## I. PINTSCH-HILLEBRAND UNIT.

(a) The Wesseling Plant has eleven generators producing a total five thousand five hundred (5,500) cubic meters/hour of process gas. This is a fairly recently developed German process and is shown on the attached diagram (Fig. 2). It consists in destructively distilling the lignite briquettes by circulation of a superheated steam-water gas mixture. The gas used is part of the already distilled product, which after mixing with steam is passed over a regenerative type, fire brick lined heater, acting batchwise at fifteen (15) minute intervals. The general reaction is as follows:

$$C + H_2O = CO + H_2 \quad - \quad 31,000 \text{ cal.}$$

$$C + 2H_2O = CO_2 + 2H_2 - \quad 21,000 \text{ cal.}$$

The endothermic heat of reaction is supplied by burning fuel gas in the section of the regenerator not in use. The distillation of the briquettes is in two stages: a preheating or drying stage, and a gasification stage Part of the recirculated gas and steam from the gasification zone passes upward through the freshly charged briquettes, driving off the moisture in the drying zone. All of the gas from the drying stage is used in recirculation as is also part of the gasification product. The former goes first through a tar catch pot, and then to an electric tar remover. This gas is always kept above the dew-point of its water content, i.e. ninety (90) degrees centigrade. On leaving this, it is joined by the second gas stream and enters the circulation blower. Steam is then injected, and the combined streams enter the regenerative heat exchanger where they are heated to one thousand three hundred (1,300) degrees centigrade.

(b) All valves controlling the circulating gas, heating gas, and air for combustion are located outside of the unit. The valves are hydraulically operated from a central control. In order to avoid burning-cycle exhaust gas from contaminating the product, a small quantity of circulating gas is allowed to leak continuously into the exhaust gas stream.

(c) The circulating gas and steam gives up all its sensible heat to the briquettes. The gasification product stream leaves



16

I. PINTSCH-HILLEBRAND UNIT (c) (Cont'd.)

The unit at seven hundred (700) degrees centigrade. It passes through a waste heat boiler. and a dust remover, before entering a water saturator which cools it down to seventy (70) degrees centigrade. It then enters an electric dust remover and is split, part going to the circulating stream as mentioned, and part to a subsequent water scrubber where it is further cooled to twenty (20) degrees centigrade. A final wash to remove very fine dust completes the process.

(d) The unit has worked very well during its three years of operation. The only point of interest is the need for briquettes of constant quality, as variation in the same cause trouble. They should all have the same compression in manufacture, which should give them a specific gravity of 1.23. The water content should remain between 13.5 and 14 percent.

(e) Since the main cause for the Wesseling Plant not meeting its guaranteed capacity was in its gas production, means were constantly being taken to remedy the lack of briquette consistency.

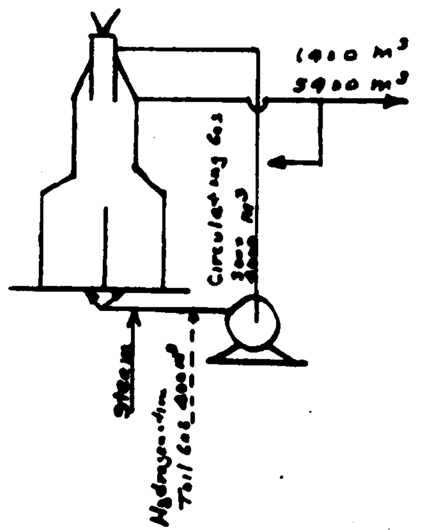
(f) The capacity of a generator is fixed by theporosity of the briquette bed. By good standardization of the briquettes, four thousand (4,000) cubic meters/hour of circulating gas and three thousand five hundred (3,500) kilogram/hour of steam can be handled. From this is produced nine thousand four hundred (9,400) cubic meters/hour of water gas which is split into five thousand four hundred cubic meters/hour of production and four thousand (4,000) cubic meters/hour of circulating gas. If the circulating gas stream is substituted by hydrogenation tail gas,, the regenerator section of the furnace can be used as a cracking furnace, as shown in the diagram (Fig.3). Hence, four hundred (400) cubic meters of tail gas gives one thousand (1,000) cubic meters of cracked gas. Furthermore, the tail gas acts just as well as the circulating has-stream mixture for preheating briquettes provided the quantity of gas circulated or injected is reduced from four thousand (4,000) to three thousand (3,000) cubic meters/hour. This results in an increase of total gas produced from five thousand four hundred (5,400) to six thousand four hundred (6,400) cubic meters/hour.

FIG. 3.

Cracking of Hydrogenation Tail Gas
In the Preheater of the Generator

Production and Circulating Gas

Solid Lines — Normal operation
Broken Lines - Addition of Hydrog. Tail Gas






12

## I. PINTSCH-HILLEBRAND UNIT. (Cont'd.)

(g) The regenerator is well fitted for cracking, as its temperature is one thousand three hundred (1,300) degrees centigrade and sufficient steam is on hand in the gas itself so that other steam injection is not necessary. Naturally, more heat has to be added to the regenerator than before in order to account for the required heat of cracking. It is theoretically possible to substitute hydrogenation tail gas for all of the circulating gas, but this was actually only approximated. The increase in gas yield is one thousand (1,000) cubic meters/hour which raises the total output of the Pintsch-Hillebrand units up to ten thousand (10,000) cubic meters/hour.

(h) As previously stated the main operating difficulties of the unit were in not getting briquettes of constant quality. When normal briquettes were obtained, the unit ran well.

(i) Another source of trouble was in the tar recovery. Calcium carbonate deposits were also troublesome, but by proper operation of the water treating plant this difficulty was removed.

(j) In conclusion, air raid damage which shut down the heating gas plant, caused the water gas unit to be used as heating gas unit. Due to its higher heating value, two thousand two hundred (2,200) as opposed to one thousand four hundred fifty (1,450) W. E., the generators were only run at sixty (60) percent full load capacity. The operation under these conditions was satisfactory.

### OPERATING DATA ON GENERATOR - FULL CAPACITY

| | |
|---|---|
| Lignite required | 3,000 Kg/h |
| Total steam required | 4,200 Kg/h |
| of which 60% was steam added | |
| 40% from saturation of circulation gas | |
| Fuel gas required 4,4 Mil. W.E./h | 3,000 nm3/h ($H_u$1460 W.E.) |
| Gas produced | 5,400 nm3/h |
| Circulating gas | 4,000 nm3/h |
| of which 70 - 90% preheat gas | |
| 30 - 10% product | |

I. PINTSCH-HILLEBRAND UNIT. (j) (Cont'd.)

TEMPERATURES

Circulating gas before heat accumulator
Circulating gas after heat accumulator
Distilled gas leaving chamber
Distilled gas leaving waste heat boiler

## II. PRODUCER GAS UNIT.

(a) The plant is equipped with eighteen generators producing three thousand (3,000) cubic meters/hour each. In these units lignite briquettes are first incompletely oxided to a mixture of $CO_2$ and CO by an air blowing (Fig. 4). The completion of the reaction to produce water gas or CO is then accomplished by injecting either steam or $CO_2$ and carbon. The reactions are as follows:

$$C + \frac{1}{2}O_2 = CO + 26{,}000 \text{ Cal.}$$
$$C + O_2 = CO_2 + 94{,}000 \text{ Cal.}$$
$$C + H_2O = CO + H_2 - 31{,}000 \text{ Cal.}$$
$$C + CO_2 = 2CO - 41{,}000 \text{ Cal.}$$

(b) The resulting gas is a mixture of $CO_2$, CO, $H_2$ and $N_2$ with a lower heating value of one thousand four hundred fifty (1,450) heat units.

(c) The gas generator has both a preheating and distillation section. Its diameter is three (3) meters.

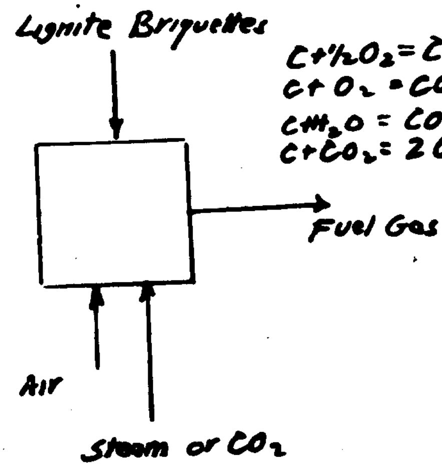
(d) The gas quantities from preheating and distillation are equal. They are cleaned and cooled in separate units, and then as heating gas are either stored in a gas holder or used directly.

(e) The blast air is saturated with water vapor or blended with $CO_2$ to maintain a proper outlet temperatures as follows:

with steam - 750° C
with CO - 650° C

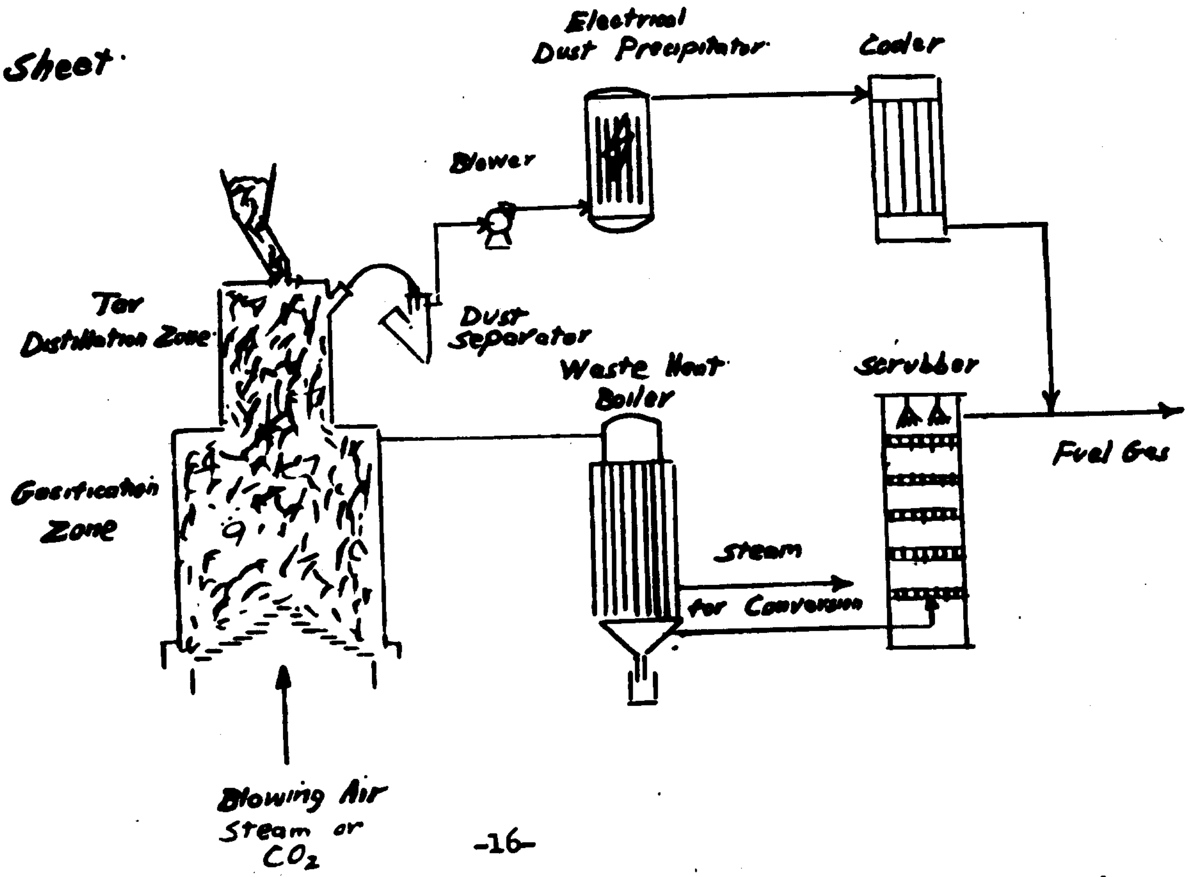
FIG. 4
Fuel Gas Unit

Principal




$C + \frac{1}{2}O_2 = CO + 20{,}000$ Cal
$C + O_2 = CO_2 + 94{,}000$ "
$C + H_2O = CO + H_2$ $-31{,}000$ Cal
$C + CO_2 = 2\,CO$ $-41{,}000$ "

Flow Sheet



II. PRODUCER GAS UNIT. (Cont'd.)

(f) The gas quantity from the preheating stage is the result of properly drying the briouettes. The outlet temperature of the preheat gas is around one hundred (100) degrees centigrade. This gas stream passes over a dust remover, an electric oil filter and a tubular cooler. The second cooler, planned for in the original design, was omitted to save material, and results in an oil loss in the outlet gas of over one (1) gram/cubic meter. The gas leaving the idstillation zone is passed through a waste heat boiler and a scrubber before joining the preheater gas stream.

(g) As orininally planned, this unit was to have been small. Due both to an increase in the total hydrogen plant, size, and also to the diversion of propane and butane from a heating gas to crack gas feed stock, the fuel gas unit had to be enlarged. This was also due to the fact that the gas resistance through the generator was higher than anticipated, because of the clogging up of the ashes in the lower part of the generator, through which the blowing air had to pass.

(h) This clogging of the ashes was greatly improved by substituting $CO_2$ for $H_2O$ in the blowing air mixture. The former was available in large quantities from the final gas washing step

(i) In this way, the $CO_2$ was converted to CO and $H_2$ while the steam formerly used was available for other uses. The ash clogging was greatly reduced with its resulting pressure drop and the capacity of the whole unit greatly increased.

(j) The analysis of the heating gas was altered by the $CO_2$ substitution but its heating value did not change.

| Gas Analysis | $CO_2$ | Heavy Hydrocarbons | CO | $H_2$ | CHy | $N_2$ | Hu |
|---|---|---|---|---|---|---|---|
| With $H_2O$ addition | 4.4 | 0.3 | 31.5 | 15.9 | 1.9 | 45.4 | 1440 |
| With $CO_2$ addition | 6.3 | 0.3 | 38.6 | 8.3 | 1.6 | 45.1 | 1430 |

(k) From an operational view point, the substitution of $CO_2$ was as follows: The capacity of the unit was raised thirty-five (35) percent, that is up to eighteen thousand (18,000) cubic meters/hour. As mentioned, the hydrogenation tail gas become avail-

II. PRODUCER GAS UNIT. (k) (Cont'd.)

able for cracking, hence producing both more hydrogen, $C_3$ and $C_4$. This was equivalent to twenty thousand (20,000) tons/year of aviation gasoline on a lignite basis and thirty-five thousand (35,000) tons/year on an oil basis.

(l) The steam from the waste heat boiler was made available to the conversion unit at 2.5 atmospheres pressure, and was equivalent to sixty thousand (60,000) cubic meters/hour of heating gas or six (6) tons/hour of steam.

(m) Firthermore, the finished heating gas outlet temperature can be dropped from seven hundred seventy (770) degrees to six hundred seventy (670) degrees centigrade, resulting in a considerable saving of heat and fuel briquettes. A further saving occurs in the use of $CO_2$ to make CC and $H_2$. Each kilogram of briouettes produces:

With $H_2O$ injection - 2.4 cu. meters heating gas
With $CO_2$ injection - 2.55 cu. meters heating gas

(n) This saving of briquettes is equivalent to sixty thousand (60,000) cubic meters of gas production, or twenty-five (25) tons per hour of briquettes.

(o) The dust and oil content of the heating gas is ten (10) milligrams of dust/cubic meters and one hundred fifty (150) milligrams of oil/cubic meters. Such quantities can cause trouble in the gas holders.

(p) After storage, the quantities drop to three (3) milligrams of dust and twenty (20) milligrams of oil/cubic meter gas, which indicates the extent of material deposits that can occur. This could be avoided by including the second oil filter as originally planned, and a fine dust separator.

(q) Another operating difficulty was the stopping up of the bottom baffles in the generator. After two years, these all had to be replaced.

(r) This was caused by both the corroding and the eroding influence of the ashes. The composition of the metals used also

II. PRODUCER GAS UNIT. (r) (Cont'd.)

played an important part in the trouble. The main point to be watched is keeping the temperature of the ashes low. It is also helped by hardening the steel, through heating to nine hundred (900) degrees centigrade, quenching followed by reheating to five hundred fifty (550) degrees centigrade and then slowly cooling in air.

OPERATING SUMMARY

| Quantities | 1943 | 1944 |
|---|---|---|
| Heating gas production | 48,000 m3/hr | 60,000 m3/hr |
| - Average per generator | 2,815 m3/hr | 3,600 m3/hr |

UNIT QUANTITIES

| | | |
|---|---|---|
| Heating gas/briquettes | 2,480 m3/ton | 2,580 m3/ton |
| Tar/Briquette | 4.8 % | 4.8 % |
| Heating value of gas | 1,444 WE/m3 | 1,430 WE/m3 |

TEMPERATURES

| | |
|---|---|
| Distilled gas leaving saturator | 70° |
| Pre-heater gas leaving preheater | 90° |

ANALYSES OF DISTILLED AND PREHEATER GAS

| | $CO_2$ | Heavy H. C. | CO | $H_2$ | $CH_4$ | $N_2$ |
|---|---|---|---|---|---|---|
| Distilled gas | 14 % | | 28% | 56% | 1 % | 1 % |
| Preheater gas | 17.5% | 0.8% | 26% | 48% | 6.5% | 1.2% |

Dust content in water gas: 1 - 2 $mg/nm^3$
Carbon content in ash : 40 - 50%



24

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## II. PRODUCER GAS UNIT. (r) (Cont'd.)

### OTHER RESULTS

### WATER GAS PRODUCTION BY MEANS OF INCREASE GENERATOR CAPACITY

| 1943 | 1944 |
|---|---|
| 48,600 $nm^3/h$ | 52,000 $nm^3/h$ |
| 4,950 $nm^3/h$ | 5,100 $nm^3/h$ |

### UNIT QUANTITIES

| | 1943 | 1944 |
|---|---|---|
| Water gas production/briquette | 1,938 $nm^3/kg$ | 1,900 $nm^3/kg$ |
| Heating gas required/water gas | 828 $WE/nm^3$ | 825 $WE/nm^3$ |
| Tar recovery | 4.8% | 4.9% |
| Outside steam/water gas | 0,126 $kg/nm^3$ | 0,125 $kg/nm^3$ |
| $CO + H_2$ in water gas | 83.5% | 84.% |