MEMORANDUM

TO: Flare Peer Review Panel Members

FROM: Research Triangle Institute for U.S. Environmental Protection Agency

DATE: May 1st, 2012

SUBJECT: Review of the *Parameters for Properly Designed and Operated Flares*

This memorandum provides background information and specific charge questions to the Flare Review Panel in its review of a report on parameters for properly designed and operated flares prepared by U.S. EPA's Office of Air Quality Planning and Standards (OAQPS). The report provides an examination of several factors that are important for a properly designed and operated flare. Based on the analysis provided in the report, the data suggest that over steaming on steam-assisted flares and excess aeration on air-assisted flares degrade flare performance. In addition, the data suggest that high winds and flame lift off can influence flare performance on all types of flares. This document will be the focus of review by the Flare Review Panel that must be completed by the end of the day on [INSERT DATE].

Background

In May 2005, the Ohio Environmental Protection Agency (OhioEPA) installed monitors at a school to investigate odor complaints. The monitoring showed high human health risk (i.e., hazard quotient 6.21 and cancer risk of 5 in 10,000) and the district closed the school. The school was located across the street from a chemical plant. In September 2005, the U.S. EPA Region 5 began investigating the chemical plant and determined that over steaming at the facility's steam-assisted flare was the likely cause of the ambient air issues.

In February 2010, the EPA, OhioEPA, and facility agreed to a consent decree requiring a new paradigm in flare monitoring that focuses on steam usage at the flare tip (i.e., combustion zone heating value and steam-to-vent-gas ratio). The consent decree also required Passive

Fourier Transform Infrared Spectroscopy (PFTIR) remote testing be performed. PFTIR remote sensing involves using a spectrometer positioned on the ground to view hot gases from the flare plume, which radiate spectra that are unique to each compound. Around the same time this consent decree was being drafted, the EPA Office of Enforcement and Compliance Assurance (OECA) requested testing be conducted pursuant to section 114 of the Clean Air Act on several other flaring facilities using PFTIR remote sensing technology. OECA's request included a requirement to test a range of operating conditions (including typical conditions) at each flaring facility. All of the PFTIR testing carried out through these actions and used as part of this report were performed and analyzed by a single company.

In May 2009, the Texas Commission on Environmental Quality (TCEQ) contracted with The University of Texas at Austin to conduct a comprehensive flare study project on full-scale steam- and air-assist flares at the John Zink Company flare demonstration facility in Tulsa, Oklahoma. The purpose of the project was to conduct field tests to measure flare emissions and collect process and operational data in a semi-controlled environment to determine the relationship between flare designs, operation, flare vent gas lower heating value and flow rate, destruction efficiency, and combustion efficiency. The study also evaluated the performance of remote sensing technologies against extractive techniques.

EPA Review of Flares

EPA used the test data from the recent PFTIR testing and TCEQ flare studies (as well as other older experimental flare efficiency studies conducted by the EPA in the early 1980s) to investigate the effects of flare performance with varying amounts of steam (for steam-assisted flares) and air (for air-assisted flares); and high wind and flame lift off situations (for both types of flares). EPA also reviewed available scientific information from peer-reviewed studies and other technical assessments about flammability, wind, and flame lift off to support our observations. Based on an analysis of the data, we have determined that there are numerous operating parameters that should be considered in order to be confident that a flare is operated consistently and properly to achieve good combustion efficiency.

We have developed a report that is organized into nine sections and nine technical appendices. Section 1.0 introduces the report and provides a summary of our primary observations. Section 2.0 identifies the experimental flare efficiency studies and flare performance test reports used in this investigation. Sections 3.0 through 8.0 describe the development of our observations. Section 9.0 provides a list of documents referenced in this report.

The primary observations made in this report are as follows:

- To identify over steaming situations that may occur on steam-assisted flares, the data suggest that the lower flammability limit of combustion zone gas (LFL_{CZ}) is the most appropriate operating parameter. Specifically, the data suggest that, in order to maintain good combustion efficiency, the LFL_{CZ} must be 15.3 percent by volume or less for a steam-assisted flare. As an alternative to LFL_{CZ}, the data suggest that the ratio of the net heating value of the combustion zone gas (NHV_{CZ}) to the net heating value of the flare vent gas if diluted to the lower flammability limit ($NHV_{VG\text{-}LFL}$) must be greater than 6.54.

- To identify excess aeration situations that may occur on air-assisted flares, the data suggest that the stoichiometric air ratio (SR) (the actual mass flow of assist air to the theoretical stoichiometric mass flow of air needed to combust the flare vent gas) is the most appropriate operating parameter. Specifically, the data suggest that, in order to maintain good combustion efficiency, the SR must be 7 or less for an air-assisted flare. Furthermore, the data suggest that the lower flammability limit of the flare vent gas (LFL_{VG}) should be 15.3 percent by volume or less to ensure the flare vent gas being sent to the air-assisted flare is capable of adequately burning when introduced to enough air.

- The data suggest that flare performance is not significantly affected by crosswind velocities up to 22 miles per hour (mph). There are limited data for flares in winds greater than 22 mph. However, a wake-dominated flame in winds greater than 22 mph may affect flare performance. The data available indicate that the wake-dominated region begins at a momentum flux ratio (MFR) of 3 or greater. The MFR considers whether there is enough flare vent gas and center steam (if applicable) exit velocity (momentum) to offset crosswind velocity. Because wake-dominated flames can be identified visually, observations could be conducted to identify wake-dominated flames during crosswind velocities greater than 22 mph at the flare tip.

- To avoid flame lift off, the data suggest that the actual flare tip velocity (i.e., actual flare vent gas velocity plus center steam velocity, if applicable) should be less than an established maximum allowable flare tip velocity calculated using an equation that is dependent on combustion zone gas composition, the flare tip diameter, density of the flare vent gas, and density of air.

- LFL_{CZ} could apply to non-assisted flares (i.e., the LFL_{CZ} must be 15.3 percent by volume or less in order to maintain good combustion efficiency). Also, the same operating conditions that were observed to reduce poor flare performance associated with high crosswind velocity and flame lift off could apply to non-assisted flares. Finally, because of lack of performance test data on pressure-assisted flare designs and other flare design technologies, it seems likely that the parameters important for good flare performance for non-assisted, steam-assisted, and air-assisted flares cannot be applied to pressure-assisted, or other flare designs without further information.

Document Availability

The report is being made available to the Panel in the form of an electronic file, which has been posted on and FTP site and shared with all members of the Panel.

Specific Charge in Reviewing the *Parameters for Properly Designed and Operated Flares*

We ask the Panel to focus on the charge questions below in their review of the report, but we would appreciate comments on any aspects of the information in the report or other flare topics. In addition, all references used in this report are available upon request.

Section 2: Available Flare Test Data

1. Please comment on the agency's criteria for excluding available flare test run data from final analyses, and whether application of these criteria may have lead to inappropriate exclusions of relevant data points.

Section 3: Steam and Flare Performance

2. Please comment on the lower flammability limit of combustion zone gas (LFL_{CZ}) as an operating parameter for indicating over steaming situations on steam-assisted flares. Comment on the agency's use of the ratio of the net heating value of the combustion zone gas (NHV_{CZ}) to the net heating value of the flare vent gas if diluted to the lower flammability limit (NHV_{LFL}) as an alternative to LFL_{CZ}. Does the flare data adequately support the EPA's observations?

3. Is there sufficient evidence that chemical interactions are occurring that make the calculated LFL_{CZ} inaccurate with respect to the 15.3% LFL_{CZ} threshold discussed? Is there other data available (that is not discussed in this report) that may help clarify our discussion about specific chemical interactions related to lower flammability limits of gas mixtures?

4. Did the agency adequately examine other operating parameters (different from LFL_{CZ}; or the ratio of NHV_{CZ} to $LFL_{VG\text{-}LFL}$) that could indicate over steaming situations? Are there specific other parameters that should be given more or less emphasis?

Section 4: Air and Flare Performance

5. Please comment on the stoichiometric air ratio (SR) as an operating parameter for indicating excess aeration situations on air-assisted flares. Additionally, also comment on whether the lower flammability limit of the flare vent gas (LFL_{VG}) is an appropriate operating parameter for determining whether the flare vent gas being sent to an air-assisted flare is capable of burning? Does the flare data adequately support the EPA's observations?

Section 5: Wind and Flare Performance

6. Please comment on the momentum flux ratio (MFR) as an operating parameter in crosswind velocities greater than 22 mph at the flare tip to indicate wake-dominated flame situations. Additionally, also comment on the agency's observation that in the absence of crosswind greater than 22 mph, a low MFR does not necessarily indicate poor flare performance. Comment on the effectiveness of observations identifying wake-dominated flames. Does the flare data adequately support the EPA's observations?

7. Did the agency adequately examine other operating parameters (different from MFR) for identifying wake-dominated flames? Are there specific other parameters that should be given more or less emphasis?

Section 6: Flare Flame Lift Off

8. Please comment on the maximum allowable flare tip velocity equation which considers combustion zone gas composition, the flare tip diameter, density of the flare vent gas, and density of air. Does the flare data adequately support the EPA's observations? Are there specific other parameters or methods/equations that should be given more or less emphasis?

Section 7: Other Flare Type Designs to Consider

9. Please comment on the applicability of the LFL_{CZ} parameter, maximum allowable flare tip velocity equation, and the observations regarding crosswind velocity to non-assisted flares, pressure-assisted flares, and other flare designs.

Section 8: Monitoring Considerations

10. Please comment on the appropriate monitoring equipment needed to ensure good flare performance and on any other known monitoring methods (not discussed in this report) for monitoring the following parameters: LFL_{CZ}, LFL_{VG}, $LFL_{VG,C}$, the ratio of NHV_{CZ} to $NHV_{VG\text{-}LFL}$, C_{CZ}, SR, MFR, and V_{max}. Also, please comment on operating scenarios and conditions where less robust monitoring equipment could be used to determine the operating parameters of interest.