A "Not-So-Standard" Look at the "Standard" Penetration Test (SPT)

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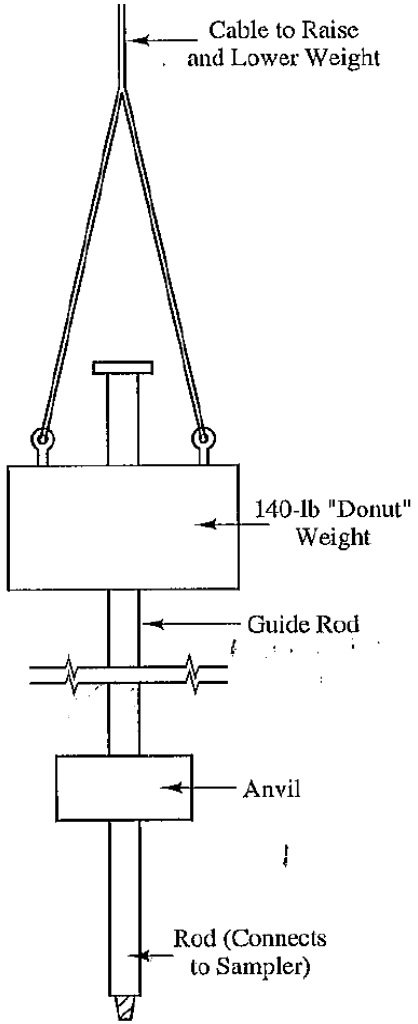
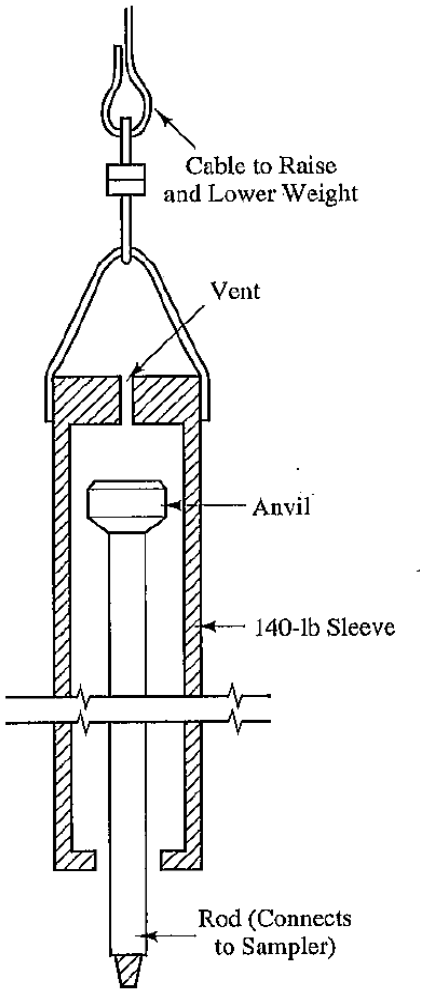
Project Background

- SPT Hammer Energy Measurements
- Why is this important?
  - Identify rig and hammer issues
  - Determine variables that affect SPT energy
  - Correlate to N_{60} (manual hammer blow count)
  - Determine soil design parameters
  - Evaluate soil liquefaction potential

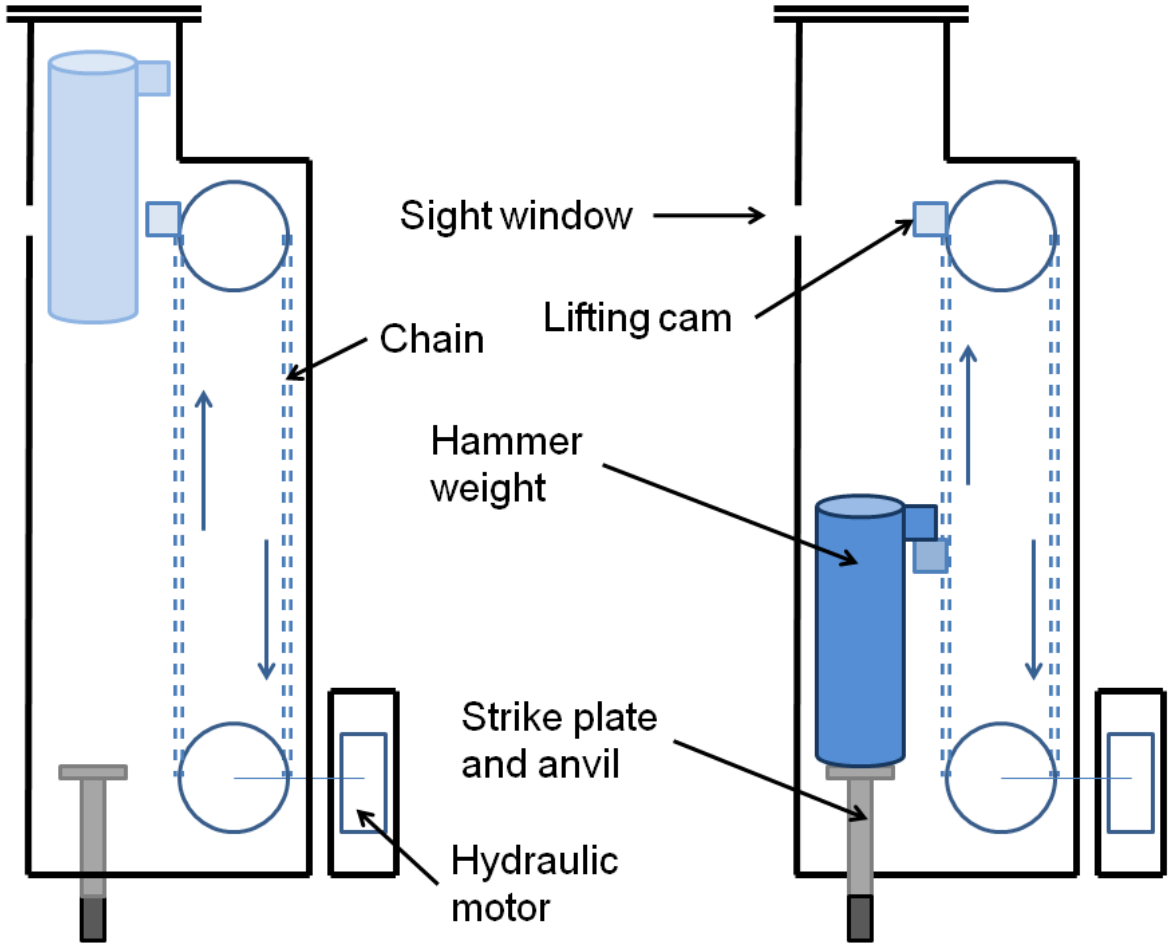
SPT Manual/Safety Hammer

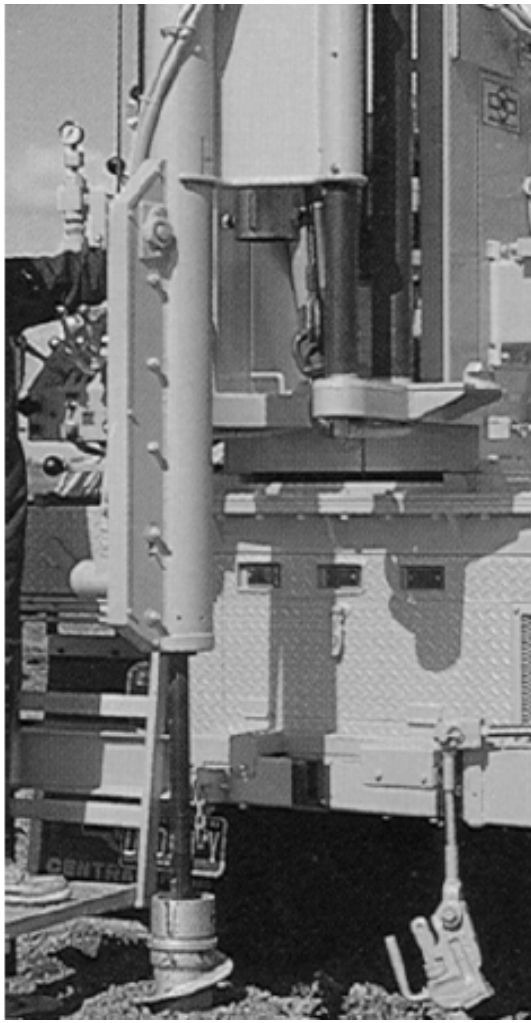




Donut Hammer **Safety Hammer**

SPT Automatic Hammers





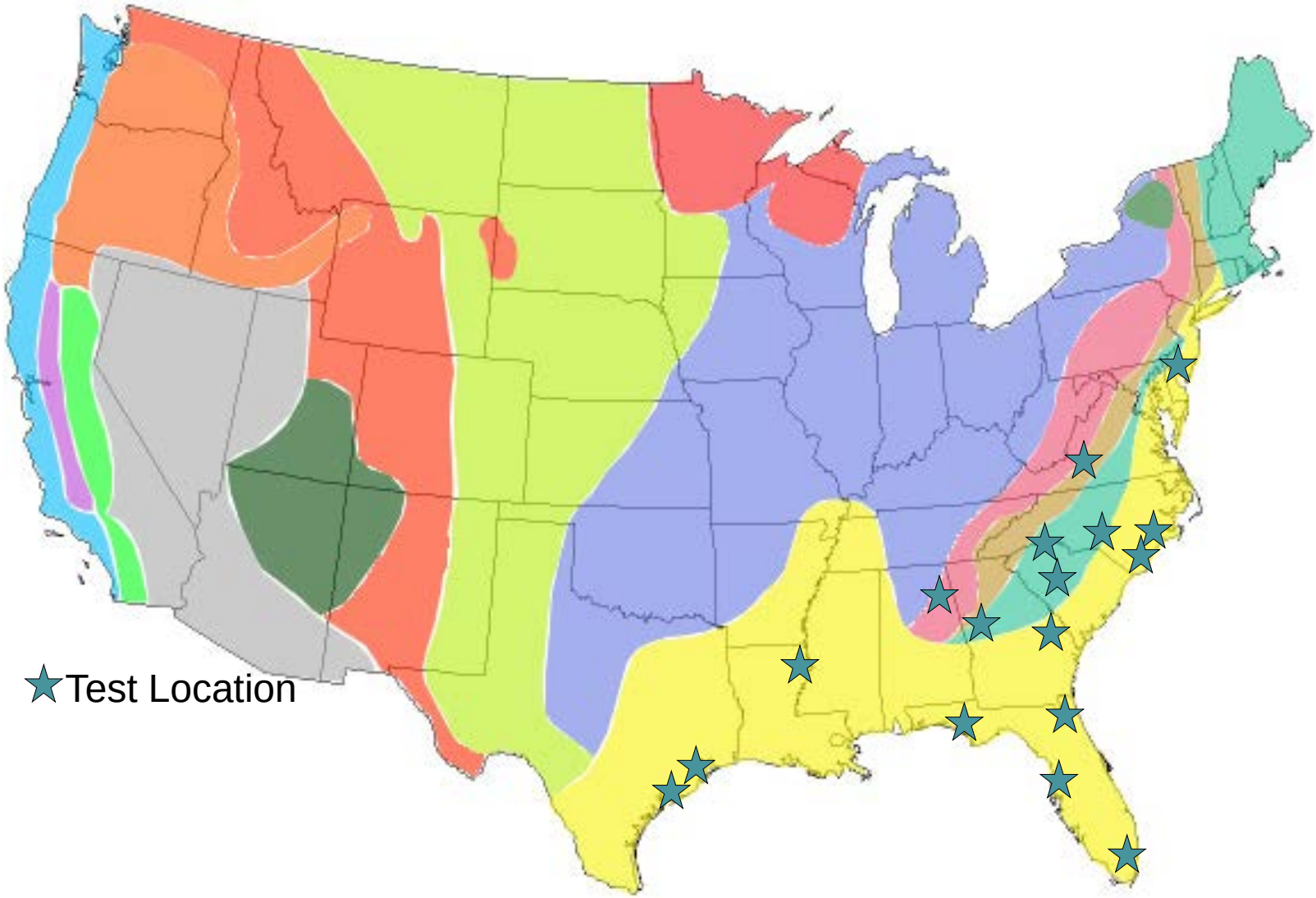
Project Background

- SPT energy measurements on projects from 2005 to-date
- Mandate for nuclear safety related projects; strict adherence to QA procedures
- Requiring energy measurements for drill rigs with **Automatic** Hammers
- Adopting ASTM D4633-05 and -10, replacing the 1986 version

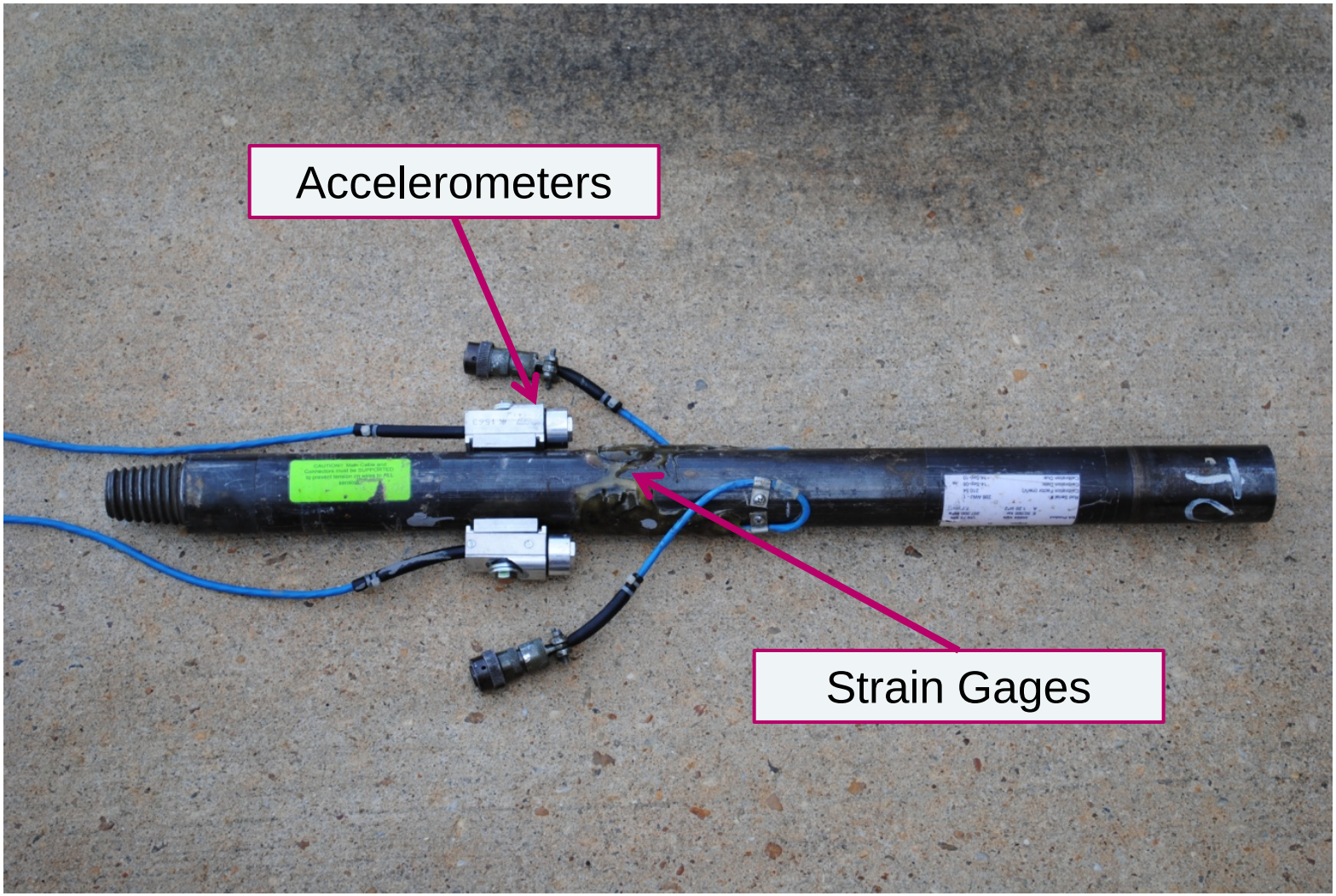
Project Background

- Access Database from:
  - Testing 54 drill rigs, SPT sampling at different depths
  - Sites in 8 states in the US
  - 17 individual project sites
  - Five physiographic regions:
    - Piedmont
    - Atlantic Coastal Plain
    - Gulf Coastal Plain
    - Blue Ridge
    - Appalachian

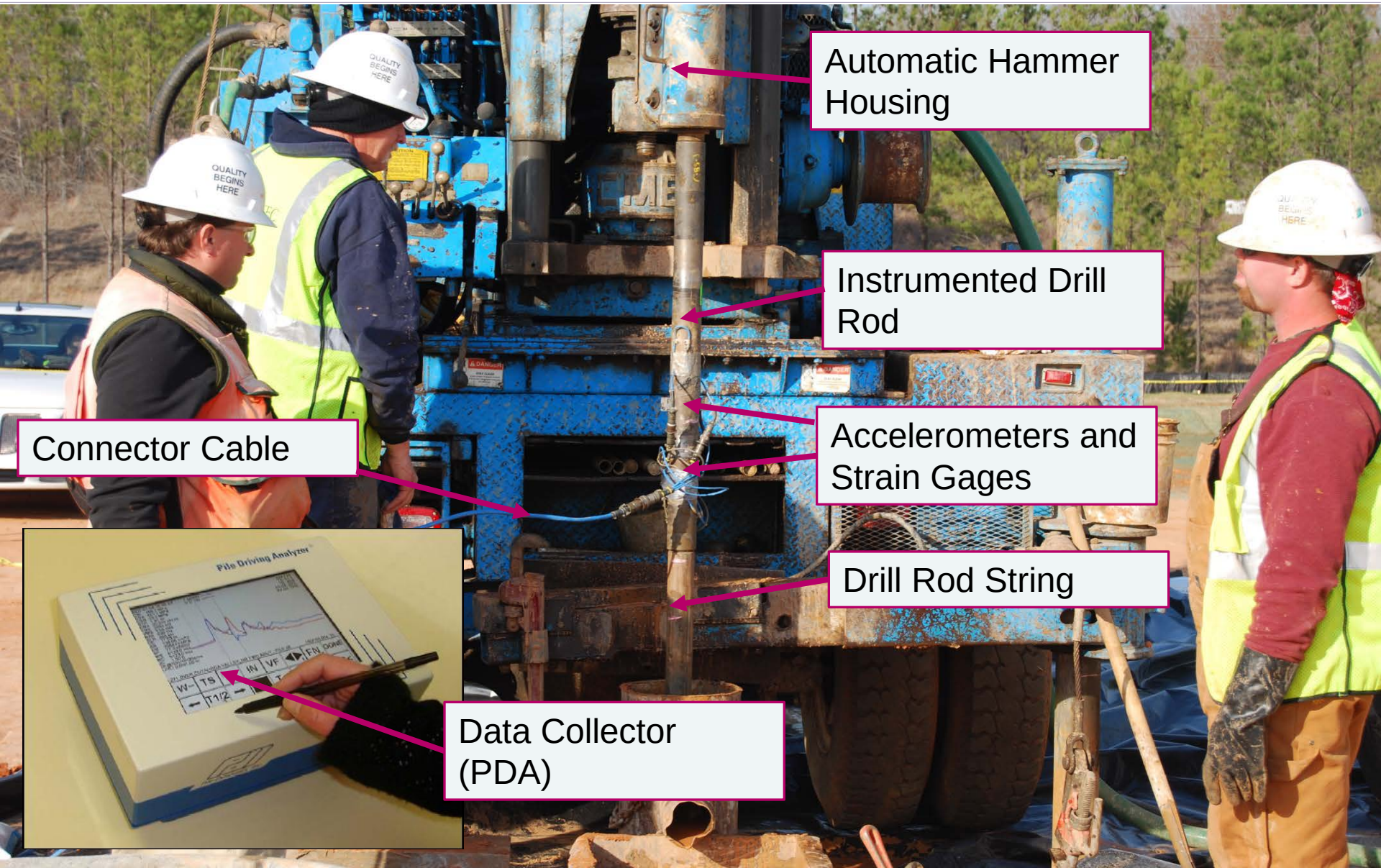
Testing Locations



Energy Testing Setup



Energy Testing Setup



Project Details

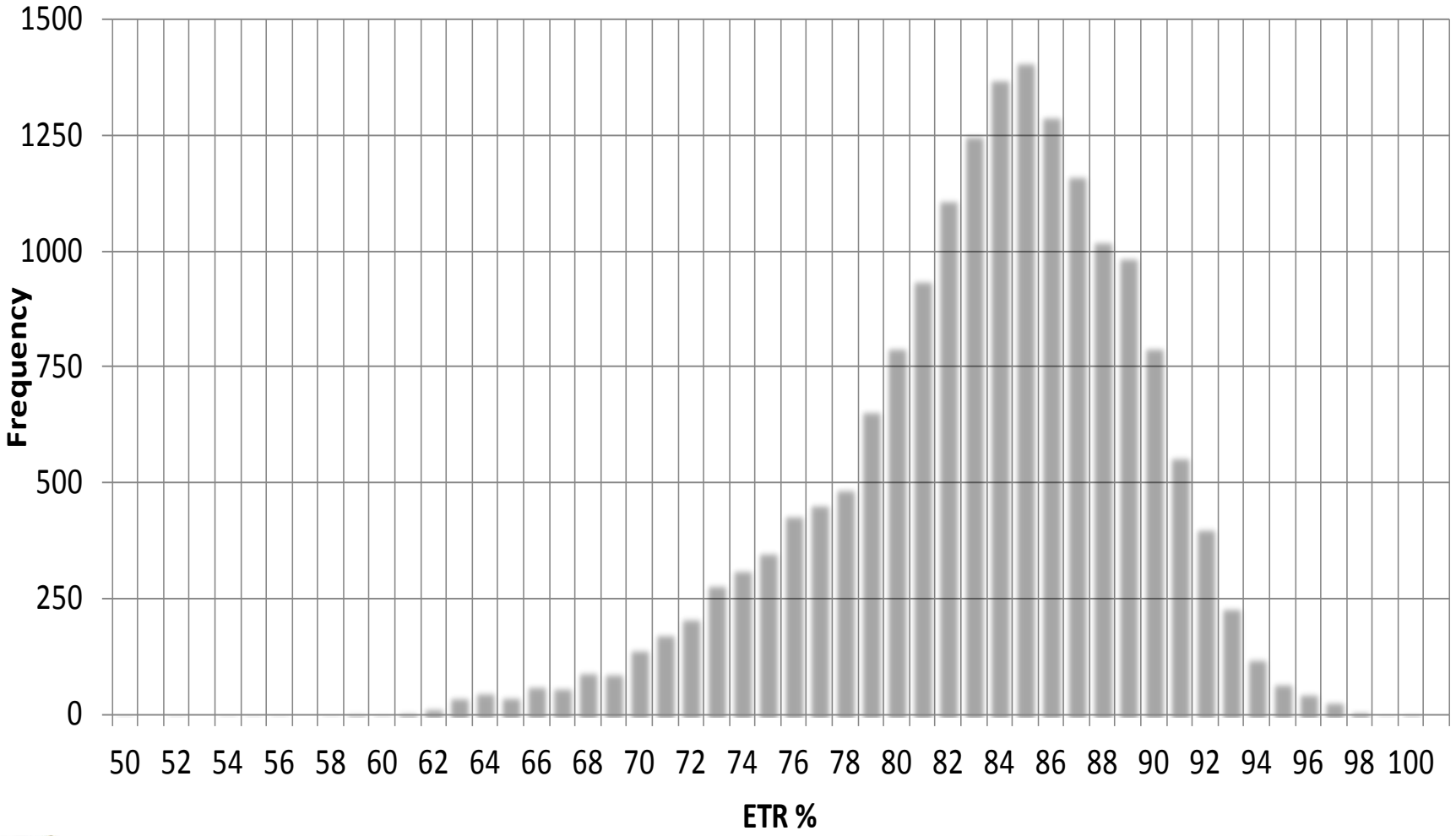
- Testing utilizing *Pile Driving Analyzer*® or *SPT Analyzer*® in over 20,000 hammer impact blows
- 530^{+} split-spoon samples in 122^{+} testing events (Mostly CME rigs; mix of ATV, track, and truck rigs)
- Sample depths: 10 to 510 feet below grade (mostly 30 to 150 feet)
- SPT N-values: 3 to 100^{+} blows per foot

Project Details

Theoretical Energy Delivered (140-lb automatic hammer traveling 2.5 feet [30 in.]) = 350 ft-lbs

- Min. measured = 221 ft-lbs (63% of Theoretical Energy Delivered)
- Max. measured = 359 ft-lbs (103%) including when hammer was not functioning properly
- Max. value of 342 ft-lbs (97%) when working properly
- 90% of measurements between 246 and 312 ft-lbs (71% and 89%)

Energy Measurement Results



Energy Measurement Results – Overall

- **Measured Auto Hammer Energy Transfer**
- **Mean Value = 290 ft-lbs (82.7%)**
  - Within One Std. Deviation
    - 261 to 307 ft-lbs. (74.5% to 87.7%)
  - Within Two Std. Deviations
    - 238 to 330 ft-lbs. (68.0% to 94.3%)

Energy Measurement Results – Rod Size

- Total of 10,328 blows for AW-J rods for 280 samples collected
- Total of 9,870 blows for N-sized rods (NW-J and N3) for 250 samples collected

ENERGY TRANSFER (AW-J RODS)

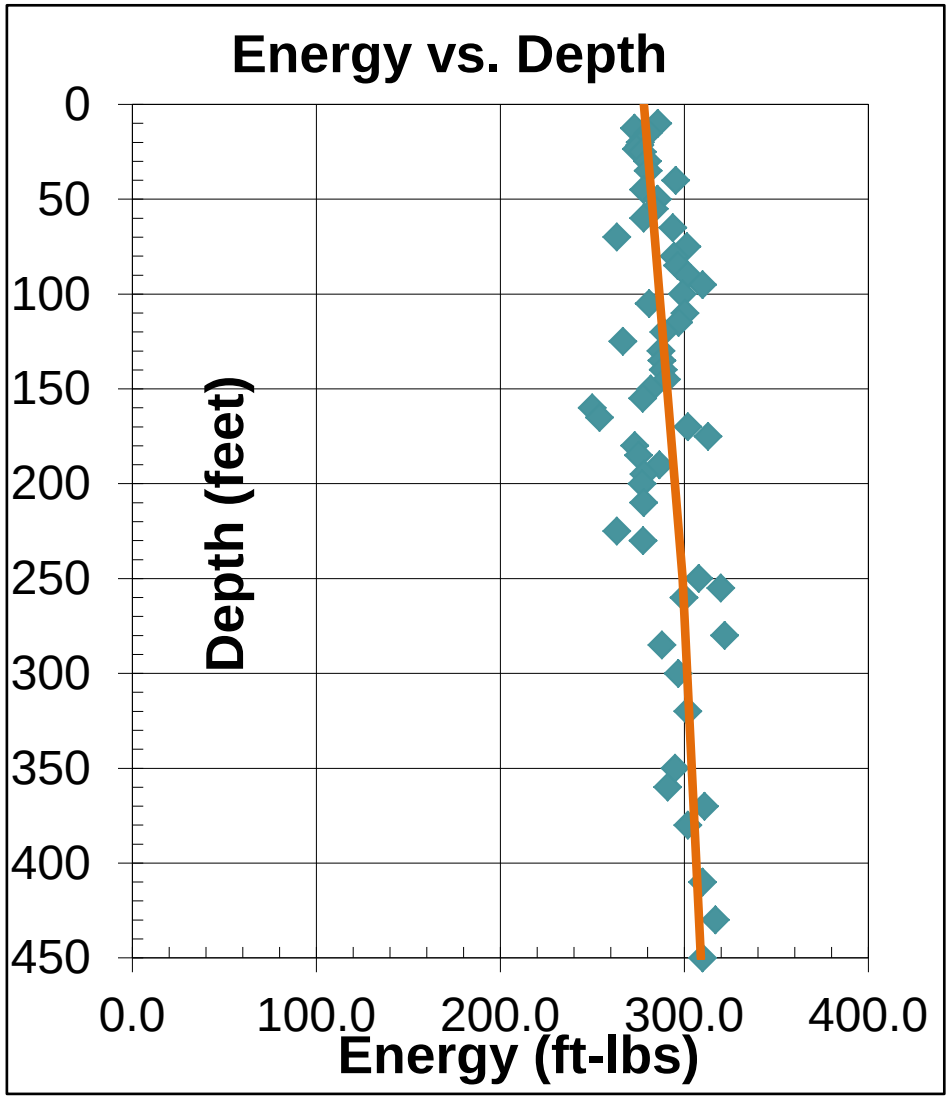
Mean Value = 290 ft-lbs. (82.8%)

ENERGY TRANSFER (N- RODS)

Mean Value = 288.4 ft-lbs. (82.4%)

Energy Measurement Results – Sample Depth

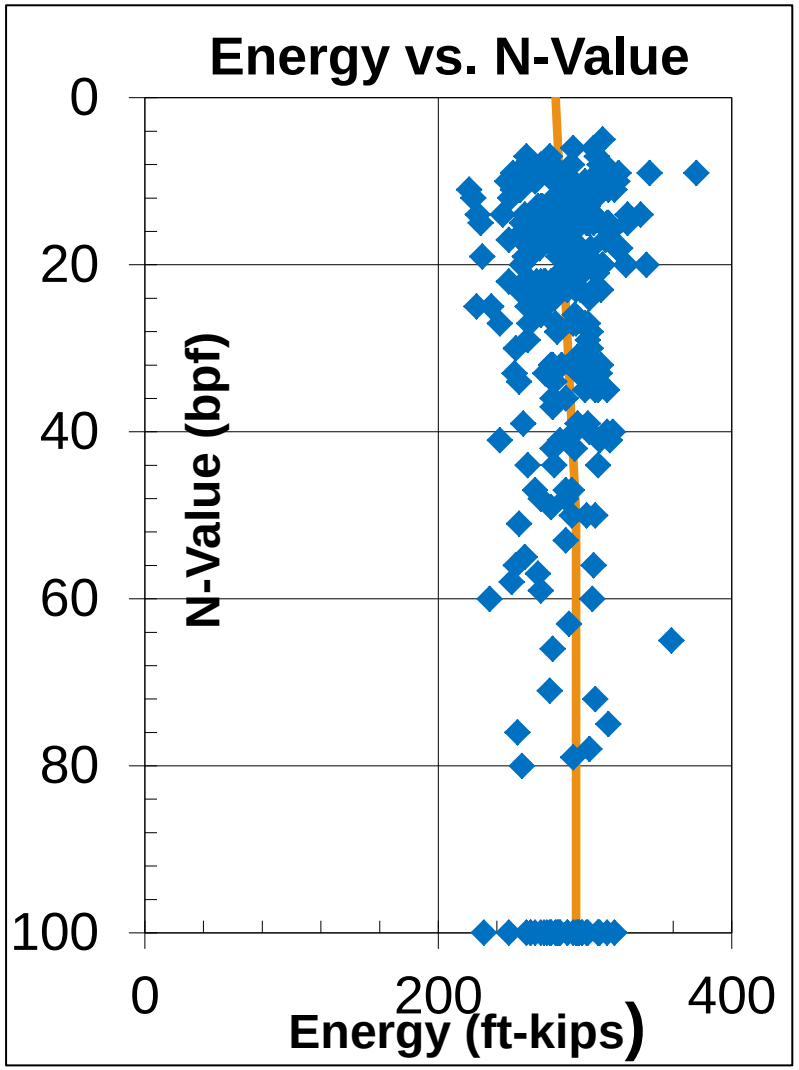
- Delivered energy increasing with depths (less increase after about 250 feet)
- Consistent with previous studies (Limited data at depths > 250 feet available in literature)



Energy Measurement Results – N-Value

- Field measured blow count versus recorded energy (no correction for depth or rod sizes)

Average energy delivered changes insignificantly for materials w/ different N-values.



Energy Measurement Results – Same Rig Variations

- Eight rigs tested multiple times over 5 years
- Three rigs tested at least 5 times over a three year period
- One rig tested seven times in 5 years.
- Rigs carefully maintained/serviced during the testing period

Same Rig Variations to the 1st time measurement:

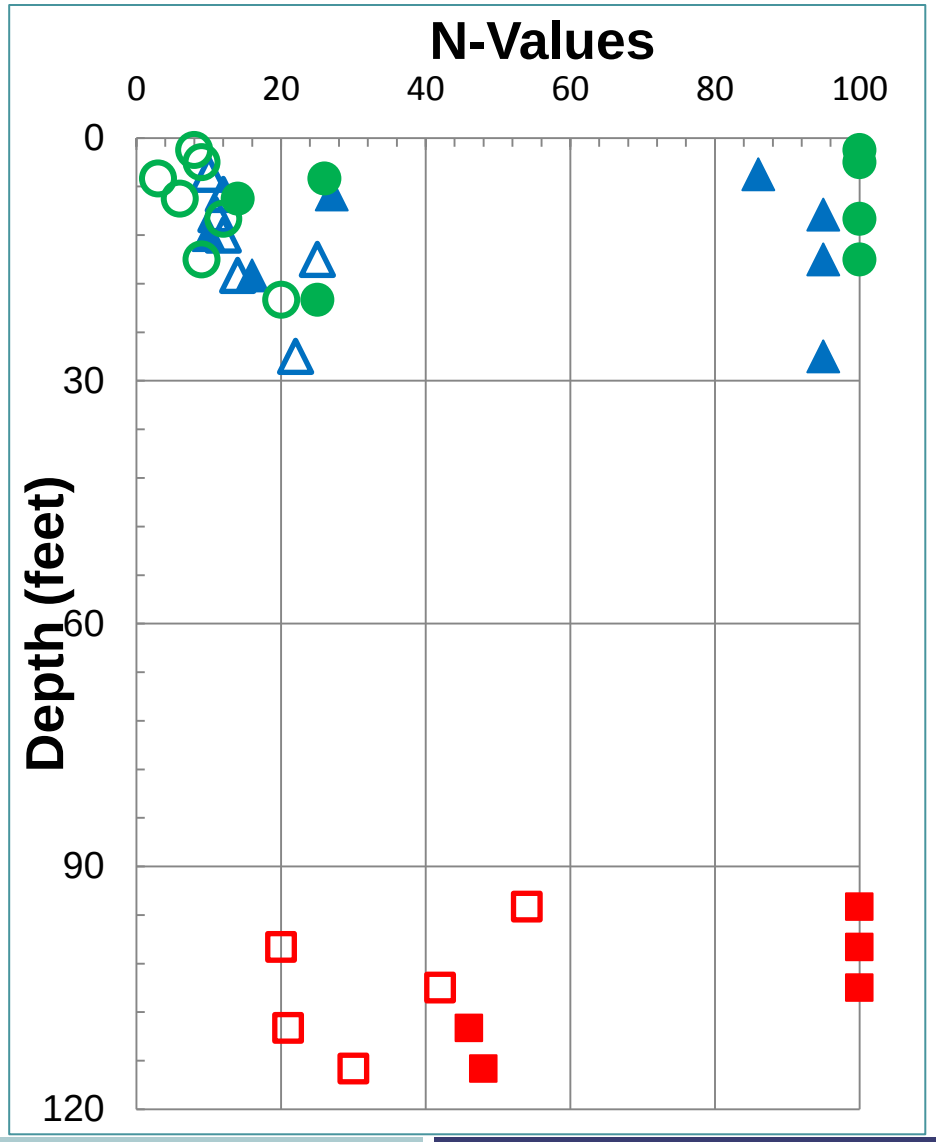
- -11% (loss in energy) to +13% (gain in energy)
- Average Change = 5% over 15-month period
- 20 of 23 re-tests w/ changes less than 10%

Energy Measurement – Identification of Hammer Issues

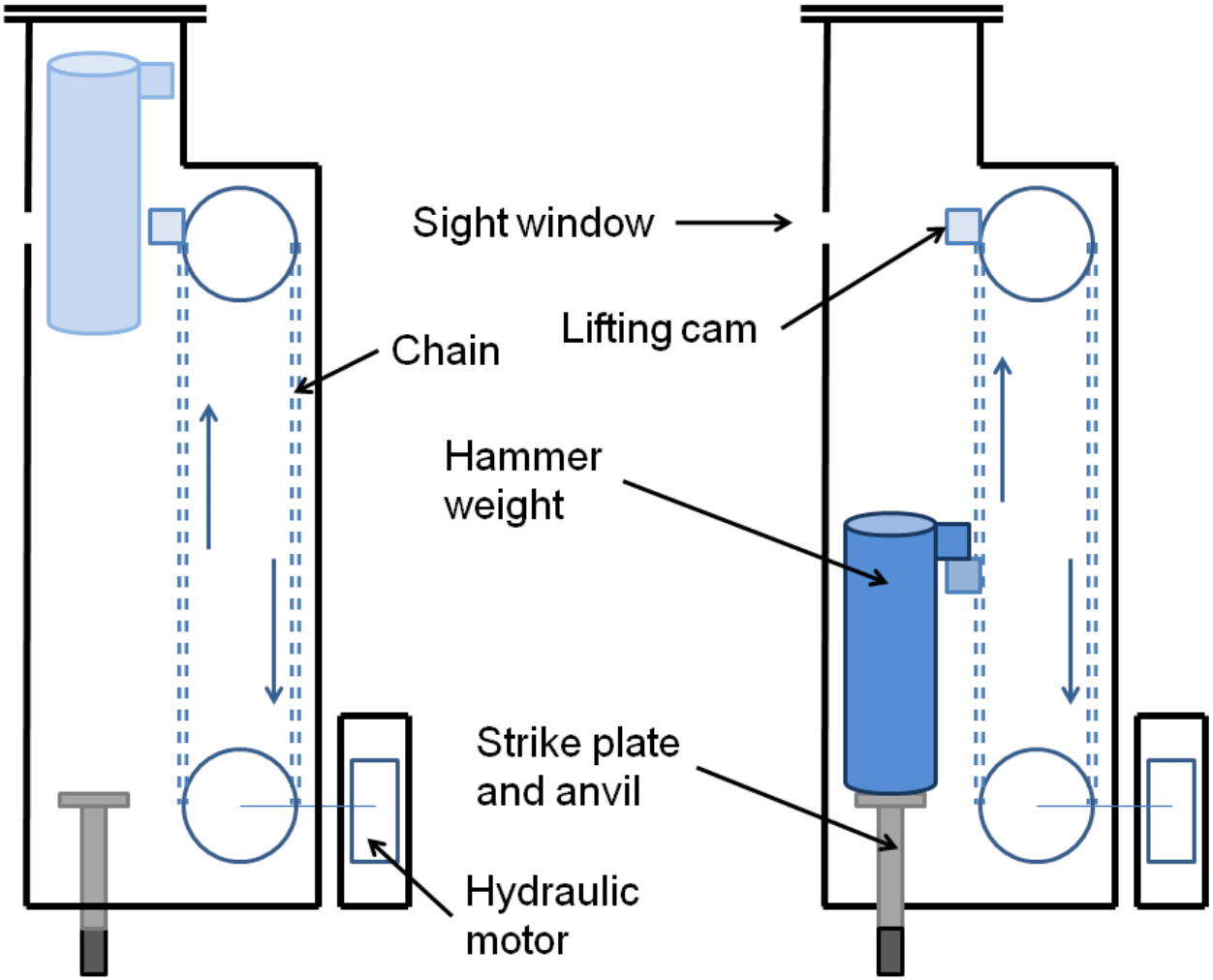
- Drilling Observations
  - Hammer “sound” or sight window concerns
  - Blow count rate (blows per minute)
- Use of SPT Energy Measurement Equipment
  - Very erratic/variable energy measurements
  - Energy measurement equipment not recording data
  - Very low energy values

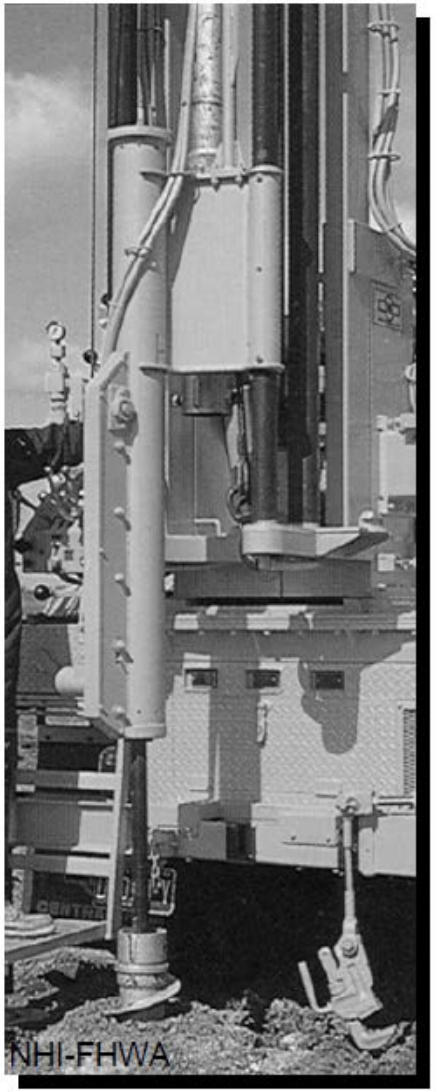
Energy Measurement – Identification of Hammer Issues

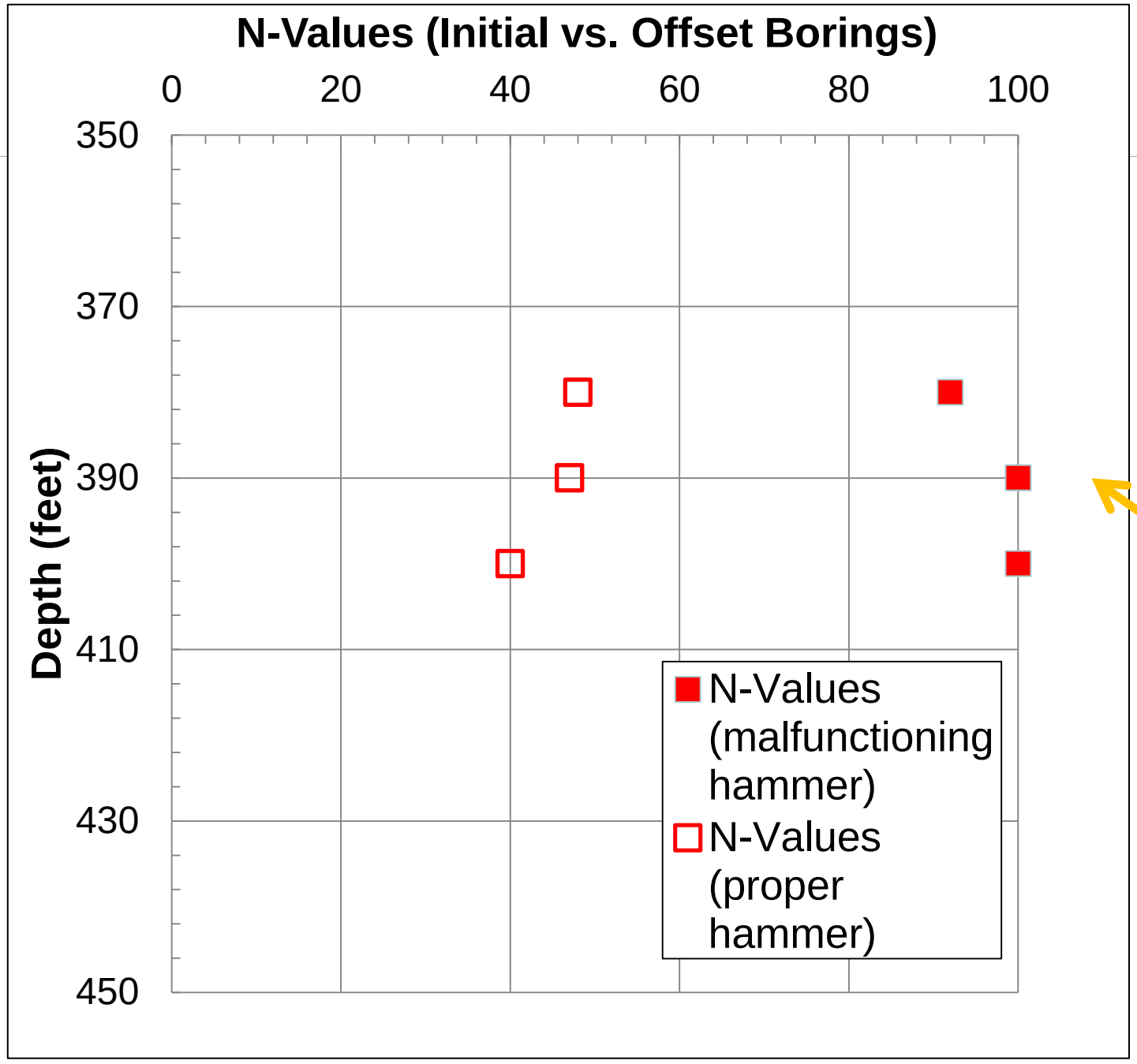
- Two offset borings drilled
- Initially, low energy measurements recorded (25-45%) *solid colored data*
- Offset boring had “typical” energy
- Lifting cam was lifting hammer weight prior to full impact
- Leads to high (incorrect) N-values – unconservative!



SPT Automatic Hammers







Note high N-values!

Energy of 42%

Conclusions

- **No significant effect on energy transfer**:
  - Rod size (AW-J vs. N-sized rods)
  - Time of testing (same rig, properly maintained over a 2 to 4 year period)
- **Energy transfer affected by:**
  - Depths (slight energy increases with depths)
  - Rig / engine operations (RPMs, blow rate)
- Reasonable average energy transfer estimate = 82%
- However, suggest that …

PERFORM ENERGY TESTING OFTEN!

Questions?