Critical Radius of Insulation

Critical radius of insulation on a pipe or wire (k/h), and whether a chosen insulation thickness raises or lowers the heat loss compared with the bare pipe.

Method: r_c = k/h (cylinder)

Input parameters

Unit system: SI

Parameter	Value	Unit
Insulation thermal conductivity	0.20000	W/(m·K)
Outside surface heat transfer coefficient	10.000	W/(m²·K)
Pipe or wire outer diameter	10.000	mm
Insulation thickness	5.0000	mm
Pipe surface temperature	80.000	°C
Ambient temperature	25.000	°C

Calculated results

Parameter	Value	Unit
Critical radius	20.000	mm
Critical outer diameter	40.000	mm
Heat loss per metre, bare	17.279	W/m
Heat loss per metre, insulated	25.663	W/m
Insulated loss as a share of bare	148.53	%

Notes for this case

- The same outside coefficient h is used bare and insulated; in practice h changes a little with diameter and surface temperature.
- The pipe is smaller than the critical radius: thin insulation increases the heat loss until the outer radius passes well beyond r_c.

Formula and method

$$r_c = \frac{k}{h}$$

$$q'_0 = 2\pi r_1 h (T_s - T_a)$$

$$q' = \frac{T_s - T_a}{\frac{\ln(r_2/r_1)}{2\pi k} + \frac{1}{2\pi r_2 h}}$$

Variables

k	insulation conductivity	W/(m·K)
h	outside surface coefficient	W/(m²·K)
D	pipe or wire outer diameter	m
t	insulation thickness	m
T_s	pipe surface temperature	K
T_a	ambient temperature	K
r_1	pipe radius	m
r_2	outer radius of insulation	m
r_c	critical radius	m
D_c	critical diameter	m

q'_0	heat loss per metre, bare	W/m
q'	heat loss per metre, insulated	W/m
q'/q'_0	insulated loss over bare loss	-

Method and standards

Heat loss through a cylindrical insulation layer is a balance of conduction resistance, which grows with thickness, and surface resistance, which shrinks as the outer area grows. The loss is greatest at the critical radius k/h.

Assumptions and limits

- Same h on bare and insulated surfaces; steady state.

References

- r_c = k/h (cylinder)

Report details

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Software release	FireCAD Calc, release of 17 November 2026
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/mechanical/heat-transfer/critical-insulation-radius

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.