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Holten, 12/14/41

CONNECTING THE PRESSURE AND LOW PRESSURE SYNTHESIS IN SERIES BASED ON 65,000 m^3 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 (N).

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 m^3 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 m^3. The CO_2 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 m^3 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 m ^{3} 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 : H_2 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:

	CO_2	CO	H_2	CH_4	N_2
Water gas analysis:	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 m^3 water gas

\+ 8,000 " washed converter gas

52,000 M^3 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 m^3 washed conv. gas)
= 51,600 m^3 water gas

Efficiency, 1-st stage

Contraction	51%
CO conversion	80%
CO_2 formation	00%
CH_4 formation	10%

Proportion of CO : H_2 utilized = 1 : 2.03
and therefore 25,400 m^3 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	35.5	4.4	12.7

The proportion CO : H_2 for 2-nd stage synthesis gas must be again raised to 1 : 1.5
Addition of washed converted gas —— 7,000 m^3 = 6,700 m^3 washed gas

which will increase the input: 51,600 + 6,700 = 58,200 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 m^3

CO conversion 50%

Contraction 44%

CO_2 formation 00%

CH_4 formation 10%

CO and H_2 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 m^3

The proportion CO : H_2 in this gas is raised to 1 : 2 by the addition of converted gas. Required amount of unwashed converted gas : 10,000 m^3

= 7,400 m^3 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 m^3/h water gas.

Input of gas into N. synthesis

18,300 + 6,700 = 28,300 m^3/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	35%

there will remain 18,200 m^3/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 m^3/h, 35% CO, 52.5% H_2, CO : H_2 = 1:1.5; CO conversion 50%

18 " 2-nd " 1800 m^3/h, 29.5% Co, 44.5% H_2, CO : H_2 = 1:1.5 CO conversion 50%

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64 " 1+2 st., 925 m^3/h (sic) 31.6% CO, 55.8%H_2, CO : H_2 = 1:1.76; CO conversion 74%

Low Pressure Synthesis:

40 reactors, single stage, 700 m^3/h, 19.6% CO, 37.8% H_2, CO : H_2 = 1:1.99 CO conversion 65%

A balance and comparison of the CO and H_2 inputs and conversion in both synthesis:

The combined input was:

CO: 19,300 m^3/h

H_2: 38,700 "

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

CO: 18,730 m^3/h

H_2: 32,600 "

Of this amount, converted:

CO: 13,900 m^3/h

H_2: 28,000 "

i.e., with a degree of conversion of

CO: 78%

H_2: 86%

Input into the N. Synthesis:

CO: 5,400 m^3/h

H_2: 10,700 "

Of this amount, converted

CO: 3,500 m^3/h

H_2: 7,200 "

which is represented by a degree of conversion of

CO: 65%

H_2: 67%

There remains in the residual gas after the N. conversion

CO: 1,900 m^3/h

H_2: 3,500 "

These figures give for the total degree of conversion of all CO and H_2 sent through the system:

90.3% for CO

91.0% for H_2

and, when distributed to the different syntheses:

D. synthesis	72.0% CO	72.5% H_2
N. "	18.3% CO	18.5% H_2

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 paraffine, 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 : H_2 = 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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i.e., with a degree of conversion of

CO: 76%

H_2: 86%

Input into the N. Synthesis:

CO: 5,400 m^3/h

H_2: 10,700 "

Of this amount, converted

CO: 3,500 m^3/h

H_2: 7,200 "

which is represented by a degree of conversion of

CO: 65%

H_2: 67%

There remains in the residual gas after the N. conversion

CO: 1,900 m^3/h

H_2: 3,500 "

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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 m^3 WATER GAS.

The medium pressure synthesis is conducted in two stages, with a $CO:H_2$ ratio of 1:1.5, and followed with a single stage low pressure synthesis with a $CO:H_2$ ratio of 1:2.

50,000 m^3 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 m^3 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, 1280 m^3/h: 33% CO, 50% H_2

24 " 2-nd " 1200 " 25.5% CO, 38% H_2

Low Pressure Synthesis:

45 reactors 720 m^3/h: 18% CO, 35.3% H_2

The total input is:

CO 17,310 m^3

H_2 34,300 "

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

CO 15,410 m^3

H_2 22,860 "

and converted:

CO 75%

H_2 85%

The amount sent through the N. synthesis is:

CO 5,780 m^3

H_2 11,340 "

and converted:

CO 4,330 m^3

H_2 8,440 "

i.e. with a degree of conversion of

CO 75%

H_2 75%

There remain in residual gas of the N. synthesis

CO 1,940 m^3

H_2 2,900 m^3

Conversion, figured to the total input is

CO 89%

H_2 91%

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

38,000 m^3 synthesis gas composed of 28.6% CO and 51.6% H_2, and in the N. synthesis:

23,000 m^3 of synthesis gas, cont aining 26.4% Co and 52.8% H_2.

		CO input	CO conversion
First case:	D. synthesis	15,410 m^3	11,530 m^3
Second "	" " (at present)	10,000 "	8,600 "
First case:	N. synthesis	5,780 "	4,330 "
Second "	" " (at present)	7,400 "	6,580 "

The compositions of the input and conversion are as follows:

Water gas input

	CO_2	CO	H_2	CH_4	N_2
	6.8	37.8	47.9	0.3	7.1
Converted gas:	27.3	5.0	62.0	0.2	5.5

Total gas addition (v. flow sheet, app. I)

39,000 m^3 water gas
7,000 " converted gas
46,000 " synthesis gas

of the following composition:

CO_2	CO	H_2	CH_4	N_2
9.9	33.0	50.0	0.3	6.8

The 7,000 m^3 converted gas have been obtained from 5,400 m^3 water gas, i.e. the water gas input into the first stage is

$$39{,}000 + 5{,}400 = 44{,}400 \text{ m}^3 \text{ water gas}$$

Contraction in the first stage 50%
CO conversion 51%

The formation of CO_2 is assumed to be = 0
" " " CH_4 = 10.4%

End gas, first stage

19.8	31.0	31.5	4.1	13.6

The proportion CO : H_2 is again restored to 1:1.5 by the addition of converted gas, for which we shall require

6,200 m^3 converted gas = 4,800 m^3 water gas.

Total input of water gas

$$44{,}400 + 4{,}800 = 49{,}200 \text{ m}^3$$

The composition of synthesis gas II:

CO_2	CO	H_2	CH_4	N_2
21.5	25.5	38.0	3.2	11.8

Gas input into second stage:

$$23{,}000 + 6{,}200 = 29{,}200 \text{ m}^3 \text{ synthesis gas II.}$$

Contraction, 2-nd stage		35%
CO conversion	"	36%
CO_2 formation	"	0%
CH_4 formation	"	10%

End gas, second stage: 19,000 m^3 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 : H_2 in the gas is raised by the addition of converted gas to 1:2, requiring

7,200 m^3 converted gas = 5,500 m^3 water gas

Producing 26,400 " synthesis gas of the composition:

31.3	16.2	31.7	6.0	14.8

Total water gas input so far:

49,200 + 5,500 = 54,700 m^3 water gas

With a required input of 60,000 m^3, there remain available

5,300 m^3 water gas
5,800 m^3 synthesis gas

which are equal to
of the following composition:

13.2	18.0	35.3	5.0	13.4

This gas is used in the one-stage low pressure synthesis. With a contraction of 33%, the 32,200 m^3 of synthesis gas will produce 21,400 m^3 end gas of the composition

46.0	7.5	15.0	11.5	20.0

No scrubbing out of CO_2 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 m^3, 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 ($CO:H_2$ = 1:1.5). The low pressure stage with 720 m^3/h/ reactor remains a safe stabilizer for the operation of the medium pressure installation.

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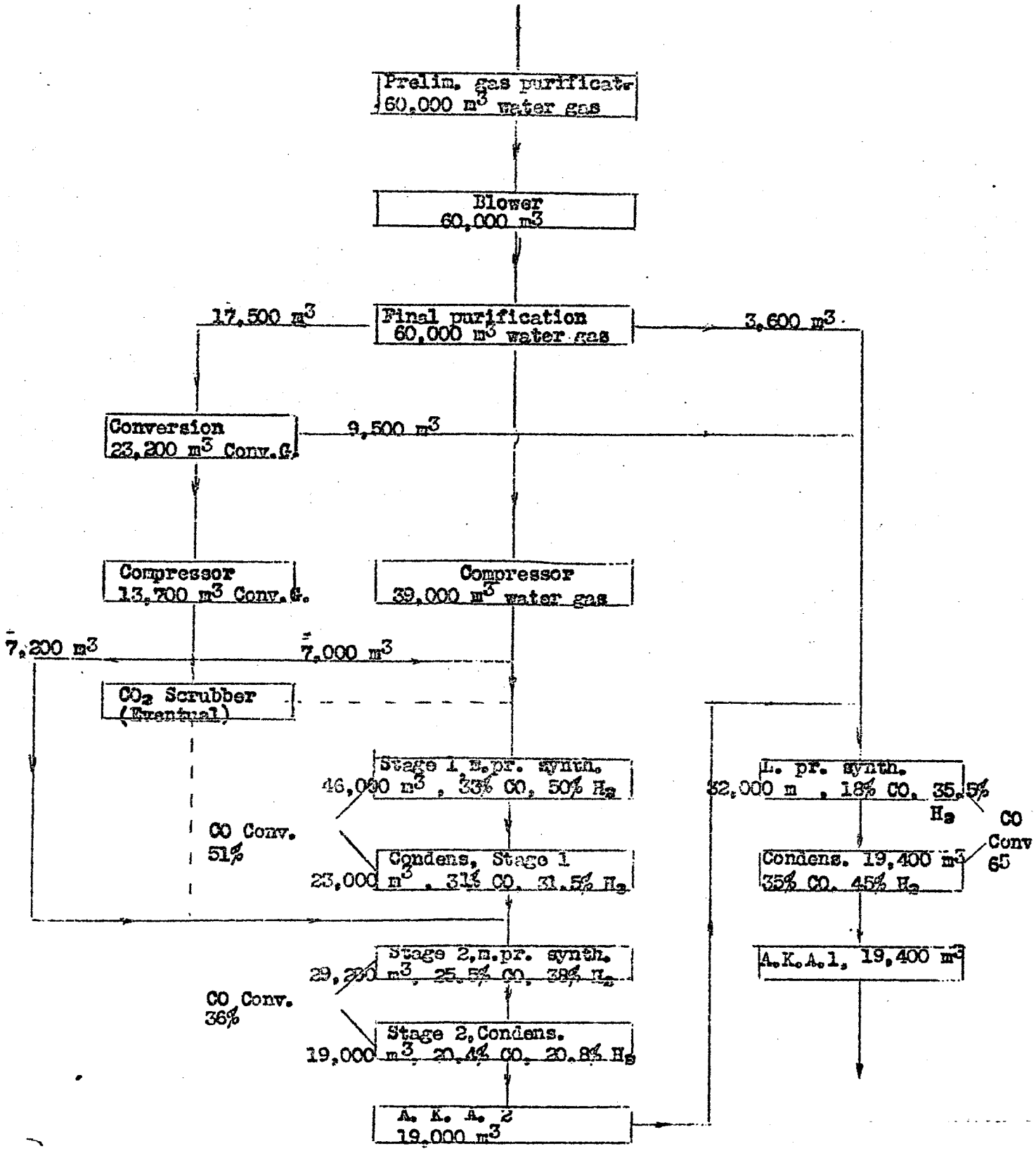
CONNECTING THE MEDIUM PRESSURE AND THE LOW PRESSURE SYNTHESIS IN SERIES. 60,000 m^3 WATER GAS INTAKE



CONNECTING THE MEDIUM PRESSURE AND THE LOW PRESSURE SYNTHESIS IN SERIES. 65,600 m^3 WATER GAS INTAKE