Colorado Procedure – Laboratory 5306

Standard Method of Test for

Certification of Consultant Nuclear Moisture/ Density and Thin Layer Density Gauges

1. SCOPE

1.1 It is the intent of these procedures to describe the certification of nuclear moisture / density (M/D) and thin layer gauges density (TLD). These procedures will apply to all gauges from engineering consulting companies contracted to perform materials testing.

1.2 The CDOT Staff Materials Nuclear Lab has a calibration bay designed to significantly reduce external influences in the calibration process. M/D gauges will not be placed into operation on CDOT projects until they have been certified within this controlled environment.

1.3 The certification of non-CDOT gauges will be valid for twelve months. Any M/D or TLD gauge that has major repairs (replacement of detection tubes, modules, or the scaler) must be re-certified before being placed on or returned to a CDOT project.

2. PRE-CALIBRATION INSPECTION

2.1 Inspect the gauge's reference standard block for any damage. The seating of the gauge in the standard block is critical for the gauge's repeatability. If a block allows variable seating or the gauge rocks in the standard block the standard block must be repaired or replaced. If the standard block is cracked, split or delaminating it must be replaced because this can affect the moisture standard count. Standard blocks are not interchangeable. Ensure that each standard block is assigned the same identification number as the gauge. If a standard block has been replaced, that gauge must be re-calibrated with the new block.

2.2 The M/D or TLD gauge should be sufficiently charged to allow for six hours of continuous operation.

3. APPARATUS

3.1 CDOT calibration bay located at the Staff Materials Laboratory - Nuclear Lab.

3.2 Calibration blocks of Magnesium/ Polyethylene(Mg/poly), Magnesium (Mg), Magnesium/ Aluminum (Mg/Al), Limestone, Granite, and Aluminum (Al).

3.3 CDOT Form # 1151: Nuclear Equipment Statistical Stability / Drift Test.

3.4 CDOT Nuclear Equipment Moisture / Density Certification Worksheet.

3.5 CDOT Form #30: CDOT CERTIFIED NUCLEAR GAUGE, label to be affixed to non-CDOT M/D gauges.

3.6 M/D or TLD gauge and reference standard block.

3.7 Calculator

3.8 Personnel Dosimeter

NOTE 1: CDOT requires personnel monitoring devices be worn by an individual within proximity to its nuclear gauges. If the company's policy is to not require personnel monitoring devices of its employees, per current Colorado Department of Public Health & Environment directives, then a letter stating that CDOT will be held harmless from any exposure to CDOT nuclear gauges must be provided and signed by the company's Radiation Safety Officer.

4. CERTIFICATION PROCEDURE

4.1 STATISTICAL STABILITY TEST

4.1.1 The M/D or TLD gauge should be turned on to allow the electronics and detector tubes to warm up for at least 30 minutes.

4.1.2 Center the reference standard block on the Magnesium / Aluminum block. The long axis of the reference standard block should match that of the calibration block, with the butt plate being in the front.

4.1.3 Place the M/D or TLD gauge on the reference standard block according to the manufacturer's instructions.

4.1.4 Complete the reference information on the NUCLEAR EQUIPMENT STATISTICAL STABILITY TEST, CDOT Form #1151 (page 1 of 2) (see example, page 5 & 8). Write the DATE, OPERATOR (PRINT FULL NAME LEGIBLY), MODEL OF GAUGE, SERIAL NO., and GAUGE NO. A gauge will be assigned a number by the Staff Materials - Nuclear Lab.

4.1.5 Perform the Statistical Stability Test. Newer model gauges can be prompted to the STAT MODE. In STAT MODE the gauge will run a twenty-minute test and perform the mathematics internally. When the gauge is finished record the average counts, ratio and each of the twenty, one-minute counts. An older model gauge will need to be placed into a one-minute time base. Twenty one-minute counts will need to be performed, recording both the density standard count and the moisture standard count. Perform the required mathematics and enter the values on the worksheet.

The ideal ratio for Troxler 3401, 3411, 3430, and 3440 Gauges is 0.25, with acceptable limits of 0.17 to 0.33.

For Troxler 3450 Gauges; record the density counts for both systems. The ideal ratio is 0.354 with acceptable limits of 0.225 to 0.465.

For Troxler 4640 Gauges; record the density counts for both systems. The ideal ratio is 0.35, with acceptable limits of 0.25 to 0.45

For Instrotek Gauges the acceptable ratio range is 0.18 to 0.35.

The ideal ratio for CPN Gauges is 1.00, with acceptable limits of 0.75 to 1.25.

4.1.6 If the gauge passes the statistical stability test proceed with the certification. If the gauge fails the statistical stability test, verify the mathematics. If the mathematics are correct, perform another statistical stability test. A second failure will require the equipment to be repaired. If a second statistical stability test passes, then proceed with the certification.

4.2 EQUIPMENT STANDARDIZATION

4.2.1 Center the reference standard block on the Magnesium / Aluminum block. The long axis of the reference standard block should match that of the calibration block, with the butt plate being in the front.

4.2.2 Place the M/D or TLD gauge on the reference standard block according to the manufacturer's instructions. Perform a standard count according to manufacturer's instructions.

NOTE 2: Thin layer density (TLD) gauges do not contain the instrumentation to test for moisture content or density at the transmission depths. TLD gauges will only be required to be certified using the Density Certification-Backscatter procedures.

4.3 MOISTURE CERTIFICATION

4.3.1 Complete the reference information on CDOT Form #723 (see example, page 6). This information is the same as the information provided on CDOT Form #1151.

4.3.2 Place the gauge on Block 2 (Mg/Poly) within the outline. Place the gauge in the backscatter position and record four one-minute moisture content readings [Note 3]. Average the four readings and record the average (see example, page 6).

NOTE 3: Newer gauges may report moisture contents as % moisture. Prompt the gauge to report moisture content in pounds per cubic foot of water. For older gauges that only output counts, the gauge operator will record four one-minute moisture counts. The four one-minute counts will be averaged and then divided by the moisture standard count to obtain a ratio. The ratio will be cross-referenced to the gauge's moisture calibration curve to obtain the moisture content.

4.3.3 Place the gauge on Block 1 (Mg) within the outline. Place the gauge in the backscatter position and record four one-minute moisture content readings. Average the four readings and record the average.

4.4 DENSITY CERTIFICATION-BACKSCATTER

4.4.1. Place the gauge on the Mg block and place the source rod in the backscatter position. CDOT defines the backscatter positions as the positioning in which the tip of the source rod obtains near contact with the block surface. Perform and record four one-minute wet density readings [Note 4]. Average the four readings and record the average (see example, page 6)

NOTE 4: Newer gauges may report both wet density and dry density. It is important to record the wet density because the reading will be compared to the wet density of the calibration blocks. Some gauges have automatic depth sensors, for those that do not, make sure to prompt the gauge to the correct depth. For older gauges that only output counts, the gauge operator will record four one-minute density counts. The four one-minute counts will be averaged and then divided by the density standard count to obtain a ratio. The ratio will be cross-referenced to the gauge's backscatter calibration curve to obtain the wet density.

4.4.2 Place the gauge on the Magnesium / Aluminum block and place the source rod in the backscatter position. Perform and record four one-minute wet density readings. Average the four readings and record the average. Repeat this step for the Limestone, Granite, and Aluminum blocks.

4.5 DENSITY CALIBRATION- TRANSMISSION

4.5.1 Place the gauge to the Magnesium block and extend the source rod no more than two inches until it has been inserted into the rod hole.

4.5.2 Extend the source rod to the 4" depth. Pull the gauge forward to eliminate any air gap between the block and source rod. Perform and record four one-minute wet density readings [Note 5]. Average the four readings and record the average (see example, page 6).

4.5.3 Extend the source rod to 6". Pull the gauge forward to eliminate any air gap between the block and source rod and perform and record four one-minute wet density readings [Note 5]. Average the four readings and record the average.

4.5.4 Extend the source rod to 8". Pull the gauge forward to eliminate any air gap between the block and source rod and perform and record four one-minute wet density readings [Note 5]. Average the four readings and record the average.

NOTE 5: Newer gauges may report both wet density and dry density. It is important to record the wet density because the reading will be compared to the wet density of the calibration blocks. Some gauges have automatic depth sensors, for those that do not, make sure to prompt the gauge to the correct depth. For older gauges that only output counts, the gauge operator will record four one-minute density counts. The four one-minute counts will be averaged and then divided by the density standard count to obtain a ratio. The ratio will be cross-referenced to gauge's transmission calibration curves to obtain the wet density.

4.5.5 Repeat the procedures indicated in Subsections 4.5.2 through 4.5.4 on the Magnesium/ Aluminum, Limestone, Granite, and Aluminum Blocks.

4.6 DRIFT TEST

4.6.1 Center the reference standard count block on the Magnesium / Aluminum block.

4.6.2 Place the M/D or TLD gauge on the reference standard block. The gauge must be properly seated in the standard block. Make sure the gauge is in its safe position with the scaler towards the front of the block.

4.6.3 Page 2 of CDOT Form #1151 (see example, page 7 & 9) will be used to record test data.

4.6.4 Perform the Drift Test. Newer model gauges can be prompted to the DRIFT MODE. In DRIFT MODE the gauge will run a twenty-minute test and perform the mathematics internally. When the gauge is finished record the average counts, drift and each of the five, four-minute counts. An older model gauge will need to be placed into a four-minute time base. Five four-

minute counts will need to be performed, recording both the density standard count and the moisture standard count.

The acceptable drift for Troxler 3401, 3411, 3430, and 3440 and Instrotek Gauges is less than 0.50% for density and less than 1.00% for moisture.

For Troxler 3450 Gauges; record the density counts for both systems. The acceptable drift is less than 0.50% for density and less than 1.00% for moisture.

For Troxler 4640 Gauges; record the density counts for both systems. The acceptable drift for system 1 is less than 0.50%, and for system 2 is less than 0.80%.

On CPN gauges the Drift Average Counts (DAC) are either acceptable or unacceptable based on the Statistical Stability Average Counts (SSAC). The DAC acceptable range is:

$$SSAC +/- 2.0 \sqrt{SSAC}$$

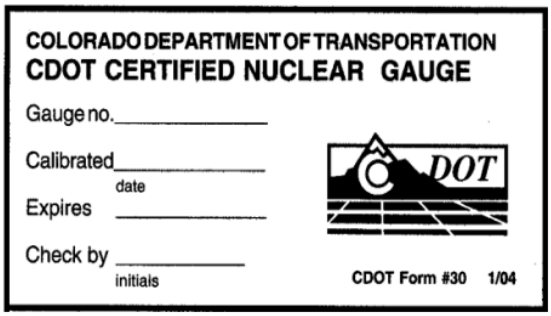
4.6.5 If the gauge fails the drift test then verify the mathematics. If the mathematics are correct, perform a second drift test. A second failure will require the equipment to be repaired.

4.7 M/D GAUGE ACCEPTANCE

4.7.1 The moisture content and wet density readings will be compared to the blocks' known moisture contents and densities. The acceptable deviance from the known moisture content is less than or equal to 1.0 PCF. The acceptable deviance from the known wet density in the backscatter position is less than or equal to 2.0 PCF. The acceptable deviance from the known wet density in the transmission positions is less than or equal to 1.0 PCF.

4.7.2 If the gauge's readings are outside the acceptable deviances on a block, rerun that block and compare the readings to the known wet density or moisture content. If after the second readings, the gauge is outside the acceptable deviance, the gauge will have to be recalibrated.

4.7.3 If the gauge passes the stat & drift tests and all the gauge readings are within the acceptable deviances, a CDOT Certified Nuclear Gauge certificate will be issued. The gauge will have a CDOT CERTIFIED NUCLEAR GAUGE, CDOT Form #30, affixed to the shell of the gauge.



COLORADO DEPARTMENT OF TRANSPORTATION

NUCLEAR EQUIPMENT STATISTICAL STABILITY/DRIFT TEST

Statistical stability test. (Allow gauge to warm up 30 minutes, perform 20 one minute counts)

Counts N (or X)	Density standard count (M/D or TLD gauge)	Moisture standard count (M/D or AC gauge)
1	3743	0.58
2	3745	0.40
3	3780	0.57
4	3753	0.35
5	3749	0.40
6	3760	0.50
7	3748	0.44
8	3743	0.55
9	3752	0.38
10	3780	0.47
11	3743	0.54
12	3768	0.46
13	3730	0.47
14	3749	0.48
15	3739	0.49
16	3759	0.58
17	3761	0.43
18	3756	0.44
19	3749	0.44
20	3769	0.51
Average counts $\bar{N}$ (or $\bar{X}$)	3753.8	0.474
Standard deviation σ (or S)	13.0731	0.00838
Ratio $[S \div (\sqrt{\bar{X}})]$	.213	.263

Ideal ratio .25 / Acceptable limits .17 - .33
(Values found in the calibration procedures)

Date: 10-26-00	Operator: Alex Baca
CDOT no.: 8198	Model of gauge: Troxler 3430-A
Gauge no.: 43448	Serial no.: 23271

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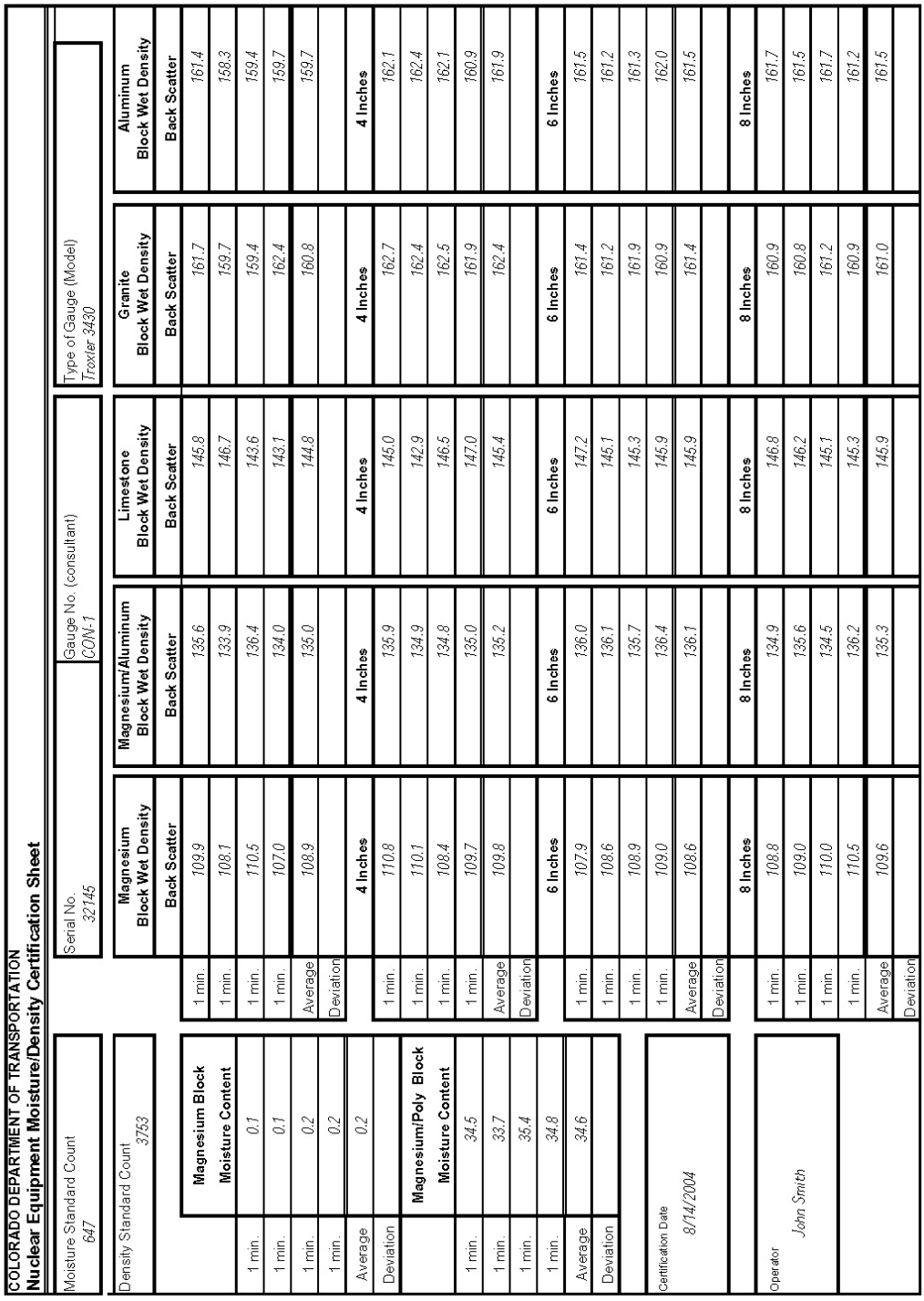

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Nuclear Equipment Moisture/Density Certification Sheet

Moisture Standard Count: *647*	Serial No.: *32145*	Gauge No. (consultant): *CON-1*	Type of Gauge (Model): *Troxler 3430*
Density Standard Count: *3753*			

	Magnesium Block Moisture Content	Magnesium Block Wet Density		Magnesium/Aluminum Block Wet Density		Limestone Block Wet Density		Granite Block Wet Density		Aluminum Block Wet Density	
		Back Scatter		Back Scatter		Back Scatter		Back Scatter		Back Scatter	
1 min.	*0.1*	1 min.	*108.9*	1 min.	*135.6*	1 min.	*145.8*	1 min.	*161.7*	1 min.	*161.4*
1 min.	*0.1*	1 min.	*108.1*	1 min.	*133.9*	1 min.	*146.7*	1 min.	*159.7*	1 min.	*158.3*
1 min.	*0.1*	1 min.	*110.5*	1 min.	*136.4*	1 min.	*143.6*	1 min.	*159.4*	1 min.	*159.4*
1 min.	*0.2*	1 min.	*107.0*	1 min.	*134.0*	1 min.	*143.1*	1 min.	*162.4*	1 min.	*159.7*
1 min.	*0.2*	Average	*108.9*	Average	*135.0*	Average	*144.8*	Average	*160.8*	Average	*159.7*
Average	*0.2*	Deviation		Deviation		Deviation		Deviation		Deviation	
Deviation		**4 Inches**		**4 Inches**		**4 Inches**		**4 Inches**		**4 Inches**	
	Magnesium/Poly Block Moisture Content	1 min.	*110.8*	1 min.	*135.9*	1 min.	*145.0*	1 min.	*162.7*	1 min.	*162.1*
		1 min.	*110.1*	1 min.	*134.9*	1 min.	*142.9*	1 min.	*162.4*	1 min.	*162.4*
1 min.	*34.5*	1 min.	*108.4*	1 min.	*134.8*	1 min.	*146.5*	1 min.	*162.5*	1 min.	*162.1*
1 min.	*33.7*	1 min.	*109.7*	1 min.	*135.0*	1 min.	*147.0*	1 min.	*161.9*	1 min.	*160.9*
1 min.	*35.4*	Average	*109.8*	Average	*135.2*	Average	*145.4*	Average	*162.4*	Average	*161.9*
1 min.	*34.8*	Deviation		Deviation		Deviation		Deviation		Deviation	
Average	*34.6*	**6 Inches**		**6 Inches**		**6 Inches**		**6 Inches**		**6 Inches**	
Deviation		1 min.	*107.9*	1 min.	*136.0*	1 min.	*147.2*	1 min.	*161.4*	1 min.	*161.5*
		1 min.	*108.6*	1 min.	*136.1*	1 min.	*145.1*	1 min.	*161.2*	1 min.	*161.2*
Certification Date: *8/14/2004*		1 min.	*108.9*	1 min.	*135.7*	1 min.	*145.3*	1 min.	*161.9*	1 min.	*161.3*
		1 min.	*109.0*	1 min.	*136.4*	1 min.	*145.9*	1 min.	*160.9*	1 min.	*162.0*
		Average	*108.6*	Average	*136.1*	Average	*145.9*	Average	*161.4*	Average	*161.5*
		Deviation		Deviation		Deviation		Deviation		Deviation	
		8 Inches		**8 Inches**		**8 Inches**		**8 Inches**		**8 Inches**	
Operator: *John Smith*		1 min.	*108.8*	1 min.	*134.9*	1 min.	*146.8*	1 min.	*160.9*	1 min.	*161.7*
		1 min.	*109.0*	1 min.	*135.6*	1 min.	*146.2*	1 min.	*160.8*	1 min.	*161.5*
		1 min.	*110.0*	1 min.	*134.5*	1 min.	*145.1*	1 min.	*161.2*	1 min.	*161.7*
		1 min.	*110.5*	1 min.	*136.2*	1 min.	*145.3*	1 min.	*160.9*	1 min.	*161.2*
		Average	*109.6*	Average	*135.3*	Average	*145.9*	Average	*161.0*	Average	*161.5*
		Deviation		Deviation		Deviation		Deviation		Deviation	

CDOT Nuclear Equipment Moisture / Density Certification Worksheet.

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NUCLEAR EQUIPMENT STATISTICAL STABILITY/DRIFT TEST

DRIFT TEST (Gauge must be on and active a minimum of 3 hours after the completion of the Statistical Stability Test, perform 5 four minute counts)

Counts N (or X)	Density standard count (M/D or TLD gauge)	Moisture standard count (M/D or AC gauge)
1	3741	647
2	3748	646
3	3746	644
4	3750	646
5	3755	641
Average counts $\bar{N}$ (or $\bar{X}$)	3748.0	644.8

[Total average = the sum of the Statistical Stability average count and the Drift Test average count, divided by 2]

Density total average = (3753.8 + 3748.0) ÷ 2 = 3750.9

Moisture total average = (647.4 + 644.8) ÷ 2 = 646.1

[Difference = the value between the Statistical Stability average count and the Drift Test average count]

Density difference = 3753.8 - 3748.0 = 5.8

Moisture difference = 647.4 - 644.8 = 2.6

[Drift = $\frac{\text{Difference}}{\text{Total average}}$ X 100 = _____ %]

Density drift = 5.8/3750.9 X 100 = .155 %

Moisture drift = 2.6/646.1 X 100 = .402 %

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NUCLEAR EQUIPMENT STATISTICAL STABILITY/DRIFT TEST

Statistical stability test, (Allow gauge to warm up 30 minutes, perform 20 one minute counts)

Counts N (or X)	Density standard count (M/D or TLD gauge)	Moisture standard count (M/D or AC gauge)
1	43091	9570
2	42685	9643
3	43121	9782
4	43167	9533
5	42925	9740
6	43157	9493
7	43370	9725
8	43249	9754
9	42827	9642
10	43047	9774
11	43165	9451
12	42912	9442
13	42762	9557
14	43031	9606
15	43092	9846
16	43373	9669
17	42875	9543
18	43193	9621
19	43052	9554
20	43335	9555
Average counts $\bar{N}$ (or $\bar{X}$)	43071.45	9625.0
Standard deviation σ (or S)	194.2891	115.2686
Ratio [$S \div (\sqrt{\bar{X}})$]	0.936	1.175

Ideal ratio 1.00 / Acceptable limits 0.75 - 1.25
(Values found in the calibration procedures)

Date: 10-27-00	Operator: Ed Moses
CDOT no.: N/A	Model of gauge: CPN MC-3
Gauge no.: JAC-1	Serial no.: M320300770

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NUCLEAR EQUIPMENT STATISTICAL STABILITY/DRIFT TEST

DRIFT TEST (Gauge must be on and active a minimum of 3 hours after the completion of the Statistical Stability Test, perform 5 four minute counts)

Counts N (or X)	Density standard count (M/D or TLD gauge)	Moisture standard count (M/D or AC gauge)
1	43230	9509
2	43042	9620
3	43177	9622
4	43128	9573
5	43066	9508
Average counts $\bar{N}$ (or $\bar{X}$)	43128.6 Pass	9566.4 Pass

[Total average = the sum of the Statistical Stability average count and the Drift Test average count, divided by 2]

Density total average = (_____ + _____) ÷ 2 = _____

Moisture total average = (_____ + _____) ÷ 2 = _____

[Difference = the value between the Statistical Stability average count and the Drift Test average count]

Density difference = _____ - _____ = _____

Moisture difference = _____ - _____ = _____

$$\text{[Drift} = \frac{\text{Difference}}{\text{Total average}} \times 100 = \text{\_\_\_\_\_ \%]}$$

Density drift = _____ X 100 = _____ %

Moisture drift = _____ X 100 = _____ %

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DAC Acceptable Range

Density

SSAC +/- $2.0\sqrt{SSAC}$

$43071.45 \pm 2.0\sqrt{43071.45}$

42656 to 43487

Moisture

$9625.0 \pm 2.0\sqrt{9625.0}$

9429 to 9821