Rotary Regenerative Air Heater (Ljungström) Effectiveness

Matrix capacity rate, NTU and effectiveness of a rotary regenerator such as a boiler Ljungström air heater (Kays–London, Razelos), with duty and outlet temperatures.

Input parameters

Unit system: SI

Parameter	Value	Unit
Rotor speed	1.5000	rpm
Gas-side sector angle	180.00	°
Air-side sector angle	140.00	°
Rotor diameter	10.000	m
Shaft (hub) diameter	1.2000	m
Matrix height (depth)	1.8000	m
Matrix material density	7,850.0	kg/m³
Matrix specific heat	0.48000	kJ/(kg·K)
Packing density (area per matrix volume)	0.35000	m²/L
Matrix porosity	80.000	%
Share of the rotor face covered by seals	8.0000	%
Gas-side heat transfer coefficient	45.000	W/(m²·K)
Air-side heat transfer coefficient	40.000	W/(m²·K)
Flue gas flow	576,000	kg/h
Flue gas specific heat	1.1000	kJ/(kg·K)
Air flow	540,000	kg/h
Air specific heat	1.0100	kJ/(kg·K)
Gas inlet temperature	360.00	°C
Air inlet temperature	30.000	°C

Calculated results

Parameter	Value	Unit
Capacity rate ratio C_min/C_max	0.86080	
Conductance ratio (C_min side / C_max side)	0.69136	
Matrix mass	218,757	kg
Matrix capacity ratio C_r/C_min	17.327	
Total matrix surface	44,866	m²
Modified number of transfer units	3.0641	
Counterflow recuperator effectiveness	79.259	%
Regenerator effectiveness (Kays–London)	79.223	%
Regenerator effectiveness (Razelos)	79.218	%
Heat recovered	39,608	kW
Gas outlet temperature	134.96	°C
Air outlet temperature	291.44	°C

Notes for this case

• Valid for (hA)* between 0.25 and 4 and ε up to about 0.9 (Lambertson; Kays and London). Leakage past the seals, which in boiler air heaters is often 5–15 % of the air, is not included.

Formula and method

$$C_r = M_w c_w N, \quad NTU_o = \frac{1}{C_{min}}\left[\frac{1}{(hA)_h} + \frac{1}{(hA)_c}\right]^{-1}, \quad \varepsilon_{cf} = \frac{1 - e^{-NTU_o(1-C^*)}}{1 - C^* e^{-NTU_o(1-C^*)}}$$

$$\varepsilon = \varepsilon_{cf}\left[1 - \frac{1}{9 C_r^{*1.93}}\right], \quad q = \varepsilon C_{min}(T_{h,i} - T_{c,i})$$

Variables

N	Rotor speed	rad/s
θ_h	Gas-side sector angle	rad
θ_c	Air-side sector angle	rad
D	Rotor diameter	m
d_s	Shaft (hub) diameter	m
H	Matrix height (depth)	m
ρ_w	Matrix material density	kg/m³
c_w	Matrix specific heat	J/(kg·K)
β	Packing density (area per matrix volume)	m²/m³
σ	Matrix porosity	-
f_s	Share of the rotor face covered by seals	-
h_h	Gas-side heat transfer coefficient	W/(m²·K)
h_c	Air-side heat transfer coefficient	W/(m²·K)
$\dot{m}_h$	Flue gas flow	kg/s
$c_{p,h}$	Flue gas specific heat	J/(kg·K)
$\dot{m}_c$	Air flow	kg/s
$c_{p,c}$	Air specific heat	J/(kg·K)
$T_{h,i}$	Gas inlet temperature	K
$T_{c,i}$	Air inlet temperature	K
C^*	Capacity rate ratio C_min/C_max	-
$(hA)^*$	Conductance ratio (C_min side / C_max side)	-
M_w	Matrix mass	kg
C_r^*	Matrix capacity ratio C_r/C_min	-
A	Total matrix surface	m²
NTU_o	Modified number of transfer units	-
ε_{cf}	Counterflow recuperator effectiveness	-
ε	Regenerator effectiveness (Kays–London)	-
ε_R	Regenerator effectiveness (Razelos)	-
q	Heat recovered	W
$T_{h,o}$	Gas outlet temperature	K
$T_{c,o}$	Air outlet temperature	K

Method and standards

ε-NTU_o method for rotary regenerators.

Assumptions and limits

- Balanced, counterflow regenerator; no leakage or longitudinal conduction.

Report details

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

This calculator online

https://calc.firecad.com/boilers-power-plant/boiler-auxiliaries/rotary-regenerator-effectiveness

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Reopens the calculator with the inputs of this report.