Induction Heating Reference Depth and Frequency

Electrical reference (penetration) depth of induction heating from resistivity, relative permeability and frequency, and the frequency that gives a chosen depth.

Method: Reference depth δ = √(ρ/(πfμ₀μ_r)) (Rudnev et al., Handbook of Induction Heating, ch. 3)

Input parameters

Unit system: SI

Parameter	Value	Unit
Resistivity of the hot workpiece	1.2000	Ω·mm²/m
Relative permeability	1.0000	
Frequency	10.000	kHz
Desired reference depth	2.0000	mm

Calculated results

Parameter	Value	Unit
Reference depth at f	5.5133	mm
Frequency for the desired depth	75.991	kHz
Share of power within δ (1 − e⁻², always 86.5 %)	86.466	%

Notes for this case

• About 86 % of the induced power is released within one reference depth. Steel above the Curie point (about 770 °C) has μ_r = 1 and ρ ≈ 1.2 μΩ·m, so δ grows sharply as the surface heats. For surface hardening a frequency giving δ about 1–1.5 times the case depth is common.

Formula and method

$$\delta = \sqrt{\frac{\rho}{\pi f \mu_0 \mu_r}}, \quad f_t = \frac{\rho}{\pi \mu_0 \mu_r \delta_t^2}, \quad P_\delta = 1 - e^{-2} \approx 86.5\ \%$$

Variables

ρ	Resistivity of the hot workpiece	Ω·m
μ_r	Relative permeability	-
f	Frequency	1/s
δ_t	Desired reference depth	m
δ	Reference depth at f	m
f_t	Frequency for the desired depth	1/s
P_δ	Share of power within δ	-

Method and standards

Electromagnetic penetration depth.

Assumptions and limits

- Flat-surface approximation (radius ⍰ δ). The share of power within δ is the constant 1 − e⁻² for this exponential decay, shown for reference.

References

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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/materials/heat-treatment/induction-hardening-depth

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.