



SUBCOMMITTEE ON MATERIALS
2016 Annual Meeting – Greenville, SC
Thursday, August 4, 2016
10:15 am-12:00 pm EST
TECHNICAL SECTION 2b
Asphalts

I. Call to Order and Opening Remarks

II. Membership

For those in attendance at the meeting see Appendix B.

Voting Members	
Blackburn, Lyndi D	Alabama
Paye, Barry C	Wisconsin
Burch, Paul	Arizona
Schiebel, Bill R	Colorado
Connery, James P.	Connecticut
Khan, Wasi U	District of Columbia
Bukowski, John R	FHWA
Ruelke, Timothy J	Florida
Wu, Peter	Georgia
Shishido, Eric	Hawaii
Pfeifer, Brian	Illinois
Kreider, Richard E.	Kansas
Myers, Allen H	Kentucky
Bradbury, Richard L	Maine
Barot, Sejal	Maryland

Grieco, John E	Massachusetts
Strizich, Matt	Montana
Tedford, Darin P	Nevada
Boisvert, Denis M.	New Hampshire
Streeter, Donald	New York State
Peoples, Christopher A	North Carolina
Ramirez, Timothy	Pennsylvania
Byrne, Michael P	Rhode Island
Egan, Brian	Tennessee
Hazlett, Darren	Texas
Andrus, Scott S	Utah
Gagulich, Mladen	Vermont
Bailey, William R	Virginia
Farley, Paul M	West Virginia
Lane, Becca	Ontario

Non-Voting Members		
Rothblatt, Evan	AASHTO	Liaison
Johnson, Brian	AMRL	Liaison
Knake, Maria	AMRL	Liaison
Lenker, Steven E.	AMRL	Member
Lutz, Robert	AMRL	Member
Arasteh, Michael	FHWA	Member
Smith, Michael Ray	FHWA	Member
Harman, Tom	FHWA	Member
Aschenbrener, Tim	FHWA	Member
Trepanier, Jim	Illinois	Member
Akisetty, Chandra K	Maryland	Member
Holt, Anne Lee	Ontario	Member
Marks, Pamela J	Ontario	Member
Gallivan, Victor Lee	Gallivan Consulting Inc.	Friend

III. Approval of Technical Section Minutes

Request discussion and approval of Mid-Year minutes from February 17, 2016 webinar meeting.

A motion was made by Maine to approve the minutes without revision. A second was made by Pennsylvania. The minutes were approved without revision.

IV. Old Business

A. SOM Ballot Items

ITEM 42 - SOM ballot item to revise M 320 to base PAV temperatures on climate when switching grades due to traffic or blending with other asphalt (RAP/RAS). See Appendix D-4 (pages 50-55) for the proposed standard and page 4 of the 2015 minutes for discussion and motion. 45 Affirmative, 0 negative, 7 No Vote. Comments from Kentucky, Massachusetts, and Oklahoma stating that footnote f is confusing. See Attachment #2 for some other potential wording. The Chair tried to propose wording to help eliminate the confusion. She also tried to add a table to help make it clearer. From Mid-year meeting, Lyndi will work on another revision to clear this up. She will email her revision out to the technical section to get comments before sending it to ballot.

[Will be published as balloted.](#)

B. TS Ballots

TS 2b-16-01 – See Appendix A for all comments.

ITEM 1 - Revise M 320, Performance-Graded Asphalt Binder, to add Note 4 to allow for extended binder grades. See attached marked up standard. 25 Affirmative, 0 Negative, 7 No Vote. Discuss comments from Kansas and Pennsylvania.

Kansas Department of Transportation (Richard E. Kreider) (richard.kreider@ksdot.org)	I suggest using the active verb tense: Note 4 —Grades outside of Table 1 or Table 2 are sometimes specified. Specify a high, low, and intermediate temperature if specified grades are beyond those listed in Table 1 or Table 2. Specify the high and low temperature grade in 6 °C increments for consistency with the PG grading system. (RAB) Change will be made editorially
Pennsylvania Department of Transportation (Timothy L Ramirez) (tramirez@pa.gov)	Affirmative with Comments: 1. The note addresses the issue without adding to the tables; however, one has to assume that the grades outside the tables are following the same specification criteria or criteria trends as the grades that are in the table. A trend would be the PAV residue criteria for DSR and the 3 degree differences as the high temp grade changes. Suggest adding a sentence to the note that states something like, "The same criteria shown in Table 1 and Table 2 will apply to the grade that is outside the grades shown in Table 1 and Table 2 except the criteria will be determined

at the high, low, and intermediate temperatures that are specifically specified."

A motion and a second was made by Pennsylvania and a second by Montana to move the standard to full SOM ballot with the note as originally balloted. The motion passed unopposed. The standard will be moved to SOM ballot as originally written.

ITEM 2 - Delete TP 78, Detecting the Presence of Phosphorus in Asphalt Binder. TP 78 is nearing the end of its life as a provisional standard. During the mid-year webinar, there was no support for adopting TP 78 as a full standard. This ballot item is to gauge the TS 2b interest in this standard. 22 Affirmative, 3 Negative, 7 No Vote. New Hampshire, Pennsylvania, and Vermont voted negative and expressed interest. Discuss moving TP 78 forward as a full standard. A motion was made by NH and a second was made by ON to move this ballot to a full standard by concurrent ballot. The motion passed unopposed.

ITEM 3 - Adopt a new provisional standard entitled, "Performance-Graded Asphalt Binder for Surface Treatments". This standard was developed for TXDOT. Attached is the proposed standard and two presentations giving background information. 24 Affirmative, 1 Negative, 7 No Vote. Comments from Maryland, New Hampshire, New York, and Tennessee (Negative).

Darren Hazlett (TX) will continue to work on this item and will report back to the TS with revisions when completed. Item is withdrawn due to negative and comments received.

TS2b-16-02 (See Appendix A)

ITEM 1 - Adopt as a provisional test method, "Determining the Fracture Energy Density of Asphalt Binder Using the Binder Fracture Energy (BFE) Test". This test method was developed in research conducted for Florida DOT. Florida DOT has requested that TS 2b consider adoption of this test method to encourage further use and research into the test method. In addition to the proposed test method, a presentation is attached from the April 18th TS 2b Webinar. The presentation gives background information on the development of the test method. 26 Affirmative, 1 Negative, 5 No Vote. Comments were received from Virginia, Pennsylvania, Georgia, Kansas, Maine, Ontario, and Texas. New York voted negative and provided extensive comments, see Appendix A. All comments were forwarded back to Florida for review and revisions as appropriate.

Comments were sent back to the researcher who developed this test procedure. The researcher and the negative voter (New York) withdrew their negative vote. Changes will be made based on comments received. A motion was made to send this standard to concurrent ballot with changes based on comments made by Florida. A second was made by New York. The motion passed unopposed.

C. Task Force Reports

Task Force 15-01 (T 48) – Task Force members are Eileen Sheehy (New Jersey) (Chair), Maria Knake (AMRL), Bill Bailey (Virginia), Jerry Peterson (Texas), and Ron Horner (North Dakota). Task Force to consider rewrite of T 48. The task force provided a draft specification for consideration. See Appendix A

The task force has provided a draft version of a standard. Previously this was a “C” standard that was a general petroleum standard. The new version is an “A” standard that is specific to Asphalt. The rates in the new standard are more forgiving.

Maine made a motion to send this revision to concurrent ballot. A second was made by Virginia. The motion passed unopposed.

Task Force 15-02 (M 320) – Task force was formed to explore the issue of extending the range of PG grades in M 320 for specialty uses. Members of the task force are Eileen Sheehy (New Jersey) (Chair), John D’Angelo (consultant), Jesus Sandoval-Gil (Arizona), Ala Mohseni (Pavement Systems), and Bill Bailey (Virginia). The task force provided revised wording that was balloted in TS 2b 2016-1. The item passed, but Lyndi was going to review the wording one more time.

Task Force 16-01 - Review ETG recommendations for elastic response, T 350, and M 332. Tanya Nash (FL), Eileen Sheehy (NJ), Barry Paye (WI), and Matt Corrigan (FHWA). Tanya left FFDOT. New task force leadership is needed to revitalize this task force. See the 2016 Mid-Year meeting minutes for details.

Corrigan (FHWA) reported on the work of the task force. The task force will continue to work on this item.

V. New Business

A. Research Proposals

Brian Egan has graciously volunteered to be our Research Liaison.

1. 20-7 RPS

- Nevada has submitted a proposal entitled, “Effect of Elevation on Rolling Thin Film Oven Aging of Asphalt Binders”. The main research objective is to provide a standardized method for adjusting RTFO times based on elevation. See Appendix A.
- 2. RPS on Recycled Tire Rubber as a Modifier in Asphalt Binders and Mixtures- A rough draft has been developed and will be reviewed by Tennessee and John D’Angelo to get something to Jack Springer before the deadline.

B. AMRL/CCRL - Observations from Assessments?

C. NCHRP Issues - Amir Hanna spoke briefly and encouraged the TS to

D. Correspondence, calls, meetings

- Email from Brian Johnson, AMRL, forwarding information from Karl Zipf, Delaware DOT – Procedure for checking the TFO/PAV pans for excessive warping, see Appendix A. A New Task force, TF 16-A was formed to review the procedures available and write a procedure for checking pans for excessive warping. Task group members: Delaware (Zipf), AI (Mike Anderson), and AMRL (Knake) to review the procedures available and write a procedure for checking pans for excessive warping.
- Email from Brian Johnson, AMRL, Timers for T201, T202, and R18: See Appendix A. It has been suggested that an interval of 6 months be considered for timers, except quartz timers. This suggestion was noted by the Tech Section but no changes to the standards are being considered at this time.
- T 240 and T 315 questions from Kathy Sokol, see Appendix A.
T240 : The single operator precision is greater than the multi-laboratory precision if your mass loss is below 0.45%. A new task force was formed, TF 16-B, to review the precision statement, review the ASTM method and more recent AMRL data. Task group members include AMRL and Virginia.
T315: Strain limits originally used were at the ends of the limits of the linear range of the material. This was done because of limitations of the DSR to reduce error. Newer DSRs

have reduced limitations. The guidance on this topic should be reviewed and revised. A new Task Force, TF 16-C, was created for this purpose. Members include: Asphalt Institute, Virginia, Nevada, John D'Angelo, Kathy Sokol

- T44: Maria Knake asked about using n-propyl bromide as a replacement for trichloroethylene. The ETG has data on this topic that they can provide. Matt Corrigan will provide the Chair with data and a recommendation for review and possible TS ballot.

E. Presentation by Industry/Academia

- Asphalt Institute REOB Guidance Document – Mike Anderson, Director of Research and Laboratory Services, Asphalt Institute
Mike Anderson from the Asphalt Institute gave a brief presentation on a new guidance document that is available on REOB. A copy of the presentation is attached to the minutes. The document is available as a free ebook and can be downloaded from AI's website.
- Jack Youtcheff (FHWA) gave a brief presentation on Delta TC from BBR data. So far they have collected data from 20 different states. They will continue to look at this data and will make a recommendation to the ETG at the next meeting. A copy of the presentation is attached to the minutes.
- Jack Spring gave a brief presentation on LTPP Bind Updates. A copy of the presentation is attached to the minutes.

F. Proposed New Standards – Determining the Fracture Energy Density of Asphalt Binder Using the Binder Fracture Energy (BFE) test

G. Proposed New Task Forces

- TF 16-A:** Review the options available and write a procedure for checking TFO/PAV pans for excessive warping. Members: Delaware (Zipf), Asphalt Institute (Mike Anderson), and AMRL (Knake)
- TF 16-B:** To review the precision statement for T240, review the ASTM method and more recent AMRL data. Members: AMRL (Knake) and Virginia (Bailey)
- TF 16-C:** Review contradictory statements in Section 12.1 and X1.8.1 regarding the linear region in T315 and consider revision to current guidance in standard. Members: Asphalt Institute (Mike Anderson), Virginia (Bailey), Nevada (Charlie Pan), John D'Angelo, Kathy Sokol.

H. Standards Requiring Reconfirmation (See Appendix C)

- M 226-80 (2012) "Viscosity-Graded Asphalt Cement"
- R 015-00 (2012) "Asphalt Additives and Modifiers"
- T 240-13 "Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)"
- T 316-13 "Viscosity Determination of Asphalt Binder Using Rotational Viscometer"

I. SOM Ballot Items (including any ASTM changes/equivalencies) (See Appendix D)

Standard Designation	Summary of Proposed Changes	TS Only, Subcommittee Only or Concurrent? (TS / S / C)
M 320	Add Note 4 to allow for extended binder grades	S
TP 78	Move to full standard	C
T48	Change to an "A" standard instead of "C" standard with extensive changes to rates and other requirements to make this standard specific to asphalt binder.	C
TPXX	Adopt as a provisional test method, "Determining the Fracture Energy Density of Asphalt Binder Using the Binder Fracture Energy (BFE) Test".	C

VI. Open Discussion

VII. Adjourn

Appendix A – Agenda
Appendix B – Attendance
Appendix C – Standards
Appendix D – Ballot Items



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I. Call to Order and Opening Remarks

II. Roll Call

Voting Members					
Blackburn	Lyndi	Alabama	Tedford	Darin	Nevada
Burch	Paul	Arizona	Boisvert	Denis	New Hampshire
Schiebel	Bill	Colorado	Sheehy	Eileen	New Jersey
Connery	James	Connecticut	Streeter	Donald	New York State
Khan	Wasi	DC	Peoples	Christopher	North Carolina
Bukowski	John	FHWA	Lane	Becca	Ontario
Nash	Tanya	Florida	Mullis	Cole	Oregon
Wu	Peter	Georgia	Ramirez	Timothy	Pennsylvania
Shishido	Eric	Hawaii	Byrne	Michael	Rhode Island
Mann	Justan	Illinois	Egan	Brian	Tennessee
Kreider	Richard	Kansas	Hazlett	Darren	Texas
Myers	Allen	Kentucky	Andrus	Scott	Utah
Bradbury	Richard	Maine	Ahearn	William	Vermont
Barot	Sejal	Maryland	Bailey	William	Virginia
Grieco	John	Massachusetts	Farley	Paul	West Virginia
Strizich	Matt	Montana	Paye	Barry	Wisconsin
Non-Voting Members					
Rothblatt	Evan	AASHTO	Arasteh	Michael	FHWA
Johnson	Brian	AMRL	Smith	Michael	FHWA
Knake	Maria	AMRL	Harman	Tom	FHWA
Lutz	Robert	AMRL	Akisetty	Chandra	Maryland
Lenker	Steven	AMRL	Gallivan	Victor	Gallivan Consulting Inc.
Aschenbrener	Tim	FHWA			

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B. TS Ballots

TS 2b-16-01 – See **Attachment #1** for all comments.

ITEM 1 - Revise M 320, Performance-Graded Asphalt Binder, to add Note 4 to allow for extended binder grades. See attached marked up standard. 25 Affirmative, 0 Negative, 7 No Vote. Discuss comments from Kansas and Pennsylvania.

Kansas Department of Transportation (Richard E. Kreider) (richard.kreider@ksdot.org)	I suggest using the active verb tense: Note 4 —Grades outside of Table 1 or Table 2 are sometimes specified. Specify a high, low, and intermediate temperature if specified grades are beyond those listed in Table 1 or Table 2. Specify the high and low temperature grade in 6 °C increments for consistency with the PG grading system. (RAB)
Pennsylvania Department of Transportation (Timothy L Ramirez) (tramirez@pa.gov)	Affirmative with Comments: 1. The note addresses the issue without adding to the tables; however, one has to assume that the grades outside the tables are following the same specification criteria or criteria trends as the grades that are in the table. A trend would be the PAV residue criteria for DSR and the 3 degree differences as the high temp grade changes. Suggest adding a sentence to the note that states something like, "The same criteria shown in Table 1 and Table 2 will apply to the grade that is outside the grades shown in Table 1 and Table 2 except the criteria will be determined at the high, low, and intermediate temperatures that are specifically specified."

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TS2b-16-02 (See Attachment #2)

ITEM 1 - Adopt as a provisional test method, "Determining the Fracture Energy Density of Asphalt Binder Using the Binder Fracture Energy (BFE) Test". This test method was developed in research conducted for Florida DOT. Florida DOT has requested that TS 2b consider adoption of this test method to encourage further use and research into the test method. In addition to the proposed test method, a presentation is attached from the April 18th TS 2b Webinar. The presentation gives background information on the development of the test method. 26 Affirmative, 1 Negative, 5 No Vote. Comments were received from Virginia, Pennsylvania, Georgia, Kansas, Maine, Ontario, and Texas. New York voted negative and provided extensive comments, [see Attachment #2](#). All comments were forwarded back to Florida for review and revisions as appropriate.

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Task Force 16-01 - Review ETG recommendations for elastic response, T 350, and M 332. Tanya Nash (FL), Eileen Sheehy (NJ), Barry Paye (WI), and Matt Corrigan (FHWA). Tanya left FFDOT. New task force leadership is needed to revitalize this task force. See the 2016 Mid-Year meeting minutes for details.

V. New Business

A. Research Proposals

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1. 20-7 RPS

- Nevada has submitted a proposal entitled, "Effect of Elevation on Rolling Thin Film Oven Aging of Asphalt Binders". The main research objective is to provide a standardized method for adjusting RTFO times based on elevation. See [Attachment #4](#)

2. Full NCHRP RPS

- B. AMRL/CCRL - Observations from Assessments?**
- C. NCHRP Issues**
- D. Correspondence, calls, meetings**

- Email from Brian Johnson, AMRL, forwarding information from Karl Zipf, Delaware DOT – Procedure for checking the TFO/PAV pans for excessive warping, see Attachment #5
 - Email from Brian Johnson, AMRL, forwarding information from Karl Zipf, Delaware DOT – Procedure for checking the TFO/PAV pans for excessive warping, see Attachment #6
 - T 240 and T 315 questions from Kathy Sokol, see Attachment #7.
- E. Presentation by Industry/Academia
- Asphalt Institute REOB Guidance Document – Mike Anderson, Director of Research and Laboratory Services, Asphalt Institute
- F. Proposed New Standards
- G. Proposed New Task Forces
- H. Standards Requiring Reconfirmation
- I. SOM Ballot Items (including any ASTM changes/equivalencies)

VI. Open Discussion

VII. Adjourn

AASHTO Electronic Balloting System Ballot Detail Report

Ballot Detail

Ballot Number: SOM_TS2B-16-01

Ballot Name: SOM_TS2B-16-01

Ballot Introduction: Technical Section 2b ballot for modifying one standard, deleting one standard, and adopting one standard.

Ballot Manager: Eileen C. Sheehy

Ballot Start Date: 4/1/2016

Ballot Due Date: 4/22/2016

SOM_TS2B-16-01

Item Number:	1
Description:	Revise M 320, Performance-Graded Asphalt Binder, to add Note 4 to allow for extended binder grades. See attached marked up standard.
Attachment(s):	M 320 extended grades.docx
Decisions:	Affirmative: 25 of 32 Negative: 0 of 32 No Vote: 7 of 32

Agency (Individual Name)		Decision
Kansas Department of Transportation (Richard E. Kreider) (richard.kreider@ksdot.org)	I suggest using the active verb tense: Note 4 —Grades outside of Table 1 or Table 2 are sometimes specified. Specify a high, low, and intermediate temperature if specified grades are beyond those listed in Table 1 or Table 2. Specify the high and low temperature grade in 6 °C increments for consistency with the PG grading system. (RAB)	Affirmative
Maryland Department of Transportation (Chandra K Akisetty) (cakisetty@sha.state.md.us)	It is good to open up the specification for extended grading. We want to refer all tests conduct at 88-22 to same standards of binder testing (include temperature and frequency etc..) to compare the results.	
Pennsylvania Department of Transportation (Timothy L Ramirez) (tramirez@pa.gov)	Affirmative with Comments: 1. The note addresses the issue without adding to the tables; however, one has to assume that the grades outside the tables are following the same	Affirmative

	specification criteria or criteria trends as the grades that are in the table. A trend would be the PAV residue criteria for DSR and the 3 degree differences as the high temp grade changes. Suggest adding a sentence to the note that states something like, "The same criteria shown in Table 1 and Table 2 will apply to the grade that is outside the grades shown in Table 1 and Table 2 except the criteria will be determined at the high, low, and intermediate temperatures that are specifically specified."	
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Item Number:	2
Description:	Delete TP 78, Detecting the Presence of Phosphorus in Asphalt Binder. TP 78 is nearing the end of its life as a provisional standard. During the mid-year webinar, there was no support for adopting TP 78 as a full standard. This ballot item is to gauge the TS 2b interest in this standard.
Attachment(s):	tp_078.docx
Decisions:	Affirmative: 22 of 32 Negative: 3 of 32 No Vote: 7 of 32

Agency (Individual Name)		Decision
New Hampshire Department of Transportation (Denis M. Boisvert) (dboisvert@dot.state.nh.us)	Although this procedure is qualitative, it is relatively simple and quick while not requiring expensive equipment. Detecting Phosphorus in PPA, REOB, or other future modifiers may still have value.	Negative
Pennsylvania Department of Transportation (Timothy L Ramirez) (tramirez@pa.gov)	Negative with comments: 1. I did not support at the mid-year web meeting as my agency has not used this standard; however, I do see the potential value in maintaining it for forensic or verification testing/analysis even though it may result in a false positive. If PPA is used as a catalyst or a cross-linking enhancer for a polymer modifier and an agency wants to verify the PPA is there, I assume this test will verify the presence of the PPA. 2. If I am a lone negative, I will withdraw it, as I can always go back and use this TP 78-09 (2013) version.	Negative
Vermont Agency of Transportation (William E. Ahearn) (bill.ahearn@vermont.gov)	The standard provided a means to reliably characterize the use of phosphorus based modification. Although industry compliance with modification rules has improved making the method less important, it remains a useful standard. Any agency in need of an immediate method to ascertain unreported modification by phosphorus compounds will need a method to do so. Although an Agency may apply an obsolete standard TP85, there is an implication that the method is not good as evidenced by discontinuance over full standard adoption. This issue may be addressed at the time of the	Negative

	motion by including the phrase "Discontinuance of this standard is accomplished for reduced administrative burden without concern for the accuracy or reliability of the method."	
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Item Number:	3
Description:	Adopt a new provisional standard entitled, "Performance-Graded Asphalt Binder for Surface Treatments". This standard was developed for TXDOT. Attached is the proposed standard and two presentations giving background information.
Attachment(s):	MP SPG.docx DOC Meeting - June 2015 - SPG Update.pptx TxDOT SPG_Oct2015_Revise.pdf
Decisions:	Affirmative: 24 of 32 Negative: 1 of 32 No Vote: 7 of 32

Agency (Individual Name)		Decision
Kansas Department of Transportation (Richard E. Kreider) (richard.kreider@ksdot.org)	Change the grades in 4.1 to match what's in Table 1. (RAB)	Affirmative
Maryland Department of Transportation (Chandra K Akisetty) (cakisetty@sha.state.md.us)	<ol style="list-style-type: none"> It's a great study and will help agencies to maintain consistency for their binders for surface treatments. NCHRP 09-50 is doing nationwide study on same project, we don't know whether TxDOT took their input. It's worth waiting for their recommendations before adopting into AASHTO (just a thought). Why is this study referring to TP5 for shear strains when T 315 is in existence? 	
Maryland Department of Transportation (Sejal Barot) (sbarot@sha.state.md.us)	<ol style="list-style-type: none"> It's a great study and will help agencies to maintain consistency for their binders for surface treatments. NCHRP 09-50 is doing nationwide study on same project, we don't know whether TxDOT took their input. It's worth waiting for their recommendations before adopting into AASHTO (just a thought). Why is this study referring to TP5 for shear strains when T 315 is in existence? 	Affirmative
New Hampshire Department of Transportation (Denis M. Boisvert) (dboisvert@dot.state.nh.us)	Not sure if additional considerations might be necessary for extreme climates that differ from that of Texas.	Affirmative
New York State Department of Transportation (Robert A Burnett) (bburnett@dot.state.ny.us)	3 degree increments for the binder grading seems unnecessary. Why was -13 dropped from the table for a high temp of 73? What about grades for northern states with lower temps?	Affirmative

	<p>If M320 needs the new Note 4, it seems this spec needs it too.</p> <p>4.1 - Neither of the grades listed as examples are in Table 1.</p>	
Tennessee Department of Transportation (Brian K. Egan) (brian.egan@tn.gov)	At this time, this provision should be a State specific standard and not a National standard. The SPG tables are only reflective of one (maybe a few states) and do not address all the climatic temperatures around the county/Canada or the use of modified binders and/or emulsions used for surface treatments.	Negative
Wisconsin Department of Transportation (Barry C Paye) (barry.paye@dot.wi.gov)	Will monitor for use and adoption by other states.	Affirmative

Attachment #2

AASHTO Electronic Balloting System

Ballot Detail Report

Ballot Detail

Ballot Number: SOM_TS2B-16-02

Ballot Name: TS2B-16-02

Ballot Start Date: 04/25/2016

Ballot Due Date: 05/16/2016

TS2b-16-02

Item Number:	1						
Description:	Adopt as a provisional test method, "Determining the Fracture Energy Density of Asphalt Binder Using the Binder Fracture Energy (BFE) Test". This test method was developed in research conducted for Florida DOT. Florida DOT has requested that TS 2b consider adoption of this test method to encourage further use and research into the test method. In addition to the proposed test method, a presentation is attached from the April 18 th TS 2b Webinar. The presentation gives background information on the development of the test method.						
Attachment(s):	Standard Testing Method for Binder Fracture Energy... BFE Test Webinar.pdf						
Decisions:	<table> <tr> <td>Affirmative:</td><td>26 of 32</td></tr> <tr> <td>Negative:</td><td>1 of 32</td></tr> <tr> <td>No Vote:</td><td>5 of 32</td></tr> </table>	Affirmative:	26 of 32	Negative:	1 of 32	No Vote:	5 of 32
Affirmative:	26 of 32						
Negative:	1 of 32						
No Vote:	5 of 32						

Agency (Individual Name)	Decision	
Georgia Department of Transportation (Peter Wu) (pwu@dot.ga.gov)	<div>1. MSCR test is currently deemed a "gold standard" for binder test to distinguish modified asphalt and unmodified binder properties. Has BEF test been compared with MSCR test? Or has BEF results been correlated to MSCR results?</div> <div>2. Have any binder service history/field performance data been collected from the asphalt pavement with high BEF value and from the asphalt pavement with low BEF value?</div>	Affirmative
Kansas Department of Transportation (Richard E Kreider) (richard.kreider@ksdot.org)	<div>No correlations to field performance from what I have read. It does appear to identify modified binders and looks encouraging if some field verification could be developed.</div> <div>Under section 5, the loading rate is noted from 100-900 mm/min. In the procedure they state to run the test at 500 mm/min. Is the comment in section 5 needed?</div> <div>The Apparatus states a load cell capable of measuring 100lbs. I would specify the strength load cell needs to be. As a high strenath load cell can't measure 100lbs accurately.</div> <div>6.2 - if only running at 500 mm/min, why the need to run at other rates? This shouldn't be a requirement unless needed. Ok, in the procedure it does state that if two successive tests are run, then re-run the test at a different rate until it passes. This sounds kind of fishy as they state in their research that the rate didn't matter.</div>	Affirmative

	<p>They state the end tab the sample adhere to can be aluminum, I assume they tested this as the pictures show a plastic material and not aluminum. (CWL)</p> <p>Reference Documents: I believe AASHTO T40 is superseded by AASHTO R66.</p>	
Maine Department of Transportation (Richard L Bradbury) (richard.bradbury@maine.gov)	<p>Numbering sequence in Section 9 needs to be corrected: 9.1.2 should be 9.2.1.</p> <p>10.3 states "Place the molds and the end tab assembly in the oven at the same temperature used to heat the asphalt binder for no more than 3 minutes." I suggest changing to a time range, such as "at least 2 but no more than 3 minutes" or similar.</p> <p>11.3.1: Suggest changing "binder recovered from old field cores." to "binder recovered from aged pavement" or "oxidized pavement."</p>	Affirmative
New York State Department of Transportation (Robert A Burnett) (bburnett@dot.state.ny.us)	<p>As written, the "Significance and Use" section tells us how they arrived at test temperature and displacement rate, but doesn't say why the test is significant or useful. The test measures fracture energy density, why is that important to know? How do I use the results in a meaningful way?</p> <p>1.1.1. "Specimen molds could be manufactured from aluminum".[rt1] [rt1]What else could they be manufactured from? Is there a specific designation for the materials? Ex. diagram for loading head specifically says 300 series stainless steel or 6061-T6 aluminum. aluminum molds. [rt1] [rt1]What do you use for release agent if molds made from something other than aluminum? (6.4.1 indicates other materials are possible)</p>	Negative
Ontario Ministry Of Transportation (Becca Lane) (becca.lane@ontario.ca)	<p>Comments:</p> <p>General Direct metric translations such as 448 N in section 6.2.2 or 163 degrees C in section 10.2 imply accuracy beyond what is desired or required. Should be rounded appropriately.</p> <p>10.3 Reference to paper clip should be changed to binder clip or foldover clip. Paper clip implies typical paper clip.</p> <p>11.1 What is a good test result? Should suggest or define basis of good/bad identification. Non-repeatable? Standard deviation? Range? End tab separation?</p> <p>15 Data interpretation is very complicated, should have software or calculation layout provided.</p> <p>17.1.5 Peak load should not be in lbs, should be metric</p>	Affirmative
Pennsylvania Department of Transportation (Timothy L Ramirez) (tramirez@pa.gov)	<p>Affirmative with comments:</p> <p>1. From webinar slides and Figures 16 in the standard, this test appears to capture different true stress vs. true strain relationships for the different types of indicated binders (unmodified, rubber modified, SBS modified, and hybrid binders). It is recommended that the TS-2b keep aware of who uses this provisional standard, if it's adopted, and their results with relation to field performance to allow for comprehensive consideration of this standard in the future for full adoption.</p> <p>2. In Section 4.4, at end of 1st sentence, revise from "binder" to "binders".</p> <p>3. In Section 5.2, 2nd sentence, revise from "0 °C and 30 °C" to "0 °C to 30 °C".</p> <p>4. In Section 5.3, 1st sentence, revise from "is found" to "was found".</p> <p>5. In Section 6.4.2, revise from "mental rings" to "metal rings".</p> <p>6. In Section 6.4.3, consider eliminating this subsection as it is similar to Section 7.3. Section 7.3 is written better. Alternatively, fully replace the text of Section 6.4.3 with the text of Section 7.3 and then delete the text in Section 7.3 so this text is only in one location.</p> <p>7. In Section 6, consider adding a subsection 6.4.4 with text "Binder Clips - paper binder clips for securing the mold assembly consisting of side plates, bottom plate, and end tabs.</p> <p>8. In Section 6, consider adding a subsection 6.4.5 with text "Trim knife - a straight edged trimming tool, such as a putty knife, for trimming the molded test specimen of excess asphalt binder after pouring the test specimen."</p> <p>9. In Figure 6-3-A, revise Note 2 from "X.X=±0.6(0.03)" to "X.X=±0.8(0.03)". Current tolerance is inconsistent with same dimensional tolerances in Figures 6-1, 6-2 and 6-4 and is inconsistent with the indicated equivalent tolerance for inches of "(0.03)".</p>	Affirmative

10. In Figure 6-3-B, revise Note 2 from " $X.X = \pm 0.6(0.03)$ " to " $X.X = \pm 0.8(0.03)$ ". Revise for same reason given in comment #9 above.
11. In Section 7.3, consider comments noted above in comment #6.
12. In Section 8, revise from "and required safety procedures" to "and safety procedures required" to be consistent with the first part of same sentence regarding the order of words where "laboratory safety procedures required" is used.
13. In Section 10.2, last sentence, add a comma after the word "process".
14. In Section 10.3, 5th sentence, revise from "paper clips" to "binder clips" as what is shown in Figure 10-2 is not a traditional paper clip, but these are more commonly referred to as "binder clips".
15. In Section 10.6, 1st sentence, revise from "straightedge" to "trim knife".
16. In Section 10.6, next to last sentence, revise from "hot knife" to "hot trim knife".
17. In Section 10.7 last sentence, revise from "that same" to "that the same" for better readability.
18. Figure 10-1 is not referenced in any part of the text. Consider referencing Figure 10-1 somewhere in the text, possibly in Section 10.8 or other appropriate Section.
19. In Section 11.2.1, 3rd sentence, which begins "Prior to running...", it is not clear what this sentence is trying to convey by indicating the specimen should be suspended in a vertical position. Perhaps is their a specific time that it should be suspended? Or, is the suspended specimen related to the next sentence which begins "Bending must be avoided..."? Otherwise, it seems obvious that the test specimen will be suspended vertically especially by Figure 9-1.
20. In Section 11.2.1, last sentence, revise from "in as short time" to "in as short of a time" for better readability.
21. In Section 14.1, 2nd sentence, consider revising from "mineral spirit cleaner" to "mineral spirit solvent" for consistency with Section 7.4 where it refers to "solvent" with mineral spirits being considered as a solvent.
22. In Section 14.1, last sentence, revise from "grease on film" to "grease or film".
23. In Section 15.1, next to last sentence, revise from "area occur, which make" to "area occurs, which makes" for better readability.
24. In Section 15.1, last sentence, revise from "Consequently, data" to "Consequently, a data" for better readability.
25. In Section 15.1.5, 3rd sentence, shouldn't "Length L" be "Length Lpeak" for consistency between the text and Figure 15-3 b?
26. In Figure 15-3 c, revise the figure labels from "L" to "L1" and from "A" to "A1" to be consistent with the text in Section 15.1.5, 3rd sentence where it refers to "Length L1" and "(Figure 15-3 c)".
27. In Section 15.1.6, Equation (1), and Equation (1)'s Where definitions, this equation's parameters and definitions do not match up cleanly with the Length and Area dimensional labels "L0", "Lpeak", "L", and "A0", "Apeak" and "A" in Figures 15-3 a, b, and c. Revise either the Figures 15-3 a, b, and c and/or Equation (1)'s parameters so that the equation and definitions match and are consistent with Figures 15-3 a, b, and c.
28. In Section 15.1.7, Equation (2) and Equation (2)'s Where definitions and Equation (3) and Equation (3)'s Where definitions, these equation's parameters and definitions do not match up cleanly with the Length and Area dimensional labels "L0", "Lpeak", "L", and "A0", "Apeak" and "A" in Figures 15-3 a, b, and c. Revise the Figure 15-3 a, b, and c and/or the Equation (2) and Equation (3) parameters so that the equations and definitions match and are consistent with Figures 15-3 a, b, and c.
29. In Section 16.1, 7th line from top, revise from "failure occur at much" to "failure occurs at much" for better readability.
30. Add Section 18 - PRECISION AND BIAS with text to indicate if P&B estimates are available or not.
31. Add Section 19 - KEYWORDS with text providing appropriate key words for this standard. Perhaps "asphalt binder, fracture, fracture energy density".
32. Add Section 20 - REFERENCES and list any research reports providing information about the development of this test and procedure.

Texas Department of Transportation (Darren Hazlett)
(darren.hazlett@txdot.gov)

We don't have any plans to use this, but we do not object to adopting it as a provisional standard.

Affirmative

	<ul style="list-style-type: none">Figures are confusing because it's hard to distinguish the parts from the dimension lines; I suggest a heavier line weight for the parts for clarity.The apparatus does not describe the load frame as necessarily vertical, but the figures and Section 9.1.1 talk about the upper and lower head. Either a) the apparatus needs to be identified as required vertical, or b) "fixed head" and "cross head" should be used instead of lower and upper head.Section 9.2 wants a "friction value" but it's very vague on what is actually measured and recorded. It's also not explained where this is used in the data interpretation; in fact the word "friction" doesn't occur again in the document. Also 9.2.2 is incorrectly numbered 9.1.2.Data interpretation: Too much explanation! Give plain instruction on how to calculate the results of the test. More background can be included in an appendix.Section 16 should be in an appendix.Although the test may have been developed for PG binder that have been RTFO and PAV aged, (and any precision and bias statement may only apply to this treatment) this is a measurement of a fundamental property, and there is no need to restrict its use to this specific aging condition.	
Virginia Department of Transportation (William R Bailey) (bill.bailey@vdot.virginia.gov)	15.1.2 and 15.1.3 It might be better to have equations in the body of the text (not in the graph)? 15.1.6. please, specify the units for A & L.	Affirmative

Standard Method of Test for

Flash ~~and Fire~~ Points of Asphalt Binder by Cleveland Open Cup

AASHTO Designation: T 48-~~06~~ (2015)XX

~~ASTM Designation: D92-05a~~



American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Method of Test for

Flash ~~and Fire Points~~ of Asphalt Binder by Cleveland Open Cup

AASHTO Designation: T 48-~~06 (2015)~~XX

~~ASTM Designation: D92-05a~~



1. SCOPE

- 1.1. This method covers the procedure for the determination of flash point of asphalt binder by the Cleveland open-cup apparatus.
- 1.2. This test method is applicable to asphalt binder with flash point between 80°C (175°F) and 400°C (750°F)
- Note 1**—Specifications commonly designate the Tag Open-Cup method (T 79) for asphalt binders and cutback asphalts having flash points below 93°C (200°F).
- 1.3. The values stated in SI units are to be regarded as the standard.
- 1.4. *This test may involve hazardous materials, operations, and equipment. This test does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

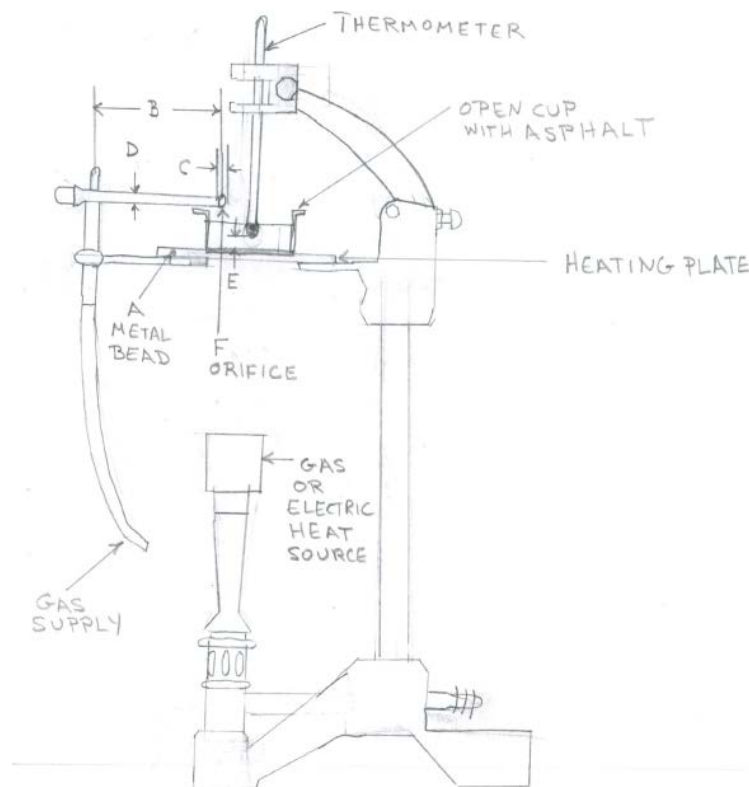
- 2.1. AASHTO Standard:
- R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
 - R 66, Sampling Asphalt Materials
 - T 79, Flash Point with Tag Open-Cup Apparatus for Use with Material Having a Flash Point Less Than 93°C (200°F)
- 2.2. ASTM Standard:
- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
 - E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
 - E220, Standard Test Method for Calibration of Thermocouples By Comparison Techniques
 - E644, Standard Test Methods for Testing Industrial Resistance Thermometers

3. SUMMARY OF TEST METHOD

- 3.1. The sample is placed in the tester and heated rapidly to begin with then at a slow rate. A small test flame is passed at a uniform rate in a level plane across the cup at specified intervals. The flash point is the lowest temperature at which application of the test flame causes the vapor at the surface of the liquid to flash.

4. APPARATUS

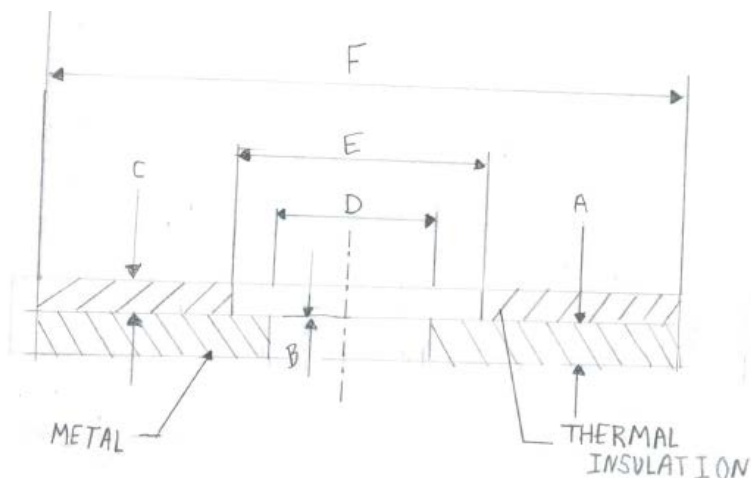
- 4.1. Cleveland Open-Cup Tester—Consisting of the following parts. The parts must conform to the dimensions shown and have the additional characteristics as noted. (See Figure 1.) The Cleveland Open Cup Tester may be manual or automated. If automated, the flash point instrument shall perform the test in accordance with Section 7.



Replace the dimensions in Figure 1 with the following:

	Millimeters		Inches	
	Min	Max	Min	Max
A—Diameter	3.8	5.4	0.15	0.21
<u>B—Radius</u>		<u>152 nominal</u>		<u>6 nominal</u>
C—Diameter	1.6	5.0	0.06	0.20
D		5.0		0.20
E	6.4, approximately		0.25, approximately	
<u>F—Diameter</u>		<u>0.8 nominal</u>		<u>0.031 nominal</u>

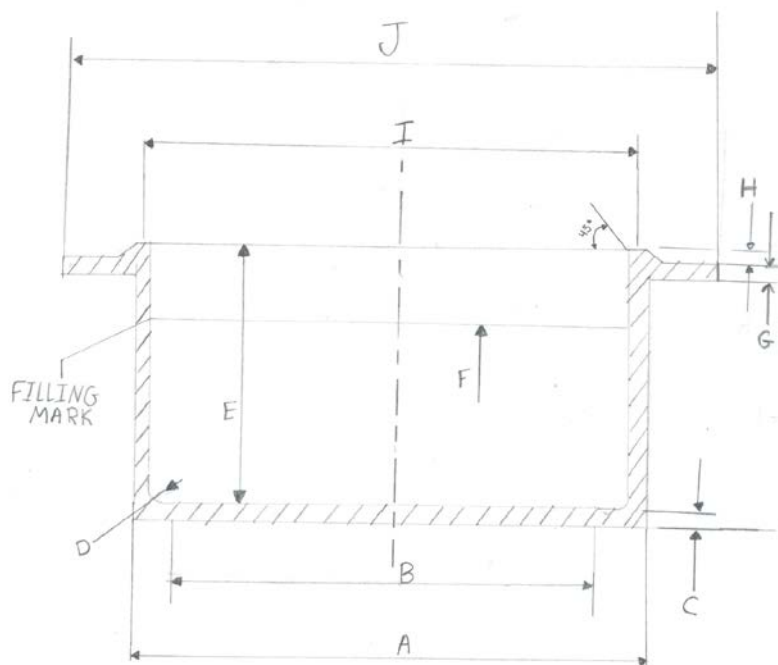
Figure 1 – Cleveland Open Cup Apparatus



Replace the dimensions in Figure 2 with the following:

	Millimeters		Inches	
	Min	Max	Min	Max
A		6.4, nominal		0.25, nominal
B	0.5	1.0	0.020	0.039
C		6.4, nominal		0.25, nominal
D—Diameter	54.5	56.5	2.15	2.22
E—Diameter	69.5	70.5	2.736	2.776
F—Diameter		150, nominal		6, nominal

Figure 2 – Heating Plate



Replace the dimensions in Figure 3 with the dimensions below. Do not include a dimension "G" as shown in Figure 3. However, include a dimension for the thickness of the flange of the test cup that is not included in Figure 3. This dimension for the thickness of the flange shall be designated "K" with the dimensional requirements as in the following table:

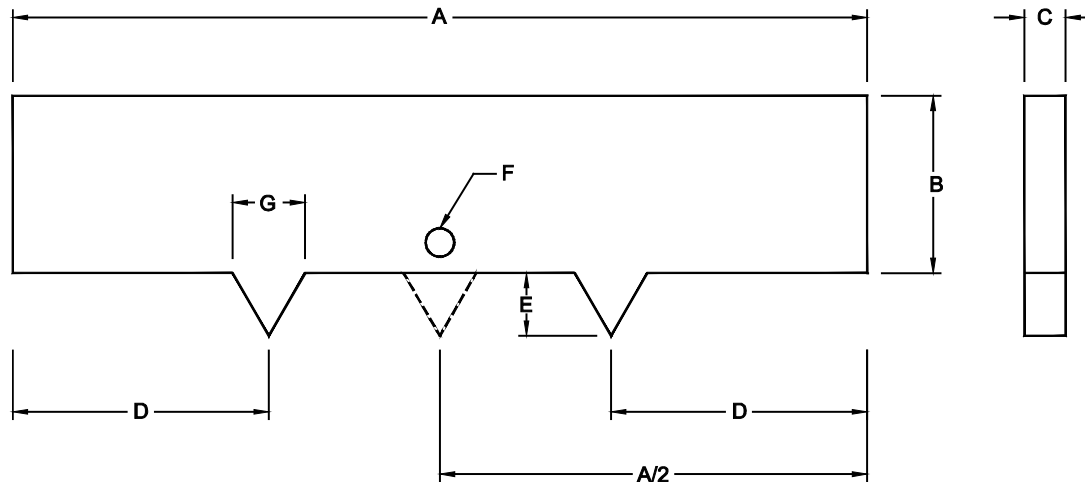
	Millimeters		Inches	
	Min	Max	Min	Max
<u>A</u>	<u>67.5</u>	<u>69</u>	<u>2.658</u>	<u>2.717</u>
B	62.5	64.0	2.46	2.52
C	2.8	3.6	0.11	0.14
D—Radius	4, approximately		0.16, approximately	
<u>E</u>	<u>32.5</u>	<u>34</u>	<u>1.280</u>	<u>1.339</u>
<u>F</u>	<u>9</u>	<u>10</u>	<u>0.354</u>	<u>0.394</u>
<u>G</u>	<u>1.8</u>	<u>3.4</u>	<u>0.07</u>	<u>0.13</u>
H	2.8	3.6	0.11	0.14
<u>I</u>	<u>67</u>	<u>70</u>	<u>2.638</u>	<u>2.756</u>
J	97	101	3.8	4.0
<u>K</u>	<u>—1.8</u>	<u>—3.4</u>	<u>—0.07</u>	<u>—0.13</u>

Figure 3 – Cleveland Open Cup

- 4.1.1. Test cup—cup made of brass or other metal of similar conductivity conforming to Figure 3. The cup may be equipped with a handle.
- 4.1.2. Heating Plate—plate that ensures the heat is evenly distributed over the bottom of the test cup and that extraneous heating to other surfaces is minimized. See Figure 2 for plate dimensions.
- 4.1.3. Heat Source—Gas burner or electric heater centered under the opening of the heating plate with no local overheating. If using a gas burner, protect the flame from drafts using suitable shields that do not project above the top of the heating plate.
- 4.1.4. Thermometer Holder—Supplied with the tester. It shall support the thermometer firmly in a vertical position.
- 4.1.5. Heating Plate Holder—Support to hold the heating plate level and steady.
- ~~4.1.1.4.1.6.~~ AI-3 Ignition Source Applicator—The device for applying the test flame may be of any suitable design, but the tip shall be 1.6 to 5.0 mm (0.06 to 0.20 in.) in diameter at the end and the orifice shall have an approximate diameter of 0.8 mm (0.031 in.). The device for applying the test flame shall be so mounted to permit automatic duplication of the sweep of the test flame, the radius of swing being not less than 150 mm (6 in.) and the center of the orifice moving in a plane not more than 2.5 mm (0.10 in.) above the cup. A bead having a diameter of 3.8 to 5.4 mm (0.15 to 0.21 in.) shall be mounted in a convenient position on the apparatus so the size of the test flame can be compared to it.
- 4.2. Thermometer—An ASTM 11C (11F) thermometer as prescribed in ASTM E1 with an accuracy of 0.2°C (0.5°F). The thermometer shall be calibrated according to the requirements specified in R 18. This thermometer shall be used to make all temperature measurements required by this method.
- 4.2.1. The test thermometer may be replaced with an alternative thermometric device, provided the following requirements are met:
- 4.2.1.1. The thermometric device shall be mounted in the same position as the test thermometer it replaces.
- 4.2.1.2. The thermometric device shall (1) have a maximum scale error no greater than that of the test thermometer it replaces, (2) be capable of indicating temperature within 0.1°C (0.2°F), and (3) have the same temperature response.

4.2.1.3. The thermometric device shall be standardized at the interval specified in R 18. Guidance for performing the standardization is given in ASTM E220 or E644.

4.2.4.3. A1.7-Filling Level Gauge(optional)—A device to aid in the proper adjustment of the sample level in the cup. It may be made of suitable metal with at least one projection, but preferably two for adjusting the sample level in the test cup to 9 to 10 mm (0.35 to 0.39 in.) below the top edge of the cup. A hole 0.8 mm (0.031 in.) in diameter, the center of which is located not more than 2.5 mm (0.10 in.) above the bottom edge of the gauge, shall be provided for use in checking the center position of the orifice of the test flame applicator with respect to the rim of the cup. (Figure 4 shows a suitable version.)



	mm	in.	
A	100	4	Nominal
B	20	0.75	Nominal
C	3.2	0.125	Nominal
D	30	1.25	Nominal
E	9–10	0.35–0.39	Nominal
F	0.8 Dia (2.5 mm above bottom edge)	0.03125 Dia (0.10 in. above bottom edge)	Maximal
G	10	0.375	Nominal

Figure 4—Filling Level Gauge

5. CALIBRATION AND STANDARDIZATION

5.1. The thermometer or thermometric device shall be standardized at the interval specified in R 18.

5.2. The performance of the apparatus shall be verified at least once per year by determining the flash point of a known reference material. Run the test according to Section 7 on a Certified Flash Point Material. The Certified Flash Point Material shall have test results for T 48 or for ASTM D92. To be considered acceptable, the flash point shall be within $\pm 8.0^{\circ}\text{C}$ ($\pm 14.4^{\circ}\text{F}$) of the certified test result. If the test result is out of tolerance, check the apparatus for compliance with Section 4 and rerun with a new sample.

6. ASSEMBLY AND PREPARATION OF APPARATUS

- 6.1. The Cleveland open-cup tester shall be placed in a firm and level position on a solid, vibration-free table in a draft-free hood or flash room, or well toward the back of a draft shield. The top of the tester shall be shielded from strong light so that the flash may be easily seen.
- 6.2. The temperature measuring device shall be positioned with the bottom of the device being 6.4 ± 1.0 mm (0.25 ± 0.04 in) above the bottom of the test cup and approximately half way between the center and the inside edge of the test cup on the side opposite the test flame applicator mounting position.
- 6.3. Follow manufacturer's instructions for setting up the manual or the automated apparatus for operation. Set the automated tester to run the test in accordance with Section 7.3.

7. PROCEDURE

- 7.1. Obtain the asphalt binder sample according to R 66. Heat the sample in its container with a loosely fitted cover in an oven not to exceed 163°C (325°F) for the minimum time necessary to ensure that the sample is completely fluid. Manually stir the sample but avoid incorporating air bubbles.
- 7.2. Fill the cup with material to be tested to the filling mark 9 – 10 mm (0.35 – 0.39 in.) below the rim of the cup. If the filling level gauge is used, fill the cup until the level of material just touches the pointers of the leveling device.
Note 2—The test sample should be at least 50°C (90°F) below the anticipated flash point.
Note 4—The sample cup may be filled away from the apparatus provided the thermometer is preset with the cup in place and the sample level is correct at the beginning of the test. A shim 6.4-mm (0.25-in.) thick is useful in obtaining the correction distance from the bottom of the bulb to the bottom of the cup.
- 7.3. Manual Flash Point Testing
- 7.3.1. Light the test flame, and adjust it to a diameter of 3.8 to 5.4 mm (0.15 to 0.21 in.).
- ~~4.2.4.~~7.3.2. For testing of a sample for which the expected flash point temperature is known, Apply heat initially at such a rate that the temperature indicated by the temperature-measuring device increases 10 to 20°C (18 to 36°F)/min. When the test specimen temperature is approximately 50°C (120°F) below the expected flash point, decrease the heat so that the rate of temperature rise during the last 28°C (50°F) before the flash point is 4 to 7°C (7 to 13°F)/min.
- 7.3.3. At approximately 28°C (50°F) below the anticipated flash point and at successive 2°C (5°F) intervals, pass the ignition taper across the sample in a continuous motion so that the time consumed for each pass is 1 s. The center of the test flame must move in a horizontal plane not more than 2.5 mm (0.10 in.) above the plane of the upper edge of the cup and pass in one direction only. At the time of the next test flame application, pass the test flame in the opposite direction of the preceding application.
Note 5: If a surface film forms on the sample, it is recommended that the film be moved to the side using a paperclip or spatula prior to application of the test flame.
- 7.3.4. From 28°C (50°F) below the anticipated flash point to the end of the test, take care to avoid disturbing the vapors in the test cup.

- 7.3.5. If a foam persists during that last 28°C (50°F) temperature rise below the anticipated flash point, end the test and disregard the results.
- 7.3.6. For testing of a sample for which the expected flash point temperature is not known, heat the sample to the temperature used for pouring in Section 7.1. Continue heating the test specimen at 4 to 710°C (7 to 1318°F)/min and testing the material every 2°C (5°F) as described in Section 44.4.57.3.2 until the flash point is obtained.
- 7.3.7. Record, as the observed flash point, the temperature read on the thermometer at the time the test flame application causes a distinct flash in the interior of the test cup.

Note 5—The application of the test flame may cause a halo or enlargement of the test flame. This is not considered the flash point. A large flame that propagates on the surface denotes that the flash point has been reached.

7.4. Automated Flash Point Testing

- 7.4.1. If necessary, light the test flame, and adjust it to a diameter of 3.8 to 5.4 mm (0.15 to 0.21 in.).

Note 6: Some automated apparatus can light and adjust the test flame automatically, and some automated apparatus pass the test flame in one single direction.

- 7.4.2. Start the automated apparatus according to the manufacturer's instructions. The automated apparatus shall conduct the procedure as required in Section 7.3.
- 7.4.3. Record, as the flash point, the temperature read on the thermometer at the time the test flame application causes a distinct flash in the interior of the test cup.

8. CALCULATIONS

- 8.1. Observe and record the ambient barometric pressure in the laboratory at the time of the test. If the barometric pressure varies from 101.3 kPa (760 mm Hg), calculate the corrected flash point as follows:

$$\text{Corrected flash point (°C)} = C + 0.25 (101.3 - A) \quad (1)$$

$$\text{Corrected flash point (°F)} = F + 0.06 (760 - B) \quad (2)$$

$$\text{Corrected flash point (°C)} = C + 0.033 (760 - B) \quad (3)$$

where:

C = observed flash point, °C,

F = observed flash point, °F,

A = ambient barometric pressure, mm HG, and

B = ambient barometric pressure, kPa.

9. REPORT

- 9.1. Report the corrected flash point, in degrees Celsius or Fahrenheit, as the "Cleveland Open-Cup Flash Point". Report flash point to the nearest whole number.

2.10. PRECISION AND BIAS

~~2.1.10.1.~~ ~~14.1~~ *Precision*—Criteria for judging the acceptability of test results for the flash point of asphalt binders obtained by this method are given in Table 1. ~~Criteria for judging the acceptability of fire point test results can be found in ASTM D92.~~

~~2.1.4.10.1.1.~~ ~~14.1.1~~ *Single-Operator Precision (Repeatability)*—The figures in Column 2 of Table 1 are the standard deviations that have been found to be appropriate for the conditions of test described in Column 1. Two results obtained in the same laboratory, by the same operator using the same equipment, in the shortest practical period of time, should not be considered suspect unless the difference in the two results exceeds the values given in Table 1, Column 3.

~~2.1.2.10.1.2.~~ ~~14.1.2~~ *Multilaboratory Precision (Reproducibility)*—The figures in Column 2 of Table 1 are the standard deviations that have been found to be appropriate for the conditions of test described in Column 1. Two results submitted by two different operators testing the same material in different laboratories shall not be considered suspect unless the difference in the two results exceeds the values given in Table 1, Column 3.

Table 1—Precision Estimates

Condition	Acceptable Standard Deviation (1s) ^a	Range of Two Results (d2s) ^a
Single-Operator Precision:		
Flash Point (°C)	3	8
Multilaboratory Precision:		
Flash Point (°C)	10	28

^a These values represent the 1s and d2s limits described in ASTM Practice C670.

Note: The precision estimates for Flash Point given in Table 1 are based on the analysis of test results from eight pairs of AMRL proficiency samples. The data analyzed consisted of results from 98 to 148 laboratories for each of the eight pairs of samples. The analysis included four binder grades: PG 52-34, PG 64-16, PG 64-22, and PG 70-22. Average flash points ranged from 268.5 to 353.5°C. The details of the analysis are in the final report for NCHRP Project No. 9-26, Phase 3.

~~2.2.10.2.~~ ~~14.2~~ *Bias*—The procedure of this test method has no bias because flash point ~~and fire point~~ can be defined only in terms of this test method.

11. KEYWORDS

11.1. Asphalt binder; Cleveland Open Cup; flash point

NCHRP 20-7
Proposed Research Needs Statement

SOM Technical Section 2b - Asphalts
Lyndi Blackburn, Chair
April 28, 2016

TITLE

Effect of Elevation on Rolling Thin Film Oven Aging of Asphalt Binders

BACKGROUND / NEEDS STATEMENT

Laboratories at elevations greater than 4000 feet consistently demonstrate lower aging than labs located below 4000 feet. This results in higher penetration values, lower viscosities, lower residue DSR values, lower creep recovery values, and higher Jnr values (mass change does not appear to be affected). It results in low AMRL proficiency sample scores, poor correlation in cooperative testing such as with the WCTG, and problems correlating with other state labs, asphalt suppliers and private testers. The existing theory is that the lower oxygen content available at higher elevations results in lower oxidative aging of the asphalt. This effect is evident by evaluation of existing data such as AMRL proficiency samples and WCTG cooperative samples. A report by the Modified Asphalt Research Center at the University of Wisconsin-Madison reviewed existing WCTG data. Their conclusions stated that elevation was a factor affecting reproducibility of PG testing and that the current RTFO procedure needed to be refined to take into account elevation of the laboratory.

A Technical Section 2b AASHTO T 240 Task Force examined this issue back in 2010 and recommended a change in the test procedure to address this issue. This change would have allowing longer aging times for high elevation labs. The task force proposal was accepted by technical section ballot. However, Technical Section 2b endorsed additional research to further study the aging issue. To date, funding for this research has yet to be approved.

RESEARCH OBJECTIVE

Perform research to provide a standardized method for adjusting RTFO times based on elevation. This would eliminate the inconsistencies obtained in test results obtained from labs with different elevations. This concept is in use already in other tests – AASHTO T48 Flash and Fire Points by Cleveland Open Cup, T78 Distillation of Cutback Asphalt Products, and R28 Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel - where corrections are made due to elevation and barometric pressure differences.

WORK TASKS

Collect existing data from AMRL proficiency samples and WCTG samples to corroborate the 4000 foot elevation threshold.

Develop a work plan to determine RTFO aging times needed at high elevations to produce test results comparable to lower elevations. Obtain various binders of various PG grades and suppliers, unmodified and modified. Identify suitable AMRL certified labs which cover different altitudes to conduct the testing. Labs at low elevations will provide baseline results, while labs at higher elevations will test using multiple RTFO aging times to provide comparison data. This could possibly be done through the existing Western Cooperative Test Group using their monthly comparative samples distributed for testing.

Analyze the test data to produce a standardized method for adjusting RTFO aging times based on elevation.

Write a proposed revision to the existing test procedure, AASHTO T 240, to incorporate this new method.

URGENCY

This problem has been apparent for years, before the introduction of PG asphalts. The difference was that with viscosity-graded asphalt cements there was only a maximum on the residue viscosity. Therefore insufficient aging only made it easier to pass the specification. However, this has changed with the advent of PG asphalts. Now incomplete aging can result in failing the minimum residue DSR and creep recovery specification as well as the maximum Jnr. Thus, this issue has taken on a new significance, beyond the problem of low ARML scores and correlation issues. Incomplete aging in the RTFO due to higher elevations can result in incorrectly failing test results, monetary damages, removal of materials, and the possibility of lawsuits. Even though only high elevation states and labs are affected, the results can be significant. It is an issue that has been ignored and needs to be addressed.

FUNDING REQUESTED AND TIME REQUIRED

It is estimated that this research will take 12 months to complete and will require **\$99,000**.

CONTACT PERSON

Darin Tedford, Chief Materials Engineer, Nevada Department of Transportation
1263 S. Stewart St. Carson City, NV 89712
(775)888-7520
(775)888-7501
dtedford@dot.state.nv.us



Effect of Laboratory Elevation on Binder Aging using the Rolling Thin Film Oven (RTFO)

Raul Velasquez

Dan Swiertz

Hussain Bahia

Modified Asphalt Research Center (MARC)

University of Wisconsin-Madison

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Abstract

The effect of laboratory elevation on the use of the Rolling Thin Film Oven Test (RTFO) to simulate short term aging of asphalt binders is discussed in detail in this report. Rheological measurements (i.e., $|G^*|$ and δ) of 14 binders before and after RTFO aging collected in laboratories located at different elevations (i.e., between 25-30 labs) were used to determine the significance of lab altitude on RTFO aging of commonly used binders. The comprehensive database of rheological properties of binders was developed and currently maintained by the collaborative effort between the Western Cooperative Test Group (WCTG), the Rocky Mountain Asphalt User-Produce Group (RMAUPG), and the Modified Asphalt Research Center (MARC) at the University of Wisconsin-Madison.

Visual and statistical analysis of more than 340 measuring points indicate that elevation of the laboratory has a statistically significant impact on RTFO aging of binders and thus can be one of the factors affecting reproducibility of Performance Grading (PG) testing between high (e.g., 6000 ft) and lower (e.g., 0 ft) elevation labs. It was observed that this elevation sensitivity of RTFO aging is binder dependent. The aging ratio, $[G^*/\sin \delta @ \text{RTFO}] / [G^*/\sin \delta @ \text{Original}]$, of some binders are independent of the elevation and barometric pressure of the laboratory. Averages for the rate of change of $G^*/\sin \delta$ after RTFO and the aging ratio as function of elevation presented in this study can be used to assess the importance of elevation when performing PG grading of binders.

Introduction

Unique to asphalt materials is that its mechanical properties depend on both time and ambient conditions (Figure 1). Asphalt pavements demonstrate significant change in physical and mechanical properties over time, and between regions as result of material aging characteristics. In addition to time and location, the aging characteristics of an asphalt binder are source specific [1]. The aging process of asphalt binders imparts certain performance based implications on the pavement, often times in a negative fashion [2].

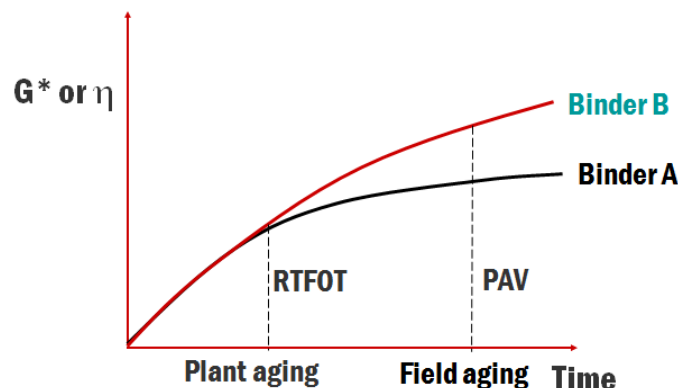


Figure 1. Schematic of Change of Asphalt Mechanical Properties as Function of Time.



Aging can be identified as the change in physical and mechanical properties with time due to changes in chemical composition. In general, four mechanisms exist by which asphalt binder ages in service [1, 2]:

- Volatilization,
- Oxidation,
- Steric hardening,
- Physical hardening

It is important to note that both steric hardening and physical hardening are the result of physical change in chemical structure, not change in composition; they can be thought of as molecular rearrangement as opposed to molecular alteration [3]. Steric and physical hardening are therefore reversible with the addition of heat or mechanical work. Only oxidation and volatilization results in compositional changes and thus are irreversible. Oxidative aging affect both the molecular structure and the molecular interaction of the binder which are crude oil source dependent [1]. Any change of asphalt chemistry and composition due to aging results in a significant change in its mechanical performance. Asphalt binder aging varies widely and it is not only a function of binder source but also temperature, depth in the pavement, mixture type, permeability, and aggregate type, among other factors [1].

In general, aging results in harder, more brittle asphalt binders. Increased elasticity in asphalt binder is also observed after oxidation (Figure 2) [2]. Field and lab aging results in distortions of the rheological master curve as shown in Figure 2. This figure shows how $|G^*|$ and δ changes for asphalt binders aged for varying temperature and lengths of time [1]. Figure 2 indicates that aging causes an increase in the complex modulus, and a decrease in the phase angle. The complex modulus is proportional to the asphalt binder stiffness; as a result of aging thus the material becomes less deformable. This effect is desirable for rutting but detrimental for fatigue and thermal cracking performance.

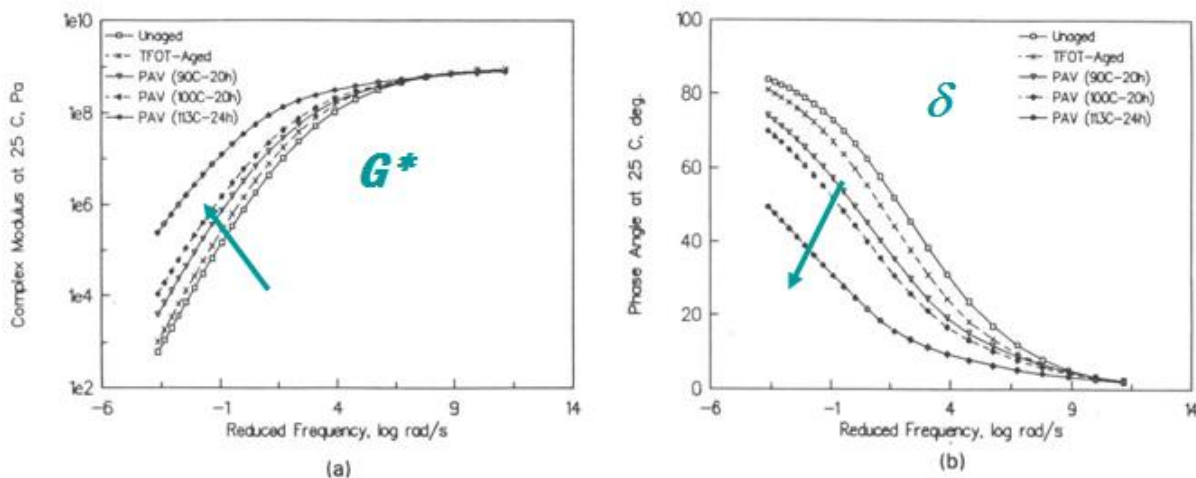


Figure 2. Effects of Aging on Rheological Behavior of Asphalt Binders [2]



Aging of asphalt pavements in service can be divided into two broad categories (Figure 1):

1. Short term (Plant)
2. Long term (Field)

Short term aging is defined as the effect of the high temperatures used in manufacturing, hot mixing, placement, and compaction on the asphalt binder. In general, volatilization is considered the primary agent of short term aging, although significant and rapid oxidation occurs as well [1]. Characteristic of short term aging is a high rate of increase in viscosity and/or stiffness with relatively little time (see Figure 1). Long term aging is defined as the service life aging associated primarily with oxidation reactions [1]. Molecules in the pavement react with environmental oxygen over time, stiffening the pavement over its service life. Characteristic of long term aging is a slowly diminishing rate of increase in viscosity and stiffness over time (Figure 1).

To take into account aging in the selection of paving materials, accelerated aging procedures have been developed to mimic field conditions. Two methods are commonly available to practitioners to simulate aging of asphalt binders: oven and pressure aging. Oven tests rely on high temperatures and thin films for aging, resulting in high volatile loss and high oxidation rates. Pressure aging makes use of oxidation through forced physical diffusion, as oxygen is forced into an asphalt film by increasing ambient pressure. In general, oven tests such as the Rolling Thin Film Oven Test (Figure 3) are used to simulate short term aging whereas pressure aging are used for estimating long term aging [1].

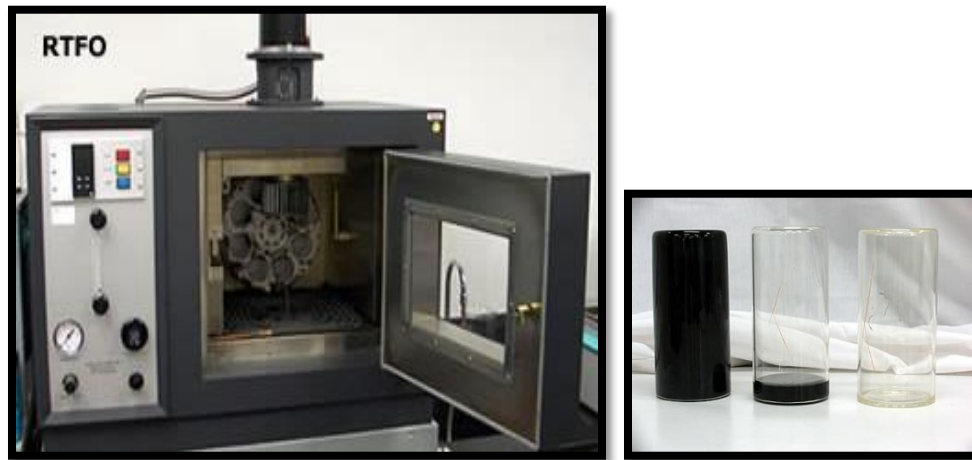


Figure 3. Rolling Thin Film Oven Test (RTFOT) to Simulate Short Term Aging.

The aim of short term laboratory aging is to simulate the effect that the production and mixing process has on the rheological properties of asphalt binder. During production and mixing, asphalt is exposed to high temperatures, and experiences rapid oxidation and volatilization. Asphalt binders that oxidize too rapidly may become too stiff in a relatively short service time.



Short term aging relies on high temperature and air flow over thin films to simulate this stage of aging [1, 2].

The Rolling Thin Film Oven Test (RTFOT) was developed in the early 1960's to simulate the aging that occurs during mixing. The RTFOT uses thin films and cylindrical bottles that are continuously rotating (Figure 3) to uniformly age the binder. RTFO testing is conducted at 163°C for 85 minutes. The RTFO is currently an ASTM as well as an AASHTO standard and it is required for Superpave PG grading of asphalt binders.

As part of regular round robin testing for the Western Cooperative Test Group (WCTG), laboratories at high elevations (i.e. greater than 4000 ft) have consistently reported lower values of $|G^*|/\sin \delta$ for RTFO aged samples. Variation of the rheological properties of binders before RTFO aging between participant laboratories has been minimal and thus raises the question of the effect of lab elevation and barometric pressure on the RTFO aging procedure. There are a significant number of labs in the Rocky Mountain Asphalt User-Produce Group (RMAUPG) and WCTG at high altitudes (e.g., 17) and thus the need to investigate this issue. Preliminary analysis of data collected shows that the cause of variation among laboratories is attributable to insufficient RTFO aging. Based on statistical analysis of a comprehensive data set, this study discusses possible methods to address this lab altitude issue.

WCTG Round Robin Database

Collaborative efforts between the Western Cooperative Test Group (WCTG), the Rocky Mountain Asphalt User-Produce Group (RMAUPG), and UWM have led to the development of a comprehensive database of asphalt binder and mixture testing performance that can be used for validation and evaluation of current (PG) and new technologies (PG+). This database is populated with WCTG's round robin binder testing program and with new testing methods developed as part of the Asphalt Research Consortium (ARC).

The database includes information on binder performance using current PG specification, PG-Plus and new technologies (e.g., Linear Amplitude Sweep, Single Edge-Notch Bending, etc). The participation in monthly testing for the database is on a volunteer basis and thus the number of participating labs varies from month to month as shown in Figure 4. Approximately 40 laboratories around the United States are helping run the tests and collecting relevant data. The binder grades available in the database represent commonly used grades used in field projects.

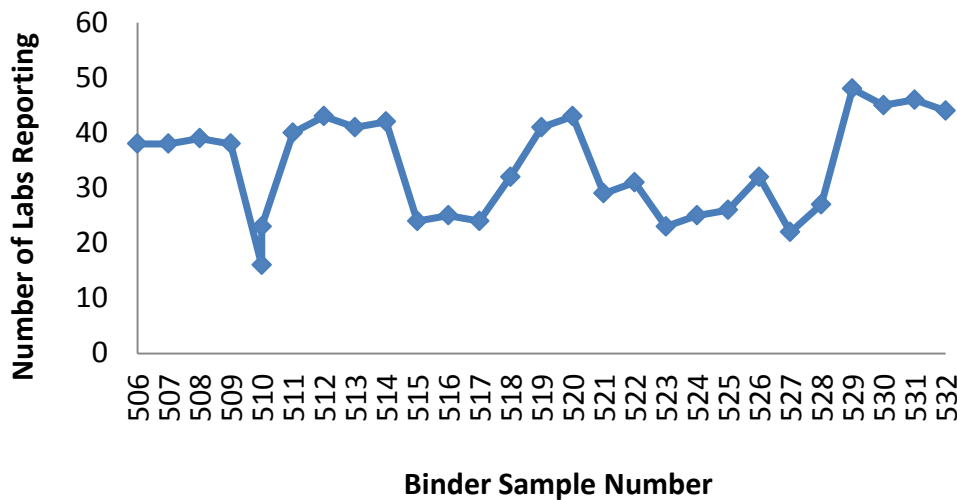


Figure 4. Reporting Laboratories in WCTG-RMAUPG-UWM Database.

The PG and PG+ test procedures included in the database are:

1. Rotational viscosity, 1 and 20 rpm (unaged)
2. $|G^*|$ and phase angle (δ) (unaged, RTFO, PAV)
3. $|G^*| / \sin \delta$ (unaged and RTFO)
4. $|G^*| \sin \delta$ at high PG temp. (PAV)
5. Toughness and tenacity (unaged)
6. Ductility (unaged, RTFO)
7. Loss on heating (RTFO)
8. Elongation recovery (RTFO)
9. BBR stiffness and m-value at 1 and 24 hrs. conditioning time (PAV)
10. Non-recoverable creep compliance (Jnr) at three stress levels (0.1, 3.2, 10 kPa) and two temperatures (RTFO)
11. Percent difference in Jnr at three stress levels (0.1, 3.2, 10 kPa) and two temperatures (RTFO)
12. Percent recovery in MSCR (%R)
13. Direct tension, failure stress and failure strain (PAV)
14. Linear Amplitude Sweep (LAS)
15. Single Edge Notch Beam (SENB)

This database has been subjected to significant changes over the past two years after feedback from WCTG users. A screen shot showing some of the fields in the database is presented in Figure 5. In the database, basic statistics are calculated for each test method as indicated in Figure 6. The statistical summary can be used to evaluate reproducibility and issues in current and newly developed testing methods. Furthermore, outliers in the database are considered in the statistical analysis as shown in Figure 7. The database also shows available precision statements to determine potential reproducibility issues with an existing testing method.



Company / Lab	WCTG Lab Number	Phone Number	Sample Number	Rotational Viscosity at 20 RPM, 135°C (nearest 0.01 Pa)	Rotational Viscosity at 1 RPM, 135°C (nearest 0.01 Pa)	Complex Shear Modulus, G* (nearest 0.01 kPa)	Phase Angle, delta (nearest 0.1 degree)
Blueknight Energy Partners/Commerce City CO	8	3032886861	520A (Holly)	1.1	125	1.07	72.4
WYODOT	40 307-777-4076		520A (Holly)	1.21	1.2	1.03	71.8
Paramount Asphalt	76 916-685-9253		520A (Holly)	1.21	1.55	1.03	72.7
ODOT	37 503-986-3074		520A (Holly)	1.215	1.3	1.04	72.2
Permann	40 406-454-9885		520A (Holly)	1.25		1.064	71.8
Montana DOT	Not Sure	(406)444-6283	520A (Holly)	1.45	1.4	1.19	71.2
PRI Asphalt Company	Not Sure	813-621-5777	520A (Holly)	1.269	1.3	1.1	71.5
BKEP Grand Junction, Co.	Not Sure	970/241/1135	520A (Holly)	1.13	1.25	1.04	72.7
Road Science LLC	63 918-960-3814		520A (Holly)	1.21	1.25	1.1	72.3
Colorado Department of Transportation		6 303-398-6530	520A (Holly)			1.03	72.6
Paramount-Nevada Asphalt Co. LLC	Not Sure	35 775-835-6366	520A (Holly)	1.14	1.3	1.05	72.8
UDOT		801-633-0667	520A (Holly)	1.149	1.3	1.047	73.6
Westest		72 303-975-9959	520A (Holly)	1.17	0.75	1.04	72.1
Western Refining		49 915-775-7859	520A (Holly)	1.25	2		
Western Refining		49 915-775-7859	520A (Holly)	1.25	2	1.07	71.6
Western Refining		49 915-775-7859	520A (Holly)	1.25	2	1.07	71.6
ALON USA		77 432-263-9450	520A (Holly)	1.18	1.4	1.09	72.4

Figure 5. WCTG Database.

(tons)	Tests on Original Binder										Tests on RTFO									
Average:	1.200	1.350	1.564	70.272	1.656	32.974	165.808	121.983	0.153	3.207	64.493	3.547	0.734	1.371	67.538	1.320	61.624	36.920	25.455	5.6
Maximum:	1.27	1.6	1.65	72.1	1.77	38.5	209	154	0.211	3.42	65.7	3.79	0.923	1.919	93.74	2.08	69.69	51.44	41.17	5.8
Minimum:	1.13	1.141	1.46	68.7	1.55	26.5	129	101	0.099	3.01	63.3	3.29	0.515	0.9	39.91	0.42	53.1	18.62	12.07	5.1
Range:	0.135	0.459	0.19	3.4	0.22	12	80	53	0.112	0.41	2.4	0.5	0.408	1.019	53.83	1.66	16.59	32.82	29.1	0.5
Standard deviation:	0.036	0.141	0.059	0.9347	0.064	3.4886	26.1745	17.0963	0.02883	0.116	0.6554	0.174	0.116739	0.2934	16.5046	0.6865	4.5913	9.5727	8.12588	0.25
Coefficient of variation:	3.0%	10.4%	3.8%	1.3%	3.9%	10.6%	15.8%	14.0%	18.8%	3.6%	1.0%	4.9%	15.9%	21.4%	24.4%	52.0%	7.5%	25.9%	31.9%	4.6
Sample #	RV at 20 RPM, 135°C (Pa-s)	RV at 1 RPM, 135°C (Pa-s)	G' @ Hi PG (kPa)	Phase Angle @ Hi PG (deg)	G' / sinδ @ Hi PG (kPa)	Ductility (cm)	Toughness (inch-lbs)	Tenacity (inch-lbs)	Loss on heating (0.001%)	G' @ Hi PG (kPa)	Phase Angle @ Hi PG (deg)	G' / sinδ @ Hi PG (kPa)	Jnr. 0.1kPa @ Hi PG	Jnr. 3.2kPa @ Hi PG	% difference in non-recoverable Jnr @ Hi PG	Jnr. 10kPa @ Hi PG	% Recovery at 0.1 kPa @ Hi PG	% Recovery at 3.2 kPa @ Hi PG	% Recovery at 10 kPa @ Hi PG	G' @ Hi PG-6
519A	1.31		1.62	71.40	1.70	35.30			0.14	3.52	63.60	6.70	0.60	1.03	41.80		63.27	43.81		5.9
519A	1.18	1.60	1.79	68.90	1.91				0.16	3.88	63.70	6.15	0.90	1.57	74.32		53.35	29.58		5.4
519A	1.19	1.32	1.50	70.20	1.59				0.21	2.95	63.90	3.29	0.66	1.17	78.92	0.42	65.64	44.65	41.17	5.0
519A	1.19	1.20	1.55	69.50	1.66	34.00	133.90	113.40	0.08	3.09	64.70	3.42	0.82	1.48	80.15	34.55	57.49	33.48	34.54	5.4
519A			7.32	27.60	15.80															
519A	1.24		1.61	69.28	1.72					3.06	64.50	3.39								
519A	1.15	1.35	1.57	69.40	1.68	30.00	147.00	101.00	0.24	3.20	64.70	3.54	0.70	1.34	91.78	0.43	62.01	37.14	36.53	5.8
519A	1.23	1.45	1.51	72.50	1.58	38.00	165.30	137.90	0.12	3.19	64.40	3.54	0.52	0.90	74.77	2.06	69.69	51.44	17.68	5.4
519A	1.18	1.15	1.58	70.44	1.67				0.25	3.42	64.30	3.79	0.78	1.27	62.31	1.72	56.29	37.28	23.68	6.2
519A	1.23	1.30	1.48	69.50	1.58				0.15	3.13	64.10	3.47	0.69	1.19	72.49	5.85	62.25	41.53	21.89	5.5
519A	1.25	1.50	1.33	70.70	1.41	36.00			0.12	3.27	63.60	3.65	0.71	1.27	79.43					5.4
519A	1.20	1.15	1.61	70.30	1.71				0.17	3.01	65.50	3.30	0.75	1.33	77.70		62.62	40.32		5.0
519A	1.27	1.55	1.65	68.70	1.82	32.20			0.18	3.25	64.40	3.60	0.65	1.13	75.13		64.12	43.73		5.4
519A	1.15	1.20	1.49	72.60	1.56	27.50			0.15	3.17	64.20	3.52	0.70	1.20	41.85	1.38	63.08	42.50	28.89	5.8
519A			1.64	71.60	1.73	28.50			0.10	3.35	64.00	3.73	0.67	1.16	42.10		61.23	40.76		5.9
519A			1.62	71.10	1.72	43.00	234.40	193.70	0.17	3.09	65.30	3.40	1.14	1.84	61.26	0.60	43.17	21.44	22.12	5.5
519A	1.22	1.14	1.56	69.70	1.66		177.90	141.80	0.14	3.17	63.90	3.53	0.59	1.05	76.99	0.55	67.23	47.43	25.07	5.8
519A	1.30	1.35	1.58	71.00	1.67				0.18	2.86	65.40	3.15								
519A	1.25	1.60	1.48	70.90	1.57	32.25			0.12	3.19	64.90	3.52	1.17	1.86	58.84		39.52	18.62		5.5
519A	1.18	1.73	1.47	69.60	1.57				0.24	2.82	65.10	3.11	0.81	1.48	82.21		61.55	37.52		4.9
519A	1.25	1.40	1.62	66.60	1.77	34.80	152.30	125.90	0.13	3.28	63.30	3.67	0.40	0.58	44.83		76.00	66.82		

Figure 6. Example of Database Basic Statistical Analysis.



Test Method Descriptive Statistics	Original Binder					
Median	1.57	1.63	1.15	71.10	1.22	18.80
Average	1.56	1.65	1.16	70.69	1.23	19.63
Range	1.65	1.85	0.47	21.70	0.82	28.00
Standard Deviation	0.24	0.42	0.08	3.05	0.12	5.70
Coefficient of Variation (COV)	15.26%	25.29%	6.61%	4.32%	9.80%	29.03%
Statistics after Removing Outliers						
Average after Processing	1.59	1.69	1.15	71.14	1.22	18.18
COV after Processing	8.75%	21.55%	4.12%	0.96%	5.00%	12.43%
Test Method Precision						
ASTM Standard Number	D 4402	D 4402	D 7175	D 7175	D 7175	D 113
ASTM 1 s% (COV%)	4.30%	4.30%	NA or Not Established	NA or Not Established	6.00%	NA or Not Established
Results COV meet ASTM (Y/N)	NO	NO			NO	
Processed COV meet ASTM (Y/N)	NO	NO			YES	
Sample Number	RV at 20 RPM, 135°C (Pa·s)	RV at 1 RPM, 135°C (Pa·s)	G* @ Hi PG (kPa)	Phase Angle @ Hi PG (deg)	G* / sind @ Hi PG (kPa)	Ductility (cm)

Figure 7. Considering Outliers and Method Precision in Database.

Information in the database can be used to determine factors affecting variability of standard PG and newly developed PG+ tests and to propose possible solutions to address this variability. For example, Figure 8 shows the fluctuation of the variation of Percent Recovery (i.e., %R) from the Multiple Stress Creep and Recovery Test (MSCR) with time. Earlier tested samples (e.g., 511A-523A) showed significantly higher inter-laboratory variation in comparison to recently tested binders (e.g., 528A-532A). This reduction in variation is the result of continuous feedback between WCTG laboratories and the administrators of the database. Significant improvements on the MSCR test procedure and calculation method have been implemented after using information in this database.

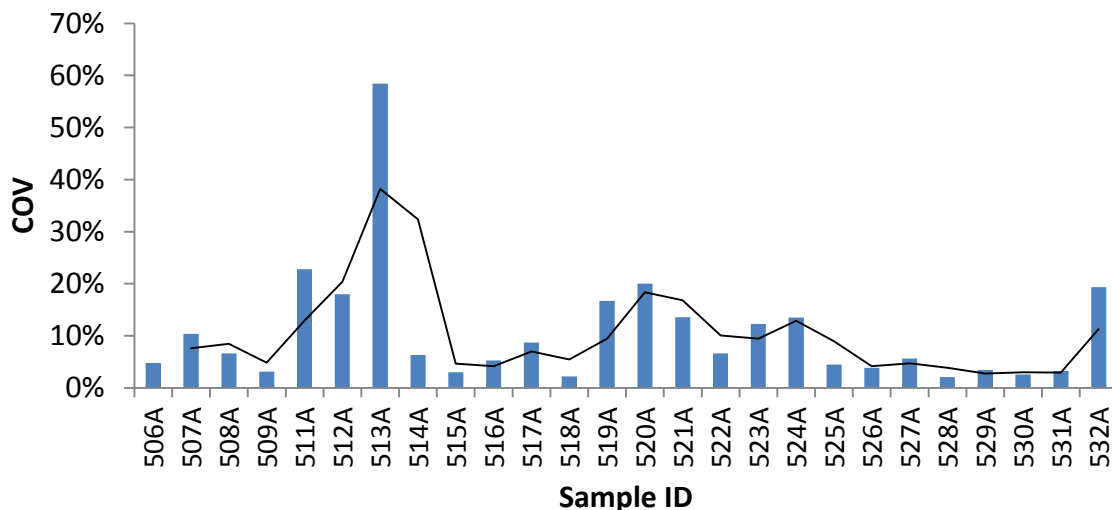


Figure 8. Coefficient of Variation for %R in MSCR Test at 3.2 kPa and High PG Temperature.



Effect of Lab Elevation on RTFO Aging

Dynamic Shear Rheometer (DSR) measurements before and after RTFO aging of 14 different asphalt binders obtained in different laboratories (i.e., 25-30) were used to visually and statistically assess the impact of lab elevation of RTFO aging. The following parameters are used as dependent variables for the analysis:

- $|G^*|/\sin \delta$ after RTFO
- Aging Ratio = $|G^*|/\sin \delta @ \text{RTFO} / |G^*|/\sin \delta @ \text{Original}$

Users of the database report elevation, barometric pressure, air flow rate, aging temperature and aging time for the RTFO test. However, only elevation and barometric pressure values change among the participant laboratories. Furthermore, there is a power law relation between elevation and barometric pressure as indicated in Figure 9 and thus only elevation and binder type are used in subsequent analysis of the RTFO aging data.

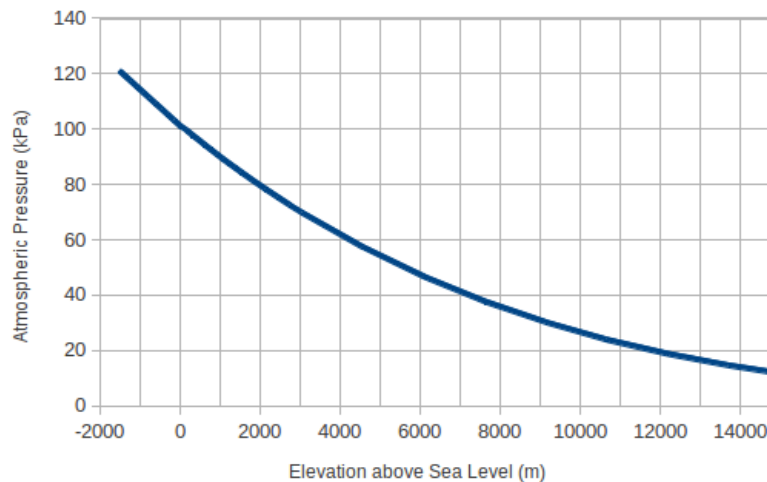


Figure 9. Relation between Atmospheric Pressure and Elevation
(http://www.engineeringtoolbox.com/air-altitude-pressure-d_462.html)

Figure 10 shows the relation between aging ratio and lab elevation for all 14 binders tested. A total of 344 points indicate a poor correlation between aging index and elevation. Generally, it is observed as expected that as elevation increases the aging ratio decreases. Oxidative aging is a diffusion-reaction process which is highly influenced by the environmental conditions including temperature (i.e., constant between labs) and pressure (different between labs). It is expected that at higher pressure (i.e., low elevation), rate of aging increases in comparison to lower pressure conditions (i.e., high elevation).

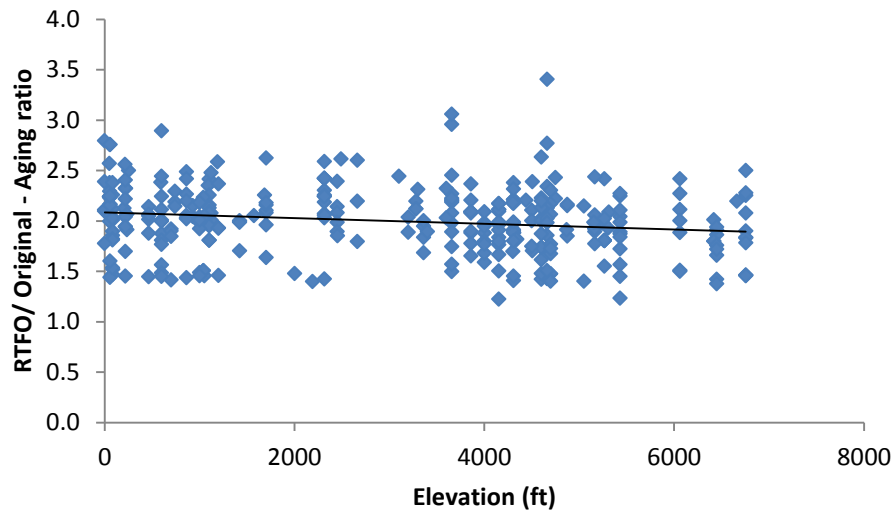


Figure 10. Aging ratio as function of elevation for all 14 binders (344 measurements).

Figure 11 shows the relation between aging ratio and the PG grade of the binders tested. Overall as PG high limit increases the aging ratio decreases. An interesting observation in Figure 11 is that as the distance between the high and low PG limit increases, the spreading of the aging ratio values increases and thus the aging susceptibility of these binders with the same PG grade can be very different.

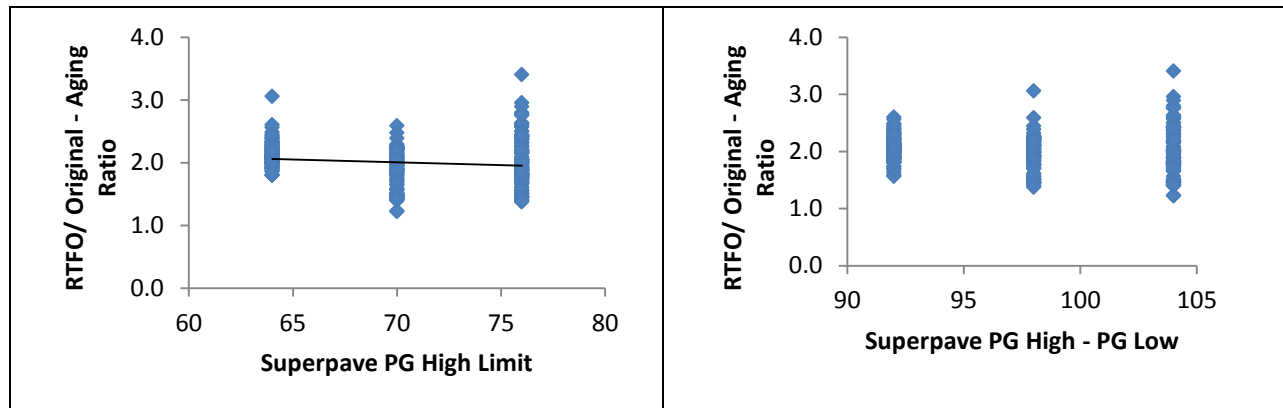


Figure 11. Aging Ratio as Function of (a) PG High Temperature Limit and (b) PG High minus PG Low Temperature Limit.

The basic statistics (e.g., average, standard deviation, median, etc) for the aging ratio and elevation are presented in Table 1. As it can be seen, a wide variety of aging susceptible binders are used in this study (i.e., aging index varies from 1.22 to 3.41) as well as laboratories located in very different elevations (i.e., elevation varies between 0 to 6775 ft).

**Table 1. Basic Statistics for Aging Ratio and Elevation.**

Variable	N	Average	Std Dev	Minimum	Median	Maximum
Aging Ratio	344	2.00	0.33	1.22	2.01	3.41
Elevation (ft)	344	3023.1	2090.4	0	3657	6755
PG HL	344	70.86	4.87	64	70	76
PG HL-LL	344	98.21	5.01	92	98	104
PG LL	344	-27.36	3.87	-34	-28	-22

The correlation matrix for the variables presented in Table 1 was calculated and only statistically significant correlations are presented in Table 2 (i.e., $R > 2/\sqrt{N}$). Table 2 shows that elevation and binder type have a significant effect on the aging ratio of the studied binders.

Table 2. Correlation between Aging Ratio and Elevation and PG High Temperature Limit.

R	Aging Ratio
Elevation (ft)	-0.1829
PG HL	-0.1303

Linear regression was performed using *aging index* as dependent variable and *elevation* and *binder type* as independent variables. Binder type was considered as a factor/dummy variable (i.e., not numerical). The R^2 of the linear regression model is **0.76** and the summary of the significance of the model is presented in Table 3. Table 4 shows the ANOVA for the independent variables used in the model. As it can be seen both elevation and binder type are statistically significant when predicting aging ratio.

Table 3. Analysis of Variance (ANOVA) of Linear Regression Model.

Source	df	SS	MS	F	p-value
Regression	14	27.63	1.97	74.53	0.00
Residual	329	8.71	0.02		

Table 4. Change in Residual Sum Squares (RSS) for fitting each term last.

Predictor	F	p-value
Elevation	59.16	0.00
Binder Type	76.73	0.00

Visual inspection of the relation between aging parameters and elevation confirm the results obtained from statistical analysis. Figure 12 shows the relation between $|G^*|/\sin \delta$ after RTFO and (a) elevation and (b) barometric pressure for selected binders. It can be seen that aging susceptibility is binder specific and that the effect of elevation and barometric pressure also depends on the binder type.

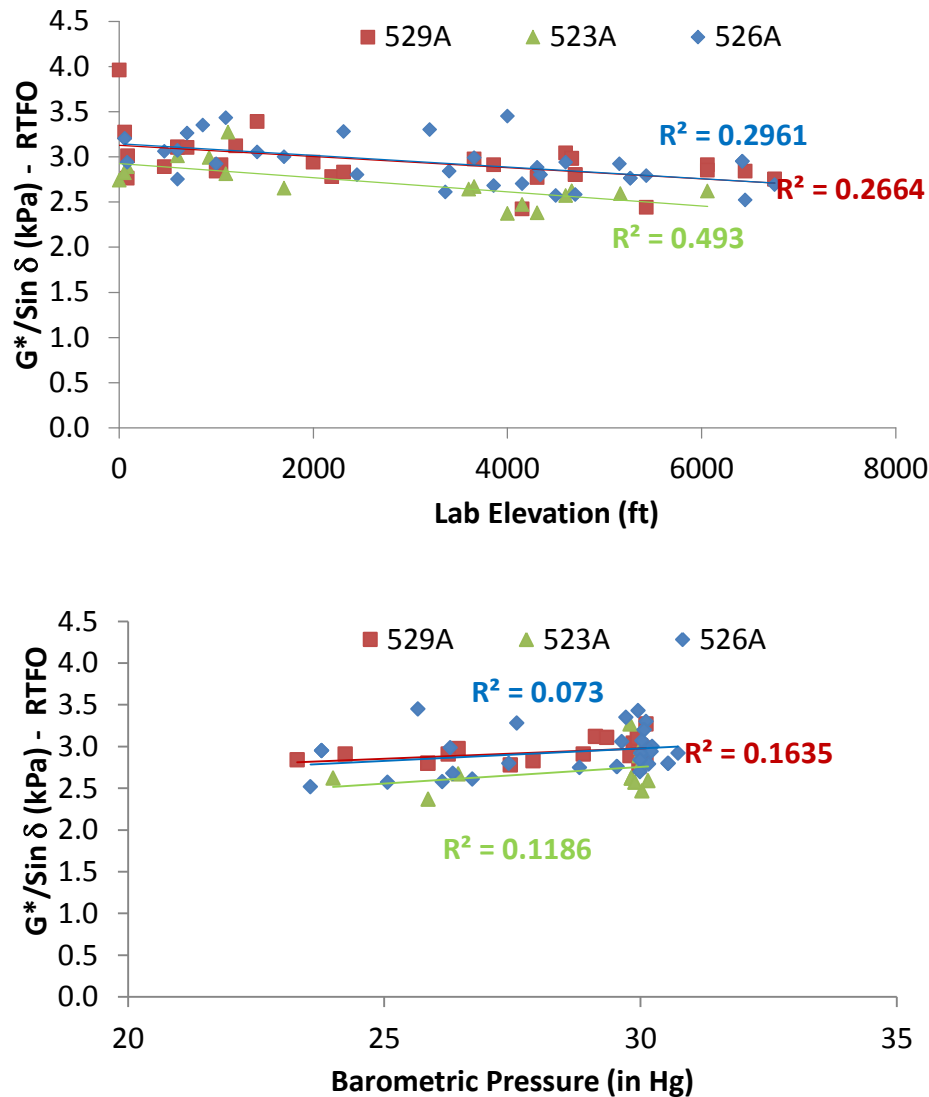


Figure 12. $G^*/\sin \delta$ as Function of (a) Elevation and (b) Barometric Pressure for Selected Binders.

Figure 13 shows how the aging ratio is affected by lab elevation and barometric pressure. Similarly to the observations in Figure 12, the significance of lab altitude depends on the binder type. For example, Figure 13 indicates that the aging index for binder 529A is not affected by elevation. It is important to note that the average aging index for binder 529A is on the lower side of the binders tested and thus it is less susceptible to aging.

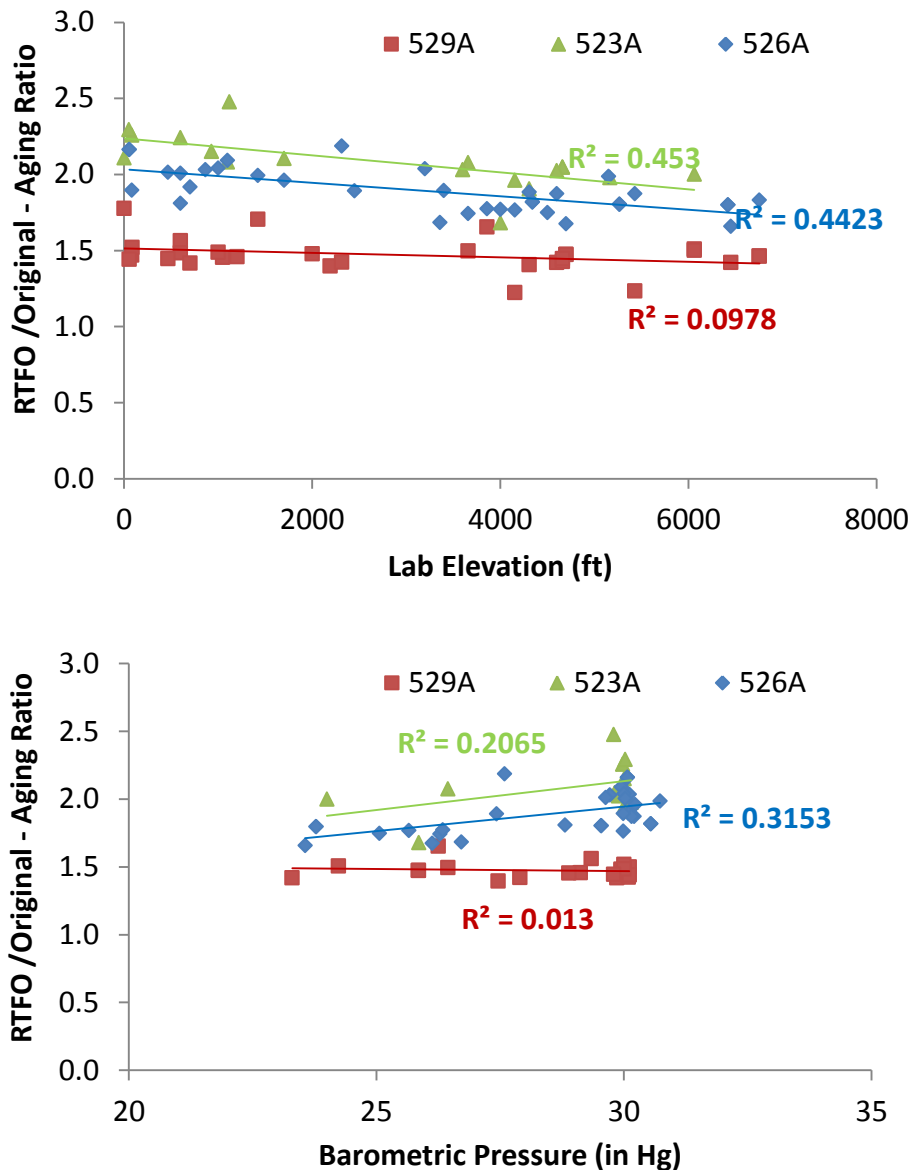


Figure 13. Aging Ratio as Function of (a) Elevation and (b) Barometric Pressure for Selected Binders.

The rate of change of $|G^*|/\sin \delta$ and the aging ratio as function of elevation is presented in Table 5 for all 14 binders investigated. As it can be seen, the effect of elevation on RTFO aging varies among the different binders. For example, the average value of $|G^*|/\sin \delta$ after RTFO reported in a laboratory located at sea level (i.e., 0 ft) in comparison to a lab at 6000 ft is 0.47 kPa higher. This change in $|G^*|/\sin \delta$ due to elevation can be significant as it can represent a change in PG grade. The average slopes presented in Table 5 can be used as first step to assess the impact of lab elevation on RTFO aging if information about binder type and source is not readily available.



Table 5. Summary of Correlations and Rate of Change of $|G^*|/\sin \delta$ and Aging Ratio as Function of Elevation.

Binder	G*/sin δ - RTFO			RTFO / Original (Aging Ratio)		
	Slope (kPa/ft)	R ²	Change/6000ft (kPa)	Slope (1/ft)	R ²	Change/6000ft (-)
519A	-3.15E-05	0.1	-0.19	-3.13E-05	0.15	-0.19
520A	-2.00E-05	0.02	-0.12	-1.93E-05	0.02	-0.12
521A	-1.64E-05	0.02	-0.1	-1.79E-05	0.05	-0.11
522A	-6.19E-05	0.28	-0.37	-3.38E-05	0.22	-0.2
523A	-7.83E-05	0.49	-0.47	-5.61E-05	0.45	-0.34
524A	-1.08E-04	0.3	-0.65	-4.81E-05	0.3	-0.29
525A	-4.58E-05	0.09	-0.27	-2.23E-05	0.04	-0.13
526A	-6.46E-05	0.3	-0.39	-4.44E-05	0.44	-0.27
527A	-4.65E-05	0.18	-0.28	-3.68E-05	0.24	-0.22
528A	-5.68E-05	0.26	-0.34	-4.00E-05	0.3	-0.24
529A	-6.19E-05	0.27	-0.37	-1.45E-05	0.1	-0.09
530A	-4.67E-05	0.13	-0.28	-3.37E-05	0.25	-0.2
531A	-2.75E-05	0.16	-0.17	-1.10E-05	0.2	-0.07
532A	-7.43E-05	0.36	-0.45	-5.60E-05	0.3	-0.34
Average	-5.29E-05	0.21	-0.32	-3.32E-05	0.22	-0.2

Conclusions and Recommendations

The effect of laboratory elevation on the use of the Rolling Thin Film Oven Test (RTFO) to simulate short term aging of asphalt binders was investigated in this study using visual and statistical analysis. A total of 344 rheological measurements of 14 binders obtained from laboratories located at different elevations (i.e., between 25-30 labs) were used to determine the significance of lab altitude on RTFO aging. Statistical analysis using linear regression indicates that elevation and binder type have a significant impact on the RTFO aging process. This result is consistent to what it is found in the literature as rate of aging is affected by both the diffusion-reaction process and the chemical reaction products. Based on the analysis of the results reported in the WCTG database, the following conclusions can be drawn:

- Elevation can be one of the factors affecting reproducibility of Performance Grading (PG) testing between high (e.g., 6000 ft) and lower (e.g., 0 ft) elevation labs.
- The RTFO sensitivity to elevation is binder dependent. The aging ratio, $[G^*/\sin \delta @ \text{RTFO}] / [G^*/\sin \delta @ \text{Original}]$, of some binders are independent of the elevation and barometric pressure of the laboratory.



- Averages for the rate of change in $|G^*|/\sin \delta$ after RTFO and the aging ratio as function of elevation reported in Table 5 can be used to assess the importance of elevation when performing PG grading of binders and/or to compare rheological measurements between labs located at different elevations.
- Analysis presented in this study can be used to refine current RTFO procedure (e.g., adjusting aging time) to take into account elevation of the laboratory and to reduce current PG testing variability.

References

1. Swiertz, D., Asphalt Aging Characteristics- Rheological Implications and Laboratory Techniques, *Internal Report*, Modified Asphalt Research Center (MARC)-University of Wisconsin-Madison, 2010.
2. Bahia, H. U., & Anderson, D. A., The Pressure Aging Vessel (PAV): A Test to Simulate Rheological Changes Due to Field Aging. *Physical Properties of Asphalt Cement Binders: ASTM STP 1241*, pp. 67-89, 1995.
3. Jones, D. R., & Kennedy, T. W., The Asphalt Model: Results of the SHRP Research Program. Austin: SHRP A-001 Draft Report, 1992.

From: Brian Johnson <bjohnson@amrl.net>
Sent: Monday, March 7, 2016 12:46 PM
To: Blackburn, Lyndi
Subject: FW: Suggestion from Delaware DOT on the TFO pans
Attachments: T179 & R28 Pans FB-2016.pdf

Lyndi,

We were given some information from Karl Zipf of Delaware DOT about how to check the TFO/PAV pans for excessive warping. Maria passed this along to the Binder ETG for potential inclusion in one of the next ballots for R28.

Karl also sent me a revision idea for T201, T202, and R18 related to checking timers. Hopefully we can go over them at the next 2b meeting in Greenville.

Regards,

Brian J. Johnson

AASHTO Accreditation Program Supervisor
4441 Buckeystown Pike
Suite A
Frederick, MD 21704

Email: bjohnson@amrl.net

Office: 240-436-4820

Mobile: 240-575-8651

www.amrl.net





State of Delaware
Department of Transportation

800 Bay Road
P.O. Box 778
DOVER, DELAWARE 19903

Jennifer Cohan
Secretary

Mr. Brian Johnson
AAP Program Supervisor
AASHTO Materials Reference Laboratory
4441 Buckeystown Pike – Suite A
Frederick, MD 217404

February 12, 2016

Dear Mr. Johnson,

AAHTO T179 “TFO” and AASHTO R28 “PAV” Pans or Containers

The Problem with T179 and R28:

During the recent AMRL inspection our laboratory was cited for an out of specification container for T179, the Thin Film Oven. In careful reading of the AASHTO standard it was realized that there is a major disconnect between T179 and R28, even though they both use the same pan.

The TFO test, T179, specifies the containers (pans) in section 5.3 and adds Note 2. The latter adds two important bits of information, discussing pan warpage and clarifying metal thickness. The PAV method, R28, describes the pans (containers) in section 6.2. It does not include the information from T179 Note 2. Leaving out the information from T179 Note 2 causes two major problems. The first is that AMRL cannot disqualify any pan used in R28 for warpage since it is not in the standard being demonstrated. Secondly, the new pans now use 26 gauge metal, which would be disqualified in R28.

There are also larger issues than the two disconnects between T179 and R28. The first is that T179 will probably be discontinued as a standard in a decade. Presently only five test laboratories are accredited for that test. Without R28 being corrected, when T179 disappears, there will no longer be the additional information on the pans.

The other larger issue is testing for pan warpage. There is not a method described in Note 2 of T179 explaining how to test for warpage or for what is considered to be slightly warped versus badly warped. There is no frequency for inspecting. There are two common unofficial techniques to check for warpage. One is to rock the pan and the other is to spin it.

Both are very subjective, operator dependent and qualification is in the eye of the beholder as to what is warped. Spinning is very dependent on the person and surface. It is especially so for pans that are marginal. On a very smooth surface, such as an epoxy counter top, one can get a partial spin for a marginal pan. On slightly textured Formica, as in the office desks, the same pan may not spin.

Necessary AASHTO Actions:

AASHTO needs to firstly make the description of the containers/pans in T179 and T28 read the same and include the Note 2 of T179. Secondly AASHTO needs to specify a method for testing for warpage and a frequency.

To develop a measurable method for warpage, several techniques were tried. One was considered to be the easiest and to give reasonable data. In all, a mixture of ten pans were examined. There were five levels of “spin”, None, Slight, Partial, Slow Spin, and Fast Spin. Since the spin test has always been non-documented and subjective, Partial Spin was considered as the cutoff point for being accepted under the slightly warped description. Partial Spin would be where a pan would spin half to a whole revolution before stopping while Slight Spin was less than a half revolution before stopping.

The easiest method to obtain a measurable value for warpage was the displacement between the edge and center. If one considers the geometry to be approximately a cone, by clamping a straight edge on one side, the displacement would be doubled. The cutoff for this method was chosen as a 0.500 mm gap at the far edge. It gives about a 0.25 mm difference from edge to center or approximately 10% of the binder depth. Inspection frequency would be annually and when put into service.

Measuring for TFO or PAV Pan Warpage – DelDOT Method:

1. The measurement is made with a feeler gauge and it is taken 0.5 – 1.0 cm from the edge of the pan. The reason for the setback is the edge is slightly rounded.
2. Inspect annually or when put into service.
3. Take a BBR mold base or similar piece of metal and mark the bar for 0.5 – 1.0 cm from the edge of the pan.
4. With the pan inverted, clamp one end of the bar to the bottom of the pan at one edge, Figure 1. The bar will lay upon the diameter of the pan.
5. With the feeler gauge, measure the gap at 0.5 – 1.0 cm in from the opposite edge of the pan, Figure 2.
6. A pan will pass if the gap is ≤ 0.500 mm (0.020 inches). The pan will fail if a 0.550 mm (0.022 inch) gauge will fit the gap.
7. A note of caution. Do not force the gauge, otherwise it will lift the bar and give a false reading.
8. A gap of 0.500 mm will be for a pan that will spin less than a full revolution on a smooth surface.
9. Pans that are convex will never spin, but clamping a bar across the surface one can see the gaps, Figure 3. In this case, the largest gap, as measured by the feeler gauge, cannot exceed 0.250 mm (0.010 inches) to be considered acceptable.

Laboratory Data:

Pan #	Cond	Spin	Edge gap mm
1	New	None	< 0.1
2	New	None	< 0.1
3	New	Slight	0.3
4	Used	Fast	1.7
5	New	Partial	0.4
6	Used	Partial	0.5
7	Used	None	0.2
8	Used	Fast	1.6
9	Used	Slow	0.6
10	Used	None	0

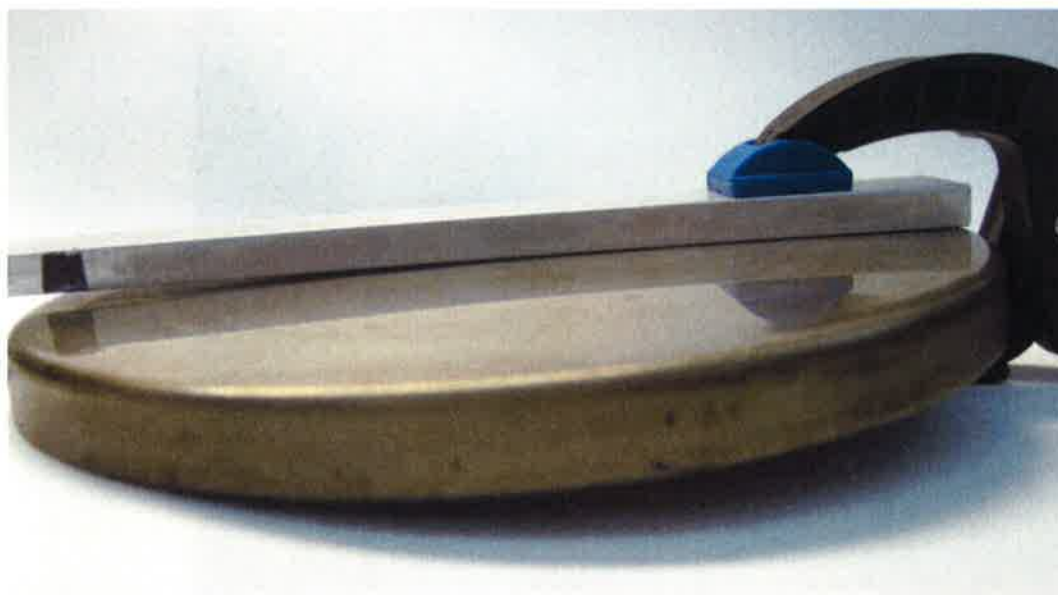


Figure 1: Inverted pan with a BBR base bar clamped at one end and laying on the diameter.



Figure 2: Measuring the edge gap with a feeler gauge. Note the 0.5 - 1.0 cm mark on the BBR base bar.



Figure 3: Pans 7 and 10 are convex. Notice the gap is mid-pan and not at the edge.

Sincerely,

Karl Zipf, Chief Chemist and QS Manager

CC: Jennifer Pinkerton

From: Brian Johnson <bjohnson@amrl.net>
Sent: Monday, March 7, 2016 2:23 PM
To: Blackburn, Lyndi
Subject: FW: T201 -202 Timers
Attachments: T201 & T202 Timers.pdf

Here is the other one on timers. He is suggesting 6 months for timers that are not quartz and 12 months for quartz timers. I will add this to the R 18 tables if 2b likes this idea. The TS might only allow quartz after seeing his example at the back.

Brian

From: Zipf, Karl (DelDOT) [<mailto:Karl.Zipf@state.de.us>]
Sent: Tuesday, March 1, 2016 3:50 PM
To: Brian Johnson
Subject: T201 -202 Timers

Brian,

I will make it easier for you. I had started to put together a letter outlining the situation and a solution to you. I got side tracked with the accreditation issues. I have now dug it out, took a pair of pictures and finished assembly. I think it is coherent, or at least more so than a string of e-mails.

I would state in R18 that timers are 'quartz timers' to remove all doubt.

Sincerely,

Karl



State of Delaware
Department of Transportation

800 Bay Road
 P.O. Box 778
 DOVER, DELAWARE 19903

Jennifer Cohan
 Secretary

Mr. Brian Johnson
 AAP Program Supervisor
 AASHTO Materials Reference Laboratory
 4441 Buckeystown Pike – Suite A
 Frederick, MD 217404

March 1, 2016

Dear Mr. Johnson,

AAHTO T201, AASHTO T202 and R18 Timer Interval

Disconnect Between T201, T202 and R18 : During the recent AMRL inspection we had a non-conformity for T201 6.4, Kinematic Viscosity and T202 6.5, Absolute Viscosity, for the timer interval for standardization. The standards state a 6 month interval. The disconnect occurs with AASHTO R18, Table A1.3. There the table clearly states that timers for T201 and T202 have an interval of 12 months. Since R18 is the basis for AASHTO Accreditation, then it should take precedence.

The recommendation from DelDOT is to make T201, T202 and R18 all agree. Should AASHOTO decide to keep the 6 month interval, and then include it in Table A1.3.

Discussion on Timers: I went through our archives of standards and my earliest copy of T201 is from 1965. For both Timers and Electrical Timing Devices, there is very little change over a half a century. However, in the fifty years, timers have changed radically. Secondly, the interval checking the timers was not present until after 2008 for T201 and T202, and this is a great mystery as to the rational of its rather recent inclusion.

I have the impression that when the standard was revised the person did not understand fully devices and how they have evolved in fifty years and was unwittingly burdened with fossil language. In the 1965 version Timers were spring activated figure 1. These were wind up affairs, just as wrist watches and probably alien to anyone under 40. Spring based timers are subject to wear and are not that accurate. Electric Timing Devices were a modern solution to this problem. They were based on an electric motor and the rotation speed was a function of the AC frequency. Timing was based on rotating wheels and Figure 2 is of an electric timing device that

is around 50 years old. Since it had mechanical parts it was subject to wear. It is rather peculiar that T201 6.4.1 and T202 6.5.1 continue with electrical timing devices. These are obsolete.

I can understand for wind up timers or electrical ones to check them for accuracy and 6 months would make sense. Why the calibration interval appeared in the last decade is a mystery, since these items are hardly if ever used in the 21st century.

Today, and for the past few decades, timing, either stop watches, timers, clocks or watches are based on the frequency of an oscillating quartz crystal. These are incredibly accurate, very stable and either they work or they do not work at all.

If one wants to make the standards reflect the 21st century, I would discard the section on “Electric Timing Devices”. For “Timers” have the following. **“Timers, with a quartz movement and a resolution of at least 0.1 seconds, needs to be verified annually to within 0.05% over 15 minutes. Any other non-quartz movement timer needs to be verified biannually to within 0.05% in 15 minutes.”**



Figure 1 Spring wound stopwatch



Figure 2 Near antique 110v powered electric timer

Sincerely,

Karl Zipf, Chief Chemist and QS Manager

CC: Jennifer Pinkerton

Blackburn, Lyndi

From: Maria Knake <mknake@amrl.net>
Sent: Thursday, March 31, 2016 1:18 PM
To: Sheehy, Eileen; Blackburn, Lyndi
Cc: Sokol, Kathy L; John Malusky; Ben Sade; Brian Johnson
Subject: T240 and T315 Questions

Hi Eileen and Lyndi,

Kathy Sokol asked a couple of questions of AMRL that are stumping us, and probably need to be addressed by TS 2b.

- When using Table 2 of T240 to determine precision estimates, it seems that the single operator precision is greater than the multilaboratory precision if your mass loss is below 0.45%. ASTM actually has different equations for precision based on whether or not the mass change is above or below 0.1%. Perhaps AASHTO should consider a similar approach? We could look at some PSP data and assist with this if need be. At the very least there should be a statement that the multi lab precision could be larger than single operator if a mass loss of 0.45% is obtained. Here is a little snippet from the Excel Spreadsheet we used to look at this:

X	Single	Multi	Single Greater Than Multi?
0.01	0.006463	0.002928	True
0.02	0.006826	0.004293	True
0.03	0.007189	0.005658	True
0.04	0.007552	0.007023	True
0.041	0.007588	0.00716	True
0.044	0.007697	0.007569	True
0.045	0.007734	0.007706	True
0.046	0.00777	0.007842	False
0.048	0.007842	0.008115	False
0.05	0.007915	0.008388	False
0.06	0.008278	0.009753	False
0.07	0.008641	0.011118	False
0.08	0.009004	0.012483	False
0.09	0.009367	0.013848	False
0.1	0.00973	0.015213	False
0.11	0.010093	0.016578	False

- Also, the AMRL data used to develop the precision statements in AASHTO is quite old. We have newer data we could provide if you would be interested updated statements.
- Moving on to T315: According to section 12 Interpretation of Results, 12.1 states: "It's not necessary to generate such sweeps during normal specification testing; however, such plots are useful for verifying the limits of the linear region".
- X1.8.1 states: "If the measurement was performed in the nonlinear range of the material, the results obtained under the standard will be considered as invalid for grading according to M 320.
- Kathy asks "we have not been performing strain sweeps based on the statement in 12.1, i.e. that it is not necessary for spec testing. Should we be doing this regularly? Otherwise how does one know if their results are in the linear region? And, then how can we state that a product meets M320 spec requirements?" The

statement in X1.8.1 is non-mandatory information (in the Appendix), but Kathy still makes a good point. I think this probably deserves some great discussion within TS 2b.

Thank you,

-Maria

Maria Knake

Program Manager, Laboratory Assessment Program

Phone: 240-436-4804

E-mail: mknake@amrl.net

AASHTO Materials Reference Laboratory (AMRL)

4441 Buckeystown Pike

Suite A

Frederick, MD 21704-7507

www.amrl.net



First Name	Last Name	Title	Email	Phone
Brian	Johnson	AASHTO	bjohnson@amrl.net	240-436-4820
Tracy	Barnhart	AASHTO	tbarnhart@amrl.net	240-436-4802
Deb	Kim	AASHTO	dkim@ashto.org	202-624-5883
Maria	Knake	AASHTO	mknake@amrl.net	240-436-4804
Steven	Ingram	AL DOT	ingrams@dot.state.al.us	334-206-2335
Scott	George	AL DOT	georges@dot.state.al.us	334-206-2201
Lyndi	Blackburn	ALDOT	blackburnl@dot.state.al.us	334-206-2203
Greg	Uherek	AMRL	guherek@amrl.net	240-436-4840
John	Malusky	AMRL	jmalusky@amrl.net	240-436-4825
Steven	Lenker	AMRL	slenker@amrl.net	240-436-4770
Michael	Benson	AR State Highway And Transport	michael.benson@arkansashighways.com	501-569-2185
Robert	Horan	Asphalt Institute	bhoran@asphaltinstitute.org	804-539-3036
Danny	Gierhart	Asphalt Institute	dgierhart@asphaltinstitute.org	405-210-7421
Jesus	Sandoval-Gil	AZ DOT	jsandoval-gil@azdot.gov	928-200-4260
Paul	Burch	AZ DOT	pburch@azdot.gov	602-712-8085
Bill	Schiebel	CO DOT	bill.schiebel@state.co.us	303-398-6501
Robert	Lauzon	CT DOT	robert.lauzon@ct.gov	860-258-0312
John	D'Angelo	D'Angelo Consulting, LLC	johndangelo@dangeloconsultingllc.com	571-218-9733
Rezene	Medhani	DC DOT	rezene.medhani@dc.gov	202-654-6030
Jennifer	Pinkerton	DE DOT	jennifer.pinkerton@state.de.us	302-760-2071
Hany	Fekry	DE DOT	hany.fekry@state.de.us	302-760-2551
Cecil	Jones	Diversified Engineering Services I	cecil.jones@nc.rr.com	919-616-5139
Mike	Voth	Federal Lands Highway - FHWA	michael.voth@dot.gov	720-963-3505
Matthew	Corrigan	FHWA	matthew.corrigan@dot.gov	202-366-1549
Jack	Springer	FHWA	jack.springer@dot.gov	202-493-3144
Jack	Youtcheff	FHWA	jack.youtcheff@dot.gov	202-493-3090
Brad	Neitzke	FHWA	brad.neitzke@dot.gov	360-619-7725
John	Bukowski	FHWA	john.bukowski@dot.gov	202-366-1287
Bob	Orthmeyer	FHWA, OTS, Resource Center	bob.orthmeyer@dot.gov	708-283-3533
Timothy	Ruelke	FL DOT	timothy.ruelke@dot.state.fl.us	352-955-6620
Frank	Fee	Frank Fee, LLC	frank.fee@verizon.net	610-608-9703
Monica	Flournoy	GA DOT	mflournoy@dot.ga.gov	404-608-4708
Neoma	Cole	GA DOT	ncole@dot.ga.gov	404-608-4817
Peter	Wu	GA DOT	pwu@dot.ga.gov	404-608-4840
Will	Rogers	Georgia Asphalt Pavement Assoc	wrogers@gahotmix.com	770-622-7798
Jim	Bibler	Gilson Company, Inc.	jbibler@gilsonco.	800-444-1508
Gerry	Huber	Heritage Research Group	gerald.huber@hrqlab.com	317-439-4680
John	Bilderback	ID DOT	john.bilderback@itd.idaho.gov	208-334-8426
LaDonna	Rowden	IL DOT	ladonna.rowden@illinois.gov	217-782-4423
Brian	Pfeifer	IL DOT	brian.pfeifer@illinois.gov	217-782-6585
Jason	Bausano	Ingevity	jason.bausano@ingevity.com	843-566-5940
Maurice	Arbelaez	InstroTek, Inc.	marbelaez@instrotek.com	919-875-8371
Christopher	Leibrock	KS DOT	cleibrock@ksdot.org	785-296-6959
Rick	Barezinsky	KS DOT	rickba@ksdot.org	785-368-6521
Brandi	Mitchell	KY TC	brandi.mitchell@ky.gov	502-564-3160
Allen	Myers	KY Transportation Cabinet	allen.myers@ky.gov	502-564-3160
Michael	Black	KY Transportation Cabinet	michael.black@ky.gov	502-564-3160
Brian	Owens	LA DOTD	brian.owens@la.gov	225-248-4131
Jason	Davis	LADOTD	jason.davis@la.gov	225-248-4106

First Name	Last Name	Title	Email	Phone
John	Grieco	MA DOT	john.grieco@dot.state.ma.us	617-951-0596
Sejal	Barot	MD SHWA	sbarot@sha.state.md.us	443-572-5037
Derek	Nener-Plante	ME DOT	derek.nener-plante@maine.gov	207-215-0849
Richard	Bradbury	MEDOT	richard.bradbury@maine.gov	207-624-3482
Kevin	Kennedy	MI DOT	kennedyk@michigan.gov	517-322-6043
Curt	Turgeon	MN DOT	curt.turgeon@state.mn.us	
Brett	Trautman	MO DOT	brett.trautman@modot.mo.gov	573-751-1036
Steve	Smith	MS DOT	ssmith1714@mdot.ms.gov	601-249-5202
James	Williams	MS DOT	jwilliams@mdot.ms.gov	601-359-7007
Ross Oak'''	Metcalfe	MT DOT	rmetcalfe@mt.gov	406-444-9201
Gerald	Reinke	MTE Services, Inc.	gerald.reinke@mtservices.com	608-779-6304
Audrey	Copeland	National Asphalt Pavement Assor	audrey@asphaltpavement.org	301-731-4748
Chris	Peoples	NC DOT	cpeoples@ncdot.gov	919-329-4000
Ron	Horner	ND DOT	rhorne@nd.gov	701-328-6904
Denis	Boisvert	NH DOT	dboisvert@dot.state.nh.us	603-271-1545
Changlin	Pan	NV DOT	cpan@dot.state.nv.us	775-888-7789
Don	Streeter	NYSDOT	donald.streeter@dot.ny.gov	518-457-4593
Lisa	Zigmund	OH DOT	lisa.zigmund@dot.ohio.gov	614-275-1351
Kenny	Seward	OK DOT	kseward@odot.org	405-522-4999
Scott	Seiter	OK DOT	sseiter@odot.org	405-521-2186
Anne	Holt	Ontario Ministry Of Transportati	anne.holt@ontario.ca	416-235-3724
Delmar	Salomon	Pavement Preservation Systems I	delmar@technopave.com	208-672-1977
David	Kuniega	PENNDOT	dkuniega@pa.gov	717-787-3966
Timothy	Ramirez	PENNDOT	tramirez@pa.gov	717-783-6602
Todd	Arnold	Pine Test Equipment, LLC	tarnold@pineinst.com	814-404-0477
Mark	Felag	RI DOT	mark.felag@dot.ri.gov	401-641-8279
Temple	Short	SC DOT	shorttk@scdot.org	803-737-6648
Merrill	Zwanka	SC DOT	zwankame@scdot.org	803-737-6682
Brian	Egan	TN DOT	brian.egan@tn.gov	615-350-4101
Danny	Lane	TN DOT	danny.lane@tn.gov	615-350-4175
Michael	Doran	TNDOT	michael.doran@tn.gov	615-350-4105
Amir	Hanna	TRB	ahanna@nas.edu	202-334-1432
Andy	Naranjo	TX DOT	andy.naranjo@txdot.gov	512-505-5858
Darren	Hazlett	TX DOT	darren.hazlett@txdot.gov	512-416-2456
Scott	Andrus	UTDOT	scottandrus@utah.gov	801-965-4859
William	Bailey	VADOT	bill.bailey@vdot.virginia.gov	804-328-3106
Charles	Babish	VADOT	andy.babish@vdot.virginia.gov	804-328-3102
Mladen	Gagulich	VTAOT	mladen.gagulich@vermont.gov	802-828-6405
Barry	Paye	WI DOT	barry.paye@dot.wi.gov	608-246-7945
John	Crane	WV DOT	john.e.crane@wv.gov	304-558-7472
Greg	Milburn	WY DOT	greg.milburn@wyo.gov	307-777-4070
Paul	Farley		paul.m.farley@wv.gov	304-558-7491

TS 2b

Designation No.	Title	ASTM Equiv.	Action Needed
M 226-80 (2012)	Viscosity-Graded Asphalt Cement		Revise or Reconfirm
M 320-16	Performance-Graded Asphalt Binder		No
M 332-14	Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test		No
R 015-00 (2012)	Asphalt Additives and Modifiers		Revise or Reconfirm
R 026-01 (2013)	Certifying Suppliers of Performance-Graded Asphalt Binders		No
R 028-12 (2016)	Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)		No
R 029-15	Grading or Verifying the Performance Grade (PG) of an Asphalt Binder		No
R 049-09 (2013)	Determination of Low-Temperature Performance Grade (PG) of Asphalt Binders		No

TS 2b

Designation No.	Title	ASTM Equiv.	Action Needed
T 044-14	Solubility of Bituminous Materials	D2042-01	No
T 048-06 (2015)	Flash and Fire Points by Cleveland Open Cup	D92-05a	No
T 049-15	Penetration of Bituminous Materials	D5/D5M-13	No
T 051-09 (2013)	Ductility of Asphalt Materials	D113-07	No
T 053-09 (2013)	Softening Point of Bitumen (Ring-and-Ball Apparatus)	D36-06	No
T 102-09 (2013)	Spot Test of Asphaltic Materials		No
T 111-11 (2015)	Mineral Matter or Ash in Asphalt Materials		No
T 179-05 (2013)	Effect of Heat and Air on Asphalt Materials (Thin-Film Oven Test)	D1754-97(2002)	No
T 201-15	Kinematic Viscosity of Asphalts (Bitumens)	D2170/D2170M-10	No
T 202-15	Viscosity of Asphalts by Vacuum Capillary Viscometer	D2171/D2171M-10	No
T 228-09 (2013)	Specific Gravity of Semi-Solid Asphalt Materials	D70-08	No
T 240-13	Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)	D2872-04	Revise or Reconfirm

TS 2b

Designation No.	Title	ASTM Equiv.	Action Needed
T 313-12 (2016)	Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)		No
T 314-12 (2016)	Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)		No
T 315-12 (2016)	Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)		No
T 316-13	Viscosity Determination of Asphalt Binder Using Rotational Viscometer		Revise or Reconfirm
T 350-14	Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)		No

TS 2b

Designation No.	Title	Pub Yr. 1	Action Needed
TP 101-12 (2016)	Estimating Fatigue Resistance of Asphalt Binders Using the Linear Amplitude Sweep	2012	No
TP 102-16	Evaluation of Asphalt Release Agents (ARAs)	2012	No
TP 122-16	Determination of Performance Grade of Physically Aged Asphalt Binder Using Extended Bending Beam Rheometer (BBR) Method	2016	No
TP 123-16	Measuring Asphalt Binder Yield Energy and Elastic Recovery Using the Dynamic Shear Rheometer	2016	No

Standard Specification for Performance-Graded Asphalt Binder

AASHTO Designation: M 320-~~16~~XX

Rationale:

This is a follow up to last year's unsuccessful TS Ballot on the same subject. Request from Ron Corun, Axion, to allow for grades outside of the tables such as a PG 88-22 that are being specified by some airports. By adding the note, the binder can be specified without adding to the tables or necessitating that the specifier include the entire standard in their specification.

The wording has been revised for this year's ballot to address comments and negatives. It is note 4 following Section 5.6.

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Specification for

Performance-Graded Asphalt Binder

AASHTO Designation: M 320-~~16~~XX



1. SCOPE

- 1.1. This specification covers asphalt binders graded by performance. Grading designations are related to the average seven-day maximum pavement design temperature and the minimum pavement design temperature. This specification contains Table 1 and Table 2. If no table is specified, the default is Table 1.
- 1.2. Table 2 incorporates R 49 for determining the critical low cracking temperature using a combination of T 313 and T 314 test procedures.
- Note 1**—For asphalt cements graded by viscosity at 60°C, see M 226.
- Note 2**—R 29 provides information for determining the performance grade of an asphalt binder.
- Note 3**—For specifying performance-graded asphalt binder using Multiple Stress Creep Recovery (MSCR), see M 332.

2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
- M 226, Viscosity-Graded Asphalt Cement
 - M 323, Superpave Volumetric Mix Design
 - M 332, Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test
 - R 28, Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
 - R 29, Grading or Verifying the Performance Grade (PG) of an Asphalt Binder
 - R 35, Superpave Volumetric Design for Asphalt Mixtures
 - R 49, Determination of Low-Temperature Performance Grade (PG) of Asphalt Binders
 - R 66, Sampling Asphalt Materials
 - T 44, Solubility of Bituminous Materials
 - T 48, Flash and Fire Points by Cleveland Open Cup
 - T 240, Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)
 - T 313, Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)
 - T 314, Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)
 - T 315, Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
 - T 316, Viscosity Determination of Asphalt Binder Using Rotational Viscometer

- 2.2. *ASTM Standards:*
- D8, Standard Terminology Relating to Materials for Roads and Pavements
 - D95, Standard Test Method for Water in Petroleum Products and Bituminous Materials by Distillation
 - D5546, Standard Test Method for Solubility of Asphalt Binders in Toluene by Centrifuge

3. TERMINOLOGY

- 3.1. *Definitions:*
- 3.1.1. Definitions for many terms common to asphalt binder are found in ASTM D8.
- 3.1.2. *asphalt binder*—an asphalt-based cement that is produced from petroleum residue either with or without the addition of nonparticulate organic modifiers.

4. ORDERING INFORMATION

- 4.1. When ordering under this specification, include in the purchase order the performance grade (PG) of asphalt binder required and the table used (e.g., (1) M 320, PG 52-16, Table 1, or (2) M 320, PG 64-34, Table 2). If no table is specified, the default is Table 1.
- 4.2. Asphalt binder grades may be selected by following the procedures described in M 323 and R 35.

5. MATERIALS AND MANUFACTURE

- 5.1. Asphalt binder shall be prepared by the refining of crude petroleum by suitable methods, with or without the addition of modifiers.
- 5.2. Modifiers may be any organic material of suitable manufacture that is used in virgin or recycled condition and that is dissolved, dispersed, or reacted in asphalt binder to enhance its performance.
- 5.3. The asphalt binder shall be homogeneous, free from water and deleterious materials, and shall not foam when heated to 175°C.
- 5.4. The asphalt binder shall be at least 99.0 percent soluble as determined by T 44 or ASTM D5546.
- 5.5. This specification is not applicable for asphalt binders in which fibers or other discrete particles are larger than 250 µm in size.
- 5.6. The grades of asphalt binder shall conform to the requirements given in Table 1 or Table 2.

Note 4—Grades outside of Table 1 or Table 2 are sometimes specified. If grades are specified beyond those listed in Table 1 or Table 2, a high, low, and intermediate temperature shall be specified. The high and low temperature grade should be specified in 6 °C increments for consistency with the PG grading system.

6. SAMPLING

- 6.1. The material shall be sampled in accordance with R 66.

7. TEST METHODS

- 7.1. The properties outlined in Sections 5.3, 5.4, and 5.6 shall be determined in accordance with R 28, T 44 or ASTM D5546, T 48, ASTM D95, T 240, T 313, T 314, T 315, and T 316.

8. INSPECTION AND CERTIFICATION

- 8.1. Inspection and certification of the material shall be agreed on between the purchaser and the seller. Specific requirements shall be made part of the purchase contract. The seller shall provide material handling and storage procedures to the purchaser for each asphalt binder grade certified.

9. REJECTION AND RETESTING

- 9.1. If the results of any test do not conform to the requirements of this specification, retesting to determine conformity is performed as indicated in the purchase order or as otherwise agreed on between the purchaser and the seller.

10. KEYWORDS

- 10.1. Asphalt binder; asphalt cement; direct tension; flash point; modifier; performance specifications; pressure aging; rheology.

Standard Specification for Detecting the Presence of Phosphorous in Asphalt Binder

AASHTO Designation: TP 78-09 (2013)¹



American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Specification for**Detecting the Presence of
Phosphorous in Asphalt Binder****AASHTO Designation: TP 78-09 (2013)¹**

1. SCOPE

- 1.1. This qualitative test method can be used to identify the presence of polyphosphoric acid (PPA) in asphalt binder or residue. If PPA is present in the binder, a blue color is developed in approximately 5 min. The test method is not quantitative, but it can detect PPA at concentrations as low as 0.1 percent. The test method can only determine the presence of phosphorus. It is not specific for the presence of PPA. A positive test result assumes that the phosphorus is from PPA. Any additive that contains phosphorus will give a false positive for the presence of PPA.
- 1.2. The values stated in SI units are to be regarded as the standard.
- 1.3. *This standard does not purport to address all of the safety concerns, if any, 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 prior to use.*

2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standard:*
■ R 66, Sampling Asphalt Materials

3. SUMMARY OF TEST METHOD

- 3.1. Butyl alcohol is used to extract some of the acid present from the asphalt. The extracted acid is then transferred to the water phase. The presence of phosphoric acid is detected by reaction with ammonium molybdate, potassium antimonyl tartrate, and ascorbic acid to form a blue color.

4. SIGNIFICANCE

- 4.1. Phosphoric acid may be added to asphalt binder to modify the physical properties of the binder. This test method detects the presence of phosphoric acid in the asphalt binder but is not a quantitative test. The result is either positive or negative that phosphoric acid is present.

5. APPARATUS

- 5.1. *Pipette*—Disposable, plastic transfer pipettes.
- 5.2. *Containers*—One-ounce cans, test tubes, or small beakers. Disposable cans or glassware are recommended to avoid contamination. If glassware is reused, it must be washed with hot (1 + 3) hydrochloric acid (1 part hydrochloric acid to 3 parts distilled water) and rinsed with distilled

water. Commercial detergents should not be used to clean the glassware because they may contain phosphates, which will interfere with the results.

Note 1—One agency found that the cans they were using for this test had been lubricated during the manufacturing process with a lubricant containing phosphates. This resulted in a positive result in this test even with the empty can. If there is doubt about the condition of the containers being used, then take the precaution of running a blank test with no asphalt.

6. REAGENTS AND MATERIALS

- 6.1. *Antimonyl Tartrate/Ammonium Molybdate Solution*—Dissolve 0.13 g of potassium antimonyl tartrate hydrate $[\text{C}_8\text{H}_4\text{K}_2\text{O}_{12}\text{Sb}_2\cdot\text{H}_2\text{O}]$ in 50 mL of distilled water. Add 5.6 g of ammonium molybdate $[(\text{NH}_4)_6\text{Mo}_7\text{O}_{24}\cdot 4 \text{H}_2\text{O}]$ and swirl until dissolved.
- 6.2. *Sulfuric Acid Solution*—1 N solution of sulfuric acid $[\text{H}_2\text{SO}_4]$. Sulfuric acid solution can be purchased in 1-L polyethylene bottles.
- 6.3. *Stock Solution*—Mix the antimonyl tartrate/ammonium molybdate solution from Section 6.1 with approximately 950 mL of 1 N sulfuric acid solution. This can be done by adding the solution from Section 6.1 to 1 L of 1 N 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.
- 6.4. *Ascorbic Acid Color Reagent*—Dissolve 0.50 g of L-ascorbic acid $[\text{C}_6\text{H}_8\text{O}_6]$ in 100 mL of the stock solution from Section 6.3. Prepare the reagent fresh daily as needed.
- 6.5. *Butyl Alcohol*—Isobutanol $[(\text{CH}_3)_2\text{CHCH}_2\text{OH}]$ or *n*-butanol $[\text{CH}_3(\text{CH}_2)_3\text{OH}]$ may be used.

7. SAMPLING

- 7.1. Sample the material in accordance with R 66. See Note 2 regarding potential concerns regarding contamination of sampling container.

8. PROCEDURE

- 8.1. Heat the asphalt and pour 1 to 2 g into a 1-oz can or other small container.
- 8.2. Place the container in an oven set at $163 \pm 10^\circ\text{C}$ for 10 min to ensure the asphalt is fluid.
- 8.3. Remove the container, and immediately add 2 mL of butyl alcohol while stirring the container.
- 8.4. Continue to stir the container and add 2 mL of distilled water.
- 8.5. While still stirring the container, add 2 mL of the ascorbic acid color reagent. After the addition of the color reagent, stop stirring and allow the sample to sit for 5 to 10 min.
- 8.6. If phosphoric acid is present in the asphalt, a blue color will develop within 5 to 10 min. Decant the solution into a second container if unable to see the color.
- Note 2**—After 30 min, the results are not reliable. The color may either fade or intensify after 30 min.
- 8.7. If a blue color appears, the sample is reported as “positive.” The sample is reported as “negative” if it does not turn blue.

Note 3—The blue color, if present, will be in the aqueous phase, which will be at the bottom. Often the top layer has a brown or green color.

- 8.8. When new reagents are prepared, prepare and run a blank (asphalt with no phosphoric acid).

9. REPORT

- 9.1. *This report shall include the following:*

9.1.1. Identification of sample.

9.1.2. “Positive” or “Negative” result.

10. PRECISION AND BIAS

10.1. *Precision*—The research required to develop precision estimates has not been conducted.

10.2. *Bias*—This test method has no bias since the values determined can only be defined in terms of this test method.

11. KEYWORDS

11.1. Asphalt; phosphoric acid; PPA.

¹ This provisional standard was first published in 2009.

Standard Method of Test for

Flash ~~and Fire~~ Points of Asphalt
Binder by Cleveland Open Cup

AASHTO Designation: T 48-~~06~~ ~~(2015)~~ XX

~~ASTM Designation: D92-05a~~



American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Method of Test for**Flash ~~and Fire~~ Points of Asphalt Binder by
Cleveland Open Cup****AASHTO Designation: T 48-~~06 (2015)~~XX****ASTM Designation: ~~D92-05a~~**

1. SCOPE

1.1. This method covers the procedure for the determination of flash point of asphalt binder by the Cleveland open-cup apparatus.

1.2. This test method is applicable to asphalt binder with flash point between 80°C (175°F) and 400°C (750°F)

Note 1—Specifications commonly designate the Tag Open-Cup method (T 79) for asphalt binders and cutback asphalts having flash points below 93°C (200°F).

1.3. The values stated in SI units are to be regarded as the standard.

1.4. This test may involve hazardous materials, operations, and equipment. This test does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standard:

- R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
- R 66, Sampling Asphalt Materials
- T 79, Flash Point with Tag Open-Cup Apparatus for Use with Material Having a Flash Point Less Than 93°C (200°F)

2.2. ASTM Standard:

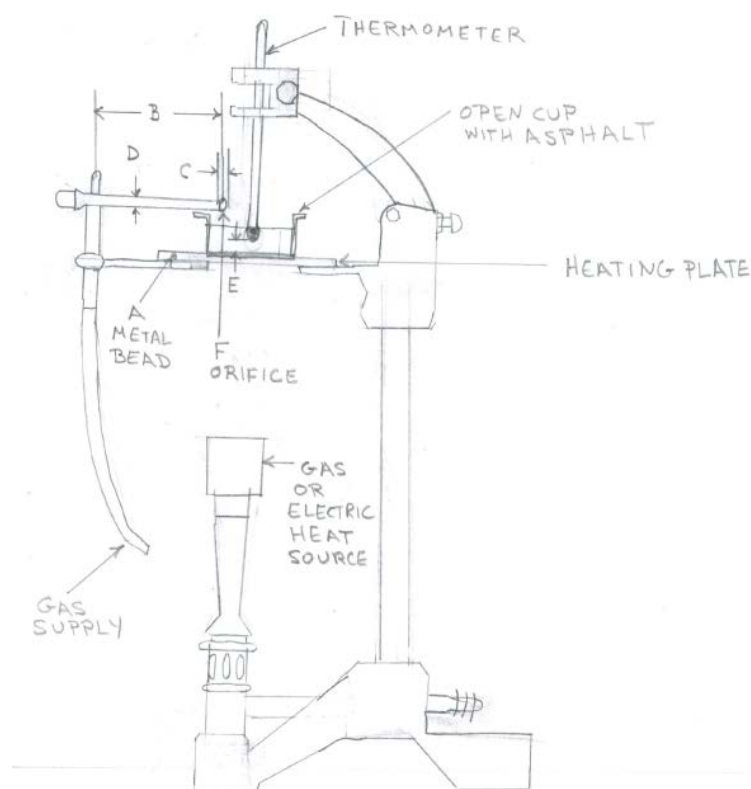
- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
- E220, Standard Test Method for Calibration of Thermocouples By Comparison Techniques
- E644, Standard Test Methods for Testing Industrial Resistance Thermometers

3. SUMMARY OF TEST METHOD

- 3.1. The sample is placed in the tester and heated rapidly to begin with then at a slow rate. A small test flame is passed at a uniform rate in a level plane across the cup at specified intervals. The flash point is the lowest temperature at which application of the test flame causes the vapor at the surface of the liquid to flash.

4. APPARATUS

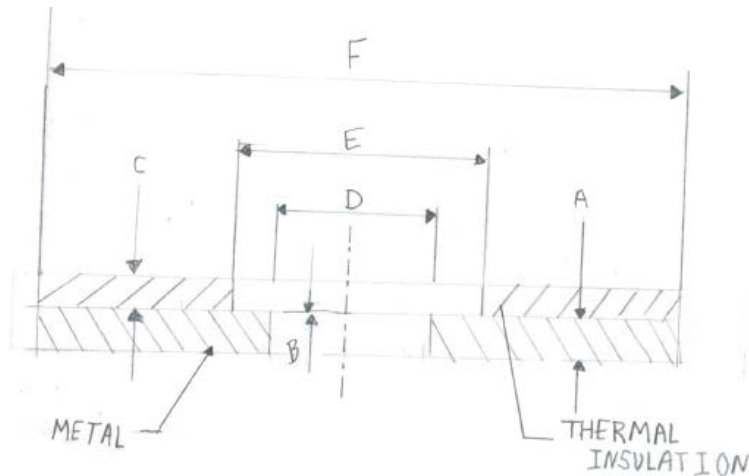
- 4.1. Cleveland Open-Cup Tester—Consisting of the following parts. The parts must conform to the dimensions shown and have the additional characteristics as noted. (See Figure 1.) The Cleveland Open Cup Tester may be manual or automated. If automated, the flash point instrument shall perform the test in accordance with Section 7.



Replace the dimensions in Figure 1 with the following:

	Millimeters		Inches	
	Min	Max	Min	Max
A—Diameter	3.8	5.4	0.15	0.21
<u>B—Radius</u>		<u>152 nominal</u>		<u>6 nominal</u>
C—Diameter	1.6	5.0	0.06	0.20
D		5.0		0.20
E	6.4, approximately		0.25, approximately	
<u>F—Diameter</u>		<u>0.8 nominal</u>		<u>0.031 nominal</u>

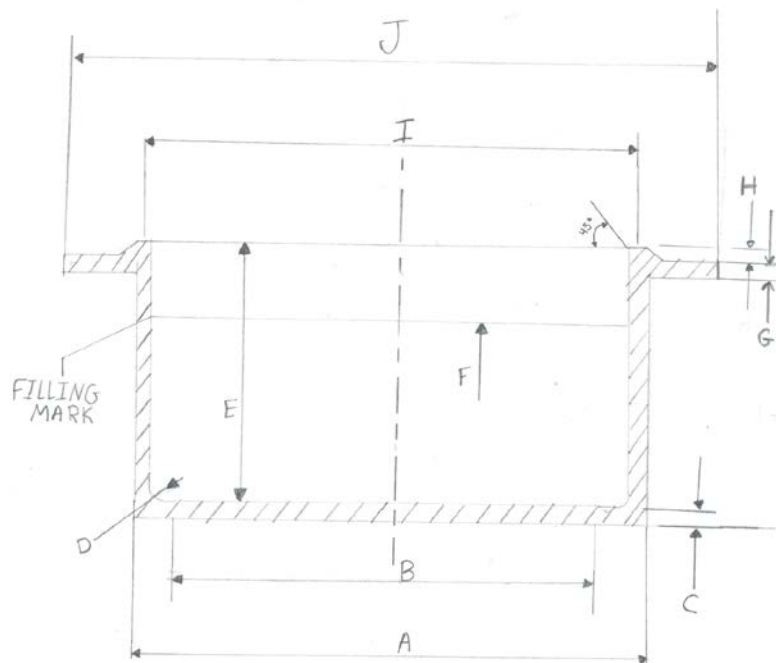
Figure 1 – Cleveland Open Cup Apparatus



Replace the dimensions in Figure 2 with the following:

	Millimeters		Inches	
	Min	Max	Min	Max
A		6.4, nominal		0.25, nominal
B	0.5	1.0	0.020	0.039
C		6.4, nominal		0.25, nominal
D—Diameter	54.5	56.5	2.15	2.22
E—Diameter	69.5	70.5	2.736	2.776
F—Diameter		150, nominal		6, nominal

Figure 2 – Heating Plate



Replace the dimensions in Figure 3 with the dimensions below. Do not include a dimension “G” as shown in Figure 3. However, include a dimension for the thickness of the flange of the test cup that is not included in Figure 3. This dimension for the thickness of the flange shall be designated “K” with the dimensional requirements as in the following table:

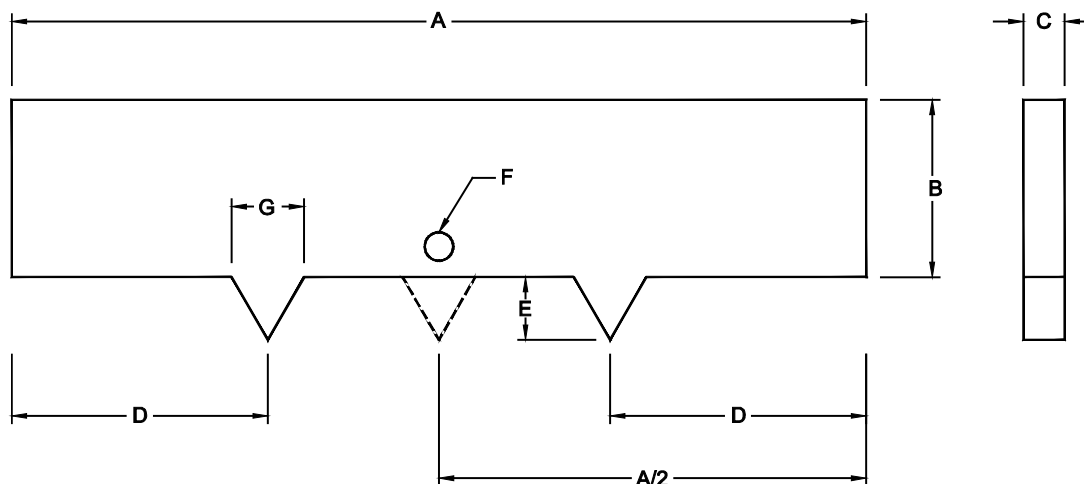
	Millimeters		Inches	
	Min	Max	Min	Max
<u>A</u>	<u>67.5</u>	<u>69</u>	<u>2.658</u>	<u>2.717</u>
B	62.5	64.0	2.46	2.52
C	2.8	3.6	0.11	0.14
D—Radius	4, approximately		0.16, approximately	
<u>E</u>	<u>32.5</u>	<u>34</u>	<u>1.280</u>	<u>1.339</u>
<u>F</u>	<u>9</u>	<u>10</u>	<u>0.354</u>	<u>0.394</u>
<u>G</u>	<u>1.8</u>	<u>3.4</u>	<u>0.07</u>	<u>0.13</u>
H	2.8	3.6	0.11	0.14
<u>I</u>	<u>67</u>	<u>70</u>	<u>2.638</u>	<u>2.756</u>
J	97	101	3.8	4.0
<u>K</u>	<u>—1.8</u>	<u>—3.4</u>	<u>—0.07</u>	<u>—0.13</u>

Figure 3 – Cleveland Open Cup

- 4.1.1. Test cup—cup made of brass or other metal of similar conductivity conforming to Figure 3. The cup may be equipped with a handle.
- 4.1.2. Heating Plate—plate that ensures the heat is evenly distributed over the bottom of the test cup and that extraneous heating to other surfaces is minimized. See Figure 2 for plate dimensions.
- 4.1.3. Heat Source—Gas burner or electric heater centered under the opening of the heating plate with no local overheating. If using a gas burner, protect the flame from drafts using suitable shields that do not project above the top of the heating plate.
- 4.1.4. Thermometer Holder—Supplied with the tester. It shall support the thermometer firmly in a vertical position.
- 4.1.5. Heating Plate Holder—Support to hold the heating plate level and steady.
- ~~4.1.4.~~ 4.1.6. ~~AI.3~~ Ignition Source Applicator—The device for applying the test flame may be of any suitable design, but the tip shall be 1.6 to 5.0 mm (0.06 to 0.20 in.) in diameter at the end and the orifice shall have an approximate diameter of 0.8 mm (0.031 in.). The device for applying the test flame shall be so mounted to permit automatic duplication of the sweep of the test flame, the radius of swing being not less than 150 mm (6 in.) and the center of the orifice moving in a plane not more than 2.5 mm (0.10 in.) above the cup. A bead having a diameter of 3.8 to 5.4 mm (0.15 to 0.21 in.) shall be mounted in a convenient position on the apparatus so the size of the test flame can be compared to it.
- 4.2. Thermometer—An ASTM 11C (11F) thermometer as prescribed in ASTM E1 with an accuracy of 0.2°C (0.5°F). The thermometer shall be calibrated according to the requirements specified in R 18. This thermometer shall be used to make all temperature measurements required by this method.
- 4.2.1. The test thermometer may be replaced with an alternative thermometric device, provided the following requirements are met:
- 4.2.1.1. The thermometric device shall be mounted in the same position as the test thermometer it replaces.
- 4.2.1.2. The thermometric device shall (1) have a maximum scale error no greater than that of the test thermometer it replaces, (2) be capable of indicating temperature within 0.1°C (0.2°F), and (3) have the same temperature response.

4.2.1.3. The thermometric device shall be standardized at the interval specified in R 18. Guidance for performing the standardization is given in ASTM E220 or E644.

4.2.4.3. A1.7-Filling Level Gauge(optional)—A device to aid in the proper adjustment of the sample level in the cup. It may be made of suitable metal with at least one projection, but preferably two for adjusting the sample level in the test cup to 9 to 10 mm (0.35 to 0.39 in.) below the top edge of the cup. A hole 0.8 mm (0.031 in.) in diameter, the center of which is located not more than 2.5 mm (0.10 in.) above the bottom edge of the gauge, shall be provided for use in checking the center position of the orifice of the test flame applicator with respect to the rim of the cup. (Figure 4 shows a suitable version.)



	mm	in.	
A	100	4	Nominal
B	20	0.75	Nominal
C	3.2	0.125	Nominal
D	30	1.25	Nominal
E	9–10	0.35–0.39	Nominal
F	0.8 Dia (2.5 mm above bottom edge)	0.03125 Dia (0.10 in. above bottom edge)	Maximal
G	10	0.375	Nominal

Figure 4—Filling Level Gauge

5. CALIBRATION AND STANDARDIZATION

5.1. The thermometer or thermometric device shall be standardized at the interval specified in R 18.

5.2. The performance of the apparatus shall be verified at least once per year by determining the flash point of a known reference material. Run the test according to Section 7 on a Certified Flash Point Material. The Certified Flash Point Material shall have test results for T 48 or for ASTM D92. To be considered acceptable, the flash point shall be within $\pm 8.0^{\circ}\text{C}$ ($\pm 14.4^{\circ}\text{F}$) of the certified test

result. If the test result is out of tolerance, check the apparatus for compliance with Section 4 and rerun with a new sample.

6. ASSEMBLY AND PREPARATION OF APPARATUS

- 6.1. The Cleveland open-cup tester shall be placed in a firm and level position on a solid, vibration-free table in a draft-free hood or flash room, or well toward the back of a draft shield. The top of the tester shall be shielded from strong light so that the flash may be easily seen.
- 6.2. The temperature measuring device shall be positioned with the bottom of the device being 6.4 ± 1.0 mm (0.25 ± 0.04 in) above the bottom of the test cup and approximately half way between the center and the inside edge of the test cup on the side opposite the test flame applicator mounting position.
- 6.3. Follow manufacturer's instructions for setting up the manual or the automated apparatus for operation. Set the automated tester to run the test in accordance with Section 7.3.

7. PROCEDURE

- 7.1. Obtain the asphalt binder sample according to R 66. Heat the sample in its container with a loosely fitted cover in an oven not to exceed 163°C (325°F) for the minimum time necessary to ensure that the sample is completely fluid. Manually stir the sample but avoid incorporating air bubbles.

- 7.2. Fill the cup with material to be tested to the filling mark $9 - 10$ mm ($0.35 - 0.39$ in.) below the rim of the cup. If the filling level gauge is used, fill the cup until the level of material just touches the pointers of the leveling device.

Note 2—The test sample should be at least 50°C (90°F) below the anticipated flash point.

Note 4—The sample cup may be filled away from the apparatus provided the thermometer is preset with the cup in place and the sample level is correct at the beginning of the test. A shim 6.4-mm (0.25-in.) thick is useful in obtaining the correction distance from the bottom of the bulb to the bottom of the cup.

- 7.3. Manual Flash Point Testing

- 7.3.1. Light the test flame, and adjust it to a diameter of 3.8 to 5.4 mm (0.15 to 0.21 in.).

- ~~4.2.4.7.3.2.~~ For testing of a sample for which the expected flash point temperature is known, Apply heat initially at such a rate that the temperature indicated by the temperature-measuring device increases 10 to 20°C (18 to 36°F)/min. When the test specimen temperature is approximately 50°C (120°F) below the expected flash point, decrease the heat so that the rate of temperature rise during the last 28°C (50°F) before the flash point is 4 to 7°C (7 to 13°F)/min.

- 7.3.3. At approximately 28°C (50°F) below the anticipated flash point and at successive 2°C (5°F) intervals, pass the ignition taper across the sample in a continuous motion so that the time consumed for each pass is 1 s. The center of the test flame must move in a horizontal plane not more than 2.5 mm (0.10 in.) above the plane of the upper edge of the cup and pass in one direction only. At the time of the next test flame application, pass the test flame in the opposite direction of the preceding application.

Note 5: If a surface film forms on the sample, it is recommended that the film be moved to the side using a paperclip or spatula prior to application of the test flame.

- 7.3.4. From 28°C (50°F) below the anticipated flash point to the end of the test, take care to avoid disturbing the vapors in the test cup.
- 7.3.5. If a foam persists during that last 28°C (50°F) temperature rise below the anticipated flash point, end the test and disregard the results.
- 7.3.6. For testing of a sample for which the expected flash point temperature is not known, heat the sample to the temperature used for pouring in Section 7.1. Continue heating the test specimen at 4 to 710°C (7 to 1318°F)/min and testing the material every 2°C (5°F) as described in Section 41.4.57.3.2 until the flash point is obtained.
- 7.3.7. Record, as the observed flash point, the temperature read on the thermometer at the time the test flame application causes a distinct flash in the interior of the test cup.

Note 5—The application of the test flame may cause a halo or enlargement of the test flame. This is not considered the flash point. A large flame that propagates on the surface denotes that the flash point has been reached.

7.4. Automated Flash Point Testing

- 7.4.1. If necessary, light the test flame, and adjust it to a diameter of 3.8 to 5.4 mm (0.15 to 0.21 in.).

Note 6: Some automated apparatus can light and adjust the test flame automatically, and some automated apparatus pass the test flame in one single direction.

- 7.4.2. Start the automated apparatus according to the manufacturer's instructions. The automated apparatus shall conduct the procedure as required in Section 7.3.
- 7.4.3. Record, as the flash point, the temperature read on the thermometer at the time the test flame application causes a distinct flash in the interior of the test cup.

8. CALCULATIONS

- 8.1. Observe and record the ambient barometric pressure in the laboratory at the time of the test. If the barometric pressure varies from 101.3 kPa (760 mm Hg), calculate the corrected flash point as follows:

$$\text{Corrected flash point (°C)} = C + 0.25 (101.3 - A) \quad (1)$$

$$\text{Corrected flash point (°F)} = F + 0.06 (760 - B) \quad (2)$$

$$\text{Corrected flash point (°C)} = C + 0.033 (760 - B) \quad (3)$$

where:

C = observed flash point, °C.

F = observed flash point, °F.

A = ambient barometric pressure, mm HG, and

B = ambient barometric pressure, kPa.

9. REPORT

- 9.1. Report the corrected flash point, in degrees Celsius or Fahrenheit, as the "Cleveland Open-Cup Flash Point". Report flash point to the nearest whole number.

2.10. PRECISION AND BIAS

~~2.1.10.1.~~ ~~14.1~~ *Precision*—Criteria for judging the acceptability of test results for the flash point of asphalt binders obtained by this method are given in Table 1. ~~Criteria for judging the acceptability of fire point test results can be found in ASTM D92.~~

~~2.1.4.10.1.1.~~ ~~14.1.1~~ *Single-Operator Precision (Repeatability)*—The figures in Column 2 of Table 1 are the standard deviations that have been found to be appropriate for the conditions of test described in Column 1. Two results obtained in the same laboratory, by the same operator using the same equipment, in the shortest practical period of time, should not be considered suspect unless the difference in the two results exceeds the values given in Table 1, Column 3.

~~2.1.2.10.1.2.~~ ~~14.1.2~~ *Multilaboratory Precision (Reproducibility)*—The figures in Column 2 of Table 1 are the standard deviations that have been found to be appropriate for the conditions of test described in Column 1. Two results submitted by two different operators testing the same material in different laboratories shall not be considered suspect unless the difference in the two results exceeds the values given in Table 1, Column 3.

Table 1—Precision Estimates

Condition	Acceptable Standard Deviation (1s) ^a	Range of Two Results (d2s) ^a
Single-Operator Precision:		
Flash Point (°C)	3	8
Multilaboratory Precision:		
Flash Point (°C)	10	28

^a These values represent the 1s and d2s limits described in ASTM Practice C670.

Note: The precision estimates for Flash Point given in Table 1 are based on the analysis of test results from eight pairs of AMRL proficiency samples. The data analyzed consisted of results from 98 to 148 laboratories for each of the eight pairs of samples. The analysis included four binder grades: PG 52-34, PG 64-16, PG 64-22, and PG 70-22. Average flash points ranged from 268.5 to 353.5°C. The details of the analysis are in the final report for NCHRP Project No. 9-26, Phase 3.

~~2.2.10.2.~~ ~~14.2~~ *Bias*—The procedure of this test method has no bias because flash point ~~and fire point~~ can be defined only in terms of this test method.

11. KEYWORDS

~~11.1.~~ ~~Asphalt binder; Cleveland Open Cup; flash point~~

Standard Method of Test for

Determining the Fracture Energy Density of Asphalt Binder Using the Binder Fracture Energy (BFE) Test

AASHTO Designation: TP-XXX (BFE)

1. SCOPE

- 1.1. This test method covers the determination of fracture energy density of asphalt binder by means of a direct tension test. For evaluation of relative cracking performance, it is recommended that this test procedure be used with asphalt binder aged using AASHTO T240 (RTFOT) plus AASHTO R28 (PAV). However, this test can be used for determination of binder fracture energy for any binder including any un-aged or aged neat binder, modified binder, and asphalt binder extracted and recovered from pavement. The test apparatus is designed for testing within the intermediate temperature range, from 0°C to 30°C.
- 1.2. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

2. REFERENCE DOCUMENTS

- 2.1. AASHTO Standards:
 - M 320 Performance-Graded Asphalt Binder
 - R 28 Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
 - R 49 Determination of Low-Temperature Performance Grade (PG) of Asphalt Binders
 - R 66 Standard Practice for Sampling Asphalt Materials
 - T 240 Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)
- 2.2. ASTM Standards:
 - C670 Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
 - E1 Standard Specification for ASTM Liquid-in-Glass Thermometers
 - E4 Standard Practices for Force Verification of Testing Machines
 - E77 Standard Test Method for Inspection and Verification of Thermometers
 - E83 Standard Practice for Verification and Classification of Extensometer Systems
- 2.3. ISO Standard:

- ISO 10012 Measurement Management Systems—Requirements for Measurement Processes and Measuring Equipment

3. TERMINOLOGY

3.1. Definitions:

- 3.1.1. *asphalt binder*—an asphalt-based cement that is produced from petroleum residue either with or without the addition of particulate organic modifiers of size less than 250 μm .

3.2. Description of terms specific to this standard:

- 3.2.1. *brittle*—type of failure in a direct tension test where the stress-strain curve is essentially linear up to the point of failure and the failure is sudden by rupture of the test specimen without appreciable reduction in cross-sectional area of the specimen.
- 3.2.2. *brittle-ductile*—type of failure in a direct tension test where the stress-strain curve is curvilinear and the failure is by the rupture of the test specimen. Limited reduction in the cross-section of the specimen occurs before rupture.
- 3.2.3. *ductile*—type of failure in a direct tension test where the specimen does not rupture but fails by flow at large strain.
- 3.2.4. *tensile strain*—axial strain resulting from the application of a tensile load and calculated as the change in length of the effective gauge length caused by the application of the tensile load divided by the original unloaded effective gauge length.
- 3.2.5. *tensile stress*—axial stress resulting from the application of a tensile load and calculated as the tensile load divided by the original area of cross-section of the specimen.
- 3.2.6. *failure*—for specimens exhibiting a stress strain curve with a single peak stress followed by a continuously increasing reduction in stress, failure is the point at which the tensile stress reaches a maximum value.
- 3.2.7. *failure stress*—the tensile stress at the point associated with failure as defined in 3.2.6.
- 3.2.8. *failure strain*—the tensile strain corresponding to the failure stress.
- 3.2.9. *necking*—disproportionately large strain localized in a small region of the asphalt binder specimen which results in a prominent decrease in local cross-sectional area.
- 3.2.10. *true stress*—ratio of the applied load to the instantaneous cross sectional area.
- 3.2.11. *true strain*—strain determined by accounting for reduction in cross-sectional area.
- 3.2.12. *fracture energy density*—maximum energy that can be stored in a unit volume of material without the occurrence of fracture.
- 3.2.13. *large strain formulation*—analysis, which include changes in geometry due to excessively large strain.
- 3.2.14. *true stress-true strain curve*—graphical representation of the relationship between true stress and true strain.

4. SUMMARY OF TEST METHOD

- 4.1. This method describes the procedure used to measure stress and strain on a fracture failure plane in an asphalt binder specimen pulled at a constant rate of displacement (displacement-control). Test specimens have a special geometry (Figure 4-1) and they are

- prepared using the specified mold. Two G10 phenolic end tabs are bonded to the asphalt binder, and they transfer the tensile load from the test machine to the asphalt binder.
- 4.2. This test method was developed for asphalt binders at intermediate temperatures where they exhibit brittle-ductile or brittle failure. The test is not applicable at temperature where failure is by ductile flow (necking).
 - 4.3. A displacement transducer is used to measure the elongation of the test specimen as it is pulled in tension at a designated displacement rate. The load developed during the test is also measured. The tensile stress and strain from initial loading through failure are determined and used to calculate and report failure stress, failure strain, and fracture energy density.
 - 4.4. Fracture energy density can be used to evaluate the relative resistance to fracture of different asphalt binders. In addition, characteristics of the resulting true stress-true strain curve can be used to identify the presence of polymer and/or rubber in the binder.

Figure 4-1—Specimen Geometry

5. SIGNIFICANCE AND USE

- 5.1. The test is designed to measure fracture energy density of asphalt binder at intermediate temperatures. Fracture energy density has been shown to be an indicator of the resistance to fracture of an asphalt binder.
- 5.2. The test can be used to differentiate unmodified and modified binders by means of either the characteristics of the true stress-true strain curve or fracture energy density value. The test can also be used as an effective tool to screen new binders that may result in deficient performance.

- 5.3. For a given binder, fracture energy density as measured by this procedure has been determined to be independent of displacement rate and testing temperature. Although test temperatures may vary from 0 °C to 30 °C, 15 °C was found to work well for a broad range of binders. Therefore, this temperature was recommended to determine fracture energy density.
- 5.4. Although the test displacement rate may vary from 100 mm/min to 900 mm/min, 500 mm/min was found to work best for a broad range of binders. Therefore, this displacement rate is primarily used to determine binder fracture energy density at 15 °C. Test outcomes at the 500 mm/min rate may require an increase or decrease in this rate as specified in the test procedure, section 11.3.1.

6. APPARTUS

- 6.1. A forced-air convection oven capable of reaching and maintaining 170±10 °C for heating asphalt.
- 6.2. A loading system capable of pulling a test specimen at constant loading rates ranging from 100 to 900 mm/min.
 - 6.2.1. Test chamber for temperature control and testing, which is capable of maintaining a temperature between 0 °C to 30 °C, ±0.2 °C.
 - 6.2.2. Load cell capable of accurately measuring tensile load up to 448 N (100 lbs).
 - 6.2.3. Load measuring and recording devices (data acquisition system) capable of acquisition rates of up to 1,000 samples per second, per channel.
- 6.3. Figure 6-1 illustrates a miniature loading frame with two (or more) parallel precision rods, which applies an axial load minimizing any eccentricity to the BFE specimen.
- 6.4. Specimen mold assemblies.
 - 6.4.1. Specimen molds shall be manufactured from aluminum, with the exception of the end tabs.
 - 6.4.2. The specimen molds include: two side plates (Figure 6-2 A), one bottom plate (Figure 6-2 B), two G10 phenolic end tabs (Figure 6-3 A) and metal rings (Figure 6-3 B).
 - 6.4.3. Binder clips (Figure 10-1).
 - 6.4.4. Trim knife (Section 10.6).
- 6.5. De-molding Gauge (Figure 6-4)



Figure 6-1(A)—Loading Frame Assemblies: Upper Loading Head



Figure 6-1(B)—Loading Frame Assemblies: Lower Loading Head



Figure 6-1(C)—Loading Frame Assemblies: Base

A

B

| | | |

Figure 6-2—Specimen Mold Components: A) Side Plate, 2 required and B) Bottom Plate.

A

B

Figure 6-3—A) Specimen Assemblies: End tab

Figure 6-3—B) Insert Metal Ring for Binder Fracture Energy Test

A

B

Figure 6-4—De-molding Gauge Assemblies: B) Pins

Figure 6-4—De-molding Gauge Assemblies: A) Plate

7. MATERIAL

- 7.1. *Asphalt binder*—PAV-aged or RTFO-plus-PAV-aged asphalt binder or recovered binder from aged pavement.
- 7.2. *Release Agent*—A mixture of 20 g of glycerin and 20 g of talc (USP) shall be used as a release agent for the aluminum molds.
- 7.3. *Release Film*—Mylar, or similar, cut to the same size as the bottom mold plate.
- 7.4. Solvent (Varsol™ or mineral spirits) or a degreasing spray cleaner formulated for use on asphalt for cleaning molds, end tabs, and plates.
- 7.5. Cotton cleaning cloths for wiping molds, end tabs, and plates.

8. HAZARDS

Use standard laboratory safety procedures required for handling the hot asphalt binder when preparing test specimens and safety procedures required when cleaning with solvents or degreasers.

9. CALIBRATION AND STANDARDIZATION

- 9.1. Initial loading pin distance adjustment.
 - 9.1.1. Adjust the distance between the two loading pins attached to the loading frame by matching the cavities of the de-molding gauge to the loading pins (Figure 9-1). The de-molding gauge should be able to slide in and out of the two loading pins smoothly. Adjust the distance between loading heads to achieve the proper spacing.

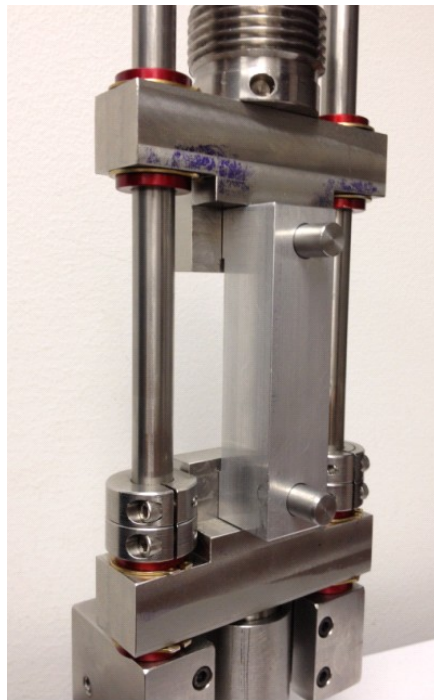


Figure 9-1—Loading Frame Pins Distance Adjustment

- 9.2. Loading frame friction calibration.
 - 9.2.1 Perform a test without a specimen to determine the frictional force of the loading frame. Repeat this friction test for various loading rates and record the average frictional force for use during data interpretation.
 - 9.2.2 The obtained frictional force needs to be subtracted from the measured force before transforming the measured force to an average true stress, as described in section 15.1.

10. PREPARATION OF SAMPLES AND TEST SPECIMENS

- 10.1. Binder conditioning—Condition the asphalt binder according to AASHTO T 240 and/or AASHTO R 28. When removing the samples from the PAV, follow the degassing process described in AASHTO R 28. Enough material should be conditioned to prepare at least six test specimens for each binder type.
- 10.2. Heat the asphalt until sufficiently fluid to pour. The specific temperature will depend on the grade of binder and its prior aging history, if any. Temperatures less than 163 °C are desirable; however, temperatures above 163 °C may be required for some modified asphalt binders or heavily aged binders. Heating time should be minimized. These precautions will help avoid additional oxidation and volatile loss. During the heating process, the sample should be covered and stirred carefully to ensure homogeneity.
- 10.3. To prepare molds—Coat the interior surfaces of the two mold side plates with the release agent to produce a thin uniform film such that no part of the metal surface is exposed. Place a single precut sheet of release film on the bottom plate of the mold. Slide one side plate on the bottom plate over the film. Place the end tabs into both ends of the mold and slide the other side plate on the bottom plate. Lock both ends with binder clips to complete mold assembly (Figure 10-1).
- 10.4. Molding—Remove the mold from the oven and place it on a flat surface. Pour the asphalt binder from one end of the mold and move toward the other end; slightly overfilling the mold. Pour the specimen in one continuous pass to avoid entraining air bubbles or gaps and as quickly as possible to avoid any excessive drop in temperature of the asphalt binder. Sample preparation is critical and is the largest source of test variation.
- 10.5. After pouring the test specimen, allow the entire assembly to cool on the bench top at ambient temperature for 30 to 60 min. Do not quench (quick or instantaneous cooling) the specimen to achieve ambient room temperature (25 °C or lower).
- 10.6. After the specimen has cooled to ambient room temperature, trim off the excess asphalt binder with a trim knife (e.g., a flat, stiff, heavy-gauge putty knife) so that the asphalt binder is flush with the top of the mold. Use care during the trimming operation so that the asphalt binder is not pulled away from the mold and the bond between the end tabs and the asphalt binder is not damaged. Slightly heating the trim knife will aid in this operation. Pull the hot trim knife along the long axis of the specimen flush with the surface of the mold to remove excess asphalt binder. After trimming, remove all debris or extraneous asphalt binder from the holes or slots in the end tabs.
- 10.7. Place the specimen and de-molding gauge in a temperature controlled chamber set to the desired test temperature. It is preferable that the same temperature chamber be used for both conditioning and testing.

10.8. De-molding—Carefully de-mold the trimmed specimen when it reaches the desired test temperature.

10.8.1. Align one end of the de-molding gauge by inserting the two pins into the gauge and the two end tabs (Figure 10-2). The de-molding gauge was designed specifically to constrain the specimen and avoid any bending during the de-molding process.

Note 1—If possible, de-mold the specimen within the environmental chamber to avoid any change in specimen temperature. If de-molding is done outside the environmental chamber, then place the de-molded specimen back into the environmental chamber for 30 minutes before testing.

10.8.2. Turn the entire assembly over, ensuring the two pins do not slide out. Gently slide the specimen and the two mold side plates toward one edge of the bottom plate until the side plate nearest to the edge is halfway across the edge. Pivot the overhanging side plate downwards using gentle pressure and de-mold that side (Figure 10-3). Slide the specimen and the second side plate toward the other edge and repeat the procedure to remove the second side plate.

10.8.3. Remove the bottom plate and the release paper. At this point, the trimmed specimen is lying on top of the aluminum gauge constricted by the two pins (Figure 10-4).

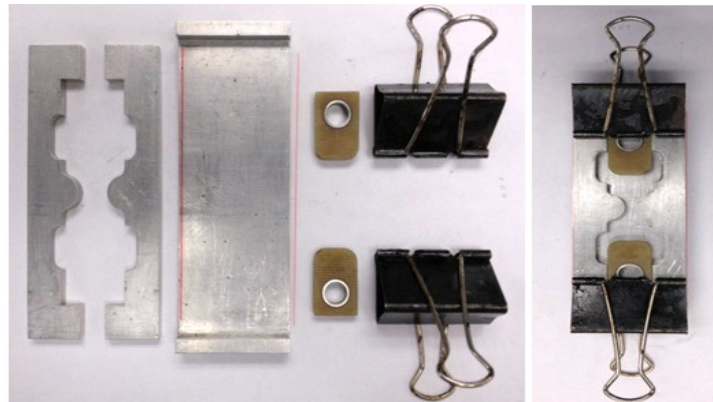


Figure 10-1—Mold Assemblies and Complete Mold Set

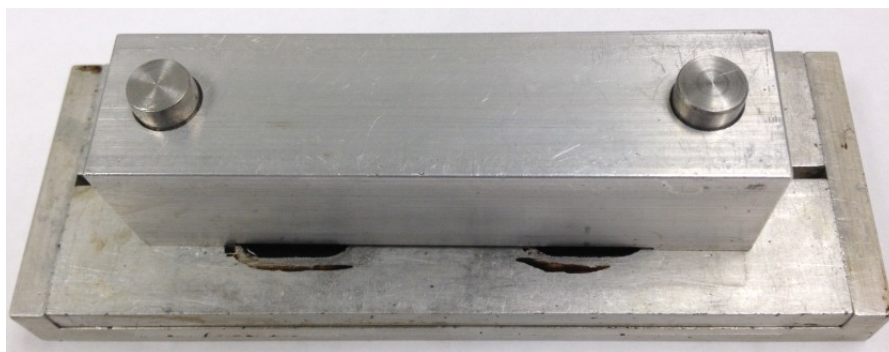


Figure 10-2—Align the De-Molding Gauge on to Assembled Molds

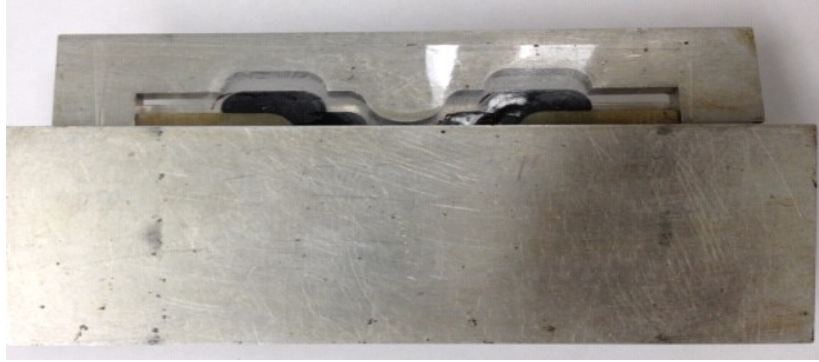


Figure 10-3—Side Plate De-molded from Test Specimen



Figure 10-4—De-molding Gauge with Specimen on It

11. TEST PROCEDURE FOR BINDER FRACTURE ENERGY TEST

11.1. Test Temperature Selection

The recommended test temperature is 15 °C as it will work well for most binders encountered. The test temperature may be lowered to 10 °C or elevated to 20 °C, if good results (difference in fracture energy density between two consecutive samples is less than 15%) cannot be obtained at 15 °C. Allow the test chamber to equilibrate for at least 3 hours.

11.2. Set Up De-Molded Specimen.

- 11.2.1. Orient the aluminum gauge together with de-molded specimen vertically and align them with the loading frame by matching the two end tabs with two grips. Gently press the aluminum gauge to mount the specimen and allow the pins to replace the two pins within the cavities of the two end tabs. Prior to running the binder fracture energy test, the de-molded specimen should be suspended in a vertical position, while avoiding any bending while handling the specimen. After the specimen is suspended in the vertical position, the bottom mount should be attached within five minutes while also avoiding specimen bending. This step should be performed in as short of a time as possible to avoid a change in the environmental chamber temperature.

11.3. Perform Binder Fracture Energy Testing

Perform the BFE test at 15 °C at a displacement rate of 500 mm/min. Test is considered successful (Figure 11-1) unless failure by necking or premature fracture occurs (Figures 11-2 and 11-3, respectively).

11.3.1. In the unlikely event that two successive tests are unsuccessful, then it may be necessary to adjust the loading rate and/or test temperature. For the case of failure by necking, this usually means that the binder is highly polymer-modified (e.g., PG 82-22 8.5% SBS), whereas premature fracture usually means the binder was excessively brittle (e.g., binder recovered from aged pavement).

- For failure by necking, increase the loading rate to 900 mm/min and continue testing at 15 °C. If failure by necking still occurs, then test temperature should be reduced to 10 °C and a loading rate of 500 mm/min should be used.
- For premature fracture, reduce the loading rate to 100 mm/min and continue testing at 15 °C. If premature fracture still occurs, then increase the test temperature to 20 °C and a loading rate of 500 mm/min should be used.

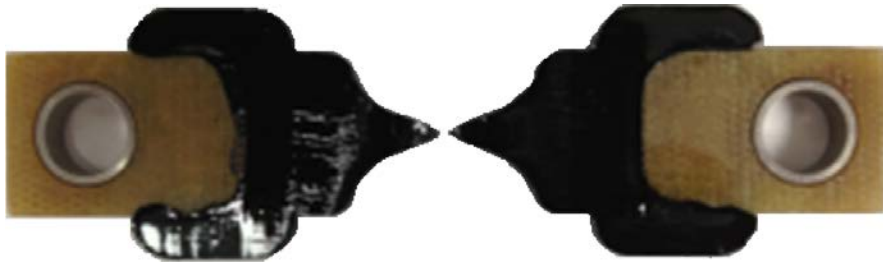


Figure 11-1—Specimen Fracture Properly



Figure 11-2—Specimen Failed to Fracture

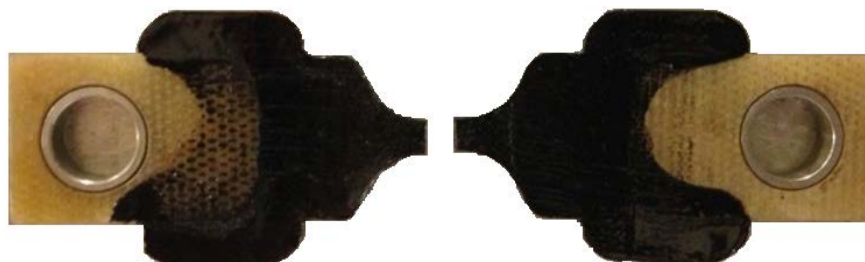


Figure 11-3—Premature Fracture Failure

12. NUMBER OF REPLICATES

- 12.1. Two successful tests should be performed.

13. FAILURE IDENTIFICATION

- 13.1. Refer to section 3.2.6.

14. CLEANING OF END TABS

- 14.1. After testing, discard the asphalt portion of the spent specimen and clean the end tabs by soaking them in solvent and wiping with a soft cloth. After wiping the end tabs, use a detergent soap solution to remove any oil film residue left by the mineral spirit solvent. Alternatively, the use of a degreasing spray cleaner may aid in this operation. Clean the end tabs thoroughly. Any grease or film on the asphalt bonding area can create a weak bond causing bond failures.

15. DATA INTERPRETATION

- 15.1. Data collected from the Data Acquisition System should be time, force, and displacement. In order to accurately calculate fracture energy density of binder, the measured force needs to be transformed to an average true stress and the measured displacement needs to be transformed to average true strain in the central cross-sectional area of the specimen where fracture initiates and propagates. FEA large deformation analysis was used to develop displacement-stress/load and displacement-strain relationships, which is valid up to the first stress peak on the time versus force plot (Figure 15-1). Beyond that point, significant reduction in cross-sectional area occurs, which makes the FEA analysis invalid. Consequently, a data analysis procedure was developed to adjust the FEA solutions by accounting for these reductions in cross-sectional area that occur at larger deformations.
- 15.1.1. Transform the measured displacement (extension) into average strain in the central cross-sectional area of the specimen, using relationship presented in Figure 15-1 based on FEA large deformation analysis.

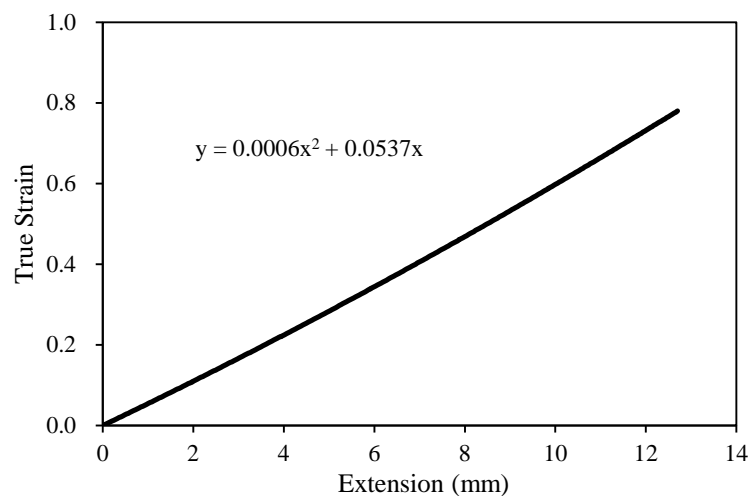


Figure 15-1—Average Strain on Middle Cross-Section/Load vs. Extension

- 15.1.2. Calculate the area of central cross-section from the measured displacement, using relationship presented in Figure 15-2 based on FEA large deformation analysis.

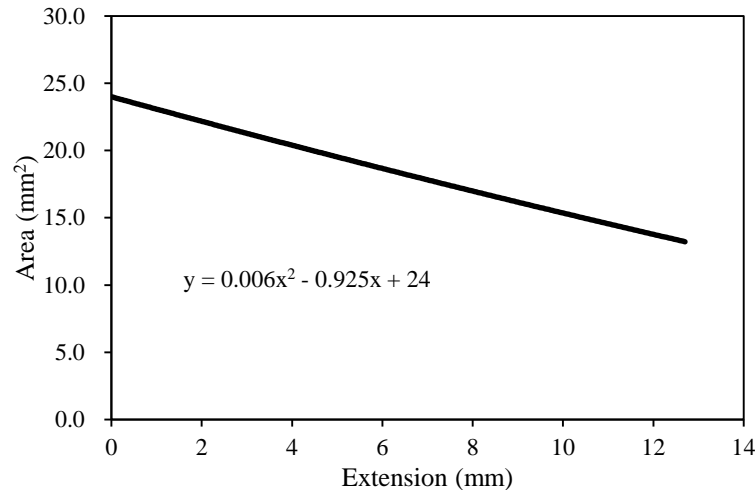


Figure 15-2—Area of Middle Cross-Section vs. Extension

- 15.1.3. Calculate the stress by dividing the measured force over the calculated area of the central cross-section calculated in step 15.1.2 and identify the first stress peak.
- 15.1.4. The FEA converted stress and strain results up to the first stress peak may be taken as accurate and used as the average true stress and average true strain response.
- 15.1.5. After the first stress peak, the assumption is that significant cross-sectional area reduction develops only in the middle section of the specimen. Based on specimen dimensions and observations during testing, the initial length of the middle section was designated to be 3 mm (0.118 in; see Figure 15-3 a). Length L_{peak} is the length of this section at the first stress peak (Figure 15-3 b) which can be calculated using relationship presented in Figure 15-4, and Length L_1 is the length of this section after the first stress peak (Figure 15-3 c) which can be calculated by adding the increase in displacement after the first stress peak (ΔL) to L_{peak} .

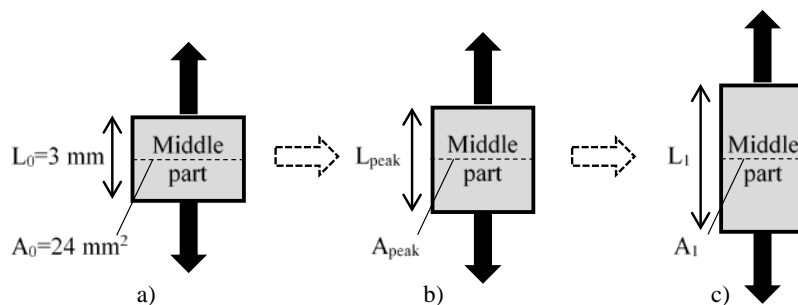


Figure 15-3—3 mm (0.118 in) Middle Section: a) Initial State, b) Elongated to L_{peak} at the First Stress Peak, and c) Further Elongated and Fractured

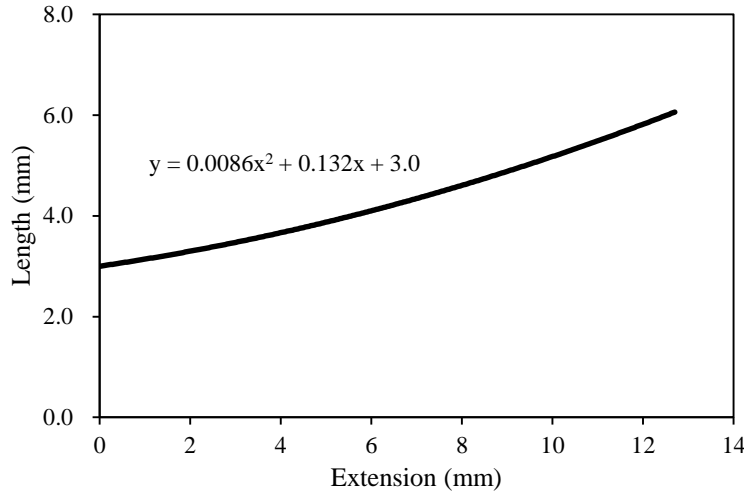


Figure 15-4—Length of 3 mm (0.118 in) Middle Part vs. Extension

15.1.6. Deformation of middle section after the first stress peak can be calculated following Equation 1, which is based on an assumed Poisson's ration of 0.5 (i.e., binder is incompressible at the relatively low bulk stress associated with tensile testing at intermediate test temperatures). Figure 15-3 illustrates the concept of the calculation.

$$A_{peak} \times L_{peak} = A_1 \times L_1 \rightarrow A_1 = A_{peak} \times \frac{L_{peak}}{L_1} \quad (1)$$

Where:

A_1 —central cross-sectional area after the first stress peak (mm^2);

L_1 —length of initial 3 mm middle part after the first stress peak (mm);

A_{peak} —central cross-sectional area at the first stress peak (mm^2), and

L_{peak} —length of initial 3 mm middle part at the first stress peak (mm).

15.1.7. True stress after the first stress peak can be calculated by Equation 2, and the true strain after the first stress peak can be calculated with the large strain formulation Equation 3.

$$\sigma = \frac{F}{A_1} = \frac{F}{A_{peak} \times \frac{L_{peak}}{L_1}} \quad (2)$$

Where:

σ —average true stress on central cross-sectional area after the first stress peak (kPa);

F —measured force (N), and

A_{peak} , L_{peak} , A_1 , and L_1 are the same as defined previously.

$$\varepsilon = \ln\left(\frac{L_1}{L_{peak}}\right) + \varepsilon_{Before} \quad (3)$$

Where:

ε —total true strain after the first stress peak

ε_{Before} —true strain at the first stress peak, and

L_{peak} and L_1 are the same as defined previously.

- 15.1.8. Plot the true stress versus true strain curve. The fracture energy density is defined as the area under the true stress versus true strain curve, and the post-peak energy after the point of initial fracture should not be considered when calculating fracture energy, as this is the energy required to split the specimen in half, rather than the energy to initiate fracture in the binder.

16. REPORT

- 16.1. Report the following information:
 - 16.1.1. Sample identification;
 - 16.1.2. Date and time of test;
 - 16.1.3. Test temperature, nearest to 0.1 °C;
 - 16.1.4. Loading rate, nearest to mm/min;
 - 16.1.5. Peak load, nearest to 0.1 N;
 - 16.1.6. Peak stress, nearest to 0.1 kPa; and
 - 16.1.7. Type of fracture observed (premature fracture, fracture or no fracture).

17. PRECISION AND BIAS

- 17.1. *Precision*—The research required to develop precision estimates has not been conducted.
- 17.2. *Bias*—The research required to establish the bias has not been conducted.

18. KEYWORDS

- 18.1. asphalt binder; true stress; true strain; fracture energy density; intermediate temperature; cracking; binder modification

19. REFERENCES

- 19.1. Niu, T., Roque, R, and Lopp, G. “Development of a binder fracture test to determine fracture energy.” *Road Materials and Pavement Design*, Vol. 15, Supplement 1, 2014, pp. 219–238.
 - 19.2. Yan, Y., Cocconcelli, C, Roque, R, Nash, T, Zou, J, Hernando, D. and Lopp, G. “Performance evaluation of alternative polymer modified asphalt binders.” *Road Material and Pavement Design*, Vol. 16, Supplement 1, 2015, pp. 389–403.
 - 19.3. Yan, Y., Chun, S. and Roque, R. “Effects of alternative polymer modifications on cracking performance of asphalt binders and resultant mixtures.” *Construction and Building Materials*, Vol. 121, 2016, pp. 569–575.
-

APPENDIX

(Nonmandatory Information)

X1. TYPICAL TRUE STRESS-TRUE STRAIN CURVES

X1.1 The BFE test is able to differentiate between unmodified and modified binders on the basis of fracture energy density value (Table X1.1) and the characteristics of the true stress-true strain curve. Each binder category has a unique true stress-true strain curve that can be employed for identification purposes: unmodified binder typically presents one true peak stress with peak strain close to 1.0 (Figure X1-1); rubber-modified binder exhibits relatively flat true stress-true strain curve until fracture (Figure X1-2); and SBS modified binder fracture occurs at a much higher true stress peak and true strain level (Figure X1-3). In rubber-modified binder, there is an initial attempt to pick up stress, however, potentially due to a lack of secondary polymer network, this phenomenon is not as pronounced as the hybrid binder (Figure X1-4) and SBS binder.

Table X1-1—Typical fracture energy density values for different binders (after RTFO plus PAV conditioning)

Binder	% SBS	% Rubber	FED (kJ/m ³)
Unmodified	0	0	2,500–3,500
Rubber-modified	0	5–12	5,000
Hybrid	1–2	min 7	6,500–7,500
SBS-modified	3–5	0	8,000–9,000
	7–9	0	16,500

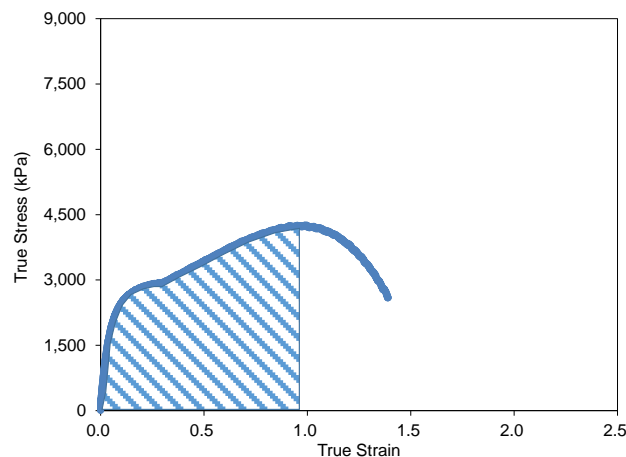


Figure X1-1—Typical true stress-true strain curve for unmodified binders

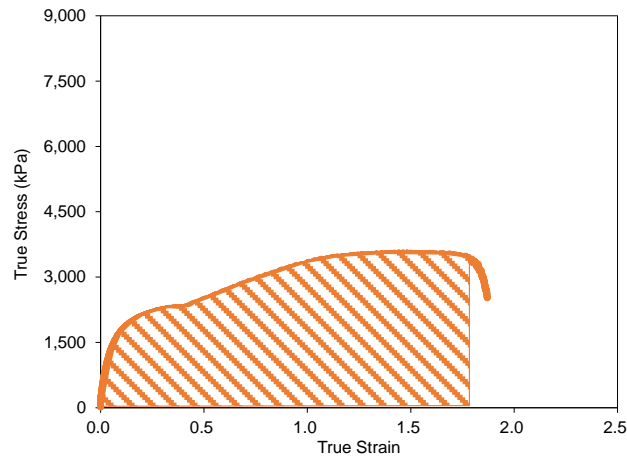


Figure X1-2—Typical true stress-true strain curve for rubber modified binder

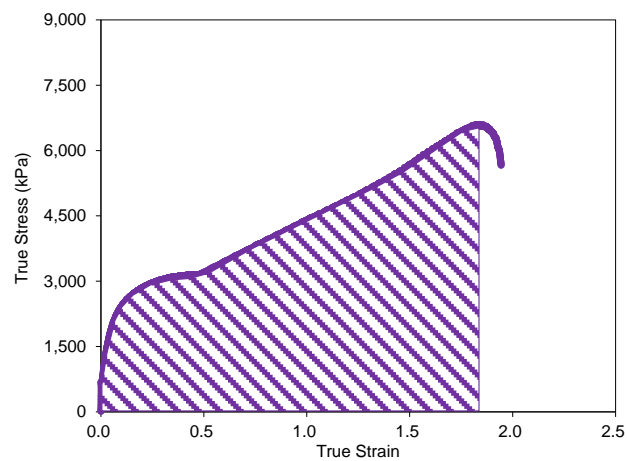


Figure X1-3—Typical true stress-true strain curve for SBS modified binder

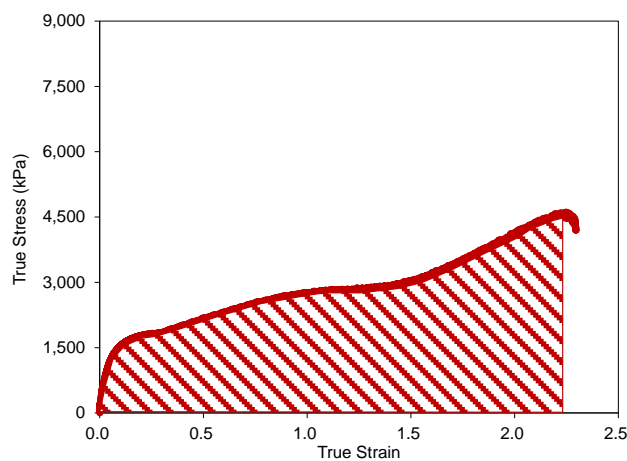


Figure X1-4—Typical true stress-true strain curve for hybrid binder

Response to comments for the Standard Testing Method for Binder Fracture Energy...

Georgia Department of Transportation

1. MSCR test is currently deemed a "gold standard" for binder test to distinguish modified asphalt and unmodified binder properties. Has BEF test been compared with MSCR test? Or has BEF results been correlated to MSCR results?

Yes, we have a paper published (second reference in Testing protocol, section 20) which compared the BFE results on seven new modified binders with MSCR results on the same binders. Both tests identified the same deficient modified binders. Compared to the MSCR test, the BFE test adds the advantage of quantitative assessment of relative binder performance based on fracture energy density values.

2. Have any binder service history/field performance data been collected from the asphalt pavement with high BEF value and from the asphalt pavement with low BEF value?

Yes, we have BFE tests conducted on recovered binders from field pavement (first reference in Testing protocol, section 20). The PMA binders exhibited higher fracture energy density values than ARB binders followed by unmodified binders. This trend matches with field performance. Of course, it would be great to test on specimens from field sections with binder as the only variable.

Kansas Department of Transportation

1. No correlations to field performance from what I have read. It does appear to identify modified binders and looks encouraging if some field verification could be developed.

Correct. Comparisons to modified and neat binders with known performance in the field have been completed.

2. Under section 5. the loading rate is noted from 100-900 mm/min. In the procedure they state to run the test at 500 mm/min. Is the comment in section 5 needed?

The fracture energy density obtained from the BFE test has been found to be displacement rate independent. 500 mm/min is recommended because it works for most of the binder types and in a previous study, least variance was observed at this rate. However, some binders may need a faster displacement rate (or lower temperature) such as heavily polymer modified binders and some may require lower displacement rate (or high temperature) such as field recovered binders. The key is to have two consecutive samples properly fractured.

3. A load cell strength will be specified.
4. See the response in item 2.
5. End tabs are two G10 phenolic end tabs (modified from the Direct Tension End Tabs).
6. Agree. Will make the change.

Maine Department of Transportation

1. Agree. Will make the change.
2. Mold preheating has been removed from the method. It was determined it was not needed.
3. Agree. Will make the change.

New York State Department of Transportation

1. Significance and Use: This section will be modified.
The binder fracture energy density has been found to correlate well with mixture cracking performance. However, measurement of fracture energy density in asphalt binder at intermediate temperature was not possible until the development of this binder fracture energy test.
2. The method will be revised to only allow aluminum molds.
3. Release agent is not needed since the molds are aluminum.

Ontario Ministry of Transportation

1. Agree. Will round according to the recommended standard. Please provide a recommendation.
2. Agree. Will make the change.
3. The difference in fracture energy density between two consecutive samples shall be less than 15%. Specimen shall fracture properly as shown in Figure 11-1. Figures 11-2 and 11-3 show two specimens failed to fracture (premature fracture and fail to fracture). End tab separation is a rare phenomenon for this test due to the specially designed specimen geometry.
4. We agree. At this time software is unavailable. We can provide assistance with the calculations if requested.
5. Agree. Will make the change.

Pennsylvania Department of Transportation

1. Agree. No response needed from us.
2. Agree. Will make the change.
3. Agree. Will make the change.
4. Agree. Will make the change.
5. Agree. Will make the change.
6. Agree. Will make the change.
7. Agree. Will make the change.
8. Agree. Will make the change.
9. Agree. Will make the change.
10. Agree. Will make the change.
11. Agree. Will make the change.
12. Agree. Will make the change.
13. Agree. Will make the change.
14. Agree. Will make the change.
15. Agree. Will make the change.
16. Agree. Will make the change.
17. Agree. Will make the change.
18. Agree. Will make the change.
19. Though somewhat obvious that test specimen will be suspended vertically, we feel it is important to specifically state that the specimen should be placed in the vertical position as soon as practical after de-molding. A time is not specified because the emphasis should be on not bending the specimen.
20. Agree. This phrasing has been revised in accordance with response to comment #19.
21. Agree. Will make the change.
22. Agree. Will make the change.
23. Agree. Will make the change.
24. Agree. Will make the change.
25. Agree. Will make the change.
26. Agree. Will make the change.
27. Agree. Will make the change.

28. Agree. Will make the change.
29. Agree. Will make the change.
30. Precision and Bias is not available at this point but this section has been added.
31. Keywords and reference have been added in the updated version.
32. Agree. Will make the change.

Texas Department of Transportation

1. Agree. Will make the change.
2. Wording was revised.
3. Agree. Will make the change.
4. Will revisit the data interpretation language, but feel the language is needed to clearly explain the procedure.
5. Agree. Will make the change.
6. Agree. The scope was modified to reflect this.

Virginia Department of Transportation

1. The graphs are an appropriate place to show these equations.
2. The units will be specified.

State-of-the-Knowledge Document on the Use of REOB/VTAE in Asphalt

AASHTO Subcommittee on Materials
Technical Section 2b Meeting

Greenville, SC

August 4, 2016

- **Task Force**
 - 18 month effort
 - 19 individuals from member companies, AI staff & a FHWA liaison
- **Document: “*State-of-the-Knowledge: The Use of REOB/VTAE in Asphalt*”**
 - approved by AI’s Technical Advisory Committee and HS&E Committee, April 12-13
 - 6 sections, ~60 pages of discussion (plus 42-page appendix that provides summary of each of the 26 published papers)
 - Designed to provide an objective and thorough review of all available information
 - Included extensive review process
 - Becomes AI’s official document on REOB/VTAE

1) General Overview & Intent of Educational Document

- Carefully defines REOB/VTAE as the non-distillable residuum from a vacuum tower in a used oil re-refinery

2) REOB / VTAE Production Overview

- Description of re-refining process from collection of used oils to REOB/VTAE production

3) Literature Review of REOB / VTAE Use and Performance in Asphalt Industry

- Review of 26 published papers pertaining to REOB/VTAE (published prior to Jan 1, 2016)

4) HSE Aspects

- Data provided demonstrating the re-refining process removes carcinogens present in the unrefined used oils
- Leaching studies show no differences between REOB/VTAE modified asphalts & unmodified asphalts
- Data shows similar fume composition for unmodified asphalt and REOB/VTAE modified asphalts

5) Discussion of Alternate Tests & Aging Protocols

- Recommend ΔT_c after 40 hours of PAV be explored as an improved method for characterizing long-term binder embrittlement
- Assist with formulation & forensic analysis, but not to be used as a purchase specification

6) FAQs by Agencies and the Answers

- Provides answers to 21 frequently asked questions

- Announcing the release of IS-235, *State-of-the-Knowledge: The Use of REOB/VTAE in Asphalt* at this meeting
- Available as free PDF download at asphaltinstitute.org/re-refined-engine-oil-bottom/
- Available as a free eBook at bookstore.asphaltinstitute.org/reobvtae

- <http://www.asphaltinstitute.org/re-refined-engine-oil-bottom/>
- 26 published papers
 - Linked to published journal
 - Currently through Dec 2015
- 30+ presentations at recent FHWA Expert Task Group (ETG) meetings and other industry meetings
 - Download directly



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Re-refined Engine Oil Bottom

The Asphalt Institute's Technical Advisory Committee has formed a task force on re-refined engine oil bottoms (REOB), also known as Vacuum Tower Asphalt Extender (VTAE). The objectives of this REOB task force are to:

- Learn more about REOB/VTAE materials, processing, effects/benefits when blended in asphalt and best practices.
- Recommend a course of action for Asphalt Institute that could include sponsoring a symposium, conducting research and/or developing information and guidance on REOB modification that may be similar to IS-220 for PPA modification.

Toward those objectives, the task force has developed this repository of REOB/VTAE information and wanted to share it with industry.

Members:

As an Asphalt Institute member you may submit Technical Question to AI Engineering Staff
You may also view all of the Asphalt Institute Regional Engineer Quarterly Reports

Re-refined Engine Oil Bottom Residue Information:

Published Papers

TITLE	AUTHOR(S)	PUBLICATION DATE
Use of Re-refined Oil Distillation Bottoms As Extenders For Roading Bitumens	P.R. Herrington	Journal of Materials Science – Vol. 27 No. 24 – December 1992
Waste Oil Distillation Bottoms As Bitumen Extenders	P.R. Herrington, V.K. Dravitzki, C.W.B. Wood, and J.E. Patrick	Road & Transport Research – Vol. 2 No. 4 – December 1993
Asphalt modification with used lubricating oil	Aaron Villanueva, Susanna Ho, and Ludo Zanzotto	Can. J. Civ. Eng. Vol. 35, 2008
Five Year Performance Review of a Northern Ontario Pavement Trial: Validation of Ontario's Double-Edge-Notched Tension Test (DENT) and Extended Bending Beam Rheometer (BBR) Test Methods	S.A.M Hesp, S.N. Genin, D. Scafe, H.F. Shurvell and S. Subramani	CTAA – 2009
Asphalt Cement Loss Tangent as Surrogate Performance Indicator for Control of Thermal Cracking	Abdolrasoul Soleimani, Shanan Walsh, and Simon A. M. Hesp	Transportation Research Record: Journal of the Transportation Research Board, No. 2126; 2009
Characteristics of Rejuvenated Bitumen With Used Lubricating Oil As Rejuvenating Agent	Kemas A. Zamhari, Madi Hermadi, Choy Wai Fun	International Conference On Sustainable Infrastructure and Built Environment in Developing Countries – November 2009 –

APPENDIX E

Questions?

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asphalt institute

Global, International, Regular, Associate and Canadian members



Affiliate and Commercial members



- Asphalt Institute supports the responsible modification of asphalt materials for improved performance and better life cycle costs, but does not endorse any specific or proprietary form of modification. Furthermore, AI encourages the continued development of performance related specs.

- REOB/VTAE Task Force formed in 2014 to develop a state of the knowledge document that will become AI's official document on REOB/VTAE use
 - About 19 AI staff and members. Includes FHWA liaison.
 - Many F-T-F and WebEx mtgs.
- Synthesized literature and other info.
 - Available to public

Purpose

- Need for objective and thorough review of available information
- Help agencies and others make informed decisions
- Focus on paving asphalts, not roofing

Scope

- “REOB/VTAE” herein refers to the residual distillation product from a vacuum tower in a re-refinery of used lubricating oil.
 - Not cleaned up WEO, or residual from only atmospheric tower or simpler used oil re-refinery
 - Not residual from a vacuum tower of a crude oil refinery (that’s asphalt!)

Terminology

- “REOB” is prevailing term by States and FHWA, while “VTAE” is preferred term by manufacturers
 - This document uses “REOB/VTAE”
 - Both “Re-refined” and “Vacuum tower” are important descriptors for this specific product (as defined above)

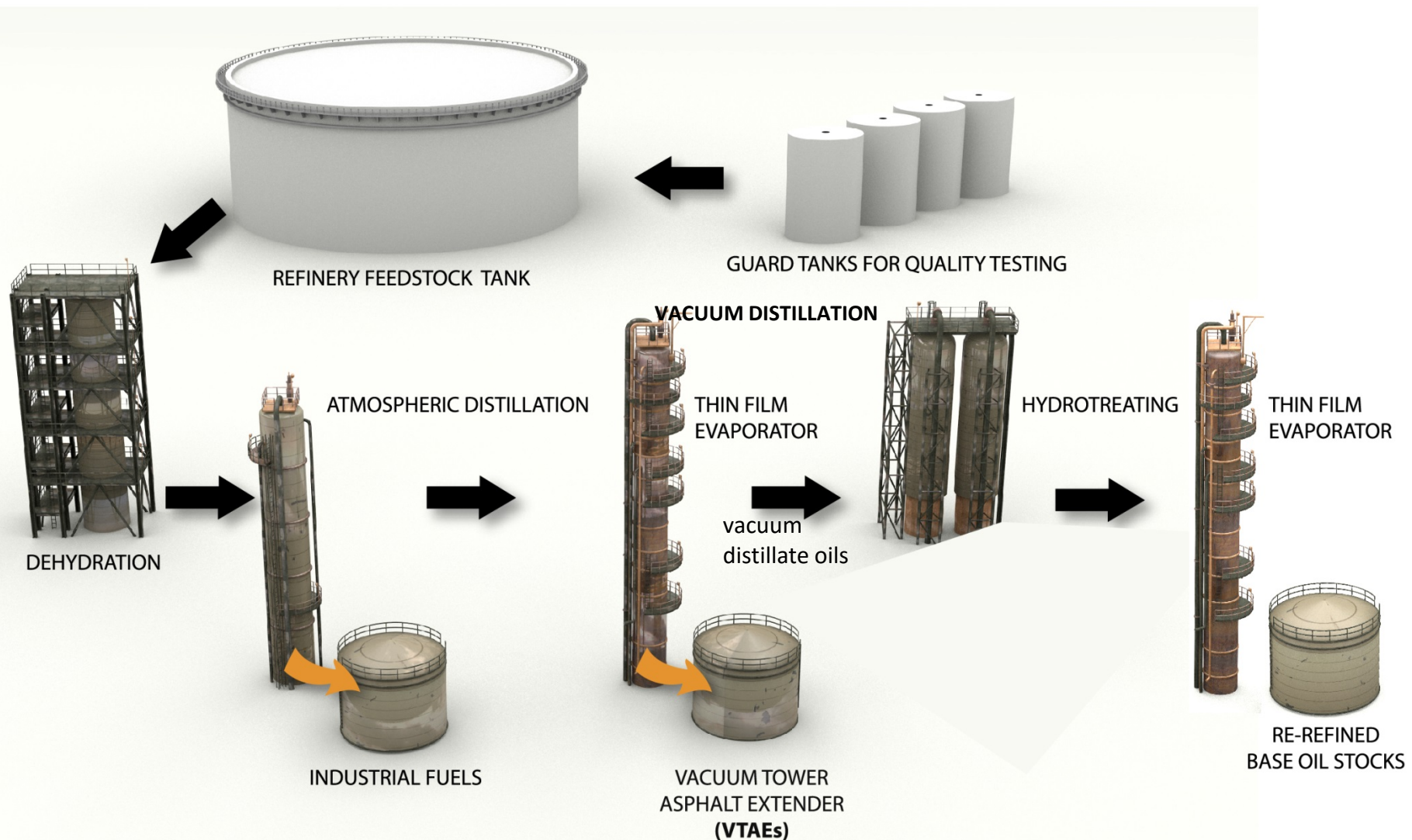
TABLE 1. Various Names Associated with REOB / VTAE

Acronym	Name
	Asphalt Flux
	Asphalt Blowdown
EOR	Engine Oil Residue
RHVDB	Re-refined Heavy Vacuum Distillation Bottoms
RHVDO	Re-refined Heavy Vacuum Distillation Oil
REOB	Re-Refined Engine Oil Bottoms
RVTB	Re-refined Vacuum Tower Bottoms
VTB	Vacuum Tower Bottom
VTAB	Vacuum Tower Asphalt Binder
VTAE	Vacuum Tower Asphalt Extender
WEOR	Waste Engine Oil Residue
WODB	Waste Oil Distillation Bottoms

Background and Use

- REOB/VTAE used to soften binders since 1980s
 - Lowers both high and low continuous PG grade
- Heightened use of blending agents to soften binders
 - Increased rates of RAP and RAS require softer grades to meet combined blend
 - Limit of crudes & refineries to produce softer grades without back blending
- FHWA testing revealed 20% of samples had REOB/VTAE
- Some states expressed concerns, even banned
- Manufacturers report typical dosages 4-8%
 - Also report 160K tons produced annually in N.A.
 - Represents roughly 0.5% of asphalt produced in N.A.
 - May not represent all re-processed engine oils in market

Section II. Production of REOB/VTAEs



- 26 published papers
 - 1992 through 2015
- Unbiased review
 - Some favorable (use is beneficial or not detrimental)
 - Some not so favorable (use is harmful or detrimental)
- Listed chronologically in a table
- Summary of papers (13 pages)
- Detailed summaries in Appendix (41 pages)
- Credit goes to Greg Harder



- REOB/VTAE - (11)
 - 8 papers by Hesp et al.
 - 2 papers (same) by Zaumanis
 - 1 paper by Uzarowski
- Waste engine oil (WEO) – (3)
 - 2 papers (same) by Zaumanis
 - 1 paper by DeDene





- REOB/VTAE – (11)
 - 3 papers by Herrington et al.
 - 1 paper by Villanueva
 - 2 papers by D'Angelo
 - 2 papers by Golalipour
 - 3 papers by Wielinski
- Waste Engine Oil (WEO) – (2)
 - 1 paper by Zamhari
 - 1 paper by Oliveira





- Current Superpave testing/specification doesn't properly predict field performance
- Need for additional aging/testing protocols
- Poor field performance of binders containing zinc
 - 15%+ REOB/VTAE estimated in binder
- Proposed extended aging/new test methods (DENT, ExBBR) would have predicted poor performance



- Binder testing showed improved properties with most blends containing up to 10% REOB/VTAE (some binder testing done at 20%)
- Additional aging was included
- Mixture testing indicated equal or improved laboratory properties up to 10% REOB/VTAE
- Limited field data – one trial showed equal performance for REOB/VTAE after 57 months

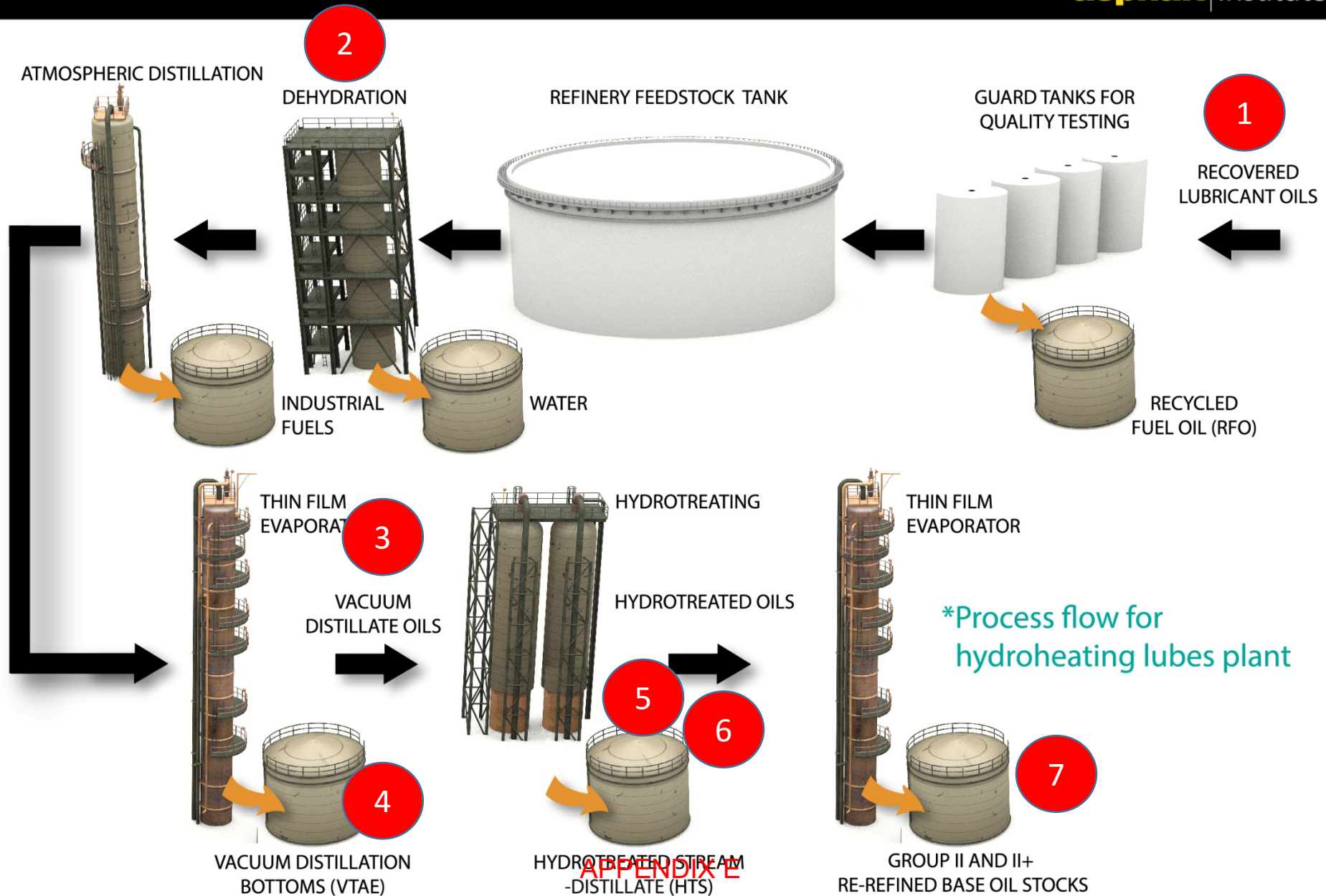
- Tested samples throughout the re-refining process for Mutagenicity Index (MI) and Polycyclic Aromatic Compounds (PACs)

1. Raw feed/unprocessed used oil
2. Dehydrated used oil
3. Vacuum oil
4. REOB/VTAE
5. Hydro treated 80 base oil
6. Hydro treated 150 base oil
7. Hydro treated low sulfur fuel/HT-LS

REOB / VTAE Processing Scheme

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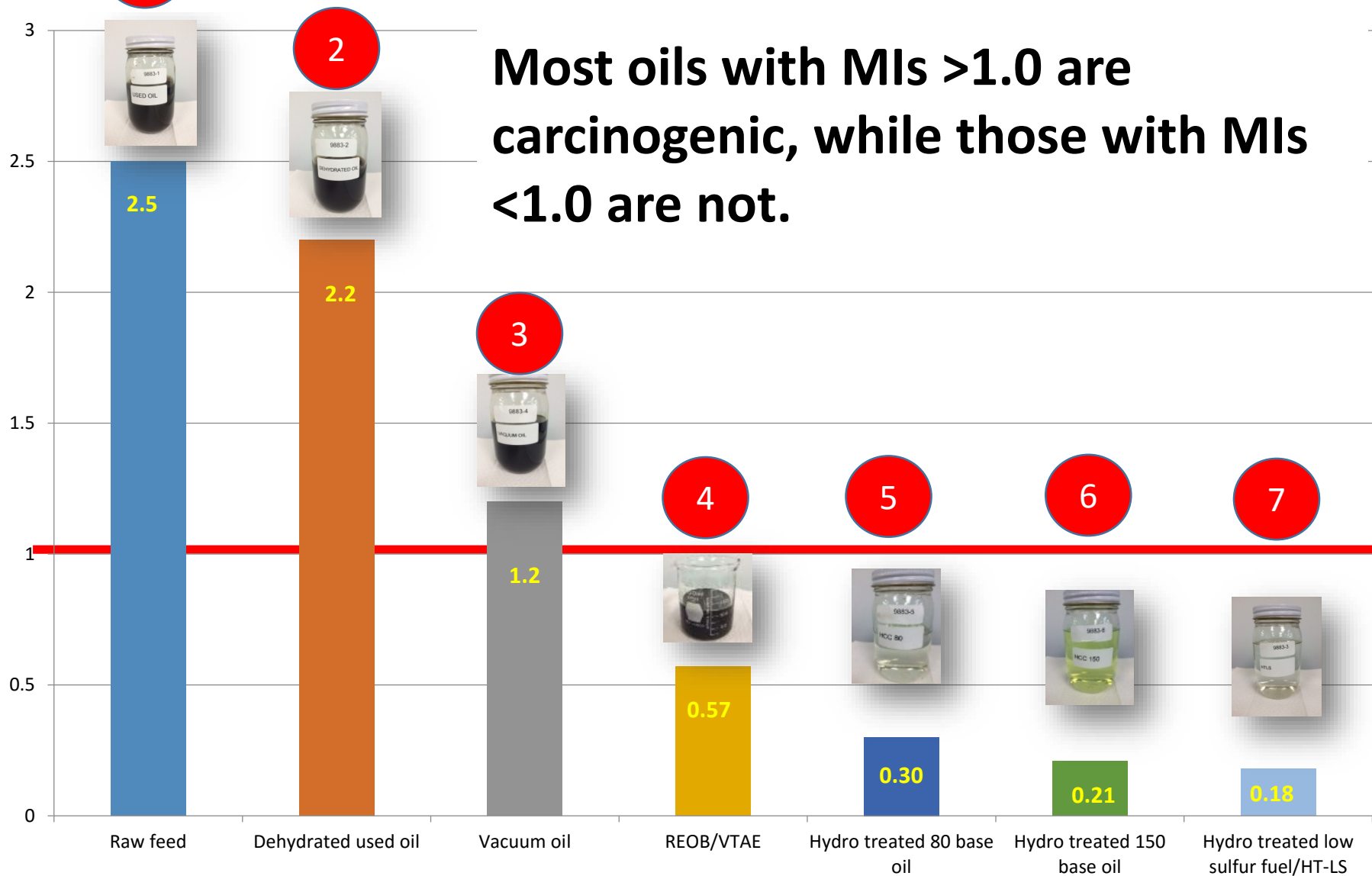
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Mutagenicity Index

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APPENDIX E

Section V: Discussion of Alternative Tests, Parameters and Aging Protocols and Relation to Binder Durability/Performance

- Outline

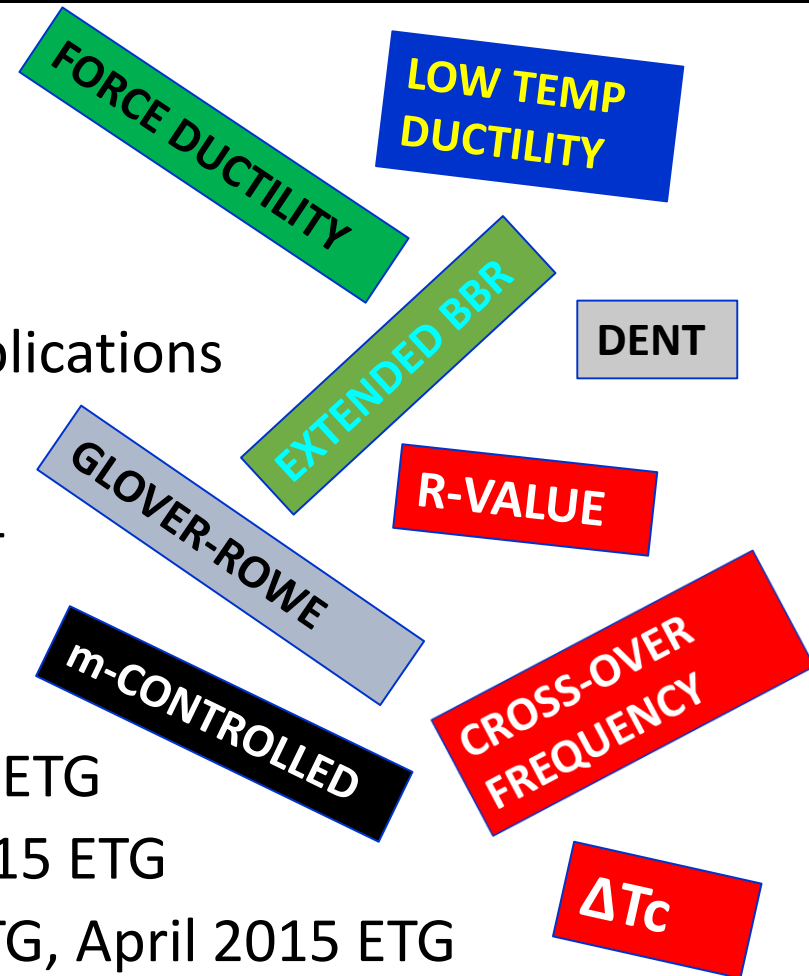
1. Background Information

- a) Kandhal
- b) Hesp, et al, Numerous Publications
- c) Charles Glover
- d) Anderson, et al AAPT 2011
- e) Rowe, AAPT 2011

2. Recent Research

- a) Gibson, FHWA, April 2015 ETG
- b) Bennert, Rutgers, April 2015 ETG
- c) Reinke, MTE, Sept 2014 ETG, April 2015 ETG

APPENDIX E



All that research leads to...

- As binders age, they lose their ability to relax stresses, mechanical or thermal
 - Ductility decreases
 - ΔT_c becomes less (more negative)
 - R-Value increases & Cross-Over Frequency decreases
 - Glover-Rowe value increases
- Binder embrittlement in field can translate to early cracking (low temp and fatigue), raveling, aggregate loss
- Important to have a means of predicting when this is expected to become an issue

These are not only REOB/VTAE issues, these are general concerns for all binders

- From standard BBR test
- $= (T_{\text{critical}} \text{ Stiffness}) - (T_{\text{critical}} \text{ m value})$
- Negative value means m-controlled.
- Becomes more negative as binder ages, loses ability to relax
 - Paraffinic additives, including REOB/VTAE, increase rate of decrease
 - Rate affected by type and amount of additives, crude source, and additive/binder interaction
- More negative with RAP and especially RAS binder
- Correlates to other binder durability parameters
- $\Delta T_c < -5^\circ\text{C}$ for 40 hr PAV has been suggested to relate to onset of binder durability distress after about 5 yrs in field
 - Not suggesting spec change at this time. More work needed

- 21 FAQs Currently
 - Submitted by user agencies
 - Concise answers based on contents of document
- Serves as a Document Summary
- Key Themes:
 - 1) Definition/variability of REOB/VTAE used in asphalt modification
 - 2) Detection of REOB/VTAE in asphalt binders / mixes
 - 3) Appropriate use, limits of REOB/VTAE

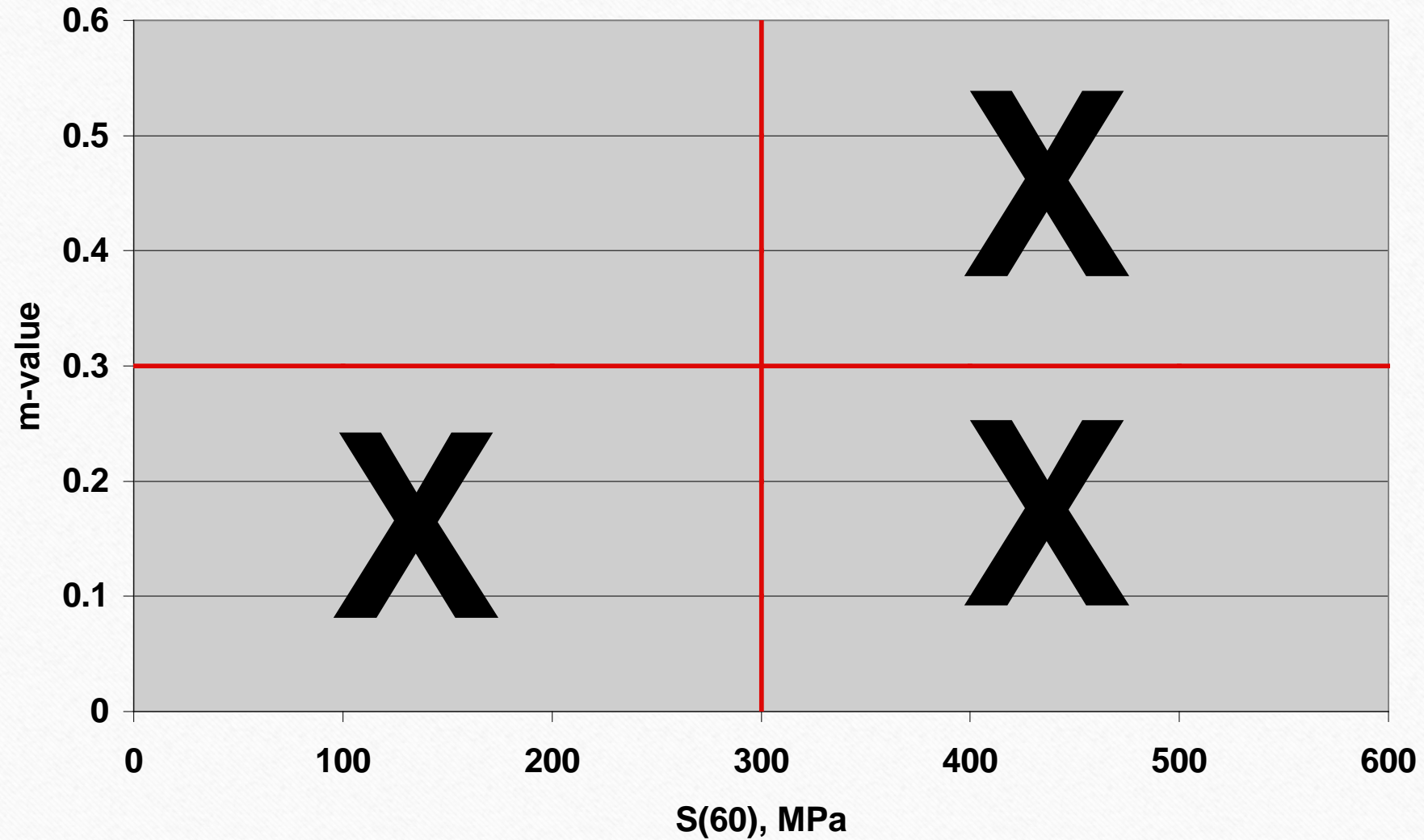
Delta Tc Range and Magnitude

Jack Youtcheff, FHWA

Raj Dongre, DLSI

WHY?

Low Temperature Specification M320 - Table 1



Background – Where are we today?

- How is the Issue being addressed? – At present – FHWA, ETG etc
 - S and m-value based approach
 - It was observed in the past that the delta T_c value is an indicator of Performance
 - G. Reinke during MnRoads evaluation
 - REOB and other softening additives affect S value more than m-value creating a difference in critical value of temperature (Delta T_c)
 - Suggestion: Specify that m-value is met at a certain S value
 - Advantage: If it works – no new tests need to be performed – just a calculation!

How?

Approach

- Calculate Delta Tc using Data Mining Techniques
 - Challenge – State validation data contains BBR info. at only one temperature!
 - To calculate Delta Tc – Need BBR S and m-value data at two temperatures!
 - Approach – Determine prediction algorithms to calculate Delta Tc.
- Delta Tc Prediction from single point BBR data
 - Rule of Thumb
 - PG specific changes in S and m-values
 - Average of all PG specific changes in S and m-value

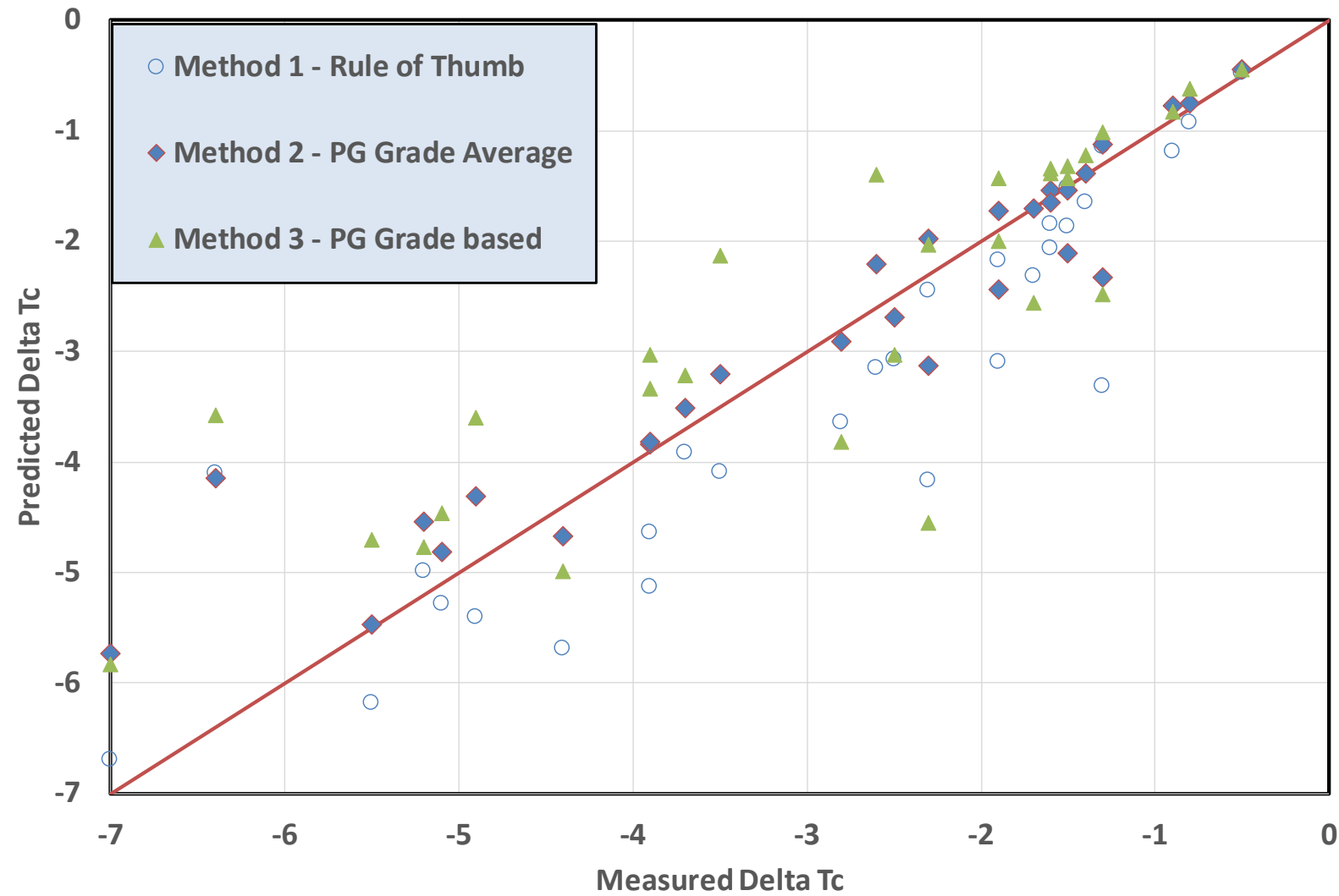
Delta Tc Prediction from single point BBR data

- Rule of Thumb (Method 1)
 - S value at 60s doubles every 6°C
 - e.g. If $S = 120$ at -18°C ; $S = 240$ at -24°C and $S = 60$ at -12°C
 - m-value changes by 0.036 every 6°C
 - e.g. If $m = 0.303$ at -18°C ; $m = 0.267$ at -24°C and $m = 0.339$ at -12°C
- Use the above rules to predict S and m at the second temp. where data is not available
- Predict Delta Tc

Delta Tc Prediction from single point BBR data

- PG Specific prediction rules (Method 2)
 - Collect a robust database of BBR S and m-values for different PG grades
 - Multiple sources of binder for each PG grade
 - Calculate PG grade specific prediction rules for S and m-value
 - Validate using independent database of S and m-value
- Use the above rules to predict S and m at the second temp. where data is not available and Predict Delta Tc
- Average of all PG specific changes in S and m-value (Method 3)
 - Predict Delta Tc

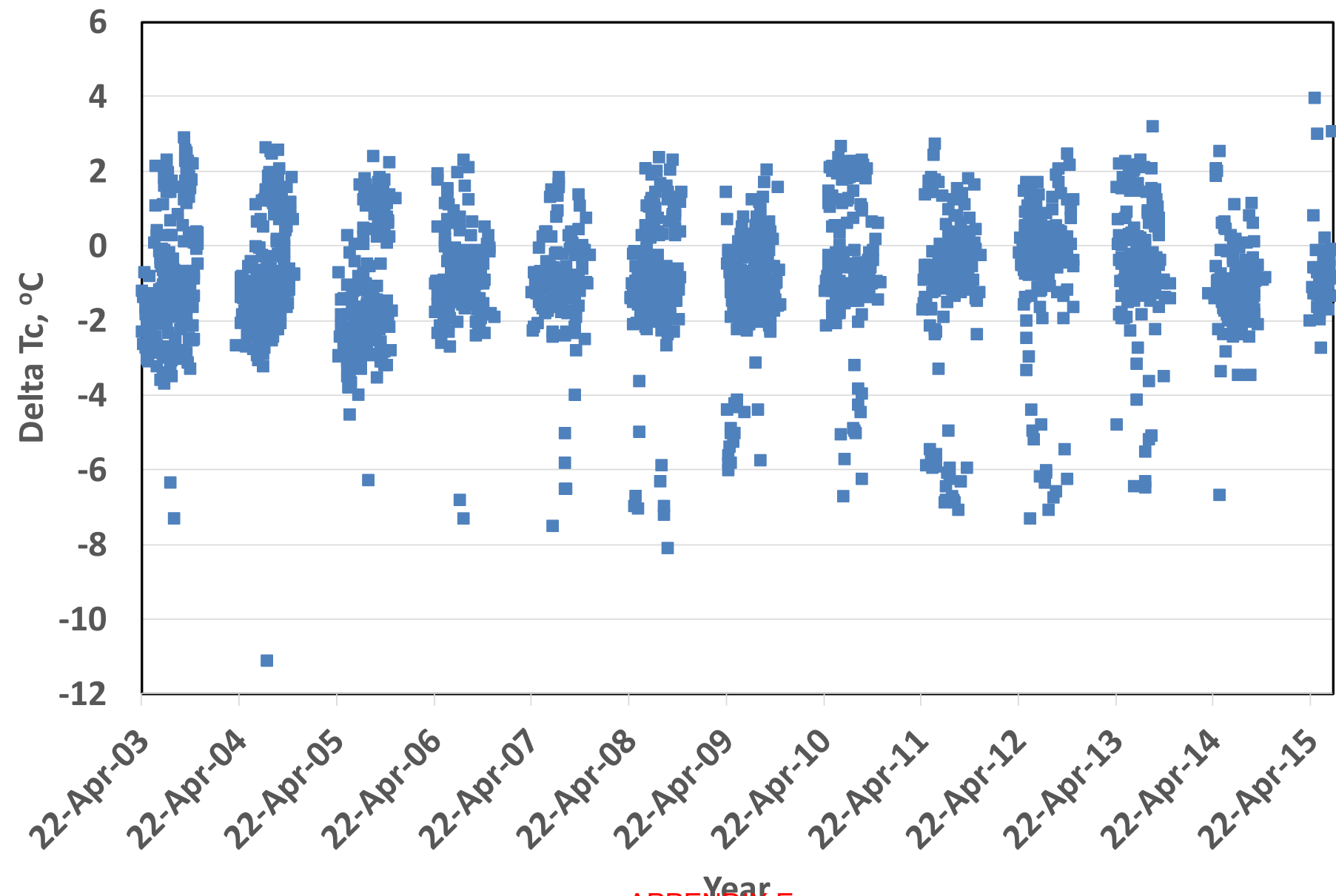
	Avg. Continuous High PG Grade, C	Avg. Continuous Low PG Grade, C	UTI	S-Ratio	m-diff./C	m-diff./6C	m-Ratio
Overall Average				2.1	0.008	0.048	0.870
PG 52-28	55.3	-33.0	88.3	2.2	0.014	0.082	0.778
PG 58-22	62.1	-29.5	91.6	2.2	0.011	0.067	0.839
PG 64-22	65.5	-29.0	94.4	2.2	0.010	0.061	0.845
PG 67-22	68.9	-25.5	94.4	2.1	0.010	0.062	0.834
PG 58-28	63.9	-25.9	89.8	2.2	0.010	0.060	0.855
PG 64-16	67.7	-23.5	91.1	2.1	0.009	0.055	0.841
PG 64-22	68.3	-25.4	93.7	2.0	0.008	0.048	0.860
PG 64-28	67.4	-27.3	94.7	2.1	0.008	0.046	0.877
PG 70-16	71.5	-27.1	98.6	2.1	0.005	0.032	0.912
PG 70-22	73.4	-28.0	101.5	2.0	0.008	0.045	0.866
PG 70-28	75.4	-27.3	102.7	2.1	0.005	0.033	0.910
PG 76-16	78.6	-21.6	100.2	2.6	0.009	0.051	0.853
PG 76-22	78.7	-26.2	104.9	2.0	0.006	0.034	0.899
PG 82-22	85.1	-25.7	110.8	2.0	0.004	0.024	0.928
PG 88-22	92.3	-24.1	116.4	2.1	0.003	0.017	0.944
PG 76-22	81.5	-28.8	110.3	2.1	0.010	0.058	0.857
PG 76-22	80.0	-28.0	108.0	2.2	0.010	0.059	0.852
PG 82-22	83.0	-26.9	109.9	2.1	0.010	0.060	0.866



State DOT - BBR S and m-value Database

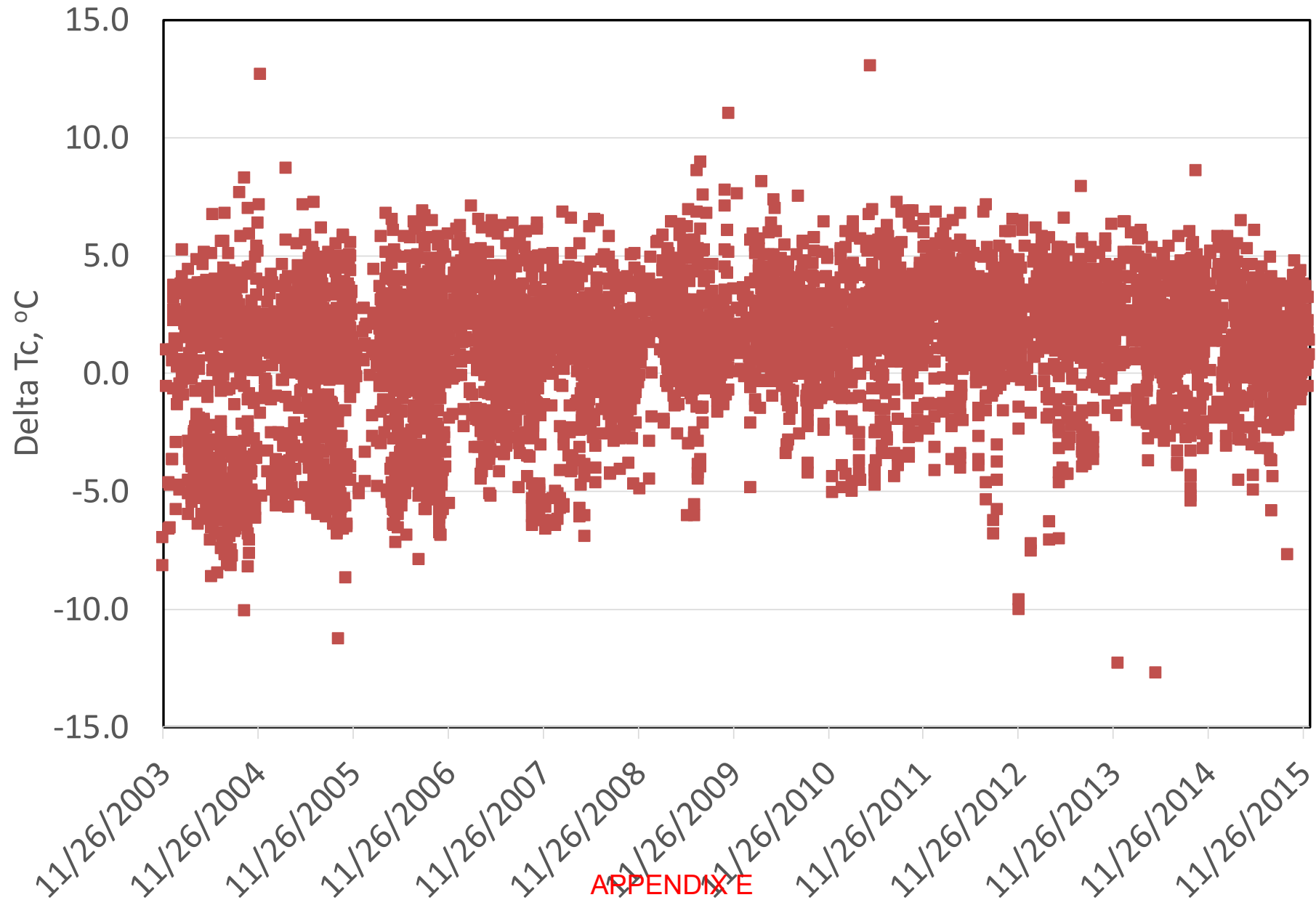
- Requested BBR validation data from all state DOTs
 - Received data from 20 State DOTs so far.
 - Analyzed data from Six States DOTs so far.
 - Used Method 2 – PG Average to predict Delta Tc
- Data Analysis Approach
 - Discrete Statistics
 - Data Mining using Probability Distribution Fitting

MAINE DOT - All PG Grades

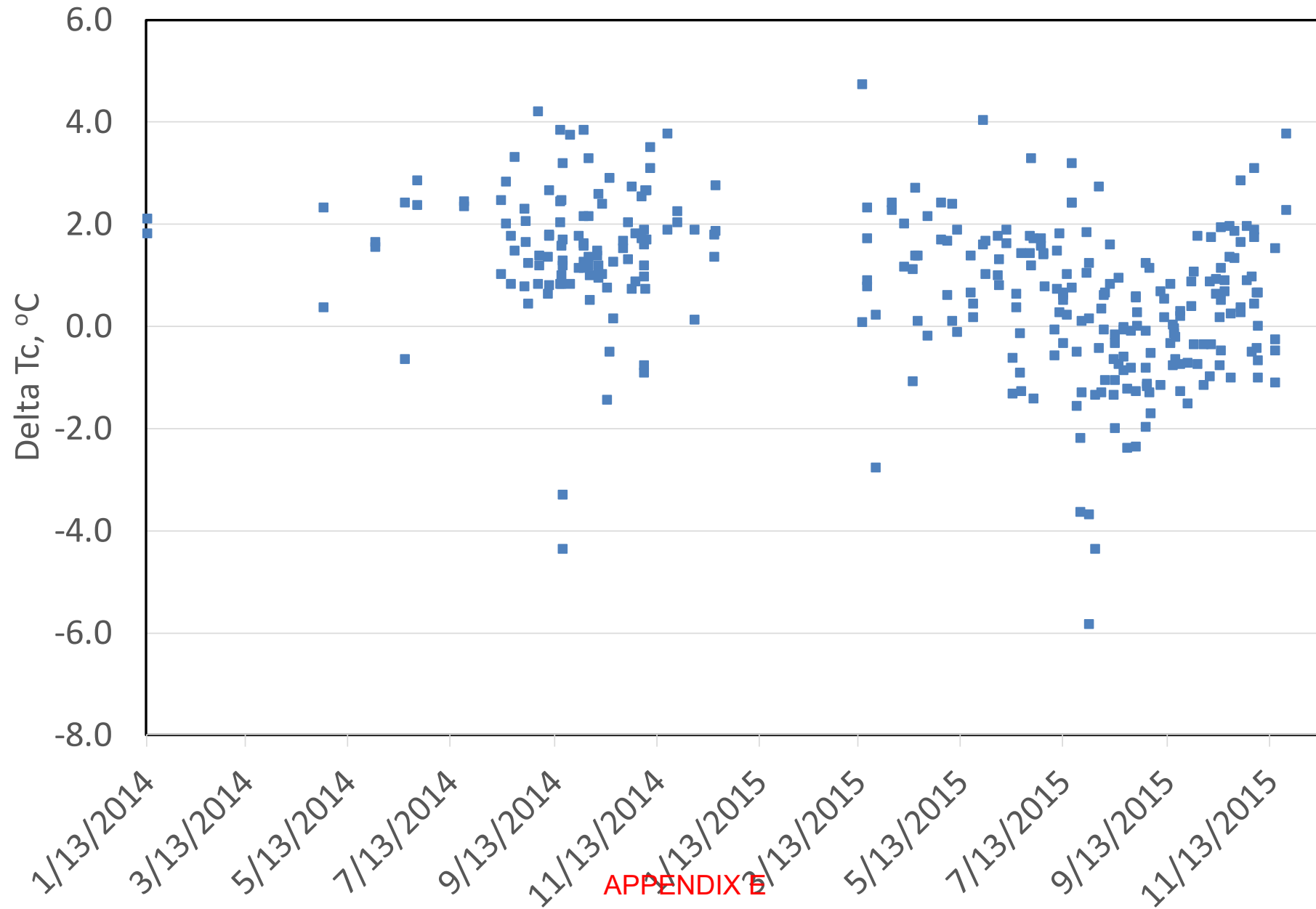


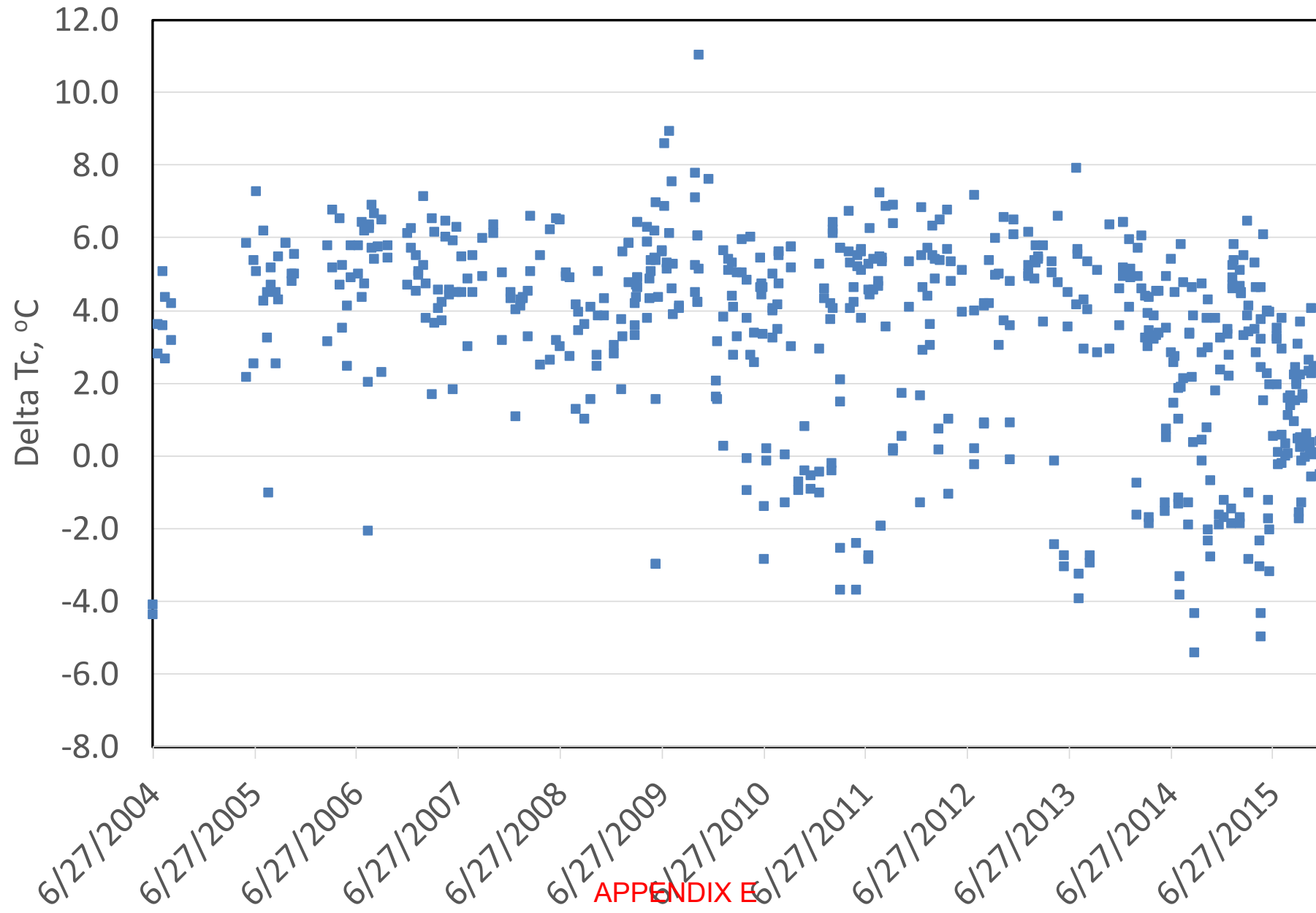
DELAWARE DOT - All PG Grades

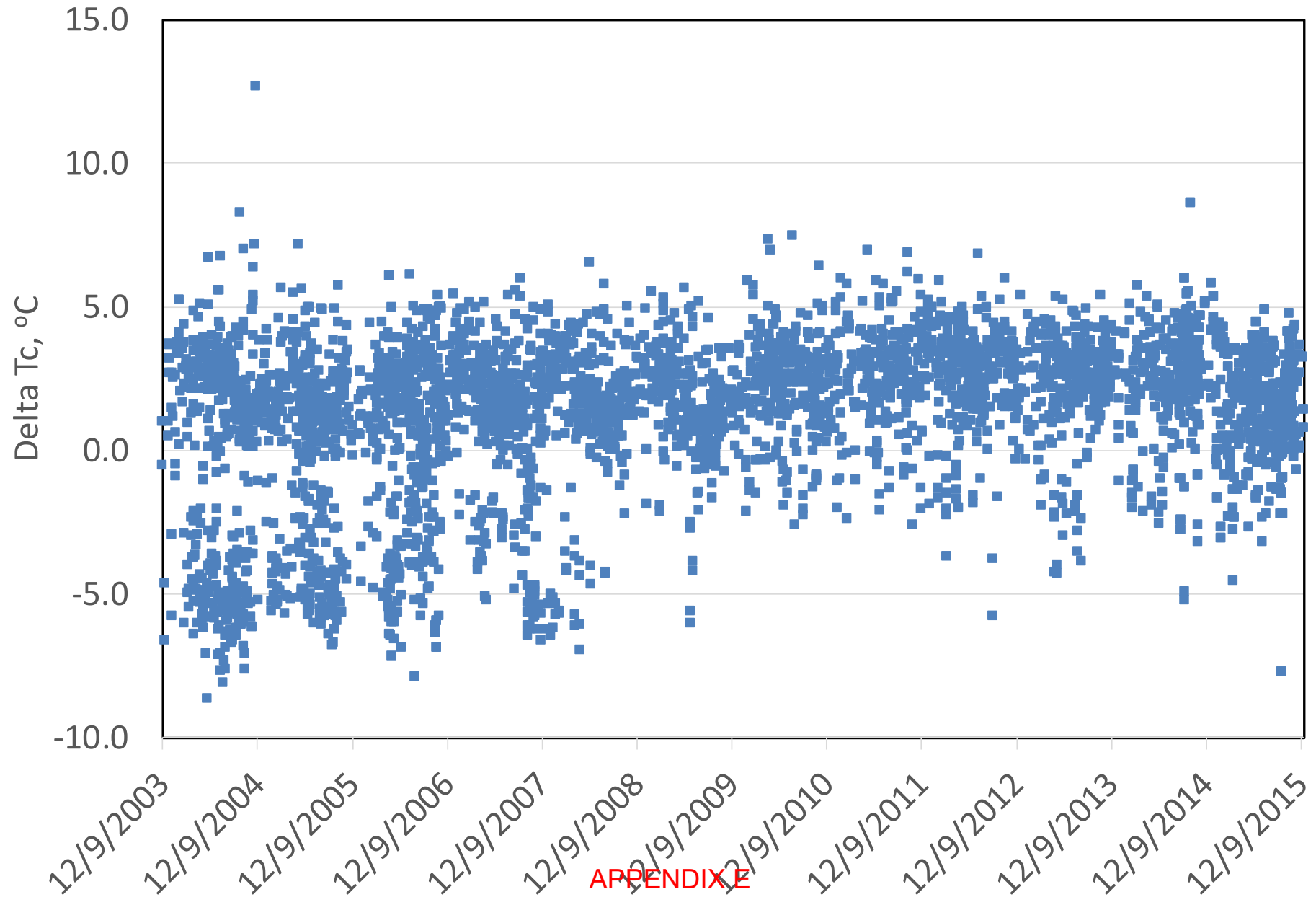
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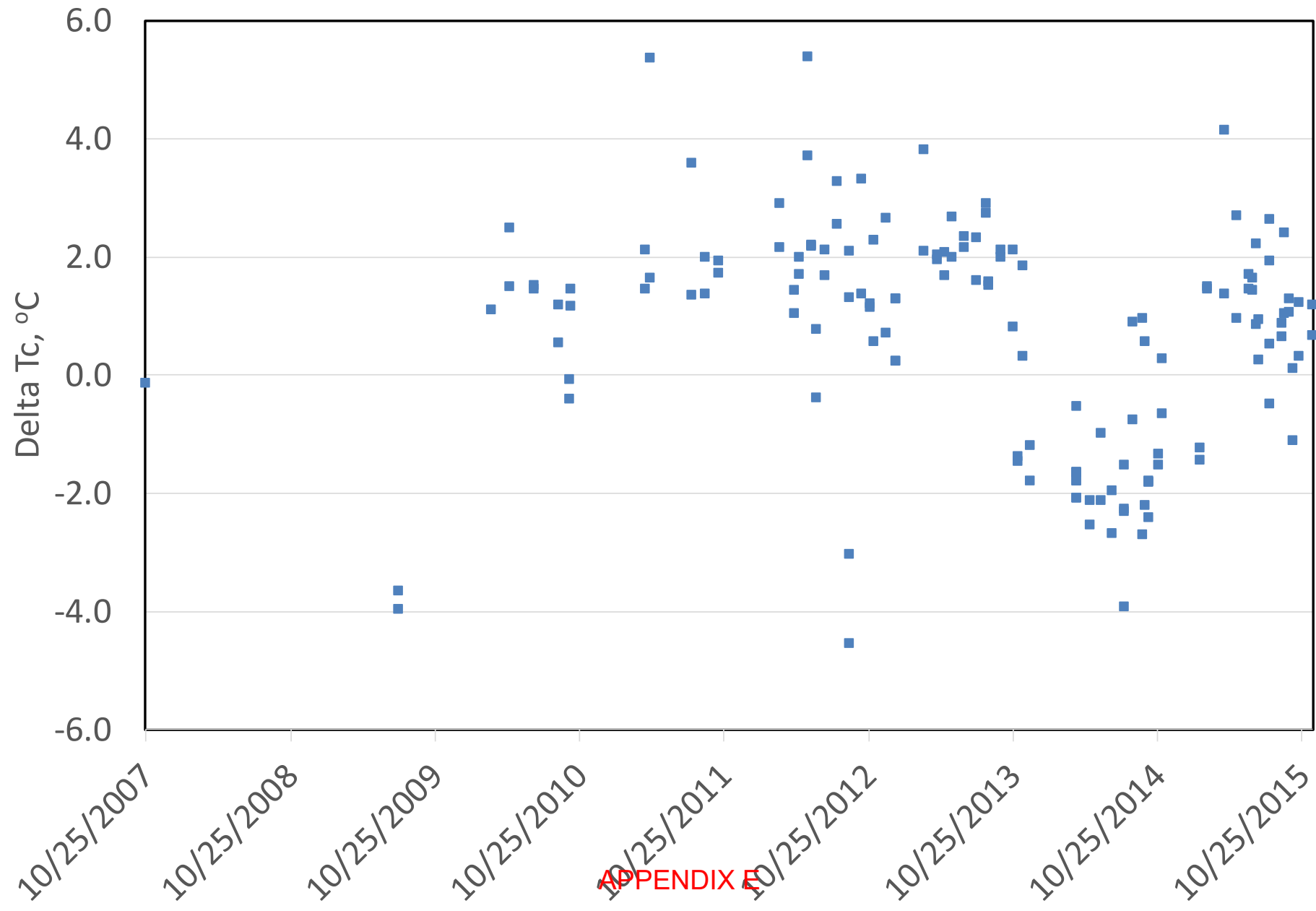


APPENDIX E

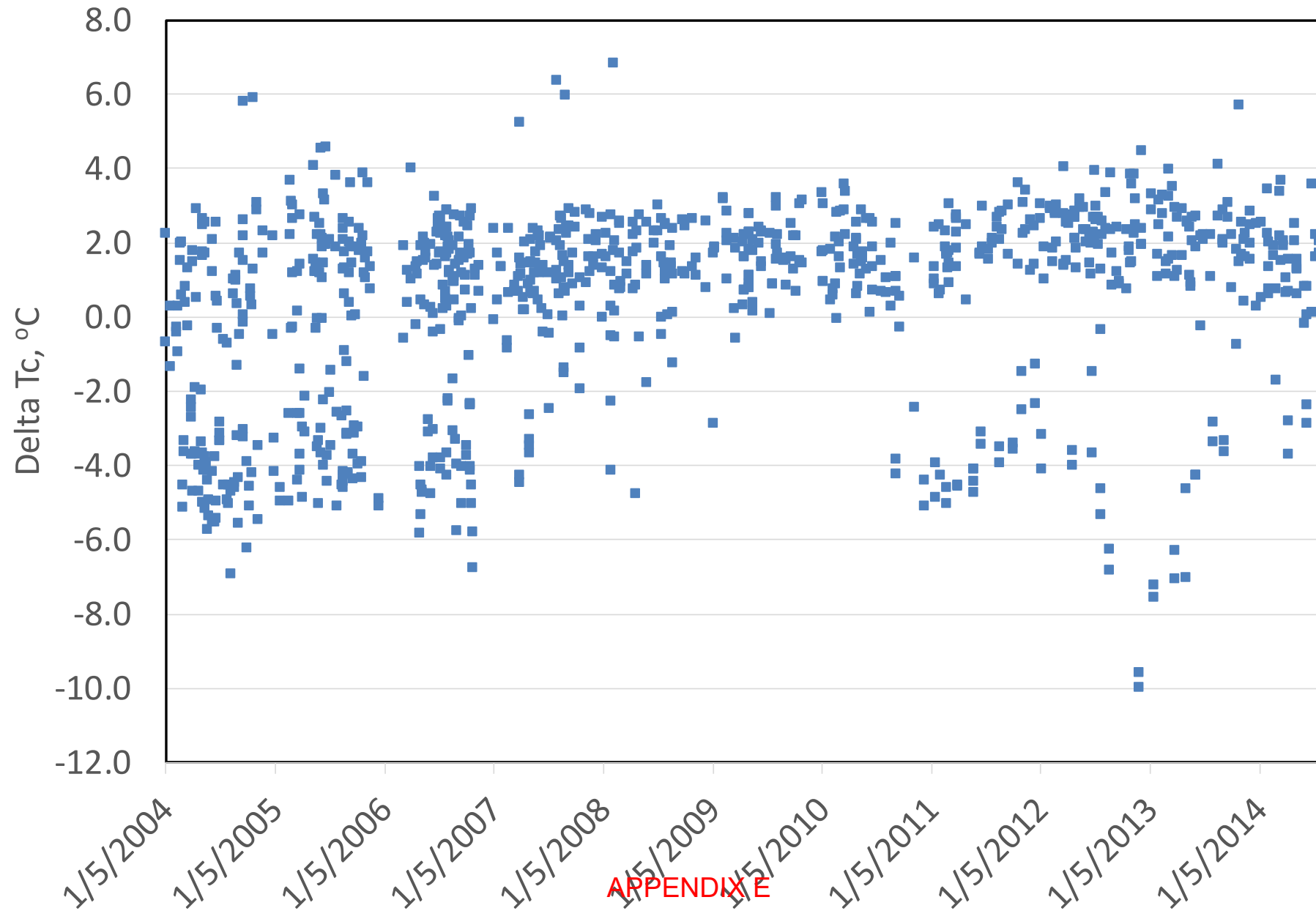


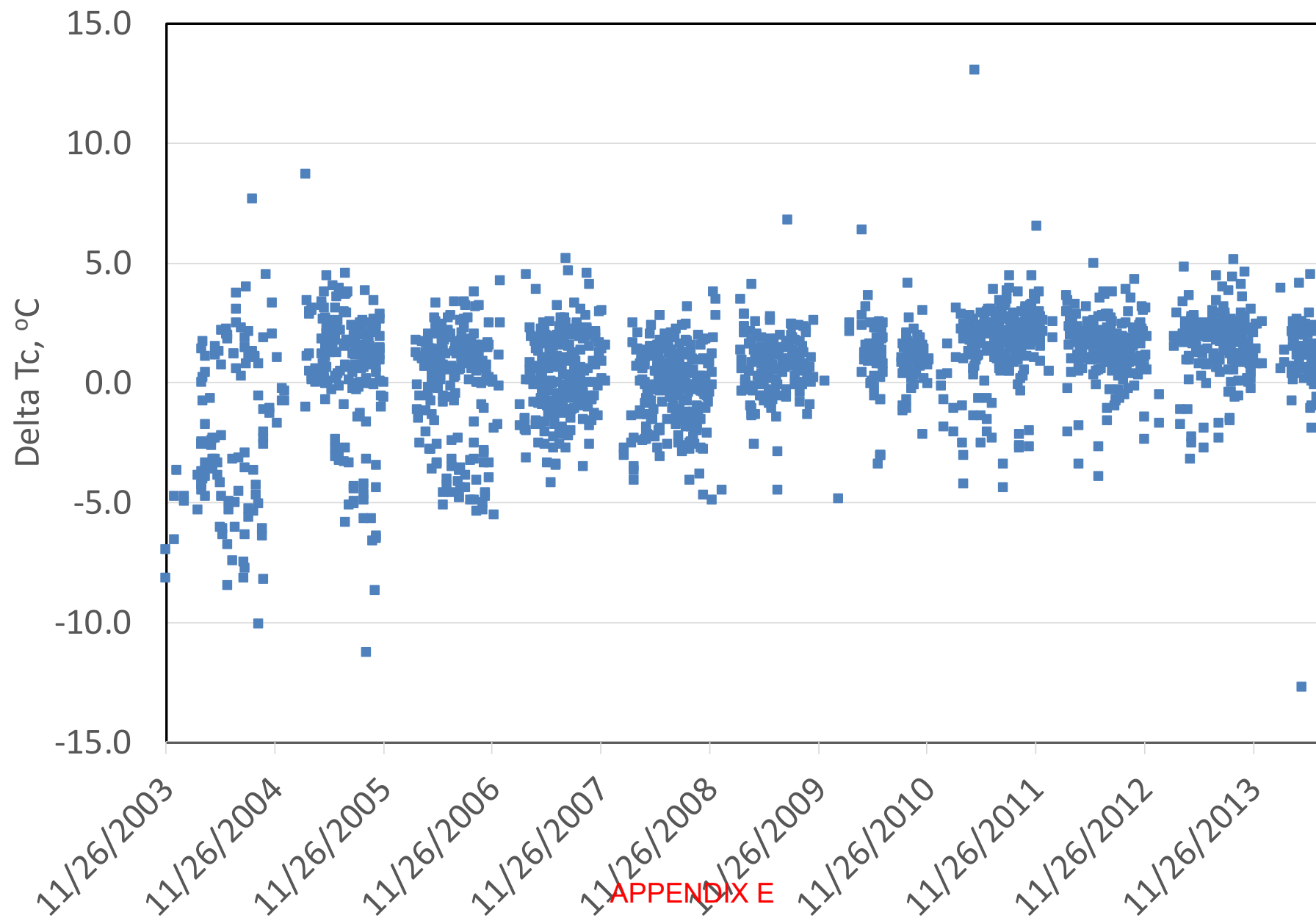




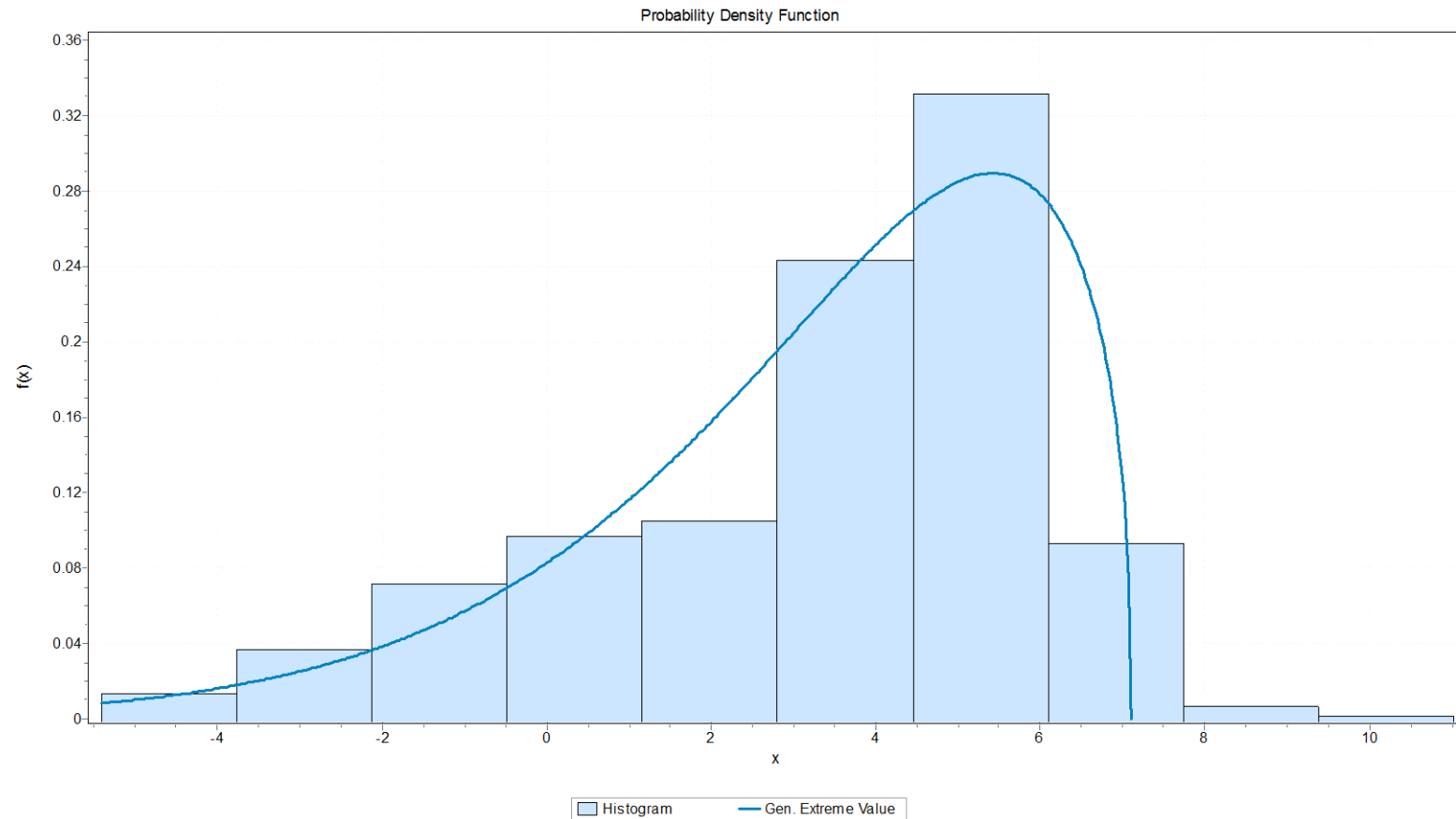


DELAWARE DOT - PG 70-22

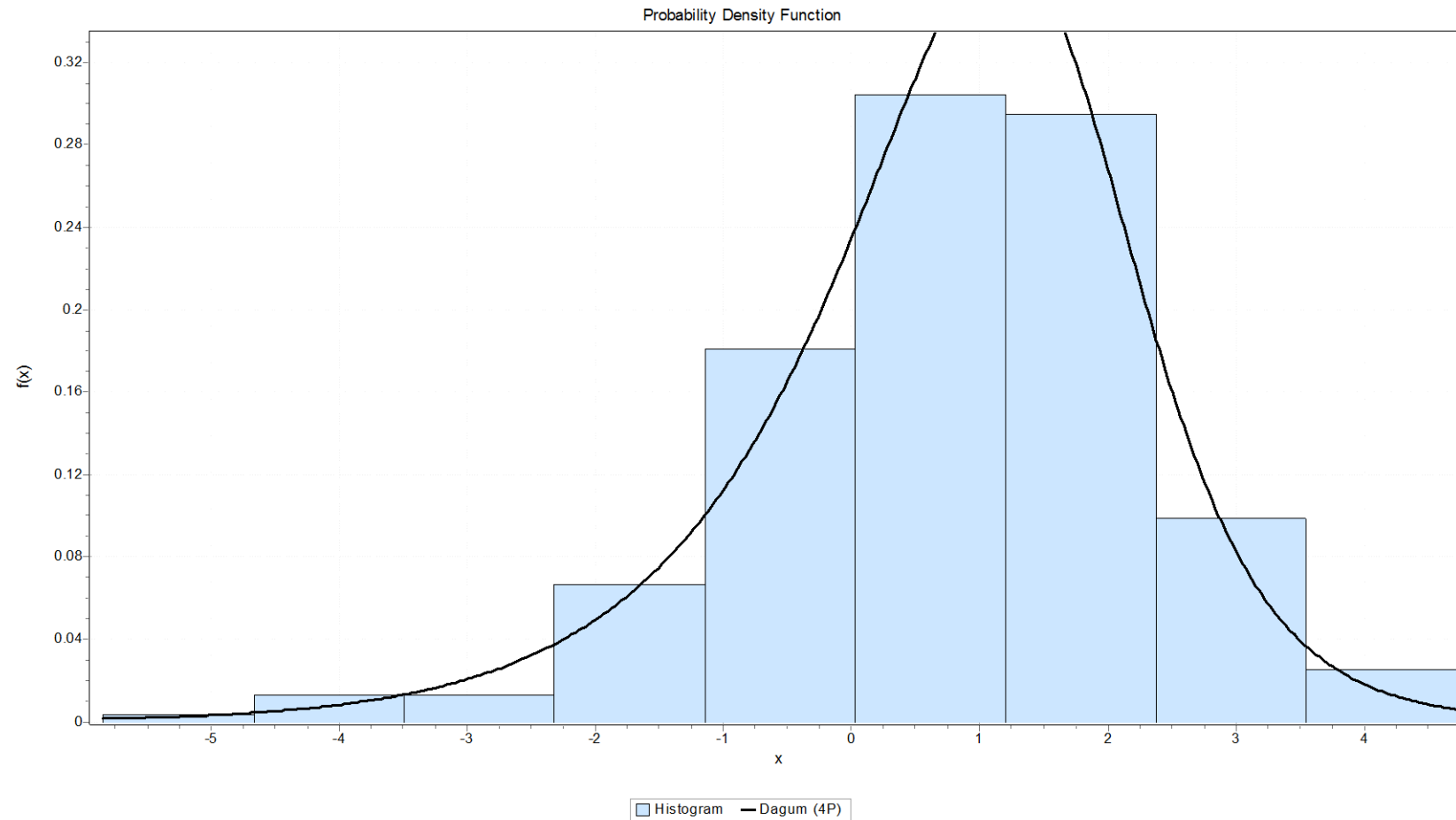




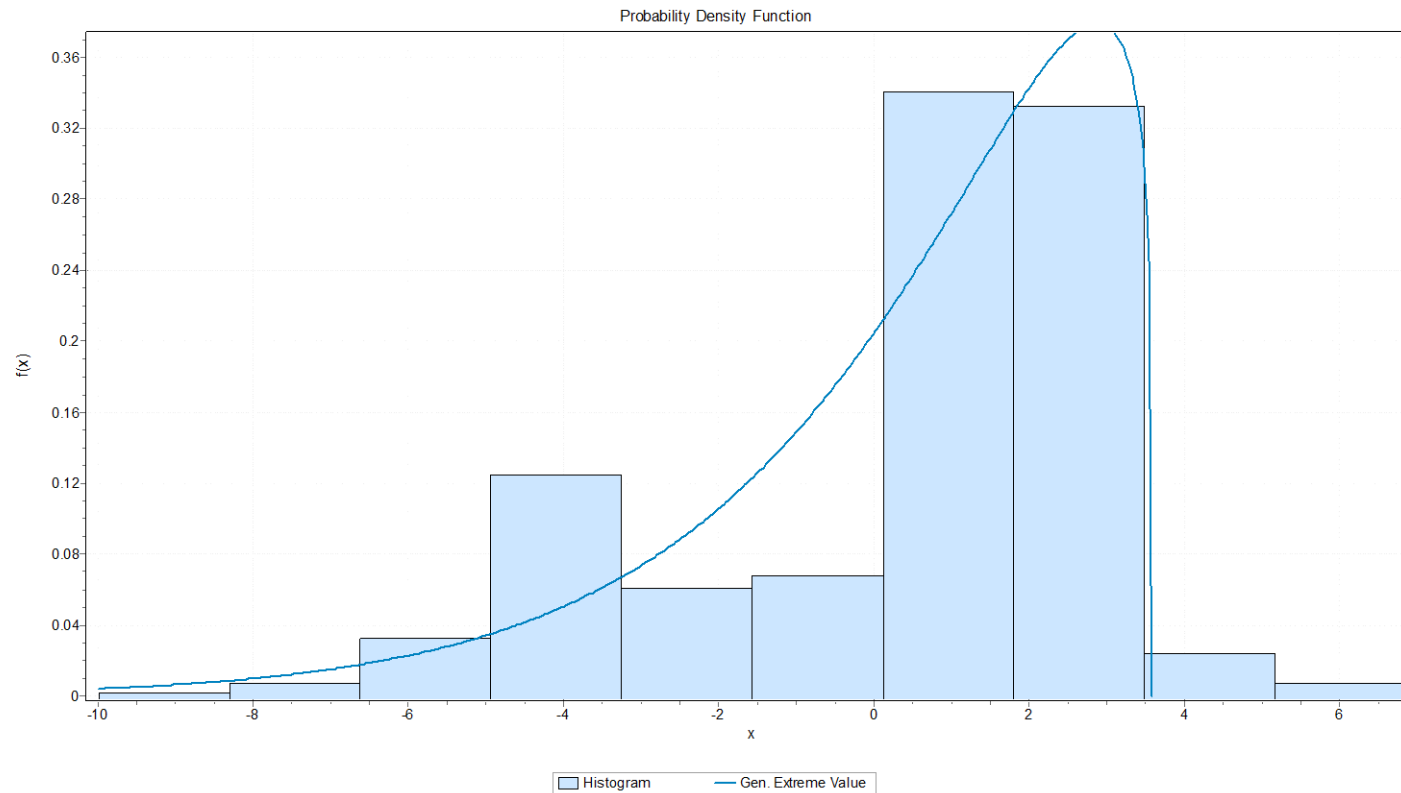
DELAWARE PG 58-28 PDF



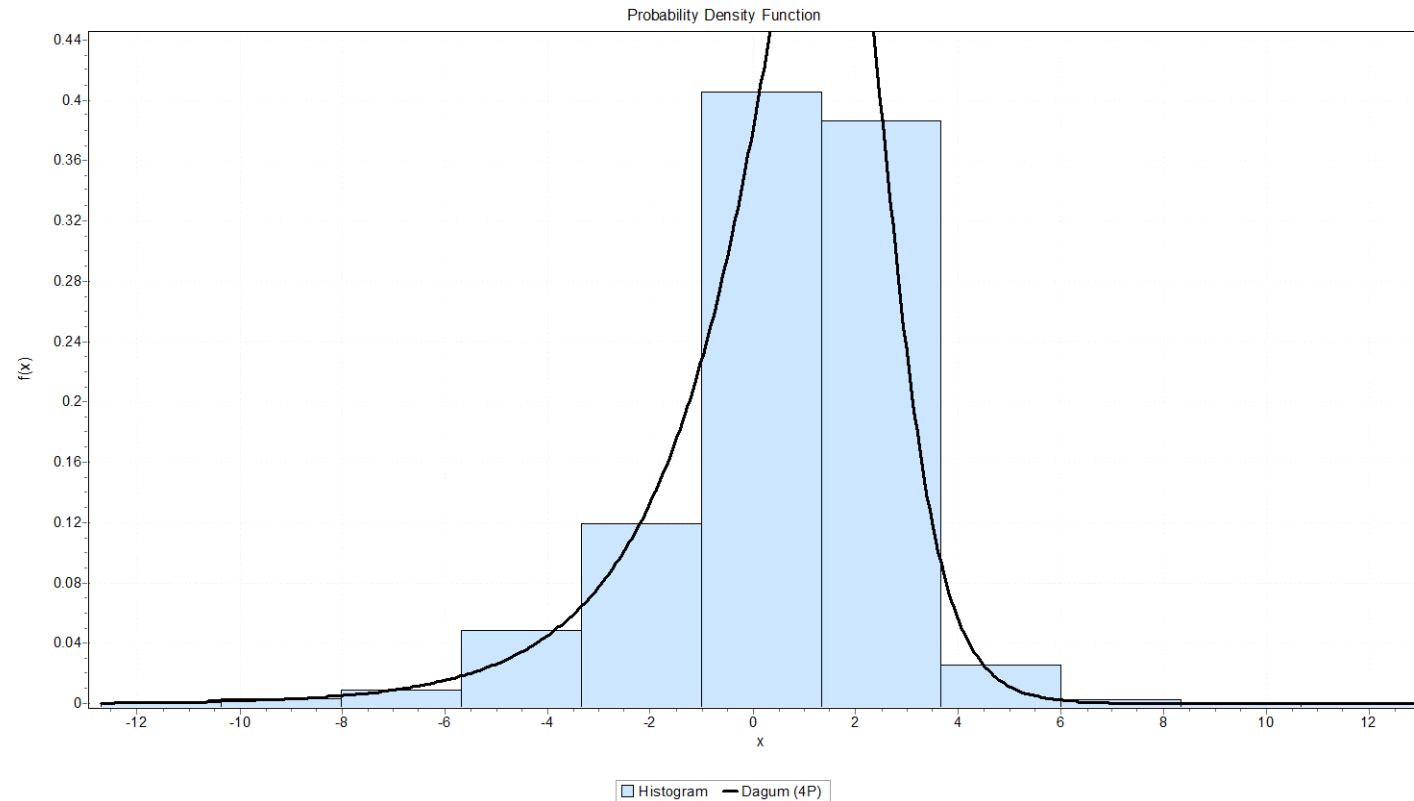
DELAWARE PG 64E-22 PDF



DELAWARE PG 70-22 PDF



DELAWARE – PG 76-22 PDF



State ID	State	Sample Size	Delta Tc, degrees C		
			Median	Minimum	Maximum
1	AR	417	-3.5	-12.4	3.6
2	CO	4275	-1.1	-14.6	12.4
3	DE (PG 58-28)	600	4.1	-5.4	11
3	DE (PG 64-22E)	315	0.9	-5.8	4.7
3	DE (PG 64-22)	3657	1.9	-8.6	12.7
3	DE (PG 70-22)	949	1.3	-10	6.8
3	DE (PG 76-22)	1961	1	-12.7	13
4	ME	2308	-1	-11.1	3.9
5	NCDOT	12,116	-0.3	-13.6	8.4
6	NE	926	2	-5.1	6.5

Findings to date

- Findings
 - Delta Tc may be predicted using simple rules based on PG Averages
 - Error in prediction is within +/- 1 degree C for most grades and binders
 - Data Mining effort
 - Delta Tc is mostly skewed to negative Delta Tc (m-controlled) for the six State DOTs analyzed
 - Delta Tc can range from as low as 3.6 to as high as -14.6 for the six State DOTs analyzed

Next Steps

- Complete analyses
- Send report back to participants
- Request field performance
- Share final analysis with ETG and SOM

Thank You!

Questions?