California Test 111
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CALIFORNIA STATE TRANSPORTATION AGENCY

DEPARTMENT OF TRANSPORTATION
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METHOD OF TESTS FOR DEVELOPING DENSITY AND MOISTURE CALIBRATION TABLES FOR NUCLEAR GAUGES

A. SCOPE

This test method describes procedures for developing density and moisture calibration constants and tables for nuclear gauges.

This test method includes 4 parts:

1. Principle of Calibration
2. Procedure for Density Calibration
3. Procedure for Moisture Calibration
4. Documentation

B. REFERENCES

California Test 226 – Determining Moisture Content by Oven Drying
ASTM D7013/D7013M - Standard Guide for Calibration Facility Setup for Nuclear Surface Gauges

C. APPARATUS

1. Nuclear Gauge: a portable instrument containing radioactive sources, detectors, electronics and battery pack.

2. Reference Standard Block: a block provided by the gauge manufacturer primarily for checking instrument operation, correcting for decay of sources over time and for establishing standard counts against which future measurements are compared.

3. Standard Calibration Density Blocks: a set of 3 blocks for density calibration. The density blocks must be traceable to National Institute of Standard and Technology (NIST).

4. Standard Calibration Moisture Blocks: a set of 2 blocks for moisture calibration.

NOTE: The depth of the standard calibration blocks must be at least 2 in. more than the maximum depth measurement by the nuclear gauge. Minimum surface dimensions of 24 in. × 17 in. for the standard density blocks have proven satisfactory. The distance from the center of test holes to the edge of the block in standard calibration density or moisture blocks must be at least 4 in. to minimize boundary effect on radioactive counts. Follow manufacturer's recommendation for use and setup of blocks having dimensions different from the ones listed above. NIST validation of the calibration blocks is to be renewed every 5 years.

D. PROCEDURES

PART 1. PRINCIPLE OF CALIBRATON

1A. DENSITY CALIBRATION

Density calibration is performed on 3 standard calibration density blocks. After standard counts are read, density count readings on each block must be taken for the specific test mode of the gauge to be calibrated. The test mode is in terms of penetration depth of the gauge source rod, and includes the backscatter (BS) detection mode and other depths, normally 2 to 12 in. penetration depths as required by the gauge. For each test mode, the relationship between count ratio and block density is expressed as:

$$\mathrm{CR} = a\ \exp\left(-b\mathrm{D}\right) - c$$

Or

$$CR = a \exp\left(-\frac{D=}{b=}\right.\quad c=$$

$$\text{Where:}\quad \mathrm{CR\ (Count\ Ratio)} = \frac{\text{Density Count Reading}}{\text{Density Standard Count}},$$

D = the equivalent soil density for the corresponding block; and

a, b, and c = constants to be determined.

NOTE:

- Thin lift gauges must be calibrated in accordance with the manufacturer's recommendations.

- Manufacturers use different methods to normalize the metal block densities in order to obtain soil equivalent density values. Follow manufacturer's recommendations for obtaining model specific normalization factors.

1B. MOISTURE CALIBRATION

The moisture calibration is performed on 2 standard calibration moisture blocks. After moisture standard counts are read, moisture count readings are taken on the 2 blocks at the moisture test mode of the gauge to be calibrated. The mathematical equation for nuclear gauge moisture calibration is expressed as:

$$\mathrm{CR} = e + f \times \mathrm{M}$$

Or

$$\mathrm{CR} \qquad - \mathrm{B})/\mathrm{A} =$$

$$\text{Where:}\quad \mathrm{CR\ (Count\ Ratio)} = \frac{\text{Moisture Count Reading}}{\text{Moisture Standard Count}},$$

M = the standard calibration block moisture; and

e and *f or A and B* = constants to be determined

PART 2. PROCEDURE FOR DENSITY CALIBRATION

2A. STANDARD COUNT – DENSITY

1. Follow manufacturer's instruction for start-up.

2. Position the reference standard block at a sufficient distance away from any objects, gauges, electronic radio or radioactive sources that may cause interference. Setting the reference standard block a minimum of 5 ft from any object and a minimum 25 ft from any gauge or radioactive source is typically sufficient to avoid such interference.

3. Place the gauge on the reference standard block in the safe position and take two 4-min standard counts. The 2 measurements taken are part of the warm-up procedure and are entered in a gauge logbook and the calibration form (Table 1), but are not used in the subsequent parts of this procedure. After the warm-up, take a minimum of 3 additional 4-min counts. Record the three 4-min counts under the label "A.M." on the calibration form (Table 1). The average of the 3 measurements is the Standard Count.

4. To express the standard count deviation limits within which the calibration of a gauge is valid, the acceptable deviation limit (ADL) is defined in this test method as:

$$ADL = 0.03n$$

   Where: n = standard count at calibration of the gauge.

   Record the ADL on the calibration form (Table 1).

2B. COUNT READINGS ON DENSITY BLOCKS

1. Follow ASTM D7013 to prepare and setup your density blocks for gauge calibration.

2. Set the gauge source rod at the desired depth and position the gauge on 1 of the 3 standard calibration density blocks with the rod in the hole. The gauge is placed so that the rod is firmly against the side of the hole nearest to the gauge.

3. Take two 4-min counts in the backscatter mode and one 4-min count at penetration depths required by the gauge. Record all data on the calibration form (Table 1). Nominal direct transmission depth defines the approximate depth at which the rod is placed. The direct transmission depth is the nominal direct transmission depth ± 0.1 in. and is defined as the actual penetration depth setting at which the soil density gauge rod is manufactured to stop.

4. Repeat Steps 2 and 3 above on the other 2 standard calibration density blocks and record all data on the calibration form (Table 1).

5. Place the gauge on the reference standard block in the safe position, take a minimum of one 4-min standard count, and record the data under the label "P.M." on the calibration form (Table 1).

2C. PRESENTATION OF CALIBRATION DATA

1. Present the calibration data from the 3 standard calibration density blocks for a gauge at all test modes on a semi-log scale plot (Figure 1).

2. Determine the "best fitting" straight line using the "Least-Square" method for each of the test modes considered. Present the correlation coefficient of the regression on the plot as shown in Figure 1. If the correlation coefficient for a test mode is less than 0.999 or the standard error of the linear regression is greater than 1 lb/ft^3, the gauge at this test mode shall be recalibrated.

3. Determine the 3 constants in the equation in Part 1A for each of the test modes using an appropriate procedure. Appendix A1 presents the Troxler method and A2 presents the CPN-Instrotek method for determining the 3 constants.

4. Generate a calibration data sheet showing count ratio vs. density (Table 2). Generate 1 sheet for each calibrated depth test mode. Present basic information of the calibration on each data sheet, including:

   - Gauge Owner
   - Gauge serial number
   - Calibration date
   - Operator
   - Count ratio vs. density sheets
   - Gauge manufacturer and model
   - Standard count and ADL
   - Gauge density count ratios
   - Calibration constants (*a*, *b*, *c*)

NOTE: For thin lift gauges, ratio vs. density calibration table (Table 2) is not required.

5. After calibration, collect the following information and keep the documents with the gauge at all times.

   a. An affixed calibration sticker that shows the gauge ID and date of calibration.

   b. Calibration data sheets showing count ratio vs. density and ADL.

   c. A copy of the valid leak test results.

6. To utilize DIRECT READOUT capabilities, the calibrating service must indicate on the count ratio vs. density calibration table (Table 2) that the gauge meets the following requirements:

   a. The constants *a*, *b*, and *c* listed on the calibration tables for each mode must be entered into the memory of the gauge.

   b. The constants are visible for review.

   c. The calibration constants in memory are the same as those in the calibration tables when the gauge is restarted.

   d. The appropriate gauge model specific equation and constants are used. Refer to the gauge manual or contact the manufacturer to obtain the correct equation

PART 3. PROCEDURE FOR MOISTURE CALIBRATION

3A. STANDARD COUNT – MOISTURE

1. Take standard counts by following the procedure in Part 2A, except read the moisture counts. Record the data under the label "Moisture Calibration" on the calibration form (Table 1).

2. To express the standard count deviation limits within which the calibration of a gauge is valid, the acceptable deviation limit (ADL) is defined in this test method as:

$$ADL = 0.03n$$

Where: n = standard count at calibration of the gauge.

Record the ADL on the calibration form (Table 1).

3B. COUNT READINGS ON MOISTURE BLOCKS

1. Follow ASTM D7013 to prepare and setup your density blocks for gauge calibration

2. Place the gauge on the first standard moisture block (dry) and take one 4-min count in the backscatter detection mode. Record the data on the calibration form (Table 1). Lift the gauge and re-place it on the same block for a second reading. Average the 2 numbers to obtain the mean count for this block.

3. Repeat Step 2 on the second standard moisture block (wet).

4. Place the gauge on the manufacturer's standard block in the safe position; take a minimum of one 4-min standard count, and record data under the label "P.M." on the calibration form (Table 1).

3C. PRESENTATION OF CALIBRATION DATA

1. Tabulate the moisture calibration on the calibration table (Table 3). Present basic information of the calibration on the table, including:

- Gauge Owner
- Gauge serial number
- Calibration date
- Operator
- Count ratio vs. moisture sheets
- Gauge manufacturer and model
- Standard count and ADL
- Gauge density count ratios
- Calibration constants (*e*,*f*) or (A,B)

2. Present the 2 data points on a normal linear scale plot and connect the points using a straight line, as shown in the figure at the end of Table 3. Calculate the intercept and slope of the straight line and determine the calibration equation.

NOTE: To utilize DIRECT READOUT capabilities, the calibrating service must indicate on the calibration table (Table 3) that the gauge meets the following requirements:

- The constants e and f or A and B listed on the calibration table must be entered into the memory of the gauge.
- Restart the gauge. The calibration constants in the memory must be the same as those in the calibration table.
- The constants are visible for review.
- The appropriate gauge model specific equation and constants are used. Refer to the gauge manual or contact the manufacturer to obtain the correct equation

3D. FIELD MOISTURE CALIBRATION PROCEDURE

If the correlation between gauge calibration moistures and oven-dry moistures is needed, the calibration moisture must be verified by performing nuclear gauge field moisture tests and relating the test results to oven-dry moistures and field densities per CTM 226.

PART 4. DOCUMENTATION

1. An affixed calibration sticker

2. Density and moisture calibration data (raw and generated) as required in Part 2C and Part 3C

   NOTE: An Excel spreadsheet that produces the nuclear gauge calibration form, count ratio vs. density table and curves, and count ratio vs. moisture table and curve is available with California Test 111 at:

3. Affidavit of Nuclear Gauge Calibration (Form TL-0114 (2014)) (Figures 2 & 3)

4. NIST traceability document

E. PRECAUTIONS

Nuclear gauge density and/or moisture calibration must be performed at least once every 12 months.

A leak test must be conducted no less than the frequency listed in the Radioactive Materials License issued by the California Department of Public Health (CDPH).

F. HEALTH AND SAFETY

Follow all rules and regulations in the operator's manual and the Radioactive Materials License issued by the California Department of Public Health under Title 17, California Code of Regulations, Division 1, Chapter 5, Subchapters 4.0, 4.5, and 4.6.

It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Prior to handling, testing or disposing of any materials, testers must be knowledgeable about safe laboratory practices, hazards and exposure, chemical procurement and storage, and personal protective apparel and equipment.

Caltrans Laboratory Safety Manual is available at:

http://www.dot.ca.gov/hq/esc/ctms/pdf/lab_safety_manual.pdf

APPENDIX A1

A PROCEDURE FOR THE DETERMINATION OF THE THREE CONSTANTS FOR DENSITY CALIBRATION

To determine the 3 constants presented in PART 1A, 3 equations are needed. With 3 standard density blocks, 3 count ratios can be obtained and, thus, 3 equations can be expressed as:

$$CR_1 = a\exp(-bD_1) - c$$

$$CR_2 = a\exp(-bD_2) - c$$

and

$$CR_3 = a\exp(-bD_3) - c$$

Where: CR_1, CR_2, and CR_3 are the density count ratios of 3 density blocks;
D_1, D_2, and D_3 are the corresponding block densities; and
a, b, and c are the 3 constants to be determined by the above 3 equations.

By rearranging the 3 equations to solve the constant c, one can obtain:

$$(D_2 - D_3)\ln(CR_1 + c) + (D_3 - D_1)\ln(CR_2 + c) + (D_1 - D_2)\ln(CR_3 + c) = 0$$

The above equation can be numerically solved for the unknown c with the Newton's method with an introduction of an error function as below:

$$f(c) = (D_2 - D_3)\ln(CR_1 + c) + (D_3 - D_1)\ln(CR_2 + c) + (D_1 - D_2)\ln(CR_3 + c)$$

The derivative of the function $f(c)$ is: $$f'(c) = \frac{D_2 - D_3}{CR_1 + c} + \frac{D_3 - D_1}{CR_2 + c} + \frac{D_1 - D2}{CR_3 + c}$$

In solving for the constant c using the Newton's method, iterations with an initial guess of $c_0 = -\frac{\min(CR_1, CR_2, CR_3)}{2}$ is required.

After each iteration the constant c is updated by:

$$c_{n+1} = \frac{c_n - f(c_n)}{f'(c_n)}$$

The constants b and a can be computed as:

$$b_{n+1} = -\frac{\ln(CR_1 + c_{n+1}) - \ln(CR_2 + c_{n+1})}{D_1 - D_2}; \text{ and}$$

$$a_{n+1} = \frac{CR_1 + c_{n+1}}{\exp(-b_{n+1}D_1)}$$

When the error function $f(c_{n+1})$ converges to zero, the 3 constants are determined.

APPENDIX A2

A PROCEDURE FOR THE DETERMINATION OF

THE THREE CONSTANTS FOR DENSITY CALIBRATION

To determine the 3 constants presented in PART 1A, 3 equations are needed. With 3 standard density blocks, 3 count ratios can be obtained and, thus 3 equations can be expressed as:

$$CR_1 = a\exp\left(-\frac{D_1}{b}\right) + c$$
$$CR_2 = a\exp\left(-\frac{D_2}{b}\right) + c$$
$$CR_3 = a\exp\left(-\frac{D_3}{b}\right) + c$$

Where: CR_1, CR_2, and CR_3 are the density count ratios of 3 density blocks;
D_1, D_2, and D_3 are the corresponding block densities; and
a, b, and c are the 3 constants to be determined by the above 3 equations

By rearranging the 3 equations to solve the constant c, one can obtain:

$$(D_2 - D_3)\ln(CR_1 - c) + (D_3 - D_1)\ln(CR_2 - c) + (D_1 - D_2)\ln(CR_3 - c) = 0$$

The above equation can be numerically solved for the unknown c with the Newton's method with the introduction of an error function as below:

$$f(c) = (D_2 - D_3)\ln(CR_1 - c) + (D_3 - D_1)\ln(CR_2 - c) + (D_1 - D_2)\ln(CR_3 - c)$$

The derivative of the function f(c) is: $f'(c) = -\frac{D_2-D_3}{CR_1-c} - \frac{D_3-D_1}{CR_2-c} - \frac{D_1-D_2}{CR_3-c}$

In solving for the constant c using the Newton's method, iterations with an initial of

$c_0 = \frac{\min(CR_1, CR_2, CR_3)}{2}$ is required.

After each iteration the constant c is updated by:

$$c_{n+1} = c_n - \frac{f(c_n)}{f'(c_n)}$$

The constants a and b can be computed as

$$b_{n+1} = -\frac{D_1 - D_2}{\ln(CR_1 - c_{n+1}) - \ln(CR_2 - c_{n+1})}$$

$$a_{n+1} = \frac{CR_1 - c_{n+1}}{\exp\left(-\frac{D_1}{b_{n+1}}\right)}$$

When the error function $f(c_{n+1})$ converges to zero, the 3 constants are determined.

Table 1: Example Nuclear Gauge Calibration Input Data Sheet

NUCLEAR GAGE CALIBRATION

Sample 1

Owner:	XYZ		Operator:	J. J		Mfr./Model:	MDX			S/N:	12345			
									NIST Certification Date:			12/4/2002		
Standard Count - Density						Moisture Calibration						Date		
Warm-up		A.M.		P.M.		Standard Count - Moisture			Gage Moisture Count			12/4/2002		
1	40429	1	40415	1	40865	Warm-up				Dry	Wet			
2	40399	2	40510			1	10630	Average	Moisture(pcf)	0.00	23.50			
		3	40548			2	10715	10673	Count-1	598	4830			
		X̄ =	40491			P.M.	10862		Count-2	586	4802			
		ADL =	1215			ADL =	320		Count Ratio	0.0555	0.4513			
		Gage Density Count - Test Mode												
Block	Density	BS	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"	12"	AC
	(pcf)		(51mm)	(76mm)	(102mm)	(127mm)	(152mm)	(178mm)	(203mm)	(229mm)	(254mm)	(279mm)	(305mm)	
142	169	13897	58068		45463		28771		16129					
(Al)		14061												
143	139.8	18471	83792		70354		48478		29115					
(AL/Mg)		18502												
144	111.3	24407	114468		103300		77168		50417					
(Mg)		24544												
Calibration Constants	*a*	2.015354	9.694428	10.960212	11.030612	12.030023	11.334446	12.819113	11.221986					
	b	0.719444	0.464270	0.971750	0.710431	1.082040	0.935203	1.310437	1.217074					
	c	-0.036946	1.452166	0.184710	0.604730	0.188019	0.276811	0.087782	0.070137					

Notes:

142, 143, and 144 are the IDs for the three density standard blocks. The EQUIVALENT soil densities are obtained by multiplying the following correction factors: 0.988 for magnesium, 0.974 for magnesium/aluminum, and 0.964 for aluminum. The EQUIVALENT soil densities of them are (1.0g/cc=62.428pcf)):

No	ID	pcf	g/cc
1	142	162.92	2.610
2	143	136.17	2.181
3	144	109.96	1.761

Table 2: Examples of Count Ratio vs. Density Data Sheet

1

Count Ratio versus Density

Back Scatter (CTM-375) **Correlation Coefficient (r):** **1.0000** **Pass**

Gage Owner: *Caltrans* Gage S/N: *10040* **Calibration Date:** *3/10/2014*

Operator: *A. Diolazo* Gage Model: *CPN MC-1DR-P* **Std Ct (at Calib):** *40491*

EQUIVALENT soil densities of the three metal standard density blocks (1.0 g/cc = 62.428 PCF) **ADL=** ± *1215*

PCF	162.92	136.17	109.96	$a=$ 2.015354
g/cc	2.610	2.181	1.761	$b=$ 0.719444
Count Ratio	0.345	0.457	0.604	$c=$ -0.036946

Count Ratio			Density	Count Ratio			Density	Count Ratio			Density
CR			G/CC	CR	to	CR	G/CC	CR	to	CR	G/CC
0.771	-	0.776	1.40	0.588	-	0.591	1.80	0.450	-	0.452	2.20
0.766	-	0.770	1.41	0.584	-	0.587	1.81	0.447	-	0.449	2.21
0.761	-	0.765	1.42	0.580	-	0.583	1.82	0.445	-	0.446	2.22
0.756	-	0.760	1.43	0.576	-	0.579	1.83	0.442	-	0.444	2.23
0.751	-	0.755	1.44	0.572	-	0.575	1.84	0.439	-	0.441	2.24
0.745	-	0.750	1.45	0.569	-	0.571	1.85	0.436	-	0.438	2.25
0.740	-	0.744	1.46	0.565	-	0.568	1.86	0.433	-	0.435	2.26
0.735	-	0.739	1.47	0.561	-	0.564	1.87	0.430	-	0.432	2.27
0.730	-	0.734	1.48	0.557	-	0.560	1.88	0.427	-	0.429	2.28
0.725	-	0.729	1.49	0.553	-	0.556	1.89	0.425	-	0.426	2.29
0.720	-	0.724	1.50	0.550	-	0.552	1.90	0.422	-	0.424	2.30
0.716	-	0.719	1.51	0.546	-	0.549	1.91	0.419	-	0.421	2.31
0.711	-	0.715	1.52	0.542	-	0.545	1.92	0.416	-	0.418	2.32
0.706	-	0.710	1.53	0.539	-	0.541	1.93	0.414	-	0.415	2.33
0.701	-	0.705	1.54	0.535	-	0.538	1.94	0.411	-	0.413	2.34
0.696	-	0.700	1.55	0.532	-	0.534	1.95	0.408	-	0.410	2.35
0.692	-	0.695	1.56	0.528	-	0.531	1.96	0.406	-	0.407	2.36
0.687	-	0.691	1.57	0.525	-	0.527	1.97	0.403	-	0.405	2.37
0.682	-	0.686	1.58	0.521	-	0.524	1.98	0.400	-	0.402	2.38
0.678	-	0.681	1.59	0.518	-	0.520	1.99	0.398	-	0.399	2.39
0.673	-	0.677	1.60	0.514	-	0.517	2.00	0.395	-	0.397	2.40
0.669	-	0.672	1.61	0.511	-	0.513	2.01	0.393	-	0.394	2.41
0.664	-	0.668	1.62	0.507	-	0.510	2.02	0.390	-	0.392	2.42
0.660	-	0.663	1.63	0.504	-	0.506	2.03	0.388	-	0.389	2.43
0.655	-	0.659	1.64	0.501	-	0.503	2.04	0.385	-	0.387	2.44
0.651	-	0.654	1.65	0.497	-	0.500	2.05	0.383	-	0.384	2.45
0.646	-	0.650	1.66	0.494	-	0.496	2.06	0.380	-	0.382	2.46
0.642	-	0.645	1.67	0.491	-	0.493	2.07	0.378	-	0.379	2.47
0.638	-	0.641	1.68	0.488	-	0.490	2.08	0.375	-	0.377	2.48
0.633	-	0.637	1.69	0.484	-	0.487	2.09	0.373	-	0.374	2.49
0.629	-	0.632	1.70	0.481	-	0.483	2.10	0.370	-	0.372	2.50
0.625	-	0.628	1.71	0.478	-	0.480	2.11	0.368	-	0.369	2.51
0.621	-	0.624	1.72	0.475	-	0.477	2.12	0.366	-	0.367	2.52
0.616	-	0.620	1.73	0.472	-	0.474	2.13	0.363	-	0.365	2.53
0.612	-	0.615	1.74	0.469	-	0.471	2.14	0.361	-	0.362	2.54
0.608	-	0.611	1.75	0.466	-	0.468	2.15	0.359	-	0.360	2.55
0.604	-	0.607	1.76	0.462	-	0.465	2.16	0.356	-	0.358	2.56
0.600	-	0.603	1.77	0.459	-	0.461	2.17	0.354	-	0.355	2.57
0.596	-	0.599	1.78	0.456	-	0.458	2.18	0.352	-	0.353	2.58
0.592	-	0.595	1.79	0.453	-	0.455	2.19	0.349	-	0.351	2.59

NOTE: When the Count Ratio falls between two densities, calculate D=-ln((CR+c)/a)/b or report the lower density value.

1

Count Ratio versus Density

50mm (2-inch) Penetration Mode Correlation Coefficient (r): 0.9992 Pass

Gage Owner: Caltrans Gage S/N: 10040 Calibration Date: 3/10/2014

Operator: A. Diolazo Gage Model: CPN MC-1DR-P Std Ct (at Calib): 40491

EQUIVALENT soil densities of the three metal standard density blocks (1.0 g/cc = 62.428 PCF) ADL= ± 1215

PCF	162.92	136.17	109.96	a= 9.694428
g/cc	2.610	2.181	1.761	b= 0.464270
Count Ratio	1.434	2.069	2.827	c= 1.452166

Count Ratio CR		Density G/CC	Count Ratio CR	to CR	Density G/CC	Count Ratio CR	to CR	Density G/CC
3.598	3.621	1.40	2.742	2.761	1.80	2.032	2.047	2.20
3.575	3.597	1.41	2.723	2.741	1.81	2.015	2.031	2.21
3.551	3.574	1.42	2.704	2.722	1.82	1.999	2.014	2.22
3.528	3.550	1.43	2.684	2.703	1.83	1.983	1.998	2.23
3.505	3.527	1.44	2.665	2.683	1.84	1.968	1.982	2.24
3.482	3.504	1.45	2.646	2.664	1.85	1.952	1.967	2.25
3.459	3.481	1.46	2.627	2.645	1.86	1.936	1.951	2.26
3.437	3.458	1.47	2.608	2.626	1.87	1.920	1.935	2.27
3.414	3.436	1.48	2.589	2.607	1.88	1.905	1.919	2.28
3.392	3.413	1.49	2.571	2.588	1.89	1.889	1.904	2.29
3.369	3.391	1.50	2.552	2.570	1.90	1.874	1.888	2.30
3.347	3.368	1.51	2.534	2.551	1.91	1.858	1.873	2.31
3.325	3.346	1.52	2.515	2.533	1.92	1.843	1.857	2.32
3.302	3.324	1.53	2.497	2.514	1.93	1.828	1.842	2.33
3.280	3.301	1.54	2.478	2.496	1.94	1.812	1.827	2.34
3.258	3.279	1.55	2.460	2.477	1.95	1.797	1.811	2.35
3.237	3.257	1.56	2.442	2.459	1.96	1.782	1.796	2.36
3.215	3.236	1.57	2.424	2.441	1.97	1.767	1.781	2.37
3.193	3.214	1.58	2.406	2.423	1.98	1.752	1.766	2.38
3.172	3.192	1.59	2.388	2.405	1.99	1.738	1.751	2.39
3.150	3.171	1.60	2.371	2.387	2.00	1.723	1.737	2.40
3.129	3.149	1.61	2.353	2.370	2.01	1.708	1.722	2.41
3.108	3.128	1.62	2.335	2.352	2.02	1.693	1.707	2.42
3.087	3.107	1.63	2.318	2.334	2.03	1.679	1.692	2.43
3.066	3.086	1.64	2.300	2.317	2.04	1.664	1.678	2.44
3.045	3.065	1.65	2.283	2.299	2.05	1.650	1.663	2.45
3.024	3.044	1.66	2.266	2.282	2.06	1.636	1.649	2.46
3.003	3.023	1.67	2.248	2.265	2.07	1.621	1.635	2.47
2.983	3.002	1.68	2.231	2.247	2.08	1.607	1.620	2.48
2.962	2.982	1.69	2.214	2.230	2.09	1.593	1.606	2.49
2.942	2.961	1.70	2.197	2.213	2.10	1.579	1.592	2.50
2.921	2.941	1.71	2.180	2.196	2.11	1.565	1.578	2.51
2.901	2.920	1.72	2.163	2.179	2.12	1.551	1.564	2.52
2.881	2.900	1.73	2.147	2.162	2.13	1.537	1.550	2.53
2.861	2.880	1.74	2.130	2.146	2.14	1.523	1.536	2.54
2.841	2.860	1.75	2.113	2.129	2.15	1.509	1.522	2.55
2.821	2.840	1.76	2.097	2.112	2.16	1.496	1.508	2.56
2.801	2.820	1.77	2.080	2.096	2.17	1.482	1.495	2.57
2.781	2.800	1.78	2.064	2.079	2.18	1.468	1.481	2.58
2.762	2.780	1.79	2.048	2.063	2.19	1.454	1.467	2.59

NOTE: When the Count Ratio falls between two densities, calculate D=-ln((CR+c)/a)/b or report the lower density value.

TABLE 3: Example Count Ratio vs. Moisture Data Sheet and Curve Fitting

6

Count Ratio versus Moisture

Gage Owner: *Caltrans*
Operator: *A. Diolazo*
Gage S/N: *MD00505650*
Gage Model: *CPN-MC-1DR-P*
Calibration Date: *3/11/2014*
Std Ct (at Calib): *9552*
ADL= *± 287*
e = *0.053497*
f = *1.042645*

Moisture calibration readings of the two moisture standard density blocks (1.0 g/cc = 62.428 PCF)

PCF	0.00	22.50
g/cc	0.000	0.360
Count Ratio	0.053	0.429

Count Ratio CR			Density G/CC	Count Ratio CR	to	CR	Density G/CC	Count Ratio CR	to	CR	Density G/CC
0.048	-	0.059	0.00	0.258	-	0.267	0.20	0.466	-	0.476	0.40
0.060	-	0.069	0.01	0.268	-	0.278	0.21	0.477	-	0.486	0.41
0.070	-	0.080	0.02	0.279	-	0.288	0.22	0.487	-	0.497	0.42
0.081	-	0.090	0.03	0.289	-	0.299	0.23	0.498	-	0.507	0.43
0.091	-	0.100	0.04	0.300	-	0.309	0.24	0.508	-	0.517	0.44
0.101	-	0.111	0.05	0.310	-	0.319	0.25	0.518	-	0.528	0.45
0.112	-	0.121	0.06	0.320	-	0.330	0.26	0.529	-	0.538	0.46
0.122	-	0.132	0.07	0.331	-	0.340	0.27	0.539	-	0.549	0.47
0.133	-	0.142	0.08	0.341	-	0.351	0.28	0.550	-	0.559	0.48
0.143	-	0.153	0.09	0.352	-	0.361	0.29	0.560	-	0.570	0.49
0.154	-	0.163	0.10	0.362	-	0.372	0.30	0.571	-	0.580	0.50
0.164	-	0.173	0.11	0.373	-	0.382	0.31	0.581	-	0.590	0.51
0.174	-	0.184	0.12	0.383	-	0.392	0.32	0.591	-	0.601	0.52
0.185	-	0.194	0.13	0.393	-	0.403	0.33	0.602	-	0.611	0.53
0.195	-	0.205	0.14	0.404	-	0.413	0.34	0.612	-	0.622	0.54
0.206	-	0.215	0.15	0.414	-	0.424	0.35	0.623	-	0.632	0.55
0.216	-	0.226	0.16	0.425	-	0.434	0.36	0.633	-	0.643	0.56
0.227	-	0.236	0.17	0.435	-	0.444	0.37	0.644	-	0.653	0.57
0.237	-	0.246	0.18	0.445	-	0.455	0.38	0.654	-	0.663	0.58
0.247	-	0.257	0.19	0.456	-	0.465	0.39	0.664	-	0.674	0.59

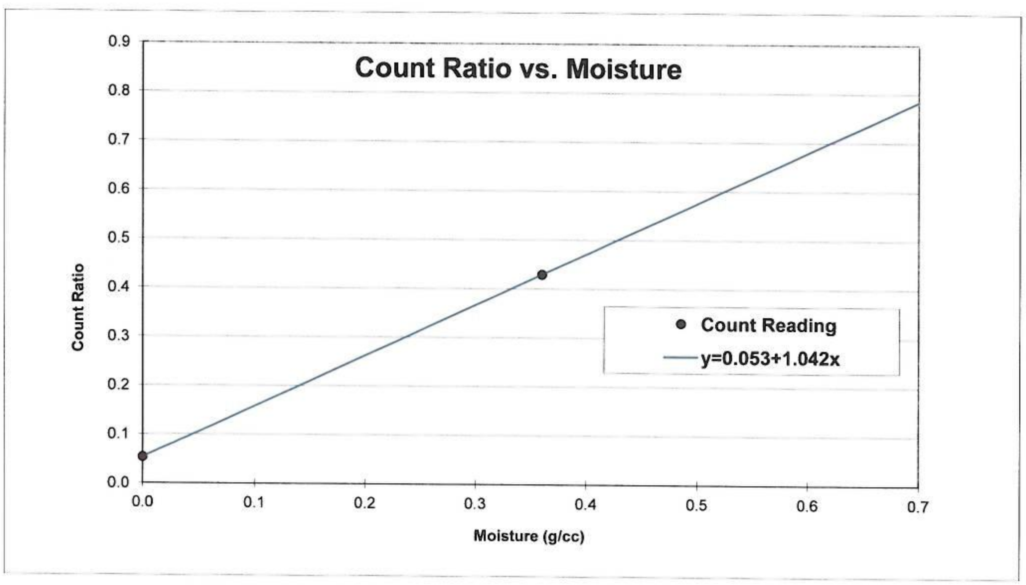
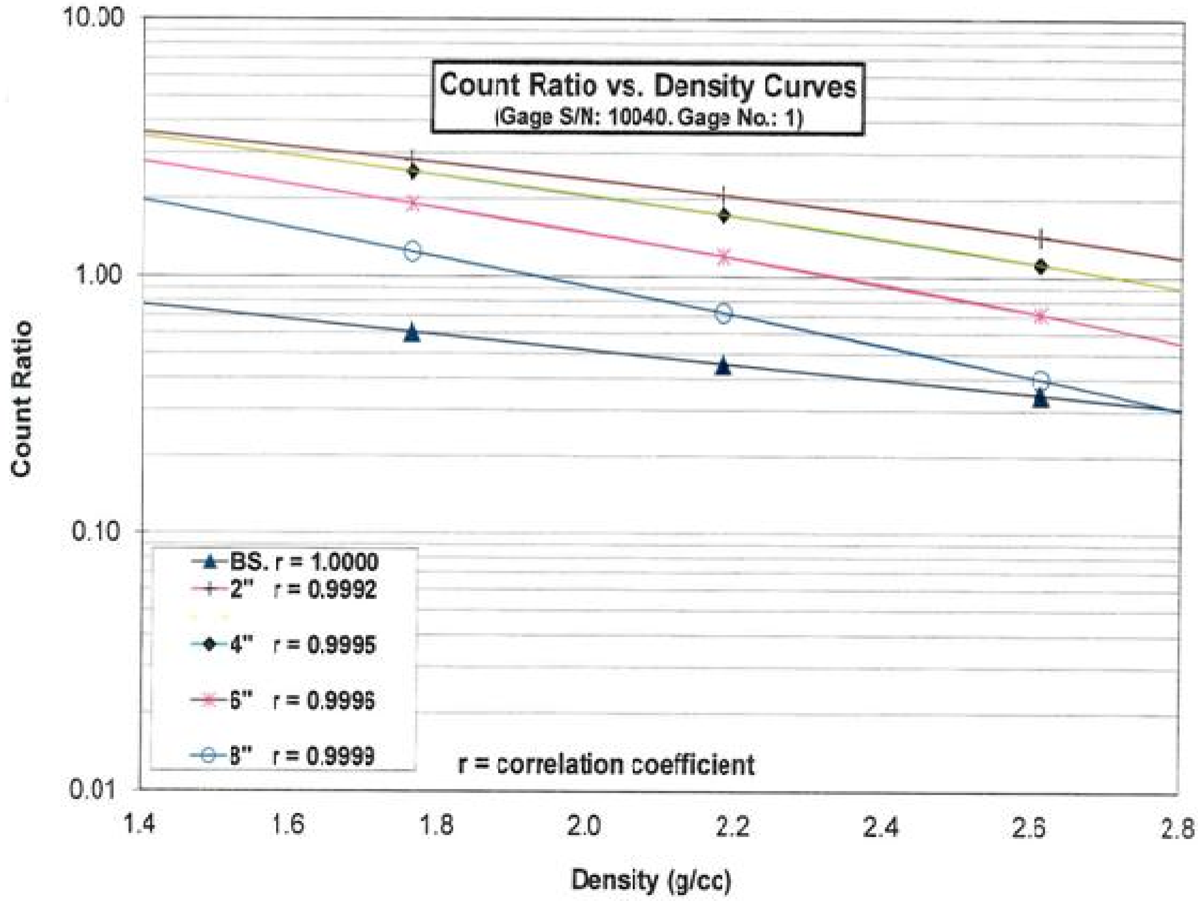


Figure 1: Example Count Ratio vs. Density for all Test Modes



Form TL-0114 (2014)

AFFIDAVIT OF NUCLEAR GAUGE CALIBRATION

Gauge Serial Number: ______________________

Model Number: ______________________

Calibration Facility: ______________________

Address: ______________________

____

____

Gauge Calibration Date: ______________________

Date of Last Leak Test: ______________________

I certify that this gauge has been calibrated in accordance with California Test 111, Developing Density and Moisture Calibration Tables for Nuclear Gauges and has had a leak test performed no less than the frequency listed in the Radioactive Materials License issued by the California Department of Public Health. Further I attest that the gauge is in safe working order.

Person performing the calibration:

______________________	______________________
Printed Name	Title
______________________	______________________
Signature	Date

I certify that I have reviewed the calibration procedure and data, and concur that it has been calibrated in accordance with California Test 111, Developing Density and Moisture Calibration Tables for Nuclear Gauges, and that all required data is attached.

Laboratory manager:

______________________	______________________
Printed Name	Title
______________________	______________________
Signature	Date

Attachments:

Calibration report	☐	Gauge calibration sheets	☐
Current block traceability	☐	Current leak test results	☐

Figure 2. Affidavit of Nuclear Gauge Calibration

DEPARTMENT OF TRANSPORTATION
California Test 111
Form TL-0114 (2014)

AFFIDAVIT OF NUCLEAR GAUGE CALIBRATION

Gauge Serial Number:	HRT 25897
Model Number:	HRT 443
Calibration Facility:	Harry Roberts Calibration Services
Address:	5280 Long Fall Road
	High Points R Us, California 99999
Gauge Calibration Date:	August 08, 2010
Date of Last Leak Test:	August 08, 2010

I certify that this gauge has been calibrated in accordance with California Test 111, Developing Density and Moisture Calibration Tables for Nuclear Gauges and has had a leak test performed no less than the frequency listed in the Radioactive Materials License issued by the California Department of Public Health. Further I attest that the gauge is in safe working order.

Person performing the calibration:

Harry Roberts Jr.	Calibration Technician
Printed Name	Title
Harry Roberts Jr.	August 08, 2010
Signature	Date

I certify that I have reviewed the calibration procedure and data, and concur that it has been calibrated in accordance with California Test 111, Developing Density and Moisture Calibration Tables for Nuclear Gauges, and that all required data is attached.

Laboratory manager:

Harry Roberts Sr.	Owner Manager
Printed Name	Title
Harry Roberts Sr.	August 09, 2010
Signature	Date

Attachments:

Calibration report	☑	Gauge calibration sheets	☑
Current block traceability	☑	Current leak test results	☑

Figure 3. Example of Affidavit of Nuclear Gauge Calibration

End of Text
(California Test 111 contains 15 pages)