

Industry Acceptance of New Technology for Soil Density Testing

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Troxler – Known for Nuclear Moisture Density Gauges Since 1960s

- Mr. William Troxler invented the nuclear moisture density gauge in the basement of his home in Raleigh, NC in the late 1950s.
- This technology largely replaced the manual methods, such as the sand cone and drive cylinder methods.
- The new technology was adopted by all state DOTs, most other government agencies and the private industry as the “industry standard” for soil moisture density measurements.



**Model
3440-
1988-
2016**



**Model
3411-
1968-1988**

**Model
3440-
Updated
2007-
present**



Troxler Gauges- History

The acceptance process did not happen overnight.

- Many studies were conducted comparing the nuclear gauges to the manual methods.
- Many DOTs wrote unique specifications and procedures for their technicians.

1962

Nuclear Moisture— Density Measurements in Construction Control

by
ALFONSO BURGERS, Graduate Assistant
and
ELDON J. YODER, Research Engineer
Purdue University
Lafayette, Indiana

INTRODUCTION

Soil strength is determined to a large extent by the soil's A soil compacted to a relatively high degree of density will have relative strength resulting not only from the densification process also from restriction of loss of strength brought about by moisture absorption. The strengths of base course materials and surfaces are also affected to a large extent by the material's density of compaction.

1963

A STUDY OF THE TROXLER NUCLEAR SOIL DENSITY AND MOISTURE GAUGES

TECHNICAL REPORT NO. 2
for

RESEARCH PROJECT HPS-1 (27)E
"Application of AASHTO Road Test Results
to Texas Conditions"

Sponsored by the Texas Highway Department
in cooperation with the
Bureau of Public Roads
Department of Commerce

May 1963

E-27-63

1975

FIELD EVALUATION OF A DIRECT TRANSMISSION TYPE NUCLEAR MOISTURE-DENSITY GAUGE

STUDY NO. 74-2

Prepared by
MISSOURI STATE HIGHWAY DEPARTMENT
Division of Materials and Research

Final Report
January 1975

in cooperation with

U. S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration

The opinions, findings, and conclusion
expressed in this publication are not
necessarily those of the Federal Highway
Administration.

Evaluation of Surface Density Nuclear Gauges for Acceptance Testing of Asphalt Concrete Overlays

Lee E. Tidwell, Randy C. Ahlrich, George L. Regan
Geotechnical Laboratory
U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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DTIC QUALITY INSPECTED 3

Final report
Approved for public release; distribution is unlimited

1993

Troxler Gauges

- DOTs develop their own specs, procedures, and training programs for nuclear gauge measurements

Kansas Department of Transportation Standard Operating Manual

	SOM: 1.13.2
SUBJECT: Radiological Safety Guidelines	VERSION: 6
	PAGE: 1 of 6
INFORMATION CONTACT: Bureau of Materials and Research	EFFECTIVE DATE: 06/01/2010
APPROVED:	, Secretary of Transportation

POLICY STATEMENT:

Kansas Department of Transportation (KDOT) employees involved with nuclear gauges shall be trained in their operation. They shall be knowledgeable of all safety precautions and shall follow the guidelines when handling or transporting a nuclear gauge.

DEFINITIONS:

Nuclear Gauge. A portable device utilizing radioactive material to determine the density and/or hydrogen content of a material is a nuclear gauge.

FIELD METHOD FOR DETERMINING IN-PLACE DENSITY OF SOILS AND
BASE MATERIALS

TXDOT DESIGNATION: TEX-115-E

Test Procedure for

FIELD METHOD FOR DETERMINING IN-PLACE DENSITY OF SOILS AND BASE MATERIALS



TXDOT Designation: Tex-115-E

Effective Date: August 1999

1. SCOPE

- 1.1 This method determines the density of untreated and treated soil and granular material compacted in the roadway or in the natural state, as exists in a cut section and borrow source prior to excavation.
- 1.2 The principal use of the in-place density is to determine the degree of compaction or percentage of the density obtained by the method outlined in Tex-113-E and Tex-114-E.
- 1.3 The term "soils" used in this procedure includes all base materials, as well as fine grain soils.

RADIATION SAFETY & NUCLEAR GAUGE TRAINING 2018



IOWA DOT

Technical Training & Certification Program

VDOT Soils and Aggregate Compaction

6

FIELD MOISTURE AND DENSITY TESTING WITH THE NUCLEAR GAUGE

LEARNING OUTCOMES

Understand the components of the nuclear gauge and how it is used to measure moisture and density
Understand the procedures for evaluating moisture and density using the direct transmission method
Understand the basic regulations that govern the storage, transport, and use of the nuclear gauge
Understand basic maintenance techniques and procedures for emergency response

INTRODUCTION

GEM-10

SAFETY PROCEDURE MANUAL FOR USE WITH NUCLEAR MOISTURE-DENSITY GAUGES



GEOTECHNICAL ENGINEERING MANUAL
GEM 10
Revision #3

AUGUST 2015



Department of
Transportation

Office of
Technical Services

Geotechnical Engineering
Bureau

Troxler Gauges- Licensing



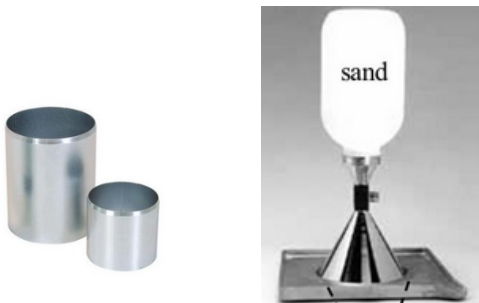
- The Nuclear Regulatory Commission was developed in 1975- this is when the licensing structure as we know it today began.
- Gauge owners have to: keep inventory, prove that dose to operators & public is low, secure the gauges, pay fees, etc.
- Over time more regulations are adopted and fees go up.
- Sept. 11, 2001 changed everything & put a spotlight on regulated material.
 - Inspection frequency increases
 - Fees increase
- Interest in alternative devices (non-nuclear) increases.



Nuclear Gauges- Alternatives?

The industry starts seriously looking into alternatives to nuclear density testing methods.

- Asphalt density- 2001- 2005
 - Several studies conducted using electromagnetic technology asphalt density gauges- mixed results
- Soil moisture & density- more difficult to address as two measurements are required.
 - Studies begin approx. 2007 to look at all possible technologies



Nuclear Gauges- Alternatives?

Using Electrical Density Gauges for Field Compaction Control

By
CHRISTOPHER L. MEEHAN
JASON S. HERTZ

Civil and Environmental Engineer
University of Delaware

December 2011

Technical Report Documentation Page		
1. Report No. FHWA/TX-06/0-4835-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Evaluation of Non-Nuclear Methods for Compaction Control	5. Report Date July 2006	
7. Author(s) Ellen M. Rathje, Stephen G. Wright, Kenneth H. Stokoe II, Ashley Adams, Ruth Tobin, Manal Salem	6. Performing Organization Code	
9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin	8. Performing Organization Report No. 0-4835-1	
	10. Work Unit No. (TRAIS)	
	11. Contract or Grant No. 0-4835	

Non-Nuclear Compaction Gauge Comparison Study Final Report

December 2007

Report 2007 – 19

State of Vermont
Agency of Transportation
Materials and Research Section

Prepared by:

Chad A. Allen
f JCB
Jeff Brown
Certifications and Independent
Assurance Technician

Prepared by Hudson Jackson, PhD, P.E

ASSESSMENT OF THE MOISTURE DENSITY INDICATION FOR THE
CONSTRUCTION QUALITY CONTROL OF COMPACTED DENSE GRADED
AGGREGATE BASE LAYERS

September 2007



US Army Corps
of Engineers®
Engineer Research and
Development Center

Device Comparison for Determining Field Soil Moisture Content

Ernest S. Berney IV, James D. Kyzar, and Lawrence O. Oyelam

November 2011



RP 210

Review of Non-Nuclear Density Gauges as Possible Replacements for ITD's Nuclear Density Gauges

By

Haifang Wen, Mark Rose, and Anthony Timm,
Washington State University

Nuclear Gauges- Alternatives?

Early studies determined that most “alternative” soil moisture density test methods were not desirable. They were:

- difficult to perform,
- required extensive calibration in the field and
- cumbersome; extra equipment needed to perform the calibrations.

Specific Negatives

- When soil properties change, new calibration for density and moisture is required.
- Sand Cone method (or a nuclear gauge) is needed for the calibration procedure in many cases.
- Some methods measure modulus rather than density, a factor that is unfamiliar to many and can't be equated to a density / percent compaction value.
- Specs have to be changed.

Nuclear Gauges- Alternatives?

Conclusion:

The nuclear density method really is the best for quick field QC of soil materials.

- Can a nuclear gauge be exempt from licensing? Why not?
- What would it take?: Source activity/ Shielding/ Other safety features/ What about the Moisture system
- This would not be an easy task!

Troxler was already working on this device as the alternative methods were being tested and found to be mostly unsatisfactory.



Nuclear Gauges- Alternatives?

The exempt status of the Model 4590 EGauge was finally granted by the NRC in September of 2014.

- No license is required in the USA!
- The details:
 - Very low source activity (Cs137- gamma source)
 - Sensitive detector
 - Background count required occasionally
 - External, non-nuclear moisture system
 - 8 inch depth maximum
- The cost savings to owners is significant.
 - License fees- \$1,500- \$10,000+ / yr
 - Badges, Leak Tests, Training- \$1000 to \$5000+ / yr
 - Time savings- 20 – 40+ hours / mo.
 - Reciprocity Fees / Forms



Nuclear Gauges- An Exempt Alternative


Next step was market testing and acceptance.

- Field testing was conducted to test all functions and software as well as the measurement results. Spring/Summer 2015
- Market Introduction was made in Spring 2015- Trade Shows, Industry Publications, Customer Demonstrations & Presentations

TROXLER ELECTRONIC LABORATORIES

EGauge


Model 4950 Soil Density Gauge




Tired of Licensing?
EGauge is the Answer

Unlike other non-licensed soil density gauges, the EGauge uses proven nuclear technology for repeatable and reproducible results!


EGauge is NRC License Exempt, meaning:




NO PAPERWORK




NO TRAINING



NO LICENSE FEES



www.troxlerlabs.com



TROXLER
The Leader in Construction Test Equipment

Nuclear Gauges- An Exempt Alternative

Market Introduction Plan:

- Identify those agencies actively studying non-nuclear alternatives (Universities, DOTs).
- Identify agencies with the need for an alternative to nuclear (transportation issues, multiple licenses, etc.).
- Identify small firms without the budget and personnel needed to have a license.

Nuclear Gauges- An Exempt Alternative

- DOT acceptance in progress:
 - Early demonstration units loaned to: TXDOT, AKDOT, ARDOT, VADOT, NCDOT, MDSHA, MSDOT, MODOT, FLDOT, ALDOT
 - More recently: SCDOT, VTDOT, WYDOT, WADOT
 - Several have since purchased at least one unit for evaluation / research
- Loaned or purchased units at universities:
 - Univ. of Delaware, Rutgers Univ., TTI, Louisiana State Univ., East Carolina Univ., Michigan Technological Univ.
- Other Government agencies:
 - Public works departments
 - Multiple unit purchased by USDA-NRCS, US Army Corp Of Engineers, Air Force

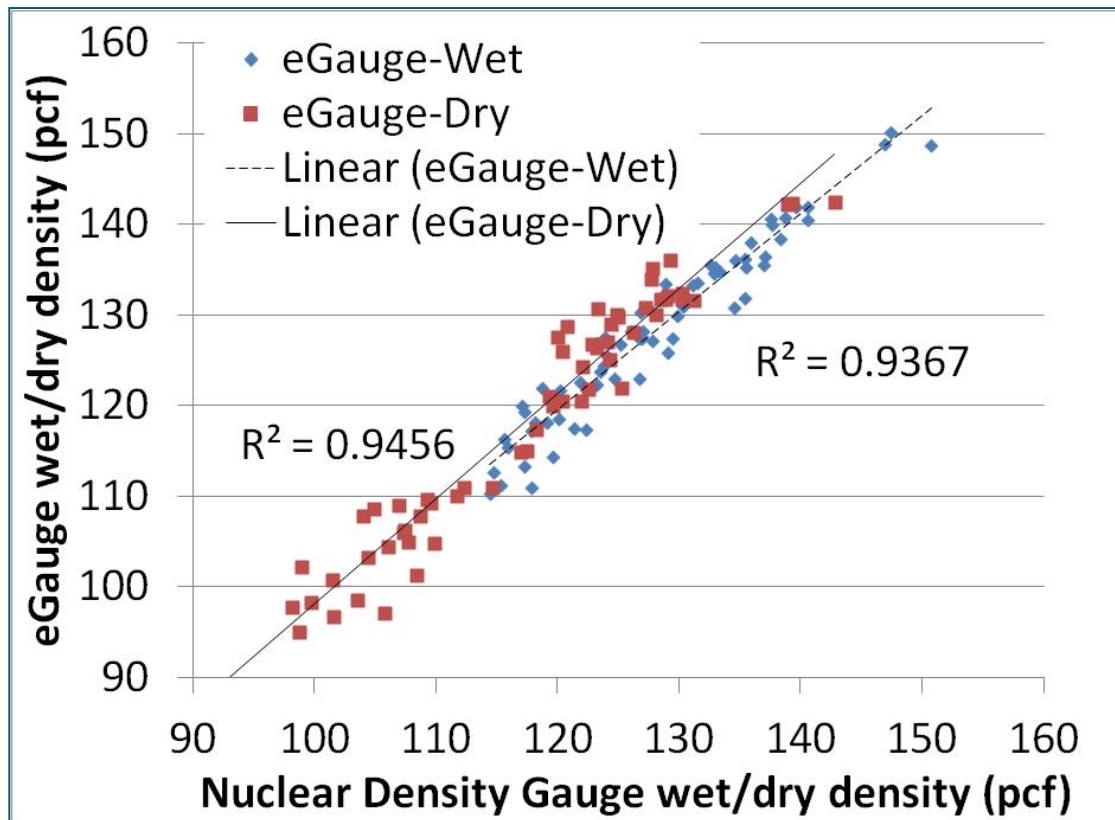
Nuclear Gauges- An Exempt Alternative

- December 2011: US Army Corp of Engineers was actively studying the available non-nuclear soil density devices.
 - The need was identified by the military- as transportation, storage and training for the nuclear gauges is becoming a challenge
- The final Beta EGauge was loaned to the COE as part of the next study in 2015.
- The published report finds that the EGauge performed very well when compared to non-nuclear devices and the typical nuclear density gauge.
- This has lead to EGauge being widely accepted by some US government agencies.

<small>Original a company name and control method. I cannot do that before I get a letter to the report review.</small>	
1. REPORT DATE (DD-MM-YYYY) November 2016	2. REPORT TYPE Final report
4. TITLE AND SUBTITLE Validation Testing of Non-Nuclear Alternatives to Measuring Soil Density	
6. AUTHOR(S) Ernest S. Berney IV, Mariely Mejias-Santiago, and Matthew D. Norris	

An Exempt Alternative- Field Data- USACOE

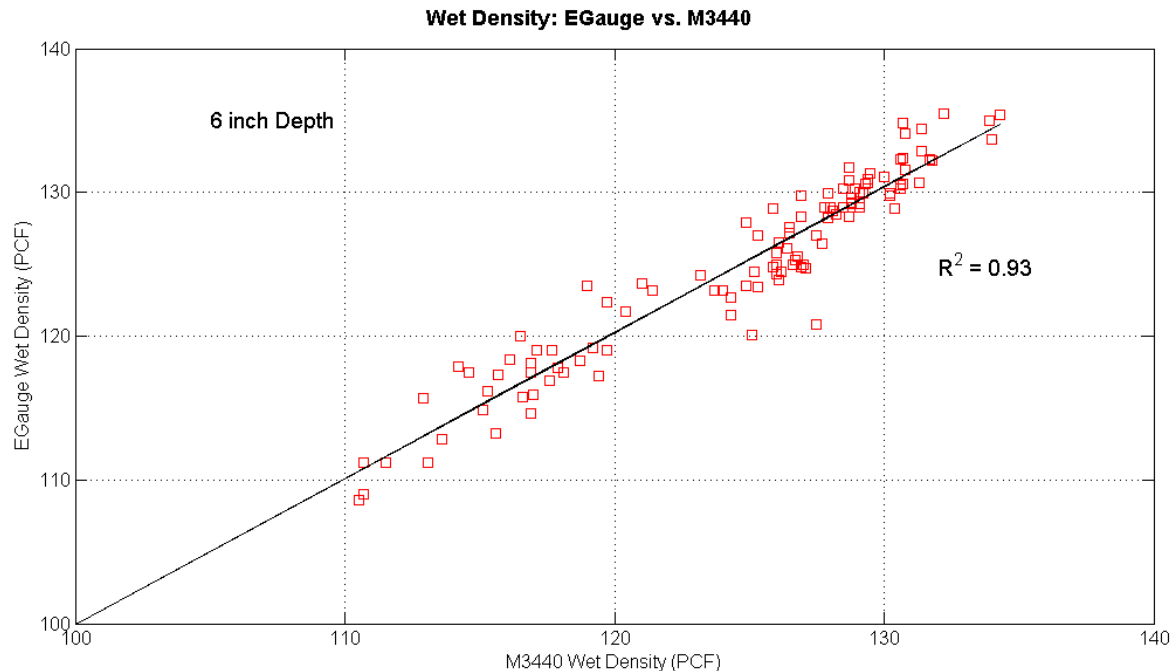
- Both wet/dry density matched NDG very well – similar system
- Moisture content was captured well given electronic system
- No calibration necessary to achieve results!



Data and from US Army Corps of Engineers ERDC Study – Dr. Ernest Berney

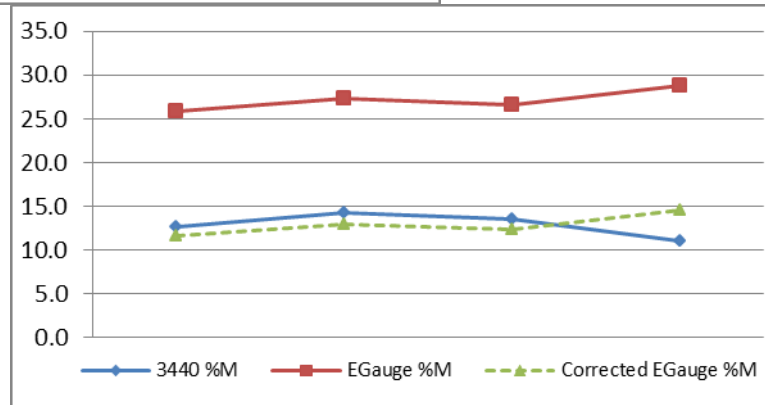
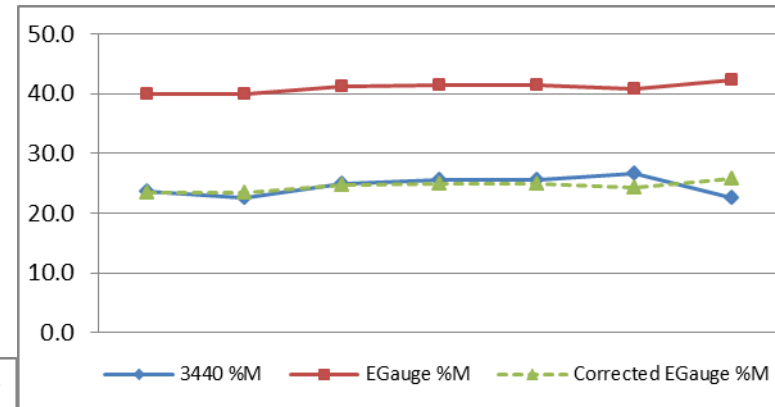
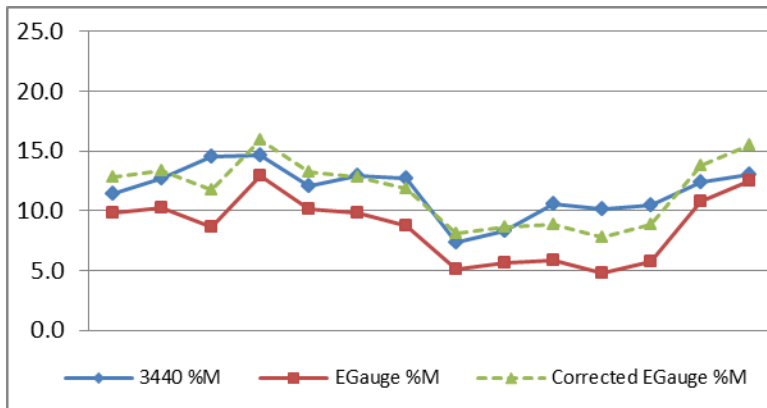
An Exempt Alternative- Field Data

- Data collected by Engineering Firm representing TXDOT on various soil types - April – June 2015.
- Excellent correlation of the Wet Density values. $R^2 = 0.93$



Field Data - Moisture Probe

The Non- Nuclear Moisture Probe data shown below was collected in April through June 2016 by an independent testing firm. This data was collected on 3 different soil types.



The red line shows the raw data resulting from the Moisture Probe using the factory calibration information. The dashed green line shows the reading after a simple offset is applied to the data.

Nuclear Gauges- An Exempt Alternative

- In July 2016 an EGauge was loaned to a grad student at Univ. of Delaware for a study of various soil moisture / density measurement methods.
- The study compared moisture and density results from the traditional nuclear gauge, drive cylinder measurement and the EGauge.
- The resulting data and conclusions were presented at IFCEE 2018.
- The published paper concludes that, “all three in situ QA/QC devices exhibited results that were in relatively good agreement with one another. The EGauge after calibration did exhibit similar or slightly better performance relative to the nuclear density gauge.”

A Comparison of In-Place Unit Weight and Moisture Content Measurements Made Using Nuclear Based Methods and the Drive Cylinder Method

William J. Baker III, S.M.ASCE¹; and Christopher L. Meehan, F.ASCE²

Proven Performance- Interlaboratory Study

On May 3, 2017 Troxler performed an Interlaboratory Study (ILS) to determine the repeatability and reproducibility of the EGauge and the moisture probe measurements. Three different soil types were tested by ten operators with ten different gauges and probes.

- The results are very comparable to that of the typical nuclear gauges.

Soil Density = Approximately 120–121

	Low-Activity Source EGauge	Model 3400-Type Gauge
Repeatability Standard Deviation	0.3 lb/ft ³	0.27 lb/ft ³
Reproducibility Standard Deviation	0.6 lb/ft ³	0.68 lb/ft ³
Repeatability Limit	0.8 lb/ft ³	0.74 lb/ft ³
Reproducibility Limit	1.8 lb/ft ³	1.91 lb/ft ³

Soil Density = Approximately 130.1–138.9

	Low-Activity Source EGauge	Model 3400-Type Gauge
Repeatability Standard Deviation	0.4 lb/ft ³	0.46 lb/ft ³
Reproducibility Standard Deviation	0.8 lb/ft ³	0.77 lb/ft ³
Repeatability Limit	1.2 lb/ft ³	1.28 lb/ft ³
Reproducibility Limit	2.2 lb/ft ³	2.15 lb/ft ³

Proven Performance- Interlaboratory Study

The moisture probe measurement results are also very comparable to that of the typical nuclear gauges.

Average moisture kg/m ³ (lb/ft ³)		Repeatability Standard Deviation kg/m ³ (lb/ft ³)	Reproducibility Standard Deviation kg/m ³ (lb/ft ³)	Repeatability Limit kg/m ³ (lb/ft ³)	Reproducibility Limit kg/m ³ (lb/ft ³)
289 -313 (18.1-19.6)					
	D6938	5.7 (0.36)	8.1 (0.50)	16 (1.0)	23 (1.4)
	Moisture Probe	10 (0.6)	11 (0.7)	28 (1.7)	31 (1.9)
138-193 (8.6-12.1)					
	D6938	6.1 (0.38)	8.5 (0.53)	17 (1.1)	24 (1.5)
	Moisture Probe	5 (0.3)	8 (0.5)	13 (0.8)	24 (1.5)



Exempt Alternative- ASTM Standard

ASTM D8167

Standard Test Method for In-Place Bulk Density of Soil and Soil-Aggregate by a Low- Activity Nuclear Method (Shallow Depth)¹

The EGauge meets this standard and is proven to provide excellent repeatability and reproducibility on several soil types.

- This is a step in the direction of acceptance by the industry for soil density measurements.
- This standard was published in June 2018.
- The moisture probe measurement standard is still pending.

Nuclear Gauge- An Exempt Alternative

- As mentioned previously, the original nuclear gauges, introduced in the early 1960s, were not immediately accepted as replacement of the sand cone method.
- The EGauge is in a similar situation.
- Several universities, DOTs and other government agencies have purchased them and are currently using and/or evaluating them.
 - Alaska DOT
 - Arkansas DOT
 - Maryland DOT
 - Florida DOT
 - Alabama DOT
 - Wyoming DOT
 - North Carolina DOT
 - Nevada DOT
 - Louisiana State Univ. (LTRC)
 - East Carolina Univ.
 - Texas A&M
 - Michigan Technological Univ.
 - USDA NRCS
 - Bureau of Land Management
 - Bureau of Indian Affairs
 - US Army Corp of Engineers
 - US Air Force

Conclusion

The EGauge is an exempt nuclear gauge for soil density measurements. The moisture probe that is provided uses electromagnetic technology for soil moisture measurements at a depth of approx. 3.5 inches.

- The EGauge has been available since October 2015.
- Studies have shown that the performance is very comparable to the traditional nuclear density gauges.
- Several DOTs are evaluating the EGauge currently.
- Many government agencies are using the EGauge.
- The EGauge meets ASTM D8167. This standard provides proven repeatability and reproducibility data for devices meeting the standard.
- The approval and acceptance process for new test methods is not quick.

