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Gas Purification by Means of Deep Temperature
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Purpose: Elimination of sulfur compounds and of carbon dioxide from the raw synthesis gas.

Method for the removal: An application of the Linde-Fränkl regenerator principle using pure nitrogen as purge gas at low temperatures.

Technical execution: 4 regenerators of equal size are used. One regenerator is always used for the cooling of the raw synthesis gas, a second is being flushed with nitrogen, the third is used for cooling the nitrogen to be used for flushing, and the fourth regenerator absorbs the cold of the pure gas. After a certain time interval, the order of arrangement of the regenerators is changed. The temperatures at the bottom (cold end) of the regenerator are maintained by the use of an expansion turbine.

The raw gas is compressed by means of a (turbo) compressor to the required pressure, cooled in a cooler set behind it, and enters the regenerator at the temperature of the surroundings. The nitrogen for purging is compressed by a blower to the required pressure for the overcoming of the resistance of two regenerators. The lower temperatures of the regeneration lie around – 294° F, or at a temperature, at which the impurities of the raw synthesis gas are deposited to a sufficient extent.

Composition of the gas: 14. % CO_2
2. % N_2
0.4% CH_4
42. % H_2
41.6% CO

Molecular weight = 19.27

R = 44 = gas constant

The specific heat of the gas at the intake of the regenerator.

c_p = 0.31 kcal/m^3 = 0.0348 BTU/ft^3.

Specific heat of nitrogen, c_{pN_2} = 0.285 kcal/^{3} = 0.0320 BTU/ft^3.

Initial pressure assumed to be 3 atm.

Partial pressures:

CO_2	= 0.42
N_2	= 0.06
CH_4	= 0.012
H_2	= 1.26
CO	= 1.248
	3.000

CO_2 begins to sublime at -89° C (-128°F) = 184°K (330° F Abs.) while all the other constituents remain in the gaseous form.

The specific heat of gases at the bottom of the regenerator at - 180° C (-292° F) (in the absence of CO_2) is

$$c_p = 0.282 \text{ kcal/m}^3 \ (0.0317 \text{ BTU/ft}^3)$$

The gas, 86% of the original amount, now consists of:

N_2	2.33%
CH_4	0.47 %
H_2	48.8%
CO	48.4%
	100.0%

Ave. mol. wt. = 15.25

The heat transfer coefficient, K - 1.405 kcal/m^2, °C, h = 0.288 BTU/ft^2,°F, h.

The back pressure of the turbine is assumed to be 1.25 atm.

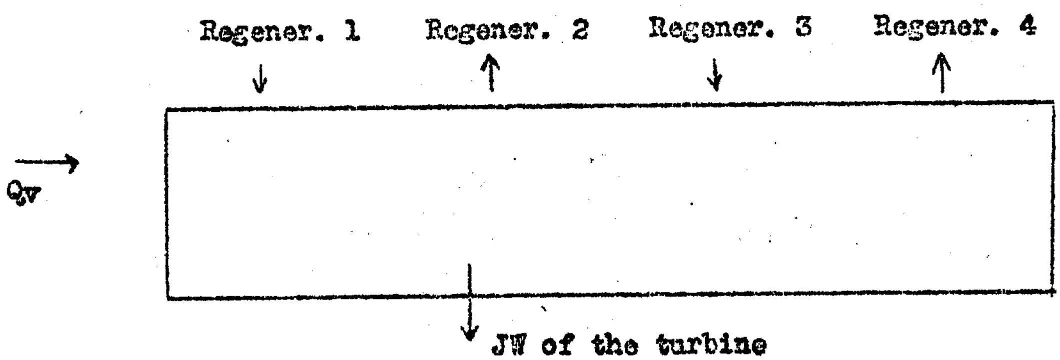
Ratio of pressures = 2.4

Temperature difference through exhausting = 14.5°C (26°F)

The specific heat of the pure gas at the warm end of the regenerator is 0.286 kcal/m^3 (0.0321 BTU/ft^3).

The specific heat of nitrogen + carbon dioxide c_p = 0.30 kcal/m^3 (0.0337 BTU/ft^3).

The heat balance of the whole system appears as follows (nitrogen forms 90% of the raw gas).



The heat condensing into the system from the outside is assumed in the computations to be 1 kcal/m^3 of the gas (0.1124 BTU/ft^3)

The work produced by the turbine amounts to about 8% of the work of the compression of the raw synthesis gas.

The principle applying to all refrigeration systems applies in this case as well: to lower the temperature only as low as necessary. The higher the starting temperature of the turbine is, the higher will also be the temperature difference produced with the same ratio of pressures.

Care must also be taken to have no unnecessarily high resistance in the valves, because all these resistances must be overcome by the work of compression.

Calculation of the regenerators

Raw gas = 2925 m^3/h (1 atm., 15° C) = 100,000 cf/h (30", 60° F)

Required nitrogen = 2630 m^3/h, (89,950 cf/h).

Available nitrogen = abt. 2800 m^3/h (95,760 cf/h)

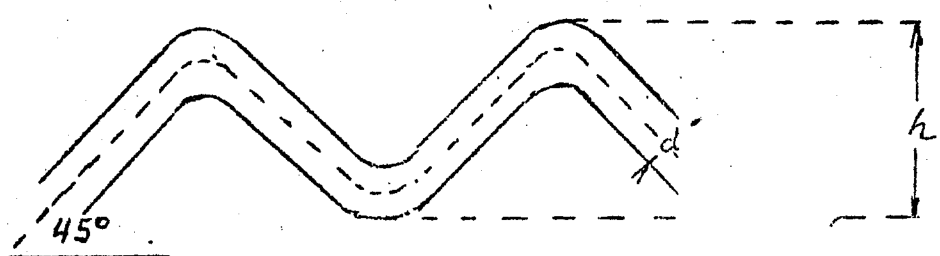
Velocity of gas in the regenerators, recalculated to 1 atm abs. and 15°C
= 1 m/sec (3.281 ft/sec)

Diameter of regenerator, inside, 1020 mm (40.16")

Filling to be used: aluminum

Dimensions	25 mm x 0.5 mm	(0.984 x 0.0020")
Length of one spiral, stretched out:		325 m (1066 ft)
corrugated:		230 m (755 ft)

Shape of the spirals.



(d) = 0.5 mm (0.0197")   (h) = 3.53 mm (0.1390")

Length of regenerator (to be filled with 200 inserts) = 5,000 mm (196.8")

Heating surface = 3,250 m^2 (34,983 sf)

Weight of aluminum = 2,195 kg (4839 lbs)

Duration of one period = $\frac{1}{20}$ h.

Resistance of filling = 25 mm water/m (0.3" water/ft)

Total resistance = 0.0125 atm (without the valves)

Proportion of space occupied by the aluminum filling = 20%

Total length of bands per regenerator (stretched out) = 65,000 m (213,252ft)

Heat transfer coefficient = 53 kcal/m^2, h, °C (10.86 BTU/sf, °F, h)

<u>Calculation of connection losses</u>

Assumed volume of one regenerator = 3.5 m^3 (123.6 cub. ft) (between the valves)

Gas volume contained about 5.25 m^3, at 1 atm., 15°C (179.9 cub. ft, 30", 60°F).

Gas volume in raw gas generator = 15.75 m^3 (538.6 cf).

After opening the by-pass valves = 10.5 m^3 (359 ft)

About 90% of this raw gas is recovered after changing connections = 9.5 m^3 (325 cf). Loss 1 m^3 (34.2 cf) per period.

Loss 1 = $\frac{1.20}{2925}$ = about 0.7%

Contamination of the raw gas by 5.25 m^3 N_2 (179.5 cf)/period = 3.6%

The second loss is caused by the connection of the next regenerator pairs. The pure gas drives before it the nitrogen in the regenerator, which must be removed through a by-pass. This involves a gas loss of about 0.5%.

A third loss is caused during the passing of about 5.25 m^3 (185.4 cf) in the purging nitrogen when changing connections from the purified gas to N_2, pure.

The total gas losses are therefore

$$0.7 + 0.5 + 3.6 = 4.8 = \text{abt } 5.\%$$