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Holten, 12/14/41

CONNECTING THE PRESSURE AND LOW PRESSURE SYNTHESIS
IN SERIES BASED ON 65,000 m³ WATER GAS.

To Dir. Alberts.

I am presenting my proposal (made in accordance with my report of 4/3/41 given in the appendix) for obtaining the greatest possible proportion of paraffin and the production of a greater liquefaction in the pressure synthesis by connecting in series the pressure synthesis (D) and the low pressure synthesis (H).

Nothing stands in the way in the operations and construction of the system of operation in series, after the assumptions made at one time regarding the reactor load and gas conversion have been confirmed, and after the installation of the large separators behind the condensation stage and heaters and in front of the synthesis stages. The construction of the third stage of condensation is ready since the middle of January, and a thruput of 25,000 m³ end gas is possible. The available condensation groups of the 1-st and second stages were then used for the end gas of the 1-st synthesis stage in parallel, and the supplementary condensation used for the end gas of the second synthesis stage.

After the shortly to-be-installed cooler elements, and with the operating level reached with three machines (with one more in reserve), the compressor installation will handle the required 62,000 m³. The CO₂ scrubber must be considered safe for operations after the installation back of it (beginning of March) of a separator the size of the scrubber proper, and a safety ball valve to automatically stop the carrying-over of water; they may accordingly be considered as available for the washing of the converted gas intended for the pressure synthesis. A gas thruput of only 10,000 m³ is possible until March, because at present the 2-nd scrubber is in use as a water separator.

With these connections, modified by to-day's proposal, all of the gas (based on 65,600 m³ of water gas) is passed thru the pressure synthesis.

except for that portion of the gas which is used after the conversion for producing the required CO : H₂ proportion of 1 : 2 in the gas used for normal pressure synthesis (cf. the operations flow sheet, app.2).

The composition of the intake and the conversion results are as follows:

Water gas analysis:	CO ₂	CO	H ₂	CH ₄	N ₂
	5.2	39.9	48.2	0.4	6.3
Converter gas (80% CO conversion)	28	6.0	61	0.3	4.7
Converter gas (75% CO ₂ removed in washing):	8.8	7.6	77.4	0.4	5.8

Input, first step:

44,000 m³ water gas

+ 8,000 m³ washed converter gas

= 52,000 m³ synthesis gas, 1-st stage (D synthesis)

The composition of this gas:	CO ₂	CO	H ₂	CH ₄	N ₂
	5.8	35	52.5	0.4	6.3

Water gas input, 1-st stage

44,000 + 7,600 (8,000 m³ washed conv. gas)
= 51,600 m³ water gas

Efficiency, 1-st stage

Contraction 51%

CO conversion 50%

CO₂ formation 00%

CH₄ formation 10%

Proportion of CO : H₂ utilized = 1 : 2.03
and therefore 25,400 m³ of the end gas after 1-st stage
has the following composition

CO ₂	CO	H ₂	CH ₄	N ₂
11.8	35.6	36.5	4.4	12.7

The proportion CO : H₂ for 2-nd stage synthesis gas must be again raised to 1 : 1.5

Addition of washed-converted gas $\text{---} 7,000 \text{ m}^3 = \underline{6,700} \text{ m}^3$ washed gas

which will increase the input: $51,600 + 6,700 = \underline{58,200} \text{ m}^3$ water gas

Composition of synthesis gas, 2-nd stage

CO ₂	CO	H ₂	CH ₄	N ₂
11.2	29.5	44.5	3.6	11.7

2-nd stage gas input: 32,400 m³

CO conversion 50%

Contraction 44%

CO₂ formation 00%

CH₄ formation 10%

CO and H₂ consumed in proportion 1 : 2.03

which results in an end gas of the following composition:

CO ₂	CO	H ₂	CH ₄	N ₂
19.6	26.3	25.3	9.1	19.7

Volume of end gas: 18,300 m³

The proportion CO : H₂ in this gas is raised to 1 : 2 by the addition of converted gas. Required amount of unwashed converted gas : 10,000 m³

= 7,400 m³ water gas

The total water gas addition figures then to

D. synth, 1-st stage D synth., 2-nd stage N. synth.

51,600 + 6,700 + 7,400 =
65,600 m³/h water gas.

Input of gas into N. synthesis

18,300 + 6,700 = 28,300 m³/h

of the following composition:

CO ₂	CO	H ₂	CH ₄	N ₂
22.5	19.0	37.8	6.1	14.6

With a:

Conversion of CO	65%
Formation of CO ₂	3%
Formation of CH ₄	15%
Contraction	36%

there will remain 18,200 m³/h of end gas of the composition
 35.8 10.4 19.2 12.1 22.6

The synthesis and converter load may be calculated from the following considerations:

Pressure Synthesis:

46 reactors, 1-st stage, 1120 m³/h, 35% CO, 52.5% H₂, CO : H₂ = 1:1.5;
 CO conversion 50%

18 " 2-nd " 1800 m³/h, 29.5% Co, 44.5% H₂, CO : H₂ = 1:1.5
 CO conversion 50%

64 " 1+2 st., 925 m³/h (sic) 31.6% CO, 55.8% H₂, CO : H₂ = 1:1.76;
 CO conversion 74%

Low Pressure Synthesis:

40 reactors, single stage, 700 m³/h, 19.6% CO, 37.8% H₂, CO : H₂ = 1:1.99
 CO conversion 65%

A balance and comparison of the CO and H₂ inputs and conversion in both synthesis:

The combined input was:

CO: 19,300 m³/h

H₂: 38,700 "

Of this amount, in the 1-st. and 2-nd. stages of the D synthesis

CO: 18,730 m³/h

H₂: 32,600 "

Of this amount, converted:

CO: 13,900 m³/h

H₂: 28,000 "

i.e., with a degree of conversion of

CO: 76%

H₂: 86%

Input into the N. Synthesis:

CO: 5,400 m³/h

H₂: 10,700 "

Of this amount, converted

CO: 3,500 m³/h

H₂: 7,200 "

which is represented by a degree of conversion of

CO: 65%

H₂: 67%

There remains in the residual gas after the N. conversion

CO: 1,900 m³/h

H₂: 3,500 "

These figures give for the total degree of conversion of all CO and H₂ sent through the system:

90.3% for CO

91.0% for H₂

and, when distributed to the different syntheses:

D. synthesis 72.0% CO 72.5% H₂

N. " 18.3% CO 18.5% H₂

The advantages of the new or old system may be judged as follows:

The total gas is worked up in three stages, with the mild conversion and starting conditions required for the operations. The mutual influences of mass relationships are here eliminated. According to the subdivision given, 80% of the CO conversion proceeds in the pressure synthesis, and 20% in the low pressure synthesis. Disregarding the increased amount of paraffins, the liquefaction in the pressure synthesis is better than in the low pressure synthesis, and this may be assumed as proven for the proportion of CO : H₂ = 1 : 1.5.

Operations are in general simplified in this method, which is desirable. The production is measured separately for the pressure and the low pressure syntheses up to the production of gasol.

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APPENDIX I

Holten, May 3, 1941

CONNECTING THE MEDIUM AND THE LOW PRESSURE SYNTHESIS
IN SERIES, ON A BASIS OF 60,000 m³ WATER GAS.

The medium pressure synthesis is conducted in two stages, with a CO:H₂ ratio of 1:1.5, and followed with a single stage low pressure synthesis with a CO:H₂ ratio of 1:2.

50,000 m³ water gas including the converted gas were sent through the system, determined by the capacity of the gas compressor, and taking into consideration the load on the pressure reactors, on the pressure condensation and the A.K. installation II. The balance of 10,000 m³ water gas were mixed with the end gas of the pressure synthesis and worked up at the low pressure synthesis.

The load on the reactors is:

Medium pressure synthesis:

36 reactors, 1-st stage, 1230 m³/h: 33% CO, 50% H₂

24 " 2-nd " 1200 " 25.5% CO, 38% H₂

Low Pressure Synthesis:

45 reactors 720 m³/h: 18% CO, 55.3% H₂

The total input is:

CO 17,310 m³

H₂ 34,500 "

of which the amount sent through the first and second stages, D synthesis:

CO 15,410 m³

H₂ 22,860 "

and converted:

CO 75%

H₂ 85%

The amount sent through the H. synthesis is:

CO 5,780 m³

H₂ 11,540 "

and converted:

CO 4,330 m³

H₂ 8,640 "

i. e. with a degree of conversion of

CO 75%

H₂ 75%

There remain in residual gas of the H. synthesis

CO 1,450 m³

H₂ 2,900 m³

Conversion, figured to the total input is

CO 69%

H₂ 51%

Were we to compare this process with the one in present day use, we would get the following results. At present we pass through the D. synthesis

33,000 m³ synthesis gas composed of 33.3% CO and 51.6% H₂, and in the H. synthesis

33,000 m³ of synthesis gas, containing 33.3% CO and 52.8% H₂.

	CO input	CO conversion
First case: D. synthesis	15,410 m ³	11,530 m ³
Second " " " (at present)	10,000 "	8,500 "
First case: H. synthesis	5,780 "	4,330 "
Second " " " (at present)	7,400 "	6,500 "

The compositions of the input and conversion are as follows:

Water gas input

	CO ₂	CO	H ₂	CH ₄	N ₂
	6.5	37.0	47.3	0.2	8.1
Converted gas:	27.3	5.0	00.0	0.3	5.8

Total gas addition (v. flow sheet, page 1)

39,000 m ³ water gas
7,000 " converted gas
<u>46,000 " synthetic gas</u>

of the following composition:

CO ₂	CO	H ₂	CH ₄	N ₂
9.9	33.0	30.0	0.2	26.9

The 7,000 m³ converted gas have been added to 5,400 m³ water gas, i.e. the water gas input into the first stage is

39,000 + 5,400 = 44,400 m³ water gas

Contraction in the first stage

CO conversion

CO₂
13.7

The formation of CO₂ is assumed to be 10

" " " CH₄

10.2

End gas, first stage

30.0	32.0	33.0	0.2	27.0
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The proportion CO : H₂ is again restored to 1:1 by the addition of converted gas, for which we shall require

6,500 m³ converted gas + 1,000 m³ water gas.

Total input of water gas

44,400 + 1,600 = 46,000 m³

The composition of synthetic gas II:

CO ₂	CO	H ₂	CH ₄	N ₂
21.5	33.5	33.0	0.2	21.8

Gas input into second stage:

39,000 + 6,500 = 45,500 m³ synthetic gas II.

Contraction, 2-nd stage	35%
CO conversion "	36%
CO ₂ formation "	0%
CH ₄ formation "	10%

End gas, second stage: 19,000 m³ of the composition

	CO ₂	CO	H ₂	CH ₄	N ₂
	33.0	20.4	20.8	7.0	18.2

The proportion of CO : H₂ in the gas is raised by the addition of converted gas to 1:2, requiring

$$7,200 \text{ m}^3 \text{ converted gas} = 5,500 \text{ m}^3 \text{ water gas}$$

Producing 26,400 " synthesis gas of the composition:

	31.3	16.2	31.7	6.0	14.8
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Total water gas input so far:

49,200 ÷ 5,500 = 54,700 m³ water gas
 With a required input of 60,000 m³, there remain available

which are equal to

of the following composition:

	13.2	18.0	35.3	5.0	13.4
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This gas is used in the one-stage low pressure synthesis. With a contraction of 33%, the 52,200 m³ of synthesis gas will produce 21,400 m³ end gas of the composition

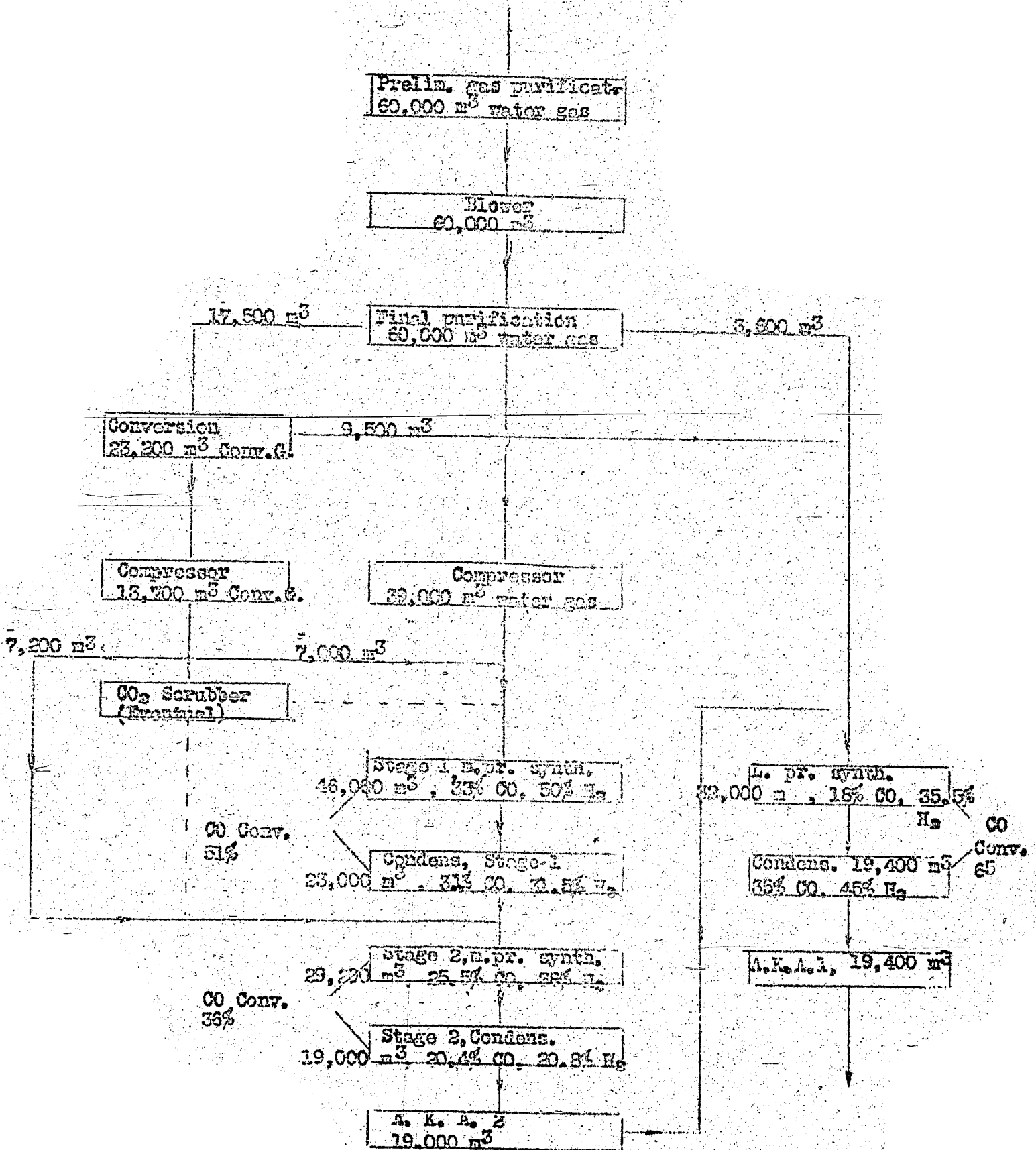
	46.0	7.5	15.0	11.5	20.0
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No scrubbing out of CO₂ from the converted gas is foreseen in the above exposition. The scrubbing of the converted gas used in the medium pressure synthesis, 1-st and 2-nd stages, must be taken into consideration. Scrubbing of the converted gas for the low pressure stage must be left out of consideration, because the capacity of the three compressors, 52,000 m³, is practically reached.

When making the decision on whether the proposed method or the old method are preferable in production, the following must be considered. The gas input and the reactor capacity are left unchanged. In case I, a considerably greater amount of CO is put in and converted in the medium pressure installation under more favorable conditions (CO:H₂ = 1:1.5). The low pressure stage with 730 m³/h/ reactor remains a safe stabilizer for the operation of the medium pressure installation.

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CONNECTING THE MEDIUM PRESSURE AND THE LOW PRESSURE
SYNTHESIS IN SERIES. 60,000 m³ WATER GAS TREATMENT



CONNECTING THE MEDIUM PRESSURE AND THE LOW PRESSURE
SYNTHESIS IN SERIES. 65,600 m³ WATER GAS INTAKE

