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Production of Synthesis Gas from Wyoming Sub-bituminous Coal

General Investigation of Methods and Flow-Sheet for Plant to Process 8,000,000 CuFt per Day

In order to obtain general information on the principal advantages and dis-advantages of the various methods of producing synthesis gas from a coal like the Wyoming coal three methods which were considered as suitable for treating this coal have been examined by calculations of the investment- and the production-cost for an industrial plant with a capacity of 100,000 Nm^3/h Ideal gas ($CO + H_2$). This corresponds to a synthesis plant for the production of 122,000 tons of primary products in 350 operating days plus 12,000 tons of liquid gas.

A high content of hydrogen, which is higher than in any German coal, indicates a very high tar content and favors by-product gasification. Two methods of this group, the Lurgi-pressure gasification process and combined carbonization-gasification have been investigated. For comparison the Koppers method of gasifying pulverized coal has been calculated, supposing that this method in the near future will be developed as the cheapest way of only gasifying carbonacious material. For this plant operating figures have been taken from a project worked out by the Koppers Company and the investment cost of the gas producers has been estimated extremely low in favor of this process.*

Only a Synthesis with an iron catalyst under 15 to 20 atm pressure has been considered suitable for a maximum yield of good quality gasoline. In this case the production of the gas cannot be calculated separate from the synthesis, because the production of the synthesis gas requires considerable quantities of energy, which is produced to a great extent in the synthesis plant and available for the gas production. The energy delivered from the synthesis plant has not been charged to the gas factory, only the investment, and the operating cost of the power station have been charged.

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* L. L. Newman

Additional energy is procured by burning coal in connection with the Koppers system or by burning coke in connection with the combined carbonization-gas producer method. As a variation and simplification of this method an exclusive production of the synthesis gas from coke has been investigated. In this case, the carbonization zone is operated with air and the carbonization gas used for heating the boilers of the powerhouse. Cracking of the carbonization gas is avoided in this case. All the gaseous hydrocarbons and most of the sulfur are carried off to the boilerhouse. A sulfur extraction plant can be avoided for the synthesis gas and the power plant is considerably lowered in its investment and operating cost by the gas firing method.

Cost of equipment is taken from figures available from plants errected in Germany. Corresponding figures for U.S.A. are calculated with the relation of 1RM = $ 0.5 for the investment cost and 1RM = $ 1.00 for the cost of labor. Cost of special work has been adjusted roughly. For a comparison only of the gas producing methods the figures can be considered as fairly reliable, though accurate figures for the various items may not easily be procured in the near future for U.S.A. manufacturing conditions.

There are two facts of a special importance, when the various methods of production are considered for U.S.A. and German or European conditions respectively:

1. Cost of labor is of a much greater influence on the production cost in the U.S.A. than in Europe and favors such methods which need very little labor as probably the gasification of pulverized coal.

2. The value of by-products, which is relatively low in U.S.A. as long as the competition of natural oil is free and unlimited for a sufficient supply and the lack of any protection of motor fuels from coal by a direct or indirect subsidiary.

In European countries, where the production of motor fuels from coal has to be realized for conditions of international trade and stabilization of currency, the

production of motor fuels is considered independent from natural oil products. By-products are very high priced there, because even then they offer the way of lowest cost for producing motor fuels from coal. The situation will become the same in the U.S.A. when it comes to any industrial production of oils from coal, because then by-products have to compete with products of Synthesis or Hydrogenation plants, and these products naturally are considerably more expensive than in Europe. For Synthesis products produced from a very cheap coal with probably the cheapest method of clear gasification (the Koppers method) the calculated production cost of the gas proves this clearly. The cost of the Synthesis gas alone amounts roughly to 5 cts. per kg. of benzine under most favorable conditions. For comparison, a much higher value than $30.00 per ton would be justified for by products of carbonization.

Table I which shows the principal figures of the considered methods, also shows the relative influence of labor cost and value of by products in percent of the total production cost. Even with a price of $25.00 per ton of by products the gas can be produced cheaper when the tar is recovered. The difference in favor of by-product gasification becomes greater with a higher tar content of the coal and with a higher price of the tar. Examination of the most important coal fields for their tar contents seem to be urgent from this view point.

Even with the low tar contents of 7.2% the production of tar amounts to roughly 50% of the production of primary Synthesis products.

B. Pionier Plant

For a pionier plant with a capacity of 8,000,000 cuFt of Ideal gas per day, a project has been worked out. Combined carbonization gasification has been provided as the most favorable method for such special conditions. Pressure-gasification has been considered for comparison. The Koppers method of gasifying pulverized coal could be examined for this relatively small production figures only very roughly because only very insufficient data are available for calculating such on equipment.

Combined carbonization-gasification not only seems to be the most economical method for industrial plants, it also allows to study without an additional cost and probably with a commercial profit of operation, the carbonization of Wyoming coal and the production of a quantity of tar sufficient for large scale experiments of hydrogenation. This is possible, because the spare unit for gasification can normally be operated as a carbohizer and used as a gas producer only in case of temporary difficulties with the other gas producer unit.

If an examination of the Lurgi-Pressure gasification process is wanted in connection with this pioneer plant, one gas producer would be installed with very litt] additional cost. Even large scale experimenting with the Koppers method could be realized with very little cost for the gas producer only, using the spare units of the oxygen plant and the waterwash equipment for such special testing.

It can be expected that 150 to 180 tons per day of a lumpy coke low in ash and sulfur content can be sold at a high price very easily. The production cost of this coke should be very low because it requires only very little labor and very little investment cost in addition to the cost of erecting and operating the gas producer plant only.

Large scale experience with carbonization in the Wyoming coal field seems to be of the greatest importance for the future development of the fuel industry. The high content of hydrogen of Wyoming coal promises very high tar content and consequently very favorable conditions for utilizing this coal for the production of motor fuels by a combination of carbonization, by-product-gasification with the synthesis of hydrocarbons and hydrogenation of tar.

Figures of a basic group of factories of such an industry treating Wyoming coal have been worked out to give a rough idea of this combination, which has been found to be the most favorable solution to the problem in Germany. (Table III)

If the carbonizer-gas producer plant is erected and operated for the

production of Synthesis gas only the cost of production is increased as can be seen from a comparison of the most important production figures. (Table II). In this case, the plant is equipped with a 100% spare-unit.

The Koppers plant requires less capital investment. The highest investment cost is required for the pressure-gasification plant. It must be remembered however that the investment figures will be slightly equalized by additional cost of the power station in case of the Koppers plant.

For the calculation of production cost power has been calculated at the relatively low cost of 0.6 cents per KWH with regard to the fact that more than 50% of the consumed power isproduced from surplus steam and residual gas of the Synthesis plant. For pressure-gasification and a combined carbonization-gasification, the available energy is sufficient or can be produced from the carbonizer gas, which has not been accounted for in the balance sheet. For these two methods the cost of energy has been reduced to 0.5 cents per KWH.

The following table (II) shows the principal figures of the various methods. These figures however should not be considered as typical for the methods in an industrial use, because the relative influence of general expense and of spare units equalizes the figures of such a small plant considerably:

TABLE II

Process	A Carbon-Gas.		B Koppers	C Pressure-G
Investment Cost (Million dollars)	3,720	3,340*	3,170	3,710
Laborers (men)	82	60	57	52
Coal-Cons. (ton/year)	208,000	79,000	57,000	72,400
By-Products				
Tar (ton/year)	14,000	5,240	—	4,080
Coke (ton/year)	60,000	—	—	—
Energy Reqn. (KWH)	4,950	4,600	4,800	3,730
Production cost for Gas				
Million dollars/year	718	867	908	893
Dollars/1000Nm^3	9.3	11.05	11.8	11.5

* Plant erected and operated for synthesis gas only.

Calculations prove that from an economical standpoint the methods which allow the recovery of tar are superior to complete gasification in the case of Wyoming coal. All three methods allow the production of a gas with a high content of CO as required for a Synthesis with an iron catalyst. With the pressure-gasification process the ratio of $CO:H_2$ however is limited to 1:

It is proposed to errect two units of the carbonizer-gas producer type, equipment with the necessary device for operating each of the units for the production of gas as well as for the carbonization of coal and the production of coke. According to calculations this seems the safest, the cheapest, and the most flexible method with respect to the requirements of a pilot-experimental plant, which should be able to handle various types of coal and from various viewpoints like tar recovery and alteration of the ratio of CO to H_2.

A possible interest in studying other methods of gasification could be satisfied very easily by erecting experimental units of gas producers of the pressure-type and of the Koppers system for gasifying pulverized coal. These experimental units should, however, be of an industrial size.

The carbonizer plant could be used also for large scale experimenting with oil shales. For the high grade shales with more than 10% oil, it might be proved as a most economical method.

Basic figures of calculations

Coal	Moisture	21.1%
	Ash	4.1%
	Tar	7.2%
	H.Cal.Value	5220 kcal/kg
Coke (with 10% volatiles) H.Cal.Value		7000 kcal/kg
Efficiency of Boilers		82%
Efficiency of Power plant		25%
Steam prod. per kg Coal		5.25 kg/kg
Steam prod. per kg coke		7.08 kg/kg
Energy per kg coal		1.52 kwh/kg
Energy per kg coke		2.03 kwh/kg
Power consumpt. for oxygen		0.60 kwh/Nm^3
Power for compressors (21 atm)		0.21 kwh/Nm^3
Steam for energy (80 to 3 at exp.)		6.0 kg/kwh

Efficiency of gasification:

I. Gasification of pulverized coal

$$\frac{\text{h. cal. val. raw gas}}{\text{h. cal. val. coal}} = 0.78$$

II. Pressure-gasification

$$\frac{\text{h. cal. val. tar} + \text{h. cal. val. raw gas}}{\text{h. cal. val. coal}} = 0.84$$

III. Carbonization-gasification

$$\frac{\text{h. cal. val. tar} + \text{h. cal. val. raw gas}}{\text{h. cal. val. coal}} = 0.82$$

Recovery of Tar:

(a) by carbonization	92% of
(b) by pressure-gasification	75% Fischer-Assay

I

Koppers
Gasification of Pulverized Coal
105,000 Nm^3/h Syn.Gas

		R.M.
1.	4 gas producers (one spare)	2,400,000
2.	Condensation plant	3,000,000
3.	Plant for drying and pulverizing the coal	4,500,000
4.	Distribution System for energy, steam & water	1,000,000
5.	Recooling system	600,000
6.	Tower plant for sulfur extraction	2,000,000
7.	Waterwash with pumps and building	5,000,000
8.	Compressor Plant 3 x 60,000 Nm^3/h	2,400,000
9.	Oxygen Plant 4 x 10,000 Nm^3/h	9,500,000
10.	Roads and tracks	1,500,000
11.	Laboratory, Office, Various buildings	1,500,000
12.	Boiler and Power Plant 3 x 15,000 KW 1/ coal fired	12,000,000
		45,400,000
	Interest during erection	1,600,000
	Miscellaneous	2,500,000
	Total Investment	49,500,000

I

Koppers

Gasification of Pulverized Coal
Production Cost per Year

		R.M.	Dollars
1.	Coal 740,000 tons @ 2.50 RM @$1.00	1,850,000	740,000
2.	Fresh Water 400 m^3/h @ 0.05 RM @$0.03	168,000	101,000
3.	Luxmass	100,000	50,000
4.	Wages & Salaries Laborers 420 @ 2500 RM @$2500	1,050,000	1,050,000
	Supervising Personnel	150,000	100,000
5.	Repair 2.5% of 49.5 Mi.RM of 24.75 Mi. Dollars	1,240,000	620,000
6.	Interest 3.5% of 49.5 Mi. RM of 24.75 Mi. Dollars	1,730,000	865,000
7.	Amortization 6.5% of 49.5 Mi. RM	3,210,000	1,605,000
8.	Interest on Operating Capital 3.5% of 3.0 Mi. RM of 1.5 Mi. Dollars	105,000	53,000
	Total	9,603,000 R.M.	$5,184,000
	Cost of Synthetic Gas 882,000,000 Nm of 20 AtA		
	per 1000 Nm	10.9 RM	$5.9

II

Lurgi-Pressure Gasification
105,000 Nm³/h Sy. Gas

Investment Cost		R.M.
1.	24 Gas Producers including condensation plant and building (3 spare)	13,000,000
2.	Pressure - water wash including buildings	6,700,000
3.	Storage tanks for oils	200,000
4.	Distribution system for Energy, Steam, Water	1,200,000
5.	Recooling System	600,000
6.	Iron oxide plant	1,000,000
7.	Roads and Tracks	1,500,000
8.	Oxygen plant with compressors for oxygen and building	12,000,000
9.	Laboratory, office, var. buildings	1,500,000
10.	Boilers and power plant 3 x 15,000 kwh 1/3 coal fired	12,000,000
		49,700,000
	Interest during erection	1,800,000
	Miscellaneous	2,500,000
	Total Investment	54,000,000

II

Lurgi-Pressure Gasification

Production Cost	R.M.	Dollars
1. Coal 945,000 tons @ 2.50 RM @ $1.00	2,362,000	945,000
2. Fresh Water 500 m^3/h @ 0.05 R.M. @$0.03	210,000	126,000
3. Wages & Salaries Laborers 600 @ 2500 R.M. @ $2500	1,500,000	1,500,000
Supervising Personnel	150,000	100,000
4. Repair 2.5% of 54.0 Mi. R.M. of 27.0 Mi. Dollars	1,350,000	675,000
5. Interest 3.5% of 54.0 Mi. R.M. of 27.0 Mi. Dollars	1,885,000	945,000
6. Amortization 6.5% of 54.0 Mi. R.M. of 27.0 Mi. Dollars	3,510,000	1,750,000
7. Interest on Operating Capital 3.5% of 5.0 Mi. R. M. of 2.5 Mi. Dollars	175,000	87,000
	11,142,000	6,128,000
Value of tar 44,200 tons @ 110 R.M. @ $30	4,862,000	1,326,000
Cost of 882 Mi. Nm^3 Gas	6,280,000	4,802,000
Cost per 1000 Nm^3	7.2	5.4

III
Carbonization-Gasification
(With Split Gas)

Investment Cost	R.M.
1. 10 Carbonizer-gas producer (including building and transport equipment)	4,800,000
2. Condensation Plant (including Cracking of CH_4)	3,500,000
3. Benzine recovery plant (including plant for distilling of scrubber-oil	2,100,000
4. Storage tanks for oils	200,000
5. Distribution system for energy, steam, water	1,200,000
6. Recooling system	600,000
7. Sulfur extraction plant	500,000
8. Water wash with pumps and building	5,000,000
9. Compressor plant 3 x 60,000 Nm/h	2,400,000
10. Oxygen Plant 4 x 10,000 Nm^3/h	9,800,000
11. Roads and Tracks	1,500,000
12. Laboratory, office and various buildings	1,500,000
13. Boiler and Power Plant 1/2 Coal Fired Equipment 3 x 15,000 KW	13,500,000
	46,600,000
Interest during erection 3.5%	1,600,000
Miscellaneous	2,000,000
Total Investment	50,200,000

III

Carbonization-Gasification
(With Split Gas)

Production Cost	R.M.	Dollars
1. Coal 995,000 tons @ 2.50 R.M. @$ 1.00	2,449,000	995,000
2. Fresh Water 500 M^3/h @ 0.05 R.M. @ $0.03	210,000	126,000
3. Wages & Salaries Laborers 550 @ 2500 R.M. @$2500	1,375,000	1,375,000
Supervising Personnel	150,000	100,000
4. Repair 2.5% of 50.2 Mi. R.M. of 25.1 Mi. Dollars	1,750,000	625,000
5. Interest 3.5% of 50.2 Mi. R.M. of 25.1 Mi. Dollars	1,750,000	875,000
6. Amortization 6.5% of 50.2 Mi. R.M. of 25.1 Mi. Dollars	3,260,000	1,630,000
7. Interest on operating capital 3.5% of 5.0 Mi. R.M. of 2.5 Mi. Dollars	175,000	88,000
Total	10,660,000	5,814,000
Value of tar 65,800 tons 100R.M. @$25	6,580,000	1,650,000
Cost of gas 882 Mi. Nm^3	4,080,000	4,164,000
per 1000 Nm^3	4.60	4.70

IV

CARBONIZER-GASPRODUCER PLANT
CARBONIZER-GAS FOR BOILER

Investment Cost	RM
1. 10 Carbonizer-producers including building and transportation	4,800,000
2. Condensation plant	3,000,000
3. Benzine recovery plant	2,100,000
4. Storage tanks for oils	200,000
5. Distribution system for energy, steam and water	1,200,000
6. Recooling system	600,000
7. Waterwash with pumps and building	5,000,000
8. Compresser plant 3 x 60000 Nm^3/h	2,400,000
9. Oxygen plant 4 x 10000 Nm^3/h	9,800,000
10. Roads and tracks	1,500,000
11. Laboratory office and buildings	1,500,000
12. Boiler and powerplant 3 x 15000 KW (gas fired)	11,000,000
	43,100,000
Interest during erection	1,500,000
Miscellaneous	2,000,000
	46,600,000

IV

CARBONIZER-GASPRODUCER PLANT
CARBONIZER-GAS TO BOILERS

Production Cost	RM	Dollars
1. Coal 925,000 tons @ 2.50 R.M. @ 1.00 Dollar	2,310,000	925,000
2. Fresh water 500 M^3/h @ 0.05 R.M. @ 0.03 Dollars	210,000	126,000
3. Wages & salaries Laborers 450 @ 2500 R.M. @ 2500 Dollars	1,125,000	1,125,000
Supervising personnel	150,000	100,000
4. Repair 2.5% of 46.6 Mio. R.M. of 23.3 Mio. Dollars	1,170,000	585,000
5. Interest 3.5% of 46.6 Mio. R.M. of 23.3 Mio. Dollars	1,630,000	815,000
6. Amortization 5.6% of 46.6 Mio. R.M. of 23.3 Mio. Dollars	3,020,000	1,510,000
7. Interest on operating capital 3.5% of 5.0 Mio. R.M. of 2.5 Mio. Dollars	175,000	87,000
Total	9,790,000	5,273,000
Value of tar 60500 tons @ 100 R.M. @ 25 Dollars	6,050,000	1,513,000
Cost of gas 882 Mio. Nm^3	3,740,000	3,760,000
per 1000 Nm^3	4.24	4.25

Table I
Investment Costs and Production Figures
100,000 Nm/h I-Gas

Process	I Gasification of Pulverized Coal		II Pressure Gasification		III Carbon.W.O_2 Gasific.W.O_2		IV Carbon.W.Air Gasific. W.O_2	
Investment Cost Million R.M.	49.5		54.0		50.2		46.6	
Million Dollars		24.75		27.0		25.1		23.3
Coal Consumption Tons/Year	740,000		945,000		995,000		925,000	
Laborers	420		600		550		450	
Wages Mil. R.M.	1.05		1.5		1.37		1.13	
Mil.Dollars		1.05		1.5		1.37		1.13
in % of Prod-Cost	(11.0)	(20)	(13.5)	(24.5)	(12.8)	(23.4)	(11.5)	(21.5)
Production Cost per year Mil. R.M.	9.6		11.14		10.66		9.79	
Mil. Dollars		5.18		6.13		5.81		5.27
Tar Production Tons/Year	--		44,200		65,800		60,500	
Value of tar Mil.R.M.	--		4.86		6.58		6.05	
Mil. Dollars		--		1.33		1.65		1.51
in % of Prod-Cost			(43.5)	(21.6)	(62.0)	(28.3)	(62.0)	(28.5)
Production Cost per 1000 Nm^3 Mil. R.M.	10.9		7.2		4.60		4.24	
Mil. Dollars		5.9		5.40		4.70		4.25

CARBONIZER-GAS PRODUCER PLANT
INVESTMENT COST AND MATERIAL
(SPARES INCLUDED)

Pionier Plant A

		M.RM	M.DOLLARS	FE to.	FIRE BR. to.
I.	Oxygen plant including building 2 x 3000 Nm^3/h	2500	1500	800 / Al.	
II.	Carbon gas producer				
	1. 2 carbonizer gas producers	700	350	600	420
	2. Carbonizer building including steel structure of bins and stairways	150	80	170	
	3. Condensation plant including operating tanks for tar	600	300	465	
	4. 2 oil scrubbers	120	60	95	50
	5. Benzine recovery plant	250	130	160	50
	6. 2 bucket conveyers (80000) 2 charging cars (50000) 2 coke conveyers (60000) (1-6)	190	120	150	
	7. Erection cost including transport	300	200	---	
	8. 2 recooling towers including pipes	60	45	15	
	9. Coke handling equipment	120	80	50	
III.	Gas compressors and water wash				
	1. 2 compressors (12000 Nm/h each)	220	160	150	
	2. 3 wash towers with pumps 1 airating tower with fan	600	400	250	
IV.	Storage tanks for tar 2500 to.	80	50	80	
V.	Electric equipment for production	85	45	10	
VI.	Foundations of machinery and bldgs.	360	250	20	
VII.	Distr. system for steam, energy, water	200	150	100	
	Total	6535	3720	3110	520

Carbonizer Gas Producer Plant
Production Cost 320 Operating Days
Pionier Pl. A

1.	Coal 208,000 tons @ $2.00		$ 416,000
2.	Fresh Water 1,000,000 M^3 @ $0.03		30,000
3.	Wages and Salaries		
	Laborers		
	Carbonization Plant	30	
	Oxygen Plant	10	
	Compressors	3	
	Waterwash	6	
	Cleaning Loading	16	
	Repair	6	
		71	
	15%	11	
		82 @ 2500	205,000
	Supervising Personnel		30,000
4.	Energy 39,300,000 KWH @ $0.005		196,000
5.	Steam 46,000 tons @ $0.8		36,800
6.	Interest and Amortization 10% of 3.72 Mi. Dollars		372,000
7.	Repair 2.5% of 3.72 Mi. Dollars		93,000
	Total cost per year		$1,378,800
	Value of Tar 14,000 tons @ $3		420,000
	Value of coke 60,000 tons @$4		240,000
	Production cost for 77 Mi. Nm Syn. Gas		$ 718,800
	Production cost per 1000 Nm^3		9.30

Koppers Pulverized Coal Gasification
Pionier Pl. B

Investment Cost and Material	M.R.M.	M. Dollars	FE To.	Fire Brick To.
I. Oxygen Plant including Building 2 x 3000 Nm/h	2,500	1,500	800	—
II. 1. Gas Producer Plant 2 producers	700	350	600	500
2. Pulverizer Plant 2 units Dryers with bin	300	160	200	—
3. Heat Exchangers and Scrubbers	80	50	60	—
4. Coal conveyers	50	30	30	—
5. Erection cost for 1-6 including transportation	220	150	—	—
6. 1 Recooling tower with pipes	35	25	10	—
7. Sulfur extraction	200	100	120	—
III. Gas Compressors and Waterwash				
1. 2 Compressors 12000 Nm^3/h each	220	160	150	—
2. 3 Wash towers with pumps 1 airating tower with fan	600	400	250	—
IV. Electric Equipment	70	40	10	—
V. Foundations of machinery and buildings	250	150	15	—
VI. Distributing system for steam, energy, water	100	75	50	—
Total	5,125	3,170	2,295	500

Koppers Pulverized Coal Gasification
Production Cost 320 Operating Days
Pionier Pl. B

1.	Coal 57,000 tons @ $1.50		$ 85,500
2.	Fresh Water 7,700,000 M^3 @ $0.03		23,100
3.	Lux mass including labor		10,000
4.	Wages and Salaries		
	Laborers		
	Pulverizer	9	
	Gasific.	9	
	Oxygen Plant	10	
	Comp.	3	
	Waterwash	6	
	Cleaning	6	
	Repair	6	
		49	
	15%	8	
		57	142,000
	Supervising Personnel		30,000
5.	Energy 37 M. KWH @ $0.006		222,000
6.	Interest and Amortization 10% of 3.17 M. Dollars		317,000
7.	Repair 2.5% of 3.17 M. Dollars		79,000
	Total cost per year		$ 908,600
	Production cost for 77 Mi. Nm^3		908,600
	Production cost per 1000 Nm^3		$ 11.80

Pressure Gasification
Pionier Pl. C.

Investment Cost and Material	I.R.M.	M. Dollars	FE To.	Fire Brick To.
I. Oxygen Plant Including Building 3 x 2000 Nm^3/h	3,000	1,700	900	--
3 Compressors for Oxygen	200	120	100	--
II. Gas Producer Plant				
1. 3 Gas producers with pipes, instruments, charging hoppers outlet of bins, automatic charging device	980	550	370	30
2. Condensation plant with oil-scrubber and Benzine recovery including pumps, pipes and operating tanks.	470	250	225	--
3. Structure for the producer-building includings bins and stairway	120	60	130	--
4. Transport means 2 bucket conveyers	60	40	50	--
5. Erection cost for II to V including transport	250	160	--	--
6. 1 Recooling tower including pipes	30	22	10	--
III. Waterwash, 3 wash towers with pumps, 1 airating tower with fan	600	400	250	--
IV. Splitting Chamber	100	55	50	30
V. Storage Tanks for 1500 tons	50	30	50	--
VI. Electric Equipment of Producer Plant	50	30	6	--
VII. Foundations of Machinery and Buildings	200	120	15	--
VIII. Distributing System for water steam, energy	150	120	80	--
IX. Sulfur extraction 2 stages	100	55	60	--
	6,360	3,712	2,296	60.

Pressure Gasification
Pionier Pl. C.
Production Cost 320 Operating Days

1.	Coal 72,400 tons @ $2.00		$ 144,800
2.	Fresh Water 800,000 M^3 @ $0.03		24,000
3.	Wages and Salaries		
	Laborers		
	Gas Producer Plant	16	
	Oxygen Plant	14	
	Water Wash	6	
	Cleaning	5	
	Repair	4	
		45	
	+ 15%	7	
		52 @ 2500	130,000
	Supervising Personnel		25,000
4.	Energy 28,500,000 KWH @ $0.005		142,500
5.	Steam 88,500 tons @ $1.20		106,100
6.	Interest and Amortization 10% of 3.71 Mi. Dollars		371,000
7.	Repair 2.5% of 3.72 Mi. Dollars		93,000
	Total cost per year		$ 1,036,400
	Value of tar 4,080 tons @ $35.00		143,000
	Production cost for 77 Mi. Nm^3		$ 893,400
	Production cost per 1000 Nm^3		$ 11.50

Table II
Production of Motor Fuels from Wyoming Coal by Combined Methods

Coal Mined 3,460,000 ton/year

Motor Fuels 420,000 ton/year

Lump Coke 300,000 ton/year

Works	Coke Sold To/year	Synth. Products To/year	By Prod. Tar To/year	Hydrog. Prod. To/year	Coal Consumption To/year
Synthesis I	—	120,000	60,500	—	930,000
Synthesis II	—	120,000	60,500	—	930,000
Carbonizer Plant	300,000	—	50,000	—	700,000
Hydrogen Plant	—	—	59,000	180,000	900,000
	300,000	240,000	230,000	180,000	3,460,000
for comparison:					
Brux Works (1)	2,000,000	—	1,000,000	800,000	8,400,000
Saxonia-Works (2)	2,100,000	—	1,450,000	1,200,000	20,000,000 (11,000,000 to. of Briquettes)

(1) One carbonization-Hydrogenation work
(2) Nine carbonizer plants, 3 hydrogenation plants 2 refineries

I Koppers - Gasification of pulverized coal.

Coal
Moist 21.1 %
Ash 4.1
Taar 7.2
H cal v 5220 Kcal/Kg

Coal 76.6 %
84.0 t/h

Pulverizer
Dryer

7.4 t/h

Steam 52.5 t/h
2.5 at
Oxygen 28300 Nm³/h

Gasproducer

Rawgas 116500 Nm³/h
CO₂ : 11.0 %
O₂ : 0.1
CO : 53.3
H₂ : 33.6
CH₄ : 0.5
N₂ : 1.5

Iron oxide
towerplant

Compr

Waterwash

for coaldryer
6500 Nm³/h

Rik. Tre

Synthesis
100000 Nm³/h

Synthes-Gas 105000 Nm³/h
CO₂ : 2 %
CO : 58.7
H₂ : 37.1
CH₄ : 0.5
N₂ : 1.7
H.C.V. 2955 Kcal/Nm³

T-Gas
Resid-Gas 30000 Nm³/h
CO₂ : 50.0%
CO : 15.0
H₂ : 13.0
CH₄ : 16.0
N₂ : 6.0
H.C.V. 2370 Kcal/Nm³

- Energy
from 50100 KW
Sy. -32500
17600 KWh
W Heat- 6500
Coal 11100

18[illegible] KW

1500 KW

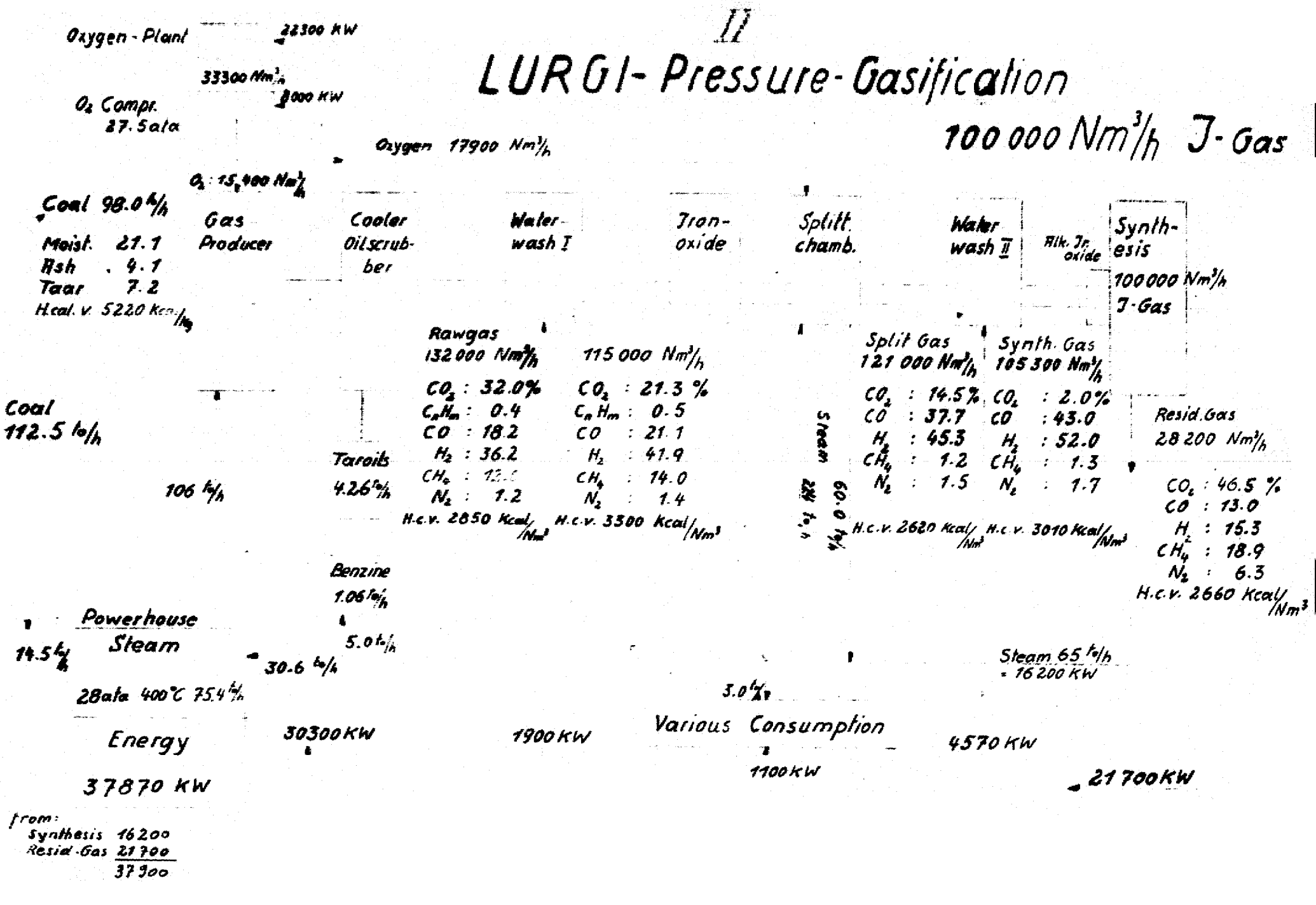
Various Consumpt.
1500 KW
1000 KW
23300 KW
4400 KW

65 t/h Steam
= 16200 KW
23500 Nm³
16300 Kg/h

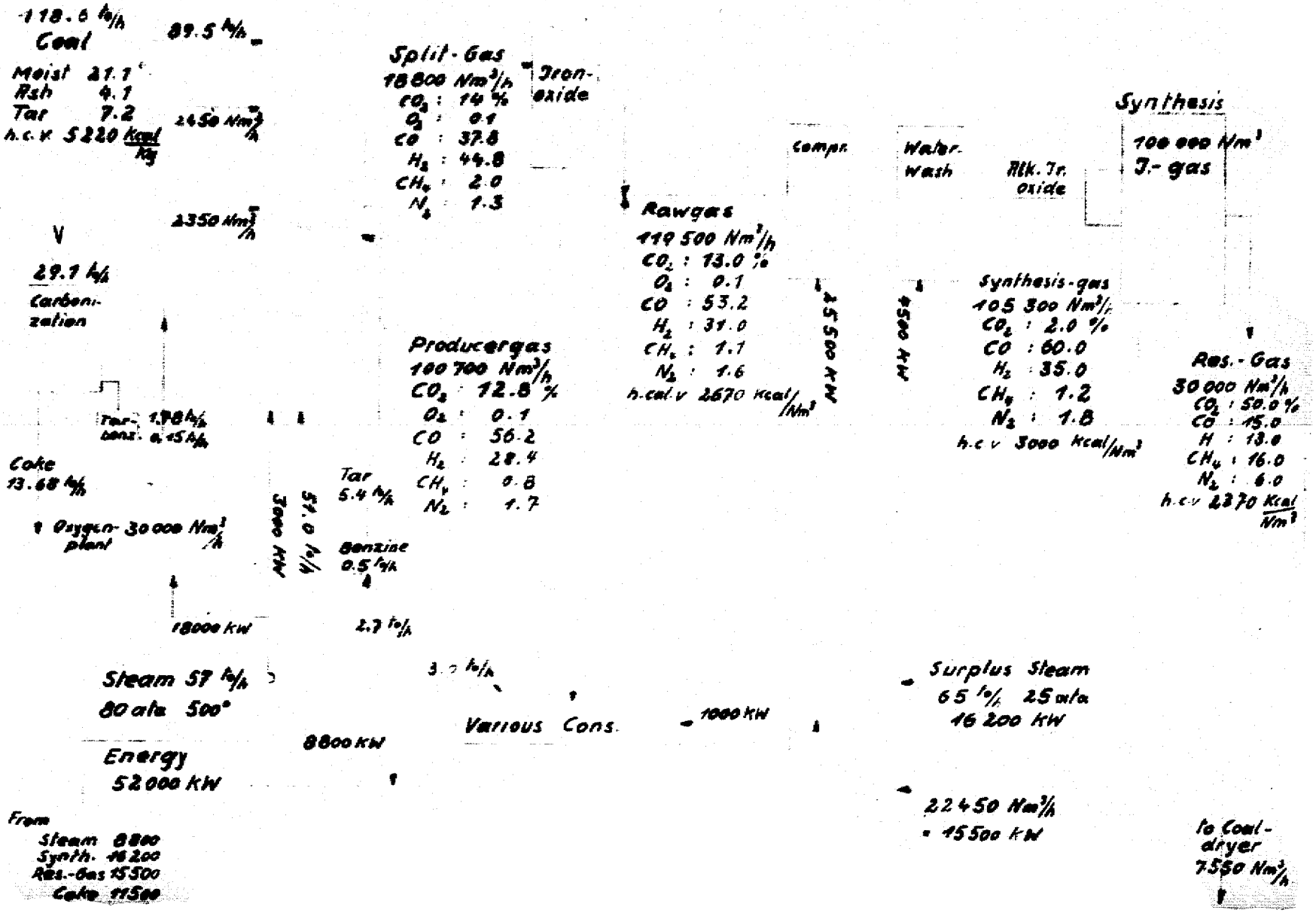
II

LURGI - Pressure - Gasification

100 000 Nm³/h J-Gas



III Carbonization - Gasification (with Splitgas)



IV Carbonization - Gasification

(Carbonizer - Gas for Boilers)

219 t/h
Coal
Moist 21.1%
Ash 4.1
Taar 7.2
H.C.V 5220 Kcal/kg

Carbon
ization

Conden
sation

to Boilers
35 000 Nm³/h

10700 Nm³/h
Dryer
Benzinerec.

Carbon-Gas
45700 Nm³/h
h.c.v 2200 Kcal/Nm³

Tar
6.6 t/h

Benzine
0.6 t/h

Gasification

Compressor

Water
wash

Alk. Fe-
oxide

Synthesis
100000 Nm³/h
J-Gas

CO_2

Oxygen
28 000 Nm³/h

Raw Gas
120 000 Nm³/h
CO_2 : 14.0%
CO : 52.7
H_2 : 30.6
CH_4 : 0.8
N_2 : 1.9

Synthesis-Gas
105 300 Nm³/h
CO_2 : 2.0%
CO : 60.0
H_2 : 35.0
CH_4 : 0.9
N_2 : 2.1
h.c.v. 3000 Kcal/Nm³

Res. Gas
30000 Nm³/h
CO_2 : 50.0%
CO : 15.0
H_2 : 13.0
CH_4 : 16.0
N_2 : 6.0
H.C.V. 2370 Kcal/Nm³

Steam 62.5 t/h
80 ata 500°C

Steam 3 ata
3.0 t/h

Steam 65 t/h 25 ata
16200 KW

Energy
Requir. 50900 KW

from
steam 10400
Res.-Gas 20700
Synthesis 16200
Carbon Gas 3600

16800 KW

3000 KW

- Var. Cons.

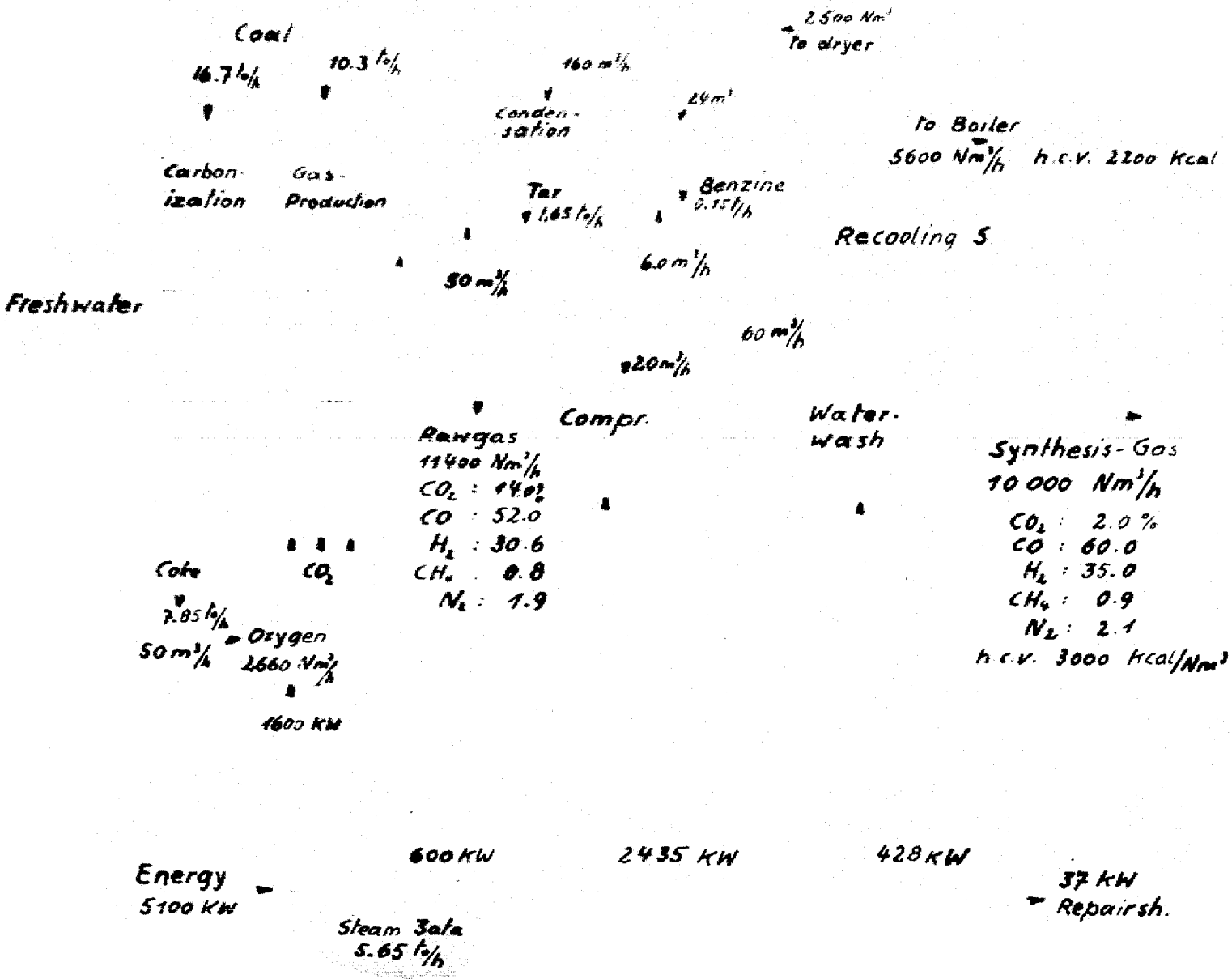
1000 KW

25600 KW

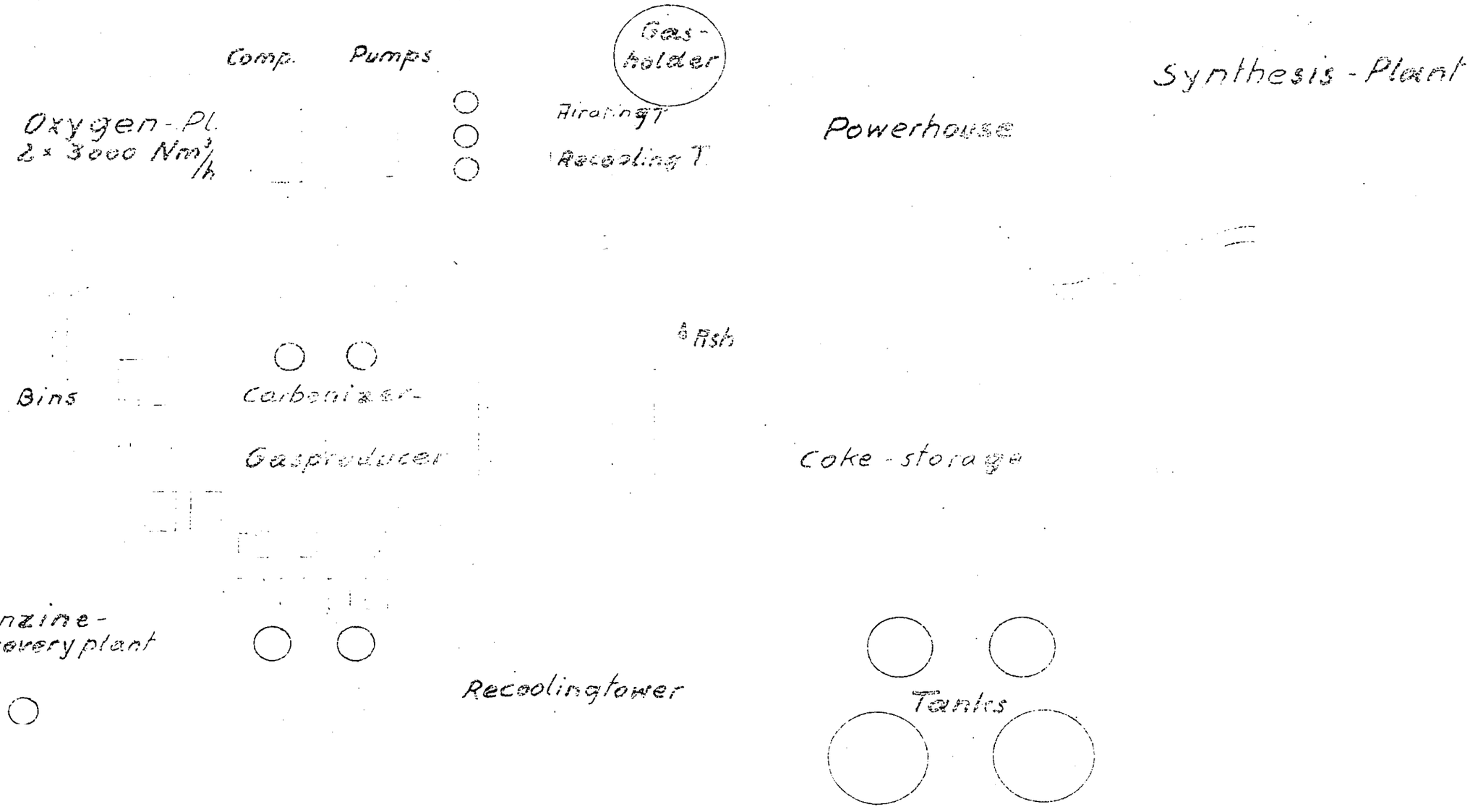
4500 KW

to Boiler
20700 KW

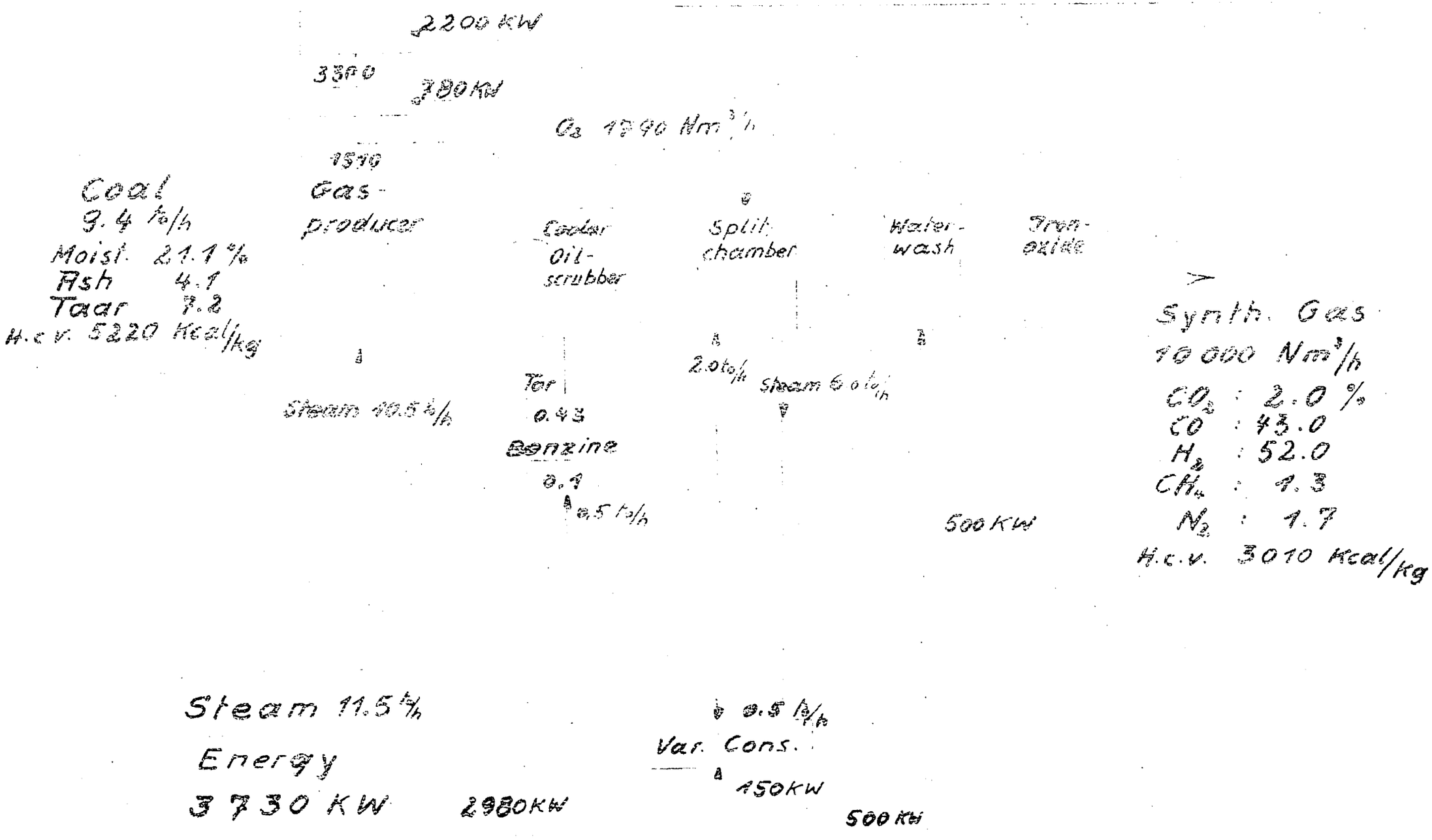
A. Carbonizer - Gasproducer
Production of 10000 Nm^3/h Synthesis-Gas



A Carbonizer - Gasproducer - Plant
10 000 Nm^3/h Synthesisgas



C. Pressure Gasification



C. Pressure-Gasification-Plant
10000 Nm^3/h Synthesisgas