# The Numbers Make a Difference: Correcting SPT Data

By Jim Belgeri, P.E., P.G.

When S&ME, Inc., a southeastern engineering and environmental services firm and NDA member, made the commitment to calibrate each of its hammer-operator systems annually and to have individual energy transfer rates (ETR) available for each hammer-operator system, there was some question if the benefit was worth the effort and cost. However, during the past six years that this practice has been in place, it has paid for itself many times over by avoiding the use of faulty data in engineering calculations.

### A New Emphasis on Energy Produced in Data Collection

S&ME drilling teams operate approximately 25 drill rigs engaged in the collection of standard penetration test (SPT) data following the American Society for Testing Materials (ASTM) D 1586 Standard *Test Method for Penetration Test and Split-barrel Sampling of Soils*. This data is collected for use in a variety of engineering applications by both outside clients as well as S&ME engineering staff. Partly because of the broader use of various autohammer designs and partly because of the arrival of earthquake engineering requirements in building codes (for example, *The International Building Code 2003*), drilling teams have had to place new emphasis on knowing the amount of energy developed in arriving at SPT N-values.

### Calculation of Correction Factors for Equipment Not in Normal Range

In recent years, virtually all SPT testing has been done using the familiar cathead and rope arrangement with a safety hammer. While there have been several studies on the energies developed by various configurations and rotational directions of the cathead, most have concluded that the amount of energy created is relatively consistent as long as approximately two wraps around the cathead are used and as long as cathead surface and rope are in generally good condition. ASTM methods allow for between 1-3/4 to 2-1/4 wraps around the cathead, depending on cathead rotation direction. (See a sketch of this arrangement in Figure 1.) Other variables include hammer weight, drop height and release technique. ASTM D 1586 does not dictate any corrections of SPT N-values if the prescribed wraps are used and cathead and rope are in good condition.

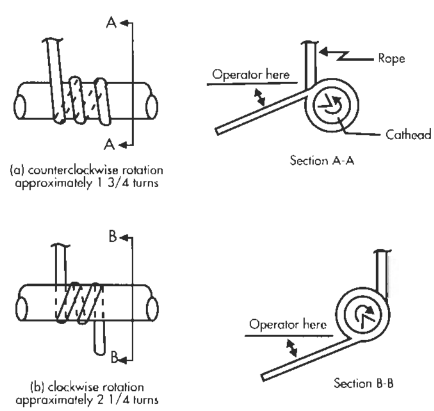


**Figure 1. Turns on Cathead**

Geotechnical practitioners have long recognized that all SPT N-values are not perfectly equal, but generally, the energy applied to the drill string by a well-trained driller using good equipment and the ASTM standards will deliver about 60 percent of the theoretical energy. The theoretical energy of the SPT is the weight of the hammer times the drop height, or 350 foot-pounds per blow. Thus, the expected energy of the SPT using a cathead and rope with a safety hammer would be about 60 percent or 210 foot pounds per blow. The N-value obtained from this test is frequently termed $N_{60}$.

In engineering practice, many properties are based on N-values and these, to date, invariably relate to $N_{60}$ values. As a result, N-values collected with a hammer system that delivers energy other than 60 percent of the theoretical force would be unreliable for use in correlations. Several researchers have proposed correction factors for the use of hammers other than the safety hammer. The correction is made by the equation below:

**$N_{60}$ = N Value Recorded in the Field ($N_{field}$) x Standard Correction or Actual Tested Energy Ratio($C_E$)**

In this equation, the $N_{60}$ is the value to be used in any correlations between N-values and other properties (e.g. shear strength, compressibility, bearing capacity, liquefaction potential), the $N_{field}$ is the N-value recorded by the drilling team in the field and the $C_E$ term is either a "standard" correction or the actual tested energy ratio of the hammer-operator to the theoretical ratio. The "standard" corrections that were proposed by Seed, et. al.[AGS1], dating back to 1985[1], are listed in Table 1 below:

**Table 1. Energy Correction Factors**

| Hammer Type | $C_E$ |
|---|---|
| **Autohammer** | **1.3** |
| Safety | 1.0 |
| Donut | 0.75 |

Some engineering firms and practitioners use the actual tested energy transfer ratio (ETR) of the equipment to correct the N-value. In that case, $C_E$ would be the actual percentage of theoretical energy divided by 60 percent, or:

**$C_E$ = ETR (in percent of theoretical) / 60 percent**

Further evaluation concludes that Seed, et. al. presumed an autohammer energy transfer ratio (ETR) of 78 percent in their "standard" correction factor. This was a fair assumption because of the expected efficiency of the autohammer systems and lack of resistance caused by rope and pulley friction. S&ME staff commonly sees ETR values in the 75 to 85 percent range. A $C_E$ of 1.3 is, thus, not a bad approximation.

## A New ASTM Standard for Energy Transfer Ratio Determination

ASTM Committee D-18 has recently balloted a new standard for determination of the ETR using the now-accepted force times velocity method (EFV). The EFV replaces the prior force squared method (EF2), which was widely regarded as too cumbersome to yield reliable and interpretable results for calculating ETR. The EFV method became feasible as a result of technology that is able to measure the force and wave velocity produced by a steel-on-steel impact like the impact produced in SPT data collection. The ASTM designation for the new standard will be D 4633 and is a total re-write of the withdrawn ASTM D 4633-86 *Standard Test Method for Stress Wave Energy Measurement for Dynamic Penetrometer Testing Systems.* It is anticipated that the standard will become effective on release of the 2006 ASTM Standards book and appear in Volume 4.08.

## Complying with the New ASTM Standard

There are a few data-acquisition systems available that comply with the upcoming ASTM standard D 4633. S&ME uses both the Pile Driving Analyzer® (PDA) and the SPT Analyzer®, manufactured by Pile Dynamics, Inc. to measure ETR. Both use similar data acquisition software and the same instrumentation to collect force and velocity inputs. The instrumentation to collect force and velocity inputs is inserted in the SPT drill string as shown in Figure 2. All instrumentation is attached to a 2-foot section of drill rod. It is preferable for the instrumented rod to have the same cross-section area as the entire string, thus, multiple rod sizes are maintained. The complete array of equipment used in the data acquisition process is shown and labeled in Figure 3.

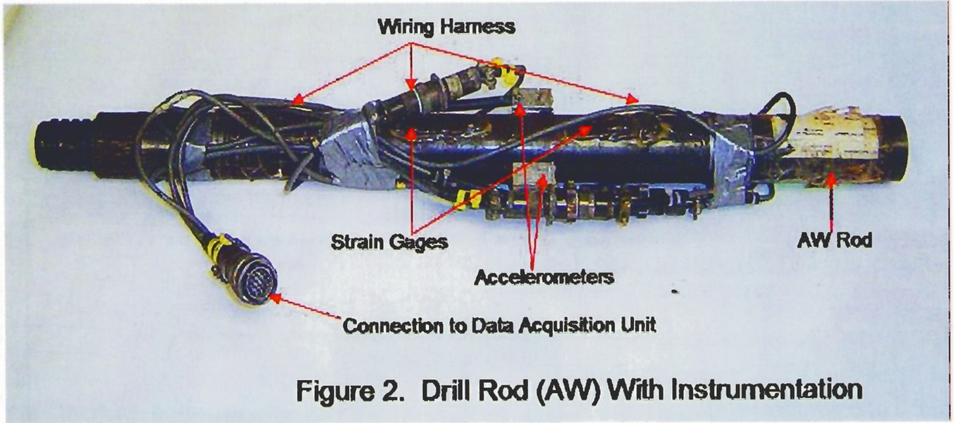

Figure 2. Drill Rod (AW) With Instrumentation

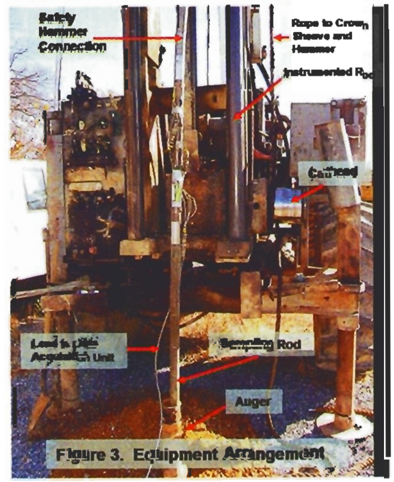

Figure 3. Equipment Arrangement

## S&ME's Solution to Help Ensure Reliable SPT Data

To help ensure reliable SPT data collection, S&ME's Field Exploration Committee chose to annually calibrate each of its hammer-operator systems and to have individual ETR's available for each hammer-operator system. In addition, when required by a client's contract, interim calibrations are made. For internal purposes, S&ME has documented established ranges of acceptable ETR's for the various types of hammer-operator systems. If a hammer operator system falls outside of the acceptance range, a review of methods and equipment is made promptly, corrections to procedures are implemented and the hammer-operator system is re-tested.

When S&ME made the commitment to individually measure hammer-operator energy, there was some question if the benefit was worth the effort and cost. The very first hammer-operator system tested was a brand new auger drill fitted with an autohammer. The expectation was that this system would be functioning to perfection.

When the first three intervals tested all showed ETR of close to 60 percent, the driller was questioned as to why the equipment was functioning so close to the average. The driller had taken the initiative to review the drill rig literature and determined that the autohammer speed could be lowered to reduce the hammer energy. Thus, the N-values of the new rig would come very close to those of the other rigs operated by the branch which were using cathead and rope with safety hammer systems. The driller achieved these results by trial and error, testing the rig as he adjusted the hammer speed.

The result of the driller's efforts was double correction. Correction was made once by the driller in the field and again by engineers in the office assuming the data needed correction since the drill used had an autohammer. The individual measurement of ETR for each drill rig has paid for itself, many times over-in that first year, by avoiding the use of faulty data.

## The Need to Continually Re-evaluate the Standards

S&ME's decision to test and document individual drill rigs' ETR helps the field staff provide outside clients and in-house engineering staff with correct SPT data. New and improved hammer systems will continue to be invented and broader use of the autohammer will occur. These innovations will call for NDA members to continue to re-evaluate how SPT data is collected and corrections calculated. Doing this will allow for more accurate engineering calculations and better, safer designs. ●

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[1]Seed, H.B., Tokimatsu, K., Harder, L.F. and Chung, R.M., 1985. **Influence of SPT Procedures in Soil Liquefaction Resistance Evaluations.** As published in ASCE Journal of Geotechnical Engineering 111(12): pp 1425-1445.