Time for Water in an Insulated Pipe to Freeze

Time for still water in an insulated pipe exposed to sub-zero air to cool to 0 °C and then to freeze a chosen fraction, from pipe size, insulation and wind.

Method: Lumped cooling and freezing of water in a pipe

Input parameters

Unit system: SI

Parameter	Value	Unit
Pipe inside diameter	50.000	mm
Pipe outside diameter	60.000	mm
Insulation thickness	25.000	mm
Insulation conductivity	0.035000	W/(m·K)
Outside heat transfer coefficient	15.000	W/(m²·K)
Initial water temperature	10.000	°C
Air temperature	-15.000	°C
Fraction of water frozen	25.000	%

Calculated results

Parameter	Value	Unit
Thermal resistance per metre	2.9492	
Time to cool to 0 °C	3.4550	h
Time to freeze the fraction	8.9418	h
Total time	12.397	h

Notes for this case

• Lumped water cooling through insulation and outside film (pipe wall and inside film neglected); freezing at 0 °C with latent heat 333.55 kJ/kg. Flowing water, heat tracing or draining prevent freezing; a pipe blocks long before it is fully frozen.

Formula and method

$$R' = \frac{\ln(r_2/r_1)}{2\pi\lambda} + \frac{1}{2\pi r_2 h_o}, \quad t_c = m' c_p R' \ln\frac{T_0 - T_a}{0 - T_a}, \quad t_f = \frac{f m' L_f R'}{0 - T_a}$$

Variables

D_i	Pipe inside diameter	m
D_o	Pipe outside diameter	m
t_{ins}	Insulation thickness	m
λ	Insulation conductivity	W/(m·K)
h_o	Outside heat transfer coefficient	W/(m²·K)
T_0	Initial water temperature	K
T_a	Air temperature	K
f	Fraction of water frozen	-
R'	Thermal resistance per metre	-
t_c	Time to cool to 0 °C	s
t_f	Time to freeze the fraction	s
t	Total time	s

Method and standards

Freeze time.

Assumptions and limits

- Still water; uniform water temperature.

References

Lumped cooling and freezing of water in a pipe

Report details

Report reference	FCC-3W7G-341A (the same inputs always give the same reference)
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Software release	FireCAD Calc, release of 22 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/hvac/chillers/pipe-freezing-time

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.