OHD L-14
METHOD OF TEST FOR BULK SPECIFIC GRAVITY, PERCENT ABSORPTION, PERCENT AIR VOIDS, PERCENT DENSITY, AND LONGITUDINAL JOINT DENSITY IN COMPACTED DENSE AND OPEN GRADED ASPHALT MIXTURES

PROCEDURE I
Determination of Bulk Specific Gravity and Percent Absorption of Compacted Specimens

Use AASHTO T 166 with the following exceptions:

1. Samples which by design contain open or interconnected voids shall be tested using OHD L-45.

2. Use Method A only.

3. If the sequence of testing has been changed to determine the dry mass last and the specimens are not required to be saved, the specimens may be dried to a constant mass at 230º ± 9ºF [110º ± 5ºC]. See T 166 for the definition of constant mass.

4. If the percent absorption is more than the limit shown in T 166, the results are invalid and shall not be used for air void or density determination.

    a. Retest the specimen using L-45.
    b. AASHTO T 275, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens, is not acceptable.

5. Optionally, the diameter and height of specimens may be recorded. Measure or calculate these according to ASTM D 3549. Report the three diameter readings to a minimum of 0.1 mm and the average to 1 mm. If measured, report the four height readings to at least 0.01 inches and the average to 0.01 inches.

PROCEDURE II
Determination of Bulk Specific Gravity of Compacted Asphalt Pavement by Use of the Nuclear Gauge

I. **SCOPE.** This test method covers the test procedure for determining the unit weight and bulk specific gravity of bituminous concrete pavement by the attenuation of gamma radiation, where the source and detectors remain on the surface. The unit weight is determined by comparing the detected rate of gamma emissions with previously established calibration data. The bulk specific gravity (G_{mb}) of the compacted bituminous mixture can be calculated using the unit weight of the mixture.

II. **SIGNIFICANCE AND USE.** The test method described is useful as a rapid, nondestructive technique for determining the relative in-place unit weight of compacted bituminous mixtures. This test method may be used to establish the proper rolling effort and pattern to achieve the required density. With proper calibration and correlation testing, this test method is suitable for quality control and acceptance testing of compacted bituminous concrete.

A. The results obtained by this test method are relative. This test method may be used for quality control and acceptance testing if correlation testing with roadway cores is performed. It is recommended that at least five (5) roadway core results be compared with their corresponding nuclear gauge results to establish the correlation. A new correlation must be established for each paving mixture, each lift, each major change in job location, and each time a significant change is made in the paving mixture or in the construction process. This correlation is necessary to achieve accurate results (see Appendix A - Correlation of Nuclear Gauge with Roadway Cores).

III. **APPARATUS.** The apparatus shall consist of the following:

A. **Nuclear Device,** an electronic counting instrument, capable of being seated on the surface of the material under test, and which contains:

1. Gamma Source, a sealed high energy gamma source such as cesium or radium.

2. Gamma Detector, any type of gamma detector such as Geiger-Mueller tubes.

B. **Reference Standard,** a block of dense material used for checking instrument operation and to establish conditions for a reproducible reference-count rate.

C. **Site Preparation Device,** a metal plate, straightedge, or other suitable leveling tool which may be used to level the test site to the required smoothness using fine sand, fly ash, cement, or similar material.

NOTE: This equipment utilizes radioactive materials which may be hazardous to the health of the users unless proper precautions are taken. Users of this equipment must become familiar with applicable safety procedures and government regulations.

IV. **CALIBRATION.** Calibrate the instrument in accordance with the manufacturer's recommendations at least once each year or at intervals recommended by the manufacturer. ASTM D 2950, Annex A1 provides additional information on calibration.

V. **STANDARDIZATION AND REFERENCE CHECK.** Nuclear test devices are subject to long-term aging of the radioactive source, detectors, and electronic systems, which may change the relationship between count rate and material density. To offset this aging, the apparatus may be standardized as the ratio of the measured count rate to a count rate made on a reference standard. The reference count rate should be of the same order of magnitude as the measured count rate over the useful density range of the apparatus.

A. Standardization of equipment should be performed at the start of each day's work, and a permanent record of this data retained.

B. Perform the standardization with the apparatus located at least 33 ft. (10 m) away, or other distance as recommended by the manufacturer from other sources of radioactivity and clear of large masses or other items which may affect the reference count rate.

C. Turn on the apparatus prior to standardization and allow it to stabilize. Follow the manufacturer's recommendations in order to provide the most stable and consistent results.

D. Using the reference standard, take the standard count in accordance with the manufacturer's recommendation.

E. If the value obtained is within the limits specified by the manufacturer, the apparatus is considered to be in satisfactory operating condition. If the value is outside these limits, allow additional time for the apparatus to stabilize, make sure the area is clear of sources of interference and then conduct another standardization check. If the second standardization check is within the limits, the apparatus may be used, but if it fails, the apparatus shall be adjusted or repaired as recommended by the manufacturer. ASTM D 2950, Section 8 provides additional information on standardization.

NOTE: For some gauges, the adjustment may be to take a series of 5 to 6 standard counts, storing each count in memory, to establish a new standard count average in the gauge. If after the additional 6 standard counts, the value obtained is not within the limits specified by the manufacturer, the apparatus shall be repaired as recommended by the manufacturer.

VI. **PROCEDURE.** In order to provide stable and consistent results, turn the instrument on prior to use to allow it to stabilize, and leave the power on during the day's testing.

A. Standardize the apparatus.

B. Select a test location. Set instrument for two minute counts. Set depth to measure.

C. Maximum contact between the base of the instrument and the surface of the material under test is critical. The maximum void shall not exceed 6 mm. Use native fines, fine sand, cement, or fly ash to fill the voids and level with the guide/scraper plate.

D. Record the unit weight to the nearest 0.1 pcf for each count. Perform one (1) count and rotate the gauge 180^{o} and take a second (2) count. If the difference in the two readings is more than 3.0 pcf, take a third (3) reading and rotate the gauge 180° and take the final fourth (4) reading. Average the 2 to 4 counts and report to 0.1 pcf.

NOTE: Do not leave the gauge on a hot surface for an extended period of time. Prolonged high temperatures may adversely affect the instrument's electronics. The gauge should be allowed to cool between measurements.

VII. **CALCULATION OF RESULTS.** Determine the bulk specific gravity as follows:

A. Determine the average unit weight for the test location.

B. Calculate the nuclear bulk specific gravity of the bituminous concrete as follows (report the value to the nearest 0.001):

$$\text{(eq. 1)} \quad NBSG = \frac{Unit\ Weight\ (pcf)}{62.4}$$

C. Using the Correlation Equation (eq. 2, general equation of a line) developed for this mixture, convert the NBSG to a correlated bulk specific gravity (see Appendix A - Correlation of Nuclear Gauge with Roadway Cores). Report G_{mb} values to the nearest 0.001.

(eq. 2) $y = m \, X \, x + b$

Where:

y = correlated G_{mb}
m = slope of the regressed line
x = NBSG
b = y-intercept of the line (This term can be positive or negative in value.)

D. The correlation must:

1. Have a minimum coefficient of determination (R^2) of 0.50 to be acceptable for acceptance of test results.
2. Determine the y-intercept (b) and slope (m). Report the values to nearest 0.0001.
3. Outliers may be removed as explained next.
   a. Outliers for G_{mb} values are determined by a mathematical analysis performed in accordance with ASTM E 178 (upper 2.5% significance level). Test results thus determined by the Engineer to be non-representative of the material being evaluated may be optionally discarded. Data not used for the correlation will be documented. The final correlation must contain a minimum of 5 sets of cores and nuclear gauge readings with a maximum of 15 sets used for the linear regression to determine (m) and (b).

PROCEDURE III
Determination of Unit Weight by Use of the Electromagenetic Density-Testing Gauge

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I. **SCOPE.** This test method covers the test procedure for determining the unit weight of bituminous concrete pavement by measuring the impedance or dielectric properties of the pavement using an electromagnetic sensing device. As the pavement is compacted, the air voids decrease and the dielectric properties change. The unit weight is determined by comparing the detected impedance or dielectric properties with previously established dielectric constants of the pavement components.

II. **SIGNIFICANCE AND USE.** The test method described is useful as a rapid, nondestructive technique for determining the relative in-place unit weight of compacted bituminous mixtures. This test method may be used to establish the proper rolling effort and pattern to achieve the required density or determination of unit weight for longitudinal joint density. The method is not suitable for acceptance testing of compacted bituminous concrete.

A. The unit weight results obtained by this test method are relative.

III. **APPARATUS.** The apparatus shall consist of the following:

A. **Electromagnetic Device,** an electromagnetic instrument, capable of being seated on the surface of the material under test.

NOTE: Because this equipment has no nuclear source, it does not require a daily “standardization check”. However, some electromagnetic gauges come with a reference block. This allows the user to check the accuracy of gauge measurements whenever desired. If the reference check fails, contact the manufacturer’s technical support.

NOTE: This equipment does not utilize material which may be hazardous to the health of the users. Users of this equipment are not required to be certified or monitored by any regulatory agency.

IV. **CALIBRATION.** Calibrate the instrument at intervals recommended by the manufacturer.

V. **PROCEDURE.**

A. The gauge will have some general settings to input, such as maximum theoretical density. There will also be inputs that are manufacturer-specific. Input these values as indicated in the manufacturer’s instruction manual. There may be adjustments needed to obtain the obtain unit weight readings in pcf.

B. Select a test location. Set instrument for single reading mode. If the gauge does not have a single reading mode, use averaging mode set to 1 test average.

C. Maximum contact between the base of the instrument and the surface of the material under test is critical. If the gauge can be rocked, select another location which will provide a stable base for the gauge. **DO NOT** use any type of fines to fill the voids and level the gauge.

D. Record the unit weight after the gauge readings stabilize. Clean the gauge foot after each use. Any material buildup will adversely affect the gauge readings.

NOTE: Do not leave the gauge on a hot surface for an extended period of time. Prolonged high temperatures may adversely affect the instrument's electronics.

NOTE: Do not use the gauge when a high level of moisture is present, for example any degree of ponding. Roadway moisture has a very high dielectric constant and will make the unit weight reading falsely high. Similarly, do not operate the gauge immediately after removing from an air-conditioned vehicle on a hot day because some internal condensation may occur.

NOTE: Be sure to remove your hand from the gauge during the reading. Your body will be grounded and affect the gauge reading to show falsely low readings.

VI. **CALCULATION OF RESULTS.** Determine the unit weight as follows:

Determine the average unit weight for the test location from direct reading or adjusted to read in pcf to nearest 0.1.

PROCEDURE IV
Calculations for Percent Air Voids, Percent Density, and Longitudinal Joint Density

I. **SCOPE.** This method of test covers procedures for determining the percent air voids, percent absorption, percent density, and longitudinal joint density in compacted dense and open graded asphalt mixtures.

A. Methods may involve hazardous materials, operations, and equipment. These methods do not purport to address all of the safety concerns associated with their use. It is the responsibility of the user of these methods to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

II. **REFERENCE DOCUMENTS.**

A. AASHTO Standards:
1. T 166, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
2. T 209, Theoretical Maximum Specific Gravity (Gmm) and Density of Hot Mix Asphalt (HMA)
3. T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

B. ASTM Standards:
1. D 2950, Standard Test Method for Density of Bituminous Concrete in Place by Nuclear Methods
2. D 3549, Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
3. E 178, Standard Practice for Dealing With Outlying Observations

C. Department Test Methods (OHDL):
1. L-45, Method of Test for Determining the Specific Gravity and Unit Weight of Compacted Bituminous Paving Mixtures using the Corelok™ Apparatus. This method is similar to T 331
2. L-56, Recommended Practice for Random Selection of Bituminous Mixture Samples

III. **TERMINOLOGY.** The terms *specific gravity* and *density* used in this method and referenced methods are in accordance with ASTM E 1547.

A. *Definitions*: common to some standards but if they differ, these will govern.
1. G_b — specific gravity of binder. Typically 1.01 unless otherwise noted on the mix design.
   G_{mb} — bulk specific gravity of a compacted asphalt mixture.
2. G_{mm} — maximum specific gravity of an asphalt mixture. Sometimes referred to as the theoretical maximum or specific gravity/gravity mix maximum as in T 209.
3. G_{sb} — aggregate bulk specific gravity.
4. G_{se} — aggregate effective specific gravity.
5. *NBSG* — nuclear bulk specific gravity (G_{mb}).
6. P_{abs} — percent of water absorbed by volume for a compacted asphalt. Computation shown in T 166.
7. P_a — *percent air voids.*
8. P_b — percent asphalt binder.
9. *pcf* — pounds per cubic foot.
10. P_s — percent stone or percent aggregate. $100 – P_b = P_s$.
11. PG_{mm} — percent maximum specific gravity of an asphalt mixtures. Referred to as percent maximum theoretical density in ODOT Standard Specifications and Special Provisions.
12. *Rice* — G_{mm} as determined by T 209.
13. *Unit Weight* — gauge density in pcf.

IV. **SIGNIFICANCE AND USE.**

A. The percent air voids in an asphalt mixture is used as one of the criteria in the design methods and for evaluation of the compaction achieved on asphalt paving projects. Air voids generally refer to laboratory compacted specimens while density usually refers to field compacted specimens of pavement though the terms can be interrelated depending on Specifications or use in equations.

V. CALCULATIONS.

A. The equations for computation of G_{mb} for lab molded specimens and roadway cores are detailed in the test method T 166 with exceptions shown in Procedure I. The equations and calculations for G_{mb} and percent of water absorbed by volume (P_{abs}) are shown in it.

B. If G_{mb} is to be determined from a correlated nuclear density-testing gauge, see Procedure II for calculation details.

C. Calculation details for maximum theoretical specific gravity (G_{mm}) from the Rice test are detailed in T 209. The equation is also listed in eq. 1 since it may be required or rearranged later for other equations. Report to 0.001 place.

$$\text{(eq. 1)} \quad G_{mm} = \frac{100}{\left(\frac{P_s}{G_{se}} + \frac{P_b}{G_b}\right)}$$

D. The computation of G_{se} is (eq. 1) rearranged as shown in eq. 2. Report to nearest 0.001.

$$\text{(eq. 2)} \quad G_{se} = \frac{P_s}{\left(\frac{100}{G_{mm}} - \frac{P_b}{G_b}\right)}$$

E. The calculation formula for percent air voids (P_a) is either eq. 3 or eq. 4. Report to nearest 0.1.

$$\text{(eq. 3)} \quad P_a = 100\, X \left[\frac{(G_{mm} - G_{mb})}{G_{mm}}\right]$$

$$\text{(eq. 4)} \quad P_a = 100\, X \left[1 - \left(\frac{G_{mb}}{G_{mm}}\right)\right]$$

F. Percent density (PG_{mm}) of roadway cores is shown in eq. 5. Report to nearest 0.1.

$$\text{(eq. 5)} \quad PG_{mm} = 100\, X \left(\frac{G_{mb}}{G_{mm}}\right)$$

Note: Computing percent air voids and percent density can be computed by subtracting either from 100 to obtain the other.

G. Percent densities (PG_{mm}) of longitudinal joints, if required, are determined in step “F” after obtaining the corrected G_{mb} from step “A” or “B” as applicable. Report result to nearest 0.1.

APPENDIX A
Correlation of Nuclear Gauge with Roadway Cores

1. On the compaction test strip or on a "lot/sublot" of asphalt concrete, identify 5 to 15 test locations. Choose random locations that might represent low, middle, and high levels of compaction. Three of the locations may include the three stratified random stations and random offsets for core density as detailed in L-56. Cut core locations should not be closer than 15 feet to each other to minimize impact to pavement structure.

2. At each location, determine the unit weight and NBSG in accordance with Alternate Method A of this procedure. The gauge positions are shown in Figure 1.

3. After tests are completed using the nuclear gauge, cut a roadway core at each location as shown in Figure 1 and determine the core bulk specific gravity in accordance with this method.

4. Use a standard Excel file recommended by ODOT to perform the correlation.

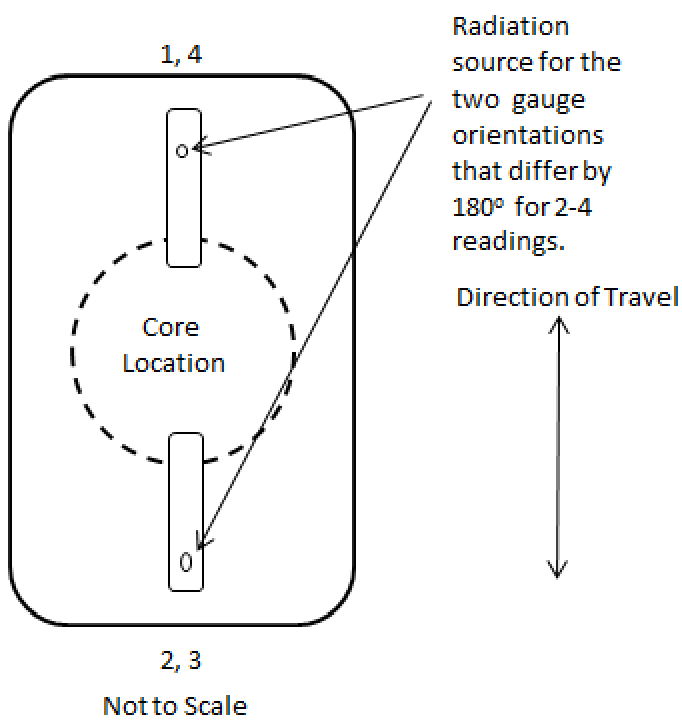
4. Graph the data as shown in Figure 2, plotting the nuclear bulk specific gravity on the horizontal axis and the core bulk specific gravity on the vertical axis.

6. Example data is shown in Figure 3.

7. For daily acceptance tests, use the Correlation Equation to determine the Bulk Specific Gravity from the Nuclear Bulk Specific Gravity.

8. A new correlation is required for each paving mixture, each lift, each major change in job location, and each time a change is made in the paving mixture or in the construction process.

FIGURE 1
GAUGE POSITIONS



Shown are the required gauge positions for density testing. Note the direction of travel. Core required for correlation purposes only, not required for routine acceptance testing.

FIGURE 2: BULK SPECIFIC GRAVITY - CORES VS. NUCLEAR

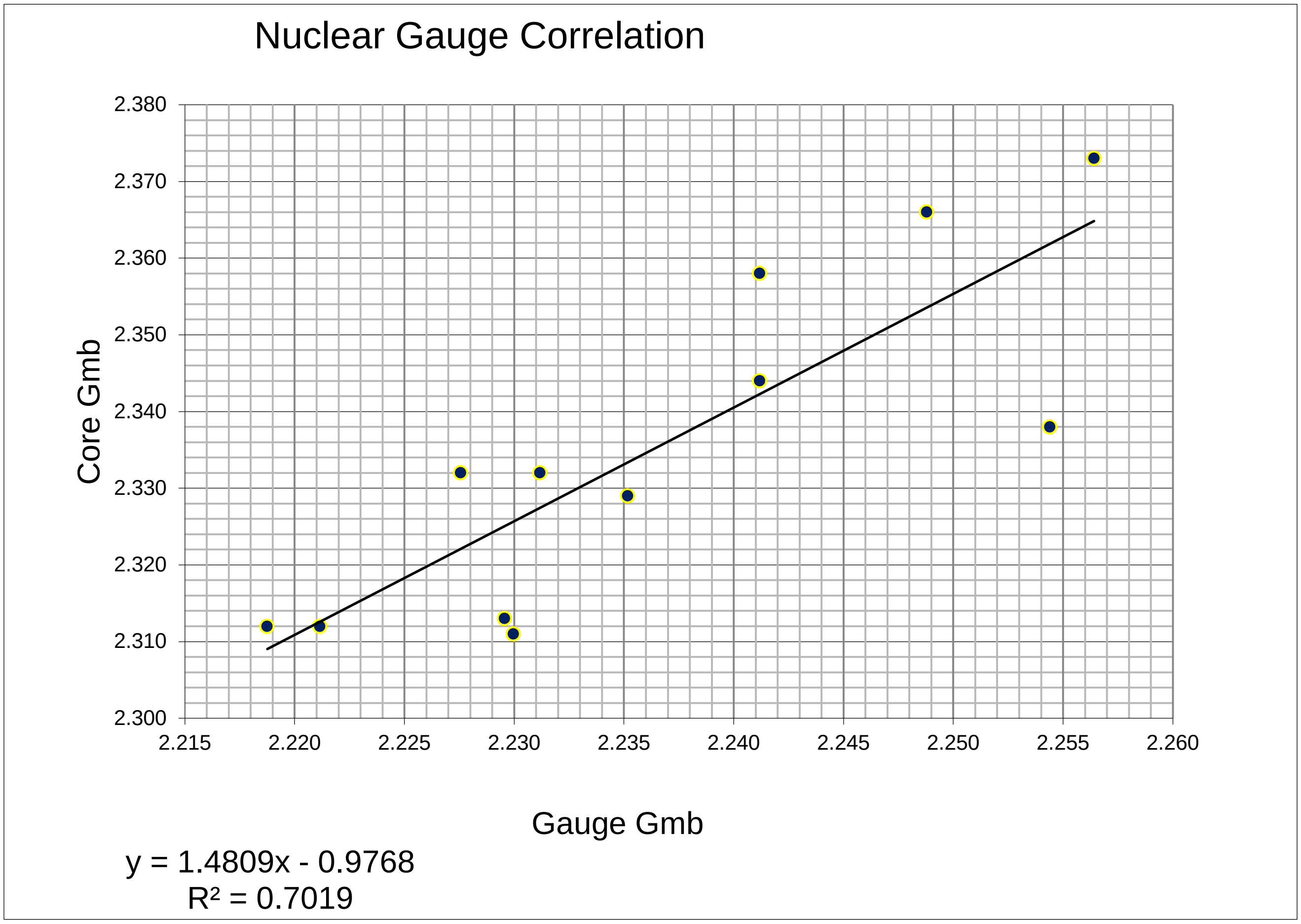


FIGURE 3: EXAMPLE DATA

v 1.00

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McAlester Residency

Correlation of Nuclear Gauge with Roadway Cores
OHD L-14 Appendix A

Project		Job Piece		Contract	
Contractor		Producer		Plant Location	
Mix Type		Design No.		Date Reported	
Gauge	Nuclear	Gauge ID		Correlation No.	

Avg. G_{mm} 2.485
Avg. Corr. PG_{mm} 94.0

Results of Correlation

m	1.4809
b	-0.9768
R^2	0.70
Gauge Correlates to Cores	TRUE

			Nuclear Gauge Readings						**OHD L-14**						ASTM	ASTM			ASTM		
		Location	Unit Weight (PCF)					Known_xs	**Roadway Core Weights (grams)**						D 3549	D 3549			D 321	Known_ys	
Lot Number	Sublot Number	Test/Core Number	1	2	3	4	Avg.	Nuclear Gauge Gmb	Air	Water	SSD	Initial Air	Sealed Air	Sealed H2O	Dia. mm	Height in.	%Abs.	SSD Gmb	Vacuum Gmb	Core Gmb	Correlated Gmb
1	1	1	139.0	139.2	139.4	139.0	139.2	2.230	1215.0	697.7	1227.8	1214.2	1215.4	685.1	150	1.17	2.4	2.292	2.311	2.311	2.326
1	1	2	141.8	136.2	139.9	141.5	139.9	2.241	1217.0	699.0	1218.3				150	1.16	0.3	2.344	#N/A	2.344	2.342
1	1	3	139.1	138.9	141.6	141.7	140.3	2.249	1212.5	702.4	1214.9				150	1.14	0.5	2.366	#N/A	2.366	2.354
1	2	1	138.4	141.7	139.5	139.8	139.9	2.241	1216.1	702.8	1218.6				150	1.15	0.5	2.358	#N/A	2.358	2.342
1	2	2	138.7	139.8	140.7	138.7	139.5	2.235	1213.3	694.1	1215.0				150	1.16	0.3	2.329	#N/A	2.329	2.333
1	2	3	141.4	139.5	140.2	141.6	140.7	2.254	1218.9	698.8	1220.2				150	1.16	0.2	2.338	#N/A	2.338	2.362
1	3	1	142.1	141.8	141.0	138.3	140.8	2.256	1214.4	704.3	1216.1				150	1.14	0.3	2.373	#N/A	2.373	2.365
1	3	2	136.3	140.7	140.0	139.5	139.1	2.230	1215.8	691.9	1217.5				150	1.17	0.3	2.313	#N/A	2.313	2.325
1	3	3	140.2	136.4	138.4	139.4	138.6	2.221	1211.6	689.0	1213.1				150	1.17	0.3	2.312	#N/A	2.312	2.313
1	4	1	138.8	136.5	139.7	141.0	139.0	2.228	1217.7	697.2	1219.4				150	1.16	0.3	2.332	#N/A	2.332	2.322
1	4	2	135.7	137.4	139.7	141.0	138.5	2.219	1211.6	689.0	1213.1				150	1.17	0.3	2.312	#N/A	2.312	2.309
1	4	3	136.9	139.3	139.7	141.0	139.2	2.231	1217.7	697.2	1219.4				150	1.16	0.3	2.332	#N/A	2.332	2.327
								#N/A										#N/A	#N/A	#N/A	#N/A
								#N/A										#N/A	#N/A	#N/A	#N/A
								#N/A										#N/A	#N/A	#N/A	#N/A

APPENDIX B
Determining Longitudinal Joint Density Using a Density-Testing Gauge

1. Perform longitudinal joint density tests at stations identified for roadway density testing, see OHD L-56.

2. At each station, determine the unit weight using a density-testing gauge at the following locations:
   - At a point centered 8 inches from the joint. Note that a lane may have two longitudinal joints.
   - At the point in the lane where the density is to be determined for roadway density testing.

3. Position nuclear density-testing gauges so that the length is parallel to the direction of traffic. At each test point, average two readings, without moving the gauge, using a minimum of one minute counts each. Two or four minute counts may be used if variability in the one minute count readings is high. Alternatively, at each test point using an electromagnetic density-testing gauge, document the unit weight reading. Because electromagnetic density-testing gauges (NNGs) read continuously, no averaging is necessary.

4. Determine the difference between the unit weights at the random testing point in the lane and 8 inches from the joint(s).

5. If the difference is less than the allowable limit or unit weight of the 8 inch joint offset location is greater than the density core's unit weight, the joint density meets specifications.

6. If the difference is greater than the allowable limit, determine the percent density, PG_{mm}, at the location 8 inches from the joint. The PG_{mm} can be computed using either a core or a correlated nuclear density-testing gauge following the procedure outlined in Appendix A to determine bulk specific gravity. NNGs are not acceptable for computation of PG_{mm}.

7. If the joint density is greater than the minimum requirement, the joint density meets specifications.

Revision Date	Revision Description
8/21/14	Updated page 3, section V(B), to reflect D 2950 limits for radiation source location limit. Removed Note 4 on page 4. NNGs “are” allowed for longitudinal joint density only.
8/15/14	Test method completely rewritten. Method references AASHTO T 166 with a few exceptions. Removed non-nuclear gauge for acceptance. Changed nuclear density gauge counts and orientation. Added additional requirements for nuclear gauge correlations. AASHTO T 275 removed as an acceptable test method. Though not detailed in the test method except here, T 275 is allowed in-lieu-of OHD L-45 for a grace period until 12/31/14.