Reducing Flare Emissions from Chemical Plants and Refineries

An analysis of industrial flares' contribution to the Gulf Coast region's air pollution problem

May 23, 2005

Industry Professionals for Clean Air

3911 Arnold Street Houston, Texas 77005 • 713-664-4151 • boblevy@houston.rr.com

Reducing Flare Emissions from Chemical Plants and Refineries

Summary

Industrial flares in Texas are neither properly represented in planning and permitting documents, nor adequately controlled by regulation. The improper representation of flare emissions leads to a large, unquantified shortfall in emissions estimates for routine flare use and significant flaring events. The inadequate regulation of flares leads to unnecessarily high emission rates and the general overuse of flares. This, combined with the highest concentration of refineries and petrochemical plants in the country, makes the Houston area a leader in ground-level ozone formation. As a group of petroleum and petrochemical industry professionals, Industry Professionals for Clean Air[1] is concerned that flare emissions of highly reactive volatile organic compounds (HRVOC), other volatile organic compounds (VOC), and air toxics are most likely *substantially* greater than predicted or permitted.

These excess emissions could explain a significant portion of the discrepancy between self-reported plant emissions and monitor-reported concentrations of ambient pollutants. It is our observation that the best practices for reducing flare emissions are not being implemented widely in the Gulf Coast region, with significant adverse effects on human health. The Texas Commission on Environmental Quality (TCEQ) and the US Environmental Protection Agency (EPA) should make immediate changes to plans and regulations as warranted by available research, review enforcement practices to identify additional issues, and expand and accelerate research efforts.

Discussion

The TCEQ unquestioningly uses high destruction efficiencies, based on combustion efficiencies established in 1983 by the EPA,[2] to establish regulatory requirements, calculate permit limits, monitor compliance, enforce control requirements and plan for attainment of air quality standards. The TCEQ presumes that flares destroy 99% of ethylene and propylene, and 98% of all other HRVOCs, entering the flare, as long as continuous monitoring data for the flare inlet demonstrates compliance with the EPA's minimum heating value and maximum exit velocity requirements.[3] Findings from the EPA 1983 Flare Study generally reflect

[1] Industry Professionals for Clean Air was founded in 2004 by petroleum and petrochemical industry professionals to identify technically sound and economically feasible options for reducing industrial air emissions in the Gulf Coast region.
[2] Marc McDaniel, EPA-600/2-83/052, Flare Efficiency Study. Engineering Science, Inc., July 1983 (EPA 1983 Flare Study).
[3] 30 TAC §115.725(d)(7). Appendix L to the TCEQ's HGB 2004 SIP Revisions does not address the destruction efficiency of other VOCs. The TCEQ's "Technical Justification For 99% Flare Efficiency," attached as Appendix L to its Revisions to the State Implementation Plan (SIP) for the Control of Ozone Air Pollution, Houston/Galveston/Brazoria Ozone Nonattainment Area (TCEQ Technical Justification) cites the EPA 1983 Flare Study as the basis for its use of high destruction efficiencies.

use of high-efficiency flares burning simple chemicals at natural gas processing plants under optimal operating parameters and wind speeds less than five miles per hour.[4] The TCEQ's approach, therefore, makes no allowance for real world operating variables. Specifically, it is based on the unrealistic assumptions that:

- plants are consistently operated according to the parameters necessary to optimize flare destruction efficiency;
- crosswinds have minimal effect on combustion efficiency; and
- flares perpetually operate at high destruction efficiency.

Based on our experience and research, we believe elevated flares present the most significant problem for controlling emissions of toxic air pollutants. Because flares are designed and used for control of emission spikes, the hourly emission rate permitted for,[5] and experienced by, a flare is likely to be the highest of any unit at a facility, even assuming a 98% to 99% VOC destruction efficiency. Accordingly, we recommend that TCEQ take action to determine more realistic flare destruction efficiencies, minimize the volume of emissions routed to elevated, unenclosed flares, and encourage the use of flare gas recovery systems, or wind-protected ground flares and thermal oxidizers.

Determine More Realistic Flare Destruction Efficiencies

Operating Parameters

TCEQ bases its determination that industrial flares operate at 98% to 99% efficiency primarily on the EPA 1983 Flare Emission Study.[6] This study also provides a basis for the EPA's regulations covering flare operations.[7] The EPA generally requires that flares operate:

- "with a flame present at all times",[8] and

---

[4] EPA 1983 Flare Study, Table 1. Flare Efficiency Test Results, p. 4.

[5] *See* URS Corp., Extraction of Allowable VOC Release Levels From TCEQ Permits, prepared for Houston Advanced Research Center Texas Environmental Research Consortium, April 15, 2004. For this study, URS reviewed "156 TCEQ accounts in the Houston Galveston Area having 2000 total HRVOC emissions greater than 10 tons per year according to reported emissions and the VOC speciation profiles used by TCEQ for photochemical modeling." Among these facilities, only flares were permitted with emission limits of 10 pounds per hour or higher.

[6] EPA 1983 Flare Study. In addition, TCEQ Work Assignment 5 Draft Flare Gas Flow Gas Rate and Composition Measurement, Methodologies Evaluation Document, prepared by Shell Global Solutions (US), Inc., p. 5-1 (Measurement Methodologies Evaluation), notes that "[s]everal pioneering studies in the 1980s demonstrated that when operated properly, flares should have destruction efficiencies between 98 and 99 percent."

[7] *See* Standards of Performance for New Stationary Sources: General Provisions; National Emission Standards for Hazardous Air Pollutants for Source Categories: General Provisions, EPA Direct Final Rule, 63 Fed. Reg. 24436, 24437 (May 4, 1998).

[8] 40 CFR §60.18(c)(2).

- "with no visible emissions…except for periods not to exceed a total of 5 minutes during any 2 consecutive hours."[9]

The waste stream routed to the flare either burns on its own or, if it has low heating value (less than 300 Btu/scf), with the assistance of a high-energy (more than 1000 Btu/scf) fuel gas, like natural gas or propane, to facilitate complete combustion.[10] Typically, operators use fuel gas, or some other purge gas, to keep slow flowing emissions moving toward the flare.[11] With or without additional fuel, the combustion of many waste streams produces smoke – i.e., visible emissions.[12] For smokeless combustion, operators typically inject steam or air to "achieve more-complete combustion."[13] The injection of steam or air (assist gas) "at the flare tip [also] increases the mixing of waste gas with air, as well as the residence time of the waste gas constituents into the flame zone, thereby increasing combustion efficiency."[14]

Operators must maintain a delicate, but essential, balance between smokeless and oversteamed emissions. Studies in the 1980s "demonstrated that assist gas to waste gas mass ratios between 0.4 and 4 were effective in reducing soot while ratios between 0.2 and 0.6 achieved the highest hydrocarbon destruction efficiency."[15] Too much assist gas (over steaming or over aerating) "may … reduce the overall combustion efficiency by cooling the flame to below optimum temperatures for destruction of some waste gas constituents, and in severe cases may even snuff the flame, thus significantly reducing combustion efficiency and significantly increasing flare exhaust gas emissions."[16] The EPA 1983 Flare Study noted: "Combustion efficiencies were observed to decline under conditions of excessive steam (steam quenching) and high exit velocities of low Btu gases."[17] Thus, EPA regulations establish parameters for heat content and exit velocity.[18]

The EPA 1983 Flare Study also demonstrated that separation of the flame from the burner tip, routinely observed during emergency flaring events under high winds and during addition of excess steam, results in a *serious drop in burning efficiency*.[19] Even if flares are operated within permit limits, we consider it likely that destruction efficiency suffers when flame separation or other characteristics indicate inadequate residence

[9] 40 CFR §60.18(c)(1).
[10] Measurement Methodologies Evaluation, p. 5-1. *See also* John F. Straitz, III, "Clearing the Air About Flare Systems," Chemical Engineering, September 1996, reprint, p. 4 (Straitz).
[11] Measurement Methodologies Evaluation, p. 1-6.
[12] Straitz, p. 5.
[13] Stratiz, p. 5.
[14] Measurement Methodologies Evaluation, p. 5-1.
[15] Measurement Methodologies Evaluation, p. 5-5.
[16] Measurement Methodologies Evaluation, p. 5-2.
[17] EPA 1983 Flare Study, p. ii.
[18] 40 CFR §60.18(c)(3) and (4).
[19] EPA 1983 Flare Study, Table 1, p. 4.

time for the waste gas – i.e., the waste gas is not present in the flame long enough to achieve optimal combustion.

In addition, the TCEQ learned from a contractor's evaluation of flare gas flow rate and composition measurement methodologies that although "data on destruction efficiency versus assist gas ratio obtained under controlled conditions would suggest that poor assist gas control might negatively impact destruction efficiencies, there are little or no data available on the impact of assist gas ratio control on destruction efficiency of operating flares."[20] Thus, "the effect of assist gas to waste gas ratio on flare combustion efficiency, as well as destruction efficiency, requires further investigation."[21] Based on a review of some 50 refinery and petrochemical plant flares, and discussions with petrochemical plant operators, the TCEQ learned that the assist gas injection rate for 90% of the flares is controlled manually "by the operator based on [visual] flare observations (either directly or on a video monitor)."[22] Nevertheless, neither the EPA's nor the TCEQ's regulations adequately address the critical role that steam content plays in flare combustion, and apparently neither agency is actively investigating steam content control for flares in the Gulf Coast region.

Furthermore, because the EPA 1983 Flare Study focused on simple hydrocarbons, subsequent analyses may not take into account the possibility that while the original compound may be destroyed, large hydrocarbons could simply be broken down into smaller hydrocarbons and other compounds, some of which may be toxic as well.

Upsets present even more of an operations problem. An evaluation of emission events in the Houston-Galveston area between January 31 and December 31, 2003 "shows that HRVOC events and possibly VOC emissions events have the potential to contribute significantly to ozone formation in HGA."[23] A 2002 TCEQ toxicological evaluation of VOC monitoring data collected downwind of three Harris County plants noted that "exposure to recurrent elevated short-term levels of 1,3-butadiene may increase the risk of reproductive and developmental effects."[24]

Consider the specific example of ExxonMobil Chemical Co., which reported for its Baytown Olefins Plant (BOP) 303.88 tons of VOC emissions due to upsets and 622.14 tons of VOC emissions total for 2000. The applicable permit allowed only 123.59 tons of VOC emissions.[25] Among other emission events in 2000,

[20] Measurement Methodologies Evaluation, p. 5-6.
[21] Measurement Methodologies Evaluation, p. 5-2.
[22] Measurement Methodologies Evaluation, p. 5-3.
[23] Cynthia Folsom Murphy and David T. Allen, Event Emissions in the Houston Galveston area (HGA), January 14, 2004(Event Emissions in HGA), p. A-31, available at www.harc.edu/harc/Projects/AirQuality/Projects/Status/H13.aspx.
[24] Joseph T. Haney, Jr., and Laura Carlisle, Toxicology & Risk Assessment, Office of Permitting, Remediation & Registration, TNRCC Interoffice memorandum to Dan Thompson, Director, Region 12, Houston, July 31, 2002, p. 3.
[25] Exxon Chemical Co. Baytown Olefins Plant, Emissions/Inspection Fee Form, Fiscal Year 2002.

ExxonMobil reported an upset, shutdown and startup for BOP from July 17, 2000 through August 18, 2000.[26] Among the responses to this upset, the plant operator "maximized steam flow to the flares to optimize combustion and minimize smoke."[27]

As noted above, too much steam can reduce combustion efficiency by cooling the flame. A TCEQ study determined that an "assist gas to waste gas mass ratio between 0.2 and 0.6 achieved the highest hydrocarbon destruction efficiency."[28] ExxonMobil reported that "[t]he hydrocarbon stream being flared during the July upset most likely required a steam to hydrocarbon ratio of 0.7."[29] IPCA does not have enough information here to accurately calculate the destruction efficiency of the BOP flare during the July 2000 upset, but our experience suggests that it is likely that the heat content was too low and the exit velocity too high for it to be 98+%, as assumed in most of the Upset/Maintenance Notification Forms filed by ExxonMobil regarding the incident.[30]

The TCEQ's new regulations regarding flares that burn HRVOCs assign 93% destruction efficiency to flares which continuous monitoring data indicates do not meet the EPA's standards for minimum heat content and maximum exit velocity.[31] Assuming 93% destruction efficiency, rather than 98% destruction efficiency, for flare operations during the BOP's July 2000 upset, the 304 tons of VOC emissions becomes 1064 tons of VOC emissions. This represents 1.7 times the 622 tons of total VOC emissions reported for the BOP in 2000.[32] Reductions in residence time during startup and shutdown operations, when flares operate at high rates for extended periods, may substantially reduce combustion efficiency, even below the 93% provided for in the new regulations.

Crosswinds

The TCEQ's assumed flare destruction efficiencies of 98+% also do not take into account routine, yet less than ideal, weather conditions, such as crosswinds. An open flame, in the absence of a crosswind, assumes a symmetrical shape of maximum volume having an equilibrium flame temperature dependent upon operating conditions. Crosswinds distort the flame, reducing flame volume and flame temperature. High combustion efficiency requires that the combustible material be present in the high temperature region of the flame for a

[26] TNRCC Upset Investigation Report, Upset No. 5355, October 27, 2000.
[27] ExxonMobil Chemical Co. Response Letter to TNRCC, August 31, 2000, p. 4.
[28] Measurement Methodologies Evaluation, p. 5-5.
[29] ExxonMobil Chemical Co. Letter to TNRCC, December 12, 2000.
[30] *See* Upset/Maintenance Notification Forms attached to ExxonMobil Chemical Co. Letter to TNRCC, Region 12, November 10, 2000.
[31] 30 TAC §115.725(d)(7).
[32] *See* 2002 Emissions/Inspection Fee Form.

significant period. Crosswinds in excess of 5 miles per hour, however, may significantly degrade combustion efficiency because they shorten the residence time of the combustible material in the flame.

The EPA 1983 Flare Study only conducted tests on flares at wind speeds up to 5 miles per hour because flame instability made it impossible to obtain proper samples at higher wind speeds.[33] Consequently, there is a significant gap in the EPA field data, but lab-scale data suggests potentially *significant reduction in combustion efficiency at high wind speeds*.[34]

Ongoing studies by the Engineering Department of the University of Alberta and the Alberta Resource Council also demonstrate the need to consider the effects of crosswinds on flares. The University of Alberta studies not only confirm findings in the EPA 1983 Flare Study regarding flame separation, they also conclusively demonstrate that crosswinds—under some conditions—have a serious deleterious effect on the combustion efficiency of an open flame.

Since significant crosswinds are usually present along the Texas Gulf Coast,[35] these wind effects must be accounted for. Yet, the TCEQ inappropriately dismissed the findings from the University of Alberta research when they reviewed the data in 2001 and 2002. We requested internal documents from the TCEQ relating to this review and found that the TCEQ dismissed the *entire body of research* from the University of Alberta based primarily on the TCEQ Staff's review of only one study.[36] In analyzing this study, the TCEQ Staff concluded that.[37]

- questionable simplifying assumptions were made in the development of a mathematical model from the experimental work on a pilot-scale facility; and

---

[33] EPA 1983 Flare Study, p. 19.
[34] *See* M.R. Johnson, O. Zastavniuk, J.D. Dale and L.W. Kostiuk, "The Combustion Efficiency of Jet Diffusion Flames in Cross-flow," presented at the Joint Meeting of the United States Sections – The Combustion Institute, Washington, D.C., March 15-17, 1999. Matthew R. Johnson, Adrian J. Majeski, David J. Wilson and Larry W. Kostiuk, "The Combustion Efficiency of a Propane Jet Diffusion Flame in Cross Flow," presented at the Fall meeting of the Western State Section of the Combustion Institute, Washington, October 26-27, 1998 (Paper #98F-38).
[35] Houston's average annual wind speed is 7.9 miles per hour and Galveston's is 11.0 miles per hour. *See* the University of Utah Department of Meteorology's Utah and National Climate Data at http://www.met.utah.edu/jhorel/html/wx/climate/windavg.html.
[36] Douglas M. Leahey, Katherine Preston and Mel Strosher, Theoretical and Observational Assessment of Flare Efficiencies, 51 J. Air & Waste Mgmt., 1610, 1611 (2001)
[37] Karen Olson, Email to Terry Blodgett, *et al*., February 27, 2002, 11:31 AM (Olson Feb. 27 Email) (from TCEQ Response to Open Records Request of Don Weaver, March 29, 2005 (Mar. 29 Response). A review of the Canadian research, and the decision to dismiss these findings, was not presented in any public document or discussion until publication of the response to comments for the midcourse revisions adopted in December 2004. However, as early as 2002, at least one TCEQ Staff member relayed her concerns about the research to ExxonMobil's Doug Deason, and discussed his convening a technical exchange on flare efficiency. *See* Olson Feb. 27 Email and Doug Deason, ExxonMobil, Email to Ellen Baldridge, EPA, February 27, 2002, 11:48 AM (from Mar. 29 Response).

- poor flare destruction efficiency results obtained with field studies of a simple oil field flare could not be extrapolated to more sophisticated plant flares "with engineered burners and good liquid knockout systems."

The University of Alberta researchers did not directly investigate commercial refinery flares with engineered flare tips, but the basic findings of this study indicate that crosswinds affect combustion efficiency under a variety of circumstances.

Thus, while we agree with these specific critiques, it is inappropriate for the TCEQ to exclude the basic research by the University of Alberta on the basis that results of a field study of an oil field flare could not be directly applied to Gulf Coast flares because of design differences.

In fact, a senior technical specialist at TCEQ acknowledged as much with respect to these studies in an email on February 27, 2002: "I do think there are several hypotheses concerning flare efficiencies that need to be tested relative to the type of flares we use in Texas."[38] The same email states that she would first like "to test some of those hypotheses" with the results of "airplane [fly over] data where three flare plumes were in the transects."[39]

Baylor University collected some samples in canisters during flyovers it conducted in 2001 for TCEQ, but after a preliminary review, TCEQ Staff "determined there wouldn't be much information gained by researching the flight and VOC canister data further."[40] We have found no documentation indicating that the EPA or the TCEQ subsequently considered the effects of crosswinds on flares in policies or guidelines related to flares. Moreover, neither the EPA nor the TCEQ routinely consider this critical variable in permit reviews, compliance investigations or emission reduction planning. The entire question of crosswinds on flare combustion efficiency appears to have *disappeared from their deliberations, without explanation, for more than two decades*.

Performance Testing

The absence of further study or testing is particularly perplexing, since the TCEQ and the EPA acknowledge problems with accurately estimating air emissions generally, and from flares in particular. The TCEQ "has determined that [VOC] emissions may be underestimated in air shed emission inventories."[41] These

---

[38] Olson Feb. 27 Email.
[39] Olson Feb. 27 Email.
[40] Doug Boyer, TCEQ Air Quality and Implementation Division, Email to Don Weaver, Apr. 19, 2005 (TCEQ Response to Open Records Request of Don Weaver, Apr. 18, 2005).
[41] Measurement Methodologies Evaluation, p. E-1.

deficiencies are important because emission inventories are the foundation for effectively controlling air pollution.[42] And, since flare emissions represent a significant portion of an industrial plant's ozone-forming emissions,[43] undercounting of flare emissions most likely represents a significant portion of underestimated emission inventories.

Flare emissions, however, are much more difficult to measure than those of other pollution control devices. According to the EPA 1983 Flare Study, "Flare emission measurement problems include: the effects of high temperatures and radiant heat on test equipment, the meandering and irregular nature of flare flames due to external winds and intrinsic turbulence, the undefined dilution of flare emission plume with ambient air, and the lack of suitable sampling locations due to flare and/or flare heights, especially during process upsets when safety problems would predominate."[44] In addition, the EPA 1983 Flare Study specifically "excluded abnormal flaring conditions which might represent large hydrocarbon releases during process upsets, start-ups and shutdowns."[45]

This, however, does not justify excusing operators from monitoring flare emissions. Without proper monitoring it is impossible to know whether flares are performing as expected. The TCEQ expects "that emissions from flares would be better estimated if they were based on waste gas flow rate and composition measurements. … The overall objective of the [TCEQ] studies on flare emissions is to obtain performance specifications that ensure quality assured sampling, testing, monitoring, measurement and monitoring systems for waste gas flow rate, waste gas composition, and assist gas flow rate."[46] Modern insertion meters can measure mass flow within ±1%, and continuous composition analyzers are readily available. However, measuring flows within an uncertainty of ± 5% to 10% "in flare systems with highly variable compositions or where the meter cannot be located in a section of pipe with a representative flow profile will be a challenge."[47]

Accordingly, the TCEQ now requires that operators of flares that burn HRVOCs – 1.3-butadiene, butenes, ethylene and propylene – continuously monitor compliance with "maximum tip velocity and minimum heat

---

[42] An analysis of scientific data on ozone formation in the Houston-Galveston area as part of the TCEQ's Texas Air Quality Study in the summer of 2000, found that "[s]ubstantially improved emission inventory data are a prerequisite for determining the sensitivity of ozone formation to reductions in the emissions of reactive hydrocarbons and oxides of nitrogen." Science Synthesis Committee, "Accelerated Science Evaluation of Ozone Formation in the Houston-Galveston Area," November 13, 2002, p. 4.
[43] For 2000, the TCEQ estimates that 12% of VOC emissions for the HGB Area "pass through the flame of a flare without burning," based generally on an assumed 98% to 99% VOC combustion efficiency. Gabriel Cantu, TCEQ, 2000 HG Speciated Point Source Modeling Inventory, October 2003, Slide 17, available at www.tnrcc.state.tx.us/air/aqp/airquality_photomod.html.
[44] EPA 1983 Flare Study, p. 1.
[45] EPA 1983 Flare Study, p. 1.
[46] Measurement Methodologies Evaluation, p. E-1.
[47] Measurement Methodologies Evaluation, p. 6-1 to 6-2.

content requirements to ensure proper combustion by the flare."[48] These new regulations do not adequately reduce flare emissions, however, because:

- In setting the appropriate assist gas flow rates and aggregate flow velocity, it is important to know the composition of the flow. The TCEQ, however, does not require continuous composition monitoring.
- Most operators control assist gas injections manually, based on the visual evaluation of the flame's smokiness by the operator. Thus, depending on the quality of the operator, significant fluctuations in heating value and exit velocities can occur over the course of an hour such that substantial short-term fluctuations in heating value could offset each other. One study notes that the ratio of assist gas to waste gas with manual control varied from about 2 to more than 50.[49] In this way, oversteaming can significantly reduce combustion efficiency without violating the minimum heat value requirement for the one-hour average.
- Although most flares are designed to be most efficient at the high volumes experienced during non-routine operations, many are routinely used for disposal of low-flow emissions.
- The TCEQ presumes that "because many of these flares are also used for non-HRVOC streams, the regulations will result in better combustion of other VOC streams as well. This improved combustion will reduce emissions of less-reactive VOCs."[50] The TCEQ, however, did not make the continuous monitoring requirement applicable to waste gas streams of other VOCs. So there is no quality control on flares that burn only other VOCs and air toxics, which could represent a significant volume of VOC emissions in the Houston Ship Channel area.
- The results of industry monitoring are not readily accessible to the public. Although the San Francisco Bay Area has far fewer industrial flares, emitting much lower volumes of pollutants, the Bay Area Air Quality Management Districts (BAAQMD) in California requires all refinery operators with elevated flares to submit monthly reports of daily quantities (and species) of releases during the period reported.[51] The BAAQMD posts these reports, complete with graphs illustrating daily spikes in emissions, on its website.[52]
- Historically, TCEQ enforcement of monitoring requirements, if any, generally comprises only minor recordkeeping violations.

[48] HGB 2004 SIP Revisions §1.6.2.1 Collateral VOC Reductions.
[49] Measurement Methodologies Evaluation, p. 5-4.
[50] HGB 2004 SIP Revisions §1.6.2.1 Collateral VOC Reductions.
[51] Bay Area Air Quality District Regulation 12-11-401.
[52] *See* http://www.baaqmd.gov/enf/flares.

- The monitoring requirements on many flares with the potential for substantial emissions are significantly weaker. Generally, these relaxed regulations require only a combination of calorimeter, engineering calculations and process knowledge for monitoring flares used for abatement of emissions from loading operations, maintenance, startup and shutdown activities, emergencies, temporary service, liquid or dual phase streams, and metal alkyl production processes.[53]
- Operators of existing facilities have until the end of 2005 to begin monitoring compliance with exit velocity and heat content regulations, even for flares emitting HRVOCs.[54]

In addition, the type of continuous monitoring required by the TCEQ may not be adequate. Flow measurement devices typically "calculate volumetric flow by sensing a velocity in the pipe and multiplying that velocity by the cross sectional area of the pipe in which the velocity is being sensed."[55] The accuracy of these measurements, however, is based on assumptions that:

- velocity is uniform across the cross section; and
- the gas is of a known composition.

Thus, frequent changes in the waste gas composition of the flow could significantly marginalize the quality of flare performance assessments.

Although safety concerns may preclude direct monitoring of emissions, parametric monitoring and remote sensing techniques do exist which would provide data more indicative of actual flare performance and emissions. For example, Open Path Fourier Transformation Infrared (FTIR) technology "can identify, measure, and speciate over 100 compounds" from a distance of more than 100 meters.[56] FTIR is particularly suited for VOC identification and quantification because VOCs present strong absorption spectra in the infrared region.[57]

In the near term, the TCEQ could follow the lead of California regulators in requiring more extensive reporting of flare operations and emissions as a means to identify priorities in reducing flare emissions and motivating operators to undertake emission reduction projects sooner rather than later. Even before the

[53] 30 TAC §115.725(e)-(k).
[54] 30 TAC §115.729(a).
[55] Measurement Methodologies Evaluation, p. 2-1.
[56] Survey and Demonstration of Monitoring Technology for Houston Industrial Emissions (Project H31.2004) ENVIRON International Corporation. Prepared for Houston Advanced Research Center, January 12, 2005, pp. 3-12 to 3-13 (Monitoring Technology for Houston).
[57] Monitoring Technology for Houston, p. 3-16.

BAAQMD issued its Flare Monitoring Rule, its staff reported that flaring dropped dramatically because of increased industry attention to flaring and flare monitoring.[58]

Require Alternatives to Elevated Flares

For more consistent reductions in flare emissions over the long term, the TCEQ could require alternatives to elevated flares. It is common practice for industry to use elevated flares for routine destruction of vent gases or off-spec hydrocarbons, not just for emergency or short-term releases. Most flares are built for non-routine events—such as upsets, startup and shutdown—so they are not designed for optimal efficiency at low temperatures and low flow rates.[59] Consequently, routine flaring may result in unnecessary emissions of HRVOCs, VOCs and toxic materials.

The TCEQ appropriately requires that many vent and relief valve emissions be controlled, rather than vented to the atmosphere. Ideally, these routine emissions should be recovered in a flare gas recovery system,[60] which recycles the valuable components of the waste stream, using an elevated flare only as a backup system.

Where gas recovery is impractical, IPCA believes TCEQ should require operators to install high efficiency combustion devices to handle all predictable demand. Enclosed ground flares, incinerators and thermal oxidizers are acceptable alternatives because they can consistently achieve high combustion efficiencies as a result of the enclosed firebox, longer residence times at high temperature and negligible wind effects.

But high-efficiency combustion devices themselves need further attention from the TCEQ as well. Like owners of motorized vehicles, operators should be required to demonstrate the emission control performance of each device on an annual basis. After the TCEQ gains experience with the results of such testing, the frequency for specific classes of equipment—or particular companies—could be adjusted to ensure that testing occurs at appropriate intervals.

While avoiding flaring of routine vent gases is important, minimizing episodic emissions may be even more critical in reducing emissions of combustion byproducts, carbon monoxide (CO), carbon dioxide (CO_2) and

[58] BAAQMD Staff Report, Regulation 12, Rule 11, p. 31-32.

[59] The University of Alberta researchers found that crosswinds are more likely to reduce combustion efficiency as heat content and exit velocity decrease. Matthew R. Johnson, *et al.*, "The Combustion Efficiency of a Propane Jet Diffusion Flame in Cross Flow," presented at the Fall Meeting of the Western States Section of the Combustion Institute, Washington, October 26-27, 1998, p. 11. ("When CO_2 is used to substitute out part of the fuel to reduce its energy density (while maintaining the same jet density and exit velocity) the efficiency is adversely affected at lower cross flow velocities compared to the pure fuel case.")

[60] P.W. Fisher and D. Brennan, "Minimize Flaring with Flare Gas Recovery," Hydrocarbon Processing, June, 2002, p. 83.

nitrogen oxides (NO_x). As demonstrated by the Baytown Olefins Plant example cited earlier, emissions from a single episodic event can exceed annual average emissions. In reviewing emission events occurring during 2003, the University of Texas' Center for Energy and Environmental Resources found that the Houston Galveston Area averaged more than one emission event *per week*: "Over an 11-month period there are 58 times (affecting 395 hours) when ethylene event emissions exceed the 2000 annual average of 586 lbs/hr and 7 times (affecting 44 hours) when event emissions exceed 5 times the annual average."[61] Unlike in the rest of Texas, and the rest of the United States, emissions in Houston "change all the time," and "[p]oor air quality [is] due mostly to days with both ozone-conducive meteorology and high emissions."[62] Hence, preventing unnecessary releases may provide the greatest decrease in overall VOC emissions while also reducing emission of combustion byproducts, CO, CO_2, and NO_x.

In an effort to reduce such variable emissions, EPA Region 6, the Texas Natural Resources Conservation Commission (TNRCC, predecessor to the TCEQ), the Louisiana Department of Environmental Quality, and 13 petrochemical facilities in Louisiana and Texas, participated in the Episodic Release Reduction Initiative. In 1999 and 2000, the Initiative participants evaluated "the causes of releases to the air associated with startups/shutdowns, equipment failures, and process upsets."[63]

In the Technical Exchange on Startup/Shutdown practices,[64] petrochemical facilities shared case studies and examples of methods used to reduce flaring. Participants noted that changes to procedures and training as well as design improvements could be used to reduce emissions.[65] Key findings on ways to reduce emissions include:

- using flare gas recovery systems for routine venting and planned shutdowns;
- improving training of operators, better documentation of procedures highlighting environmental impacts, and allowing additional time for startup and shutdown; and
- reducing flaring among ethylene producers by recycling off-spec streams to furnace feed, augmenting the plant's steam capacity, and using a ground flare to handle off-spec and startup loads.

---

[61] Event Emissions in HGA, p. A-21.
[62] Harvey Jeffries, *et al.* Stochastic Emissions Inventories for Houston Point Sources, Concepts and Examples, presentation to TCEQ, October 2000, Slide 2, available at airchem.sph.unc.edu/Research/Projects/Texas/MCCG/ (emphasis in original).
[63] The Episodic Release Reduction Initiative, July 5, 2001 (ERRI), p. 1, at www.epa.gov/region6/6en/a/erri.htm.
[64] ERRI, Appendix F, pp.32-36.
[65] *See* ERRI, Appendix F, p.34.

The Initiative's findings need to be circulated to other facilities to encourage process modifications that reduce emissions. TCEQ might consider how regulations could be structured to encourage the programs and practices that have resulted in significant emission reductions below those of the baseline period.[66]

More extensive testing and reporting by plant operators on the operating parameters and performance of flares and other waste gas combustion devices also would help the TCEQ enforce existing regulations and identify priorities for reducing the use of elevated flare stacks as emission control devices.

Recommendations

1. Enforce existing requirements for flare operations *rigorously and consistently*.

2. Expand and accelerate TCEQ, EPA and others' research on the factors affecting combustion efficiency of flares, alternatives to flares and flare monitoring technologies.

3. Revise TCEQ policies and guidelines for estimating flare emissions. At a minimum, the effects of steam and crosswinds should be factored into emission estimates for rulemaking, permitting, enforcement, reporting and planning activities. These effects must be based on best available data rather than assumed values.

4. Conduct a rulemaking proceeding for regulations requiring more extensive monitoring and reporting of flare emissions. At a minimum, operators should be required to report daily emissions each month, and the TCEQ should post these reports on its website.

5. Develop a strategy to increase the use of flare gas recovery systems or, where impractical, use of more effective destruction technologies, such as enclosed ground flares or thermal oxidizers, rather than elevated flare stacks, as emission control devices.

6. Use elevated flare stacks only for release of combustibles in emergencies, for safety reasons, or as necessary during planned startups or shutdowns of equipment.

[66] "The baseline period included emissions from participating companies that were not part of the facilities' regulatory permits. These emissions include those from the Emergency Response Notification System (ENRS) database plus SO_2 emissions not otherwise captured." ERRI, p. 2 "As of December 31, 2000, the numbers of releases of hazardous chemicals (CERCLA plus SO_2) were 28% lower than the average for 1994 through 1999. The pounds of emissions from such releases were 48% lower." ERRI, p. 12.

7. Divert uncontrolled emissions from vents and relief valves to vapor recovery systems and other alternatives to flares, with flares serving only as a backup system. The TCEQ should set a goal for eliminating uncontrolled, authorized VOC emissions by a specified date, and systematically review its regulations and permitting policies to identify steps towards that goal.

8. Test high efficiency combustion devices, such as enclosed ground flares and thermal oxidizers, regularly to demonstrate emission control performance.