From: Benton, Christopher
To: Aimee Wilson/R6/USEPA/US@EPA
Subject: RE: Enterprise - Question on emissions
Date: 05/22/2012 03:04 PM
Attachments: API 560 Annex G.pdf

Aimee
Responses to each of the questions in your May 21, 2012 e-mail are provided below.

Thank you and please let me know if you have any additional questions.

Chris Benton
Enterprise Products
Manager - Environmental Permitting
1100 Louisiana
Houston, TX 77002
Office: (713) 381-5437
Cell : (832) 398-1849

From: Aimee Wilson [mailto:Wilson.Aimee@epamail.epa.gov]
Sent: Monday, May 21, 2012 8:55 AM
To: Benton, Christopher
Subject: RE: Enterprise - Question on emissions

Chris,

I have a few more questions.

Do you have benchmark data to show the heaters selected are the most efficient?

No, benchmark data is not available. As stated in the previous responses, the heaters and associated systems to maximize overall efficiency are designed specifically for the proposed process and are in part based on Enterprise experience with near identical units already in operation at Mont Belvieu and elsewhere.

Page 6-9 - For the hot oil heater, it states that thermal efficiency will be calculated using accepted API methods to show compliance with 85% efficiency. Which methods are you considering using. I will need to reference which methods are approved. We will need the calculation methodology as well. Where did the 89% efficiency come from?

The calculation method will use Equation G-1 from API 560 (4th ed.) Annex G, a copy of which is attached. 89% is the maximum design efficiency guaranteed by the vendor for the heater in a new, steady state, full load operating condition. It does not reflect actual operating conditions, load variations, or loss of efficiency over time that is unavoidable even for well-maintained equipment. The proposed standard of 85% takes these factors into consideration.

We will need some way for you to show that the regen heaters are 80% efficient. Where did the 80% efficiency come from? Can you use the API methods on it? Can you monitor exhaust temperature? If this is not possible, please propose an output based BACT limit.

As with the Hot Oil Heaters, 80% is the maximum design efficiency guaranteed by the vendor for the heaters in a new, steady state, full load operating condition. It does not reflect actual operating conditions, load variations, or loss of efficiency over time that is unavoidable even for well-maintained equipment. For these heaters, even more so than for the Hot Oil Heaters, their actual operation is cyclic, which significantly reduces actual efficiency. Total emissions from these two heaters combined are less than 14% of the total project GHG emissions even if operated at full load continuously. In actual operation, GHG emissions from these heaters will be an even smaller fraction of the total project emissions. For these reasons, Enterprise believes that establishing and demonstrating compliance with a hard efficiency limit does not provide a means of limiting actual tons per year of GHG emissions by a significant amount, and thus will not result in a significant environmental benefit.

Page 6-11 - What exactly is a "flare system analyzer"? Is this a gas composition analyzer?

Yes, this is just a reference to the flow rate and composition analyzers identified in Step 1.

Do you know the energy penalty for CCS (page 6-7)?

No, this has not been quantified. There is clearly a significant energy cost associated with CCS, and the intent was just to point it out qualitatively. Enterprise believes that the cost arguments already provided adequately demonstrate that CCS is not a viable alternative, and further quantification of cost, energy, or environmental impacts is not necessary to support this conclusion.

Thanks,
Aimee

Aimee Wilson
Air Permits Section (6PD-R)
U.S. Environmental Protection Agency
1445 Ross Avenue
Dallas, Texas 75202
214-665-7596

From: "Benton, Christopher" <CRBENTON@eprod.com>
To: Aimee Wilson/R6/USEPA/US@EPA
Date: 05/16/2012 11:51 AM
Subject: RE: Enterprise - Question on emissions

Aimee,

Please find attached the updated application for the PSD GHG Permit Application for the Eagleford Frac Project. This application contains the most recent TCEQ application update as indicated by Mr. Shanon DiSorbo below. Please take note that we made a typo in our most recent response on May 2, 2012. Each fractionation unit is capable of processing 1***1***0,000 bbls/day. I believe you now have all you need based upon our discussions over the past weeks to finalize your review of the application. Additionally, we are working with Alfred and Tina on the BSA and hope to have the requested revisions to the them by the end of the month.

Thank you and please let me know if you have any additional questions.

Chris Benton
Enterprise Products
Manager - Environmental Permitting
1100 Louisiana
Houston, TX 77002
Office: (713) 381-5437
Cell : (832) 398-1849

From: Aimee Wilson [mailto:Wilson.Aimee@epamail.epa.gov]
Sent: Wednesday, April 11, 2012 11:25 AM
To: Shanon DiSorbo
Cc: Benton, Christopher; Steve Langevin
Subject: RE: Enterprise - Question on emissions

Shanon,

Thanks for the update. When you have the TCEQ application update, please send me a copy.

Thanks,
Aimee

From: "Shanon DiSorbo" <DiSorboS@rpsgroup.com>
To: Aimee Wilson/R6/USEPA/US@EPA
Cc: "Steve Langevin" <LangevinS@rpsgroup.com>, "Benton, Christopher" <CRBENTON@eprod.com>
Date: 04/11/2012 11:21 AM
Subject: RE: Enterprise - Question on emissions

Aimee –

I am responding for Chris. He is headed out of town for a meeting and asked that I give you an update. As it turns out, the project will now be subject to PSD for CO. After a meeting with yesterday with our heater vendor, it was recommended that we increase the annual CO concentration estimate from the hot oil heaters from 30 ppm to 50 ppm. As a result, the project annual emissions will exceed the 100 tpy threshold for CO and trigger PSD.

We are in the process of updating the TCEQ application. We will send you an update when submitted. Therefore, our project is once again a dual-PSD permit with TCEQ reviewing the non-GHG pollutants and EPA reviewing the GHG pollutants. The additional impacts/Class I requirements will be done by TCEQ.

If you have any further questions, please let us know.

Regards,

Shanon

Shanon DiSorbo
RPS
832-239-8019
281-513-5886 (cell)

From: Aimee Wilson [mailto:Wilson.Aimee@epamail.epa.gov]
Sent: Tuesday, April 10, 2012 2:11 PM
To: Benton, Christopher
Cc: Shanon DiSorbo; Steve Langevin
Subject: RE: Enterprise - Question on emissions

It looks like we may have to request some additional information. Since this is a non dual-PSD permitting scenario, we will have to do some additional impact analysis and Class I requirements differently than we have done for the dual-PSD permitting scenarios. This permit will be under a lot more scrutiny than others - especially since this will probably be the first one we issue that is a non dual-PSD.

From: "Benton, Christopher" <CRBENTON@eprod.com>
To: Aimee Wilson/R6/USEPA/US@EPA
Cc: Steve Langevin <LangevinS@rpsgroup.com>, Shanon DiSorbo <DiSorboS@rpsgroup.com>
Date: 04/10/2012 11:23 AM
Subject: RE: Enterprise - Question on emissions

In this case you may assume they are the same for PSD applicability. All of this is described in detail in section 7 of the TCEQ application we provided as an attachment to our recent revision to the GHG PSD permit application. I am still working on your questions from earlier today as well.

Thanks.

Chris Benton
Enterprise Products
Manager - Environmental Permitting
1100 Louisiana
Houston, TX 77002
Office: (713) 381-5437
Cell : (832) 398-1849

From: Aimee Wilson [mailto:Wilson.Aimee@epamail.epa.gov]
Sent: Tuesday, April 10, 2012 11:06 AM
To: Benton, Christopher
Cc: Steve Langevin; Shanon DiSorbo
Subject: Enterprise - Question on emissions

Can you provide me with the NO2 emissions for PSD? The NNSR permit application only identifies NOx.

Thanks,
Aimee

RPS Group Plc web link: http://www.rpsgroup.com [attachment "GHG Application Rev 2.pdf" deleted by Aimee Wilson/R6/USEPA/US]

From: Benton, Christopher
To: Aimee Wilson/R6/USEPA/US@EPA
Subject: Enterprise Eagleford Fractionation GHG Permit - Response to Questions
Date: 05/02/2012 07:18 AM
Attachments: EPA NOD Response 5 1 2012.pdf

Aimee,

Attached is our response to your questions we discussed over the phone on March 30, 2012 and in a follow-up email on April 10, 2012. We are in the final stages of revising both the TCEQ PSD application and the EPA GHG application. We will send you both of these shortly.

In the meantime, please let me know if you have any further questions or comments.

Thank you,

Chris Benton
Enterprise Products
Manager - Environmental Permitting
1100 Louisiana
Houston, TX 77002
Office: (713) 381-5437
Cell : (832) 398-1849

Enterprise Mont Belvieu Complex
Eagleford Fractionation Project GHG Permit Application
Response to EPA Comments
May 1, 2012

1. Questions from March 30, 2012 telephone conversation with Chris Benton

   a. Information explaining why the heaters were chosen in terms of efficiency.

Response: The heaters are not selected "off the shelf"; rather, they are designed to satisfy their specific intended process function while minimizing emissions of CO and NO_x which largely dictates the actual efficiency. Because the heaters are new, the design incorporates many state-of-the-art efficiency features, including insulation to minimize heat loss and heat transfer components that maximize heat recovery while minimizing fuel use. Additional information addressing heater design and efficiency will be added to the BACT analysis in the revised application.

   b. Propose the method of tracking efficiency in terms of a permit condition.

Response: Enterprise will propose actual thermal efficiencies in % to be demonstrated on a 12-month rolling average basis for the two hot oil heaters. The calculation will be based on fuel temperature, ambient temperature, stack exhaust temperature, and stack O2 concentration, all of which will be monitored on an hourly basis. Because the regen heaters are much smaller (<30 MMBTU/hr) and operate intermittently, they are much smaller sources of GHG emissions. For these reasons, Enterprise does not believe that an efficiency standard is necessary to ensure on-going permit compliance .

   c. What is the function of the regen heaters?

Response: The regen heaters are used for the amine and dehy regeneration steps of the process. The details of their use is shown on the process flow diagram in Figure 4-1 of the permit application.

   d. What is the capital cost of the project?

Response: The capital cost of the project is expected to be about $500,000,000 based on current estimates.

   e. What is the production capacity of the proposed facilities?

Response: The capacity of each fractionation unit is 100,000 barrels per day, nominal.

2. Comments on BACT Analysis in attachment to April 3, 2012 Completeness Determination letter.

Response: The BACT analysis in the revised application will address the items in the attachment to your letter. Per Item 1 of the attachment, additional information will be added to the CCS cost analysis to compare the cost of CCS with the capital cost of the

project. The remainder of the BACT analysis will be revised per the general comments in Item 2 of the attachment to your letter.

3. April 9, 2012 e-mail to Chris Benton - Were any other options evaluated as controls in lieu of the flare? Thermal oxidizer, vapor recovery unit, etc.? Why was a flare chosen?

Response: One of the primary reasons that a flare was selected was for emergency releases. Although every possible effort is made to prevent such releases, they can occur, and the design must allow for them. A thermal oxidizer is not capable of handling the sudden large volumes of vapor that could occur during an upset release. The same constraints exist with a vapor recovery unit. For this reason, even if a thermal oxidizer or vapor recovery unit was used for control of routine vent streams, the flare would still be necessary and would require continuous burning of natural gas in the pilots, which add additional CO_2, NO_x, ***and CO emissions.***

The proposed flare is also designed for 99.5% DRE of VOCs; therefore, use of a thermal oxidizer would not result in significantly less VOC emissions. A flare is also more suited to non-continuous streams than a thermal oxidizer, which would have to be maintained in hot standby mode, thus creating additional emissions of CO_2, NO_x, ***and CO.***

A vapor recovery unit is not considered technically feasible for the amine regeneration stream, as it is not well suited to low levels of hydrocarbon in a large inert stream. A vapor recovery unit would require a chiller to condense the VOC in the stream. The stream contains significant amounts of CO_2 ***and water that would condense and cause icing of the equipment.***

4. April 10, 2012 e-mail to Chris Benton – Is the flare air assisted, steam assisted, not assisted?

The proposed flare is air-assisted, and its specifications will be similar to the existing flares at the Mont Belvieu Complex. Attached is additional information on the flare efficiency of the flare to be installed. The emissions calculations for the flare will be included in the revised TCEQ application that will be sent to you separately. These flare calculations were inadvertently left out of the application we previously sent to you.

Enterprise Products Operating LLC
Mont Belvieu Complex - Eagleford Frac
APPENDIX B.2 - Flare Emission Calculations (SK25.001)

Flaring Parameters

	Maximum Flow		Heat Content	VOC Content	Stream MW	Heat Input to Flare
	(scf/yr)	(scf/hr)	(Btu/scf)	(Weight %)	(lb/lbmole)	(MMBtu/hr)
Process Gas	697,646,400	79,640	127	0.45	43.4	10.128
Natural Gas	278,031,548	31,739	1021	4.29	17.6	32.416

Process & MSS Gas Emission Factors

Pollutant	Factor	Units	Source
NO_x	0.084	lb/MMBtu	TCEQ Flare Guidance (2000) Table 5
CO	0.260	lb/MMBtu	TCEQ Flare Guidance (2000) Table 5
VOC	0.0026	lb/Mscf	Material balance & 99.5% DRE[1], per TCEQ Guidance, 2000
SO_2	0.025	lb/Mscf	Material balance w/inlet H_2S[2], per TCEQ guidance, 2000

[1] $EF_{VOC} = W_{VOC}$ in gas (%)/100, lb VOC/lb gas * MW_{gas}, lb/lbmole * 1 lbmole gas/379.5 scf gas * 1000 scf/Mscf * (1-99.5/100)

[2] $EF_{SO2} = Y_{H2S}$ in gas (%)/100, lbmol H_2S/lbmole gas * 1 lbmol gas/379.5 scf gas * 1 lbmol SO_2/1 lbmol H_2S * 64 lb SO_2/lbmol SO_2 * 1000 scf/Mscf

Natural Gas Emission Factors

Pollutant	Factor	Units	Source
NO_x	0.084	lb/MMBtu	TCEQ Flare Guidance (2000) Table 5
CO	0.260	lb/MMBtu	TCEQ Flare Guidance (2000) Table 5
VOC	0.0099	lb/Mscf	Material balance & 99.5%DRE[1], per TCEQ Guidance, 2000
SO_2	0.0025	lb/Mscf	Gas specification

[1] $EF_{VOC} = W_{VOC}$ in gas (%)/100, lb VOC/lb gas * MW_{gas}, lb/lbmole * 1 lbmole gas/379.5 scf gas * 1000 scf/Mscf * (1-99.5/100)

[2] $EF_{SO2} = Y_{H2S}$ in gas (%)/100, lbmol H_2S/lbmole gas * 1 lbmol gas/379.5 scf gas * 1 lbmol SO_2/1 lbmol H_2S * 64 lb SO_2/lbmol SO_2 * 1000 scf/Mscf

Emission Calculations

	Maximum Emission Rates							
	NO_x		CO		VOC		SO_2	
	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr
Process Gas	0.85	3.73	2.63	11.53	0.20	0.90	2.01	8.82
Natural Gas	2.72	11.93	8.43	36.92	0.32	1.38	0.08	0.35
TOTAL	3.57	15.65	11.06	48.45	0.52	2.28	2.09	9.18

Enterprise Products Operating LLC
Mont Belvieu Complex - Eagleford DIB
APPENDIX B.7 - Flare Emission Calculations (EPN SK25.001)

Flaring Parameters

	Maximum Flow		Heat Content	VOC Content	Stream MW	Heat Input to Flare
	(scf/yr)	(scf/hr)	(Btu/scf)	(Weight %)	(lb/lbmole)	(MMBtu/hr)
Process Gas	2,863,907	327	2998	100.00	58.1	0.980
Natural Gas	0	0	1021	4.29	17.6	0.000

Process & MSS Gas Emission Factors

Pollutant	Factor	Units	Source
NO_x	0.084	lb/MMBtu	TCEQ Flare Guidance (2000) Table 5
CO	0.260	lb/MMBtu	TCEQ Flare Guidance (2000) Table 5
VOC	0.7650	lb/Mscf	Material balance & 99.5% DRE[1], per TCEQ Guidance, 2000
SO_2	0.000	lb/Mscf	Material balance w/inlet H_2S[2], per TCEQ guidance, 2000

[1] $EF_{VOC} = W_{VOC}$ in gas (%)/100, lb VOC/lb gas * MW_{gas}, lb/lbmole * 1 lbmole gas/379.5 scf gas * 1000 scf/Mscf * (1-99.5/100)

[2] $EF_{SO2} = Y_{H2S}$ in gas (%)/100, lbmol H_2S/lbmole gas * 1 lbmol gas/379.5 scf gas * 1 lbmol SO_2/1 lbmol H_2S * 64 lb SO_2/lbmol SO_2 * 1000 scf/Mscf

Natural Gas Emission Factors

Pollutant	Factor	Units	Source
NO_x	0.084	lb/MMBtu	TCEQ Flare Guidance (2000) Table 5
CO	0.260	lb/MMBtu	TCEQ Flare Guidance (2000) Table 5
VOC	0.0099	lb/Mscf	Material balance & 99.5%DRE[1], per TCEQ Guidance, 2000
SO_2	0.0025	lb/Mscf	Gas specification

[1] $EF_{VOC} = W_{VOC}$ in gas (%)/100, lb VOC/lb gas * MW_{gas}, lb/lbmole * 1 lbmole gas/379.5 scf gas * 1000 scf/Mscf * (1-99.5/100)

[2] $EF_{SO2} = Y_{H2S}$ in gas (%)/100, lbmol H_2S/lbmole gas * 1 lbmol gas/379.5 scf gas * 1 lbmol SO_2/1 lbmol H_2S * 64 lb SO_2/lbmol SO_2 * 1000 scf/Mscf

Emission Calculations

	Maximum Emission Rates							
	NO_x		CO		VOC		SO_2	
	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr
Process Gas	0.08	0.36	0.25	1.12	0.25	1.10	0.00	0.00
Natural Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.08	0.36	0.25	1.12	0.25	1.10	0.00	0.00

FLARE EFFICIENCY DETERMINATION
UF- 510 / FC 3326

FLARE TIP TYPE/SIZE: FCA - 14 / 42 / 3

ASSISTED: YES AIR

DESIGN CONDITIONS:
FLOW: 295435 lb/h
M.W: 42
TEMP: 100 deg F

CALORIFIC VALUE OF WASTE GAS STREAM:
ENRICHED NO
ENRICHMENT NA lb/h of NA
TOTAL 19691 Btu/lb (est)
2175 Btu scf

PERMITTED MAXIMUM EXIT VELOCITY: 400 fps

TIP ACTIVE DIAMETER: 41.5 inches

For enriched case, active diameter encloses combined flows NA
For non-circular configurations [FCA flares], active diameter uses the equivalent discharge point which supports the base of the flame. YES

ACTIVE TIP OUTLET AREA: 9.93 sq.ft

VOLUME FLOW AT DESIGN: 753 scfs

ACTUAL EXIT VELOCITY: 76 fps

THESE CONDITIONS MEET CRITERIA OF 40 CFR 60.18 YES

FOR THOSE FLARES WHICH MEET THE CRITERIA OF 40 CFR 60.18 IN NORMAL OPERATIONS, CONVERSION WILL BE BETTER THAN 99% IF CORRECTLY OPERATED WITH A CLEAN, BUT NOT OVER-STEAMED/OVER-AIRED OR NON-LUMINOUS FLAME,.
IT IS PRACTICAL TO EXPECT 99.95% CONVERSION FOR EVERYDAY CONDITIONS AND 99.5 % CONVERSION FOR MINOR EMERGENCIES. SEE ALSO COMMENTARY AND TABLES

CERTIFIED:

David Shore

CHIEF ENGINEER.

FLARE EFFICIENCY DETERMINATION
UF- 548 / FC 3568

FLARE TIP TYPE/SIZE:	FCA - 20 / 48-54 / 3		
ASSISTED:	YES	AIR	
DESIGN CONDITIONS:			
FLOW:	250,000	lb/h	
M.W:	42.18		
TEMP:	100	deg F	
CALORIFIC VALUE OF WASTE GAS STREAM:			
ENRICHED	NO		
ENRICHMENT	NA	lb/h of	NA
TOTAL	19691	Btu/lb (est)	
	2175	Btu scf	
PERMITTED MAXIMUM EXIT VELOCITY:	400	fps	
TIP ACTIVE DIAMETER:	53.5	inches	
For enriched case, active diameter encloses combined flows		NA	
For non-circular configurations [FCA flares], active diameter uses the equivalent discharge point which supports the base of the flame.		YES	
ACTIVE TIP OUTLET AREA:	15.61	sq.ft	
VOLUME FLOW AT DESIGN:	635	scfs	
ACTUAL EXIT VELOCITY:	41	fps	
THESE CONDITIONS MEET CRITERIA OF 40 CFR 60.18		YES	

FOR THOSE FLARES WHICH MEET THE CRITERIA OF 40 CFR 60.18 IN NORMAL OPERATIONS, CONVERSION WILL BE BETTER THAN 99% IF CORRECTLY OPERATED WITH A CLEAN, BUT NOT OVER-STEAMED/OVER-AIRED OR NON-LUMINOUS FLAME,.
IT IS PRACTICAL TO EXPECT 99.95% CONVERSION FOR EVERYDAY CONDITIONS AND 99.5 % CONVERSION FOR MINOR EMERGENCIES. SEE ALSO COMMENTARY AND TABLES

CERTIFIED:

David Shore

CHIEF ENGINEER.

FLARE EFFICIENCY DETERMINATION
FLARE EFFICIENCY

COMMENTARY

The efficiency of combustion of hydrocarbons in elevated flares has been the subject of investigation by the EPA and other regulatory agencies in the USA and overseas. These reports are listed later in this document.

As a result of investigations, performed by these agencies on Flaregas (and other) Flare designs, a pattern of information has developed which allows realistic estimates to be made of the combustion and destruction efficiencies in the flare flame.

This information is summarized below, and in the attached assessments of the EPA data.

1. Elevated Flare Flames burn well as long as a stable flame is assured by the presence of (flame-holding) stabilizers and continuously burning pilots.

2. The limit of stability is closely related to the combustion properties of the gas and has been defined on the basis of intrinsic calorific value and gas exit speed. These parameters are combined in EPA regulations numbered 40 CFR 60.18 and 40 CFR 63.11, and are provided in the following text.

3. Only flames operating at, or below the limit of stability exhibit efficiencies less than 98%.
   Almost all other conditions exhibit better than 99.5% conversion.

4. Smokeless flares operating with clean flames exhibit combustion efficiencies approaching 100% unless over-steamed or over-aired.

5. For steam assisted flares, the steam flow rate affects both the smokeless performance and the combustion efficiency of the flare. Peak efficiency in the reports is related to a clean flame with approximately 0.5 wt/wt steam ratio. Efficiency of over-steamed flames is reduced, although it is still better than 99%.

6. For air assisted flares, the air flow rate affects both the smokeless performance and the combustion efficiency of the flare. Peak efficiency in the reports is related to a clean flame with less than 100% stoichiometric air being provided by blowers.
   For the tested Flare tips, efficiency of over-aired flames reduces significantly, approaching extinction at the lower explosive limit (approx 150% stoichiometric air).

7. Un-assisted flares, steam assisted flares without steam or air assisted flares with inoperative blowers can be considered to combust all hydrocarbons to an efficiency certainly greater than 98% and probably better than 99.5%, even when making smoke.

8. Destruction efficiency of original Hydrocarbon is probably better than 99.9% for the most hydrocarbons and better than 99.5% for the worst VOC materials.

The reports show that there is no easy test to establish a "break-point" of efficiency. The testing has established that 98% efficiency tends to be an approximate break-point between burning something and not burning at all, such that, for a lean gas with little intrinsic heating value, when the efficiency falls to 98% the flame is likely to go out. However, for high calorific value fuels, this is an extremely unlikely event.

Most EPA associated agencies currently accept 98% or 99% conversion as a base line.

The presence or absence of smoke is something of an indicator of efficiency within this 2% range. At the cleanest, visible flame conditions, the combustion efficiency approaches 100%. At "dirty" conditions the efficiency is almost invariably better than 99%. Flames which are "too" clean, (i.e.: at significant reductions in luminosity by over-airing or over-steaming) tend to reduce in efficiency again until they reach a point of being extinguished. However, this is not a design condition and can usually be remedied by operational adjustments to the steam or air flow rates.

The pollution which results from reduced efficiency seems to produce soot (dirty flame only), carbon monoxide and unburned hydrocarbon with roughly equal concentrations adding up to the cumulative inefficiency stated above.

The complete published series of US test results is available, in the form of reports as listed below, from
NTIS, Springfield, Virginia 22161,
"Evaluation of the Efficiency of Industrial Flares:"

Test Results	- EPA-600/2-84-095
Flare Head Design and Gas Composition	- EPA-600/2-85-106
H_2S Mixtures/Pilot Assisted Flares	- EPA-600/2-86-080.

An earlier study, which established typically similar results on refinery gases, was performed in the Federal Republic of Germany by the German equivalent of the Oil Industry Institute and is also available from
DGMK, 2000 Hamburg 1, Nordkanalstrasse 28, Germany
"Entwicklung schadstoffarmer Industriefackeln:" Teilvorhaben 135-02.

For the purposes of EPA, or equivalent documentation, the flare operator should review his own flare operations to see whether they fall in the limiting stability range or whether they are well inside safe operation and with a high intrinsic calorific value.

FLARE EFFICIENCY

40 CFR 60.18 / 63.11 VELOCITY FORMULÆ

The maximum permitted gas exit velocities for non-assisted, gas assisted and steam assisted tips, on the basis of 40 CFR 60.18 and 40 CFR 63.11 are described by the following formulae:

The maximum permitted velocity limit for non-assisted and steam assisted tips is given by the relationship:

Velocity (using scfs) = $26.6 * 10^{(CV/850)}$
{max = 400 fps equivalent CV = 1000 Btu/scf}

An alternative design velocity may be used for gases with greater than 8% Hydrogen content such that:

Velocity (using scfs) = $12.8 * (H_2 \text{ vol\%} - 6)$
{max = 122 fps equivalent H_2 vol% = 15.5 vol%}

The maximum permitted velocity limit for air assisted tips is given by the relationship:

Velocity (using scfs) = 28.6 + (0.0867 * CV)

Standard volume (scf) is calculated at 68°F and a pressure of 760 mm Hg.;
CV is calorific value (based on combustion at 77°F) expressed in Btu/scf
limited to a minimum value = 300 Btu/scf for assisted flares;
or 200 Btu/scf for non-assisted/gas assisted flares.

FLARE EFFICIENCY

GUIDE TO OVERALL COMBUSTION EFFICIENCY ESTIMATION BASED ON THE VISUAL APPEARANCE OF A FLARE FLAME

[Assumes hydrocarbon predominance]

Flame Appearance	**Efficiency %**
Any Combustion Reaction	>= 98.0
Any *Visible* Hydrocarbon Flame	> = 99.0
Clean, Red/yellow	> = 99.5
Clean, Sharp, Bright Yellow/white	Close to 100
Clean, Yellow Flame with Reduced Luminosity	> = 99.5
Barely Visible (Transparent) Hydrocarbon Flame	> = 99.0

FLARE EFFICIENCY

GUIDE TO EMISSIONS ESTIMATION

On the basis of results published in the referenced documents, the following estimations are suggested for emissions calculations.

Total Inefficiency <= 2% (see text)

Inefficiencies are expressed by mass of carbon in the gas;

Particulate

Depends on nature of original gas and operating conditions;
Greatest efficiencies assume smokeless operation with zero effective particulate output;

Unburned Hydrocarbons

0.50% of Aromatics (and related hydrocarbons) in original gas;
0.05% of other hydrocarbons in original gas;
40% x residual inefficiency converted to CH4;

Carbon Monoxide - CO

60% x residual inefficiency converted to CO;

Hydrogen Sulphide - H2S

67% x inefficiency for hydrocarbons;
Inefficiencies are expressed by total mass of H2S;

Nitrogen Oxides - NOx

a) for Hydrocarbon flare flames less than 100 million Btu/h

$$\text{Total NOx (lb/h)} = \frac{\{\text{Heat release (Btu/h)}\}^{1.8}}{25{,}000{,}000{,}000{,}000}$$

b) for Hydrocarbon flare flames greater than 100 million Btu/h

$$\text{Total NOx (lb/h)} = \frac{\{\text{Heat release (Btu/h)}\}^{1}}{10{,}000{,}000}$$

c) Effects of organically bound Nitrogen are considered to be additive based on the total elemental Nitrogen (N) in the original compound converted at 45 wt of Nox per 14 wt of *atomic* Nitrogen.

$$\text{Fraction converted to Nox} = \frac{\{\text{Heat release (Btu/h)}\}^{0.5}}{100{,}000} = 0.1 \text{ max}$$