

## **Review comments for "Test Procedure for Determining Annual Flash Emission Rate of Methane from Crude Oil, Condensate, and Produced Water"**

Prepared by Albert Presto, PhD  
Assistant Research Professor  
Department of Mechanical Engineering  
Center for Atmospheric Particle Studies  
Carnegie Mellon University

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This procedure describes methods for determining flashing emissions (releases of volatile gases, particularly methane, entrained in liquids) from oil, condensate, and produced water associated with oil and natural gas development. Emissions estimates are required to determine appropriate actions based on the proposed greenhouse gas emissions standards for oil and natural gas facilities in California.

Briefly, the procedure has three major steps: (1) sample collection on-site, (2) sample analysis to determine gas/liquid ratios and methane content of flashed vapors, and (3) estimation of annual emissions from the gas/liquid ratio, annual liquids production, and operating days per year. All sampling and analysis steps reference test procedures published by ASTM, U.S. EPA, and GPA (Gas Processors Association). Overall, the proposed method provides a reasonable framework for estimating greenhouse gas emissions from flashing.

This review was performed in response to an August 10, 2016 California Air Resources Board request for review signed by Elizabeth Scheehle, Chief, Oil and Gas and GHG Mitigation Branch placed to Gerald Bowes, Manager of the CalEPA Scientific Peer Review Program. Dr. Bowes invited my participation in the peer review process in a letter dated August 22, 2016. In particular, it is Attachment 2 of the August 10 letter which is the focus for reviewers, and which contains the conclusions to be reviewed. Attachment 2 describes the scientific basis of the test procedures for the proposed rule.

My suitability to perform this review, and my perspective in making comments, relies primarily on my recent research. My research group has conducted several projects to measure methane emissions from oil and gas facilities, with a specific focus on methods to determine facility-wide emissions of methane and other gases using mobile sampling techniques such as the tracer flux method. We have used the data collected at numerous O&G facilities to scale up our measurements to basin-wide estimates. We recently published estimates of methane emissions from natural gas wells in the Marcellus Shale in Pennsylvania and West Virginia (M. Omara et al, *Environmental Science & Technology*, 2016), and are currently expanding our analysis to include the ten largest gas basins in the continental US.

Below, I provide comments based on three specific conclusions posed to the reviewers.

Comments related to Conclusion #1: "The test procedure provides a sound approach for taking samples of oil, condensate, and produced water upstream from oil and gas production separator and tank systems." (Sections 1-9 of the test procedure and pages 78-81 of the ISOR)

1. Based on review of the attached Test Procedures, the proposed sampling methods appear appropriate.
2. The procedures outlined in Sections 1-9 should provide samples of sufficient quality to determine flashing emissions.

3. To maintain consistency with the text above it, Item 3.8 should note that flashing can occur both when pressure falls or when temperature increases.
4. Steps 9.6 and 9.7 both say to open valve D. This is confusing - it seems like users are supposed to open the valve twice without closing it between steps. Also, once valve C and D are both opened, sample will enter the piston sampler, even if the pressure is not equalized.
5. Should the procedure include language about the required cleanliness of double valve or piston samplers prior to sampling or describe the procedures to clean samplers between samples? GPA 2286-95 notes that samplers need to be cleaned, but it may be worthwhile to reiterate this in the test procedure document.

Comments related to Conclusion #2: "Test procedure provides a sound approach for preparing and analyzing samples of oil, condensate, and produced water. . ." (Sections 10, 12-14, and test method files)

1. The relevant sections of the test procedure and attached test methods seem appropriate to achieve the goals of the sample analysis.
2. It may be worthwhile to mention the information in item 10.1(b) (duplicate sample collection) in the preceding sections (8 and 9) describing sample collection. Different personnel may read different, and limited, portions of the test procedure, and it may help personnel charged with collecting samples to have the duplicate sample criteria stated explicitly along with sampling procedures.
3. 10.2(d) and other references to sample temperature. While it is likely that under most conditions the sample will be collected at temperatures above typical room temperature, situations may arise when the sample temperature is below typical room temperature. The procedure should outline what steps to if this is the case.
4. 10.3(d) 0.2 cubic feet per barrel of liquid are very inconvenient units, especially since samples are collected in milliliters (and I presume most lab technicians will work in milliliters in the laboratory). It would be useful to note typical gas volumes. E.g., for a sample with a 500 ml total volume, the gas volume must be at least 24 ml (assuming the same temperature and pressure for the liquid and gas and 31.5 gallons per barrel).
5. 12.1.a - what are storage requirements for the sketch? Hard copy, electronic, or both? Please specify.

Comments related to Conclusion #3: "The test procedure provides a sound approach for calculating the emissions of methane and various other pollutants from flashed gases from oil and gas production. . ." (Section 11)

1. Annual flash emissions are estimated by collecting a sample, determining the gas/oil ratio, and then applying that ratio across the entire year. It seems that the annual emissions are therefore calculated from a single sample collected somewhere during the course of a year. This may create some uncertainty in the estimate of annual emissions, as described below.
2. The calculations used to determine the annual emission rate (Equations 1-3 in Section 11) are all appropriate.
3. It is difficult to tell if the approach outlined in the method represents an upper or lower bound estimate for annual emissions. It will depend in large part on whether or not the sample was collected on a day with "normal" operations. For example, how the sampling temperature compares to typical temperatures over the year.
4. The body of research surrounding methane emissions from O&G consistently shows the importance of super emitters. This is sometimes referred to as a fat-tail problem. Most facilities have low emissions, and a small number of facilities have large emissions. These super emitters dominate the overall emissions. For example, in many cases 10% or 20% of the sites sampled

contribute more than 50% of the total emissions. A key strategy in reducing overall emissions is to target super emitters. Recent research from the Environmental Defense Fund and other groups suggests that super emitters are the result of unwanted process conditions – tanks with relief valves stuck open or other major leaks that can be remedied through maintenance. One complication regarding super emitters is whether or not super emitting sites have consistently high emissions (“once a super emitter, always a super emitter”) or if the large emissions are episodic.

Thus questions to consider regarding the proposed test method are (i) whether or not super emitters will be identified, and (ii) if emissions from sites identified as super emitters will be consistently high, or if the emissions will change over time. The answer to the first question is likely “yes.” The second question is more difficult, as there is uncertainty in what creates super emitters, and all of the contributing variables are not known. In my opinion, one potential way to help flag the potential for super emitters will be to note how variables (temperature, production volume) on the day of sampling compare to typical annual values.

5. A second possibility for verifying super emitters would be to require follow up sampling if the calculated annual emissions are above a certain threshold. E.g., sites with the top 5% or 10% of calculated emission rates (or gas/oil ratios, which is used to calculate annual emissions) could be retested soon after the initial test in order to determine if the emissions are consistently high.
6. The method employed here assumes that: (i) the analyzed sample is representative of produced liquids on the day of sampling, (ii) that the same composition of liquids (water and oil) and flashing vapors persist over the course of the year, and (iii) that operating and ambient conditions on the day of sampling are representative of the entire year. The first assumption can be checked by comparing two separate samples collected on the same day. Verifying assumption (ii) would require collecting samples on multiple days or at different times of year. It is not clear if collecting multiple samples each year is within the scope of the proposed rules. The third assumption can be verified by comparing operating conditions on the day of sampling to typical day-to-day conditions, and by comparing ambient outdoor temperature on the sampling date to historical meteorological data.
7. It may be worthwhile to implement a system to “flag” data or sampling dates that fall outside of the typical range, e.g., if samples were collected on an abnormally hot or cold day.
8. The annual flash emissions estimate also seems to tacitly assume that all flashed vapors are vented to the atmosphere (e.g., that no vapor recovery or destruction systems are in place). Assuming all flashed vapors are released to the atmosphere would help push the estimated emissions towards the upper limit, though that estimate may be tempered by some of the other uncertainties listed above. If a flashed vapor recovery system is in place, the proposed method would likely over estimate emissions. For sites with flashed vapor recovery or vapor destruction systems, it may be worthwhile to calculate the potential emissions using the proposed method, as well as the expected emissions, where the latter assumes a recovery or destruction efficiency.