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Statistical Comparison of ASTM D7520 to EPA Reference Method 9 on Opacity from Stacks with Diameters Over 7 Feet

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Abstract

This research attempts to demonstrate the applicability of ASTM D7520 on measuring the opacity of visible emissions from large stacks [i.e. stacks with exit diameters >7 feet (2.13 m)]. During the creation of ASTM D7520-09, a standard that utilizes the Digital Camera Opacity Technique (DCOT), a limit-of-use restriction of DCOTs to stacks with a diameter of less than 7 feet was inserted into the standard. This limit exists due to a lack of data on the use of ASTM D7520 on large stacks. EPA Reference Method 9, the current compliance method for the monitoring of opacity, does not contain any such limit in its applicability. [2, 3, 4] Thus, this research using EPA Method 301 statistical comparison [5] was performed. At four separate facilities (coal-fired power, natural gas-fired power, steel production, and cement production), research showed no statistically significant difference between ASTM D7520 and EPA Reference Method 9 on measuring opacity from stacks with exit diameters greater than 7 feet (2.13 m).

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Keywords: ASTM D7520, alt 082, DCOT, DOCS II, visible emissions, opacity, Method 9

Nomenclature

Code of Federal Regulations (CFR)
Digital Camera Opacity Technique (DCOT)
Digital Opacity Compliance System Second Generation (DOCS II)
Environmental Protection Agency (EPA)
Office of Air Quality Planning and Standards (OAQPS)
EPA Reference Method 9 (M9)
Quality Assurance (QA)
Regions of Interest (ROI)
Visible Emissions Observation (VEO)

Introduction

ASTM D7520 is a consensus standard for the Digital Camera Opacity Technique (DCOT), which is used in scenarios where Environmental Protection Agency (EPA) visible emission observation method EPA Reference Method 9 (M9) has historically been utilized. During the course of developing ASTM D7520, a 7-foot (2.13 meters) internal stack diameter use-limitation was inserted into the standard in 2009 [1]. This was due to the fact that while copious amounts of data from M9 certification smoke schools existed to demonstrate DCOTs were directly comparable to M9 observers, data did not exist comparing M9 observers to DCOTs specifically on large diameter stacks [i.e. stacks with diameters greater than 7 feet (2.13 m)]. Within EPA Reference Method 9, humans are certified as M9 observers in much the same way DCOTs certify, and have no such "large diameter stack" limitation [2]. Supported by studies dating back to the early 1970s, humans certified to M9 are able to use their certification on all forms of visible emission observations [3, 4]. As a result of these historical studies, the EPA Office of Air Quality Planning and Standards (OAQPS) has supported the use of M9 on large diameter stacks, as has all 50 States and their respective localities for the enforcement of opacity regulations for decades. To address the elimination of the large stack limit in ASTM D7520-09, the ASTM work-item committee and the EPA agreed that an EPA Method 301 study should be performed directly comparing the opacity results of M9 certified observers with DCOT opacity results on sources with large diameter stacks. The test methods are outlined in the EPA Method 301 Field Validation of Pollutant Measurement Methods from Various Waste Media appendix within the Code of Federal Regulations (CFR) [5]. The DCOT system used in the study was the Digital Opacity Compliance System Second Generation (DOCS II) created by Virtual Technology, LLC, which is certified to the performance criteria of ASTM D7520 [1]. This 301 study is a comparison of an alternative method (DOCS II) to the existing compliance test method (M9) by way of Quadruplet sampling. No analyte spiking or isotopic sampling treatments are applicable. The samples were instantaneously and permanently recorded observations made by M9-certified observers and instantaneously and permanently captured imagery from digital cameras for the DOCS II-certified method. Thus, sample shelf life and stability calculations were not required. These statistical comparisons contained here-in demonstrate there was no statistically significant difference between ASTM D7520 DOCS II and EPA Reference Method 9 with respect to large diameter stacks, e.g. internal diameters over 7 feet (2.13 m).

Methods

Site Assessment and Selection

Required site criteria included a stack diameter over 7 feet (2.13 m), and at the request of the EPA OAQPS, sources were to be varied and include at least one of the following: coal-fired power generation, natural gas power generation, cement production facility, to increase variation of source process the study also included a steel production facility. Prior to site selection, a list of possible sites that met EPA OAQPS guidance for the studies was compiled from state and local permit databases. Each industrial facilities operating permit was reviewed to ascertain that the emission points had exits larger than 7 feet (2.13 m). In addition, the permits ensured that the facilities were in operation and under normal operating conditions. Facilities that met the initial criteria were added to an initial facility list. Next, using Google Earth satellite imagery, each of the facilities surrounding geography and topography was reviewed to verify the facility had adequate observation positions offering: sun position compliance, slant angle compliance, open space out of the way of facility operations, minimal interferences (from pedestrian and vehicle traffic, dust, and other fugitive emissions) as well generally secure, safe, and healthy conditions. To account for sun compliance and slant angle, the site needed to have large enough surrounding area where observation positions would be in both sun and slant angle compliance, while not interfering with the operations of the plant or catching other interferences such as facility traffic and/or pedestrian/freeway traffic. Additionally, each facility's site was reviewed to insure the planned observation positions were also free of interferences from other emission points and unrelated fugitive sources that could impact the study. The planned observation positions were then tested for sun and slant angle compliance for a minimum of one hour to complete the required observations, e.g. (9) x (6 minute observations) = 54 minutes. Due to the length of the study (generally about 1 hour and 30 minutes including set up time) emission-point configuration with respect to sun travel was assessed so that it was possible to maintain sun compliance for the duration of the study. Based on the facility operating permits, the configuration of the emissions points was established. For example, the presence of multiple flues within the stack and their orientation with respect to sun travel was examined to ensure observations could be made on single emission points without interference. Each of the four selected facilities used in this comparison study met the criteria listed and further refinement based on relationships with facilities, regulatory agencies, and regional landowners. The facilities used in this study were AK Steel Middletown Works Coke Plant in Middletown, OH; Navajo Generating Station (NGS) in Page, AZ; Drake Cement in Paulden, AZ; and Encina Power Station in Carlsbad, CA. Further, NGS operates scrubbers creating "wet stacks", while all others are dry.

Field Personnel

A 301 Field Team consisted of, two EPA Reference Method 9-certified observers and two DOCS II-certified camera operators. Each 301 Field Team was positioned to observe a source, such that they were clustered together in a place compliant with sun angle and other M9 viewing related considerations [2]. Due to the automated nature of the DOCS II system, the M9 observers were also able to be the DOCS II camera operators. Each camera was equipped with a tripod and an intervalometer (programmable electronic shutter release trigger) set to capture an image every 15 seconds. M9 observers were equipped with Android devices running a field application that triggered them with an audible tone to read the smoke plume every 15 seconds. The field application was also used to automate collection of all the M9 and DOCS II required field data, such as GPS location, weather, source location, observer distance to source, slant angle to source, and sun location. The camera date and times were synchronized with the Android field application devices, to insure the images captured and the human observations were recorded at the same time. Personnel were selected for the study per the following credentials: EPA Reference Method 9 Certified Visible Emission Observer, DOCS II Certified Camera Operator (see Table 1 and Attachment B), and Visible Emission Observation (VEO) field experience of a minimum of 1 year. Each 301 Field Team consisted of two persons that met the credential requirement. After arriving at the facility location, all the pre-evaluated criteria were reassessed on-site to ensure their accuracy and dependability. Once the site locations were deemed adequate, the sample collection began. To reduce study costs associated with training and certification, a single team of personnel was utilized at all facilities. Table 1 below lists all the study personnel and their role on the team. Additionally, the analysis of the digital images was performed completely independent of the field M9 VEOs. The two completed records, M9 VEOs and DOCS II VEOs, followed a strict chain of custody, fully enforced and auditable via the field application and the DOCS II system. This chain of custody ensured the M9 VEOs recorded in the field and the VEOs derived by DOCS II Analysis were not visible between the personnel. M9 VEOs were completed in the field and locked, prior to upload of the imagery to the DOCS II system. Further, the DOCS II Analysts were physically located thousands of miles away from the facilities and each other. Table 1 in Attachment A contains study personnel and their associated roles while Attachments C and D show personnel VEO Certifications.

Field Process

The data collection process was the same at each individual facility. To start, M9 observers and the DOCS II cameras were synchronized electronically in time via synchronization of the field application Android devices and the camera clocks. Then after a countdown, each M9 observer and each DOCS II operator began recording data. For M9, this involved entering visually determined opacity values into the field application every 15 seconds as prompted by the field application. DOCS II, imagery collection began by starting the intervalometer to record a digital image every 15 seconds synchronized with the field application in time via the starting count down. Due to human fatigue, each session of data gathering was limited to approximately an hour. This typically produced nine paired sets (two M9 and two DOCS II; eighteen total sets) of 24 readings. Each "set" contains 6 minutes and 24 opacity readings. At times, a break between each 6-minute reading was taken, due to meteorological conditions and/or human fatigue. However, if it was advantageous in regards to various conditions, continuous 6-minute readings were performed. Certified DOCS II Analysts, who were thousands of miles away from the field site and each other, subsequently analyzed the images captured to determine their opacity. The statistical comparison of M9 VEOs with DOCS II digital image-derived VEOs is the basis for the data analyzed herein.

Digital Imagery Opacity Analysis

Analysis of the 301 Field Team digital imagery was performed by Certified DOCS II Analysts with the following credentials: DOCS II Analyst Certification, DOCS II Camera Operator Certification (see Table 1 and Attachment B), and a minimum 1 year field experience with DOCS II Analysis Engine. Each data Analysis team consisted of two Analysts that met the required credentials and were also residing in different Virtual Technology offices to ensure maximum independence. Each DOCS II Analyst member performed the following completely independently: received DOCS II notification that a 301 Field Team (X) "Facility" was ready for analysis, opened (X) "Facility" record, verified information on properties, source, plume, location sections of the DOCS II database, opened the Analysis Engine, set total average rule, and then reviewed all 240+ images. Images were analyzed by marking Regions of Interest (ROI) at a point on the plume with the highest apparent opacity (foreground ROI), and then marking the “background ROI” at point of best contrast outside the plume in the image, as close to the same horizontal plane as the “foreground ROI” as possible. Then, the software was allowed to run an initial automatic analysis, to copy the positioned ROIs across all images. The analyst then reviewed the other 239 images to ensure the ROIs were in acceptable positions given changes in wind drift of the plume, light intensity, and shadowing. After analysis was completed, the record was sent back to the Quality Assurance (QA) personnel. QA of the DOCS II analysis and field records was performed by personnel who is DOCS II Camera Operator Certified (see Table 1 and Attachment B) and has a minimum of 1 year field experience performing QA on DOCS II VEO records. The M9 VEOs do not require secondary analysis, as the records are finalized in the field upon completion. Thus, M9 VEOs can only be viewed in final locked status by the originating Field user, e.g. the person who entered the opacity values.

Data Reduction

Data Reduction of the finalized set of DOCS II VEO and M9 VEO records was performed by personnel meeting the following required credentials: 10 years statistics in Excel experience, DOCS II QA trained, and DOCS II Analyst Certified (see Table 1 and Attachment B). Upon finalization of (X) “Facility” records, the Data Reduction personnel were notified by the QA Team member that the source data was final, locked, and ready for data reduction to be performed. The Data Reduction person then instructed the data QA person to export the (X) “Facility” DOCS II VEO records into the designated cloud library as Excel files. Next, the Data Reduction person then notified the field team to export the corresponding (X) “Facility” M9 VEO records into the same designated cloud library as Excel files. The individual Excel files were then combined by the Data Reduction person into “Method 301” template spreadsheets. These spreadsheets were prepared in discussions with the EPA OAQPS Alternative Methods personnel to ensure the proper calculations were being performed. Once the (X) “Facility” M9 VEO and (X) “Facility” DOCS II VEO records were combined into the 301 Data Reduction Spreadsheets, each tab of M9 (X) “Facility” and DOCS II (X) “Facility” source data was visually compared with the originating source to ensure error free data reductions. The Data Reduction Spreadsheets calculated the critical values for Precision and Bias in accordance with the prescribed method [5]. Once complete, the Data Reduction personnel notified the publication personnel that the data reduction is complete.

Bias

In Paragraph 11.1 of Method 301 in the Code of Federal Regulations (CFR) [5], it is outlined that bias must be tested for statistical significance at the 95% confidence level by calculating the *t* statistic. In order to determine statistical significance, mathematical bias and standard deviation must be derived. Mathematical Bias (mean of the differences between methods) was determined via the following equation:

$$d_i = \frac{(V_{1_i} + V_{2_i})}{2} - \frac{(P_{1_i} + P_{2_i})}{2} \tag{1}$$

Where V_{1i} = first measured value in the validated method sample pair, V_{2i} = second measured value in the validated method sample pair, P_{1i} = first measured value in the alternative method sample pair, and P_{2i} = second measured value in the alternative method sample pair. The Standard Deviation was determined via the following equation:

$$SD_d = \sqrt{\frac{\sum_{i}^{n}(d_i - d_m)^2}{n-1}} \tag{2}$$

Where d_i = difference between results of the ith sample (min -max), d_m = the mean of the paired sample differences, and n = total number of paired samples. The *t* value was determined by using the following equation:

$$t = \frac{|d_m|}{\frac{SD_d}{\sqrt{n}}} \tag{3}$$

Where d_m =mathematical bias, SD_d = standard deviation, and n = total number of paired samples. Once the *t* value was derived, it was compared to a value from a reference table [5]. The value from the reference table depends on the degrees of freedom and confidence limit. These Quadruplet replicate systems study utilized 9 samples. Thus, the reference table critical t value was 2.306. If the calculated t value was less than the critical value, the bias was not statistically significant.

Precision

Paragraph 11.2 of Method 301 in the CFR [5] dictates that the precision must be tested for statistical significance at the 95% confidence level by calculating the F statistic. In order to determine statistical significance, variance for the validated and alternative methods must be derived. Variance for the alternative method was determined via the following equation:

$$S_p^2 = \frac{\sum_i^n d_i^2}{2n} \quad (4)$$

Where di = difference between the ith pair of samples collected using the alternative method and n = total number of paired samples. Variance for the validated method was determined as was done for the alternative method above. The F value (precision results) was determined by using the following equation:

$$F = \frac{S_p^2}{S_v^2} \quad (5)$$

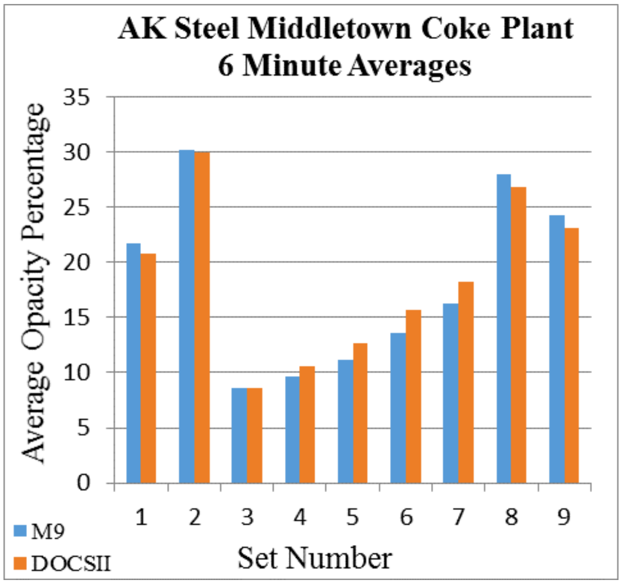
Where S^2_P = Estimated variance of the alternative method and S^2_v = Estimated variance of the validated method. Once the F value was derived, it was compared to a value from a reference table [5]. The value from the reference table depends on the degrees of freedom (paired sample size - 1) and confidence limit. As this quadruplet replicate system study utilized 9 samples, the reference table critical F value was 3.18. If the calculated F value was less than the critical value, the difference in precision was not statistically significant.

Results

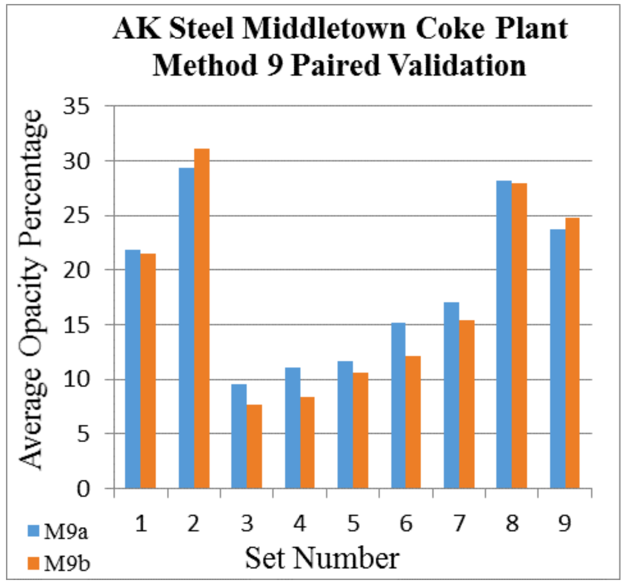
Following the statistical comparison between EPA Reference Method 9 and ASTM D7520 DOCS II, the two methods were found to be interchangeable at all observed opacities (0%-40%). The bias and precision limits of each study from each source and location were under the established limits (see Table 2 below). Paired t-test sampling revealed that there was no significant difference in performance between the two methods when measuring opacity of large stacks, e.g. internal diameters over 7 feet (2.13 m). Included below are graphs from each study and source location. Average opacity levels between each method are illustrated to show the paired validation of each method, as well as combined average opacity for each six minute set for both methods. In summary, no statistically significant difference was observed between the two methods when measuring opacity on stacks with diameters over 7 feet (2.13 m). The following Table 1 illustrates the individual facility bias (*t* value) and precision (F value) results, while figures (1 - 4) show VEO opacity averages and are supported by Tables 3 through 6 in Attachment B.

TABLE 1 – Precision and Bias results of tests from all four study locations.

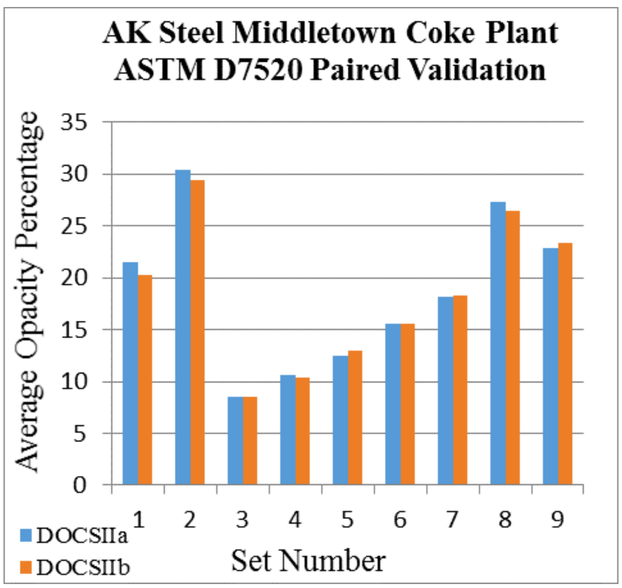
Facility	**Range of Opacity**	**Stack Diameter ft. (m)**	**Location**	**Test Date**	**Precision Results (F)** **Limit: 3.18**	**Bias Results (*t*)** **Limit: 2.306**
AK Steel Middletown Coke Plant	0-40%	14.1’ (4.3 m)	Middletown, OH	2/24/15	0.13	0.69
Navajo Generating Station	0-35%	24.5’ (7.5 m)	Page, AZ	4/18/15	1.42	0.34
Drake Cement	0-5%	19.7’ (6 m)	Paulden, AZ	4/24/15	1.27	1.33
Encina Power Station	0-5%	21.3’ (6.5 m)	Carlsbad, CA	4/26/15	2.36	1.18



(a)

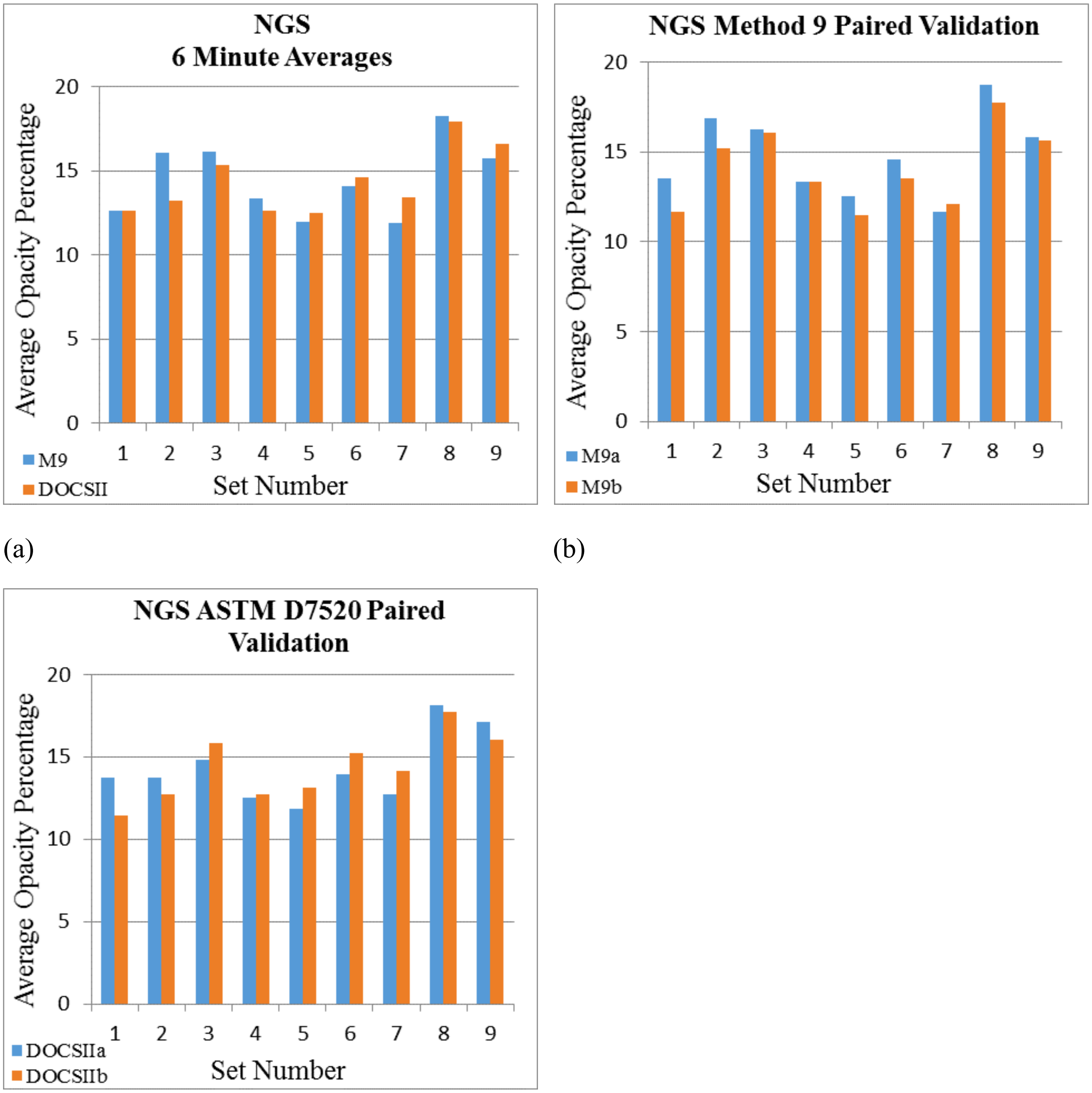


(b)



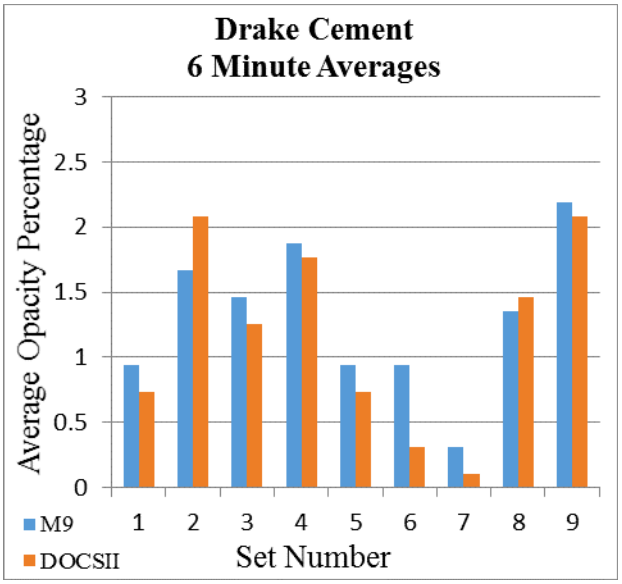
(c)

FIG. 1: Graph (a) represents the EPA Reference Method 9 VEO compared to the ASTM D7520 DOCS II VEO, each averaged to six minute opacity values as stipulated by M9 [2]. Graph (b) represents the average opacity for each M9 observer on each six minute set. Graph (c) depicts the average opacity for each DOCS II six minute set. These graphs represent data from AK Steel Middletown Coke Plant in Middletown, OH.

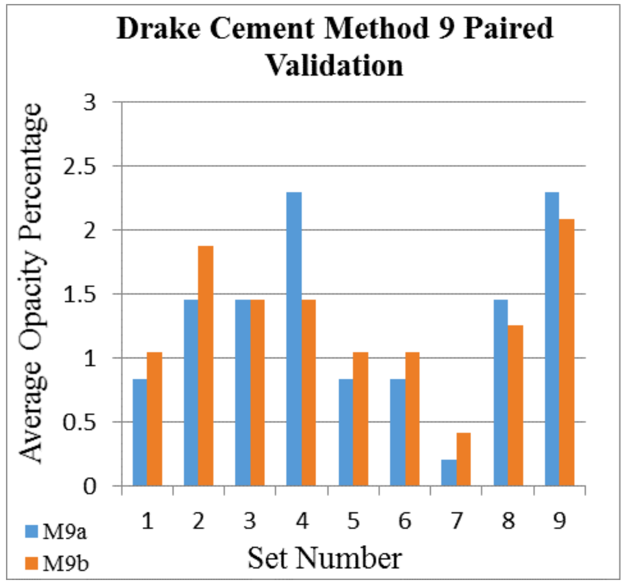


(a) (b) (c)

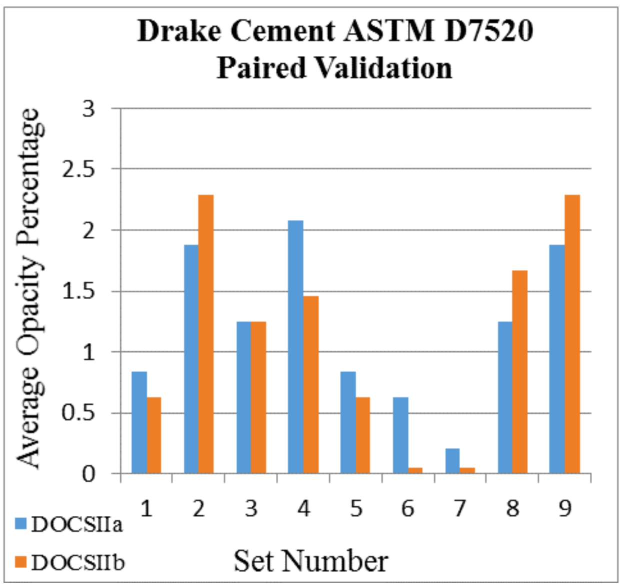
FIG. 2: Graph (a) represents the EPA Reference Method 9 VEO compared to the ASTM D7520 DOCS II VEO, each averaged to six minute opacity values as stipulated by M9 [2]. Graph (b) represents the average opacity for each M9 observer on each six minute set. Graph (c) depicts the average opacity for each DOCS II six minute set. These graphs represent data gathered from Navajo Generating Station in Page, AZ.



(a)



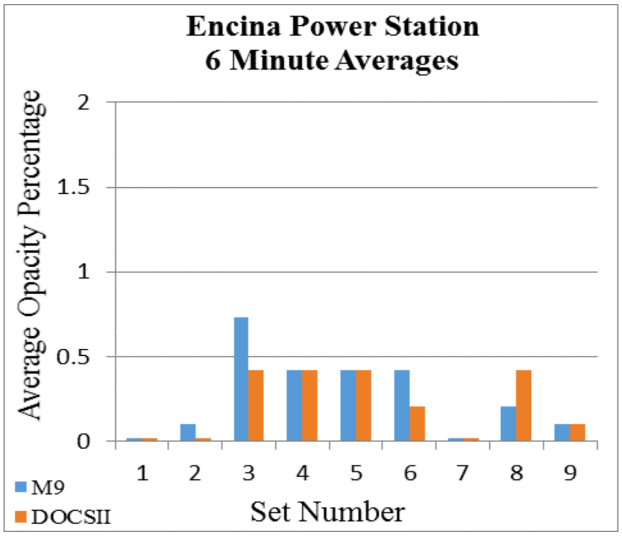
(b)

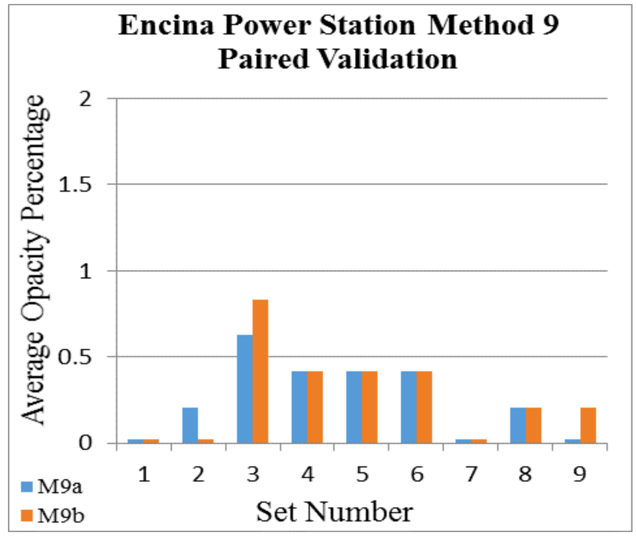


(c)

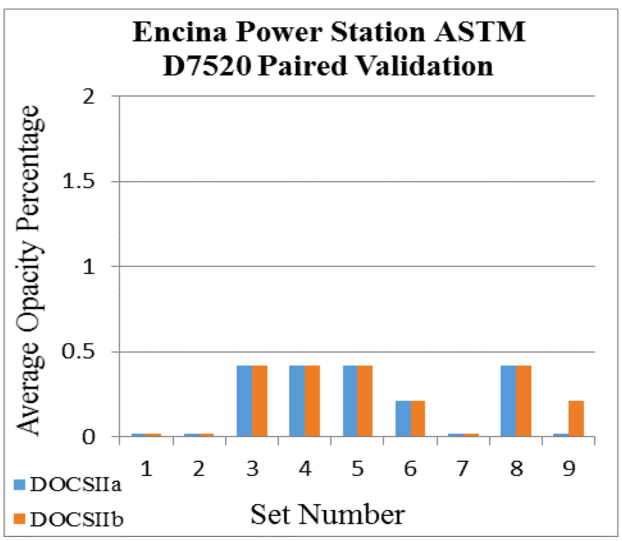
FIG. 3: Graph (a) represents the EPA Reference Method 9 VEO compared to the ASTM D7520 DOCS II VEO, each averaged to six minute opacity values as stipulated by M9 [2]. Graph (b) represents the average opacity for each M9 observer on each six minute set. Graph (c) depicts the average opacity for each DOCS II six minute set. These graphs represent data gathered from

Drake Cement in Paulden, AZ. Note the change of scale, as the low opacity of this facility required the scales of the graphs to change in order to better visualize the deviation of the methods.





(a) (b)



(c)

FIG. 4: Graph (a) represents the EPA Reference Method 9 VEO compared to the ASTM D7520 DOCS II VEO, each averaged to six minute opacity values as stipulated by M9 [2]. Graph (b) represents the average opacity for each M9 observer on each six minute set. Graph (c) depicts the

average opacity for each DOCS II six minute set. These graphs represent data gathered from Encina Power Station in Carlsbad, CA. Note the change of scale, as the low opacity of this facility required the scales of the graphs to change in order to better visualize the deviation of the methods.

Discussion

Performance of ASTM D7520 on measuring opacity from stacks over 7 feet (2.13 m) in diameter is not statistically significantly different than that of the current compliance test method, EPA Reference Method 9. Thus, ASTM D7520 should have the same applicability on the same breadth of sources as EPA Reference Method 9 (i.e. no stack diameter limit). Due to various difficulties including legal complications of observing very high opacities (> 40%) and the requirement to perform the comparison under normal operating conditions, higher opacity comparisons would have to be performed at facilities outside the U.S. Similar EPA Method 301 studies have been completed at EPA Reference Method 9 certification smoke schools, where opacities range from 0-100%, and the stacks are typically less than 12 inches in diameter. These smoke school studies were used to establish the precision and bias sections of ASTM D7520 and continue today with each new camera certified to D7520. Large stack diameter is, in general, only found at actual industrial facilities, not in certification systems that can be manipulated and are exempt from CFR visible emission regulations. Reference Method 9 "smoke readers" certify their eyes on smoke generators with stack diameters of <2 feet (<61 cm). Once certified, they observe and measure the opacity of visible emissions from any source, regardless of stack diameter. To reflect the proven statistical interchangeability of the two methods, both standards, and applicability therein, should in essence mirror each other. Given the results of this study and the copious amounts of data supporting the interchangeability of ASTM D7520 and EPA Reference Method 9, the ASTM D7520 standard should be amended and the large stack restriction eliminated.

References

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ATTACHMENT A

LIST OF STUDY PERSONNEL AND ASSOCIATED ROLES

TABLE 2

Role	Personnel
M9 VEO & DOCS II VEO Operator #1	Allison Dolan
M9 VEO & DOCS II VEO Operator #2	Scott Hicks
DOCS II Analyst #1 & Data Reduction	Pat Grieco
DOCS II Analyst #2 & Data Reduction	Shawn Dolan
Quality Assurance Personnel	Sarah Karp

ATTACHMENT B

SPPORTING DATA: FACILITY VISIBLE EMISSIONS OBSERVATION OPACITY AVERAGES

TABLE 3 – AK Steel Middletown Coke Plant VEO opacity average for each six minute, 24 reading set (total of 9). This table presents data from Figure 1, Graphs (b) and (c) in numerical form, rounded to the nearest hundredth.

AK Steel Middletown Coke Plant VEO Opacity Averages (%)				
Set	M9a	M9b	DOCSIIa	DOCSIIb
1	21.88	21.46	21.46	20.21
2	29.38	31.04	30.42	29.38
3	9.58	7.71	8.54	8.54
4	11.04	8.33	10.63	10.42
5	11.67	10.63	12.5	12.92
6	15.21	12.08	15.63	15.63
7	17.08	15.42	18.13	18.33
8	28.13	27.92	27.29	26.46
9	23.75	24.79	22.92	23.33

TABLE 4 – Navajo Generating Station VEO opacity average for each six minute, 24 reading set (total of 9). This table presents data from Figure 2, Graphs (b) and (c) in numerical form, rounded to the nearest hundredth.

Navajo Generating Station VEO Opacity Averages (%)				
Set	M9a	M9b	DOCSIIa	DOCSIIb
1	13.54	11.67	13.75	11.46
2	16.88	15.21	13.75	12.71
3	16.25	16.04	14.79	15.83
4	13.33	13.33	12.5	12.71
5	12.5	11.46	11.88	13.13
6	14.58	13.54	13.96	15.21
7	11.67	12.08	12.71	14.17
8	18.75	17.71	18.13	17.71
9	15.83	15.63	17.08	16.04

TABLE 5 – Drake Cement VEO opacity average for each six minute, 24 reading set (total of 9). This table presents data from Figure 3, Graphs (b) and (c) in numerical form, rounded to the nearest hundredth.

Drake Cement VEO Opacity Averages (%)				
Set	M9a	M9b	DOCSIIa	DOCSIIb
1	0.83	1.04	0.83	0.63
2	1.46	1.88	1.88	2.29
3	1.46	1.46	1.25	1.25
4	2.29	1.46	2.08	1.46
5	0.83	1.04	0.83	0.63
6	0.83	1.04	0.63	0.05
7	0.21	0.42	0.21	0.05
8	1.46	1.25	1.25	1.67
9	2.29	2.08	1.88	2.29

TABLE 6 – Encina Power Station VEO opacity average for each six minute, 24 reading set (total of 9). This table presents data from Figure 4, Graphs (b) and (c) in numerical form, rounded to the nearest hundredth.

Encina Power Station VEO Average Opacity (%)				
Set #	M9a	M9b	DOCSIIa	DOCSIIb
1	0.02	0.02	0.02	0.02
2	0.21	0.02	0.02	0.02
3	0.63	0.83	0.42	0.42
4	0.42	0.42	0.42	0.42
5	0.42	0.42	0.42	0.42
6	0.42	0.42	0.21	0.21
7	0.02	0.02	0.02	0.02
8	0.21	0.21	0.42	0.42
9	0.02	0.21	0.02	0.21

ATTACHMENT C

EPA REFERENCE METHOD 9 CERTIFICATIONS

Arizona Smoke School LLC

Certificate of Completion

This certifies that Allison Dolan Successfully participated in EPA Method 9 Visible Emissions Training on **April 11, 2015** and is qualified to evaluate Visible Emissions for a period of six (6) months from the date of certification.

Instructor

Arizona Smoke School LLC

Certificate of Completion

This certifies that Allison Dolan Successfully participated in EPA Method 9 Visible Emissions Training on **Sept. 26, 2014** and is qualified to evaluate Visible Emissions for a period of six (6) months from the date of certification.

Instructor

Arizona Smoke School LLC

Certificate of Completion

This certifies that Scott Hicks Successfully participated in EPA Method 9 Visible Emissions Training on **April 11, 2015** and is qualified to evaluate Visible Emissions for a period of six (6) months from the date of certification.

Instructor

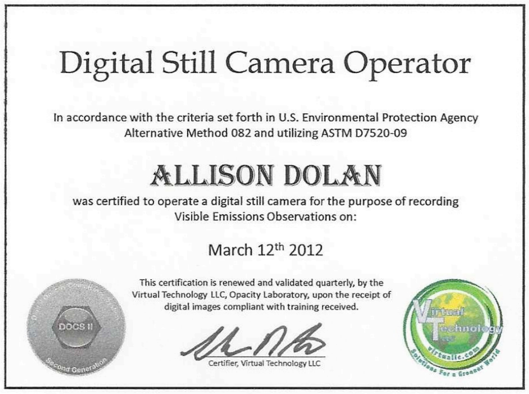
Arizona Smoke School LLC

Certificate of Completion

This certifies that Scott Hicks Successfully participated in EPA Method 9 Visible Emissions Training on **Sept. 26, 2014** and is qualified to evaluate Visible Emissions for a period of six (6) months from the date of certification.

Instructor

ATTACHMENT D
ASTM D7520 DOCS II CERTIFICATIONS


Digital Still Camera Operator

In accordance with the criteria set forth in U.S. Environmental Protection Agency Alternative Method 082 and utilizing ASTM D7520-09

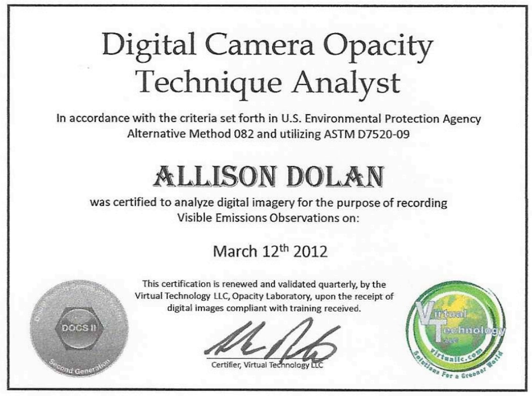
ALLISON DOLAN

was certified to operate a digital still camera for the purpose of recording Visible Emissions Observations on:

March 12th 2012

This certification is renewed and validated quarterly, by the Virtual Technology LLC, Opacity Laboratory, upon the receipt of digital images compliant with training received.

Certifier, Virtual Technology LLC


Digital Camera Opacity Technique Analyst

In accordance with the criteria set forth in U.S. Environmental Protection Agency Alternative Method 082 and utilizing ASTM D7520-09

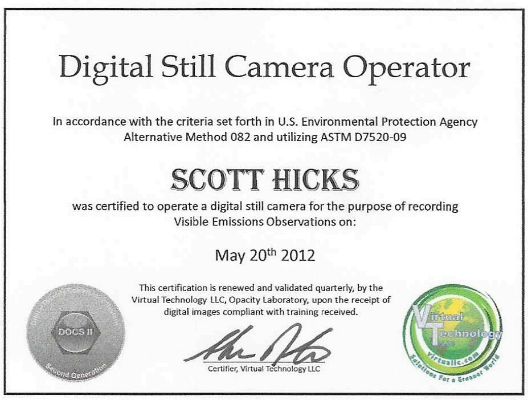
ALLISON DOLAN

was certified to analyze digital imagery for the purpose of recording Visible Emissions Observations on:

March 12th 2012

This certification is renewed and validated quarterly, by the Virtual Technology LLC, Opacity Laboratory, upon the receipt of digital images compliant with training received.

Certifier, Virtual Technology LLC


Digital Still Camera Operator

In accordance with the criteria set forth in U.S. Environmental Protection Agency Alternative Method 082 and utilizing ASTM D7520-09

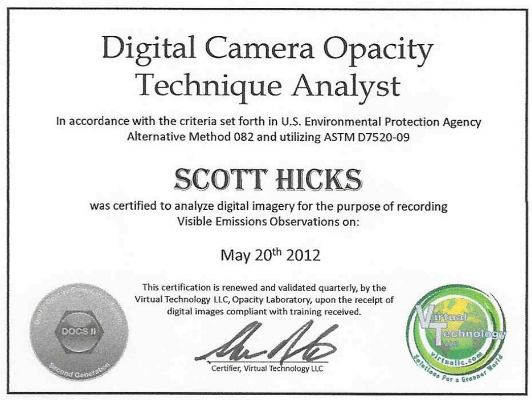
SCOTT HICKS

was certified to operate a digital still camera for the purpose of recording Visible Emissions Observations on:

May 20th 2012

This certification is renewed and validated quarterly, by the Virtual Technology LLC, Opacity Laboratory, upon the receipt of digital images compliant with training received.

Certifier, Virtual Technology LLC


Digital Camera Opacity Technique Analyst

In accordance with the criteria set forth in U.S. Environmental Protection Agency Alternative Method 082 and utilizing ASTM D7520-09

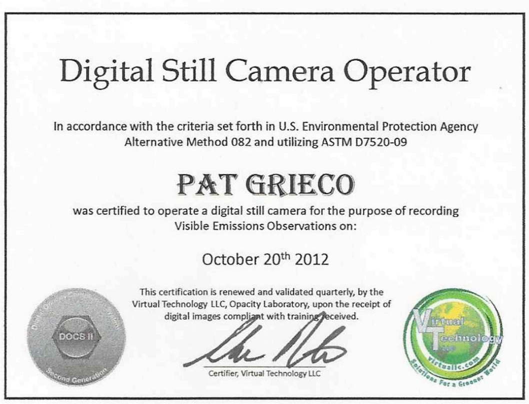
SCOTT HICKS

was certified to analyze digital imagery for the purpose of recording Visible Emissions Observations on:

May 20th 2012

This certification is renewed and validated quarterly, by the Virtual Technology LLC, Opacity Laboratory, upon the receipt of digital images compliant with training received.

Certifier, Virtual Technology LLC


Digital Still Camera Operator

In accordance with the criteria set forth in U.S. Environmental Protection Agency Alternative Method 082 and utilizing ASTM D7520-09

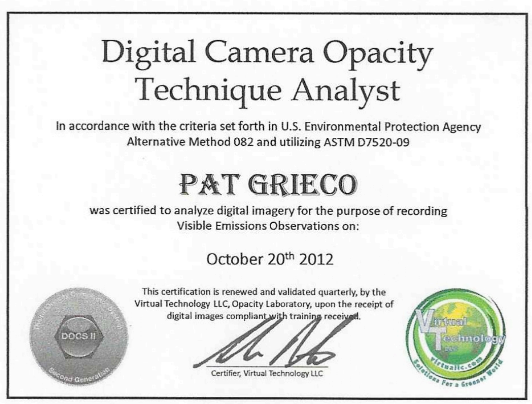
PAT GRIECO

was certified to operate a digital still camera for the purpose of recording Visible Emissions Observations on:

October 20th 2012

This certification is renewed and validated quarterly, by the Virtual Technology LLC, Opacity Laboratory, upon the receipt of digital images compliant with training received.

Certifier, Virtual Technology LLC


Digital Camera Opacity Technique Analyst

In accordance with the criteria set forth in U.S. Environmental Protection Agency Alternative Method 082 and utilizing ASTM D7520-09

PAT GRIECO

was certified to analyze digital imagery for the purpose of recording Visible Emissions Observations on:

October 20th 2012

This certification is renewed and validated quarterly, by the Virtual Technology LLC, Opacity Laboratory, upon the receipt of digital images compliant with training received.

Certifier, Virtual Technology LLC

Digital Still Camera Operator

In accordance with the criteria set forth in U.S. Environmental Protection Agency Alternative Method 082 and utilizing ASTM D7520-09

SHAWN DOLAN

was certified to operate a digital still camera for the purpose of recording Visible Emissions Observations on:

October 20th 2012

This certification is renewed and validated quarterly, by the Virtual Technology LLC, Opacity Laboratory, upon the receipt of digital images compliant with training received.

Certifier, Virtual Technology LLC

Digital Camera Opacity Technique Analyst

In accordance with the criteria set forth in U.S. Environmental Protection Agency Alternative Method 082 and utilizing ASTM D7520-09

SHAWN DOLAN

was certified to Analyze Digital Imagery for the purpose of determining Opacity of subject Air Emissions in Visible Emissions Observations on:

October 20th 2012

This certification is renewed and validated every 3.5 years from date of issue, by the Virtual Technology LLC, Opacity Laboratory, upon the review of VEO records Analyzed by the certified Analyst compliant with training received.

Certifier, Virtual Technology LLC

Digital Still Camera Operator

In accordance with the criteria set forth in U.S. Environmental Protection Agency Alternative Method 082 and utilizing ASTM D7520-09

SARAH KARP

was certified to operate a digital still camera for the purpose of recording Visible Emissions Observations on:

May 20th 2012

This certification is renewed and validated quarterly, by the Virtual Technology LLC, Opacity Laboratory, upon the receipt of digital images compliant with training received.

Certifier, Virtual Technology LLC

Digital Camera Opacity Technique Analyst

In accordance with the criteria set forth in U.S. Environmental Protection Agency Alternative Method 082 and utilizing ASTM D7520-09

SARAH KARP

was certified to Analyze Digital Imagery for the purpose of determining Opacity of subject Air Emissions in Visible Emissions Observations on:

May 20th 2012

This certification is renewed and validated every 3.5 years from date of issue, by the Virtual Technology LLC, Opacity Laboratory, upon the review of VEO records Analyzed by the certified Analyst compliant with training received.

Certifier, Virtual Technology LLC

Digital Camera Opacity Technique Quality Assurance

In accordance with the criteria set forth in U.S. Environmental Protection Agency Alternative Method 082 and utilizing ASTM D7520-09

SARAH KARP

was certified to perform Quality Assurance for Visible Emissions Observations on:

May 20th 2012

This certification is renewed and validated quarterly, by the Virtual Technology LLC, Opacity Laboratory, upon the receipt of digital images compliant with training received.

Certifier, Virtual Technology LLC