min. oil products:

$$\frac{24590 \times 100000}{28000} = 88000t$$

Heat value of pipe line gas (Ferngas):

= 4400 Kcal/Nm^3

= 0.6 kg/Nm^3

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