Induction Coil Electrical Efficiency (Cylinder or Slab)

Electrical efficiency of a solenoid induction coil heating a cylinder or slab from coil and workpiece sizes, resistivities, permeability and frequency.

Input parameters

Unit system: SI

Parameter	Value	Unit
Workpiece shape	Solid cylinder in a round coil	
Coil inside diameter (cylinder)	140.00	mm
Workpiece diameter (cylinder)	100.00	mm
Perimeter of the coil opening (slab)	1,200.0	mm
Perimeter of the slab (slab)	900.00	mm
Resistivity of the coil copper (at its temperature)	0.020000	Ω·mm²/m
Resistivity of the workpiece (at its temperature)	1.2000	Ω·mm²/m
Relative permeability of the workpiece	1.0000	
Frequency	1,000.0	Hz

Calculated results

Parameter	Value	Unit
Reference depth in the coil copper	2.2508	mm
Reference depth in the workpiece	17.435	mm
Coil electrical efficiency factor	0.22242	
Coil electrical efficiency	81.805	%
Workpiece size to reference depth (cylinder)	5.7357	

Notes for this case

- Long single-layer solenoid, pronounced skin effect, no other conductive parts nearby. Smaller coil-to-workpiece gaps and magnetic or high-resistivity loads give high efficiency.

Formula and method

$$\eta_{el} = \frac{1}{1 + \frac{D_1'}{D_2'}\sqrt{\frac{\rho_1}{\mu_r \rho_2}}}, \quad D_1' = D_1 + \delta_1, \quad D_2' = D_2 - \delta_2, \quad \delta = \sqrt{\frac{\rho}{\pi f \mu_0 \mu_r}}; \quad \text{slab}: \ \eta_{el} = \frac{1}{1 + \frac{F_1}{F_2}\sqrt{\frac{\rho_1}{\mu_r \rho_2}}}$$

Variables

load	Workpiece shape	-
D_1	Coil inside diameter (cylinder)	m
D_2	Workpiece diameter (cylinder)	m
F_1	Perimeter of the coil opening (slab)	m
F_2	Perimeter of the slab (slab)	m
ρ_1	Resistivity of the coil copper (at its temperature)	Ω·m
ρ_2	Resistivity of the workpiece (at its temperature)	Ω·m
μ_r	Relative permeability of the workpiece	-
f	Frequency	1/s
δ_1	Reference depth in the coil copper	m

δ_2	Reference depth in the workpiece	m
factor	Coil electrical efficiency factor	-
η_{el}	Coil electrical efficiency	-
D_2/δ_2	Workpiece size to reference depth (cylinder)	-

Method and standards

Electrical efficiency of a long solenoid coil.

Assumptions and limits

- Long single-layer coil; pronounced skin effect.

Report details

Report reference	FCC-3B7E-AB9T (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/materials/steelmaking-foundry/induction-coil-electrical-efficiency

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Reopens the calculator with the inputs of this report.