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RE: Flare Task Force Stakeholder Group

Mr. Anderson,

In development of the new SIP rules and the effort to collect additional data related to flare performance, the following information is provided. The comments contained, here in, provide additional details regarding consideration of the use of pressure-assisted flare technology, as well as practical experience utilizing thermal oxidizers.

Pressure-assisted Flares

As currently written, 30 TAC 115 Subchapter H, Division 1 allows the use of flares to control subject vent streams; however the flare type is restricted to steam-assisted, air-assisted, or non-assisted flares by referencing the requirements of 40 CFR §60.18(c)(2)-(6) & (d). 40 CFR §60.18 was originally developed around non-assisted, air-assisted, and steam-assisted flare technologies and did not specifically address pressure-assisted flares.

Pressure-assisted flares utilize the waste gas pressure to create a condition where air is drawn into contact with the gas and mixed to achieve smokeless combustion. This results in high exit velocities greater than 400 ft/sec. Pressure-assisted flares operate at sonic exit velocities at the tip, typically Mach 1.0 or greater.

More information about pressure-assisted flares can be found as follows:
http://www.epa.gov/ttn/catc/dir1/fflare.pdf
http://www.johnzink.com/products/flares/pdfs/flar_hydra.pdf

Pressure-assisted flares can be utilized for both routine process operations and maintenance activities. One of my clients desires to use a pressure-assisted flare to control HRVOC-containing streams under 30 TAC §115.725 (i). The issue is that HRVOC hourly average mass emission rates cannot be accurately calculated per 30 TAC §115.725(g)(2)(E) because the flare tip velocity exceeds the maximum allowable velocity in 40 CFR §60.18. At the lower DRE (93%), HRVOC emissions will be over-reported and the 1200 lb/hr site cap in 30 TAC 115.722 will be exceeded.

The Dow Chemical Company (Dow) also operates facilities in the HGA that utilize the pressure-assisted flare technology. Dow approached TCEQ about the use of these flares to comply with the current HRVOC requirements. In order to review the request, TCEQ required additional data. Dow contracted John Zink to develop a test protocol to demonstrate that the destruction efficiency of pressure-assisted flares is equal to or better than other flare types, even though the exit velocity is higher. The test program was executed at John Zink's test facility located in Tulsa, Oklahoma.

Dow in conjunction with John Zink presented the attached paper on the results of the pressure-assisted flare emissions testing conducted at the John Zink facility to simulate the Dow application. The testing conducted actually captured the inlet flare gas and the flue gas, so that the DRE could be demonstrated. The testing concluded that combustion stability is a major factor in flare burner performance and pressure-assisted flares have the capability to perform at performance level's comparable to steam-assisted and air-assisted flares.

Since several facilities in the HGA and BPA could potentially utilize pressure-assisted flares, it would be prudent in development of the new SIP rules and the review of the effectiveness of 40 CFR §60.18 to include language in the state rules to address the use of these flares for compliance. I do not have access to the test results from Dow; however, it was noted in the attached paper that both TCEQ and EPA witnessed the testing and assisted in the development of the test plan and protocol. Presumptively, TCEQ is currently in receipt of this testing.

Thermal Oxidizers

When utilizing thermal oxidizers to comply with HRVOC, the compliance demonstration for routine operation falls into 30 TAC §115.725(a), which requires that the thermal oxidizer be tested and an appropriate operating parameter be selected during the testing and subsequently tracked to demonstrate compliance. Vendor data and/or process knowledge is allowed for the estimation of MSS activities and emission events in the use of thermal oxidizers (or other control devices besides flares) under 30 TAC §115.725(a)(3); however, this does not apply to routine operations. There is no option to utilize vendor data or process knowledge for routine operations that are limited in scope, similar to the various compliance options offered for flares in 30 TAC §115.725(e) – (k). Is it possible that options for alternates to testing (rather than monitoring, as was done for flares) could be developed for various limited duration routine operating scenarios (such as limited use < 720 hours/year, marine loading, pipeline maintenance, etc.) for thermal oxidizers and other control devices? What I was hoping could be addressed is adding options for using alternate control devices (like thermal oxidizers or vapor combustors) where costly performance testing would not be required in some limited routine operations and vendor guarantees and engineering calculations could be substituted for the testing. This would provide more compliance flexibility and perhaps entice more industry personnel to employ the use of this alternate control.

When controlled in a flare, VOCs with 3 carbons or less are destroyed by 99%. Conversely, all hydrocarbons controlled in a thermal oxidizer are destroyed by 99.99%. In effect, the thermal oxidizers are 100 times more efficient in removing HRVOC (with less than 3 carbon atoms) than a flare. This comes at price, though, since incinerators (thermal oxidizers) with a maximum rated capacity greater than 40 MMBtu/hr are subject to 30 TAC 117 and the NOx Cap and Trade Program. 30 TAC §117.303(a)(4)(A) specifies that incinerators (thermal oxidizers) with a maximum rated capacity less than 40 MMBtu/hr are exempt from the NOx Cap and Trade Program. Flares, regardless of size, are also currently exempt. The NOx emission factors for flares are between 0.0485 - 0.0680 lb NOx/MMBtu. The vendor guaranteed NOx rate for a thermal oxidizer is typically 0.15 lb NOx/MMBtu. To control a thermal oxidizer with a capacity larger than 40 MMBTU/hr to the 30 TAC 117 limit would require the installation of additional control, typically Selective Catalytic Reduction (SCR), and the introduction of new emission hazards, NH_3. To avoid this issue, the thermal oxidizer must be sized below 40 MMBtu/hr; however, this is not sufficient to control the entire flare load at most operating facilities. Therefore, use of the flare to control both routine and emergency conditions is still necessary. If TCEQ's objective is to utilize a thermal oxidizer as a primary replacement for flares, this issue needs to be addressed such that the thermal oxidizer can be sized to handle the entire flare load during normal operating conditions (which will most likely be in excess of 40 MMBTU/hr). What is the trade off between lower HRVOC emissions and higher NOx formation? Is it possible that this can somehow be addressed with the current cap and trade programs for NOx and HRVOC such that equivalent HRVOC credits can be utilized to offset increases in NOx emissions?

Additionally, another issue that arises with the use of a thermal oxidizer is testing. Typical NSR boiler plate language for a thermal oxidizer mandates testing to demonstrate 99.99% DRE. The detection limits of the current EPA Reference Methods make this task very difficult. Measuring the flow rate of the inlet using Method 1-4 is not typically an issue nor is measuring the composition of the inlet stream using Method. However, because the thermal oxidizers have such high destruction efficiencies, Method 18 cannot be used to accurately measure the composition of the outlet. When Method 18 is used, many of the components in the outlet stream are well below the detection limits of the respective component. Using the detection limit or even one half the detection limit to calculate the DRE often results in not being able to mathematically prove 99.99%. Instead, Method 18 is limited to verify that the probability of the unit's DRE is approaching 99.99% (example DRE > 99.78%), but cannot confirm 99.99%. TCEQ should consider altering the standard NSR boiler plate language to allow more flexibility in demonstration of compliance by perhaps allowing a comparable ppm stack outlet concentration comparable to the 99.99% DRE that can be tested utilizing Method 25A. This is similar to the approach allowed in most federal rules and would make compliance demonstration achievable.

I hope that this information will assist you in the development of the new rule language. If you have any questions or concerns, please feel free to contact me at 832-202-4211. I appreciate you providing the opportunity for feedback.

Thank you,

Trisha Froemming, PE

Attachments - John Zink Study - Pressure Assisted Flares.pdf

Attachments

Pressure-Assisted Flare Emissions Testing

By

Vance Varner[1], Scott Fox[2], Robert Schwartz[3] and Russell Wozniak[4]

Presented at the

American – Japanese Flame Research Committees
International Symposium
Hawaii, October 2007

ABSTRACT:
Due to increased concern regarding air emissions of highly-reactive volatile organic compounds (HRVOC) in the Greater Houston area, emissions from various sources in the area are now subject to much more scrutiny by the Texas Commission on Environmental Quality. One potential source of emissions is from flares whose design and operation is addressed by the EPA through the Federal Code of Regulation 40-CFR Section 60.18. In particular, this standard sets forth the relationship between volumetric heating value of the flare gasses and the maximum allowable exit velocity. Depending on the specific flare type and gas heating value, maximum allowable exit velocities are generally limited to less than about 400 feet per second. This code was originally developed around non-assisted, air-assisted, and steam-assisted flare technology. Pressure assisted flares are not specifically addressed by the regulation. Pressure assisted flares often operate with an exit velocity of about Mach 1.0, which is much higher than allowed by 40-CFR-60.18. In partnership, John Zink and Dow set out to demonstrate that the destruction efficiency for pressure assisted flares is equal to or better than other flare types, even though the exit velocity is higher. Several different pressure assisted flare burners were tested using various gas mixtures, and the emissions from the flames were captured and measured.

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[4]The Dow Chemical Company, © 2007 by John Zink Company, LLC

Introduction

A number of process industry operations in the Texas gulf coast area are served by flares that provide safe, effective disposal of combustible gases. Recently, the efficacy of a small number of these flares came into question. The Dow Chemical Company (Dow) is among the companies that use flares. Dow and a flare designer/supplier, John Zink Company LLC (Zink), partnered in undertaking a test program that would determine the destruction removal efficiency (DRE) of the flares in question.

This test program was a significant undertaking executed at Zink's test facility located in Tulsa, Oklahoma and witnessed by representatives of the US EPA and the Texas Commission on Environmental Quality (TCEQ).

Background

Concern about emissions in the Houston – Galveston area prompted the TCEQ and a large number of researchers to collect ground-level and airborne emissions data along the Texas gulf coast. The first study was conducted in the late summer of 2000 (Texas Air Quality Study I). A follow-up study was conducted in the late summer of 2006 (Texas Air Quality II). As a result of Texas Air Quality Study I, several volatile organic compounds (VOC's) were detected in concentrations that exceeded the levels that were predicted based on plant annual emission inventory reports. Some of these VOC's, known to be major contributors to ozone, have been designated as Highly Reactive Volatile Organic Compounds (HRVOC's) by the TCEQ. Ethylene, propylene, butenes, and 1,3-butadiene are among the hydrocarbon compounds designated as HRVOC's. Dow operates several flares that handle compounds designated as being HRVOC's.

The apparent discrepancy between the plant reports and the aerial measurements caused the TCEQ to search for potential sources of HRVOC emissions. The TCEQ identified certain types of process equipment as being suspect for under reporting of emissions - flares, vents, cooling towers and fugitives. In the case of flares, any understatement or overstatement of flare DRE was probably due to a lack of specific knowledge of flare DRE's.

TCEQ Regulatory Review

The TCEQ developed regulations to address HRVOC emissions in the area from flares, cooling towers, vents, and fugitive sources. For flares, the regulations mandate that all flares meet the requirements outlined in the Code of Federal Regulations, Title 40, Part 60.18 (Part 60.18) when combusting HRVOC materials. Part 60.18 contains both requirements and guidance for the operation of certain types of flares: steam-assist, air-assist and non-assisted flares. However, there are no requirements or guidance provided for pressure-assisted flares such as the Dow flares in question.

A key regulatory issue addressed in Part 60.18 is the maximum allowable flare gas velocity at the burner exit. Previous testing has shown that there is a relationship between gas exit velocity and flame stability. These tests also demonstrate that flame stability is a key parameter that determines flare emissions. In turn, there is a relationship between gas heating value and exit velocity. Actually, relating heating value to gas exit velocity is a convenient simplification because several other factors also influence flame stability. Fuel characteristics are discussed in more detail later in this paper. It is sufficient here to note that, in general, the more stable the flame the higher the DRE. Conversely, a flare flame that is near the point of blowing out will generate higher emissions.

The impact of Part 60.18 on flare gas exit velocity can be demonstrated as follows: Assume a gas with a heating value, as determined by the methods in the regulation, greater than 1000 Btu/scf (37.23 MJ/scm). For this heating value the maximum gas exit velocity for a steam-assisted, air-assisted or non-assisted flare is 400 feet per second (122 m/s). Even if these flares are firing propane with a heating value of 2315 Btu/scf (86.20 MJ/scm), the maximum allowable gas exit velocity is still 400 feet per second; (122 m/s) this corresponds to a Mach number of approximately 0.5. In contrast, pressure-assisted flare burners generally operate at sonic exit velocities at the tip. (Mach. 1.0 is 820 feet per second [250 m/s] for propane.)

Dow has requested approval from TCEQ for the use of pressure-assisted flares for combusting HRVOC compounds in certain applications. The TCEQ's review of Dow's request resulted in a number of questions and requests for information. Lacking regulatory guidance, and with a limited amount of publicly available performance data on pressure-assisted flare burners, Dow and TCEQ agreed to conduct a series of flare efficiency tests in support of Dow's claimed DRE's. These tests were to demonstrate that the DRE's of Dow's pressure-assist flare burners are equal to or better than flares that meet the exit velocity restrictions contained in Part 60.18.

Smokeless Flaring

Smoke from a flare represents incomplete combustion caused by insufficient air. For those gases that will smoke when flared, some means of assisting the mixing of combustion air and the gas is required to achieve effective disposal (smokeless burning). Steam-assist and forced air-assist are commonly used to provide the mixing energy. However, there is another assist means, pressure-assist, which is very effective. A pressure-assisted flare burner takes advantage of the waste gas pressure (energy) to create a condition whereby air is drawn into contact with the gas, and mixed together with the gas in such a manner as to achieve smokeless burning. Exit velocities up to and including sonic are utilized. In general, a higher the exit velocity results in more air mixed with the waste gas stream prior to burning. However, the advantages of high exit velocities can be lost if the flare designer fails to provide adequate flame stability. Pressure assisted flare burners must be carefully designed for stability.

Designing a flare for stable burning requires a comprehensive knowledge of the combustion characteristics of the gas to be burned and a general understanding of fluid dynamic principles. Flames can be stabilized mechanically, aerodynamically, or by using a combination of both techniques. The Dow pressure-assist flare burners are aerodynamically stabilized and operate at gas exit velocities of Mach 1.0. At these high exit velocities the burners remain stable even in high wind conditions.

By their nature, pressure-assisted flare burners have a smaller outlet area as compared to a corresponding conventional steam or air-assist flare. This area can be utilized to design a burner with a single exit port or divided into a number of ports strategically arranged to provide stability and smokeless flaring.

In practice, pressure-assisted flare burners are used as a single flare burner or in groups of many identical burners. Multiple burner systems commonly employ a burner staging technique in order to greatly expand the capacity range of effective burning. Dow flares, employing this staging technique, have been in service for over 30 years.

Development of a Test Protocol

Zink has been an active participant in numerous flare emissions test programs and operates a flare test facility that is well suited for flare emissions studies. Dow recognized the advantages in working with Zink and turned to Zink for support in preparation of a test protocol and test execution.

Dow, Zink, TCEQ, US EPA and a third-party analytical service worked together to develop a test protocol that would guide the testing of flare burners representative of those in service at various Dow locations. Preparation of the protocol required careful consideration of each application to assure that the tests would have a meaningful relationship to actual operating conditions. A review of Dow's pressure-assist flare burner usage determined that two flare burner designs with significantly different exit areas, together with the proper fuel selection would represent all of the Dow of pressure-assist flare burner applications in question. Both flare burners are multi-armed with one or more ports per arm.

The test protocol covered a number of subjects including the following:

- Fuel composition
- Test equipment process design
- Sample acquisition and analysis
- QAQC activities
- Meteorological data

These subjects are discussed below.

Fuel composition: The flare burners selected for testing are in applications where they burn ethylene, propylene, or a mixture of both. At the time of the tests, Zink's test facility could not handle ethylene. Therefore, Zink proposed conducting the flare efficiency tests using propylene or mixtures of propylene and nitrogen. Zink's proposed fuel selection was supported by the following technical analysis:

As noted earlier in this paper, burner flame stability is important if a flare burner is to achieve good emissions performance. Tests conducted by the EPA, CMA and Zink, EPA and EER and the EPA with Dupont clearly demonstrate that the burning efficiency of a flare is directly related to flame stability.

The tests conducted by the EPA, CMA and Zink in 1982, state the following in the project report: *"Flaring low BTU content gases at high exit velocities, causing flare flame lift off, may result in low combustion efficiencies..."*

The report on the tests conducted by the EPA and EER in 1985 states the following: *"Destruction efficiencies greater than 98 percent were attained when the gas heating value was at least 1.2 times the minimum gas heating value required for stability."*

The report on the tests conducted by the EPA and Dupont in 1996 states the following: *"All the measurements of destruction efficiencies at conditions more* *stable than lift off were above 99 percent. Further, control efficiencies greater than 98 percent were found at hydrogen contents below the lift off curve."*

In summary, all of the cited references demonstrate a positive link between flare flame stability and high flare efficiency. Therefore, a gas that has a higher propensity to create a stable flame is more likely to achieve higher burning efficiencies. Gas properties that play a key role in determining burner flame stability include the following: flammability limits, flame speed, and ignition temperature.

A pressure-assisted flare burning a gas that has wide flammability limits is easier to stabilize than one with narrow flammability limits. For example, hydrogen is much easier to stabilize than methane; one reason is hydrogen's much wider flammability limits (Upper Flammability Limit [UFL] = 4.0 % and Lower Flammability Limit [LFL] = 74.2 %) vs. methane (UFL = 5.0 % and LFL = 15 %). Stated another way, it is less difficult to achieve a flammable mixture of hydrogen and air, than a flammable mixture of methane and air.

Another important property that contributes to hydrogen being more stable than methane is flame speed. A higher burning velocity means that the combustion reactions occur at a much faster rate, thus promoting a more stable flame. Hydrogen has a much higher laminar burning velocity than methane over the entire flammability range. For example, hydrogen has a maximum laminar burning velocity in air of 9.3 feet per second (2.83 m/s) vs. methane at 1.48 feet per second (1.45 m/s).

Ignition temperature is another important property that gives hydrogen superior stability. Hydrogen has an ignition temperature of 1062°F vs. 1170°F (572 °C / 632 °C) for methane. In a continuum of combustion the lower ignition temperature suggests more rapid ignition of the gas air mixture and a more stable flame.

The analysis discussed above demonstrates that a comparison of certain fuel properties can be useful in estimating the relative stability performance of different fuels. Applying the same analysis to ethylene and propylene shows that ethylene has wider flammability limits, a lower ignition temperature and a faster flame speed. Therefore, it was accepted that propylene, as a fuel, will not perform as well as ethylene and that the DRE's obtained from testing propylene would be lower than they would be if ethylene had been used as fuel.

In order to demonstrate the range of performance and flexibility of their pressure-assisted flare burners, Dow decided that each of the selected test flare burners should be tested on a fuel with a heating value lower than the heating value of gases flared at their facilities. The reduction in heating was achieved by blending propylene with nitrogen. Combining the selected test flare burners and the test fuels results in the test matrix shown in Table 1.

Test	Flare Burner	Target Flow		Fuel	
		Lbs/hr	Kg/hr	HC	HC+N2
A	Large	5,000	2,270	√	
B	Large	8,000	3,640	√	
C	Large	5,000	2,270		√
D	Small	1,200	550	√	
E	Small	1,200	550		√

Table 1 Test Matrix

<u>Test equipment process design:</u> After establishing the test matrix, it was necessary to select/design the equipment and instrumentation necessary to carry out the test plan. Zink's existing flare test and development center provided the infrastructure required to support the test program. The arrangement of equipment is shown in Figure 1. The propylene component of the fuel arrived on site via tanker truck and was off loaded into a liquid storage tank. Nitrogen arrived in gaseous form in cylinder truck loads. Nitrogen was used as a purge gas as part of the system safety plan and as a component in the test fuel. During testing the flow of propylene or nitrogen was measured using an orifice metering system. A static mixer in the fuel line assured a homogenous mixture. The rate of

propylene and nitrogen consumption was very high and timely replenishment required careful planning. Test flow rates were regulated and recorded by the control room based computer network.

Sample acquisition and analysis: Acquisition of a representative flue gas sample was an important element in the test program. Previous test programs experienced difficulty with this element. Zink engineers devised a sample collector that concentrated the flue gas and protected the sample suction point from the wind. The sample collector was supported by a 180 foot (55 m) tall crane and maintained in position by guy line tenders. The position of the collector, relative to the flare flame, was constantly monitored using flue gas temperature, flue gas oxygen level and visual sighting. From time to time, the observations would indicate the need to reposition the collector to enhance the quality of the sample. The handling crew would then work in coordination with the crane operator to achieve a better position for the collector.

A continuous flue gas sample was drawn through the sample probe located within the collector. The flue gas sample passed through a heat traced and insulated sample line and into the analytical service instrument trailer. The flue gas sample was divided with a portion going to the total hydrocarbons analyzer. The remaining portion of the sample was dried and directed to analyzers for measuring CO, O_2, CO_2 and NOx. The analyzer outputs were routed to a data logger.

The methods and procedures used for the flue gas analysis were in accordance with US EPA guidelines and methodology. For example, the analysis used for total hydrocarbons followed the requirements of US EPA Method 25A.

QA/QC activities: Quality assurance and control procedures followed US EPA requirements and included calibration checks, zero and span checks and background measurements. Pretest and post test calibrations took place with each test run. Certain parameters such as fuel composition and flue gas composition were checked using two different methods.

Meteorological data: Wind speed, ambient wet and dry bulb temperature, local atmospheric pressure and humidity were observed and data logged throughout the testing activities.

Test execution:

Preparation, review, modification and approval of the test protocol required approximately ten months to complete. The effort invested in the protocol was rewarded when the test execution portion of the program moved rapidly and without any major problem. Logistics played a major role in the test execution. From maintaining an adequate test fuel inventory, to organizing rotating shifts of operating personnel, to coordination of third party services providers such as the crane, the team members responsible for logistics were very busy.

Prior to any test facilities activities, an Environmental Health and Safety review of the test setup operation plan was conducted. Areas of responsibility were defined, and work assignments made. For example, the chief operator was assigned the responsibility for interfacing with the local fire department and airport air traffic control.

Execution of the test program was very expensive and manpower intensive, and lasted several days once it was started. Fuel and manpower were the major costs incurred. Approximately 20 operators, technicians, engineers, company representatives and regulatory agency observers were involved during the testing. From time to time additional workers were required to assist in setup or breakdown of equipment.

A total of five different combinations of burner and fuel were tested. Each combination was tested for three, 15 to 20 minute "on the record" runs. A pre-run period took place before the "on the record" portion of each run. During the pre-run the fuel flow would be started and the flow rate adjusted to approximately the target value. As the test flow rate was established, the sample collector was lifted and guided into position above the flame. Instruments and data loggers were checked for proper function. When operation reached a near steady state condition the run would go "on the record" for 15 to 20 minutes. At the end of the "on the record" period the run would continue until the flue gas analysis team leader confirmed that sampling was completed. At this point Fuel flow would be stopped.

As shown in Figure 2, testing took place in an open area. Wind velocity varied throughout the testing. The average wind speed for all test runs was about 6 MPH (10 KPH) and the maximum about 16 MPH (26 KPH). Wind was not a problem during the tests. The position of the sample collector relative to the flame was constantly monitored and the collector repositioned as necessary.

Results and Conclusions

A dedicated industrial-scale flare test facility offers many advantages over "in-the-field" testing. This is even more important when the test focus is flare emissions. Increased safety and the ability to control and measure key parameters are a few of the benefits gained.

Large scale flare testing, although very expensive and difficult to execute, can yield valuable information regarding flare performance. The test program reported on herein demonstrated that the DRE's of the flare burner designs tested are at least as good as the performance level's reported for previous tests of steam-assist and air-assist flares.

Combustion stability is a major factor in flare burner performance. A well designed and properly operated pressure-assisted flare burner with a stable flame will achieve 99+% DRE, which is the same or better than the efficiency of those flares that meet the requirements of Code of Federal Regulations, Title 40, Part 60.18.

Wind velocities up to 16 MPH (26 kph) had no identifiable impact on DRE results.

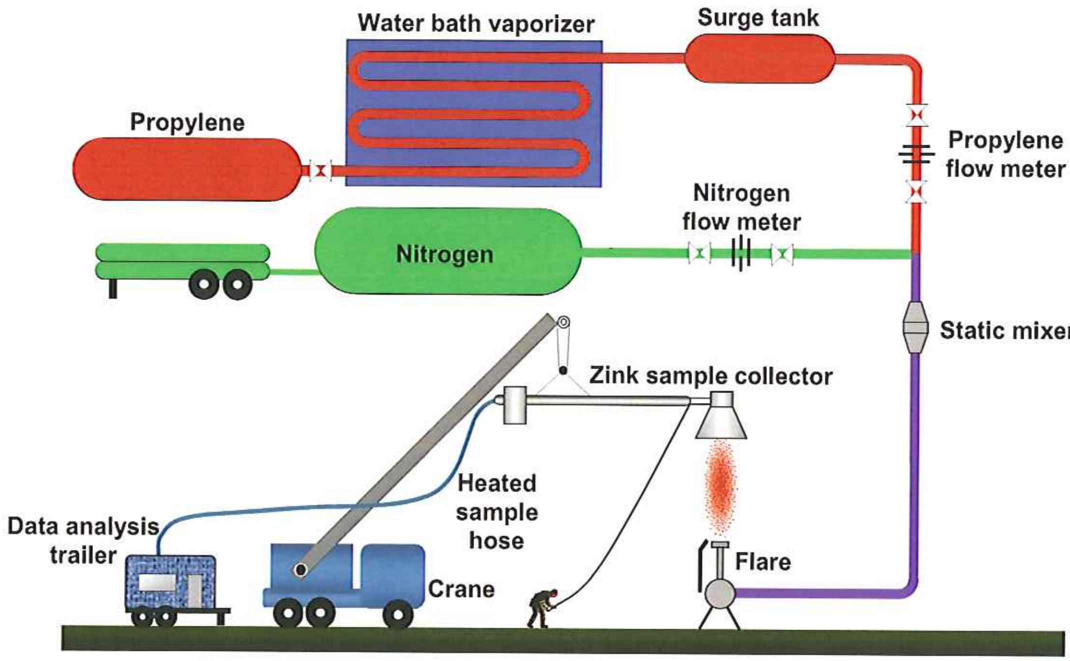

Figure 1
Flare Emissions Testing Equipment Arrangement

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Figure 2
Overall View of Flare Emissions Test

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