

STANDARD OPERATING PROCEDURE

Cosmic-Ray Neutron Sensor (CRNS) Field Servicing & Calibration SOP

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TITLE:	Cosmic-Ray Neutron Sensor Calibration	REVISION:	1.0
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1. Purpose & Scope

This SOP specifies field installation, detector gas pressure auditing, high-voltage plateau verification, and calibration procedures for Cosmic-Ray Neutron Sensors (CRNS, e.g., Hydroinnova CRS-1000). CRNS provides non-contact, field-scale (200 m radius, 10–70 cm depth) average soil moisture measurements based on epithermal neutron moderation.

2. Technical Principles & Moderation Equations

Fast cosmic-ray neutrons entering the atmosphere are moderated (slowed down) primarily by hydrogen atoms in soil water. The moderated epithermal neutron intensity (N, counts/hour) detected by moderated Helium-3 or Boron Trifluoride (BF₃) proportional counter tubes is inversely proportional to soil gravimetric water content (ω, kg/kg):

$$\omega = [a_0 / ((N / (N_0 \cdot f_p \cdot f_{vv} \cdot f_i)) - a_1)] - a_2 - \omega_{lat} - \omega_{SOC}$$

where $a_0 = 0.0808$, $a_1 = 0.372$, $a_2 = 0.115$; N_0 is the site-specific dry-soil neutron count rate; f_p is atmospheric pressure correction factor; f_{vv} is water vapor factor; f_i is incoming cosmic-ray intensity factor from a neutron monitor; ω_{lat} is lattice water; and ω_{SOC} is soil organic carbon.

3. Step-by-Step Calibration Procedure

1. **Proportional Counter Tube Inspection:** Inspect high-voltage cables, BNC connectors, and NEMA-4X weatherproof enclosure seals. Verify internal desiccant color is blue.
2. **High-Voltage (HV) Plateau Sweep:** Connect pulse counter and sweep HV bias from 1100 V to 1500 V DC in 25 V increments. Identify plateau region where count rate variation is <1%/100V. Set operating bias to center of plateau (typically 1350 V DC).
3. **Pulse Height Discriminator Calibration:** Set lower-level threshold (LLD) above electronic noise floor (~100 mV) to isolate true α-particle ionizations from γ-ray background.
4. **Barometric Pressure Sensor Calibration:** Verify internal barometric pressure sensor against certified NIST microbarometer (±0.5 hPa accuracy). Calculate $f_p = \exp(\beta \cdot (P - P_{ref}))$ where $\beta \approx 0.0076 / \text{hPa}$.
5. **Soil Core Calibration Sampling:** Collect 18 soil cores across 6 radial directions (at 25 m, 75 m, 150 m distances) and 3 depth intervals (0–10, 10–25, 25–50 cm). Oven-dry at 105°C for 24 hours to determine reference gravimetric moisture and derive N_0 .

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