# Transformer Health Prediction - Equations and Limits

## Dissolved Gas Analysis (DGA)

Equation:

• R₁ = C₂H₂ / C₂H₄

• R₂ = CH₄ / H₂

• R₃ = C₂H₄ / C₂H₆  
Limits:

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Normal | Warning | Critical |
| Hydrogen (H₂) (ppm) | < 150 | 150 - 300 | > 300 |
| Methane (CH₄) (ppm) | < 120 | 120 - 400 | > 400 |
| Ethylene (C₂H₄) (ppm) | < 50 | 50 - 200 | > 200 |
| Ethane (C₂H₆) (ppm) | < 65 | 65 - 250 | > 250 |
| Acetylene (C₂H₂) (ppm) | < 1 | 1 - 10 | > 10 |
| Carbon Monoxide (CO) (ppm) | < 500 | 500 - 1000 | > 1000 |
| Carbon Dioxide (CO₂) (ppm) | < 3500 | 3500 - 10,000 | > 10,000 |

## Partial Discharge Measurement

Equation:

• Q = V / Z (pC)

• E = Q × V (mJ)  
Limits:

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Normal | Warning | Critical |
| Partial Discharge Intensity (pC) | < 50 | 50 - 500 | > 500 |
| Pulse Repetition Rate (Hz) | < 10 | 10 - 100 | > 100 |
| Discharge Energy (mJ) | < 0.1 | 0.1 - 1 | > 1 |

## Dissipation Factor (Tan Delta) & Capacitance

Equation:

• tan(δ) = P / Q

• C = Q / V (µF)  
Limits:

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Normal | Warning | Critical |
| Tan Delta (%) | < 0.5% | 0.5 - 1% | > 1% |
| Capacitance Change (%) | < 5% | 5 - 10% | > 10% |

## Insulation Resistance Measurement

Equation:

• IR = V / I (MΩ)  
Limits:

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Normal | Warning | Critical |
| Insulation Resistance (MΩ) | > 1000 | 500 - 1000 | < 500 |
| Moisture in Oil (ppm) | < 20 | 20 - 35 | > 35 |

## Winding Resistance Measurement

Equation:

• R = V / I (Ω)  
Limits:

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Normal | Warning | Critical |
| Winding Resistance Change (%) | < 2% | 2 - 5% | > 5% |

## Dielectric Constant Measurement

Equation:

• εᵣ = C\_measured / C\_vacuum  
Limits:

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Normal | Warning | Critical |
| Dielectric Constant | 2.2 - 2.5 | 2.5 - 3.0 | > 3.0 |
| Moisture in Oil (ppm) | < 20 | 20 - 35 | > 35 |

## Oil & Winding Temperature Monitoring

Equation:

• ΔT = T\_winding - T\_ambient

Limits:

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Normal | Warning | Critical |
| Oil Temperature (°C) | < 65 | 65 - 85 | > 85 |
| Winding Temperature (°C) | < 95 | 95 - 110 | > 110 |

## Frequency Response Analysis

Equation:

• Δf = f\_measured - f\_expected

Limits:

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Normal | Warning | Critical |
| Resonance Frequency Shift (Hz) | < 5 | 5 - 10 | > 10 |
| Magnitude Deviation (dB) | < 2 | 2 - 5 | > 5 |

## Degree of Polymerization (DP) Measurement

Equation:

• DP = M\_cellulose / M\_glucose

Limits:

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Normal | Warning | Critical |
| DP Value | > 800 | 400 - 800 | < 400 |
| Moisture in Paper (%) | < 2% | 2 - 4% | > 4% |

## Moisture or Water Particle Measurement

Equation:

• C\_moisture = Moisture Content (ppm) / Oil Volume (L)

Limits:

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Normal | Warning | Critical |
| Moisture in Oil (ppm) | < 20 | 20 - 35 | > 35 |
| Relative Humidity (%) | < 60% | 60 - 75% | > 75% |