D.L. Davis ~~[illegible]~~, [illegible] → RB **VISTA**
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To RON BRYAN
LC VCM

Date 5/20/85

RON,

I THOUGHT THIS ARTICLE MIGHT BE OF INTEREST IF THE FLARE ISSUE EVER GETS SERIOUS. I NOTICED THAT THE EPA'S STDS. ARE FOR "CONTINUOUS FLARE RELEASES, NOT EMERGENCY FLARE RELEASES." HOWEVER, I NOTICE ON THE 3RD PG. (TABLE 2) THAT THEY'RE PROPOSING TO TEST EDC/VCM (OR HAVE TESTED?). I DIDN'T SEE ANY MENTION OF CONTROLLING PRODUCTS OF COMBUSTION, ALTHOUGH Cl- AND S-CONTAINING COMPOUNDS ARE LISTED. IT'S INTERESTING TO SEE THAT IT'S AT LEAST BEING LOOKED INTO.

[signature]

- Using efficiency of 98% mentioned in article the maximum concentration of VCM that can be fed to flare without exceeding 10ppm limit is 0.05% which is much lower than our headers run.

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U.S. EPA's Flare Policy: Update and Review

It is recommended EPA change its flare policy to accept the more general concept of flame stability as an indicator of efficient flare operation.

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The effect of flaring operations on the environment continues to be of concern to regulatory agencies and industry. Recent regulatory initiatives by the U.S. Environmental Protection Agency (EPA) have established regulatory performance and design standards for flare operations.

EPA flare policy

EPA's present flare policy, developed by its Office of Air Quality Planning and Standards, was presented at a meeting of the National Air Pollution Control Technique Advisory Committee in November of 1983 (*1*). Based on the test data (*2–9*), EPA concluded that 98% combustion efficiency can be achieved by steam-assisted, air-assisted and nonassisted flares if operated within the following combustion gas heat content and exit gas velocity ranges:

	Heat Content Greater Than	Exit Gas Velocity Less Than
Steam-Assisted Flares	300 Btu/scf (std. ft^3) (11.2 MJ/m^3)	60 ft/s (18.3 m/s)
Nonassisted Flares	200 Btu/scf (7.4 MJ/m^3)	60 ft/s (18.3 m/s)
Air-Assisted Flares	$V = 28.75 + 0.867\,HC$	

where

V = maximum exit gas velocity in ft/s at standard conditions (ft × 0.3048 = m)
HC = heat content of the gas in Btu/scf (Btu/scf × 3.725×10^{-2} = MJ/m^3)

This policy was used as the basis for the 15 or more regulations in various stages of development, Table 1, to uniformly regulate flare practices. EPA's intent is to regulate continuous flare releases, not emergency flare releases. Thus, the above limitations are intended to be applied to continuous, nonemergency, releases.

Chemical industry response

The first promulgated regulation, in which the EPA flare limitations were adopted, was the New Source Performance Standard (NSPS) for Synthetic Organic Chemical Industry (SOCMI) Fugitive Emissions. The Chemical Manufacturers Association filed a petition (*10*) to reconsider or stay the flare limitations contained in the Fugitive Emission NSPS. The basis for the petition was:

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Table 1. Regulations under development or issued by EPA where flares are used as a control device.

New Source Performance Standards

- Synthetic Organic Chemical Manufacturing: Fugitive Emissions
- Synthetic Organic Chemical Industry: Air Oxidation Processes
- Distillation Operations
- Refinery Fugitive Emissions
- On-Shore Natural Gas Processing Plants
- Resin Polymer Manufacture
- Synthetic Organic Chemical Manufacturing: Reactor Vent Emissions

National Emission Standards for Hazardous Air Pollutants

- Benzene Fugitive Emissions
- Benzene in Coke Oven by Products Plants
- Benzene From Ethylbenzene/Styrene Manufacture
- Benzene From Maleic Anhydride Manufacture

Control Technical Guidelines (Regulates Existing Sources)

- Equipment/Leaks From On-Shore Natural Gas Processing Plants
- Resin Polymer Plants
- Refinery Fugitive Emissions
- Synthetic Organic Chemical Manufacturing Industry: Fugitive Emissions

- EPA-sponsored R&D work on flares, completed in 1983 by Energy and Environmental Resources (EER) Inc., showed flares to be efficient control devices at high velocities. This work was not completed in time for EPA to consider the data in its policy formulation. This study is discussed further below.
- The 60 ft/s (18.3 m/s) maximum velocity limitation was chosen based on the range of available test data as of November, 1983. Although some higher velocity test data were available, EPA chose 60 ft/s (18.3 m/s) as an upper velocity limit. No test data were available to EPA at the time which indicated that flares were inefficient above velocities of 60 ft/s (18.3 m/s).
- The flare velocity limitation would cause serious operating problems to existing flare operations with SOCMI sized to handle emergency releases and used to handle continuous releases. Some existing flare installations cannot comply with the 60 ft/s (18.3 m/s) limitation, thus requiring construction of an additional control device.
- Flare gas velocity measurements are difficult to obtain.
- The use of flares to resolve certain technical and safety problems would be limited.
- The flare exit velocity restrictions will unnecessarily increase costs to SOCMI because they: increase pilot gas requirements and capital costs due to larger flares; can shorten flare tip life due to exposure of the flare tip to lower operating velocities and resulting higher temperatures; and increase purge gas requirements.

At the same time, the petition was submitted to EPA; the Chemical Manufacturers Association filed a petition for review of flare limitations with the U.S. Court of Appeals for the District of Columbia Circuit. That case has now been settled (*13*). In the settlement, EPA agreed to propose to allow continuous flaring of high Btu gases (above 1,000 Btu/scf, 37.25 MJ/m^3) at velocities up to 400 ft/s (122 m/s) while retaining the 60 ft/s (18.3 m/s) velocity limitation for gases with heat content between 300 to 1,000 Btu/scf (11.2–37.2 MJ/m^3). The EPA will also clarify provisions in the regulations dealing with the issues of applicability to startup and shutdown emissions, calculation and measurement of exit velocities and how EPA intends to modify the regulations as new information becomes available. The schedule for EPA's regulatory proposal is not clear yet.

EPA R&D on flare

EPA has recently completed an "Evaluation of the Efficiency of Industrial Flares Test Results (*11*)"; the work was performed in 1983 under contract from EPA (No. 68-02-3661) to Energy and Environmental Research Corp. The EPA Flare R&D program has been subjected to peer review via a technical advisory panel. The panel is made up of flare and combustion experts from industry, flare manufacturers, and state and federal EPA personnel. The panel has reviewed and commented on the scope, work plans and results of EPA's flare R&D program.

The scope of the work completed in 1983 included measurement of combustion efficiency for a wide range of operating conditions typical of commercial flares. Tests were performed on 3, 6 and 12 in. (7.6, 15.2 and 30.5 cm) in diameter; steam-assisted flare tips of various commercial and noncommercial designs.

Gas samples obtained from a multiport probe suspended over the flare flame were analyzed and combustion efficiencies calculated for the range of the following variables:

- Propane/nitrogen mixtures of 270–2,350 Btu/ft^3 (10.0–87.5 MJ/m^3).
- Exit gas velocities of 0.2 to 420 ft/s (0.06–128 m/s).

The results pertinent to the development of EPA's

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flare policy are:

- Flares operating in the region of unstable flames can have low efficiency.
- Combustion efficiency was high for flares with high velocities provided the gas mixture properties were in the region of flame stability.

The results from this study form the main technical basis of the Chemical Manufacturers Association Petition to EPA described above.

EPA has an additional Flare R&D program under way under contract to Energy and Environmental Research (EER) Corp. of Irvine, Calif. The work is being managed by EPA's Industrial Environmental Research Laboratory under Contract No. 68-02-3661. The objectives of the study for fiscal year 1984 were:

- To extend the existing data base generated by EER in 1983 for simple pipe flares to flare heads of different design.
- To evaluate the impact of different relief gas compositions on flare combustion efficiency and pollutant emissions.
- To investigate the destruction efficiency of individual components in flared gases.

An additional study objective to be funded under a separate task agreement in fiscal year 1985 involves assessing the impact of flare pilots on flare operating parameters and on flare efficiency.

The 1983 EER flare efficiency data include those on steam-assisted and nonassisted flares. The flare tips tested have been both EER and commercial flare vendor designs. The 1984 study plans include testing a pressure flare design and air-assisted flare, and a Coanda flare. The flare tips tested in this program are intended to be designed and supplied by flare manufacturers. The test matrix will involve testing the flares fired with various hydrocarbon (propane)/nitrogen mixtures. The combustion efficiency will be determined at an operating condition approaching the flame stability limit for the gas mixture tested. By testing various Btu contents achieved by increasing nitrogen dilution, a range of Btu contents and exit velocities will be established, within which efficient flare operations can be assured.

The term flame stability means that a flame is maintained. Flame instability occurs when the jet velocity exceeds the flame velocity and the flame goes out. To establish the region of stable, efficient flames, the EER test protocol calls for testing each gas mixture of differing Btu content at increasing velocity until the flame is nearly extinguished. The extended 20-min efficiency test is then conducted at a velocity slightly lower than the velocity needed to extinguish the flame. The full range of tests over all Btu content values will be conducted for a pressure flare, an air-assisted flare and the Coanda flare. A full range of tests over all Btu values for each vendor flare design is not planned. One flare tip of each type will be evaluated over all the conditions of the test matrix. The variation in performance, if any, among the vendor designs will be assessed by running one test condition of a constant Btu content for all designs.

Table 2. Compounds proposed to be laboratory-tested for combustion efficiency by Energy and Environmental Research Corp.

Aliphatic Hydrocarbons	Compounds with Low Heating Values
Acetylene	CO_2 Dilution
Ethylene	Methyl Chloride
Propylene	Chloroethane
Butane	Ethylene Dichloride
2–3 Butadiene	Vinyl Chloride
	Phosgene
	Hydrogen
Aromatic Hydrocarbons	Sulfur Compounds
Benzene	Hydrogen Sulfide
One of Toluene or Xylene	Carbon Disulfide
Chlorobenzene	Ethylene Mercaptan
Oxygenated Compounds	Nitrogen Compounds
Carbon Monoxide	Ammonia
Acetone	Hydrogen Cyanide
Acetaldehyde	Acrylonitrile
Ethylene Oxide	Ethylene Diamine

To evaluate the combustion efficiency of various gases, about 30 compounds or mixtures will be tested in an enclosed laboratory-scale combustion chamber. The compounds or mixtures will be burned using a $\frac{1}{16}$ in. (1.58 mm) jet. Liquid compounds will be saturated with the flare gas via atomization prior to burning. The laboratory-scale combustion efficiencies will be ranked, and five or so gas mixtures will be tested using EER's pilot-scale field test facility using a steam-assisted flare tip.

The different gas compositions to be investigated in the laboratory include aliphatic, aromatic and oxygenated hydrocarbons, low heating value compounds, sulfur compounds, and nitrogen compounds. A preliminary list of compounds proposed for laboratory testing is presented in Table 2. The combined laboratory screening and field test program has been designed to assess the impact of flare gas composition on flare combustion efficiency and potential pollutant emissions. The compounds described above were selected based on a balance of varying chemical structure and elemental composition. The field testing and laboratory work described above were completed in December 1984.

Additional flare test work is planned by EPA in fiscal year 1985. One of the tasks planned by EPA/EER involves determining the impact of flare pilots on flare efficiency and operating parameters. This task is planned because the 1983 program and the bulk of the 1984 program were conducted without using continuous flare pilots. Because industrial flare operations cannot be safely operated without continuous pilots, EPA/EER is to examine the impact of flare pilots. Variables to be examined under this task are flame stability, combustion efficiency, pilot gas thermal input in relation to flare gas thermal release, pilot location, the effect of flare gas exit velocity and others.

Impact of flare R&D on EPA policy

EPA's flare policy is based on the range of experimental data in various studies that show efficient flare operation, i.e., combustion efficiencies greater than 98%. Various researchers have measured Btu content, exit gas velocity, and other variables during studies where flare combustion efficiency was measured. Because of the difficulty in obtaining data at high exit gas velocity, EPA's early flare policy limited the range of efficient flare operations based on available data to 60 ft/s (18.3 m/s). During the 1983 studies conducted at EER's El Toro, Calif. test site where a 3 in. (7.6 cm) flare was tested at velocities up to 428 ft/s (130 m/s) (*11*), the EPA concluded that the velocity limit for efficient flaring should be higher. Per the terms of the EPA/CMA settlement agreement (*13*), EPA will propose to allow continuous flaring of relief gases up to velocities of 400 ft/s (122 m/s).

Unfortunately, EPA's interpretation of test data does not necessarily define the complete realm of efficient flare operations. According to available test data, the presence of a stable flare flame indicates that efficient combustion is taking place. The term "stable flame" means that a flame is maintained. Flame instability and resulting inefficient combustion occur when the flare exit gas velocity exceeds the flame velocity and the flame goes out. Flare flame stability is affected by the properties of the flared gas including heat content, flammability limits, and flame speed. To some extent flare flame stability can also be affected by flare design and operational features.

Flame lift-off from the flare tip, in and of itself, is not necessarily an indicator of an unstable flame. Most of the high velocity tests performed in the 1983 EER study (*11*) were partially listed. Only when the flame is lifted to the point of being extinguished is inefficient combustion observed.

In summary

EPA's flare policy should change to accept the more general concept of flame stability as an indicator of efficient flare operation. The strict exit gas velocity and Btu content limits, which EPA has proposed, may define stable flames for certain gas mixtures. Flame stability does not necessarily behave in a step function manner, changing from 400 ft/s (122 m/s) above 1,000 Btu/scf (37.2 MJ/m^3) dropping to 60 ft/s (18.2 m/s) below 1,000 Btu/scf (37.2 MJ/m^3).

A stable flame can possibly be "measured" by infrared, remote-sensing instrumentation or other means, rather than relying on strict Btu content and exit gas velocity limits.

We recommend that:

- EPA or others conduct the necessary R&D to establish flame stability as a measure of flare efficiency.
- EPA change its regulatory policy to accept flame stability as an alternate means of assessing efficient flare operation.

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