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ENCLOSURE (B) 14

STUDIES ON THE MANUFACTURE OF ACETYLENE
FROM HYDROCARBON GASES BY ELECTRIC ARC

by

ENG. LT. COMDR. T. YAMAMOTO

ENG. LIEUT. T. KONOSU

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SUMMARY

Gas produced by petroleum cracking, which was composed of the lower hydrocarbons, methane, ethane, propane, ethylene and propylene etc., was subjected to cracking by an electric arc of 1000 kilowatts discharge. The cracked gas thus obtained was composed of 20% acetylene and 50% hydrogen. The construction of the cracking apparatus and the accessories of the plants were investigated to obtain data for design of the commercial plant.

I. INTRODUCTION

This research was begun by Eng. Capt. Dr. C. FUJIO in 1928 in the chemical laboratory of Tokuyama Fuel Depot. Methane, ethane, and ethylene were cracked with a high tension spark, under atmospheric pressure, to acetylene and hydrogen. In 1930, a pilot plant (15 kilowatts, 150,000 volts) for the utilization of the natural gas was erected in the research laboratory of SHINCHIKU, Formosa. In 1935, to avoid the injurious effect on the insulation of the electric circuit caused by a high frequency oscillating current due to the spark, cracking of the gas under diminished pressures such as 100mm Hg was studied, and an apparatus was constructed having a capacity of 40 kilowatts and 40,000 volts. It seemed that the characteristics of the discharge with this apparatus were not spark but glow. Though the power consumption per cubic meter of acetylene was 10 kilowatts, the concentration of acetylene was only 8%.

Finally, in 1940 a 1000 kilowatt plant was designed. The apparatus, as will be seen in Figure 1 (B)14, consists of a cracking tube made of iron and a carbon electrode. 800 volts direct current was used instead of the alternating current previously used, and the gas was cracked at 200mm Hg pressure. This pilot plant was transported from Formosa to TOKUYAMA and was operated there from 1940 to 1941 with a cracked gas from the gyro plant. This report is a record of the experiments at TOKUYAMA.

Six commercial plant sets, each having a capacity of 3,000 kilowatts, were erected in 1943 on the basis of these data at the Second Fuel Depot of YOKKAICHI to prepare acetylene as the source of butanol.

II. DETAILED DESCRIPTIONA. Description of Apparatus

The flow sheet of the plant is shown by Figure 1(B)14. The gas from the gyro plant was stored in a gas holder and introduced to one of two cracking units made of steel, and shown in Figure 2(B)14. The cracked gas was cooled by passing it through two water coolers, and carbon particles were removed with a Cottrell precipitator and a cyclone dust catcher. To protect the wall of the reaction chamber from the heat of the arc, the gas was introduced in a high speed swirling motion. The electric circuit of the apparatus consists of an induction regulator to control the voltage, a reactor to stabilize the arc, a transformer, and a mercury rectifier. The plus terminal of the rectifier was connected to the upper electrode of the cracking apparatus, and the minus terminal, connected to the body of the cracking apparatus, was grounded. The upper electrode was composed of carbon insulated from the body. The inspection holes were covered with a cobalt glass plate to permit observation of the arc flame. Cracked gas was introduced tangentially into the reaction chamber through the holes surrounding the electrode and was given a spinning motion. The starting electrode was moved by hand. The electrode and the cracking chamber were cooled by a strong flow of cold water. Twenty tons per hour

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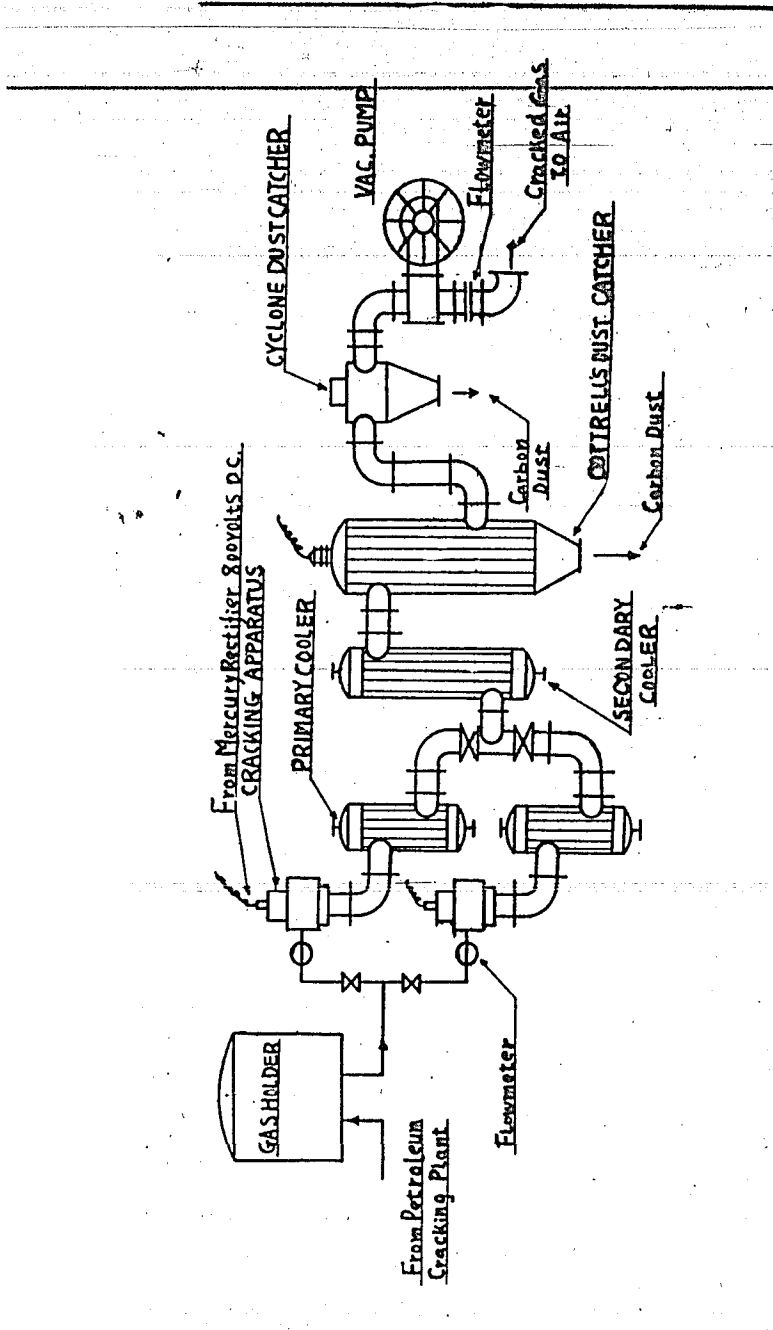


Figure 1(b)14
FLOWSHEET OF ARC CRACKING

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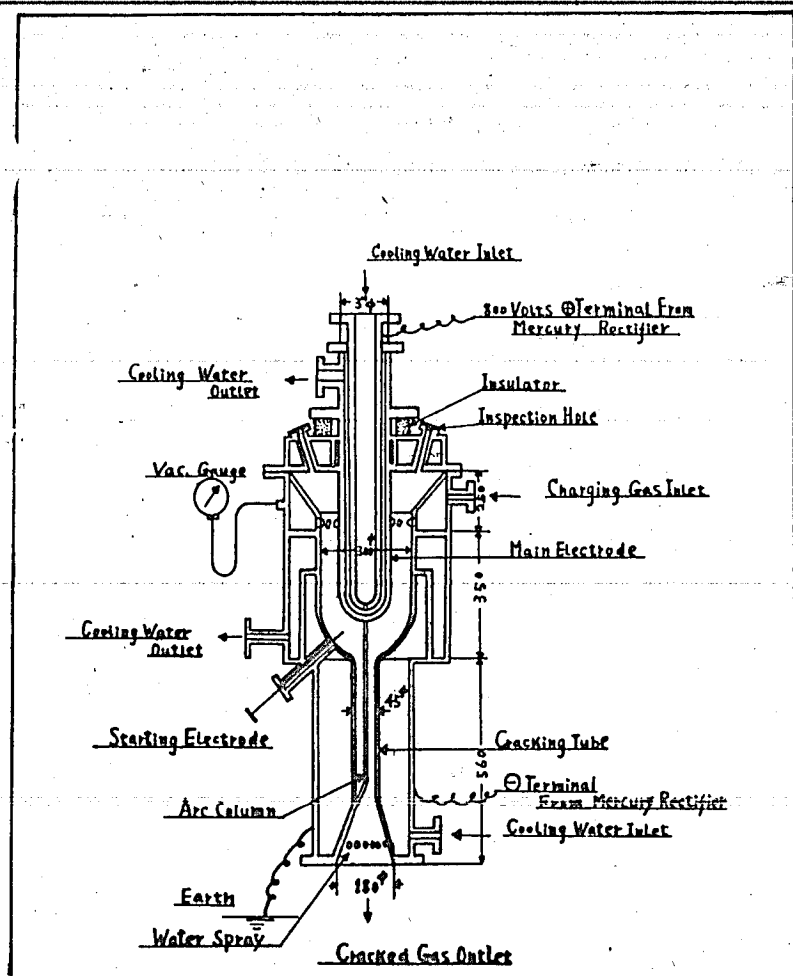


Figure 2(B)14
ARC CRACKING APPARATUS

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of cooling water was required for the copper electrode. The carbon electrode was not cooled.

B. Test Procedure

To start the apparatus, it was evacuated with a pump and the gas was introduced. This process was repeated for several times to expell all of the air from the apparatus. After controlling the gas velocity and gas pressure, the arc was started with the starting electrode. The arc between the electrodes was blown down by the gas flow to the bottom of the reaction tube. The cracked gas, quenched to about 400°C with water spray, passed into two coolers in which the temperature was kept at 30°C, and then into the Cottrell dust catcher. Gas was analyzed by the Hemple and Podbielniak methods.

C. Experimental Results

As will be seen in the experimental results shown in Tables I(B)14, II(B)14 and III(B)14, the composition of the cracked gas was not affected by the charging gas. Considerations as to the conditions for the smooth running operation of the apparatus were as follows:

1. Gas Pressure

A lower pressure is better for maintaining arc stability and avoiding a complexity of reaction products.

2. Arc Current

The stability of the arc and the capacity of the apparatus will be increased with increasing arc current, but the later is limited by the cooling temperature of the electrode.

3. Composition of the Charged Gas

Although the composition of the charged gas has no serious effect on the acetylene concentration of the cracked gas or on the arc stability, gas with high olefine content forms excessive carbon dust.

4. Arc Stability

The stability of arc is mainly dependent on the gas velocity. When the velocity is too rapid to have a smooth spinning motion, the arc is unstable.

D. Operating Difficulties

1. The Electrode

When the reaction started, carbon formed by cracking of hydrocarbons was deposited on the upper carbon electrode and consequently, the current was decreased and the voltage became irregular. To maintain smooth running for a long time the deposited carbon had to be eliminated by breaking mechanically or by lifting the upper electrode by means of a gear. The use of these devices to remove deposited carbon was not successful. Consequently, when the current became irregular, the gas was changed to another apparatus. The interval of continuous running through each arc by this method was about seven hours.

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TABLE I(B)14
DATA OF CRACKING WITH CARBON ELECTRODES

No. of Exp.	Gas Pressure in mm. Hg.	Arc Current in Amp.	Voltage at Electrode in Volt.	DIA of Cracking Tube in mm.	Length of Cracking Tube in mm.	Properties of Upper Electrode	Vol. of Gas Charged in ml/lit.	Vol. of Gas Produced in ml/lit.	Time of Exp. in min.	Time of Voltage Drop at (S)	Concn. of C ₂ in Gas in (S)	Production of C ₂ in ml/lit.	Total Power Consumed in K.W.Hr.	Power Consumption per ml of C ₂
1	150	650	870	53	440	+	110	253	43	14	25.5	64.5	500	9.0
2	200	650	843	53	440	+	120	262	24	40	20.5	62.7	560	9.1
3	110	600	764	53	480	+	110	306	100	47	24.4	73.5	470	6.4
4	130	600	750	53	482	+	115	290	250	49	24.4	68.0	450	6.6
5	200	600	741	53	460	+	105	407	120	50	20.4	83.1	445	5.4
6	200	650	720	53	475	-	105	315	90	50	22.5	71.0	467	6.0
7	200	680	719	53	475	-	125	338	100	50	23.5	79.4	468	6.1
8	200	650	750	50	460	+	120	307	90	53	22.0	67.4	487	7.2
9	200	630	610	50	430	+	100	231	200	39	24.4	56.4	372	6.7
10	200	650	590	53	460	+	100	200	350	60	23.5	54.2	360	7.0
11	200	650	600	53	460	+	100	229	370	46	21.6	63.2	385	6.1

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TABLE II(B)14 ANALYTICAL DATA OF GAS CHARGED

Exp. No.	CO ₂	O ₂	CO	H ₂	N ₂	C ₂ H ₂	CH ₄	C ₂ H ₄ + C ₃ H ₆	C ₃ H ₆ + C ₃ H ₈	C ₄ H ₈ + C ₄ H ₁₀
1	1.0	0.5	1.0	0.8	0.8		30.4	22.3	26.2	14.1
2	0.9	0.5	2.9	4.5	2.4		7.7	12.2		5.7
3	1.0	0.3	0.3	7.2	1.4		42.0	35.0	12.5	
4	0.7	0.1	0.2	7.2	0.5		36.1	33.5	18.5	
5	0.7	0.1	0.1	7.2	0.5		36.1	33.5	18.5	
6	1.4	0.2	0.1	6.7	0.7		36.4	36.0	16.3	
7	1.5		0.2	4.7	4.7		32.7	43.6	15.2	
8	0.7	0.1		4.5	0.7		35.2	34.8	18.4	3.4
9				3.9	0.4		24.5	19.6	30.7	18.5
10		0.2	0.2	2.3	0.9		24.2	26.2	30.9	20.6
11		0.1	0.1	8.1	1.6		42.6	33.3	11.0	

TABLE III(B)14 ANALYTICAL DATA OF GAS CRACKED

Exp. No.	CO ₂	O ₂	CO	H ₂	N ₂	C ₂ H ₂	CH ₄	C ₂ H ₄ + C ₃ H ₆	C ₃ H ₆ + C ₃ H ₈	C ₄ H ₈ + C ₄ H ₁₀
1		0.8	2.7	60.7	5.2	24.8	4.8	0.9	5.7	
2	0.7	0.4	2.2	57.2	1.8	23.3	5.9	7.1	12.1	
3	1.0	0.1	2.5	55.4	0.3	24.0	6.8	7.5	8.5	
4	1.1	0.4	0.9	43.5	3.0	23.8	14.0	7.2	15.3	
5	0.4	0.5	0.8	41.3	4.6	20.4	11.7	9.8	10.7	
6	0.8	0.2	1.0	43.5	3.4	22.4	15.8	11.6	19.8	
7	0.5	0.7	0.6	47.4	4.3	23.5	12.4	9.4	15.0	
8	0.2	0.9	0.9	46.7	3.5	22.0	5.6	16.9	15.1	
9	1.9	0.3	0.9	38.6	3.2	24.4	7.4	17.8	15.5	
10	1.5	0.5	1.1	41.5	3.0	23.5	4.5	19.5	16.1	
11	0.6	1.8	0.6	39.6	9.0	21.5	14.2	10.3	49.4	

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2. Arc Stability.

In order to obtain concentrated acetylene from the cracking process, a stable arc is required. This seems to depend on the reactance of the electric circuit, the discharging current (when the discharging current is too small, the arc is apt to cut.), the gas velocity, the type of the apparatus and the electrode materials. When a copper electrode was used, though a stable arc was obtained and the carbon deposition was smaller than with the carbon electrode, the copper electrode was apt to be perforated by the arc in a comparatively short time.

3. Carbon Dust

In the cracking reaction of the hydrocarbons, acetylene was formed, but an undesirable result was the formation of carbon. This was almost completely removed by using a Cottrell precipitator. (See Appendix)

III. CONCLUSIONS

- A. The apparatus used in the process consists of an iron cracking tube and a carbon electrode utilizing 1000 kilowatts and 8000 volts of direct current.
- B. By the arc cracking of the gaseous hydrocarbons from the gyro cracking plant, a cracked gas composed of 20% acetylene, and 50% hydrogen was obtained.
- C. The normal operation was continued for seven hours without difficulty.
- D. The trouble caused by carbon deposits on the electrode could not be avoided by lifting the electrode or breaking the deposited carbon mechanically.
- E. For maintenance of the stable arc, more experiments are required.

APPENDIX

The carbon caught by the Cottrell precipitator consisted of extremely fine particles. In the commercial plant the carbon dust was with drawn from the bottom of the Cottrell precipitator by the suction of a water jet. The carbon dust floating on the waste water was gathered and was tested as carbon black. Since it had absorbed oil formed by the acetylene polymerization, it was heated to 700°C for 15 minutes in a closed iron box. A test was made comparing the carbon black with that obtained by the channel method.

The carbon obtained by arc cracking was inferior to the channel method carbon in respect to ash content and blackness, but conformed to the specification of carbon black for the rubber industry and printing ink as a second grade quality material.

ENCLOSURE (B)

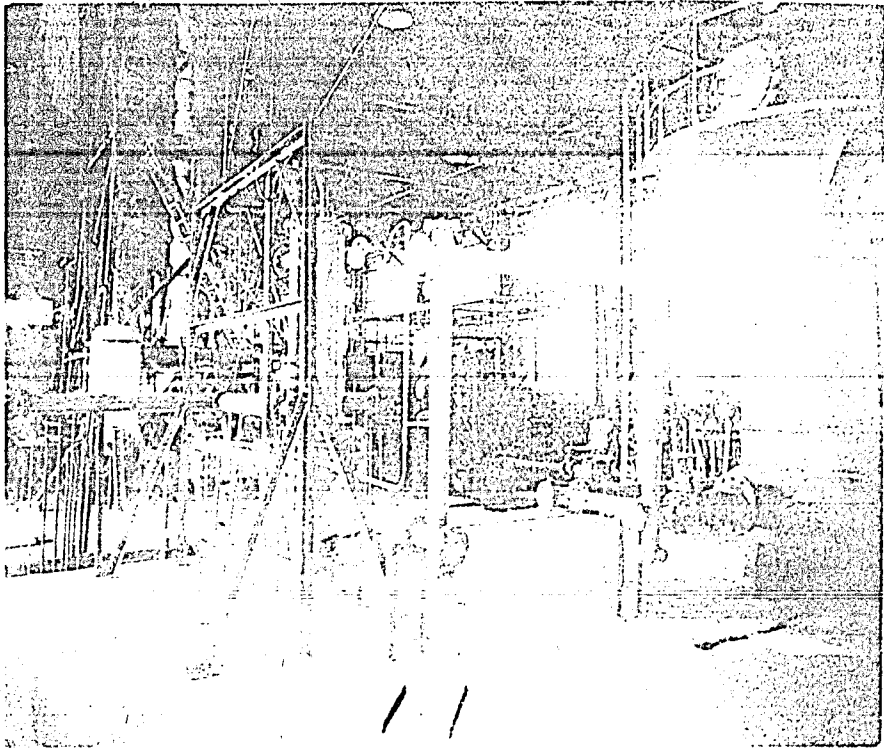


Figure 3(b)1a
PHOTOGRAPH OF THE INTERIOR OF A WASTEWATER TREATMENT
PLANT SHOWING THE PIPING AND STRUCTURE