COMPLAINT and request for investigation of fraud, waste and abuse by a high-ranking EPA official leading to severe underreporting and lack of correction of methane venting and leakage throughout the US natural gas industry

Filed on June 8, 2016
With the Office of Inspector General of the US Environmental Protection Agency
by
NC WARN

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NC WARN

Building people power for climate & energy justice

June 8, 2016

Inspector General Arthur A. Elkins, Jr.
U.S. Environmental Protection Agency
Office of Inspector General
1200 Pennsylvania Avenue, N.W. (2410T)
Washington, DC 20460

Re: COMPLAINT and request for investigation of fraud, waste and abuse by a high-ranking EPA official leading to severe underreporting and lack of correction of methane venting and leakage throughout the US natural gas industry

Dear Inspector General Elkins:

NC WARN, a nonprofit founded in 1988 in North Carolina, has members across this state who are deeply concerned about the impacts on the climate crisis from methane venting and leakage in natural gas mining, production and distribution. In investigating methane impacts we have come across systematic fraud, waste and abuse by a high-ranking EPA official and possibly others in the data collection, results and process of two of the major studies used by EPA in developing policies and regulation.

NC WARN hereby files this complaint and request for your investigation of allegations we are bringing before you. Based on our extensive review of documentation and direct accounts from a credible whistleblower, we believe there has been a persistent and deliberate cover-up that has prevented the agency from requiring the natural gas industry to make widespread, urgently needed and achievable reductions in methane venting and leakage (“emissions”) across the nation’s expanding natural gas infrastructure.

Studies relied upon by EPA to develop policy and regulations were scientifically invalid. Several researchers were biased and had direct conflicts of interest. Industry influence may have contributed to the non-disclosure of flaws in the studies and to the resulting cover-up.

For more than two years the whistleblower, engineer Touché Howard, has repeatedly urged various EPA officials to address and resolve technical problems that have led to greatly underestimated methane emissions in natural gas production. To date, these problems have not

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been addressed. When we learned of this, we reached out to Mr. Howard to better understand these problems, which eventually led to this complaint.

The Office of Inspector General (OIG) issued a report on July 25, 2014 that was critical of EPA efforts to reduce methane emissions. That report looked at the natural gas *distribution* sector, in which reductions of emissions could result in a 1% decrease in industry-wide emissions. By contrast, our complaint involves the production sector, which constitutes 82% of total potential emission reductions (EPA-OIG 2014, 17). Thus, underestimating methane emissions from the production sector has a far greater impact on climate, safety and public health than underestimating leakage in the distribution sector.

Due to warnings by the global scientific community about the urgency of making dramatic reductions in greenhouse gas emission, and because methane emissions from the gas industry are now considered by leading researchers to be the largest source of climate-disrupting emissions in the United States, and because methane and toxic air emissions pose an unresolved hazard to both gas industry workers and surrounding communities, we urge you to expedite this investigation to the greatest extent possible.

BACKGROUND

Methane, a greenhouse gas judged by the Intergovernmental Panel on Climate Change to be 100 times more potent than carbon dioxide over a ten-year period in terms of climate impacts, is the dominant component of natural gas. Consequently, there is growing concern that the heat-trapping characteristics of emissions of methane in the natural gas system substantially exceed any climate benefits that might be gained as the electric power industry and others replace coal and oil with natural gas, including fracking gas, also referred to as shale gas.

Routine emissions, via planned venting – both continuous and intermittent – and from unintentional leakage throughout the various sectors of the oil and gas industry infrastructure, have recently been identified as the largest source of greenhouse gas pollution in the US. Such ongoing emissions account for at least 29% of total US methane emissions, and possibly much more, as described below (Vaidyanathan 2015).

The natural gas industry has displayed a persistent interest in downplaying emissions and preventing regulation requiring the industry to either reduce or capture and re-use emissions. The industry has also played both a participatory and funding role in studies of emissions, including those involved in this complaint.

As noted by Dr. Robert Howarth, a leading methane emissions expert from Cornell University, the rapid growth of the US natural gas industry in recent years due to extraction of shale gas has led to increasing concern about the growing levels of methane emissions reported in most studies. A notable exception was a study published in September 2013 by the Environmental Defense Fund (EDF) and the University of Texas at Austin (UT), listed as Allen et al. (2013) in Figure 1 below.

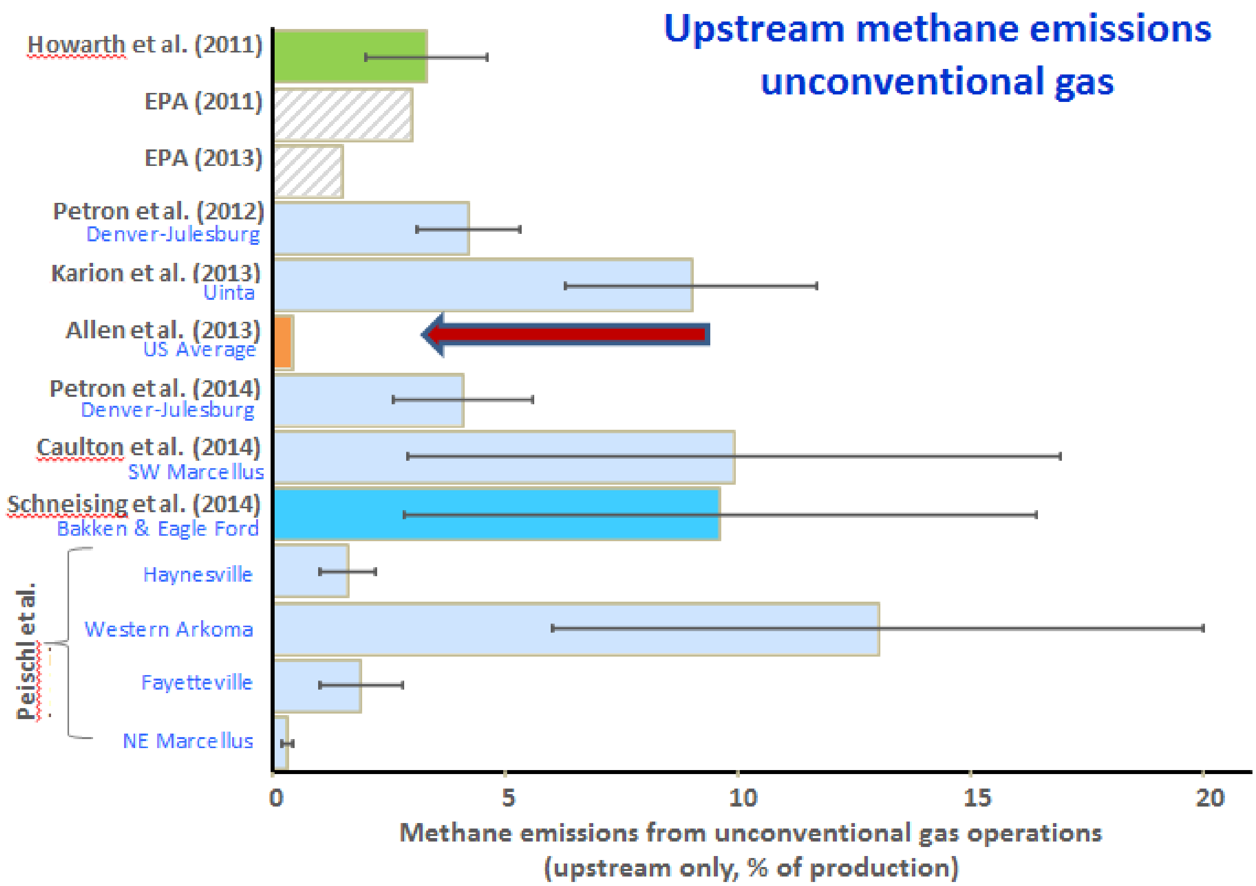

Figure 1. Comparison of methane emission studies across the US, showing the average findings much higher than those from the Allen et al. (2013) study (Howarth 2016, 17, modified).

Due to conflicting data on methane leakage rates, EDF launched a series of 16 studies in 2012 costing $18 million to look at emissions from the life-cycle of natural gas production, with funding from individuals, foundations ($12 million), and industry ($6 million) (Bagley and Song 2015). Oil and gas companies provided 90% of the funding for the Allen et al. (2013) study, which was part of the EDF series and was published in the *Proceedings of the National Academy of Sciences*.

The UT team was led by Dr. David Allen, who also served as Chair of the EPA Science Advisory Board at the time. This study (Allen et al. 2013) reported on emissions from well sites in the production sector and was highly publicized in the news media and disseminated widely by UT team members.

In December of 2014, the UT team published a follow-up study targeting methane emissions from pneumatic devices at production sites (Allen et al. 2014). Pneumatic devices typically rely on natural gas from the site to operate and, as such, vent gas either intermittently or continuously during routine operation. Because of the large number of these devices in use in the production

sector in the US – approximately 500,000 according to Allen et al. (2014) – they are currently considered by EPA to be the dominant source of methane emissions at production sites.

Unfortunately, both of these studies had significant technical problems that caused underreporting of emissions from production sites, but those problems were not disclosed or acknowledged by the study authors.

Allen et al. (2013) relied on the Bacharach Hi-Flow Sampler (BHFS) for measurements made at chemical injection pumps, equipment leaks, pneumatic controllers and tanks (although tank emission data were not included in the emission inventory for this study). However, since the publication of the 2013 study, it has been demonstrated that sensor failure can cause the BHFS not to switch from its low scale to its high scale, resulting in underreporting of emission rates by orders of magnitude (Howard et al. 2015). Further study then showed that this BHFS sensor failure clearly caused underreporting of emission rates in Allen et al. (2013) (Howard 2015b). See Appendix C for Dr. Allen's comment on Howard (2015b) and Mr. Howard's response to the comment.

The Allen et al. (2014) study of pneumatic devices relied on both the BHFS and Fox flow meters, and this study also underreported emission rates due to an undisclosed problem with the flow meter calibration. Independent tests conducted during that project indicated that one of the two Fox flow meters was underreporting by a factor of three, and that no routine calibrations were in place to discover such problems (Howard 2015a). The study authors did not disclose those independent tests or the full extent of the flow meter calibration problems. As a result, at least half of their emissions measurements may be biased low by a factor of two or more. (See Appendix D.)

In addition, UT collected substantial data on tank emissions during Allen et al. (2013) but did not use it, even though this data set might be one of the most extensive and up-to-date data sets available for tank emissions. It is clear that existing tank models do not work well, and tanks might be the dominant source of methane emissions at well sites, by far. At the same time, all indications are that the BHFS was experiencing widespread sensor failure while used by the UT team to make these measurements, and it seems likely that the UT team would have encountered tank emissions large enough that this sensor failure would be obvious. (See Appendix E.)

These problems were brought to the attention of Dr. Allen, other project participants and multiple EPA officials by engineer Touché Howard. Despite his years of expertise in emissions measuring, the fact that he invented the measuring technology that led to the BHFS and his involvement in the EDF project, Howard's repeated attempts to bring the problems summarized above to the attention of the project's leaders and to other EPA officials – through direct communications and a series of peer-reviewed analyses in publicly available journals – have repeatedly been ignored or misrepresented to date. This is in spite of clear, direct evidence that includes observation of BHFS and Fox flow meter failures by technicians and other project participants.

In fact, problems with the BHFS underreporting emissions had been identified as early as 2012 in a paper co-authored by EPA researcher Eban Thoma (Modrak 2012).

In July 2015, Bacharach, Inc. posted a revised BHFS manual on its website (Bacharach 2015) shortly after a reporter asked the company to comment on the sensor failure (Song 2015). The update recommends daily rather than monthly calibration in the case of mixed gas streams and warns of the possibility of sensor transition failure, recommending some minimal workarounds. The revision does not recommend updating the firmware, nor does it indicate the scale of the problem or offer a meaningful way to prevent it. The question is whether Bacharach's revision was in response to the concerns raised by Mr. Howard or whether they were also notified of the problem by members of the Allen 2013 or 2014 team or other users. As far as we know, Bacharach did not issue a product alert to existing users of the BHFS at the time the manual was revised.

It appears that the goal of the UT team was not to critically examine the problems but to convince EDF and its production committee members that no problems existed. We believe Mr. Howard was specifically prevented from providing input because the UT team knew that he would be able to show that their counterarguments were faulty and the resulting studies scientifically invalid.

The problems Mr. Howard identified have not been openly addressed or corrected, resulting in the failure of the EPA to accurately report methane emissions for more than two years, much less require reductions. Meanwhile, the faulty data and measuring equipment are still being used extensively throughout the natural gas industry worldwide.

Non-disclosure and cover-up could have widespread implications. The BHFS has been used at all stages of natural gas processing, transmission, storage and distribution to determine methane emissions (see Figure 2). It is also one of the devices approved by EPA for mandatory reporting of methane emissions under Subpart W of the Greenhouse Gas Reporting Program (EPA 2016b).

Because EPA, academic and industry personnel have ignored or misrepresented these problems instead of addressing them with Mr. Howard in a professional manner, methane emissions remain poorly quantified, although it seems very likely that they are much higher than estimated by EPA. For example, a 2016 EDF study (Lyon 2016) found methane leakage rates 90% higher than original estimates, with 90% of the leaks coming from tanks (McKenna 2016). Current scientific consensus, as shown in Figure 1, is that the methane emissions from natural gas production and distribution are much higher than indicated by the invalid Allen studies.

SUMMARY OF SPECIFIC ALLEGATIONS DETAILED IN APPENDIX A

Since being made aware of the flaws in Allen et al. (2013) and Allen et al. (2014), Dr. Allen misused his authority, gave false or misleading information, provided inadequate documentation and delayed producing requested documentation, thus minimizing and failing to disclose the serious malfunctioning of the BHFS and Fox flow meters and the consequent effect on test results.

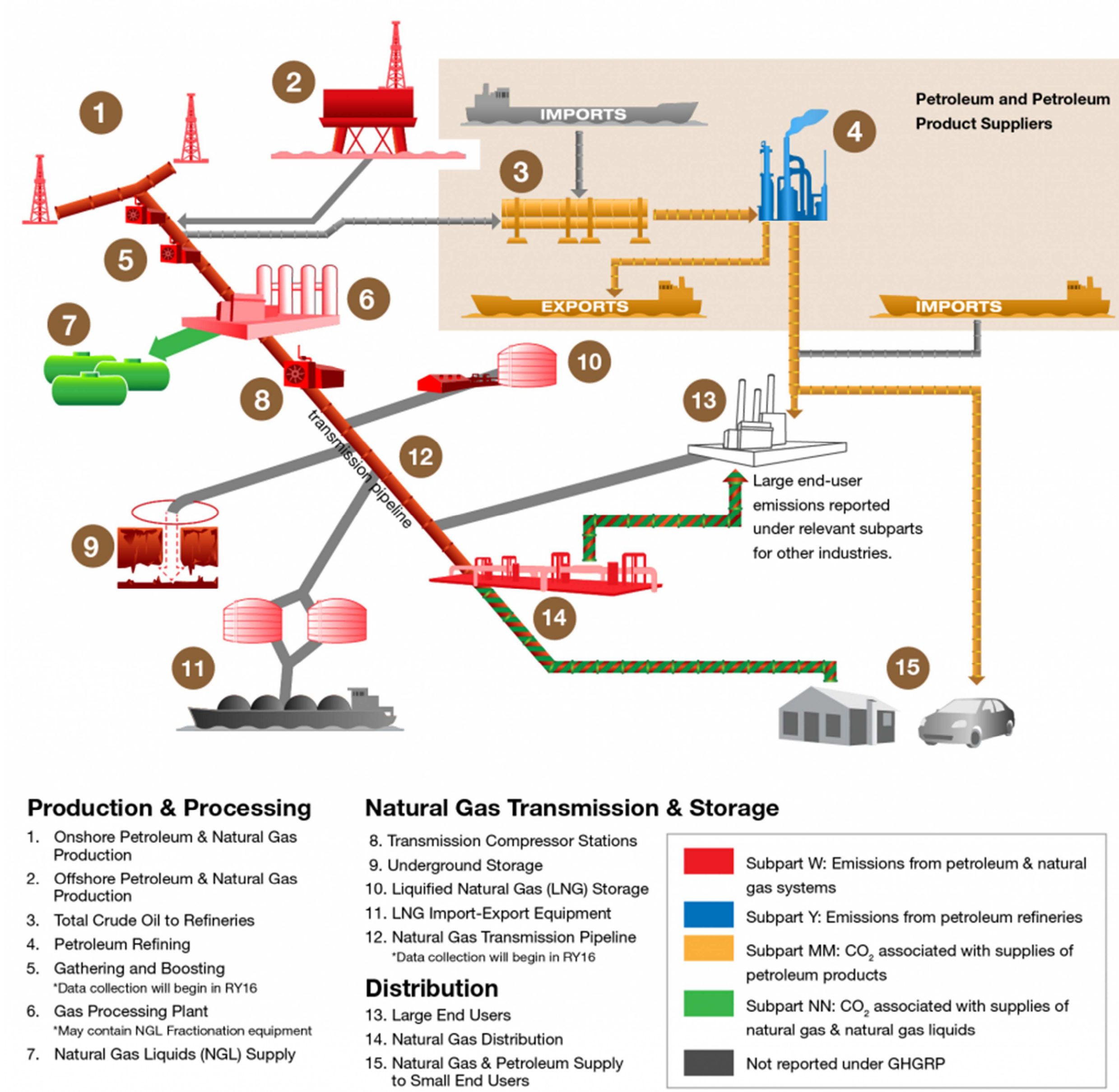

Figure 2. Natural gas production sectors in which the Bacharach Hi-Flow Sampler (BHFS) is used. Diagram source: https://www.epa.gov/ghgreporting/ghgrp-and-oil-and-gas-industry.

Dr. Allen knew or should have known that the malfunctioning BHFS resulted in invalid data that should not have been used for Allen et al. (2013). Dr. Allen knew or should have known that the malfunctioning BHFS, as well as problems with the Fox flow meters, resulted in invalid data being published in Allen et al. (2014). Allen misrepresented to Mr. Howard that his concerns would be addressed. In refusing to address the issue of invalid data, and refusing to communicate further with Mr. Howard, Dr. Allen's actions resulted in delay and misuse of EPA funds.

Dr. Allen, as principal researcher, had a duty to investigate and disclose to the EPA, EDF and other researchers issues that indicated severe problems with the BHFS, the tank data and the pneumatic device study (Allen et al. 2014).

The confidential rebuttal memo (undated, see Appendix B) that Dr. Allen distributed to members of the production team was intended to mislead the EDF production committees about the significance and scope of the problems with the BHFS.

Dr. Allen and the UT team further misled the editor and readers of *Environmental Science & Technology* in Dr. Allen's response to Howard's Comment on Allen et al. (2014).

In March of 2014, Dr. Allen failed to disclose to EPA, industry, EDF and Bacharach, Inc. that the BHFS sensor failure had been clearly demonstrated, and that problems with the BHFS appeared to have been only partially resolved with updated firmware and frequent calibrations.

Dr. Allen, as chair of the EPA Science Advisory Board from 2012 to 2014, was a paid Special Government Employee. As such, he had the additional duty to fully divulge his biases toward industry and his direct conflicts of interest. His disclosure statements in the Allen et al. (2013, 17768) and Allen et al. (2014, 639) studies show his research and consulting have long been funded by the oil and gas industry, bringing the validity of his studies further into question.

RAMIFICATIONS FOR CLIMATE, SAFETY, HEALTH

It has been demonstrated that sensor failure can cause the BHFS to underreport leak rates and other emission rates by orders of magnitude. Accurate sampling and monitoring by Dr. Allen and the UT team would have given EPA a fuller understanding of the devastating impacts of methane venting and leakage. Because of this failure, EPA funds have been wasted, fraud has been committed, and improper and unlawful actions have been taken. More important, the scientific basis for properly regulating methane emissions from the natural gas industry, and the resulting impact on the climate crisis, have been put back nearly three years.

The Allen studies are high-profile studies that have been widely cited (197 times as of April 2016) and presented before White House and Congressional staff and, as such, have given policy makers and the public an incorrect view of methane emissions from production sites. Specifically, policy makers may underestimate the impact of natural gas use on the climate and on public health (from toxic air emissions), and thus fail to take action to guard against these problems. In some cases (e.g. Denton, TX) state legislatures have overridden local legislation enacted to address the concerns of citizens based on a misguided understanding of methane impacts.

Since 2012, the attorneys general of seven states, led by New York Attorney General Eric T. Schneiderman, have been pressing EPA to regulate methane emissions not just from new natural gas facilities but also from existing ones. In April 2016 a coalition of 12 US mayors asked President

Obama to address the issue of methane leaking from existing oil and gas production sites (see Appendix F).

The flaws in the Allen studies have enormous environmental, health, and safety implications. The BHFS is currently the standard instrument in the natural gas industry worldwide for measuring methane emissions. The analysis by Mr. Howard (2015b) indicates that BHFS sensor failure could occur in all segments of the natural gas industry, not just in production. Consequently, sensor failure in the BHFS may cause both underreporting of methane emissions as well as emissions of heavier hydrocarbons and air toxics, resulting in the underestimation of the health effects from air emissions at oil and natural gas facilities. This problem may have affected other research and government programs, causing methane emission inventories to be biased low, including the inventories compiled by the US EPA Subpart W Greenhouse Gas Reporting program (US CFR 2014), the American Carbon Registry (ACR 2010), and the United Nations Clean Development Mechanism (UN CDM 2009).

Most important, however, the BHFS is also used to prioritize the repair of natural gas leaks, and if a large leak were not repaired because the BHFS underestimated it, this could lead to catastrophic component failure and/or explosion.

A HIGHLY CREDIBLE WHISTLEBLOWER

Touché Howard's education and unique background make him an extremely credible whistleblower. He holds a B.S. in Chemical Engineering, and an M.S. in Environmental Engineering specializing in air emissions and transport, and he has over 25 years of experience measuring methane at natural gas production sites around the world.

Mr. Howard is the inventor of the Hi-Flow Sampler (US Patent RE37,403), a device to measure natural gas leaks that is approved by the EPA and is used by the natural gas industry worldwide. He developed the Hi-Flow Sampler in the early 1990s, assigning the patent to the Gas Research Institute in 2003. Mr. Howard did not participate in development of the commercial version – the Bacharach Hi-Flow Sampler or BHFS – and does not own any rights to the BHFS, nor has he ever financially benefitted from sales of the BHFS, which cost approximately $20,000 each, with about 500 in use.

Mr. Howard has served as a project manager and trainer for fugitive emission measurement and management programs since 1989 at over 500 natural gas facilities. He recently provided instrumentation, training, field measurements, and analysis for a nationwide methane emissions measurement program focused on above- and below-ground leakage from natural gas distribution systems. Mr. Howard has published over 20 papers on topics including methane and other emissions from natural gas and oil production facilities, including a 2015 study by Brian K. Lamb, Touché Howard and others that is used by the EPA in its April 2016 *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014* (EPA 2016a, 3-80).

Mr. Howard has gained the respect of colleagues across the field and of leading researchers, for example, Dr. Robert Howarth of Cornell University, a leading researcher of methane emissions and their impacts on climate change. (See Dr. Howarth's letter endorsing Mr. Howard's work, Appendix G.)

Perhaps most salient to this complaint is that, in addition to EPA's reliance on Mr. Howard's expertise, EDF was well aware of his credentials because his instruments, training, field measurements, and analysis were being used for the Washington State University study of methane emissions from natural gas distribution systems, which EDF also sponsored. Dr. Allen initially relied significantly on Mr. Howard, recognizing that Mr. Howard's expertise in emission measurements, particularly with high flow sampling technology, exceeded that of the UT team – until he identified problems with their high-profile studies. (See Attachment H, Vita of Touché Howard.)

INDUSTRY INVOLVEMENT & POSTURE

The Energy Policy Act of 2005 exempted hydraulic fracturing ("fracking") from federal clean air and clean water rules (Song 2016). Emissions factors were developed in the early 1990s and need to be updated to reflect the increase in fracked wells (Song and Bagley 2015).

Indeed, until May 12, 2016, when the EPA released its final rule on emission standards for new oil and gas wells and well-site equipment (EPA 2016), there was no federal regulation and very little state regulation of methane leakage and venting from natural gas production. The EPA has yet to release rules for existing wells, so methane emissions from 75% of oil and gas equipment are still not regulated.

Yet the gas industry is digging in its heels and vowing to fight the new EPA rules, complaining the rules are an economic burden (Davenport 2016). Unfortunately, this fight will be waged using faulty data from the scientifically invalid UT studies. Even more concerning, those data were produced by scientists with a probable bias, if not a direct conflict of interest, due to their prior associations with the industry – see disclosures at Allen et al. (2013) and Allen et al. (2014). Ninety percent of the funding for Dr. Allen's 2013 study came from the oil and gas industry.

Reliance on the Allen studies has allowed the oil and gas industry to continue to claim that emissions are low and that, as a result, no regulation is needed. The American Petroleum Institute (API) hailed the conclusions of Allen et al. (2013) as "proving" that emissions are low (Wines 2013), with other industry groups touting "exceedingly low leakage rates," and claiming that, despite dramatic increases in US natural gas production since 2005, methane emissions from natural gas production have fallen 38% since 2005 (Brown 2015).

Comments submitted by API on EPA's draft *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014* support the findings of Allen et al. (2013) and Allen et al. (2014), minimize the concerns brought up by Howard (2015b) and support use of the BHFS, noting that "the Hi-Flow instrument

is one of a very few existing devices for cost-effectively quantifying natural gas emissions from fugitive and venting at the emission source" (API 2016).

Industry also claims that emissions from shale basins (Brown 2014) and natural gas extraction are down significantly (Dyer 2016) thanks to the findings of the flawed Allen studies. Even more troublesome, the industry has cited Allen et al. (2013) as proof of far lower leakage rates, claiming that spiking methane emissions are due to wetlands and agriculture, and that natural gas will actually solve the climate problem (Brown 2016).

In response to an EPA rule proposed in September 2015 (Federal Register 2015), global oil and gas law firm Jones Day asserts that regulations are not needed, and complains about rules covering compressors, pneumatics and storage tanks, also objecting to the proposed requirement that leaks be repaired within 15 days. Jones Day and oil and gas law firm Bracewell (Snyder 2016) each assert that the cost to capture emissions could exceed the direct monetary value of the recovered natural gas (Jones Day 2015).

CONCLUSION

Dr. Allen was Chair of the EPA Science Advisory Board during the period addressed in this complaint. EPA has relied upon Dr. Allen, so he had a special obligation to address the flaws in his studies and fully disclose this and known problems with the BHFS to EPA policy makers. The BHFS is an EPA-approved instrument and is currently the standard instrument in the natural gas industry worldwide for measuring methane emissions from venting and leakage. Although upgrading its firmware may reduce sensor failure, it does not eliminate it, and it is likely that most BHFS's in use have older firmware more susceptible to sensor failure. The presence of such a problem that can result in large leaks being reported as an order of magnitude smaller than they actually are presents a frightening safety and public health issue and an abject failure by EPA to help stem global climate disruption.

The OIG is tasked with investigating claims of fraud, waste, and abuse. The above summary and attached exhibits demonstrate clear examples of fraud relating to the studies conducted on EPA's behalf, studies EPA has relied upon to prepare rules, guidance documents, and emission standards. EPA has wasted its funds by expending countless hours following up on the flawed studies. There is a clear pattern of abuse of process and conflict of interest in the data collection, preparation, and dissemination of the Allen studies. Too much was covered up and hidden from scientific scrutiny and EPA review.

The OIG is further tasked with investigating complaints of EPA-related criminal activity. In this case, the EPA OIG is required to investigate fraud and false statements pursuant to 18 U.S.C. § 1001.

THEREFORE, NC WARN requests the following:

1. The OIG should conduct an expedited investigation of the allegations in this complaint;

2. The OIG should request a retraction of the Allen et al. (2013) and Allen et al. (2014) studies, with a resulting reexamination by EPA of all policies, regulations, technical documents and international treaties that have relied on these studies;

3. The OIG should require EPA to conduct a complete (and scientifically valid) study to accurately quantify methane venting and leakage throughout the natural gas production and distribution system; and

4. The OIG should investigate the EPA's use of researchers who have industry bias and direct conflicts of interest.

Moreover, because of the extreme urgency of the climate crisis and the significant climate impact of methane venting and leakage in the natural gas industry, and because nearly three years have been lost as a result of the actions outlined in this complaint, we recommend these immediate policy changes as a way of redressing the damage that has been done:

1. EPA should institute a zero emission goal for methane;

2. EPA should initiate a full regimen for oversight, testing and remediation of methane emissions in the natural gas industry; and

3. EPA should take into account the global warming potential of methane emissions over a 20-year (not 100-year) timeframe.

We look forward to cooperating with you to determine the extent and remedy of this issue. In addition to the appendices included herein, we have other correspondence, studies, and an extensive timeline of events that will be made available upon request.

Sincerely,

Jim Warren
Executive Director

cc: EPA Administrator Gina McCarthy
UT Austin President Gregory L. Fenves
EDF President Fred Krupp
Dr. David Allen

VERIFICATION

I, Touché Howard, verify that the contents of the above Complaint submitted to the U.S. Environmental Protection Agency's Office of Inspector General are true to the best of my knowledge, except those matters stated on information and belief, and as to those matters, I believe them to be true.

Harry McVern Touché Howard

Date: June 1, 2016

Sworn to and subscribed before me this the 1st day of June, 2016.

Notary Public

My Commission expires: 1/6/2018

ANNA HENRY
NOTARY PUBLIC, NORTH CAROLINA
WAKE COUNTY
MY COMMISSION EXPIRES
1/6/2018

VERIFICATION

I, Jim Warren, verify that the contents of the above Complaint submitted to the U.S. Environmental Protection Agency's Office of Inspector General are true to the best of my knowledge, except those matters stated on information and belief, and as to those matters, I believe them to be true.

Jim Warren

Date: 6/1/16

Sworn to and subscribed before me this the 1st day of June, 2016.

Notary Public

My Commission expires: 1/6/2018

ANNA HENRY
NOTARY PUBLIC, NORTH CAROLINA
WAKE COUNTY
MY COMMISSION EXPIRES
1/6/2018

APPENDIX A. Allegations

A. Scope of Review

The EPA provides the following definitions and examples of Fraud, Waste and Abuse (EPA 2016c):

Fraud: a false representation about a material fact, any intentional deception designed to unlawfully deprive the United States or EPA of something of value or to secure for an individual a benefit, privilege, allowance or consideration to which he or she is not entitled, inadequate or missing documentation, delays in producing requested documentation, false or misleading information, lack of communication and/or support for ethical standards by management.

Waste: involves the taxpayers not receiving a reasonable value for money in connection with any government-funded activities due to inappropriate act or omission. Most waste does not involve a violation of law, but relates primarily to mismanagement, inappropriate actions, and inadequate oversight.

Abuse: behavior that is deficient or improper, misuse of authority, misusing the official's position for personal gain, and conflict of interest. Abuse does not necessarily involve fraud or violations of laws, regulations, or provisions of a contract.

The EPA OIG also reviews complaints of EPA-related criminal activity. In this case, the EPA OIG is required to investigate fraud and false statements pursuant to 18 U.S.C. § 1001:

> (a) Except as otherwise provided in this section, whoever, in any matter within the jurisdiction of the executive, legislative, or judicial branch of the Government of the United States, knowingly and willfully—
>
> > (1) falsifies, conceals, or covers up by any trick, scheme, or device a material fact;
> >
> > (2) makes any materially false, fictitious, or fraudulent statement or representation; or
> >
> > (3) makes or uses any false writing or document knowing the same to contain any materially false, fictitious, or fraudulent statement or entry;
>
> shall be fined under this title, imprisoned not more than 5 years or, if the offense involves international or domestic terrorism (as defined in section 2331), imprisoned not more than 8 years, or both. If the matter relates to an offense under chapter 109A, 109B, 110, or 117, or section 1591, then the term of imprisonment imposed under this section shall be not more than 8 years.

B. List of Specific Allegations

a. *Phase I Study (Allen et al. 2013): The principal researcher of the University of Texas at Austin studies, Dr. David Allen, who was EPA Science Advisory Board Chair from 2012 to 2014, misused his authority, gave false or misleading information, provided inadequate documentation and delayed producing requested documentation, thus minimizing and failing to disclose to the EDF Production Group (EDF staff scientists and managers, the Technical Working Group, representatives from project sponsors, the Steering Committee and the Science Advisory Committee) the serious malfunctioning of the Bacharach Hi-Flow Sampler (BHFS), the tool used to measure methane leakage in Allen et al. (2013). Dr. Allen knew or should have known that the malfunctioning BHFS resulted in invalid data that should not have been used for the Allen et al. (2013) results.*

i. In October 2013, Dr. Allen, who led the UT team for the Phase I study that directly measured methane leakage in the natural gas production sector, was informed by Mr. Howard of the fact that the main measurement tool being used for the Phase I study (Allen et al. 2013), the BHFS, was malfunctioning. Since the BHFS is a widely used tool to measure natural gas methane emissions, this means that invalid results have widespread, profound implications. Rather than act on this information by disclosing it to other research participants, Dr. Allen misused his authority, and gave false or misleading information to the EDF Production Group between October 2013 and January 2014, minimizing Mr. Howard's concerns.

ii. Between November 2013 and January 2014, Dr. Allen knowingly misrepresented to Mr. Howard that Dr. Allen would stop the next phase of the research, Phase II (Allen et al. 2014), due to Mr. Howard's concerns about the BHFS malfunctioning. Dr. Allen misused his authority by falsely telling Mr. Howard that Dr. Allen would involve Mr. Howard in quality assurance for Phase II, which focused on emissions from pneumatic devices using the BHFS (as well as Fox flow meters).

iii. This delay also resulted in Mr. Howard's inability to respond publicly in a scientific journal, the Proceedings of the National Academy of Sciences (PNAS), about how problems with the BHFS might affect Allen et al. (2013). Dr. Allen's knowing misrepresentations to Mr. Howard that they would collaborate on this issue resulted in the expiration of the three-month window (October to December 2013) that Mr. Howard had to respond publicly in the journal PNAS to Dr. Allen and the UT team on the malfunctioning of the BHFS.

iv. Therefore, these delays and intentional misrepresentations resulted in a misuse of funds by the EPA, since Dr. Allen, as Chair of the EPA Science Advisory Board, knew or should have known that the malfunctioning of the BHFS resulted in bad data for Allen et al. (2013). These intentional misrepresentations raise serious questions about the scientific validity of the findings in Allen et al. (2013) and demonstrate a clear conflict of interest in Dr. Allen's publication of data he knew or should have known to be false. As an EPA employee at the time, Dr. Allen had a clear duty to investigate underreporting of the BHFS.

b. *Phase II Study (Allen et al. 2014, pneumatics): Dr. Allen misused his authority, gave false or misleading information, provided inadequate documentation and delayed producing requested documentation by minimizing and failing to disclose to the EDF Production Group the serious malfunctioning of the Bacharach Hi-Flow Sampler (BHFS). Dr. Allen knew or should have known that the malfunctioning BHFS, as well as problems with the Fox flow meters, resulted in invalid data. Dr. Allen and the UT team misrepresented to Mr. Howard that his concerns would be addressed. In refusing to address the issue of invalid data, and refusing to communicate further with Mr. Howard, Dr. Allen's actions resulted in delay and misuse of EPA funds.*

i. In March 2014, Mr. Howard and industry colleagues conducted field tests of the University of Texas (UT) BHFS and Fox flow meters on pneumatic devices. (These field tests were not part of Phase I or Phase II UT studies, but were done separately during the Phase II study timeframe as a result of the concerns of Mr. Howard and UT team members about the malfunctioning of the BHFS.) Pneumatic devices deserve special attention as the EPA reports there were 977,000 pneumatic devices used in US natural gas production in 2012.

ii. In March 2014, in connection with these field tests, Mr. Howard made an agreement with members of the UT team to present a joint statement to the EDF production committees about the problems with both the BHFS and Fox flow meters, and how these problems may have affected research results. However, rather than work on a joint statement, the UT team immediately presented the March 2014 test results of the BHFS without Mr. Howard's knowledge or input.[1] (However, whether problems with the Fox flow meter were disclosed in that meeting is unknown.)

[1] These test results from the March 2014 field tests were included in both Howard et al. (2015) and Howard (2015b).

iii. Dr. Allen then refused to communicate further with Mr. Howard, resulting in a further delay of the investigation because Mr. Howard assumed he was still collaborating with the UT team on Phases I and II when, in fact, the UT team had no intention of working with him. By preventing Mr. Howard's input, the UT team was able to minimize the problems with the BHFS to all team members, including the EDF Production Group.

iv. The problems with the Phase II data set, which Mr. Howard made clear to the UT team in emails (available upon request),[2] included:

1. No routine calibration on the Fox flow meters while in the field.
2. One Fox flow meter (out of two that were used in the study) was reading far too low, and without routine calibrations there was no way to determine if the other meter also had problems.

v. Matt Harrison, a member of the UT team, told Mr. Howard in an email dated 6/23/14 (available upon request) that he was "taking a big scientific risk" in publishing his results criticizing Allen et al. (2013) without first seeing the Phase II data. Dr. Allen had previously asserted that if Mr. Howard completed a Non-Disclosure Agreement (NDA), he would be able to see the Phase II data. However, even after Mr. Howard completed an NDA, Dr. Allen withheld the data he had promised Mr. Howard. (Detailed timeline available).

vi. Because the UT team refused to disclose the Phase II data, Mr. Howard had no way to evaluate the UT team's assertion that the Phase II results confirmed Dr. Allen's conclusions that problems with the BHFS did not affect the Phase I results. The Phase II data were never made available to Mr. Howard until they were published six months later, in late 2014 (Allen et al. 2014), and the results showed that Mr. Howard's analysis was correct.

vii. Dr. Allen published the Allen et al. (2014) pneumatic data but did not disclose the tests that Mr. Howard conducted in March 2014 showing that the performance of one of the Fox flow meters used was far worse than indicated in their supplemental information. Mr. Howard published

[2] Mr. Howard reviewed the meter problems in an email exchange with Matt Harrison (2014-03-21 Matt Harrison) in which Mr. Harrison suggests Mr. Howard take the reference to the meter out of the joint statement. Ms. Carrie Reese with Pioneer Natural Resources confirmed she had notified EDF of the meter problem (2014-05-19 Carrie Reese). After the study was published, Mr. Howard reviewed meter problems with EDF in detail; EDF initially said it would investigate but then stopped responding (2014-12-12 Steve Hamburg). All emails available upon request.

a comment on Allen et al. (2014) (Howard 2015a) and Dr. Allen published a response to the comment (Allen 2015).

viii. The UT team failed to disclose that independent testing of their Fox flow meters demonstrated that at least one meter was underreporting far worse than the authors indicated. This failure alone necessitates the retraction of Allen et al. (2014). However, the UT team should provide the complete data set to EPA, the editor of the *Environmental Science & Technology* journal and the EDF production science advisory committee in order to assist with investigating whether the UT team took other actions to hide the poor performance of these flow meters. For instance, it is important to determine whether the UT team: did immediate follow-up testing after Mr. Howard demonstrated the problems with one Fox flow meter but did not disclose this; cleaned or otherwise tried to improve the performance of the faulty Fox flow meter before the end-of-project calibration test was conducted; or manipulated data points to create a location in the data set where the start of the meter problem could be artificially identified so no data would have to be eliminated.

ix. Therefore, the delays, knowing misrepresentations, and lack of communication in addressing problems with the Phase II data have resulted in a knowing misuse of EPA resources by Dr. Allen, as Chair of the EPA Science Advisory Board and a paid employee of EPA.

c. *The UT team knew or should have known the BHFS measurements of tanks were underreporting emissions.*

i. The UT team knew or should have known its BHFS was underreporting tank data in Phase I (Allen et al. 2013). As part of that study, 124 tanks were measured. These data were not used for the Allen et al. (2013) inventory calculations, though they were published on the UT website. This data set is extremely important as it is one of the most up-to-date, comprehensive data sets of tank emissions available. Tank emissions are an enormous source of methane emissions at production sites, and thus this data set, if accurate, could have provided significant insight into total methane emissions from the production sector (McKenna 2016).

ii. A key question is whether or not the UT team recognized this data set was faulty but did not disclose this fact. (Further discussion is provided in Appendix E). If the UT team knew the tank data were faulty, the following points must be considered:

1. That Dr. Allen published tank data on the UT website that he knew were invalid without any notation that they might be faulty;
2. That Dr. Allen was aware that the BHFS was underreporting data for tank emissions but *did not report this* to EPA, even though he was chair of the EPA Science Advisory Board and the BHFS is approved by EPA to make Subpart W measurements of tanks in the transmission, storage and processing sectors; and
3. That Dr. Allen knew, when Mr. Howard first reported his concerns about the BHFS sensor failure in late 2013, that the BHFS was underreporting tank emissions, so that Dr. Allen should have acted on Mr. Howard's concerns immediately.

iii. Therefore, the delays, use of false or misleading information, knowing misrepresentations and lack of communication in addressing problems with the tank data have resulted in a knowing misuse of EPA resources.

d. Dr. Allen, as principal researcher, had a duty to investigate and disclose to the EPA issues that indicated severe problems with the BHFS, the tank data and the Phase II pneumatic device study.

i. As chair of the EPA Science Advisory Board, Dr. Allen had a legal, ethical and moral duty to investigate and disclose issues in his research that indicated such a severe problem with the BHFS, a widely-used instrument approved by EPA for Subpart W Greenhouse Gas emission measurements (EPA 2016b), with enormous environmental, health and safety implications, including:

1. the impact on climate of underreported methane emissions due to BHFS sensor failure in Allen et al. (2013) as well as on other GHG inventories such as EPA Subpart W, since such underreporting could adversely affect public policy;
2. the impact on community health from underestimates of air toxic emissions inventories that may also be derived from inventories such as those listed in (1) above; sites with heavier hydrocarbons have both the greatest air toxics impact and the greatest likelihood of underreporting due to BHFS, and this underreporting could prevent policy makers from taking adequate action to protect the health of communities near oil and gas facilities; and
3. the impact on safety and health resulting from significant leaks going unidentified and unrepaired due to BHFS sensor

failure, since large leaks could lead to catastrophic failure as well as contribute significantly to air pollution impact on nearby communities.

ii. Dr. Allen took specific actions to delay the BHFS underreporting investigation and disclosure, and to discredit the valid concerns of Mr. Howard, including:

1. repeatedly leading Mr. Howard to believe that the UT team would collaborate with him to investigate and disclose the BHFS sensor failure;
2. leading EDF staff and committees to believe that he would address the issue of BHFS sensor failure with Mr. Howard while actually refusing to communicate with Mr. Howard; and
3. disseminating arguments against the effect of BHFS sensor failure on the Phase I data set that Dr. Allen knew to be false in a confidential memo (Appendix B) without giving Mr. Howard any notification or opportunity to respond.

iii. Comments sent to EPA by Dr. Allen on leaks (Allen 2014a) and pneumatics (Allen 2014b) submitted in June 2014 included data Dr. Allen knew to be false and misleading.

iv. Therefore, the delays, knowing misrepresentations and lack of communication in addressing problems with the BHFS and Fox flow meters resulted in a knowing misuse of EPA resources.

e. The confidential, undated rebuttal memo (Appendix B) that Dr. Allen distributed to members of the production team was intended to mislead the EDF production committees about the significance and scope of the problems with the BHFS.

i. Between July and October 2014, Dr. Allen wrote a confidential rebuttal memo that was distributed to EDF and its production committees (academic and industry representatives), without Mr. Howard's knowledge or input. This rebuttal memo argued that Mr. Howard was wrong about the BHFS sensor failure's effect on the Allen et al. (2013) study.

ii. This rebuttal memo was not released to the public and was only obtained through a Freedom of Information Act request.

iii. Mr. Howard was never allowed to speak with members of the EDF production committees at any time, even after the rebuttal memo came to light, so that the issue of BHFS failure was never addressed.

iv. Dr. Allen's rebuttal failed to disclose that the UT BHFS tested in March 2014 had a newer version of firmware than when used in Phase I and that Heath Consultants, distributor of the BHFS as well as the company with the most experience with the BHFS, had reported that new firmware had addressed *some* of the problems with the BHFS underreporting of methane leaks.

v. Therefore, Dr. Allen knowingly misrepresented, and failed to disclose material information he knew or should have known to be incorrect in the rebuttal memo, resulting in a misuse of EPA resources.

f. *Dr. Allen and the UT team also misled the editor and readers of* Environmental Science & Technology *in Dr. Allen's response (Allen 2015) to Mr. Howard's comment (Howard 2015a) on Allen et al. (2014).*

i. Dr. Allen failed to disclose that the UT BHFS tested in the UT laboratory and in the March of 2014 field testing had a newer version of firmware than when used in Phase I and that Heath Consultants stated that new firmware had addressed only some of the problems with the BHFS.

ii. Dr. Allen asserted that the March 2014 field tests conducted by Mr. Howard in the presence of members of the UT team were not done correctly and that proper protocols were not followed.

iii. Therefore, Dr. Allen knowingly misrepresented and failed to disclose material information he knew or should have known about the updated firmware and its effect on the problems with the BHFS, resulting in a misuse of EPA resources.

g. *In March 2014, Dr. Allen failed to disclose to EPA, industry and Bacharach, Inc. that BHFS sensor failure had been clearly demonstrated, and that problems with the BHFS appeared to have been only partially resolved with updated firmware and frequent calibrations.*

i. Dr. Allen knew or should have known that his efforts to prevent investigation and disclosure of the BHFS sensor failure would likely result in invalid study results.

ii. Consequently, at least an additional two years of EPA Subpart W emissions data may have been underreported. In addition, community health and worker safety may have been needlessly impacted.

iii. Therefore, Dr. Allen knowingly misrepresented, and failed to disclose material information he knew or should have known to be incorrect when he asserted that updated firmware and more frequent calibrations resolved the problems with the BHFS, resulting in a misuse of EPA resources.

h. As demonstrated in his disclosure statements in Allen et al. (2013) and Allen et al. (2014), Dr. Allen has a long history of consulting for industry and leading industry-controlled and industry-funded studies. His biases, and direct conflict of interest, may have contributed to his failure to disclose malfunctioning tools and faulty data.

APPENDIX B. Discussion of Confidential Allen Memo

Statement by Touché Howard

In October of 2014, while addressing my concerns about sensor failure in the Bacharach Hi-Flow Sampler (BHFS) via conference call with the American Petroleum Institute, one of the participants said, "I don't even know why we're having this call. I have a memo from David Allen saying this isn't a problem." When I later asked why I hadn't been shown this memo, Matt Harrison of URS Corporation said that it was confidential but that it focused on regional differences and also the Phase II results (Allen et al. (2014), at that time not yet published). I was very surprised to learn of the existence of this memo, since I was given no opportunity to respond to it or to understand its contents, and it was clear that it minimized the problem of BHFS sensor failure. Even after publication of Allen et al. (2014), after which the contents of the memo would no longer be confidential due to Phase II data, my repeated requests to EDF and Dr. Allen to see this memo were ignored.

The memo ("Analysis of HiFlow Sampler Cross-Over Performance in University of Texas Methane Studies") was eventually released under a Texas Open Records Act request in November of 2015 (although I only discovered that in April of 2016) and is attached at the end of this appendix. Unfortunately, the arguments made in this memo are not only faulty, but also ones that Dr. Allen and his colleagues had reason to know were incorrect. Consequently, it appears that Dr. Allen specifically tried to mislead EDF and its production committees about the severity of the BHFS failure issue and its effect on Allen et al. (2013). The arguments made in the memo are discussed below.

1) The memo states that laboratory testing, done in the fall of 2013, showed that the UT BHFS did not exhibit sensor failure. However:
    a. All of this testing was done after the UT BHFS firmware was upgraded, but the memo excludes that point and makes no mention anywhere that Heath Consultants technicians had reported that upgraded firmware had dramatically improved the performance of BHFS's that were known to be underreporting.
    b. The UT person in charge of laboratory testing reported that they calibrated their BHFS before every test, which was not the protocol used in Allen et al. (2013) as reported by a URS field technician. Recent calibration was seen to eliminate the sensor failure on the UT instrument (which had new firmware) during the March 2014 field testing.
2) The memo states that the March 2014 field testing I conducted showed only one failure, and that failure was not representative because their protocol was to calibrate any time the instrument was turned on and the test emission rate of 60 scfh (standard cubic feet per hour) was greater than 98% of the Allen et al. (2014) emission rates. However:
    a. Again, they do not disclose that the March 2014 testing was conducted on samplers that had their firmware upgraded, and that this upgrade was reported

to dramatically improve the performance of BHFS's that were underreporting leak rates.

b. During the March 2014 field tests, I was given the UT BHFS to test after the UT team had conducted a bump test (as opposed to a full calibration). The UT team never suggested prior to the testing that it should be fully calibrated and only performed such a calibration *after* the sensor failure occurred. Another field technician from URS specifically stated that they didn't routinely calibrate during Allen et al. (2013) (Phase I) or during the work he had done on Allen et al. (2014) (Phase II, ongoing at the time of these tests). This was corroborated by the fact that the UT BHFS internal log indicated that it had not been calibrated for two weeks prior to these tests, even though it was being used for the UT Phase II program during that time.

c. The complaint that the test flow rate was atypical because it was greater than 98% of the sources measured during Phase II is very misleading, as the UT team knows. The test flow rate of 60 scfh is actually a relatively low emission rate that the BHFS might need to measure in any routine field measurement program. Moreover, as both Allen et al. (2013) and Allen et al. (2014) point out and as has been shown in other studies, the large emitters are the most important. The UT team knows that it is critical that the BHFS be able to accurately measure the larger emission rates. Results from the 2% of pneumatic devices measured in Allen et al. (2014) (Phase II) that were larger than the test flow rate of 60 scfh accounted for 31% of the total emission rate measured in that work. In the Fort Worth study (ERG 2011), 10% of all the sources measured by BHFS were >60 scfh and made up 63% of the total emission rate, and several sources were observed to be at the top capacity of the BHFS. Sources >0.4 scfm (24 scfh, the approximate emission rate requiring the BHFS to transition to its high scale) in the Fort Worth study made up 20% of all sources but 81% of the total emission rate. BHFS sensor failure does not appear to have been prevalent during that study (as discussed in Howard et al. 2015) but this distribution of emission rates shows how critical it is for the BHFS to be able to measure larger emission rates. If BHFS sensor failure had occurred in the Fort Worth study and caused underreporting of all sources >0.4 scfm (24 scfh), then the reported measurements would have been too low by a factor of five.

3) The memo states that analysis of Infrared (IR) Camera scans did not indicate that any large leakage had been missed. However:

   a. It is not possible to accurately quantify emissions using the IR camera due to variations in camera performance and dilution of the source due to wind speed and turbulence changes. During the Fort Worth study (ERG 2011) the daily IR camera performance checks indicated over an order of magnitude variation in how well a known source could be detected.

4) The memo states that the average of pneumatic device emission measurements Allen et al. (2013) made by the BHFS are greater than in Allen et al. (2014), made by Fox flow meters, and then goes on to state that if BHFS sensor failure had caused underreporting in the 2013 study, the 2013 emission rates would have been lower than 2014. However:
   a. The 2013 pneumatic measurements made by BHFS inadvertently focused almost exclusively on devices that were emitting (over 95% were emitting) whereas the 2014 pneumatic measurements were comprehensive (all pneumatics were measured and the frequency of emitting devices is less than 25%). If both measurement methods were accurate, this would cause the 2013 average emission rates to be 4 to 5 times greater than 2014. Additionally, as discussed in Howard (2015a), other problems may have biased the 2014 measurements low, such as resetting pneumatics by installing flow meters and at least one flow meter with a dirty sensor.
   b. Although the memo (in Figure 3) presents a comparison of 2013 to 2014 emission rate versus concentration, it does not explain the significance of the dramatic difference in the patterns between the two graphs which I had repeatedly predicted would exist. The 2014 data, measured by Fox flow meter instead of BHFS, does in fact show that high emitters occur at sites with lower methane content; these are notably absent in the 2013 data measured by BHFS. This is particularly significant because these were graphs generated by the UT team (as opposed to myself), they were aware of the significance in the difference of the patterns, but do not discuss this difference at all in the memo.

Unfortunately, all of the arguments in the memo are so flawed that it appears that the goal of the UT team was not to critically examine the issue but to convince EDF and its production committee members that no problems existed. These committee members would not have had the specific expertise needed to evaluate these arguments, but if I had been allowed to rebut these arguments, I would have been able to prevent the committee members from being misled. It seems likely that I was specifically prevented from providing input because the UT team knew that I would be able to show that their arguments were completely invalid.

Analysis of HiFlow® Sampler Cross-Over Performance in University of Texas Methane Studies

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Allen et al. (2013) provided unprecedented direct measurements of methane emissions from a variety of natural gas production equipment in the United States. Some investigators have recently challenged the validity of the data collected in Allen et al. (2013) based on the assertion of a cross-over malfunction with the HiFlow® sampler used for measurements of emissions from sources such as leaks and pneumatic controllers. Briefly, the HiFlow® sampler has two measurement modes: a low hydrocarbon concentration mode that uses catalytic oxidation and a higher hydrocarbon concentration mode that uses a thermal conductivity measurement. The transition between these modes occurs at when the hydrocarbon percentage in the leak exceeds approximately 5% of the total sample volume. Given the approximate overall sample intake rate of the HiFlow® sampler used in some measurements in Allen et al. (2013) and Allen et al. (2014) of 8 scf/min, the approximate size of the leak would be 24 scf/h for the cross-over between measurement modes to occur. The potential cross-over malfunction would occur if the instrument fails to transition between the two measurement modes, displaying an erroneous low value for the leak rate. This commentary outlines the steps that were taken by the Allen et al. (2013, 2014) study team to investigate the potential for the cross-over malfunction with the HiFlow® sampler used in Allen et al. (2013, 2014). While this evidence cannot resolve the existence of the cross-over malfunction for the entire population of HiFlow® samplers, the evidence does indicates that the cross-over malfunction was not a major cause of measurement error in Allen et al. (2013).

Laboratory Testing of the HiFlow® sampler

After being used for field work in Allen et al. (2013) and before field work in Allen et al. (2014), the HiFlow® sampler and UT-Austin was modified by the manufacturer to report data at 2-3 second time resolution. In order to test the HiFlow® sampler after these modifications, laboratory testing was undertaken using pure methane and a wet gas surrogate (70.5% methane by volume) to compare the performance of the HiFlow® sampler to two other measurement devices (a mass flow controller and a supply gas meter with readings based on gas cooling of a heated flow sensing element). The performance of the HiFlow® sampler is documented extensively in the Supporting Information for Allen et al. (2014). Figure 1 shows sample data from one of the laboratory tests and demonstrates three instances of the HiFlow® sampler measurement exceeding 24 scf/h, indicating that the HiFlow® sampler was able to transition between the two measurement modes.

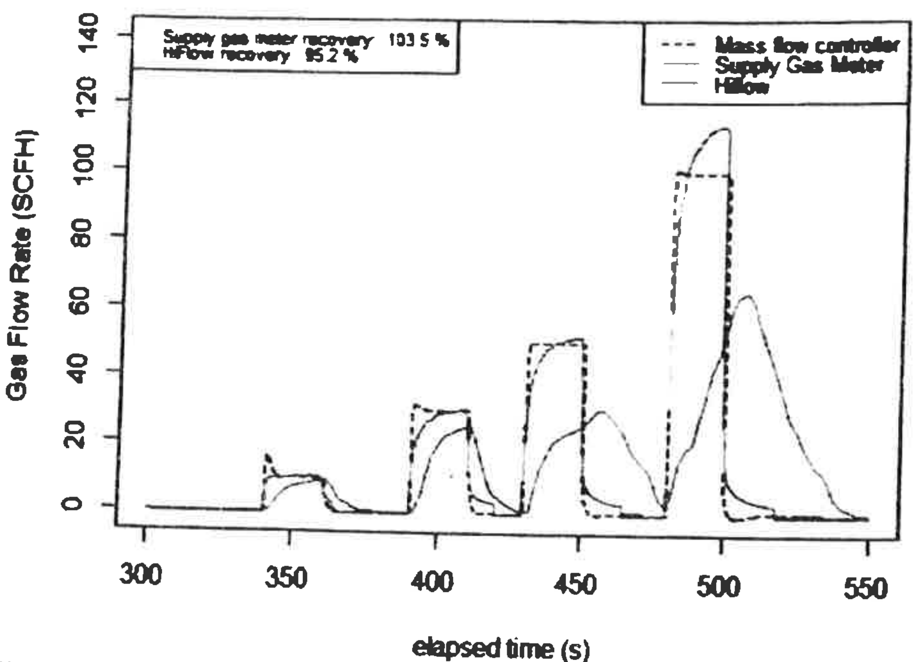

Figure 1. Laboratory test comparing the gas flow rate measurements of a mass flow controller, a Fox Thermal Instruments FT2A meter, and the UT-Austin HiFlow® sampler. The test consisted of four actuations of 20 seconds duration with maximum flows of 10, 30, 50, and 100 scf/h with an interval of 30 seconds between actuations (Allen, et al., 2014).

Field Testing of the UT-Austin HiFlow® sampler

The Allen et al. (2014) study team participated in field testing of the UT-Austin HiFlow® sampler, with tests designed by investigators who have proposed the cross-over malfunction, at actual natural gas production sites with methane concentrations ranging from 77.0% to 90.8%. As shown in Figure 2, the UT-Austin HiFlow® sampler was able to cross-over between measurement modes during simulated pneumatic controller actuations (Figure 2A and 2C) and while in use on an actual pneumatic controller (Figure 2D). During this field work, the UT-Austin HiFlow® sampler only failed to cross-over between measurement modes on a single test (out of XX tests). This single cross-over failure occurred at the driest (90.8% methane composition) site. The Allen et al. (2014) does not believe that the single failed test was representative of typical use of the HiFlow® sampler for two reasons. First, the UT-Austin HiFlow® sampler was powered down prior to sampling when the protocol for Allen et al. (2014) indicated that the calibration needed to be checked for the HiFlow® sampler each time it was turned on due to the potential for drift in the upper end calibration. Second, the test was conducted by the investigators, who have proposed the cross-over malfunction, outside typical operation conditions for the HiFlow® sampler by minimizing the intake air for sample dilution and by choosing a methane emission flow rate (~60 scf/h) that was above the average flow rate for 98% of the pneumatic controllers in Allen et al. (2014). After calibration, the UT-Austin HiFlow® sampler (Figure 2A) successfully crossed-over between measurement modes at a higher leak rate.

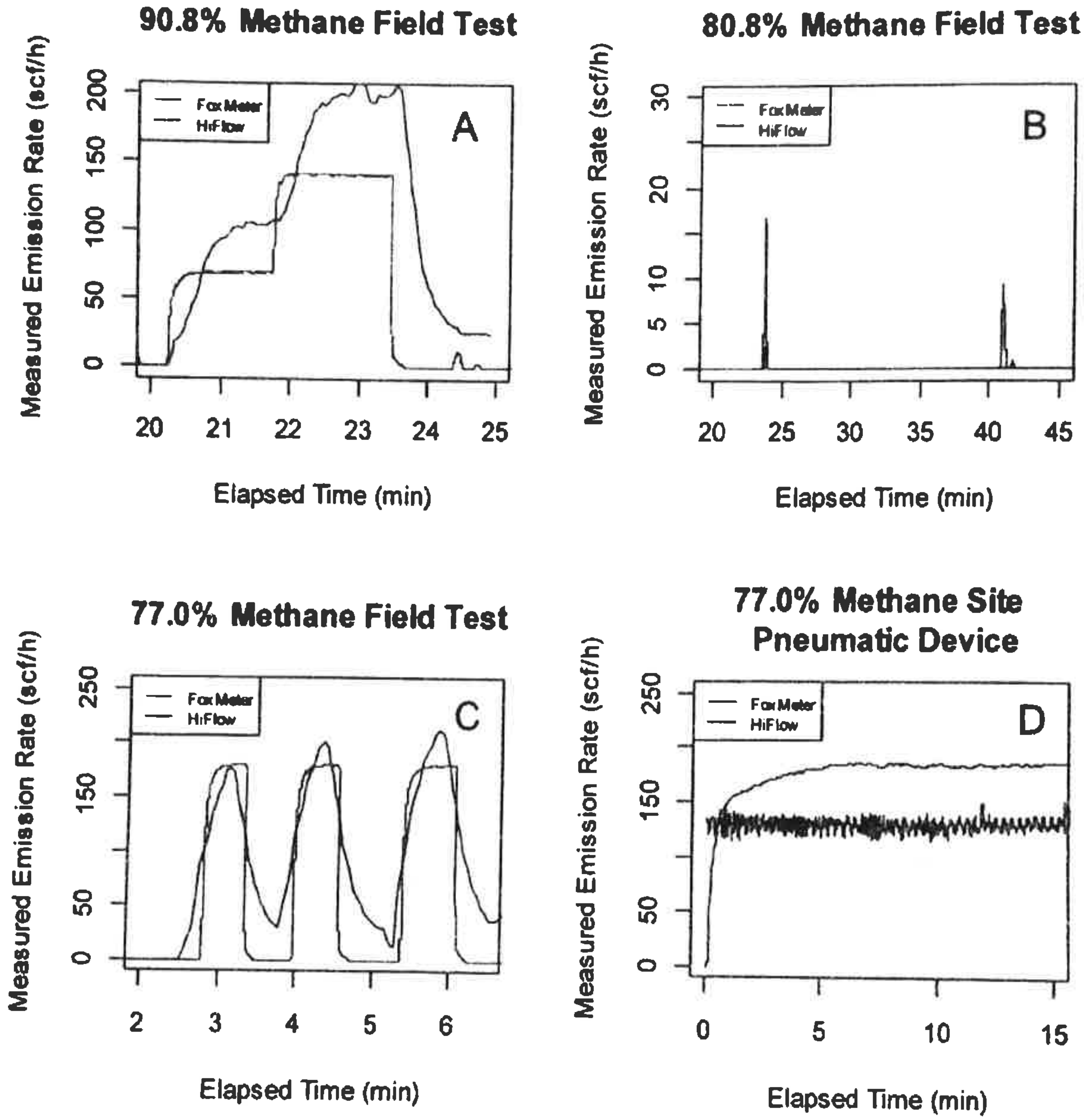

Figure 2. Results from field testing of the UT-Austin HiFlow® sampler. Plots A,B, and C were simulated actuation patterns using a rotameter and field gas. Plot D is a dual measurement on an in-service pneumatic controller with the measurement procedure described in Allen et al. (2014).

Analysis of Infrared Camera Scans from Allen et al. (2013)

Infrared (IR) video camera scans were taken and archived during field work for Allen et al. (2013) for some sites. If the cross-over problem were to have been prevalent, then the expectation would have been to find scans for which a large leak was detected by IR but that was not measured by the HiFlow® sampler. For pneumatic controllers, IR scans were available for 118 of the 305 (39%) devices in Allen et al. (2013). From this subset of data, 5 devices were found to have detectable emissions in the IR scan that were not measured in the subsequent HiFlow® measurement (it was not possible to simultaneously image the emissions using the IR camera and capture all of the emissions in a HiFlow® enclosure). None of these IR images appeared to be of large emissions, in the judgment of the Allen et al. (2014) study team. In

addition, 7 devices without emissions in the IR camera scan were found to have emissions between 0.2 and 5.0 scf/h, indicating that the intermittent venting of some pneumatic controllers was likely responsible for the difference in emissions detection between the two methods.

Comparison to Pneumatic Controller Measurements in Allen et al. (2014)

Based on the result from Allen et al. (2013) that emissions from pneumatic controllers, which were a subset of the devices that had been measured with the HiFlow® sampler, were higher than predicted based on existing inventories of natural gas production emissions, Allen et al. (2014) was undertaken as a follow-up study to investigate this source category. Allen et al. (2014) changed the primary measurement technique to focus on the measurement of supply gas to the controller using a Fox Thermal Instruments FT2A device rather than the exhaust gas measurement technique of Allen et al. (2013) using the HiFlow® sampler. This change in instrumentation was prompted by the desire to obtain higher time resolution data (0.1 second) than the HiFlow® sampler could provide (2-3 second) in order to better characterize the operation of the sampled pneumatic controllers. A comparison of pneumatic controller emission measurements at different natural gas methane compositions from Allen et al. (2013) to supply gas meter measurements in Allen et al. (2014) is available in Figure 3. It is important to note the difference in sampling strategy in Allen et al. (2014), which measured emissions from controllers on all types of natural gas and oil wells, compared to Allen et al. (2103), which focused on pneumatic controllers on recently-completed, hydraulically-fractured wells.

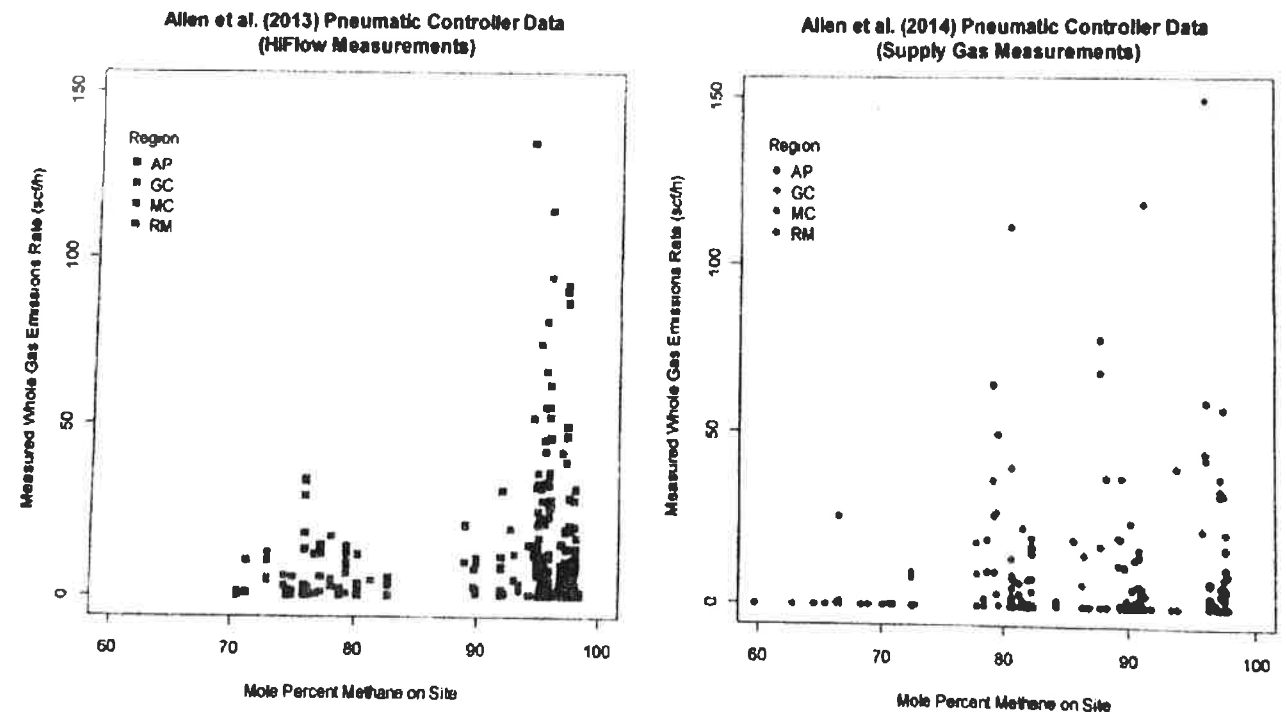

Figure 3. Comparison of the whole gas emission rate per pneumatic controller versus the mole percent methane in the site sales gas concentration for Allen et al. (2013), which was measured using the UT-Austin HiFlow® sampler, and the subset of data from Allen et al. (2014) that was collected using the Fox Thermal Instruments FT2A supply gas meter. Note that the dotted gray line represents the approximate cross-over hydrocarbon leak rate (24 scf/h) for the UT-Austin HiFlow® sampler at a total gas draw-in rate (including air) of 8 scf/min.

If the cross-over malfunction were to have been a major source of instrument error in Allen et al. (2013), the expectation would be that the results would be biased low compared to measurements in Allen et al. (2014); however, the average whole gas emission rate per controller of 5.5 scf/h was lower in Allen et al. (2014) than the average reported in Allen et al. (2013) of 11.2 scf/h. For wet gas sites (<85% methane composition) where investigators citing the cross-over malfunction have posited a higher rate of cross-over failure, the average whole gas emission rate per controller was 6.3 scf/h and 5.3 scf/h for Allen et al. (2013) and Allen et al. (2014), respectively. In addition, the claim that the lower frequency of high emission rates for controllers at wet gas sites does not account for regional differences in pneumatic controller emissions that were documented in both Allen et al. (2013) and Allen et al. (2014). In both these studies, the emission rate from pneumatic controllers in the Rocky Mountain region was substantially lower than other regions such as the Gulf Coast, which Allen et al. (2014) attributes to lower rates of continuous bleed controllers in the sampled population. In Allen et al. (2013), 25% of the measured pneumatic devices on wet gas sites were located in the Rocky Mountain region. Excluding devices in the Rocky Mountain region, the average whole gas emissions rate per device on wet gas sites was 8.0 scf/h in Allen et al. (2013) and 7.7 scf/h in Allen et al. (2014). For the Gulf Coast region, which had the largest number of wet gas measurements in both studies, 13% and 14% of pneumatic controllers on wet gas sites had an average emissions rate that exceeded 24 scf/h in Allen et al. (2013) and Allen et al. (2014), respectively.

Summary

While a cross-over malfunction issue may exist with some population of HiFlow® samplers, the evidence does indicates that the malfunction was not a major source of instrument error for the UT-Austin HiFlow® sampler used in Allen et al. (2013). The UT-Austin HiFlow® sampler was able to cross-over between measurement modes in controlled laboratory and field work settings. In addition, many of the findings for pneumatic controllers in Allen et al. (2013), such as the regional difference in controller emissions, were confirmed with a different measurement tool in Allen et al. (2014).

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Howard et al. citation

Energy Science & Engineering
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Comment on "University of Texas study underestimates national methane emissions inventory at natural gas production sites due to instrument sensor failure"

Journal:	*Energy Science & Engineering*
Manuscript ID:	ESE-2015-08-0064
Wiley - Manuscript type:	Response
Search Terms:	Natural gas, Environment
Abstract:	Howard (2015) claims an underestimation of emissions due to sensor failure in our report of methane emissions from natural gas production sites (Allen, et al., 2013). We disagree with these assertions.

Howard (2015) claims an underestimation of emissions due to sensor failure in our report of methane emissions from natural gas production sites (Allen, et al., 2013). We disagree with these assertions.

Howard (2015) asserts that the HiFlow® sampler, which has been used extensively in measuring natural gas emissions since the 1990s, has a design flaw that causes the instrument to fail to detect emissions that have high concentrations of heavier hydrocarbons, and that this sensor failure caused underestimated emissions in Allen et al. (2013). The primary evidence presented in support of this hypothesis is data from our previous work (Allen, et al., 2013), in which the fraction of devices with high emission rates was greater for sites with low heavy hydrocarbon concentrations in the produced gas (high methane concentrations) than for sites with lower methane concentration. Howard (2015) is correct in noting that we observed significant variations in methane emission rates in different natural gas production regions in the United States, however, he assumes that all regions should have similar emission rates and that therefore the differences are due to a failure of the HiFlow® sampler; this assumption is flawed. Different regions have great variations in operating practices, equipment on site, and local regulations. For example, parts of the Rocky Mountain region where Allen, et al. (2013) made measurements (which has high concentrations of heavier hydrocarbons in produced gas, low concentrations of methane), require leak detection and repair, control devices on tank venting and the installation of low bleed controllers. These controls are not currently required in many other regions, causing regional differences in emission rates. Other studies, in addition to Allen, et al. (2013), have observed regional differences in emission rates. For example, Peischl, et al. (2015) have reported very different emission rates in different natural gas production regions with high methane concentrations (dry gas), ranging from a low of 0.18-0.41% of gas production in the northeast Marcellus, to rates of 1.0 to 2.1% in the Haynesville (a factor of 5 difference between two regions, both with dry gas (high methane fractions)). These are both regions sampled by Allen, et al (2013) and these differences (a factor of 5) point out the importance of local regulations, age of equipment, type of equipment and multiple other factors that influence emission differences between regions, in regions with similar methane content of produced gas.

As additional evidence of a problems with the of the HiFlow® sampler, Howard (2015) describes field testing of the HiFlow® sampler at a single field site. As described in a recent rebuttal to a comment that made a similar claim (Allen, et al., 2015a):

> "The study team [of Allen, et al., 2013] participated in a two-day field test of several HiFlow® samplers. Participants in the field testing included our team, the commenter, a consulting firm, an instrument provider and consulting firm, and a natural gas producer. During this field test, the UT HiFlow® sampler [the sampler used in Allen, et al. (2013, 2015b)] successfully crossed-over on sites with methane concentrations in the produced gas ranging from 77%−91%. Over two days of testing, the UT HiFlow® sampler crossed-over successfully in all but one test; that test occurred at a site with produced gas containing 91% methane. Subsequent examination of the instrument indicated that it had lost calibration after losing power, then being restarted by personnel not on our study team. The sampling protocol in Allen et al. required a calibration check each time the HiFlow® sampler was turned on. Once the calibration protocol was followed, the HiFlow® sampler resumed proper operation."

Howard (2015) notes the successful operation of our HiFlow® sampler at test sites with methane concentrations as low as 77%, but does not explain how this is consistent with his assertion that the HiFlow® instrument consistently fails at low methane concentrations. In the same rebuttal (Allen, et al., 2015a) we noted that we had also done laboratory testing of the HiFlow® sampler used by Allen, et al. (2013), and additional data analyses of infrared camera data also collected by Allen, et al. (2013). That information will not be repeated here, but the data and analyses indicate that sensor failure did not significantly impact the measurements made with the HiFlow® sampler, in either Allen et al. (2013) or subsequent work using the sampler (Allen, et al., 2015b).

The previously published rebuttal (Allen, et al., 2015a) also compares results among multiple studies of emissions from pneumatic controllers, using the HiFlow® sampler and other types of sampling devices. Howard (2015) argues that these comparisons should not be considered. However, these two studies, using two different measurement methods, showed the same type of regional distributions of emissions for pneumatic controllers (high emissions per controller in the Gulf Coast, low emissions per controller in the Rocky Mountains). The average emissions measured using a supply gas meter (Allen, et al., 2015b) were in fact lower, by about a factor of 2, than the emissions reported in Allen, et al. (2013) made using the HiFlow® sampler. This is just the opposite of the effect that would be expected if the HiFlow® sampler were missing high emitting devices.

Finally, in Allen et al. (2013), measurements were made downwind of about 13-20% of the sampled sites (the percentage depended on the type of site), to independently assess whether the on-site measurements, including the emissions measured using the HiFlow® sampler, were accurately quantifying emissions. Howard (2015) uses these data to perform a number of complex comparisons, which focus on percentage differences between the on-site and downwind measurements, particularly at sites with low methane concentrations in produced gas. These analyses obscure 2 simple facts.

1. The independent downwind measurements in the Rocky Mountain region (10 sites with 40 wells), the region with the lowest average methane concentration in produced gas, reported by Allen, et al. (2013), are lower (0.66 standard cubic feet per minute (scf/m) per site, or 0.17 scf/m per well) than in other regions with higher methane concentrations in the gas. For example, in the Mid-Continent region, emissions at 5 sites with 10 wells averaged 3.0 scf/min per site or 1.5 scf/min per well. Thus, the independent downwind concentrations also found regional differences in emission rates; regions with low methane fractions in produced gas were observed in the downwind sampling to have lower emissions than regions with higher methane fractions.
2. The average per well emissions in the Rocky Mountains, made using independent downwind sampling at sites with 40 wells, were low. The average emission rates from these wells were less than half of the emissions that would be expected from just one high emission rate source per well that Howard (2015) argues should be prevalent at sites with high methane concentrations. Simply stated, if there were missing emissions of the magnitude asserted by Howard (2015), they would have significantly increased measured downwind concentrations. The downwind data, made completely independently of the

HiFlow® measurements, indicate a lower frequency of high emitting sources at sites with low methane concentrations in produced gas in the Allen, et al. (2013) data set.

Overall, based on multiple independent measurements (IR camera scans, downwind sampling, and parallel direct flow and HiFlow® measurements) we conclude that sensor failure did not significantly impact the measurements made with the UT HiFlow® sampler in either Allen et al. (2013) or Allen, et al. (2015b).

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Disclosures
The authors declare the following competing financial interest(s): Lead author David Allen has served as chair of the Environmental Protection Agency's Science Advisory Board (2012-2015), and in this role was a paid Special Governmental Employee. He is also a journal editor for the American Chemical Society and has served as a consultant for multiple companies, including Eastern Research Group, ExxonMobil, and Research Triangle Institute. He has worked on other research projects funded by a variety of governmental, nonprofit and private sector sources including the National Science Foundation, the Environmental Protection Agency, the Texas Commission on Environmental Quality (TCEQ), the American Petroleum Institute and an air monitoring and surveillance project that was ordered by the U.S. District Court for the Southern District of Texas. David Sullivan has worked on other research projects funded by the TCEQ, the California Air Resource Board, the Texas Air Research Center, and the U.S. District Court for the Southern District of Texas. Matt Harrison, who worked for URS at the time of the publication of the original papers (Allen, et al., 2013; Allen, et al., 2015b), is now an employee of AECOM, a company that purchased URS. Financial support for the original reports (Allen, et al., 2013; Allen, et al., 2015b) was provided by were Environmental Defense Fund (EDF), Anadarko Petroleum Corporation, BG Group plc, Chevron, ConocoPhillips, Encana Oil & Gas (USA) Inc., Pioneer Natural Resources Company, SWEPI LP (Shell), Southwestern Energy, Statoil, Talisman Energy USA and XTO Energy, a subsidiary of ExxonMobil. Funding for EDF's methane research series, including the University of Texas study, is provided for by Fiona and Stan Druckenmiller, Heising-Simons Foundation, Bill and Susan Oberndorf, Betsy and Sam Reeves, Robertson Foundation, Alfred P. Sloan Foundation, TomKat Charitable Trust, and the Walton Family Foundation.

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Dr. Allen and colleagues from the University of Texas (UT) (1) argue that sensor transition failure in the Bacharach Hi-Flow Sampler (BHFS) did not affect their 2013 UT study (2) as I presented in (3). This is a welcome and critically important discussion because sensor failure in the BHFS may cause both underreporting of methane (CH_4) emissions and underestimation of the health effects from air emissions at oil and natural gas (NG) facilities. Most importantly, however, the BHFS is also used to prioritize the repair of NG leaks, and if a large leak were not repaired because the BHFS underestimated it, this could lead to catastrophic component failure and/or explosion.

Although the rebuttal by (1) contends that the BHFS has been used since the 1990's, the BHFS has actually only been commercially available since 2003. High flow sampling measurements of NG leaks made prior to this were done with custom built instruments based on my design, which Bacharach, Inc. then developed into the BHFS. However, I am not affiliated with Bacharach, Inc. and I was not associated with the development of the BHFS.

The primary evidence of sensor failure is not the lack of high emitters in the UT BHFS data set (2) as stated by (1) but rather the direct experimental observance of this failure, which has been reported in (4) and (5), and, as summarized in (3), has been observed in four out of six samplers that were tested using NG with CH_4 content of < 91%. However, because the UT BHFS data set (2) contains measurements of several different types of sources with wide ranges of natural gas compositions, it provides a unique opportunity to evaluate the possibility that the occurrence of sensor failure might be widespread. It is certainly important to recognize that the BHFS measurements in (2) were biased low by sensor failure so that this data set is not relied upon to inform public policy. However, the much more important result of my analysis (3) of the UT BHFS data set is that sensor failure could indeed be widespread, since it appears to have occurred when measuring NG streams with CH_4 concentrations as high as 97%. This means that BHFS measurements throughout all sectors of the NG industry could be affected.

A third point of confusion is the contention by (1) that air pollution regulations in the Rocky Mountain region resulted in lower emission rates in that region, and that this explains the lack of high emitters at sites with lower CH_4 content observed in their study because that region also had a lower CH_4 content in the wellhead gas. Air pollution regulations might indeed result in lower emission rates in the Rocky Mountain region, but my analysis in (3) explains in detail that this is clearly not the cause of the scarcity of high emitters at sites with wellhead gas of lower CH_4 content. To summarize, my analysis explains that:

1) Even when the Rocky Mountain region is excluded, there are still almost four times fewer high emitters at sites with wellhead NG compositions < 91% CH_4 than sites with > 91% CH_4;
2) Pneumatic device emissions measured using flowmeters in a UT follow-up study (6) show a complete reversal of the pattern of pneumatic device emissions measured by BHFS in the UT study (2), i.e., when measured by flow meters, there was a larger occurrence of high emitters at sites with low well head gas CH_4 content;
3) Emission rates measured by BHFS reported by (2) within a single region – Appalachia – show a dramatic pattern of decreasing occurrence of high emitters as wellhead CH_4 concentration decreases over a narrow range from 98 to 95% CH_4; and

4) Although the downwind tracer measurements (discussed in further detail below) made by (2) confirm that emission rates in the Rocky Mountain region were lower than other regions, these measurements also confirm that the BHFS measurements are too low at sites with low wellhead gas CH_4 content, even in the Rocky Mountain region.

It was also asserted by (1) that both field and laboratory testing showed little evidence of the sensor failure. As described in (3), I tested the sampler used in the UT study after the publication of their initial results in (2) in the presence of members of the UT field team and observed the sensor failure during this testing (4). This failure occurred even though the sampler had been upgraded to a new generation of firmware after it was used to conduct the measurements made during the initial UT study (2). After I conducted this field testing, I immediately interviewed two experienced BHFS technicians not associated with the UT team who reported that the new generation of firmware had eliminated problems in their samplers that caused leaks to be reported too low. Given the dramatic improvement in performance of samplers reported by these technicians using the updated generation of firmware, it is not surprising that the sensor failure only occurred sporadically in the UT sampler during the field tests and was not observed in their laboratory tests. Indeed, it is rather surprising that sensor failure occurred at all in a unit with updated firmware, although this highlights that the factors affecting sensor failure are still not well understood. I immediately relayed these reports of improved performance of samplers with updated software to the UT team in March of 2013, so the authors of (1) and (2) are well aware that the performance of the UT sampler could have been much worse when it was used for the original UT study (2), during which time it had older firmware. It is also interesting to note that during the March 2013 field testing, the UT team had a second BHFS that they did not allow me to test, stating that it had too many problems to make testing it worthwhile, although the nature of those problems was not specified.

The rebuttal (1) further asserts that the reason sensor transition failure occurred in the UT sampler during the field testing I conducted was that the proper UT calibration protocol was not followed. As I explained in (3), the UT team made no effort to conduct calibrations after the instrument was turned off and on but only did so after sensor failure was noted. Consequently, in contrast to what they have stated in (1), it does not appear that the UT protocol was to calibrate any time the instrument was turned on.

Allen and his colleagues (1) also state that because the average emission rates of pneumatic devices measured by flow meters in their follow-up study (6) are lower than those measured by their BHFS in (2), this disproves the possibility of sensor failure since sensor failure should cause the BHFS measurements to be lower. However, as I explained in (3), the pneumatic device data collected by BHFS (2) were clearly not a random sample but instead focused only on emitting devices and inadvertently excluded zero emission sources. This is one reason why average pneumatic device emission rates calculated from the BHFS data (2) are higher than those calculated from the flow meter data (6). Additionally, much of the pneumatic device data collected by flow meters (6) was likely biased low due to calibration problems. The authors of (6) only calibrated their meters before and after their field work, and claim in their supplemental information that they only became aware of a calibration problem with one meter during their post project calibration. However, as I reported in (7), I also tested the UT flow meters in March of 2013 while the measurements for the follow-up study (6) were ongoing, again in the presence of the UT field team. During these tests, one of their two primary meters indicated flow rates that were a factor of three lower than the actual flow rates released through the meters. Even

after applying their post project calibration correction (6), the flow rates measured by this faulty meter during these tests would still be a factor of two lower than the actual flow rates. These two additional failures of quality assurance – the inadvertent exclusion of zero emitters from a supposedly random sample of devices in (2) and the inadequate calibration of flow meters in (6) – further highlight the need for dramatic improvements in greenhouse gas measurements programs.

Allen and colleagues (1) also maintain that infrared camera data showed no evidence that the BHFS did not accurately measure high emitters; however, there is ample evidence that infrared camera visualization cannot be currently used to quantify leaks. For instance, during the Ft. Worth Air Quality study (8), daily QA checks on the IR camera indicated variations in factors of up to 15 in the distance at which a known leak could be identified, much less quantified, under calm conditions. This large variability, even under calm conditions, demonstrates the huge uncertainty in trying to quantify emission rates with an IR camera, since any air movement near the leak would dramatically increase this variability.

Finally, their rebuttal (1) also states that my comparison (3) of the downwind tracer measurements to the on-site emissions measurements in the UT study (2) is "complex" and obscures the fact that the average emission rates from wells in the Rocky Mountain region were too small for the sensor failure to have occurred. In particular, they state: "The average per well emissions in the Rocky Mountains, made using independent downwind sampling at sites with 40 wells, were low. The average emission rates from these wells were less than half of the emissions that would be expected from just one high emission rate source per well that Howard (2015) argues should be prevalent at sites with high methane concentrations. Simply stated, if there were missing emissions of the magnitude asserted by Howard (2015), they would have significantly increased measured downwind concentrations."

However, this claim by (1) ignores the fact that the downwind tracer technique was used to measure CH_4 emissions not from individual wells but from sites with an average of almost five wells per site, so the emission rates per site are much higher than the emission rates per well. In fact, the average emission rate per site measured by downwind tracer in the Rocky Mountain region was 0.66 scfm, over 50% greater than the expected BHFS sensor transition threshold of 0.4 scfm at a sample flow of 8 scfm. If the BHFS sample flow were reduced to 4 scfm due to low battery power or a tightly wrapped enclosure, then sensor transition failure could occur when measuring a source as small as 0.2 scfm. Consequently, a single measurement of a high emitter at these sites that was biased low by sensor failure could cause the observed underreporting of BHFS measurements compared to the tracer data.

To illustrate this, and because Dr. Allen and colleagues (1) found my comparison in (3) of their downwind tracer and on-site data (2) to be complex, I have tried to simplify that analysis here. Figure 1 presents the downwind tracer and on-site data from the UT study (2). For this analysis, I have removed only the two sites at which 98% or more of the reported on-site totals were comprised of estimated emissions, as opposed to actual BHFS measurements, since such a large fraction of estimated emissions would prevent a reasonable evaluation of the BHFS performance.

As seen in Figure 1, the downwind tracer data do in fact indicate that there are real regional differences in CH_4 emissions from natural gas production, as (1) have asserted and as I have acknowledged in (3).

However, Figure 1 also shows clearly that the lower emissions in the Rocky Mountain region do not preclude the occurrence of BHFS sensor failure. When comparing the results on a site by site basis, the on-site totals (which as noted previously were a combination of BHFS measurements added to estimates of sources not measured) are substantially lower than the downwind tracer results for the Rocky Mountain and Mid-Continent sites where CH_4 content was less than 82%, and substantially higher for sites in Appalachia where CH_4 content was greater than 97% (sensor transition failure is much more likely at CH_4 concentrations less than 97% (3)). Only one out of 13 sites with CH_4 content < 82% (RM-5) had reported on-site emissions greater than the emissions measured by tracer, while all four sites with CH_4 content > 97% had on-site emissions greater than those measured by tracer. The ratio of total on-site emissions to downwind tracer emissions for each region was as follows: Mid-Continent: 0.586; Rocky Mountain: 0.461; and Appalachia: 1.44.

Since the reported on-site emissions were greater than those measured by downwind tracer at all sites with well gas content of CH_4 > 97% (the Appalachia region) where the BHFS likely functioned properly, I conclude that the estimation methods used by the UT study (2) actually overestimate emission rates as compared to actual whole-site emissions measured by downwind tracer analysis. Consequently, although this simplified comparison indicates that the on-site data are a factor of two too low at the Mid-Continent and Rocky Mountain sites, the actual effect of BHFS sensor failure is probably larger because the overestimates of emissions from the sources that were not measured somewhat obscures the underreporting by the BHFS, and I've discussed this in detail in (3). Therefore, although this direct comparison of the downwind tracer measurements to the on-site data for each site independently verifies the BHFS sensor failure, it does not reflect the full magnitude of the problem.

Given that the BHFS sensor failure can cause underreporting of natural gas emission rates which could create critical safety, health, and environmental problems, it is disappointing that (1) are willing to ignore the clear evidence – provided by their own downwind tracer measurements – of the effects of sensor failure in the UT BHFS (2) data set. The lead author of (1) and (2) served as the chair of the EPA Science Advisory Board during the period of research conducted by (2), and as such has a special obligation to disclose this issue since the BHFS is an EPA approved instrument. The BHFS is currently the standard instrument in the natural gas industry worldwide for measuring leak rates, and although upgrading firmware may reduce sensor failure, it does not eliminate it, and it is likely that most BHFS's in use have older firmware more susceptible to sensor failure. The presence of such a problem that can result in large leaks being reported as an order of magnitude or more lower than they actually are presents a frightening safety issue. It may have also caused many CH_4 emission inventories to be biased low, including those compiled by the USEPA Subpart W Greenhouse Gas Reporting program (9), the American Carbon Registry (10), and the United Nations Clean Development Mechanism (11).

For the last 12 years I have served as a professional firefighter, and in that role I have seen the tragic consequences that can occur when safety issues are ignored. Unfortunately, the misguided defense by such prominent researchers (1) of the UT BHFS data set (2) creates a distraction from the critical safety, health, and environmental problems that the BHFS sensor failure presents to the oil and NG industry. I call upon the authors and sponsors of the UT study (2) to meet their obligations to the safety of industry personnel and to the health of communities near oil and NG facilities by retracting the UT BHFS data set (2) so that this critically important problem can be recognized and addressed immediately.

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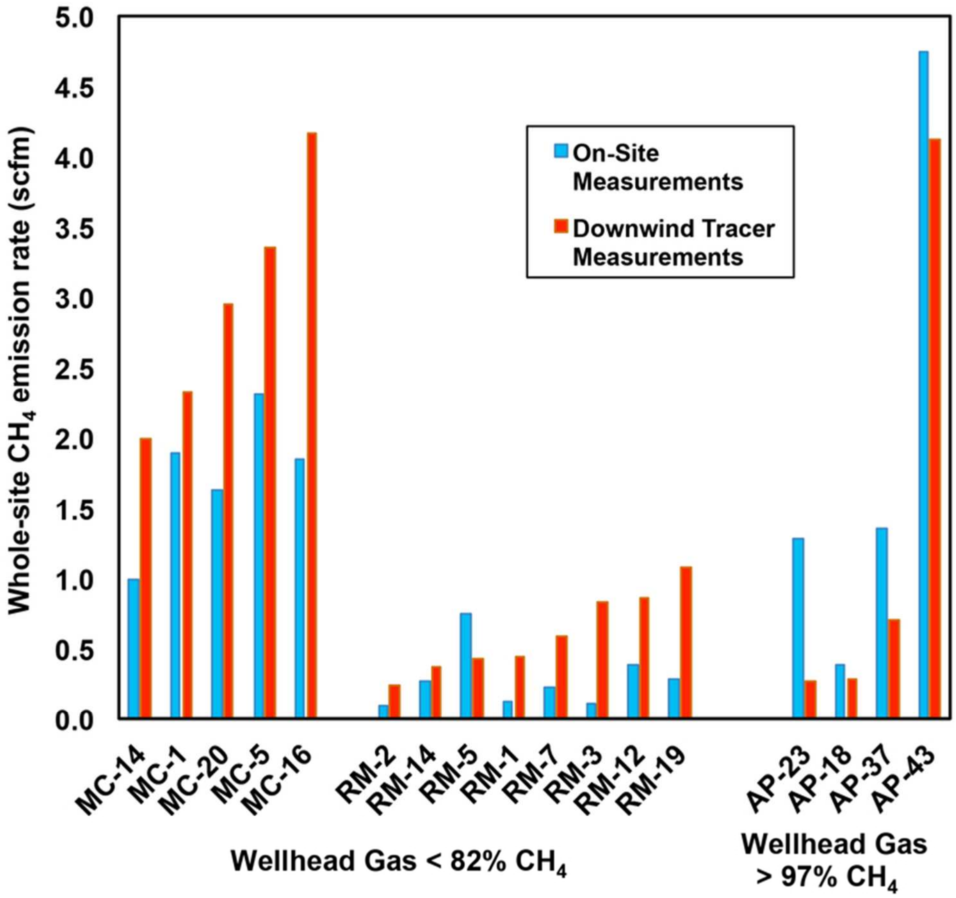
Figure Captions

Figure 1. Comparison of downwind tracer measurements to reported on-site emission rates (compiled from BHFS measurements and estimates of sources not measured) in the UT study (2). Sites with lower CH4 wellhead gas content, where the BHFS is likely to experience sensor failure, have dramatically lower on-site emission rates compared to emission rates at the same sites measured by downwind tracer techniques. This comparison provides independent corroboration of the BHFS sensor failure, even in the Rocky Mountain region where tracer measurements indicate lower regional emission rates. BHFS = Bacharach Hi-Flow Sampler; MC = Mid-continent; RM = Rocky Mountain; AP = Appalachia.



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Appendix D. Problems with the Fox Meter

Analysis by Touché Howard of Fox Meter Calibration Problems in the Allen et al. (2014) EDF Phase II Study of Pneumatic Devices

In December of 2014, Allen et al. (2014) published a study of emission rates from pneumatic devices conducted by the University of Texas (UT) and sponsored by EDF and corporate partners. This study, also known as the UT Phase II pneumatic study, was a follow-up to Allen et al. (2013) (known as UT Phase I). There may be almost 1,000,000 pneumatic devices in the production segment of the oil and gas industry and they may contribute over 25% of methane emissions from this segment. Additionally, at sites with higher compositions of heavier hydrocarbons, pneumatic devices may contribute substantially to the release of air toxics that could affect the health of surrounding communities. Consequently, accurate measurements of pneumatic emission rates are crucial for understanding the true contribution of these devices to both methane and air toxics emissions throughout this segment of the industry and to provide good guidance to policy makers and community representatives.

A total of approximately 360 devices were measured in the Phase II Allen et al. (2014) study. There were two major differences between the Phase I and Phase II studies, however. First, the Phase I study inadvertently focused on devices that were emitting, as opposed to the random sample that was intended (Allen et al. 2014, Howard 2015b), while the goal of the Phase II study was to measure every pneumatic that it was possible to survey at each site visited, providing a more representative sample. Second, the primary measurement method for Phase II was to install a Fox FT-2 flow meter in the supply gas line with some measurements made using the Bacharach Hi-Flow Sampler (BHFS); during Phase I all measurements were made using the BHFS.

The Phase II field program ran from approximately December of 2013 through at least March of 2014. The final end date is not known. On March 18, 2014, while conducting an independent test of the UT BHFS that had been used during the Phase I program, I also tested the two Fox meters that the UT team was using for Phase II. (I was not associated with the UT team but these tests were set up by Carrie Reese of Pioneer Natural Resources because I had expressed concern that the UT BHFS had experienced sensor failure during Phase I (Howard 2015b).)

While testing the two UT Fox flow meters against my rotameter, I found that one of their Fox flow meters (Fox Meter A) was reporting emission rates too low by almost a factor of three (e.g., if the actual emission rate was 60 scfh, the Fox meter would report the rate as 21 scfh, and a correction factor of 2.86 would be required). The other meter compared well with my rotameter, indicating my test method was accurate, and these tests were made in the presence of the UT team including Matt Harrison and Adam Pacsi, as well as Carrie Reese of Pioneer Natural Resources and Tom Ferrara of Conestoga Rovers and Associates (now GHD).

Upon seeing the problem with Fox Meter A during my test on March 18, 2014, Matt Harrison of URS (now AECOM), the lead consultant for the UT team, stated: "Yeah, everyone knows that meter is flaky. You can hook it up to a pneumatic, hear the pneumatic fire, and not see anything on the meter."

The UT team took Fox Meter A out of service that day and the data sheets from the test were provided to them. Additionally, Carrie Reese confirmed to me that she reported the meter problem to Dr. Ramon Alvarez at EDF when she returned from the field.

Surprisingly, the UT team was doing no calibration checks in the field to prevent problems like this. My test was the first check of the meters that had been done since the meters had been calibrated at the start of the project. Because many of the sites the UT team surveyed had higher concentrations of heavier hydrocarbons, there was a high possibility that one or both meters could become fouled, given that the heavier hydrocarbons are often seen to accumulate on the pneumatic devices. Additionally, the Fox flow meter manual specifically states that the meter will read too low if it becomes dirty.

However, when the Phase II Allen et al. (2014) study was published in December of 2014, I was surprised to see that no mention was made of the March 18, 2014 Fox flow meter test. Instead, in a footnote in their supplementary information, the authors indicate that during their post calibration check they found that one meter was reporting too low by 34%, requiring a correction factor of 1.52. (Consequently, if the UT correction factor were applied to correct the results of the faulty meter on the day that I tested it, the corrected results would still be about half the actual flow rate, since I found it to be measuring low by a factor of almost 3.) Additionally, in order to determine at what point the meter calibration problem started, they reviewed the quality assurance checks that had been made by doing a subset of simultaneous measurements comparing the Fox flow meters to the BHFS.

Unfortunately, the failure of the authors to disclose the test I conducted invalidates the Allen et al. (2014) data set, because they specifically suppressed that independent testing showed the performance of their faulty meter was much worse than they reported in their supplementary information. Moreover, beyond this failure to report the March 18, 2014, flow meter test, there are additional troubling questions.

First, it seems inconceivable that any researcher, once shown by independent tests that an instrument was giving incorrect results, would not immediately test that instrument themselves and immediately institute more rigorous calibration checks of the instruments. However, this is what is implied by Allen et al.'s (2014) supplemental information and by Allen et al.'s (2015) response to my letter to ES&T (Howard 2015a), where they state that they found the problem during their post project calibration check. Consequently, this indicates that they took no action when I demonstrated that one Fox flow meter was reading far too low.

If this is the case, then the failure to immediately investigate this problem and to implement improved calibration checks indicates a complete disregard for quality assurance, and provides further evidence that the data set should not be relied upon.

However, it seems more likely that the authors did in fact investigate the problem and conducted their own tests of the Fox flow meter immediately after the March 18, 2014, tests, but did not disclose that they had done this. If so, this raises the troubling possibility that the authors may have then tried to correct the problem by cleaning the meter, but did not disclose that they had done that. This would explain why the meter performance improved between the March 18, 2014, test and the UT post project calibration test. (It is also possible that the meter performance simply varied greatly over time, but this would be another indication of poor data quality.) If the authors cleaned Fox flow meter A but did disclose this fact, and then went on to claim that the post project calibration was representative of the meter performance from the point they supposedly identified where the problem occurred, then this would be an additional fraud.

So the key questions for the EPA OIG and the editor of ES&T to ask regarding this issue are:

1) Did the authors of Allen et al. (2014) really not do any further investigation of the Fox flow meter problem after it was identified on March 18, 2014, but actually waited until the end of the project to do any other calibration checks?
2) If this is not the case, and the UT team actually did test their Fox flow meters immediately after the March 18, 2014 test, did the UT team also clean or adjust Fox flow meter A in any way to try to correct the problem, so that in fact the post project calibration check is not representative of the meter performance?

There are also serious questions about how the authors identified when they thought the meter calibration problem started during their field program. Because they did not conduct any routine calibration checks, there was no way to identify when this problem occurred in real time. Their solution was to compare the subset of 29 BHFS measurements that were made simultaneously with the 333 Fox flow meter measurements.

In Allen et al. (2014) the authors state, "Because we were making measurements using both the UT HiFlow sampler and the flow meters for a subset of controllers in the field, we were able to identify the site at which a step change occurred in the flow measurement performance of the Fox A meter, due to deposits on the thermal conductivity sensor. We applied a correction factor, based on pre- and post-study testing done in our laboratory, to the flow rate."

There are three critical problems with this approach. First, it assumes that the performance of the meter would remain constant once the problem occurred, and it's clear from the difference in response during the March 18, 2014, test and the post project calibration that this wasn't the case.

Second, the authors say they identified a step change in the meter response between meter measurements on subsequent days using the BHFS measurements. This would indicate that the change was equal to or greater than the decrease in response seen when they did the post project calibration, which was a decrease of 0.34, meaning that post project the meter read only 0.66 of the correct response. However, as seen in Figure 1, two thirds of the measurements made by Fox Meter A that the UT team flagged for correction read less than 0.66 of the BHFS measurements, and most were substantially worse than this. Consequently, it would not be possible based on these data for the authors to know at which of these times – if any – the meter became dirty. There is simply far too much uncertainty in these comparisons.

The third (and most troubling) issue with how the authors tried to identify where the meter problem occurred centers on how unlikely it is that the problem occurred where they say it did. Again, the key issue is that the authors state that the problem was identified by a step change in the meter performance that occurred in between two back-to-back meter tests that each had a BHFS measurement as well.

Because the authors pinpointed that the meter problem occurred specifically in between two measurements that each had BHFS measurements as well, they were able to implement their post project calibration correction without eliminating any data. In contrast, if the meter problem had occurred at a point in the data collection when a BHFS measurement hadn't been made simultaneously, then some amount of data would have had to be eliminated.

A thought experiment may make this clearer. If there were a corresponding BHFS measurement for every Fox flow meter measurement, then no matter when the Fox Meter A problem occurred, the BHFS measurement would be able to pinpoint it, assuming that the measurements made by the BHFS and Fox meters were accurate.

However, there were only 29 BHFS measurements that were made simultaneously with the 330 Fox flow meter measurements, and these BHFS measurements were not spaced evenly throughout the project. Instead, there were long periods where no BHFS measurements were made, and other periods where multiple BHFS measurements were made on a given site. For instance, no BHFS measurements were made in the Appalachia region, so if the problem had been discovered after that region had been done, all of the data collected by Fox Meter A in that region would have had to be discarded.

Since only 29 simultaneous BHFS measurements were made along with the 333 Fox flow meter measurements, this means that there was at best a 9% chance that the Fox meter problem would occur between two subsequent Fox meter measurements that also had BHFS measurements. However, as seen in Figure 2, most of the BHFS and Fox flow meter measurements are either too small or don't agree well enough (within a factor of two, since their reported correction was only 1.52) to be able to identify where this meter problem occurred. In fact, only 5 of the 333 Fox meter measurements (1.5%) are large enough and also

have BHFS measurements that agree well enough that they could be considered candidates for identifying where the meter problem occurred.

But of those five, only four were measured using Fox Meter A, and of those four, only one measurement also had another measurement immediately before it with no other measurements taken in between.

Consequently, there is only one place in this data set of 333 measurements that had all the necessary information (large enough readings, adequate agreement between the BHFS and the Fox flow meter, and back-to-back measurements with no measurements in between) that could possibly be used to identify where this meter problem occurred without the need to discard any of the Fox flow meter data. This equates to a 0.3% chance of the meter problem actually occurring just at the right spot where all these variables aligned so that no data would have to be eliminated. But that, in fact, is exactly where the authors say the meter problem occurred.

The most charitable interpretation of this unlikely scenario is that the authors did not understand how terrible their quality assurance results were, and they picked the only spot that happened to meet the requirements that they needed, even though it is clear that the BHFS measurement comparisons were far too uncertain to make such a determination.

However, given that the authors hid the existence of the March 18, 2014, test from the ES&T journal editor, reviewers, and readers, it is possible that they also manipulated data points in order to create a place in the data set that would allow them to create this scenario. It may not be possible to determine if this occurred, but it is a clear possibility.

Although I originally thought that it might be possible for the UT team to use the data from the other meter, the failure to fully disclose the Fox Meter A problem and the poor quality assurance comparisons with the BHFS measurements have since made it clear that this data set cannot be salvaged.

Figure 1.

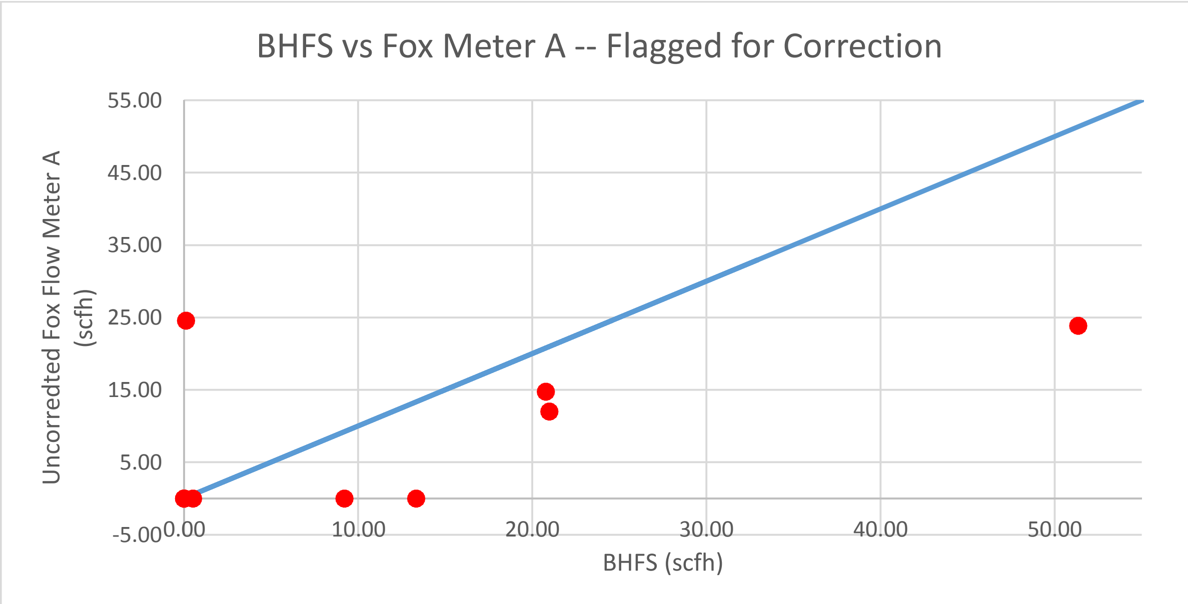
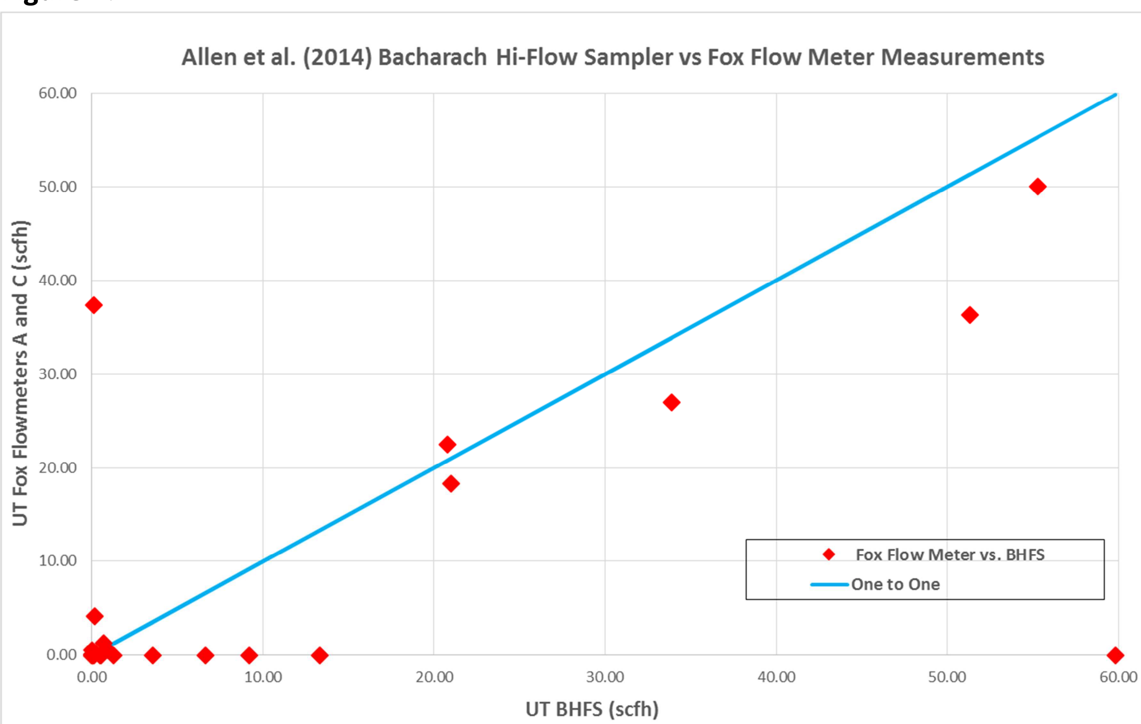


Figure 2.



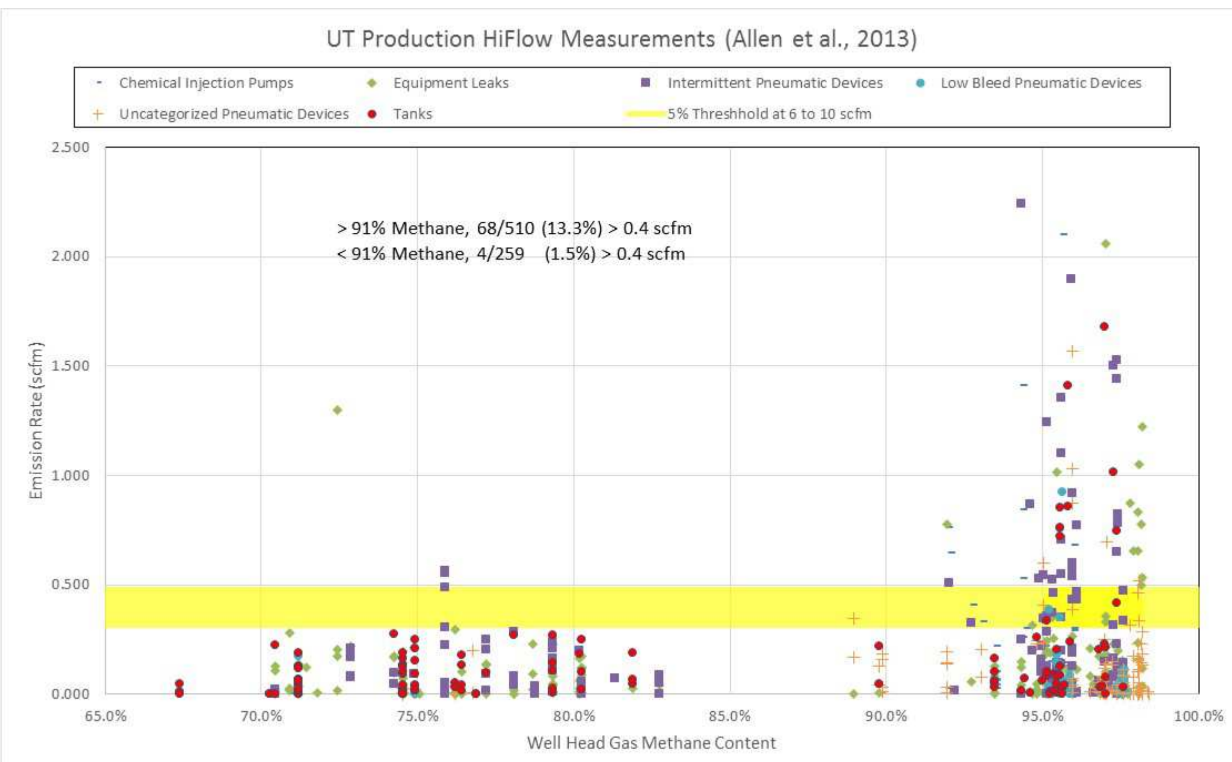
Appendix E. Tank Emissions Data

Analysis by Touché Howard

Allen et al. (2013) ("UT Phase I") collected methane emissions data using the Bacharach Hi-Flow Sampler (BHFS) for pneumatic devices, chemical injection pumps, equipment leaks, and tanks. Although they published all of these data, the only category they did not use to calculate their national emissions estimate were the tank data. This raises the possibility that the University of Texas (UT) team did not use the tank data because they were aware that the Bacharach Hi-Flow sampler was underreporting emission rates from tanks, but did not disclose that information.

We know from Howard (2015b) that all of the UT Phase I BHFS measurements were affected by sensor transition failure, which causes the BHFS to underreport emission rates when it does not transition from the low scale to the high scale. This problem appears more prevalent when the methane content of the site gas is lower (<95%). However, in the UT Phase I study, the BHFS was able to measure at least a few high emitters of pneumatic devices, chemical injection pumps, and equipment leaks at sites having gas with less than 95% methane. For tanks, however, the BHFS was not able to measure any high emitters until the site gas methane content was greater than 95.5% (Figure 1), so it appears the sensor failure was very prevalent when measuring tanks.

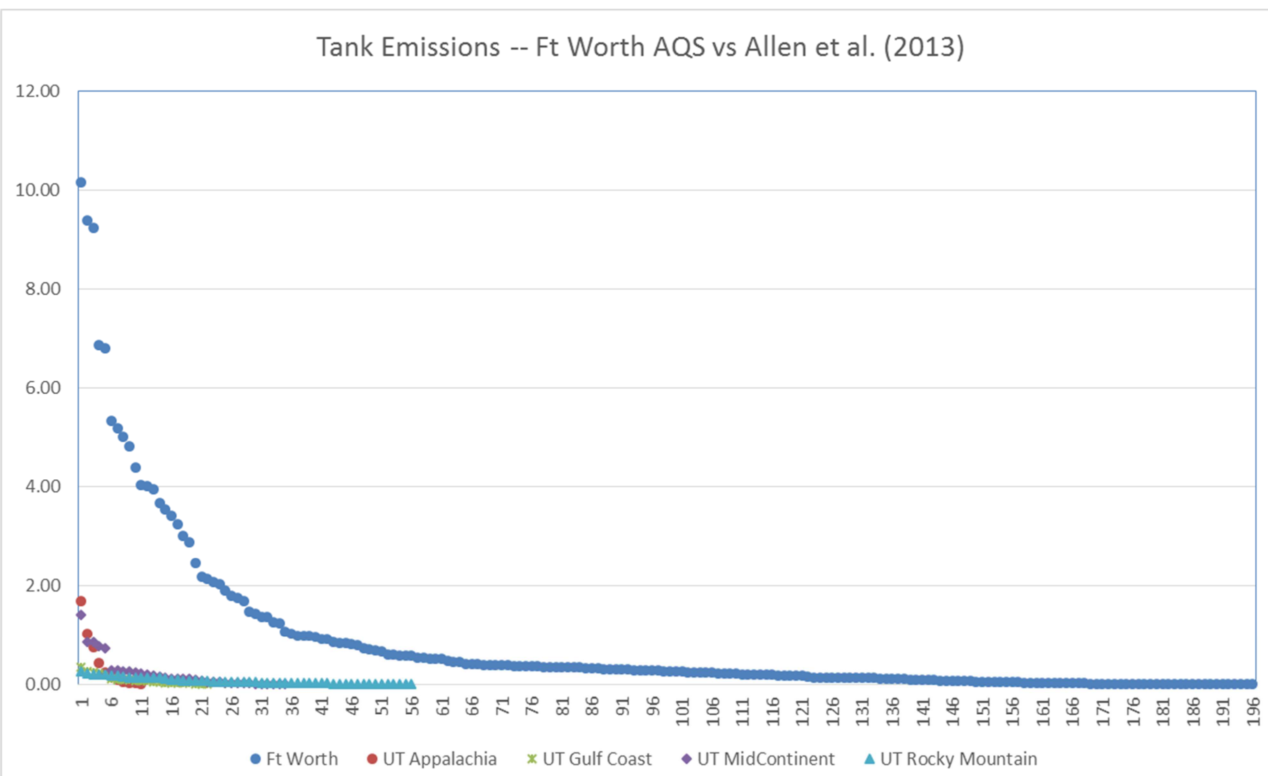
Figure 1.



This is consistent with Modrak et al. (2012), where those authors found that the BHFS consistently underreported emissions from tanks, although it was not until Howard et al. (2015) reanalyzed those data that it became apparent that this was due to sensor transition failure. (This paper was initially brought to my attention in late 2012 by Matt Harrison of URS Corporation, who was the lead consultant for the UT field team measurements.) It is also consistent with my own recent experience using a BHFS to measure emissions from tanks. Even though that sampler had new generation software and a current calibration, both of which should improve the sampler's performance (Howard et al. 2015), that BHFS repeatedly experienced sensor failure while measuring emissions from tanks, resulting in severe underreporting. Additionally, I was told by a representative of Heath Consultants (the US distributor for the Bacharach sampler) in June of 2015 that they did not recommend using the Bacharach sampler to measure tank emissions.

Finally, Figure 2 compares the UT Phase I (Allen et al. 2013) tank data to tank data gathered in the Fort Worth Air Quality study (ERG 2011), and indicates the tank emissions measured in the UT Phase I project appear to be unrealistically low, most likely due to BHFS sensor failure. Canister data collected from the outlet of the BHFS used during the Fort Worth study indicated the sampler used in that study was able to accurately measure emissions except in a few instances (Howard et al. 2015), probably because the natural gas in the Fort Worth area has a very high methane content.

Figure 2.



Because the Appalachia region measured by UT Phase I (Allen et al. 2013) also had a very high methane content in the natural gas (generally greater than 95% methane), it would be expected that the BHFS might still make accurate measurements of tank emissions in that region. This appears to have been the case, since 27% of the tank measurements that UT made in Appalachia exceed 0.4 scfm (standard cubic feet/minute), similar to the 31% of the tank measurements in the Fort Worth study that exceed 0.5 scfm. This threshold of 0.4 scfm is the emission rate above which the BHFS must transition from its low scale to its high scale to make accurate measurements, so it appears that a similar number of successful transitions occurred in both the UT Appalachia measurements and the Fort Worth measurements. However, only 14% of the UT measurements in the Midcontinent region and none of the measurements in the Gulf Coast or Rocky Mountain regions exceeded this threshold, indicating that the measurements in these regions (which had lower methane content in the site gas) were affected by sensor transition failure. (Note: if measurements were made in the Rocky Mountain region at the outlet of emission controls, then it would be expected that those measurements would be lower.)

This threshold of 0.4 scfm also represents an emission rate range for tank emissions where the emissions become noticeable due to smell and the shadows cast by the emission plume. Based on personal experience, tank emission rates greater than 1 scfm become very obvious, and both the Fort Worth data and the UT Appalachia data indicate that approximately 18% of tank emission rates would be greater than 1 scfm (again, this might be reduced somewhat by controls in the Rocky Mountain region).

Consequently, it seems odd that the UT team could make 124 measurements of tank emissions using the BHFS without noticing that it wasn't working well, and raises the possibility that the reason they didn't use those data was because they knew the sampler was underreporting emissions from tanks, even if they didn't know at the time that the problem was sensor transition failure.

The supplementary information from Allen et al. (2013) gives two reasons for not using the tank data. The first was:

"Emissions for tanks were not examined because access to the multiple potential leak sites on tanks would have required a lift at each site, severely limiting the number of sites that could have been visited." SI, page S-25.

Although that's true, the UT teams were still able to make 124 tank measurements, and 68 of those were outside of the Rocky Mountain region, where some tank vents may have gone to combustors to reduce emissions. It's not clear if they used the BHFS to measure emissions from combustors since that exhaust stream might be too hot, but if they did, those data could also be used.

They also state in Table S6-1:

Emissions from these tanks, while a potentially large source, are considered well defined and known, with working models and equations of state. Therefore these were not a primary study target, but were measured in some opportunistic cases.

Unfortunately, in contrast to their statement above, emissions from tanks are not well defined or easily modeled. Tank emissions are not caused solely by dissolved methane coming out of the liquids in the tanks, but are also due to leaking inlet valves and other episodic events, such as thief hatches (access ports for sampling) leaking or being left open, or leaking pressure relief valves.

The UT Phase I data themselves show that tank models are uncertain. They used tank models to estimate emissions for the 20 sites at which they also did downwind tracer emission measurements. There is only enough information to compare their modeled tank emissions to their actual measured tank emissions at 8 of those sites, but for those 8 sites, the measured emissions are more than a factor of ten larger than the modeled emissions, so clearly the models are not accurate.

Additionally, based on the tank modeling they did at the subset of 20 sites, tank emissions would comprise approximately 50% of the total site emissions, whereas the other categories they measured by BHFS (pneumatic devices, chemical injection pumps, and equipment leaks) would comprise the other 50% of emissions. This means that tanks could by far be the most dominant methane source at production sites in routine operation.

A recent study published by EDF (Lyon et al. 2016) in fact confirms this, where helicopter surveys found that 92% of the large emitters at production sites are from tanks.

Consequently, UT had a large data set of tank measurements, and although not all the tanks were measured, this would not prevent them from using the measurements they did make to calculate emission factors (average emission rates). That’s how the pneumatic device data were used – not all the pneumatic devices at sites were measured, but the UT team still used those data to calculate average emission factors. And although tank emissions can be highly variable due to unpredictable events, that’s just as true for the pneumatic devices, and makes the use of real data all the more important.

Furthermore, the UT team could have also used their tank data to evaluate current tank models, which would have been a valuable research topic on its own.

In summary, UT collected substantial data on tank emissions during Phase I (Allen et al. 2013) but didn’t use it, even though this data set might be one of the most extensive data sets available for tank emissions. It’s clear that tank models don’t work well and that tanks might by far be the most dominant source of methane emissions at well sites. At the same time, all indications are that the BHFS was experiencing widespread sensor failure while used by the UT

team to make these measurements, and it seems likely that the UT team would have encountered tank emissions large enough that this sensor failure would be obvious.

Additionally, in an August 11, 2014 email, Dave Allen stated the following to me:

Note that the tanks data were included in the data set for completeness and transparency, but since we did not analyze them, they did not go through the same level of quality assurance as the other data. We do not suggest using those data in any analyses.

I was surprised for him to say that for two reasons. First, even though they didn't use the data for calculating their national emission inventory, they did publish it, and without any qualification – nothing in Allen et al. (2013) suggests any problems with the tank data. Second, Dave Allen knew I had been working with his data set for almost a year at that point, and this is the first time he'd ever said anything about not using the tank data.

Unfortunately, the UT teams' reluctance to use their tank data, followed by Dave Allen's insistence that the UT Phase I tank data should not be used for any purpose, raises the question of whether he and his team knew that the BHFS was underreporting tank emission rates during their Phase I measurement program before they published those data in September of 2013. If so, the implications are:

1) Dr. Allen published data on tank emissions that he knew were too low.
2) Dr. Allen has known since 2013 that the BHFS underreports tank emissions. Even if they didn't understand at that time that the problem was sensor transition failure, Dave Allen should have reported the problem to the EPA since the BHFS is specified as a measurement method for tanks under EPA Subpart W for transmission sites, and he was chair of the EPA Science Advisory Board at the time.
3) Once I reported to Dr. Allen (initially in October of 2013) that I had seen sensor failure in the BHFS that caused the sampler to underreport emissions, and that it seemed clear this problem had affected his Phase I (Allen et al. 2013) data, he and Matt Harrison would have immediately recognized that this same problem was the cause of underreporting in their tank data. In that case, they've known since at least October 2013 that I was correct that the BHFS sensor failure affected their data set and that problems with the BHFS are in fact widespread, but have tried continuously to cover it up.

If they knew the BHFS was underreporting tank emissions, this problem might have been discussed – even in emails – by several people throughout the project, especially when the problem was first noticed. If UT did know early on that there were problems with the BHFS underreporting tank emissions, there might be sufficient evidence to establish that fact.

APPENDIX F. Seven States Pushing EPA to Review Methane Emissions

In December 2012, New York Attorney General Eric T. Schneiderman and a coalition of seven states (CT, DE, MD, MA, NY, RI and VT) notified the EPA of their intent to sue the EPA for failing to address methane emissions from the oil and gas industry (NY AG 2012), as these emissions contribute substantially to climate change. Schneiderman noted that rules must cover all *existing* sources, not just new wells, and that affordable methods for controlling methane emissions are available.

In January 2015, Attorney General Schneiderman issued a follow-up press release applauding EPA's decision to address methane emissions from new wells, again noting that the EPA must also act on existing wells and on-site equipment, which account for the vast majority of emissions (NY AG 2015). Attorney General Schneiderman's coalition filed comments on EPA white papers advocating for the direct regulation of methane from both new and existing oil and gas development and delivery equipment, and held the filing of its lawsuit in abeyance pending EPA's actions.

In December 2015, Mr. Schneiderman and attorneys general from Massachusetts, Oregon, Rhode Island and Vermont filed a notice with EPA, again urging the EPA to cover methane emissions from existing (not just new) oil and gas equipment, asserting that the Clean Air Act requires EPA to regulate these emissions (Schneiderman et al. 2015).

In March 2016, in conjunction with a meeting between President Obama and Canadian Prime Minister Justin Trudeau discussing how to reduce methane emissions, the EPA announced it would limit emissions from *existing* oil and gas facilities (Page 2016). EPA Administrator Gina McCarthy said the agency will start work immediately on the rules, with the first step being to ensure that data on methane emissions are accurate. McCarthy noted that the oil and gas sector is "complex, with hundreds of thousands" of emissions sources.

In April 2016, a coalition of 12 mayors from across the U.S., including Chicago, Los Angeles, Denver and New York, asked President Obama to address the issue of leaking methane from existing oil and gas production sites (Garcetti et al. 2016).

Cornell University

Department of Ecology and Evolutionary Biology

February 8, 2016

To whom it may concern:

As an expert on methane emissions from the oil and gas industry, I write to endorse the findings of Touche Howard as laid out in two peer-reviewed papers he published in 2015:

> Howard T, Ferrarab TW, Townsend-Small A. Sensor transition failure in the high flow sampler: Implications for methane emission inventories of natural gas infrastructure. *J Air Waste Manag Assoc.* 2015; 65: 856-652.
>
> Howard T. University of Texas study underestimates national methane emissions inventory at natural gas production sites due to instrument sensor failure. *Energy Sci Eng.* 2015; first published online: 4 Aug 2015, DOI: 10.1002/ese3.81

These papers are written with great care and precision. I have prominently cited both in my review paper also published in 2015:

> Howarth, R.W. 2015. Perspectives on air emissions of methane and climatic warming risk from hydraulic fracturing and shale-gas development: Implications for policy. *Energy & Emission Control Technologies* 3: 45-54.

I have extensive experience in assessing the quality and reliability of scientific papers, shown in part by my 22 years of experience as Editor-in-Chief of two peer-reviewed journals, *Biogeochemistry* and *Limnology & Oceanography*. Please feel free to contact me for further information on my background or on my evaluation of the work of Touche Howard.

Sincerely,

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David R. Atkinson Professor of Ecology and Environmental Biology

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Appendix H. Vita of Touché Howard

Touché Howard

Education

B.S. Chemical Engineering, University of Idaho, 1984.

M.S. Environmental Engineering, Washington State University, 1991. Specialization in air pollution emissions and transport.

Experience

Special Projects Manager, Indaco, Inc.
Pullman, WA/ Fayetteville, NC/Durham, NC (1988 – present)

Mr. Howard is the inventor of the Hi-Flow Sampler (US Patent RE37,403) and the developer of the Vent-Bag™ , both of which are used to measure natural gas leak rates and are measurement methods approved under the EPA Mandatory Reporting Rule (MRR) for Greenhouse Gases for natural gas compressor stations and tanks. Mr. Howard has also served as a project manager and trainer for fugitive emission measurement and management programs since 1989. In this capacity, he has conducted measurement and training programs at over five hundred natural gas facilities throughout North America, Europe, and the Former Soviet Union. He has also assisted clients in submitting comments to the EPA during rulemaking periods. Mr. Howard recently provided instrumentation, training, field measurements, and analysis for a nationwide methane emissions measurement program focused on above and below ground leakage from natural gas distribution systems. Representative projects include:

- Nationwide leak measurements at natural gas distribution systems conducted in cooperation with 15 natural gas distribution companies (Sponsor: Environmental Defense Fund/Private Clients).
- Leak measurements from abandoned oil and gas wells (Sponsor: Environmental Defense Fund)
- Leak measurements at over 200 natural gas compressor stations in the United States (Sponsors: US EPA/GRI/Private Clients).
- Measurement of trends in leak rates at natural gas compressor stations and metering and regulating stations (Sponsors: PRCI/GRI/US EPA).
- Leak measurements and training using the Hi-Flow sampler at natural gas compressor stations and metering and regulating stations in Russia (Sponsor: US EPA and private clients).
- Leak measurements and training using the Hi-Flow sampler at natural gas compressor stations and metering and regulating stations in Ukraine (Sponsors: US DOE, US AID, and private clients).
- Leak measurements and training using the Hi-Flow sampler at metering and regulating stations in Ukraine (Sponsors: Private Clients).
- Leak measurements and training at natural gas compressor stations and from underground pipelines in Kyrgyzstan, Kazakhstan, and Uzbekistan (Sponsor: European Commission).

- Development of a unified leak measurement data base integrating data from six different companies with over 7000 measurements from approximately 100 sites (Sponsor: Private clients).
- Fugitive air emissions measurements from over fifty Arctic oil production facilities (Sponsors: BP/ARCO).
- Risk evaluation of sour gas well head accidents using field tracer techniques (Sponsor: Energy Resources Conservation Board, Alberta, Canada)
- Evaluation of chemical emission models for area sources using field tracer techniques (Sponsor: American Petroleum Institute).
- Preparation of monitoring plans for EPA GHG MRR programs.
- Quality assurance reviews of EPA MRR leak measurement data.

Research Assistant
Lab for Atmospheric Research, Washington State University – Pullman, WA (1984 – 1987)

- Operation of WSU Clean Air Facility at Palmer Station, Antarctica for a one year period monitoring remote greenhouse gases and ozone depleting chemicals.
- Development of SF6 measurement instrumentation
- Assisted in building ventilation studies, wind tunnel simulations, and dispersion measurements at Arctic oil facilities.
- Measurement of emissions from refinery wastewater facilities.

Patents, Licenses, and Certifications

- US Patent RE37,403 – “A High Flow Sampler for Leak Measurements at Process Components”
- Registered professional engineer (1993-2012)
- Firefighter I and II (State of North Carolina, NFPA 1001 1997)
- Rescue Technician – NFPA 1006
- Emergency Medical Technician – Intermediate (State of North Carolina)
- Hazardous Material Technician Level II (NFPA 472 1997)
- Swift Water Rescue Technician -- Advanced (NFPA 1670)
- Urban Search and Rescue -- Structural Collapse Rescue Technician

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