Common Formulas used in Eddy Current Testing

Conductivity (σ) in % IACS

$$\sigma_{\%\,IACS} = \frac{172.41}{\rho}$$

ρ = Resistivity in μΩcm

Material Resistivity (ρ)

$$\rho = \frac{100}{\sigma_{MS/m}}$$

ρ = Resistivity in μΩcm

Magnetic Permeability ($\boldsymbol{\mu}$)

$$\mu = \left(\frac{B}{H}\right)$$

μ = Permeability (H/m)
B = Magnetic Flux Density (Wb)
H = Applied Magnetic Field (A/m)

Fill Factor (η)

$$\eta = \frac{d^2}{D^2}$$

d = smaller diameter
D = larger diameter

Conductivity (σ) in MS/m

$$\sigma_{MS/m} = (\sigma_{\%IACS})(.58)$$

Material Resistivity (ρ)

$$\rho = \frac{172.41}{\sigma_{\%IACS}}$$

ρ = Resistivity in μΩcm

Magnetic Relative Permeability ($\boldsymbol{\mu_r}$)

$$\mu_r = \left(\frac{u}{u_0}\right)$$

μ_r = relative permeability
μ = material's permeability in H/m
μ_0 = permeability of free space in H/m
(Constant of 0.000001257)

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Common Formulas used in Eddy Current Testing

Standard Depth of Penetration (δ) When Resistivity is Known

$$\delta \text{ (inches)} = 1.98\sqrt{\frac{\rho}{f \times \mu_r}}$$

$$\delta \text{ (mm)} = 50.3\sqrt{\frac{\rho}{f \times \mu_r}}$$

ρ = Resistivity in μΩcm

f = Frequency in Hz

μ_r = Relative Permeability

Standard Depth of Penetration (δ) When Conductivity (%IACS) is Known

$$\delta \text{ (inches)} \approx \frac{26}{\sqrt{f\mu_r\sigma}}$$

$$\delta \text{ (mm)} \approx \frac{661}{\sqrt{f\mu_r\sigma}}$$

σ = Conductivity in %IACS

f = Frequency in Hz

μ_r = Relative Permeability

Test Frequency Required to Achieve 1δ at a Specific Depth

$$f = \frac{1.98^2 \times \rho}{\delta^2}$$

f = test frequency in Hz

1.98 = constant to determine the standard frequency in Hz

ρ = the material's resistivity in microhm centimeters (μΩcm)

δ = standard depth of penetration inches

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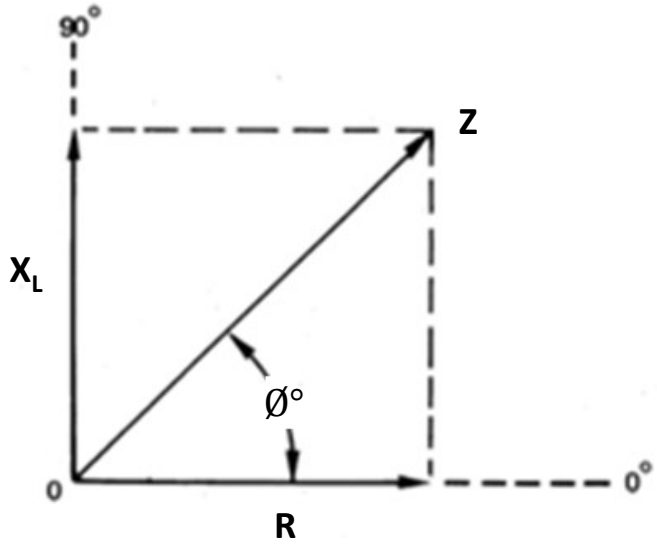
Other Formulas used in ECT

Impedance Phase Angle

$$tan\emptyset = \frac{X_l}{R} \quad or \quad \emptyset = arctan\ \frac{X_l}{R}$$

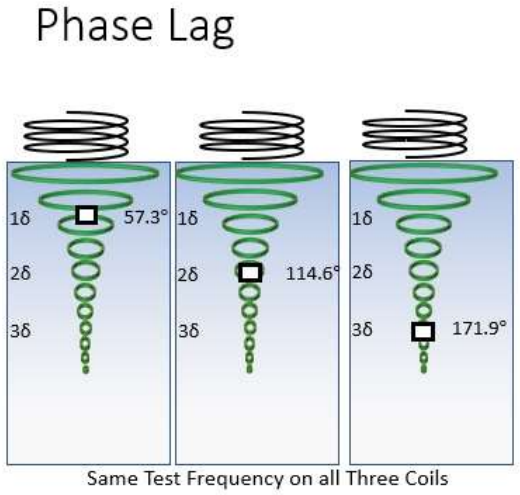
$\emptyset$ = Phase angle in degrees
X_l = Inductive Reactance in ohms (Ω)
R = Resistance in ohms (Ω)



Phase Lag (in material)

$$\theta = \left(\frac{x}{\delta}\right) \cdot 57.3$$

x = Distance below the surface
δ = Standard depth of penetration



Discontinuity Depth	Current Density	Phase Lag in Material	Phase Lag on Display
Surface	100%	0.0°	0.0°
1δ	36.8%	57.3°	114.6°
2δ	13.5%	114.6°	229.2°
3δ	5.0%	171.9	343.8°

Assuming that the material thickness exceeds five skin depths and that a large-diameter coil is used, theory states that the display of a series of fixed-size voids would perform (approximately) as indicated as their depth form the surface varies, as shown in the table above.

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Other Formulas used in ECT

Inductance

$$L = \frac{0.8(rN)^2}{6r+9l+10b}$$

$L =$ coil inductance in microhenries (μH)
$N =$ number of turns in the coil
r = coil radius in inches
l = length of the coil in inches
B = depth or thickness of coil in inches

Impedance

$$Z = \sqrt{X_L{}^2 + R^2}$$

Z = Impedance in ohms (Ω)
X_L = Inductive Reactance in ohms (Ω)
R = Resistance in ohms (Ω)

Inductive Reactance (X_l)

$$X_l = 2\pi f L$$

X_l = Inductive Reactance in ohms (Ω)
π = constant of 3.1416
f = test coil frequency in hertz
L = coil inductance in henries

Coil Merit

$$Q = \left(\frac{X_l}{R}\right)$$

$Q =$ merit of the coil
$X_l =$ the inductive reactance in ohms (Ω)
$R =$ resistance in ohms (Ω)

Current (Ohm's Law)

$$I = \left(\frac{V}{R}\right)$$

$I =$ Electrical Current in amperes (amps)
$V =$ EMF in volts
$R =$ resistance in ohms (Ω)

Inches/mm Conversion

1 Inch = 25.4 mm

1 Inch = 2.54 cm

1/25.4 = .03937

Convert inches to mm: inch X 25.4

Convert mm to inches: mm X . 0.0393701

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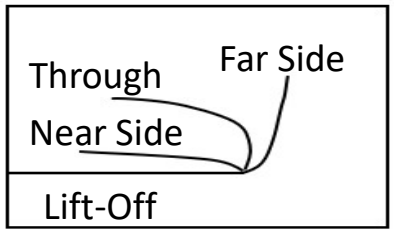
F90 Frequencies for Flaw Detection

F90 Frequency for Surface Testing (kHz)

$$F90_{kHz} = \frac{1.6\rho}{t_{mm}{}^2} \qquad F90_{kHz} = \frac{.0025\rho}{t_{in}{}^2}$$

F90 Frequency for Surface Testing (Hz)

$$F90_{Hz} = \frac{1600\rho}{t_{mm}{}^2} \qquad F90_{Hz} = \frac{2.5\rho}{t_{in}{}^2}$$

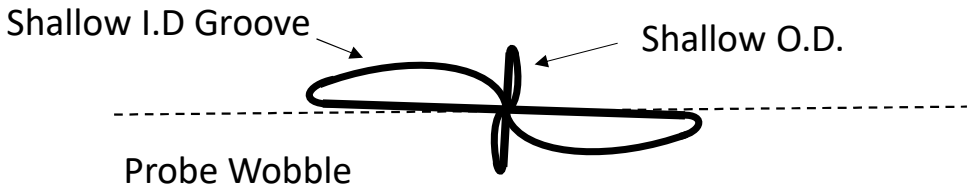


F90 Frequency for Tube Testing (kHz)

$$F90_{kHz} = \frac{3\rho}{t_{mm}{}^2} \qquad F90_{kHz} = \frac{0.00465}{t_{in}{}^2}$$

F90 Frequency for Tube Testing (Hz)

$$F90_{Hz} = \frac{3000\rho}{t_{mm}{}^2} \qquad F90_{Hz} = \frac{4.65\rho}{t_{in}{}^2}$$



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Symbols

Common Greek Letters (Symbols) used in Eddy Current Testing Formulas

β "beta" – Phase Lag (° or rads)

δ "delta" – Standard Depth of Penetration

η "eta" – Fill Factor

θ "theta" – Degrees

μ "mu" – Permeability

ρ "rho" – Resistivity

σ "sigma" – Conductivity

θ "phi" – Magnetic Flux

π "pi" – 3.14159 (Math Constant)

Scientific Notation

Frequently in ECT mathematics, frequency and depth of penetration charts (and various formulas) use scientific notation. For example, $4 \cdot 10^{6}$ is equal to 4,000,000 whereas $4 \cdot 10^{-6}$ is equal to .000004 and so on. The following tables list some examples of scientific notation:

Multiple	Prefix	Symbol	Sub-multiple	Prefix	Symbol
10^{12}	tera	T	10^{-1}	deci	d
10^{9}	giga	G	10^{-2}	centi	c
10^{6}	mega	M	10^{-3}	milli	m
10^{3}	kilo	k	10^{-6}	micro	μ
10^{2}	hecto	h	10^{-9}	nano	n
10^{1}	deca	da	10^{-12}	pico	p