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

August 13, 2024

Arthur Eberle, B.B. ChE, MBA
Chief Executive Officer
Compliance Assurance Associates, Inc.
682 Orvil Smith Road
Harvest, Alabama 35749

Dear Mr. Eberle:

I am writing in response to your submittal dated June 18, 2024, 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 June 18, 2024, 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 July 24, 2024, you provided our office with an in-person demonstration of your VR Method 9 training system, along with a 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: 2024.08.13 10:24:22 -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

Independent Third-Party Review and Oversight of Compliance Assurance Associates, Inc.'s Method 9 VR Certification Study

Jeremiah Burley
Jermiah@techburley.com
Date: June 18, 2024
PN 123001101

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Introduction

EPA Method 9 is a proven and accepted method for enforcement and compliance assurance monitoring (CAM). An alternative method, *ALT-152 Alternative Method for Method 9 Certification Training* (ALT-152), was approved to allow a virtual reality (VR) system with a series of video clips to provide equivalent training.

This report outlines the procedures Compliance Assurance Associates, Inc. (CAA) used to demonstrate an equivalent or better training result using VR than the original Method 9 training. Thus, CAA's training/certification method should be approved under ALT-152.

Background

EPA Method 9 certification is achieved by completing a visual test of opacity determinations at an in-person event known as a "smoke school." Using a smoke generator, students are shown various opacities of white and black smoke. After this smoke demonstration, students are tested on their ability to assess the opacity of 25 black smoke plumes and 25 white smoke plumes.

CAA's alternative method replaces the in-person smoke school with a virtual one. Students, using a virtual reality (VR) headset, viewed demonstrations of smoke values and were tested on their ability to assess the opacity of 25 black smoke plumes and 25 white smoke plumes.

The administration of the certification procedure is the only difference between the proposed alternative method and EPA Method 9.

The benefits of the proposed alternative method are listed in CAA's Test Plan, previously submitted to the EPA by CAA.

Testing Summary & Objective

EPA-650/4-75-009, also titled "Evaluation and Collaborative Study of Method for Visual Determination of Opacity of Emissions from Stationary Sources," was published in January 1975. The purpose of the study was to statistically evaluate EPA Method 9 by obtaining observation data from certified observers. Nine evaluators who were previously certified at an in-person smoke school observed 20 runs of white smoke from a smoke generator and 16 runs of black smoke.

For CAA's VR Study, 13 students were trained and certified using an application on a VR headset. The students were shown standard values for white and black smoke and had the option to take practice tests. Students completed the certification test on VR headsets and had the option to retake it until successful completion. No students had previous experience with in-person EPA Method 9 testing or opacity observations.

After successfully completing the VR certification test, the students (also called evaluators) had the opportunity to observe opacity from a smoke generator at an in-person event at the CAA office.

Evaluators observed 20 runs of white smoke and 16 runs of black smoke. Opacity observation data was collected, and the average absolute deviation of the evaluator's observations from the transmissometer readings was calculated for each smoke color.

The average absolute deviation of the observations made by evaluators certified with the VR headset was compared to the average absolute deviation of observations made by evaluators certified at an in-person smoke school as recorded in EPA-650/4-75-009 Tables A-1 and A-2 (See Appendix B).

CAA Method 9 Certification Procedure Using VR Method

CAA used the following procedure to certify 13 participants in this study.

1. Students were provided with a VR headset and logged into the virtual smoke school application using unique credentials.
2. Standard opacity values of white smoke were displayed to the student.
3. Students were offered the option to take a white smoke practice test or begin the certification test for white smoke.
4. After completing the white certification test, students proceeded to black smoke testing.
5. Standard opacity values of black smoke were displayed to the student.
6. Students were offered the option to take a black smoke practice test or begin the certification test for black smoke.
7. Students took the black smoke portion of the test, in which 25 randomly selected black plume opacities were shown. For each opacity, students recorded their reading in 5% increments.
8. Students were certified based on 50 consecutive points, 25 white and 25 black, and graded. If they failed, they restarted on another 50 consecutive points.

Students who completed the certification test with an average error of less than 7.5% per smoke color and without any single deviation exceeding 15% were considered certified.

Students who did not pass the certification test were required to continue testing until they successfully certified or chose to end the test (uncertified).

CAA In-Person Observations Using Smoke Generator

On June 8, 2024, 13 evaluators who were certified using the VR application met at the CAA office to conduct in-person observations using a smoke generator.

Twenty (20) runs of white smoke and sixteen (16) runs of black smoke were performed.

- Each run consisted of 25 consecutive readings taken at 15-second intervals.
- Observations by the evaluators were synced by an announcement from the test administrator at each reading. The test administrator/system recorded the average of the transmissometer reading based on a 5-second sample.
- Evaluators recorded their opacity readings in 5% increments on a supplied form.
- Evaluators could select their background while making observations while adhering to positioning requirements for sun and wind.

As described in EPA-650/4-75-009, the plume opacity ranged from 0 to 40%. During runs, the opacity was held constant, increased, or decreased. The number of times the plume opacity was changed, the point at which it was changed, and the amount it was changed varied from run to run.

Appendix A provides the technical details regarding CAA's alternative method for certification used for these 13 observers.

Weather Conditions

Test conditions during the testing day are presented in Table 1

Table 1. Weather and Observation Conditions During In-Person Field Testing

Test Date: June 8, 2024		
Color	Black Smoke	White Smoke
Time	8:00 – 11:15 am	1:00 – 4:30 pm
Temperature	65-75 F	80 F
Wind	0-5 mph	3-7 mph
Sky Conditions	Overcast	Broken/clear
Observer Position	Distance 1: 45 feet Direction 1: West Background – Blue sky/white clouds	Distance 2: 61 feet Direction 2: North 1-2 PM Distance 3: 57 feet Direction 3: East, after 2 PM Background – Deciduous Tree

Testing Observations and Challenges

Due to the nature and purpose of this VR Study, smoke test points were not repeated but adhered to a 15-second interval throughout the 25 test point run. As a result, some challenges were encountered. The following observations were made during the in-person field testing and were not unexpected.

- At times, during the period of smoke reading, the wind would blow over the stack, making it difficult to read the opacity values accurately. Even though the wind was only one (1) to seven (7) MPH, wind gusts impacted the accuracy of some of the readings.
- During some five-second smoke readings, the opacity would vary slightly, making it difficult to read accurately.
- Due to the sun angle, the observers had to move locations three (3) times during their readings. The sun angle issue created some disorientation and made some opacity readings difficult.

Data Analysis & Results

Each run consisted of 25 consecutive opacity readings taken at 15-second intervals. The statistical average of each evaluator's observations was determined and recorded for each run. The statistical average of the transmissometer readings for each run was also determined and recorded.

The difference between each evaluator's average reading and the transmissometer average reading was determined for each run and recorded as the deviation in percent opacity. The absolute average deviation of all evaluator deviations was calculated per smoke color.

Per 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."*

CAA's VR certification method achieved statistically higher accuracy compared to evaluators performing readings during the 1975 study:

Results	The 1975 Study	CAA VR Study	Difference
White Smoke	3.74	3.58	The CAA study was ~3.5% better than the 1975
Black Smoke	3.33	3.07	The CAA study was ~7.7% better than the 1975

Based on the results above, **I recommend CAA's VR training/certification method be approved for use in Method 9 certification.**

Jeremiah Burley, Study Oversight Manager

Appendix A - Alternative Method 152 Specifications

The following document originated from the VR Study conducted by Gabriel Keilholz and titled, "Alternative Method for Conducting Method 9 Observer Certification and Training Plume Demonstrations."

This document contains an alternative to section 3.2 of Method 9 (40 CFR part 60, Appendix A) and relies in part on use of a smoke generator meeting the requirements of section 3.3 of Method 9. Candidate observers wear a virtual reality (VR) headset to view a demonstration of smoke plume opacity values with the option to take practice tests and are then tested on their ability to assess the opacity of 50 plumes of unknown value, 25 black smoke and 25 white smoke, in order to determine if they can be certified. The administration of the demonstration plumes for training purposes and the certification procedure itself are the only difference between this alternative test method and Method 9.

In order to become certified under this alternative, candidate observers must complete a virtual training course in order to become familiar with background information on Method 9 equivalent to that in the "Visible Emissions Field Manual EPA Methods 9 and 22," Report No EPA 340/1-92-004, December 1992 and "Visible Emissions Evaluation Procedures Course," APTI 325-95-1, January 1995, and to become familiar with the VR headset and its use. Next, a candidate observer will use a VR headset and certification software meeting the requirements detailed in the sections below. The candidate observer will log in to the certification application using unique credentials to allow certification data to be unique to that candidate observer. Upon login, at least four standard values ranging between 0 and 100% opacity will be displayed to the candidate observer. After the standard values are displayed, the candidate will have the option to take practice tests or may begin the certification test for the first smoke color. During the certification test, candidates assign an opacity reading in 5% increments to 25 randomly selected plumes. After completion of the certification test for the first smoke color, the candidate observer proceeds to standard values for the second smoke color and repeats this process. At the completion of each run consisting of 25 black and 25 white readings, the candidate must certify that their answers are their own and the score of the candidate is determined. Candidates who complete the certification test with an average error of less than 7.5% per smoke color and without any single deviation exceeding 15% will be considered certified. If a candidate fails to qualify, the complete run of 50 readings must be repeated in any retest.

Appendix A – continued

Requirements for Creating Black and White Smoke Plume Video Recordings for VR Headset Certification Application

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.
- Angle between camera lens and stack exit must be ≤18°.
- A white balance reference must be recorded in each frame.
- Color depth of the source video must be ≥12-bit.
- Video must be recorded in RAW or equivalent visually-lossless codec.
- The source video frame rate must be ≥24 fps.
- Timecode must be recorded per frame.
- Resolution of the source video must be ≥4096 horizontal lines and ≥2160 vertical lines.
- The stack exit must be nominally in the center of the frame during recording.
- The depth of field must be sufficient to ensure the stack exit and plume are in focus and a clear background for the plume.

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.
- 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.

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.
- Visual aids, including Ringelmann charts, must not be visible to the student.
- Resolution must be ≥4096 horizontal lines and ≥2160 vertical lines.
- Video bitrate must be ≥1 Mbps for every 160 lines of horizontal resolution.
- Video frame rate must be ≥24 fps.

Appendix A – continued

Application Requirements for VR Headset Certification

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.
- Must provide a practice test of at least five questions per smoke color.
- Students must be shown 5-10 continuous seconds of smoke for each certification plume observation.
- Each video clip must be representative of a single opacity ranging from 0-100%.
- 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.
- 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.
- Each observation must be digitally recorded before proceeding to the next question.
- The probability for receiving the same 25, -question test sequence must be greater than one in a million.
- The test must be completed within 90 minutes of initiation.
- Students must certify that their answers are their own.
- 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.
- If a student fails the test, a complete run of 25 black smoke readings and 25 white smoke readings must be repeated.

Appendix A – continued

Application Data Collection, Storage, and Retention Requirements

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.
- Date and time of video recordings.
- Camera position relative to stack and sun during recording.
- Source video files used to create test videos.
- Transmissometer data during video recording.
- Rolling averages for test videos.
- Student identification.
- Identification of each video clip shown during each certification test.
- Grading results including deviation per reading and total score per smoke color for each certification test.
- Date, start time and completion time of each certification test.
- Application version of the virtual opacity testing software and VR headset firmware and OS version used during test.

VR Headset Requirements

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.
- Horizontal field of view (FOV) of display must be >90 Degrees, measured as described by the manufacturer.
- Horizontal pixels per degree (PPD) of display must be >17.
- Must block ambient light.
- Must respond to the user rotating head left, right, up and down.

Appendix B – Comparative Results

Table B-1. Results from 1975 Collaborative Study for *White Smoke* Deviation for Method 9 Observers

Deviation from Transmissometer - Original EPA Study											
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	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	4.04
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-White Smoke:				3.71

Table B-2. Results from 1975 Collaborative Study for *Black Smoke* Deviation for Method 9 Observers

Deviation from Transmissometer - Original EPA Study											
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	-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-Black Smoke:				3.33

Table B-3. Results from CAA's VR Study for *White Smoke* Deviation for Method 9 Observers

Deviation From Transmissometer - VR Certification Study															
White Smoke															
Run Number	Observer 25266	Observer 25271	Observer 25273	Observer 25276	Observer 25304	Observer 25313	Observer 25316	Observer 25320	Observer 25342	Observer 25348	Observer 25349	Observer 25353	Observer 25354	Overall Deviation Per Run	Absolute Deviation Per Run
1	1.00	-3.20	4.80	0.80	3.40	0.80	1.40	7.20	0.20	-1.20	-2.20	-2.20	1.80	0.97	2.32
2	-0.34	0.66	0.86	1.46	1.06	0.86	1.06	4.46	0.26	1.06	-7.14	-6.54	-3.34	-0.44	2.24
3	2.68	12.88	4.48	4.88	7.08	5.88	2.88	4.68	8.08	6.68	2.68	0.68	0.68	4.94	4.94
4	1.52	1.52	1.92	3.92	10.32	-3.48	2.92	5.92	6.24	-1.68	6.12	1.12	-0.28	2.77	3.61
5	2.36	5.16	4.36	2.96	4.56	1.36	3.96	3.36	4.16	6.96	2.56	2.96	2.56	3.64	3.64
6	-1.56	0.24	4.84	6.24	6.44	-1.56	4.84	6.64	4.84	-1.56	-0.16	-5.76	-0.76	1.75	3.50
7	-0.12	4.68	4.88	5.88	4.88	2.48	3.08	3.08	6.28	5.48	-0.52	-0.12	0.68	3.13	3.24
8	0.61	0.41	1.81	4.61	2.21	-3.39	0.41	-0.19	2.41	-6.19	-4.79	-7.39	-5.19	-1.13	3.05
9	0.29	7.29	5.89	6.09	6.09	1.29	24.49	5.49	8.09	4.89	1.09	0.09	0.09	5.48	5.48
10	-7.72	-2.72	-2.72	2.68	-2.52	-5.92	-3.32	-0.12	-2.12	-5.92	-3.72	-9.12	-6.72	-3.85	4.26
11	-4.86	1.34	-0.86	-5.06	-3.46	-0.86	-0.66	0.14	-7.46	-6.46	-0.26	-6.26	-6.06	-3.14	3.37
12	-10.11	-7.71	-4.51	-5.11	-9.71	-7.51	-5.51	-4.31	-9.71	-12.51	-8.11	-13.71	-7.71	-8.17	8.17
13	2.98	7.78	4.08	-0.62	-1.22	3.38	-0.42	2.38	0.58	0.58	-2.82	-0.82	2.58	1.41	2.33
14	-7.66	-4.46	-4.06	-8.86	-7.26	-2.86	-4.66	0.74	-3.66	-12.46	-1.66	-7.86	-3.46	-5.24	5.36
15	-2.54	2.06	1.06	-0.94	0.06	2.26	0.66	2.66	-0.74	-0.34	-0.94	-3.14	2.06	0.17	1.50
16	-2.04	1.76	2.56	-0.44	-2.44	1.56	-0.24	1.56	-2.44	0.56	-6.64	-6.44	-0.24	-1.00	2.23
17	0.90	7.50	0.50	-4.90	-3.10	3.10	-0.10	4.10	3.50	-2.10	-5.70	-6.70	-4.70	-0.59	3.61
18	-2.30	3.30	0.10	-2.50	-2.50	-0.30	-2.10	1.50	1.70	-0.10	-2.50	-7.50	-3.70	-1.30	4.95
19	-0.09	3.71	-0.69	-1.49	-1.69	1.51	-2.29	-2.49	0.11	3.51	0.91	0.91	-0.89	0.08	2.32
20	-3.62	-3.02	-6.02	-8.22	-6.02	-4.22	-6.22	-5.02	-4.82	-4.42	-0.82	-5.82	-6.02	-4.95	1.56
													Absolute Average Deviation White Smoke		3.58

Table B-4. Results from CAA's Study for *Black Smoke* Deviation for Method 9 Observers

Deviation From Transmissometer - VR Certification Study															
Black Smoke															
Run Number	Observer 25266	Observer 25271	Observer 25273	Observer 25276	Observer 25304	Observer 25313	Observer 25316	Observer 25320	Observer 25342	Observer 25348	Observer 25349	Observer 25353	Observer 25354	Overall Deviation Per Run	Absolute Deviation Per Run
1	-4.66	-4.86	-5.06	0.34	-4.06	-5.66	-4.06	-2.46	-5.06	-11.46	-1.86	-5.06	-8.26	-4.79	4.84
2	-4.65	-2.25	-7.85	-2.85	-7.45	-3.05	-7.45	0.15	-7.65	-4.65	-3.65	-3.85	-4.85	-4.62	4.64
3	-0.17	-1.77	-2.97	-0.37	-1.77	1.63	-2.17	-0.57	2.83	2.83	-0.17	-2.97	3.63	-0.16	1.84
4	5.38	-4.22	-5.42	1.78	-2.02	-0.02	-4.22	6.18	4.38	3.98	-3.02	-7.42	3.38	-0.09	3.96
5	1.16	-1.64	-2.64	0.16	-1.64	-1.24	-2.64	-0.04	1.76	3.56	-2.24	-2.44	-1.24	-0.70	1.72
6	1.13	-10.27	-1.27	-9.27	-5.87	-1.27	-8.87	-4.07	-1.07	-6.87	-7.67	-8.87	-0.67	-4.99	5.17
7	1.37	-4.83	-5.03	-4.23	-6.03	-1.03	-5.43	1.77	-1.03	-0.23	-5.63	-2.23	0.37	-2.48	3.02
8	-3.16	-7.36	-8.96	-8.16	-6.96	-1.96	-10.56	1.84	-0.56	-4.56	-7.36	-6.16	-2.96	-5.15	5.43
9	2.60	0.00	-3.80	2.20	0.40	1.80	-3.00	2.00	4.00	1.60	-4.00	-4.80	2.40	0.11	2.51
10	0.94	-3.46	-6.66	0.94	-1.66	2.94	-7.46	2.34	4.74	-0.86	-7.26	-3.26	-1.06	-1.52	3.35
11	0.26	-3.74	-0.74	-0.34	0.26	-1.34	-1.94	0.86	0.66	2.86	-2.34	-2.74	0.06	-0.63	1.40
12	-0.33	-5.13	-0.73	-4.13	-7.93	-3.13	-2.33	2.27	-0.13	-1.73	-3.73	-1.13	-3.53	-2.44	2.79
13	1.23	-0.97	4.63	-1.97	0.23	-1.17	-2.57	-1.17	3.43	-0.57	-3.97	1.63	3.83	0.20	2.11
14	-1.75	-2.35	7.05	0.25	-2.35	-0.35	-4.55	2.25	0.65	-0.35	0.05	2.05	3.45	0.31	2.11
15	0.66	-0.74	5.66	-1.74	-1.74	-1.54	-4.54	8.26	0.86	0.06	0.46	-0.14	4.06	0.74	2.34
16	-1.55	-2.35	-0.95	-1.95	-2.15	-2.35	-2.35	-1.35	2.05	1.45	-2.35	-2.35	-0.55	-1.29	1.83
													Absolute Average Deviation Black Smoke		3.07

Appendix C – Terms

ALT-152	Alternative Method for Method 9 Certification Training
CAA	Compliance Assurance Associates. Smoke school and credentialing organization.
CAM	Compliance assurance monitoring
VR	Virtual Reality

Attachment B

Requirements for VR certification

The following is documentation of how all requirements were met for VR certification and is a compilation of other documentation which may have been communicated separately.

Included below is a recap of the requirements for creating black and white smoke videos for the purpose of VR certification. All requirements were met.

Requirements for Creating White and Black Smoke Videos for VR headset	Alt Method 152	CAA
Sun	Must be in 140-degree sector behind camera	140-degree sector behind camera ---
Angle between camera lens and stack exit	must be ≤18°	must be ≤18° ---
white balance reference	must be recorded in each frame	recorded in each frame
Color depth of the source video	must be ≥12-bit	12-bit Canon RAW
Video	must be recorded in RAW or equivalent visually-lossless codec	Canon RAW lossless codec
The source video frame rate	must be ≥24 fps	29.97 fps
Timecode	must be recorded per frame	recorded per frame: not visible to user but remains with final video to reference the chart data (available only in editing software)
Resolution of the source video	must be ≥4096 horizontal lines and ≥2160 vertical lines	8K - 8192x4320
The stack exit	must be nominally in the center of the frame during recording	Meets this criterion – video clips available
The depth of field	must be sufficient to ensure the stack exit and plume are in focus and a clear background for the plume	Meets this criterion – video clips available

Included below is a recap of the requirements for the smoke generator use while creating videos for VR certification. The smoke generator was validated according to traditional Methos 9 requirements, with documents on file and the chart recorder software applied automatic timestamps according to android time.

Requirements for the smoke generator	ALT - 152	CAA
Smoke Generator	Must be designed and calibrated according to Method 9, section 3.3	Meets this criterion – validation document on file and available upon request
Opacity data from transmissometer	Must be recorded to nearest 0.1% at least 4 times per second	Recorded to nearest 0.01% 8 times per second
Timestamp	Each recording must have a timestamp with resolution of at least one-tenth of a second.	Chart has timestamp to one-hundredth of a second

Included below is a recap of the requirements for processed videos. All videos were processed using Adobe Premiere pro as well as a cloud-based converter for compression.

Requirements for processed videos	ALT-152	CAA
Audio/auditory hints	Must be removed	Removed during processing and muted through the application
Visual aids	Must not be visible	None were introduced. References only visible before the test
Resolution	must be ≥4096 horizontal lines and ≥2160 vertical lines	Processed resolution is 4K - 4096x2160
Video bitrate	≥1 Mbps for every 160 lines of horizontal resolution	Processed videos provided programmer are approximately 4 Mbps for every 160 lines of horizontal resolution – see attached appendix
Video frame rate	≥24 fps	29.97 fps

Included below is a recap of Application requirements for certification using the VR headset. The software used is a web-based application using a custom algorithm for selection of smoke plume examples. The algorithm is designed to meet a high standard of variation intended to exceed the "one in a million" requirement set forth in the ALT-152 method.

Application Requirements for VR Headset Certification	ALT -152	CAA
References	Must display at least four opacities between 5% and 100% opacity for each smoke color	25%,50%,75% were shown to all trainees per this test, a 100% reference can be shown/added if desired
Practice test	Must provide a practice test of at least five questions per smoke color	Practice of up to 25 questions
Plume duration	5-10 continuous seconds of smoke for each certification plume observation	All clips are 5 seconds minimum, clip length has been edited to try to maintain consistency and eliminate any indication of values
Opacity value	Each video clip must be representative of a single opacity ranging from 0-100%	All clips show an opacity value recorded to the nearest 5% increment. No clip is allowed
Opacity calculation	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	All clip averages are within 2.0%, based on an average of 8 readings per second for the duration of the clip. The range of all values within any average does not extend outside +/- 2.5% of the assigned opacity value.
Plume example selection	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	Algorithm designed to present a selection of examples from a library of >600 clips per smoke color representing all opacities between 0% and 100% in 5% increments. At least 25% of examples will be greater than 50% opacity.

Answer recording	Each observation must be digitally recorded before proceeding to the next question	Students may not proceed without answering the current question.
Repeat test probability	The probability for receiving the same 50-question test sequence must be greater than one in a million	Algorithm designed to meet or exceed the one in a million standard while maintaining the above criteria
Test duration	The test must be completed within 90 minutes of initiation	Students must initiate final grading within 90 minutes of starting the white section of the test
Answer verification	Students must certify that their answers are their own	Upon successful completion a digital signature asserting that these are their own readings required before certification issued
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 25different 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	Grading algorithm designed to meet the requirements of a traditional Method 9 exam. Additional criteria for exam of specific state requirements are included. 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.
Failure and retesting	If a student fails the test, a complete run of 25 black smoke	The software is designed to allow the student to restart the test upon grading and failure. If a student fails the test, a complete

	readings and 25 white smoke readings must be repeated	run of 25 black smoke readings and 25 white smoke readings must be repeated

Included below is a recap of the requirements for data collection, storage and retention related to certifications using ALT-152 to qualify students. It is understood that all records be retained for a minimum of 5 years.

Application Data Collection, Storage, and Retention Requirements (5 Years)	ALT-152	CAA
Camera	Make and model of camera used to record test videos	Canon R5C
Lens	Make and model of lens used to record test videos	Canon EF 70-200mm f /2.8 IS III USM
Video records	Date and time of video recordings	Recorded in chart document
Camera position	relative to stack and sun during recording	Distance and direction recorded for each session
Source videos	video files used to create test videos	All RAW videos are archived, list of videos used in each certification test is maintained with a complete chain of custody to the smoke Generator/Smoke meter Calibration and NSIT filters.
Transmissometer	Transmissometer data during video recording	Each point recorded locally and in cloud, backed up on multiple hard drives
Point values	Rolling averages for test videos	Digital chart recorder calculates point value data
Student data	Student identification	Identified with unique Student Record number, student Verification required and stored online.

Clip identification	Identification of each video clip shown during each certification test	Recorded through specific filenames designed to identify original files
Grading results	deviation per reading and total score per smoke color for each certification test	Recorded online with student records
Test information	Date, start time and completion time of each certification test	Recorded online with student records
Application information	Application version of the virtual opacity testing software and VR headset firmware and OS version used during test	Recorded online with student records

Included below is a recap of the requirements for the VR headset along with a comparison of specifications for the two headsets we used for certifying students. While both headsets we utilized met all requirements, the results were significantly improved with the Meta Quest 3. For this reason, until technology offers a better balance between performance and cost, we will be recommending the Meta Quest 3 as the minimum option.

Requirements for VR headset	Alt Method 152 Requirement	CAA on META 2	CAA on META 3
Refresh Rate	must be >60Hz	90hz refresh rate	90hz refresh rate
Horizontal field of view (FOV) of display measured as described by the manufacturer	must be >90 degrees,	Approximately 97 degrees	Approximately 110 degrees
Horizontal pixels per degree (PPD) of display	must be >17	Approximately 20 pixels	Approximately 25 pixels

ambient light	Must block	allows complete light exclusion	allows complete light exclusion
Must respond to the user rotating	left, right, up and down	Provides full 360-degree rotation capability	Provides full 360-degree rotation capability

Appendix: **Proprietary to CAA and should not be shared, provided to others or made public.**

Video bitrate	≥1 Mbps for every 160 lines of horizontal resolution	Process videos provided programmer are approximately 4 Mbps for every 160 lines of horizontal resolution – see attached appendix

The CODEC used provides a more secure environment that would prevent a potential user from hacking the system making an impossible to fail test. The bit rate will be above and below this requirement, however it is our understanding that the affected (changing) parts of the video will be **processed at a higher rate** than those parts not providing the user with a realistic experience. Therefore, the relevant video is being processed at a higher rate than this requirement but it can only be estimated what that rate is for that portion of the video.

This is new technology that was used in the training of our test group and proved effective in the Training Effectiveness Test conducted on June 8th, 2024. This CODEC allows the relevant changes to be transferred at a higher rate and the unchanging/irrelevant portions to transfer at a lower rate, resulting in a better user experience. We believe this fully meets the intent of the requirement, that the training provides a realistic experience and this is demonstrated by the effectiveness training study.

Statement from our programming group:

Here is my input regarding these requirements:

· Resolution must be ≥4096 horizontal lines and ≥2160 vertical lines
· Video bitrate must be ≥1 Mbps for every 160 lines of horizontal resolution
· Video frame rate must be ≥24 fps.

Our smoke videos meet these requirements. The video formatting we use does not have a CBS (Constant Bit Rate) of 1 Mbps for every 160 lines. Instead, we use a newer more flexible encoding scheme, VBR (Variable Bit Rate). This scheme uses higher bit rates when the scene contains a lot of action and lower bit rates when the scene has less action. Since the action in our smoke videos is limited to the changes and movement of the smoke plume itself, the VBR encoding is ideal, resulting in high resolution and frame rate, but yields a smaller video file and faster load times.

Prior Communications via email regarding details specific to bit rate and VR headsets utilized should also be considered proprietary