June 20, 2011

Russ Nettles
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Submitted electronically to siprules@tceq.texas.gov

Re:2010 TCEQ Flare Study Project Draft Final Report (TCEQ PGA No. 582-8-862-45-FY09-04, Tracking No. 2008-81)

Dear Mr. Nettles:

The American Petroleum Institute (API), the National Petrochemical and Refiners Association (NPRA), and the American Chemistry Council (ACC) appreciate the opportunity to provide comments on the 2011 TCEQ Flare Study Project Draft Final Report.

API, NPRA, and ACC are trade associations that are involved with all aspects of the oil, natural gas, and chemical industries. Our members, many located in Texas, make extensive use of flares to assure the safety of our operations and to control emissions.

Overall we commend this effort. This study project was well executed by TCEQ's University of Texas contractor and numerous subcontractors and adds valuable information to the flare literature. We believe the report will be an important source of information as flare science continues to develop. Therefore, it is critical that the report be as clear and objective as possible.

Our overarching comments are set forth immediately below. Attached to this letter are additional general and our specific comments on the Draft Final Report, including the associated Draft Final Executive Summary.

- We recommend the limitations of the study be clearly noted in the front of the report and summarized in the executive summary so that broad generalizations and unwarranted extrapolations are not made. For instance, the following variables were not addressed in the study or the data was inadequate to allow conclusions to be drawn:
    - the impact of wind;
    - the impact of other flare gas compositions, in particular
        - the markedly differing effects of dilution by nitrogen vs. carbon dioxide, and

  - the behavior of hydrogen-bearing mixtures, which are recognized in 40 CFR 60.18 and other sources as behaving entirely differently from hydrocarbon-only mixtures[1];

- the impact of other flare designs[2], particularly different steam injection designs and the impact of other combinations of flare head exit velocity and diameter, and
- the limitations associated with scale-up to larger diameter flares.

Similarly, the testing contained some major limitations in selected configurations. Some of these limitations were reviewed in the draft executive summary (e.g., page 5), but are not noted in the report. A discussion of the testing limitations should be included in the final report.

- The executive summary is not useful in its current form. The executive summary is 30 pages in length, as compared to a total report of 100 pages. Such an extensive executive summary will cause the major study conclusions to be deemphasized (in this case they are buried on page 29) and will result in differences in conclusions, tone, and impressions between the summary and the report. We strongly recommend a short (e.g., 1-3 pages) executive summary be developed in place of the draft summary.

  Page 29 of the draft should be the basis for the final executive summary and only a minimal number of figures should be included (probably only ES-9b and 10b - Destruction and Recovery Efficiency (DRE) vs. Combustion Zone Net Heating Value (NHV_{czg})). The balance of the draft final executive summary and the other figures should be included in the report itself or, as is true for most of the material, simply dropped because they are already included in the body of the report. Since we do not know if this suggestion will be adopted and because the draft final executive summary parallels the report itself, we have made specific comments on it in the attachment. Those comments should be taken as also applying to the similar content in the report itself, even where we do not specifically reference both.

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[1] The vent gas compositions tested are not representative of most flares. In particular, the benefit of hydrogen on flare CE and DRE was not tested or quantified. Hydrogen, due to its high combustion efficiency and rate, improves the CE of other constituents in the vent gas.
See for example: Demonstration of Hydrogen Use in Steam- and Air-Assisted Flares, Alexis McKittrick, Combustion R&D, Praxair, Inc., June 9, 2009;
http://www.afrc.net/assets/fordownload/flareforum/2009_boston/demonstration_of_hydrogen_use_in_steam-and_air-assisted_fla.pdf; Flame Stability Limits and Hydrocarbon Destruction Efficiencies of Flares Burning Waste Streams Containing Hydrogen and Inert Gases; Peter M. Walsh, GE – Energy and Environmental Research Corporation, et al, November 6, 2002;
http://www.afrc.net/assets/fordownload/flareforum/2002_houston/flame_stability_limits_and_hydrocarbon_destruction_efficienc.pdf

[2] For example, annular elevated flare heads, multipoint elevated flare heads, high-pressure sonic elevated flare heads, low-pressure steam nozzles, and high-pressure sonic steam nozzles.

- The report section on “conventional” emissions estimates (Chapter 9) and the equivalent section of the draft executive summary are likely to be misused, represent an inaccurate comparison, and are outside the scope of the research effort and should be deleted. It is self-evident that if an emissions estimate assumes a specific DRE and if that DRE is not in actuality met, then the emissions estimate will be off by the amount that the assumption is in error. It is also unreasonable and misleading to compare annual average DRE’s (used for normal emission estimating), with short term DRE’s measured for operating conditions for which the researchers have no data on which to base assumptions about their prevalence or duration in the current population of real world flares. The operating conditions for which low DRE’s were identified in the study are not typical and thus cannot be compared to the annual average values used for emission estimating.

  There is as much analysis, if not more, on this one point than any other aspect of this study and yet evaluating emission estimating protocols is not listed as a primary objective of the study nor was that a factor in the study design. While perhaps interesting to explore, it is outside the scope of this research effort. Furthermore, listing "typical hydrocarbons found in plume" does not give perspective on the quantities or even relatives amounts of those species or consider whether sources account for these emissions in developing flare emission estimates (the discussion seems to assume they do not, though no data is presented to support such an assumption). It seems that the content of pages 26 through 28 of the executive summary and Chapter 9 of the report is unnecessary, generally unsupported by data, and outside the bounds of the study objectives. These discussions certainly do not belong in a “research” report.

- The steam-to-vent gas conclusions in the report could be misinterpreted to imply that flares should be operated with less steam than the manufacturer recommendation. Such a conclusion could compromise the mechanical integrity of the flare and the flare tip. The report should make it very clear that minimum steam levels needed to assure flare integrity should always be maintained.

- We recommend some additional data analysis be developed and incorporated into the report.
  - Trace species emissions should be cross-plotted with combustion efficiency (CE), DRE, and CZ-NHV to test for any correlation.
  - Methane and propylene emissions should be plotted vs. various correlating variables (e.g., CZ-NHV) to determine if the combustion efficiency of each primary species in the vent gas differs.
  - A cross-plot of DRE and CE should be provided.

    From a VOC emissions perspective, DRE is more important than CE. However, for an operating flare, and assuming that PFTIR is shown accurate for all vent gas compositions, only PFTIR can be used to provide an estimate of flare emissions. Since PFTIR can only provide CE (not DRE), one needs to be able to estimate DRE from CE based upon extractive measurements. If no correlation exists, then the cross-plots will also indicate this and the use of CE for predicting flare emissions will be called into question.

- Particulate matter (PM) data at the incipient smoke point was collected during this test program. That data should be included in the report following an opportunity for public review and comment. If the report needs to be issued, but the PM data is not available, the report should note that the PM data will be released for review and comment when the data is available.

If you have questions or would like amplification on any points, please contact Matt Todd at (202) 682-8176.

Sincerely,

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American Petroleum Institute (API),
National Petrochemical and Refiners Association (NPRA), and
American Chemistry Council (ACC)

Comments on TCEQ Flare Study Project Draft Final Report and Executive Summary

General Comments on Draft Report and Executive Summary (in addition to those provided in the cover letter.)

- It is important to note that this study was limited in its scope of parametric variation. Thus we recommend 'comprehensive' be removed from the title of study. The testing was well-executed, but a "comprehensive" experimental full-scale flare emissions study project is a practical impossibility.

- The TCEQ preliminary results presentation had a set of statistics that helped them derive an estimate of "typical" flare sizes[3]. We recommend this information be included in Section 2 of the report, to add perspective on the choice of flare sizes and tips tested.

- There is virtually no mention in the report of the uncertainty in the flow measurements. Realizing that flow is used in calculation of x-axis parameters (S/VG, Steam, NHV_{czg}), it's important to mention the uncertainty in these values as it enters into the scatter of the data seen in the plots.

- Rank ordering data from various methods by extractive measurements, gives the impression that the extractive measurements are the correct values. Similar ranks (and plots) could be made by rank ordering PFTIR, AFTIR, or Telops data. For the precision discussion, it probably makes sense to illustrate the relative standard deviation of each method separately, rather than arbitrarily selecting one method as the base case. This allows independent comparison of the data.

  Given the standard error associated with the determination of each compound used in the calculation of combustion efficiency (CE), a statistical roll-up of the uncertainty associated with the determination of each component analyzed into the total analytical uncertainty of the combustion efficiency measurement should be provided. This would allow one to assess the magnitude of the analytical uncertainty in the combustion efficiency measurement versus the total uncertainty observed in the data (process + analytical uncertainty).

[3]http://www.tceq.texas.gov/assets/public/implementation/air/rules/Flare/Presentation_2010FlareStudy_PreliminaryResults_Accessible.pdf

An error assessment, particularly as a function of decreasing CE, is needed for the extractive measurements in order to put the comparison into perspective. It would seem that there is decreasing accuracy with decreasing CE. Is that true for all measurements or a particular technique? What is the standard deviation of the individual measurements across repetition? Rank ordering in terms of CE rather than on a measurement by measurement basis seams to disadvantage the comparison.

- The estimated error in the DRE and CE calculations is important throughout the report and conclusions should be tested against the impact of the estimated error. For example, on page 90 of the draft, the difference between 95.9% and 95.0% DRE is concluded to indicate a slight adverse affect. It is unclear however if 0.9% is discernable as an adverse affect given the error estimates.

- Since there is no gold standard for this type of testing, a discussion of the accuracy of the data is difficult. However, we suggest that since numerous methods were used to analyze the DRE and CE data, that there should be some discussion of the likely “accuracy” of the DRE/CE of the data ($\pm$ %).

- Blind testing seems to support the validity of IMAACS PFTIR (if used properly) for remote measurement of CE. Comparison of this methodology to other tests is critical to establish any possible biases due to the low elevations of the flare tested at JZ. This comparison should be provided in the report.

- While the discussion of combustion by-products is important, the current discussion mentions only what compounds were consistently detected but nothing about the relative concentration of those by-products or their significance versus fuel stripping (i.e., the fuel, in this case waste gas, that is stripped away from the combustion zone and those remains unburned). Combustion is complex and clearly non-fuel components can both be manufactured in the flame as well as burn out in the flame. The report and any discussion in the executive summary should not only discuss that by-products are formed, but also assess their relative importance in the overall carbon balance. While it is important to know that these components can form, it is equally important to explain that they do not represent a significant portion of the carbon emitted. Also significant, as indicated at the June 1st report rollout, is that when operating conditions led to reduced CEs, the absolute amount of carbon going to by-products did not change (e.g., hydrocarbon byproducts remain relatively constant with drops in CE due to increased fuel stripping and CO production).

- The draft report includes numerous charts depicting DRE vs. Combustion Zone Net Heating Value (CZNHV). These charts seem to draw the conclusion that ~200 BTU/scf CZNHV is necessary for 98% DRE. This is probably true for the gases tested, but other gases and gas mixtures can have different flammability characteristics that would change this conclusion, when they are combusted. Indeed determining the flammability characteristics of complex mixtures is a challenge that warrants additional research, particularly when the mixtures include incombustible species or hydrogen, as the combustion mixing rules that apply to these situation are still an active research area[4] While recent studies and testing have made progress in this area, definitive conclusions of how to predict the flammability characteristics of complex mixtures remains an inexact science that warrants further investigation and regulatory flexibility. As new theoretical models and data become available, a working model may well be found, but it is premature to think we currently understand all the possible outcomes from the myriad of flare gas compositions that may be experienced in practice.

- The study should consider how the observed sensitivity of CEs and DREs attributed in the TCEQ study project draft report was impacted by variations in the modes of center and upper steam usage.

- The report should provide further information on use of PFTIR. The draft report provides positive feedback on the PFTIR sampling. However, PFTIR failed blind validations in the TCEQ 2004 Phase I trials. This report should acknowledge the other blind validation studies results and note the limitations on use of the PFTIR. It is quite relevant to connect the two studies and speak to enhancements or lack thereof since the 2004 set of recommendations. We would be particularly interested in understanding 1) how the spectrometer was positioned to get an accurate measure of the overall combustion and the basis for selecting that position and 2) whether an improved detector design was used in this test to improve the overall sensitivity of the measurement.

- While there is a short discussion about the impacts of wind, there is no concrete wind conclusion. If UT feels that there is insufficient data to draw specific conclusions then they should state that as a conclusion.

- We do not believe that CE plots are needed every time a DRE plot is presented. It does seem counter-intuitive that there would be cases where the CE was dramatically higher than DRE. In fact, we would have thought that DRE would always be higher than CE given that any amount of flare gas that is 100% combusted is certainly destroyed. We

[4] See, for instance "Emissions from Elevated Flares – A Survey of the Literature", Gogolek, P., et al, International Flaring Consortium, April 2010.

imagine cases of incomplete combustion where more of the flare gas is destroyed but only is converted to CO rather than to CO_2. Yet, Figures ES-14a and b show that the last point on the graph (60,000 lbs/hr of air, for example) has a DRE slightly over 65%, but a CE of over 80%. How can this be?

- Multiple mentions are made that DRE/CE > 99% cannot be achieved with flare manufacturer recommendations regarding minimum center and upper steam. As mentioned in our cover letter, it should be made clear that for safety reasons sources should not ignore the minimum steam requirements in order to achieve a 99% CE/DRE. Furthermore, in the real world, this is incorrect, since supplemental gas can be added, albeit at a cost, to adjust the gas heating value.

  It would be helpful to real world operators to test what conditions (T/D %, NHV, S/VG ratio, etc) are required to achieve 99% DRE/CE at the minimum flare manufacturer recommended steam rates.

- It would be helpful to see comparison plots of propane/propylene. Specifically, compare S7/S12, S8/S14, and S11/S13.

- We recommend that specification sheets be included in the report appendices for each tested flare.

- As a general comment, it would be helpful to add curve fits and error bars to the plots with data and to use smaller "dots" on the graphs. Similarly, for the graphs where the text discusses a specific value, draw this line on the graph. For example (page 7), "The 2,342 lb/hr vent gas flow rate was able to sustain a 99% DRE up to a S/VG=0.29". On the associated graph include a vertical line through the 99% DRE and 0.29 S/VG.

- For the air-assisted flare tests where the efficiency scale only is carried down to 84% consider incorporating a "zoom in graph" similar to those for steam flares. For the air flare tests (e.g., graphs 5-22-5-23) include corresponding charts that show the ratio described in the text as "X A/F". Showing these curves against absolute air flow rate is helpful (as has been included in the report), but it would also be valuable to see graphs of efficiency plotted versus the ratio of actual air to stoichiometric air.

- For the propane tests, it would be helpful to include graphs plotted against CZNHV as is done for the propylene tests. While propane was not part of the intended test program, having these results adds significant importance to the report, and partially addresses one of the biggest concerns with the testing - the limited fuels tested. Such graphs should include "zoomed in", efficiencies above 85% and include graphs plotted versus S/VG ratio, as was done for the propylene tests. In fact, we recommend plotting both propane and propylene on the same graphs.

- Graphs use an inconsistent descriptor for propylene, sometimes referring to it as propene. A common descriptor should be used throughout the report.

Specific Comments

Page 2: first bullet: "VOC" should be defined in its first appearance

Page 2, second bullet: The bullet says "various operating conditions, including low vent gas rates," seems to imply that there would be other conditions that were not low vent gas rates.

Page 2, third bullet: The rest of the report predominantly references back to 99% DRE - the objective and the conclusions should be consistent on that point.

Page 2, Project Scope and Design: The report says, "i.e., with diameters less than three inches" - there were a number of studies that do not fall into that range. It would be better stated, "i.e., many of which with diameters less than three inches." Additionally, it is imprecise to assume that the flare test results will be applicable to other flares. Without testing, it is inaccurate to say that results "will be applicable" to other flares. Hence, the last sentence should read ".....and the results may be applicable to these and other flare designs..." rather than "....and the results will be applicable to these and other flare designs...."

Pages 2 and 4: The fourth stated objective of the study is to "Identify and quantify the hydrocarbon species in the flare plumes visualized with passive infrared cameras." The report and summary should identify which passive infrared camera was used to identify when hydrocarbon species could be visualized in order to fulfill this objective.

Page 3: The comment should be moved to after "(ARI)." The word nominal is repeated a lot.

Page 4, Equation 2: This equation usually includes soot in the denominator (though the value is usually assumed negligible). The soot term should be included or the reason for leaving it out explained.

Page 5: The statement that the "ratio of natural gas to propylene was 1:4 by volume" should probably be modified to indicate that was the case when there was a natural gas and propylene mixture as some of the tests appear to be straight propylene. Furthermore, the information from the last paragraph on the page should be moved up regarding the variability in the LHV as it becomes more clear why 350 Btu/scf was selected. Similar to the earlier comment, what is the basis for the assumption that the range of operation for typical flow rates used in industry is less than 0.5%? Are there available statistics for this? Such a statement must be supported by data.

Page 5: Identify which department in EPA reviewed the quality assurance plan.

Page 7: Explain why was a flow rate of 0.1% capacity in the air assisted flare thought to be too low?

Page 7: The first comparison in the summary of flare tests results seems a bit unfair. The first S:VG ratio of 0.25 or less excludes any center steam. Then, the higher flow rate is cited as allowing a S:VG ratio of 0.29, but that includes center steam. Later on, it is noted that center steam has a different impact than tip steam. It would seem that the S:VG ratio between flares of different flow rates should be comparable regarding ratios of tip to center steam to be comparable.

Page 7: As the flow rates are listed as "nominal", what is the variation in actual flow rates? How was the amount of center steam applied decided?

Page 8: The ratios of center vs. tip steam change among the S3 and S4 data sets. It is unclear from the chart which is which. We presume that the red and yellow markers are those with center steam at 500 lb/hr that spanned ISP to <snuff. If so, that should be stated. If not, the red and yellow markers should be explained.

Pages 9-10: How does the conclusion that center steam acts differently than tip steam in terms of reduced combustion efficiency compare to the results shown in these two figures? The S:VG ratio of center steam as compared to tip steam is significantly different for each of these flares, yet all of the data appears to collapse given this the total S:VG ratio. Is that the suspected cause of the scatter in the plots on page 10? Perhaps it would be ideal to use separate S3 and S4 symbols in these plots.

Similarly on page 13: We would segregate the S5 and S6 data - while the center steam rates were the same, the ratio of center steam to flow was dramatically different.

Page 18, last paragraph: Explain how the CE can be higher than the DRE.

Pages 21 and 22: The DRE is less than the CE for tests S12-14 and A7. Can this be explained?

Page 23: Were the AFTIR and PFTIR CE values developed independently by IMAACs and transmitted to the TCEQ study team, or was AFTIR data used to improve PFTIR predictions? If the predicted CEs were independently developed by IMAACs, how was this verified by the TCEQ study team? Also, it would be helpful if the referenced Telops mass flow data were include in the final report.

Page 24, last paragraph of steam section: The reference to Table 10-1 should be to ES-2.

Page 25 and page 111: In the NMR footnote, “vales” should be “values.”

Page 26 and Chapter 9: The use of the word "Conventional" is not accurate in describing "prescribed" emissions estimating guidance for flares and should be dropped. If these discussions are maintained, despite our cover letter recommendation to delete them, they should be titled "Comparison of Estimated Flare Emissions with Measured Emissions," and "conventional" should be replaced with "prescribed" throughout.

Page 27 and Table 6-1: These lists of compounds need some significance/magnitude. Are they ppm? ppb? %? Without an idea of quantity, this table has no value. Certainly the values depend on the efficiency found in a particular test. You can limit the quantity of data required here by using the average of all cases with efficiency above 90%, a limitation you used to create table ES-4 and 6-2 as well.

Page 29:

> Care should be taken to be very precise regarding center steam usage. Point Number 3 is not clear that all center steam was eliminated for the S/VG = 0.25 resulting in >99% CE.
>
> We suggest Point 4 be changed to describe that the "flare performance curve of DRE vs steam assist has a narrow set of operating conditions before the steam is sufficient that the DRE falls off…"
>
> In Point 5, it seemed that TCEQ is touting a multiple of the air assist quantity of about 10 times… perhaps this is a function of discussing the DRE>99% as opposed to 98%?
>
> Bullet 6 is not a significant finding of the report and does not reflect research results. It essentially says that conventional emission estimation methods are good so long as their assumptions are good. Which is a self-evident. Bullet 6 should be deleted.
>
> Some assessment of the error in the ARI methods alone would seem fitting here, as well.

Page 45: It is difficult to follow the first paragraph on this page (continuing paragraph from page 44). It reads that it was desirable, but unachievable to increase the range to 0.5%. Therefore, the vent gas flow rates were increased to 0.25% and 0.65%. What does this mean?

Page 47, Table 3-1: In Table 3-1 some of the tests are defined as ISP to <Snuff. Snuff is defined as "Visible Flame Extinguished" at the bottom of the table. In practice the snuff point was not defined by visible or not visible flames, but rather by poor measured efficiencies. The test continued at steam rates beyond visible to measure lower efficiency points. Correct this definition and its relation to efficiency (not visible plume). For these runs also include the steam rates that were found to correlate to these limits.

Page 49: Include the results of tests S1, S2, A1, A2, as these are also very helpful in understanding the issue of flare efficiency. Do their CZHV values add up? Even if "not a full data set", these tests are valuable and should be included.

Page 49, last sentence of the first paragraph: The word "in" is missing between “included” and “the.”

Page 68: On the no center steam tests, please include a zoom in graph down to 84% efficiency (or higher).

Page 80: The statement is made that "It appears that until the CZG NHV gets above 300 Btu/scf......." However, the graphs show no data between 250 and 300, and hence one can only make reference to CEs above 250 BTU/scf. Change the CZG NHV value to 250 (from 300) in this sentence. Furthermore, the last sentence states “There is insufficient data to estimate a similar value for Test Series S7 through S11,” though it appears there is enough data to estimate a value of 240 BTU/scf.

Page 87: There are very large discrepancies between CE and DRE at low vent gas rates (e.g., red square dataset). How is this explained?

Page 125: Conclusions 1 and 3 should be combined. Conclusion 1 is a bit misleading in that DRE/CE > 99% is only achievable at the T/D % tested without any center steam. Center steam is required for long-term commercial operation, so tests without center steam appear to have limited commercial relevance.

Conclusion 2 does not appear to be new information. It should be deleted.