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"PYROLYSIS OF COAL AND COAL TAR PRODUCTS"

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INTRODUCTION

The history of organic chemistry is intimately tied to the history of the production and refining of coal tars. From the heyday of the period when the prime source of organic chemicals (the dye stuffs, the medicinals, the preservatives, the disinfectants) was black coal tar, to the present (when almost any organic chemical whose structure can be conceived, may be synthesis almost directly from carbon, hydrogen, oxygen and nitrogen), the tar by-product from coal pyrolysis has been processed for the 10% low boiling products to supply the fine organic chemicals market. The 90% residue remaining after refining has been channeled to wherever it would fit, from creosote oils for wood preservation to bituminous products for construction and road building, or to fuel for boilers and open hearths whenever the general economy drove the price of the residues into the fuel range.

The work reported herein was done in an attempt to:

1. Upgrade the residue products from coal tar refining.
2. Seek a method of increasing the yield of highly aromatic tar from coal by direct pyrolysis under equilibrium conditions as opposed to pyrolysis under a dynamic temperature situation as found in the slot type coke oven.

To accomplish these aims, certain assumptions had to be made in order to circumvent the prejudice that had persisted for almost a century as to the nature of tar formation in coal processing. These assumptions can be listed as:

1. The products to be derived from coal by pyrolysis are not indigenous to the coal, but are controlled by the process conditions imposed during such pyrolysis.
2. The tar and light oils recovered from carbon-hydrogen-oxygen-nitrogen fragments, of free radical type, along the path of distilling pyrolysis products as these products pushed through the bed of coal maintained at temperatures in the region of 1800° F.

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3. The evidence for 2 lay in the fact that while the material collected as tar and oil left the pyrolytic chamber in the vapor phase with a coke residue in the chamber, these tars and oils can not be redistilled under any conditions without leaving a substantial residue of coke similar in nature to the coke left in the pyrolytic chamber wherein the tar and oil had their genesis as a vapor.

EXPERIMENTAL - General Attitudes

Unlike research on fine, purified organic chemicals, the field of coal and coal products exploration is characterized by the need of a combined chemist and engineer approach. On one hand, the reactions which occur are obviously governed by the known laws of rates and energy utilization. On the other hand, so little is known of the composition of the starting materials that inference, assumptions as to the specific reactions occurring, thermo-chemical calculations, or model structures, while extremely useful, can lead to serious oversight if taken as gospel over experimental observations, because the large number of components to be dealt with necessitates quantities of materials for test tube operation normally considered as pilot plant studies in the fine chemical field. Furthermore, in order to achieve the extremely short residence times and steady-state operation, a continuous flow system is required.

Accordingly, a rather elaborate description of the ground rules, feedstock identification, apparatus, and operating procedure, is given. The methods of analysis which are not unique are described by reference.

EXPERIMENTAL - Ground Rules

With these assumptions in mind, it was decided to attempt to reproduce and apply the pyrolytic conditions found in the slot type coke oven in such a fashion that:

1. The temperature of pyrolysis would remain constant.
2. The heat rate applied to the feedstock would be at a rate approaching 2000° F per second.
3. The pyrolytical action on the feedstock would be imposed for that period necessary to raise the temperature of the feedstock to 1400 to 1800° F.
4. The pyrolytical products would be quenched to ambient temperatures at the same or faster rate as the feedstock was raised to pyrolysis conditions.

EXPERIMENTAL - Feedstock Identification

In order to demonstrate the general applicability of the system, it was decided to use the following materials as feedstock:

1. The liquid oil fractions from coke oven tar refining left after the removal of tar acids, tar base, naphthalene, resin and solvents from that fraction of coke oven tar that boils up to 270°C termed by the industry - carbolic oil.
2. The high boiling residues from the distillation refining of the crude quinoline fraction (230 to 250°C) extracted from coke oven tar carbolic oil.
3. A coal tar from low temperature pyrolysis of an Appalachian coal via the "Disco" process.
4. A coal tar from the low temperature pyrolysis of Texas lignite (Rockdale) in the Parry fluid bed process.
5. A bituminous coal of Eastern origin.

EXPERIMENTAL - Apparatus Description

The apparatus used is diagrammed as flow sheet and in detail on Figures 1, 2, 3, and 4. Figure 1 represents the apparatus in flow sheet. Figure 2 represents the heating chamber and reforming column for effecting the heating and reforming operations in connection with the pyrolysis of liquid feedstocks. Figure 3 is a horizontal section of the heating chamber taken on the line 3 - 3 of Figure 2. Figure 4 represents the cooled nozzle for spraying liquid feedstocks into the heating chamber.

Referring to Figure 1 of the drawing, the numerals 1 and 1A represent storage tanks for the feedstock, which are suitably provided with the heating jackets to maintain their contents in fluid form, and which are adapted to be alternately connected to the feed line 3 by suitable valved connections 2. The line 3 is connected to the inlet of a pump 4 for the feedstock, which in turn is connected by a suitable conduit 5 to the inlet 6 of the jacketed spray nozzle 7 which is mounted with its spray tip 8 within a heating chamber 9.

The heating chamber 9 is adapted to be heated to temperatures above 600°C by external heat such as hot flue gases, gas flame, or the like, contacting the outer walls 10 of the chamber within a suitable furnace 11. The heating chamber is formed of suitable material to withstand the temperature, such as 310 steel, the inner surface of which is lined with a thin lining of refractory material such as alumina or an alumina-silica fire clay, which functions as cracking catalyst.

Heating chamber 9 is also supplied with an inlet for superheated steam 15 which is supplied through conduit 16 from a steam superheater 17 adapted to superheat by indirect contact steam supplied to the superheater by a conduit 18 from a steam generator 19. Water for generation of the steam is supplied from a suitable reservoir 22 thru valved connection 23 by a pump 24 and a conduit 25.

The heating chamber 9 communicates directly with an elongated reforming column 30 which is suitably heated to temperatures above 600°C by indirect heat, within a heating jacket 31. The chamber 30 is formed of suitable material capable of withstanding the elevated temperatures, such as 310 stainless steel.

The outlet 32 of column 30 is connected to the inlet 33 of a condenser 34 adapted to be cooled by a suitable fluid flowing through a jacket 35. The outlet 36 of the condenser is connected to a primary liquid product receiver 37 which leads to a reflux condenser 38. The vapor outlet 39 of the reflux condenser is connected by a conduit 40 to a condenser 41, the outlet 42 of which is connected by a dip pipe 43 which leads into oil scrubber 44 which is partially filled with mineral oil adapted to scrub the gases and vapors passing through it. The outlet 45 of the scrubber is connected by a conduit 46 to an empty overflow chamber 47 which, in turn, is connected by conduit 48 with a dip pipe 49 which leads into a scrubber 50 partially filled with a suitable mineral acid adapted to remove ammonia and organic bases present in the gas and vapor mixture passing through it. The outlet 51 of the scrubber 50 is connected by a conduit 52 with an overflow chamber 53 which, in turn, is connected through conduit 54 with a dip pipe 55 which leads into a scrubber 56 partially filled with 20% aqueous sodium hydroxide for removal of H₂S. The outlet 57 of the caustic scrubber 56 is connected by a conduit 58 to an overflow chamber 59 which, in turn, is connected in series with two vessels 60 and 61 which are surrounded by a dry-ice-acetone mixture jackets 62 and 63 to reduce the temperature. The outlet 66 of the chamber 61 is connected by a conduit 67 with a gas sampler 68 which, in turn, is connected by a conduit 69 to a wet test meter 70, the outlet of which is connected to a flare 75 by a conduit 74.

Referring to Figures 2 and 3 of the drawing, the heating chamber 9 consists of a shell 80 formed of 310 stainless steel, mounted in spaced relation within a furnace 81 and surrounded by flues 82, 83, 84 and 85 carrying burner gases from gas burners 87. The exits from the flues are connected to a stack (not shown). The inner surface of the heater 9 is coated with a thin layer of alumina-silica fire clay 79. The heater 9 is provided with a jacketed spray nozzle 7 which is mounted centrally of one wall of the chamber 9 so as to project a fine dispersion of the liquid fed into the chamber onto the hot inner walls of the chamber.

As shown in Figure 4, the jacketed spray nozzle 7 consists of a tube 100 surrounded by two progressively larger tubes 101 and 102 mounted in spaced relation to provide a narrow passage 105 between them and between tubes 100 and 101 for the flow of temperature-regulating fluid, such as water, steam, oil, etc., depending on the temperature to be maintained. Tubes 101 and 102 are provided with couplings 103 and 104 for the entrance and exit of the temperature-regulating fluid. The inner end of the tube 100 is provided with a spray tip 8 which is of the type normally employed for dispersing oil in the form of a cone into an oil burner of the conventional type. Such nozzles are rated according to the number of gallons per hour of No. 2 fuel oil which they are adapted to deliver as spray under a head of 100 p. s. i. g.

The heater 9 is also provided with an inlet 15 for superheated steam which is mounted within the heater on the opposite wall from the spray nozzle 7 so as to deliver superheated steam into the interior of the chamber 9 in intimate contact with the spray of feedstock from nozzle 7.

The reforming column 30 is mounted on the heating chamber 9 in direct communication with the interior thereof, and is surrounded by heating jacket 31. It is provided with a screen 110, 16 mesh stainless steel screen, mounted near the bottom thereof and adapted to retain a column of reforming catalyst 29 within the column 30.

The apparatus is provided with suitable temperature-recording mechanism connected to thermocouples at the following points: 115 within the interior of the heater 9; 116 in the interior of the heating column 30; 117 in the interior of the heating column 30 near the top thereof; 118 in the outlet 32 of the column 30; 119 at the outer wall of the column 30; 120 in the interior of the jacketed nozzle 7; and 121 in the interior of the steam inlet 15.

The apparatus is further provided with means for recording pressures (not shown) at suitable points within the apparatus, such as the interior of the heating chamber 9, the top of the column 30, the steam superheater 17, and the conduit 5 of the spray nozzle inlet 6. Suitable heating jackets (not shown) are also provided for the lines and other parts carrying fluids at temperatures above atmospheric temperature.

EXPERIMENTAL - Operating Procedure

In the operation of the apparatus referred to above, with oil feedstocks, the heating chamber 9 and reforming column 30 are first brought to temperature by suitable passage of burner gases through the furnace 11 and heating jacket 31. Water is then introduced into the steam generator 19 and heat is supplied to the steam superheater 17, and superheated steam is pumped into the heating chamber 9. If coke is employed in the reforming column 30, which constitutes the preferred practice, some water-gas is formed in the reforming column and passes through the system and is burned at the flare 75. Operation is continued until the system is cleared of air by the passage of steam, evidenced by condensation of water in the condenser 34 and primary liquid product receiver 37.

Pump 4, supplying the particular liquid feed to be pyrolyzed, is then placed in operation and the temperature-regulating fluid is passed through the tubes 101 and 102 to regulate the temperature of the feed and maintain it at the desired temperature. To prevent the starting material from undergoing undesirable preliminary decomposition, with resultant plugging of the spray nozzle, the feed to the pyrolyzer is preferably maintained at a temperature below 150°C, and usually at a temperature merely sufficient to insure adequate fluidity for spraying through the spray nozzle. Ordinarily the feed is adequately fluid at temperatures lower than 110°C.

Adequate pressure is exerted by pump 4 to secure a fine dispersion of the feed within the heating chamber 9, depending upon the rate of feed desired and the size of the spray tip 8. The rate of feed of superheated steam through inlet 15 is then adjusted to the desired ratio with respect to the feed of stock through the spray tip 8.

Operation is then continued with adjustment of the heat supplied to the heating chamber 9 and reforming column jacket 31; since with continued operation the supply of heat required to maintain operating temperature decreases, presumably by reason of the fact that exothermic as well as endothermic reactions occur in the heating chamber and reforming column.

Tars produced by the process are condensed and collected in the receiver 37 together with unreacted steam which condenses as water. Light oil fractions are absorbed and removed in the mineral oil scrubber 44. Organic bases and ammonia are removed in the acid scrubber 50. Hydrogen sulfide is removed in the alkaline scrubber 56.

The tars do not always form completely in receiver 37, but sometimes tars also are formed farther along in the recovery system. Thus tar has been found to collect in the oil scrubber 44, and in some cases a crystalline material was formed in vessels 60 and 61 which, when warmed to room temperature, formed a tar.

With pulverized coal, the oil feed mechanism was replaced by a screw feeder and the coal was blown into the chamber by superheated steam as it left the water cooled screw within the chamber. The operation of this type of mechanism proved extremely difficult, and in most cases, impossible. This was in 1953.

EXPERIMENTAL - Material Balances and Yields

Interpretation of the data demanded accurate account of the distribution of the intake materials. Accordingly, all feedstock, water, sweep gases were measured by weight or volume and subsequently converted to weight. The weight of all samples taken was accounted for and such weight prorated to the proper part of the flow sheet. Wherever possible, quantities were obtained by direct weight before, during, and after each experimental run.

An accurate log of each run was maintained which permitted logical distribution of losses in the calculation of the yields. Yields could then be based on the hydrocarbon feedstock, the steam feed, or a combination. In this fashion, some assessment of the origin of the products could be made.

EXPERIMENTAL - Analytical

Composition of the gases was determined by mass spectral analysis (Consolidated Electrodynamics) on samples taken continuously throughout the run.

Composition of the tars and light oils was determined by analysis of component fractions cut from the tar by fractional distillation, using a 1 inch by 36 inch Stedman packed column operated at maximum efficiency. One percent readings were taken for the drawing of boiling curves and fractions were cut to correspond to standard cuts used in the coal tar refining industry - pre-benzene, benzene toluene, solvent naphtha, high flash solvents, naphthalene, crude quinoline, creosote oils and pitches. Analysis of these fractions were by methods standard to the industry and published in the ASTM Specifications, the British* Methods of Testing Coal Tar Products and publications of tar refiners in the United States.

RESULTS AND DISCUSSION OF THE RESULTS

Results, along with conditions that produced such results, are given in Tables I thru V. In Tables III and IV, the format is so arranged as to facilitate comparison between individual feedstocks and products derived therefrom. The data presented, of necessity, are selected. In making the selection, considerable effort was made to include representative results where such results were relatively representative. However, wherever observation indicated that an apparent variation could not be assessed against known difficulties in experimental technique, these are recorded and so annotated.

While not shown in all cases where the cracking temperature was below 700°C very little reaction took place other than the formation of coke in the chamber by distillation of the light ends. As indicated in Table I, in all cases the water fed to the reaction reacted to some small percentage. And while there is some indication of straight water gas reaction, there is also evidence that the water may have decomposed and added to the carbon-hydrogen fragments as tar. One thing was noted throughout the experiments - the use of steam drastically inhibited carbon lay-down and coke formation.

In all cases, the most drastic change in composition of the feedstock occurred by gasification. Gas yields varied from 4% for the tar base residues to 41% for the lignite tars. Both low temperature tars produced high gas yields.

The light oils, oils with densities lower than water at room temperature, were produced in about the same quantities regardless of feedstock, and for the most part, were a crude BTX fraction.

Considering Table II, the obvious points of departure are the production of unsaturated gases as opposed to more stable hydrocarbons. Acetylene seems to be the function of the cracking temperature varying from a trace to 2.0% over a temperature range of 750°C to 925°C. However, about 150% more acetylene was derived from coal at 825°C than from lignite tar at

* Tar Products Test Committee, Gomersal

925°C. No data were collected to differentiate between the reaction temperature and the feedstock as the cause of this difference. However, since at 800°C high temperature coke oven tar yields about .3% acetylene, it seems logical to assess this increase in this product against the feedstock.

A second observation deals with the ease with which primary aromatics are produced. Benzene, while not shown specifically in Table II as such, is the predominant component of the solvents to 200°C. This situation also holds for the tar acids and bases. Pyridine and quinoline form almost 80% of their corresponding fraction while substituents in these genera are absent or present only in minor quantities.

Naphthalene, a most valuable constituent in coal tar, volumewise, forms readily at all temperatures employed. The compound, almost completely absent from tars produced by carbonizing coal in 500°C range, is obtained in yields upward to 14% of the feedstocks. Not shown because of doubtful reliability are yields of naphthalene as high as 28% of the feedstocks charged - using either carbohc oil residues or the lignite tar from the Parry process.

The resulting pitches are peculiar in that for comparable softening points the quinoline insoluble component is low. As they stand, these products are easily employed in saturation operations. No molecular weight distributions were obtained on these materials, but the high benzene insoluble, coupled with the low quinoline value, would indicate a product of low molecular weight in narrow distribution - a product of high uniform quality.

With respect to the effect of this type of treatment on high boiling tar bases, Table II indicates that pyridine, quinoline, and a high nitrogen content pitch can be formed from this heterogeneous low value crude. This type of pitch may well have seeding advantage in the electrode formation process because of the nitrogen backbone in its polymer structure.

Concerning the work with Pond Creek coal, the results should not be taken in any sense other than the indicative. Extreme difficulty was encountered with the feed mechanism and a really reliable set of data could not be obtained. Insufficient tar was recovered for accurate evaluation, but by ordinary smell, the tar would be classified as produced at high, rather than low temperature carbonization.

Table IV lists the proximate analysis of the coal use. No other information, other than the name, was available. The coal appeared dried and aged. However, if it were aged, the aging was insufficient to destroy coking properties.

Since there has been much argument as to the paraffin nature of low temperature tars, a paraffin distribution study was run on the feedstock to Run No. 3. The producer of this tar indicated that yields of 20 to 25% tar might be expected from the coal used. And while this sample contained approximately 40% uncarbonized or partially carbonized coal, he said production would yield

tars of 1 to 5% solids content. This pyrolytic study and the resultant paraffin distribution analysis were run on tar that had been cleaned by filtration.

Table III lists the results of this study. While there is no major paraffin component in this low temperature tar, those that are there appear to be evenly distributed. On pyrolysis, these are cracked to low boilers and fragments which appear to cyclize to aromatics.

Table V attempts a comparison between the pyrolysis products as they are formed on contact with the hot chamber and the flared gases after tar removal by condensation and scrubbing. These samples were taken and quenched immediately in a bath of dry ice and acetone and kept at that temperature until admission to the mass spectrometer.

It can be seen that the hydrogen, methane and acetylene that appear on pyrolysis are rapidly transformed to tar and oil products in the period of time necessary to traverse the apparatus - about 2 seconds. Another observation was noted in this same work. The material withdrawn from the cracking chamber crystallized out as a fine white crystal on the walls of the trap. When allowed to come to room temperature in not less than five minutes, the white crystals first turned to a pale yellow, then a bright brown-red, then a brown. At those stages, melting began and the brown crystals coalesced to form droplets of black tar.

This work is a summary of a much more complete study that covers some 5 years of effort and explored in replication, a wide variety of feedstocks.

Nevertheless, regardless of the source of the feed, the data so obtained fits the general pattern of the results reported here.

TABLE I

OPERATING CONDITIONS, MATERIAL BALANCES, YIELDS

1. Source of Feedstock	Neutral Oils H. T. Co. Tar		Tar Base Residues H. T. Co. Tar		Appalachian Coal Tar-Low Temp. Carb.		Texas Lignite Tar Low Temp. Carb.		Pond Creek Coal	
	grams ¹ wt%	900° C	grams ² wt%	800° C	grams ³ wt%	750° C	grams ⁴ wt%	925° C	grams ⁵ wt%	825° C
2. Run No.										
3. Pyrolysis Temperature										
4. Weight of Feedstock Charged	10,000	50%	20,000	50%	7,920	54%	22,000	50%	309	46%
5. Weight of Water Charged	10,000	50%	20,000	50%	6,800	46%	22,000	50%	475	54%
6. Total Input	20,000	100%	40,000	100%	14,720	100%	44,000	100%	784	100%
7. Weight of Products Recovered	8,730	43.5	19,534	48.7	7,640	52.0	22,510	51.5	319	39.5%
8. Weight of Water Recovered	8,900	44.5	19,000	47.5	6,600	44.7	20,500	46.5	300	39.5% ⁵
9. Total Output	17,630	88.5	38,534	96.2	14,240	96.7	43,010	98.0	619	79.0%
10. Material Balance (Line 9/Line 5)		88.5		96.2		96.7		98.0		79.0%
DISTRIBUTION OF PRODUCTS										
11. Tar Recovered	5,783	66.4	17,074	87.3	3,450	45.0	10,700	47.4	35	10.7
12. Light Oil Recovered	680	7.8	900	4.6	455	6.0	800	3.6	4	1.2
13. Trapped Oils	340	3.9	260	1.4	150	2.0	390	1.7	10	3.1
14. Flared Gases	1,052	11.9	780	4.0	2,015	26.4	9,200	41.0	270	85.0
15. Carbon	875	10.0	520	2.7	1,570	20.6	1,420	6.3	---	---
16. Total	8,730	100.0	19,534	100.0	7,640	100.0	22,510	100.0	319	100.0

TABLE II

ANALYSIS OF PRODUCTS

Source of Feedstock	1		2		3		4		5	
	Neutral Oils H. T. Co. Tar	Tar Base Resi- dues - H. T. Co. Tar	Appalachian Coal Tar-Low Temp. Carb.	Texas Lignite Tar Low Temp. Carb.	Pond Creek Coal					
Flared Gases(Below 75°C)	0.00	12.3%	0.00	3.98	0.00	26.61	0.00	40.10	85.0	
Hydrogen	2.88	0.57	0.82	0.82	1.65	0.82	0.00	1.65	47.3	
Methane	3.98	1.00	9.25	1.00	9.79	9.25	9.79	9.79	15.7	
Nitrogen	1.77	0.51	0.43	0.51	10.42	0.43	10.42	10.42	0.0	
Carbon Monoxide	1.74	1.11	8.00	1.11	0.00	8.00	0.00	0.00	17.0	
Acetylene	1.00	0.27	Trace	0.27	1.40	Trace	1.40	1.40	2.1	
Ethylene	0.07	0.01	5.25	0.01	8.73	5.25	8.73	8.73	0.6	
Ethane	0.05	Trace	0.90	Trace	1.16	0.90	1.16	1.16	0.4	
Oxygen	0.00	0.16	0.55	0.16	0.00	0.55	0.00	0.00	0.0	
Carbon Dioxide	0.81	0.14	1.10	0.14	4.23	1.10	4.23	4.23	1.98	
Propylene	0.00	0.00	0.31	0.00	2.70	0.31	2.70	2.70	0.0	
n-Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	
Total from 75 to 200°C	1.30	7.80	0.00	6.33	7.00	14.70	10.00	11.10	0.0	
Solvents	0.66	4.67	1.36	1.36	1.51	10.54	8.11	9.51	0.0	
Tar Acids	0.34	0.66	0.00	0.00	5.49	4.16	1.50	0.75	0.0	
Tar Bases	0.30	2.47	4.97	4.97	0.00	0.00	0.39	0.90	0.0	
Total from 200 to 250	19.50	22.70	96.00	46.55	22.60	6.30	16.29	9.00	0.0	
Solvents & Oils	13.86	6.32	5.43	6.58	4.30	3.85	12.12	1.00	0.0	
Naphthalene	0.15	13.91	0.00	0.00	0.00	1.44	0.00	7.00	0.0	
Tar Acids	2.22	1.00	0.25	0.05	14.10	1.39	3.17	0.32	0.0	
Crude Quinoline	3.27	1.47	90.32	39.92	0.00	0.00	1.00	0.68	0.0	

No volatile components below 400°C

Apparently normal
HT CO

TABLE II (Contd)

Source of Feedstock	Neutral Oils		Tar Base Resi-		Appalachian Coal		Texas Lignite		Pond Creek
	H. T. Co. Tar	10.90	3.00	10.62	Tar - Carb.	Low Temp.	Tar Carb.	Low Temp.	
Run Number	1	2	3	4	5				
Total from 250 to 300°C	76.00	10.90	3.00	10.62	---	---	16.90	0.10	
Solvent & Oils	66.83	8.73	0.30	9.90	---	---	8.91	0.10	
Tar Acids	3.62	1.01	0.00	0.05	---	---	4.67	---	
Tar Bases	5.55	1.16	2.70	8.47	---	---	3.42	---	
Total from 300 to 330°C	0.00	6.40	0.00	6.01	---	---	25.00	4.10	
Solvents & Oils	0.00	4.88	0.00	0.72	---	---	17.13	3.27	
Tar Acids	0.00	1.09	0.00	0.00	---	---	4.46	0.70	
Tar Bases	0.00	0.43	5.28	---	---	---	3.41	0.13	
Total above 330°C	3.00	16.60	1.00	10.98	68.30	31.40	31.80	35.20	
Carbon Produced	0.00	10.60	0.00	2.66	2.10*	20.70	0.00	0.00	

*Distillation loss -
Not carbon

TABLE III

ANALYSIS OF THE PITCHES

	No		135°C	46°C	188°C
	98°C	Pitch			
Softening Point(R&B)	Fluid	153°C			
Pitch Carbon Insoluble in CS ₂	0.1%	56.0%	37.7%	8.1%	54.8%
Pitch Carbon Insoluble in Quinoline	0.1%	50.0%	0.5	0.4%	5.0%
Pitch N ₂ Content	0.4%	4.0%	0.9	0.7%	1.0%
Pitch Ash Content	0.0%	0.0	0.2	1.0%	0.2%

TABLE IIICOMPARISON OF PARAFFIN CONTENT OF FRACTIONSLow Temperature Tar (Run #3) Vs. Reformed Low Temperature Tar

Fraction by Boiling Point	<u>Feedstock</u>		<u>Product</u>	
	% of Feedstock	% of Fraction	% Product	% of Fraction
75 to 90°C	0.00	0.00	0.00	0.00
90 to 125°C	1.17	17.00	1.42	71.00
125 to 150°C	0.10	17.80	0.00	70.00
150 to 200°C	1.01	18.60	0.01	0.10
200 to 230°C	2.84	18.50	0.04	0.10
230 to 250°C	1.69	22.20	0.00	0.00

TABLE IVANALYSIS OF COAL USED

Name	
Volatile Matter	17.0%
Fixed Carbon	79.0%
Ash	6.0%
Moisture	0.0%

TABLE V.COMPARISON OF GAS COMPOSITION (Run No. 5)Cracking Chamber Vs. Flared Gas

<u>Component</u>	<u>Cracking Chamber (wt %)</u>	<u>Flared Gas</u>
Hydrogen	70.4	55.8
Methane	22.1	18.5
Water	0.2	0.2
Carbon Monoxide	0.0	20.0
Nitrogen	0.0*	0.0
Acetylene	4.2	2.4
Ethylene	0.3	0.7
Ethane	0.3	0.5
Oxygen	0.7	0.0
Argon	0.0	0.0
Carbon Dioxide	1.5	2.2
Benzene	0.2	0.0

* Not representative since gas was analyzed
on a nitrogen-free basis

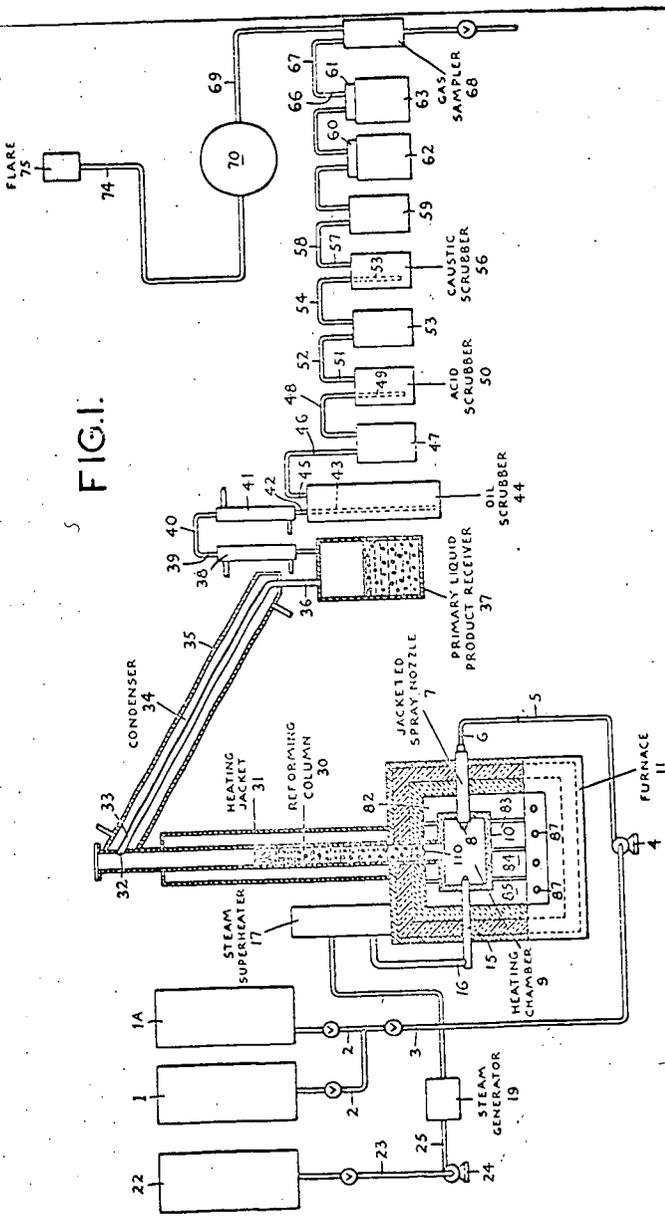


FIG. 1.

FIG. 4.

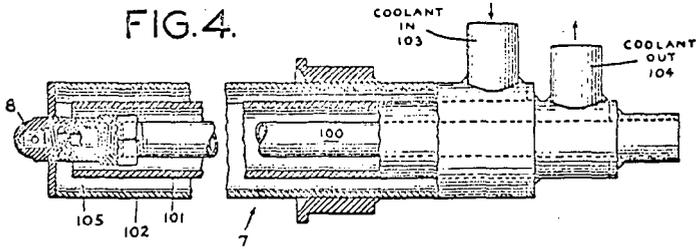


FIG. 3

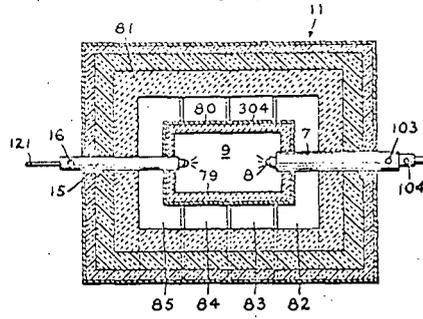


FIG. 2.

