of the CIOS report. However no such form of apparatus was mentioned by Totzek to the present investigators and it is entirely different from the form under development at Rheinpreussen from 1940 to 1944, and likewise from the form shown in the proposal for Brabag-Zeitz in 1942, Figure 11, page 27. Therefore it is believed that the patent sketch does not illustrate what Koppers ultimately regarded as an operable unit.

The expected performance of the Brabag Schwarzheide unit is given on page 33.

X. PREDICATED PLANT PERFORMANCE

Since it was impossible to obtain actual experimental data for any of the Koppers work on powdered coal gasification it is difficult to appraise the validity of claims made on different occasions for the operating characteristics of their process. However these claims are reproduced on the following pages in chronological order for whatever value they may have.

A. Brabag-Zeitz Proposal

Apparently the first proposal for a commercial unit for Brabag-Zeitz came late in 1941 since a Koppers memorandum dated 19 December 1941 (TOM Reel 43 frame 237) refers to previous discussions and gives some data on expected performance of the unit, which was to gasify 300 tons per day of lignite coke containing 20% ash. The oxygen consumption was estimated to be 0.51 m^3 per Kg coke and the gas production was to be 2.18 Nm^3 per Kg coke. The gas composition was stated to be as follows:

CO_2	18.61 vol %
CO	40.25 vol %
H_2	40.25
N_2	0.73
H_2S	0.16

The only information available regarding the design of this plant is Koppers drawing IAK 131,928 reproduced in part as Figure 11, page 27.

A Koppers memorandum dated 13 April 1942 (TOM Reel 43 frame 225) includes a cost estimate apparently prepared for Brabag-Zeitz and covering the gasification of powdered lignite instead of lignite coke. From these data Table I, page 30, has been prepared. Comparative operating costs for a Winkler unit are included in the original document indicating a figure of 2.11 Pfg per Nm^3 $CO+H_2$ for Winkler compared with 1.82 Pfg per Nm^3 $CO+H_2$ for Koppers. However the comparison is admitted to be questionable since the Winkler data were based on the gasification of lignite coke, which was given the same money value as the raw lignite assumed for the Koppers process. The Winkler process was claimed by Totzek to be inoperable on raw lignite.

TABLE I

BRABAG ZEITZ POWDERED LIGNITE GASIFICATION PROPOSAL

		Pfg.
Investment, including reserve Cowper	RM5300000	
Operating Costs per Nm^3 water gas		
1. Amortization and Interest 15%		0.1870
2. 0.16 Nm^3 oxygen at Pfg. 3.1		0.4960
3. 0.539 Kg coal at RM 9 per ton		0.4770
4. 24 worker shifts per day at RM 2 per hour including supervision		0.0560
5. 0.120 Kg outside steam at RM 1.50 per ton		0.0180
6. 0.035 Kw hr Power at Pfg. 1.5		0.0525
7. 20 liters circulating water at Pfg. 2.0 per m^3		0.0400
8. 0.53 liters boiler feed water at Pfg. 20.0 per m^3		0.0105
9. 650 Kcal outside heat at RM 1.0 per million Kcal		0.0650
10. 2.5% repair costs basis investment		0.0477
Total		Pfg. 1.5497

Production 760,000 Nm^3 water gas per 24 hrs.
645,000 Nm^3 $CO + H_2$ per 24 hrs.
Operating cost total per Nm^3 $CO + H_2$ Pfg. 1.82

(B) Rheinpreussen Proposal (1941-1942)

Although operating conditions for this unit are not specified, some data on the quantities involved are given in a memorandum dated July 16, 1942 regarding operating costs of several alternative proposals for Rheinpreussen. From this letter Table II, page 31, has been prepared, summarizing the cost calculations for a bituminous coal dust gasification unit with five operating generators, for the direct production of synthesis gas having a $CO:H_2$ ratio of 1:2 and producing 60,000 m^3 per hour or 1,440,000 m^3 per day. The product gas composition was expected to be as follows:

CO_2	18% vol
CO	27
H_2	54
N_2	1
	100%

TABLE II

RHEINPREUSSEN POWDERED COAL GASIFICATION PROPOSAL

Expenditures, daily

1.	Coal 514 tons	at RM 14.0	RM 7200
2.	Oxygen 230,000 m^3	at RM 0.025	5750
3.	51 man-shifts labor	at RM 12.0	612
4.	Power 36,000 Kcal	at RM 0.02	750
5.	Circulating water 25,000 m^3	at RM 0.02	500
6.	Fresh water 2500 m^3	at RM 0.02	50
7.	Boiler feed water 720 m^3	at RM 0.20	144
8.	Fuel gas 547 x 10^6 Kcal	at RM 4.50	2460
9.	Steam, 3 atm. abs. 662 tons	at RM 1.50	994
10.	Amortization, interest, maintenance 14% of RM 9,000,000		3450
	Total daily expense		21880

Credit, daily

1.	Steam, 16 atm. abs. 700 tons	at RM 3	2100
Net operating expense			19780

Operating cost per Nm^3 synthesis gas	Pfg. 1.370
Operating cost per Nm^3 $CO + H_2$	Pfg. 1.690

(C) Totzek Address of 12 June 1942

Table III, page 32 summarizes the estimated performance figures for the Koppers process on different coals as taken from an attachment to the Totzek paper. Graphical representations of heat balances and operating costs for the production of synthesis gas or fuel gas from the different solid fuels are given in the original paper.

TABLE III

SUMMARY OF ESTIMATED PERFORMANCE DATA, 1942

		BITUMINOUS COAL		LIGNITE		LIGNITE COKE
COAL ANALYSIS						
Water	Wt. %	1.95		13.00		5.0
Ash	Wt. %	8.93		5.95		21.0
Volatile	Wt. %	22.30		51.40		6.3
Crucible Coke	Wt. %	77.70		48.60		93.7
Gross Heating Value	Kcal/kg. Btu/lb.	7650 13,770		5120 9220		6054 10,900
		SYNTHESIS GAS	FUEL GAS	SYNTHESIS GAS	FUEL GAS	FUEL GAS
PRODUCT GAS COMPOSITION						
CO_2	Vol. %	11	7	14	6	6
CO	Vol. %	54	21	35	27	26
H_2	Vol. %	34	16	50	20	18
N_2	Vol. %	1	56	1	47	50
Gross Heating Value	Kcal/Nm^3 Btu/$ft.^3$	2505 281	1023 115	2342 263	1329 149	1253 141
PLANT QUANTITIES						
Gas Production	Nm^3/24 hr. 1000 $ft.^3$/24 hr.	760,000 26,800	1,280,000 45,200	760,000 26,800	985,000 34,800	1,045,000 36,900
CO + H_2 Production	Nm^3/24 hr. 1000 $ft.^3$/24 hr.	669,000 23,600		645,000 22,800		
Coal Dust Consumption	Tons/24 hr.	362 399	388 428	400 441	400± 441	357 394
Plant Cost	RM	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
Gas Yield	Nm^3 per kg. Coal $ft.^3$/lb.	2.1 34	3.3 53	1.9 30	2.44 39.1	2.93 46.9
Gas Heat Content	Kcal per kg. Coal Btu/lb.	5260 9470	3390 6100	4450 8010	3275 5895	3666 6600
Steam Production	kg. per kg. Coal lb./lb.	0.985 (2 ATU.)	2.85 (20 ATU.)	0.665 (2 ATU.)	1.0 (2 ATU.)	1.29 (2 ATU.)
Steam Consumption	kg. per kg. Coal lb/lb.	0.300 (2 ATU.)	0.45 (2 ATU.)	0.510 (2 ATU.)	0.1 (2 ATU.)	0.31 (2 ATU.)
Excess Steam	kg. per kg. Coal lb/lb.	0.685 (2 ATU.)	2.85 (2 ATU.)	0.155 (2 ATU.)	0.9 (2 ATU.)	0.98 (2 ATU.)
Fuel Gas Consumption	Kcal per kg. Coal Btu/lb	254 457		450 810		
Oxygen Consumption	Nm^3 per kg. Coal $ft.^3$/lb	0.525 8.4		0.304 4.9		

(D) Brabag Schwarzheide Proposal (1943)

The data for the proposed Brabag-Schwarzheide plant are taken from documents on TOM Reel 43, Frames 210-218, which were also summarized in CIOS Report XXVIII-36, Item 30.

Brabag-Schwarzheide required a plant to produce 100,000 Nm^3/hr. of synthesis gas (CO/H_2 = 1.65/1), from upper Silesian coal or low-temperature coke, for medium pressure Fischer synthesis over an iron catalyst. The coal and coke specifications were not given except that it would be ground so that 75 per cent would pass through a 49,000 mesh sieve. The finished gas must be free of condensible hydrocarbons and the sulfur removal must present no difficulties.

The coal and product gas analyses were given as follows:

Coal Analysis		Product Gas Analysis	
Water	1.95 wt %	CO_2	11.0 vol. %
Ash	8.75 wt. %	CO	54.0 vol. %
Volatile	22.3 wt. %	H_2	34.0 vol. %
Residue	77.7 wt. %	N_2	1.0 vol. %
Gross heating value		Net heating value	
kcal/kg. Btu/lb.	7650 13,770	kcal/Nm^3 Btu/ft^3	2505 281

On the basis of 1 kg 1 lb. of powdered coal the following quantities were estimated.

Gas production	Nm^3 ft^3	2.10	33.6
Oxygen consumption	Nm^3 ft^3	0.57	9.1
CO_2	Nm^3 ft^3	0.14	2.2
Fuel consumption	kcal Btu	350	630
Steam production kg. at 16	atm. abs. 350°C. 662°F	0.71	
Steam consumption kg. at 3	atm. abs. sat.	0.40	

For the production of 100,000 Nm^3/hr. (3,500,000 ft^3/hr.) of synthesis gas for 8000 hours per year Koppers proposed to build six units (one in reserve) each costing 2.7 million R.M. or a total cost of 16.2 million R.M. It was estimated that the gas would cost 1.7 pfg. per Nm^3.

(E) Estimates Obtained by Navy Technical Mission (1945)

The documents obtained by U.S. Navy investigators include five pages of data on heat and material balances, dated Essen, June 4, 1945 and apparently prepared specifically for the Navy investigators. These data are not the same as any given in the Appendix to the Totzek address of June 12, 1942. Two graphical representations of heat balances included with the Navy

documents likewise differ from any in the Totzek paper. The data for Rheinpreussen bituminous coal differ slightly from similar data given to FIAT investigators. Simplified diagrams of the pilot plant equipment were the same in each case.

The data for the gasification of bituminous coal and lignite are summarized in Table IV, below:

TABLE IV

KOPPERS DUST GASIFICATION DATA GIVEN TO U. S. NAVY INVESTIGATORS JUNE 1945

	Bituminous Coal	Lignite
Raw Dust Analysis Wt. %		
Water	1.95	13.00
Ash	8.75	5.18
H_2	4.27	4.71
Carbon	80.50	56.20
Combustible S.	1.88	0.33
Nitrogen	1.19 }	20.58
Oxygen	1.46 }	
Gross heating value, kcal/kg Btu/lb.	7977 14,360	5313 9560
Extraneous steam Nm^3/Kg $ft.^3/lb.$	1.407 22.5	0.860 13.8
Extraneous oxygen Nm^3/Nm^3 gas $ft.^3/ft.^3$	0.246	0.206
Extraneous oxygen Nm^3/Kg $ft.^3/lb.$	0.608 9.7	0.379 6.1
Preheat temperature °C. °F	1200 2192	1200 2192
Reactor exit temperature °C. °F	1200 2192	1000 1832
% Carbon conversion	94	95
Thermal Gasification Efficiency %	75	79.6
Synthesis gas produced Nm^3/Kg $ft.^3/lb.$	2.47 39.6	1.84 29.5
$CO+H_2$ in gas produced vol. %	84	80
Product gas analysis vol. %		
CO_2	15.0	19.0
CO	42.0	35.0
H_2	42.0	45.0
N_2	1.0	1.0

The heat balance for the bituminous coal operation is shown diagramatically by Figure 13, page 35, and for lignite by Figure 14, page 36.

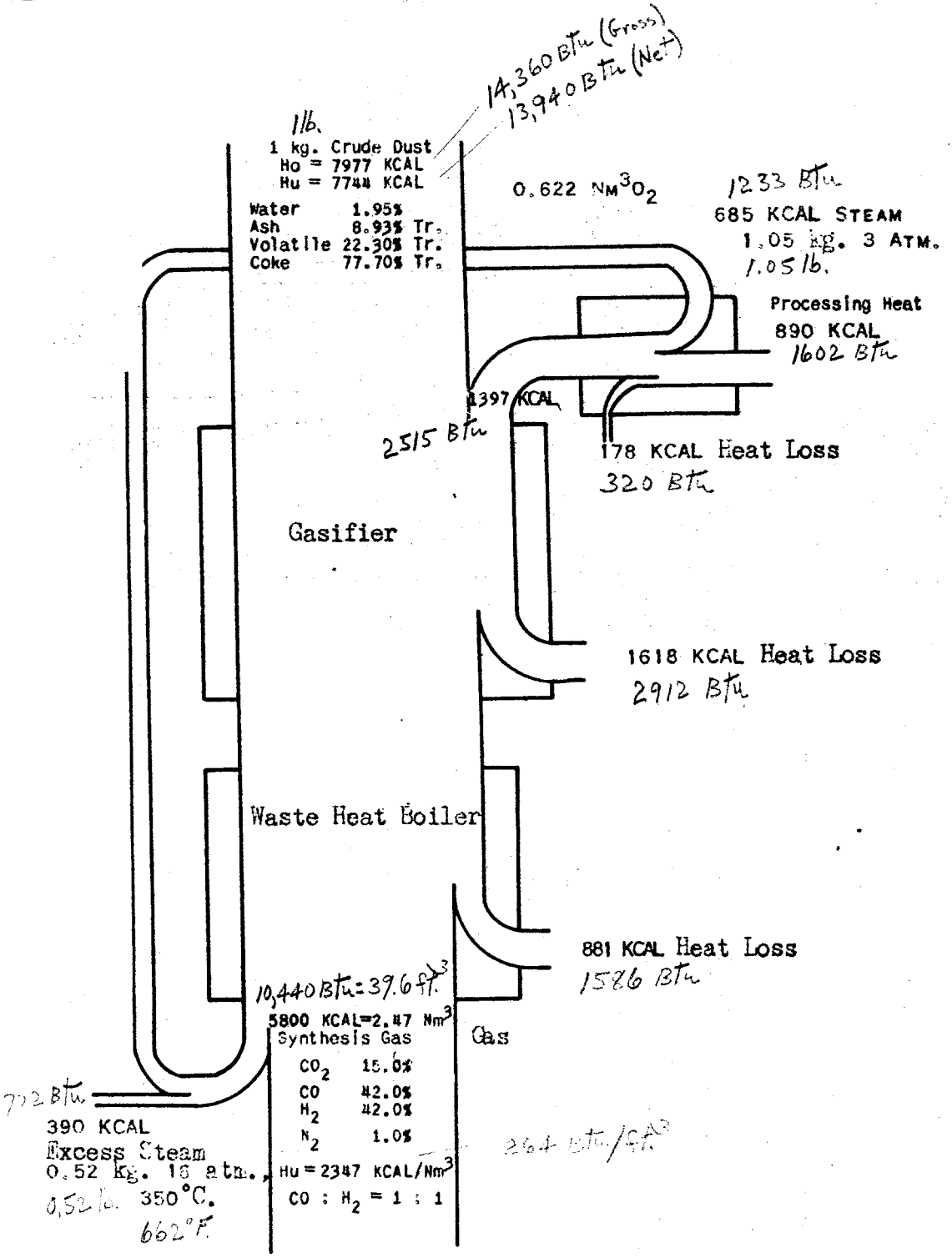

FIGURE 13

HEAT FLOW DIAGRAM FOR SYNTHESIS GAS PRODUCTION FROM BITUMINOUS COAL DUST

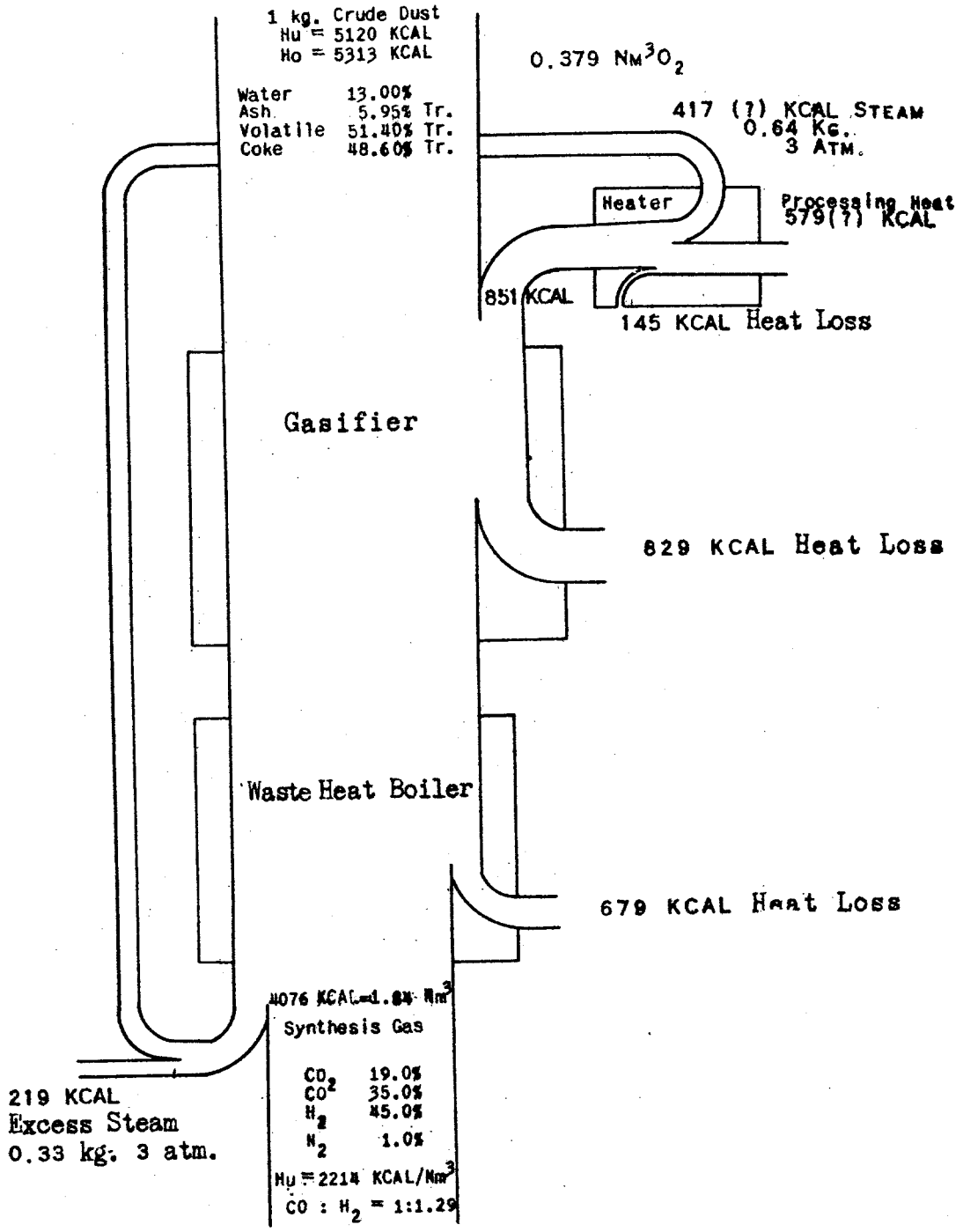

FIGURE 14

HEAT FLOW DIAGRAM FOR SYNTHESIS GAS PRODUCTION FROM LIGNITE DUST