OFFICE OF AIR QUALITY PLANNING AND STANDARDS
RESEARCH TRIANGLE PARK, NC 27711

September 18, 2025

Gabriel Keilholz
Director of Operations
VR Smoke School, LLC.
66 Morning Glory Ln
Bonnots Mill, MO 65016

Dear Mr. Keilholz:

This letter amends the original version dated September 9, 2025. The letter was amended to correct the date the information in Attachment B was received.

I am writing in response to your submittal dated July 29, 2025, in which you seek approval of your virtual reality (VR) Method 9 training system for use as described in ALT-152. ALT-152 was approved on August 22, 2022, as a broadly applicable alternative test method to the certification procedures required for opacity observers under section 3.2 of Method 9 – *Visual Determination of the Opacity of Emissions from Stationary Sources* (40 CFR part 60, Appendix A). The U.S. Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards is the delegated authority for approval/disapproval determinations on any major alternatives to test methods and other compliance determination procedures required under 40 CFR parts 59, 60, 61, 63, and 65.

ALT-152 requires other entities who seek to conduct Method 9 observer training and certification, according to specifications therein, must:

- Have a documented certification system that meets all the criteria contained in ALT-152 including the attachment and provide a demonstration to our office; and
- Have performed and submitted to our office for review and approval a successful demonstration of the VR training system according to EPA-650/4-75-009.

On July 29, 2025, you submitted to our office for review a report (Attachment A) containing the results of the demonstration of your VR Method 9 training system according to EPA-650/4-75-009. Additionally, on May 27, 2025, you provided our office with access to your domain to allow us to evaluate your VR Method 9 training system, along with a criteria list (Attachment B) detailing how your system meets or surpasses the criteria contained in ALT-152.

Based on a thorough review of your submittals, we conclude that your VR headset-based alternative method for conducting Method 9 plume demonstrations and certification yields observers that are capable of conducting opacity observations with equivalent or better accuracy as observers certified

using the existing Method 9 procedures. Therefore, with this letter, I approve the use of your VR headset-based alternative method for conducting Method 9 plume demonstrations and certification as described in ALT-152. A copy of this letter will be posted as ALT-152A on the EPA website at *https://www.epa.gov/emc/broadly-applicable-approved-alternative-test-methods.*

If you have any questions regarding this approval or need further assistance, please contact Kim Garnett at (919) 541- 1158 or *garnett.kim@epa.gov*.

Sincerely,

STEFFAN JOHNSON

Digitally signed by STEFFAN JOHNSON
Date: 2025.09.18 07:46:12 -04'00'

Steffan M. Johnson, Group Leader
Measurement Technology Group

Attachments

cc: Kim Garnett, OAQPS/AQAD (garnett.kim@epa.gov)
Gregory Fried, OECA/OC (fried.gregory@epa.gov)
Regional Testing Contacts

Attachment A

VR Smoke School, LLC
66 Morning Glory Lane
Bonnots Mill, MO 65016

To:

July 28, 2025

Kim Garnett
USEPA/OAQPS/MTG (E143-02)
109 TW Alexander Drive
PO Box 12055
Research Triangle Park, NC 27711

Mrs. Garnett:

Attached is the test report for the comparative study required by ALT-152. All conditions established in the test plan submitted on June 16, 2025 were adhered to without deviation.

Sincerely,

Gabriel Keilholz
Director of Operations

EPA-650/4-75-009 Comparative Study for EPA ALT-152 Approval

VR Smoke School, LLC

July 28, 2025

Introduction

EPA Method 9 is a well-established procedure for determining the opacity of visible emissions. ALT-152 was approved in 2023 as an alternative certification method and allows observers to earn their EPA Method 9 certification using a Virtual Reality (VR) headset instead of attending an in-person smoke school.

The 1975 EPA publication *EPA-650/4-75-009* established acceptable deviation standards for both white and black smoke based on observations from individuals trained at traditional, in-person smoke schools. To gain approval as an ALT-152 provider, applicants must certify observers using a virtual reality (VR) headset and training program. These VR-trained observers must then demonstrate their ability to accurately assess smoke opacity during an in-person observation event. The deviation results from these field observations must meet or exceed the benchmark standards set forth in *EPA-650/4-75-009*.

This report presents the evaluation results of observers who were trained and certified with the VR Smoke School, LLC program.

Summary of Results

One of the primary objectives of *EPA-650/4-75-009* was to evaluate the accuracy of opacity determinations made by individuals certified at an in-person smoke school. In the study, nine observers completed 20 sampling runs of white smoke and 16 runs of black smoke. Their determinations were compared to true opacity values measured by an in-stack transmissometer. The mean absolute deviation from the in-person certified observers was 3.74 for white smoke and 3.33 for black smoke (Appendix A).

Following the specifications outlined in the test plan submitted on June 16, 2025, nine students were trained and certified using the VR Smoke School, LLC program on a VR headset. Students were presented with standard values for both white and black smoke and were given the opportunity to take practice tests before attempting the certification test. Upon successful completion of the certification test, students were considered certified. Both the VR Smoke School program and the required hardware meet all requirements established in ALT-152.

The nine VR-certified observers then participated in an in-person field test, during which they observed 20 sampling runs of white smoke and 16 sampling runs of black smoke produced by a smoke generator. Field test conditions are detailed in Appendix C. Observer determinations were compared to true opacity values measured by an in-stack transmissometer of a smoke generator. The subject smoke generator was evaluated on April 4, 2025 to meet the specifications of EPA Method 9 Section 3.3.2 and the report is available upon request. The mean absolute deviation for the VR-certified observers was 1.68 for white smoke and 2.48 for black smoke (Appendix B).

As stated in *EPA-650/4-75-009*, “accuracy is measured by the deviation of the observer’s determination from the true opacity as measured by the in-stack transmissometer.” On average, opacity determinations made by observers certified with the VR Smoke School program were 55.1% more

accurate for white smoke and 25.5% more accurate for black smoke compared to determinations made by observers certified at an in-person smoke school. These findings show that the training and certification provided through the VR Smoke School program are at least equal in effectiveness to those offered by traditional in-person smoke schools. As such, we respectfully request that the VR Smoke School program be approved for ALT-152 certification.

Appendix A

EPA-650/4-75-009

Deviation Data

Deviation from Transmissometer - Original EPA Study											
Run Number	*Black Smoke*										
	Observer 1	Observer 2	Observer 3	Observer 4	Observer 5	Observer 6	Observer 7	Observer 8	Observer 9	Overall Deviation Per Run	Absolute Deviation Per Run
1	-10.6	-14.6	-13.0	-11.8	-16.0	-13.6	-13.4	-13.2	-9.6	-12.87	12.87
2	-3.4	-1.2	-0.8	-0.4	-0.2	-3.2	0.4	-2.4	1.2	-1.11	1.47
3	-6.0	-5.8	-3.4	-2.0	-3.8	-5.2	-2.8	-4.2	-3.0	-4.02	4.02
4	-2.4	-5.6	-4.4	-0.4	-2.8	-0.4	0.0	0.2	-3.0	-2.09	2.13
5	-4.9	-0.9	0.3	1.7	0.5	-0.3	0.7	0.7	0.1	-0.23	1.12
6	-6.4	-10.8	-10.2	-11.4	-7.2	-10.4	-11.2	-11.2		-9.85	9.85
7	2.6	0.0	1.0	0.0	-0.6	1.0	0.2	1.4		0.70	0.85
8	-4.4	-3.6	-4.2	-3.4	-7.6	-3.8	-6.0	-5.8		-4.85	4.85
9	-5.0	-7.4	-1.2	-1.4	-6.2	-2.8	-6.4	-2.6		-4.13	4.13
10	-1.6	-2.8	0.2	0.4	-2.0	-1.2	-1.8	0.0		-1.10	1.25
11	0.6	0.2	-0.8	3.0	-0.8	5.0	-0.2	1.2		1.03	1.48
12	1.0	-11.2	-3.0	1.2	1.2	3.0	1.8	0.4		-0.70	2.85
13	1.0	-2.4	2.0	3.6	1.2	3.6	-0.4	-0.8		0.98	1.88
14	-1.2	-1.0	2.4	2.4	1.0	2.6	-0.6	-0.4		0.65	1.45
15	0.2	-2.6	0.4	5.6	1.0	1.8	1.0	0.8		1.03	1.68
16	-0.2	-2.0	1.0	2.0	0.8	2.2	-0.2	-2.4		0.15	1.35
									Absolute Average Deviation		3.33

Deviation from Transmissometer - Original EPA Study											
Run Number	*White Smoke*									Overall Deviation Per Run	Absolute Deviation Per Run
	Observer 1	Observer 2	Observer 3	Observer 4	Observer 5	Observer 6	Observer 7	Observer 8	Observer 9		
1	2.8	2	0.8	3.2	0.6	7.4	1	0.6	3	2.38	2.38
2	-3	-4.6	-2.4	-2.6	-5.4	-3	-5.2	-0.8	1.2	-2.87	3.13
3	-0.4	-3.4	-0.6	-0.4	-3.2	-0.6	-2.6	-0.6	0.8	-1.22	1.40
4	3.2	4.4	0	-1.2	-10.2	-1.6	-9.2	1.2	0.2	-1.47	3.47
5	-1.1	-2.7	-0.3	-0.3	-0.9	0.5	-0.5	-0.9	-1.1	-0.81	0.92
6	0.9	-0.1	0.3	1.9	1.1	1.1	1.3	0.3	1.9	0.97	0.99
7	1.2	0.8	-0.6	-0.4	0	0.6	-0.4	0	-0.2	0.11	0.47
8	-2.8	-11.4	-9.4	-9.6	-13.8	-13	-12.6	-6.6	-6.6	-9.53	9.53
9	-2.8	-10	-11.8	-8.8	-5.8	-8	-4.8	-8.4	-9.4	-7.76	7.76
10	-3	-4.8	-4	-4.6	-2.4	-4.6	-3.4	-5.2	-3.8	-3.98	3.98
11	4.3	4.3	6.1	6.5	5.7	4.3	3.3	3.3		4.73	4.73
12	0	-2.2	0	-1.2	-0.6	-2.4	-3.4	-3.4		-1.65	1.65
13	1	-0.2	3.4	1.6	2.4	2.4	-0.3	-0.8		1.19	1.51
14	1.8	3.6	4.6	8.2	4.2	0.8	2.4	1.4		3.38	3.38
15	3.9	6.5	3.1	4.1	5.3	-1.5	-0.5	-3.5		2.18	3.55
16	0.9	-1.9	-0.5	-2.7	-3.7	-13.1	-7.7	-8.1		-4.60	4.83
17	5.8	5.6	7.6	6.4	3.4	1.8	5.6	-0.2		4.50	4.55
18	-7.8	-8	-3.2	-7.2	-9.6	-9.6	-9	-9.8		-8.03	8.03
19	-3.9	-1.7	1.7	-2.3	-1.7	-5.7	-2.9	-7.7		-3.03	3.45
20	-2.2	-4.4	-4.8	-4.6	-5.2	-7.2	-5.4	-6.6		-5.05	5.05
									Absolute Average Deviation		3.74

Appendix B

Observer Deviation Data

Deviation from Transmissometer - VR Smoke School, LLC Test Data											
	Black Smoke										
Run Number	Observer 1	Observer 2	Observer 3	Observer 4	Observer 5	Observer 6	Observer 7	Observer 8	Observer 9	Overall Deviation Per Run	Absolute Deviation Per Run
1	0.0	1.4	-1.0	1.2	7.4	1.2	-0.6	4.6	-1.2	1.44	2.07
2	3.6	-2.8	-1.4	-3.4	3.0	-0.4	0.2	-1.4	2.4	-0.02	2.07
3	3.0	-2.8	-2.4	-2.0	0.6	-1.8	-0.2	0.0	1.6	-0.44	1.60
4	2.8	-5.0	-3.8	-4.8	4.4	-3.4	5.8	1.8	2.4	0.02	3.80
5	1.6	-5.0	-3.6	-4.6	-0.6	-1.0	1.6	4.4	1.2	-0.67	2.62
6	1.0	-1.6	-0.2	-1.2	1.4	0.6	3.2	5.0	1.4	1.07	1.73
7	3.0	-4.4	-3.2	-3.0	1.0	0.0	5.0	3.4	-1.2	0.07	2.69
8	-1.2	-7.0	-6.6	-5.4	-2.0	-1.2	-1.0	-1.4	-3.4	-3.24	3.24
9	-3.4	-11.6	-11.4	-9.6	-6.0	-7.4	-3.0	-6.4	-5.6	-7.15	7.15
10	0.0	-1.4	-2.0	-2.4	0.4	2.0	-1.4	-1.6	0.4	-0.67	1.29
11	0.0	-3.8	-3.6	-0.2	2.6	2.8	1.2	2.4	-0.6	0.09	1.91
12	0.8	-1.6	1.0	0.4	2.4	1.2	2.0	-0.6	1.0	0.73	1.22
13	1.0	-2.0	-0.2	0.2	1.8	2.4	1.0	0.6	1.4	0.69	1.18
14	3.0	-3.6	-1.4	0.6	2.0	3.6	5.4	-3.2	3.0	1.04	2.87
15	1.4	-0.4	0.2	0.2	0.8	0.6	1.2	0.6	0.2	0.53	0.62
16	1.2	-8.0	-6.2	-5.2	-1.6	-4.2	0.6	-4.6	-1.4	-3.27	3.67
									Absolute Average Deviation		2.48

Deviation from Transmissometer - VR Smoke School, LLC Test Data											
	White Smoke										
Run Number	Observer 1	Observer 2	Observer 3	Observer 4	Observer 5	Observer 6	Observer 7	Observer 8	Observer 9	Overall Deviation Per Run	Absolute Deviation Per Run
1	-1.0	-1.6	-1.6	-1.8	-2.8	-1.2	-0.2	0.8	-1.2	-1.18	1.36
2	2.8	0.2	1.4	3.2	0.8	5.0	3.0	10.4	4.8	3.51	3.51
3	1.2	-0.6	-1.8	0.0	1.2	1.6	1.4	3.2	1.2	0.82	1.36
4	3.0	-1.8	-0.2	1.8	0.6	2.6	0.0	2.0	1.8	1.09	1.53
5	0.6	-0.2	-0.6	1.6	2.4	1.0	0.6	4.2	0.4	1.11	1.29
6	1.4	0.6	-1.2	2.0	1.6	0.0	0.0	5.4	0.4	1.13	1.40
7	3.2	-0.4	-1.2	3.2	1.4	3.2	2.4	2.0	3.4	1.91	2.27
8	1.4	-1.0	-3.4	1.8	-1.0	1.2	1.8	1.8	1.0	0.40	1.60
9	1.6	-1.4	-1.0	3.4	0.2	1.2	0.6	3.8	1.6	1.11	1.64
10	0.4	-0.2	-2.2	-0.2	1.8	0.0	-0.2	2.0	0.4	0.20	0.82
11	0.8	-5.6	-5.0	0.4	1.2	-2.4	-0.6	2.4	-1.0	-1.09	2.16
12	3.0	-0.2	-0.2	3.8	4.4	3.0	2.8	2.8	3.0	2.49	2.58
13	1.2	-4.2	-3.8	1.8	-0.6	0.6	1.6	3.6	0.6	0.09	2.00
14	-1.2	-7.2	-6.6	0.0	1.0	-0.2	-0.4	0.2	1.0	-1.49	1.98
15	1.2	-4.6	-3.8	0.2	3.0	1.2	1.4	-1.2	0.2	-0.27	1.87
16	0.0	0.4	0.0	-0.2	1.2	0.0	0.0	-0.2	0.0	0.13	0.22
17	0.6	-1.6	-0.6	-0.4	-1.4	0.2	-0.4	-0.8	0.4	-0.44	0.71
18	2.0	-3.6	-2.2	-1.4	4.6	0.8	1.6	2.0	1.2	0.56	2.16
19	0.8	-5.4	-4.0	0.6	1.0	0.4	1.4	2.8	1.0	-0.16	1.93
20	0.8	-1.8	-0.6	0.0	3.0	0.8	0.2	-3.2	0.4	-0.04	1.20
									Absolute Average Deviation		1.68

Appendix C

Test Conditions

Test Dates & Times

- July 22, 2025, 8:40 A.M. – 11:30 A.M.
- July 23, 2025, 8:37 A.M. – 11:42 A.M.

Weather & Meteorological Data

July 22, 2025

- Temperature
    - Start: 82°F
    - End: 90°F
- Wind
    - Start: Variable direction, <5mph
    - End: Variable direction, <5mph
- Sky Conditions
    - Start: 10% cloud cover
    - End: 10% cloud cover

July 23, 2025

- Temperature
    - Start: 81°F
    - End: 88°F
- Wind
    - Start: Variable direction, <5mph
    - End: Variable direction, <5mph
- Sky Conditions
    - Start: 0% cloud cover
    - End: 0% cloud cover

Positioning Data – Observer to Stack

July 22, 2025

- Distance – 60 feet
- Direction - 250°
- Background – Sky

July 23, 2025

- Distance – 70 feet
- Direction - 260°
- Background – Deciduous trees

VR Smoke School, LLC
66 Morning Glory Lane
Bonnots Mill, MO 65016

May 27, 2025

TO:
Kim Garnett
garnett.kim@epa.gov
USEPA/OAQPS/MTG
109 TW Alexander Drive
P.O. Box 12055
Research Triangle Park, NC 27711

Dear Mrs. Garnett:

As specified in ALT-152, an approved system must "*Have a documented certification system that meets all the criteria contained in this determination including the attachment and provide a demonstration to our office*."

The following is a list of all ALT-152 criteria, along with an explanation of how the VR Smoke School program satisfies each. Please let me know if you have any questions or need additional information.

Sincerely,

Gabriel Keilholz
Director of Operations

VR Smoke School Program Checklist for ALT-152 Criteria

Recordings of black and white smoke to be displayed on the VR headset must meet the following conditions:

- Sun must be within 140° sector behind the camera lens;
    - **Condition met and recorded in sketch layout**
- Angle between camera lens and stack exit must be ≤18°;
    - **Condition met and recorded in sketch layout**
- A white balance reference must be recorded in each frame;
    - **Condition met and visible in all videos**
- Color depth of the source video must be ≥12-bit;
    - **Source video is 12-bit**
- Video must be recorded in RAW or equivalent visually-lossless codec;
    - **Source video was recorded in RAW**
- The source video frame rate must be ≥24 fps;
    - **Source video is ≥24 fps**
- Timecode must be recorded per frame;
    - **Condition met and recorded in RAW video files**
- Resolution of the source video must be ≥4096 horizontal lines and ≥2160 vertical lines;
    - **Source video is ≥4096 horizontal lines and ≥2160 vertical lines**
- The stack exit must be nominally in the center of the frame during recording;
    - **Condition met and visible in videos**
- The depth of field must be sufficient to ensure the stack exit and plume are in focus and a clear background for the plume.
    - **Condition met and visible in videos**

The smoke generator used to create black and white smoke videos must meet the following conditions:

- The smoke generator must be designed and calibrated according to Method 9, section 3.3;
    - **The smoke generator was designed and calibrated to meet Section 3.3 requirements and recorded in a report.**
- Opacity data from the transmissometer must be recorded to the nearest 0.1% at least four times per second. Each recording must have a timestamp with resolution of at least one-tenth of a second.
    - **All conditions are met and recorded in the opacity data file.**

Processed videos to be used for the certification test on the VR headset must meet the following conditions:

- Audio from the scene must be removed to eliminate mechanical or other auditory hints;
    - **All audio has been removed from videos**
- Visual aids, including Ringelmann charts, must not be visible to the student;
    - **No visible aids are present in videos**
- Resolution must be ≥4096 horizontal lines and ≥2160 vertical lines;
    - **Processed videos are ≥4096 horizontal lines and ≥2160 vertical lines**
- Video bitrate must be ≥1 Mbps for every 160 lines of horizontal resolution;
    - **Processed videos have a bitrate of ≥1 Mbps for every 160 lines of horizontal resolution**
- Video frame rate must be ≥24 fps.
    - **Processed videos have a frame rate ≥24 fps**

The application on the VR headset used to train and certify students must meet the following conditions:

- Must display at least four opacities between 5% and 100% opacity for each smoke color as part of a standard value demonstration;
    - **Condition met and visible in visual test**
- Must provide a practice test of at least five questions per smoke color;
    - **Condition met – students can review as many practice questions as they need**
- Students must be shown 5-10 continuous seconds of smoke for each certification plume observation;
    - **Condition met – videos range from 5-7 seconds**
- Each video clip must be representative of a single opacity ranging from 0-100%;
    - **Condition met – each video represents a single opacity value**
- The opacity of the smoke displayed during each test question must be +/- 2.5% of stated value based on a 3-second rolling average of four readings per second;
    - **Condition met and provable with opacity data**
- Each certification plume video clip must be selected from ≥600 video clips per smoke color with a minimum of 25% of the certification plumes being greater than 50 percent opacity with all opacities from 0-100% represented;
    - **Condition met – there are ≥600 video clips per smoke color and at least 25% are greater than 50% opacity. All opacities from 0-100% are represented.**
- Each observation must be digitally recorded before proceeding to the next question;
    - **Condition met – student answers are recorded prior to proceeding to the next question**

- The probability for receiving the same 50-question test sequence must be greater than one in a million;
    - **Condition met – the probability is greater than one in a million**
- The test must be completed within 90 minutes of initiation;
    - **Condition met - a 90 minute timer starts when the test is initiated**
- Students must certify that their answers are their own;
    - **Condition met – an attestation page is included in the program**
- To receive certification as a qualified observer, a candidate must be tested and demonstrate their ability to assign opacity readings in 5% increments to 25 different black plumes and 25 different white plumes, with an error not to exceed 15% opacity on any single reading and an average error not to exceed 7.5% opacity per smoke color;
    - **Condition met – tests are automatically graded based on these criteria**
- If a student fails the test, a complete run of 25 black smoke readings and 25 white smoke readings must be repeated.
    - **Condition met**

The following data relating to the VR application must be electronically collected and stored for a minimum of five (5) years:

- Make and model of camera and lens used to record test videos;
    - **Recorded and will be stored for >5 years**
- Date and time of video recordings;
    - **Recorded and will be stored for >5 years**
- Camera position relative to stack and sun during recording;
    - **Recorded and will be stored for >5 years**
- Source video files used to create test videos;
    - **Recorded and will be stored for >5 years**
- Transmissometer data during video recording;
    - **Recorded and will be stored for >5 years**
- Rolling averages for test videos;
    - **Recorded and will be stored for >5 years**
- Student identification;
    - **Recorded and will be stored for >5 years**
- Identification of each video clip shown during each certification test;
    - **Recorded and will be stored for >5 years**
- Grading results including deviation per reading and total score per smoke color for each certification test;
    - **Recorded and will be stored for >5 years**
- Date, start time and completion time of each certification test;

    - **Recorded and will be stored for >5 years**
- Application version of the virtual opacity testing software and VR headset firmware and OS version used during test.
    - **Recorded and will be stored for >5 years**

The VR headset used for observer certification and presentation of demonstration plumes for training must meet the following conditions:

- Refresh rate of headset must be >60Hz;
    - **Condition met – only headsets with a refresh rate of >60Hz can be used to earn certification from the VR Smoke School program**
- Horizontal field of view (FOV) of display must be >90 Degrees, measured as described by the manufacturer;
    - **Condition met – only headsets with a FOV of >90 degrees can be used to earn certification from the VR Smoke School program**
- Horizontal pixels per degree (PPD) of display must be >17;
    - **Condition met – only headsets with a PPD of >17 can be used to earn certification from the VR Smoke School program**
- Must block ambient light;
    - **Condition met – only headsets that block ambient light can be used to earn certification from the VR Smoke School program**
- Must respond to the user rotating head left, right, up and down.
    - **Condition met – only headsets that track head movement can be used to earn certification from the VR Smoke School program**