STANDARD OPERATING PROCEDURE

Flexible Composite Material (FCM) Conformal Dielectric Sensor SOP

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1. Purpose & Scope

This SOP details fabrication inspection, conductive textile track testing, baseline capacitance zeroing, and mechanical strain/moisture calibration protocols for Flexible Composite Material (FCM) dielectric sensors. FCMs utilize elastomer matrices (e.g., PDMS, silicone) filled with conductive nanomaterials or integrated with conductive yarns for wearable, structural-conformal, or curved-surface sensing.

2. Technical Principles & Conformal Permittivity Equations

FCM sensors act as deformable parallel-plate or interdigital capacitors. Under mechanical strain ($\varepsilon = \Delta L/L_0$) or dielectric moisture loading (ε_r), sensor capacitance C varies according to:

$$\mathbf{C = \varepsilon_0 \varepsilon_r \cdot [(W \cdot L) / d] \cdot (1 + \varepsilon) / (1 - \nu\varepsilon)}$$

where W is electrode width, L is length, d is dielectric thickness, and ν is Poisson's ratio of the polymer matrix ($\nu \approx 0.48$ for PDMS). Dielectric gauge factor (GF_ε) and moisture sensitivity S_m are extracted by separating strain-induced geometric change from dielectric permittivity shift.

3. Step-by-Step Calibration Procedure

1. **Visual & Electrical Continuity Check:** Inspect FCM matrix for micro-tears, delamination, or oxidation. Measure conductive thread/track resistance using four-wire Kelvin sensing (Acceptance limit: **<2.5 Ω/cm**).

2. **Unstrained Baseline Zeroing:** Mount FCM on a rigid, non-conductive Teflon calibration jig in a zero-strain (ε=0) state. Connect to LCR meter (10 kHz, 1.0 V_{rms} test signal). Record baseline capacitance C_0 (Acceptance limit: **12.5 pF ± 0.5 pF**).

3. **Tensile Strain Calibration Sweep:** Mount FCM in automated tensile testing stage. Apply tensile strain from ε = 0% to 30% in 5% increments. Record capacitance C(ε), confirm linearity ($R^2 > 0.995$), and calculate strain gauge factor.

4. **Dielectric Moisture / Relative Humidity Response:** Place FCM in environmental chamber with fixed tension. Step relative humidity from 20% to 90% RH at 25°C. Record capacitance response C(RH) and establish polynomial calibration curve.

5. **Bending & Curvature Test:** Wrap FCM around cylindrical mandrels of known radii (R = 50 mm, 25 mm, 10 mm) to verify curvature immunity and shielding rejection.

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