Colorado Procedure – Laboratory 5302-10

Standard Method of Test for

Calibration of CDOT Nuclear Moisture/ Density Gauges

1. SCOPE

1.1 It is the intent of these procedures to describe the calibration of a nuclear moisture/density (M/D) gauge. These procedures will apply only to CDOT M/D gauges.

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

1.3 All CDOT M/D gauges will be calibrated biennially, with a calibration check performed annually. Any M/D gauge that has major repairs (replacement of detection tubes, modules, or the scaler) must be re-calibrated before being placed on or returned to a CDOT project.

1.4 The validity of the test results obtained by the M/D gauge in the field are only as good as the gauge itself. Daily reference standard counts are an essential element in the determination of a gauge's reliability and repeatability. These standard counts often provide advance information of deteriorating components.

1.5 Examples for Troxler gauges will be on pages 5 through 7.

2. PRE-CALIBRATION INSPECTION

2.1 Inspect the gauge's U.S. DOT Type "A" carrying case to ensure that all requirements (physical integrity and labeling) are met. Clean the carrying case, make any repairs and replace required labels (Radioactive Yellow II or DOT Type "A" Radioactive) if necessary.

2.2 Inspect the gauge's reference standard block for any damage. The seating of the gauge on the standard block is critical for the gauge's repeatability. If a block allows variable seating or the gauge rocks on 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.

NOTE 1: Prior to all calibrations an inspection must be performed in accordance with Troxler's *Inspecting Source Rods* and *Inspecting Sliding Blocks.* Troxler Form #108542 must be completed. The intent of these procedures is to verify the radiological integrity of the gauge by checking for the existence of micro- cracks within the welds and excessive rod and sliding block wear.

2.3 Inspect the M/D gauge for damage or non-compliance with radioactive source labels. If the label on the source rod handle is in any way illegible it must be replaced. Clean the shell and base plate of the gauge of any soil or asphalt, being careful to direct the base away from anyone in the immediate area. The Radiation Safety Officer will remove the base plate so that proper cleaning and lubrication can be performed. Remove the sliding block and spring. Clean the block and cavity of all soil and grease. Replace the wiper (scraper) ring in the base plate. The source rod should be extended quickly, to reduce exposure to radiation, to inspect the rod for damage and to be cleaned. Lubricate the sides of the sliding block and place the sliding block and spring in the cavity. If the sliding block does not completely close, check that there are no obstructions holding it open. If no obstructions are found replace the sliding block spring. Re-attach the base plate and extend the source rod to verify proper alignment.

Remove the scaler and inspect both the scaler and the inside of the gauge for damage, moisture and soil. Clean if necessary. Re-attach the scaler.

2.4 The M/D gauge should be sufficiently charged to allow for six hours of continuous operation. Do not charge the gauge unless it has indicated that it needs a charge. However, discharging the batteries and then applying a full 14 hour charge may be advisable.

2.5 If the pre-calibration inspection has been

completed and all necessary repairs have been accomplished, the calibration can begin.

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 Form # 723: Nuclear Equipment Moisture / Density Calibration Sheet.

3.5 M/D gauge and reference standard block.

3.6 Gauge binder with all of the required documentation.

3.7 Calculator capable of performing statistics.

3.8 Personnel Dosimeter.

4. CALIBRATION PROCEDURE

4.1 STATISTICAL STABILITY TEST

4.1.1 The M/D gauge should be turned on to allow the electronics and detector tubes to warm up for 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 gauge on the reference standard block according to the manufacturer's instructions. The scaler end of either gauge must be toward the front of the blocks with the source rod in the safe position.

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). Write the DATE, OPERATOR (PRINT FULL NAME LEGIBLY), MODEL OF GAUGE, and SERIAL NO. The CDOT NO. and GAUGE NO. should be written down as they appear on the equipment.

4.1.5 Perform the Statistical Stability Test. Troxler and Instrotek 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. CPN gauges will need to be placed into a one-minute time base. Twenty one-minute counts will 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 3430 & 3440 Gauges is 0.25, with acceptable limits of 0.17 to 0.33.

The acceptable ratio range for Instrotek Gauges is 0.18 to 0.35.

The acceptable ratio range for CPN Gauges is 0.75 to 1.25.

4.1.6 If the gauge passes the statistical stability test proceed with the calibration. If the gauge fails the statistical stability test, verify the mathematics. If the mathematics check, perform another statistical stability test. A second failure will require the equipment to be repaired. If a second statistical stability test passes, then a third must be performed with a passing ratio achieved.

4.2 MOISTURE CALIBRATION

4.2.1 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. The Moisture Reference Standard Count value is the average moisture counts from the statistical stability test listed to the tenths place. The Moisture Standard Count Total is the Moisture Reference Standard Count times 10.

4.2.2 Place the gauge on Block 2 (Mg/Poly) within the outline. Place the gauge in the backscatter position and record two four-minute moisture counts, and two one-minute moisture counts. Multiply the four-minute counts by four and add the counts. Place this number in the Total space.

4.2.3 Place the gauge on Block 1 (Mg) within the outline. Place the gauge in the backscatter position and record two four-minute moisture counts and two one-minute moisture counts. Also record the density counts in the 0 inches column under the Magnesium Block Readings. Multiply the four-minute counts by four and add the counts.

Place this number in the Total space.

4.3 DENSITY CALIBRATION-BACKSCATTER

4.3.1 Complete the reference information on CDOT Form #723 (see example, page 6). The Density Reference Standard Count value is the average density counts from the statistical stability test listed to the tenths place. The Density Standard Count Total is the Density Reference Standard Count times 10.

4.3.2 The Magnesium block backscatter counts should have been recorded during the step indicated in Subsection 4.2.3.

4.3.3. If the counts were not recorded place the M/D gauge on the Mg block and place the source rod in the backscatter position. Perform and record two four-minute counts and two one-minute counts. Multiply the 4-minute counts by four and add the counts.

4.3.4 Place the M/D gauge on the Magnesium/ Aluminum block and place the source rod in the backscatter position. Perform and record two four-minute counts and two one-minute counts. Multiply the 4-minute counts by four and add the counts. Repeat this step for the Limestone, Granite, and Aluminum blocks.

4.4 DENSITY CALIBRATION- TRANSMISSION

4.4.1 Return 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.

4.4.2 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 two four-minute counts and two one-minute counts in the 4-inch column. Multiply the 4-minute counts by four and add the counts (see example, page 6).

4.4.3 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 two four-minute counts and two one-minute counts in the 6 inch column. Multiply the 4 minute counts by four and add the counts.

4.4.4 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 two four-minute counts and two one-minute counts in the 8 inch column. Multiply the 4-minute counts by four and add the counts.

4.4.5 Repeat the steps indicated in the Subsections 4.4.2 through 4.4.4 on the Magnesium/ Aluminum and Aluminum Blocks.

4.5. DRIFT TEST

4.5.1 The M/D gauge should be on and active for a minimum of three hours after the completion of the statistical stability test

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

4.5.3 Place the M/D 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.

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

4.5.5 Perform the Drift Test. Troxler and Instrotek 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. CPN gauges will need to be placed into a four-minute time base. Five four-minute counts will be performed, recording both the density standard count and the moisture standard count.

The acceptable drift for Troxler and Instrotek Gauges is less than 0.50% for density and less than 1.00% for moisture.

On CPN Gauges the Drift Average Counts (DAC) are either acceptable or unacceptable bases on the Statistical Stability Average Counts (SSAC).

$$DAC = SSAC + /- \sqrt{SSAC}$$

4.5.6 If the M/D gauge passes the drift, then new calibration constants and tables can be generated. If the gauge fails the drift test verify the mathematics. If the mathematics are confirmed, perform another drift test. A second failure will require the equipment to be repaired.

4.6 M/D GAUGE ACCEPTANCE

4.6.1 The computer within the Nuclear Lab will generate new calibration constants. Input of the standard count totals and calibration block measure count totals will allow the computer to analyze the shape of the calibration curve for their

acceptance or rejection. Occasionally individual blocks will need to be re-tested to verify the recorded measure counts.

4.6.2 Program the new constants following the manufacturer's instructions.

4.6.3 Center the reference standard block on the Mg/Al block. The long axis of the reference standard block should match that of the block, with the butt plate being in the front.

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

4.6.5 Place the gauge on the Limestone Block and place the source rod in the backscatter position. Perform and record four one-minute **wet** density readings [Note 2.] Average the four readings and record the average.

4.6.6 Place the gauge on the Granite Block and repeat the step indicated in Subsection 4.6.5.

4.6.7 Place the gauge on the Limestone Block and extend the source rod no more than two inches until it has been inserted into the rod hole.

4.6.8 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 2]. Average the four readings and record the average.

4.6.9 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 2]. Average the four readings and record the average.

4.6.10 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 2]. Average the four readings and record the average.

NOTE 2: 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 don't make sure to prompt the gauge to the correct depth.

4.6.11 Repeat the steps indicated in the Subsections 4.6.6 through 4.6.10 on the Granite Block.

4.6.12 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.

4.6.13 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 re-calibrated.

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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	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	0.0838
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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CDOT Form # 1151

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Nuclear Equipment Moisture/Density Calibration Sheet

CDOT Equipment No.	Serial No.	Gauge No. (Consultant)	Type of Gauge (Model)
8198	23271	43448	Troxler 3430-A

Moisture Reference Standard Count	Density Reference Standard Count	Density Standard Count Total
647.4	3753.8	37538

Moisture Standard Count Total: 6474

	Moisture Block # 1 Readings		Magnesium Block Readings	Magnesium/ Aluminium Block Readings	Limestone Block Readings	Granite Block Readings	Aluminium Block Readings
			0 inches	0 inches	0 inches	0 inches	0 inches
4 min.	23	x4	1416 x4	948 x4	818 x4	670 x4	667 x4
4 min.	23	x4	1419 x4	954 x4	817 x4	672 x4	668 x4
1 min.	23		1393	964	810	670	667
1 min.	21		1422	959	817	667	673
Total	228		14155	9531	8167	6705	6680
Ratio							
			4 inches	4 inches	4 inches	4 inches	4 inches
4 min.			4895 x4	2993 x4	2466 x4	1758 x4	1748 x4
4 min.			4888 x4	2992 x4	2468 x4	1754 x4	1763 x4
1 min.			4869	3010	2478	1761	1756
1 min.			4880	2992	2463	1756	1751
Total			48881	29942	24677	17565	17551
Ratio							
			6 inches	6 inches	6 inches	6 inches	6 inches
4 min.			3944 x4	2232 x4	1819 x4	1224 x4	1225 x4
4 min.			3934 x4	2236 x4	1823 x4	1223 x4	1216 x4
1 min.			3928	2250	1812	1233	1220
1 min.			3937	2249	1794	1225	1218
Total			39377	22371	18174	12246	12202
Ratio							
			8 inches	8 inches	8 inches	8 inches	8 inches
4 min.			2729 x4	1421 x4	1111 x4	712 x4	714 x4
4 min.			2747 x4	1424 x4	1120 x4	715 x4	713 x4
1 min.			2748	1422	1107	703	708
1 min.			2720	1398	1115	709	717
Total			27372	14200	11146	7120	7133
Ratio							

	Moisture Block # 2 Readings	
4 min.	380	x4
4 min.	381	x4
1 min.	375	
1 min.	377	
Total	3796	
Ratio		

Calibration Date: 10-26-00

Operator: Alex Baca

CDOT Form #723 1/01

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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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