STANDARD OPERATING PROCEDURE

# Delta-T ThetaProbe (ML3) & WET High-Frequency Impedance Probe Calibration

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## 1. Purpose & Scope

This Standard Operating Procedure (SOP) defines field servicing, baseline zeroing, and soil-specific 100 MHz impedance calibration protocols for the Delta-T ThetaProbe (ML3) and WET Sensor array. The probe measures complex apparent dielectric constant ($\varepsilon_r$), volumetric water content (VWC), and pore-water electrical conductivity ($\sigma_p$).

## 2. Technical Principles & Calibration Equations

The ThetaProbe consists of a 100 MHz sinusoidal oscillator, a custom impedance matching network, and four stainless steel rods forming a coaxial standing-wave transmission line. The output analogue voltage ($V_{out}$, 0–1.0 V DC) is proportional to apparent refractive index (&sqrt;$\varepsilon_r$):

$$\&sqrt;\varepsilon_r = 1.0 + 6.1 \blacksquare V_{out} + 0.6 \blacksquare V_{out}^{2}$$

Volumetric water content (VWC, $m^3/m^3$) is derived via the generalized linear refractive model:

$$VWC = (\&sqrt;\varepsilon_r - a_0) / a_1$$

where $a_0 = 1.60$ and $a_1 = 8.40$ for mineral soils, or $a_0 = 1.30$ and $a_1 = 7.70$ for organic soils.

## 3. Step-by-Step Field Calibration Procedure

1. **Visual & Mechanical Inspection:** Inspect four stainless steel sensing rods for bending, pitting, or alignment skew. Ensure rod parallel gap spacing is exactly 15.0 mm.

2. **Air Baseline Test:** Clean sensing rods with isopropyl alcohol and dry thoroughly. Hold probe suspended in open air >30 cm away from metal or body structures. Record output voltage $V_{air}$ (Acceptance limit: **0.000 V ± 0.015 V**, &sqrt;$\varepsilon_r \approx 1.0$).

3. **Deionized Water Baseline Test:** Insert probe fully into a container of deionized water ($\sigma < 2$ µS/cm) at 20.0°C. Record output voltage $V_{water}$ (Acceptance limit: **0.850 V ± 0.025 V**, &sqrt;$\varepsilon_r \approx 8.95$, $\varepsilon_r \approx 80.1$).

4. **Soil Core Insertion & Alignment:** Using the alignment guide tool, press probe rods vertically into undisturbed soil core without twisting or creating air gaps around rods.

5. **Pore-Water EC Correction (WET Sensor):** For WET probes, record bulk conductivity ($\sigma_b$) and dielectric permittivity ($\varepsilon_r$) simultaneously to compute pore-water EC via Hilhorst model: $\sigma_p = (\varepsilon_p \cdot \sigma_b) / (\varepsilon_r - \varepsilon_{\sigma b=0})$.

| PREPARED & VERIFIED BY LEAD FIELD TECHNICIAN | FIELD APPROVAL SIGN-OFF |
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