COLORADO DEPARTMENT OF TRANSPORTATION

LABORATORY MANUAL OF TEST PROCEDURES

2020

(With 2023 Revisions)

COLORADO
Department of Transportation

This Manual is will be updated every 5 Years in its entirety with the most recent approved revisions and edits.

Revisions to individual CP-Ls will be added and updated annually when available in accordance with the information presented in the Introduction

2020 CDOT Laboratory Manual of Test Procedures
Revised 2024

Introduction

The purpose of the Laboratory Manual of Test Procedures (LMTP) is to provide an official guide to CDOT personnel, consultants, and contractors for the uniform testing on CDOT projects for tests that are not normally performed by project personnel. It is not the intent to publish a complete summary of the testing methods and procedures. **Referenced AASHTO or ASTM test procedures are available through CDOT's internal website as a Materials / Geotechnical Resource.** This resource is not available to non-CDOT personnel.

The manual is published in dual units using the Standard English units and the International System of Units (SI Modernized Metric).

The reproduction cycle for this manual will be approximately five years. **It is available as a hard copy and an electronic document available in its entirety on both the internal and external CDOT website listed below. Within this cycle revisions of an existing CP-L or the creation of a new CP-L will be posted on an annual basis within the first week of April if possible. The effective date of a revised CP-L and its associated Index will be on the page's header.** When a new production run is required and there have been changes to CP-Ls the manual will be designated as (With 20XX Revisions) written directly under the reproduction cycle date on the Cover Page, as necessary until another reproduction cycle is required. It is the LMTP owner's responsibility to ensure that this manual is current based on the web postings of all implemented changes.

We encourage efforts to develop better, more accurate, or faster methods of testing. Many of the Colorado Procedures for Laboratories are the result of suggestions from CDOT personnel, consultants, and the construction and paving industry. **However, testing on a construction project must comply with the test procedures specified in the Contract.**

Before new procedures can be utilized, the procedure must be reviewed and approved by the Materials Advisory Committee (MAC) and the FHWA. After review and approval of a new test procedure (CP-L) the procedure will be included in this manual and specified in future construction contracts. In addition, the procedure used must be the same as that specified in the project specifications. If this rule is not followed, the acceptance or rejection action cannot be supported and may result in legal rulings against the Department in cases of litigation.

The 202O (With 2021 Revisions) CDOT Laboratory Manual of Test Procedures has been updated with a new chapter "Electronic Documentation" with instructions to meet the recommendations for updating manuals to comply with Procedural Directive 21.1 "Requirements for the Retention of Records for Specified Design, Construction, Engineering, and Specialty Groups (Paper and Electronic) eff. June 20, 2019 and Procedural Directive 508.1 "Requirements for the Use of the Professional engineer's Seal" eff. May 21, 2019

If any questions arise concerning this Laboratory Manual of Test Procedures, telephone the Documentation Unit of the Central Laboratory at 303-398-6566 or submit either the *CP-L Comment Form* or the *Comments and/ Corrections Form* on the following pages.

A centralized location for all CDOT Materials related documents and publications is located at:

https://www.codot.gov/business/designsupport/materials-and-geotechnical

General correspondence (letters and envelopes), large packages, bulk mail samples of materials, and nuclear gauges should be addressed to or delivered to:
Attn: (Individual's Name), CDOT, 4670 North Holly Street, Unit A, Denver, CO 80216-6408

If you have any questions concerning this manual please contact:
edward.trujillo@state.co.us (303) 398-6566.

2020 CDOT Laboratory Manual of Test Procedures Dedication

LMTP Documents: A special thank you is extended to the members and participants of the MAC Meetings and the associated task forces who are constantly striving to improve testing methodology and CDOT specifications so that the roads in Colorado are progressively built better and are safer for the motoring public.

SUMMARY of
Listed Revisions, Additions, and Deletions

Changes of significance within a particular CP-L will contain a "- 21", for example, at the end of the title to coincide with the fiscal year of the revision. Changes to specific text from the previous version will have a solid RED side-bar in either the left or right applicable margin. The current revisions, additions and Deletions are highlighted in RED.

Changes from the 2012 and 2020 LMTP (Only the CP-L number will be referenced, not the Sections &/or Subsections)**:**

Chemical Properties
CP-L 2103-21 Sections 1.2, 2.12, Method B (Colorimeter), Method C, 5, 5.1, 5.2,5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 6, 6.1, 6.2
CP-L 2104-21 Sections 1.2, 4.13, Method B (Titration), Method C 5, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 6,6.1, 6.2

Bituminous
CP-L 2202-15
CP-L 2203-13
CP-L 2210-24 Section 5.1
CP-L 2211-15
CP-L 2212-15
CP-L 2213-19 Section 4.4, New CP-L 2213 form.
CP-L 2214-15
CP-L 2215-15

Soils
CP-L 3101-16 Deleted 01-01-2016
CP-L 3102-13 Deleted Complete Chapter
CP-L 3103-19 Section 10.6.1
CP-L 3104-15
CP-L 3105-13
CP-L 3106-13

Geology
CP-L 3201-21 (Complete re-write of the CP-L)
CP-L 3210-05 Forms examples

Concrete
CP-L 4101-19 Title procedures.
CP-L 4102-13
CP-L 4203-21 Section 10.3

Physical Properties (Aggregate)
CP-L 4201-16 Deleted Replaced with ASTM C 1260
CP-L 4202-16 Deleted Replaced with ASTM C 1567
CP-L 4209-21 (Complete re-write of the CP-L)
CP-L 4211-15
CP-L 4215-15
CP-L 4216-10

Physical Properties (Concrete)
CP-L 4301-18 New Chapter
CP-L 4302-18 New Chapter

Flexible Pavement
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CP-L 5101-15
CP-L 5106-21 Section 5.2
CP-L 5109-16
CP-L 5110-15
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CP-L 5112-20-24 Section 5.3. Section 4.1, 5.3, 6.1.2, 6.1.4, 6.2.1.1, 6.2.1.2, 9.1.
CP-L 5114-20 Section 6.2.1.2
CP-L 5115-22 Section 11.1.3
CP-L 5116-15
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CP-L 5140-15
CP-L 5145-15
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Nuclear
CP-L 5301-20 Section 5.1, New Leak test envelope.
CP-L 5302-15
CP-L 5303-14
CP-L 5304-16 Deleted 03-10-2016
CP-L 5305-15
CP-L 5306-20 Section 4.7.3, New label.

Electronic Documentation-21 New Chapter

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Any errors that may still exist within this manual are solely the oversight of the Editor.

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CDOT Manuals and Forms: Comments and Corrections

Click on the following link to fill out the form and click "submit" the form will automatically be sent to edward.trujillo@state.co.us with your comment and corrections :

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This form may be utilized if you have discovered an issue the CDOT Field Materials Manual or have a suggestion for improvement. It is important that you are as specific as possible by referencing the CP number, CP-L number, the Chapter Section / Subsection number, or the Form number.
E-mail or attach all supporting documents for future reference to: edward.trujillo@state.co.us or call 303-398-6566 for assistance with this form.

Thank you for your help in making the CDOT Materials Manuals or Forms better publications by notifying us of errors or points of confusion that require clarity.

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Colorado Procedure – Laboratory 2103-21

Standard Method of Test for

Determining the Sulfate Ion Content in Water or Water-Soluble Sulfate Ion Content in Soil

1. SCOPE

1.1 This method establishes a procedure for determining the amount of sulfate ions present in water or determining the water soluble sulfate ion content in soil effecting CDOT projects.

1.2 Method A describes the procedure for determining the concentration of sulfate ions present in water. Method B describes the concentration of water soluble sulfate ions present in soil using the Colorimeter. Method C describes the concentration of water soluble sulfate ions present in soil using the X-Ray.

2. APPARATUS

2.1 Colorimeter - Hach models: Pocket Colorimeter II, DR 820, DR 850, DR 950 or equivalent.

2.1.1 Sample Cells – As recommended by the colorimeter manufacturer.

2.2 Glassware – 500 ml Erlenmeyer Flasks, 500 ml graduated cylinder.

2.3 Pipet - graduated 10 ml with bulb.

2.4 Filter Papers - #42 Whatman

2.5 Timer - readable to 1 second.

2.6 Drying apparatus - Any suitable device capable of drying samples at a temperature not exceeding 60°C (140°F).

2.7 Misc. Equipment - Funnel, Rubber Stoppers.

2.8 Barium Chloride - Pre-measured packet.

2.9 Sieves - #4 and #40.

2.10 Digestion heat source – Any suitable device that will maintain the temperature of the solution @ 140°F (+/- 5°F) throughout the digestion period.

2.11 Distilled water

Note 1: Clean all glassware with distilled water prior to each use.

2.12 X-Ray capable of measuring water soluble sulfate ions.

METHOD A
(Sulfate Ion Content in Water)

3. PROCEDURE

3.1 Use a pipet to place 10 ml of sample into 2 sample cells. One will serve as the blank and the other as the reacted sample. If the sample exhibits turbidity or color then place a filter paper in the funnel and filter the sample until a clear sample is obtained.

3.2 Set the timer for 5 minutes. Add reagent to one of the cells. Cap the cell and shake vigorously. Place the sample in a location where it will be undisturbed and start the timer.

3.3 Within 5 minutes after the timer goes off place the blank into the colorimeter and cover. Zero the meter according to the manufacturer’s recommendations.

3.4 Remove the blank and replace it with the reacted test sample and cover. Take the reading in accordance with manufacturer recommendations.

3.5 Record reading. If the reading exceeds the limits of the meter or reports the meter’s maximum reading (refer to the manufacturer’s manual) the sample will need to be further diluted with distilled water. Discard test and repeat steps 3.1 through 3.5 with new diluted sample. **See Example 1, Method A**

4. CALCULATION

4.1 Correct the reading obtained in Subsection 3.5 using the Standard Sulfate Solution correction curve (see Section 7). To find the correction locate the reading on the bottom scale, follow a vertical line to the curve and then a horizontal line to the vertical scale.

Note 2: Some colorimeter models may have a user defined correction curve stored, automatically correcting the reading. When using this feature, follow the manufacturer’s procedure to produce the correction curve.

4.2 Multiply the corrected reading by the total dilution**. See example 1, Method A.** This will give the parts per million

METHOD B
(Water Soluble Sulfate Ion Content of Soil, Colorimeter)

5. PROCEDURE

5.1 Obtain sample according to CP 24 or as required by the Pipe Material Selection Policy.

5.2 Dry the sample to constant weight at a temperature not exceeding 60°C (140°F).

5.3 Process the material over a #4 sieve being careful to dislodge any material adhering to the aggregate particles and avoid breaking down the natural size of the particles.

5.4 Process the minus #4 material using a rubber coated pestle until it passes the #40 sieve being careful to dislodge any material adhering to the aggregate particles and avoid breaking down the natural size of the particles. Repeat until no additional minus #40 material is produced.

5.5 Prior to obtaining a test sample, ensure sample is mixed so that uniformity of the sample is achieved. Obtain a representative 25g test sample and place it in a clean, 500 ml flask.

5.6 Add 250 ml of distilled water to the flask. Mix thoroughly, by shaking, using sufficient effort so that no material is left on the bottom of the flask (this is the 1st 10:1 dilution). Seal the flask with a rubber stopper and let the sample sit undisturbed for a minimum of 16 hours. Maintain the temperature of the solution @ 140°F (+/- 5°F).

5.7 After completion of the soaking period if the sample exhibits turbidity (cloudiness) filter the solution through a #42 Whatman filter paper until a clear sample is attained.

5.8 Use a pipet to place 25 ml of the solution into a 500 ml clean flask and add 225 ml of distilled water and mix thoroughly. (This is the 2nd 10:1 dilution, 10:1 + 10:1 =100:1 dilution ratio). * If the sample doesn't require further dilution, this 100:1 dilution would be the final dilution ratio used in the calculation.

5.9 Use a pipet to place 10 ml of solution into 2 sample cells. Add reagent into one of the cells. Cap the cell and shake vigorously. Place the sample in a location where it will be undisturbed and let stand for a minimum of 5 minutes but not more than 10 minutes.

5.10 Place the blank into the colorimeter, cover, and zero the meter. Replace the blank with the reacted sample, cover, and take the reading according to manufacturer's instructions.

5.11 Record reading. If the reading exceeds the machines capabilities the sample will need to be further diluted. **See Example 1, Method B.**

6. CALCULATION

6.1 Correct the reading obtained in Subsection 5.11 using the Standard Sulfate Solution correction curve (see Section 7). To find the correction, locate the reading on the bottom scale, follow a vertical line to the curve and then a horizontal line to the vertical scale.

Note 3: Some colorimeter models may have a user defined correction curve stored, automatically correcting the reading. When using this feature, follow the manufacturer's procedure to produce the correction curve.

6.2 Multiply corrected reading by the total dilution; **See Example 1, Method B.** This will give the parts per million.

6.3 Divide the parts-per-million (ppm) obtained in Subsection 6.2 by 10,000 to obtain the percent sulfate in soil by mass.

METHOD C
(Water Soluble Sulfate Ion Content of Soil, X-Ray)

5. PROCEDURE

5.1 Obtain sample according to CP 24 or as required by the Pipe Material Selection Policy.

5.2 Dry the sample to constant weight at a temperature not exceeding 60°C (140°F).

5.3 Process the material over a #4 sieve being careful to dislodge any material adhering to the aggregate particles and avoid breaking down the natural size of the particles.

5.4 Process the minus #4 material using a rubber coated pestle until it passes the #40 sieve being careful to dislodge any material adhering to the aggregate particles and avoid breaking down the natural size of the particles. Repeat until no additional minus #40 material is produced.

5.5 Prior to obtaining a test sample, ensure sample is mixed so that uniformity of the sample is achieved. Obtain a representative 25g test sample and place it in a clean, 500 ml flask.

5.6 Add 250 ml of distilled water to the flask. Mix thoroughly, by shaking, using sufficient effort so that no material is left on the bottom of the flask (this is the 1st 10:1 dilution). Seal the flask with a rubber stopper and let the sample sit undisturbed for a minimum of 16 hours. Maintain the temperature of the solution @ 140°F (+/- 5°F).

5.7 After completion of the soaking period if the sample exhibits turbidity (cloudiness) filter the solution through a #42 Whatman filter paper until a clear sample is attained.

5.8 Use a pipet to place 10 ml of solution into sample cell. Insert sample cell into x-ray, cover, and take the reading according to manufacturer’s instructions. Record reading.

Note 4: X-ray is capable of determining both water soluble sulfate and chloride simultaneously.

6. CALCULATION

6.1 Multiply reading by the total dilution of 10. This will give the parts per million.

6.2 Divide the parts-per-million (ppm) obtained in Subsection 6.1 by 10,000 to obtain the percent sulfate in soil by mass.

Standard Sulfate Solution Correction Curve

7. GENERATING CORRECTION CURVE

7.1 Using reagent grade sulfate standard solution prepare samples at 10 ppm increments across the range of the colorimeter in 250 ml beakers. See Example 2.

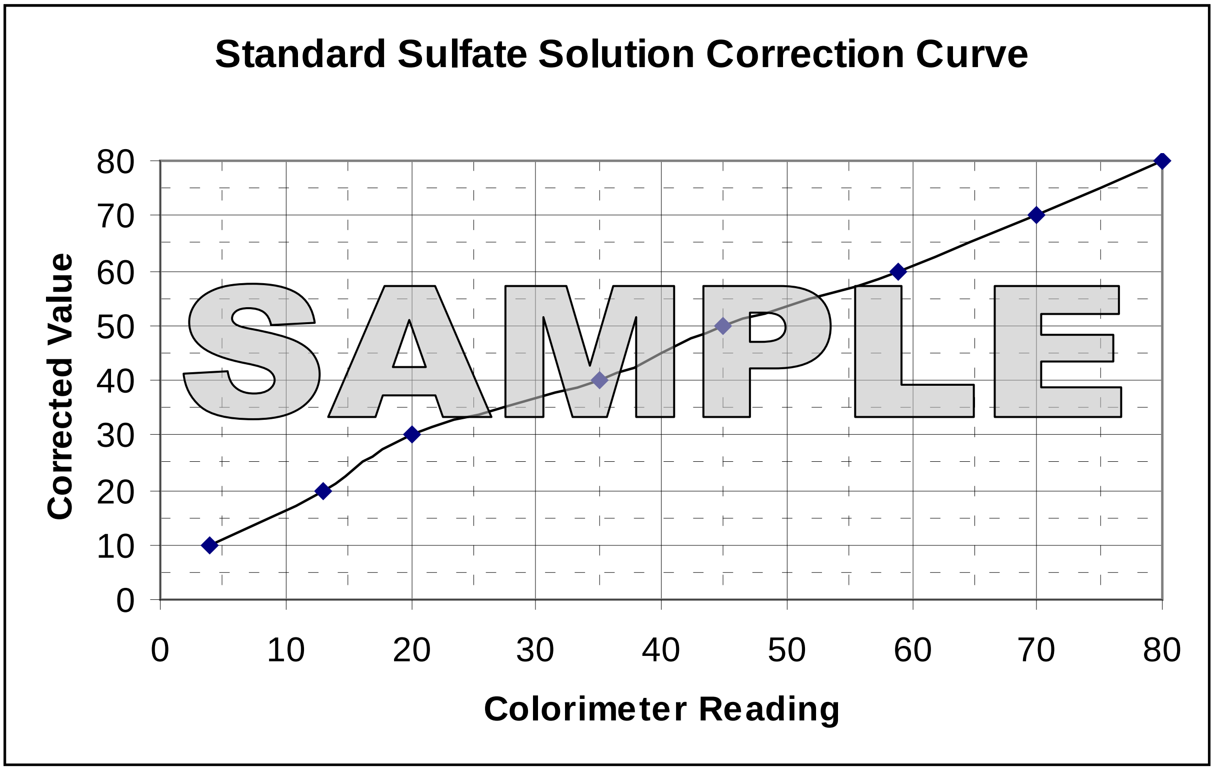
7.2 For each dilution fill 2 sample cells to the 10 ml line. One will be the blank and the other will be the reacted sample. Add reagent to one of the cells. Shake the cell vigorously and let stand undisturbed for 5 minutes but not more than 10 minutes.

7.3 Place the blank into the colorimeter, cover, and zero the meter. Replace the blank with the reacted sample, cover, and take the reading. Record the reading.

7.4 Once all the readings are obtained graph the results and draw the correction curve. See example.

7.5 Correction curves shall be run upon receipt of a new lot of reagent or every 6 months (whichever comes first), or when results are in question.

Sample Correction Curve



Example Curve

Curves are specific to each colorimeter and each lot of reagent.

Water Soluble Sulfates
Worksheet

Project No. ____________________________ **Contract ID** ______________________

Sample I.D._______________________ **Sample Location** _______________________

Soil Description_________________________ **Tested By**: _______________________

Sample Date ____________ **Receive Date** ____________ **Test Date** _____________

A) Number of Dilutions _________

Saturation Date _____________ B) Final Dilution _________

Saturation Time _____________ C) Reading __________

Test Start Time _____________ D) Corrected Reading __________

E) Sulfate Concentration __________

E = (B x D) (ppm or %)

Simplified Procedure

1) Dry soil (140°F / 60°C) and process through the #4 sieve.
2) Process a representative sample through a #40 sieve.
3) Place a 25g representative sample into clean container.
4) Add 250 ml of distilled water and shake well (This is a 10:1 dilution).
5) Let the container stand undisturbed for a minimum of 16 hrs maintaining the solution @ 140°F (+/- 5°F).
6) Pipet 25 ml of the 10:1 dilution and deposit into a clean 500 ml flask (do not disturb sediment). If sample exhibits turbidity then filter until clear.
7) Dilute test sample to 250 ml by adding 225 ml of distilled water (This is the second 10:1 dilution multiplied by the first 10:1 dilution makes this a 100:1 dilution and the final dilution if the sample doesn't require further dilution).
8) Pipet 10 ml of sample into the sample cells (1 blank and 1 reaction cell).
9) Add reagent to 1 cell, shake well and let stand a minimum of 5 min. but not more than 10 min.
10) Place blank into the colorimeter and zero the meter.
11) Replace blank with reacted cell and take the reading.
12) Record the reading and correct it by using the Standard Sulfate Solution Correction Curve.
13) Corrected reading multiplied by the final dilution = ppm, divide ppm by 10,000 to get % sulfate by mass.
14) If the reading exceeds the limits of the meter or the maximum value of the meter is displayed, discard the test samples and the blank. Clean the sample cells. Dilute the sample further by taking 25 ml from the 10:1 test sample (step 4) and dilute to 500 ml. (200:1 final dilution). Repeat steps 8 – 12. Continue dilutions until a reading is obtained.

Example 1

Method A: Sulfate Ion Content in Water

If the Sulfate level is too high for the Colorimeter to read and the sample requires a larger dilution to get a reading:

Dilution examples:
10ml sample diluted to 50ml = 5:1 dilution
10ml sample diluted to 100ml = 10:1 dilution
10ml sample diluted to 200ml = 20:1 dilution
10ml sample diluted to 300ml = 30:1 dilution
10ml sample diluted to 400ml = 40:1 dilution etc.

Once a reading is obtained, correct it using the Standard Sulfate Solution Correction Curve.

Multiply the corrected reading by the total dilution used.

Example:
The colorimeter reported a reading of 25. Using the correction curve the corrected reading is 24.
The sample was diluted to **200ml**, the total dilution would be **20:1**, so take the **corrected reading** and multiply it by **20** to get the sample's sulfate ion content in parts per million (ppm).
24 x 20 = 480 ppm.

Method B: Water Soluble Sulfate Ion Content in Soil (Colorimeter)

If the Sulfate level is too high for the Colorimeter to read and the sample requires a larger dilution to get a reading:

Dilution examples:
<u>*Using the 10:1 diluted sample from subsection 5.6</u>
25ml sample diluted to 250ml = 10:1
25ml sample diluted to 300ml =12:1
25ml sample diluted to 350ml =14:1
25ml sample diluted to 400ml = 16:1
25ml sample diluted to 450ml = 18:1
25ml sample diluted to 500ml = 20:1 etc.

or

25ml sample diluted to 250ml = 10:1
12.5ml sample diluted to 250ml =20:1
6.25ml sample diluted to 250ml =40:1
3.125ml sample diluted to 250ml =80:1

Determining the final dilution ratio, multiply the **10:1** dilution from subsection **5.6** by the second dilution ratio.

Example:
The colorimeter reported a reading of 37. Using the correction curve the corrected reading is 39.
25ml of the 10:1 diluted sample from subsection 5.6 was diluted to 500ml (20:1) multiply 10 x 20 =200.
The final dilution is 200:1.

Multiply your corrected reading from the Standard Sulfate Solution Correction Curve by the final dilution ratio to get the sample's sulfate ion content in parts per million (ppm).
39 x 200 = 7,800 ppm.

Divide the ppm by 10,000 to obtain the percent Sulfate in Soil by mass.
7,800 ppm / 10,000 = 0.78 %.

Example 2

Generating a Correction Curve

Apparatus:

9 - 250ml beakers
1,000 ppm Sulfate Standard Solution:
Distilled water

Place 100 ml of distilled water in a 250 ml beaker – This is the 0 ppm sample.

Place 1 ml Sulfate Standard Solution in a 250 ml beaker and dilute to 100 ml - This is the 10 ppm.

Place 2 ml Sulfate Standard Solution in a 250 ml beaker and dilute to 100 ml - This is the 20 ppm sample.

Place 3 ml Sulfate Standard Solution in a 250 ml beaker and dilute to 100 ml - This is the 30 ppm sample.

Place 4 ml Sulfate Standard Solution in a 250 ml beaker and dilute to 100 ml - This is the 40 ppm sample.

Place 5 ml Sulfate Standard Solution in a 250 ml beaker and dilute to 100 ml - This is the 50 ppm sample.

Place 6 ml Sulfate Standard Solution in a 250 ml beaker and dilute to 100 ml - This is the 60 ppm sample.

Place 7 ml Sulfate Standard Solution in a 250 ml beaker and dilute to 100 ml - This is the 70 ppm sample.

Place 8 ml Sulfate Standard Solution in a 250 ml beaker and dilute to 100 ml - This is the 80 ppm sample.

Plot the colorimeter reading on the horizontal axis vs. the known sample ppm on the vertical axis. Starting on the 0 ppm point use a straight line to connect each of the points.

Example: A point is a known 10 ppm solution but the colorimeter shows a reading of 8. Plot a point at 10 on the horizontal axis and 8 on the vertical axis. Repeat this for each of the 9 samples

Colorado Procedure – Laboratory 2104-21

Standard Method of Test for

Determining the Chloride Ion Content in Water or Water-Soluble Chloride Ion Content in Soil

1. SCOPE

1.1 This method covers the procedures for chloride ion content determination in soil or water.

1.2 Method A describes the procedure for determining the concentration of chloride ions present in water. Method B describes the concentration of water soluble chloride ions present in soil using titration. Method C describes the concentration of water soluble chloride ions present in soil using the X-Ray.

2. REFERENCED DOCUMENTS

2.1 AASHTO Standards:
T291 Determining Water-Soluble Chloride Ion Content in Soil.

2.2 Colorado Procedures:
CP 30 Sampling of Aggregates
CP 32 Reducing Field Samples of Soil and Aggregate to Testing Size.

2.3 Other Procedures:
HACH Method 8207 Silver Nitrate Method (10 to 10,000 mg/L as Cl-).

Note 1: This method was adapted from AASHTO T291 and HACH Method 8207.

3. SIGNIFICANCE AND USE

3.1 This method is capable of detecting chloride concentrations up to 10,000 parts per million in water or 3.00% in soil.

3.2 Iron in excess of 10 mg/L masks the endpoint.

3.3 Orthophosphate in excess of 25 mg/L will precipitate silver.

3.4 Sulfite in excess of 10 mg/L will cause interference. If sulfite interference is suspected, eliminate it by adding three drops of 30% hydrogen peroxide in subsection 5.7 or 7.13.

3.5 If sulfide interference is suspected, eliminate it by adding the contents of one Sulfide Inhibitor Reagent Powder Pillow to approximately 125 mL of sample, mixing for one minute, and then filtering through a folded filter paper prior to subsections 5.3 or 7.9.

3.6 Cyanide, iodide, and bromide interfere directly and while titrating they appear as chloride. No attempt to remove these is made because they are usually present in insignificant quantities compared to chloride.

4. APPARATUS

4.1 Balance that reads a minimum of 500 g, accurate to 0.1 g.

4.2 Oven capable of drying samples at a temperature not exceeding 140°F.

4.3 Sieve – 2.00mm (No. 10) and a pan.

4.4 Sample Splitter – Meeting the requirements of CP 32.

4.5 Pulverizing Apparatus

4.6 HACH digital titrator and delivery tube.

4.7 Chloride 2 Indicator Powder Pillows.

4.8 Silver Nitrate titrate cartridges, 0.2256 N and 1.128 N.

4.9 Sulfide Inhibitor Reagent Powder Pillow.

4.10 Deionized water.

4.11 Graduated cylinder.

4.12 Erlenmeyer Flask.

4.13 X-Ray capable of measuring water soluble chloride ions.

METHOD A
(Chloride Ion Content in Water)

5. PROCEDURE

5.1 Obtain a sample as required by Pipe Materials Selection Policy.

5.2 If the sample exhibits turbidity then filter the sample through a 0.45 micron membrane filter.

5.3 Check the pH with a meter or with phydrion paper. If the pH is in the range of six through eight, proceed to the next step. If the pH is below six, add sodium bicarbonate to adjust the pH to a range of 6 to 8. If the pH is above 8, add nitric acid to adjust the pH to a range of 6 to 8.

Note 2: Determine the amount of acid or base necessary in a separate sample because pH electrodes will introduce chloride into the sample

5.4 Select the sample volume and Silver Nitrate Titration Cartridge corresponding to the expected chloride concentration from *Table 1*.

5.5 Insert a clean delivery tube into the titration cartridge. Attach the cartridge to the titrator body.

5.6 Turn the delivery knob to eject a few drops of titrant. Reset the counter to zero and wipe the tip.

5.7 Use a graduated cylinder or pipet to measure the sample volume from *Table 1*. Transfer the sample into a clean 250 mL Erlenmeyer flask. Dilute to 100 mL with deionized water.

5.8 Add the contents of one Chloride 2 Indicator Powder Pillow and then swirl to mix.

5.9 Place the delivery tube tip into the solution and swirl the flask while titrating with silver nitrate until the solution changes from a yellow to a red-brown color. Record the number of digits required from the digital titrator.

6. CALCULATION

6.1 Use the following formula to calculate the concentration of chloride:

(Digits Required) x (Digit Multiplier) = mg/L or parts-per-million (ppm)

METHOD B
(Chloride Ion Content in Soil, Titration)

7. PROCEDURE

7.1 Obtain a sample according to CP 24 or as required by Pipe Materials Selection Policy.

7.2 Dry the sample to a constant weight at a temperature not exceeding 140°F.

7.3 Process the material over a No. 10 sieve being careful to dislodge any material adhering to the aggregate particles and avoid breaking down the natural size of the particles.

7.4 Split the processed soil into a 100 g sample and place it into a sealable sample cup.

7.5 Add 300 mL of distilled water (3:1 dilution).

7.6 Seal the container and shake vigorously for 20 +/- 1 seconds.

7.7 Let the sample sit at room temperature for 1 hour and then repeat the shaking process and let the sample sit for another hour.

7.8 If the sample exhibits turbidity after the completion of Subsection 7.7 then filter the sample through a 0.45 micron membrane filter.

7.9 Check the pH with a meter or with phydrion paper. If the pH is in the range of six through eight, proceed to the next step. If the pH is below six, add sodium bicarbonate to adjust the pH to a range of 6 to 8. If the pH is above 8, add nitric acid to adjust the pH to a range of 6 to 8.

Note 4: Determine the amount of acid or base necessary in a separate sample because pH electrodes will introduce chloride into the sample

7.10 Select the sample volume and Silver Nitrate Titration Cartridge corresponding to the expected chloride concentration from *Table 1*.

7.11 Insert a clean delivery tube into the titration cartridge. Attach the cartridge to the titrator body.

7.12 Turn the delivery knob to eject a few drops of titrant. Reset the counter to zero and wipe the tip.

7.13 Use a graduated cylinder or pipet to measure the sample volume from *Table 1*. Transfer the sample into a clean 250mL Erlenmeyer flask. Dilute to 100-mL with deionized water.

7.14 Add the contents of one Chloride 2 Indicator Powder Pillow and then swirl to mix.

7.15 Place the delivery tube tip into the solution and swirl the flask while titrating with silver nitrate until the solution changes from a yellow to a red-brown color. Record the number of digits required from the digital titrator.

8. CALCULATION

8.1 Use the following formula to calculate the concentration of chloride:

(Digits Required) x (Digit Multiplier) x 3 = mg/L or parts-per-million (ppm) Chloride)

Note 5: Multiplying by 3 takes into account the 3:1 dilution of the soil in water.

8.2 Divide the ppm obtained from the calculation and divide by 10,000 to obtain the percent chloride in soil by mass.

Table 1: **Concentrations**

Range (mg/L as Cl-)	Sample Volume (mL)	Titration Cartridge (N AgNO3)	Digit Multiplier
10-40	100	0.2256	0.1
25-100	40	0.2256	0.25
100-400	50	1.128	1.0
250-1000	20	1.128	2.5
1000-4000	5	1.128	10.0
2500-10000	2	1.128	25.0

METHOD C
(Chloride Ion Content in Soil, X-Ray)

5. PROCEDURE

5.1 Obtain sample according to CP 24 or as required by the Pipe Material Selection Policy.

5.2 Dry the sample to constant weight at a temperature not exceeding 60°C (140°F).

5.3 Process the material over a #4 sieve being careful to dislodge any material adhering to the aggregate particles and avoid breaking down the natural size of the particles.

5.4 Process the minus #4 material using a rubber coated pestle until it passes the #40 sieve being careful to dislodge any material adhering to the aggregate particles and avoid breaking down the natural size of the particles. Repeat until no additional minus #40 material is produced.

5.5 Prior to obtaining a test sample, ensure sample is mixed so that uniformity of the sample is achieved. Obtain a representative 25g test sample and place it in a clean, 500 ml flask.

5.6 Add 250 ml of distilled water to the flask. Mix thoroughly, by shaking, using sufficient effort so that no material is left on the bottom of the flask (this is the 1st 10:1 dilution). Seal the flask with a rubber stopper and let the sample sit undisturbed for a minimum of 16 hours. Maintain the temperature of the solution @ 140°F (+/- 5°F).

5.7 After completion of the soaking period if the sample exhibits turbidity (cloudiness) filter the solution through a #42 Whatman filter paper until a clear sample is attained.

5.8 Use a pipet to place 10 ml of solution into sample cell. Insert sample cell into x-ray, cover, and take the reading according to manufacturer’s instructions. Record reading.

Note 6: X-ray is capable of determining both water soluble sulfate and chloride simultaneously.

6. CALCULATION

6.1 Multiply reading by the total dilution of 10. This will give the parts per million.

6.2 Divide the parts-per-million (ppm) obtained in Subsection 6.1 by 10,000 to obtain the percent chloride in soil by mass.

BITUMINOUS INDEX - 20

Colorado Procedures – Laboratory:

Test of Protective Covering for Bridge Deck Waterproofing Membrane	CP-L 2202
Pliability and Thickness of Prefabricated Reinforced Membrane	CP-L 2203
Determining Toughness and Tenacity of Rubberized Asphaltic Materials	CP-L 2210
Elastic Recovery	CP-L 2211
Residue by Evaporation of Asphalt Emulsion	CP-L 2212
Coating of Bitumen-Aggregate Mixtures	CP-L 2213
Verification of Binder Acidity	CP-L 2214
Effect of Heat and Air on a Moving Film of Asphalt (replaced Subsection only)	CP-L 2215

Standard Test Procedures: AASHTO / ASTM

	AASHTO	**ASTM**
Loss on Heating of Oil and Asphaltic Compounds		D 6
Relative Density of Solid Pitch and Asphalt (Displacement Method)		D 71
Crack Filler, Hot-Applied, for Asphalt Concrete and PCCP		D 5078
Joint and Crack Sealants, Hot Applied, for Asphalt Concrete and PCCP (Type I and Type II)		D 6690
Performance-Graded Asphalt Binder	M 320	
Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)	R 28	
Grading or Verifying the Performance Grade (PG) of an Asphalt Binder	R 29	
Penetration of Bituminous Materials	T 49	
Float Test for Bituminous Materials	T 50	
Ductility of Asphalt Materials	T 51	
Softening Point of Bitumen (Ring-and-Ball Apparatus)	T 53	
Emulsified Asphalts	T 59	
Saybolt Viscosity	T 72	
Specific Gravity of Semi-Solid Asphalt Materials	T 228	

Colorado Procedure – Laboratory 2202-15

Standard Method of Test for

Test of Protective Covering for Bridge Deck Waterproofing Membrane

1. SCOPE

1.1 This Procedure describes the method of test for the protective covering for bridge deck waterproofing membrane.

2. APPARATUS

2.1 Metal test block, 2" x 2" x 3", with rounded corners of 1/2" radius.

2.2 Water bath, automatically controlled, permitting accurate and uniform control of immersion temperature of 77°F ± 0.2°.

2.3 Oven, capable of maintaining a temperature of 176°F ± 5°.

2.4 Balance, having sufficient capacity and sensitive to 0.01 grams.

3. PREPARATION OF SPECIMENS

3.1 Cut from the sample at least 5 test specimens, not from adjacent locations in the sheet, and each being 1" x 8" for the bend test.

3.2 Cut two test specimens, each approximately 4" x 4" for original weight, weight loss, and behavior on heating tests. Specimens shall not be from the ends or sides, and shall not be from adjacent locations in the sheet.

4. TEST PROCEDURES

4.1 Place the bend-test specimens (from Subsection 3.1) in the water bath at 77°F for 30 minutes. Remove and immediately bend each specimen, with the weather-side up, at a uniform rate over the rounded edge of the test block. While bending the specimens over the block, exert only the pressure needed to keep it in contact with the block (avoid kinking). Any surface rupture exceeding l/8" in length is to be considered a failure. At least 4 of 5 strips shall pass the bend test.

4.2 Measure 4" X 4" specimen (from Subsection 3.2) to the nearest 1/32" (0.8 mm) and calculate surface area. Place in a desiccator for 24 hours. Remove, weigh to the nearest 0.01 grams, and record as "original specimen weight." By means of a thin wire fastened through holes punctured near one edge, suspend the specimen vertically in the center of an oven maintained at 176°F for 2 hours ± 5 minutes. Remove, cool in a desiccator until room temperature is obtained, weigh, and record as "specimen after-heating weight."

5. CALCULATIONS AND REPORT

5.1 There is no designated CDOT Form used for recording / reporting information for this CP-L.

5.2 Report all bend test results that fail to meet specifications.

5.3 Calculate the average loss of volatile matter as follows:

Volatile matter loss in percent =

$$\frac{\text{orig. specimen wt. minus specimen wt. after heating}}{\text{original specimen weights}}$$

5.4 Calculate the weight per sq ft as follows:

$$\mathrm{Wt/ft^2} = \mathrm{D}\left[\frac{0.317472}{\mathrm{X}}\right]$$

Where:

D = original specimen weight as described in Subsection 4.2

X = square inches of sample to the nearest 0.01

5.5 Report any change in appearance of the specimen such as blistering, absorption of the asphalt coatings, or displacement of the coating.

Colorado Procedure – Laboratory 2203-13

Standard Method of Test for

Pliability and Thickness of Prefabricated Reinforced Membrane

1. SCOPE

1.1 This procedure describes the method of test for pliability and thickness of prefabricated reinforced membrane material to be used as a bridge deck waterproofing membrane.

2. APPARATUS

2.1 Cold chamber, capable of maintaining 10°F ± 2°.

2.2 Mandrel, 1 inch diameter.

2.3 Micrometer, capable of measuring to 0.001 inches.

3. PREPARATION OF SPECIMENS

3.1 Cut three test specimens, each 1" x 4" from sample representing material to be used. Test specimens shall not be cut from ends or sides, or adjacent locations in the sheet.

4. TEST PROCEDURE

4.1 Measure and record the thickness of test strips using micrometer. Measure two locations on each strip approximately 1/2 inch from the edge and 1 inch from each end.

4.2 Place the test strips in the cold chamber at 10°F for a minimum of 2 hours.

4.3 While in the cold chamber and using gloves, bend the specimens 180° over the 1 inch mandrel at a steady rate. Bending time should be approximately 5 seconds. Inspect for cracks.

5. REPORTING

5.1 There is no designated CDOT Form used for recording / reporting information for this CP-L.

5.2 Average the six thickness measurements and report as thickness in mils (0.001 inches).

5.3 Report as a failure if any cracks are evident.

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Colorado Procedure – Laboratory 2210-24

Standard Method of Test for

Determining Toughness and Tenacity of Rubberized Asphaltic Materials

1. SCOPE

1.1 This procedure describes the method of test for determining the toughness and tenacity of rubberized asphaltic materials.

2. APPARATUS

2.1 Container - metal, cylindrical in shape, flat bottom, nominal capacity of 90 ml (3 oz.), nominal inside dimensions of 55 mm (2-1/8 in.) in diameter, and 35 mm (1-3/ 8 in.) in depth.

Note 1: Containers known as tin boxes or seamless ointment boxes may be obtained in dimensions conforming to the above requirements. (Gill style sample cups, 3oz.)

2.2 Tension Head - polished metal, hemispherical shape, having an 11 mm (7/16 in.) radius to which it is integrally connected to a 6.4 mm (1/4 in.) diameter stem approximately 33 mm (1-5/16 in.) in length, which is then connected to the testing machine head. The stem of the tension head shall be fitted with a small pin to prevent twisting of the head when adjusting. The tension head shall be fitted with a knurled screw to permit accurate adjustment of the head into the sample in the container.
(See Figure No. 1).

2.3 Spider - the support for the tension head shall consist of a cylindrical center section through which the stem of the tension head may freely move parallel to the axis of the cylinder. The inner wall of the cylinder shall be grooved to receive the pin mounted on the stem of the tension head in order to prevent twisting of the head during adjustment. The cylinder shall be fitted with three arms, equally spaced at 120°, extending from the center and notched to receive the lip of the sample container there by centering the spider and the tension head in the container (See Figure No. 1).

2.4 Testing Apparatus - shall be capable of uniform movement of 50 cm (20 in.) per minute, shall have a minimum load capacity of 110 kg (50 lbs.), shall be sensitive to 0.5 kg (1.1 lb.), and be equipped with a recorder capable of continuous graphic recording of forces and distances involved
(See Figure No. 2).

3. PREPARATION OF SPECIMENS

3.1 The test specimens shall be heated at a constant temperature of 300°F for a period of 90 minutes. Pour 36 ± 0.1 grams into each container, and carefully lower the head by means of the knurled screws until immersed in the sample to a depth of exactly 11 mm (7/16 in.) (See Figure No. 1). It is important that the head is centered in the specimen. Cool the container and head at ambient laboratory temperature for 60 minutes, then place in a waterbath maintained at 77°F. After 60 minutes remove the specimen from the bath and immediately place in the testing machine in which all charts, gears, and other parts have been prepared and calibrated.

4. TEST PROCEDURE

4.1 Operate the testing machine at an extension rate of 50 cm (20 in.) per minute. A continuous automatic recording of force vs. the distance value shall be made. The extension shall be continued until (a) the asphalt column breaks, (b) either the curve reaches a zero force, or it stabilizes at a constant force close to zero (this situation is caused by the mass of asphalt that ends up sticking to the tension head), or (c) the machine's extension limit (maximum of 30 inches) is reached.

5. CALCULATIONS

5.1 The toughness of the specimen is calculated in inch-pounds of work required to separate the tension head from the specimen in the container under the prescribed test conditions. It is computed in inch-pounds from the area under the curve plotted by the graphic recorder (See Figure No. 3).

The tenacity of the specimen is calculated as an integral part of the toughness measurement. The portion of the area under the curve is determined by tangentially extending the curve as it decreases from the maximum force value (initial peak force) to the zero-force line and calculating all the area from the tangent line to where the curve dives down to the theoretical zero force load. This value is also calculated in inch-pounds of work (See Figure No. 3).

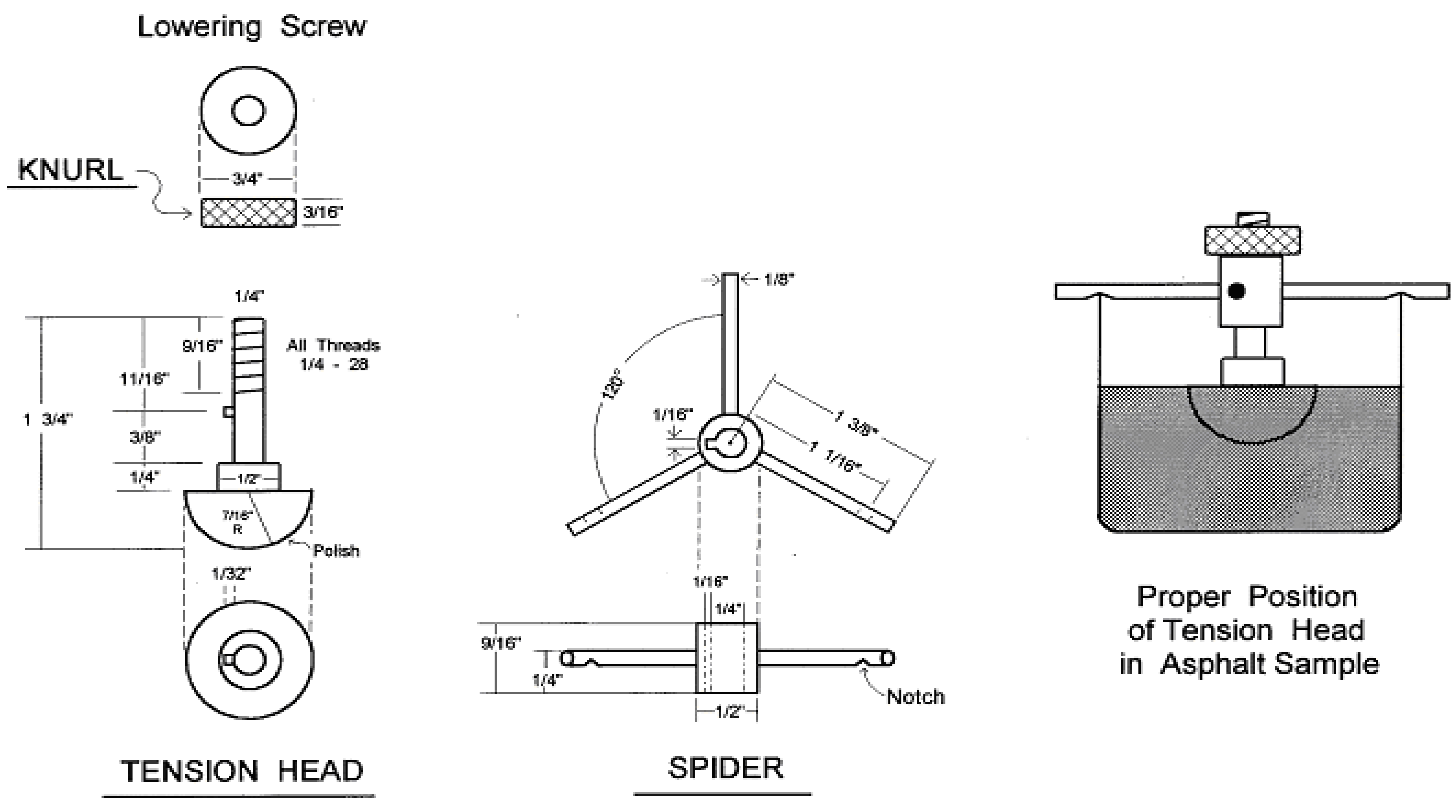
6. REPORT

6.1 There is no designated CDOT Form used for recording / reporting information for this CP-L.

6.2 Each sample shall be tested in triplicate. Report the average of the two closest test results for toughness and tenacity according to calculations in Subsection 5.1

ASPHALT TOUGHNESS AND TENACITY TEST EQUIPMENT

DETAIL OF TESTING DEVICE



TENSION HEAD

SPIDER

Proper Position
of Tension Head
in Asphalt Sample

Figure No. 1

TYPICAL TEST APPARATUS FOR TOUGHNESS AND TENACITY MEASUREMENT ON RUBBERIZED ASPHALT

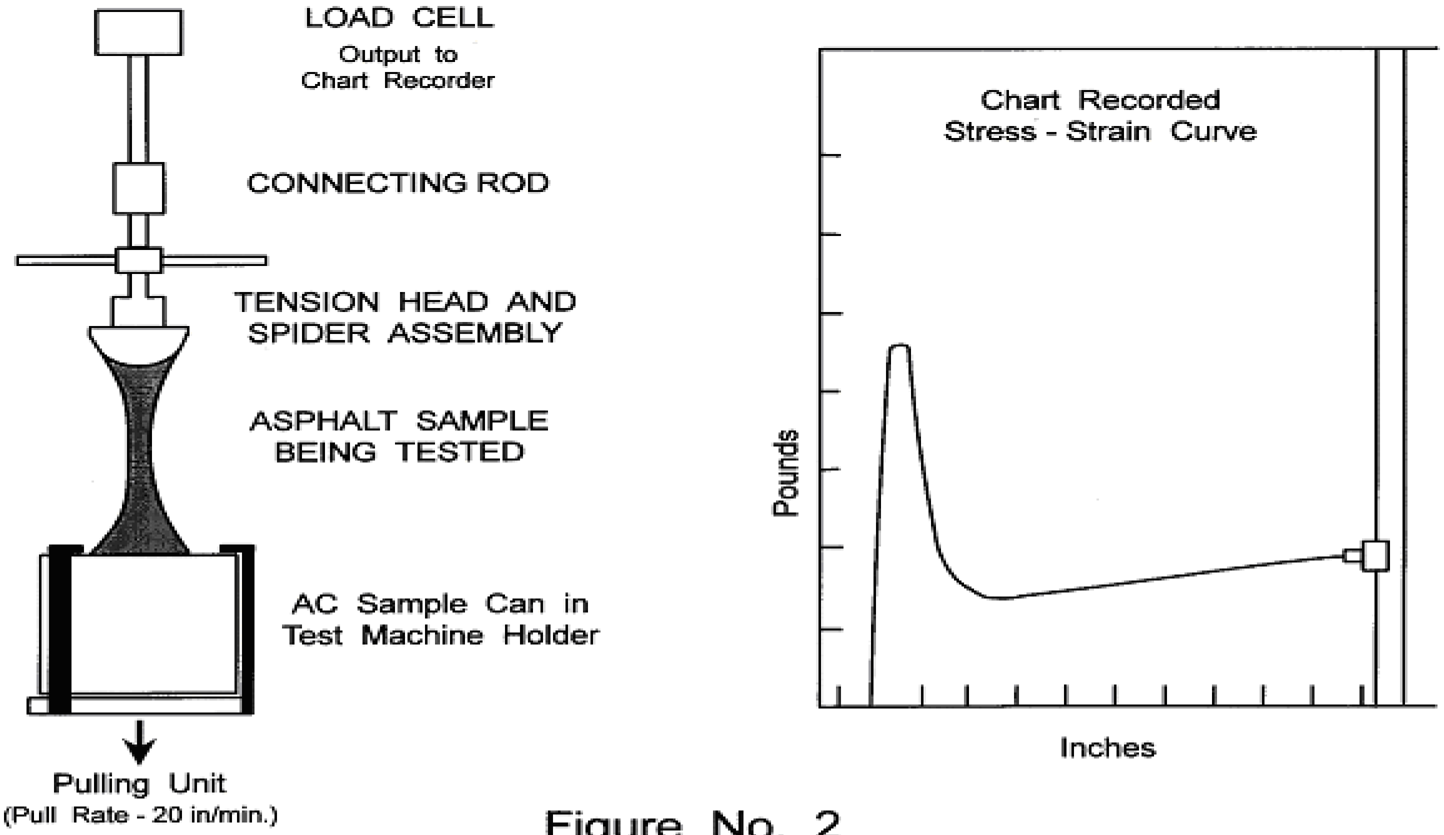
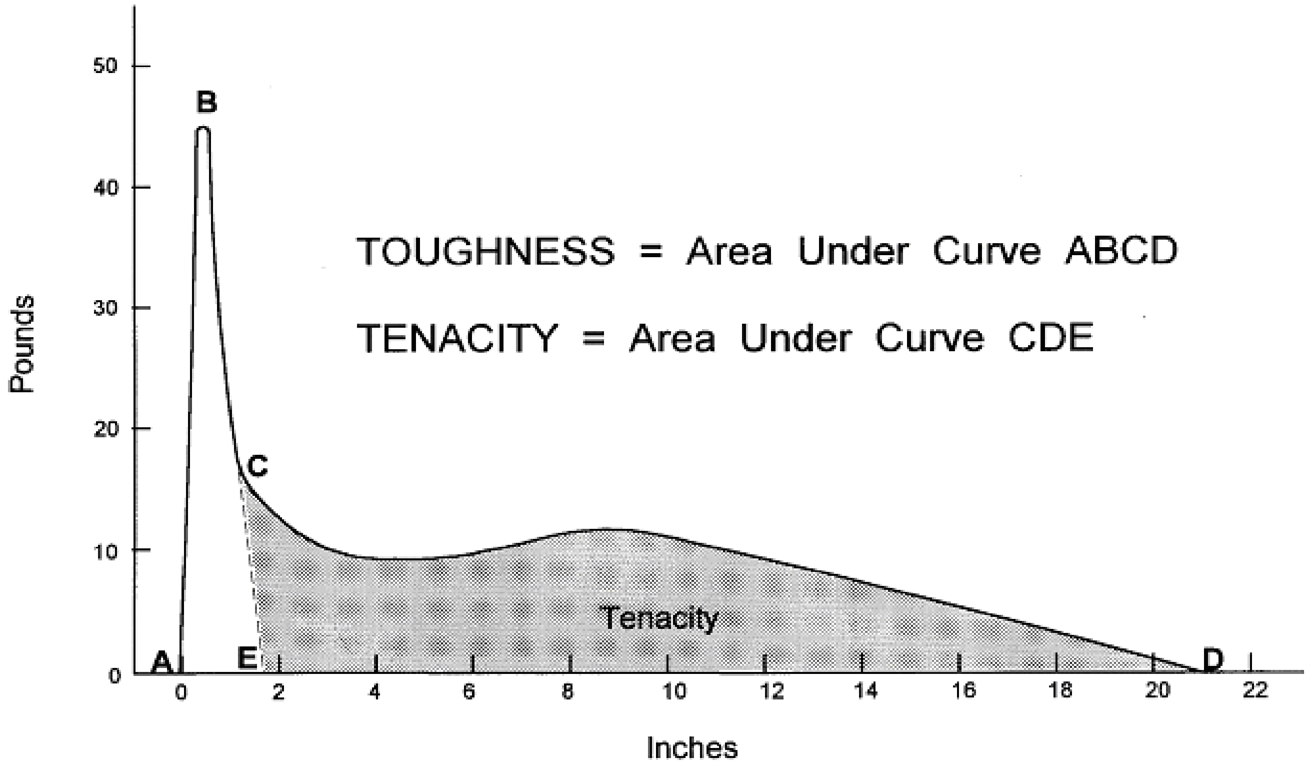


Figure No. 2

Figure 2

Calculation of Toughness and Tenacity
Typical Stress - Strain Curve for Rubberized Asphalt



TOUGHNESS = Area Under Curve ABCD

TENACITY = Area Under Curve CDE

Figure No. 3

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Colorado Procedure – Laboratory 2211-15

Standard Method of Test for

Elastic Recovery

(This procedure is used in conjunction with AASHTO T 51.)

1. SCOPE

1.1 The elastic recovery of a polymer modified asphalt cement is evaluated by the percentage of recoverable strain measured after elongation during a conventional ductility test. Unless otherwise specified, the test shall be made at the temperature of 77°F (25°C ± 0.5°) and with a speed of 50 mm/min. ± 5.0%.

2. REFERENCE DOCUMENTS

2.1 AASHTO T 51: Ductility of Asphalt Materials

ASTM E 1: Specification for ASTM Liquid-in-Glass Thermometer

3. APPARATUS

3.1 *Molds*

3.1.1 *Mold* - (Method A) This mold is used in the testing of superpave material. The mold shall be similar in design to that described for use in the ductility test (AASHTO T 51), Figure 1, except that the sides of the mold assembly, part a and a’, shall have STRAIGHT sides, producing a test specimen with a cross section area of 100 mm^2.

3.1.2 *Mold* - (Method B) This mold is used in testing residue from polymer modified emulsions. The mold shall be similar in design to that described for use in the ductility test (AASHTO T 51), Figure 1.

3.2 *Water Bath* - The water bath shall be maintained at the specified test temperature, varying not more than 0.18°F (0.1°C) from this temperature.

3.3 *Testing Machine* - For pulling the briquette of bituminous material apart, any apparatus may be used which is so constructed that the specimen will be continuously immersed in water, as specified, while the two clips are pulled apart at an uniform speed without undue vibration.

3.4 *Thermometer* - An ASTM 63C or 63F thermometer shall be used.

3.5 *Scissors* - Any type of conventional scissors capable of cutting polymer modified asphalt at the test temperature.

METHOD A

4. PROCEDURE FOR TESTING SUPERPAVE MATERIAL

4.1 Prepare test specimens and condition as prescribed by AASHTO T 51.

4.2 Elongate the test specimen at the specified rate to a deformation of 100 mm.

4.3 Immediately cut the test specimen into two halves, at the midpoint, using the scissors. Keep the test specimen in the water bath in an undisturbed condition for 1 hour.

4.4 After the 1 hour time period, move the elongated half of the test specimen back into position near the fixed half of the test specimen so the two pieces of polymer modified asphalt just touch. Record the length of the specimen as X.

5. REPORT

5.1 There is no designated CDOT Form used for recording / reporting information for this CP-L.

5.2 Calculate the percent recovery by the following procedure:

$$\text{Recovery,\%} = \frac{(100 - X)}{100} \bullet 100$$

Where: X = Specimen length in mm.

METHOD B

6. PROCEDURE FOR TESTING POLYMER MODIFIED EMULSIONS

6.1 Prepare test specimens and condition as prescribe by AASHTO T 51.

6.2 Elongate the test specimen at the specified rate to a deformation of 200 mm.

6.3 After 200 mm elongation has been reached, stop the ductilometer and hold specimen in its elongated position for 5 minutes. At this time, cut the test specimen into two halves, at the midpoint, using the scissors. Keep the test specimen in the water bath in an undisturbed condition for 1 hour.

6.4 After the 1 hour time period, move the elongated half of the test specimen back into position near the fixed half of the test specimen so the two pieces of polymer modified asphalt just touch. Record the length of the specimen as b.

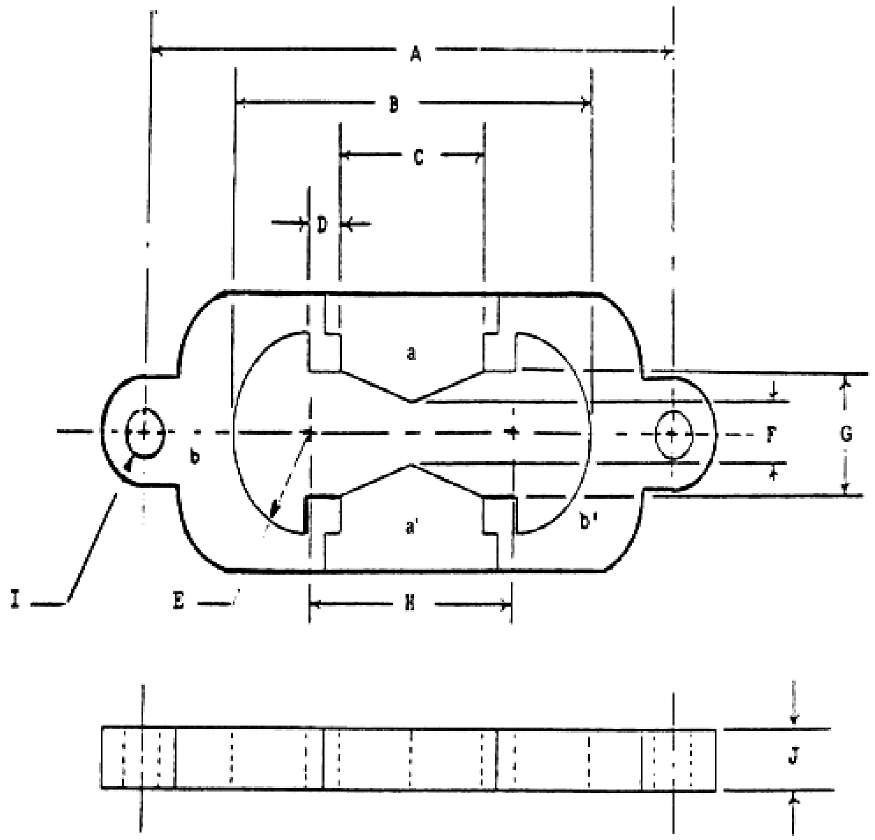
7. REPORT

7.1 There is no designated CDOT Form used for recording / reporting information for this CP-L.

7.2 Calculate the percent recovery by the following procedure:

$$\textbf{Recovery, \%} = \frac{\mathbf{(200 - b)}}{\mathbf{200}} \bullet 100$$

Where: b = Specimen length in mm.



A—Distance between centers, 111.5 to 113.5 mm.
B—Total length of briquet, 74.5 to 75.5 mm.
C—Distance between clips, 29.7 to 30.3 mm.
D—Shoulder, 6.8 to 7.2 mm.
E—Radius, 15.75 to 16.25 mm.
F—Width at minimum cross section, 9.9 to 10.1 mm.
G—Width at mouth of clip, 19.8 to 20.2 mm.
H—Distance between centers of radii, 42.9 to 43.1 mm.
I—Hole diameter, 6.5 to 6.7 mm.
J—Thickness, 9.9 to 10.1 mm.

FIG. 1 Mold for Ductility Test Specimen

Colorado Procedure – Laboratory 2212-15

Standard Method of Test for

Residue by Evaporation of Asphalt Emulsion

1. SCOPE

1.1 This procedure describes the method of test to determine the percent residue of asphalt emulsion and to provide emulsion residue for further testing. The results of this test or tests on the residue may be used for acceptance, but not for rejection. If this test or subsequent tests on the emulsion residue fail to meet specifications, the test must be repeated using residue by distillation (AASHTO T 59) to determine conformance with the specifications.

2. REFERENCE DOCUMENTS

2.1 AASHTO T 59: Emulsified Asphalts

3. APPARATUS

3.1 Disposable aluminum cake pan of approximate dimensions 4” wide by 8” long by 2.5” deep.

3.2 Heating plate that is capable of maintaining a temperature of 400°F.

3.3 Thermometer capable of measuring temperatures of up to 700°F (ASTM 10F).

3.4 Balance having sufficient capacity and sensitive to 0.1 grams.

4. TEST PROCEDURE

4.1 Weigh an empty aluminum pan with the thermometer in it and record on worksheet.

4.2 Pour 200 ± 1 g of thoroughly mixed emulsion into the pan.

4.3 Weigh the aluminum pan, thermometer, and emulsion and record on worksheet.

4.4 Place the aluminum pan with the thermometer and emulsion onto the hot- plate fully preheated to 250°F.

4.5 Stir occasionally and take care to avoid boil over or splatter. If any emulsion is lost, the test is invalid and must be repeated with a new emulsion sample and pan.

4.6 Heat emulsion sample to 250°F then increase the hot plate temperature to 400°F.

4.7 Stir occasionally, take a temperature reading periodically, and adjust heat as needed to bring emulsion temperature to 400°F.

4.8 Once the emulsion temperature has reached 390°F, start the 15-minute timer. Maintain the temperature at 400°F ± 10° for 15 minutes.

4.9 Remove pan, emulsion, and thermometer from heating plate, weigh, and record weight.

4.10 Pour residue into appropriate molds for further testing.

5. CALCULATIONS AND REPORT

5.1 Record and report results on an emulsified asphalt worksheet.

5.2 Calculate percent residue using the following equation:

$$\text{Percent residue} = [(d - a)/(c - a)]\,100$$

Where:

a = weight of pan and thermometer
c = weight of pan, thermometer, and emulsion before evaporation
d = weight of pan, thermometer, and emulsion after evaporation

Colorado Procedure – Laboratory 2213-19

Standard Method of Test for

Coating of Bitumen-Aggregate Mixtures

1. SCOPE

1.1 This procedure describes a method for determining the ability of an aggregate to be coated by an emulsion. The procedure will be performed using emulsion and aggregate sampled from a chip seal project.

2. APPARATUS

2.1 Containers for mixing, having rounded corners, such as seamless tin cans, able to easily hold 100g of aggregate.

2.2 Balance, with a minimum capacity of 200g, accurate to 0.1g.

2.3 Spatula, steel, with a stiff blade approximately 25 mm wide by 100 mm long.

2.4 Constant Temperature Oven, capable of maintaining 275°F ± 2° (135°C ± 1°).

3. TEST PROCEDURE

3.1 Obtain emulsion of the same type that will be used on the project.

3.2 Thoroughly heat the emulsion to 140°F (60°C) and stir so that it is uniform.

3.3 Weigh 100 ± 1g of aggregate into a clean mixing container.

3.4 Add 8.0 ± 0.2g of emulsion to the aggregate.

3.5 Mix the emulsion and aggregate vigorously at room temperature with the spatula until all aggregate is coated, but for no more than 5 minutes.

3.6 By observation, estimate the percentage of the total visible area of the coated aggregate as 95 percent or above, or below 95 percent. Any thin brownish, translucent areas are to be considered fully coated. If the coated area is 95 percent or greater, proceed to Section 4; otherwise, continue at Subsection 3.7.

3.7 Weigh 100 ± 1g of aggregate into a clean mixing container.

3.8 Add 2g of water to the aggregate and mix thoroughly.

3.9 Add 8.0 ± 0.2g of emulsion to the aggregate.

3.10 Mix the emulsion, water, and aggregate vigorously at room temperature with the spatula until all aggregate is coated, but for no more than 5 minutes.

3.11 By observation, estimate the percentage of the total visible area of the coated aggregate as 95 percent or above, or below 95 percent. Any thin brownish, translucent areas are to be considered fully coated. If the coated area is 95 percent or greater, proceed to Section 4. Otherwise, continue at Subsection 3.12.

3.12 Oven-cure the coated aggregate from Subsection 3.11 in the original container, uncovered, at 275°F (135°C) for 2 hours ± 15 minutes. The ventilating port of the oven should be open during this curing step. After curing, immediately remix with the spatula while the mixture cools to room temperature, or until the bituminous material ceases to drain off the aggregate. Coating must be complete after remixing, that is to say, no bare spots are permissible.

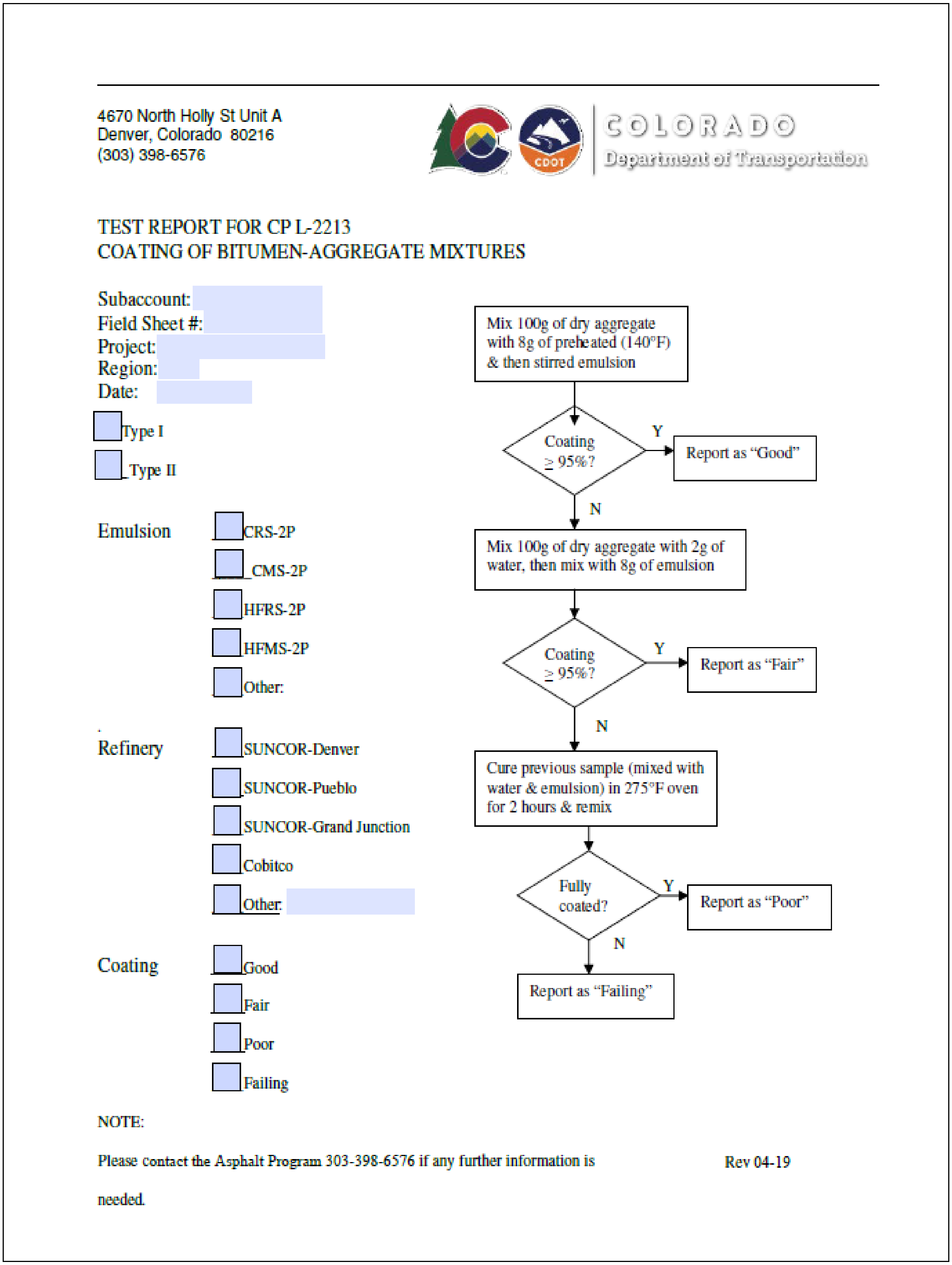
4. REPORT

4.1 If the aggregate mixture from Subsection 3.6 was coated 95% or above, report the coating as “Good”.

4.2 If the aggregate mixture from Subsection 3.11 was coated 95% or above, report the coating as “Fair”.

4.3 If the aggregate mixture from Subsection 3.12 was fully coated, report the coating as “Poor”. If it was not fully coated, report the coating as “Failing".

4.4 Test Report CP-L 2213 Coating of Bitumin-Aggregate Mixtures (Form Attached).



4670 North Holly St Unit A
Denver, Colorado 80216
(303) 398-6576

COLORADO
Department of Transportation

TEST REPORT FOR CP L-2213
COATING OF BITUMEN-AGGREGATE MIXTURES

Subaccount:
Field Sheet #:
Project:
Region:
Date:

☐ Type I

☐ Type II

Emulsion
- ☐ CRS-2P
- ☐ CMS-2P
- ☐ HFRS-2P
- ☐ HFMS-2P
- ☐ Other:

Refinery
- ☐ SUNCOR-Denver
- ☐ SUNCOR-Pueblo
- ☐ SUNCOR-Grand Junction
- ☐ Cobitco
- ☐ Other:

Coating
- ☐ Good
- ☐ Fair
- ☐ Poor
- ☐ Failing

NOTE:

Please contact the Asphalt Program 303-398-6576 if any further information is needed.

Rev 04-19

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Colorado Procedure – Laboratory 2214-15

Standard Method of Test for

Verification of Binder Acidity

1. SCOPE

1.1 This method covers the detection of acid modification of asphalt binders.

2. REFERENCED DOCUMENTS

2.1 FHWA Turner-Fairbanks Research Lab Procedures:

Note 1: Susan P. Needham Test Method for Detecting the Presence of Phosphoric Acid in Asphalt as last revised on 9/20/2013.

Note 2: This method is adapted from ASTM test method D 515-88 "Standard Test Methods for Phosphorus in Water."

3. APPARATUS

3.1 Disposable, plastic transfer pipettes.

3.2 Glass beakers: 150 ml or 250 ml. Glass stirring rods.

3.3 Balance that reads a minimum of 500 g, accurate to 0.1 g.

3.4 Distilled or Purified water.

3.5 Constant temperature chamber or water bath capable of maintaining the Ascorbic Acid Color Reagent temperature at approximately 4°C.

3.6 Antimonyl tartrate / Ammonium molybdate Solution: Dissolve 0.13g of potassium antimonyl tartrate hydrate [$C_8H_4K_2O_{12}Sb_2 \cdot H_2O$] in 50 ml of distilled water. Add 5.6g of ammonium molybdate [$(NH_4)_6Mo_7O_{24} \cdot 4\,H_2O$] and swirl until dissolved.

3.7 1N Sulfuric Acid Solution*:* [H_2SO_4]. This can be purchased in 1-liter polyethylene bottles.3.8Stock Solution Mixture*:* Mix the solution from Subsection 2.6 and approximately 950ml of solution from Subsection 2.7. This can be done by adding solution from Subsection 2.6 to the 1 liter of 1N sulfuric acid if there is sufficient space in the bottle. The exact amount of sulfuric acid is not critical. This solution is stable for 1 year.

3.9 Ascorbic Acid Color Reagent*:* Dissolve 0.50 g of L-Ascorbic Acid [$C_6H_8O_6$] in 100 ml of the Stock Solution Mixture (see Subsection 2.8). This reagent is stable for a week if stored at 4°C; or, prepare the reagent fresh daily as needed.

3.10 Iso Butanol*:* [$(CH_3)_2CHCH_2OH$] (n-butanol also can be used).

3.11 X-ray fluorescence spectrometer

4. SIGNIFICANCE AND USE

4.1 This method is used to determine if asphalt binder was modified with phosphoric acid. The color change of the wash is an indication of the presence of acid modification.

This method serves as a positive or negative detection of acid in asphalt. This process is not quantitative.

5. PROCEDURE

METHOD A – WET CHEMISTRY

5.1 Carefully heat the asphalt sample taking care to prevent local overheating. Heat until the sample is sufficiently fluid to pour. Shake or stir the sample thoroughly before pouring.

5.2 Pour 1 to 2 grams of asphalt sample into glass beakers.

5.3 Add 2 ml of butyl alcohol, while swirling the container.

5.4 Continue to swirl the container and add 2 ml of distilled water.

5.5 While still swirling the container, add 2 ml of the Ascorbic Acid Color Reagent.

5.6 If phosphoric acid is present in the asphalt, a blue color will develop within 5-10 minutes.

6. DETERMINATION

6.1 Determination of Acid Modification.

6.1.1 When the color of the wash is blue in color or tint, the binder is positive for acid modification.

6.2 If the sample is suspected of acid modification further analysis may be performed using X-Ray Fluorescence Spectrometry in Method B.

7. PROCEDURE

METHOD B – X-RAY SPECTROSCOPY

7.1 Procedure is internal to CDOT Chemistry Lab.

Colorado Procedure – Laboratory 2215-15

Standard Method of Test for

Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin Film Oven Test)

(This procedure is used in conjunction with AASHTO T 240-13.)

7. PROCEDURE

Note: Replace Subsection 7.6 of AASHTO T 240 with the following:

7.6 With the oven at operating temperature, arrange the containers holding the asphalt in the carriage so that the carriage is balanced. Fill any unused spaces in the carriage with empty containers. Close the door and rotate the carriage assembly at a rate of 15 ± 0.2 R/min. Start the airflow at a set rate of 4000 ± 300 ml per minute corrected to standard barometric pressure and temperature. Maintain the samples in the oven with the air flowing and the carriage rotating for 85 minutes. The test temperature 163°C ± 0.5° (325°F ± 1°) shall be reached within the first 10 minutes – otherwise discontinue the test.

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SOIL INDEX - 16

Colorado Procedures – Laboratory:

Standard Test Procedures: AASHTO / ASTM

	AASHTO	ASTM
Liquid Limit of Soils, Determining the	T 89	
Plastic Limit and Plasticity Index of Soils, Determining the	T 90	
Moisture-Density Relations of Soils Using 2.5-kg Rammer & 305-mm Drop	T 99	
Specific Gravity of Soils	T 100	
Moisture-Density Relations of Soils Using 4.54-kg Rammer & 457-mm Drop	T 180	
Resistance R-Value and Expansion Pressure of Compacted Soils (Replaced CP-L 3101 in Total)	T 190	
Unconfined Compressive Strength of Cohesive Soil	T 208	
Permeability of Granular Soils (Constant Head)	T 215	D 2434
One-Dimensional Consolidation Properties of Soils	T 216	
Density of Soil-in-Place by Block, Chunk, or Core Sampling	T 233	
Direct Shear Test of Soils Under Consolidated Drained Conditions	T 236	
Slake Durability of Shales and Similar Weak Rocks		D 4644

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Colorado Procedure – Laboratory 3101-19

Standard Method of Test for

Resistance R-Value and Expansion Pressure of Compacted Soils or Aggregates by Means of Hveem Stabilometer

(Refer to AASHTO T 190-09)

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Colorado Procedures – Laboratory 3103-19

Standard Method of Test for

Specific Gravity of Soils

(AASHTO T 100 is the primary procedure with CP-L 3103 modifying select subsections only.
AASHTO T 100 and CP-L 3103 must be used together.)

AASHTO T 100:
Will be used to determine the bulk specific gravity and absorption, except for Subsections: 5.1.1 (replacement), 5.1.5, 5.1.6, 5.1.7 (addition) of *Apparatus*; Subsection 8.1 (replacement) of *Sample*; Subsections 9.1, 9.2, 9.3 (replacements) of *Procedure*; Subsections 10.1.1, 10.1.2 and 10.6.1 (additions) of *Calculation and Report*.

5. APPARATUS

5.1.1 *Erlenmeyer flask* - A minimum 1000 ml glass flask with sufficient capacity for a 500g ± 0.5g sample. The stopper shall be composed of a suitable rubber, and of such size and shape that it can easily be inserted to a fixed depth in the neck of the bottle, and shall have a small hole through its center to permit the emission of air and surplus water.

5.1.5 *Sieves* - A 3/4" (19 mm), 3/8" (9.5 mm), and No. 4 (4.75 mm)

5.1.6 *Flat Glass*- Suitable piece that fits smoothly over and seals the mouth of the flask.

5.1.7 **Optional:** A vibrating table with variable frequency control and of sufficient capacity to shake without damaging the sample or flask.

8. SAMPLE

8.1 A test sample weighing 500g ± 0.5g shall be obtained which passes the 3/4 inch (19 mm) sieve, and is either retained on the No. 4 (4.75 mm), and/or is retained on the 3/8 inch (9.5 mm) sieve. A representative percent from each of the two smallest sieves will be included in the sample being tested.

9. PROCEDURE

9.1 After thoroughly washing to remove dust or other coatings from the surface of the particles, immerse in water at room temperature for a minimum of 15 hours.

9.2 Remove the sample from the water and roll it in a large, dry, absorbent cloth until all visible films of water are removed. Take care to avoid evaporation of water from aggregate pores during the Operation of surface-drying. Determine the mass of the test sample in the saturated surface-dry (SSD) condition. Record this and all subsequent weights to the nearest 0.1g.

9.3 After determining the mass, immediately place the saturated surface-dry (SSD) test sample in the glass flask. Fill the flask with sufficient water to completely cover the sample to a minimum of 1 inch. The water temperature shall be 23°C ± 1.7° (73.4°F ± 3°). Remove entrapped air by subjecting the contents to a vacuum of 13.33 kPa (100 mm Hg) or less absolute pressure. Evacuate all air for 20 minutes. Gently agitate the flask once the vacuum has stabilized and at five-minute intervals thereafter. Remove the vacuum pump line from the flask and completely fill the flask with water at 23°C ± 1.7° (73.4°F ± 3°). Slide the flat piece of glass over the mouth of the flask in a manner that will exclude any free air in the vessel. Wipe all visible water from the outside of the flask and glass. Weigh the combination of flask, glass, water, and sample and then record to the nearest 0.1g.

Optional: If using a vibrating table, secure the flask on the vibrating table and turn on. Adjust frequency of the vibrating table such that the material within the flask does not rotate. Process the aggregate for a time-period not to exceed 10 + 1 minutes.

10. CALCULATION AND REPORT

10.1.1 Calculate the specific gravity of the aggregate, based on water at a temperature of 23°C ± 1.7° (73.4°F ± 3°), as follows:

$$\text{Bulk Specific Gravity} = A/(B - C)$$

Where:

A = Weight of oven-dry test sample in air,
B = Weight of saturated-surface-dry test sample in air (SSD),
C = Weight of saturated test sample in water

[Where: Weight of flask, water, glass plate, and sample - (minus) Weight of calibrated flask, water and glass plate]

10.1.2 Calculate the absorption as follows:

$$\text{Absorption} = [(B - A)/A] \times 100$$

Where:

A and B are as previously stated.

10.6.1 Report the results of the specific gravity to the nearest 0.01 and the absorption to the nearest 0.001.

Colorado Procedure – Laboratory 3104-15

Standard Method of Test for

Determining the Durability of Shales for Use as Embankments

(Designated as CP 26 prior to the 2010 FMM.)

1. SCOPE

1.1 Shales, as Highway Embankments (or construction material), should be classified as Soil-like (non-durable) or Rock-like (durable). This method of test is intended to distinguish between durable shales that can be used in rock-fills from non-durable shales that must be placed and compacted as soil. This procedure describes two methods (A and B) which may be used in the Region or Central Laboratory.

2. REFERENCED DOCUMENTS

2.1 *ASTM Procedures:*

D 4644-08 Standard Test Method for Slake Durability of Shales and Similar Weak Rocks

3. SUMMARY OF METHODS

3.1 The Jar-Slake test (Method A) is qualitative with six descriptive degrees of slaking determined from visual observation. The Jar-Slake test is recommended as the basic screening test.

3.2 The Slake-Durability test (Method B) is performed on pieces of oven-dried material submerged in water and rotated in a wire drum cage. The Slake-Durability test is considered as the main index test.

METHOD A - JAR-SLAKE TEST

4. APPARATUS

4.1 *Drying Apparatus* - An oven or other suitable device.

4.2 *Jar* - A glass jar or other suitable glass container having a capacity of at least one pint (0.5 L).

5. PROCEDURE

5.1 Oven dry the material to a constant weight (mass) at 230°F ± 9° (110°C ± 5°).

5.2 Place a chunk of the oven dried material (approx. 100 - 200g.) in the glass jar or container.

5.3 Fill the container with tap water so as to completely cover the sample.

5.4 The degree of slaking is determined from visual observation after 24 hours.

NOTE 1: The reaction to the Jar-Slake test usually occurs within the first 10 to 30 minutes. A standard of 24 hours is recommended for initial testing. As experience is gained within a particular formation, the time can be reduced to 2 hours or less.

6. ANALYSIS

6.1 The six values of the Jar-Slake index, I_J, are listed below:

I_J	DESCRIPTIVE BEHAVIOR
1.	Degrades into a pile of flakes or mud
2.	Breaks rapidly and/or forms many chips
3.	Breaks rapidly and/or forms few chips
4.	Breaks slowly and/or forms several fractures
5.	Breaks slowly and/or forms few fractures
6.	No change

METHOD B - SLAKE-DURABILITY TEST

7. APPARATUS

7.1 *Drying Apparatus* - An oven or other suitable device.

7.2 *Balance* - A balance of suitable capacity and sensitive to 1.0g.or less.

7.3 *Drum* - A wire drum cage (No. 10 screen) capable of being rotated at 20 rpm.

8. PROCEDURE

8.1 Oven dry the material to a constant weight (mass) at 230°F ± 9° (110°C ± 5°).

8.2 Obtain 10 representative pieces of oven-dried material weighing (with a mass of) approximately 40 to 60 grams each.

8.3 Obtain the weight (mass) of the total mass and record as the dry weight (mass) in grams before testing.

8.4 Place the total sample in the wire drum cage, submerge in water, and rotate at 20 rpm for 10 minutes.

8.5 Remove the sample retained in the wire drum cage and again oven-dry to a constant weight at 230°F ± 9° (110°C ± 5°).

8.6 Repeat the procedure as in 8.4 above.

8.7 Repeat the procedure as in 8.5 above.

8.8 Obtain the weight (mass) of the retained sample and record as the dry weight (mass) in grams after testing.

8.9 Calculate the Slake-Durability index, I_D, from the following formula:

$$I_D = \frac{Dry\ weight\ after\ testing}{Dry\ weight\ before\ testing} x\,100$$

9. CLASSIFICATION CRITERIA

9.1 Material with a Jar-Slake index (I_J) of 1 or 2, obviously should be considered Soil-like without further testing.

9.2 Material with a Jar-Slake index (I_J) greater than 2 should be subjected to the Slake-Durability test.

9.3 Recommended durability index tests and suggested classification criteria for shale like materials used as Highway Embankments is as follows:

SLAKE-DURABILITY TEST

I_D % Retained	Type of Retained Wet Material	Classification
<60%	T_2,T_3	S-N
60% to 90%	T_1S,T_3	S-N
60% to 90%	T_1H,T_2	R-D
>90%	T_1S,T_3	S-N
>90%	T_1H,T_2	R-D

TYPE:

T_1S - Soft, can be broken apart or remolded.

T_1H - Hard, cannot be broken apart.

T_2 - Retained particles consist of large and small hard pieces.

T_3 - Retained particles are all small fragments.

CLASSIFICATION:

S-N – Soil-like (Non-durable)

R-D – Rock-like (Durable)

Colorado Procedure - Laboratory 3105-13

Standard Method of Test for

Grain Size Analysis of Soil for AASHTO Classification

(This procedure modifies Colorado Procedure 21. The current CP 21 is to be used with this procedure.)

1. SCOPE

1.1 This method covers the determination of the particle size distribution of soil material for AASHTO classification.

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards:*

M 145 Classification of Soils and Soil- Aggregate Mixtures for Highway Construction Purposes
T 265 Moisture Content of Soils
T 311 Grain-Size Analysis of Granular Soil Materials

2.2 *Colorado Procedures:*

CP 20 Dry Preparation of Disturbed Soil Samples for Test
CP 21 Mechanical Analysis of Soils

3. APPARATUS

Note: Colorado Procedure (CP) 21 shall be used to determine the sieve analysis of soils with the following exceptions:

3.4 *Sieves* – Sieves of the following sizes conforming to AASHTO M 92: 3-in. (75 mm), 1-in. (25.0 mm), 3/4-in. (19.0 mm), 3/8-in (9.5mm), No. 4, No. 10, No. 40, and No. 200.

3.4.1 The separation sieve shall be the #4 sieve.

5. PROCEDURE

5.2.4 Weigh and record the material retained on the plus (+) #4 sieve cumulatively in pounds (lbs.).

7. RECORD

7.1 CDOT Form #1045, Gradation Work Sheet.

7.2 CDOT Form #555, Preliminary Soil Survey.

Mathematically Scalping a Gradation

(Instructions for when a Preliminary Soil Survey has been performed.)

When less than 75 percent is passing the 3/4 inch sieve, divide the 3/8 inch sieve percent by the 1 inch sieve percent and then multiply the quotient by 100. The result will yield the "as run" gradation reported on CDOT Form #555. Perform this calculation on each successive sieve. When more than 75 percent is passing the 3/4 inch sieve, use the 3/4 inch sieve percent as a divisor and then perform the same calculation on each successive sieve.

			< 75%					
Sieve	**3**	**1**	**3/4**	**3/8**	**#4**	**#10**	**#40**	**#200**
% Passing	100	66	61	50	45	41	28	16
As Run		100	100	76	68	62	42	24

Scalp
(50 / 66) * 100 = 76

			> 75%					
Sieve	**3**	**1**	**3/4**	**3/8**	**#4**	**#10**	**#40**	**#200**
% Passing	100	99	98	95	90	80	57	21
As Run		100	100	97	92	82	58	21

Scalp
(95 / 98) * 100 = 97

Cumulative Setup for a R-Value

			< 75%					
Sieve	**3**	**1**	**3/4**	**3/8**	**#4**	**#10**	**#40**	**#200**
% Passing	100	66	61	50	45	41	28	16
As Run		100	100	76	68	62	42	24

Scalp
(50 / 66) * 100 = 76

	R-value Setup	
100	76	68
	X	X
	12	12
+ 3/8	288	
+ #4	384	
- #4	1200	

(100-76) * 12 = 288
(100-68) * 12 = 384

Colorado Procedure - Laboratory 3106-13

Standard Method of Test for

Grain Size Analysis of Soil for Unified Soil Classification System

(This procedure modifies Colorado Procedure 21. The current CP 21 is to be used with this procedure.)

1. SCOPE

1.1 This method covers the determination of the particle size distribution of soil material for Unified Soil Classification System (USCS).

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards:*

M 145 Classification of Soils and Soil - Aggregate Mixtures for Highway Construction Purposes
T 265 Moisture Content of Soils
T 311 Grain-Size Analysis of Granular Soil Materials

2.2 *ASTM Standards:*

D2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)

2.3 *Colorado Procedures:*

CP 20 Dry Preparation of Disturbed Soil Samples for Test
CP 21 Mechanical Analysis of Soils

3. APPARATUS

Note: Colorado Procedure (CP) 21 shall be used to determine the sieve analysis of soils with the following exceptions:

3.4 *Sieves* – Sieves of the following sizes conforming to AASHTO M 92: 3-in. (75 mm), 1.5-in. (37.5mm), 3/4-in. (19.0 mm), 3/8-in (9.5mm), No. 4, No. 10, No. 20, No. 40, No. 50, No. 100, and No. 200.

3.4.1 Sample shall not be split.

5. PROCEDURE

5.2.4 Weigh and record the material retained cumulatively in grams.

7. RECORD

7.1 CDOT HQ Soils database work sheet.

For Geotechnical Samples Only

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GEOLOGY INDEX - 19

Colorado Procedures – Laboratory:

Standard Test Procedures: AASHTO / ASTM

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Colorado Procedure – Laboratory 3201-21

Standard Method of Test for

Continuous Penetration Test

1. SCOPE

1.1 This method describes a procedure for driving a washer to obtain a measure of the resistance of the soil to penetration.

2. APPARATUS

2.1 Washer Assembly - The washer shall be two inches in diameter and not less than 1/8 inch in thickness with a center hole not more than 13/16 inch in diameter. The drive shoe for the washer shall be of the same diameter as the drive rod ("A" rod) and shall have the dimensions indicated in the attached drawing (See Figure No.1).

3. PROCEDURE

3.1 With the washer mounted on the drive shoe and resting on the ground surface, drive the washer with blows from the 140 lb. hammer falling 30 inches until the rate of penetration reaches 120 blows per foot.

Note 1: The height of hammer fall may be visually estimated by the hammer operator.

3.2 Record the number of blows required to effect each foot of penetration.

Note 2: If less than 1 foot is penetrated at the end of the drive, the log shall state the number of blows and the fraction of 1 foot penetration.

3.3 Record blow counts on CDOT Form 334, Penetrometer Log.

3.4 Plot data from the test in graph form showing depth at which each blow count was obtained as a function of the blow count obtained, for each foot of penetration.

4. REPORT

4.1 Record in the field the data obtained from penetration tests and include the following:

4.1.1 Name and location of job.

4.1.2 Date of penetration test.

4.1.3 Surface elevation (if available).

4.1.4 Names of crewmen.

4.1.5 Centerline station and offset (if available).

4.1.6 Number of blows per foot.

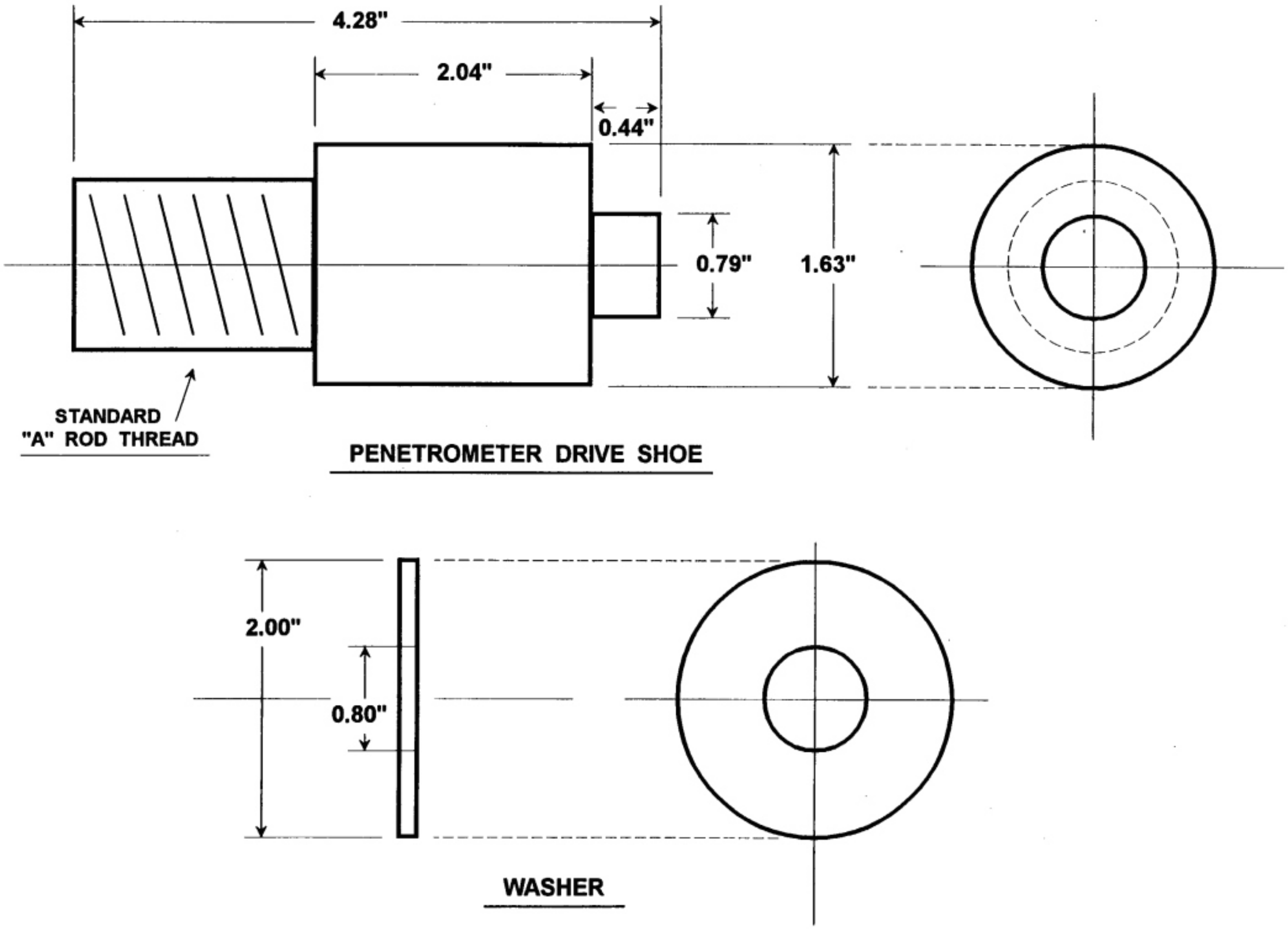

4.28"
2.04"
0.44"
0.79"
1.63"
STANDARD "A" ROD THREAD
PENETROMETER DRIVE SHOE
2.00"
0.80"
WASHER

Figure . 1

Colorado Procedure – Laboratory 3201-21

Standard Method of Test for

Continuous Penetration Test

1. SCOPE

1.1 This method describes a procedure to measure of the resistance of the soil to penetration and the soil's relative density.

2. APPARATUS

2.1 A disposable drive cone shall be used. The cone will have a minimal diameter no smaller than the diameter of the drive rod and the drive coupling. A drive cone diameter of 2 inches in diameter is typical as shown in Figure 1.

2.2 The drive coupling for the cone shall be of the same diameter as the drive rod and shall be only long enough to allow for secure connection to the drive rod, to hold the drive cone, and be of sufficient material to not be damaged during the driving and retrieval process. See Figure 1.

2.3 A drill rig with an automatic 140 lb. hammer with a consistent freefall drop of 30 inches, a drive anvil, drive rod (typically "A" rod), and a winch and mast with sufficient strength to extract the drive rod and drive coupling.

3. PROCEDURE

3.1 Attach the drive coupling onto the drive rod, and place a drive cone into the drive coupling. These components make up the drive assembly. Place the drive assembly so the cone is on the ground surface pointing down.

3.2 Mark each foot from the ground surface (or the last foot mark from the previous drive) the length of the drive rod. Mount a drive anvil to the drive rod and place the hammer fully on the anvil. Adjust drive cone, drive rod, and hammer as needed so the entire assembly is vertical.

3.3 Drive the rod into the ground. Care must be taken to ensure the rod remains vertical while driving and is in line with the hammer; otherwise, the drive assembly may deviate and equipment extraction may become difficult and potentially dangerous.

3.4 Count and record the number of blows required to drive each foot of penetration on CDOT Form #334, *Penetrometer Log*. Add drive rods and repeat steps 3.2 and 3.3 until desired total depth is obtained or the rate of penetration exceeds 120 blows per foot.

Note 1: If the drive rod is pushed down a foot by the weight of the hammer when it is resting on the anvil, the blow count will be recorded as zero.

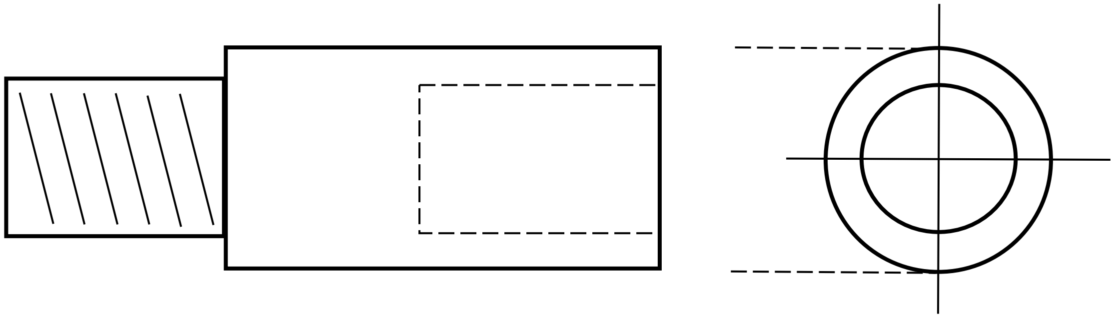
Note 2: If less than 1 foot is penetrated at the end of the drive, the log shall state the number of blows and the fraction of 1 foot penetration.

3.4 When the desired total depth has been reached, the drive rod and attached drive coupling shall be pulled from the ground and retrieved for future use. The drive cone will be left in the ground.

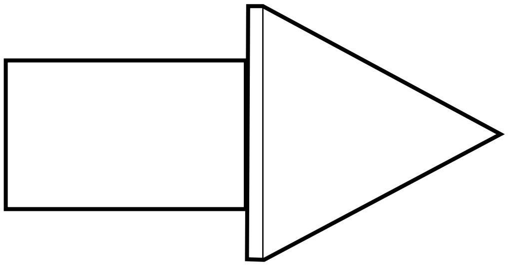
3.5 Any hole left as the result of performing the penetrometer will be backfilled with native material removed as a result of the penetrometer process. If native material is not available, bentonite chips shall be used to prevent potential subsurface impacts from surface operations.

4. REPORT

4.1 Report data from the test in boring log, geology sheet, or graph form showing depth at which each blow count was obtained as a function of the blow count obtained, for each foot of penetration.



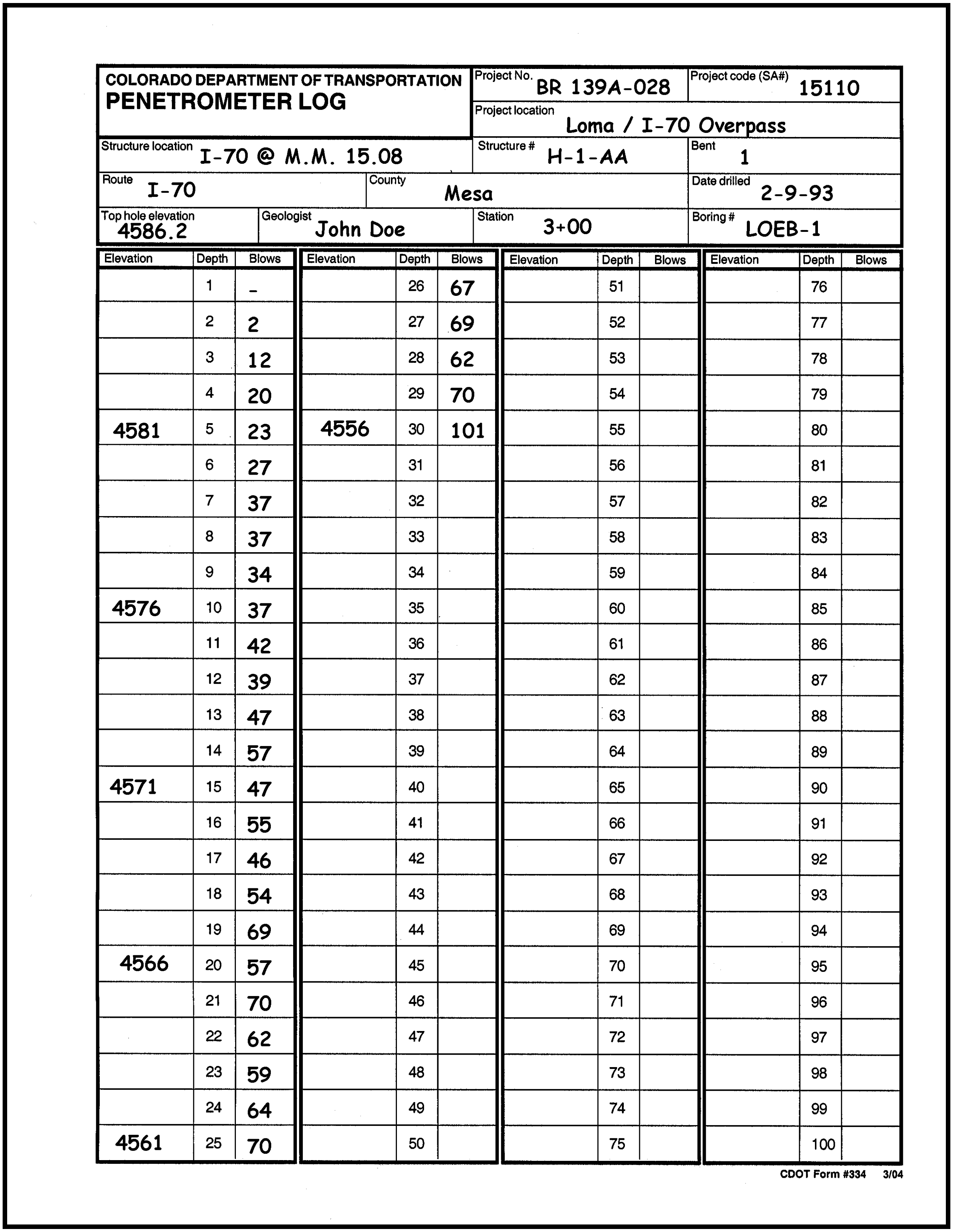
Penetrometer Drive Coupling, Typical



Penetrometer Drive Cone, Typical

Figure 1

CDOT Forms Applicable for Geology Testing - 05



COLORADO DEPARTMENT OF TRANSPORTATION

PENETROMETER LOG

Project No. BR 139A-028

Project code (SA#) 15110

Project location Loma / I-70 Overpass

Structure location I-70 @ M.M. 15.08

Structure # H-1-AA

Bent 1

Route I-70

County Mesa

Date drilled 2-9-93

Top hole elevation 4586.2

Geologist John Doe

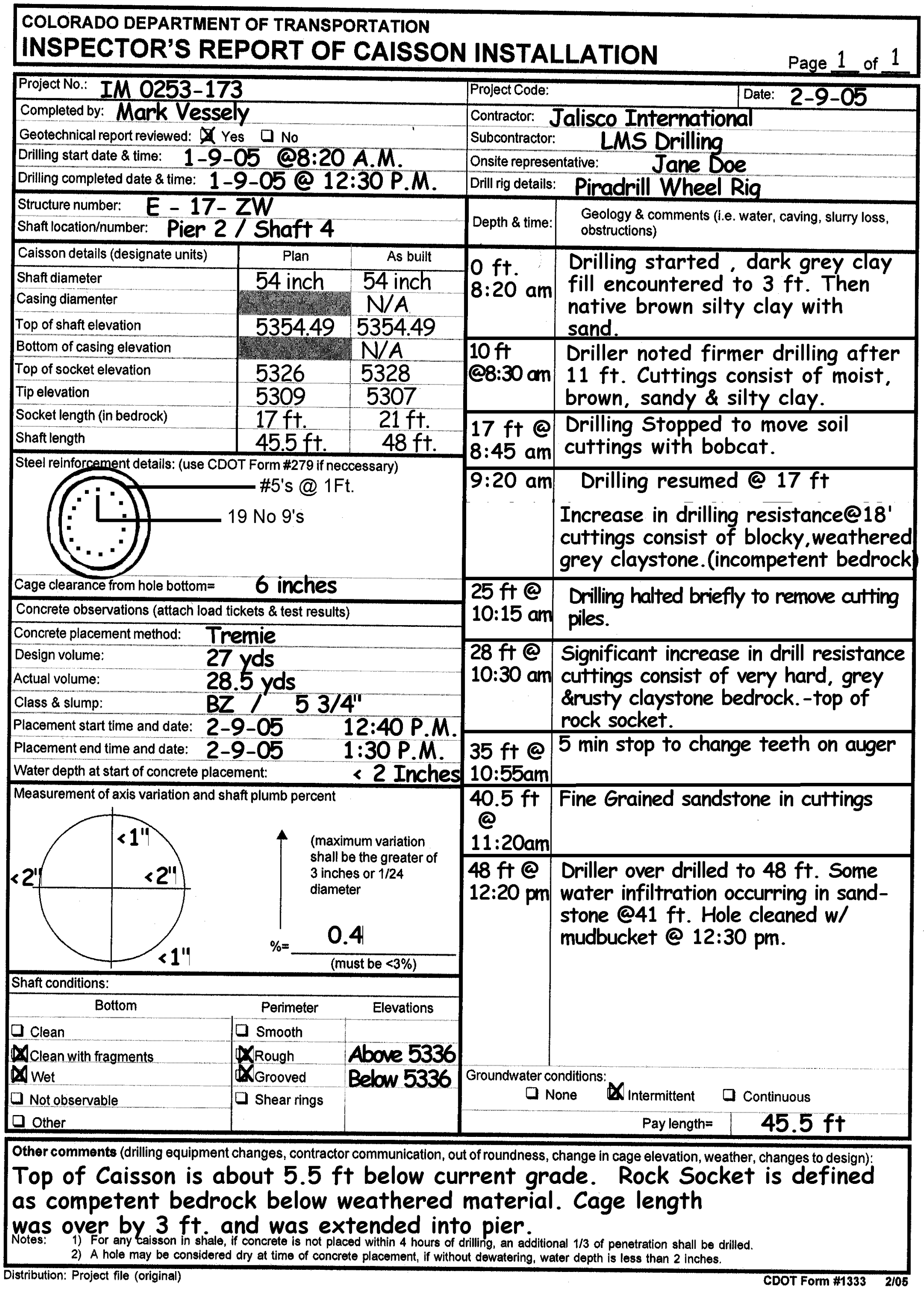
Station 3+00

Boring # LOEB-1

Elevation	Depth	Blows	Elevation	Depth	Blows	Elevation	Depth	Blows	Elevation	Depth	Blows
	1	-		26	67		51			76	
	2	2		27	69		52			77	
	3	12		28	62		53			78	
	4	20		29	70		54			79	
4581	5	23	4556	30	101		55			80	
	6	27		31			56			81	
	7	37		32			57			82	
	8	37		33			58			83	
	9	34		34			59			84	
4576	10	37		35			60			85	
	11	42		36			61			86	
	12	39		37			62			87	
	13	47		38			63			88	
	14	57		39			64			89	
4571	15	47		40			65			90	
	16	55		41			66			91	
	17	46		42			67			92	
	18	54		43			68			93	
	19	69		44			69			94	
4566	20	57		45			70			95	
	21	70		46			71			96	
	22	62		47			72			97	
	23	59		48			73			98	
	24	64		49			74			99	
4561	25	70		50			75			100	

CDOT Form #334 3/04

CDOT Form 334



COLORADO DEPARTMENT OF TRANSPORTATION

INSPECTOR'S REPORT OF CAISSON INSTALLATION

Page 1 of 1

Project No.: IM 0253-173	Project Code:
	Date: 2-9-05
Completed by: Mark Vessely	Contractor: Jalisco International
Geotechnical report reviewed: ☒ Yes ☐ No	Subcontractor: LMS Drilling
Drilling start date & time: 1-9-05 @8:20 A.M.	Onsite representative: Jane Doe
Drilling completed date & time: 1-9-05 @ 12:30 P.M.	Drill rig details: Piradrill Wheel Rig

Structure number: E - 17- ZW

Shaft location/number: Pier 2 / Shaft 4

Caisson details (designate units)	Plan	As built
Shaft diameter	54 inch	54 inch
Casing diamenter	▨	N/A
Top of shaft elevation	5354.49	5354.49
Bottom of casing elevation	▨	N/A
Top of socket elevation	5326	5328
Tip elevation	5309	5307
Socket length (in bedrock)	17 ft.	21 ft.
Shaft length	45.5 ft.	48 ft.

Steel reinforcement details: (use CDOT Form #279 if neccessary)

#5's @ 1Ft.

19 No 9's

Cage clearance from hole bottom= 6 inches

Concrete observations (attach load tickets & test results)

Concrete placement method: Tremie

Design volume: 27 yds

Actual volume: 28.5 yds

Class & slump: BZ / 5 3/4"

Placement start time and date: 2-9-05 12:40 P.M.

Placement end time and date: 2-9-05 1:30 P.M.

Water depth at start of concrete placement: < 2 Inches

Measurement of axis variation and shaft plumb percent

<1"

<2"

<2"

<1"

(maximum variation shall be the greater of 3 inches or 1/24 diameter

%= 0.4

(must be <3%)

Shaft conditions:

Bottom	Perimeter	Elevations
☐ Clean	☐ Smooth	
☒ Clean with fragments	☒ Rough	Above 5336
☒ Wet	☒ Grooved	Below 5336
☐ Not observable	☐ Shear rings	
☐ Other		

Depth & time:	Geology & comments (i.e. water, caving, slurry loss, obstructions)
0 ft. 8:20 am	Drilling started , dark grey clay fill encountered to 3 ft. Then native brown silty clay with sand.
10 ft @8:30 am	Driller noted firmer drilling after 11 ft. Cuttings consist of moist, brown, sandy & silty clay.
17 ft @ 8:45 am	Drilling Stopped to move soil cuttings with bobcat.
9:20 am	Drilling resumed @ 17 ft Increase in drilling resistance@18' cuttings consist of blocky,weathered grey claystone.(incompetent bedrock)
25 ft @ 10:15 am	Drilling halted briefly to remove cutting piles.
28 ft @ 10:30 am	Significant increase in drill resistance cuttings consist of very hard, grey &rusty claystone bedrock.-top of rock socket.
35 ft @ 10:55am	5 min stop to change teeth on auger
40.5 ft @ 11:20am	Fine Grained sandstone in cuttings
48 ft @ 12:20 pm	Driller over drilled to 48 ft. Some water infiltration occurring in sand-stone @41 ft. Hole cleaned w/ mudbucket @ 12:30 pm.

Groundwater conditions: ☐ None ☒ Intermittent ☐ Continuous

Pay length= 45.5 ft

Other comments (drilling equipment changes, contractor communication, out of roundness, change in cage elevation, weather, changes to design):

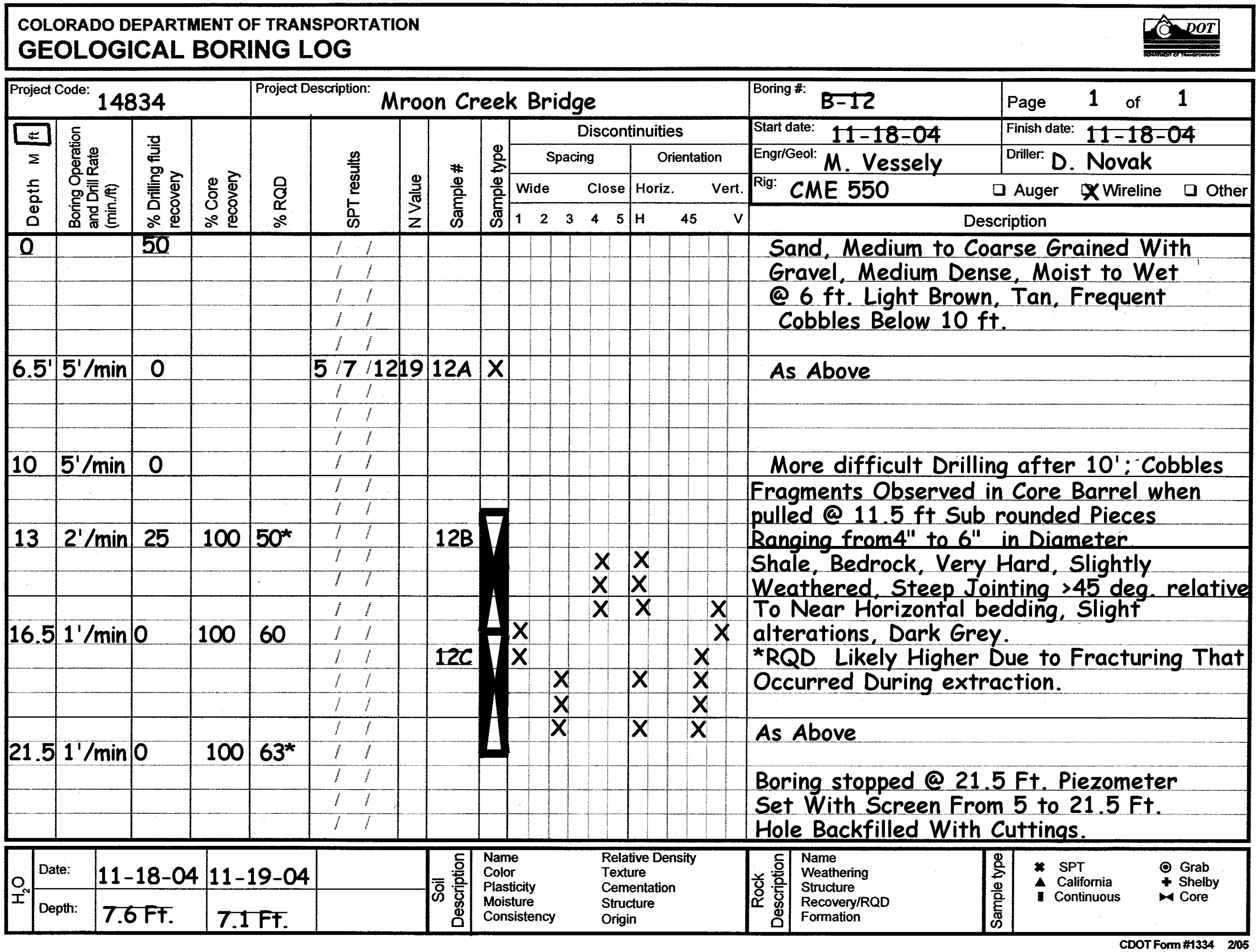
Top of Caisson is about 5.5 ft below current grade. Rock Socket is defined as competent bedrock below weathered material. Cage length was over by 3 ft. and was extended into pier.

Notes:
1) For any caisson in shale, if concrete is not placed within 4 hours of drilling, an additional 1/3 of penetration shall be drilled.
2) A hole may be considered dry at time of concrete placement, if without dewatering, water depth is less than 2 inches.

Distribution: Project file (original)

CDOT Form #1333 2/05

CDOT Form 1333



COLORADO DEPARTMENT OF TRANSPORTATION

GEOLOGICAL BORING LOG

Project Code: 14834

Project Description: Mroon Creek Bridge

Boring #: B-12

Page 1 of 1

Start date: 11-18-04

Finish date: 11-18-04

Engr/Geol: M. Vessely

Driller: D. Novak

Rig: CME 550 ☐ Auger ☒ Wireline ☐ Other

Depth M [✓ ft]	Boring Operation and Drill Rate (min./ft)	% Drilling fluid recovery	% Core recovery	% RQD	SPT results	N Value	Sample #	Sample type	Discontinuities Spacing Wide 1	2	3	4	Close 5	Orientation Horiz. H	45	Vert. V	Description
0		50			/ /												Sand, Medium to Coarse Grained With
					/ /												Gravel, Medium Dense, Moist to Wet
					/ /												@ 6 ft. Light Brown, Tan, Frequent
					/ /												Cobbles Below 10 ft.
					/ /												
6.5'	5'/min	0			5 /7 /12	19	12A	X									As Above
					/ /												
					/ /												
					/ /												
10	5'/min	0			/ /												More difficult Drilling after 10'; Cobbles
					/ /												Fragments Observed in Core Barrel when
					/ /												pulled @ 11.5 ft Sub rounded Pieces
13	2'/min	25	100	50*	/ /		12B	⧓									Ranging from4" to 6" in Diameter
					/ /							X		X			Shale, Bedrock, Very Hard, Slightly
					/ /							X		X			Weathered, Steep Jointing >45 deg. relative
					/ /							X		X		X	To Near Horizontal bedding, Slight
16.5	1'/min	0	100	60	/ /				X							X	alterations, Dark Grey.
					/ /		12C	⧓	X						X		*RQD Likely Higher Due to Fracturing That
					/ /						X			X	X		Occurred During extraction.
					/ /						X				X		
					/ /						X			X	X		As Above
21.5	1'/min	0	100	63*	/ /												
					/ /												Boring stopped @ 21.5 Ft. Piezometer
					/ /												Set With Screen From 5 to 21.5 Ft.
					/ /												Hole Backfilled With Cuttings.

H_2O			
Date:	11-18-04	11-19-04	
Depth:	7.6 Ft.	7.1 Ft.	

Soil Description: Name, Color, Plasticity, Moisture, Consistency, Relative Density, Texture, Cementation, Structure, Origin

Rock Description: Name, Weathering, Structure, Recovery/RQD, Formation

Sample type: ✖ SPT ▲ California ▮ Continuous ⦿ Grab ✚ Shelby ⧓ Core

CDOT Form #1334 2/05

CDOT Form 1334

Rock hardness

Very plastic	Claystone, clayey fault gouge & rocks altered to clay Knife: easily cut
Plastic	Claystone, clayey fault gouge & rocks altered to clay Knife: can be cut
Friable	Brittle rocks which can be broken in the hand or by light blows w/ pick point.
Very low	Knife: Easily gouged deeply or carved
Low	Knife: Deep gouges or scrapes are difficult
Moderate	Knife: Readily scrached (leaves dust & scratch is readily visible when dust blown away)
Hard	Knife: Can be scratched W/ difficulty (leaves only little dust & often only faintly visible)
Very Hard	Knife: Cannot be scratched

Shale bedrock hardness

N	*Field Approximation*
<20	Clay (weathered claystone)
20 - 30	Firm
30 - 50	Med hard
50 - 80	Hard
>80	Very hard

Weathering

UnW	Unweathered except for joints, fresh fabric
SlW	Slightly weathered, not indented by steel nail
MdW	Moderately weathered, breaks with difficulty
HiW	Highly weathered, rock-like, easily broken
Dec	Decomposed, soil-like

Discontinuities

1. Very wide	> 3m	> 10 ft.
2. Wide	90cm - 3m	36 in. - 10 ft.
3. Mod close	30cm - 90cm	12 in. - 36 in.
4. Close	5cm - 30cm	2 in. - 12 in.
5 Very close	< 5cm	< 2 in.

Fractures

Fault	A fracture along which there has been an observable displacement. Faults are rarely single planar units; normally they occur as parallel or sub-parallel sets of fractures along which movement has taken place to a greater or lesser extent.
Bedding	A surface parallel to the surface of disposition, which may or may not have a physical expression. Note that the original attitude of the bedding plane should not be assumed to be horizontal.
Foliation	The parallel orientation of platy minerals, or mineral banding in metamorphic rock.
Joint	A fracture in which there has been no observable relative movement. In general joints intersect primary surfaces such as bedding, cleavage & schistocity. A series of parallel joints is called a joint set; two or more intersecting sets produce a joint system; two sets of joints nearly at right angles to one another are said to be conjugate.
Cleavage	Parallel fractures formed in incompetent layers in a series of beds of varying degrees of competency. In general, the term implies that the cleavage planes are not controled by mineral particles in parallel orientation.
Schistocity	The foliation in schist or other coarse-grained crystalline rock do to the arrangement of mineral grains of the platy or prismatic type. Usually mica.

Rock alteration

Unaltered	Rock shows no discoloration, loss of strength or other effects of weathering or alteration
Slight	Rock is slightly discolored but not noticeably lower in strength than fresh rock
Moderate	Rock is discolored & noticeably weakened, but a 50mm core cannot usually be broken by hand across the rock fabric
High	Rock is weakened to such an extent that a 50mm core can be broken readily by hand across the rock fabric
Extreme	The material is discolored & the original minerals of the rock have been almost entirely altered to secondary minerals, even though the original fabric may be intact

Particle size

<3/4 in.	Sand
3/4 in. - 3 in.	Gravel
3 in. - 1 ft.	Cobble
>1 ft.	Boulder

Relative density of granular soils

N	*Desc*	*Field Approximation*
0 - 4	VLoose	Easily penetrated many inches (>12) with 1/2 in. rebar pushed by hand
4 - 10	Loose	Easily penetrated several inches with 1/2 in. rebar pushed by hand
10 - 30	MDense	Easily to moderately penetrated with 1/2 in. rebar driven with 5 lb. hammer
30 - 50	Dense	Penetrated 1 ft with difficulty using 1/2 in. rebar driven with 5 lb. hammer
>50	VDense	Penetrated only a few inches with 1/2 in. rebar driven with 5 lb. hammer

Consistency of cohesive soils

N	*Desc*	*Field Approximation*
<2	VSoft	Squeezes between fingers when fist is closed; easily penetrated several inches by fist
2 - 4	Soft	Easily molded by fingers; easily penetrated several inches by thumb
4 - 8	MStiff	Molded by strong pressure of fingers; can be penetrated several inches by thumb with moderate effort
8 - 15	Stiff	Dented by strong pressure of fingers; readily indented by thumb but can be penetrated only with great effort
15 - 30	VStiff	Readily indented by thumb nail
30 - 60	Hard	Indented with difficulty by thumb nail
>60	VHard	

CDOT Form 1334

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CONCRETE INDEX - 19

Colorado Procedures – Laboratory

Standard Test Procedures: AASHTO / ASTM

	AASHTO	**ASTM**
Air Content of Freshly Mixed Concrete by the Pressure Method	T 152	C 231
Air Content of Freshly Mixed Concrete by the Volumetric Method	T 196	C 173
Splitting Tensile Strength of Cylindrical Concrete Specimens	T 198	C 496
Capping Cylindrical Concrete Specimens	T 231	C 617
Temperature of Freshly Mixed Portland Cement Concrete		C 1064
Preparing Concrete Blocks for Testing Sealants, for Joints and Cracks		D 1985

Colorado Procedure – Laboratory 4101-19

Standard Method of Test for

Preparing Concrete Blocks for Testing Sealants, For Joints and Cracks

(This procedure modifies ASTM D 1985-13. ASTM D 1985 and CP-L 4101 must be used together.)

NOTE: Replace Section 5, *Concrete Block Preparation*, of ASTM D 1985-13 with the following:

5.1 Prepare the concrete in accordance with the procedure described in Test Method ASTM C 192 / C102M using the following mix design:

Concrete Mix Proportions for 1 Cubic Yard SSD Batch Weight:

Cement, Type I/II	528 lb
Fly-Ash, Class F	132 lb
Coarse Aggregate, Morrison Quarry, #57/67	1750 lb
Sand, Washed, Brighton Pit	1100 lb
W/C Ratio	0.50

Note: Contact Aggregate Industries' Materials Dispatch at 303-987-1234 to obtain the required aggregates.

5.2 Use a metal or plastic mold provided with a metal or plastic base plate. Provide means for securing the base plate to the mold. Make the assembled mold and base plate water-tight and oil with mineral oil before use. Fill the mold with concrete prepared in accordance with Subsection 5.1 to overflowing and vibrate externally for 30 seconds. Screed (level) the concrete to a smooth surface with a wooden float and level off with a metal straightedge drawn across the top with a sawing motion. Cure as specified in Test Method ASTM C 192 / C 192M. After curing for not less than 14 days, cut the slab of concrete into individual blocks using a 40 by 60-grit diamond saw blade rotating at a peripheral speed of 3050 ± 150 m/min. (10 000 ± 500 ft/min.). Each test block should be 25mm x 50mm x 75mm (1" x 2" x 3"). Any face contacting the test material must be saw cut. While the blocks are still wet from the sawing operation, scrub the surfaces of the blocks lightly with a non-metallic stiff-bristle brush while holding under a stream of running water. Stocks of prepared blocks may be stored under standard conditions indefinitely, but store such blocks in a 100% humidity environment for not less than 7 days prior to use.

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Colorado Procedure – Laboratory 4102-13

Standard Method of Test for

Specific Gravity and Absorption of Fine Aggregate

(This procedure modifies AASHTO T 84-08. AASHTO T84 and CP-L 4102 shall be used together)

1. SCOPE

1.1 This method covers the determination of the specific gravity and absorption of fine aggregate.

1.2 This test method is identical to AASHTO T84. *Specific Gravity and Absorption of Fine Aggregate,* with the following exceptions:

7. PREPARATION OF TEST SPECIMEN

Delete Subsection 7.2.1 and replace with the following:

7.2.1 *Cone Test for Surface Moisture*—Hold the mold firmly on a smooth non-absorbent surface with the large diameter down. Place a portion of the partially dried fine aggregate loosely in the mold by filling until overflow occurs and heaping additional material above the top of the mold by holding it with the cupped fingers of the hand holding the mold. Lightly tamp the fine aggregate into the mold with 25 light drops of the tamper. Each drop should start about 5 mm (0.2 in.) above the top surface of the fine aggregate. Permit the tamper to fall freely under gravitational attraction on each drop. Adjust the starting height to the new surface elevation after each drop and distribute the drops over the surface. Remove loose sand from the base and lift the mold vertically. If surface moisture is still present, the fine aggregate will retain the molded shape. When the fine aggregate slumps slightly, it indicates that it has reached a surface-dry condition. “Slumps slightly" is defined as when the face slumps at least 25% and no more than 50% after the cone has been vertically lifted.

The following two pictures illustrate the ideal slumping at SSD:

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Colorado Procedure – Laboratory 4103-21

Standard Method of Test for

Unrestrained Shrinkage of Concrete

(This procedure modifies ASTM C 157-08. ASTM C 157-08 and CP-L 4103 shall be used together.)

Scope

1.1 This method establishes a procedure for determining the unrestrained shrinkage of Concrete mixtures.

1.2 This test method is identical to ASTM C157-08 *Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete*, with the following exceptions:

10. Procedure for Curing of Specimens

Delete Subsection 10.3 and replace with the following:

10.3 After the initial comparator reading, (*taken no later than 24 hours of batching)*, store the specimens in lime-saturated water at 73 ± 3 °F [23 ± 2 °C] until they have reached an age of 7 days, including the period in the molds. At the end of the curing period, take a second comparator reading after the specimens have been brought to a more closely controlled temperature as was done prior to the earlier reading and in the manner described above.

11. Procedure for Storage of Specimens

Delete Subsection 11.1, 11.1.1 & 11.1.2 and replace with the following:

11.1 *Air Storage*—Store the specimens in the drying room, so that the specimens have a clearance of at least 1 in. or 25 mm on all sides. Take comparator readings of each specimen after periods of air storage after curing of 4, 7, 14, and 28 days. Preferably, take these readings in a room maintained at a relative humidity of 50 ± 4 % while the specimens are at a temperature of 73 ± 3 °F [23 ± 2 °C].

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PHYSICAL PROPERTIES INDEX - 16

Colorado Procedures – Laboratory

Physical Testing of Quicklime, Hydrated Lime, and Limestone **{ASTM C 110, Primary Procedure, (this CP-L modifies select Subsections}**	CP-L 4209
Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus	CP-L 4211
Determination of Percent Moisture in Rock Salt	CP-L 4215
Determination of Salt Content of Sanding Materials	CP-L 4216
Surface Abrasion Resistance of Polyester Concrete	CP-L 4301
Method of test for Bonding Strength of Polyester Concrete to Concrete	CP-L 4302

Standard Test Procedures: AASHTO / ASTM

	AASHTO	ASTM
Steel Strand, Uncoated Seven-Wire for Concrete Reinforcement	M 203	A 416
Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing	T 11	C 117
Bulk Density ("Unit Weight") and Voids in Aggregate	T 19	C 29
Organic Impurities in Fine Aggregate for Concrete	T 21	C 40
Sieve Analysis of Fine and Coarse Aggregates	T 27	C 136
Sieve Analysis of Mineral Filler for Hot Mix Asphalt (HMA)	T 37	D 546
Preformed Expansion Joint Fillers for Concrete Construction	T 42	D 545
Tension Testing of Metallic Materials	T 68	E 8
Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials	T 80	E 18
Specific Gravity and Absorption of Fine Aggregate	T 84	C 128
Specific Gravity and Absorption of Coarse Aggregate	T 85	C 127
Determining the Liquid Limit of Soils	T 89	

	AASHTO	**ASTM**
Determining the Plastic Limit and Plasticity Index of Soils	T 90	
Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine	T 96	C 131
Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate	T 104	C 88
Clay Lumps and Friable Particles in Aggregates	T 112	C 142
Lightweight Pieces in Aggregate	T 113	C 123
Moisture-Density Relations of Soils Using a 4.54-kg [10-lb] Rammer and a 457-mm [18-in.] Drop	T 180	
Mechanical Testing of Steel Products	T 244	A 370
Reducing Samples of Aggregate to Testing Size	T 248	C 702
Total Evaporable Moisture Content of Aggregate by Drying	T 255	C 566
Uncompacted Void Content of Fine Aggregate	T 304	C 1252
Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus	T 327	D 6928
Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)		C 1260
Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)		C 1567
Physical Testing of Quicklime, Hydrated Lime, and Limestone		C 110
Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine		C 535
Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate		D 4791
Determining the Percentage of Fractured Particles in Coarse Aggregate		D 5821

Note:

CP-L 4201 has been deleted. The test is replaced in its entirety by ASTM C 1260.

CP-L 4202 has been deleted. The test is replaced in its entirety by ASTM C 1567.

Colorado Procedure – Laboratory 4209-21

Standard Method of Test for

Physical Testing of Hydrated Lime and Limestone

1 SCOPE:

1.1 This test method determines the particle size distributions of limestone and hydrated lime by washing.

2 APPARATUS:

2.1 The sieves used shall conform to the requirements of Specification E11. Preferably the sieves should have a minimum depth of 4-in.

2.2 Spray Nozzle, conforming to the requirements of Test Method C430.

2.3 Pressure Gauge shall be graduated in 1-psi increments, and shall have a maximum capacity of 30-psi. The accuracy at 10 psi shall be +/- 0.25 psi

2.4 Attach a pressure gauge to the water faucet and tubing to the output side of the pressure gauge. On the other end of the tubing attach the spray nozzle

3 PROCEDURE:

3.2 Nest a No. 30 sieve over a No. 200 sieve.

3.3 Sample and weigh 100 g (+/- 5g) of the limestone or hydrated lime.

3.4 Starting with the top sieve, wash the material through each sieve by means of a stream of water from the nozzle after adjusting the water pressure to 10 +/- 0.25 psi. Carefully wash the sample through each sieve without allowing any splashing over the sides of the sieve.

NOTE 1: Take care not to let water accumulate on the No. 200 sieve, because the openings will become clogged and the operation may not be able to be completed in 30 min.

3.5 After the sample is washed through the top sieve, separate it from the next sieve and repeat the washing procedure with the next finer sieve.

3.6 When washing is complete the water should be clear, that is no particles can be seen in a beaker of the rinse water, but in no case shall washing be less than 5 minutes or last longer than 30 min.

3.7 Dry the material retained on each sieve at a temperature of 110 + 5°C for at least one hour, cool and determine the mass.

4. Report:

4.1 Report the results of the sieve analysis as the percentages retained on each sieve.

Colorado Procedure – Laboratory 4211-15

Standard Method of Test for

Resistance of Coarse Aggregate to Degradation By Abrasion in the Micro-Deval Apparatus

(This procedure is based upon AASHTO T 327-06. AASHTO T 327-06 or any subsequent revision may not be used in place of this procedure.)

1. SCOPE

1.1 This method covers a procedure for testing coarse aggregate for resistance to abrasion using the Micro-Deval apparatus.

2. REFERENCE DOCUMENTS

2.1 AASHTO Standards:
M 92, Standard Specification for Wire - Cloth Sieves for Testing Purposes.
T 11, Materials Finer Than 75-µm Sieve in Mineral Aggregates by Washing
T 27, Sieve Analysis of Fine and Coarse Aggregates

Colorado Procedures:
CP 31, Sieve Analysis of Aggregates

3. SUMMARY OF METHOD

3.1 The Micro-Deval Test is a measure of abrasion resistance and durability of mineral aggregates resulting from a combination of actions including abrasion and grinding with steel balls in the presence of water. A sample with standard grading is initially soaked in water for 15 to 19 hours. The sample is then placed in a jar mill with 2.0 liters of water and an abrasive charge consisting of 5000 grams of 9.5 mm diameter steel balls. The jar, aggregate, water, and charge are revolved at 100 rpm for 2 hours. The sample is then washed and oven dried. The loss is the amount of material passing the 1.18 mm sieve expressed as a percent by mass of the original sample.

4. SIGNIFICANCE AND USE

4.1 The Micro-Deval Test is a test of coarse aggregates to determine abrasion loss in the presence of water and an abrasive charge. Many aggregates are weaker when wet than when dry. The use of water in this test measures the reduction in resistance to degradation, in contrast to some other tests which are conducted on dry aggregate. It furnishes information helpful in judging the toughness / abrasion resistance and durability / soundness of coarse aggregate subject to abrasion and weathering action when adequate information is not available from service records.

4.2 The Micro-Deval test is a useful test for detecting changes in properties of aggregate produced from a source as part of a quality control or quality assurance process.

5. TERMINOLOGY

5.1 *Constant Mass* - Test samples dried at a temperature of 110°C ± 5° to a condition such that it will not lose more than 0.1 percent moisture after 2 hours of drying. Such a condition of dryness can be verified by weighing the sample before and after successive 2-hour drying periods. In lieu of such a determination, samples may be considered to have reached constant mass when they have been dried at a temperature of 110°C ± 5° for an equal or longer period than that previously found adequate for producing the desired constant mass condition under equal or heavier loading conditions of the oven.

6. APPARATUS

6.1 Micro-Deval Abrasion Machine - A jar rolling mill capable of running at 100 ± 5 rpm.

6.2 Containers - Stainless steel Micro-Deval abrasion jars having a 5-liter capacity with a rubber ring in the rotary locking cover. External diameter is 194 202 mm, internal height is 170 to 177 mm. The inside and outside surfaces of the jars shall be smooth and have no observable ridges or indentations.

6.3 Abrasion Charge - Magnetic stainless steel balls are required. These shall have a diameter of 9.5 ± 0.5 mm. Each jar requires a charge of 5000 ± 5 g of balls.

6.4 Sieves - Sieves with square openings and of the following sizes conforming to AASHTO M 92 specifications: 19.0 mm, 16.0 mm, 12.5 mm, 9.5 mm, 9.0 mm, 6.3 mm, 4.75 mm, and 1.18 mm.

6.5 Oven - The oven shall be capable of maintaining a temperature of 110°C ± 5°.

6.6 Balance - A balance or scale accurate to 1.0 g.

7. TEST SAMPLE FOR INDIVIDUAL STOCKPILES

7.1 The test sample shall be washed and oven-dried at 110°C ± 5° to constant mass, separated into individual size fractions in accordance with CP 31, and recombined to meet the grading as shown in Subsection 7.2 below.

7.2 Gradation A

This gradation is to be used when the nominal maximum aggregate size is 16.0 mm or greater. An oven-dried sample of 1500 ± 5 g shall be prepared as follows:

Passing	Retained	Mass
19.0 mm	16.0 mm	375 g
16.0 mm	12.5 mm	375 g
12.5 mm	9.5 mm	750 g

7.3 Gradation B

This gradation is to be used when the nominal maximum aggregate size is 12.5 mm or greater, but less than 16.0 mm. An oven-dried sample of 1500 ± 5g shall be prepared as follows:

Passing	Retained	Mass
12.5 mm	9.5 mm	750 g
9.5 mm	6.3 mm	375 g
6.3 mm	4.75 mm	375 g

7.4 Gradation C

This gradation is to be used when the nominal maximum aggregate size is less than 12.5 mm. An oven-dried sample of 1500 ± 5 g shall be prepared as follows:

Passing	Retained	Mass
9.5 mm	6.3 mm	750 g
6.3 mm	4.75 mm	750 g

8. TEST SAMPLE FOR COMBINED SPECIMENS

8.1 This gradation is used when a combined gradation is to be tested. The test sample shall be washed and oven-dried at 110°C ± 5° to constant mass, separated into individual size fractions in accordance with CP 31, and recombined to meet the grading as shown in Subsection 8.2 or 8.3.

8.2 Gradation D

An oven-dried sample of 1500 ± 5 g shall be prepared as follows:

Passing	Retained	Mass
19.0 mm	16.0 mm*	250 g
16.0 mm	12.5 mm	250 g
12.5 mm	9.5 mm	500 g
9.5 mm	6.3 mm	250 g
6.3 mm	4.75 mm	250 g

* If the top size isn't a part of the mix gradation, add the mass to the 16.0 mm to 12.5 mm mass.

8.3 If the top size of the combined gradation is less than 12.5 mm, then Gradation B (Subsection 7.3) shall be used.

9. TEST PROCEDURE

9.1 Prepare a representative 1500 ± 5 g sample. Record the Mass 'A' to the nearest 1.0 g.

9.2 Saturate the sample in 2.0 ± 0.05 liters of tap water (temperature 20°C ± 5°) for 15 to 19 hours. This may be done in the Micro-Deval container or some other suitable container.

9.3 Place the sample in the Micro-Deval abrasion container with 5000 ± 5g of steel balls and the water used in Subsection 9.2 to saturate the sample. Place the Micro-Deval container on the machine.

9.4 For Gradation A (shown in Subsection 7.2) run the machine at 100 ± 5 rpm for 2 hours ± 1 minute or 12,000 ± 100 revolutions. For Gradation B (shown in Subsection 7.3) run the machine for 105 ± 1 minutes or 10,500 ± 100 revolutions. For Gradation C (shown in Subsection 7.4) run the machine for 95 ± 1 minutes or 9,500 ± 100 revolutions. For Gradation D (shown in Subsection 8.2) run the machine for 105 ± 1 minutes or 10,500 ± 100 revolutions.

9.5 Carefully pour the sample over two superimposed sieves: 4.75 mm and 1.18 mm. Take care to remove the entire sample from the stainless steel jar. Wash and manipulate the retained material with water, using a hand held water hose, and your hand until the washings are clear and all material smaller than 1.18 mm passes the sieve. Remove the stainless steel balls using a magnet or other suitable means. Discard material smaller than 1.18 mm.

9.6 Combine the material retained on the 4.75 mm and 1.18 mm sieves, being careful not to lose any material.

9.7 Oven dry the sample to constant mass at 110°C ± 5°.

9.8 Weigh the sample to the nearest 1.0g. Record the Mass 'B'.

10. CALCULATIONS

10.1 Calculate the Micro-Deval abrasion loss as follows, to the nearest 0.1%.

$$\text{Percent Loss} = \frac{(A - B) \times 100}{A}$$

11. REPORT

11.1 The report shall include the following:

11.1.1 The nominal maximum aggregate size of the aggregate tested and the gradation (A, B, C, or D) used.

11.1.2 The percent loss of the test sample to one decimal place.

12. CONTROL OF ABRASION CHARGE

12.1 Every 10 samples, but at least every week in which a sample is tested, the abrasion charge must be placed on a 9 mm screen to check for loss of size due to wear. Any balls that fall through the screen are out of specification and must be discarded.

13. PRECISION AND BIAS

13.1 The multi-laboratory precision has been found to vary over the range of this test. The figures given in Column 2 are the coefficients of variation that have been found to be appropriate for the materials described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests expressed as a percent of their mean.

Aggregate Abrasion Loss (%)	Coefficient of Variation (% of mean)[A]	Acceptable Range of Two Results (% of mean)[A]
5	10.0	28
12	6.4	18
17	5.6	16
21	5.3	15

[A]: These numbers represent, respectively, the [1s] and [d2s] limits as described in ASTM C 670.

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Colorado Procedure – Laboratory 4215-15

Standard Method of Test for

Determination of Percent Moisture in Rock Salt

(Designated as CP 35 prior to the 2010 FMM.)

1. SCOPE

1.1 This method describes the procedures for the quantitative determination of the percent moisture contained in rock salt.

2. APPARATUS

2.1 *Balance or Scale* - Balance of sufficient capacity and sensitive to 0.1 grams or 0.02 percent of the principal sample weight, whichever is greater.

2.2 *Drying Apparatus* – Oven or other suitable device.

2.3 *Sample Splitter* – Riffle type sample splitter to reduce sample to test portion size in accordance with CP 32, Method A (except that moisture shall not be added.)

2.4 *Small Flat, Square-End Scoop with Sides* - If selecting the specimen in accordance with CP 32 Method C.

3. FIELD SAMPLE

3.1 Obtain the field sample from random parts of the load as it is being transferred from the conveyance vehicle to the stockpile.

3.2 Seal the container lid with tape or other airtight method to prevent moisture evaporation before weighing the specimen.

4. SIZE OF TEST SPECIMEN

4.1 The minimum weight of the test specimen shall be 500 grams.

5. PROCEDURE

5.1 Immediately after obtaining the specimen, weigh to the nearest 0.1g and then dry to a constant weight of not over 220°F ± 5° (105°C ± 5°). When dry, weigh to the nearest 0.1g and report as oven dry weight.

6. CALCULATIONS

6.1 Determine the total percent moisture on an oven dry basis as follows:

$$\begin{array}{c}\%\text{ Moisture} \\ \text{oven dry} \\ \text{basis}\end{array} = \frac{\text{Wet wt. - Dry wt.}}{\text{Dry wt.}} \times 100$$

Colorado Procedure – Laboratory 4216-10

Standard Method of Test for

Determination of Salt Content of Sanding Materials

(Designated as CP 34 prior to the 2010 FMM.)

1. SCOPE

1.1 This procedure covers the extraction of salt from the salt-aggregate sanding materials to determine salt content.

2. PREPARATION OF SPECIMEN

2.1 The sample from which the specimen is selected shall be obtained by usual stockpile sampling method. The specimen shall be reduced to test size in accordance with CP 32. The specimen size shall be governed by nominal particle size in the mixture as used in CP 31.

Method A - Vacuum Extractor

3. APPARATUS

3.1 *Vacuum extractor* - Complete with vacuum pump, gasket, filter paper, support plate, and funnel ring.

3.2 *Filter paper*, 5 to 40 micrometer.

3.3 *Oven or hot plate*.

3.4 *Stainless steel beaker*, approximately 9 qt. (9 L) capacity.

3.5 *Plastic wash bottle*.

3.6 *Drying pan*.

3.7 *Mixing spoon*, approximately 12" (300 mm) long.

3.8 *Balance or Scale* - Balance of sufficient capacity and sensitive to 0.1 grams or 0.02 percent of the principal sample weight, whichever is greater.

4. SAFETY

4.1 Drain extractor immediately after use.

5. PROCEDURE

5.1 Split sample into a test portion of proper size. Either dry the entire sample to a constant weight (mass) in a 230°F ± 9° (110°C ± 5°) oven or on a hotplate; or split the sample into two test portions of proper size, using one portion for moisture correction. Dry the moisture correction portion to a constant weight (mass) in a 230°F ± 9° (110°C ± 5°) oven or on a hotplate. Determine the percent moisture.

5.2 Place test specimen in a tared stainless steel beaker and weigh to nearest 0.1g.

5.3 Pour an adequate quantity of water over the specimen so that all salt will dissolve and agitate thoroughly. Allow specimen to soak for a least 16 hours at 175°F ± 9° (80°C ± 5°). Stir the sample a minimum of three times during the soak. Alternatively to soaking for 16 hours at 175°F ± 9° (80°C ± 5°), place the specimen and water on stove or hot plate and heat the mixture so that the water boils moderately for at least 3 hours. Add water as necessary to maintain sample submersion. If the specimen is boiled, use a beaker or other suitable container which is adequately deep to prevent loss of the specimen caused by boiling over the sides of the container.

5.4 Place a tared, dried, filter on filter support plate, taking care to center position ring and tighten.

5.5 After allowing sufficient time for salt to dissolve, decant the solution (liquid) into the extractor. Add an appropriate amount of water to the sample and agitate it then decant into the extractor. Repeat this process until the water is clear.

5.6 The filter(s) must be dried, weighed, and the tare subtracted to determine the weight (mass) of the aggregate in the filter. This weight (mass) must be included in the extracted dry weight (mass) of the specimen.

Note: If a large amount of minus #200 material is in the sample, the filter may have to be changed.

Method B - Simple Wash

6. APPARATUS

6.1 *Funnel* and support to hold filter paper.

6.2 *Filter paper*, 5 to 40 micron.

6.3 *Oven or hot plate*.

6.4 *Drying pan*.

6.5 *Mixing spoon*.

6.6 *Balance or Scale* - Balance of sufficient capacity and sensitive to 0.1 grams or 0.02 percent of the principal sample weight, whichever is greater.

7. PROCEDURE

7.1 Split sample into a test portion of proper size. Either dry the entire sample to a constant weight (mass) in a 230°F ± 9° (110°C ± 5°) oven or on a hotplate; or split the sample into two test portions of proper size, using one portion for moisture correction. Dry the moisture correction portion to a constant weight (mass) in a 230°F ± 9° (110°C ± 5°) oven or on a hotplate. Determine the percent moisture.

7.2 Place test specimen in a tared drying pan and weigh to nearest 0.1g.

7.3 Pour an adequate quantity of water over the specimen so that all salt will dissolve and agitate thoroughly. Allow specimen to soak for a least 16 hours at 175°F ± 9° (80°C ± 5°). Stir the sample a minimum of three times during the soak. Alternatively to soaking for 16 hours at 175°F ± 9° (80°C ± 5°), place the specimen and water on stove or hot plate and heat the mixture so that the water boils moderately for at least 3 hours. Add water as necessary to maintain sample submersion. If the specimen is boiled, use a beaker or other suitable container which is adequately deep to prevent loss of the specimen caused by boiling over the sides of the container.

7.4 Place a tared, dried, filter on the funnel ring.

7.5 After allowing sufficient time for salt to dissolve, decant the solution (liquid) through the filter. Add an appropriate amount of water to the sample and agitate it then decant into the filter. Repeat this process until the water is clear.

7.6 The filter(s) must be dried, weighed, and the tare subtracted to determine the weight (mass) of the aggregate in the filter.

8. CALCULATIONS

8.1 Using the percent moisture determined from the moisture specimen, correct the original moist weight (mass) of the extraction portion, to a dry weight (mass) as follows:

$$\begin{matrix}\text{Dry}\\\text{Weight}\end{matrix} = \frac{\begin{matrix}\text{Wet wt. of}\\\text{extraction specimen}\end{matrix}}{100 + \begin{matrix}\text{\% Moisture in}\\\text{Moisture Specimen}\end{matrix}} \times 100$$

8.2 Where the contract specifies that the percent salt is based on the dry weight (mass) of the sand, calculate the percentage of salt as follows:

$$\%\,\text{salt} = \frac{\text{Dry Weight - Ext. dry wt.}}{\text{Ext. dry wt.}} \times 100$$

Where "Ext. dry wt." is the dry weight (mass) of the specimen after extraction. Report to the nearest 0.1 percent.

8.3 If the contract specifies that percent salt is based on the dry weight (mass) of the salt sand mix, the equation for percent salt is:

$$\%\ salt = \frac{Dry\ Weight\ -\ Ext.\ dry\ wt.}{Dry\ Weight}\ x\ 100$$

Report to the nearest 0.1 percent.

Colorado Procedure – Laboratory 4301-18

Standard Method for

SURFACE ABRASION RESISTANCE OF POLYESTER CONCRETE

1. SCOPE

1.1 This surface abrasion test method describes the procedure used to measure the ability of a polyester concrete specimen to resist surface abrasion by impact of steel balls in the presence of water.

2. APPARATUS

2.1 A mechanical shaker capable of agitating a mold assembly containing the test specimen, water, and steel balls, in a vertical direction at 1,200 cycles/min +/- 10 cycles/minute with a 1 in. stroke.

2.2 One steel test mold, 4 in. diameter by 5 in. high, fitted with a watertight base and cover. A 1/8 in. steel ring, triangular in cross-section, and inserted to form a lip, encircles the mold interior 2 in. above the bottom and combines with the base to hold the sample in place and protect the vulnerable edges of the specimen. See Figure 1.

2.3 Eight chrome steel balls, 13/32 in. diameter and weighing 4.5 g ± 0.3 g each. Total mass of the 8 balls shall be between 32 g and 38 g.

2.4 One 200 mL graduated cylinder.

2.5 A scale with a capacity of 1000 g and accuracy of ± 0.1 g.

2.6 ½ in. × 1 in. × 6 in. rubber tamper

3. SPECIMEN FABRICATION

3.1 Temperature of the air in the vicinity of the mixing area, the dry materials, molds, base plates, and mixing bowl shall be maintained from 68 to 77ºF.

3.2 Preparation of Materials. Care must be taken to avoid contamination of individual components. The hazards of each individual component must be recognized.

3.2.1 Materials shall be brought to a uniform temperature in the range of 68 to 77ºF prior to mixing.

3.2.2 The moisture content of the aggregate shall not exceed one half of the absorption of the aggregate. The aggregate shall be 100 % passing the ½ in. sieve. Care should be taken to avoid segregation of aggregate.

3.3 Mix the polyester concrete as specified by the manufacturer in the electric mixer or by hand in a batch of such size to yield 10 % excess after molding test specimens. Hand-mixing procedures are not applicable to air entrained mixes or mixes with no measurable slump. Follow the manufacturer's recommendations as to the order of addition and mixing times. Materials shall be mixed thoroughly in the time allotted.

3.4 Begin molding the specimens within 1 min after completion of the mixing.

3.5 Specimen Mold Preparation. Cover the interior and exterior of the assembled molds with a mixture of one part paste wax dissolved in 2 to 3 parts toluene and allow to dry before using.

3.6 Mix the materials as specified by the material supplier in an electric mixer, drum or open tub type, in a batch of such size to yield 5 % excess after molding test specimens.

3.7 Place a layer of the batched material in each compartment of the mold approximately 1 in. deep.

3.8 Tamp the batch in each compartment 25 times with a ½ in. × 1 in. × 6 in. rubber tamper in a spiral motion, making sure all edges are tamped. Tamping shall be completed in each compartment before going on to the next.

3.9 When the tamping of the first layer in all compartments is completed, jig the mold to remove entrapped air along the sides.

3.10 Fill the compartments and tamp as specified for the first layer. Upon completion, the material should extend slightly above the top of the molds.

3.11 With a trowel, force the batch downward into the mold. When compaction is completed, strike off the top surface and finish to a smooth surface with a steel straightedge.

3.12 The specimens shall be soaked in water for a minimum of 2 hours prior to testing.

4. PROCEDURE

4.1 Surface dry the specimen, weigh, and record mass to the nearest gram.

4.2 Place specimen in the test mold with the surface to be tested facing up. Place the mold with specimen on the test mold base and add 8 steel balls and 200 mL of water. Attach the cover and clamp the assembly to the mechanical shaker.

4.3 Agitate the assembly at 1,200 cycles/min ± 10 cycles/min for 3 min ± 5 s and remove from the mechanical shaker.

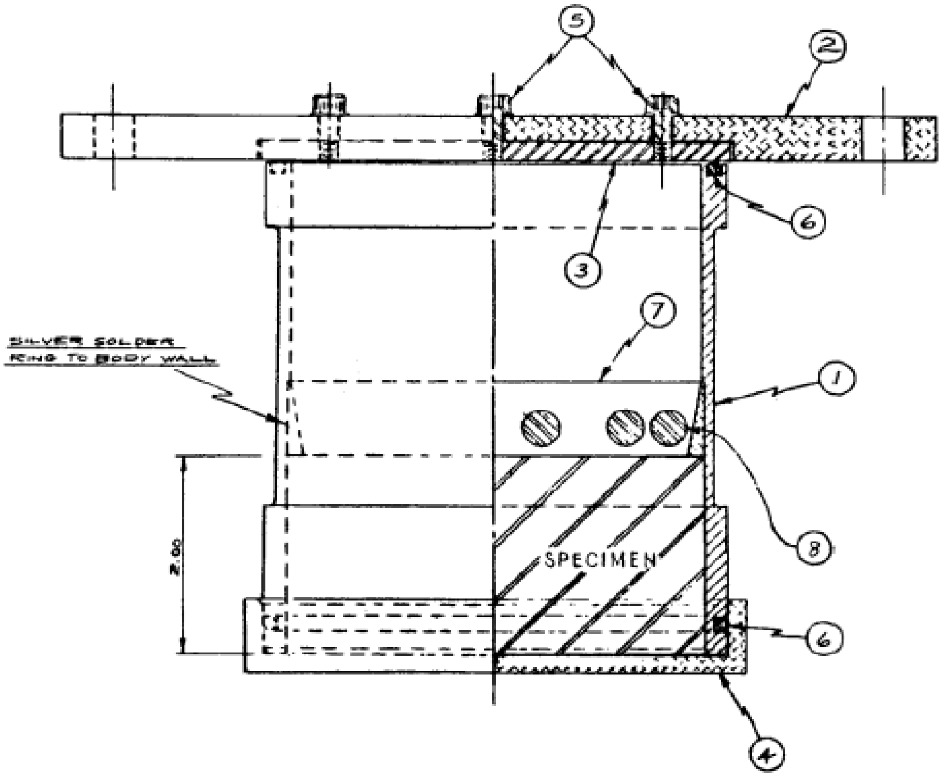
4.4 Remove the specimen from the test mold. Flush off the abraded material, dry the surface, weigh, and record the mass to the nearest gram.

5. CALCULATIONS

5.1 The abrasion loss in grams is calculated by subtracting the mass of the saturated surface dry specimen after the test from the mass of the surface dry specimen before test.

6. REPORT

6.1 Report the amount of abrasion loss in grams. The age of the concrete shall be included in the report.



LIST OF MATERIAL					
8	8	Ball Bearings	$^{13}/_{32}$ inch dia., 4.5 g, Steel		
1	7	Retaining Ring	4140 Steel		
2	6	"O" Ring	4 $^{3}/_{16}$ in. ID x 4 $^{5}/_{16}$ in. OD x $^{1}/_{8}$ in. dia. Neoprene		
4	5	Cap Screws	10-32NF Socket, Filister HD		
1	4	Base	Alum		
1	3	Wear Plate	4140 Steel		
1	2	Cover	Alum		
1	1	Body	Mild Steel		
No. Req.	Part No.	Description	Stock Size	Material	Remarks

Figure 1

Colorado Procedure – Laboratory 4302-18

Standard Method of Test for

METHOD OF TEST FOR BONDING STRENGTH OF POLYESTER CONCRETE TO CONCRETE

1. SCOPE

1.1 This method covers the determination of the bonding strength of polyester concrete materials by a simple beam with center-point loading.

2. Referenced Documents

2.1 ASTM Procedures:

C78 Flexural Strength of Concrete (Using Simple Beam with Third Point Loading)
C305 Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency
C192 Making and Curing Concrete Test Specimens in the Laboratory

3. APPARATUS

3.1 Testing machine conforming to ASTM C 78

3.2 Apparatus for bonding test:

3.2.1 The Base Plate for this test shall be similar to the one specified in ASTM C 78 with a support length (L) of 9 in.

3.2.2 A diagram of the apparatus and load-applying bar is shown in Figures 1 and 2. The load-applying bar shall provide a uniform point load along the length of the bond interface.

3.3 Electrically driven mechanical mixer with paddle and mixing bowl, as specified in ASTM C305, Sections 4.1, 4.2, and 4.3.

3.4 Concrete mixer, scales, tamping rods, miscellaneous equipment and molds shall conform to ASTM C 192. The molds shall have internal dimensions of 3 in. × 3 in. × 12 in.

4. SPECIMEN FABRICATION

4.1 PCC Blocks. Portland cement concrete blocks shall be made from aggregate passing the 3/8 in. sieve. The concrete mix shall have a nominal cement content of 675 lb/yd^3, achieve a minimum compressive strength of 4,500 psi in 28 days and have an air content of 5 to 7 %.

4.1.1 Prepare the materials according to ASTM C192

4.1.2 Mix the concrete according to ASTM C192

4.1.4 Cast the concrete beams according to ASTM C192

4.1.3 Initial cure the concrete according to ASTM C192 for 1 day

4.1.4 Moist cure the concrete according to ASTM C192 until the concrete is 28 days old.

4.1.5 Remove the PCC Blocks from the moist room and place in dry storage. PCC blocks shall be aged for 6 months prior to use.

4.2 PCC Block Sample Preparation:

4.2.1 Cut the PCC blocks approximately in half with a concrete saw with a water-cooled, diamond matrix cutting edge blade. The saw cut shall be at right angles to the length of the block. Care shall be taken to avoid contamination of the cut face, especially with oil.

4.2.2 Wash the PCC blocks with clean water to remove all loose particles.

4.2.3 PCC blocks shall be placed in a rustproof container and covered with a minimum of 1 in. of water for a minimum of 48 hr prior to use..

4.2.4 Remove PCC blocks from the water, rinse them with clean water and dry them with a clean paper towel.

4.2.5 Apply ¾ in. wide masking tape around the perimeter of the cut face. The tape application shall be even with the cut face and not protrude more than 1/32 in. beyond the cut face.

4.2.6 Place the taped block into a 3 in. × 3 in. × 12 in. mold coated with a suitable mold release. The cut face shall be not less than 5 in. from the end of the mold. Secure the block in the mold.

Note 1: A mixture of one part paste wax dissolved in 2 to 3 parts toluene is a suitable mold release.

4.2.7 Cover the SSD bond blocks with a damp towel until ready to place the material to be tested. This is done to retain the SSD condition of the block.

4.3 Bond Test Sample Fabrication:

4.3.1 Temperature of the air in the vicinity of the mixing area, the dry materials, molds, base plates, and mixing bowl shall be maintained from 68 to 77ºF.

4.3.2 Follow the material suppliers' instructions for applying a bonding coat to the bond surface of the PCC sample block in the mold.

4.3.3 Mix the polyester concrete as specified by the manufacturer in the electric mixer or by hand in a batch of such size to yield 10 % excess after molding test specimens. Follow the manufacturer's recommendations as to the order of addition and mixing times. Materials shall be mixed thoroughly in the time allotted.

4.3.4 Begin molding the specimens within 1 min after completion of the mixing.

4.3.5 Place the batched material in the mold in two equal layers. Compact each layer with a wooden tamper approximately ¾ in. × 3 in. × 18 in., 20 strokes for each layer or until a homogeneous specimen is obtained.

4.3.6 Spade the PCC bond block-bonding surface with a spatula to effect maximum contact of the batched material with the PCC.

4.3.7 Jig the mold between each layer to remove entrapped air.

4.3.8 Compact and strike off the material to the top of the mold, and finish to a smooth surface with a steel trowel.

4.3.9 Cure the material according to the manufacturer's recommendations.

5. PROCEDURE

5.1 Turn the test specimen on its side with respect to its position as molded so the top as molded is facing the operator.

5.2 Center the bond face line on the support block.

5.3 Center the loading system in relationship to the applied force.

5.4 Lower the spherical head of the testing machine until there is just enough clearance between the spherical head and the test specimen to permit insertion of the load-applying bar without it tipping over. The load-applying bar shall be placed directly on the bond face line of the specimen.

5.5 Apply the load continuously at a rate of 1500 lb/min until the specimen breaks. The specimen will break at the bond line, in the PCC or in the material being tested.

5.6 Calculate the modulus of rupture in bond as follows:

$$R = \frac{3Pl}{2bd^2}$$

Where:

R = modulus of rupture, psi
P = maximum applied load, lb
l = span length, in.
b = average width of specimen at the point of fracture, in.
d = average depth of specimen at the point of fracture, in.

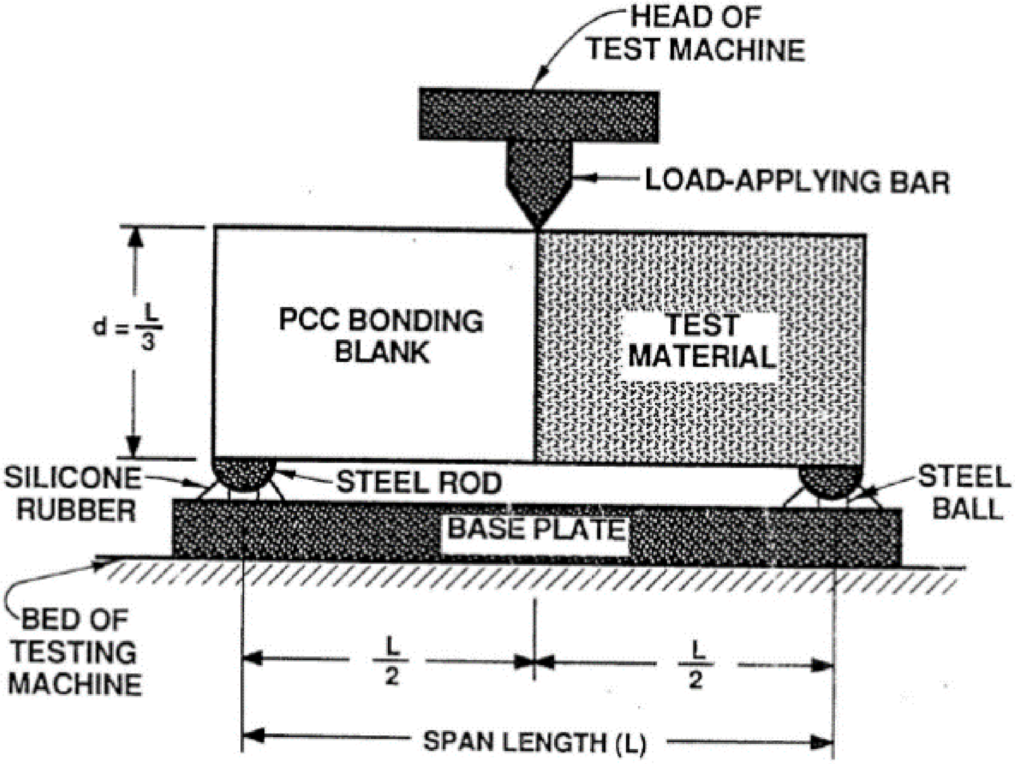
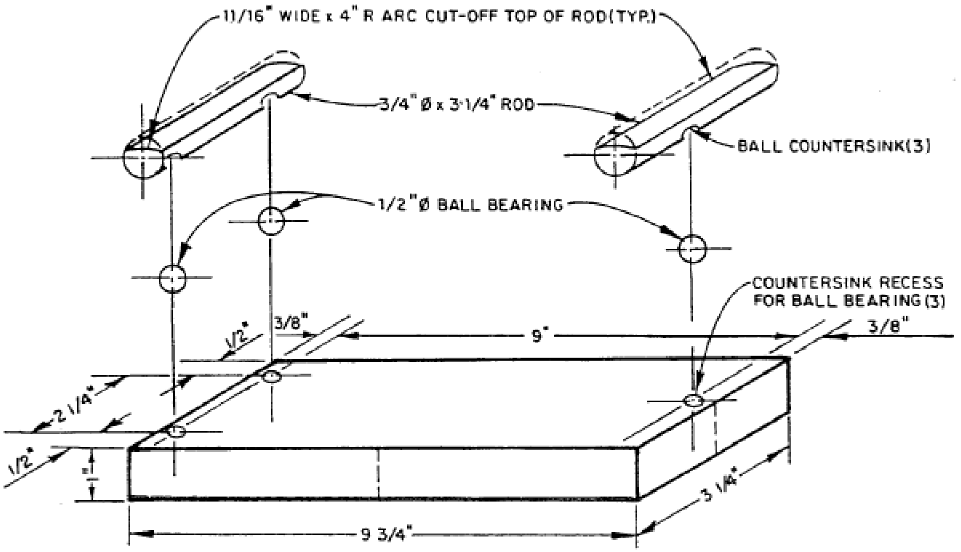
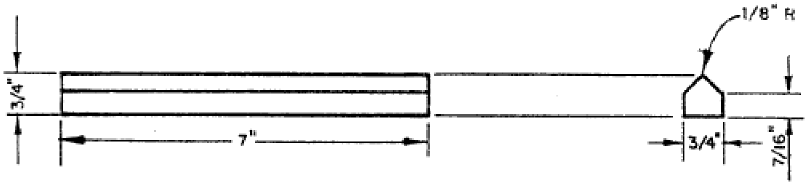


Figure 1 Apparatus for Bonding Strength Test in Center Point Loading



BASE PLATE



BAR FOR "BOND" TEST

NOTE:

1. Ball bearings silver soldered to counter-sink in ¾ in. diameter × 3¼ in. rod.
2. Rods cemented to base with silicon rubber.

Figure 2 Plan of Apparatus for Bond Test of Concrete Overlay and Patching Materials

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FLEXIBLE PAVEMENT INDEX - 16

Colorado Procedures – Laboratory

Standard Test Procedures: AASHTO

Colorado Procedure – Laboratory 5100-15

HMA Testing Troubleshooting Guide

1. SCOPE

1.1 This guide suggests some areas to investigate when various Hot Mix Asphalt (HMA) testing problems arise. This guide is not intended to be comprehensive.

2. REFERENCED DOCUMENTS

2.1 No documents are directly or indirectly referenced in this procedure.

3. APPARATUS

3.1 Thermometers- Conforming to the requirements of ASTM. The thermometers shall be capable of reading 77°F by 0.2°F, 140°F by 0.2°F, 300°F by 1°F.

4. MAXIMUM SPECIFIC GRAVITY OF HMA

4.1 Check temperature of water bath – required to be 77°F ± 1° (25°C ± 0.5°).

4.2 Make sure plastic cover of scale has not warped to where it is rubbing scale pan.

4.3 Make sure scale is level.

4.4 Make sure vacuum pump oil is clean and at proper level.

4.5 Make sure silica gel is dry.

4.6 Make sure all hose connectors are tight, including stoppers in bottles.

4.7 Make sure manometer has no air bubbles in the mercury column.

4.8 Flasks should be calibrated every month [weight filled with 77°F (25°C) water and lid].

4.9 Are there screens covering the openings in the stoppers to prevent crumbs from being drawn up into the vacuum system?

4.10 Is the filter on the pump inlet clean?

4.11 Was the sample split correctly, not segregated?

4.12 Check the valves to make sure they are open or shut as required.

4.13 Is agitation correct?

5. BULK SPECIFIC GRAVITY

5.1 Make sure suspension apparatus is not rubbing the side of the tank or the side of the opening on which the scale rests.

5.2 Make sure scale is level.

5.3 Make sure temperature of tank is 77°F ± 1.8° (25°C ± 1°).

5.4 Make sure tank is in an overflow condition.

5.5 Make sure the plastic cover on the scale has not warped to where it is rubbing the scale pan.

5.6 Make sure no dirt or foreign objects are touching the scale pan.

5.7 Make sure the rings at the bottom of the specific gravity (SpG) molds are clean.

5.8 Make sure molds are elevated in ovens and air can freely circulate under them before use for compactions.

6. STABILOMETER

6.1 Make sure stabilometer has sufficient oil in it.

6.2 Don't stop short of 100 when obtaining displacement.

6.3 Make sure the needle on the Ph gauge is lined up precisely.

6.4 Remove all air bubbles from the body of the stabilometer.

6.5 Is there compensation for slop between yoke guide collar and turns displacement yoke?
6.6 Does the handle turn smoothly when obtaining displacement?

6.7 Is the oven temperature 140°F ± 5° (60°C ± 3°)?

6.8 Are the specimens at the required temperature for a minimum of 2 hours for a force draft oven and 3 hours for a non-force draft oven?

6.9 Make sure calibration cylinder and follower have correct diameter dimensions.

6.10 Avoid tilting the stabilometer and make sure it is always held in the upright position.

7. RESISTANCE TO MOISTURE INDUCED DAMAGE

7.1 Make sure the specimen is square in the loading frame.

7.2 Make sure the loading blocks are clean, so that the sample does not sit off-center.

7.3 Make sure the samples are not removed from the water bath too early, preventing a temperature change.

7.4 Are the specimens at 77°F ± 1° (25°C ± 0.5°) for a minimum of 2 hours?

7.5 Is the vacuum pump oil clean, at a proper level, and the silica gel dry?

7.6 Is the scale level?

7.7 Is the 77°F (25°C) tank in an overflow condition?

7.8 Is the suspension apparatus free?

7.9 Is the manometer free of air bubbles?

7.10 Is the freezer temperature 0°F ± 5° (-18°C ± 3°)?

7.11 If the incubator does not have refrigeration, is it capable of maintaining a temperature of 77°F ± 1.8° (25°C ± 1°) when the ambient temperature is above 77°F?

8. SUPERPAVE GYRATORY COMPACTOR

8.1 Make sure the rings at the bottom of the molds are clean.

8.2 Make sure the ram face and the height calibration cylinder are clean.

8.3 Make sure the turntable is fully rotated to the right when the mold is inserted.

8.4 Make sure the bottom disc is fully down before dumping sample into the mold.

8.5 Is the top of the sample level after loading it into the mold?

9. IGNITION FURNACE

9.1 Make sure ceramic hearth or cage is not rubbing the wall of the chamber.

9.2 Make sure ceramic tubes are not rubbing openings in the floor of the chamber - slamming door can cause the scale to move.

9.3 Make sure nothing is rubbing the pan on the external scale.

9.4 Make sure specimen or moisture correction sample is thoroughly dry.

9.5 Don't weigh specimen and moisture correction sample at widely different times - you want them to have equal percentages of moisture when initially weighed.

10. GRADATIONS

10.1 Make sure nothing is rubbing the scale pan.

10.2 Inspect the wet sieve for stretching, holes, or cracks.

10.3 Make sure each sieve in the stack is cleaned the same each time - don't leave different amounts of material in them each time

Colorado Procedure – Laboratory 5101-15

Standard Method of Test for

Verification of Laboratory Equipment Used to Test Bituminous Mixtures

1. SCOPE

1.1 This method of test covers the verification of laboratory equipment used to test bituminous mixtures and provides documentation that the verification has been done as per AASHTO R 18- 01.

2. REFERENCED DOCUMENTS

2.1 *Colorado Procedures:*

CP 31 Sieve Analysis of Aggregates.

CP 44 Bulk Specific Gravity and Percent Relative Compaction of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens.

CP 51 Determining the Maximum Specific Gravity of HMA.

CP-L 5106 Resistance to Deformation of Bituminous Mixtures by Means of Hveem Apparatus.

CP-L 5109 Resistance of Compacted Bituminous Mixture to Moisture Induced Damage.

CP-L 5115 Standard Method for Preparing and Determining the Density of Bituminous Mixture Test Specimens Compacted by the Superpave Gyratory Compactor.

CP-L 5120Determination of the Asphalt Binder Content of Bituminous Mixtures by the Ignition Method.

2.2 CDOT Laboratory Inspection Manual Procedures:

HMA – 1 Standardization of Low Temperature Oven or Freezer

HMA – 2 Superpave Gyratory Compactor Mold Check

HMA – 3 Superpave Gyratory Compactor Ram Head Check

HMA – 4 Troxler Gyratory Compactor True Mold Angle Check

HMA – 5 Troxler Gyratory Compactor Pressure Check

HMA – 7 Troxler Gyratory Compactor Height Calibration and Rotation Check

HMA – 8 Vacuum System Check

HMA – 9 Standardization of Water Baths

HMA – 10 Stabilometer Check

HMA – 11 United Press Load Cell Check

G-1 Verification of Balance

G-2 Standardization of Oven Temperature

G-3 Calibrated Thermometer Check

G-4 Standardization of Liquid-in-Glass / Digital Thermometers

A-1 Sieve Check

A-2 Sieving Adequacy Check

2.3 *AASHTO Standards:*

T 30 Mechanical Analysis of Extracted Aggregate.

T 209 Theoretical Maximum Specific Gravity (Gmm) and Density of Hot Mix Asphalt.

T 312 Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor.

2.4 *ASTM Standards:*

E 11 Specification for Woven Wire Test Sieve Cloth and Test Sieves.

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates.

3. APPARATUS

3.1 *Thermometers* - Conforming to the requirements of ASTM E 1. The thermometers shall be capable of reading 77°F by 0.2°F, 140°F by 0.2°F, 230°F by 0.5°F, 275°F by 0.5°F, 300°F by 0.5°F, 325°F by 0.5°F.

3.2 *Vernier Caliper (or other measuring device*) - capable of measuring 0 to 6 inches in increments of 0.001".

3.3 *Dial Gauge* - capable of measuring 1 inch in increments of 0.001".

3.4 *Height calibration spacer and performance verification kit* - for the Troxler Superpave Gyratory Compactor.

3.5 *Stopwatch or timer* - with certificate of calibration.

3.6 *Verified weights* - traceable to the National Bureau of Standards.

3.7 *Inside diameter micrometer* - capable of measuring 100 mm in increments of 0.01 mm.

3.8 *Comparator* - with reticles for examining sieves finer than No. 4.

3.9 *Manometer* - free of air bubbles.

4. EQUIPMENT VERIFICATION

4.1 The CDOT Laboratory Inspection Manual has worksheets to aid with verifications.

4.2 Conduct verifications and calibrations as per the following table:

Table 1: General Equipment & Asphalt Equipment

Table 1: General & Asphalt Equipment

EQUIPMENT	PROCEDURE	REQUIREMENT	INTERVAL
Balances	Outside Certified Contractor or G-1	Calibration or Check	12 Mo.
Compression Testing Machine, Load Cells	Outside Certified Contractor or HMA-11	Check	12 Mo.
Superpave Gyratory Compactor: Ram Pressure, Angle of Gyration, Frequency of Gyration, LVDT or Height Calibration	HMA-4, 5, 7	Check	12 Mo.
Superpave Gyratory Compactor, Ram Head and Base Plate	HMA-2 & 3	Check	12 Mo.
Mechanical Shakers	A-2	Check	12 Mo.
Sieves	A-1	Check	12 Mo.
Superpave Molds	HMA-2	Check	12 Mo.
Ovens	G-2	Standardization or Check	12 Mo.
Low Temperature Oven & Freezer	HMA-1	Standardization or Check	12 Mo.
Water Bath	HMA-9	Standardization or Check	12 Mo.
Test Thermometers	Outside Certified Contractor or G-3 & G-4	Check	12 Mo.
Vacuum / Pressure Measurement Devices	Outside Certified Contractor or HMA-8	Check	12 Mo.
Vacuum System	HMA-8	Check	12 Mo.
Ignition Oven Internal Scale	Outside Certified Contractor or G-1	Calibration or Check	12 Mo.
Stabilmeter Followers, Calibration Cylinders	HMA-10	Check	12 Mo.

Appendix A, CP-L 5101

Routine Maintenance Recommendations For Superpave Gyratory Compactors

Follow the maintenance schedule in Table 1 for optimum equipment performance and decreased machine wear. Consult manufacturer maintenance guide in operations manual for complete details.

Table 1: Superpave Gyratory Compactor Maintenance

FREQUENCY	ITEM	TROXLER 4140 A & B	PINE AFGC125X	PINE AFG1	COMMENTS
Daily	Ram Head/Ram Foot	Clean with degreaser		Anti-Seize Lubricant	Easier to clean when hot.
Daily	Molds	Clean with degreaser			Easier to clean when hot.
Daily	Mold Base Plate/ Mold Top	Clean with degreaser	Lubricate with Molybdenum di-sulfide powder	Clean	Easier to clean when hot. Make sure area where base plates and mold make contact is clean.
Daily	Support Ring and Cam Followers	Clean & Grease with Magnalube			Clean with dry clean cloth.
Daily	Carriage Base Plate		Lubricate with Molybdenum di-sulfide powder		
Daily	Compaction Chamber/		Clean	Clean	
Daily/Per Cycle	Turn Table	Use Clean Dry Cloth			Do not use degreaser. Clean every cycle if fines fall on table after each compaction.
Every 5 hours	Mold Rollers		Grease with Molybdenum di-sulfide Mobilgrease Special		
Initial 5 hours/ Every 25 hours	Ball Screw Bearings, Ball Screws, Actuator Bearings and Carriage Base bearing		Grease with Molybdenum di-sulfide Mobilgrease Special	Grease	
Every 25 hours	Fixed Ring Surface		Oil (SAE 30)		
Every 25 hours	Mold Clamp Pivot and Mold Top Clamps			Anti-Seize Lubricant	
Every 80 hours	Brake Disk	Clean with degreaser			Use clean dry cloth.

Table 1: Superpave Gyratory Compactor Maintenance (Continued)

FREQUENCY	ITEM	TROXLER 4140 A & B	PINE AFGC125X	PINE AFG1	COMMENTS
Every 80 hours	Chamber shafts	Grease with Magnalube			
Every 80 hours	Loading Head and Thrust Bearing	Clean & Grease with Magnalube			
Every 80/ 100 hours	Drive chain	Check Tension	Oil (SAE 30) and check tension		Lubricate chain with Magnalube if needed.
Every 100 hours	Ram Key		Lubricate with Molybdenum di-sulfide powder		If key is worn rotate to use unworn side.
Every 500 hours	Ram	Add Grease			
Every 500 hours	Rotation Gear Box	Change Oil			
Every 1000 hours	System	Contact Troxler for overhaul			Done by Manufacturer
Every 1000 hours	Carriage Base Drive Reducer		Gear oil ISO Grade 460		
	Hydraulic Power Pack		Automatic Transmission Fluid		

Appendix B, CP-L 5101

Equipment Calibration and Standardization Recommendations For Flexible Pavement Equipment

Follow the best practices in Table 1 for more reliable equipment calibrations and standardizations. All of the information in Table 1 is not required but considered best practices and goes above what is required to ensure more accuracy when calibrating and standardizing equipment.

Table 1: Equipment Calibration and Standardization Best Practices

ITEM	COMMENTS
Balances	1. Make sure balances are cleaned and leveled. 2. Make sure balances are not rubbing or touching anything, such as suspension wires or sample holders touching bulk chamber walls.
Compression Testing Machine, Load Cells	1. Recommend testing different load cells against each other before calibration. 2. Recommend taking at least one reading from load cell or at least until pressure values from load cell stabilize. Pressure values drift down after a few readings (For Troxlers).
Superpave Gyratory Compactor: Verify Ram Pressure, Angle of Gyration, Frequency of Gyration, LVDT	1. Recommend always doing height calibration first especially when switching Ram Heads. 2. Make sure when verifying the angle with the TMA, it is squared and straight with the compactor. 3. Do not adjust pressure on gyratory compactors to match external load cell if pressure is within specification. Have compactor serviced if pressure is out of specification when it is set to proper compactor pressure.
Superpave Gyratory Compactor (continued), Verify Ram Head, Base Plate and Cam Followers	1. For the most accurate measurement, it is recommended to take the Ram Head off of the compactor. 2. Although this verification is only required every 12 months, frequently checking Ram Head diameters during the construction season is recommended when Ram Heads are close to being out of the specified range. 3. The grooves in cam followers should be no more than 0.012” deep. If so, replace.
Mechanical Shakers	1. Make sure sample for sieve adequacy is of appropriate size as not to over load the sieves.

Table 1: Equipment Calibration and Standardization Best Practices (Cont.)

ITEM	COMMENTS
Sieves	1. When measuring sieve openings make sure the calipers are straight and parallel with the wires.
Molds, Superpave	1. A dial bore gauge is a better piece of equipment than calipers for measuring mold diameter. 2. Make sure device used for measuring is perpendicular to plane of measurement. 3. Although this verification is only required every 12 months, frequently checking mold diameters during the construction season is recommended when molds are close to being out of the specified range.
Ovens	1. Recommend checking temperature of various shelves where samples are to be placed. 2. Recommend using pan or beaker of sand to stick thermometer to keep temperature fluctuations down from opening and closing doors.
Test Thermometers	1. Quite often shipping thermometers can cause them to take on bubbles in the liquid. Be sure to check for bubbles in the mercury on a regular basis and especially upon receiving thermometers after shipping.
Vacuum System	1. Verify regularly that oil is free of water and examine desiccating crystals. 2. Check the manometer to make sure it is free of air bubbles.
Stabilometer, Molds, Followers, Calibration Cylinders	1. Check condition of stabilometer diaphragm. If membrane is dry and cracked replace.

Colorado Procedure – Laboratory 5106-21

Standard Method of Test for

Resistance to Deformation of Bituminous Mixtures by Means of Hveem Apparatus

(This procedure is based upon AASHTO T 246-93 (ASTM D 1560-81). AASHTO T 246-10 (ASTM D 1560-09) or any subsequent revision may not be used in-place of this procedure.)

1. SCOPE

1.1 This method covers the determination of the resistance to deformation of compacted bituminous mixtures by measuring the lateral pressure developed from applying a vertical load by means of the Hveem Stabilometer.

2. APPARATUS

2.1 *Stabilometer* - Hveem stabilometer (Figure 1) is a triaxial testing device consisting essentially of a rubber sleeve within a metal cylinder containing a liquid which registers the horizontal pressure developed by a compacted test specimen as a vertical load is applied. Pressure gauges must have increments to at least the nearest 1 psi.

2.2 *Testing Machine* - Compression testing machine having a minimum capacity of 44.5 kN (10,000 lbf).

2.3 *Oven* - An oven capable of maintaining a temperature of 60°C ± 3º (140°F ± 5º).

2.4 *Calibration Cylinder* - Hollow metal cylinder having the following dimensions: 100.00 ± 0.13 mm (3.937 ± 0.005 in.) for specimens compacted in a mold having an internal diameter of 100 mm (3.937 in.) [e.g. Superpave compactor] and having a height of at least 4.5 inches (114 mm).

2.5 *Follower* - One solid wall metal follower sized according to the diameter of the specimens being tested. A 100.3 ± 0.25 mm (3.949 ± 0.010 in.) diameter follower shall be used for samples compacted in a mold having an internal diameter of 100 mm (e.g. Superpave compactor). The follower shall be 125 ± 25 mm (5 ± 1 in.) high.

3. TEST SPECIMENS

3.1 *Size of Specimens - Superpave gyratory compactor* - Test specimens shall be 100 mm (3.937 in.) in diameter as produced by the Superpave gyratory compactor in conformance with CP-L 5115. The Stabilometer value shall be corrected as indicated in Subsection 6.2 and by Figure 2.

3.2 *Compaction of Specimens* - Test specimens shall be formed and compacted in accordance with CP-L 5115.

3.3 *Bulk Specific Gravity of Test Specimens* - Test specimens shall have their bulk specific gravity determined according to CP 44 and their height determined to the nearest 0.1 mm (0.004 in.). Use the height determined by the compaction machine if the machine's height has been calibrated that day.

4. ADJUSTMENT OF STABILOMETER

4.1 Adjust the Stabilometer base so that the distance from the bottom of the upper tapered ring to the top of the base is 89 mm (3.5 in.).

4.1.1 Heat the Stabilometer base, follower, and metal calibration cylinder in a 60°C ± 3º (140°F ± 5º) oven for a minimum of 1 hour. Place the Stabilometer on the heated base and insert the follower into the Stabilometer chamber. Turn the handle of the Stabilometer until the pressure gauge reads 20 psi. (138 kPa). Allow the pressure of the Stabilometer oil to stabilize. Remove the follower, remove the metal calibration cylinder from the oven and insert the metal calibration cylinder into the Stabilometer chamber. Turn the pump handle clockwise until the indicator on the pressure gauge reads 100 psi. Allow the oil pressure to stabilize.

4.1.2 As soon as the oil pressure stabilizes, adjust the amount of air in the air cell so that when the horizontal pressure is increased from 5 psi to 100 psi by turning the pump handle at the approximate rate of two turns per second, the turns indicator will show an increase of 2.00 ± 0.05 with the calibration cylinder in place.

Note: One method for calibrating the Stabilometer is contained in the Appendix at the end of this procedure.

4.1.3 Approximately once per month during the calibration process, after the Stabilometer is in calibration and before testing begins, with the calibration cylinder still inserted and the gauge pressure at 5 psi (34.5 kPa) verify that the exposed piston length is 2.8 ± 0.2 inches (71.0 ± 5.0 mm). Add or remove oil as necessary.

4.2 With the Stabilometer and stage base in position on the platen, adjust the testing machine so that the load will be applied at the rate of 0.05 in./min. (1.3 mm/min).

5. PROCEDURE

5.1 Bring the specimen to a temperature of 60°C ± 3º (140°F ± 5º) by placing it in a 60°C ± 3º (140°F ± 5º) oven for a minimum of 2 hours and a maximum of 24 hours. The minimum sample heating time should be increased to 3 hours in ovens which do not have forced draft air flow.

5.2 Talcum powder, cornstarch or other similar fine, dry powder may be applied to the circumference of the asphalt specimen or the stabilometer membrane to reduce asphalt residue left on the membrane during testing.

5.3 Place the compacted specimen into the Stabilometer. Make sure that the specimen goes into the Stabilometer straight and that it is firmly seated level on the base. Place the follower on top of the specimen and turn the displacement pump until a horizontal pressure of exactly 34.5 kPa (5 psi) is recorded on the Stabilometer gauge. If the testing machine has a spherically seated type of upper head, the locking shims used during the fabrication of the test specimen must be removed prior to performing the Stabilometer test. Start the vertical movement of the press at a speed of 1.3 mm/min. (0.05 in./min.). Stop the vertical movement of the press when the vertical load reaches 22.3 kN (5,000 lbf). The Stabilometer gauge reading shall be obtained immediately upon reaching 22.3 kN (5,000 lbf). Reduce the vertical load to 4.45 kN (1,000 lbf) and then adjust the horizontal pressure to 34.5 kPa (5 psi). When adjusting the horizontal pressure, decrease the horizontal pressure to below 34.5 kPa (5 psi) and then raise the pressure up to 34.5 kPa (5 psi) to ensure that any play is removed from the "turns" indicator assembly. This will result in a further reduction of the vertical load to less than 4.45 kN (1,000 lbf); this is normal and no compensation need be made. Measure the number of turns of the pump handle required to raise the horizontal pressure from 34.5 to 689 kPa (5 to 100 psi) with the specimen in place. Turn the pump handle in a single, smooth, continuous motion at approximately two turns per second when applying this pressure. The number of turns measured is the displacement reading, D. In measuring the displacement the vertical load will increase and at times exceed 4.45 kN (1,000 lbf). As before, these changes in load are characteristic and no adjustment or compensation is required.

6. CALCULATIONS

6.1 Determine the Stabilometer value of the specimen as follows:

$$S = \frac{\mathbf{22.2}}{\left[\left(P_h \times D\right) / \left(P_v - P_h\right)\right] + \mathbf{0.222}}$$

Where:

S = Stabilometer value,
P_h = horizontal pressure, for corresponding P_v in kPa (or psi),
D = displacement on specimen,
P_v = Vertical pressure (typically 2830 kPa (410 psi) for Superpave Gyratory compacted specimens.

6.2 Calculate a height correction for each sample as follows:

For specimen heights greater than 2.5"

$$\mathbf{C = (H - 2.5) \times (0.107 + 0.786S - 0.009886S^2)}$$

For specimen heights less than 2.5"

$$\mathbf{C = (H - 2.5) \times (0.15 + 1.10S - 0.01384S^2)}$$

Where:

C = correction factor added to the stability value calculated in Subsection 6.1.
S = Stabilometer value,
H = specimen height in inches to 0.1.

7. REPORT

7.1 There is no designated CDOT Form used for recording or reporting information for this CP-L.

7.2 The report shall include the following:

7.2.1 Stabilometer value. (Corrected)

7.2.2 Bitumen content.

DRAWING BELOW NOT TO SCALE

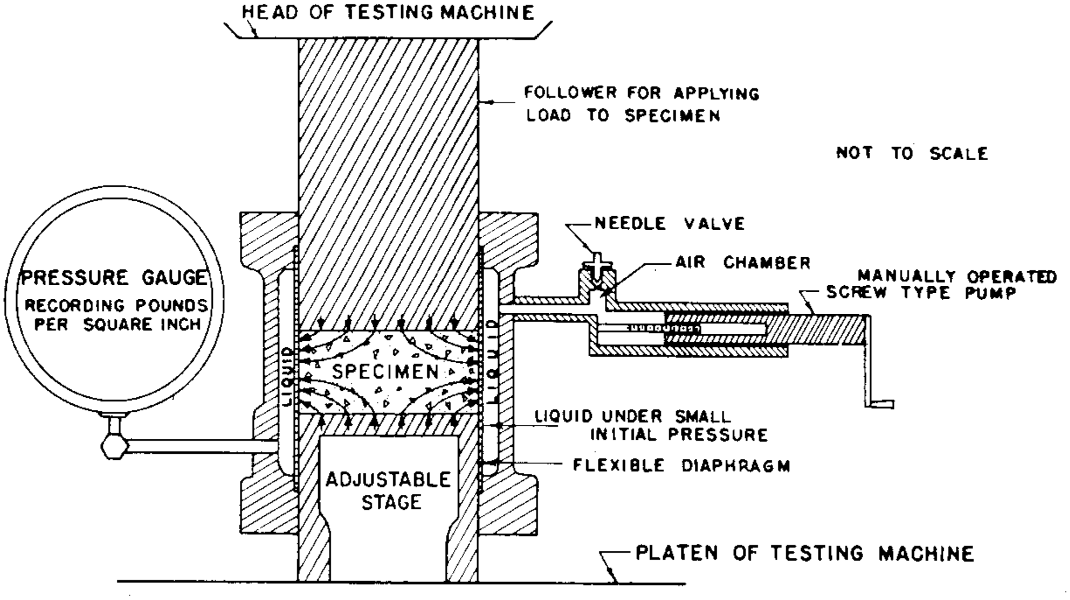

Figure 1: Diagrammatic Sketch of the Hveem Stabilometer

Note: The specimen is given lateral support by the flexible sidewall, which transmits horizontal pressure to the liquid. The magnitude of the pressure can be read on the gauge.

CHART FOR CORRECTING STABILOMETER VALUES TO SPECIMEN HEIGHT OF 2.50"(64mm)

Height correction should be made using the table and chart below.

Example: Overall height of 2.74"(69mm), select correction curve "B". Stabilometer value uncorrected = 35
Stabilometer value corrected = 38.

Overall Specimen Ht.	Correction Curve
2.80" to 3.00"(71mm to 76mm)	A
2.60" to 2.79"(66mm to 70mm)	B
2.40" to 2.59"(61mm to 65mm)	C
2.20" to 2.39"(56mm to 60mm)	D
2.00" to 2.19"(51mm to 55mm)	E

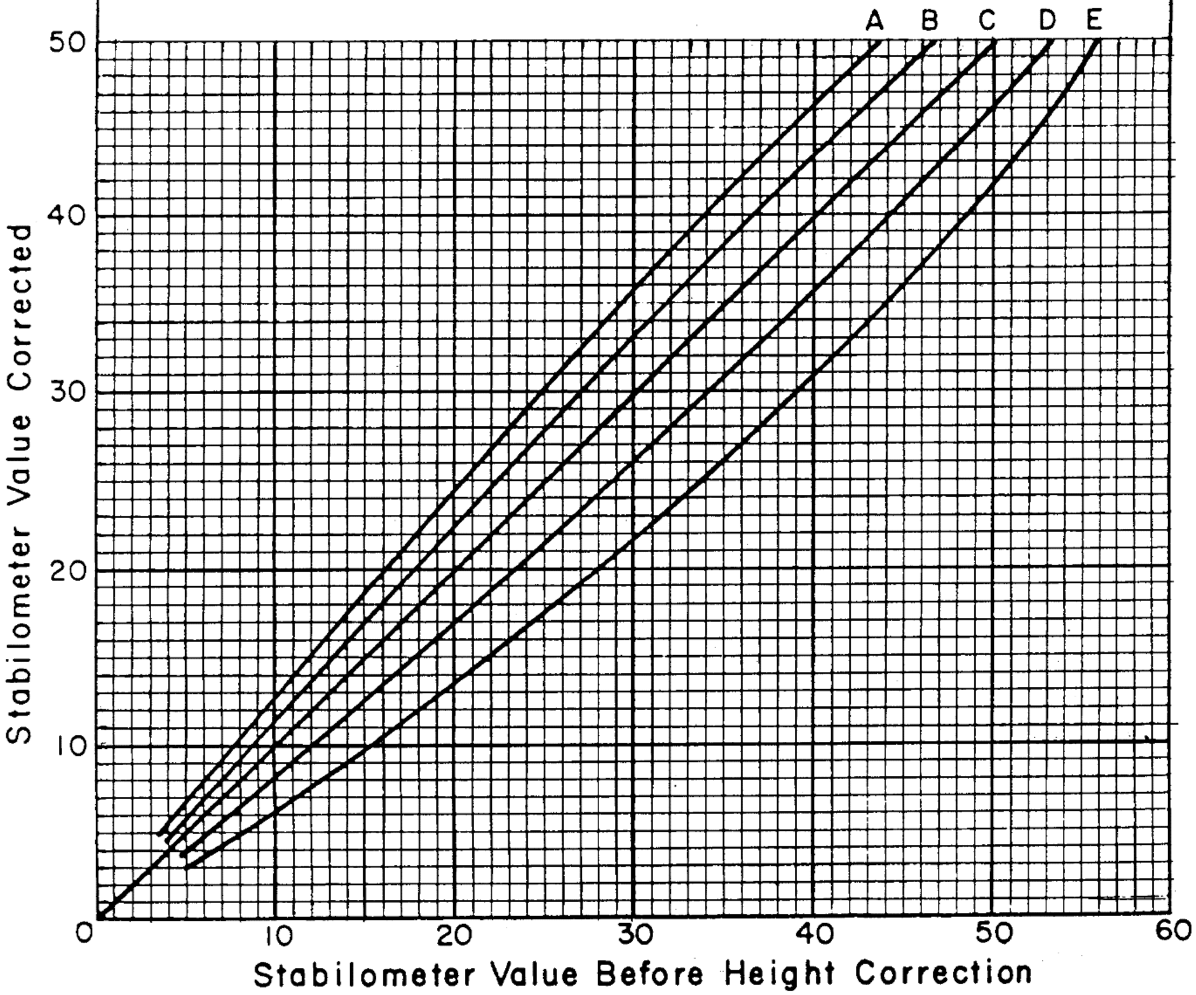

FIGURE 2: CHART FOR CORRECTING STABILOMETER VALUES TO SPECIMEN HEIGHT

APPENDIX

Calibrating the Stabilometer.

1. Perform Subsections 4.1, 4.1.1, and 4.1.2 of CP-L 5106. As soon as the oil pressure stabilizes, turn the pump handle clockwise until the horizontal pressure slightly exceeds 100 psi, and then back off the pressure to 100 psi.

2. Immediately adjust the turns-displacement dial gauge to 4.0.

3. Immediately turn the pump handle smoothly counter-clockwise exactly two turns, making sure that the turns indicator dial gauge does not stick.

4. The horizontal pressure should be 5 ± 0.5 psi.

5. If the horizontal pressure is too high, you can bleed off the excess by placing a finger over the opening in the air cell valve, opening the valve and barely lifting the finger off the valve by slowly rolling the finger off and back over the opening until the needle indicates 5 psi. Close the valve.

6. If the horizontal pressure is too low, turn the pump handle counter-clockwise an additional 0.75 to 1.75 turns. Open the air cell valve to allow air into the air cell and then close it again. **(Note: This step will work whether the horizontal pressure is too high or too low, so this step can be followed instead of step 5.)** To check the calibration, lower the horizontal pressure to 1 to 2 psi, and then raise it back to 5 psi.

7. Zero the turns indicator dial (or set it on a whole number, such as 2.00). Raise the horizontal pressure to 100 psi by turning the pump handle at a rate of two turns per second.

8. If the turns indicator dial does not show an increase of 2.00 ± 0.05, repeat steps 1 through 7.

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Colorado Procedure – Laboratory 5109-16

Standard Method of Test for

Resistance of Compacted Bituminous Mixture to Moisture Induced Damage

(This is based upon AASHTO T 283-02. AASHTO T 283-07 or any subsequent revision may not be used in-place of this procedure.)

1. SCOPE

1.1 This method covers preparation of specimens and measurement of the change of diametral tensile strength resulting from the effects of saturation and accelerated water conditioning of compacted bituminous mixtures in the laboratory. The results may be used to predict long-term stripping susceptibility of the bituminous mixtures, and evaluating liquid anti-stripping additives, which are added to the asphalt cement or pulverulent solids, such as hydrated lime, which are added to the mineral aggregate.

1.2 This method is also referred to as the Lottman.

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards*:

M 156	Requirements for Mixing Plants for Hot Mixed, Hot-Laid Bituminous Paving Mixtures
T 166	Bulk Specific Gravity (Gmb) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
T 167	Compressive Strength of Hot Mix Asphalt
T 168	Sampling Bituminous Paving Mixtures
T 209	Theoretical Maximum Specific Gravity (Gmm) and Density of Hot Mix Asphalt (HMA)
T 245	Resistance to Plastic Flow of Asphalt Mixtures Using Marshall Apparatus
T 246	Resistance to Deformation and Cohesion of Hot Mix Asphalt (HMA) by Means of Hveem Apparatus
T 247	Preparation of Test Specimens of Hot Mix Asphalt (HMA) by Means of California Kneading Compactor
T 269	Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

2.2 *ASTM Standards*:

D 3387	Test Method for Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Corps of Engineers Gyratory Testing Machine (GTM)
D 3549	Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
D 4013	Practice for Preparation of Test Specimens of Bituminous Mixtures by Means of Gyratory Shear Compactor

2.3 *Colorado Procedures:*

CP 44 Bulk Specific Gravity and Percent Relative Compaction of Compacted Bituminous Mixtures Using Saturated Surface- Dry Specimens
CP 51 Determining the Maximum Specific Gravity of HMA
CP-L 5115 Standard Method for Preparing and Determining the Density of Bituminous Mixture Test Specimens Compacted by the Superpave Gyratory Compactor

3. SIGNIFICANCE AND USE

3.1 As noted in the scope, this method is intended to evaluate the effects of saturation and accelerated water conditioning of compacted bituminous mixtures in the laboratory. This method can be used (a) to test bituminous mixtures in conjunction with mixture design testing and (b) to test bituminous mixtures produced at mixing plants.

3.2 Numerical indices of retained indirect tensile properties are obtained by comparing the retained indirect properties of saturated, accelerated water-conditioned laboratory specimens with the similar properties of dry specimens.

4. SUMMARY OF METHOD

4.1 Test specimens of laboratory produced material are tested using the proposed asphalt binder at the optimum asphalt cement content (see Note 1). Each set of specimens is divided into subsets. One subset is tested in dry condition for indirect tensile strength. The other subset is subjected to vacuum saturation followed by a freeze and warm water soaking cycle and then tested for indirect tensile strength. Numerical indices of retained indirect tensile strength properties are computed from the test data obtained on the two subsets: dry and conditioned.

5. APPARATUS

5.1 *Superpave Gyratory Compactor* - as per CP-L 5115.

5.2 *Vacuum Container*:

5.2.1 The vacuum container must be capable of withstanding the full vacuum applied, and each must be equipped with the fittings and other accessories required by the test procedure being employed.

5.2.2 A metal or plastic bowl with a diameter and height sufficient to cover the samples with water when the vacuum is applied. The capacity of the vacuum container should be between 2000 and 10,000 mL. The size selected depends on the minimum sample size requirements given in Section 6.1. Avoid using too small of a sample in a large container.

5.3 *Balance and water bath* - (from T 166).

5.3.1 *Water bath:*

5.3.1.1 *Water bath* - Capable of maintaining a temperature of 140°F ± 1.0° (60°C ± 0.5°).

5.3.1.2 *Water bath* - Capable of maintaining a temperature of 77°F ± 1.0° (25°C ± 0.5°).

5.4 *Freezer* - Maintained at -2.5°F ± 7.5° (-19°C ± 4°).

5.5 *Plastic film (Plastic Wrap or equivalent*) for sample wrapping.

5.6 Heavy-duty leak proof *plastic bags or leak proof container* to enclose the saturated specimens, and *masking tape*.

5.7 *Aluminum or steel pans* - having a surface area of 40-100 square inches (250-640 cm^2) in the bottom and a depth of approximately 1 to 3 inches (25 mm to 75 mm).

5.8 *Forced air draft oven* - capable of maintaining a temperature of 140°F ± 1.8° (60°C ± 1°).

5.9 *Loading jack and ring dynamometer* -from AASHTO T 245, or a mechanical or hydraulic testing machine from AASHTO T 167 to provide a range of accurately controllable rates of vertical deformation including 5.1 and 50.8 mm (0.2 and 2 inches) per minute.

5.10 *Loading Strips* - Steel loading strips with a concave surface having a radius of curvature equal to the nominal radius of the test specimen. For specimens 100 mm (3.937 inches) in diameter the loading strips shall be 12.7 mm (0.5 inches) wide, and for specimens 150 mm (5.906 inches) in diameter the loading strips shall be 19.05 mm (0.75 inches) wide. The length of the loading strips shall exceed the thickness of the specimens. The edges of the loading strips shall be rounded by grinding.

5.11 *Vacuum Measurement Device* - Mercury manometer or digital vacuum gauge is to be connected in line with the vacuum vessel. The digital vacuum gauge shall have been initially NIST traceable. If a digital vacuum gauge is used or the mercury manometer is suspected of being inaccurate, then once a year they shall be certified. The mercury manometer shall be free of air bubbles to obtain the correct reading.

5.12 *Bleeder Valve* - attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum container.

5.13 *Low Temperature Oven* - capable of maintaining a temperature of 77°F ± 1.0°(25°C ± 0.5°)

5.14 *Vacuum Pump*—Capable of evacuating air from the vacuum container to a residual pressure of a minimum of 4.0 kPa (30 mm Hg).

5.14.1 When a vacuum pump is used, a suitable trap of one or more filter flasks, or equivalent, shall be installed between the vacuum vessel and vacuum source to reduce the amount of water vapor entering the vacuum pump.

6. PREPARATION OF LABORATORY MIXED AND FIELD PRODUCED TEST SPECIMENS

6.1 Specimens approximately 100 mm (3.937 inches) in diameter and approximately 63.5 mm (2.5 inches)) thick are normally used. Specimens of other dimensions may be used if desired and should be used if the aggregate present is larger than 1 inch (25.4 mm), and is not permitted to be scalped out. Table 1 in CP-L 5115 can be used to determine the approximate sample size to be adjusted in Section 6.4.

6.2 *Laboratory Mixed Material* - After mixing, the mixture shall be placed in an aluminum or steel pan and cooled at room temperature for 2 ± 0.5 hours. Then the mixture shall be placed in a 140°F ± 1.8° (60°C ± 1°) oven for 20 ± 4 hours, followed by 2.5 ± 0.5 hours at the compaction temperature of the binder in CP-L 5115 for short-term aging. The pans should be placed on spacers to allow air circulation under the pan if the shelves are not perforated. This short-term aging procedure is used for laboratory mixed samples only. Field produced material is not short-term aged before the compaction procedure.

6.3 Lottman specimens shall have the same mix compaction temperature specifications and mold temperature specifications as volumetric specimens (CP-L 5115). For Lottman specimens (CP-L 5109), enter the final sample height (corrected if necessary to achieve the desired sample air voids) into the compactor control panel. Variations in sample heights and/or weight, which result in Lottman specimens having 7 ± 1.0 percent air voids, are permitted.

6.3.1 The suggested calculation to determine Lottman height is as follows:

$$\frac{(\mathbf{Ave.\ Bulk\ SpG\ @\ N(des)\ x\ Ave.\ Ht.\ @\ N(des)})}{(\mathbf{0.925\ x\ Rice})}$$

6.4 Reduce field produced sample to the proper sample weight as per CP 55. Adjustment of sample voids may be done by adjusting sample weights. If a sample has a sample weight of 1150 grams and a specific gravity of 94.5% of the theoretical maximum specific gravity (Rice value) (with 5.5% air voids) and the target specific gravity is 93% of the theoretical maximum specific gravity (with 7% air voids), the sample weight may be reduced according to the formula: target sample weight = (1150 x 93%) / 94.5%. The target sample weight would be approximately 1132 grams.

6.5 Samples shall be placed in an oven at the compaction temperature for the specified time in CP-L 5115 before compaction begins. Both Laboratory and Field produced samples shall be compacted to 7 ± 1.0 percent air voids (calculated in Subsection 7.4). This level of voids can be obtained as specified in CP-L 5115.

6.6 After extraction from the molds, the specimens should not be tested until they reach room temperature.

7. EVALUATION OF TEST SPECIMENS AND GROUPING

7.1 Determine theoretical maximum specific gravity of mixture by CP 51.

7.2 Determine specimen thickness by CP-L 5115.

7.3 Determine bulk specific gravity by CP 44. Express volume of specimens in cubic centimeters.

7.4 Calculate air voids using the formula:

$$\mathbf{V_a = 100\left[1 - \left(\frac{G_{mb}}{G_{mm}}\right)\right]}$$

Where:

V_a = air voids content (percent),
G_{mb} = bulk specific gravity of compacted sample,
G_{mm} = theoretical maximum specific gravity of mixture.

7.5 Sort specimens into two subsets of three specimens each so that average air voids of the two subsets are approximately equal.

8. MOISTURE CONDITIONING OF TEST SPECIMENS (5 Minute Saturation Method)

8.1 The dry subset shall be conditioned as follows:

8.1.1 The dry specimens shall be wrapped in plastic film (Plastic Wrap or equivalent) and placed in a heavy duty, leak proof plastic bag or placed unwrapped in a leak proof container. The dry specimens shall be placed in the 77°F ± 1.0° (25°± 0.5°C) water bath with the conditioned specimens for 3.5 ± 0.5 hour for 100 mm (3.937 inches) diameter specimens. 150 mm (5.906 inches) diameter specimens shall remain in the 77°F ± 1° (25°C ± 0.5°) water bath for 6 ± 2 hours , and then tested as described in Section 9. It is critical that the dry specimens remain dry if this method is used.
Alternatively, the dry specimens may remain unwrapped and stored in a low temperature oven capable of holding a temperature of 77°F ± 1.0° (25°C ± 0.5°) until tested as described in Section 9.

8.2 The moisture conditioned subset shall be conditioned as follows:

8.2.1 Place the moisture conditioned specimens in the vacuum container which is supported above the container bottom by a spacer or with the specimen being placed on its side. Fill the container with potable water at room temperature so that the specimens have at least one inch of water above their surface. Apply a vacuum of 28 ± 2 mm of Hg for a period of 5 ± 0.25 minutes. The vacuum shall be monitored using a mercury manometer or digital vacuum gauge and adjusted using a bleeder valve. Begin timing the vacuum application when the applied vacuum reaches the specified level. After the 5 ± 0.25 minutes, slowly remove the vacuum and leave the specimen submerged in water for a short time (greater than 5 seconds).

NOTE 1: If calculating saturation and/or swell, then as soon as possible after removing the specimen from the water, determine bulk specific gravity of the saturated specimen by CP 44. Calculate the level of saturation and swell as defined in Section 12.

8.2.2 Place the specimens under water for one second then wrap the wet, vacuum saturated specimens tightly with a plastic film (Plastic Wrap or equivalent). Place each wrapped specimen in a plastic bag and seal the bag or place it in a leak proof container.

8.2.3 Place the plastic bag or container containing the specimen in a freezer at -2.5°F ± 7.5° (-19°C ± 4°) for a minimum of 16 hours for 100 mm (3.937 inches) diameter specimens. 150 mm (5.906 inches) diameter specimens shall remain in the freezer for a minimum of 40 hours.

8.2.4 After removal from the freezer, place the moisture conditioned specimens into a 140°F ± 1.0° (60°C ± 0.5°) water bath for 24 ± 1 hour. As soon as possible after placement in the water bath or, if possible, before placement in the water bath, remove the specimens from the container or plastic bag and remove the plastic film from the specimens.

8.2.5 After 24 ± 1 hours in the 140°F ± 1.0° (60°C ± 0.5°) water bath, remove the specimens and place them in a water bath already at 77°F ± 1° (25°C ± 0.5°) for 3.5 ± 0.5 hour for 100 mm (3.937 inches)diameter specimens. 150 mm diameter specimens shall remain in the 77°F ± 1° (25°C ± 0.5°) bath for 6 ± 2 hours. It may be necessary to add ice to the water bath to prevent the water temperature from rising above 77°F ± 1° (25°C ± 0.5°). Not more than 15 minutes should be required for the water bath to reach 77°F ± 1° (25°C ± 0.5°). Test the specimens as described in Section 9.

9. TESTING

9.1 Determine the indirect tensile strength (PEAK or MAX LOAD) of dry and conditioned specimens at 77°F ± 1° (25°C ± 0.5°).

9.2 Remove each specimen from the 77°F ± 1° (25°C ± 0.5°) water bath or low temperature oven (dry sample only) and place between the two steel loading strips. Place the specimen and loading strips between the two bearing plates in the testing machine. Care must be taken so that the load will be applied along the diameter of the specimen. Apply the load to the specimen, by means of the constant rate of movement of the testing machine head, at 0.2 inches per minute.

9.3 Record the maximum compressive strength noted on the testing machine (PEAK or MAX LOAD). If desired, continue loading until a vertical crack appears. Remove the specimen from the machine and pull it apart at the crack. Inspect the interior surface for stripping and record the observations

9.4 Repeat steps 9.2 - 9.4 for each of the dry and moisture conditioned specimens.

10. CALCULATIONS

10.1 Calculate the tensile strength as follows:

$$\mathbf{S_t = \frac{2P}{\pi t D}}$$

Where:
S_t = tensile strength, psi,
P = maximum load, pounds,
t = specimen thickness (height), inches, to 0.01 of an inch,
D = specimen diameter, 3.937 inches for 100 mm molds or 5.906 inches for 150 mm molds.

10.2 Express the numerical index or resistance of asphalt mixtures to the detrimental effect of water as the ratio of the original strength that is retained after the freeze-warm water conditioning.

Calculate Percent Tensile Strength Retained (%TSR) as follows:

$$\%\boldsymbol{TSR} = (\boldsymbol{S_2} \,/\, \boldsymbol{S_1})\,\mathbf{100}$$

Where:
S_1 = average tensile strength of dry subset,
S_2 = average tensile strength of moisture conditioned subset

11. REPORT

11.1 Average % Voids

11.2 Dry Average Tensile Strength (S_1)

11.3 Wet Average Tensile Strength (S_2)

11.4 Percent Tensile Strength Retained (TSR)

12. ADDITIONAL TESTING FOR INFORMATION ONLY

12.1 Calculate % Saturation and Swell, as soon as possible after removing the conditioned specimens from the vacuum container in Section 8.2.1. Determine saturated samples surface dry weight (B_{sat}) and mass of the saturated sample, in water (C_{sat}) by CP 44. Calculate the level of saturation and percent swell as defined in Section 12.2 and 12.3 respectively. After recording the weights, place the specimens under water for one second and continue to Subsection 8.3.2.

12.2 Calculate the level of saturation as follows:

$$\mathbf{s} = \frac{\mathbf{B_{sat} - A}}{\mathbf{(B - C)x}\left[\mathbf{1} - \left[\frac{\mathbf{A}}{\mathbf{Gx(B - C)}}\right]\right]}\mathbf{x100}$$

Where:
s = level of saturation (%),
A = mass in grams of the dry sample in air,
B = mass in grams of the surface-dry sample in air,
B_{sat} = mass in grams of the surface-dry sample, in air, after saturation,
C = mass in grams of the sample, in water,
G = maximum specific gravity by CP 51.

12.3 Calculate the Percent Swell as follows:

$$\%\ \mathbf{swell} = \frac{\mathbf{(B_{sat} - C_{sat}) - (B - C)}}{\mathbf{(B - C)}}\ \mathbf{x\ 100}$$

Where:
B = mass in grams of the surface-dry sample in air,
B_{sat} = mass in grams of the surface-dry sample, in air, after saturation,
C = mass in grams of the sample, in water
C_{sat} = same as C except that the sample has been saturate

Colorado Procedure – Laboratory 5110-15

Standard Method of Test for

Resilient Modulus Test (M_R)

1. SCOPE

1.1 This method covers procedures for preparing and testing laboratory fabricated or field recovered cores of bituminous mixtures to determine resilient modulus (M_R) values using the repeated load indirect tension test. The M_R can be used in determining the structural contribution of the mix to the pavement performance.

2. APPARATUS

2.1 *Mark III Resilient Modulus Device* - manufactured by Retsina Co., or equivalent.

3. TEST SPECIMENS

3.1 Test specimens are compacted using a Superpave Gyratory compactor and test method CP-L 5115. Specimens are stored for a minimum of 2 hours in a 77°F cabinet. These specimens generally are the same specimens that will be used for Hveem stability, and this test is performed before heating.

4. PROCEDURE

4.1 Place yoke assembly of the Resilient Modulus Device on the holder.

4.2 Back out the screw so that the transducer sensors will clear the sample. Back out the four clamping screws and gently insert the sample into the center of the yoke. Place sample squarely on the centering strip. Gently tighten the clamping screws, keeping the sample centered and square in the yoke. Tighten only until snug.

4.3 Place the assembly in the loading device, align on the center strip. DO NOT LIFT BY THE YOKE!

4.4 Lift the loading shaft and place the top loading block on the specimen, 180 degrees from the bottom centering strip. Allow the shaft to seat against the ball on top of the loading block.

4.5 Zero the recording meter. Set the multiplier knob to 200 and turn on the meter. Adjust the zero control until the meter reads just above zero.

4.6 Tighten the right transducer advancement- screw until an increased meter reading of about 2.0 is obtained. Tighten the left transducer until an additional 2.0 is obtained.

4.7 Reset the zero-knob to just above zero until both the "High" and "Low" pilot lights are out.

4.8 Set Mode switch to "Operate".

4.9 Record the deflection in micro-inches from the meter. If the reading is out of range, change the multiplier to a higher or lower setting. Reset the zero-knob if one of the indicator lights comes on, and then take another reading.

4.10 Rotate the sample 90 degrees and repeat measurements. Deflection readings should be within 10 percent. Sometimes a specimen is non -isotropic and a larger difference will exist.

5. CALCULATIONS FOR M_R

5.1 Calculate the M_R as follows:

$$M_R = \frac{P\ (gamma + .0234)}{t * delta}$$

Where:

P = dynamic load in lbs.,
gamma = 0.35 (assumed for Poisson's Ratio),
t = specimen thickness, inches to 0.1,
delta = deflection in inches (micro-inches X 10^{-6}) obtained by multiplying the meter reading by the multiplier.

6. NOTES ON TEST PROCEDURES

6.1 Usually a 75 psi load is used on sound, dry samples. In some cases lower pressure may be required to minimize damage to the sample; therefore, if in doubt, start with a lower pressure.

7. REPORT

7.1 There is no designated CDOT Form used for recording / reporting information for this CP-L.

Colorado Procedure – Laboratory 5111-15

Standard Method of Test for

Determining the Percent of Recycling Agent to Use for Cold Recycling of Asphalt Concrete

1. SCOPE

1.1 This procedure is used to determine the percent of recycling agent for asphalt concrete when the cold method of recycling is used.

2. APPARATUS

2.1 *Jaw crusher* - which can be adjusted to produce material passing the No. 4 sieve. A sledge hammer may be used to reduce oversize particles enough to permit the material to be fed into the crusher.

2.2 *Two ovens* - one forced draft oven capable of maintaining a temperature of 140° F ± 5° (60°C ± 2.8°) and another capable of maintaining a temperature of 300°F ± 9° (149°C ± 5°).

2.3 *Balance* - 5 kg capacity, accurate to one gram.

2.4 *Sieves* - U.S. Standard sizes; 1 ¼ in. (31.5 mm), 1 in. (25.0 mm), 3/4 in. (19.0 mm), 1/2 in. (12.5 mm), 3/8 in. (9.5 mm), No. 4, No. 8, No. 16, No. 30, No. 100, No. 200.

2.5 *Sample splitter* - suitable for splitting aggregates up to 1 ¼ in. (31.5 mm).

2.6 *Pans* - approximately 10 in. (250 mm) diameter, 3 in. (75 mm) deep.

2.7 *Trowels* and other small tools.

3. MATERIALS

3.1 Emulsified recycling agent, either HFMS-2sP, or as specified.

3.2 Take a minimum of 50 pounds of the pavement to be recycled. At a minimum, one full-depth 6” diameter core shall be taken every half-mile of each lane (between wheel paths). Cores should also be taken in the shoulder, if the shoulders are to be recycled. More samples should be taken if visual observations show significant variations in the existing mat. Significant variations may be defined by pavement condition, thickness, surface course, etc. Samples are required for a separate design of each significant variation in the pavement. In order to properly design for a 4” recycle depth, a minimum of 20 cores (4” thick - 6”diameter) are required for each significant variation in the existing mat. If the recycle depth is only 2” in depth, 40 cores (2” thick - 6” diameter) are required. If the material is sampled by milling, the milling machine shall be similar to the type of milling machine that will be used during the recycling process. Small milling machines are not recommended. Milled material shall be approximately 50 pounds (23 kg) of each pavement type to be recycled.

4. PREPARATION OF SAMPLES

4.1 Crushing

A. Pavement cores or chunks
  1. Trim samples so that only the portion designated for recycling remains.
  2. Crush the material proposed for recycling to minus 1 1/4 in. (31.5 mm).

B. Milled pavement is preferable to cores for cold recycle design.
(If milled pavement of the proposed production milling operation is available)
  1. Crush oversized material so that the sample is 100% passing the 1 1/4 in. (31.5 mm).

4.1.1 Perform a mix design on the material as received after crushing, preferably at a medium gradation as defined below. It may be necessary to recombine millings in the laboratory to target these established gradation ranges.

Sieve Sizes	Fine	Medium	Coarse
31.5 mm (1.25”)	100	100	100
25 mm (1”)	100	100	90-100
19 mm (3/4”)	95-100	85-96	75-92
4.75 mm (No. 4)	55-75	40-55	30-45
600 μm (No. 30)	15-35	4-14	1-7
75 μm (No. 200)	1-7	0-3	0-3

5. PROCEDURE

5.1 Prepare one sample to be used for determination of asphalt content and aggregate gradation according to CP-L 5120, *Determination of the Asphalt Binder Content of Bituminous Mixtures by the Ignition Method*. Sample size is determined by Nominal Maximum Aggregate size.

5.2 Prepare one sample in accordance with Subsection 4.1 to be used to determine the maximum theoretical specific gravity in accordance with CP 51 of the unmixed material.

5.2.1 Dry the unmixed sample to a constant mass at 250°F for 2 hours ± 30 minutes.

5.2.2 Determine the maximum specific gravity of the sample according to CP 51. Do not break down agglomerates that will not break easily with a spatula.

Note 1: The specific gravity of the unmixed sample will require that the dry-back procedure be used.

5.3 Prepare one sample in accordance with Subsection 4.1 to be used to determine the maximum theoretical specific gravity in accordance with CP 51 for the mixed material.

5.3.1 Add 2% by weight (mass) of water to this sample.

5.3.2 Add 2.4% emulsion by weight (mass) if HFMS-2sP is used. Add 3.5% emulsion by weight (mass) if CSS Special is used.

5.3.3 Mix the RAP and water first prior to the addition of the emulsion. Mixing with a mechanical mixer is preferred to hand mixing. Mixing time should not exceed 60 seconds.

5.3.4 Dry the mixed sample to a constant mass at 250°F for 2 hours ± 30 minutes.

5.3.5 Determine the maximum specific gravity of the sample according to CP 51. Do not break down agglomerates that will not break easily with a spatula.

5.3.6 Other maximum specific gravities will be back-calculated based on the emulsion content. (See Section 6 if lime is added to samples.)

5.4 A minimum of three emulsion contents is recommended for each mix design evaluation. Prepare a total of 27 specimens in accordance with Subsection 4.1. At the proposed emulsion content, a set of nine specimens will be needed. Three specimens will be required for Hveem Stability Testing in accordance with Section 7 and six specimens will be required for Moisture Susceptibility Testing (Lottman) in accordance with Section 9. Specimen size will be the amount of material necessary to produce a 61.0 mm to 66.0 mm tall puck. (Approximately 470 x Rice Value)

5.4.1 If the mix is initially evaluated without lime, it will be necessary to prepare ten additional samples for comparisons at optimal emulsion content, one for specific gravity, three for stability, and six for Lottman. See Section 6, Lime.

5.5 Dry the 27 specimens for compaction to a constant weight (mass) at 140°F (60°C).

5.5.1 Remove specimens from oven and cool at room temperature for 2 hours ± 30 minutes.

5.6 Add 2% water by weight (mass) to a dry specimen and mix thoroughly (hand mixing is acceptable, but mechanical mixing is preferred).

5.7 Add the initial emulsion content, normally 0.8% emulsion (HFMS-2sP) or 2.0% CSS Special, by weight (mass) and thoroughly mix at room temperature, 75 ± 5°F (24 ± 2.8°C) (mechanical mixing preferred). Mixing time should not exceed 60 seconds.

5.7.1 Immediately after mixing, compact the specimen in accordance with CP-L 5115 for 30 gyrations. The compaction should be done at room temperature 75°F ± 5° (24°C ± 2.8°), and the mold shall not be heated.

5.7.2 Extrude specimen immediately after compaction and carefully remove paper disks. Place pucks in a flat pan. Dry in a forced air oven at 140°F (60°C) to a constant mass, but for no more than 48 hours and no less than 16 hours. After curing, cool the puck at room temperature 75°F ± 5° (24°C ± 2.8°), for 12 to 24 hours.

5.8 Repeat step (Subsections) 5.6 and 5.7 for the remaining eight specimens needed for the specified emulsion content.

5.9 Repeat step (Subsection) 5.6 and in step (Subsection) 5.7, increase the amount of emulsion to 1.3% for HFMS-2sP or 2.5% for CSS for the next nine specimens.

5.10 Repeat step (Subsection) 5.6 and in step (Subsection) 5.7, increase the amount of emulsion to 1.8% for HFMS-2sP or 3.0% for CSS for the next nine specimens.

5.11 If needed, repeat step (Subsection) 5.9 by increasing the emulsion (HFMS-2sP or CSS) in increments of 0.5% for the next nine specimens.

Note 2: If virgin aggregate is added, greater amounts of emulsion may be required.

6. LIME

6.1 If lime is specified by the Engineer, 1.5 % by weight (mass) should be added to all samples in Section 5.

6.1.1 The lime slurry will be a homogeneous slurry mix heated to 140°F (60°C) and have a dry solids content of not less than 30 percent.

6.2 If it is not specified by the Engineer, it is recommended to add 1.5 % by weight (mass) to a set of nine specimens at the optimum emulsion content as determined in Section 11 and prepared in accordance with Subsections 5.6 and 5.7.

6.2.1 Compare the results from the mix with lime to the results from the mix without lime at the optimal emulsion content in order to determine if the addition of lime is beneficial.

7. BULK SPECIFIC GRAVITY OF COMPACTED SAMPLES

7.1 Specific Gravity - Use CP 44 to calculate air voids for each compacted sample.

8. HVEEM STABILITY

8.1 Three compacted specimens from Section 5 will be used for Hveem Stability testing, in accordance with CP-L 5106 for each emulsion content.

8.2 Stabilometer Test - Test for Stabilometer value at room temperature 75°F ± 5° (24°C ± 2.8°), in accordance to CP-L 5106, Subsection 5.1.

9. RESISTANCE TO MOISTURE INDUCED DAMAGE – LOTTMAN TESTING.

9.1 Six compacted specimens from Section 5 will be used for Lottman testing in accordance with CP-L 5109 for each emulsion content.

Note 3: These samples were compacted at 30 gyrations without regard to target void content.

10. REPORTING OF RESULTS

10.1 There is no designated CDOT Form used for recording / reporting information for this CP-L.

10.2 Report percent asphalt and gradation of aggregate.

10.3 Report the type and percent of recycling agent used for each set of specimens.

10.4 Report printout from Flex program showing Voids, Stability, Maximum Specific Gravity, Bulk Specific Gravity, TSR from Lottmans, etc from each compacted sample.

11. RECOMMENDATION

11.1 The optimal emulsion content is determined as the highest emulsion content providing the highest stability, with the highest TSR from Lottman testing, and voids between 6% and 12% in the compacted sample, with no evidence of surface flushing or bleeding.

Note 4: Slight flushing is considered no flushing.

11.1.1 It is recommended that raveling be less than 2% loss for high traffic areas.

11.2 If a mix is evaluated with and without lime, it is recommended that a 10% difference in TSR is significant and would warrant the use of lime in the mix design.

11.3 It is recommended that once the mix design is completed, a separate mix design be developed either using a fine or coarse gradation using the target criteria found in Subsection 4.1.1. This information will be used to make field adjustments as necessary to the optimal emulsion content.

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Colorado Procedure – Laboratory 5112-24

Standard Method of Test for

Hamburg Wheel-Track Testing of Compacted Bituminous Mixtures

(This document is a description of the test method used by the Colorado Department of Transportation to test samples in the Hamburg Wheel-Tracking Device.)

1. SCOPE

1.1 This method describes the testing of submersed, compacted bituminous mixtures in a reciprocating rolling wheel device. This test provides information about the rate of permanent deformation from a moving, concentrated load. A laboratory compactor is used to prepare slab specimens. Alternatively, field cores of large diameter (10 in.) or saw-cut slab samples may be tested.

1.2 The potential for moisture damage effects is evaluated since the specimens are submerged in temperature-controlled water during loading.

2. REFERENCED DOCUMENTS

2.1 Colorado Procedures:

CP 44 Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
CP 51 Determining the Maximum Specific Gravity of Bituminous Mixtures
CP 55 Reducing Field Samples of Hot Mix Asphalt to Testing Size
CP-L 5116 Linear Kneading Compaction of Bituminous Mixtures

2.2 AASHTO Procedures:

T 324-22 Hamburg Wheel-Track Testing of Compacted Hot-Mix Asphalts (HMA)

3. SIGNIFICANCE AND USE

3.1 This test measures the rutting and moisture susceptibility of an asphalt paving mixture.

4. SUMMARY OF METHOD

4.1 A laboratory-compacted slab of a bituminous mixture, a saw-cut slab, or a core taken from a compacted pavement, is repetitively loaded using a reciprocating steel wheel. The specimen is submerged in a temperature-controlled water bath at the temperature specified in Table 1 of this procedure. The deformation of the specimen, caused by the wheel loading, is measured.

4.2 The impression is plotted as a function of the number of wheel passes. An abrupt increase in the rate of deformation coincides with stripping of the asphalt from the aggregate in the specimen.

5. APPARATUS

5.1 *Hamburg Wheel-Tracking Machine* - An electrically powered machine capable of moving a 203.6 mm (8 in.) diameter, 47 mm (1.85 in.) wide steel wheel over a test slab. The load on the wheel is 158 Ibs. (705 N). The wheel shall reciprocate over the slab, with the position varying sinusoidally over time. The wheel shall make approximately 50 passes across the slab per minute. The maximum speed of the wheel shall be approximately 0.305 m/s (1.1 ft/sec), and will be reached at the midpoint of the slab.

5.2 *Temperature Control System* - A water bath capable of controlling the temperature within ± 0.5°C over a range of 25° to 70°C. This bath shall have a mechanical circulating system to stabilize temperature within the specimen tank.

5.3 *Impression Measurement System* - A LVDT device capable of measuring the depth of the impression of the wheel within 0.01 mm, over a minimum range of 20 mm. The system shall be mounted to measure the depth of the impression at the midpoint of the wheel's path on the slab. The impression shall be measured at least every 100 passes of the wheel. This system must be capable of measuring rut depth without stopping the wheel. This measurement must be referenced to the number of wheel passes.

If the LVDT is temporarily not working, measurements may be taken through the center of the sample in the direction of the wheel path. Eleven measurements shall be taken 1 inch apart every 1,000 passes. The rut will be the average of the eleven measurements and shall be reported for every 1,000 passes.

5.4 *Wheel Pass Counter* - A non-contacting solenoid that counts each wheel pass over the slab. The signal from this counter shall be coupled to the wheel impression measurement, allowing for the rut depth to be expressed as a fraction of the wheel passes.

5.5 *Sample Mounting System* - A stainless steel tray that can be mounted rigidly to the machine. This mounting must restrict shifting of the sample to within 0.5 mm during testing. The system shall suspend the sample, allowing for free circulation of the water bath on all sides. The mounting system shall be designed to provide a minimum of 2 cm of free circulating water on all sides of the sample.

6. SAMPLE PREPARATION

6.1 Laboratory Produced Mix

6.1.1 *Mixing* - Materials mixed in the laboratory shall be brought to mixing temperature (Table 1) in a forced draft oven and mixed in a mechanical mixer for 3 to 5 minutes or until complete coating of the aggregates is achieved.

6.1.2 *Splitting* - Material mixed in the laboratory shall be placed in open pans. The amount (weight) of material is determined by calculating the number of grams of mix needed to attain an air void target of (7.0% ± 1% for slabs) or (7.0% ±0.5% for Superpave gyratory cylindrical samples). To do this, multiply the volume of the sample in cubic centimeters by the sample's maximum specific gravity, and then remove a percentage of the mix equal to the targeted air voids. The pans should contain less than 77 kg/m^2 (15.9 Ib/ft^2) of material.

6.1.3 *Aging* - The mixed material shall be short-term aged by placing the open pans in a forced draft oven at the compaction temperature (Table 1) for 2 hours to age the material before compaction. If it is known that the material being designed will stay at elevated temperatures in the field for longer than 2 hours, then the aging time can be increased.

6.1.4 *Compacting* - The slabs must be compacted to Target Air Void Content (7% ± 1.0%) such that the void distribution is consistent throughout the sample. Samples shall be 12.5 in. (320 mm) long and 10.25 in. (260 mm) wide. A slab thickness of 1.5 in. (38 mm) to 4 in. (100 mm) can be used. The slab thickness shall be at least twice the maximum nominal aggregate size. Alternatively, Superpave gyratory cylindrical samples may be used, and shall be compacted to target air void content of (7.0% ± 0.5%). They should be prepared as described in T 324-22. Compacted slabs shall be cooled at normal room temperature on a clean, flat surface until the sample is cool to the touch.

6.1.5 *Bulking* - The bulk specific gravity shall be performed in accordance with CP 44.

6.1.6 *Slab Mounting* - Use Plaster-of-Paris to rigidly mount the slab in the mounting trays. The plaster shall be mixed at approximately a 1:1 ratio of plaster to water. Pour the plaster to a height equal to that of the slab so that the air space between the slab and the tray is filled. The plaster layer underneath the slab shall not exceed 0.08 in. (2 mm). Allow the plaster to set for at least one hour.

6.2 Field Produced Mix

6.2.1 Field Loose Mix

6.2.1.1 *Splitting* - The mix received from the field shall be heated for 3 hours (± 0.5) in a forced draft oven at the compaction temperature (Table 1) and then separated into pans for compaction. The amount of material is determined by calculating the number of grams of mix needed to attain an air void target of (7.0 % ± 0.5 % for slabs) or (7.0% ± 0.5% for Superpave gyratory cylindrical samples). To do this, multiply the volume of the sample in cubic centimeters by the sample's maximum specific gravity, and then remove a percentage of the mix equal to the targeted air voids. The open pans should contain less than 77 kg/m^2 (15.9 lb/ft^2) of material.

6.2.1.2 *Compacting* – Prior to compaction, the material shall be heated in a forced-draft oven at the temperature specified in Table1, until at least 15 minutes after the specimens have been brought to compaction temperature, not exceeding 4 hours. The slabs must be compacted to (7.0 % ± 1.0 %) voids such that the void distribution is consistent throughout the sample. Samples shall be 12.5 in. (320 mm) long and 10.25 in. (260 mm) wide. A slab thickness of 1.5 in. (38 mm) to 4 in. (100 mm) may be used. The slab thickness shall be at least twice the maximum nominal aggregate size. Alternatively, Superpave gyratory cylindrical samples may be used, and shall be compacted to target air void content of (7.0% ± 0.5%). They should be prepared as described in T 324-22. Compacted slabs shall be cooled at normal room temperature on a clean, flat surface until the sample is cool to the touch.

6.2.1.3 *Bulking* - The bulk specific gravity shall be performed in accordance with CP 44.

6.2.1.4 *Slab Mounting* - Use Plaster-of-Paris to rigidly mount the slab in the mounting trays. The plaster shall be mixed at approximately a 1:1 ratio of plaster to water. Pour the plaster to a height equal to that of the slab so that the air space between the slab and the mold is filled. The plaster layer underneath the slab shall not exceed 0.08 in. (2 mm). Allow the plaster to set for at least one hour.

6.2.2 Field Compacted Core / Slab

6.2.2.1 *Cutting* - Field cores or field slabs shall consist of wet saw-cut compacted samples taken from asphalt pavements. Field cores shall be 10 in. in diameter. Field slabs shall be wet saw-cut to approximately 10.25 in. (260 mm) wide and 12.5 in. (320 mm) long. A slab thickness of 1.5 in. (38 mm) to 4 in. (100 mm) may be used. The height of a field core or field slab is typically 1.5 in. (138 mm), but may be adjusted to fit the specimen mounting system by wet saw cutting.

6.2.2.2 *Bulking* - The bulk specific gravity is typically not performed on cores/slabs, however, it can be performed in accordance with CP 44.

6.2.2.3 *Core/Slab Mounting* - Use Plaster-of-Paris to rigidly mount the core/slab in the mounting trays. The plaster shall be mixed at approximately a 1:1 ratio of plaster to water. Pour the plaster to a height equal to that of the core/slab so that the air space between the core/slab and the mold is filled. The plaster layer underneath the slab shall not exceed 0.08 in. (2 mm). Allow the plaster to set for at least one hour.

Table 1

Asphalt Grade	Mixing Temperature	Compaction Temperature
PG 58-28	154° C (310° F)	138° C (280° F)
PG 58-34	154° C (310° F)	138° C (280° F)
PG 64-22	163° C (325° F)	149° C (300° F)
PG 64-28	163° C (325° F)	149° C (300° F)
PG 70-28	163° C (325° F)	149° C (300° F)
PG 76-28	163° C (325° F)	149° C (300° F)
	± 2.8° C (5°F)	

7. PRE-TEST PROCEDURE

7.1 The test temperature should be selected as follows:

SHRP High Temp PG	Test Temp
58	45° C
64	50° C
70	55° C
76	55° C

7.2 Fill the wheel-tracking device with hot water.

8. TEST PROCEDURE

8.1 When the water has been at test temperature for 45 minutes, lower the wheels onto the slabs.

8.2 Begin the test.

8.3 The wheel-tracking device will shut off when 10,000 cycles have occurred.

9. REPORT

9.1 The report shall include the following parameters:
Number of passes
Maximum impression
Test temperature
Sample(s) air voids
Creep slope
Strip slope
Stripping inflection point

Note 1: Maximum Rut depth greater than 4mm before 10,000 passes is a failure.

The regression table on the PMW Wheel tracker software program is used to calculate the Stripping Inflection Point (SIP). The low creep / high creep and the low strip / high strip data are inputted manually into the software where the SIP is calculated.

10. CALIBRATION / EQUIPMENT VERIFICATION

10.1 Verify that the water bath temperature is within 0.5°C of the temperature readout on the micro control unit every 6 months.

10.2 Verify that the LVDT height is within 0.05 mm between the three (10, 20, and 30 mm) calibration blocks.

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Colorado Procedure – Laboratory 5114-20

Standard Method of Test for

French Rut Testing of Compacted Bituminous Mixtures

(This document is a description of the test method used by the Colorado Department of Transportation to test samples in the French Rutting Tester.)

1. SCOPE

1.1 This method describes the testing of compacted bituminous mixtures in a rolling wheel device. This test provides information about the rate of permanent deformation from a moving, concentrated load. A special laboratory compactor has been designed to prepare slab specimens. Alternatively, saw-cut field slabs may be tested.

2. REFERENCED DOCUMENTS

2.1 Colorado Procedures:

CP 44	Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
CP 55	Reducing Field Samples of Hot Mix Asphalt to Testing Size

3. SIGNIFICANCE AND USE

3.1 This test may simulate traffic loading that occurs in the field. The load is concentrated to produce measurable deformations after a single day of testing.

4. SUMMARY OF METHOD

4.1 A laboratory-compacted slab of a bituminous mixture, or a saw-cut field slab taken from a compacted pavement, is repetitively loaded with an 1,124 Ib. (5,000 N) force while a rubber tire inflated to 87 psi (0.6 MPa) rolls across the slab for 10,000 cycles (20,000 passes). Test temperatures can range from 40° to 60°C. The deformation of the slab is first measured at 1,000 cycles at room temperature before heat is applied to obtain an initial testing surface ("zero"). The slab is heated for 12 hours for 100 mm samples or 4 hours for 50 mm samples. At the end of 10,000 cycles, the deformation of the slab is again measured.

4.2 The depth of deformation is reported in mm as an average of the fifteen measurements after 10,000 cycles.

5. APPARATUS

5.1 *French Rutting Tester* - A self contained chamber with a temperature regulation device, a table platform that can lift the sample to the tire with a predetermined amount of force, and a motor to move the tires across the slabs at a rate of one cycle per second.

5.2 *Sample Securing Molds* - With dimensions of 19.7x 7.1x 3.9in. (500 x 180 x 100 mm) or 19.7 x 7.1 x 2 in. (500 x 180 x 50 mm).

5.3 *Depth Gauge and Support System* - Accurate to 0.01 mm.

5.4 *Tire Pressure Gauge* - To check the air pressure in the contact tires.

5.5 *Temperature Probe* - Which shall be placed in a compacted asphalt core stored inside of the testing chamber. As an alternative, the probe can be placed directly into one of the asphalt slabs by drilling a hole in the slab 1.2 in. (30 mm) from the side of the slab and 2.75 in. (70 mm) from the end of the slab.

6. SAMPLE PREPARATION

6.1 Laboratory Produced Mix

6.1.1 *Mixing* - Material mixed in the laboratory shall be brought to mixing temperature (Table 1) in a forced draft oven and mixed in a mechanical mixer for 3 to 5 minutes or until complete coating of the aggregates is achieved.

6.1.2 *Splitting* - Materials mixed in the laboratory shall be placed in open pans. The amount (weight) of material is determined by calculating the number of grams of mix needed to attain an air void target of 6% (± 2%). To do this, multiply the volume of the sample (width x length x height) in cubic centimeters by the sample's maximum specific gravity, and then remove a percentage of the mix equal to the targeted air voids. Note: The volume of the 50 mm slab is 4,500 cc and the 100 mm slab is 9,000 cc.

6.1.3 *Aging* - The mixed material shall be short term aged by placing the open pans in a forced draft oven at the compaction temperature (Table 1) for 3 hours. If it is known that the material being designed will stay at elevated temperature in the field for longer than 3 hours, then the aging time can be increased.

6.1.4 *Compacting* - Material shall be compacted into slabs. The slabs must be compacted to 6% ± 2% voids such that the void distribution is consistent throughout the sample. Samples shall be 19.7 in. (500 mm) long and 7.1 in. (180 mm) wide. A slab thickness of 2 in. (50 mm) or 4 in. (100 mm) can be used. The slab thickness shall be at least twice the maximum nominal aggregate size. Compacted slabs shall be cooled at normal room temperature on a clean, flat surface until the sample is cool to the touch.

6.1.5 *Bulking* - The bulk specific gravity shall be performed in accordance with CP 44.

6.1.6 *Slab Mounting* - Compacted slabs are secured in the molds used for the French Rutting Tester. They must fit snugly and should be the approximate height of the molds.

6.2 Field Produced Mix

6.2.1 Field Loose Mix

6.2.1.1 *Splitting* - The mix received from the field shall be heated for 3 hours (± 0.5) in a forced draft oven at compaction temperature (Table 1) and then separated into pans for compaction. The amount of material is determined by calculating the number of grams of mix needed to attain an air void target of 6% (± 2%). To do this, multiply the volume of the sample (width x length x height) in cubic centimeters by the sample's maximum specific gravity, and then remove a percentage of the mix equal to the targeted air voids. Note: The volume of the 50 mm slab is 4,500 cc and the 100 mm slab is 9,000 cc.

6.2.1.2 *Compacting* - Prior to compaction, the material shall be heated in a forced-draft oven at the temperature specified in Table 1, until at least 15 minutes after the specimens have been brought to compaction temperature, not exceeding 4 hours. The slabs must be compacted to 6% ± 2% voids such that the void distribution is consistent throughout the sample. The samples shall be 19.7 in. (500 mm) long and 7.1 in. (180 mm) wide. A slab thickness of 2 in. (50 mm) or 4 in. (100 mm) can be used. The slab thickness shall be at least twice the maximum nominal aggregate size. Compacted slabs shall be cooled at normal room temperature on a clean, flat surface until the sample is cool to the touch.

6.2.1.3 *Bulking* - The bulk specific gravity shall be performed in accordance with CP 44.

6.2.1.4 *Slab Mounting* - Compacted slabs are secured in the molds used for the French Rutting Tester. They must fit snugly and should be the approximate height of the molds.

6.2.2 Field Compacted Slab

6.2.2.1 *Cutting* - Slabs taken from pavements shall be cut to approximately 19.7 in. (500 mm) long and 7.1 in. (180 mm) wide. The height of a slab is typically 4 in. (100 mm), but may be cut to fit the 2 in. (50 mm) molds if there is not enough material.

6.2.2.2 *Bulking* - The bulk specific gravity is typically not performed on field slabs, however, it can be performed in accordance with CP 44.

6.2.2.3 *Slab Mounting* - The saw-cut field slabs are secured in the molds used for the French Rutting Tester. They must fit snugly and should be the approximate height of the molds. If the slab does not fit the mold snugly, use Plaster-of-Paris to fill in the space between the mold and the slab. The plaster shall be mixed at approximately a 1: 1 ratio of plaster to water.

Table 1

Asphalt Grade	**Mixing Temperature**	**Compaction Temperature**
PG 58-28	154° C (310° F)	138° C (280° F)
PG 58-34	154° C (310° F)	138° C (280° F)
PG 64-22	163° C (325° F)	149° C (300° F)
PG 64-28	163° C (325° F)	149° C (300° F)
PG 70-28	163° C (325° F)	149° C (300° F)
PG 76-28	163° C (325° F)	149° C (300° F)

± 2.8° C (5°F)

7. PRE-TEST PROCEDURE

7.1 Place the mold/slab on the table surface and secure it.

7.2 Check and/or inflate the tires to 87 psi (0.6 Mpa).

7.3 Record the following items on the French Data Recording Sheet: slab number (field sheet number), mold number, test temperature, and test date (tomorrow's date).

7.4 Close and fasten the doors on each side of the French Rutting Tester.

7.5 The "zero" reading is determined by loading the slab with 1,000 cycles at room temperature.

7.6 Take the rut measurement and record it on the Data Recording Sheet to the nearest 0.01 mm.

7.7 The environment that the pavement will be exposed to establishes the test temperature. It is determined from the 7-day high air temperature within the proximity of the nearest weather station from the project. The corresponding test temperatures are:

Environment	**7- day mean**	**Test Temperature**
Cool	**27.0- 30.9**	**50° C**
Moderate	**31.0- 36.0**	**55° C**
Hot	**> 36.0**	**60° C**
Very Cool	**< 27.0**	**40° C or 45° C**

7.8 Turn on the heater. The 4-inch slab(s) must be at test temperature for 12 hours prior to testing. The 2-inch slabs must be at test temperature for 4 hours prior to testing.

8. TEST PROCEDURE

8.1 Check and/or inflate the tires to 87 psi (0.6 Mpa). The tire pressure will need to be decreased due to the higher air temperature in the tire that comes from the increased temperature in the chamber.

8.2 Run 10,000 cycles.

9. POST-TEST PROCEDURE

9.1 After testing has been completed, take the final measurement per Subsection 7.6.

10. REPORT

10.1 The report shall include the following parameters:

- Maximum Impression, mm
- Number of Passes
- Test Temperature
- Sample Air voids

11. CALIBRATION / EQUIPMENT VERIFICATION

11.1 The French Rutting Tester shall be calibrated semi-annually, at a minimum, with a calibrated proving ring.

11.2 Check the accuracy of the temperature readout with a calibrated thermometer at a minimum of every 3 months, or whenever the temperature appears to be incorrect.

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Colorado Procedure – Laboratory 5115-16

Standard Method of Test for

Preparing and Determining the Density of Bituminous Mixture Test Specimens Compacted by the Superpave Gyratory Compactor

(This procedure is based upon AASHTO T 312-14. AASHTO T 312-14 or any subsequent revision may not be used in place of this procedure.)

1. SCOPE

1.1 This standard covers the compaction of 150 mm diameter and 100 mm diameter test specimens of hot mix asphalt (HMA) using the Superpave gyratory compactor.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations before use.

2. REFERENCED DOCUMENTS

2.1 AASHTO Standards:

- T 312 Preparing and Determining the Density of Asphalt Mixture Specimens using the Superpave Gyratory Compactor

- M 231 Weighing Devices Used in the Testing of Materials

2.2 Colorado Procedures:

- CP 44 Bulk Specific Gravity and Percent Relative Compaction of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
- CP 51 Determining the Maximum Specific Gravity of HMA

- CP-L 5101 Verification of Laboratory Equipment Used to Test Bituminous Mixtures
- CP-L 5106 Resistance to Deformation of Bituminous Mixtures by Means of Hveem Apparatus
- CP-L 5109 Resistance of Compacted Bituminous Mixture to Moisture Induced Damage

2.3 Other Standards:

- ASME B46.1 Surface Texture (Surface Roughness, Waviness, and Lay)

3. SIGNIFICANCE AND USE

3.1 This standard is used to prepare specimens for determining the mechanical and volumetric properties of HMA. The specimens simulate the density, aggregate orientation, and structural characteristics obtained in the actual roadway when proper construction procedure is used in the placement of the paving mix.

3.2 This test method may be used to monitor the density of test specimens during their preparation. It may also be used for field control of an HMA production process.

NOTE 1: It is expected that the density of every specimen after gyration number 10 will approach a straight line when plotted versus the base 10 logarithms of the number of gyrations. The line will become asymptotic as it approaches 100 percent of the theoretical maximum specific gravity.

4. APPARATUS

4.1 Superpave Gyratory Compactor – An electrohydraulic or electromechanical compactor that conforms to AASHTO T 312, with a ram and ram heads as described in Subsection 4.2. The axis of the ram shall be perpendicular to the platen of the compactor. The ram shall apply and maintain a pressure of 600 ± 18 kPa to a specimen cross-section with a diameter of 150 mm or a diameter of 100 mm (see Note 2). The compactor shall tilt specimen molds at an angle of 1.25 ± 0.02 degrees (21.8 ± 0.35 mrad) for 100mm molds measured externally and at an angle of 1.16 ± 0.02 degrees (20.2 ± 0.35 mrad) for 150 mm molds measured internally and gyrate specimen molds at a rate of 30.0 ± 0.5 gyrations per minute throughout compaction.

NOTE 2: This stress calculates to 10600 ± 310 N total force for 150 mm specimens. This stress calculates to 4710 ± 140 N total force for 100 mm specimens.

4.1.1 Specimen Height Measurement and Recording Device - When specimen density is to be monitored during compaction, a means shall be provided to continuously measure and record the height of the specimen, to the nearest 0.1 mm during compaction, once per gyration.

4.1.2 Computer, Printer, and Software - The system may include a connected printer capable of printing test information, such as specimen height per gyration. In addition to a printer, the system may include a computer and suitable software for data acquisition and reporting.

4.2 Ram Heads and End Plates - Ram heads and endplates shall be fabricated from steel with a minimum Rockwell hardness of C 48. The ram heads shall stay perpendicular to their axis. The platen side of each endplate shall be flat and parallel to its face. All ram and endplate faces (the sides presented to the specimen) shall be flat to meet the smoothness requirement in Sections 4.2.1 and 4.2.2. For 150 mm molds, ram and endplate faces shall have a diameter of 149.50 to 149.75 mm. For 100 mm molds, ram and endplate faces shall have a diameter of 99.60 to 99.77 mm.

4.2.1 Specimen Molds (150 mm specimens) - Specimen molds shall have steel walls that are at least 7.5 mm thick and are hardened to at least a Rockwell hardness of C 48. The inside finish of the molds shall have a root mean square (rms) of 1.60 µm or smoother (see Note 3). Molds shall have an inside diameter of 150.00 ± 0.10 mm, measured according to CP-L 5101, and be at least 250 mm in length.

4.2.2 Specimen Molds (100 mm specimens) - Specimen molds shall have steel walls that are at least 7.0 mm thick and are hardened to at least a Rockwell hardness of C 48. The inside finish of the molds shall have a root mean square (rms) of 1.60 µm or smoother (see Note 3). Molds shall have an inside diameter of 100.00 ± 0.10 mm, measured according to CP-L 5101, and be at least 250 mm in length.

NOTE 3: Smoothness measurement as per ASME B 46.1. One source to obtain these for a surface comparator, which is used to verify the rms value of 1.60 µm, is GAR Electroforming, Danbury, Connecticut.

4.3 Wide-Mouth Funnel - approximately 230 mm (9 in.) in diameter and 75 mm (3 in.) deep with the mouth that conforms to the top inside edge of the mold.

4.4 Thermometers – Digital, armored, glass, or dial-type thermometers with metal stems for determining the temperature of aggregates, asphalt, and asphalt mixtures between 10°C to 232°C.

4.5 Balance - A balance meeting the requirements of AASHTO M 231, Class G5 for determining the mass of aggregates and asphalt.

4.6 *Forced-Draft Oven* - A forced-draft oven, thermostatically controlled to ± 3°C, for heating aggregates, asphalt, and equipment as required. The oven shall be capable of maintaining the mixing and compaction temperatures specified in this procedure.

4.7 *Miscellaneous* - flat bottom metal pans for heating aggregates; scoop for batching aggregates; containers: grill-type tins, and beakers; containers for heating asphalt; large mixing spoon or small trowel; large spatula; gloves for handling hot equipment; paper disks, 150 mm diameter or 100 mm diameter depending on sample size; lubricating materials recommended by the compactor manufacturer; mechanical mixer (optional).

5. HAZARDS

5.1 Use standard safety precautions and protective clothing when handling the hot paving mix and preparing test specimens.

6. CALIBRATION

6.1 The Superpave gyratory compactor requires calibration as detailed in the Manufacturer's Manual of Operation and Maintenance.

7. PREPARATION OF APPARATUS

7.1 At least 5 minutes before the paving mix is ready for placement in the mold, turn on the main power on the compactor.

7.2 For Superpave compactors, perform the height verification as specified in the Manufacturer's Operations Manual. Verify the machine settings are correct for angle, pressure, and number of gyrations.

7.3 Verify that the automatic counter is reset and is set to shut off when the proper number of gyrations has been reached.

NOTE 4: Unless directed otherwise, the number of gyrations applied to volumetric specimens will be N(design). Hveem Stability using CP-L 5106 will be determined for specimens compacted to N(design). Specimens used for the Lottman test (CP-L 5109) are compacted until the specimen reaches a pre-determined void content.

7.4 Lubricate any bearing surfaces as needed per the manufacturer's instructions.

7.5 When specimen density/height are to be monitored, the following additional item of preparation is required. Immediately before the time when the paving mix is ready for placement in the mold, turn on the device for measuring and recording the height of the specimen and verify that the readout is in the proper units, mm. Verify that the recording device is ready, and, if used, prepare the computer to record the height data and enter the header information for the specimen.

8. PLANT SAMPLES

8.1 For plant-produced HMA only, a minimum of three volumetric specimens per field sample shall be compacted. To produce 100 mm volumetric specimens, split out material having a mass, in grams, equal to the multiplier from Table 1 × the Theoretical Maximum Specific Gravity (CP 51) of the material to be compacted or the Theoretical Maximum Specific Gravity from the Form #43. Other multipliers may be used that satisfy the conditions of Subsection 10.2 regarding specimen dimensions. To make 150 mm volumetric specimens, split out material having a mass, in grams, equal to 1670 × the Theoretical Maximum Specific Gravity of the material to be compacted or the Theoretical Maximum Specific Gravity from the Form 43. Before compaction, heat the specimens in a forced-draft oven, having the compaction temperature specified in Table 2, until at least 15 minutes after the specimens have been brought to compaction temperature, not to exceed 4 hours. Plant-produced material should be maintained at a temperature above 200°F for more than 1 hour after it is produced and before compaction. This may occur during the transport of the samples or during the time that the specimens are being heated before compaction. For plant-produced HMA, resume the procedure at Subsection 10.3.

Table 1

Number of Gyrations	Multiplier
50	470
75	474
100	478
125	482
SMA	470

9. LABORATORY-MIXED SAMPLES

9.1 For laboratory-mixed volumetric specimens, compact at least one specimen at each of three or more different asphalt cement contents to produce specimens that span the target air void content. Weigh cumulatively into a separate pan for each test specimen the quantity of each size fraction of aggregate required to produce a batch that will result in a compacted specimen having a mass equal to the multiplier from Table 1 × the Theoretical Maximum Specific Gravity for 100 mm diameter specimens, or, having a mass of (1670 ± 4) × the Theoretical Maximum Specific Gravity for 150 mm diameter specimens. If lime is added to the dry aggregates, it shall be hydrated using the same proportion of water expected to be added during mix production. Specimens may be produced which exceed the recommended mass as long as their mass is corrected to the specified sample mass before compaction.

9.2 Place the pans and the asphalt binder container in the oven and heat to the required mixing temperature.

9.2.1 Mixing temperatures for Hveems and Lottmans are given in Table 2.

9.3 Charge the mixing bowl with the heated aggregate in one pan and mix thoroughly. Form a crater in the dry blended aggregate and weigh the required amount of asphalt binder into the mix. Immediately initiate mixing.

9.4 Every attempt should be made to minimize the amount of time that the asphalt binder is held at mixing temperature in the oven.

9.5 Mix the aggregate and asphalt binder as quickly and thoroughly as possible to yield a paving mix having a uniform distribution of asphalt binder. As an option, mechanical mixing may be used.

9.6 After completing the mixture preparation, place the loose mix in a shallow, flat pan. Heat the mixture in a forced-draft oven at compaction temperature for not less than 2 hours and not more than 3 hours. For laboratory-produced HMA, resume the procedure at Subsection 10.3.

10. COMPACTION PROCEDURE

10.1 If compacting an SMA Mix, see Appendix A for special handling recommendations.

10.2 For this Colorado Procedure, specimen diameters shall be 100 mm unless directed otherwise. Heights shall be 63.5 ± 5.0 mm for 100 mm volumetric diameter specimens and shall be 100 ± 5 mm for 150 mm diameter specimens. Specimens having heights outside this range should be discarded and new specimens compacted having masses which are corrected to yield specimen heights within this range. Laboratory-mixed specimens having heights outside this range must be discarded.

10.2.1 Lottman specimens shall have the same mass as volumetric specimens of the same diameter unless a change in mass is being used to obtain the desired void content.

10.3 Place a compaction mold and base plate in an oven at compaction temperature at least 60 minutes before the estimated beginning of the compaction (during the time the mixture is being conditioned).

10.4 Compaction temperatures for Hveems and Lottmans have been determined for many different sources of AC and are summarized in Table 2.

TABLE 2

Superpave Binder Grade	Lab Mixing Temp.	Lab Compaction Temp.
PG 58-28	310° F (154° C)	280° F (138° C)
PG 58-34	310° F (154° C)	280° F (138° C)
PG 64-22	325° F (163° C)	300° F (149° C)
PG 64-28	325° F (163° C)	300° F (149° C)
PG 70-28	325° F (163° C)	300° F (149° C)
PG 76-28	325° F (163° C)	300° F (149° C)

All temperatures in this table have tolerance of
± 2.8°C (± 5°F)

10.4.1 Set the number of gyrations to N(des) for specimens being evaluated for volumetric properties and Hveem Stability (CP-L 5106). Make sure the height setting will not stop the compactor before the desired number of gyrations is applied.

10.4.2 Lottman specimens shall have the same mix compaction temperature specifications and mold temperature specifications as volumetric specimens. For Lottman specimens (CP-L 5109), enter the final sample height (corrected if necessary to achieve the desired sample air voids) into the compactor control panel. Variations in sample heights, which result in Lottman specimens having 7 ± 1 percent air voids, are permitted.

10.4.2.1 The suggested calculation to determine Lottman height is as follows:

$$\frac{\textbf{(Ave. Bulk SpG @ N(des) x Ave. Ht. @ N(des)}}{\textbf{(0.925 x Rice)}}$$

10.5 When the compaction temperature is achieved, remove the heated mold and base plate from the oven and place them on a non-metallic surface. Place a paper disk on the bottom of the mold. Place the wide-mouth funnel onto the top of the mold. The time the mold is out of the oven should be minimized as much as possible.

10.6 Stir the mixture only as necessary to reduce segregation and place the mixture into the mold in one lift. Care should be taken to avoid segregation in the mold. Segregation may be determined by examining the compacted specimen. The entire surface of non-segregated specimens will have a uniform texture. After all the mix is in the mold, level the mix if necessary and place another paper disk on top of the material. Any handling of the mix (including leveling) after loading should be minimized to the greatest practical extent.

10.7 Load the specimen mold with paving mix into the compactor and center the loading ram.

10.8 Press the start button and lower the ram until the pressure on the specimen reaches 600 kPa ± 18 kPa. The time taken between removing the sample from the oven until the START button is pressed should be no more than 60 seconds.

10.9 Apply a 1.25 ± 0.02 degrees (21.8 ± 0.35 mrad) angle tilt for 100 mm molds measured externally and an angle of 1.16 ± 0.02 degrees (20.2 ± 0.35 mrad) for 150 mm molds measured internally to the mold assembly and begin the gyratory compaction.

10.10 Allow the compaction to proceed until the desired number of gyrations is reached and the gyratory mechanism shuts off.

10.11 Remove the mold from the compactor, and extrude the specimen from the mold.

NOTE 5: Extrusion can be accomplished immediately for most HMA paving mixes. For lean, rich, or tender mixtures, a cooling period of 5 to 10 minutes in front of a fan may be necessary before extruding the specimen.

10.12 Remove the paper disks from the top and bottom of the specimens.

NOTE 6: Before reusing the mold, place it in an oven at compaction temperature for at least 15 minutes. The use of multiple molds will speed up the compaction process. It is recommended that a minimum of 3 molds be used to assure that 15 minutes between usages is achieved.

11. DENSITY PROCEDURE

11.1 The following steps are required in addition to those specified in Sections 8, 9, and 10.

11.1.1 Determine the maximum specific gravity (Gmm) of the loose mix, per CP 51, using a companion sample

11.1.2 Use the compactor's output to record the specimen height to the nearest 0.1 mm after each revolution.

11.1.3 Record the mass of the extruded specimen to the nearest 0.1 gram and determine the bulk specific gravity (G_{mb}) of the extruded specimen per CP 44.

12. DENSITY CALCULATIONS

12.1 At the completion of the bulk specific gravity test, the percent compaction at various numbers of gyrations can be determined as follows:

$$C_x = \frac{G_{mb} h_m}{G_{mm} h_x} \times \mathbf{100}$$

Where:
C_x = Corrected relative density at "x" gyrations expressed as a percentage of the Maximum Theoretical Specific Gravity,
G_{mb} = Measured bulk specific gravity of the extruded specimen,
G_{mm} = Theoretical Maximum Specific Gravity of the mix,
h_m = Measured height in millimeters of the specimen reported by the Superpave compactor at the final gyration,
h_x = Height in millimeters of the specimen after "x" gyrations.

12.2 Determine the bulk specific gravity of specimens at various numbers of gyrations as follows:

$$G_{mbx} = \frac{G_{mbf} h_m}{h_x}$$

Where:
G_{mbx} = Bulk specific gravity of the specimen after "x" gyrations,
G_{mbf} = Measured bulk specific gravity of the extruded specimen,
h_m = Measured height in millimeters of the specimen reported by the Superpave compactor at the final gyration,
h_x = Height in millimeters of the specimen after "x" gyrations.

12.3 Determine the percent air voids at various numbers of gyrations (P_{ax}) as follows:

$$P_{ax} = \mathbf{100} - C_x$$

Where:
P_{ax} = Percent air voids of the specimen after "x" gyrations.

13. REPORT

13.1 There is no designated CDOT Form used for recording/reporting information for this CP-L.

13.2 The report should include the following items or allow the following items to be calculated.

13.3 Project name.

13.4 Specimen identification.

13.5 Date of test reporting.

13.6 Percent binder in the specimen, to the nearest 0.1 percent.

13.7 Nominal diameter of the mold used (d).

13.8 The number of gyrations used to compact the specimen.

13.9 Maximum specific gravity (Gmm) of the specimen by CP 51, to nearest 0.001.

13.10 Bulk specific gravity (Gmb) of the compacted specimen by CP 44, nearest 0.001.

13.11 Height of the specimen after selected gyrations (h_x), nearest 0.1 mm.

13.12 Relative density (C_x) expressed as a percent of the air voids of the compacted specimen, to the nearest 0.1 percent.

13.13 Hveem Stability to the nearest whole number.

14. PRECISION AND BIAS

14.1 Precision - The results of two properly conducted tests on the same material, by the same operator, using the same equipment, should be considered suspect if the bulk specific gravities differ by more than 0.020.

- When three replicate specimens are analyzed, and two of the three results differ from the average by more than 0.011, complete retesting is required.

- If one of the three results differs from the average by more than 0.011, exclude that single result from the reported average. If the remaining two results differ by more than 0.020, complete retesting is required.

Such occurrence that differs by more than the maximum allowable range is a warning that there may have been some error in the test procedure, or some departure from the prescribed conditions of the test on which the limits appearing in the test method is based.

14.2 Bias - A bias for this test method will be determined at a later date, and included in future revisions.

Appendix A, CP-L 5115

Special Handling Recommendations for SMA Mixes

Perform the following steps when handling laboratory-produced mix sample material.

(1) Set up an individual sample without mineral filler.

(2) Stir set-up dry and then mix with 3% water (without mineral filler).

(3) Heat both set-up and mineral filler to the required mixing temperature (325°F for PG 76-28).

(4) Mix set-up by hand with enough asphalt cement to accommodate both the set-up and the mineral filler.

(5) Blend proper amount of hot mineral filler to premixed set-up.

(6) Heat for 2 hours at compaction temperature. Excessive heating time or temperature appears to increase drain down.

(7) Stir mortar back into set-up if there is any drain down.

(8) Compact to 100 gyrations.

(9) Set oven temperatures either 1°C or 2°F higher than specified for compaction. (**Note:** To ensure repeatability, it is very important to compact these samples at the specified temperature). By heating samples 1°C above the specified temperature and transferring the set-up and starting compaction as fast as possible without spilling, (approximately 45 seconds from oven to the start of compaction), the sample is compacted at the proper temperature. Individual labs should check the cooling rate of samples using their mode of sample preparation to ensure the mix is at the proper temperature during compaction.

Perform the following steps when handling project-produced mix sample material.

(1) If possible, split out samples to the test size for compaction and Rice specific gravity determination at the mixing plant immediately after sampling. The samples should then be mixed as required to reintroduce drained asphalt cement after heating for the proper time at the compaction temperature.

(2) (Optional) To prepare a can that has cooled, remove the lid, place it upside down on a large pan (24"x 24"), heat for 3 hours at 300°F. This should keep any drain down in the set-up pan, instead of the bottom of the sample can.

(3) Before compaction be sure to scrape the pan bottom and stir mortar back into the mix before loading the mold. Spray all utensils with a release agent to prevent SMA from sticking to utensils.

Colorado Procedure – Laboratory 5116-15

Standard Method of Test for

Linear Kneading Compaction of Bituminous Mixtures

(This document is a description of a method used by the Colorado Department of Transportation to compact asphalt slabs in the Linear Kneading Compactor.)

1. SCOPE

1.1 This method describes the compacting of bituminous mixtures in a linear driven, kneading machine. Slabs can be made for either the French Rutting Tester or the Hamburg Wheel-Tracking Device.

2. REFERENCED DOCUMENTS

2.1 Colorado Procedures:

CP 44 Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
CP 55 Reducing Field Samples of Hot Mix Asphalt to Testing Size

3. SIGNIFICANCE AND USE

3.1 The Linear Kneading Compactor easily and safely prepares uniform asphalt specimens in the laboratory that would be representative of those taken from an actual road surface. It simulates the rolling action of paving equipment used in the field.

4. SUMMARY OF METHOD

4.1 A mold is filled with a weighed amount of mix calculated from the desired final density and the mold volume. Downward motion of a rolling wheel applies a force to the top of the compacting plates while the mold moves back and forth on a sliding table. A linear compression wave is produced in the mix by the bottom edges of the plates as the roller pushes down on each one successively. This kneading action allows the mix to be compacted without fracturing the aggregate.

5. APPARATUS

5.1 *Linear Kneading Compactor* - An electronically powered machine that has a motor which turns a ball screw mechanism, the nut of which is fastened to a specimen table. There is a hydraulic ram and hand pump to move the roller down for compaction of the bituminous mixture. The table has two mold lock levers that clamp down on the mold to hold the mold in place. The Linear Kneading Compactor is totally enclosed and is locked to prevent access to the moving parts during compaction. A digital meter is mounted on the machine to give a constant readout of the height of the roller.

5.2 *Molds / Compaction-plates* - There are two sets of molds and compaction-plates for compacting slabs for either the French Rutting Tester or the Hamburg Wheel-Tracking Device.

5.2.1 When compacting slabs for the Hamburg Wheel-Tracking Device, a mold 12.5 in. (320 mm) long and 10.25 in. (260 mm) wide is used. There are two bottom-plates inside the Hamburg mold that are 1 in. (25 mm) and 0.5 in. (13 mm) thick. The compaction-plates are 10.1 in. (257 mm) long and 3.5 in. (89 mm) high. Slab thicknesses of 1.5 in. (38 mm) to 3 in. (76 mm) can be obtained by changing the bottom-plates and varying the heights to which the samples are compacted.

5.2.2 When compacting slabs for the French Rutting Tester, a mold 19.7 in. (500 mm) long, 7.1 in. (180 mm) wide, and 7.0 in. (178 mm) deep is used. There are two different sets of compaction plates and they can be used to make slabs of either 2 in. (50 mm) in one lift or 4 in. (100 mm) in two lifts.

6. SAMPLE PREPARATION

6.1 Prepare the asphalt samples according to either the French Rut Testing Procedure (CP-L 5114) or the Hamburg Wheel-Track Testing Procedure (CP-L 5112).

7. PRE-TEST PROCEDURE

7.1 Place the two halves of the appropriate mold together around the bottom plate(s) and hand tighten using the knobs. If compacting a slab for the French Rutting Tester, no rectangular bottom plate is used.

7.2 Center the mold using the marks on the table. Tighten the mold lock levers over the mold wings with the large Allen wrench.

7.3 Place a 1/8 in. (3 mm) aluminum plate inside the bottom of the mold. The plate will provide additional support for the bottom of the slab while it is being removed following compaction.

7.4 Spray the inside of the mold, the surface of the aluminum plate, and the bottom of the compaction-plates with a release agent (PAM™ or lecithin pan spray) to prevent sticking.

7.5 Set the black switch (top center of the control panel) to "GERMAN" or "FRENCH", depending on the type of slab that is going to be compacted.

7.6 Ensure that the "FAST/SLOW" switch is set to the "FAST" position.

8. TEST PROCEDURE

8.1 After the bituminous mixture has reached its compaction temperature (Table 1), carefully pour it from the pan into the mold to minimize any segregation of the mixture. Rod the corners with a metal spatula. Build the corners up slightly, as they will tend to have a high air void content.

8.1.1 A 100 mm tall slab for the French Rutting Tester is compacted in two lifts. Half of the material is poured into the mold and is compacted using the larger, 7 in. (178 mm) long and 6.5 in. (165 mm), compaction-plates. The other half of the material is poured into the mold and is compacted using the smaller, 7 in. (178 mm) long and 3.5 in. (89 mm), compaction-plates.

8.2 Place the compaction-plates on top of the mixture inside of the mold with the sprayed side down. Make sure that the compaction-plates are placed together tightly and are vertical.

8.3 Slide the transparent safety guard to the right until it is completely closed.

8.4 Press the green "POWER ON" button. If the power does not come on, make sure that the transparent safety guard is completely closed. After the digital height readout reads 10.28, press the green "START CYCLE" button.

8.5 Pump the hand pump on the hydraulic ram until the roller comes into contact with the compaction-plates. Continue to pump until the desired roller height is reached. If the pressure gauge exceeds 6,000 psi, the machine will shut off and you will have to re-perform the procedure in Subsection 8.4.

8.5.1 The desired roller height for compacting a Hamburg slab is 6.58 on the digital meter.

8.5.2 The desired height for compacting the first lift of a French slab (2 in./50 mm), using the larger compaction-plates, is 8.50 on the digital meter. The desired height for the second lift (4 in./100 mm), using the smaller compaction-plates, is 7.46 on the digital meter.

8.6 As the desired roller height is approached, proceed toward the final height slowly. Allow approximately 3 to 5 passes to occur before continuing to lower the roller, as it takes a few passes before the roller settles down to obtain a constant height.

8.7 Once the desired roller height is achieved, press the red **"STOP CYCLE"** button. The table will return to its original (home) position. Once the table has stopped, press the **"POWER OFF"** button. This will allow the safety guard to be opened.

Table 1

Asphalt Grade	**Mixing Temperature** *	**Compaction Temperature***
PG 58-22	154° C (310°F)	138° C (280° F)
PG 58-28	154° C (310°F)	138° C (280° F)
PG 58-34	154° C (310°F)	138° C (280° F)
PG 64-22	163° C (325°F)	149° C (300° F)
PG 64-28	163° C (325°F)	149° C (300° F)
PG 70-28	163° C (325°F)	149° C (300° F)
PG 76-28	163° C (325°F)	149° C (300° F)

*** ± 2.8°C (± 5°F)**

9. POST-TEST PROCEDURE

9.1 Loosen the mold lock levers with the large Allen wrench.

9.2 Turn the knobs so that the mold may be pulled into two halves.

9.3 Remove the compaction-plates from the top of the compacted slab and label it with the field sheet number and slab number (1 or 2).

9.4 Slide the slab off of the table and place it on a clean, flat surface to allow it to cool. Ensure that the aluminum plate remains on the bottom of the slab while moving it to help support the slab.

10. REPORT

10.1 It is not necessary to record any information for this operation and no calculations are required.

11. MAINTENANCE

11.1 The Linear Kneading Compactor is very low maintenance. The bearings are of a Teflon-like material and are self-lubricating.

11.2 The screw on which the table rides requires only a very light amount of oil. If you touch the screw and there is any oil at all on your finger, it does not need any oil. If it does need lubrication, use light weight machine oil.

11.3 The hydraulic fluid does not need to be changed. There should be enough hydraulic fluid to cover the metal rod within the pump. Leave the cap to the hydraulic pump in the "VENT” position.

11.4 The roller, molds, table, and compaction plates can be cleaned with 140 solvent. To get to the roller, the plexi-glass top must be removed with a small Allen wrench. When replacing the top, do not over tighten the screws, as they can easily be stripped.

12. CALIBRATION / EQUIPMENT VERIFICATION

12.1 There are no calibration procedures necessary for this machine.

Colorado Procedure – Laboratory 5117-15

Standard Method of Test for

Superpave Design for Hot Mix Asphalt

1. SCOPE

This procedure is used to determine or verify the optimum binder content of an asphalt paving mix.

2. REFERENCED DOCUMENTS

2.1 AASHTO Standards:

T 11	Materials Finer than the No. 200 Sieve in Mineral Aggregates by Washing
T 27	Sieve Analysis of Fine and Coarse Aggregates
T 40	Sampling Bituminous Materials
T 90	Determining the Plastic Limit and Plasticity Index of Soils
T 96	Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
T 218	Sampling Hydrated Lime
T 304	Un-compacted Void Content of Fine Aggregate

2.2 Colorado Procedures:

CP 30	Sampling of Aggregates
CP 31	Sieve Analysis of Aggregates
CP 37	Plastic Fines in Graded Aggregates and Soils by Sand Equivalent Test
CP 44	Bulk Specific Gravity and Percent Relative Compaction of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
CP 45	Determining Percent of Particles with Two or More Fractured Faces
CP 51	Determining the Maximum Specific Gravity of HMA
CP 52	Contractor Mix Design Approval Procedures
CP-L 4211	Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus
CP-L 5106	Resistance to Deformation of Bituminous Mixtures by Means of Hveem Apparatus
CP-L 5109	Resistance of Compacted Bituminous Mixture to Moisture Induced Damage
CP-L 5115	Preparing and Determining the Density of Bituminous Mixture Test Specimens Compacted by the Superpave Gyratory Compactor

3. SIGNIFICANCE AND USE

3.1 This procedure may be used to select and evaluate materials for Superpave mix designs.

4. SUMMARY OF METHOD

4.1 Aggregate samples are blended in the proportions recommended by the Contractor. Specimens are set up and mixed with the binder to be used on the project and various criteria, such as voids, are determined and examined. If the criteria are met, the optimum binder content is either chosen or verified and other properties of the mix are examined for compliance with specifications.

5. APPARATUS

5.1 Ovens capable of maintaining the following temperatures:

Temperature	Tolerance
60° C	3° C
110° C	5° C
163° C	2.8°C

6. SAMPLING

6.1 Sample aggregates in accordance with CP 30.

6.2 Binder samples will be taken in accordance with AASHTO T 40.

6.3 Hydrated lime samples will be taken in accordance with AASHTO T 218.

7. AGGREGATE TESTING

7.1 Aggregates shall be tested for the following:

7.1.1 Gradations per CP 31.

7.1.2 Sand Equivalence using CP 37.

7.1.3 Plastic Index using AASHTO T 90.

7.1.4 LA Abrasion using AASHTO T 96.

7.1.5 Micro-Deval Abrasion using CP-L 4211.

7.1.6 Fractured Faces using CP 45.

7.1.7 Fine Aggregate Angularity using AASHTO T 304.

7.2 If only one blend is to be run, portions of each source may be combined as per the Contractor’s recipe before separating the rock fractions from the -#8. The rock fractions shall be separated on the #8, #4, 3/8”, ½”, ¾”, 1” and 1½” screens.

7.3 Theoretical Rejection of Baghouse Fines:
If the mix design is for a job that will have theoretical rejection of baghouse fines, the aggregates shall be separated on the 1 ½”, 1”, ¾”, ½”, 3/8”, #4, #8, #16, #30, #50, #100, and #200 screens.

8. SAMPLE PREPARATION

8.1 Using the gradations obtained in Section 7 and the proportions from the Contractor's proposed Mix Design, calculate the weight of each portion needed for two specimens for Maximum Specific Gravity, four Bituminous Mixture Test Specimens for Voids, six Lottman specimens and, if desired, three Ignition Furnace Correction Factors.

8.1.1 If the mix design is for a job that will have Theoretical Rejection of Baghouse Fines, the aggregates are put together from the Contractor's proposed Mix Design, including the calculated effect of the material that will be rejected by the Contractor's equipment.

8.1.2 The presence of adherent fines may produce a gradation that is finer than is intended. Therefore, the gradation is washed to determine how closely the sample matches the Contractor's target.

8.1.3 Through trial and error, the batch weights for individual sieves sizes are modified and washed to achieve conformance to the target gradation according to the following recommendation:
(% passing #200 ± 0.5%, and all other sieves ± 1%.)

8.2 Using weights from Subsection 8.1 or 8.1.3, set up specimens as mentioned there. It may be desirable to set up the Maximum Specific Gravity specimens first and run CP 51 before setting up the voids specimens. This way, the maximum specific gravity can be multiplied by the multiplier from Table 1 for 100 mm specimens (or multiplied by 1670 for 150 mm) to obtain specimen weights that will compact to the proper height. Likewise, the voids specimens can be compacted before setting up the Lottman specimens. The heights and specific gravities of the voids specimens can be used to calculate the desired Lottman heights. It is important that the -#8 fragments do not become segregated during this process.

8.3 Heat the Maximum Specific Gravity specimens and the desired binder to the appropriate mixing temperature as per CP-L 5115. The binder must not be overheated to where its properties are damaged.

8.4 Weigh the preheated, buttered mixing bowl. Place the specimen in the mixing bowl, being careful to clean all the fines from the sample pan into the mixing bowl. Determine the specimen weight and calculate the weight of binder needed [specimen weight * percent binder / (100-percent binder)]. Add the calculated amount of binder and mix the aggregate with the binder thoroughly, until there are no thin spots on the aggregate. After mixing is complete, place the mixture in a pan for aging. Be sure to scrape the mixing bowl until it reaches the original weight and be sure to clean all of the mix and binder from the mixing paddle and utensils into the pan.

8.5 Repeat Subsection 8.4 for the other maximum specific gravity specimens and age them for 2 – 3 hours per CP-L 5115.

8.6 After removing the maximum specific gravity specimens from the oven, spread them out and allow them to cool to room temperature. Determine the Maximum Specific Gravity per CP 51.

8.7 Multiply the average maximum specific gravity by the multiplier from Table 1 for 100 mm specimens (use a multiplier of1670 for 150 mm) to obtain the total mix weight for the voids specimens.

Table 1

Number of Gyrations	Multiplier
50	470
75	474
100	478
125	482
SMA	470

8.8 Set up, mix, and age voids specimens at the anticipated optimum binder content, at optimum plus 0.5 percent binder, at optimum minus 0.5 percent binder and optimum minus 1.0 percent binder as per Subsections 8.4 and 8.5.

8.9 Compact the voids specimens to the desired number of gyrations according to CP-L 5115.

8.10 After the voids specimens have cooled to room temperature; determine the bulk specific gravities of them per CP 44. Place the voids specimens in the 60°C oven and determine the stabilities per CP-L 5106. After determining the percent voids, the VMA, the VFA, and the stabilities, create graphs or otherwise plot the data versus binder content. Determine the binder content where the voids are at 4% (unless some other value is desired). Inspect the other criteria to see if the mix passes everything at the optimum binder content. If it does, proceed with running the Lottman test as per CP-L 5109.

9. REPORT

9.1 Report test results on CDOT Form 429 per CP 52.

Colorado Procedure – Laboratory 5120-20

Standard Method of Test for

Determination of the Asphalt Binder Content of Bituminous Mixtures by the Ignition Method

1. SCOPE

1.1 This method of test determines the asphalt binder content of bituminous mixtures by heating the mixture until the asphalt binder fraction of the mix ignites and is burned away. The gradation of the remaining aggregate is then determined using CP 31. This procedure includes infrared heat source ignition furnaces. This procedure shall not be used for determining the asphalt binder content of cores or otherwise obtained samples from existing bituminous pavements.

1.2 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1 Colorado Procedures:

CP 30	Sampling of Aggregates
CP 31	Sieve Analysis of Aggregates
CP 41	Sampling Bituminous Paving Mixtures
CP 55	Reducing Field Samples of Hot Mix Asphalt to Testing Size
CP 85	Binder and Asphalt Cement Content of Asphalt Mixtures by the Nuclear Method

3. SUMMARY OF TEST METHODS

3.1 A specimen of bituminous mixture is heated in a furnace at a high enough temperature to ignite the asphalt binder fraction, which burns away. The asphalt binder content is calculated by dividing the mass loss of the specimen after ignition by the mass of the bituminous mixture before ignition. A correction factor is determined for each bituminous mixture and then applied to the measured asphalt binder content of field produced bituminous mixtures.

4. SIGNIFICANCE AND USE

4.1 This method can be used for quantitative determinations of asphalt binder content and gradation in HMA mixtures and pavement samples for quality control, specification acceptance, and mixture evaluation studies. This method does not require the use of solvents. Residual aggregate obtained by this test method may be used for gradation analysis according to CP 31.

5. REDUCING PRODUCTION SAMPLES TO TEST SIZE

Note 1: The word *specimen* represents a test portion of bituminous mixture sample. When the specimen's mass exceeds the capacity of test equipment, it shall be divided into multiple units, tested, and the results averaged.

Note 2: The word *sample* represents a quantity of bituminous mixture gathered from a stockpile or roadway in accordance with CP 41.

5.1 If the bituminous mixture is not sufficiently soft to separate with a spatula or trowel, place it in a pan and warm it in an oven at the binder compaction temperature until it can be separated.

5.1.1 Sampling of HMA shall be done according to CP 41. One specimen conforming to the appropriate column of Table 1 shall be selected from each bituminous mixture production sample in accordance with CP 55. Extreme care must be taken to obtain representative specimens.

5.2 The specimens shall conform to the mass requirements shown in the appropriate column of Table 1.

6. CORRECTION FACTOR

6.1 Virgin Aggregates

6.1.1 This method may be affected by the type of aggregate in the mixture. Accordingly, to optimize accuracy, a correction factor will be established with the testing of a set of correction factor samples for each mix type. This procedure must be performed before any acceptance testing is completed.

6.1.2 The correction factor process should be repeated each time there is a change in the mix ingredients or design.

6.1.3 According to the requirements of Section 5 and using the Calculation in Subsection 9.1, prepare two correction factor samples at the design asphalt content. Mixing temperatures have been determined for many different binder grades and are summarized in CP-L 5115 Table 2. Aggregate used for the correction factor specimens shall be sampled from stockpiled material produced in the current construction season and designated for use on the candidate project. Any method may be used to combine the aggregates, lime, fibers, additives, RAP and other components of the mix design; however, an additional “blank” specimen shall be batched and tested for aggregate gradation according to CP 31. The washed gradation shall fall within the mix design tolerances.

Note 3: Mixing equipment, including bowls, wire whips, spoons, and spatulas should be buttered prior to the correction factor. If necessary, prior to mixing, prepare a butter mix at the design asphalt content. The purpose of the butter mix is to condition the mixing bowl by providing a coating of asphalt and fines in the bowl. Mix and discard the butter mix prior to mixing any of the correction factor specimens to ensure an accurate asphalt content.

6.1.4 If they are going to be burned immediately, the freshly mixed specimens may be placed directly in the sample baskets. If allowed to cool, the samples shall be heated at the binder compaction temperature for 30 minutes. Do not preheat the sample baskets.

6.1.5 Test specimens in accordance with Sections 7, 8 and 9.

6.1.6 Determine the measured asphalt contents for each sample by calculation.

6.1.7 Perform a gradation analysis on the residual aggregate as indicated in Section 12. Compare this gradation to the gradation of the unburned, “blank”, specimen to evaluate the amount of aggregate breakdown

6.1.8 If the difference between the measured asphalt contents of the two samples exceeds 0.15 percent, the results should be discarded, new samples obtained, and the measured asphalt contents of the material retested. Retest as needed until the measured asphalt contents agree to within 0.15 percent. Determine the correction factor from the two results that are within 0.15 percent. Calculate the difference between the actual and measured asphalt contents for each sample. The correction factor is the average of the differences expressed in percent by weight of the asphalt mixture.

Note 4: Each ignition furnace will have its own unique asphalt binder correction factor determined in the location where testing will be performed.

6.2 Aggregates with Reclaimed Asphalt Pavement (RAP)

6.2.1 This Method may be affected by the type of aggregate in the mixture. Accordingly, to optimize accuracy, a correction factor will be established with the testing of a set of correction factor samples for each mix type. This procedure must be performed before any acceptance testing is completed.

6.2.2 The correction factor process should be repeated each time there is a change in the mix ingredients or design.

6.2.3 Determine the bitumen content of RAP per Section 7, 8, and 9 or use the bitumen content submitted with the mix design.

6.2.4 Sampling of RAP will be conducted using CP 30. Reduce to proper test sample size using CP 55. Two individual samples will be used to determine the average bitumen content using Section 7, 8, and 9.

Table 1: Size of Specimen

Nominal Maximum Aggregate Size (mm)	Sieve Size	Specimen Weight Range (g)
4.75	No. 4	1200 - 1300
9.5	3/8 in.	1200 - 1300
12.5	½ in.	1800 - 1900
19.0	¾ in.	2200 - 2300
25.0	1 in.	3000 – 3100*****
37.5	1 ½ in.	4000 – 4100*****

* Specimens shall either be divided in half or thirds, each individual part Will be tested, and then the results averaged.

6.2.5 Sample size will be determined by using Table 1.

6.2.6 According to the requirements of Section 5 and using the Calculations in Section 9, prepare two correction factor samples at the design asphalt content. Mixing temperatures have been determined for many different binder grades and are summarized in CP-L 5115 Table 2. Aggregate used for the correction factor specimens shall be sampled from stockpiled material produced in the current construction season and designated for use on the candidate project. Any acceptable method may be used to combine the aggregates; however, an additional "blank" specimen shall be batched and tested for aggregate gradation according to CP 31. The washed gradation shall fall within the mix design tolerances.

6.2.7 If they are going to be burned immediately, the freshly mixed specimens may be placed directly in the sample baskets. If allowed to cool, the samples shall be heated at the binder compaction temperature for 30 minutes. Do not preheat the sample baskets.

6.2.8 Test specimens in accordance with Sections 7, 8 and 9.

6.2.9 Determine the measured asphalt contents for each sample by calculation.

6.2.10 Perform a gradation analysis on the residual aggregate as indicated in Section 12. Compare this gradation to the gradation of the unburned, “blank”, specimen to evaluate the amount of aggregate breakdown.

6.2.11 If the difference between the measured asphalt contents of the two samples exceeds 0.15 percent, the results should be discarded, new samples obtained, and the measured asphalt contents of the material retested. Retest as needed until the measured asphalt contents agree to within 0.15 percent. Determine the correction factor from the two results that are within 0.15 percent. Calculate the difference between the actual and measured asphalt contents for each sample. The correction factor is the average of the differences expressed in percent by weight of the asphalt mixture.

Note 5: Each ignition furnace will have its own unique asphalt binder correction factor determined in the location where testing will be performed.

7. APPARATUS

7.1 *Ignition furnace* - A forced air ignition furnace that heats the samples by convection method or direct irradiation method that is capable of maintaining the required temperature. There must be an internal balance thermally isolated from the furnace chamber that is readable to 0.1 g. The balance shall be capable of weighing a minimum 3000 gram sample in addition to the sample baskets. A data collection system will be included so that the weight can be automatically determined and displayed during the test. The furnace shall have a built in computer program to calculate change in mass of the sample baskets and provide for the input of a correction factor for aggregate loss. The furnace shall provide a printed ticket with the initial specimen mass, specimen mass loss, temperature compensation, correction factor, corrected asphalt content (percent), test time, and test temperature. The furnace chamber dimensions shall be adequate to accommodate a sample size of at least 3000 grams. The furnace shall provide an audible alarm and indicator light when the sample mass loss does not exceed 0.01 percent of the total sample mass for three consecutive minutes. The furnace door shall be equipped so that the door cannot be opened during the test. A method for reducing furnace emissions shall be provided. The furnace shall be vented into a hood or to the outside and shall have no noticeable odors escaping into the laboratory. The furnace shall have a fan to pull air through the furnace to expedite the test and to reduce the escape of smoke into the laboratory.

Note 6: The furnace shall also allow the operator to adjust the change in ending mass loss percentage to 0.02 percent.

7.2 *Sample basket(s)* - of appropriate size that allows the samples to be thinly spread and allows air to flow up through and around the sample particles. Sets with two or more baskets shall be nested. The sample shall be completely enclosed with screen mesh, perforated stainless steel plate, or other suitable material.

Note 7: Screen mesh or other suitable material with maximum and minimum opening of 2.36 mm (No. 8) and 600 microns (No. 30) respectively has been found to perform well.

7.3 *Catch Pan* - of sufficient size to hold the sample basket(s) so that aggregate particles and melting asphalt binder falling through the screen mesh are caught.

7.4 *Oven* - capable of maintaining specified compaction temperature ± 5°C (± 9°F) throughout the oven chamber.

7.5 *Balance* - of sufficient capacity and conforming to the requirements of AASHTO M 231 Class G2 for weighing specimen in basket(s).

7.6 *Safety Equipment* - safety glasses or face shield, high temperature gloves, long sleeve jacket, a heat resistant surface capable of withstanding 650°C (1202°F) and a protective cage capable of surrounding the sample baskets during the cooling period.

7.7 *Miscellaneous Equipment* - a pan larger than the sample basket(s) for transferring the sample after ignition, as well as spatulas, bowls, and wire brushes.

8. TEST PROCEDURE

8.1 All production specimens shall have a moisture correction determined in accordance with CP 43. Alternatively, the ignition sample specimen obtained per Section 5 above may be dried to 0.00% moisture prior to placement in the furnace. The specimen is considered to be at 0.00% moisture per the process and tolerance in CP 43, method B, section 13.2.

8.2 Preheat the ignition furnace to 538°C (1000°F) or per manufacturer's directions. Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically.

8.3 Weigh and record the mass of the sample basket(s) and catch pan (with guards in place).

8.4 Prepare the sample as described in Section 5. Evenly distribute the sample in the sample basket(s) that have been placed in the catch pan, taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the specimen.

8.5 Weigh and record the total mass of the sample, basket(s), catch pan, and basket guards. Calculate and record the initial mass of the specimen (total mass minus the mass of the specimen basket assembly).

8.6 Input the initial mass of the specimen in whole grams into the ignition furnace controller. Verify that the correct mass has been entered.

8.7 Open the chamber door, and place the sample baskets in the furnace. Close the chamber door, and verify that the sample mass (including the basket(s)) displayed on the furnace scale equals the total mass recorded in Subsection 8.5 within ± 5 g. Differences greater than 5g or failure of the furnace scale to stabilize may indicate that the sample basket(s) are contacting the furnace wall. Initiate the test by pressing the start/stop button. This will lock the sample chamber and start the combustion blower.

Note 8: The furnace temperature will drop below the set point when the door is opened, but will recover with the door closed and when ignition occurs. Sample ignition typically increases the temperature well above the set point, depending on sample size and asphalt content.

8.8 Allow the test to continue until the stable light and audible stable indicator indicates the test is complete (the change in mass does not exceed 0.01 percent for three consecutive minutes). Press the start/stop button. This will unlock the sample chamber.

Note 9: A change in ending mass loss percentage of 0.02 may be substituted when aggregate that exhibits an excessive amount of loss during ignition testing is used. The precision and bias statement was developed using 0.01 percent. Both precision and accuracy may be adversely affected by using 0.02.

8.9 Remove the specimen basket assembly after ignition and allow it to cool at room temperature for 40 +/- 5 minutes. Weigh the basket assembly containing the residual aggregate and record the weight. The amount of time elapsed between removal from the furnace and weighing on the external scale should be the same for correction factors and plant produced material, within 5 minutes.

8.10 Determine the uncorrected asphalt binder content for the external scale.

8.11 Determine the corrected asphalt binder content for the external scale.

8.12 See Section 12 to perform gradation on burn-off sample.

9. CALCULATIONS

9.1 **Laboratory Mixed Specimen**.
This section includes one method of determining the correction factor.

9.1.1 Calculate the weight of aggregate needed for each specimen as follows:

$$Ws = \frac{Wm(100 - Pb)}{100}$$

Where:
Ws = Weight of aggregate in specimen,
Wm = Total mix weight of specimen,
Pb =Target percent of binder in mix.

Calculate the weight of binder to be added to the aggregate:

$$W_b = \frac{P_b W_s}{100 - P_b}$$

Where:
W_b = Weight of binder to be added to the aggregate specimen,
Pb = Target percent of binder in mix,
Ws = Weight of aggregate in specimen.

9.1.2 The uncorrected asphalt binder content of a specimen is determined using an external scale as follows:

$$P_{b(uncorr)} = \frac{W_{m(initial)} - W_{m(final)}}{W_{m(initial)}} \times 100$$

Where:

$P_{b(uncorr)}$ = Percent uncorrected asphalt binder determined by the mass loss measured on an external scale,

$W_{m(initial)}$ = External scale weight of the hot mix specimen before ignition

$W_{m(final)}$ = External scale weight of the hot mix specimen after ignition.

9.1.3 The asphalt binder correction factor is the percent of binder in the laboratory-mixed specimen minus the uncorrected percent binder in the same specimen after ignition:

$$Cf = Pb - Pb\ (uncorr)$$

Where:

Cf = Asphalt binder correction factor,

Pb = Target percent of binder in mix,

$P_{b(uncorr)}$ = Percent uncorrected asphalt binder determined by the mass loss measured on an external scale.

9.1.4 The corrected asphalt binder content for field-produced specimens is:

$$P_{b(corr)} = P_{b(uncorr)} + C_f - P_W$$

Where:

$P_{b(corr)}$ = Corrected percent asphalt binder in field-produced specimens,

$P_{b(uncorr)}$ = Percent uncorrected asphalt binder determined by the mass loss measured on an external scale,

Cf = Asphalt binder correction factor,

P_w = Percent moisture determined in accordance with CP 85, Section 10.

9.2 **Laboratory-Mixed Specimen Using RAP.**

9.2.1 Calculate the weight of aggregate and RAP needed for each specimen as follows:

$$Wst = \frac{Wmt(100 - Pb)}{100}$$

Where:

Wst = Weight of aggregate and RAP,

Wmt = Target mix weight of specimen,

Pb = Target percent of binder in mix.

The weight of virgin aggregate required in a specimen containing RAP is:

$$\mathbf{Wsv = \frac{Wst(100-Pr)}{100}}$$

Where:
Wsv = Weight of virgin aggregate needed,
Wst = Weight of aggregate and RAP,
Pr = Percent RAP in mix.

9.2.2 The weight of RAP required in the specimen is:

$$\mathbf{Wr = \frac{Wst \times Pr}{100}}$$

Where:
Wr = Weight of RAP needed in the specimen,
Wst = Weight of aggregate and RAP,
Pr = Percent RAP in mix.

9.2.3 The weight of binder in the RAP is:

$$\mathbf{Wbr = \frac{Wr \times Pbr}{100}}$$

Where:
Wbr = Weight of binder in the RAP portion of the specimen,
Wr = Weight of RAP needed in the specimen,
P_{br} = Percent binder in the RAP.

9.2.4 The weight of binder to be added to the aggregate and RAP specimen is:

$$\mathbf{Wba = (Wsv + Wr – Wbr) \times (Pb/(100-Pb))-Wbr}$$

Where:
Wba = Weight of binder to be added to the aggregate and RAP specimen,
Wsv = Weight of virgin aggregate needed,
Wr = Weight of RAP needed in the specimen,
Wbr = Weight of binder in the RAP portion of the specimen,
Pb = Target percent of binder in mix.

9.2.5 The weight of the mixed specimen is:

$$\mathbf{Wma = Wsv + Wr + Wba}$$

Where:
Wma = Actual total mix weight of specimen,
Wsv = Weight of virgin aggregate needed,
Wsr = Weight of RAP needed in the specimen,
Wba = Weight of binder to be added to the aggregate and RAP specimen.

9.2.6 The actual percent binder in the mixed specimen is:

$$\mathbf{Pbm = \frac{100 \times (Wba + Wbr)}{Wma}}$$

Where:
Pbm = percent binder in the mixed specimen,
Wba = Weight of binder to be added to the aggregate and RAP specimen,
Wbr = Weight of binder in the RAP portion of the specimen,
Wma = Actual total mix weight of specimen.

9.3 **Laboratory-Mixed Specimen Using Two or More RAP Stockpiles.**

9.3.1 The example below is for two RAP stockpiles. More than two RAP stockpiles may be calculated in a similar fashion.

9.3.1.1 Spreadsheet may be obtained through the Flexible Pavement Unit of the Central Laboratory (303) 398-6533.

9.3.2 Calculate the weight of aggregate and RAP needed for each specimen as follows:

$$\mathbf{Wst = Wmt\ (100 - Pb)\ /100}$$

Where:
Wst = Weight of aggregate and RAP,
Wmt = Target mix weight of specimen,
Pb = Target percent of binder in mix.

The weight of virgin aggregate required in a specimen containing RAP is:

$$\mathbf{Wsv = Wst(100\text{-}Pr)/100}$$

Where:
Wsv = Weight of virgin aggregate needed,
Wst = Weight of aggregate and RAP,
Pr = Percent RAP in mix.

9.3.3 The weight of RAP required in the specimen is:

$$\mathbf{Wr1 = Wst \times Pr1/100}$$
$$\mathbf{Wr2 = Wst \times Pr2/100}$$

Where:
Wr1 = Weight of RAP1 needed in the specimen,
Wr2 = Weight of RAP2 needed in the specimen,
Wst = Weight of aggregate and RAP,
Pr1 = Percent RAP1 in mix,
Pr2 = Percent RAP 2 in mix.

9.3.4 The weight of binder in the RAP is:

$$\mathbf{Wbr1 = Wr1 \times Pbr1/100}$$
$$\mathbf{Wbr2 = Wr2 \times Pbr2/100}$$
$$\mathbf{WbrTotal = Wbr1 + Wbr2}$$

Where:
Wbr1 = Weight of binder in the RAP1 portion of the specimen,
Wbr2 = Weight of binder in the RAP2 portion of the specimen,
Wbr Total = Total weight of binder in the RAP portion of the specimen,
Wr1 = Weight of RAP1 needed in the specimen,
Wr2 = Weight of RAP2 needed in the specimen,
Pbr1 = Percent binder in the RAP1,
Pbr2 = Percent binder in the RAP2.

9.3.5 The weight of binder to be added to the aggregate and RAP specimen is:

$$\mathbf{Wba = (Wsv + Wr1 + Wr2 - WbrTotal) \times (Pb/(100-Pb))-WbrTotal}$$

Where:
Wba = Weight of binder to be added to the aggregate and RAP specimen,
Wsv = Weight of virgin aggregate needed,
Wr1 = Weight of RAP1 needed in the specimen,
Wr2 = Weight of RAP2 needed in the specimen,
WbrTotal = Total weight of binder in the RAP portion of the specimen,
Pb = Target percent of binder in mix.

9.3.6 The weight of the mixed specimen is:

$$\mathbf{Wma = Wsv + Wr1 + Wr2 + Wba}$$

Where:
Wma = Actual total mix weight of specimen,
Wsv = Weight of virgin aggregate needed,
Wr1 = Weight of RAP1 needed in the specimen,
Wr2 = Weight of RAP2 needed in the specimen,
Wba = Weight of binder to be added to the aggregate and RAP specimen.

9.3.7 The actual percent binder in the mixed specimen is:

$$\mathbf{Pbm = 100 \times (Wba + WbrTotal)/ Wma}$$

Where:
Pbm = Percent binder in the mixed specimen,
Wba = Weight of binder to be added to the aggregate and RAP specimen,
WbrTotal = Total weight of binder in the RAP portion of the specimen,
Wma = Actual total mix weight of specimen

9.4 **Glossary.**

Cf = Asphalt binder correction factor

Pb = Target percent of binder in mix

Pb(uncorr) = Percent uncorrected asphalt binder determined using an external scale

Pbr = Percent binder in the RAP

Pbm = Percent binder in the mixed specimen

Pr = Percent RAP in the mix

Pr1 = Percent RAP1 in mix

Pr2 = Percent RAP 2 in mix.

Pw = Percent moisture determined by CP 85, Section 10

RAP = (Reclaimed Asphalt Pavement) which includes the aggregate and binder

Wb = Weight of binder to be added to aggregate *not* containing RAP

Wba = Weight of binder to be added to the aggregate and RAP specimen

Wbr = Weight of binder in the RAP portion of the specimen

WbrTotal = Total weight of binder in the RAP portion of the specimen,

Wm = Total mix weight of specimen

Wma = Actual total mix weight of specimen

Wmt = Target mix weight of specimen

Wm(final) = External scale weight of the hot mix specimen after ignition

Wm(initial) = External scale weight of the hot mix specimen before ignition

Ws = Weight of aggregate in specimen

Wr = Weight of RAP needed in specimen

Wr1 = the weight of RAP1 needed in the Specimen

Wr2 = the weight of RAP2 needed in the specimen

Wst = Weight of aggregate and RAP in specimen

Wsv = Weight of virgin aggregate needed in specimen having RAP.

10. Section 10 (Deleted)

11. Section 11 (Deleted)

12. GRADATION

12.1 Empty the residual aggregate from the baskets into a flat pan. Use a small wire brush to ensure that any residual fines are removed from the baskets. Weigh the residual aggregate on an external scale and record the weight.

Note 10: If the potential presence of lime in asphalt paving mixture needs to be determined, introduce water over the residual aggregate and add 2-4 drops of phenolphthalein alcohol indicator into the sample. Let it rest for 10 seconds and look for the indicator to show the potential presence of lime.

12.2 Perform a gradation analysis in accordance with CP 31.

12.3 If aggregate degradation is suspected, or if the test results will be used for project acceptance, Subsections 12.3.1 to 12.3.6 may be used to verify whether aggregates have a tendency to degrade.

12.3.1 Obtain a sample of the final aggregate blend in question from a conveyor belt discharge or a stopped conveyor belt according to CP 30.

12.3.2 Using a sample splitter, split a sample weighing at least four times the sample size specified in Table 1 into four specimens having approximately equal mass. Set two specimens aside.

12.3.3 Mix two of the aggregate specimens with asphalt cement to yield specimens having an asphalt binder content within 0.5 percent of the mix in question.

12.3.4 Test the two mixed specimens as specified in Section 7.

12.3.5 Using CP 31, determine the gradation of the two specimens, which were mixed with asphalt binder and ignited. Determine the gradation of the two specimens, which were set-aside in Subsection 12.3.2.

12.3.6 Calculate the average percent passing each sieve size for the two sets of two specimens. For a RAP mix, test the virgin aggregate gradation without RAP. Mathematically add the RAP gradation results from the mix design to the virgin gradation at the percent used in the mix design for the unburned sample. Mix the virgin aggregate with RAP at the mix design percentages and burn. Compare the differences between the unburned and the burned sample.

Compare the average gradation at each sieve size for the two sets of specimens. If the difference for any single sieve exceeds the allowable difference for that sieve as listed in Table 2, then aggregate gradation correction factors (equal to the resultant average differences) for **all** sieves shall be applied to all acceptance gradation test results determined by CP 31, prior to final rounding and reporting. If the 0.075-mm (No. 200) sieve is the only sieve outside the limits in Table 2, apply the aggregate correction factor to only the 0.075-mm (No. 200) sieve.

The aggregate correction factor calculation shall be calculated to the nearest 0.1% for all sieves except the #200 sieve. The #200 sieve shall be calculated to the nearest 0.01%. Those corrections are applied to the non-rounded percent passing. The final reported percent passing is rounded to the whole percentage for all sieves except the reported #200 sieve. The reported #200 sieve is rounded to the nearest 0.1%.

Table 2 - Permitted Sieving Difference

Sieve	Allowable Difference
Sizes larger than or equal to 2.36 mm (No.8)	+/- 5.0 percent
Sizes larger than 0.075 mm (No. 200) and smaller than 2.36 mm (No. 8)	+/- 3.0 percent
Sizes 0.075 mm (No. 200) and smaller	+/- 0.5 percent

13. REPORT

13.1 There is no designated CDOT Form used for recording / reporting information for this CP-L.

13.1.1 The report shall include the following information:

13.1.2 Date of correction factor determination.

13.1.3 Identification of aggregate and mix type.

13.1.4 Correction factor.

13.1.5 Corrected asphalt content (nearest 0.01%).

13.1.6 Aggregate gradation, if performed.

14. PRECISION AND BIAS

14.1 The precision for this test method is as follows:

Standard Deviation

Type Index	Virgin Mixes, %	RAP Mixes, %
Single-laboratory	0.15	0.20
Multi-laboratory	0.30	0.40

14.2 A bias for this test method will be determined at a later date, and included in future re*vision*s.

APPENDIX

Laboratory Mixed Specimen

Input Values	Examples
Total Mix Weight of Specimen (Wm)	7600.0
Target Percent of Binder in Mix (Pb)	5.00

Calculated Values	Examples	Calculations
Weight of Aggregate in Specimen (Ws)	7220.0	Ws = Wm * (100 - Pb) / 100
Weight of Binder to be added to the Aggregate Specimen (Wb)	**380.0**	Wb = (Pb * Ws) / (100 - Pb)

Laboratory - Mixed Specimen Using RAP

Input Values	Examples
Target Mix Weight of Specimen (Wmt)	1850.0
Target Percent of Binder in Mix (Pb)	5.30
Percent RAP in Mix (Pr)	20.00
Percent Binder in the RAP (Pbr)	4.64

Calculated Values	Examples	Calculations
Weight of Aggregate and RAP (Wst)	1752.0	Wst = Wmt * (100 - Pb) / 100
Weight of Virgin Aggregate needed (Wsv)	1401.6	Wsv = Wst * (100 - Pr) / 100
Weight of RAP needed in the Specimen (Wr)	350.4	Wr = Wst * Pr / 100
Weight of Binder in the RAP portion of the Specimen (Wbr)	16.3	Wbr = Wr * Pbr / 100
Weight of Binder to be added to the Aggregate and RAP Specimen (Wba)	**80.9**	Wba = (Wsv + Wr - Wbr) * (Pb / (100 - Pb)) - Wbr
Actual Total Mix Weight of Specimen (Wma)	1832.8	Wma = Wsv + Wr + Wba
Percent Binder in the Mixed Specimen (Pbm)	5.3	Pbm = 100 * (Wba + Wbr) / Wma

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Laboratory - Mixed Specimen Using Two RAP Stockpiles

Input Values	Examples
Target Mix Weight of Specimen (Wmt)	2050.0
Target Percent of Binder in Mix (Pb)	5.20
Percent RAP1 in Mix (Pr1)	15.00
Percent RAP2 in Mix (Pr2)	3.00
Percent Binder in the RAP1 (Pbr1)	5.80
Percent Binder in the RAP2 (Pbr2)	18.50

Calculated Values	Examples	Calculations
Weight of Aggregate and RAP (Wst)	1943.4	Wst = Wmt * (100 - Pb) / 100
Percent RAP in Mix (Pr)	18.0	Pr = Pr1 + Pr2
Weight of Virgin Aggregate needed (Wsv)	1593.6	Wsv = Wst * (100 - Pr) / 100
Weight of RAP1 needed in the Specimen (Wr1)	291.5	Wr1 = Wst * Pr1 / 100
Weight of RAP2 needed in the Specimen (Wr2)	58.3	Wr2 = Wst * Pr2 / 100
Weight of Binder in the RAP1 portion of the Specimen (Wbr1)	16.9	Wbr1 = Wr1 * Pbr1 / 100
Weight of Binder in the RAP2 portion of the Specimen (Wbr2)	10.8	Wbr2 = Wr2 * Pbr2 / 100
Total Weight of Binder in the RAP portion of the Specimen (WbrTotal)	27.7	WbrTotal = Wbr1 + Wbr2
Weight of Binder to be added to the Aggregate and RAP Specimen (Wba)	**77.4**	Wba = (Wsv + Wr1 + Wr2 - WbrTotal) * (Pb/(100-Pb))-WbrTotal
Actual Total Mix Weight of Specimen (Wma)	2020.8	Wma = Wsv + Wr1 + Wr2 + Wba
Percent Binder in the Mixed Specimen (Pbm)	5.2	Pbm = 100 * (Wba + WbrTotal) / Wma

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Colorado Procedure – Laboratory 5140-15

Standard Method of Test for

Mix Design for Hot In-Place Recycling of Asphalt Pavements

1. SCOPE

1.1 This procedure is used to determine the properties of an asphalt pavement to be hot in-place recycled, the amount of rejuvenating agent to be used in hot in-place recycling, and to design the hot in-place recycled mix.

2. APPARATUS

2.1 *Vacuum extractor* capable of performing AASHTO T 164, Method D.

2.2 *Distillation equipment* required to perform AASHTO R 59, Recovery of Asphalt Binder from Solution by Abson Method.

2.3 Asphalt binder test equipment required to perform penetration at 77˚F (AASHTO T 49) and viscosity at 140˚F (AASHTO T 202).

2.4 Mix design test equipment required to perform CP 51, CP 44 and CP-L 5106, CP-L 5109, and CP-L 5115.

2.5 *Two ovens*, one capable of maintaining a temperature of 60˚C (140˚F) forced draft and another capable of maintaining a temperature of 135˚C (275˚F).

2.6 *Balance*, 5 kg capacity; accurate to 0.1 gram.

2.7 *Sieves*, U.S. Standard sizes: 1 in., 3/4 in., 1/2 in., 3/8 in., Nos. 4, 8, 16, 30, 50, 100, and 200.

2.8 *Sample splitter* for aggregates, 1 in., riffle type.

2.9 Appropriate *sample pans* and *tools* needed for the above procedures.

3. MATERIALS

3.1 Rejuvenating Agents; ARA, ARA-1, or grades specified in ASTM D 4552.

3.2 Samples of pavement to be recycled. Approximately 50 pounds of each pavement type will be required.

4. PREPARATION OF SAMPLES

4.1 Obtain properties of existing pavement using core samples taken from each separate pavement type to be recycled. Trim cores to the proper depth so that only the portion to be recycled is used for testing.

4.1.1. For each separate pavement type, perform AASHTO T 164 and AASHTO R 59, Recovery of Asphalt Binder from Solution by Abson Method to determine asphalt content, gradation of aggregate, penetration (77˚F) and viscosity (140˚F) of the existing binder.

4.1.2 Reheat and breakup sufficient material from cores to measure the maximum specific gravity of the mix, Hveem stability, voids, and effective VMA of the existing pavement using the appropriate end-point pressure for the road to be recycled. The effective VMA will be higher than the bulk VMA normally reported in CDOT test reports.

4.1.3 Determine the tensile strength ratio of the existing pavement according to CP-L 5109 using reheated and remolded roadway samples.

5. RECOMMENDATION

5.1 For design purposes, the stiffness of the recycling agent should be the same as regular HMA (0.44).

6. DETERMINING THE BINDER FOR THE NEW MIX

6.1 Determining the amount and type of rejuvenating agent to be used.

Using the test results from the existing HMA; the penetration or viscosity of binder, percent binder and aggregate, and gradation of aggregate.

Calculate the asphalt demand of the old pavement using the following formula:

$$P = \frac{4R + 7S + 12F}{100} \times 1.1$$

Where:

P = Total % asphalt required in recycled mix, (old asphalt + rejuvenating agent)
R = Rock (retained on #8 sieve),
S = Sand (passing #8 sieve; retained on #200),
F = Fines (passing #200 sieve).

The following nomographs may be used to predict the penetration and viscosity of the resulting mix of binder and rejuvenating agent. If they are not close to the desired results, a different viscosity / rejuvenating agent may need to be specified.

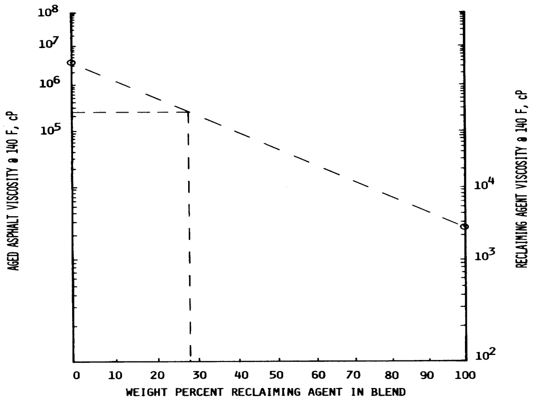


Figure 1, Nomograph for Viscosity.

To use: draw a straight line connecting viscosity of aged asphalt with viscosity of reclaiming agent, draw a vertical line up from the percent reclaiming agent in blend. The two lines intersect at the predicted approximate viscosity of the recycled asphalt.

6.2 An alternate method for determining whether the desired result will be obtained in rejuvenation of the aged binder is to treat the roadway material with the appropriate amount of rejuvenating agent, heat the mix for 90 ± 15 minutes at 300°F (149°C) and perform an extraction (AASHTO T 164 Method D) and AASHTO R 59, Recovery of Asphalt Binder from Solution by Abson Method.

This alternate procedure may also be used when virgin aggregate and asphalt cement are added to the recycled HMA. (A minimum of 55 pounds of virgin mix per square yard of pavement is required for most applications)

7. DETERMINING THE AGGREGATE FOR THE NEW MIX

7.1 Determining the amount and type of virgin aggregate and asphalt cement to be added.

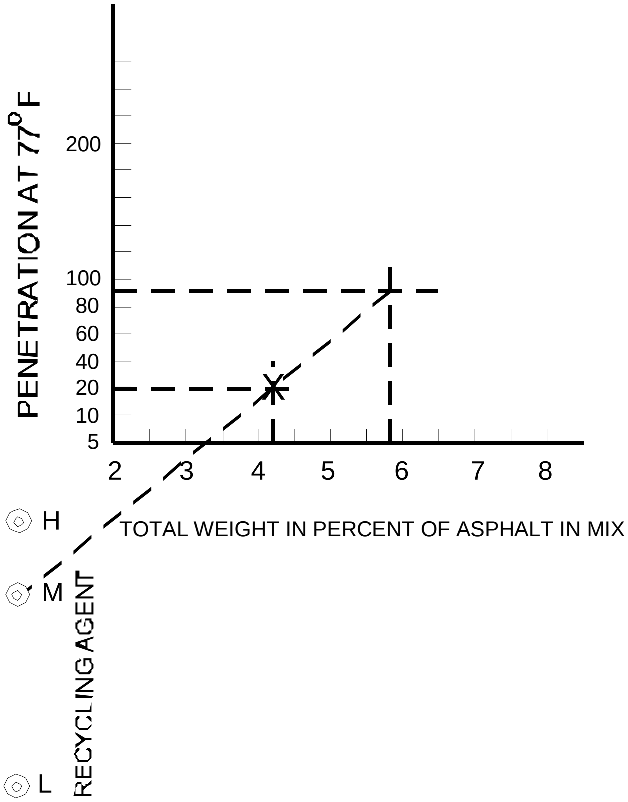
Different amounts and/or gradations of virgin mix may be added to the recycled HMA to bring the final mix to the desired properties specified for the project.

From the original extraction and gradation data of the existing HMA, plot the gradation on a 0.45 power chart to help determine the gradation of virgin mix, which may be needed. Adjust the added mix to optimize the voids, VMA, and stability of the final mix so that it will meet the criteria for the project.

Combined mix may then be tested in the lab according to CP-L 5106, CP-L 5109 and CP-L 5115 to determine if the hot-in-place recycled mix will meet the requirements of the project.

8. REPORTING

8.1 There is no designated CDOT Form used for recording / reporting information for this CP-L.



To use: Enter a point, "X", corresponding to asphalt content and penetration in aged pavement. Draw a straight line from the selected origin,(L- low, M-med, H-high) O, through "X". Intersection of this line with a vertical line representing desired asphalt content of recycled pavement (aged asphalt + recycling agent) gives predicted approximate penetration of rejuvenated asphalt.

Figure 2, Nomograph for Penetration

Colorado Procedure – Laboratory 5145-15

Standard Method of Test for

Contractor Asphalt Mix Design Approval Procedures Utilizing RAP Millings from the Same Project

1. SCOPE

1.1 This practice describes Reclaimed Asphalt Pavement (RAP) sampling and testing requirements for HMA mixture designs that will incorporate RAP millings from the same project.

2. REFERENCED DOCUMENTS

2.1 Colorado Procedures:

CP 31 Sieve Analysis of Aggregates
CP 32 Reducing Field Samples of Soil and Aggregate to Testing Size
CP 51 Determining the Maximum Specific Gravity of HMA
CP 52 Contractor Asphalt Mix Design Approval Procedures
CP-L 5120 Determination of the Asphalt Binder Content of Bituminous Mixtures by the Ignition Method

2.2 AASHTO Procedures:

T 164 Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA)

3. SAMPLING RAP FROM THE EXISTING HMA MAT

3.1 Determine the percentage of RAP and the associated tonnage that can/will be utilized in the HMA for the project. Determine the amount of milling (tons) to be generated from the project. If there is no allowance for the Contractor to retain RAP from the project and it is desired to do so, the Contractor shall submit a Value Engineering Change Proposal (VECP) detailing cost savings to the project that can be achieved if it is desired to incorporate RAP from the project into the HMA mix. If successful in obtaining a percentage of the RAP from a project through the use of a VECP, the Contractor will be allowed to choose the area of the roadway from which the RAP will be taken.

3.2 At a minimum, samples of the HMA mat to be processed and incorporated into the mix design shall be taken every half mile in each lane for that portion of the roadway where RAP is to be obtained. Samples should also be taken in the shoulder if RAP from the shoulder areas are to be incorporated into the HMA for the project as well. Samples shall be taken using a mill type device similar to that which will be utilized on the project, and the mill depth shall be set to the depth equal to that specified for the milling in the contract documents. RAP millings shall be collected and marked as to where the millings were obtained. **(or)**

Full-depth 6" diameter (or larger) cores shall be taken every half-mile of each lane. Cores should also be taken in the shoulder, if the shoulder millings will be incorporated into the project HMA mix design.

Milled areas and core holes shall be patched immediately by the Contractor after sampling is completed.

A sufficient amount of millings, or number of cores shall be taken at each test location to ensure an adequate amount of RAP is obtained to perform a full HMA mix design. It is required that at a minimum, a total of 80 pounds of RAP material be obtained for initial testing purposes as well as for inclusion into the mix design.

3.3 Samples, either millings or cores, shall be taken if visual observations show significant variations in the existing mat along the project length. If the project is designated as a mill and fill (same day) type project, sufficient material shall be obtained from each mile of the project to perform additional testing of the RAP materials as detailed in Subsection 5.2 of this procedure.

4. PREPARATION OF SAMPLES

4.1 Processing/Crushing:

A. Pavement Cores
  1. Trim samples so only that portion designated for milling remains.
  2. Crush the material proposed for milling to minus 1-1/4 inch.

B. Milled Pavement
  1. Crush oversized material using a jaw crusher so that the sample is 100% passing the 1-1/4 inch.

4.2 Combining Samples: Processed and crushed pavement samples shall be combined to form a composite RAP sample. Composite RAP samples shall be tested as described in the Subsection 5.1 of this procedure

5. TESTING OF RAP SAMPLES

5.1 The following testing shall be performed on the combined, composite samples of RAP. The test samples shall be split out and reduced to the appropriate sample size using CP 32. Testing to be performed on the composite sample shall include the following:

- AC Content, determined in accordance with AASHTO T 164, Method A or B. The Contractor may propose a RAP asphalt content correction factor to be used in conjunction with CP-L 5120 per the Reclaimed Asphalt Pavement Standard Special Provision 401.02(b)1C.
- Gradation, determined in accordance with CP 31.
- Effective Specific Gravity, determined through CP 51.

5.2 For a mill and fill type project, additional testing for AC content, gradation, and effective specific gravity, as outlined in 5.1, shall be required for each mile of roadway and/or shoulder that will be milled. This information shall be used to determine whether adjustments to the mix design will be required as the project proceeds, since a composite sample may not be representative of the RAP properties at project startup, or at various locations along the project length. The Contractor will be required to pave with a virgin mix design until a sufficient amount of processed RAP has been stockpiled and tested to allow full production of a RAP HMA mix.

6. ASPHALT MIX DESIGN

6.1 The test results obtained in Section 5 shall be used to develop an asphalt mix design for the project. The asphalt mix design shall be developed in conformance with CP 52.

7. RAP PROCESSING TESTING

7.1 The RAP millings shall be tested per the Contract requirements. The test results obtained during RAP processing shall be compared to the RAP test results used to develop the mix design. Adjustments shall be made to the mix design, if needed, prior to beginning paving operations so that the required volumetric properties can be produced. Any changes made to the mix design and the subsequent volumetric test results shall be reported to the Region Materials Engineer so that the mix design can be re-evaluated, and a new Form #43 issued if acceptable.

7.2 The uniformity requirements contained in the project contract shall apply to the processed RAP used in the mix design.

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Colorado Procedure – Laboratory 5150-15

Standard Method of Test for

Adjusting Moisture Requirement to Hydrate Lime in Asphalt Mixes

1. SCOPE

1.1 This method can be used to adjust the amount of moisture required to properly hydrate lime in asphalt mixes.

2. REFERENCED DOCUMENTS

2.1 *Colorado Procedures:*

CP 30	Sampling of Aggregates
CP 31	Sieve Analysis of Aggregates
CP 41	Sampling Hot Mix Asphalt
CP-L 5109	Resistance of Compacted Bituminous Mixture to Moisture Induced Damage
CP-L 5115	Standard Method for Preparing and Determining the Density of Bituminous Mixture Test Specimens Compacted by the Superpave Gyratory Compactor
CP-L 5120	Determination of the Asphalt Binder Content of Bituminous Mixtures by the Ignition Method

3. SIGNIFICANCE AND USE

3.1 As noted in the Scope, this method is intended to adjust the amount of moisture necessary to properly hydrate the lime in asphalt mixes. The current requirements are to hydrate the aggregates 2% above Saturated Surface Dry (SSD) conditions. This amount of moisture may not necessarily be required for mixes to pass the Tensile Strength Retained (TSR) requirements of the contract documents.

3.2 Contractors may elect to use this procedure to reduce the amount of moisture required to hydrate the lime. The reduction of the amount of moisture in mixes lowers energy costs by reducing the amount of moisture that must be dried out of the aggregates prior to mixing with asphalt cement.

4. SUMMARY OF METHOD

4.1 Test specimens of laboratory produced material are mixed in accordance with CPL 5115 and tested per CPL 5109 at 2% moisture and 1% lime. Test specimens must have TSR ≥ 90%. If TSR is ≥ 90%, ½% lime is added to specimens with no moisture. If TSR is ≥ 80% move to production verification phase.

4.2 Before project production commences, the Contractor shall produce at least 100 tons of mix with 1% lime and no additional moisture added to the aggregates. Cold feed and HMA samples will be obtained. If gradation, binder content and volumetric properties meet targets and if the TSR is ≥ 80%, the Contractor may submit a written request to waive the contract moisture requirement.

5. APPARATUS

5.1 *SuperPave Gyratory Compactor* - will be used for CP-L 5115.

5.2 *Vacuum container* - ASTM D 2041 and vacuum pump or water aspirator from CP 51 including manometer or vacuum gauge.

5.3 *Water bath:*

5.3.1 *Water bath* - Capable of maintaining a temperature of 140°F ± 1.0° (60°C ± 0.5°).

5.3.2 *Water bath* - Capable of maintaining a temperature of 77°F ± 1.0° (25°C ± 0.5).

5.4 *Freezer* - Maintained at -2.5°F ± 7.5° (-19°C ± 4°)

5.5 *Plastic film* for wrapping, heavy-duty leak proof *plastic bags* to enclose the saturated specimens, and *masking tape*.

5.6 *Aluminum or steel pans* - having a surface area of 40-100 square inches (250-640 cm^2) in the bottom and a depth of approximately 1 to 3 inches (25 mm to 75 mm).

5.7 *Forced air draft oven* - capable of maintaining a temperature of 140°F ± 1.8° (60°C ± 1°).

5.8 *Loading jack and ring dynamometer* -from AASHTO T 245, or a mechanical or hydraulic testing machine from AASHTO T 167 to provide a range of accurately controllable rates of vertical deformation including 0.2 and 2 in. per minute (5.1 and 50.8 mm per minute).

5.9 *Loading Strips* - Steel loading strips with a concave surface having a radius of curvature equal to the nominal radius of the test specimen. For specimens 4 inches (101.6 mm) in diameter the loading strips shall be 0.5 inches (12.7 mm) wide, and for specimens 6 inches (152.4 mm) in diameter the loading strips shall be 0.75 in. (19.05 mm) wide. The length of the loading strips shall exceed the thickness of the specimens. The edges of the loading strips shall be rounded by grinding.

6. PREPARATION OF LABORATORY MIXED TEST SPECIMENS DURING MIX DESIGN

6.1 During mix design, mix a sample according Subsection 6.2 of CP-L 5109. All specimens will contain 1% lime and 2% moisture.

6.2 Compact all specimens per Section 6 of CP-L 5109 and evaluate per Section 7 of CP-L 5109.

6.3 Condition, test and calculate per CP-L 5109 Sections 8, 9, 10, and 11.

6.4 If a test specimen TSR is calculated ≥ 90%, repeat Subsection 6.2 with a set of test specimens mixed at ½% lime and no moisture added for hydration.

6.5 Repeat Subsection 6.3 of this procedure. If a test specimen TSR is calculated ≥ 80%, move to production verification phase.

7. PRODUCTION VERIFICATION

7.1 Before production begins mix at least 100 tons of material for sample collection with 1% lime and no moisture.

7.2 Obtain enough cold feed samples per CP 30 to perform testing according to CP 31.

7.3 Obtain Hot Mix Asphalt Sample in accordance with CP 41 to perform testing according to CP-L 5109, CP-L 5120, and CP-L 5115.

7.4 Perform all testing for procedures in Subsections 7.2 and 7.3 of this procedure.

7.5 If TSR on samples obtained from plant are ≥ 80% and all test results for volumetric properties and gradations are within mix design target values, submit results to Engineer for consideration for lowering contract required moisture content amount.

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NUCLEAR INDEX - 19

Colorado Procedures – Laboratory:

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Colorado Procedure – Laboratory 5301-20

Standard Method of Test for

Leak Wipe Procedure for Nuclear Gauges

1. SCOPE

1.1 The Colorado Department of Public Health & Environment requires that all nuclear gauges be leak wiped. This condition within Colorado Department of Transportation Radioactive Materials License is set forth to enable the licensee to detect the presence of removable radioactive contamination. Leak wipes will also be performed if a nuclear gauge has been involved in an accident or if any CDOT personnel possess an unexplainably high radioactive exposure on their personnel dosimeters.

2. APPARATUS

2.1 Leak Test Wipes Report, provided by Staff Materials – Nuclear Lab.

2.2 Leak Test Envelope, CDOT Form 549, provided by Staff Materials – Nuclear Lab.

2.3 Filter Paper, 1 Qualitative, 4.25 cm Circles.

2.4 Forceps.

2.5 Dowel, 1/4" to 3/8", or an unused standard size pencil (19/64") with an attached eraser.

2.6 Nuclear M/D or AC gauge.

3. WIPING OF MOISTURE/DENSITY GAUGES

3.1 Complete the information requested on the Leak Test Envelope. Write the equipment's Gauge No. and CDOT No. on the envelope. Place an X in the M/D Gauge block. Write the corresponding Wipe No. from the Leak Test Wipe Report on the envelope and write the appropriate date on both the report and the envelope.

3.2 Remove the scaler from the gauge.

3.3 Clasp the edge of one filter paper in the forceps. From this point on the filter paper should not be touched, possibly contaminating yourself.

3.4 With the forceps in one hand and the dowel (or eraser end of a pencil) in the other hand, press the filter paper on and around the edges of the CAUTION RADIOACTIVE MATERIAL label and rub.

3.5 The Americium 241:Beryllium source has now been wiped so as to collect any possible Alpha radioactive contamination.

3.6 Turn the gauge on its side with the base facing away from you. The gauge should be in the safe position and you should have maintained hold of the forceps.

3.7 Following the same procedure of holding the forceps and the dowel (or eraser end of a pencil) press the dirty side* of the filter paper within the scraper ring. Press firmly and rub both the brass ring and the exposed tungsten block.

Note 1: The dirty side of the filter paper is the side that has already made contact with the AM-241:BE source.

3.8 The Cesium 137 source has now been wiped to collect any possible Beta radioactive contamination.

3.9 Place the filter paper in the Leak Test Envelope by holding the envelope open and releasing the filter paper from the forceps.

3.10 Seal the envelope to prevent possible loss of the filter paper.

3.11 Replace the scaler, ensuring that the ribbon cable is fully attached.

3.12 Inspect the gauge to ensure that it is in full compliance with all labeling requirements and perform any maintenance / repairs that are necessary.

4. WIPING OF ASPHALT CONTENT GAUGES

4.1 Complete the information requested on the Leak Test Envelope. Write the equipment's Gauge No. and CDOT No. on the envelope. Place an X in the AC Gauge block. Write the corresponding Wipe No. from the Leak Test Wipe Report on the envelope and write the appropriate date on both the report and the envelope.

4.2 Open the door on the gauge.

4.3 Clasp the edge of one filter paper in the forceps. From this point on the filter paper should not be touched, possibly contaminating yourself.

4.4 With the forceps in one hand and the dowel (or eraser end of a pencil) in your other hand, press the filter paper in the round indentation on the inside top plate within the sample chamber and rub.

4.5 The Americium 241:Beryllium source has now been wiped to collect any possible Alpha radioactive contamination. The wiping is done at this location because no polyethylene and cadmium shielding exist at this point.

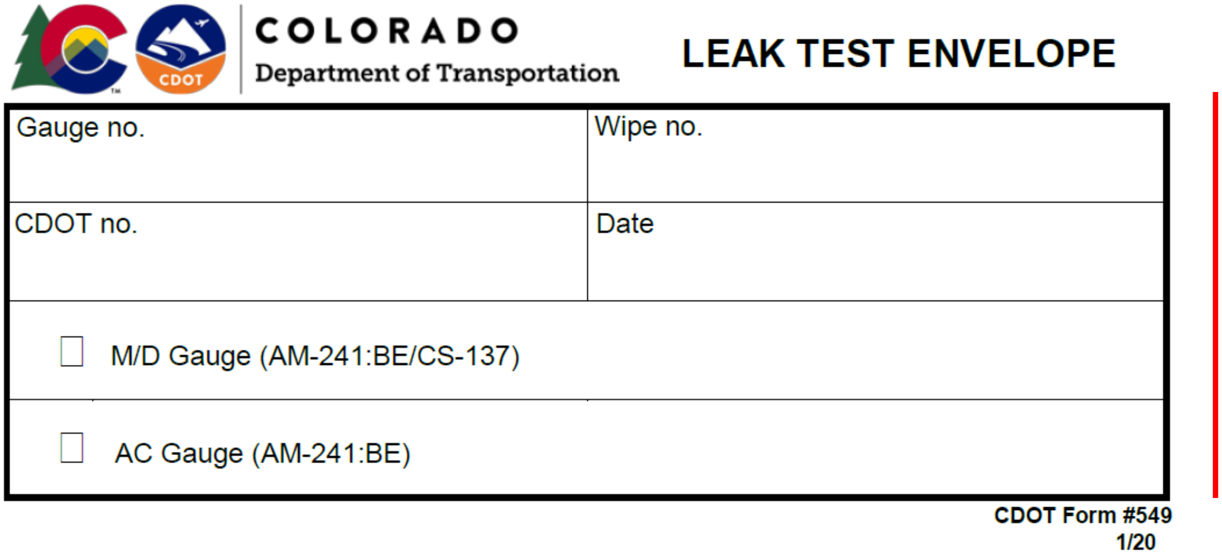
4.6 Place the filter paper in the Leak Test Envelope by holding the envelope open and releasing the filter paper from the forceps.

4.7 Seal the envelope to prevent possible loss of the filter paper.

4.8 Inspect the gauge to ensure that it is in full compliance with all labeling requirements and perform any maintenance / repairs that are necessary.

5. LEAK TEST WIPE ANALYSIS

5.1 The completed Leak Test Wipes Report and all Leak Test Envelopes shall be forwarded to Staff Materials – Nuclear Lab for analysis.



COLORADO
Department of Transportation

LEAK TEST ENVELOPE

Gauge no.	Wipe no.
CDOT no.	Date
☐ M/D Gauge (AM-241:BE/CS-137)	
☐ AC Gauge (AM-241:BE)	

CDOT Form #549
1/20

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Colorado Procedure – Laboratory 5302-15

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.

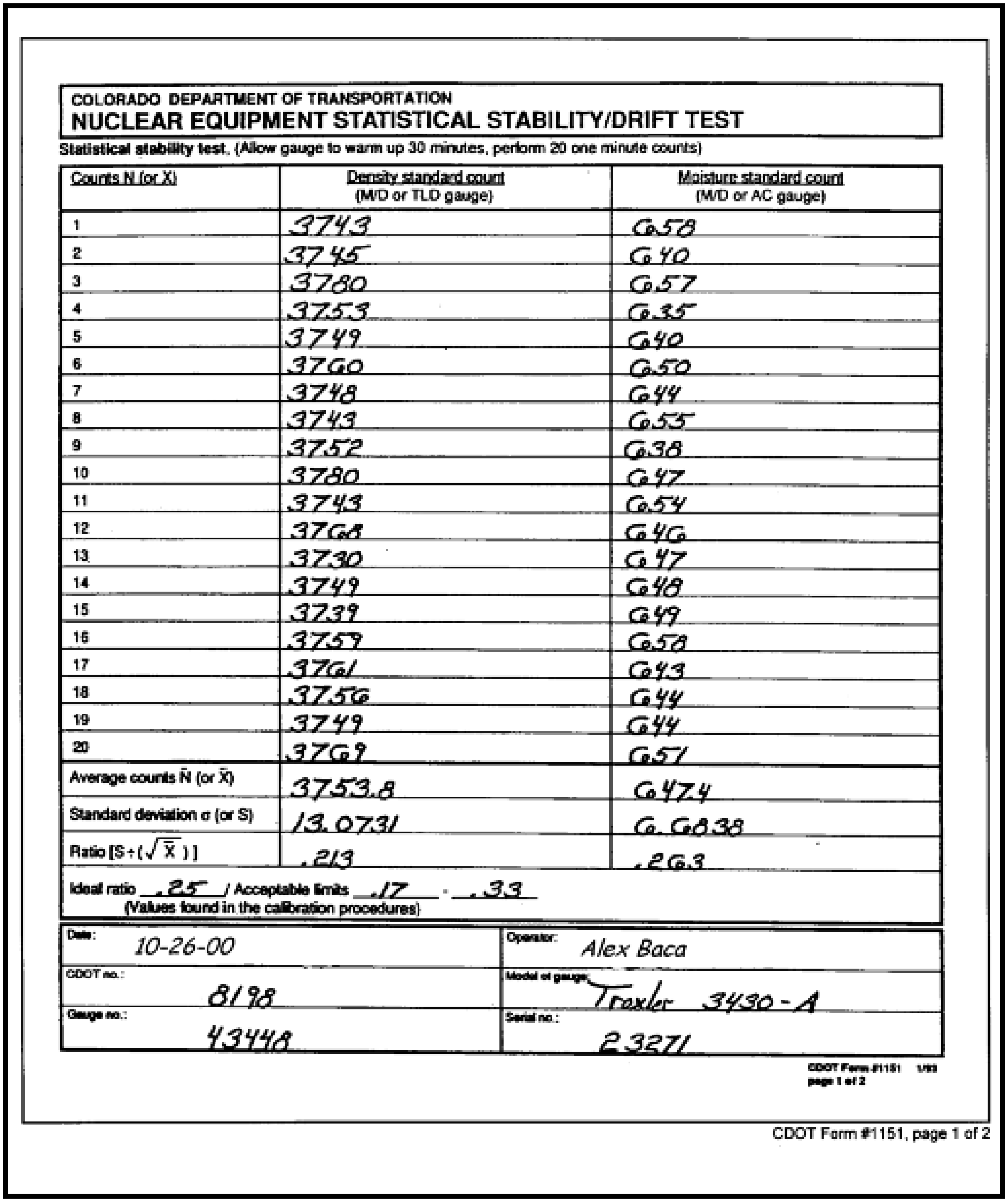
4.6.10 Extend the source rod to 8”. Pull the gauge forward to eliminate any air gap between the block and source rod and perform and record four one-minute **wet** density readings [Note 2]. Average the four readings and record the average.

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.



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	658
2	3745	640
3	3780	657
4	3753	635
5	3749	640
6	3760	650
7	3748	644
8	3743	655
9	3752	638
10	3780	647
11	3743	654
12	3768	646
13	3730	647
14	3749	648
15	3739	649
16	3759	658
17	3761	643
18	3756	644
19	3749	644
20	3769	651
Average counts $\bar{N}$ (or $\bar{X}$)	3753.8	647.4
Standard deviation σ (or S)	13.0731	6.6838
Ratio [S ÷ ($\sqrt{\bar{X}}$)]	.213	.263

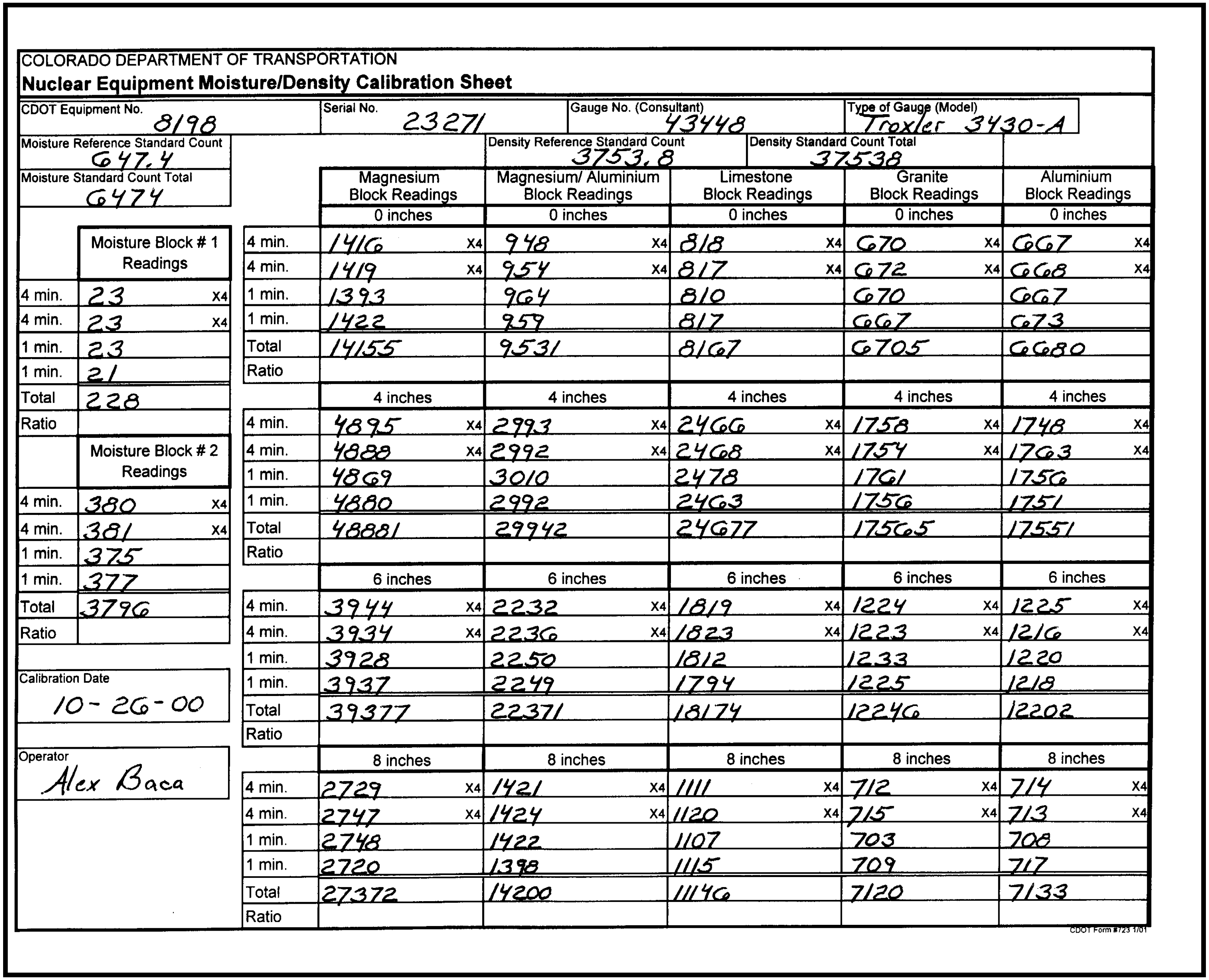
Ideal ratio .25 / Acceptable limits .17 - .33
(Values found in the calibration procedures)

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

CDOT Form #1151 1/93
page 1 of 2

CDOT Form #1151, page 1 of 2

CDOT Form 1151



COLORADO DEPARTMENT OF TRANSPORTATION

Nuclear Equipment Moisture/Density Calibration Sheet

CDOT Equipment No. 8198

Serial No. 23271

Gauge No. (Consultant) 43448

Type of Gauge (Model) Troxler 3430-A

Moisture Reference Standard Count 647.4

Density Reference Standard Count 3753.8

Density Standard Count Total 37538

Moisture Standard Count Total 6474

	Moisture Block # 1 Readings
4 min.	23 X4
4 min.	23 X4
1 min.	23
1 min.	21
Total	228
Ratio	

	Moisture Block # 2 Readings
4 min.	380 X4
4 min.	381 X4
1 min.	375
1 min.	377
Total	3796
Ratio	

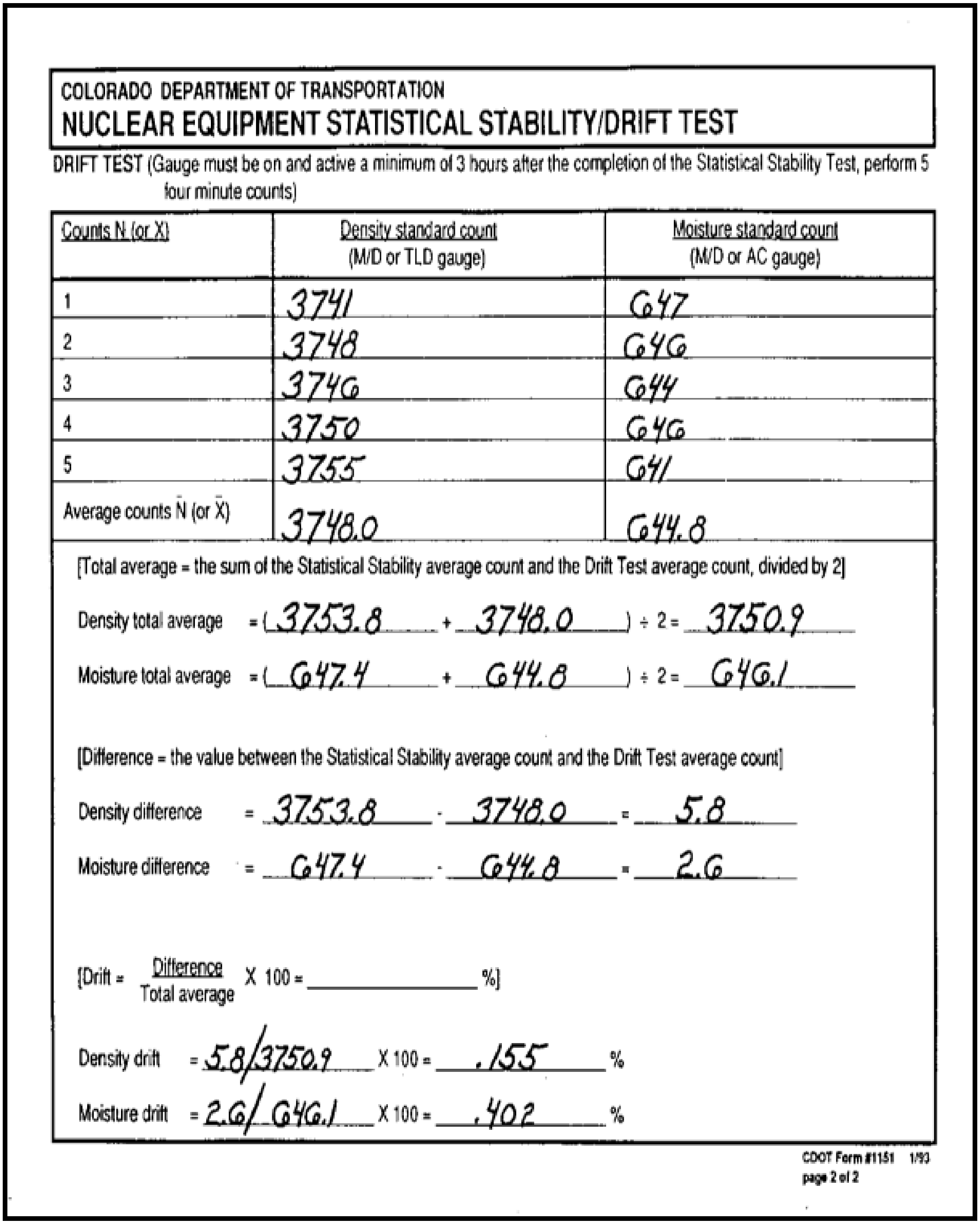
Calibration Date 10-26-00

Operator Alex Baca

	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.	1416 X4	948 X4	818 X4	670 X4	667 X4
4 min.	1419 X4	954 X4	817 X4	672 X4	668 X4
1 min.	1393	964	810	670	667
1 min.	1422	959	817	667	673
Total	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					

CDOT Form #723 1/01

CDOT Form 723



COLORADO DEPARTMENT OF TRANSPORTATION

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 %

CDOT Form #1151 1/93
page 2 of 2

CDOT Form 1151

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Colorado Procedure – Laboratory 5303-14

Standard Method of Test for

Calibration Check of CDOT Nuclear Moisture/Density Gauges

1. SCOPE

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

1.2 Since CDOT M/D gauges are calibrated biennially, a calibration check will be performed immediately afterwards by Region Lab personnel. On the year when no calibration is performed, all Regions will run a calibration check.

1.3 The calibration check performed immediately after a calibration is designed to establish values between the gauge and a different set of standards. The calibration check performed on the off year is used as a basis of comparison or to check the validity of the current calibration table and constants.

2. PRE-CALIBRATION CHECK INSPECTION

2.1 Inspect the gauge's U.S. DOT Type "A" carrying case to ensure that all Manufacturer (Troxler, Instrotek, CPN) transportation requirements are met: such as physical integrity and labeling. Clean the carrying case, make any repairs, and replace either of the required two "RADIOACTIVE YELLOW II" labels or the "DOT TYPE "A" RADIOACTIVE" label if necessary.

2.2 Inspect the gauge's reference standard block for any damage. The seating of the gauge on a reference standard block is critical to its repeatability; therefore, any block that allows variable seatings shall be repaired or replaced. If the reference standard block is cracked, split, or delaminating it shall also be replaced because this can affect either the density or moisture counts. Reference standard blocks are not interchangeable; therefore, ensure that it is assigned the same identification number as the gauge.

2.3 Inspect the M/D gauge for damage or non-compliance with required radioactive source labels. If the label on the source rod handle is in any way illegible it shall be replaced. Clean the shell and the base plate of the gauge of any soil or asphalt contamination, being careful to direct the base away from anyone in the immediate area. The On-Site Radiation Safety Officer is the only authorized person in the field to remove the base plate so that proper cleaning and lubrication can be performed. Remove the sliding shield and the shield spring. Clean the old grease and dirt out of the cavity and off all of the parts. Remove the retaining ring and extract the scraper ring from the base plate. Installing a new scraper ring is very important to minimizing moisture and soil contamination within a gauge. The source rod should be extended quickly, to reduce exposure to radiation, and inspected for any damage, as well as to be cleaned. Lubricate the bearings and the sliding shield. Install the sliding shield and spring into the cavity and re-attach the base plate. Extend the source rod through the base plate to verify the proper alignment.

Remove the scaler and inspect both the scaler and the inside of the gauge body. Verify that the electronics are clean, dry, and undamaged. If all electronic connections are solid re-attach the scaler.

2.4 The M/D gauge should be sufficiently charged to allow for four hours of continuous operation. Do not charge the gauge unless it has indicated that it needs a charge. However, if in doubt let the batteries run down and then apply a full 14 hour charge.

2.5 If the Pre-Calibration Inspection has been completed and all necessary repairs have been accomplished the calibration check can begin. If the gauge has been returned from Staff Materials then this inspection has already been performed.

3. APPARATUS

3.1 CDOT calibration check blocks are located at Staff Materials – Nuclear Lab (for Region 1 only).

3.2 Region 2-5, calibration check blocks of:

3.2.1 Moisture Cal-Check Stand,
3.2.2 1/2" Polyethylene Sheet,
3.2.3 3/4" Polyethylene Sheet,
3.2.4 Low-Density Concrete Block,
3.2.5 Medium-Density Concrete Block,
3.2.6 High-Density Concrete Block,

3.3 CDOT Form #1151: NUCLEAR EQUIPMENT STATISTICAL STABILITY / DRIFT TEST.

3.4 CDOT NUCLEAR EQUIPMENT CALIBRATION CHECK WORKSHEET (Regions 2 - 5).

3.5 CDOT NUCLEAR EQUIPMENT MOISTURE/DENSITY ANNUAL CHECK SHEET. (Region 1).

3.6 M/D gauge and reference standard block that have passed the pre-calibration check inspection.

3.7 Operators shall wear a personnel dosimeter, have the gauge binder with all of the required documentation, and a calculator.

4. CALIBRATION CHECK PROCEDURE

4.1 STATISTICAL STABILITY TEST

4.1.1 The M/D gauge should be turned on allowing the electronics to warm up for a 30 minute period before proceeding.

4.1.2 For Regions 2 - 5, the reference standard block shall be placed upon the High-Density Transmission block and centered. The long axis of the reference standard block should match that of the cal-check block, with the butt plate end being in the front. There must be at least one meter of clearance on all sides of this block. For Region 1 the reference standard block shall be placed on the Magnesium/Aluminum block.

4.1.3 Place the M/D gauge on the reference standard block. Follow Manufacturer instructions for reference standard block placement. The scaler end is toward the front of the blocks.

4.1.4 Complete the reference information on the NUCLEAR EQUIPMENT STATISTICAL STABILITY TEST, CDOT Form 1151 (page 1 of 2). Write the date, operator, CDOT No., model of gauge, gauge #, and serial #.

4.1.5 Perform the Statistical Stability Test. Most gauges will 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 model gauges 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 3430 and 3440 gauges is 0.25, with acceptable limits of 0.17 to 0.33.

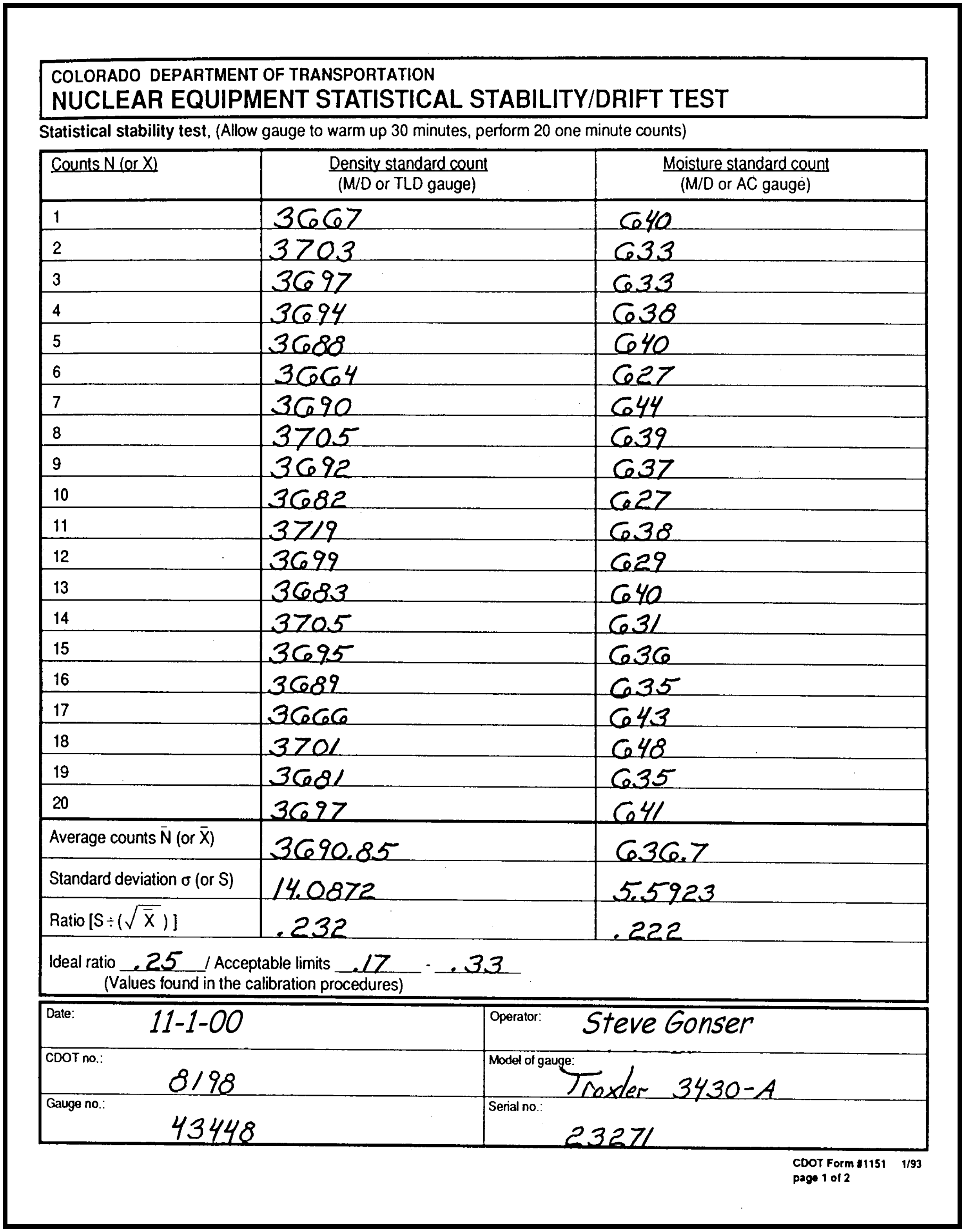
For Troxler 3450 gauges; record the density counts for both systems. The ideal ratio is 0.354 with acceptable limits of 0.225 to 0.465.

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

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

The acceptable limits on Instrotek 3500 gauges are 0.18 to 0.35.

4.1.6 If the gauge passes the statistical stability test proceed with the calibration check. 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 proceed with the calibration check.



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	3667	640
2	3703	633
3	3697	633
4	3694	638
5	3688	640
6	3664	627
7	3690	644
8	3705	639
9	3692	637
10	3682	627
11	3719	638
12	3699	629
13	3683	640
14	3705	631
15	3695	636
16	3689	635
17	3666	643
18	3701	648
19	3681	635
20	3697	641
Average counts $\bar{N}$ (or $\bar{X}$)	3690.85	636.7
Standard deviation σ (or S)	14.0872	5.5923
Ratio $[S \div (\sqrt{\bar{X}})]$	.232	.222

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

Date: 11-1-00	Operator: Steve Gonser
CDOT no.: 8198	Model of gauge: Troxler 3430-A
Gauge no.: 43448	Serial no.: 23271

CDOT Form #1151 1/93
page 1 of 2

CDOT Form # 1151

4.2 EQUIPMENT STANDARDIZATION

4.2.1 Center the reference standard block on the High-Density Concrete block. The long axis of the reference standard block should match that of the block, with the butt plate being in the front.

4.2.2 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.

4.3 MOISTURE CALIBRATION CHECK

[REGIONS 2 - 5]

4.3.1 Complete the reference information on the CDOT NUCLEAR EQUIPMENT CALIBRATION CHECK WORKSHEET. This information is the same as the information provided on CDOT Form 1151.

4.3.2 Set up the moisture cal-check stand in an area with a meter of clearance on all sides. Set the 1/2" Polyethylene sheet within the stand. The sheet should be marked, such as FR for front-right, because repeatability can only be attained through minimizing variables.

4.3.3 Place the gauge on the 1/2" Polyethylene sheet within the outline. Place the gauge in the backscatter position and record four one-minute moisture content readings [Note 1]. Average the four readings and record the average

Note 1: Gauges may report moisture contents as percent moisture. Prompt the gauge to report moisture content in pounds per cubic foot of water.

4.3.4 Place the 3/4" Polyethylene sheet beneath the 1/2" sheet within the stand. The sheet should also be marked to ensure consistency.

4.3.5 Place the gauge on the 3/4" Polyethylene sheet within the outline. Place the gauge in the backscatter position and record four one-minute moisture content readings [Note 1]. Average the four readings and record the average

[REGION 1]

4.3.6 Follow Subsections 4.3.1 through 4.3.3 of Colorado Procedure L 5306.

4.4 BACKSCATTER CALIBRATION CHECK [REGIONS 2 - 5]

4.4.1 Place the gauge on the Low-Density Concrete 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 attains near contact with the block surface. 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.

4.4.2 Place the gauge on the Medium-Density Concrete 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 High-Density Concrete Block.

[REGION 1]

4.4.3 Follow Subsections 4.4.1 through 4.4.2 of Colorado Procedure L 5306. The only deviation to CP-L 5306 will be not utilizing the Limestone and the Granite blocks.

4.5 TRANSMISSION CALIBRATION CHECKS [REGIONS 2 - 5]

4.5.1 Place the gauge on the Low-Density Concrete 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 3]. Average the four readings and record the average.

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 3]. 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 3]. Average the four readings and record the average.

Note 3: 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.

4.5.5 Repeat procedures 4.5.2 through 4.5.4 on the Medium-Density and High-Density Blocks.

[REGION 1]

4.5.6 Follow Subsections 4.5.1 through 4.5.5 of Colorado Procedure L 5306. The only deviation to CP-L 5306 will be not utilizing the Limestone and the Granite blocks.

COLORADO DEPARTMENT OF TRANSPORTATION
NUCLEAR EQUIPMENT CALIBRATION CHECK WORKSHEET

CDOT Equipment No. 8257	Serial No. 34551	Gauge No. (consultant) 33448	Type of Gauge (Model) 3430
Moisture Standard Count 703	Density Standard Count 2960	Circle One	Post Calibration Check One Year Check

	Moisture Block 1/2" Readings (Wet PCF)
1 min.	4.2
1 min.	4.2
1 min.	4.1
1 min.	4.1
Average	4.2

	Moisture Block 1/2" & 3/4" Readings (Wet PCF)
1 min.	27.1
1 min.	27.5
1 min.	27.6
1 min.	27.1
Average	27.3

Check Date
1/25/2006

Operator

	L Block Readings	M Block Readings	H Block Readings
	0 Inches	**0 Inches**	**0 Inches**
1 min.	104.5	134.6	150.8
1 min.	105.0	134.8	150.3
1 min.	104.5	136.0	150.9
1 min.	104.6	136.3	150.5
Average	104.7	134.9	150.6
Error			
	4 Inches	**4 Inches**	**4 Inches**
1 min.	103.6	129.9	147.5
1 min.	103.6	129.9	147.4
1 min.	103.8	130.2	147.7
1 min.	103.6	130.2	147.9
Average	103.7	130.1	147.6
Error			
	6 Inches	**6 Inches**	**6 Inches**
1 min.	103.1	128.3	147.1
1 min.	103.1	128.3	147.0
1 min.	103.1	128.6	146.7
1 min.	103.2	128.3	147.3
Average	103.1	128.4	147.0
Error			
	8 Inches	**8 Inches**	**8 Inches**
1 min.	103.5	127.4	146.5
1 min.	103.5	127.5	146.4
1 min.	103.4	127.5	146.2
1 min.	103.5	127.1	146.2
Average	103.5	127.4	146.3
Error			

4.6 DRIFT TEST

4.6.1 The M/D gauge should be on and active a minimum of 3 hours after the completion of the Statistical Stability Test. If a calibration check has been performed, a minimum of three hours has passed, with the gauge extremely active.

4.6.2 The reference standard block shall be placed upon the High-Density Block and centered. Establish the same placement that existed during the stat test. For Regions 1and 6 the reference standard block shall be placed on the Magnesium/Aluminum block..

4.6.3 NUCLEAR EQUIPMENT DRIFT TEST, CDOT Form #1151 (page 2 of 2), will be used to record the respective counts.

4.6.4 Perform the Drift Test. Most 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 model gauges 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 Instrotek 3500 and Troxler 3430, 3440 and 3450 gauges 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:

$$\text{SSAC} \pm 2.0\sqrt{\text{SSAC}}$$

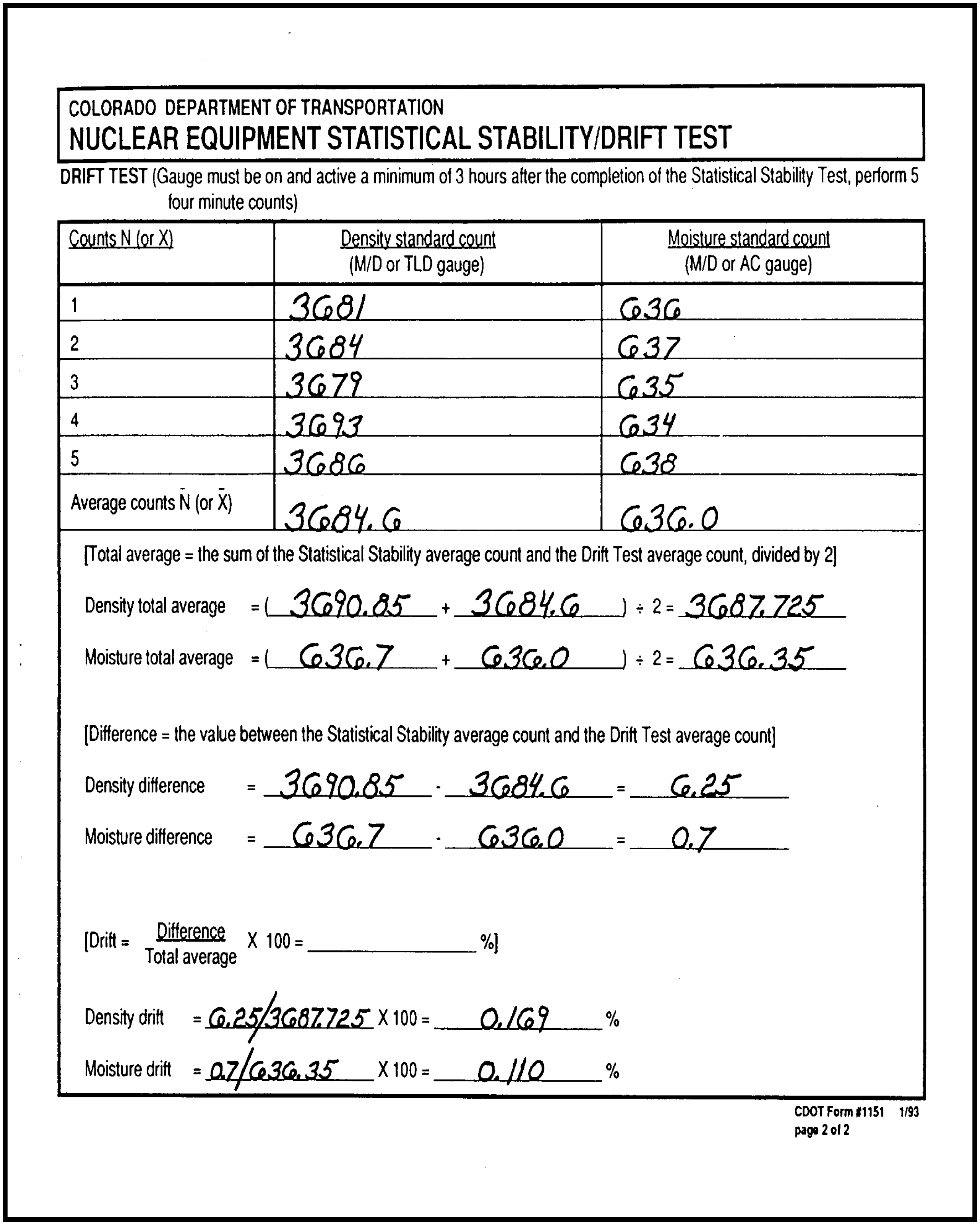
4.6.5 If the M/D gauge passes the drift test, then proceed to Subsection 4.7. If the gauge fails the drift test, verify the mathematics. If the failure is valid perform another drift test, whereby a second failure will require the equipment to be repaired.

4.7 ANALYSIS OF CALIBRATION CHECK

4.7.1 If this calibration check has been performed after a Calibration at Staff Materials, check your PCF of water and PCF of each of the three density blocks against the established ranges of other gauges. If the gauge falls outside of the range, contact Staff Materials-Nuclear Lab.

4.7.2 If this calibration check has been performed on an "off" year, the values need to be compared against the previous year's calibration check. The moisture content and wet density readings will be compared to the block's moisture contents and densities that were established after the Calibration. The acceptable deviance from the 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.

4.7.3 If the gauges 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 calibrated.



COLORADO DEPARTMENT OF TRANSPORTATION

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	3681	636
2	3684	637
3	3679	635
4	3693	634
5	3686	638
Average counts $\bar{N}$ (or $\bar{X}$)	3684.6	636.0

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

Density total average = (3690.85 + 3684.6) ÷ 2 = 3687.725

Moisture total average = (636.7 + 636.0) ÷ 2 = 636.35

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

Density difference = 3690.85 - 3684.6 = 6.25

Moisture difference = 636.7 - 636.0 = 0.7

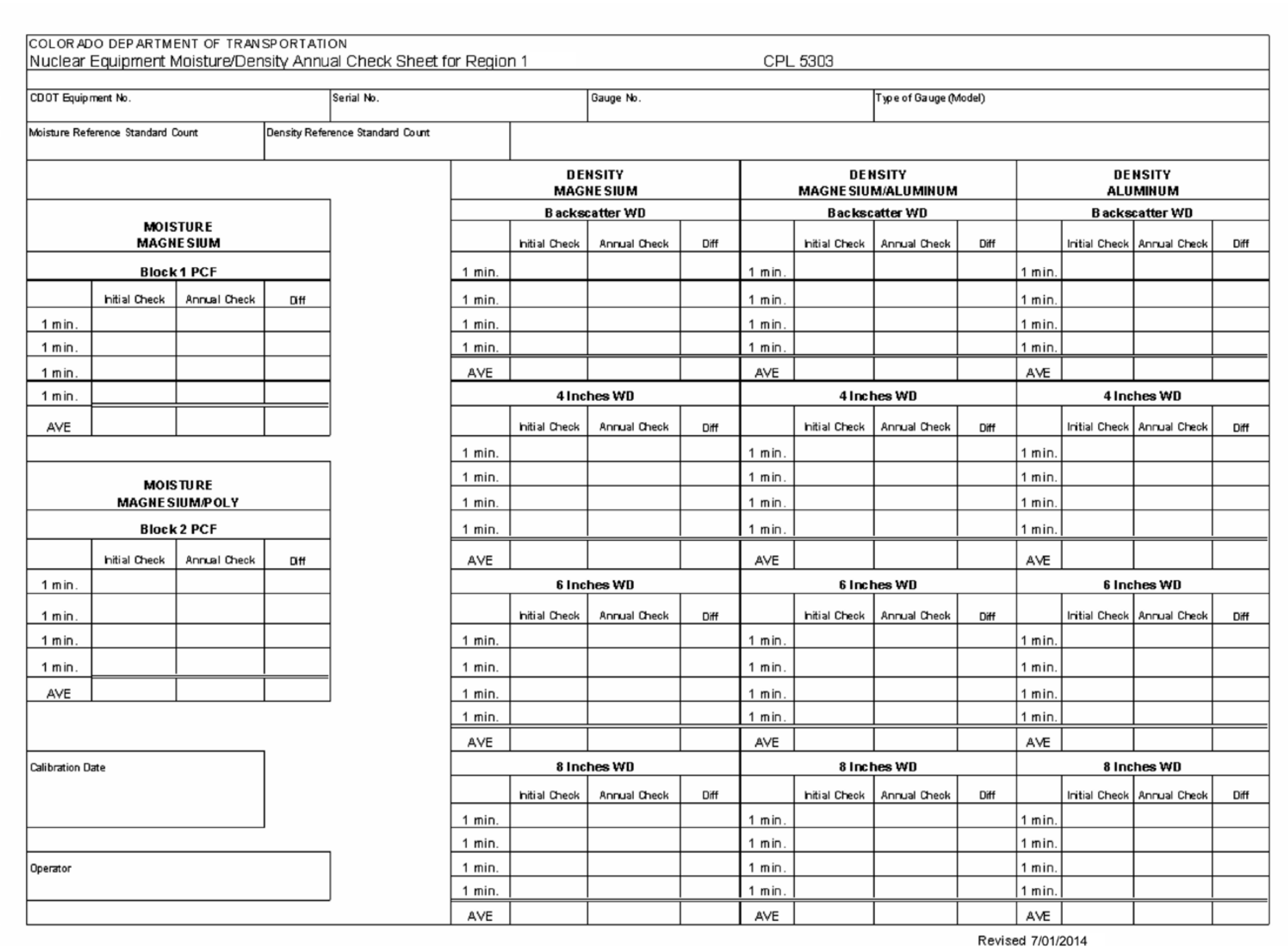
[Drift = $\frac{\text{Difference}}{\text{Total average}}$ X 100 = ________ %]

Density drift = 6.25/3687.725 X 100 = 0.169 %

Moisture drift = 0.7/636.35 X 100 = 0.110 %

CDOT Form #1151 1/93
page 2 of 2

CDOT Form 1151



COLORADO DEPARTMENT OF TRANSPORTATION

Nuclear Equipment Moisture/Density Annual Check Sheet for Region 1 CPL 5303

CDOT Equipment No.	Serial No.	Gauge No.	Type of Gauge (Model)
Moisture Reference Standard Count	Density Reference Standard Count		

MOISTURE
MAGNESIUM

Block 1 PCF

	Initial Check	Annual Check	Diff
1 min.			
1 min.			
1 min.			
1 min.			
AVE			

MOISTURE
MAGNESIUM/POLY

Block 2 PCF

	Initial Check	Annual Check	Diff
1 min.			
1 min.			
1 min.			
1 min.			
AVE			

Calibration Date

Operator

DENSITY MAGNESIUM				DENSITY MAGNESIUM/ALUMINUM				DENSITY ALUMINUM			
Backscatter WD				**Backscatter WD**				**Backscatter WD**			
	Initial Check	Annual Check	Diff		Initial Check	Annual Check	Diff		Initial Check	Annual Check	Diff
1 min.				1 min.				1 min.			
1 min.				1 min.				1 min.			
1 min.				1 min.				1 min.			
1 min.				1 min.				1 min.			
AVE				AVE				AVE			
4 Inches WD				**4 Inches WD**				**4 Inches WD**			
	Initial Check	Annual Check	Diff		Initial Check	Annual Check	Diff		Initial Check	Annual Check	Diff
1 min.				1 min.				1 min.			
1 min.				1 min.				1 min.			
1 min.				1 min.				1 min.			
1 min.				1 min.				1 min.			
AVE				AVE				AVE			
6 Inches WD				**6 Inches WD**				**6 Inches WD**			
	Initial Check	Annual Check	Diff		Initial Check	Annual Check	Diff		Initial Check	Annual Check	Diff
1 min.				1 min.				1 min.			
1 min.				1 min.				1 min.			
1 min.				1 min.				1 min.			
1 min.				1 min.				1 min.			
AVE				AVE				AVE			
8 Inches WD				**8 Inches WD**				**8 Inches WD**			
	Initial Check	Annual Check	Diff		Initial Check	Annual Check	Diff		Initial Check	Annual Check	Diff
1 min.				1 min.				1 min.			
1 min.				1 min.				1 min.			
1 min.				1 min.				1 min.			
1 min.				1 min.				1 min.			
AVE				AVE				AVE			

Revised 7/01/2014

CDOT NUCLEAR EQUIPMENT CALIBRATION CHECK WORKSHEET for REGION 1

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Colorado Procedure – Laboratory 5304-16

Standard Method of Test for

Calibration of CDOT Nuclear Thin Layer Density Gauges

Deleted 3-10-2016

Colorado Procedure – Laboratory 5305-15

Standard Method of Test for

Leak Wipe Analysis for Nuclear Gauges

1. SCOPE

1.1 The Colorado Department of Public Health & Environment requires that all nuclear gauges be leak wiped. This condition within the Colorado Department of Transportation's Radioactive Materials License is set forth to enable the licensee to detect the presence of removable radioactive contamination. Leak wipes are also performed if a nuclear gauge is involved in an accident or if any CDOT personnel possess an unexplainably high radioactive exposure on their personnel dosimeters. Leak wipes are performed by the Region On-site RSOs using CP-L 5301 and submitted to CDOT Staff Materials and Geotechnical Branch's Nuclear Lab for analysis.

2. APPARATUS

2.1 Ludlum Model 2929 Dual Channel Scaler with 43-10-1 Detector. Make sure the annual calibration is up to date.

2.2 Leak Test Wipes Report completed by region on-site RSOs.

2.3 Leak Wipe Envelope with leak wipe filter paper enclosed.

2.4 Forceps

2.5 2.0 inch diameter aluminum planchet.

2.6 Leak Wipe Report Form.

2.7 High Voltage Adjustment Form.

3. HIGH VOLTAGE ADJUSTMENT

3.1 Connect the cable to the 43-10-1 detector and power on the Ludlum 2929 and allow to warm up for five minutes.

3.2 Determine the current activity of the calibration standards using the following formula:

$$A_t = A_o\, e^{\frac{-0.693t}{t_{\frac{1}{2}}}}$$

Where:

A_t =Current activity in decays per minute (dpm)

A_o = Original activity in dpm

t = Age of standard in months

$t_{\frac{1}{2}}$ = Half-life of standard in months

Examples:

For the AM-241 standard on August 1, 2001

A_o = 17.3 Bq or 1038 dpm on August 5, 1986

(1 Bq=1 decay per second)

t = 15 years or 180 months

$t_{\frac{1}{2}}$ = 458 years or 5496 months

$$A_t = 1038e\frac{-0.693*180}{5496} = 1015dpm$$

For the CS-137 on August 1, 2001

A_o = 14.5 Bq or 870 dpm on August 12,1986

t = 15 years or 180 months

$t_{\frac{1}{2}}$ = 30 years or 360 months

$$A_t = 870e\frac{-0.693*180}{360} = 615dpm$$

3.3 Set the HV knob to 600 volts. The knob will have a setting of 2.40.

3.4 Place a new planchet in the sample chamber. Close and lock the sample chamber.

3.5 Perform and record a one-minute count. These counts are the background counts. Make sure to record both the alpha and beta counts.

3.6 Increase the voltage by 25 volts and repeat the procedure in Subsection 3.5 until the voltage reaches 900 volts. Every 0.10 on the knob is 25 volts.

3.7 Remove the planchet from the sample chamber and using the forceps place the CS-137 standard on a new planchet with the engraved side down. Place the planchet in the sample chamber. Close and lock the sample chamber.

3.8 Set the voltage to 600 volts. Perform and record a one-minute count. Make sure to record both the alpha and beta counts.

3.9 Increase the voltage by 25 volts and repeat the procedure in Subsection 3.5 until the voltage reaches 900 volts.

3.10 Remove the CS-137 standard and planchet and place the AM-241 standard on a new planchet with the engraved side down. Place the planchet into the sample chamber. Close and lock the sample chamber.

3.11 Set the voltage to 600 volts. Perform and record a one-minute count. Make sure to record both the alpha and beta counts.

3.12 Increase the voltage by 25 volts and repeat the procedure in Subsection 3.5 until the voltage reaches 900 volts.

3.13 Calculate the CS-137 (beta source) efficiency and the AM-241 (alpha source) efficiency where:

$$\text{efficiency} = \frac{\text{cnts} - \text{bkgrd cnts}}{\text{current activity}}$$

Definition:
counts- cnts
background-bkgrd

3.14 Calculate the CS-137 cross-talk where: $\text{crosstalk} = \frac{\text{alpha cnts} - \text{alpha bkgrd cnts}}{\text{beta cnts} - \text{beta bkgrd cnts}}$

3.15 Calculate the AM-241 cross-talk where: $\text{crosstalk} = \frac{\text{beta cnts} - \text{beta bkgrd cnts}}{\text{alpha cnts} - \text{alpha bkgrd cnts}}$

3.16 Pick the high voltage setting using the following criteria:

a) CS-137 2pi efficiency is greater than or equal to 28.00%.
b) AM-241 2pi efficiency is greater than or equal to 30.00%.
c) CS-137 cross-talk is less than or equal to 1.0%
d) AM-241 cross-talk is less than or equal to 10.0%
e) Alpha background count is less than 3 cpm
f) Beta background count is less than 80 cpm

When more than one voltage setting meets all the above criteria pick the one with the lowest AM-241 cross-talk.

4. LEAK WIPE ANALYSIS

4.1 The legal limit for removable radioactive material on a sealed source is 0.005 micro curies (µCi) or 11,100 dpm. The desired Lower Limit of Detection (LLD) is 0.00005 µCi. Use the following equation to determine the Alpha and Beta counting times for the desired LLD:

$$Count\ Time = \frac{2\sqrt{2} * 1.645\sqrt{bkgrd\ cnt}}{LLD * Efficiency\ * 2{,}220{,}000}$$

Round the calculated count time to the next whole minute and use the larger of the Alpha or Beta count times.

4.2 Take and average ten background counts at the voltage selected in Subsection 3.16 with a new planchet and a clean filter paper to calculate the LLD using the following equation:

$$LLD = \frac{2\sqrt{2}\ *\ 1645\sqrt{Bkgrd\ Cnt}}{Cnt\ Time *\ Efficiency\ *\ 2{,}220{,}000}$$

4.3 Calculate and record the alpha and beta cpm for 0.00005 µCi of contamination where:

$$alpha = 111 * AM - 241\ efficiency + alpha\ bkgrd\ cpm$$

$$beta = 111 * CS - 137\ efficiency + beta\ bkgrd\ cpm$$

Multiply the alpha and beta counts per minute by the count time determined in the procedure in Subsection 4.1. Any test with counts below these would be reported as 0.00005 µCi

4.4 Set the high voltage to the setting selected in Subsection 3.16 and the count time to the count time selected in Subsection 4.1.

4.5 Select an envelope and record the leak wipe test number on the Leak Wipe Report Form.

4.6 Open the envelope and with the tweezers place the filter paper on a new planchet with the "dirty" side up.

4.7 Place the planchet in the sample chamber. Close and lock the sample chamber

4.8 Perform and record a count. Make sure to record both alpha and beta counts. If the Alpha counts are lower than the Alpha counts for 0.00005 µCi, report 0.00005 µCi for Alpha. If the Beta counts are lower than the Beta counts for 0.00005 µCi, report 0.00005 µCi for Beta. If the counts are higher than the count for 0.00005 µCi then use the following equations to determine the measured activity:

$$Alpha\ \mu Ci = \frac{Alpha\ cnt - Alpha\ bkgrd\ cnt}{2{,}220{,}000 * cnt\ time * Am - 241\ efficiency}$$

$$Beta\ \mu Ci = \frac{Beta\ cnt - Beta\ bkgrd\ cnt}{2{,}220{,}000 * cnt\ time * Cs - 137\ efficiency}$$

4.9 If the measured activity is greater than 0.005 µCi, check your math and if it is still above 0.005 µCi rerun the test. If it still is above 0.005 µCi notify the CDOT RSO immediately

4.10 Remove the planchet from the sample chamber and place the filter paper back in the envelope with the tweezers.

4.11 Repeat the procedures in Subsections 4.4 through 4.9 until all leak wipes have been tested.

4.12 If the leak wipe analysis is not completed in one day then for each additional day of testing use the voltage determined in the procedure in Subsection 3.16 and perform and record a one-minute background count. Perform the calculations in the procedure in Subsection 4.3 and repeat the procedures in Subsections 4.4 through 4.10 until all leak wipes have been tested.

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Colorado Procedure – Laboratory 5306-20

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) 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:

$$\mathbf{SSAC \pm 2.0\sqrt{SSAC}}$$

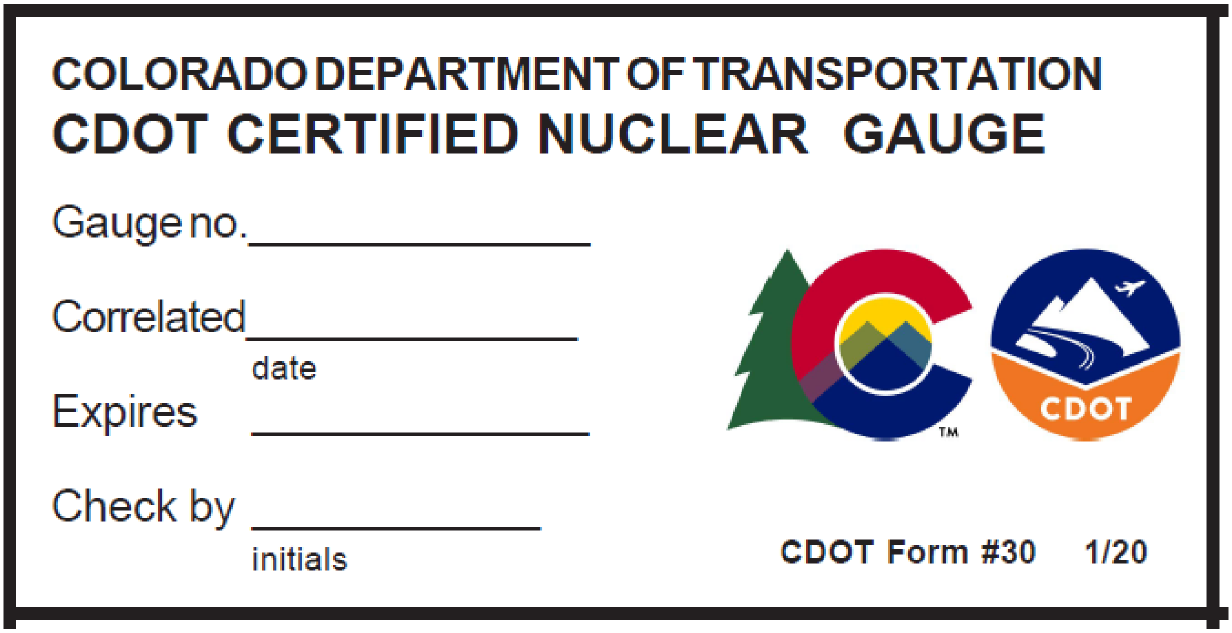
4.6.5 If the gauge fails the drift test then verify the mathematics. If the mathematics are correct, perform a second drift test. A second failure will require the equipment to be repaired.

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

CDOT CERTIFIED NUCLEAR GAUGE

Gauge no.________________

Correlated________________

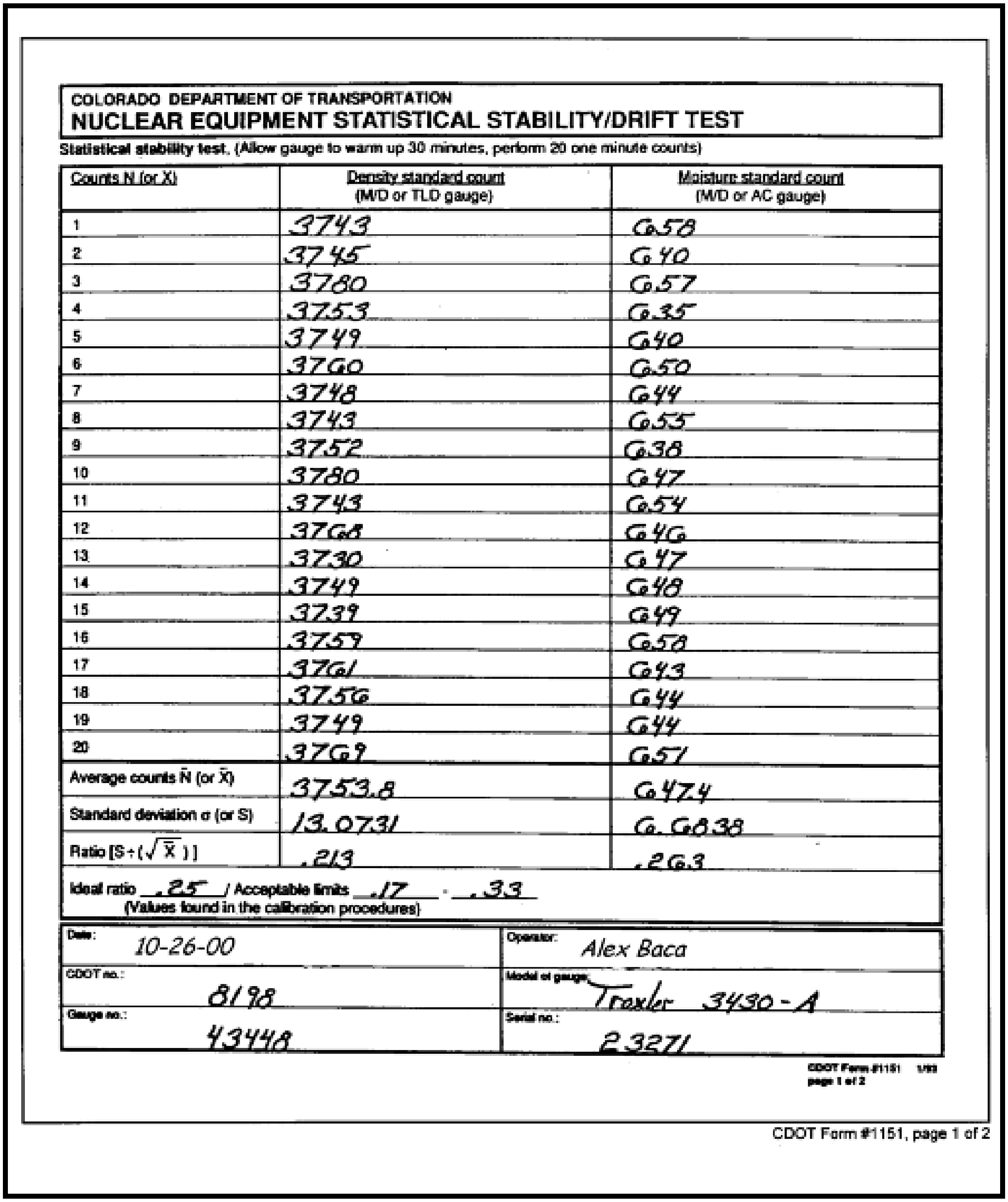
date

Expires ________________

Check by ______________

initials

CDOT Form #30 1/20



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	658
2	3745	640
3	3780	657
4	3753	635
5	3749	640
6	3760	650
7	3748	644
8	3743	655
9	3752	638
10	3780	647
11	3743	654
12	3768	646
13	3730	647
14	3749	648
15	3739	649
16	3759	658
17	3761	643
18	3756	644
19	3749	644
20	3769	651
Average counts $\bar{N}$ (or $\bar{X}$)	3753.8	647.4
Standard deviation σ (or S)	13.0731	6.6838
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, Page 1

COLORADO DEPARTMENT OF TRANSPORTATION

Nuclear Equipment Moisture/Density Certification Sheet

Moisture Standard Count 647

Density Standard Count 3753

Serial No. 32145

Gauge No. (consultant) CON-1

Type of Gauge (Model) Troxler 3430

	Magnesium Block Moisture Content
1 min.	0.1
1 min.	0.1
1 min.	0.2
1 min.	0.2
Average	0.2
Deviation	

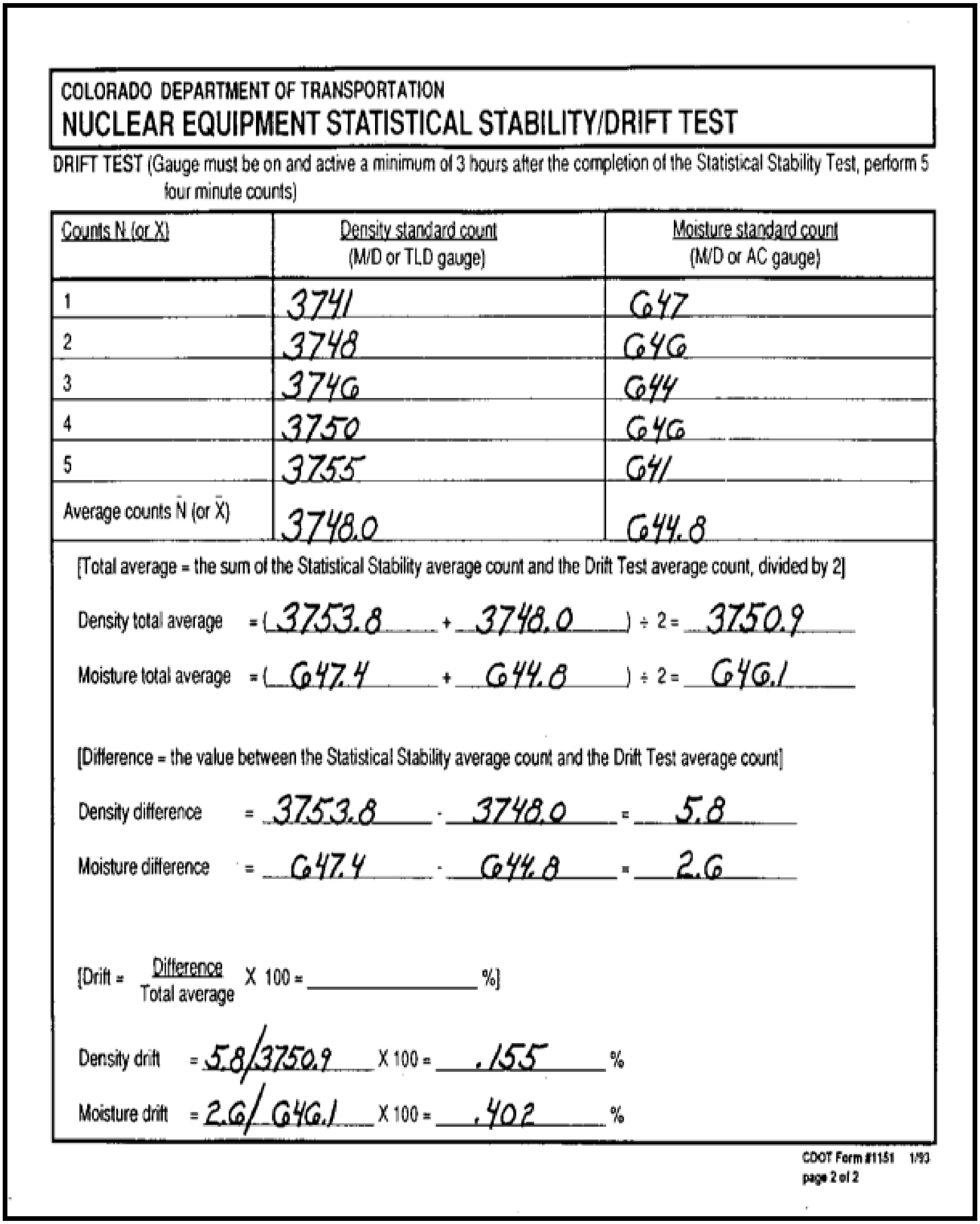
	Magnesium/Poly Block Moisture Content
1 min.	34.5
1 min.	33.7
1 min.	35.4
1 min.	34.8
Average	34.6
Deviation	

Certification Date 8/14/2004

Operator John Smith

	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.	109.9	135.6	145.8	161.7	161.4
1 min.	108.1	133.9	146.7	159.7	158.3
1 min.	110.5	136.4	143.6	159.4	159.4
1 min.	107.0	134.0	143.1	162.4	159.7
Average	108.9	135.0	144.8	160.8	159.7
Deviation					
	4 Inches	4 Inches	4 Inches	4 Inches	4 Inches
1 min.	110.8	135.9	145.0	162.7	162.1
1 min.	110.1	134.9	142.9	162.4	162.4
1 min.	108.4	134.8	146.5	162.5	162.1
1 min.	109.7	135.0	147.0	161.9	160.9
Average	109.8	135.2	145.4	162.4	161.9
Deviation					
	6 Inches	6 Inches	6 Inches	6 Inches	6 Inches
1 min.	107.9	136.0	147.2	161.4	161.5
1 min.	108.6	136.1	145.1	161.2	161.2
1 min.	108.9	135.7	145.3	161.9	161.3
1 min.	109.0	136.4	145.9	160.9	162.0
Average	108.6	136.1	145.9	161.4	161.5
Deviation					
	8 Inches	8 Inches	8 Inches	8 Inches	8 Inches
1 min.	108.8	134.9	146.8	160.9	161.7
1 min.	109.0	135.6	146.2	160.8	161.5
1 min.	110.0	134.5	145.1	161.2	161.7
1 min.	110.5	136.2	145.3	160.9	161.2
Average	109.6	135.3	145.9	161.0	161.5
Deviation					

CDOT Nuclear Equipment Moisture / Density Certification Worksheet.



COLORADO DEPARTMENT OF TRANSPORTATION

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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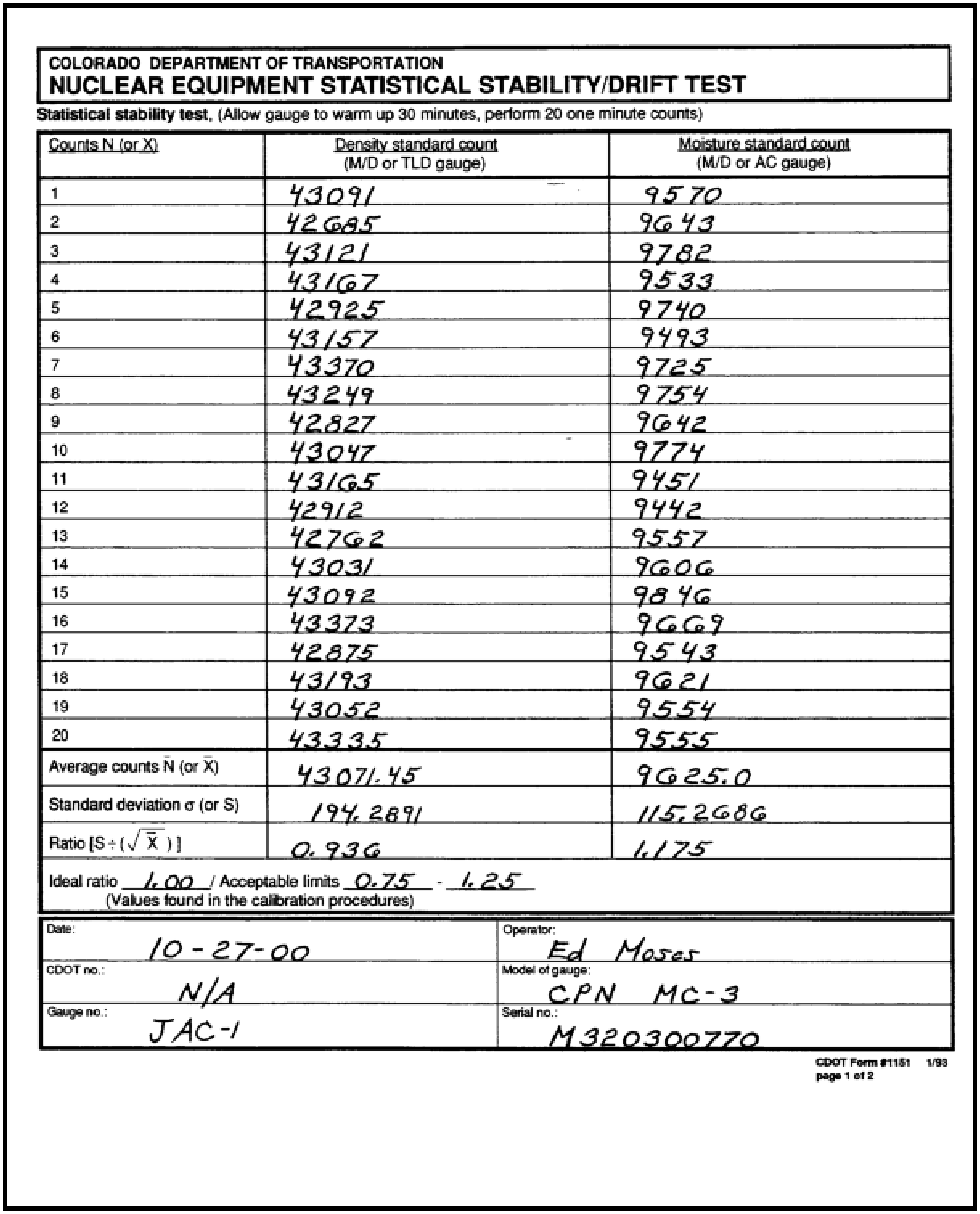
CDOT Form 1151, Page 2



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	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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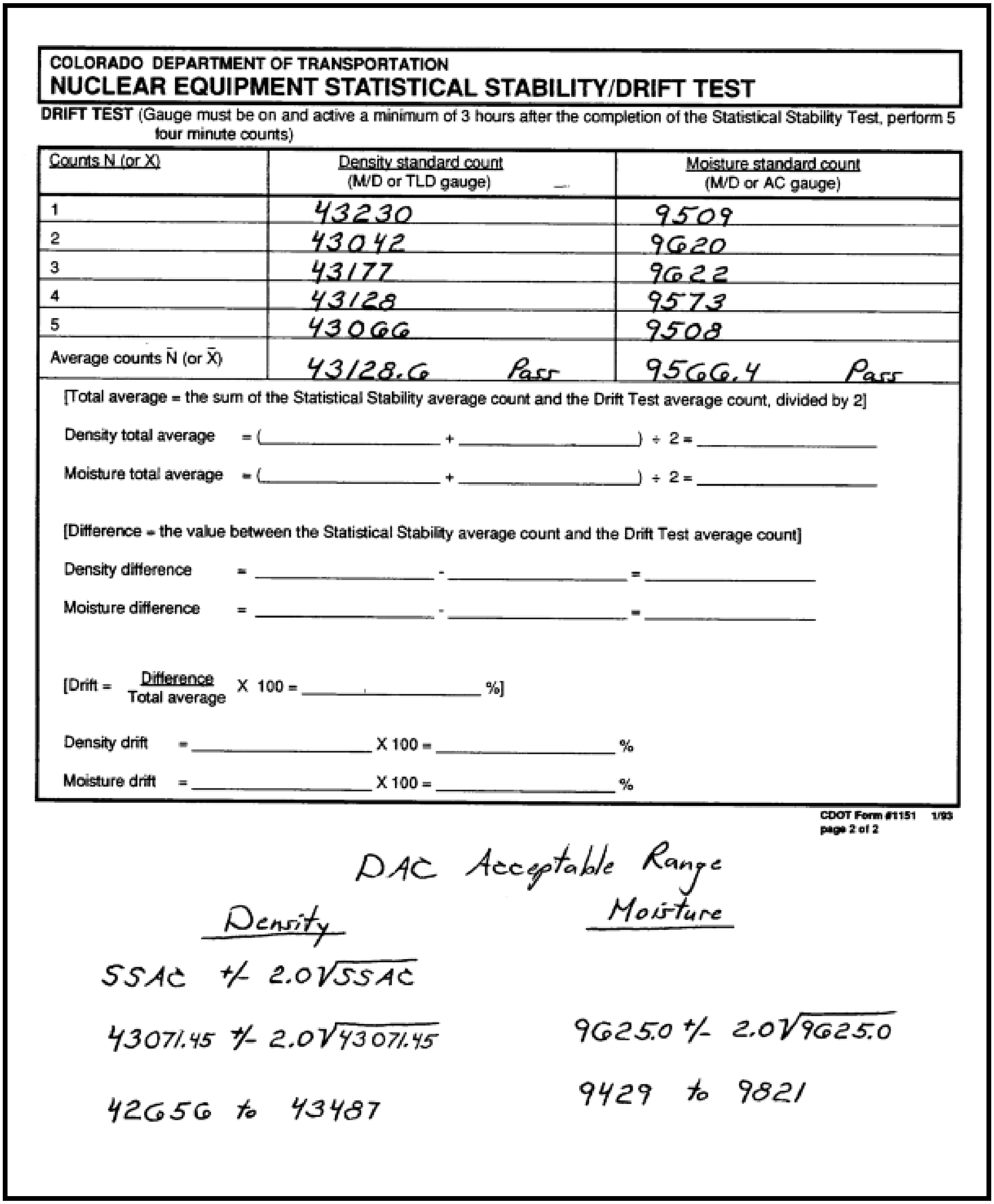

COLORADO DEPARTMENT OF TRANSPORTATION

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 = __________ - __________ = __________

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

Density drift = __________ X 100 = __________ %

Moisture drift = __________ X 100 = __________ %

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DAC Acceptable Range

Density	Moisture
SSAC +/- 2.0$\sqrt{SSAC}$	
43071.45 +/- 2.0$\sqrt{43071.45}$	9625.0 +/- 2.0$\sqrt{9625.0}$
42656 to 43487	9429 to 9821

CDOT Form 1151, Page 2

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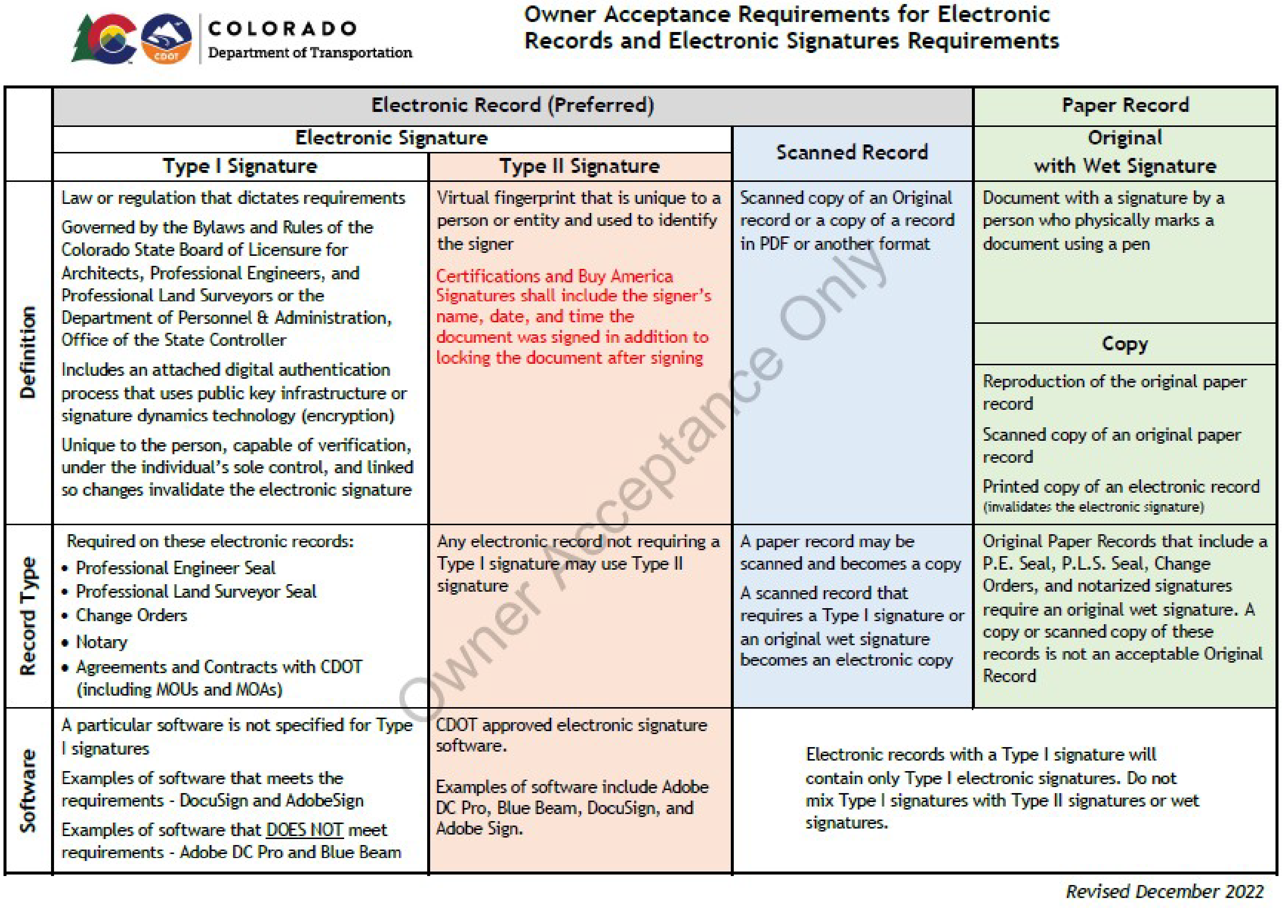
CDOT Project/Materials Electronic Documentation - 24

CDOT is transitioning toward accepting all submittals, forms, project records, and supporting documents in electronic format. This Manual reflects technology as of 7/01/2020. Users should work in partnership with CDOT staff to continue to advance this effort in between Manual updates. Please refer to the Owner Acceptance Requirements for Electronic Records and Electronic Signature Guidelines below.

Also refer to: CDOT Standards and Specifications Section 105.08, Document Management and Professional Engineer and Professional Land Surveyor Electronic Seals.



COLORADO
Department of Transportation

Owner Acceptance Requirements for Electronic Records and Electronic Signatures Requirements

	Electronic Record (Preferred)			Paper Record
	Electronic Signature		Scanned Record	Original with Wet Signature
	Type I Signature	Type II Signature		
Definition	Law or regulation that dictates requirements Governed by the Bylaws and Rules of the Colorado State Board of Licensure for Architects, Professional Engineers, and Professional Land Surveyors or the Department of Personnel & Administration, Office of the State Controller Includes an attached digital authentication process that uses public key infrastructure or signature dynamics technology (encryption) Unique to the person, capable of verification, under the individual's sole control, and linked so changes invalidate the electronic signature	Virtual fingerprint that is unique to a person or entity and used to identify the signer Certifications and Buy America Signatures shall include the signer's name, date, and time the document was signed in addition to locking the document after signing	Scanned copy of an Original record or a copy of a record in PDF or another format	Document with a signature by a person who physically marks a document using a pen
				Copy
				Reproduction of the original paper record Scanned copy of an original paper record Printed copy of an electronic record (invalidates the electronic signature)
Record Type	Required on these electronic records: • Professional Engineer Seal • Professional Land Surveyor Seal • Change Orders • Notary • Agreements and Contracts with CDOT (including MOUs and MOAs)	Any electronic record not requiring a Type I signature may use Type II signature	A paper record may be scanned and becomes a copy A scanned record that requires a Type I signature or an original wet signature becomes an electronic copy	Original Paper Records that include a P.E. Seal, P.L.S. Seal, Change Orders, and notarized signatures require an original wet signature. A copy or scanned copy of these records is not an acceptable Original Record
Software	A particular software is not specified for Type I signatures Examples of software that meets the requirements - DocuSign and AdobeSign Examples of software that DOES NOT meet requirements - Adobe DC Pro and Blue Beam	CDOT approved electronic signature software. Examples of software include Adobe DC Pro, Blue Beam, DocuSign, and Adobe Sign.	Electronic records with a Type I signature will contain only Type I electronic signatures. Do not mix Type I signatures with Type II signatures or wet signatures.	

Revised December 2022

1. Description of Bentley Software Tools and Adobe Sign

Adobe Sign

Adobe Sign is the electronic signature and professional seal software selected by CDOT and required for use on Project Records including CDOT Form 90 Change Modification Orders (CMO), which facilitates automated workflows including the ability to route Project Records for acknowledgments, electronically sealing, and/or signing. DocuSign is the electronic signature program selected for use on a document requiring a CDOT Controller or State Controller signature (contracts)

Deliverables Management

CDOT uses a series of tools in the Bentley suite for design, construction, and engineering documents. One of them is ProjectWise Deliverables Management. This is a cloud-based service that streamlines how a project team works with transmittals, submittals, and Requests for Information (RFI). It provides improved visibility into these processes and retains confidentiality when legally required.

ProjectWise Deliverables Management is utilized to ensure that documents are submitted, completed, and processed on schedule. Functions include ensuring delivery to correct parties, enabling faster reviews and responses, automating an audit trail thereby increasing accountability with detailed recordkeeping, connecting the entire supply chain through a secure cloud platform, and leveraging project dashboards to monitor workflows and evaluate project performance. ProjectWise Deliverables Management is capable of handling reference files used in design.

Bentley Client Connect

The Cloud-based software tool hosted in the Bentley / Microsoft Azure Cloud is used for document collaboration. Project Share connects to and synchronizes with ProjectWise Explorer, such that files placed in a Project Share folder, which is synchronized with ProjectWise Explorer, are automatically copied to the same folder in ProjectWise Explorer. Note that Project Share is not used for DGN reference files in design.

ProjectWise Explorer

Bentley Client Connect (PW Connection) Explorer is the Electronic Document Management System (EDMS) for all active project electronic project records outlined in the CDOT Record File Plans.

2. Definitions (Please also use the Definitions in the PDs if they are necessary for your Manual. The PDs are available in Word format in the Workshop Documents folder)

Adobe Acrobat DC. The software selected by CDOT and required for users to create and/or modify a PDF (portable document format) Project Record, to retain a record in an ISO Compliant format. By using Adobe Acrobat DC tools, the software "Smart Scans" Project Records to meet state and federal legal requirements before archiving in ProjectWise Explorer used for Type 2 signatures.

Adobe Sign. The Type 1 electronic signature and professional seal software selected by CDOT and required for use on Project Records that require a Professional Engineer, Professional Architect, or Land Surveyor Seal such as Final Material Certification and Explanation of Exceptions (CDOT Forms 473 & 474). Also used for the Form 90 for Change Orders, which facilitates automated workflows including the ability to route Project Records for acknowledgments, electronically sealing, and/or signing.

Local Agency Records

On Local Agency projects with CDOT oversight, Local Agencies follow their record retention schedules that adhere to the Inter-Governmental Agreement with CDOT. However, specific documents in the CDOT Record File Plans are required to be retained by CDOT and must be provided to the CDOT Local Agency Coordinator by the local agency or its representative. Refer to CDOT records management for Local Agency record requirements.

Local Agency E-Signature Guidelines

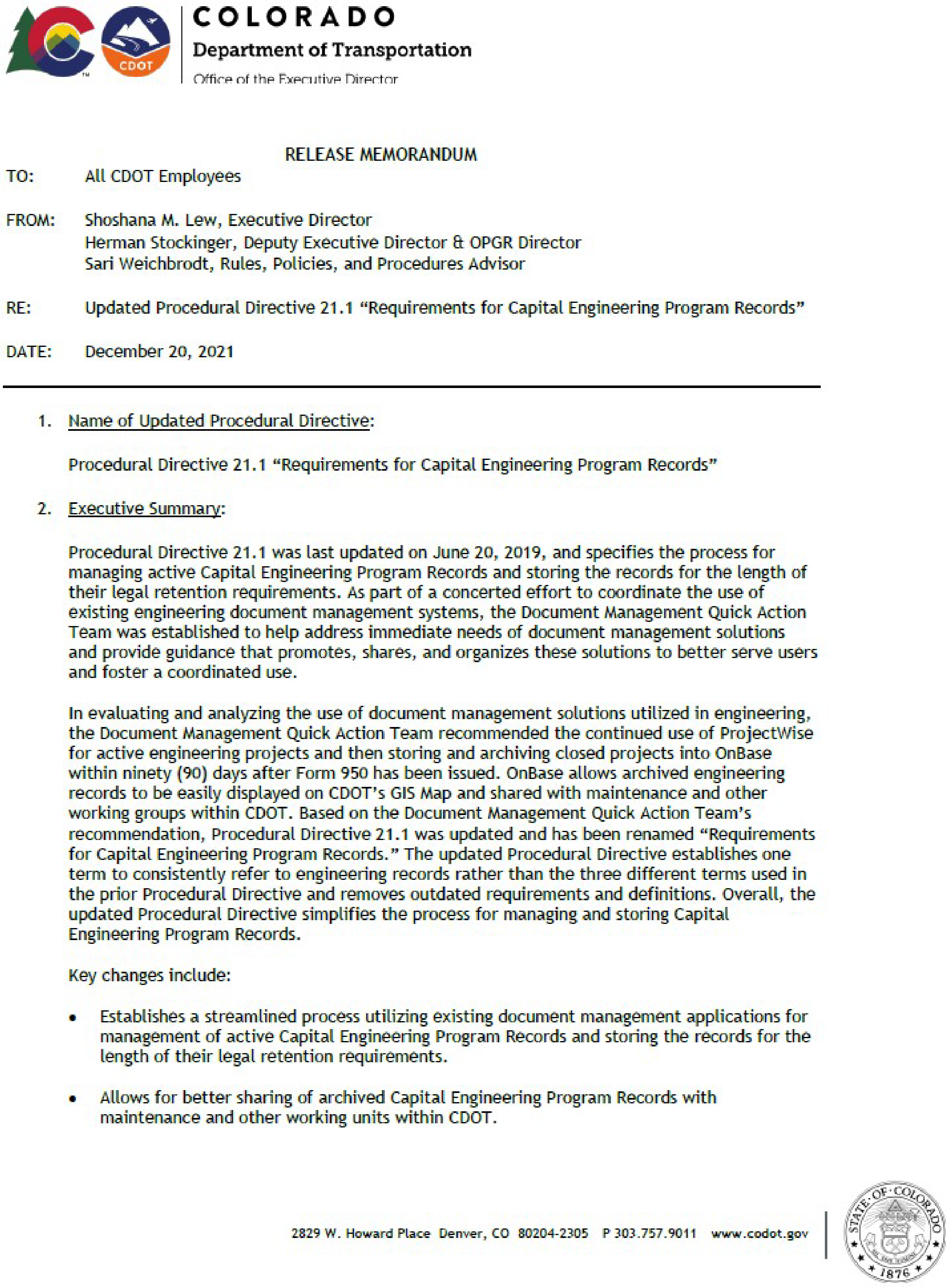
5. Procedural Directive (PD) 508.1 "Requirements for the Use of the Professional Engineer's Seal"

General Description

PD 508.1 defines the procedures for the use of the Professional Engineer seal by CDOT employees, consultants, contractors, and local agencies who perform engineering work for CDOT.

All CDOT, local agencies, and consulting Engineers must utilize electronic sealing (rather than mechanical sealing on paper). CDOT has designated CDOT employees will use Adobe Sign for electronic Seals.

6. Updated Procedural Directive 21.1 "Requirements for Capital Engineering Program Records"



COLORADO
Department of Transportation
Office of the Executive Director

RELEASE MEMORANDUM

TO: All CDOT Employees

FROM: Shoshana M. Lew, Executive Director
Herman Stockinger, Deputy Executive Director & OPGR Director
Sari Weichbrodt, Rules, Policies, and Procedures Advisor

RE: Updated Procedural Directive 21.1 "Requirements for Capital Engineering Program Records"

DATE: December 20, 2021

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1. Name of Updated Procedural Directive:

   Procedural Directive 21.1 "Requirements for Capital Engineering Program Records"

2. Executive Summary:

   Procedural Directive 21.1 was last updated on June 20, 2019, and specifies the process for managing active Capital Engineering Program Records and storing the records for the length of their legal retention requirements. As part of a concerted effort to coordinate the use of existing engineering document management systems, the Document Management Quick Action Team was established to help address immediate needs of document management solutions and provide guidance that promotes, shares, and organizes these solutions to better serve users and foster a coordinated use.

   In evaluating and analyzing the use of document management solutions utilized in engineering, the Document Management Quick Action Team recommended the continued use of ProjectWise for active engineering projects and then storing and archiving closed projects into OnBase within ninety (90) days after Form 950 has been issued. OnBase allows archived engineering records to be easily displayed on CDOT's GIS Map and shared with maintenance and other working groups within CDOT. Based on the Document Management Quick Action Team's recommendation, Procedural Directive 21.1 was updated and has been renamed "Requirements for Capital Engineering Program Records." The updated Procedural Directive establishes one term to consistently refer to engineering records rather than the three different terms used in the prior Procedural Directive and removes outdated requirements and definitions. Overall, the updated Procedural Directive simplifies the process for managing and storing Capital Engineering Program Records.

   Key changes include:

   - Establishes a streamlined process utilizing existing document management applications for management of active Capital Engineering Program Records and storing the records for the length of their legal retention requirements.
   - Allows for better sharing of archived Capital Engineering Program Records with maintenance and other working units within CDOT.

2829 W. Howard Place Denver, CO 80204-2305 P 303.757.9011 www.codot.gov

- Establishes an automatic process to transfer Capital Engineering Program Records from ProjectWise to OnBase.

- Other minor changes were made to the Procedural Directive.

3. Offices to Contact with Questions:

   The Office of Policy and Government Relations at 303.757.9441 or sari.weichbrodt@state.co.us.
   The Records Management Program at 303.512.4905 or tammi.haddad@state.co.us.

4. Effective Date of Updated Procedural Directive: December 20, 2021

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APPENDIX A- SAMPLE PROCESSING PROCEDURE-21

Samples which are received, tested, and reported by the STAFF MATERIALS LABORATORY, are processed in the following manner:

IDENTIFICATION

All materials and samples must be logged-in at the receiving dock. Samples must be identified as to:

- DATE RECEIVED
- ITEM NUMBER
- PROJECT NUMBER
- PROJECT CODE
- NUMBER OF SAMPLES

SELECTION

The selection of samples is handled by field project personnel. Staff Materials is responsible for the testing of samples submitted by field personnel. The only exceptions to this are samples of asphalt cement and liquid asphalt. In this case, one sample out of five is selected at random. If this sample meets specifications, the other four are discarded. If not, the other four samples are tested and reported.

CONDITIONING

Samples which require conditioning will be conditioned per the appropriate test procedure.

STORAGE

Samples will be stored in the proper environment prior to testing. An example of this is concrete cylinders, which must be stored (cured) in a 100% humidity environment.

RETENTION

Samples of all materials will be retained until no further question remains as to the properties of the material.

DISPOSAL

All materials which are not hazardous will be placed in the large trash container immediately adjoining the Laboratory. Materials which are hazardous will be handled per Staff Materials procedure for handling hazardous materials.

APPENDIX B - DEFINITIONS

Note: Definitions applicable to a specific material can be found in the respective chapter.

Acceptance Program:

All factors that comprise CDOT's determination of the quality of the product as specified in the contract requirements. These factors include verification sampling, testing, and inspection.

Accredited Laboratory:

A laboratory that is accredited by the AASHTO Accreditation Program.

Batch:

A unit or subdivision of a lot, such as a mixer load of concrete, a batch of bituminous mix, or a square yard of base course.

Bias:

Constant error in one direction, which causes the average test result to be offset from the true average value.

Central Laboratory Check Samples and Tests:

Random representative samples submitted to CDOT's Central and/or Region Laboratory to additionally evaluate quality of field produced products and materials, and to perform tests not within the capabilities of the Field and/or Region Laboratories.

Check Sample:

A Replicate Sample, usually from Project Samples or Verification Samples, which is submitted to the Central or Region Laboratory for an independent check. Independent checks on HBP include: Hveem Stability (CP-L 5105), Lottman (CP-L 5109), and Air Voids (CP-L 5105). For Superpave mixes S, SX, and SG independent checks include: volumetric properties at N_{design} and Hveem Stability (CP-L 5106). The purpose of these samples is for the Central or Region Laboratory to verify acceptability and quality of field produced material and to perform tests that are not within the capabilities of the field.

Coefficient of Variation:

The Standard Deviation divided by the mean.

$$CV = \delta/\overline{x}$$

Comparative Sample:

One of several samples resulting from a closely controlled small Batch or increment which has been thoroughly mixed and then reduced by quartering or splitting into a number of Replicate Samples. For CDOT purposes the Central Laboratory will make Groups of Comparative Samples on various materials. One or more will be sent to each participating Region Laboratory for testing to determine acceptability of procedures, methods, and equipment.

Control Chart:

Chart or graph, usually conspicuously displayed in the field materials laboratory where an up-to-date plot of Control and Verification Test results is kept.

Control Sample:

A sample taken during the process from any of the components for a manufactured (constructed) product before being incorporated into the final mixture, or a sample taken from the final mixture or product before the material has reached its final position and condition in the completed construction.

Designated Agent:

An employee or employees of the State, local agency, or a consultant or independent laboratory which is employed, paid by, and / or directly accountable to CDOT or a public agency excluding the contractors' or vendors' personnel.

Group:

Replicate Test Specimens taken from the same Batch Sample.

Independent Assurance Program (IA):

Activities that are unbiased and an independent evaluation of all the sampling and testing procedures and testing equipment, and in some cases the witnessing of certain specified samples and sampling techniques used in the acceptance program.

Independent Assurance Sampling-Testing and Witnessing of Testing or Sampling:

A sample taken and tested, or a sample that is witnessed only at a random location or time, the point to be designated by: Region Laboratory personnel, or project personnel, or CDOT's designated agent not associated with Project Verification Sampling and Testing; or the Contractor's (or his representative) not associated with Project Quality Control Sampling and Testing; or by an FHWA Engineer. The person who designates the point for sampling and who performs the actual test may physically do the sampling or project testing personnel may do the sampling in the presence of the IA person. Certain specified IA samples may be witnessed only. These samples are to be taken in the presence of both the project and IA personnel. These samples shall be taken by contractor's personnel or his representative. For more details and information, see the CDOT, Quality Assurance Program for Construction and Materials Sampling and Testing.

Lot:

An isolated quantity of material from a single source. A measured amount of construction material assumed to be produced by the same process.

Nominal Maximum:

The size of aggregate is the smallest sieve opening through which the entire amount of aggregate is permitted to pass.

Note: For Item 403, Nominal / Maximum size should be defined as: one sieve size larger than the first sieve to retain more than ten percent of the aggregate.

Owner Acceptance (OA): All those planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality.

Owner Verification Testing (OVT): All those planned and systematic testing verifications necessary to provide confidence that a product or service will satisfy given requirements for quality.

Practice:

A definitive procedure for performing one or more specific operations or functions that does not produce a test result.

Precision:

A generic concept related to the closeness of agreement between test results obtained under prescribed like conditions from the measurement process being evaluated.

Proficiency Samples:

Homogeneous samples that are distributed and tested by two or more laboratories.

Process Control (PC): All contractor/vendor operational techniques and activities that are performed or conducted to fulfill contract requirements

***Quality Assurance* (QA):**
All those planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality.

***Quality Control* (QC):**
All contractor/vendor operational techniques and activities that are performed or conducted to fulfill contract requirements.

Qualified Laboratories:

Laboratories that participate in a qualification program, approved by CDOT that shall include provisions for checking testing equipment and maintaining records of all equipment calibrations and equipment checks. All testing equipment used to conduct testing shall conform to the standards specified in the testing procedure.

Random Sample:
A sample drawn from a Lot in which each increment in the lot has an equal probability of being chosen.

Random Sample, Stratified:
When a Lot is subdivided into approximately equal Sub-lots and samples are selected from each sub-lot by a Random process.

Reasonable Conformance:
When construction and materials substantially comply with the plans and specifications. Clearly stated acceptance plans assist the Project Engineer in making his decision as to reasonable conformance.

Repeatability:
The range within which repeated measurements are made by the same operator on the same apparatus on Replicate Test Specimens. Essentially, the precision of the test.

Replicate Samples or Test Specimens:
Multiple Samples or Test Specimens as nearly identical as possible, under the stated conditions, usually from a thoroughly mixed larger sample that has been reduced in size by quartering or splitting.

Reproducibility:
The range within which check measurements by different operators on different apparatus should agree under definitely stated conditions. Usually performed on Test Specimens from Replicate Samples.

Sample:
A small part of a Sub-lot or Batch, which represents the whole. A sample may be divided into several Test Specimens.

***Standard Deviation* (σ):**
A measure of the dispersion of measurements from their average; the square root of the quantity of individual deviations from the mean, squared, summed, and divided by the number of samples.

$$\sigma = \sqrt{\frac{\Sigma(X - X)^2}{N}}$$

State personnel:

An employee or employees of CDOT.

Sub-lot:

The largest, clearly identifiable subdivision of a Lot. Usually specified in the Field Materials Manual Sampling Schedule as the largest quantity that may be represented by a single sample.

System Basis, IA:

A system where the minimum frequency is based on a unit of material production and/or a unit of time.

Test Method:

A definitive procedure for the identification, measurement, and evaluation of one or more qualities, characteristics, or properties of a material, product, system or service that produces a test result.

Test Specimen:

That part of a Sample actually tested. Usually obtained by reducing the Sample by quartering, splitting, or taking an aliquot (usually a liquid portion removed from the whole) quantity.

Variation:

Differences, due to any cause, in measured values of a measurable characteristic.

Vendor:

A supplier of materials incorporated into the project, which is not the contractor. May or may not be the Manufacturer.

Verification Sampling and Testing:

Sampling and testing performed to validate the quality of the product for acceptance.

Verification Sample:

A sample used to make a decision as to the acceptability of the material being sampled. Reasonable Conformance and amount of payment will be based on this sample. The specifications designate the point of verification sampling. Refer to the Schedule.

APPENDIX C - ACRONYMS

3R	Resurfacing, Restoration, Rehabilitation
AAP	AASHTO Accreditation Program
AASHTO	American Association of State Highway and Transportation Officials
ABC	Aggregate Base Course
ACI	American Concrete Institute
ACPA	American Concrete Pavement Association
ACPA	American Concrete Pipe Association
AI	Asphalt Institute
AIF	Asphalt Industry Forum
AMRL	AASHTO Materials Reference Laboratory
APA	Asphalt Pavement Analyzer
APL	Approved Product List
ARA	Asphalt Rejuvenating Agent
ASTM	American Society of Testing and Materials
ATSSA	American Traff1c Safety Services Association
BMP	Best Management Practices
CAGE	Colorado Association Geotechnical Engineers
CAPA	Colorado Asphalt Pavement Association
CBC	Concrete Box Culvert
CCA	Colorado Contractors Association
CCRL	Cement and Concrete Reference Laboratory
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CFR	Code of Federal Regulations
CIP	Complete-in-Place
CIPR	Cold-in-Place Recycle
CIR	Cold-in-Place Recycle
COC	Certificate of Compliance
CMO	Contract Modification Order
CP	Colorado Procedure
CP-L	Colorado Procedure – Laboratory
CPM	Counts Per Minute
CRS	Colorado Revised Statutes
CRSI	Concrete Reinforcing Steel Institute
CTP	Check Testing Program
CTR	Certified Test Reports

CTS	Compaction Test Section
D/A	Dust to Asphalt
DMS	Dynamic Message Sign
DRB	Dispute Resolution Board
DSR	Dynamic Shear Rheometer
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPE	Expert Product Evaluator
FAA	Fine Aggregate Angularity
FAPG	Federal Aid Policy Guide
FDR	Full Depth Reclamation
FHWA	Federal Highway Administration
FIPI	Finding In the Public Interest
FIR	Field Inspection Review
FMM	Field Materials Manual
FOR	Final Office Review
FPOG	Flexible Pavement Operators Group
FQC	Field Quality Control
FWD	Falling Weight Deflectometer
HAZMAT	Hazardous Material
HBP	Hot Bituminous Pavement
HIPR	Hot-in-Place Recycle
HIR	Hot-in-Place Recycle
HITEC	Highway Innovative Technology Evaluation Center
HMA	Hot Mix Asphalt
HRI	Half-Car Roughness Index
HSP	High Speed Profiler
IA	Independent Assurance Program
IAT	Independent Assurance Sampling and Testing
I/D P	Incentive/Disincentive Payment
IGA	Inter-Governmental Agreement
IRI	International Roughness Index
JMF	Job Mix Formula
JSA	Job Safety Analysis
LabCAT	Laboratory for Certification of Asphalt Technicians
LA	Local Agency
LACA	Local Agency Certification Acceptance
LCCA	Life Cycle Cost Analysis

LIMS	Laboratory Information Management System
LMTP	Laboratory Manual of Test Procedures
LOI	Loss on Ignition
LOS	Level of Service
MAC	Materials Advisory Committee
MCR	Minor Contract Revision
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MQL	Moving Quality Level
SDS	Safety Data Sheets
MUTCD	Manual on Uniform Traffic Control Devices
NCAT	National Center for Asphalt Technology
NCHRP	National Cooperative Highway Research Program
NDT	Non-Destructive Testing
NEPA	National Environmental Protection Act
NHS	National Highway System
NICET	National Institute for Certification of Engineering Technologies
NIST	National Institute of Standards and Technology
NOV	Notice of Violation
NPCA	National Precast Concrete Association
NPS	Non-Project Specific
NTPEP	National Transportation Product Evaluation Program
OGFC	Open Grade Friction Course
OA	Owner Acceptance
OVT	Owner Verification Testing
PCCP	Portland Cement Concrete Pavement
PEC	Product Evaluation Coordinator
PF	Pay Factor
PG	Performance Graded
PPM	Parts Per Million
ProMIS	Project Management Information System
PS&E	Plans, Specifications and Estimate
PSI	Preliminary Site Investigation
QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
QCP	Quality Control Plan
QIC	Quality Implementation Council
QL	Quality Level

QML	Qualified Manufacturers List
QPM	Quality Pavement Management
RAP	Reclaimed Asphalt Pavement (previously Recycled)
RAS	Reclaimed Asphalt Shingles
RE	Resident Engineer
RECP	Rolled Erosion Control Product
RMAEC	Rocky Mountain Asphalt Education Center
RME	Region Materials Engineer
ROD	Record of Decision
ROW	Right of Way
RSAR	Roadway Surface Accomplishment Report
RSO	Radiation Safety Officer (Nuclear Gauge Equipment)
RSO	Region Safety Officer
RTD	Region Transportation Director
RTFO	Rolling Thin Film Oven
SHRP	Strategic Highway Research Program
SMA	Stone Matrix Asphalt
SME	Subject Matter Expert
SOW	Scope of Work
SpG	Specific Gravity
SSD	Saturated Surface Dry
SUPERPAVE	Superior Performing Asphalt Pavements
TCLP	Toxicity Characteristic Leaching Procedure
TCP	Traffic Control Plan
TRM	Turf Reinforcement Mat
VCA	Voids in Coarse Aggregate
VFA	Voids Filled with Asphalt
VMA	Voids in the Mineral Aggregate
VMA	Viscosity Modifying Admixture
VTM	Voids in Total Mix
WASHTO	Washington Association of State Highway and Transportation Officials
WAQTC	Western Alliance for Quality Transportation Construction
WCTG	Western Cooperative Test Group

APPENDIX D - METRIC CONVERSION TABLES

Conversion Factors - U.S. to Metric S.I.

Quantity	U.S.	Metric Unit (SI)	Multiply by
Length	mile	kilometer (km)	1.609 344
	yard	meter (m)	0.914 4
	foot	meter (m)	0.304 8
	foot	millimeter (mm)	304.8
	inch	millimeter (mm)	25.4
Area	acre	Hectares (ha)	0.404 685 6
	square yard	square meter (m^2)	0.836 127 36
	square foot	square meter (m^2)	0.092 903 04
	square inch	square millimeter (mm^2)	645.16
Volume	cubic yard	cubic meter (m^3)	0.764 555
	cubic foot	cubic meter (m^3)	0.028 316 8
	cubic inch	cubic millimeter (mm^3)	16 387.064
	gallon	Liter (L)	3.785 41
Mass	ton	metric ton (t)	0.907 184
	pound	kilogram (kg)	0.453 592
	ounce	gram (g)	28.3495
Temperature	°Fahrenheit	°Celsius	(°F-32) 5/9
Pressure	psi	kilopascals (kPa)	6.894 76

Conversion Factors - Metric S.I. to U.S.

Quantity	**Metric Unit (SI)**	**U.S.**	**Multiply by**
Length	kilometer (km)	mile	0.621 371
	meter (m)	yard	1.093 6
	meter (m)	foot	3.280 84
	millimeter (mm)	foot	0.003 28
	millimeter (mm)	inch	0.039 37
Area	Hectares (ha)	acre	2.471 054
	square meter (m2)	square yard	1.195 99
	square meter (m2)	square foot	10.763 91
	square millimeter (mm2)	square inch	0.001 55
Volume	cubic meter (m3)	cubic yard	1.307 95
	cubic meter (m3)	cubic foot	35.314 72
	cubic millimeter (mm3)	cubic inch	0.000 061
	Liter (L)	gallon	0.264 172
Mass	metric ton (t)	ton	1.102 31
	kilogram (kg)	pound	2.204 62
	gram (g)	ounce	0.035 274
Temperature	°Celsius	°Fahrenheit	(°C x 1.8) + 32
Pressure	kilopascals (kPa)	psi	0.145 038

Metric Decimal Prefixes

Prefix	Magnitude	Expression
kilo	10^3	1000 (one thousand)
milli	10^{-3}	0.001 (one thousandth)

For a more information on Metric S.I. units see CDOT's *Metric Conversion Manual.* Other good reference include AASHTO R1-91 and ASTM E 380-92.

Sieve Sizes English - Metric

English **Metric**	
3"	76.2 mm
2 1/2“	63.5 mm
2 “	50.8 mm
1 1/2 ”	38.1 mm
1 “	25.4 mm
3/4 “	19.0 mm
1/2 “	12.7mm
3/8 “	9.51 mm
# 4	4.75 mm
# 8	2.36 mm
# 16	1.18 mm
# 30	600 mu
# 50	300 mu
# 100	150 mu
# 200	75 mu

APPENDIX E - MATERIALS TESTING ACCURACY CRITERIA

The following table is the official testing accuracy criteria for the Colorado Department of Transportation and shall be strictly adhered to.

		MEASURE TO NEAREST	**REPORT TO NEAREST**
SOILS	Sieve Analysis		
	(Except -#200)	1.0 g	1%
	Minus No. 200	0.1 g	0.1%
	Atterberg Limits	0.01 g	1%
	Density	-----	0.1 lb/ft^3 (1 kg/m^3)
	Relative Compaction	0.1 lb/ft^3 (1 kg/m^3)	0.1%
	Moisture Content		
	D/M Gauge	0.1 lb/ft^3 (1 kg/m^3)	0.1%
	Dry Weight	0.1 g	0.1%
BASE AGGREGATES	Sieve Analysis		
	(Except -#200)	1.0 g	1%
	Minus No. 200	0.1 g	0.1%
	Atterberg Limits	0.1 g	1%
	Density	-----	0.1 lb/ft^3 (1 kg/m^3)
	Relative Compaction	0.1 lb/ft^3 (1 kg/m^3)	0.1%
	Moisture Content		
	D/M Gauge	0.1 lb/ft^3 (1 kg/m^3)	0.1%
	Dry Weight	0.1 g	0.1%
CONCRETE	Sieve Analysis		
	(Except -#200)	1.0 g	1%
	Minus No. 200	0.1 g	0.1%
	(*)Sand Equivalent	0.1	1 (*)
	Moisture in Aggregate	0.1 g	0.1%
	Air Content	-----	0.1%
	Fineness Modulus	-----	0.01
	Slump	-----	1/4 inch (5 mm)
	Compressive Strength	1 psi (0.01 MPa)	10 psi (0.1 MPa)
	Flexural Strength	1 psi (0.01 MPa)	5 psi (0.05 MPa)
	Thickness	0.05 in (1.3 mm)	0.1 in (2.5 mm)

BITUMINOUS PVMT.	Moisture in Mix	0.1 g	0.01%
	Sieve Analysis		
	(Except -#200)	1.0 g	1%
	Minus No. 200	0.1 g	0.1%
	Asphalt Content		
	(CP-L 5120)	0.1 g	0.01%
	(CP 85)	1.0 g	0.01%
	Hveem Stability	-----	1
	Voids in Mineral Aggregate	-----	0.1%
	Air Voids	-----	0.1%
	Lottman TSR	-----	1%
	Lottman Wet TS	1 lb.f (1 N)	1 psi (1 KPa)
	Lottman Dry TS	1 lb.f (1 N)	1 psi (1 KPa)
	Filler	0.1 g	0.1%
	Specific Gravity	0.1 g	0.001
	Specific Gravity D/M Gauge	-----	0.001
	Relative Compaction	0.01	0.1%

(*)Report to the next highest whole number per CP 37.

APPENDIX F – JOB SAFETY ANALYSIS (JSA) – MATERIALS INDEX

The following documents are intended to assist with the safe implementation and interpretation of the AASHTO, ASTM, CDOT Miscellaneous, Colorado Procedures, and Colorado Procedures for Laboratory Testing.

Job Safety Analysis (JSA) documents are posted on CDOT's Materials and Geotechnical web site at the address of http://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/jsa The JSA's shall be reviewed and updated.

Questions or perceived errors should be directed to the applicable Region Materials Engineer or Program Manager within the Central Laboratory. The following test methods and procedures have applicable JSAs or are under development.

AASHTO Test Methods:

- R 28
- T 59
- T 84
- T 85
- T 90
- T 96
- T 190
- T 240
- T 313
- T 331
- T 334

ASTM Test Methods:

- A 370 (Rebar)
- A 370 (Strand)
- C 39
- C 78
- C 114
- C 138 / C 231
- C 143
- C 151
- C 185
- C 452
- C 496
- C 535
- C 617
- C 1260
- D 244

CDOT Miscellaneous:

- Continuous Sampler Penetration
- FWD Testing
- Hard Rock Coring
- Soil (Auger) Drilling
- Soil Profile
- Standard Penetration Test

CP Test Methods:

- CP 20
- CP 21
- CP 30
- CP 31
- CP 31A / CP 31B
- CP 32
- CP 34 / CP 35
- CP 34
- CP 37
- CP 41A
- CP 41B
- CP 41C
- CP 43
- CP 44
- CP 45
- CP 46
- CP 51
- CP 53
- CP 55
- CP 58
- CP 61
- CP 66
- CP 67
- CP 68
- CP 80
- CP 81
- CP 82
- CP 85

CP-L Test Methods:

- CP-L 2103
- CP-L 2104
- CP-L 2212
- CP-L 3101
- CP-L 3103
- CP-L 4209
- CP-L 4211
- CP-L 4301
- CP-L 4302
- CP-L 5106
- CP-L 5109
- CP-L 5115
- CP-L 5120
- CP-L 5301
- CP-L 5302 / CP-L 5304
- CP-L 5303
- CP-L 5305
- CP-L 5305

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