Carbonatation: Limestone, Kiln Gas and CO_2 Pump

Limestone and coke for a CaO dose, CO_2 produced, kiln gas at a CO_2 strength and the CO_2 pump displacement, following Hugot's example (ch. 27, pp. 422–425).

Method: Hugot; Handbook of Cane Sugar Engineering; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Crushing rate	100.00	t/h
CaO per tonne cane Hugot Table 27.1: single or continuous double carbonatation about 18 kg/t cane.	18.000	kg/t
$CaCO_3$ in the limestone	90.000	%
Limestone margin	1.0500	
Coke per limestone Hugot: 8–10 kg per 100 kg limestone.	8.0000	%
Carbon in the coke	85.000	%
CO_2 in the kiln gas at the pump (wet basis) By volume in the gas as pumped, which is nearly saturated with water after washing. An analyser on dried gas reads higher: y_wet = y_dry (1 − p_w/p_g), with p_w the water vapour pressure at the gas temperature (about 20 kPa at 60 °C).	30.000	%
Gas temperature at the pump	60.000	°C
Gas pressure at the pump (absolute)	680.00	mmHg
Pump capacity margin	1.1000	
Pump volumetric efficiency	70.000	%

Calculated results

Parameter	Value	Unit
Limestone per tonne cane	37.481	kg/t
Coke per tonne cane	2.9985	kg/t
CO_2 produced per tonne cane	24.171	kg/t
CO_2 density at the pump	1.4404	kg/m³
Kiln gas at the pump	5,593.7	m³/h
CO_2 pump displacement	8,790.1	m³/h

Notes for this case

- Hugot's example (100 t/h, 18 kg CaO/t, 30 % CO_2, 60 °C, 68 cmHg) needs about 8 700 m³/h of pump displacement.

Formula and method

$$m_L = d\frac{M_{CaCO_3}}{M_{CaO}}\frac{k}{p}, \quad m_{CO_2} = m_L\left(p\frac{M_{CO_2}}{M_{CaCO_3}} + c_k C\frac{M_{CO_2}}{M_C}\right), \quad \dot{V}_p = \frac{A\, m_{CO_2}}{\rho_{CO_2}\, y_{CO_2}}\frac{k_s}{\eta_v}$$

Variables

A	Crushing rate	kg/s
d	CaO per tonne cane	kg/kg
p	$CaCO_3$ in the limestone	-
k	Limestone margin	-

c_k	Coke per limestone	-
C	Carbon in the coke	-
y_{CO_2}	CO_2 in the kiln gas at the pump (wet basis)	-
T_g	Gas temperature at the pump	K
p_g	Gas pressure at the pump (absolute)	Pa
k_s	Pump capacity margin	-
η_v	Pump volumetric efficiency	-
m_L	Limestone per tonne cane	kg/kg
m_k	Coke per tonne cane	kg/kg
m_{CO_2}	CO_2 produced per tonne cane	kg/kg
ρ_{CO_2}	CO_2 density at the pump	kg/m³
$\dot{V}_g$	Kiln gas at the pump	m³/s
$\dot{V}_p$	CO_2 pump displacement	m³/s

Method and standards

Hugot's kiln and pump calculation with exact molar masses.

Assumptions and limits

- Complete calcination and combustion (coke burnt fully to CO_2).
- The CO_2 fraction is on the wet gas at the pump. A dry-basis analyser reading must be reduced by (1 − p_w/p_g) first; using it directly understates the pump volume (about 25 % at 60 °C and 68 cmHg).
- The limestone margin also scales the coke and the CO_2 produced: the CO_2 from surplus limestone is counted as available gas.

References

- Hugot
- Handbook of Cane Sugar Engineering
- 3rd ed. (Elsevier, 1986)
- ch. 27
- lime kiln and CO_2 pump
- pp. 419–425 (eqns 27.1–27.3 and example)
- Stoichiometry $CaCO_3 \rightarrow CaO + CO_2$
- $C + O_2 \rightarrow CO_2$; ideal-gas CO_2 density

Report details

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Release checks	2 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/sugar-ethanol/clarification/carbonatation-co2-gas

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.