Cooling Tower KaV/L (Merkel Number)

Tower characteristic KaV/L by the Merkel equation with the four-point Chebyshev integration, from hot and cold water temperatures, wet bulb and L/G ratio.

Method: F. Merkel (1925) evaporative cooling theory; four-point Chebyshev integration as used in cooling tower practice; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Hot water temperature	41.000	°C
Cold water temperature	32.000	°C
Inlet air wet-bulb temperature	27.000	°C
Liquid-to-gas ratio (water per kg of dry air)	1.1000	kg/kg
Atmospheric pressure	1.0132	bar

Calculated results

Parameter	Value	Unit
Tower characteristic (Merkel number)	1.1232	
Range	9.0000	K
Approach	5.0000	K
Exit air enthalpy per kg dry air	126.44	kJ/kg

Formula and method

$$\frac{KaV}{L} = \int_{T_{cold}}^{T_{hot}} \frac{c_w \, dT}{h_w - h_a} \approx \frac{c_w \, R}{4} \sum_{i=1}^{4} \frac{1}{h_{w,i} - h_{a,i}}$$

$$T_i = T_{cold} + \{0.1, 0.4, 0.6, 0.9\} \, R \qquad h_{a,i} = h_{a,1} + \frac{L}{G} \, c_w \, (T_i - T_{cold}) \qquad h_{a,2} = h_{a,1} + \frac{L}{G} \, c_w \, R$$

$$h_{sat}(t) = c_{p,da} \, t + W_s \, (h_{g0} + c_{p,v} \, t) \qquad W_s = \frac{M_w}{M_{da}} \frac{p_s}{p - p_s}$$

Variables

T_{hot}	hot water temperature	K
T_{cold}	cold water temperature	K
T_{wb}	inlet air wet-bulb temperature	K
L/G	liquid-to-gas ratio	kg/kg
p	atmospheric pressure	Pa
KaV/L	tower characteristic (Merkel number)	–
R	range	K
A	approach, $T_{cold} - T_{wb}$	K
$h_{a,2}$	exit air enthalpy	J/kg
$h_{a,1}$	inlet air enthalpy, saturated at T_{wb}	J/kg
$h_w\$, \$h_{sat}$	saturated air enthalpy at water temperature	J/kg
h_a	air enthalpy along the tower	J/kg
c_w	specific heat of water (IF97, mean temperature)	J/(kg·K)

t	temperature in °C	°C
W_s	saturation humidity ratio	kg/kg
p_s	saturation pressure of water (IF97)	Pa
$c_{p,da}$$, $$c_{p,v}$$, $$h_{g0}$	1006 J/(kg·K), 1860 J/(kg·K), 2 501 000 J/kg (ASHRAE)	–
$M_w$$, $$M_{da}$	molar masses of water and dry air	kg/kmol

Method and standards

Merkel's equation with the usual simplifications (Lewis factor 1, evaporation loss neglected), integrated by the four-point Chebyshev rule used in cooling tower practice. Inlet air enthalpy is taken as saturated air at the wet bulb. Moist-air enthalpy by the ASHRAE ideal-gas expression; saturation pressure and water specific heat by FireCAD's IAPWS-IF97.

Assumptions and limits

- Counterflow; Lewis factor 1; no evaporation loss in the water balance; air leaves unsaturated or just saturated.
- The driving force is checked only at the four Chebyshev points; the air line could touch the saturation curve between them, and the four-point rule is less accurate at a small approach (below about 3 K).
- G in L/G is the dry-air mass flow, matching the enthalpy per kg of dry air.
- Wet bulb from 0.01 °C (the triple point) upwards: the saturation pressure is that over liquid water, so sub-zero wet bulbs are not accepted.

References

• F. Merkel (1925) evaporative cooling theory
• four-point Chebyshev integration as used in cooling tower practice
• ASHRAE Handbook—Fundamentals (2017) ch. 1 moist-air enthalpy
• IAPWS R7-97(2012) IF97

Report details

Report reference	FCC-8DE1-WSDD (the same inputs always give the same reference)
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Release checks	3 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/boilers-power-plant/condensers-cooling/cooling-tower-merkel

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Reopens the calculator with the inputs of this report.