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Energy Input into the Synthesis (May 1944) (Total Synthesis)

A) Energy Input

1). Coke

For 1 nm^3 synthesis gas with 83.5% actives $\frac{32,207,400}{46,860,650}$ =

0.6873 kg. crude coke with 5.8% water and 8.45% ash have been used, which with a heating value of pure coke = to 8,000 kcal/kg. corresponds to

$0.6873 \times 6,860$ = 4,715 kcal/nm^3 synthesis gas

$\eta = \frac{2,576}{4,715}$ = 54.6%

computed to ideal gas

$\frac{4,715}{0.835}$ = 5,647 kcal/nm^3 ideal gas

1 nm^3 ideal gas produces 137.3 g total products,

1 kg of total products require therefore

$\frac{5,647}{0.1373}$ = 41,129 kcal/kg total products

2). Electric Power

Consumed of the additionally added energy

6,904,120 kwh, which were obtained with a coal consumption of 9.7 kg/1Kwh. (upper heat value of coal = 6,500 kcal/kg)

6,904,120 x 0.7 x 6,500 = 31,413,750,000 kcal were required, or

$$\frac{31,413,750,000}{5,377,310} = 5,842 \text{ kcal/kg total products}$$

3). Steam (18 atm)

15,937 to high pressure steam were used with a heat content of i = 746 kcal/kg (16.5 atm, 340°C).

Only the heat content (heat loss) come into consideration because when the steam requirements and consumption are balanced there remains an excess on the credit side of the steam obtained.

15,937,000 x 746 = 11,889,000,000 kcal., or

$$\frac{11,889,000,000}{5,377,310} = 2,211 \text{ kcal/kg total products}$$

4). Accordingly total heat conversion

1)	Coke	41,129 kcal/kg total prod.	83.6%
2)	Electric Power	5,842 " " " "	11.9%
3)	Steam	2,211 " " " "	4.5%
		49,182	100.0%

B). Energy taken away

1). Off gas; after the use in the final purification (1,232,000 nm^3) 11,760,890 nm^3 remain available, with 2.225 kcal/nm^3 = 26,145,730,000 kcal.

$\frac{26,145,730,000}{5,377,310}$ = 4,862 kcal/kg total products

2). Middle Pressure Steam (9 atm)

Available 4,711,000 kg at 663 kcal/kg = 3,123,400,000 kcal or

$\frac{3,123,400,000}{5,377,310}$ = 581 kcal/kg total products

3). Low Pressure Steam (2.5 atm)

Available 18,322,000 kg. at 652 kcal/kg = 11,952,500,000 kcal or

$\frac{11,952,500,000}{5,377,310}$ = 2,223 kcal/kg total products

3). Accordingly total energy taken out

1). Off gas 4,862 kcal/kg total products = 9.9%

2). Steam 2,804 " " " " = 5.7%

3). Conversion $\frac{41,516}{49,182}$ " " " $\frac{=84.4\%}{100.00\%}$

C). Specific Coke Consumption

Recalculated to a coke of 8,000 kcal/kg pure coke will figure

to a conversion of $\frac{41,516}{8,000}$ = 5.19 kg pure coke/kg total products

or 5.19 x $\frac{5,377,310}{4,941,980}$ = 5.65 kg pure coke/kg liquid products.

D). Direct Measurements

The following values have been calculated from the coke actually put in

Raw coke input = 32,207,400 kg (5.8% water + 8.45% ash) =

32,207,400 x 0.8575 = 27,617,850 kg pure coke or

$\frac{27,617,850}{5,377,310}$ = 5.14 kg pure coke/kg total products

$\frac{27,617,850}{4,941,980}$ = 5.59 kg pure coke/kg liquid products

E). Accuracy

The values obtained from direct measurements differ therefore from the calculated values by

$\frac{(5.14 - 5.19) \times 100}{5.19} = \frac{-0.05 \times 100}{5.19}$ = about - 1.0%, or

$\frac{(5.59 - 5.65) \times 100}{5.65} = \frac{-0.06 \times 100}{5.65}$ = about -1.1%

F). Conversion Efficiency

The products formed consisted of

			10^6 kcal	%
20.3% =	1,090,290 kg	paraffin x 11,000 =	11,993.2	= 19.8
41.0% =	2,205,470 kg	oil x 11,200 =	24,701.3	= 40.8
30.6% =	1,646,220 kg	gasoline x 11,400 =	18,766.9	= 31.0
8.1% =	435,330 kg	gasol x 11,800 =	5,136.9	= 8.4
100.0% =	5,377,310 kg	total prod. x11,280 =	60,598.3	= 100.0%

Heat Balance

Input	kcal/kg total product		%
Coke	41,129	=	83.6
Power	5,842	=	11.9
Steam	2,211	=	4.5
Total	49,182	=	100.00%

Output	kcal/kg total product		%
Production	11,280	=	23.0 η
Off gas	4,862	=	9.9
Steam	2,804	=	5.6
Losses	20,236	=	61.5
Total	49,182	=	100.0%

η = 23% or $\frac{23.0}{0.836}$ = 27.5% of the heat of coke brought in.

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Energy Input into the Synthesis (May 1944)
Normal Pressure Synthesis

A). Energy Input

1). Coke (v total synthesis) = 5,647 kcal/nm^3 ideal gas

1 nm^3 ideal gas produces 129.6 g total products

$\frac{5,647}{0.1296}$ = 43,573 kcal/kg total production

2). Power

Supplied 434,060 kwh =

434,060 x 07 x 6,500 = 1,975,000,000 kcal, or

$\frac{1,975,000,000}{1,511,880}$ = 1,306 kcal/kg total production

3). High Pressure Steam (18 atm)

Consumption 4,347 te i=746 kcal/kg

$\frac{3,242,900,000}{1,511,880}$ = 2,145 kcal/kg total product

4). Accordingly, the energy input

	kcal/kg total product	%
Coke	43,573	92.6
Power	1,306	2.8
Steam	2,145	4.6
Total	47,024	100.0%

B). Energy carried out

1). The off gas, 4,448, 700 nm^3 with 2,270 kcal/nm^3 =

= 10,189,350,000 kcal, so that after the adsorption during the final purification (0.3 x 1,232,010 x 2,225 = 822,350,000 kcal), 9,367,000,000 kcal remain available, or

$\frac{9,367,000,000}{1,511,880}$ = 6,196 kcal/kg total production.

2). Middle Pressure Steam (9 atm)

Excess = 1,414 te i = 663 kcal/kg

$\frac{937,480,000}{1,511,880}$ = 620 kcal/kg total products

3). Low Pressure Steam (2.5 atm)

Excess = 5,066 te i = 652 kcal/kg

$\frac{3,302,400,000}{1,511,880}$ = 2,184 kcal/kg total production

4). Energy Production

	kcal/kg total production	%
1). Off gas	6,196	13.2
2). Steam	2,804	6.0
3). Conversion	38,024	80.8
Total	47,024	100.0

C). Specific Coke Consumption

This represents a conversion, after recalculation to pure coke of 8,000 kcal/kg

$\frac{38,024}{8,000}$ = 4.75 kg pure coke/kg total products

or $4.75 \times \frac{1,511,880}{1,366,750}$ = 5.26 kg pure coke/kg liquid products

D). Direct Measurement

Pure Coke conversion = 8,517,850 kg, corresponding to

$\frac{8,517,850}{1,511,880}$ = 5.64 kg pure coke/kg total production

$\frac{8,517,850}{1,366,750}$ = 6.23 kg pure coke/kg liquid products

E). Accuracy

The direct measurement values differ from calculated values by

$\frac{(5.64 - 4.75) \times 100}{4.75} = \frac{0.89 \times 100}{4.75} = + 18.7\%$

$\frac{(6.23 - 5.26) \times 100}{5.26} = \frac{0.97 \times 100}{5.26} = + 18.5\%$

F). Conversion Efficiency

The products consisted of

					10^6 kcal	%
90.4	% oil	=	1,366,750	kg x 11,200	=	15,444.3 = 90.0
	% gasoline	=		kg x 11,400		
	9.6 gasol	=	145,130	kg x 11,800	=	1,712.5 = 10.0
100%	Total Prod.	=	1,511,880	kg x 11,350	=	17,156.8 = 100.0

Heat Balance

Input	kcal/kg total prod.	%
Coke	43,573	92.6
Power	1,306	2.8
Steam	2,145	4.6
Total	47,024	100.0

Carried out

Production	11,350	24.1% = η
Off gas	6,196	13.2
Steam	2,804	6.0
Loss	26,674	56.7
Total	47,024	100.0

η = 24.1%, or $\frac{24.1}{0.926}$ = 26% of the heat of coke introduced.

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Energy input of the Synthesis (May 1944)
Pressure Synthesis

A). Energy Input

1). Coke (v total synthesis) 5,647 kcal/nm^3 ideal gas

1 nm^3 ideal gas produced 140.6 g total product, or 1 kg total products require

$\frac{5,647}{0.1406}$ = 40,164 kcal/kg total product

2). Power

6,470,060 kwh were consumed, and with a coal consumption of 0.7 kg/kwh (heating value = 6,500 kcal/kg of coal),

6,470,060 x 0.7 x 6,500 = 29,438,770,000 kcal have been required, or

$\frac{29,438,770,000}{3,865,430}$ = 7,616 kcal/kg total products

3). Steam (18 atm)

Consumption 11,590,000 kg i = 746 kcal/kg

11,590,000 x 746 = 8,646,000,000 kcal, or

$\frac{8,646,000,000}{3,865,430}$ = 2,236 kcal/kg total production

4). Accordingly, energy input

	Kcal/kg total products	%
1). Coke	40,164	80.3
2). Power	7,616	15.2
3). Steam	2,236	4.5
Total	50,016	100.0

B). Energy carried out

The residual gas, 7,274,000 nm^3 with 2,270 kcal/nm^3 contained 16,512,000,000 kcal, and after using up in the final gas purification (0.7 x 1,232,000 x 2,225 = 1,918,800,000 kcal). There remained available 14,593,200,000 kcal, or

$\frac{14,593,200,000}{3,865,430}$ = 3,775 kcal/kg total production

2). Middle Pressure Steam (9 atm)

Available 3,297 te 1 = 663 kcal/kg

$\frac{2,185,900,000}{3,865,430}$ = 566 kcal/kg total product

3). Low Pressure Steam (2.5 atm)

Available 13,266 te 1 = 652 kcal/kg

$\frac{8,649,400,000}{3,865,430}$ = 2,238 kcal/kg total production

4). Accordingly, total energy carried out

	kcal/kg total products	%
1). Off gas	3,775	7.6
2). Steam	2,304	5.6
3). Conversion	$\frac{43,437}{50,016}$	$\frac{86.8}{100.0}$
Total		

C). Specific Coke Consumption

Recalculated to pure coke with 8,000 kcal/kg indicates a conversion of

$\frac{43,437}{8,000}$ = 5.43 kg of pure coke/kg total products, or $543 \times \frac{3,865,430}{3,575,230}$ =

= 5.87 kg pure coke/kg liquid products

D). Direct Measurements

Pure coke conversion $27,617,850 \times \frac{32,332,700}{46,860,550}$ = 19,100,000 kg

$\frac{19,100,000}{3,865,430}$ = 4.94 kg pure coke/kg total products

$\frac{19,100,000}{3,575,230}$ = 5.34 kg pure coke/kg liquid products.

E). Accuracy

The direct measurement values differ from calculated values by

$$\frac{(5.43 - 4.94)\ 100}{5.43} = \frac{-0.49 \times 100}{5.43} = -9.0\%$$

$$\frac{(5.87 - 5.34)\ 100}{5.87} = \frac{-0.53 \times 100}{5.87} = -9.0\%$$

F). Conversion Efficiency

The product formed consisted of

			10^6 kcal	%
28.2%	paraffin = 1,090,290 kg x 11,000		= 11,993.2	= 27.6
	oil = kg x 11,200			
64.3	2,484,940		= 28,079.8	= 64.5
	gasoline kg x 11,400			
7.5	gasol = 290,200 kg x 11,800		= 3,424.4	= 7.9
100.0	total prod. = 3,865,430 kg x 11,260		= 43,497.4	= 100.0

Heat Balance

Input	kcal/kg total product	%
Coke	40,164	80.3
Power	7,616	15.2
Steam	2,236	4.5
Total	50,016	100.0

Carried out

Production	11,260	=	22.5 = η
Off gas	3,775		7.6
Steam	2,804		5.6
Losses	32,177		64.3
Total	50,016		100.0

η = 22.5% or $\frac{22.5}{0803}$ = 28% of the heat of coke.

Summary

	Normal Pressure synth.	Pressure synth.	Total Synth.
A). Heat Balance			
Input: Coke	92.6 - 100.0	80.3 - 100.0	83.6 -100.0
Power	2.8 - -	15.2 - -	11.9 - -
Steam	4.6 - -	4.5 - -	4.5 - -
Carried out:			
Production	24.1 - 26.0	22.5 - 28.0	23.0 - 27.5
Off gas	13.2 - 14.3	7.6 - 9.5	9.9 - 11.8
Steam	6.0 - 6.5	5.6 - 7.0	5.6 - 6.7
Losses	56.7 - 53.2	64.3 - 55.5	61.5 - 54.0
B). Specific Coke Consumption			
From the heat balance	4.75	5.43	5.19
Direct Measurements	5.64	4.95	5.14
Difference, %	+18.7	-9.0	-1.0

The work of compression in the pressure synthesis amounts therefore to 12% of the total heat conversion. It can not be recovered, and from a purely economic standpoint it represents a pure loss. This is the reason for a higher raw coke consumption in the heat balance of the pressure synthesis than in the low pressure synthesis.

Energy Balance of Synthesis
(May 1944)