IMPROVE sampler Technical System Audits (TSAs) summary

February 8
2017

This report gives an overview of the TSAs conducted during 2016.

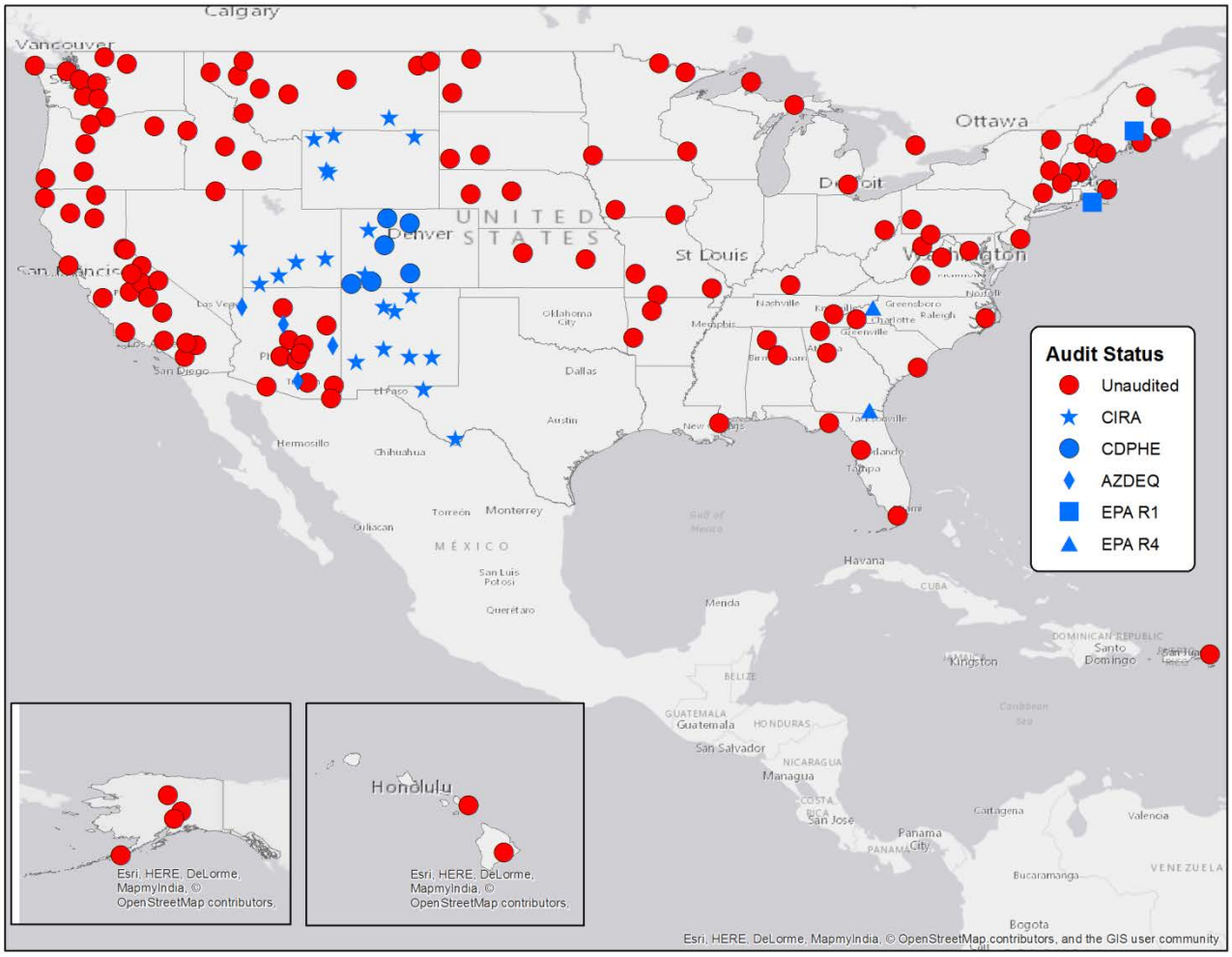
IMPROVE
QA/QC

INTRODUCTION

The Technical system audits (TSAs) of IMPROVE samplers are conducted to ensure the sampler is operating in accordance with the IMPROVE program's quality assurance project plan (QAPP) and relevant standard operating procedures (SOPs). The TSAs consist of assessing sampler siting criteria, sampler integrity, operator technique, flow rates, vacuum pressure, temperature, and sampler time. This document summarizes the results of audits conducted in 2016.

Thirty six IMPROVE sampling sites were audited in 2016 by individuals representing several different organizations: Andy Clifton from Arizona Department of Environmental Quality (AZDEQ), Cindy Wike, Clyde Sharp, and Bret Harkwell from Colorado Department of Public Health and Environment (CDPHE), Chris St Germain representing EPA Region 1, Marshal Varnum from EPA Region 4, and Derek Day from the Cooperative Institute for Research in the Atmosphere (CIRA). The map below shows all IMPROVE monitoring sites and those audited during 2016. The legend indicates which agency conducted the site audit.

Figure 1 Audits Completed During 2016



SAMPLER SITING CRITERIA

The IMPROVE sampler siting criteria are thoroughly explained in SOP 126 and therefore not reiterated here. In general, the TSA process notes and documents site properties which could impede sampling aerosol of a regional background nature. Impediments include significant local sources of particulates (automotive, wood smoke, dust etc.), obstructions such as trees or buildings which would hamper ambient air flow to the sampler inlet. Problems are reported on the TSA form and the site operator is notified if corrective action is needed (i.e. trees trimmed or brush cleared).

SAMPLER INTEGRITY

The TSAs ensure the sampler stand is maintained such that routine access does not pose operator hazards and that the IMPROVE modules are protected from direct sunlight. The sample stand should also protect the operator and cartridges during filter changes particularly during rain or snow events. The IMPROVE modules are checked to ensure they are fastened securely to the structure, and inlet stacks are seated properly into each module. Electrical wiring and connections are visually examined and photos are taken.

OPERATOR TECHNIQUE

Site operators should be aware of SOP 201, which is a very good overview of the IMPROVE sampler and sampling process. The site operator is made aware of this resource by the TSA form they are asked to complete prior to the site visit; however, if the operator is present during a TSA they are reminded this resource is available. Tuesday is sample change day throughout the IMPROVE network and consequently the only day which guarantees the individual conducting the TSA can meet with the site operator to observe the sample change process. It is important that good sample change technique is being employed to reduce the risk of sample contamination.

SAMPLER FLOW RATES

The IMPROVE sampler's $PM_{2.5}$ modules utilize two pressure transducers to calculate sampler flow rate. The primary transducer measures the pressure drop across the cyclone (CYC). The secondary transducer measures the pressure drop at the critical orifice/needle valve (ORI) which is used to set the sampler flow rate. The PM10 module utilizes only the transducer at the critical orifice for flow rate calculations. The pressure drop measured by each transducer is converted to flow rate based on the calibration curve generated during the UC Davis biannual maintenance/calibration visit to the site. During the field audits, a NIST traceable tetraCal flow meter is the standard to which the IMPROVE flow rates are compared.

Figures 2-5 show flow rate comparisons between the tetraCal and each IMPROVE module for all TSAs conducted in 2016. The nominal flow rate of the sampler is 22.8 liters per minute (lpm) for the PM2.5 modules and 16.9 lpm for the PM10 module (shown by the solid red lines in the figures). Also shown, for comparison purposes, is a solid black 1:1 line and red dashed lines showing ±10% from the nominal value.

Table 1 Module A statistics

Statistic	Audit Flow Rate	ORI Flow Rate	CYC Flow Rate
Minimum	21.39	21.09	22.17
1st Quartile	21.94	22.40	22.61
Median	22.19	22.81	22.90
Mean	22.28	22.90	22.88
3rd Quartile	22.57	23.07	23.12
Maximum	23.49	27.38	23.57

Figure 2 Comparison of flow rates from Technical System Audits for module A.

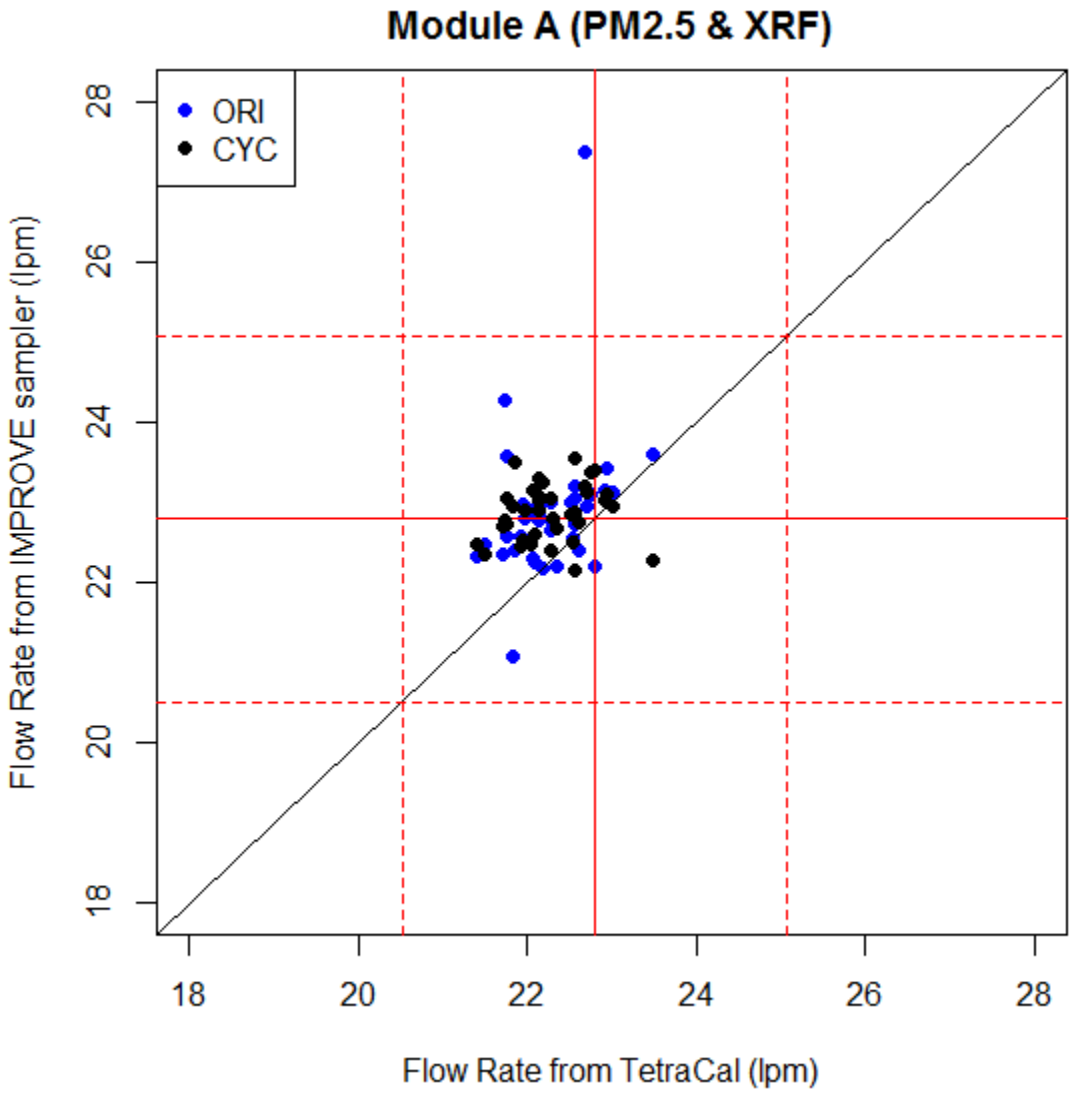


Table 2 Module B statistics

Statistic	Audit Flow Rate	ORI Flow Rate	CYC Flow Rate
Min	20.56	21.84	21.37
1st Qu	21.80	22.38	22.63
Median	22.20	22.74	22.97
Mean	22.21	22.78	22.99
3rd Qu	22.62	23.07	23.30
Max	25.06	24.37	24.55

Figure 3 Comparison of flow rates from Technical System Audits for module B.

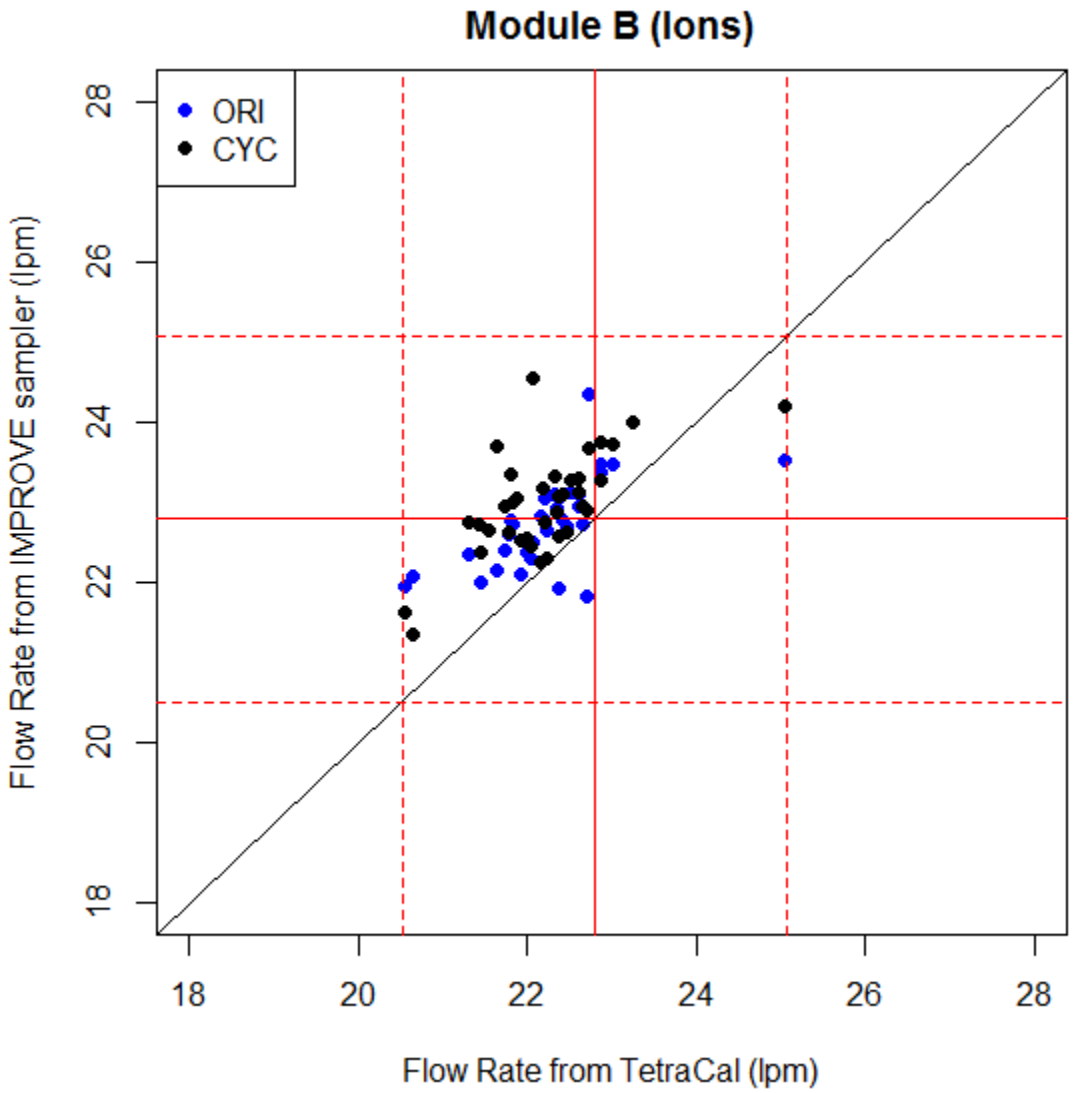


Table 3 Module C Statistics

Statistic	Audit Flow Rate	ORI Flow Rate	CYC Flow Rate
Min	20.65	22.05	21.54
1st Qu	22.11	22.69	22.91
Median	22.55	23.02	23.18
Mean	22.58	23.06	23.32
3rd Qu	22.84	23.24	23.58
Max	24.64	25.20	26.25

Figure 4 Comparison of flow rates from Technical System Audits for module C.

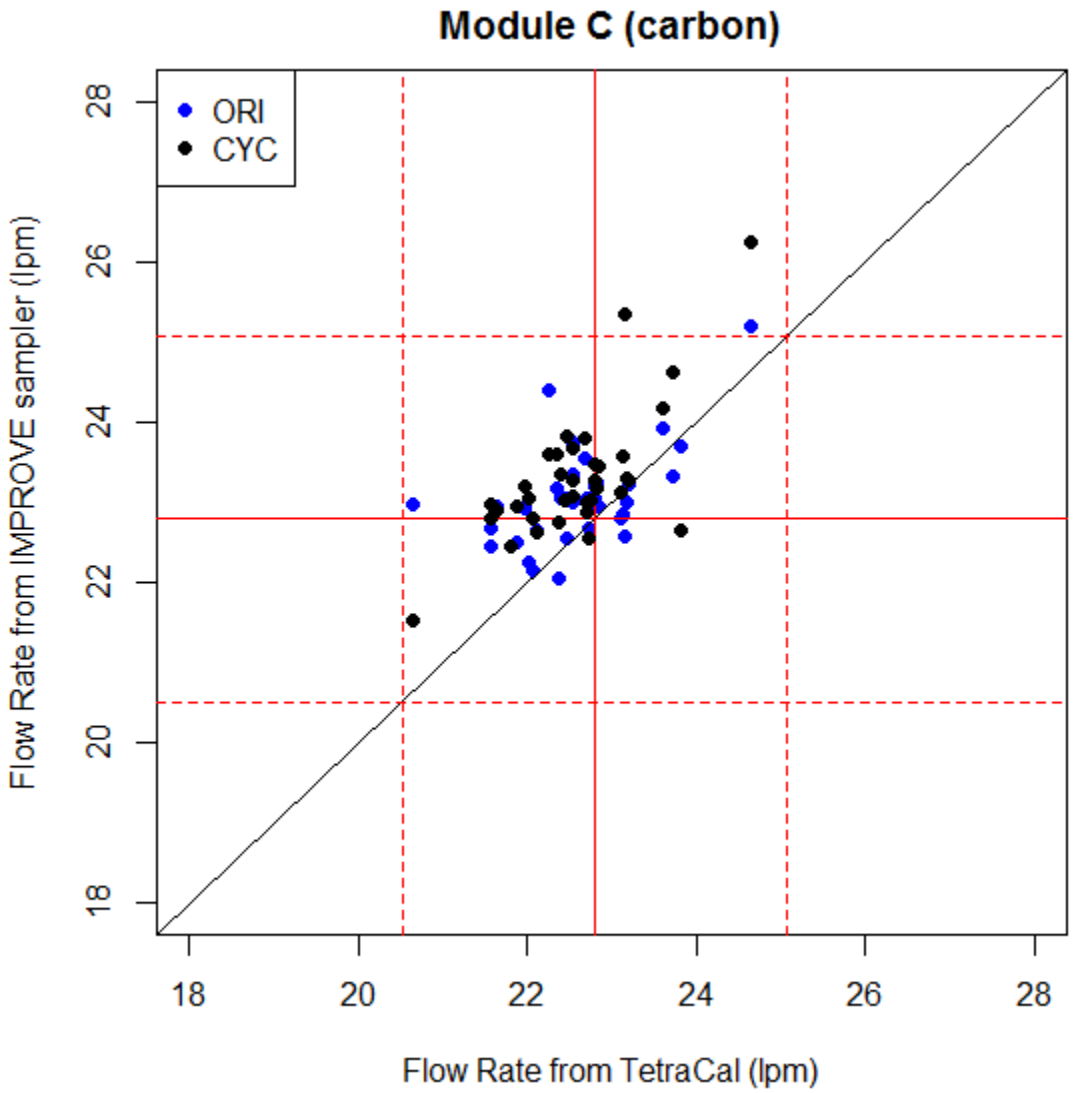
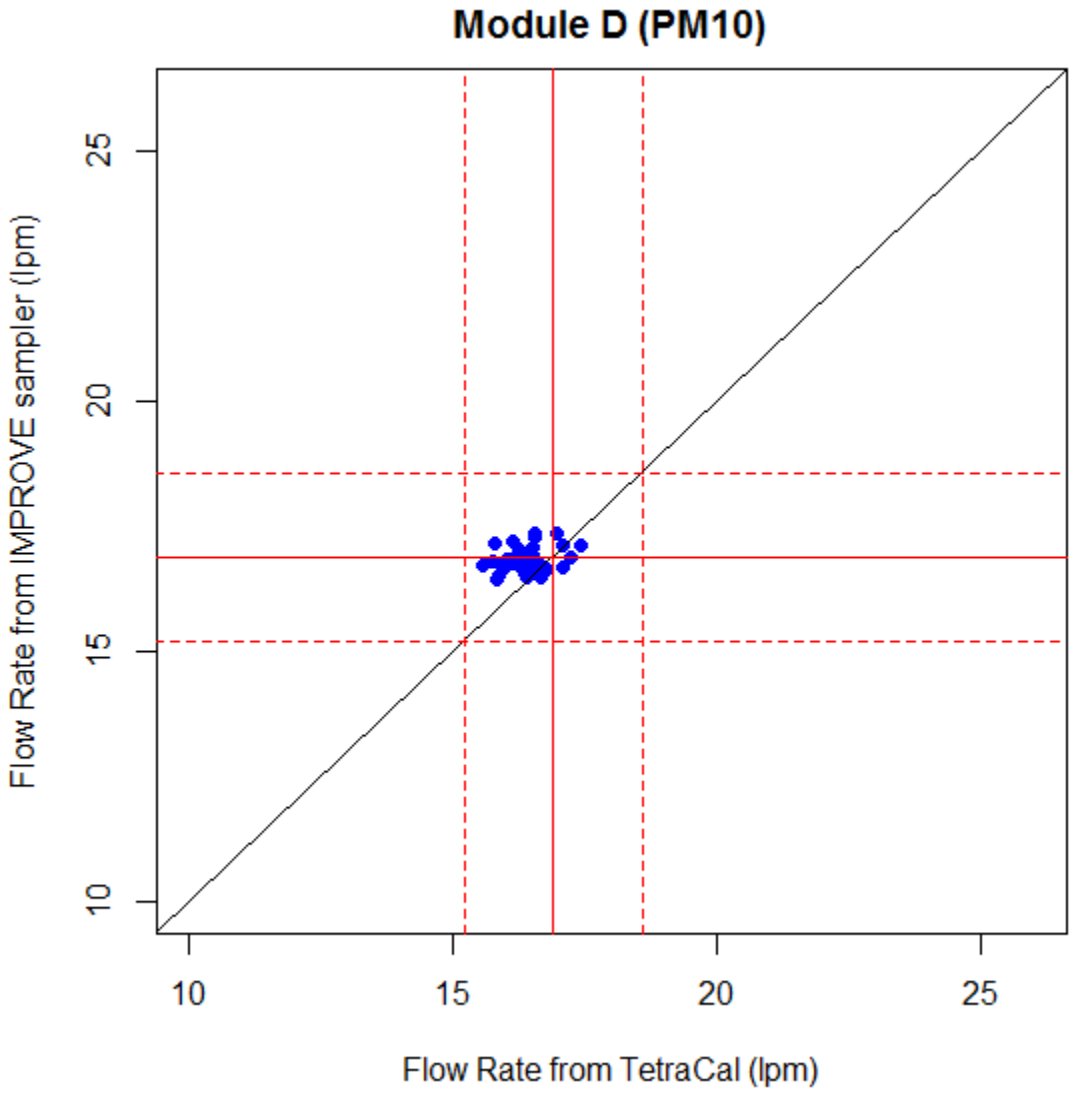


Table 4 Module D statistics

Statistic	Audit	ORI
Min	15.56	16.45
1st Qu	16.07	16.69
Median	16.36	16.82
Mean	16.37	16.86
3rd Qu	16.55	17.01
Max	17.41	17.39
NA's	2	2

Figure 5 Comparison of flow rates from Technical System Audits for module D.



A comparison of flow rate means shows the tetraCal, in general, was slightly lower than the nominal flow rate value. The ratio of tetraCal flow/nominal flow, for Module A was 0.9772; for Module B the ratio was 0.9741; Module C ratio was 0.9904; and the Module D ratio was 0.9686. A similar analysis shows the IMPROVE sampler flow rate measurements were slightly higher than the nominal flow rate values. On average, Module A was 1.0035 greater; Module B was 1.0075 greater; Module C was 1.00228 greater; and Module D was 0.9976 less. The TSA flow rate failure is defined by the following equation:

$$[ABS(Qt - Qcyc)/Qt]*100\% > 10\%.$$

Where *Qt* is the flow rate of the tetraCal, *Qcyc* is the flow rate of the IMPROVE sampler calculated using the pressure drop across the cyclone. Note *Qori* is used in this equation for the PM10 sampler and as a backup for the PM2.5 modules. There were instances when either the CYC or the ORI flow rate failed for a particular module, however, there were no instances when both flow rates failed for the same module. This indicates there was always at least one good measure of sample flow rate for all samplers tested.

SAMPLER VACUUM

The vacuum pressure is measured by starting the modules pump, closing a ball valve (see Figure 6), which prevents air flow through the system and subsequently reading the ORI transducer. This measurement is labeled MaxORI on the TSA form. It is indicative of pump strength, air leakage through the system, or proper transducer operation. The TSA test fails if the MaxORI pressure drop is less than 33mV; a pressure drop of 40mV is not uncommon. The TSA measurement is different from the MaxORI readings obtained during routine sample changes because the TSA test measures pressure drop through the entire sample train while during routine sample changes the pressure drop is measured from the solenoids to the pump. There were instances when the IMPROVE MaxORI passed, while the TSA MaxORI test failed. An overview of these results is given in Table 6.

TEMPERATURE

The IMPROVE sampler temperature is monitored to accurately calculate sampler flow rates. During TSAs the sampler temperature is compared to the NIST traceable temperature of the tetraCal. The TSA temperature fails if the sampler temperature is more than 10^{o}C different from the tetraCal temperature. There were no temperature failures for the 2016 TSAs. Temperature comparisons are shown in Table 5.

SAMPLER TIME

The sampler time is compared to cell phone time and adjusted if the difference is greater than 5 minutes. Sampler time comparisons are shown in Table 5.

Figure 6 Photo showing sampler flow rate and vacuum checks during audit.

Table 5 Audit results

		TIME			TEMP			MOD A					MOD B					MOD C					MOD D		
Site Name	Audit Date	AUDIT	IMPROVE	<5	AUDIT	IMPROVE	<10	AUDIT	VAC	(A-V)/A*100%	MAG	(A-M)/A*100%	AUDIT	VAC	(A-V)/A*100%	MAG	(A-M)/A*100%	AUDIT	VAC	(A-V)/A*100%	MAG	(A-M)/A*100%	AUDIT	VAC	(A-V)/A*100%
BALD	7/27/2016	9:04	9:08	Pass	23.40	24.33	0.93	22.30	22.77	2.09	22.82	2.33	22.17	22.83	2.96	22.26	0.41	22.72	22.69	0.14	22.55	0.77	16.53	16.82	1.73
MEAD	6/7/2016	11:51	11:53	Pass	38.50	38.42	0.08	21.76	23.59	8.41	23.06	5.99	22.72	24.37	7.26	23.69	4.26	22.26	24.42	9.70	23.60	6.01	15.77	17.17	8.88
SAWE	7/7/2016	12:04	12:05	Pass	38.40	39.48	1.08	22.95	23.44	2.13	23.12	0.73	23.01	23.48	2.04	23.74	3.17	23.15	22.58	2.45	25.37	9.60	16.97	17.38	2.39
SYCA	8/24/2016	12:35	12:33	Pass	30.60	32.90	2.30	22.92	23.16	1.03	23.03	0.50	22.86	23.38	2.26	23.75	3.91	23.13	22.87	1.12	23.58	1.95	16.49	17.08	3.59
GRSA	5/16/2016	9:35	9:31	Pass	11.30	13.29	1.99	21.39	22.34	4.44	22.49	5.15	21.42	22.74	6.14	22.74	6.18	23.17	23.02	0.66	23.30	0.57	15.56	16.75	7.66
MEVE	5/17/2016	9:12	9:10	Pass	14.10	15.17	1.07	21.70	22.37	3.08	22.70	4.59	21.30	22.35	4.95	22.75	6.80	21.65	22.97	6.07	22.91	5.82	15.95	16.69	4.64
WHRI	6/22/2016	11:25	11:26	Pass	26.30	28.09	1.79	22.14	22.85	3.21	23.03	4.02	22.38	23.06	3.04	23.09	3.19	22.40	23.05	2.91	23.36	4.27	15.93	16.71	4.88
ROMO	7/6/2016	9:10	9:09	Pass	24.60	23.30	1.30	22.14	22.79	2.95	22.92	3.50	22.62	22.96	1.48	23.13	2.24	22.81	23.05	1.07	23.29	2.11	16.36	16.82	2.80
MAVI	6/22/2016	10:41	10:41	Pass	25.90	26.33	0.43	22.71	22.95	1.04	23.13	1.87	23.26	24.00	3.18	24.01	3.21	22.54	23.02	2.11	23.08	2.37	0.00	0.00	NA
LIGO	3/29/2016	12:12	12:13	Pass	14.80	16.81	2.01	21.92	22.59	3.06	22.45	2.43	21.74	22.41	3.10	22.97	5.65	21.57	22.45	4.09	22.80	5.72	16.30	16.82	3.18
OKFE	7/12/2016	11:36	11:36	Pass	36.90	41.83	4.93	23.49	23.62	0.56	22.28	5.14	25.06	23.54	6.07	24.20	3.44	23.82	23.70	0.49	22.67	4.85	17.41	17.12	1.67
ROMO	7/6/2016	9:10	9:09	Pass	24.60	23.30	1.30	22.14	22.94	3.63	23.08	4.27	22.62	23.11	2.16	23.30	3.01	22.81	23.20	1.71	23.48	2.93	16.36	16.93	3.48
LIGO	5/24/2016	11:51	11:51	Pass	21.70	23.00	1.30	22.28	23.02	3.34	23.06	3.51	21.88	23.07	5.45	23.06	5.40	22.44	23.05	2.73	23.03	2.63	16.49	16.93	2.64
FLTO	8/5/2016	8:46	8:44	Pass	19.50	20.00	0.50	22.56	23.07	2.24	22.17	1.73	22.34	22.94	2.68	22.89	2.45	22.82	23.25	1.89	23.18	1.57	15.84	16.45	3.84
CANY	8/8/2016	7:56	7:55	Pass	31.10	32.79	1.69	22.69	27.38	20.68	23.20	2.26	22.86	23.48	2.69	23.28	1.83	22.55	23.76	5.36	23.69	5.05	16.55	17.39	5.07
CAPI	8/3/2016	8:40	8:40	Pass	24.80	25.97	1.17	23.01	23.14	0.56	22.95	0.27	22.47	22.70	1.00	22.64	0.74	23.21	23.24	0.13	23.29	0.34	17.08	17.13	0.29
GRBA	8/11/2016	11:30	11:31	Pass	27.30	29.73	2.43	22.75	23.11	1.60	23.39	2.82	22.51	23.14	2.79	23.29	3.48	23.60	23.94	1.46	24.19	2.49	16.54	17.29	4.52
ZICA	8/15/2016	8:24	8:24	Pass	27.50	26.90	0.60	22.57	23.21	2.85	23.57	4.43	22.33	23.11	3.49	23.33	4.48	22.69	23.57	3.89	23.80	4.91	16.14	17.23	6.73
BRCA	8/16/2016	8:20	8:21	Pass	20.60	22.21	1.61	22.51	23.01	2.21	22.87	1.59	21.83	22.73	4.11	23.02	5.44	22.70	23.03	1.47	22.89	0.82	16.47	16.69	1.33
WEMI	8/18/2016	7:50	7:47	Pass	16.20	13.52	2.68	22.54	22.55	0.04	22.51	0.15	21.93	22.12	0.85	22.53	2.72	22.84	22.97	0.56	23.47	2.76	15.86	16.53	4.25
BOLA	9/22/2016	9:25	9:24	Pass	15.30	15.28	0.02	21.97	22.81	3.82	22.90	4.25	21.79	22.62	3.79	22.63	3.83	22.54	23.35	3.59	23.28	3.29	16.00	16.87	5.43
BRID	9/23/2016	9:13	9:13	Pass	10.20	10.47	0.27	21.50	22.49	4.62	22.36	3.99	21.80	22.79	4.52	23.36	7.13	21.96	22.94	4.46	23.21	5.67	15.73	16.82	6.92
YELL	9/27/2016	11:12	11:12	Pass	16.60	19.39	2.79	22.57	22.74	0.75	22.89	1.42	22.66	22.74	0.37	22.97	1.35	23.10	22.82	1.23	23.14	0.16	16.37	16.56	1.16
NOAB	10/4/2016	7:55	7:56	Pass	6.70	7.65	0.95	22.27	22.66	1.76	22.42	0.67	22.41	22.78	1.64	23.10	3.09	22.71	23.06	1.53	23.02	1.37	0.00	0.00	NA
NOCH	10/5/2016	10:15	10:16	Pass	6.80	5.42	1.38	22.81	22.22	2.58	23.42	2.69	22.71	21.84	3.83	22.91	0.86	23.73	23.34	1.64	24.63	3.79	16.64	16.48	0.94
THBA	10/7/2016	10:16	10:17	Pass	10.50	10.58	0.08	22.62	22.40	0.99	22.76	0.62	22.37	21.93	1.98	22.59	1.00	22.35	23.18	3.73	23.60	5.60	17.09	16.70	2.27
SHMI	9/27/2016	10:46	10:45	Pass	22.50	21.63	0.87	22.05	22.92	3.93	22.48	1.96	22.20	23.06	3.88	22.76	2.51	22.46	22.55	0.38	23.83	6.12	16.22	17.05	5.14
MOZI	9/13/2016	11:09	11:09	Pass	11.50	14.58	3.08	21.82	21.09	3.33	22.95	5.19	22.00	22.38	1.74	22.56	2.56	21.80	22.45	2.98	22.45	2.96	16.38	16.51	0.81
WHPE	10/31/2016	10:03	10:06	Pass	7.80	7.18	0.62	22.36	22.21	0.67	22.69	1.49	22.04	22.30	1.16	22.45	1.85	22.37	22.05	1.42	22.76	1.75	16.32	16.64	1.99
SAPE	11/3/2016	7:29	7:28	Pass	4.50	4.95	0.45	22.08	22.27	0.84	22.61	2.38	20.56	21.95	6.78	21.64	5.26	22.07	22.16	0.42	22.82	3.39	16.13	16.79	4.09
BOAP	11/4/2016	8:45	8:42	Pass	13.10	15.05	1.95	21.86	22.40	2.49	23.50	7.50	21.44	22.01	2.67	22.39	4.45	20.65	22.99	11.33	21.54	4.33	16.32	16.82	3.08
GICL	11/8/2016	9:34	9:33	Pass	14.10	17.63	3.53	21.76	22.58	3.77	22.74	4.52	22.07	22.50	1.93	24.55	11.26	22.11	22.65	2.43	22.64	2.38	15.92	16.64	4.52
GUMO	11/9/2016	9:40	9:40	Pass	13.00	11.76	1.24	22.19	22.19	0.01	23.26	4.81	21.63	22.17	2.49	23.70	9.57	21.88	22.51	2.88	22.97	4.98	16.44	16.97	3.20
BIBE	11/10/2016	10:18	10:20	Pass	15.70	15.17	0.53	22.06	22.32	1.17	23.15	4.93	20.64	22.09	7.04	21.37	3.54	22.01	22.25	1.11	23.05	4.74	16.76	16.67	0.54
SACR	11/15/2016	10:30	11:28	Pass	20.20	18.92	1.28	22.14	22.92	3.54	23.32	5.35	22.19	22.80	2.76	23.19	4.48	24.64	25.20	2.25	26.25	6.54	17.24	16.88	2.10
WHIT	11/16/2016	9:44	9:41	Pass	17.80	18.45	0.65	21.94	22.98	4.76	22.53	2.67	22.23	22.67	1.98	22.32	0.41	22.76	23.06	1.30	23.04	1.23	16.61	16.79	1.09
BAND	11/17/2016	9:39	9:38	Pass	13.70	16.00	2.30	21.73	24.28	11.73	22.79	4.89	21.54	22.66	5.22	22.65	5.16	21.57	22.69	5.18	22.99	6.57	16.21	16.94	4.51

Table 6 Audit Notes

Site ID	Audit Date	Audit Issues and Field Notes	Corrective Actions
BALD	7/27/2016	Clock reset	
MEAD	6/7/2016	Excavating to the East about 10 meters from the site. Started around 5/23/16	
SAWE	7/7/2016	All pass	
SYCA	8/24/2016	New Site location, Garland Prairie Rd. and Thomas Loop Rd. Parks, Arizona	
GRSA	5/16/2016	All pass	
MEVE	5/17/2016	All pass	
WHRI	6/22/2016	All pass	
ROMO	7/6/2016	All pass	
MAVI	6/22/2016	No D module audit (stack unmovable)	
LIGO	3/29/2016	All pass large tree was removed	
OKFE	7/12/2016	All pass	
ROMO	7/6/2016	This audit was done in conjunction with CDPHE for Auditor Observations	
LIGO	5/24/2016	This audit was done in conjunction with Dennis Crumpler for Auditor Training	
FLTO	8/5/2016	Brush encroachment. The cassette caps not kept in plastic bags.	I left a note for the operator, notified USFS, and will follow-up with email.
CANY	8/8/2016	Mod A MaxVac Fail; Mod A ORI Fail; Mod C Maxvac Fail	UCDavis was notified.
CAPI	8/3/2016	Sampler not operating upon arrival; Tree nearby asked them to trim it. Time reset.	UCDavis notified – they received new controller. Will follow up with email about tree.
GRBA	8/11/2016	Tree nearby asked them to trim it.	NPS notified; will follow up with email.
ZICA	8/15/2016	Reset Clock	
BRCA	8/16/2016	Reset Clock	
WEMI	8/18/2016	Sampler stand needs work. A few trees are too tall and too close. The trees will be trimmed back. Channel B MaxORI fail.	USFS notified about stand; will follow –up with email. UCDavis notified about sampler.

BOLA	9/22/2016	Initial B module flow rate failure.	The proper plug was inserted then all modules passed. UCDavis notified about flagging data.
BRID	9/23/2016	All pass but I had to remove D sampler from the stand to put tube back in.	
YELL	9/27/2016	All pass.	
NOAB	10/4/2016	All Pass but no D module audit (stack unmovable)	
NOCH	10/5/2016	All pass	
THBA	10/7/2016	All pass but I had to remove D sampler from the stand to remove stack to perform audit (used a bit of vacuum grease to reinstall).	
SHMI	9/27/2016	All pass	
MOZI	9/13/2016	All pass	
WHPE	10/31/2016	All modules passed flow and vacuum checks; discussed two trees that need to be trimmed; chair lift was operated on diesel during winter of 2015.	USFS and UCDavis notified about chair lift; will follow-up about tree via email.
SAPE	11/3/2016	Mod A MaxVac Fail but flow rate was fine; Mod B was 10% low (almost fail)	UCDavis was notified about vacuum.
BOAP	11/4/2016	Mod A CYC flow rate 8-9% off. Mod C flow rate is 9% off and ORI failed.	UCDavis was notified about ORI fail.
GICL	11/8/2016	Mod B CYC flow rate failed.	UCDavis was notified about flow rate fail.
GUMO	11/9/2016	Mod B cyclone 10-11% off; failed on second check.	UCDavis was notified.
BIBE	11/10/2016	All flow rates passed but Mod B flow rate is 9% off.	
SACR	11/15/2016	Time was 1 hour off (appears someone changed the time to daylight savings). Module C is operating about 8% over nominal flow rate.	Clock reset.
WHIT	11/16/2016	All flow rates are good. MaxOri channel A failed.	UCDavis was notified.
BAND	11/17/2016	Module A ORI transducer not working (MaxORI and ORI flow calculation failed).	UCDavis was notified.