Cost Analysis of Highly Reactive Volatile Organic Compound Controls on Refineries and Chemical Plants – Project 2009-52

Control of HRVOC Emissions in Flares at Low Flow Conditions – Project 2009-53

Prepared for:
Texas Commission on Environmental Quality
Austin, Texas

Prepared by:
ENVIRON International Corporation
Houston, Texas

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Abbreviations

ANOVA:	Analysis of Variance
BACT:	Best Available Control Technology
Btu:	British Thermal Unit
DRE:	Destruction and Removal Efficiency
EPA:	United States Environmental Protection Agency
EI:	Emission Inventory
FGR:	Flare Gas Recovery
FTIR:	Fourier Transform Infrared
HARC:	Houston Advanced Research Center
HGB:	Houston-Galveston-Brazoria
HDPE:	High Density Polyethylene
HECT:	Highly Reactive Volatile Organic Compound Emissions Cap and Trade
HRVOC:	Highly Reactive Volatile Organic Compound
IR:	Infrared
LAER:	Lowest Achievable Emission Rate
LDPE:	Low Density Polyethylene
LLDPE:	Linear Low Density Polyethylene
M:	Thousand
MECT:	Mass Emission Cap and Trade
MM:	Million
MMscf/hr:	Million Standard Cubic Feet per Hour
MSS:	Maintenance Startup and Shutdown
NNSR:	Nonattainment New Source Review
NSR:	New Source Review
PE:	Polyethylene
PP:	Polypropylene
PSD:	Prevention of Significant Deterioration
ppm:	Parts per Million
ppmw:	Parts per Million by Weight
RACT:	Reasonably Available Control Technology
RN:	Regulated Entity Number
SBR:	Styrene-Butadiene Rubber
scf:	Standard Cubic Feet
scfm:	Standard Cubic Feet per Minute
TCEQ:	Texas Commission on Environmental Quality
tph:	Tons per Hour
tpy:	Tons per Year
VOC:	Volatile Organic Compound

Executive Summary

Overview

In continuation of the information collected as part of Project 2008-104 (*Cost Analysis of HRVOC Controls on Polymer Plants and Flares*), for Projects 2009-52 and 2009-53 the TCEQ directed ENVIRON to gather and analyze certain additional data on projects undertaken by facilities in Harris County to reduce the emissions of highly reactive volatile organic compounds (HRVOC) and on flares, respectively. Specifically, the purpose of Project 2009-52 is to collect additional information on HRVOC emission reduction projects at refineries and chemical plants and to use this information to perform an analysis of the costs of controlling HRVOC emissions from different types of facilities. The purpose of Project 2009-53 is to gather information comparing the maximum design capacity and the average routine loading for flares in HRVOC service at various facilities.

The list of HECT-affected facilities was provided by the TCEQ and included chemical manufacturing facilities, polymer facilities, refineries and terminals. In order to collect this information, ENVIRON prepared a single questionnaire, pertaining to both HRVOC emission reduction projects and flares, that was sent to selected Harris County facilities.

HRVOC Emission Reduction Projects Survey

The 35 sites that participated in the Phase 1 and Phase 2 surveys provided information on 54 HRVOC emission reduction projects. Key findings are as follows:

- The 9 polymer plants that participated in the study implemented 30 projects resulting in a collective reduction in HRVOC emissions of approximately 346 tons per year at an average cost of $14,774 per ton controlled.

- The 16 chemical plants – including olefins-producing facilities – that participated in the study implemented 20 projects resulting in a collective reduction in HRVOC emissions of approximately 361 tons per year at an average cost of $5,390 per ton controlled.

- The 3 petroleum refineries that participated in the survey implemented four projects that resulted in HRVOC emission reductions. However, only one of these projects was implemented for the purpose of reducing long-term HRVOC emissions. That one project resulted in HRVOC emission reductions of 13.5 tons per year at an average cost of $17,778 per ton controlled.

- Of the 8 terminals that participated in the study, none indicated that they had implemented projects for the purpose of reducing HRVOC emissions.

- Of the 54 HRVOC emission reduction projects identified by this survey, 30 involved changes in operating procedures, 17 involved flare minimization, and 7 involved installation of vent gas controls. No facility implemented a change in process to reduce HRVOC emissions.

- 76% of the total HRVOC emission reduction projects had a total annual cost less than or equal to $250,000.

- A majority of the HRVOC emission reduction projects, as reported by survey respondents, resulted in emission reductions of 20 tpy or less.

- Out of the four industrial sectors surveyed, polymer and chemical plants implemented the highest number of HRVOC emission reduction projects and achieved the largest reductions in HRVOC emissions.

- Polymer plants achieved the greatest reduction in HRVOC emission when compared to their HECT allowance allocation – approximately 55%. Chemical plants achieved HRVOC emission reductions equal to approximately 48% of their HECT allowance allocation and petroleum refineries achieved HRVOC emission reduction equal to approximately 16% of their HECT allowance allocation.

- Statistical analysis indicates that the differences in observed mean HRVOC emission reductions as a percent of HECT allowance allocations across different industry sectors are not statistically significant. The differences in observed means between chemical and polymer plants could be due to chance.

Flare Survey

The sites that participated in the studies provided information on 82 flares in HRVOC service. The following key statistics on flare loading are derived from the information provided:

- Under routine operating conditions:
  - For small flares with a design capacity of less than 1.0 MMscf/hr, 28% of flares operate at less than or equal to 5% of design capacity and 68% of flares operate at less than or equal to 25% of design capacity, on average.
  - For medium flares with a design capacity between 1.0 and less than 10 MMscf/hr, 53% of flares operate at less than or equal to 1% of design capacity and 88% of flares operate at less than or equal to 5% of design capacity, on average.
  - For large flares with a design capacity greater than 10 MMscf/hr, 92% of flares operate at less than or equal to 0.5% of design capacity and 100% of flares operate at less than 2.75% of the design capacity, on average.

- On average, flares in HRVOC service at:
  - Terminals operate at approximately 20% of design capacity;
  - Chemical plants operate at approximately 11% of design capacity; and
  - Polymer plants operate at approximately 4% of design capacity.

Insufficient information was provided by the petroleum refineries that responded to the survey to estimate routine flare loading as a percentage of design capacity.

- Most of the flares surveyed, approximately 82%, are designed to handle routine as well as emergency flows.

- Out of all flares surveyed, 32% of flares operate at less than or equal to 0.5% of the maximum design capacity under routine operations; 62% of flares operate at less than or equal to 5% of the maximum design capacity; Almost 85% flares operate at less than or equal to 25% of the maximum design capacity. Of the flares surveyed, only one flare operates at 50% of the design capacity. This is the maximum among all flares.

- Statistical analysis indicates that variations across industry sectors in the observed means of routine flare loading as a percent of design capacity are statistically significant at the 5% level. A pair-wise comparison of industry sectors shows that the difference between polymer plants and terminals is the only statistically significant difference at the 95% confidence level although the difference between chemical plants and terminals is almost statistically significant (significant at the 94% confidence level).

1 Introduction

1.1 Project Purpose

During 2008, ENVIRON conducted a study to evaluate the costs to reduce highly reactive volatile organic compound (HRVOC) emissions from polymer (primarily polyethylene and polypropylene) and olefins (primarily ethylene and propylene) production facilities in Harris County. This study also included an analysis of costs to further reduce HRVOC emissions from flaring and identification of projects, including costs that facilities have already undertaken to reduce HRVOC emissions. The final report for Project 2008-104, entitled *Cost Analysis of HRVOC Controls on Polymer Plants and Flares* (Work Order 582-07-84005-FY08-12) was submitted to the TCEQ in August 2008. As noted in the conclusions of that report, insufficient information was available to determine whether polymer plants undertook more or fewer projects or if the cost effectiveness of those projects was higher or lower than those projects undertaken by other types of facilities.

As follow-on to the 2008 or “Phase 1” investigations, the TCEQ directed ENVIRON to gather information on HRVOC emission sources in Harris County that were not included in the 2008 investigations; specifically, petroleum refineries, olefins and non-olefins producing chemical plants, and storage terminals. The information collected as part of the 2009 or “Phase 2” investigations entitled *Cost Analysis of HRVOC Controls on Refineries and Chemical Plants* (TCEQ Project 2009-52), is to be combined with the information collected during Phase 1 and a more thorough and analysis of HRVOC emission control measures and costs performed. This information and analysis may be used by TCEQ to evaluate whether the initial HRVOC allowance allocations were equitable and in identifying areas where HRVOC emissions might be further reduced at the lowest costs.

As part of 2008 studies, ENVIRON investigated the feasibility and cost of reducing flows to flares at selected polymer production and olefin production facilities. The study results indicated that many of the flares used to control routine HRVOC emissions are actually designed to handle much larger flows. For Project 2009-53, entitled *Control of HRVOC in Flares at Low Flow Conditions*, ENVIRON has been directed by the TCEQ to gather additional information on typical or routine flow rates and compare those values to flare design capacities. Information collected and analyzed as part of Project 2009-53 may be used by the TCEQ to support their on-going investigations of flare performance.

Since the analysis conducted for Project 2009-52 requires use of information collected during Project 2008-104, information collected during the previous study is included within the Facility Survey Findings section (Section 4) of this report. Also included from the previous study are relevant sections of background information (Section 2) and the catalog of potential control measures (Section 3).

1.2 Project Scope

TCEQ Projects 2009-52 and 2009-53 are being conducted concurrently and in an integrated fashion. Therefore, the following scope of work is inclusive of both projects. The scope of work includes the following tasks:

Task 1. Develop Work Plan describing the work to be performed for the TCEQ.

Task 2. Prepare questionnaire to be sent to selected Harris County sites for gathering information on HRVOC emission reduction projects and flare data.

Task 3. Gather and compile information from facilities.

Task 4. Develop draft interim report on Control of HRVOC Emissions in Flares at Low Flow Conditions.

Task 5. Prepare final report comparing the economic feasibility of reducing HRVOC emissions from polymer processing to the costs that have been incurred by other industry sectors to reduce HRVOC emissions and the cost to further reduce HRVOC emissions by reducing flaring.

For Task 2, ENVIRON prepared a single questionnaire for gathering the following:

- Information on HRVOC emission reduction projects and their costs at refineries, chemical plants and other HRVOC Emissions Cap and Trade (HECT)-affected facilities to be used for performing an analysis of the costs of controlling HRVOC emissions from different types of facilities.

- Information to better understand HRVOC emissions from flares operating at low flow conditions, including design flow rates for flares used to abate routine HRVOC emissions along with the typical or average flow rates to the flares as determined using the flow monitors required by the HRVOC rules in Chapter 115, Subchapter H, Division 1.

TCEQ Projects 2009-52 and 2009-53 are a continuation of TCEQ Project 2008-104 (*Cost Analysis of HRVOC Controls on Polymer Plants and Flares*). For TCEQ Project 2008-104 (hereafter referred to as “Phase 1”), ENVIRON prepared questionnaires for flare issues and polymer production issues that were sent to Harris County industrial facilities identified by the TCEQ. For TCEQ Projects 2009-52 and 53 (hereafter referred to as “Phase 2”), ENVIRON prepared a single questionnaire pertaining to both HRVOC emission reduction projects and flares that was sent to another set of Harris County facilities selected by the TCEQ. Both the Phase 1 polymer production issues and flare questionnaire templates and the Phase 2 questionnaire are included in Appendix A.

For both Phase 1 and Phase 2, the TCEQ provided ENVIRON a list of sites to survey. For Phase 2, the TCEQ provided separate lists: one for sites with flares to survey and another for sites subject to the HECT Program that were not surveyed as part of Phase 1 but were to be surveyed as part of Phase 2. The former are sites that operate flow-monitored flares subject to HRVOC rules and the HECT Program. The latter are petroleum refineries, chemical manufacturing plants and storage terminals that are subject to the HRVOC rules and the HECT Program. ENVIRON contacted each company listed in Tables 1 (TCEQ List of HECT Sites to Survey) and 2 (TCEQ List of Flares to Survey) and provided participating sites with the questionnaire. Tables 1 and 2 include both Phase 1 and Phase 2 sites that received the questionnaire.

Of the 16 Phase 1 sites that were contacted:

- 11 participated by responding to the survey and/or meeting with ENVIRON personnel to discuss their responses.
- Five sites declined to participate.

Of the 38 Phase 2 sites that were contacted:

- 24 provided the requested information.
- Six sites declined to participate.
- Three sites that initially committed to participate did, in fact, not provide the requested information.
- One site was sold in 2007 and did not participate.
- One site is permanently shutdown.
- One site claimed to have no HRVOC emissions.
- Two sites that participated in the Phase 1 investigations requested that ENVIRON rely upon that information for Phase 2 efforts.

Although not specifically identified by the TCEQ for participation in the flare survey portion of Phase 2, the companies listed in Table 2 provided flare data in response to Questions 9 and 10 of the survey. Data provided by these companies is included in the findings section of this final report.

Table 1. TCEQ List of HECT Sites to Survey

Company Name	Site Name	TCEQ Account Number	TCEQ RN	Industry Category	Project Phase
Albemarle Corporation	Albemarle Houston Plant	HG0225N	RN100218247	Chemicals	Phase 2
American Acryl LP	American Acryl LP	HX1772C	RN101379287	Chemicals	Phase 2
Basell USA Inc.	Basell USA Bayport Plant	HG0323M	RN100216761	Polymers	Phase 1
BASF Corporation	BASF Corporation Pasadena	HG1249P	RN100225689	Chemicals	Phase 2
Bigler Land, L.L.C.	Bigler Pasadena Plant	HX0055V	RN102528197	Chemicals	Phase 2
Celanese LTD	Celanese Clear Lake Plant	HGA058F	RN100227016	Chemicals	Phase 2
Chevron Phillips Chemical Company, L.P.	Chevron Cedar Bayou Chemical Plant	HG0310V	RN103919817	Polymers/Chemicals	Phase 1
Chevron Phillips Chemical Company, L.P.	Chevron Phillips Pasadena Plastics Complex	HG0566H	RN102018322	Polymers	Phase 1
Dow Chemical Company	Clear Lake Operations	HGA005E	RN104150123	Chemicals	Phase 2
Dow Chemical Company	Dow Chemical La Porte Site	HG0769O	RN102414232	Chemicals	Phase 2
EI Dupont de Nemours and Company	EI Dupont de Nemours La Porte Plant	HG0218K	RN100225085	Chemicals	Phase 2
Enterprise Products Operating LP	Almeda LPG Facility	HG0157F	RN102940103	Terminal	Phase 2
Enterprise Products Operating LP	EPOLP Houston Ship Channel Marine Loading Facility	HX1182G	RN102580834	Terminal	Phase 2
Enterprise Products Operating LP	Morgans Point Plant	HG0714Q	RN100210665	Terminal	Phase 2
Equistar Chemicals LP	Equistar Chemicals Channelview Complex	HG0033B	RN100542281	Chemicals	Phase 2

Table 1. TCEQ List of HECT Sites to Survey

Company Name	Site Name	TCEQ Account Number	TCEQ RN	Industry Category	Project Phase
Equistar Chemicals LP	Equistar Chemicals La Porte Complex	HG0770G	RN100210319	Polymers/Chemicals	Phase 1
Exxon Mobil Corporation	Exxon Mobil Baytown Facility	HG0232Q	RN102579307	Refinery	Phase 2
Exxon Mobil Corporation	Exxon Mobil Chemical Baytown Olefins Plant	HG0228H	RN102212925	Chemicals	Phase 2
ExxonMobil Chemical Company	Mobil Chemical Houston Olefins Plant	HG0035U	RN102576063	Chemicals	Phase 2
ExxonMobil Chemical Company	ExxonMobil Chemical Baytown Chemical Plant	HG0229F	RN102574803	Polymers/Chemicals	Phase 1
Georgia Gulf Chemicals & Vinyls LLC	Georgia Gulf Chemicals & Vinyls	HG0276T	RN100213958	Chemicals	Phase 2
Ineos Nova, L.L.C.	Nova Chemicals Bayport Site	HG3307M	RN100542224	Chemicals	Phase 2
Innovene Polyethylene North America	BP Solvay Polyethylene NA	HG0665E	RN102537289	Polymers/Chemicals	Phase 1
Innovene Polymers, Inc.	Battleground Polyethylene Plant	HX2897U	RN100229905	Polymers	Phase 1
Intercontinental Terminals Company	Intercontinental Terminals Deer Park Terminal	HG0403N	RN100210806	Terminal	Phase 2
Johann Haltermann LTD	Haltermann Plant 1	HG0319D	RN100219237	Chemicals	Phase 2
Johann Haltermann LTD	Haltermann Plant 2 Channelview	HG0929Q	RN102610912	Chemicals	Phase 2
Kaneka Texas Corporation	Kaneka Texas Corporation	HG1065E	RN100218841	Terminal	Phase 2
Kirby Inland Marine, LP	Barge Cleaning Facility	HG9625W	RN102204211	Terminal	Phase 2

Table 1. TCEQ List of HECT Sites to Survey

Company Name	Site Name	TCEQ Account Number	TCEQ RN	Industry Category	Project Phase
LBC Houston LP	LBC Houston Bayport Terminal	HG0029P	RN101041598	Terminal	Phase 2
Lyondell Chemical Worldwide Co.	Lyondell Chemical Bayport Plant	HG0537O	RN102523107	Chemicals	Phase 2
Lyondell-Citgo Refining LP	Lyondell-Citgo Refining	HG0048L	RN100218130	Refinery	Phase 2
Millennium Petrochemicals Inc	Millennium Petrochemicals La Porte Plant	HX1726J	RN100224450	Chemicals	Phase 2
Natural Gas Odorizing Inc	Natural Gas Odorizing	HG0512H	RN100683952	Terminal	Phase 2
Nisseki Chemical Texas Inc	Nisseki Chemical Texas Inc	HG3626Q	RN102887270	Chemicals	Phase 2
Odfjell Terminals Houston, LP	Odfjell Terminals	HG1006U	RN100218411	Terminal	Phase 2
Pasadena Refining Systems, Inc.	Pasadena Refinery	HG0175D	RN100716661	Refinery	Phase 2
Shell Deer Park Refining Company	Shell Oil Deer Park	HG0659W	RN100211879	Refinery	Phase 2
Sunoco Inc. (R&M)	Bayport Polyethylene Plant	N/A	RN103773206	Polymers	Phase 1
Sunoco Inc. (R&M)	Sunoco R&M Bayport Polypropylene	HGA009I	RN100524008	Polymers	Phase 1
Sunoco Inc. (R&M)	Sunoco La Porte Plant	HG0825G	RN102888328	Polymers	Phase 1
Targa Midstream Services LP	Galena Park Terminal	HG0786O	RN100214212	Terminals	Phase 2
Texas Petrochemicals LP	Texas Petrochemicals Houston Facility	HG0562P	RN100219526	Chemicals	Phase 2
The Lubrizol Corporation	Lubrizol Bayport Plant	HG0460B	RN101058410	Chemicals	Phase 2
The Lubrizol Corporation	Lubrizol Deer Park Plant	HG0459J	RN100221589	Chemicals	Phase 2

Table 1. TCEQ List of HECT Sites to Survey

Company Name	Site Name	TCEQ Account Number	TCEQ RN	Industry Category	Project Phase
Total Petrochemicals USA	Total Petrochemicals La Porte Plant	HG0036S	RN100212109	Polymers	Phase 1
Total Petrochemicals USA	Total Petrochemicals Bayport Plant	HG4662F	RN100909373	Polymers	Phase 1
Valero Refining-Texas LP	Valero Refining Houston Refinery	HG0130C	RN100219310	Polymers	Phase 2

Table 2. TCEQ List of Flares to Survey

Company Name	Site Name	TCEQ Account Number	TCEQ RN	Industry Category	Phase 1 or Phase 2	Number of Flares
Albemarle Corporation	Albemarle Houston Plant	HG0225N	RN100218247	Chemicals	Phase 2	2
BASF Corporation	BASF Pasadena	HG1249P	RN100225689	Chemicals	Phase 2	2
Basell USA Inc.	Basell USA Bayport Plant	HG0323M	RN100216761	Polymers	Phase 1	3
Celanese Ltd.	Celanese Clear Lake Plant	HG0126Q	RN100227016	Chemicals	Phase 2	1
Chevron Phillips Chemical Company, L.P.	Chevron Cedar Bayou Chemical Plant	HG0310V	RN103919817	Polymers/ Chemicals	Phase 1	3 (Polymers) 5 (Chemicals)
Chevron Phillips Chemical Company LP	Chevron Phillips Chemical Company	HG0566H	RN102018322	Polymers	Phase 1 & Phase 2	4
EI Dupont de Nemours and Company	EI Dupont de Nemours La Porte Plant	HG0218K	RN100225085	Chemicals	Phase 2	1
Enterprise Products Operating LLC	Almeda LPG Facility	HG0157F	RN102940103	Terminal	Phase 2	1
Equistar Chemicals LP	Channelview Complex	HG0033B	RN100542281	Chemicals	Phase 1 & Phase 2	9
Equistar Chemicals LP	Equistar Chemicals La Porte Complex	HG0770G	RN100210319	Polymers/ Chemicals	Phase 1	2 (Polymers) 2 (Chemicals)
ExxonMobil Chemical Company	Exxon Mobil Chemicals Baytown Olefins Plant	HG0228H	RN102212925	Chemicals	Phase 1 & Phase 2	3

Table 2. TCEQ List of Flares to Survey

Company Name	Site Name	TCEQ Account Number	TCEQ RN	Industry Category	Phase 1 or Phase 2	Number of Flares
ExxonMobil Chemical Company	ExxonMobil Chemical Baytown Chemical Plant	HG0229F	RN102574803	Polymers	Phase 1 & Phase 2	2
ExxonMobil Oil Corporation	ExxonMobil Baytown Facility	HG1276M	RN102579307	Refinery	Phase 1	9
Intercontinental Terminals Company LLC	Intercontinental Terminals Deer Park Terminal	HG0403N	RN100210806	Terminal	Phase 2	6
Lyondell Chemical Worldwide Inc	LCC Bayport Lyondell	HG0537O	RN102523107	Chemicals	Phase 2	1
Lyondell Citgo Refining LP	Houston Refining	HG0048L	RN100218130	Refinery	Phase 2	6
Millennium Petrochemicals Inc	Millennium Petrochemicals La Porte Plant	HX1726J	RN100224450	Chemicals	Phase 2	1
Natural Gas Odorizing Inc	Natural Gas Odorizing	HG0512H	RN100683952	Chemicals	Phase 2	1
Nisseki Chemical Texas Inc	Nisseki Chemical Texas	HG3626Q	RN102887270	Chemicals	Phase 2	2
Odfjell Terminals Houston Inc	Odfjell Terminals	HG1006U	RN100218411	Terminals	Phase 2	1
Pasadena Refining System Inc	Pasadena Refining System	HG0175D	RN100716661	Refinery	Phase 2	2
Shell Oil Company	Shell Oil Deer Park	HG0659W	RN100211879	Refinery	Phase 1 & Phase 2	9
Texas Petrochemicals LP	Houston Plant	HG0562P	RN100219526	Chemicals	Phase 2	1

Table 2. TCEQ List of Flares to Survey

Company Name	Site Name	TCEQ Account Number	TCEQ RN	Industry Category	Phase 1 or Phase 2	Number of Flares
The Dow Chemical Company	The Dow Chemical Company Clear Lake Operations	HGA005E	RN104150123	Chemicals	Phase 2	1
Total Petrochemicals USA	Total Petrochemicals Bayport Plant	HG4662F	RN100909373	Polymers	Phase 1	2
Total Petrochemicals USA	Total Petrochemicals La Porte Plant	HG0036S	RN100212109	Polymers	Phase 1	Not Specified

Table 3. List of Additional Sites Providing Flare Data

Company Name	Site Name	TCEQ Account Number	TCEQ RN	Industry Category	Phase 1 or Phase 2	Number o Flares
Enterprise Products Operating LLC	Morgans Point Complex	HG0714Q	RN100210665	Terminal	Phase 2	2
Enterprise Products Operating LLC	Almeda LPG Terminal	HG0157F	RN102940103	Terminal	Phase 2	1
Enterprise Products Operating LLC	EPOLP Houston Ship Channel Marine Loading Facility	HX1182G	RN102580834	Terminal	Phase 2	1
Georgia Gulf Chemicals & Vinyls LLC	Georgia Gulf Chemicals & Vinyls	HG0276T	RN100213958	Chemicals	Phase 2	1
Ineos Nova LLC	Nova Chemicals Bayport Site	HG3307M	RN100542224	Chemicals	Phase 2	1
Innovene Polymers, Inc.	Battleground Polyethylene Plant	HX2897U	RN100229905	Polymers	Phase 1	1
Innovene Polyethylene North America	BP Solvay Polyethylene NA	HG0665E	RN102537289	Polymers	Phase 1	1
Johann Halterman LTD	Johann Halterman	HG0139D	RN100219237	Chemicals	Phase 2	1
Targa Midstream Services LP	Galena Park Terminal	HG0786O	RN100214212	Chemicals	Phase 2	1

1.3 Project Methodology

Following approval of the Phase 2 questionnaire by the TCEQ, ENVIRON contacted each Phase 2 site listed in Tables 1 and 2. ENVIRON sent the Phase 2 questionnaire to the sites that agreed to participate in the survey. ENVIRON requested information on projects that have been implemented to reduce HRVOC emissions at the site and their costs, and on any other HRVOC emission reducing projects that have been considered but not implemented along with the reason for not implementing the project (e.g., cost, technical feasibility). Specifically, ENVIRON requested the following information related to HRVOC emission reduction projects from each surveyed site:

- List of products manufactured at site.
- Identification of source types (e.g., cooling towers, process vents, and flares) in HRVOC service and included in HECT Program cap.
- Description of HRVOC emission reduction projects - including estimated HRVOC reduction, capital cost and annual cost.
- Description of HRVOC emission reduction projects considered, but not implemented.
- Details regarding HRVOC emission reduction methods that would be technically feasible for new facilities that manufacture the same product, but not for existing facilities.
- Details regarding anything unique that would make HRVOC emission reduction more difficult or expensive.
- Description of investments made to reduce the fugitive release of HRVOCs – including estimated HRVOC reduction, capital cost and annual cost.
- Details regarding any process units that have been shutdown or derated as a strategy for complying with the HECT Program cap.
- Description of any Flare Gas Recovery (FGR) projects as well as FGR projects considered, but not implemented.
- Identification of process vents in HRVOC service routed to control devices other than flares (e.g., thermal oxidizers, process heaters).
- Description of other projects not specifically carried out to reduce HRVOC emissions, but resulted in reducing HRVOC emissions.

ENVIRON used the information gathered from the questionnaires along with results previously obtained in the 2008 ENVIRON study to compare the economic feasibility of reducing HRVOC emissions from polymer processing to the costs that have been incurred by other industry sectors to reduce HRVOC emissions and the cost to further reduce HRVOC emissions by reducing flaring.

ENVIRON requested the following information related to flare operation from each surveyed site:

- Number of flares in HRVOC service.
- Flare service type (routine, upset/maintenance, or both).
- Flare design capacity.
- Average routine flow rate (excluding upset/maintenance) for calendar year 2008[1].
- Average upset/maintenance flow rate for calendar year 2008[2].
- Hours of operation (routine and upset/maintenance) for calendar year 2008[3].

Using this data, ENVIRON determined the average routine flow as a percentage of design capacity for each flare, performed additional statistical analyses, and made comparisons within and across industry sectors.

1.4 Data Quality Assurance

Information contained within this report is presented as it was reported by participating industrial sites to ENVIRON. Data validation activities performed by ENVIRON were limited to email correspondence and telephone conversations with participants regarding perceived anomalies and/or clarification of projects performed. If confirmed by survey respondents as accurate, data is included in the findings and analysis presented within this report.

[1] Phase 1 flare survey did not specify calendar year 2008. Phase 1 respondents provided data for a variety of years.

[2] Phase 1 flare survey did not request upset/maintenance flow rates.

[3] Phase 1 flare survey did not request hours of operation data.

2 Background

2.1 Emissions from Polymer Production Processes

HRVOC compounds are used extensively in the manufacture of polymers.[4] Examples include:

- Use of ethylene in the manufacture of polyethylene (PE). PE is a thermoplastic (becomes soft when heated and hard when cooled) that is heavily used in consumer products (e.g. plastic shopping bags). PE is classified into a large number of categories based on its density and branching. Examples include high-density PE (HDPE), low-density PE (LDPE), and linear low-density PE (LLDPE).

- Use of propylene in the manufacture of polypropylene (PP). Like PE, PP is a thermoplastic that finds wide use in a variety of applications.

- Use of 1,3-butadiene in the manufacture of synthetic rubbers such as polybutadiene and styrene butadiene rubber (SBR). SBR is widely used in the manufacture of automobile tires.

- Use of butenes in the manufacture of synthetic rubbers such as polyisobutylene and as copolymers. A copolymer is a polymer derived from two or more monomers. An example is SBR which is derived from styrene and 1,3-butadiene.

Figure 1 presents a simplified process flow diagram for manufacturing polymer pellets.[5] For polymer products other than pellets, downstream operations may vary. For example, when manufacturing a polymer flake or powder, there will not be an extruder. Similarly, SBR is typically not extruded but sold as SBR crumb.

Sources of HRVOC from a polymer manufacturing process may include one or more of the following:[6]

- Monomer or comonomer storage

- Process fugitives

- Cooling tower heat exchange system losses

- Process vents upstream of the extruder (e.g. reactor, resin degassing)

[4] A polymer is a large molecule composed of repeating structural units. Examples include polyethylene and polypropylene.

[5] Technical Guidance for Chemical Sources: Polyethylene and Polypropylene Manufacturing, Draft RG-244, TCEQ Air Permits Division, February 2001.

[6] Ibid

- Extruder
- Polymer storage and loading
- Wastewater treatment facilities

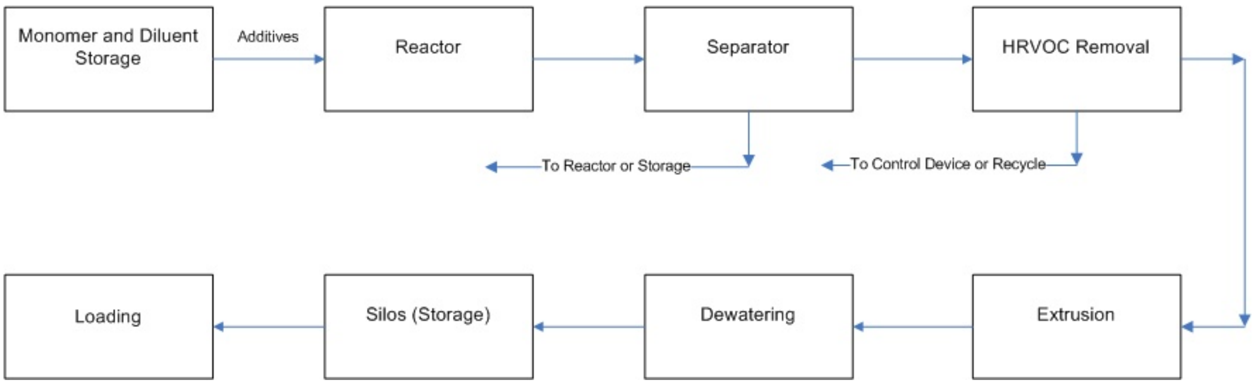

Figure 1. Simplified Polymer Process Flow Diagram

2.2 Special Inventory of HRVOC Emissions

In June 2007, the TCEQ conducted a special emissions inventory, requesting HRVOC emissions data from those sources in Harris County, Texas, that are subject to HRVOC emissions cap-and-trade (HECT) program requirements. The reporting period for this special inventory was February 1, 2006, through January 31, 2007.

Special inventory responses were categorized based upon the primary activity at the site:

- Chemical manufacturing (non-olefin, non-polymer)
- Olefins manufacturing[7]
- Polymer manufacturing
- Petroleum Refining
- Independent storage terminals (not dedicated to an individual refinery, olefins, chemical or polymer manufacturing site)

HRVOC special inventory responses are summarized in Tables 4 and 5. The values shown in Table 4 are total emissions for each industry sector. Emissions for the five industry sectors combined are shown in the far right column. The percentages presented in Table 5 are for total

[7] An "olefin," or alkene, is an unsaturated chemical compound containing at least one carbon-carbon double bond. The simplest olefin is ethylene which has the following chemical structure: $H_2C=CH_2$.

emissions reported by that industry sector. Percentages for the five combined sectors are presented in the far right column. Values presented in Tables 4 and 5 are taken from summaries provided by TCEQ personnel. ENVIRON has not reviewed the special inventory submittals nor validated the values provided.

Table 4. HRVOC Special Inventory Summary (Mass)

Source	Emissions by Industry Sector (tons)					
	Chemical[2]	Olefins	Polymers	Refining	Terminal[2]	Combined[2]
Flares	278.3	376.7	460.0	308.7	45.8	1,469.5
Cooling Towers	35.4	18.1	20.9	88.1	0.1	162.6
Other Vents	97.5	157.1	221.1	125.0	1.7	602.4
Fugitives	19.6	115.5	22.0	26.0	0	183.1
Total[2,3]	443.2	667.4	724.1	547.8	50.9	2,433.4
Type						
MSS & Events	34.8	124.8	81.0	83.2	0.0	323.8
Uncontrolled[1]	136.4	245.3	234.0	135.9	1.8	753.4
Controlled[1]	259.5	297.3	409.0	328.8	45.9	1,340.5

[1] Uncontrolled and controlled routine emissions. MSS and event emissions are accounted for separately.

[2] Total includes emissions from sites that were not broken down by source or type of emissions.

[3] Total includes fugitive emissions from equipments leaks which are not subject to HECT.

Table 5. HRVOC Special Inventory Summary (Percentage)

Source	Emissions by Industry Sector (%)					
	Chemical[1]	Olefins	Polymers	Refining	Terminals[1]	Combined
Flares	64.6	56.4	63.5	56.3	96.3	60.8
Cooling Towers	8.2	2.7	2.9	16.1	0.1	6.7
Other Vents	22.6	23.5	30.5	22.8	3.6	24.9
Fugitives	4.5	17.3	3.0	4.7	0.0	7.6
Type						
MSS & Events	8.1	18.7	11.2	15.2	0.0	13.4
Uncontrolled[2]	31.7	36.8	32.3	24.8	3.8	31.2
Controlled[2]	60.2	44.5	56.5	60.0	96.6	55.4

[1] Emissions (%) were determined using 430.8 tons as the total emissions for the Chemical sector and 47.6 tons as the total emissions for the Terminals sectors.

[2] Uncontrolled and controlled *routine* emissions. MSS and event emissions are accounted for separately.

As shown in Table 5, the information contained within the special inventory submittals indicate that approximately 61% of total reported HRVOC emissions are controlled using flares. This includes MSS and events that are controlled by flare. The 55.4% noted as "controlled" does not include MSS and events. Therefore, approximately 64% of routine emissions are controlled.

2.2.1 HECT Allowance Allocations

Under the HECT, allowances are allocated by the TCEQ to affected sites in Harris County according to the procedures defined by rule in 30 TAC §101.394. The initial allocation occurred January 1, 2007, with subsequent allocations occurring January 1 of each year thereafter. Covered facilities at these sites include flares, cooling tower heat exchange systems and vent gas streams. Fugitive emissions are not covered by the HECT.

On August 18, 2006, the TCEQ published a list of HECT allowance allocations. A total of 51 sites in Harris County were allocated 3,451.5 tons of HRVOC. Table 6 presents a comparison of HRVOC emissions reported as part of the special inventory, by industry sector, with the HECT allowance allocation for that sector. The allowance allocation shown is only for those facilities that reported emissions as part of the special HRVOC emissions inventory. Since all facilities with HECT allowance allocations did not respond to the special inventory request, the summation of allowance allocations does not equal the total number of allowances allocated (3,451.5. tons) but does account for over 98% of the allocations.

There are several sites that could be included in more than one industry sector. In those cases, the site is placed into the industry sector that seems to best represent their primary business. For example, a petroleum refinery with a collocated chemical plant will be included in the Refining Industry sector.

Table 6. Comparison of HRVOC Emissions and HECT Allowance Allocations

Industry Sector	HRVOC Emissions (tons)[1]	Annual HECT Allowance Allocation (tons)	Emissions as a % of Allowance Allocation
Chemical	411.2	718.6	57.2
Olefins	551.9	1,123.8	49.1
Polymers	702.0	496.1	141.5
Refining	521.8	996.7	52.4
Terminals	47.6	57.0	83.5
Combined	2,234.5	3,392.2	65.9

[1] Total emissions from emission points covered by the HECT: flares, cooling towers and other vents. Fugitive emissions are not covered by the HECT. Does not included uncharacterized emissions from Chemical and Terminals sectors.

As shown in Table 6, during the period covered by the special inventory, polymer production plants were more likely than petroleum refineries, olefins plants, chemical plants, or independent storage terminals to have emissions that exceed their HECT allowance allocation.

2.3 TCEQ Guidance for Controlling Emissions from Polymer Plants

Prior to developing a catalog of potential control strategies that may be available for further reducing emissions of HRVOC from polymer plants, ENVIRON first reviewed previous TCEQ guidance on the subject. TCEQ guidance issued in February 2001 by the Air Permits Division provides the following regarding control of emissions from PE and PP manufacturing facilities undergoing New Source Review (NSR) permitting.[8]

- Best Available Control Technology (BACT) for all types of processes requires control of all waste gas streams upstream of the extruder.
- Control devices specified by guidance are as follows:
  - For vent streams, combustion using a flare, incinerator, boiler, heater, etc.
  - For fugitive emissions, a 28 VHP fugitive monitoring program.[9]
- Maximum allowable residual volatile organic compound (VOC) – which for PE and PP manufacturing facilities would be all HRVOC – in the polymer at the first uncontrolled vent should be less than 90 parts per million by weight (ppmw) for all manufacturing processes with the exception of high-pressure polyethylene manufacturing processes where guidance states a limit of 100 ppmw.
- Total non-fugitive VOC emissions, including HRVOC emissions, should generally be less than 200 pounds per million pounds (MM lb) of product.

The most recent published TCEQ guidance on BACT for PE and PP production facilities (October 17, 2006), is more restrictive than the 2001 technical guidance document. Specifically, it requires that total non-fugitive, uncontrolled VOC (including HRVOC) emissions are to be reduced to less than 80 pounds per MM lb of PE or PP produced.[10]

It should be noted that HRVOC fugitive monitoring requirements for affected facilities under 30 TAC Subpart H, Division 3, is more stringent than the requirements of 28 VHP.

2.4 Flare Issues Under Evaluation

The TCEQ recently formed a Flare Task Force Stakeholder Group, whose stated goal is to make a comprehensive evaluation of all aspects of flares, including:

- Interaction of flares and air quality issues, such as ozone and air toxics;
- Understanding of flare use and efficiency; and
- Adequacy of state regulations for flares.

[8] Technical Guidance for Chemical Sources: Polyethylene and Polypropylene Manufacturing, Draft RG-244.

[9] The revised requirements of 28 VHP are specified in TCEQ guidance issued in May 2008: http://www.tceq.state.tx.us/assets/public/permitting/air/Guidance/NewSourceReview/rev28vhp_508.pdf

[10] TCEQ Chemical Sources, Current Best Available Control Technology (BACT) Requirements, Polyethylene and Polypropylene Facilities, October 2006. (http://www.tceq.state.tx.us/assets/public/permitting/air/Guidance/NewSourceReview/bact/bact_polys.pdf)

The aspect most related to this current project is the understanding of flare use and efficiency. In a recent Flare Task Force presentation (TCEQ 2009), the TCEQ identified the following factors as potentially impacting flare performance:

- Meteorology
- Flare waste gas stream flow rate
- Flare waste gas stream composition
- Physical design characteristics and maintenance
- Assist flow rates

The focus of Project 2009-53 is on determining whether the low flows identified during the 2008 ENVIRON study are typical of flares used for HRVOC controls at other facilities. Flares that operate in both routine and upset/MSS service operate typically with a high turndown ratio, or conversely, at a low percentage of design capacity. Turndown ratio is the total design capacity compared to the actual flare waste gas stream flow rate. As presented in the 2008 ENVIRON study, flare waste gas flow rates during routine operations are often less than one percent of total design capacity.

In a recent Flare Task Force presentation (TCEQ 2009), the TCEQ quantified the number of flares in service as reported in the 2006 Emission Inventory (EI). EI data indicate that there are 1,132 flares in service statewide with 521 flares in the Houston-Galveston-Brazoria (HGB) area. A summary of the service types reported in the 2006 EI for flares in the HGB area is presented in Table 7.

Table 7. Service Type Reported in 2006 TCEQ Emission Inventory for Flares in HGB Area

Service Type	Number	Percentage of Total (%)
Routine Only	110	21
Emergency Only	63	12
Both Routine and Emergency	280	54
Not Specified	68	13
Total	521	100

More than half of the flares in the HGB area are in both routine and upset/MSS service. Approximately 13 percent of the flares in HGB are not specified; therefore, it is possible that the number of flares in the HGB area in both routine and upset/MSS service is higher. Figure 1 presents the spatial distribution of the flares within the HGB area.

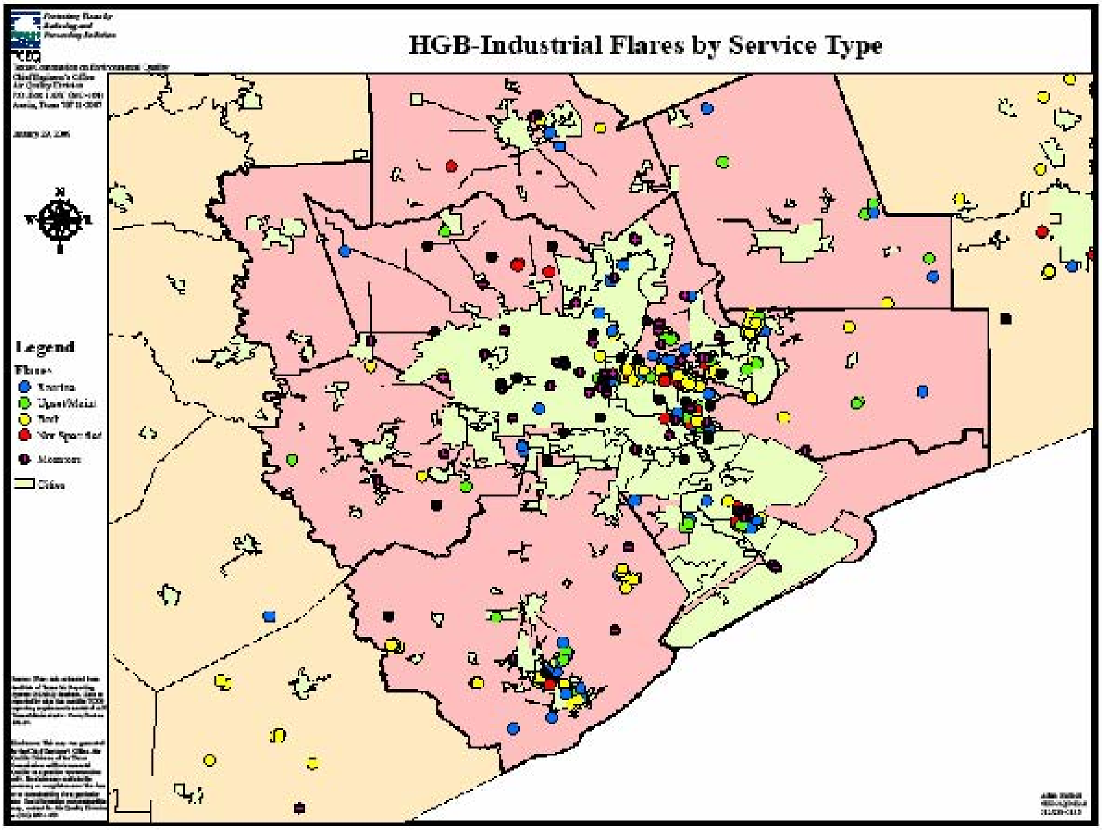

Figure 2. HGB Industrial Flares by Service Type
(Source: TCEQ)

3 Catalog of Potential Control Technologies

3.1 Overview

Methods identified for potentially reducing HRVOC emissions include:

- Process changes,
- Changes in operating procedures,
- Vent stream controls, and
- Flare minimization.

Each of these is discussed in turn within this section.

3.2 Process Changes

For existing production facilities, short of replacing older technology with newer technology, there are limited opportunities for making process changes that reduce HRVOC emissions. One of these limited opportunities discussed in a 1997 EPA document on the polymer industry is changing catalysts.[11] This document suggests that there are opportunities to replace an older catalyst with a newer, better catalyst, resulting in overall yield improvements, and, thus, reducing the amount of un-reacted monomer that remains in the polymer. This information is somewhat misleading. A polymer manufacturing facility must use a catalyst that is most appropriate for their process and the polymer properties sought.

For example, a gas phase PE reactor may use an older catalyst that has lower reactivity and selectivity than a newer, better catalyst. However, the newer, better catalyst may not be suitable for use in the gas phase reactor, but can only be used in a high pressure slurry PE process. Additionally, use of the old catalyst may be necessary to produce the desired PE properties.

3.3 Changes in Operating Procedures

As with process changes, there may be opportunities to modify operating procedures to reduce emissions of HRVOC. Potential changes in operating procedures may range from enhanced maintenance activities to the use of sophisticated dynamic simulation algorithms to reduce losses during non-steady state operating conditions, such as those that occur during startup and shutdown.

3.3.1 Enhanced Maintenance

There may be opportunities to improve maintenance of existing equipment and reduce losses of HRVOC during normal operations and/or scheduled maintenance activities. Examples of enhanced maintenance activities may include more aggressive investigation and timely

[11] Profile of the Plastic Resin and Manmade Fiber Industries, Sector Notebook Project, EPA-310/R-97-006, September 1997.

corrective action of leaking pressure safety valves (PSV), leaking compressor seals, leaking valves and flanges, leaking heat exchangers, etc. However, sites subject to the HECT are already required to monitor cooling tower return lines for leaking heat exchange systems and implement stringent fugitive monitoring and control requirements.[12] [As noted previously, fugitive emissions are not included in the HECT.]

Enhanced maintenance may also include use of predictive and preventive maintenance processes. The predictive maintenance process involves review of the equipment types, the failure mechanisms associated with those equipment types and the associated mean time to failure. Preventive maintenance takes the next step and focuses maintenance on taking action before equipment fails. This preventive maintenance can lead to higher reliability, greater on-stream time, and fewer unscheduled maintenance shutdowns.

Required HRVOC monitoring of flare headers and cooling tower returns has resulted in some subject facilities implementing enhanced maintenance programs.[13] For example, one site uses the HRVOC monitoring system as a feedback mechanism. When flaring, operators use the HRVOC monitoring system to help identify the source of the flows (e.g., PSV leaks, open valves). The monitors do not identify specific equipment, but the ability to speciate the compounds going to the flare helps to narrow troubleshooting efforts to a particular process area.

Some sites are also using passive infrared (IR) cameras to find and eliminate/reduce emissions of HRVOC. As part of the HARC H-76 project, ENVIRON found that, as of the summer of 2006, three of the nine surveyed sites were using the IR cameras to locate potential sources of HRVOC emissions.[14] Uses of the IR cameras include:

- Integration of IR cameras into routine leak detection and repair (LDAR) programs.
- Use of IR cameras to monitor for emissions during startup and shutdown. Camera findings are used to direct corrective measures.

As discussed in the Project H-76 report, those companies that have embraced use of the passive IR cameras are strong supporters of using this technology to find and fix sources of emissions.

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[12] Any process unit or process within a petroleum refinery, synthetic organic chemical, polymer, resin, or methyl tert-butyl ether manufacturing process or natural gas/gasoline processing operation in the 8-county Houston/Galveston/ Brazoria area in which an HRVOC is a raw material, intermediate, final product, or in a waste stream is subject to the requirements of 30 TAC 115, Subchapter H, Division 3 which specifies monitoring and control requirements for fugitive emissions from equipment.

[13] "*How Chemical Manufacturing and Petroleum Refining Facilities in Harris County are Using Point Source Monitoring to Identify and Reduce HRVOC Emissions,*" HARC Project H76, ENVIRON, prepared for the Houston Advanced Research Center, October 2006.

[14] Ibid

As part of an agreement with the City of Houston, one facility in Harris County has installed a fence line Fourier Transform Infrared (FTIR) monitoring system to monitor for 1,3-butadiene.[15] While not initially intended as a tool for improving maintenance or operating practices, the fence line FTIR system has allowed the facility to identify operations and activities that result in emissions of 1,3-butadiene and to use that information in taking corrective action..

3.3.2 Dynamic Process Simulation

Understanding how operating conditions affect waste gas production can lead to improved operating techniques. Rather than relying solely on engineering trial-and-error and operator experience to modify operating procedures to minimize flaring, dynamic process simulation has been used to minimize HRVOC flaring during shutdown and startup at an ethylene production facility.[16] In the referenced study performed by Lamar University in cooperation with LyondellBasell's Equistar Channelview Plant, dynamic process simulation was used to critically evaluate potential process and procedural modifications prior to the actual shutdown/startup or upset event. Dynamic simulation was developed for the recovery section of the ethylene plant and used to examine the following process steps:

- Approaching shutdown,
- Startup with recycle ethane, and
- Starting the cracked feed and increasing the feed to normal production rates.

The researchers found that dynamic process simulation provides an insight into process behavior that is not readily apparent through steady state simulation and process engineering calculations. Process simulations are performed using standard software, such as Aspen Plus and Aspen Dynamics™. Operators can use the results of the dynamic process simulations to modify control settings during shutdown/startup and upset conditions to minimize flaring of off-specification (off-spec) streams.

Results of the Equistar Channelview Plant dynamic process simulation study are as follows:[17]

- Actual flaring associated with shutdown and startup of the ethylene plant was 75% less than a previous startup of a similar plant at the site.
- Flaring emissions from the shutdown and startup were 56% less than the estimates made prior to the turnaround.

Using dynamic process simulation, other ethylene production facilities have reduced HRVOC emissions from flaring. Examples include:

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[15] Ibid

[16] Flare Minimization via Dynamic Simulation. Singh, A., K. Li, H. H. Lou, J. R. Hopper, H. B. Golwala and S. Ghumare. *Int. J. Environment and Pollution*. Vol. 29, Nos. 1/2/3, pp. 19-29.

[17] Ibid

- Huntsman Petrochemical reduced flaring to less than 3.5 hours during a startup event, and

- BASF-TOTAL reduced flaring by 50% compared to a previous startup.[18]

This project has not determined if dynamic process simulation can be applied to polymer manufacturing plants.

3.4 Vent Stream Controls

Based on our review of EPA's RACT/BACT/LAER Clearinghouse (RBLC), ENVIRON identifies three technologies that have been used to control HRVOC emissions from process vents at polymer manufacturing plants: flares, thermal oxidizers and boilers. Additionally, while not an ultimate control device, air and steam stripping have been used to remove un-reacted monomer from SBR crumb prior to finishing. While not identified in the RBLC review, ENVIRON is aware that polymer plant waste gas streams containing HRVOC have also been managed using catalytic oxidizers. Each of these technologies is briefly described within this section. Also included are brief discussions of other control technologies considered: adsorption, biofiltration, Bekaert burners and refrigerated condensers.

It is important to keep in mind that the technical feasibility, including process safety considerations, and economic feasibility of any control system can only be determined on a case-by-case basis.

Costs are not included within these general discussions of control technologies. Costs of control are highly dependent upon a number of design and operating variables and often cannot be estimated accurately within even one or two orders of magnitude without specific information as to the application. For example, USEPA Air Pollution Control Technology Fact Sheet EPA-452/F-03-019 provides the following range of costs for flares.

Capital Cost: .... $13 to $21,000 per standard cubic foot per minute (scfm) of flow

Operation & Maintenance Cost: .... $1 to $10 per scfm

Annualized Cost: .... $3 to $300 per scfm

Cost Effectiveness: .... $15 to $5,000 cost per ton of pollutant controlled

It is questionable if even this very broad range brackets actual costs that might be incurred for flaring of one or more process vent streams. Meaningful control costs can only be determined on a case-by-case basis.

[18] Near-Zero Flare for Chemical Process Industry via Plant-wide Optimization and Simulation. Xu, Q., K. Li and J. L. Gossage. TERC SAC Meeting, Houston, Texas. February 2008.

3.4.1 Flaring

Flaring is a combustion control process in which the combustible material to be flared is piped to a remote, usually elevated location, and burned in an open flame in the air using a specially designed burner tip, auxiliary fuel, and steam or air to promote mixing for nearly complete (>98%) destruction efficiency. Completeness of combustion in a flare is governed by flame temperature, residence time in the combustion zone, turbulent mixing of the gas stream components to complete the oxidation reaction, and available oxygen for free radical formation.[19]

Flares that conform to the design requirements of 40 CFR 60.18 are assumed by rule to achieve 98% destruction efficiency for C4 HRVOCs (1,3-butadiene and butenes) and 99% destruction efficiency for C2-C3 HRVOCs (ethylene and propylene).[20] The design requirements of 40 CFR 60.18 include the following:

- Flame present at all times.
- Minimum net heating value of the gas being burned of 300 Btu/scf (steam or air-assisted) or 200 Btu/scf (non-assisted).
- Maximum exit velocity of 60 feet per second for steam-assisted or non-assisted flares. Velocity limits for air-assisted flares are dependent upon the net heating value of the gas being combusted.

Flares are commonly used to control HRVOC emissions at petroleum refineries, chemical plants, olefins manufacturing plants, polymer manufacturing plants and for-hire storage terminals. Review of the RBLC identified use of flaring to control emissions from product storage and product loading at the Chevron Phillips Chemical Company Pasadena Plastics Plant. The permit for this application was dated December 15, 1998.

Flaring of HRVOC emissions from extruders and finishing operation vent streams has been limited for a number of reasons, including: cost of capture (e.g. installation of hooding on extruders, etc.), cost of supplemental fuel, and safety (air in flare header resulting in a potentially explosive waste stream). To illustrate the cost of supplement fuel, assume a 1,000 standard cubic feet per minute vent stream containing 200 ppm ethylene – approximately 4 tons/year – is routed to a flare for control. The heat value of the ethylene at this concentration is approximately 0.3 Btu/scf. To meet the 40 CFR 60.18 design requirement of 300 Btu/scf for a steam-assisted flare, this vent stream will either need to be combined with a higher heat content vent stream prior to flaring or supplemented with a fuel, such as natural gas. If a supplementary fuel is used, approximately 429 scfm of natural gas will need to be added to the vent stream to raise the heat content to 300 Btu/scf. On an annual basis, this equates to approximately 225.5 million scf (MMscf). Assuming a natural gas price of $9.00 per MMBtu, supplemental fuel for flaring this 1,000 scfm vent gas stream will cost approximately $2,000,000 per year. The

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[19] USEPA Air Pollution Control Technology Fact Sheet EPA-452/F-03-019

[20] 30 TAC 115.725(d) contains several references to these control efficiencies.

incremental cost of control for this vent stream using a flare, just considering the cost of the supplemental fuel, is approximately $500,000 per ton. This cost of control would apply to any 200 ppm ethylene vent stream that is flared. Additionally, the use of supplemental fuel would result in additional CO and NO_x emissions from the flare.

3.4.2 Thermal Oxidation

There are two general types of thermal oxidizers (TO) in common use: regenerative and recuperative. A regenerative thermal oxidizer, or RTO, uses a high-density media such as a ceramic packed bed still hot from a previous cycle to preheat an incoming waste gas stream. The preheated waste gases then enter a combustion chamber where they are heated by auxiliary fuel combustion (e.g. natural gas) to a final oxidation temperature typically between 1,400 and 1,500°F. The hot exit gases are directed to one or more ceramic packed beds where the heat from the gases is absorbed before they are vented to the atmosphere. An RTO will typically achieve a control efficiency of 95 to 99%.[21]

Recuperative TOs are comprised of the combustion chamber, waste gas preheater and, if appropriate, a secondary energy recovery preheater. Recuperative TOs can recover up to 70% of the waste heat from the exhaust gases and achieve destruction efficiencies ranging from 98% to as high as 99.9999%.[22]

The typical design conditions required to achieve at least 98% destruction efficiency in a recuperative TO are:

- Minimum combustion temperature of 1,600°F,
- Combustion chamber residence time of 0.75 second, and
- Proper mixing.

Figures 3 and 4 present typical configurations for regenerative and recuperative TOs, respectively.[23]

[21] USEPA Air Pollution Control Technology Fact Sheet EPA-452/F-03-021

[22] USEPA Air Pollution Control Technology Fact Sheet EPA-452/F-03-020

[23] USEPA Air Pollution Cost Control Manual, 6th Edition, EPA-452/B-02-001, January 2002

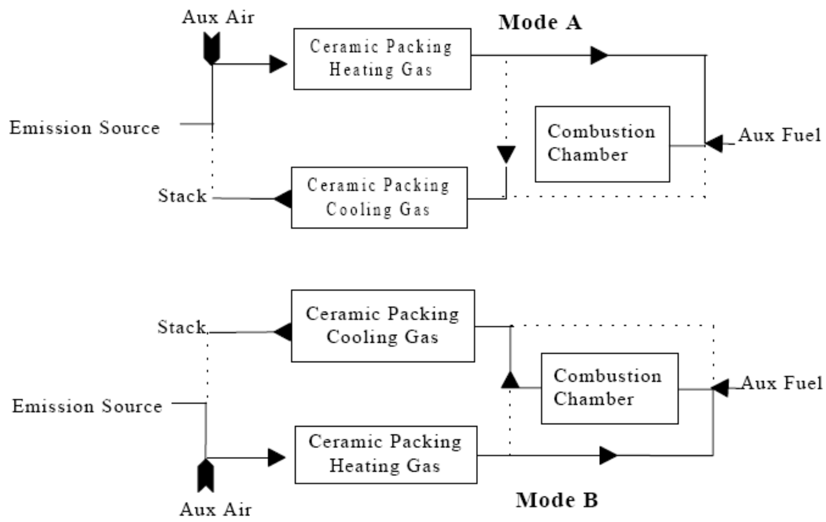

Figure 3. Typical Configuration – Regenerative Thermal Oxidizer

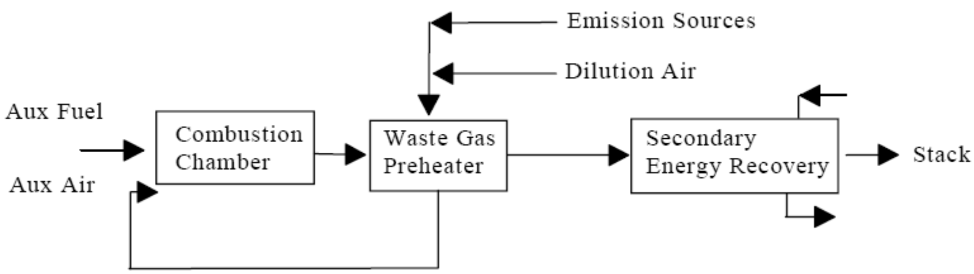

Figure 4. Typical Configuration – Recuperative Thermal Oxidizer

Table 8 summarizes the findings of the RBLC review (last 10 years) with respect to control of HRVOC emissions from polymer plants using thermal oxidation. This listing is not comprehensive. Sources that did not undergo federal NSR, either Prevention of Significant Deterioration (PSD) or Nonattainment NSR (NNSR), will not be listed in the RBLC.

Table 8. Examples of Thermal Oxidation Used to Control HRVOC Emissions

Company:	Fagerdala Pac-Lite Incorporated
Location:	St. Clair, Michigan
Permit Date:	02/01/2001
Process Description:	Expandable polypropylene bead production.
Control Application:	Emissions from the fluidized bead dryer and regrind extruder are controlled by thermal oxidizer. Die area is hooded.
Control Efficiency:	85%
Company:	Formosa Plastics Corporation
Location:	Point Comfort, Texas
Permit Date:	03/09/1999
Process Description:	Polypropylene plant with multiple trains with two reactors each.
Control Application:	Process off-gases are routed to incinerator. Reactor gases are routed to flare header in case of an upset.
Control Efficiency:	Unknown. HRVOC emissions are limited to 31.5 lb/MMlb for Train 4, 133 lb/MMlb for Trains 1-3.
Company:	Total Petrochemicals USA (formerly Atofina Petrochemicals Inc.)
Location:	La Porte, Texas
Permit Date:	11/05/2001
Process Description:	Polypropylene production
Control Application:	Backup thermal oxidizer. Areas of process controlled are not identified.
Control Efficiency:	99.99%
Company:	Goodyear Tire and Rubber Company
Location:	Beaumont, Texas
Permit Date:	02/19/2004
Process Description:	Styrene butadiene rubber production
Control Application:	Regenerative thermal oxidizer. Application is unspecified.
Control Efficiency:	Not specified

3.4.3 Catalytic Oxidation

Catalytic oxidizers operate similar to thermal oxidizers with the primary difference being that, after passing through the flame zone, the waste gases pass through a catalyst bed. The catalyst has the effect of increasing the reaction rate, enabling oxidation of the organics in the waste stream at a lower reaction temperature than would be required in a thermal oxidizer to achieve the same destruction efficiency. Catalysts also allow for a reduced residence time and, thus, allow for smaller oxidizers. The waste gas is typically heated to between 600°F and 800°F before entering the catalyst. Control efficiencies as high as 95-99% can be achieved with catalytic oxidation. [24]

Catalytic oxidizers are subject to plugging as well as catalyst deactivation or poisoning. Therefore, they are not as widely applicable as thermal oxidizers. As with any control approach, however, technical and economic feasibility can only be evaluated on a case-by-case basis.

Figure 5 presents a typical configuration for a catalytic oxidizer. [25]

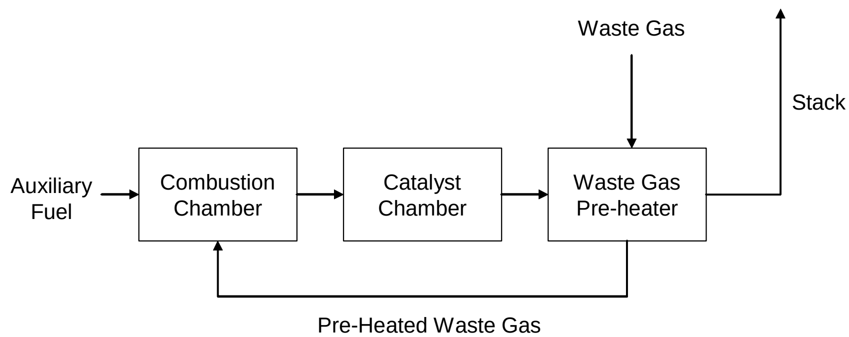

Figure 5. Typical Configuration – Catalytic Oxidizer

Review of the RBLC did not identify any application of catalytic oxidizers to control emissions of HRVOC from polymer plants in the last 10 years. However, as noted previously, this listing is not comprehensive. As discussed in Section 4 of this report, catalytic oxidizers have been used at sites in Harris County to control emissions of HRVOC.

3.4.4 Boilers and Process Heaters

Boilers and process heaters, under certain process conditions, may be used to combust waste streams containing HRVOC. Considerations in burning HRVOC waste gas streams in boilers and process heaters include the following: [26]

- Most chemical plants, olefins manufacturing plants and polymer plants do not have fuel gas headers that facilitate collection of waste gases for use as fuels. This may limit or eliminate consideration of this control option.
- Boilers designed specifically for HRVOC control use discrete or vortex burners.[27]

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[24] USEPA Air Pollution Control Technology Fact Sheet EPA-452/F-03-021

[25] EPA Air Pollution Cost Manual, 6th Edition, EPA-452/B-02-001, January 2002

[26] Some of the items listed are derived from discussions with industry personnel.

[27] Polymer Manufacturing Industry, Background Information for Proposed Standards, EPA-450/3-83-019a, September 1985.

- Use of high concentration ethylene streams as a fuel tends to result in more nitrogen oxides (NO_X) formation than the burning of natural gas.[28]

- The combustion characteristics of certain olefin derivatives, such as propylene oxide, make it unsuitable for combustion in boilers or process heaters because it combusts explosively. This characteristic could also limit the use of thermal or catalytic oxidizers.

- Olefins such as ethylene and propylene may polymerize in a fuel gas header, resulting in plugged lines with associated safety and performance implications.

While not common, there are examples of boilers being used to control emissions from polymer plants. In a 1985 document, EPA identifies two polypropylene plants and a high density polyethylene (HDPE) plant that route off-gases to a boiler for control.[29]

In addition, ENVIRON identified one facility during review of the RBLC (last 10 years) that was permitted to use a boiler to control emissions of HRVOC from a polymer production facility (Table 9). Note that this listing is not comprehensive. Sources that did not undergo federal NSR, either PSD or NNSR, will not be listed in the RBLC.

Table 9. Examples of Boilers or Process Heaters Used to Control HRVOC Emissions

Company:	Total Petrochemicals USA (formerly Atofina Petrochemicals Inc.)
Location:	La Porte, Texas
Permit Date:	11/05/2001
Process Description:	Polypropylene production
Control Application:	Waste heat boiler and regenerative gas heater. Areas of process controlled are not identified.
Control Efficiency:	99.99%

In addition to the application identified in Table 9, within the description for a project at the Chevron Phillips Chemical Company Pasadena, Texas, plant (permit date of 02/23/2000) is the following:

"The Phillips Chemical Company seeks authorization to use certain PE and PP process off gases as fuel at existing flares located within their Houston Chemical Complex. The process off gases are generated on-site at process units and were used as fuel at four on-site boilers; however, the boilers are being permanently shutdown . . . Certain PE/PP off gases will be routed to the flare fuel gas system for use as flare fuel gas."

[28] Ethylene has a high heat content: approximately 1,600 Btu/scf compared with approximately 1,000 Btu/scf for methane (natural gas). Consequently, unless specifically designed for burning ethylene, the combustion device will burn hotter and have higher NO_X emissions.

[29] EPA-450/3-83-019a

It is ENVIRON's understanding that as part of their strategy for complying with the NO_X Mass Emission Cap and Trade (MECT) program, Chevron Phillips Chemical shut down their boilers and started purchasing steam from a nearby cogeneration facility. As documented in the RBLC, however, boilers were used for controlling PE and PP emissions prior to that time.

If technically and economically feasible, due to the high temperature and long residence times typical of boilers and process heaters, high destruction efficiencies (greater than 98%) can be achieved.[30]

The use of flares, thermal oxidizers, catalytic oxidizers and/or boilers to reduce HRVOC emissions from polymer plants is built upon the assumption that the uncontrolled emissions can be effectively captured. The effective, efficient and safe capture of reactive monomer streams must be evaluated on a case-by-case basis.

3.4.5 Bekaert Burners

Another alternative to flaring is use of Bekaert CEB® burners[31]. Bekaert burners use a meshed fiber surface that divides the main flame into tiny flames thereby resulting in more complete combustion of the HRVOC in the waste gas stream. Bekaert reports that HRVOC destruction efficiencies as high as 99.99% have been achieved at operating temperatures of 2,000-2,200°F with NO_X emissions less than 15 ppm. The capacity on the largest burner model Bekaert currently makes is approximately 2,500 scfm. As discussed in Section 4, with one exception, the annual average flare flowrates at the Harris County polymer production facilities surveyed is less than 2,500 scfm. However, to handle emergencies and other large releases, the flare design capacities are much greater than 2,500 scfm.

Figure 6. Bekaert Burners

Based on information provided by Bekaert, there are six of their systems currently in use in the Houston area. Four of these are at petrochemical plants. The largest system in use is used to control emissions (non-HRVOC) from barge loading and unloading operations. Since the burner uses fine fiber mesh, presence of particulate matter in the waste gas stream may clog the flame openings thereby impairing performance.

Figure 6 shows in-field installation of two Bekaert CEB® Model 4500 burners (Source: Bekaert website). Currently, these are Bekaert's largest models.

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[30] Ibid

[31] Information on Bekaert burners is derived from discussions with Mr. Timothy F. Egan, Bekaert Corporation, and from their website: http://www.bekaert.com/flaring

3.4.6 Stripping

Stripping is used in SBR production to remove un-reacted monomer from the rubber crumb, with the overheads routed to a combustion device for destruction. Stripping is common in SBR production facilities; however, the intent of the stripping is primarily to remove the un-reacted styrene. The un-reacted 1,3-butadiene is removed through flash distillation and reduction in system pressure.

Review of the RBLC identified two facilities where stripping is used to control emissions from SBR production facilities. Table 10 summarizes the findings.

Table 10. Examples of Stripping Used to Control HRVOC Emissions

Company:	Firestone Polymers LLC
Location:	Lake Charles, Louisiana
Permit Date:	07/30/2003
Process Description:	Styrene butadiene rubber production
Control Application:	Steam stripping of solvent from crumb rubber. Emissions stream from stripping operation is collected and routed to flare
Control Efficiency:	Unknown
Company:	Goodyear Tire and Rubber Company
Location:	Beaumont, Texas
Permit Date:	02/19/2004
Process Description:	Styrene butadiene rubber production
Control Application:	Air stripping. Application is unspecified.
Control Efficiency:	Not specified

While search of the RBLC did not identify any instances of either air or steam stripping being used to control emissions from PE or PP production facilities, as discussed in Section 4, nitrogen stripping is used to remove un-reacted monomer in PE and PP production facilities.

3.4.7 Adsorption / Concentration

Adsorption is the attachment of gaseous molecules to the surface of a solid. During adsorption, a gas molecule migrates from the gas stream to the surface of the solid where it is held by physical attraction. Adsorption in the form of a concentrator can be used to raise the concentration of an organic vapor to provide more economical treatment in downstream combustion or condensation devices. Activated carbon is the most widely used adsorbent for VOCs. Other adsorbents include zeolites and certain synthetic polymers.[32]

[32] *Choosing an Adsorption System for VOC: Carbon, Zeolite, or Polymers?* EPA Technical Bulletin, EPA 456/F-99-004, May 1999.

Factors that influence the performance of activated carbon in controlling gas phase VOC emissions include:[33]

- The type of compound to be removed. In general, compounds with a high molecular weight and higher boiling point are better adsorbed.
- Concentration. The higher the concentration the better the adsorption.
- Temperature. The lower the temperature the greater the adsorption capacity.
- Pressure. The higher the pressure the greater the adsorption capacity.
- Humidity. The lower the humidity the greater the adsorption capacity.

As shown in Table 11, HRVOCs are low molecular weight compounds with low boiling points.[34]

Table 11. Physical Properties of HRVOCs

Compound	Molecular Weight	Boiling Point (°C)
Ethylene	28	-104
Propylene	42	-48
1,3-Butadiene	54	-4
1-Butene	56	-5
2-Butene (cis & trans)	56	+3
Isobutylene	56	-7

Vents from extruders and downstream operations will typically have low HRVOC concentrations and pressures close to ambient. Collectively, this information indicates that activated carbon would, most likely, be a poor choice for either direct control of HRVOC emissions or for use in a concentrator. The limitations affecting adsorption using activated carbon would also be expected to affect adsorption using zeolites or polymer adsorbents.

Concentrator suppliers have stated that, for a concentrator to be effective, the boiling point of the material to be adsorbed should be higher than the inlet gas phase temperature, but lower than the desorption temperature. For applications involving the HRVOCs listed in Table 11, the boiling points would be less than the desorption temperature; however, they would not be above the inlet temperature. This "rule of thumb" confirms that HRVOCs are not amenable to adsorption or concentration.

[33] EPA Air Pollution Cost Manual. 6th Edition, EPA/452/B-02-001, January 2002.

[34] Chemical Engineer's Handbook, 5th Edition, edited by Robert H. Perry and Cecil H. Chilton, McGraw-Hill Book Company, 1973.

Review of the RBLC did not identify any application of adsorption for the control of HRVOC emissions from polymer plants in the last 10 years.

3.4.8 Biofiltration / Bioscrubbing

Biofiltration involves routing a vent gas stream through a biologically active media, similar to compost, where the pollutants of interest are adsorbed and/or absorbed and biologically degraded into water and carbon dioxide. A bioscrubber is similar in function; however, the control system involves a tower packed with synthetic media that supports a biological culture. Biofiltration and bioscrubbing have been successfully applied in a number of full-scale applications to control odors, VOC and emissions of air toxics from a wide range of sources. Application of biofiltration and bioscrubbing are typically limited to relatively low concentration vent streams – approximately 1,000 ppm or less – and the pollutants need to be water soluble.[35] HRVOC compounds are generally slightly soluble to insoluble in water, making them poor candidates for control through biofiltration.

3.4.9 Refrigerated Condensers

A refrigerated condenser is a control device that is used to cool an emission stream containing organic vapors and to condense the organic vapors into a liquid that is then collected and either recycled or disposed of. Refrigerated condensers work best on emission streams containing high concentrations of VOC. To achieve any reduction, even on saturated streams, the condenser must achieve a temperature that is lower than the boiling point of the compound in question.

HRVOC emissions from extruders and downstream operations are poor candidates for control through use of refrigerated condensers because: 1) the boiling points are low (refer to Table 11) and 2) the concentration of HRVOC in the vents is expected to be low.

3.4.10 Non-Thermal Plasma

Low-temperature, non-thermal plasma (NTP) is a developing technology that may, in the future, be an option for controlling emissions of HRVOC.[36] The basic principle of NTP is the use of electricity to create a plasma – an ionized gas containing free electrons.[37] These energetic electrons excite, dissociate and ionize molecules to produce chemically active radicals and ions. In the laboratory, NTP has been shown to have ability to destroy a number of different VOCs and polycyclic aromatic hydrocarbons (PAHs).[38] Pilot-scale experiments conducted at pulp mills

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[35] EPA Survey of Control Technologies for Low Concentration Organic Vapor Gas Streams. EPA/456/R-95-003, May 1995.

[36] Pulsed Corona Plasma Pilot Plant for VOC Abatement in Industrial Streams as Mobile and Educational Laboratory. Tak, G., Gutsol, A. and Fridman, A., 2005. (http://plasma.mem.drexel.edu/publications/documents/ISPC-ID670.pdf)

[37] Application of Non-Thermal Plasma for Air Pollution Control (http://miedept.mie.uic.edu/lab/kennedy/Application_Plasma_4.htm)

[38] Pulsed Corona Plasma Pilot Plant for VOC Abatement in Industrial Streams as Mobile and Educational Laboratory. Tak, G., Gutsol, A. and Fridman, A., 2005. (http://plasma.mem.drexel.edu/publications/documents/ISPC-ID670.pdf)

and wood product plants have shown VOC destruction efficiencies greater than 98%.[39] In theory, NTP could be used to treat industrial waste gas streams containing HRVOC across a wide range of flow rates.[40] NTP, however, has not been demonstrated on a commercial scale nor has it been demonstrated to control emissions of HRVOC.

3.5 Flare Minimization

Flare minimization refers to the reduction in the number of instances of flaring, both during routine operations and during startup, shutdown and malfunction, and to the reduction in the quantity of material flared. The concept of flare minimization applies to both stream recycling/reuse and flare gas recovery.

3.5.1 Recycling/Reuse

As discussed in Section 2.2, a significant percentage of HRVOC emissions occur during maintenance, startup, and shutdown (MSS) activities and during emission events. Through certain capital investments (e.g. the addition of process loops and storage capacity) and changes in the way that the production units are managed during MSS activities, the amount of HRVOC released to the flare header can be significantly reduced. Following are two examples of recycling and reuse at Harris County facilities.

- One Harris County olefins producer implemented a flare minimization program that resulted in reduced flaring during the shutdown and startup of the unit. The shutdown and startup of the unit is a sequence of steps where each section of the process is shutdown or started before the next section. Past practice had been to vent to the flare during this sequence until the unit was gas-free during shutdown or until producing on-specification product when going through startup. The operator made modifications to the process that allowed for streams to be recycled within the unit that dramatically reduced the amount of material sent to the flare during shutdown and startup.

- As discussed in the HARC Project H-76 report, as of 2006, one Harris County olefins producer was planning on sending off-specification HRVOC to an off-site salt dome storage facility for later reprocessing. This would result in a reduction in HRVOC emissions from flaring by approximately 17 tons/year at a projected capital cost of approximately $700,000.[41]

[39] Pulsed Corona Plasma Technology for Treating VOC Emissions from Pulp Mills, July 28, 2004. (http://www.osti.gov/energycitations/servlets/purl/826442-clriuJ/826442.PDF)

[40] Destruction of Highly Diluted Volatile Organic Compounds (VOCs) in Air by Dielectric Barrier Discharge and Mineral Bed Adsorption. Martin, L., Ognier, S., Gasthauer, E., Cavadias, S., Dresvin, S. and Amouroux, J. *Energy & Fuels*. Vol. 22, 576-582, 2008.

[41] *How Chemical Manufacturing and Petroleum Refining Facilities in Harris County are Using Point Source Monitoring to Identify and Reduce HRVOC Emissions*, HARC Project H-76, ENVIRON International Corporation, prepared for the Houston Advanced Research Center, October 2006.

3.5.2 Flare Gas Recovery

Flare Gas Recovery (FGR) refers to taking low pressure waste gases in the flare header, compressing the gases, and then reprocessing them or using them as a fuel gas in the plant. When the flow is less than or equal to the capacity of the FGR system, the flare gas will be recovered. During these periods of normal operations, emissions from the flare will approach zero. When the flare gas flow rate is greater than the capacity of the FGR system, the excess flare gas will flow through a liquid seal drum and to the flare tip for combustion. FGR systems are designed for recovering waste gases during normal operations. During non-routine operating conditions (e.g. MSS and emission events), excess waste gas will flow to the flare for combustion.

Potential benefits of FGR include:

- Waste gas may have substantial heating value and could be used as a fuel source in the plant, thereby reducing fuel purchase costs;
- Waste gas could be used as feedstock or product in certain applications; and
- Emissions from flaring would be reduced.

FGR is widely used in petroleum refineries. As part of multi-facility, “global” consent agreements with the USEPA, a number of major petroleum refining companies have committed to installing FGR at one or more of their refineries. The Harris County refineries that are part of global consent agreements with EPA are:

- ExxonMobil Baytown Refinery,
- Shell Deer Park Refinery, and
- Valero Houston Refinery.[42]

The ExxonMobil, Shell and Valero global consent agreements do not require the installation of FGR at these refineries. However, the ExxonMobil and Shell agreements specify compliance with the emission limits of New Source Performance Standard (NSPS) Subpart J (40 CFR 60.104(a)); specifically the provision that

> *“No owner or operator subject to the provisions of this subpart shall: (1) Burn in any fuel gas combustion device any fuel gas that contains hydrogen sulfide (H2S) in excess of 230 mg/dscm (0.10 gr/dscf).”*

Compliance may require the installation of FGR on some flares. Assuming the FGR system is sized to handle worst-case flows during normal operations, emissions from these flares during normal operations should be limited to pilot gas combustion, or very close to zero.[43]

[42] *Petroleum Refinery Consent Decree Emission Reduction Assessment for Ozone and Regional Haze SIPs,* ENVIRON International Corporation, prepared for the Texas Commission on Environmental Quality, November 2007.

There are a number of potential limitations to use of FGR in olefins, derivatives (e.g. propylene oxide production) and polymer manufacturing facilities. These include:[44]

- Refineries have fuel gas headers that collect high heat content waste streams from around the refinery, compress it, and send it to boilers and/or process heaters for use as a fuel. Olefins, derivatives and polymer production facilities do not typically have this same infrastructure.

- The combustion characteristics of high concentration olefin or olefin derivative streams may not be conducive to use as a fuel. For example, propylene oxide burns explosively.

- Use of the olefin or olefin derivative as a fuel may result in undesirable environmental impacts. For example, ethylene burns very hot and results in the formation of excess NOX.

- The olefins may polymerize in the flare header, leading to plugging with associated safety and performance implications.

As with all other emission control approaches, the technical and economic feasibility of flare gas recovery must be evaluated on a case-by-case basis.

[43] Ibid.
[44] Developed during discussions with industry representatives during the survey portion of the project.

4 HRVOC Emission Reduction Projects Survey Findings

As discussed in the Introduction, ENVIRON prepared and sent questionnaires to certain Harris County industrial sites for the purpose of gathering information on projects that have been implemented to reduce HRVOC emissions at those sites, the costs of those projects, and on other HRVOC emission reduction projects that have been considered but not implemented. For Phase 1, ENVIRON developed separate questionnaires for flare issues and polymer production issues. For Phase 2, ENVIRON prepared a single questionnaire pertaining to both HRVOC emission reduction projects and flares that was sent to another set of Harris County facilities selected by the TCEQ. Both the Phase 1 polymer production issues and flare questionnaire templates and the Phase 2 questionnaire are included in Appendix A.

For Phase 1, the TCEQ identified 16 sites in Harris County to receive one or both of the surveys. Of the 16 sites, 11 participated by responding to the surveys and/or meeting with ENVIRON personnel to discuss their responses. Participating sites included 4 olefin plants and 9 polymer plants. Two sites, out of the 11 that participated in Phase 1, are involved in the manufacture of both polymers and olefins. Additionally, one site that did not provide a response to the survey suggested that information obtained as part of HARC Project H76 be included in this investigation. That site contains both petroleum refining and olefins production operations.

For Phase 2, the TCEQ identified 38 sites in Harris County to receive the survey. Of the 38 sites, 24 participated by responding to the survey. Participating sites included 12 chemical manufacturing facilities; 8 terminals; 2 polymer facilities (flare survey only); and 2 refineries.

Synthesized survey findings from Phases 1 and 2 are presented and discussed within this section.

4.1 Facility Questionnaire Results

4.1.1 Industry Types Surveyed

ENVIRON received survey responses from the following types of facilities:

- Polymer manufacturing facilities
  - Polyethylene – low density, high pressure process
  - Polyethylene – low density, low pressure process
  - Polyethylene – high density, gas phase process
  - Polyethylene – high density, liquid-phase slurry process
  - Polyethylene – high density, liquid-phase solution process
  - Polypropylene – liquid-phase slurry process
  - Polypropylene – gas phase process
- Chemical, including olefins and non-olefins, manufacturing facilities

- Petroleum refineries
- Storage terminals

The number of facilities represented by the above-listed categories is presented in Figure 7.

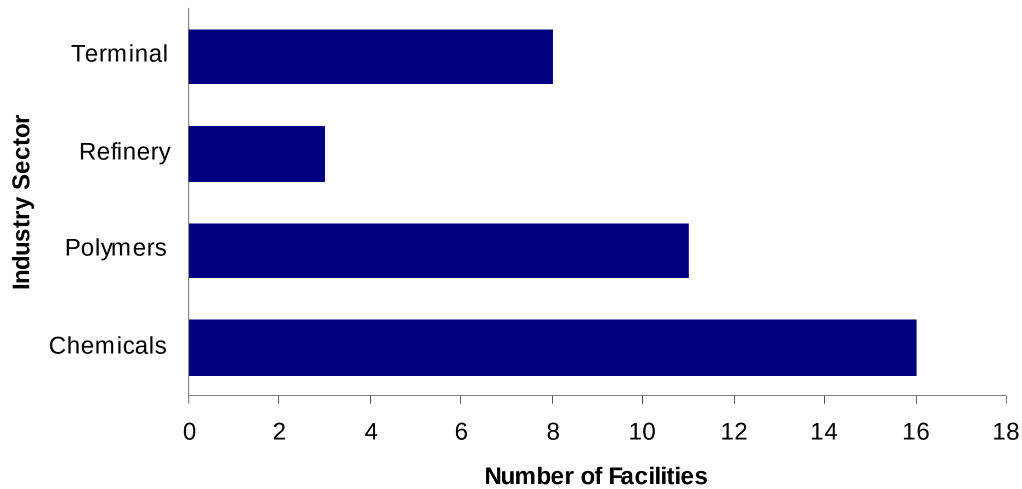

Figure 7. Type and Number of Facilities

4.1.2 Process Vent Control Techniques

ENVIRON asked survey respondents whether process vents were recycled back to the process or routed to a control device. For Phase 1 polymer plants, process vents include those located upstream of the extruder.

Responses are summarized in Table 12. The number of process units utilizing each control technique is presented in the table. All polymer plants surveyed operate multiple process units.

Table 12. Summary of Process Vent Control Techniques by Process Type for Polymers

Industry Sector	Recycled	Flare	Boiler	Process Heater	Thermal Ox	FGR	CatOx
PE – low density, high pressure	2	1	1	0	1	0	1
PE – low density, low pressure process	1	1	0	0	0	0	1
PE – high density, gas phase process	1	2	0	0	1	0	1
PE – high density, liquid-phase slurry	11	12	8	0	0	0	0
PE – high density, liquid-phase solution	1	1	0	1	1	0	0

Table 12. Summary of Process Vent Control Techniques by Process Type for Polymers

Industry Sector	Recycled	Flare	Boiler	Process Heater	Thermal Ox	FGR	CatOx
PP – liquid-phase slurry	6	6	1	0	0	3	0
PP – gas phase	5	5	1	0	0	2	0

For Phase 2 facilities, 11 process vents are recycled to process; 369 process vents are routed to a control device; and 258 process vents are uncontrolled.

4.1.3 Finishing Operations

ENVIRON asked Phase 1 polymer plant survey respondents whether finishing vents (i.e., extruder and downstream to storage and loading) are routed to a control device. Nine polymer facilities responded to this part of the survey.

- No Control. Of the nine facilities that responded to this part of the survey, five facilities have no control on the extruder, product storage or loading operations. Emissions from these facilities are from uncontrolled atmospheric vents.
- Thermal Oxidation. Two facilities use thermal oxidizers to control HRVOC emissions from the extruders and/or downstream operations. One facility routes the emissions from extruder vents to a thermal oxidizer. The other facility routes emissions from dryer vents and storage silos to a thermal oxidizer.
- Catalytic Oxidation. One facility routes intermediate storage emissions generated from the high-pressure LDPE manufacturing process to a catalytic oxidizer.
- Flare. One facility routes its dryer vents to a flare for control, but other finishing vents are uncontrolled.

Table 13. Summary of HRVOC Emission Reduction Projects

Project ID	Project Name	Industry Sector	Capital Cost ($)	HRVOC Reduction (tpy)	Phase 1 or Phase 2
P1	Vent Gas Recovery	Polymers (Polyethylene – low density, high pressure process)	650,000	40	Phase 1
P2	Ethylene Recovery Unit	Polymers (Polypropylene – gas phase process)	1,000,000	15	Phase 1
P3	De-inventory to propylene storage[1]	Polymers (Polypropylene – liquid-phase slurry process)	50,750	See note 1 below	Phase 1
P4	Installation of Regenerative Thermal Oxidizer	Polymers (Polyethylene – low density, high pressure process)	11,500,000	143	Phase 1
P5	Changes to startup procedure[2]	Polymers (Polyethylene – liquid-phase process)	0	0.5	Phase 1
P6	Replacement of Catalytic Oxidizer with Thermal Oxidizer with higher DRE	Polymers (Polyethylene – liquid-phase solution process)	364,000	0.5	Phase 1
P7	Re-routing of extruder vents from carbon beds to thermal oxidizer	Polymers (Polyethylene – liquid phase process)	127,000	1	Phase 1
P8	Installation of PSA system	Polymers (Polypropylene – liquid-phase slurry and gas-phase processes)	7,000,000	42	Phase 1
P9	PSA system operability improvements	Polymers (Polypropylene – liquid-phase slurry and gas-phase processes)	400,000	1	Phase 1
P10	Implementation of more efficient purge bin distributor design	Polymers (Polypropylene – liquid-phase slurry and gas-phase processes)	800,000	20	Phase 1
P11	Routing of relief devices to flare[3]	Polymers (Polypropylene – gas phase process)	175,000	See note 3 below	Phase 1
P12	Installation of HRVOC caps and plugs[3]	Polymers (Polypropylene –gas-phase process)	75,000	See note 3 below	Phase 1
P13	Implementation of leak detection probe[3]	Polymers (Polypropylene – gas phase process)	8,000	See note 3 below	Phase 1

Table 13. Summary of HRVOC Emission Reduction Projects

Project ID	Project Name	Industry Sector	Capital Cost ($)	HRVOC Reduction (tpy)	Phase 1 or Phase 2
P14	Installation of HRVOC awareness monitors[3]	Polymers (Polypropylene – gas phase process)	15,000	See note 3 below	Phase 1
P15	Installation of HRVOC sample points and caps and plugs[4]	Polymers (Polypropylene – liquid-phase slurry and gas-phase processes)	93,500	See note 4 below	Phase 1
P16	Installation of pump trap on compressor[4]	Polymers (Polypropylene – liquid-phase slurry and gas-phase processes)	130,000	See note 4 below	Phase 1
P17	Routing of pump off-gas flow to Flare Gas Recovery system[4]	Polymers (Polypropylene – liquid-phase slurry and gas-phase processes)	47,100	See note 4 below	Phase 1
P18	Installation of HRVOC monomer efficiency monitors[4]	Polymers (Polypropylene – liquid-phase slurry and gas-phase processes)	26,000	See note 4 below	Phase 1
P19	Implementation of leak detection probe[4]	Polymers (Polypropylene – liquid-phase slurry and gas-phase processes)	6,000	See note 4 below	Phase 1
P20	Implementation of atmospheric PSV monitoring[4]	Polymers (Polypropylene – liquid-phase slurry and gas-phase processes)	53,000	See note 4 below	Phase 1
P21	Enhancement of propylene storage sample system[4]	Polymers (Polypropylene – liquid-phase slurry and gas-phase processes)	59,000	See note 4 below	Phase 1
P22	Flare Gas Recovery system upgrade[4]	Polymers (Polypropylene – liquid-phase slurry and gas-phase processes)	321,000	See note 4 below	Phase 1
P23	Flare Gas Recovery system upgrade[4]	Polymers (Polypropylene – liquid-phase slurry and gas-phase processes)	20,000	See note 4 below	Phase 1
P24	Improve Butene Utilization	Chemicals	122,000	4.9	Phase 2
P25	Reduce Ethylene Emissions from Atmospheric Tanks	Chemicals	149,000	12.6	Phase 2
P26	Install a Pressure Controller	Chemicals	0	NS[5]	Phase 2
P27	Optimize Vent Gas Compressor Timing	Chemicals	0	0.3	Phase 2

Table 13. Summary of HRVOC Emission Reduction Projects

Project ID	Project Name	Industry Sector	Capital Cost ($)	HRVOC Reduction (tpy)	Phase 1 or Phase 2
P28	Convert Atmospheric Vent to 'Emergency Only' Vent	Chemicals	31,000	0.25	Phase 2
P29	Modify Emergency Vent Control Logic	Chemicals	28,000	NS[5]	Phase 2
P30	Install a Compressor	Chemicals	500,000	20	Phase 2
P31	Upgrade Heat Exchangers	Chemicals (Olefins)	2,120,000	NS[5]	Phase 2
P32	Install Monitoring Systems	Chemicals (Olefins)	75,000	NS[5]	Phase 2
P33	Shutdown Process Analyzer	Chemicals (Olefins)	0	0.1	Phase 2
P34	Install a Flare Stack	Refinery	40,700,000	NS[5]	Phase 2
P35	Coker Blow-down Routed to Flare	Refinery	1,200,000	13.5	Phase 2
P36	Online Monitoring	Chemicals (Olefins)	NS	5	Phase 2
P37	Bundle Upgrades	Chemicals (Olefins)	NS	15	Phase 2
P38	Vent Gas Recovery	Chemicals (Olefins)	NS	45	Phase 2
P39	Fenceline Monitoring	Chemicals (Olefins)	NS	15	Phase 2

[1] Estimated HRVOC reductions between 1 - 3 tph depending on frequency and duration of shutdown. Facility did not provide detailed information regarding the frequency and duration of shutdown; therefore, annualized HRVOC reductions were not estimated.

[2] Startup performed once every two to three years. The estimated HRVOC reductions are annualized.

[3] Facility provided total HRVOC emission reductions attributed to projects P11 – P14 of 27.14 tpy. However, HRVOC emission reductions attributed to each project were not available.

[4] Facility provided total HRVOC emission reductions attributed to projects P15 – P23 of 21.67 tpy. However, HRVOC emission reductions attributed to each project were not available.

[5] Facility was unable to estimate HRVOC emission reductions due to the project. Therefore, HRVOC emission reductions are not specified.

4.1.4 HRVOC Emission Reduction Projects

ENVIRON asked Phase 1 and Phase 2 survey respondents whether any projects had been implemented to reduce emissions in response to the HRVOC rules. Projects could include, but were not limited to, process changes, changes in operating procedures, vent stream controls and/or flare minimization. Excluded from the survey were costs associated with installation of HRVOC monitoring equipment and any emission reductions that may have resulted from more robust monitoring of emissions. A detailed analysis of the costs of control and HRVOC emission reductions associated with the installation of HRVOC monitoring equipment is included in *How Chemical Manufacturing and Petroleum Refining Facilities in Harris County Are Using Point Source Monitoring to Identify and Reduce HRVOC Emissions*.[45]

Table 13 summarizes the projects identified by Phase 1 and Phase 2 survey respondents. Additional details regarding the projects referenced in Table 13 are provided below.

- **Project P1.** The facility collected emissions from 8 continuous hourly production silos. Each storage silo stores approximately one hour's worth of production. HRVOC emissions collected from these intermediate storage silos are routed to a catalytic oxidizer for control. Previously, emissions from these production silos were uncontrolled. HRVOC emission reductions due to the implementation of this project are estimated to be approximately 40 tpy.

- **Project P2**. The facility installed an ethylene recovery unit on an off-gas stream to recover up to 3,000,000 pounds of ethylene from the flare header system. Taking into account an assumed 99% destruction and removal efficiency (DRE), the recovery of 3,000,000 pounds of ethylene translates to post-flare HRVOC emission reductions of approximately 15 tpy.

- **Project P3.** This project consisted of piping modifications which allowed the facility to recycle liquid slurry back to monomer storage instead of flaring during shutdown. Depending on the duration of shutdown, HRVOC emission reductions are estimated to be between 1 and 3 tons per hour (tph) during the event.

- **Project P4.** The facility installed an RTO for MON/HRVOC compliance requirements. Post-extruder HRVOC emissions from the pellet dryer vent, compressor distance pieces and the pellet silo storage vents are routed to the thermal oxidizer. Previously, these emission sources were uncontrolled. HRVOC emission reductions due to the implementation of this project are estimated to be approximately 143 tpy.

- **Project P5.** The facility implemented procedural changes to pressure check the reactor before startup. Isobutane is used instead of ethylene as part of the reactor start-up procedure, thereby reducing the use of ethylene during this process. This operational

[45] *How Chemical Manufacturing and Petroleum Refining Facilities in Harris County are Using Point Source Monitoring to Identify and Reduce HRVOC Emissions*, HARC Project H76, ENVIRON International Corporation, prepared for the Houston Advanced Research Center, October 2006.

procedure is repeated once every two to three years. Annualized HRVOC emission reductions are estimated to be approximately 0.5 tpy.

- **Project P6.** The facility replaced an existing catalytic oxidizer with a thermal oxidizer that achieves a higher DRE. HRVOC emission reductions due to this project are estimated to be approximately 0.5 tpy.

- **Project P7.** The facility rerouted the extruder vents from existing carbon adsorber beds to a thermal oxidizer. HRVOC emission reductions due to this rerouting are estimated to be approximately 1 tpy.

- **Project P8**. The facility installed a Pressure Swing Absorption (PSA) system to capture all continuous vent streams that were previously routed to the flare for control. These vent streams consist primarily of nitrogen (75%), with the remainder being propylene (25%). The PSA system recovers, condenses and recycles propylene back to the process in liquid form. Also, nitrogen is recycled back to the process. HRVOC emission reductions due to this project are estimated to be approximately 42 tpy.

- **Project P9**. The facility made improvements to the operability of its PSA system and routed additional small vents (e.g., analyzer vents, dry gas seals) to the PSA. HRVOC emission reductions due to this project are estimated to be approximately 1 tpy.

- **Project P10**. The facility implemented a more efficient distributor design on its purge bin. The redesigned distributor results in greater volatilization of the monomer from the polypropylene flake prior to the flake entering atmospheric storage vessels, thereby reducing atmospheric emissions. HRVOC emission reductions due to this project are estimated to be approximately 20 tpy.

- **Projects P11 through P14**. The facility implemented several projects related to reducing atmospheric emissions of HRVOC from atmospheric relief valves and fugitive components.46 Projects included the following:

  - *Routing of atmospheric relief devices to flare.* Pressure relief devices on the polypropylene dryers, which were previously routed to the atmosphere, were tied in to the flare header.

  - *Installation of HRVOC caps and plugs*. All the caps and plugs in VOC service were replaced with plugs painted fluorescent yellow for easy identification and were tethered to a cable so that they could be found easily if not in place.

  - *Implementation of leak detection probe.*

[46] Unlike other polymer facilities surveyed, this facility implemented projects primarily related to fugitive emission reductions and monitoring.

- *HRVOC awareness monitors.* Project involved installation of a monitor in the control room to allow for continual monitoring of the monomer efficiency, HRVOC permit compliance and energy utilization at the unit.

Additionally, process improvements and improvements in operational reliability, mechanical integrity and monomer efficiency have contributed to HRVOC emission reductions at the facility. HRVOC emission reductions due to the capital projects and other improvements are estimated to be 27.14 tpy.

- **Projects P15 through P23**. The facility implemented several projects related to reducing atmospheric emissions of HRVOC from atmospheric relief valves and fugitive components and to upgrading the existing Flare Gas Recovery (FGR) system. Projects included the following:

  - *Installation of HRVOC sample points and caps and plugs.* Project involved the installation of HRVOC sampling points on various process vent streams. The project also involved purchasing miscellaneous piping caps and plugs for lines in hydrocarbon service. All the caps and plugs in VOC service were replaced with plugs painted fluorescent yellow for easy identification and were tethered to a cable so that they could be found easily if not in place.
  - *Installation of pump trap on compressor.* Project involved installing a skid mounted pump trap system on the sour oil/seal gas return line located in the propylene distillation section. This system allows for the separation of propylene entrained in the sour oil, allowing the propylene emissions to discharge to the flare header instead of the atmosphere.
  - *Routing of off-gas flow to FGR.* Project involved installation of pipe with control valve to allow off-gas from compressor pump trap to be separately fed to FGR. Project was needed to optimize monomer efficiency.
  - *Installation of HRVOC monomer efficiency monitors.* Project involved installation of monitors in control rooms to allow for continuous monitoring of HRVOC and monomer efficiency.
  - *Implementation of leak detection probe*.
  - *Implementation of atmospheric PSV monitoring*. Wireless pressure transmitters were installed on pressure relief valves, which are routed to the atmosphere, and tied into the DCS so that the time and duration of each pressure relief event could be monitored.
  - *Enhancement of propylene storage sample system*. Sampling system on the propylene storage bullets was tied to the flare header to prevent atmospheric releases while sampling.
  - *Two FGR upgrades*. One project improved the reliability of the FGR system from 95% to 99%. A second project improved the reliability of the FGR and improved the recovery of propylene and hexane.

Additionally, process improvements and improvements in operational reliability, mechanical integrity and monomer efficiency have contributed significantly to HRVOC emission reductions at the facility. HRVOC emission reductions due to the capital projects and other improvements are estimated to be 21.67 tpy.

- **Project P24.** The facility uses HRVOC feed to manufacture monomer. The project involved control of reactor vents during HRVOC feed to improve HRVOC usage and utilization and minimize losses. Previously, emissions from reactor loading operations were uncontrolled. HRVOC emission reductions due to the implementation of this project are estimated to be 4.9 tpy.
- **Project P25.** Due to low pressure in atmospheric pressure tanks, the carryover material (ethylene) from the reactor escapes through the atmospheric vents. In an effort to reduce these ethylene emissions, the reactor pressure is lowered when the reactor is flared and then purged with nitrogen. Low pressure helps to reduce HRVOC emissions through atmospheric vents and nitrogen purge helps to bubble-out ethylene in the reactor solution. HRVOC emission reductions of approximately 12.6 tpy were realized as a result of implementing this change in operational procedure.
- **Project P26**. Maintaining the cooling water pressure above the process pressure prevents ethylene emissions in case of a condenser tube leak. This project involved the installation of a pressure control device and upgrading the operating procedures in order to maintain the cooling water pressure above the process pressure. HRVOC emission reductions due to the implementation of this project were not specified by the respondent. Site personnel told ENVIRON that the site does not have HRVOC emission reduction data for this project.
- **Project P27.** This project was a procedural change to optimize the timing of vent gas compressor startup in order to reduce ethylene emissions to flare during process startups. Annualized HRVOC emission reductions are estimated to be approximately 0.3 tpy.
- **Project P28.** The facility converted an uncontrolled atmospheric vent from operation as a startup/shutdown vent to an 'emergency only' vent and diverted the vent stream to a flare. HRVOC emission reductions due to this project are estimated to be approximately 0.25 tpy.
- **Project P29.** The facility modified vent control logic and hardware to reduce the probability of unintended activation of the release vent. HRVOC emission reductions due to the implementation of this project were not specified by the respondent. Site personnel told ENVIRON that the site does not have HRVOC emission reduction data for this project.
- **Project P30.** The process at the facility consists of a reaction between isobutylene and various other raw materials. However, the reaction is not 100% efficient. The unreacted isobutylene used to be stripped out of the product and recycled back to the process. However, a mass balance identified that 10-20% of unreacted isobutylene was lost to the flare. The project consisted of installation of a compressor in place of the scrubbers to reduce the amount of isobutylene flared. It is estimated that only 1% of unreacted

HRVOC is currently flared. HRVOC emission reductions due to this project are estimated to be approximately 20 tpy.

- **Project 31.** The project consisted of replacing the existing heat exchangers in HRVOC service with new heat exchangers to minimize HRVOC emissions and leak potential. The facility has 3 such units with a 7 to 10 year turnaround cycle. HRVOC emission reductions due to the implementation of this project were not specified by the respondent. Site personnel told ENVIRON that the site does not have HRVOC emission reduction data for this project.
- **Project 32.** This project consisted of installation of an independent pressure transmitter to each relief valve that vented to the atmosphere. This project was carried out to improve monitoring of relief valves. HRVOC emission reductions due to the implementation of this project were not specified by the respondent. Site personnel told ENVIRON that the site does not have HRVOC emission reduction data for this project.
- **Project 33.** The existing GC analyzer at the facility did not have a flame ionization detector (FID) coupled to it. Gas streams analyzed by the GC were vented to the atmosphere. This project involved coupling a FID to the GC. HRVOC emission reductions due to this project are estimated to be approximately 0.1 tpy.
- **Project 34.** This project consisted of installation of a flare stack to reduce short-term emissions from episodic events. The flare was primarily installed due to reliability concerns for a compressor in pure ethylene service. However, the facility anticipated limited reduction in HRVOC emissions due to the project. HRVOC emission reductions due to the implementation of this project were not specified by the respondent. Site personnel told ENVIRON that the site does not have HRVOC emission reduction data for this project.
- **Project 35.** This project consisted of routing coker blow-down emissions to the flare. HRVOC emission reductions due to this project are estimated to be approximately 13.5 tpy.
- **Project 36 through Project 39**. The facility implemented several projects related to reducing HRVOC emissions. As shown in Table 13, these projects were related to installation of online HRVOC monitors, bundle upgrades, vent gas recovery and fenceline monitoring of certain HRVOCs. However, additional details of these projects were not provided by the survey respondent. The total HRVOC emission reductions due to these projects are estimated to be approximately 80 tpy.

ENVIRON also asked respondents about HRVOC emission reduction projects that had been considered, but not implemented. Details related to those projects are discussed below.

- **Storage Silo Control.** This project would have reduced monomer emissions from storage silos at a polyethylene manufacturing facility (low density, high pressure process). The project would have involved the installation of multiple transfer lines to different storage silos to route low heat value waste gas streams to a catalytic oxidizer. If implemented, the project would have required a capital investment of approximately $5MM for a catalytic oxidizer to reduce HRVOC emissions by up to 40 tpy.

- **Propylene Nitrogen Recovery Unit (PNRU).** The implementation of the PNRU project would have reduced HRVOC emissions by recovering the monomer (propylene) and reusing it in the polypropylene production process. For safety reasons, nitrogen, which is inert, would be used to recover propylene. In a typical PNRU application, the vent stream from the resin degassing bin is compressed and then cooled to condense the propylene. The gas leaving the condenser, which contains a significant amount of propylene, is fed to a membrane unit. The membrane unit separates the stream into a propylene-enriched permeate stream and a purified nitrogen stream. The permeate stream is recycled to the inlet of the compressor and then to the condenser, where the propylene is recovered. The purified nitrogen stream is recycled to the degassing bin.[47]

  Two different polymer manufacturing facilities have considered installation of a PNRU. Implementation of the two PNRU projects would involve capital expenditures of greater than $1 MM and $12 MM, respectively.48 Neither facility provided any information regarding estimated HRVOC emission reductions that would have been achieved by the implementation of PNRU.

- **Isobutane Nitrogen Recovery Unit (INRU).** The INRU is conceptually similar to PNRU except that it would be used to recover isobutane from the polyethylene production process. In addition to recovering isobutane, ethylene would potentially be recovered using INRU. Neither cost nor potential HRVOC emission reduction information was provided by the facility that considered this project.

- **Off-gas Recycle.** The off-gas recycle project would recycle the reactor off-gas back to the polypropylene production process. To make the necessary modifications and process changes would require a capital investment in excess of $1 MM.

- **Route Vents to Flare Header.** This project would involve routing reactor vents and atmospheric relief valves to a process flare header. While not yet implemented, the survey respondent indicated that the facility is proceeding with implementation in the near future. The flare header must be modified to handle the large potential flow during emergency shutdown. The facility plans to install a distributed control system (DCS) to program the shutdown sequence. The current estimated cost for this project is $8 MM. No estimate of the reduction in HRVOC emissions to be realized was provided. Routine emissions at this facility are routed to a thermal oxidizer. This project would only affect MSS and event emissions.

- **Ethylene Recovery Unit.** This project would involve routing intermediate flake tanks vents to an Ethylene Recovery Unit (ERU). Currently, these intermediate tanks are uncontrolled. Because the flake tanks are designed for atmospheric pressure, the facility would have to design a pressure control scheme, install piping and auxiliary

[47] http://www.mtrinc.com/polypropylene_production.html

[48] The $12 MM estimate is considered more refined; the greater than $1 MM provided by one facility is considered a rough estimate of the minimum amount of capital investment required.

equipment in addition to the ERU. The estimated cost for this project is $10 MM. No estimate of the reduction in HRVOC emissions to be realized was provided.

- **Process to Process Heat Exchangers.** This project would involve rerouting the process stream containing HRVOCs from the cooling tower to a heat exchanger, thereby reducing the HRVOC emissions. However, this project would have been cost prohibitive, as defined by the site, costing in excess of $500,000 for each heat exchanger, resulting in a minimal HRVOC emission reduction.

- **Recycle Raw Material.** This project would recycle process stream HRVOC raw materials, at a chemicals manufacturing facility, back to the production process instead of venting to a flare. However, the project would not be feasible due to the sensitivity of the batch production process to inert materials, e.g. nitrogen, in the recycle stream.

- **Ethylene Recovery System.** This project would use membrane separation and absorption to recover ethylene from the primary purge stream. However, extensive retrofitting to incorporate this technology into the existing plant design would be cost prohibitive, as defined by the site.

- **Analyzer Emissions Control.** This project would involve installation of a control device to reduce propylene emissions from a Gas Chromatogram (GC) analyzer instead of venting the injected stream to the atmosphere. The project was not implemented due to the limited emission reduction potential of the project, estimated to be 0.5 tpy of HRVOC.

- **Vapor Balancing System.** A vapor balancing system would recover propylene and isobutylene emissions from truck loading and unloading operations instead of routing them to a flare system. However, due to space requirements, the existing 40+ year-old equipment in the loading area would have to be relocated. This would significantly increase the incremental costs associated with such a system and make this project infeasible.

- **Vapor Recovery and Controlled Process Vent.** The implementation of this project would result in a reduction of 4 tpy of HRVOC emissions from storage operations. The project would involve installation of a chiller/vapor recovery unit on a storage tank to recover vapors that would otherwise be lost as breathing or working losses to the flare system. The emission reduction estimates are based on actual flare loading and assumptions on the chiller recovery efficiency. A high cost-benefit ratio, as defined by the facility, makes this project infeasible. However, the facility is trying to gather funds for the project and is hopeful that the project will be implemented.

- **Flare Gas Recovery.** The facility intended to install a flare gas recovery system. The facility currently has 4 such systems installed. However, due to questionable emission reductions data and an unrefined cost estimate, a cost-benefit analysis was not conducted for this project.

- **Heat Exchanger Upgrade.** The facility intended to upgrade heat exchangers in HRVOC service. However, due to questionable data and unrefined cost estimate, a cost to benefit analysis was not conducted for this project.

4.1.5 Excess Monomer Removal

ENVIRON asked Phase 1 polymer plant survey respondents whether excess monomer was removed from resins prior to finishing operations (i.e., extruder vents and vents downstream of the extruder). Nine polymer facilities responded to this part of the survey. Responses are discussed below.

- **No Control.** Four of the nine facilities that responded to this part of the survey did not report any processes in place to recover raw materials prior to finishing operations.[49]

- **Catalytic Oxidation.** One facility routes emissions from a tertiary degasser for LLDPE and HDPE to a catalytic oxidizer.

- **Hot Nitrogen Purge.** One facility purges the polyethylene and polypropylene fluff with hot nitrogen into a closed loop system which also includes the extruder feed tank. Residual hydrocarbons recovered are eventually sent to the flare. In another **facility,** excess monomer is recovered from the polymer slurry prior to the production of pellets. In the liquid-phase slurry process, hot nitrogen stripping is used to recover the monomer in downstream units. For the liquid-phase solution process, the excess monomer is stripped using nitrogen and a system of centrifuges and flash dryers.

- **Low Pressure Recovery.** One facility uses a low pressure recovery compressor to recover nitrogen, ethylene and isobutane from the facility's intermediate polyethylene flake storage tanks. These intermediate tanks store polyethylene flake prior to extrusion. The recovery compressor routes the nitrogen, ethylene and isobutane to a flare. This stream is approximately 99% isobutane.

- **Ethylene Recovery Unit.** The same facility employing low pressure recovery also utilizes an Ethylene Recovery Unit ("ERU"). The ERU is a three step, cryogenic process, by which ethylene is recovered from the resins prior to finishing operations. Recovered ethylene is recycled to the process, routed to a boiler as fuel or routed to a flare if the boiler is not operational. Note that both the low pressure recovery system and the ERU were installed by the facility prior to the advent of the HRVOC rules.

- **Pressure Swing Absorption.** One facility utilizes a Pressure Swing Absorption ("PSA") system to capture all continuous vent streams that were previously routed to the flare for control. These vent streams consist primarily of nitrogen (75%), with the remainder being propylene (25%). The PSA system recovers, condenses and recycles propylene back to the process in liquid form. Also, nitrogen is recycled back to the process.

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[49] Although these four facilities did not report any processes in place to recover raw materials prior to finishing operations, these facilities may operate a closed loop system with nitrogen purge.

4.1.6 Costs of HRVOC Emission Reduction Projects

Table 14 summarizes the cost effectiveness of HRVOC reduction projects implemented by various facilities as listed in Table 13. The largest project in terms of total capital investment, P34, was implemented specifically to reduce HRVOC emissions during episodic events, not for controlling routine HRVOC emissions. Also, P4 was implemented for MON/HRVOC compliance, not just for controlling HRVOC emissions.

ENVIRON asked survey participants to provide estimates of total capital investment as well as direct and indirect annual costs. As noted in Table 14, annual cost information was not made available for all projects. Some facilities indicated they do not track annual costs for these projects separately from other annual costs. As shown in Table 14, there is a wide range in cost effectiveness, ranging from $2,012 to $195,600 per ton per year of HRVOC controlled. Projects P27 and P33 are excluded from the range because of zero capital and annual costs.

Table 14. Cost Effectiveness of HRVOC Emission Reduction Projects							
Project ID	**Capital Cost ($)**	**Annualized Capital Cost [1] ($)**	**Direct and Indirect Annual Cost ($)**	**Total Annual Cost[2] ($)**	**HRVOC Emission Reduction (tpy)**	**Cost Effectiveness[3] ($/tpy)**	**Phase**
P1	650,000	130,000	5,000	135,000	40	3,375	Phase 1
P2	1,000,000	200,000	NS	200,000	15	13,333	Phase 1
P3	50,750	10,150	NS	10,150	See Note[4]	N/A	Phase 1
P4	11,500,000	2,300,000	120,000	2,420,000	143	16,923	Phase 1
P5	0	0	0	0	0.5	N/A[5]	Phase 1
P6	364,000	72,800	25,000	97,800	0.5	195,600	Phase 1
P7	127,000	25,400	5,000	30,400	1	30,400	Phase 1
P8	7,000,000	1,400,000	NS	1,400,000	42	33,333	Phase 1
P9	400,000	80,000	NS	80,000	1	80,000	Phase 1
P10	800,000	160,000	NS	160,000	20	8,000	Phase 1
P11 – P14	273,000	54,600	NS	54,600	27.14	2,012	Phase 1
P15 – P23	755,600	151,120	NS	151,120	21.67	6,974	Phase 1
P24	122,000	24,400	0	24,400	4.9	4,980	Phase 2
P25	149,000	29,800	0	29,800	12.6	2,365	Phase 2
P26	0	0	5,000	5,000	NS	NA	Phase 2
P27	0	0	0	0	0.3	0	Phase 2
P28	31,000	6,200	0	6,200	0.25	24,800	Phase 2
P29	28,000	5,600	0	5,600	NS	NA	Phase 2
P30	500,000	100,000	50,000	150,000	20	7,500	Phase 2
P31	2,120,000	424,000	0	424,000	NS	NA	Phase 2

Table 14. Cost Effectiveness of HRVOC Emission Reduction Projects

Project ID	Capital Cost ($)	Annualized Capital Cost [1] ($)	Direct and Indirect Annual Cost ($)	Total Annual Cost[2] ($)	HRVOC Emission Reduction (tpy)	Cost Effectiveness[3] ($/tpy)	Phase
P32	75,000	15,000	0	15,000	NS	NA	Phase 2
P33	0	0	0	0	0.1	0	Phase 2
P34	40,700,000	8,140,000	890,000	9,030,000	NS	NA	Phase 2
P35	1,200,000	240,000	0	240,000	13.5	17,778	Phase 2
P36	NS	NS	NS	NS	5	NA	Phase 2
P37	NS	NS	NS	NS	15	NA	Phase 2
P38	NS	NS	NS	NS	45	NA	Phase 2
P39	NS	NS	NS	NS	15	NA	Phase 2

[1] Based on five-year project life and a discount rate of 0%.

[2] Total Annual Cost = Annualized Capital Investment + Direct and Indirect Annual Cost

[3] Cost Effectiveness = Total Annual Cost / Total HRVOC Emission Reduction

[4] Estimated HRVOC reductions between 1 - 3 tph depending on frequency and duration of shutdown. Facility did not provide detailed information regarding the frequency and duration of shutdown; therefore, annualized HRVOC reductions were not estimated.

[5] Startup performed once every two to three years. The estimated HRVOC reductions are annualized. Total capital investment and annual costs are negligible, so cost of control is effectively zero but HRVOC emission reductions are low.

4.1.7 Flare Reduction and Minimization Projects

ENVIRON asked survey respondents whether any projects had been implemented to reduce or minimize flaring. Responses are summarized in Table 15.

Table 15. Summary of HRVOC Flare Reduction and Minimization Projects

Project ID	Project Name	Process Type	Capital Cost ($)	HRVOC Reduction (tpy)	Phase
F1	Flare Gas Recovery	Polypropylene – gas phase process	608,400	12 – 14	Phase 1
F2	Flare Gas Recovery[1]	Polypropylene – liquid-phase slurry and gas phase processes	970,000	5 – 10	Phase 1
F3	Vent Recycle	Polyethylene – low density, high pressure process	50,000	10 – 12	Phase 1
F4	Modifications to Shutdown Procedure	Polyethylene – low density, high pressure process	N/A	N/A	Phase 1
F5	Modifications to Shutdown Procedure	Polyethylene - high density, gas phase process	N/A	2	Phase 1
F6	Ethylene Recovery Unit	Polypropylene – gas phase process	1,000,000	15	Phase 1
F7	De-inventory to propylene storage[2]	Polypropylene – liquid-phase slurry process	50,750	See note below	Phase 1
F8	Modifications to Startup and Shutdown Procedures	Polypropylene – liquid-phase and gas phase processes	N/A	N/A	Phase 1
F9	Chiller Replacement Project	Olefins	3,500,000	85	Phase 1
F10	Flareless Startup and Shutdown	Olefins	1,100,000	50 – 100	Phase 1
F11	Rerouting Degassing Vent	Olefins	106,250	6.75	Phase 1
F12	Modifications to Startup Procedure	Polyethylene – liquid phase process	0	0.5	Phase 1
F13	Addition of Calorimeters to Vent Gas Monitoring System	Polyethylene – liquid phase process	183,000	1	Phase 1
F14	Flare Gas Recovery	Refinery	17,900,000	9	Phase 1
F15	Flare Gas Recovery	Refinery	34,500,000	45	Phase 1

Table 15. Summary of HRVOC Flare Reduction and Minimization Projects

Project ID	Project Name	Process Type	Capital Cost ($)	HRVOC Reduction (tpy)	Phase
F16	Heavy Ends Stream Recovery	Olefins	220,000	50	Phase 1
F17	Olefins Flare Reduction	Olefins	550,000	9	Phase 1
F18	Off-spec monomer to off-site storage	Olefins	700,000	17	Phase 1

[1] Project is installed, but not yet operating.
[2] Estimated HRVOC reductions between 1 - 3 tph depending on frequency and duration of shutdown.

Projects P2, P3 and P5 from Table 13 also appear as Projects F6, F7 and F12 in Table 15. These projects cannot be classified solely as polymer projects as their implementation also affected HRVOC emissions through flaring. Therefore, these projects are included in the discussion of both polymer plant and flare projects.

Additional details concerning the projects referenced in Table 15 are provided below.

- **Project F1.** The facility is using an existing compressor to remove the waste gas from the flare header using suction pressure. The waste gas is the reactor off-gas from the polypropylene (gas phase) process. This waste gas is sold to a neighboring facility for use as boiler fuel. HRVOC emission reductions are estimated to be between 12 and 14 tpy.

- **Project F2.** The facility installed a compressor to remove the waste gas from the flare header using suction pressure. The waste gas is the reactor off-gas from the polypropylene (liquid-phase slurry and gas phase) processes. When operational, HRVOC emission reductions are estimated to be between 5 and 10 tpy.

- **Project F3.** The facility added a recycle stream from the purge gas vessel. These emissions are routed back to the process (polyethylene – low density, high pressure). Reductions in HRVOC emissions due to reduced flaring as a result of vent recycle are estimated to be 10 to 12 tpy.

- **Projects F4, F5, F8, and F12.** Several facilities have modified their startup/shutdown procedures to minimize flaring emissions. One such modification to shutdown procedures (Project F4) is to reduce the reactor pressure before flaring. Reactor off-gas is recompressed and sent to purification step to recover ethylene. In another project (Project F5), the facility changed the product transition procedure to route the initial purge from the flare to the site's ethylene unit fuel gas system. This reduced 19,000 lbs of ethylene per product transition or approximately 300,000 lbs/yr out of the flare. Assuming 99% flare destruction efficiency, the estimated HRVOC emission reductions are 2 tpy. In Project F12, modifications to startup procedures include pressure checking the reactor with isobutane instead of ethylene, resulting in annualized HRVOC emission reductions of approximately 0.5 tpy.

- **Project F6.** The facility installed an ethylene recovery unit on an off-gas stream to recover up to 3,000,000 pounds of ethylene from the flare header system. Taking into account an assumed 99% DRE, the recovery of 3,000,000 pounds of ethylene translates to post-flare HRVOC emission reductions of approximately 15 tpy.
- **Project F7.** This project consisted of piping modifications which allowed the facility to recycle liquid slurry back to monomer storage instead of flaring during shutdown. Depending on the duration of shutdown, HRVOC emission reductions are estimated to be between 1 and 3 tph during the event.
- **Project F9.** The facility implemented this project to condense and recover C4 compounds (mostly 1,3-butadiene) from vent streams in the olefins plant. This project has reduced the load on vent recovery compressors, thereby minimizing or eliminating the bypass of HRVOCs to the flare. HRVOC emission reductions due to minimized flaring are estimated to be approximately 85 tpy.
- **Project F10.** The facility was able to achieve 75 – 80% reduction in HRVOC emissions due to flaring with the implementation of “flareless” startup/shutdown procedures. These reductions in flaring translate into HRVOC emission reductions of 50 to 100 tpy.
- **Project F11.** The facility rerouted the propylene compressor degassing pot vent back to the process. The vent was previously routed to the flare. Reductions in HRVOC emissions due to flaring as a result of vent recycle into the process are estimated to be approximately 6.75 tpy.
- **Project F13.** The facility added calorimeters to the already existing vent gas monitoring system. The addition of calorimeters allows operations personnel to identify any spike in the heat value of the waste gas stream in a timely manner. This is also helpful in identifying a source that may be inadvertently venting to the flare. This project has resulted in a reduction of 0.5 to 1 tpy of HRVOC emissions due to flaring.
- **Project F14 and F15.** The refinery implemented two flare gas recovery projects. The flare gas recovery systems have resulted in HRVOC reductions of approximately 9 and 45 tpy, respectively. Additional details regarding these projects are not available; however, it is known that the projects were not implemented for purpose of achieving HRVOC emission reductions.
- **Project F16 and F17.** The olefins plant implemented two flare minimization projects. The flare minimization projects have resulted in HRVOC reductions of approximately 50 and 9 tpy, respectively. Additional details regarding these projects are not available.
- **Project F18.** The facility sends off-specification monomer from the process to off-site salt dome storage well during start-up and shutdown, resulting in HRVOC reductions of approximately 17 tpy.

4.1.8 Flare Gas Recovery

Six polymer manufacturing facilities and one refinery responded to this part of the survey. Two facilities, both polypropylene manufacturers, have installed FGR systems for flare minimization.

Four facilities have not implemented FGR. Responses from two facilities discussing why they have not implemented FGR are as follows:

- At one facility, the flare controls only relief devices and emergency emissions. The flare header normally handles low flow rates. Therefore, a compressor installed for FGR would only run for short periods of time.

- At an olefins facility, tie-ins do not exist in the existing plant layout; therefore, any modification would require a major turnaround. Because it is an olefins plant, any oxygen ingress into the process resulting from operation of the FGR system could result in a dangerous situation. Another challenge for the olefins plant is the storage of off-spec material for future reuse. Currently, the plant is not equipped to store off-spec material or reuse it.

- At a refinery, FGR systems exist on 4 out of 8 flares. These flares were installed, almost 20 years ago, before the HRVOC rules were formulated.

4.1.9 Costs of HRVOC Flare Reduction and Minimization Projects

Table 16 summarizes the cost effectiveness of HRVOC flare reduction and minimization projects implemented by polymer plants, olefins plants and refineries listed in Table 15. Only Phase 1 survey respondents have implemented HRVOC flare reduction and minimization projects. No Phase 2 survey respondents identified any projects categorized as HRVOC flare reduction and minimization projects.

As shown in Table 16, there is a wide range in cost effectiveness, ranging from $880 to nearly $400,000 per ton of HRVOC controlled. As mentioned during discussion of the projects, the two refinery HRVOC abatement projects were not implemented for the purpose of reducing emissions of HRVOC. Excluding these two projects, cost effectiveness ranges from $880 to $51,600 per ton of HRVOC controlled.

Table 16. Cost Effectiveness of HRVOC Flare Reduction and Minimization Projects							
Project ID	**Capital Cost ($)**	**Annualized Capital Cost [1] ($)**	**Direct and Indirect Annual Cost ($)**	**Total Annual Cost[2] ($)**	**HRVOC Emission Reduction (tpy)**	**Cost Effectiveness[3] ($/tpy)**	**Phase**
F1	608,400	121,680	N/A	121,680	13	9,360	Phase 1
F2	970,000	194,000	N/A	194,000	7.5	25,867	Phase 1
F3	50,000	10,000	N/A	10,000	11	909	Phase 1
F4	N/A	N/A	N/A	N/A	N/A	N/A	Phase 1
F5	N/A	N/A	N/A	N/A	2	N/A	Phase 1
F6	1,000,000	200,000	N/A	200,000	15	13,333	Phase 1
F7	50,750	10,150	N/A	10,150	See Note[5]	N/A	Phase 1
F8	N/A	N/A	N/A	N/A	N/A	N/A	Phase 1
F12	0	0	0	0	0.5	N/A	Phase 1
F13	183,000	36,600	15,000	51,600	1	51,600	Phase 1
F9	3,500,000	700,000	50,000	750,000	85	8,824	Phase 1
F10	1,100,000	220,000	N/A	220,000	75	2,933	Phase 1
F11	106,250	21,250	N/A	21,250	6.75	3,148	Phase 1
F16	220,000	44,000	N/A	44,000	50	880	Phase 1
F17	550,000	110,000	N/A	110,000	9	12,222	Phase 1
F18	700,000	140,000	N/A	140,000	17	8,235	Phase 1
F14	17,900,000	3,580,000	N/A	3,580,000	9	397,778	Phase 1
F15	34,500,000	6,900,000	N/A	6,900,000	45	153,333	Phase 1
w/ Refinery	61,438,400	12,287,680	65,000	12,352,680	346.75	35,624	Phase 1

Table 16. Cost Effectiveness of HRVOC Flare Reduction and Minimization Projects

Project ID	Capital Cost ($)	Annualized Capital Cost [1] ($)	Direct and Indirect Annual Cost ($)	Total Annual Cost[2] ($)	HRVOC Emission Reduction (tpy)	Cost Effectiveness[3] ($/tpy)	Phase
w/o Refinery	9,038,400	1,807,680	65,000	1,872,680	292.75	6,397	Phase 1

[1] Based on five-year project life and a discount rate of 0%
[2] Total Annual Cost = Annualized Capital Investment + Direct and Indirect Annual Cost
[3] If the facility provided a range of HRVOC emission reductions, the median is used.
[4] Cost Effectiveness = Total Annual Cost / Total HRVOC Emission Reduction
[5] Estimated HRVOC reduction between 1 - 3 tph depending on frequency and duration of shutdown.

4.2 Analysis

4.2.1 Types of HRVOC Emission Reduction Projects

Survey participants provided information on 54 HRVOC emission reduction projects. A summary of these projects by industry sector and type is presented in Table 17. The types of projects are defined as follows:

Process Change: .... Change in how the product is made. For example, changing from a gas phase process to a liquid phase slurry process.

Change in Operating Procedures: .... Change in operating procedures such as enhanced maintenance or use of more robust process simulation to reduce emissions during startup and shutdown.

Vent Gas Control: .... Installation of controls on vent streams where none existed previously or upgrading to control systems with higher control efficiencies, such as routing vent streams to a thermal oxidizer instead of a flare.

Flare Minimization:............................ Recovery of material for reuse instead of sending it to the flare header and/or recovering material in the flare header for beneficial reuse.

Table 17. Summary of Project Type by Industry Sector

Industry Sector	Number of Plants Participating[1]	Type of HRVOC Emission Reduction Project			
		Process Change	Change in Operating Procedure	Vent Gas Control	Flare Minimization
Polymers	9	0	16	7	7
Chemicals[2]	16	0	14	0	6
Refinery	3	0	0	0	4
Terminals	8	0	0	0	0
Total	36	0	30	7	17

[1]Two of the survey respondents manufacture both polymers and olefins at the site. One site contains both refining and olefins manufacturing operations.
[2] Chemicals sector includes olefin plants.

As shown, no facility implemented a change in process for the purpose of reducing emissions of HRVOC.

4.2.2 Cost Effectiveness of Emission Reduction Projects

Table 18 presents a plant-by-plant summary of projects that have been undertaken to reduce emissions of HRVOC. Only sites that implemented HRVOC emission reduction projects are listed in Table 18.

Table 18. Cost and Emission Reduction Summary by Plant

Site[1]	Number of Projects	Total Annual Cost[2] ($)	HRVOC Emission Reduction (tpy)	Cost Effectiveness[3] ($/tpy)
Polymer 1	4	145,000	53	2,736
Polymer 2	1	200,000	15	13,333
Polymer 3	4	325,830	20.5	15,894
Polymer 4	1	2,420,000	143	16,923
Polymer 5	4	179,800	3	59,933
Polymer 7	3	1,640,000	63	26,032
Polymer 8	4	54,600	27.14	2,012
Polymer 9	9	151,120	21.67	6,974
Polymer Plant Subtotal	*30*	*5,116,350*	*346.31*	*14,774*
Chemicals 1	1	140,000	17	8,235
Chemicals 2	1	21,250	6.75	3,148
Chemicals 3	2	970,000	160	6,063
Chemicals 4	2	154,000	59	2,610
Chemicals 5	2	54,200	17.5	3,097
Chemicals 6	4	16,800	0.55	30,545
Chemicals 7	1	150,000	20	7,500
Chemicals 8	3	439,000	0.1	4,390,000
Chemicals 9	4	NS	80	NA
Chemicals Plant Subtotal	*20*	*1,945,250*	*360.9*	*5,390*
Refinery 1	2	10,480,000	54	194,074
Refinery 2	1	9,030,000	NS	NA
Refinery 3	1	240,000	13.5	17,778
Refinery Subtotal (without Refinery 1 and 2)	*1*	*240,000*	*13.5*	*17,778*
Total (w/ Refinery 3)	**51**	**7,301,600**	**720.71**	**10,131**

[1] Polymer Plant 6 did not implement any projects in response to the HRVOC rules.
[2] Total Annual Cost = Annualized Capital Investment + Direct and Indirect Annual Costs. Annualized Capital Investment assumes a 5-year project life and a discount rate of 0%. In many cases direct and indirect annual costs are not provided.
[3] Cost Effectiveness = Total Annual Cost / Total HRVOC Emission Reduction

As previously noted, the refinery projects at Refinery 1 and 2 were not undertaken for the sole purpose of reducing emissions of HRVOC. In many cases, the annual direct and indirect costs (e.g. natural gas to fuel a thermal oxidizer) have not been provided by survey respondents. In those cases, the actual annual costs and the cost of controlling HRVOC emissions will be greater than what is reported herein.

Figure 8 graphically presents the annual costs for HRVOC emission reduction projects and the resulting reduction in annual emissions for surveyed facilities from all industry sectors. Only facilities that provided the total annual cost and HRVOC emission reduction information have been included in the figure.

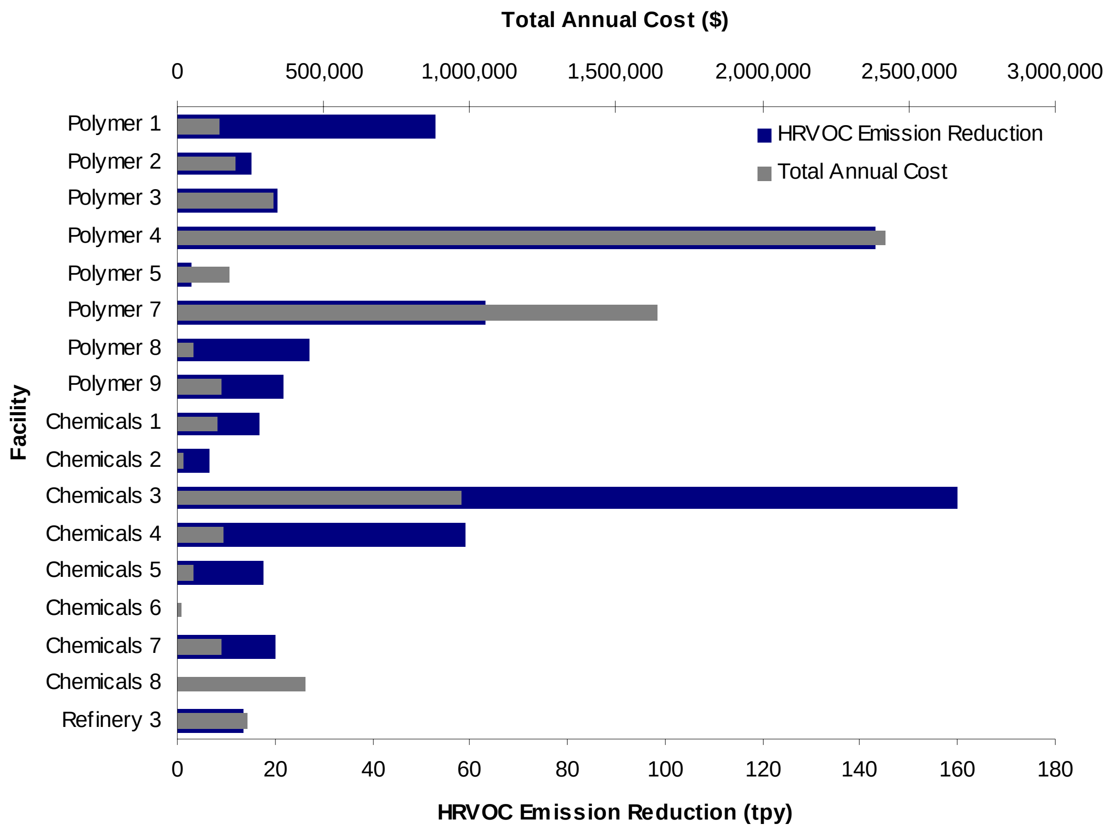

Figure 8. Cost and Emission Reduction Summary – Facility

As can be seen from Figure 8:

- There is large variation in the amount of HRVOC emission reductions achieved at polymer plants, chemical plants and refineries;
- The amount of money spent on HRVOC emission reduction projects annually varies from $16,800 for a chemical plant (Chemicals 6) to $2,420,000 for a polymer plant (Polymer 4); and
- The reduction in HRVOC emissions achieved varies from 0.1 tpy to 160 tpy, both for a chemical plant (Chemicals 8 and Chemicals 3, respectively).

Since the projects were not undertaken for purposes of reducing HRVOC emissions, Refinery 1 and Refinery 2 are not included in Figure 8.

4.2.3 Statistical Analysis of HRVOC Survey Data

Figure 9 presents a frequency histogram of the total annual cost of HRVOC emission reduction projects. Excluded are projects where HRVOC emission reductions are not known and/or the capital cost for the project is zero or unknown (Projects P3, P11 - P14, P15 – P23, P26, P27, P29, P31 - P34, P36 - P39, F4, F7, and F8). Since the projects were not undertaken for the purpose of reducing HRVOC emissions, Projects F14 and 15 are also excluded.

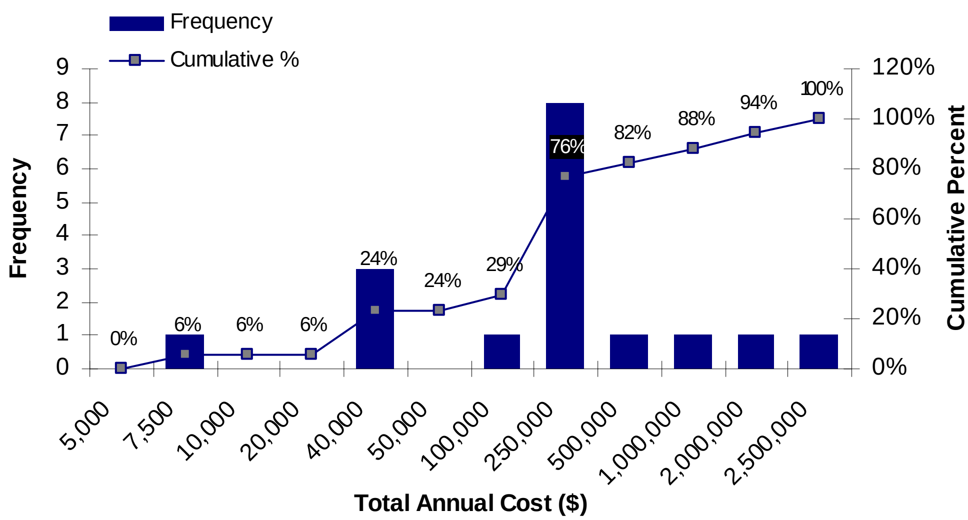

Figure 9. Total Annual Cost – Frequency and Cumulative Percentage

As shown in Figure 9, of the 17 projects included in the figure, the total annual cost of 13 projects (76% of the total projects) is less than or equal to $250,000.

Figure 10 presents a frequency histogram for the HRVOC emission reductions achieved. As shown in Figure 10, of the 17 projects included in the figure, 9 projects (53% of the total projects) resulted in HRVOC emission reductions of 20 tpy or less.

Figure 11 is a graphical representation of total HRVOC emission reduction achieved by surveyed facilities that undertook HRVOC emission reduction projects as a percentage of annual HECT allowance allocations.[50] Figure 11 shows that the polymer plants surveyed have a total HECT allowance allocation of approximately 275 tons and achieved a total HRVOC emission reduction of 150.3 tons, or 55% of their allocation. The chemical facilities surveyed have a total HECT allowance allocation of approximately 1,035 tons and achieved an HRVOC

[50] It is important to note that three facilities included in this analysis had operations in multiple sectors, namely, polymers, chemicals and refining. The facilities were grouped into the polymer, chemical or refinery sector on the basis of the primary Standard Industrial Classification (SIC) code, solely for the purposes of this analysis.

emission reduction of approximately 498 tons, or 48% of their allocation. Refineries had a total HECT allowance allocation of 770 tons and reduced their HRVOC emissions by approximately 126.5 tons or 16% of their allocation. None of the terminals surveyed undertook HRVOC emission reduction projects.

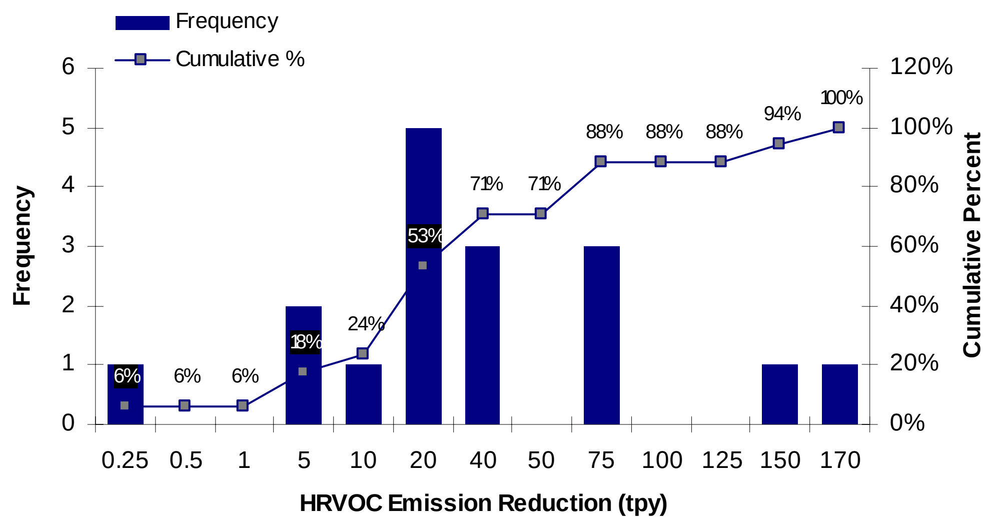

Figure 10. HRVOC Emission Reduction – Frequency and Cumulative Percentage

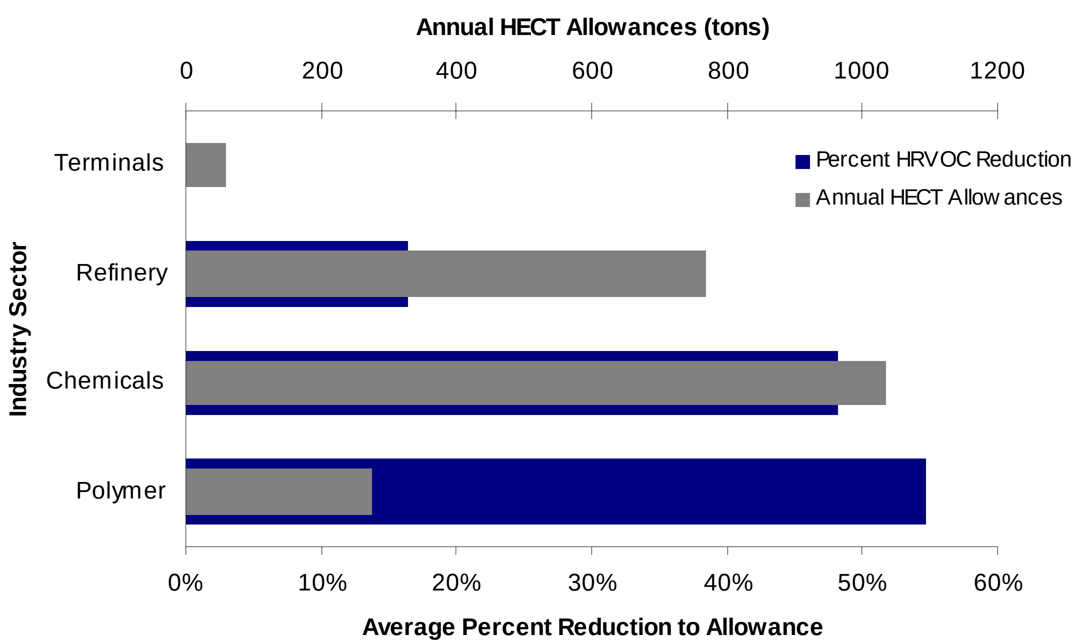

Figure 11. HRVOC Emission Reduction as Compared to HECT Allowance Allocations

Figure 12 presents the 95% confidence interval for the average HRVOC emission reduction as percent HECT allowance for chemical plants and polymer plants. Terminals are not included in this analysis since they did not undertake any HRVOC emission reduction projects. Refineries are also not included since the percent HECT allowance could only be calculated for one refinery.[51]

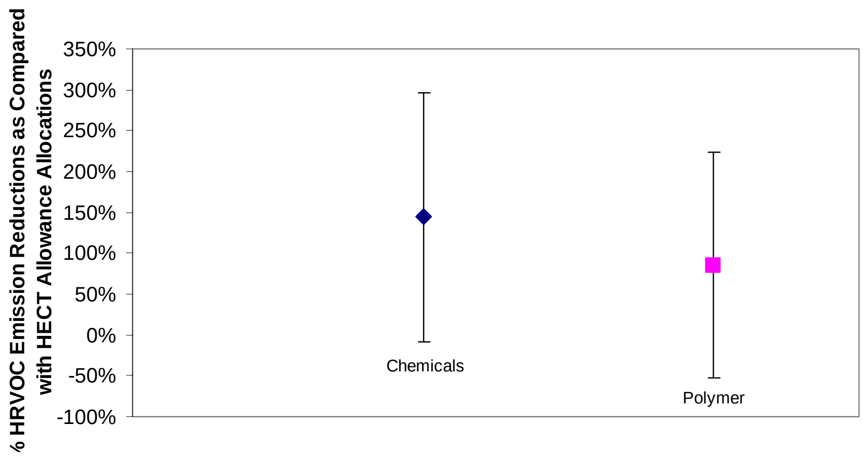

Figure 12. HRVOC Emission Reduction as Compared to HECT Allowance Allocations by Industry Sector with 95% Confidence Interval

As shown in Figure 12, the Chemicals interval overlaps with the Polymer interval, which indicates that the differences in the observed mean HRVOC emission reductions as a percentage of HECT allowance allocations between Chemicals and Polymer plants are not statistically significant. For the sake of completeness, a Student's t-test was performed to confirm that the difference in mean percent of HECT allowance between chemical plants and polymer plants is statistically significant. A two-tail test is used as the differences could be positive or negative. A t-test allowing for unequal variances in the mean percent of HECT allowance between these two industry sectors results in a p-value of 0.48, well above the value of 0.05 (corresponding to a 95% confidence level) typically used to determine statistical significance. A more powerful t-test based on the assumption of equal variances results in a slightly higher p value (0.67) which is still not statistically significant. These results show that the available data are not sufficient to identify a statistically significant difference in the percent of HECT allowance between these two industry sectors. We note that this conclusion is based on the assumptions that the observed percentage of HECT allowance allocations represent random, independently-drawn samples from each industrial sector and that the percentages are at least approximately normally distributed.

4.2.4 Projects Not Undertaken

As discussed in Section 4.1.4, there are a number of HRVOC emission reduction projects that were not undertaken by the facilities. Based on discussions with industry personnel, the reasons include:

- They did not need additional reductions in HRVOC emissions. This was because 1) emissions were already less than their HECT allowance allocation; and/or 2) the company manages their HRVOC emissions as a portfolio across a number of sites that may include polymer plants, olefins and chemical manufacturing sites and/or petroleum refineries and the portfolio as a whole may be sufficient.

- The cost of additional reductions in HRVOC emissions exceeded internal financial thresholds.

- These are significant space limitations that would impact the ability to add new equipment.

- The facility is large, complex or old which would make upgrades or modifications difficult.

None of the companies surveyed have undertaken projects for the purpose of selling excess allowances. Reasons include:

- With little or no market activity to-date, there are not good pricing signals as to what HECT allowance vintages may be worth in the future. Therefore, there is insufficient information available to make sound investment decisions.

- Since MSS and event emissions (up to 1,200 pounds per hour) count toward the HECT annual cap, companies are unwilling to sell allowance stream ownership.

5 Flare Survey Findings

5.1 Collected Information

Tables 19 and 20 present the flare data summary for routine loading and emergency loading, respectively. The tables present a merged summary of the data collected during Phase 1 and Phase 2 of the study. It is important to note that the data is presented as reported by facilities in response to the facility and flare questionnaires sent out by ENVIRON. Data fields in Table 19 and Table 20 are defined as follows.

- *Flare ID* is the ENVIRON-assigned identification number for the facility flare.
- I*ndustry Sector* refers to one of the 4 manufacturing sectors targeted for this study: polymer, chemicals, refinery and terminals.
- *Service* refers to the type of operation associated with the flare. The flare can be in routine, emergency (upset/MSS) or both routine and emergency service.
- *Flare Design Capacity* is the maximum flow rate, in MMscf/hr, that can be handled by the flare. [This is not the smokeless capacity, which may be considerably less than the maximum design capacity.]
- *Average Routine Flow Rate* is the average flow rate, in MMscf/hr, to the flare when operating under normal (non-emergency) service. For single flares operating in both routine and emergency service, facilities may or may not separate emergency loading when reporting routine flows to the flare.
- *Average Upset/MSS Flow Rate* is the average flow rate, in MMscf/hr, to the flare when operating under emergency service.
- *Percentage of Design Capacity* is the ratio of the average routine or emergency loading to the flare to its maximum design flow rate, expressed as a percentage.
- As specified above, the reported average routine flow rates may contain loading during emergency events also. This has been specified in Table 19 and Table 20, if provided by the respondent.
- *Routine or Emergency Hours of Operation* refers to the total number of hours in 2008 the flare was in routine service or events/MSS service, respectively.
- *Percentage of Total Hours* is the ratio of the routine or emergency service hours to the total hours of operation for the flare, expressed as a percentage.
- *Average Routine Flow Rate* and Average Upset/Maintenance Flow Rate Data Source refers to the source of flare loading data at the facility. Sources of flare data may include flow meter data, estimates based on year-round operation and HRVOC database.
- *Not Specified (NS)* means that at the time of writing this report the facility had not provided the data. However, this data may be included in the final report.

Table 19. Flare Survey Data Summary – Routine Flaring

Flare ID	Industry Sector	Service	Flare Design Capacity (MMscf/hr)	Average Routine Flow Rate (MMscf/hr)	Average Routine Flow Rate as a % of Design Capacity	Routine Hours of Operation (hr)	Percentage of Total Hours	Average Routine Flow Rate Contains Upset/MSS Emissions?	Average Routine Flow Rate Data Source
1	Polymer	Both	12.66	0.010	0.08%	NS	NA	NS	NS
2	Polymer	Both	5.51	0.030	0.54%	NS	NA	NS	NS
3	Polymer	Both	9.44	0.010	0.11%	NS	NA	NS	NS
4	Chemicals	Both	NS	NS	NA	NS	NA	NS	NS
5	Chemicals	Both	NS	NS	NA	NS	NA	NS	NS
6	Chemicals	Both	NS	NS	NA	NS	NA	NS	NS
7	Chemicals	Upset/MSS	NS	NA	NA	NA	NA	NA	NA
8	Chemicals	Both	NS	NS	NA	NS	NA	NS	NS
9	Polymer	Both	8.50	0.013	0.15%	NS	NA	Yes	Flow meter data – 2008 YTD
10	Polymer	Both	0.20	0.008	3.85%	NS	NA	Yes	Flow meter data – 2008 YTD
11	Polymer	Both	2.00	0.010	0.50%	NS	NA	Yes	Flow meter data – 2008 YTD
12	Chemicals	Both	2.66	0.007	0.25%	NS	NA	NS	NS
13	Chemicals	Both	1.95	0.074	3.80%	NS	NA	NS	NS
14	Chemicals	Both	37.13	0.076	0.21%	NS	NA	NS	NS
15	Chemicals	Both	26.36	0.061	0.23%	NS	NA	NS	NS
16	Chemicals	Both	0.38	0.012	3.11%	NS	NA	NS	NS
17	Chemicals	Both	1.50	0.017	1.12%	NS	NA	NS	NS

Table 19. Flare Survey Data Summary – Routine Flaring

Flare ID	Industry Sector	Service	Flare Design Capacity (MMscf/hr)	Average Routine Flow Rate (MMscf/hr)	Average Routine Flow Rate as a % of Design Capacity	Routine Hours of Operation (hr)	Percentage of Total Hours	Average Routine Flow Rate Contains Upset/MSS Emissions?	Average Routine Flow Rate Data Source
18	Chemicals	Routine	0.63	0.058	9.06%	NS	NA	No	NS
19	Chemicals	Routine	0.20	0.077	37.78%	NS	NA	No	NS
20	Chemicals	Both	0.23	0.066	28.52%	NS	NA	NS	NS
21	Chemicals	Both	8.34	0.051	0.61%	NS	NA	No	Flow meter data
22	Chemicals	Both	0.05	0.014	28.01%	NS	NA	No	Flow meter data
23	Polymer	Both	NS	0.004	NA	NS	NA	No	Flow meter data
24	Chemicals	Both	0.316	0.001	0.20%	NS	NA	No	Flow meter data
25	Polymer	Both	NS	0.000	NA	NS	NA	No	Flow meter data
26	Polymer	Both	3.06	0.024	0.80%	NS	NA	Yes	Flow meter data – 2007
27	Polymer	Both	5.34	0.031	0.58%	NS	NA	Yes	Flow meter data – 2007
28	Polymer	NS	NS	NS	NA	NS	NA	NS	NA
29	Chemicals	Both	10	0.03	0.30%	8,500	96.77%	No	Flow meter data
30	Chemicals	Routine[1]	3.6	0.51	14.17%	8,470	96.69%	No	Estimate based on year-round operation
31	Chemicals	Routine[1]	3.3	0.79	23.94%	8,450	96.46%	No	Estimate based on year-round operation
32	Chemicals	Both	0.325	0.043	13.23%	6,824	78.85%	No	Flow meter data
33	Chemicals	Both	0.5	0.12	24.00%	8,544	97.27%	Yes	Flow meter data
34	Terminal	Upset/MSS	0.1	NA	NA	NA	NA	NA	NA

Table 19. Flare Survey Data Summary – Routine Flaring

Flare ID	Industry Sector	Service	Flare Design Capacity (MMscf/hr)	Average Routine Flow Rate (MMscf/hr)	Average Routine Flow Rate as a % of Design Capacity	Routine Hours of Operation (hr)	Percentage of Total Hours	Average Routine Flow Rate Contains Upset/MSS Emissions?	Average Routine Flow Rate Data Source
35	Chemicals	Both[2]	0.7	0.2	28.57%	8,618	100.00%	No	Estimate based on year-round operation
36	Chemicals	Upset/MSS	7.9	NA	NA	NA	NA	NA	NA
37	Chemicals	Upset/MSS	16.8	NA	NA	NA	NA	NA	NA
38	Chemicals	Upset/MSS	16.8	NA	NA	NA	NA	NA	NA
39	Chemicals	Both	0.1173	0.0042	3.58%	8,064	99.41%	No	Flow meter data
40	Chemicals	Both	0.00387	0.0006	15.50%	8,064	99.41%	No	Flow meter data
41	Chemicals	Both	3.5	0.072	2.06%	8,755	99.67%	No	Flow meter data
42	Chemicals	Both	0.0024	0.00049	20.42%	8,774	99.89%	Yes	Estimate based on year-round operation
43	Terminal	Upset/MSS	0.12	NA	NA	NA	NA	NA	NA
44	Terminal	Upset/MSS	NS	NA	NA	NA	NA	NA	NA
45	Terminal	Upset/MSS	0.14	NA	NA	NA	NA	NA	NA
46	Polymer	Both	4.7	0.13	2.77%	7,462	87.49%	Yes	Estimate based on year-round operation
47	Polymer	Both	4.7	0.19	4.04%	7,390	84.13%	Yes	Estimate based on year-round operation
48	Polymer	Both	4.4	0.11	2.50%	7,142	81.31%	Yes	Estimate based on year-round operation
49	Polymer	Both	0.2	0.08	40.00%	8,739	99.49%	Yes	Estimate based on year-round operation
50	Terminal	Both	0.3	0.02	5.00%	8,760	99.85%	No	Flow meter data

Table 19. Flare Survey Data Summary – Routine Flaring

Flare ID	Industry Sector	Service	Flare Design Capacity (MMscf/hr)	Average Routine Flow Rate (MMscf/hr)	Average Routine Flow Rate as a % of Design Capacity	Routine Hours of Operation (hr)	Percentage of Total Hours	Average Routine Flow Rate Contains Upset/MSS Emissions?	Average Routine Flow Rate Data Source
51	Polymer	Both[2]	NS	0.0002	NA	3	100.00%	No	Flow meter data
52	Polymer	Both	NS	0.1678	NA	8,410	95.76%	No	Flow meter data
53	Polymer	Both	NS	0.2369	NA	6,497	93.48%	No	Flow meter data
54	Polymer	Both	NS	0.0758	NA	8,238	94.49%	No	Flow meter data
55	Chemicals	Both	12.1	0.315	2.60%	8,087	92.10%	No	Flow meter data
56	Chemicals	Both	31.3	NS	NA	NS	NA	No	NA
57	Chemicals	Both	26.7	0.0921	0.34%	8,231	93.70%	No	Flow meter data
58	Refinery	Both	NS	0.0808	NA	7	0.48%	No	Flow meter data
59	Refinery	Both	NS	0.386	NA	7,731	90.09%	No	Flow meter data
60	Refinery	Both	NS	0.0212	NA	7	16.67%	No	Flow meter data
61	Refinery	Both	NS	0.572	NA	1	1.23%	No	Flow meter data
62	Refinery	Both	NS	0.1624	NA	31	31.31%	No	Flow meter data
63	Refinery	Both	NS	0.1508	NA	8,449	96.19%	No	Flow meter data
64	Refinery	Both	NS	0.1585	NA	133	27.65%	No	Flow meter data
65	Refinery	Both	NS	0.0179	NA	4,618	91.30%	No	Flow meter data
66	Refinery	Both	NS	0.0312	NA	8,444	96.13%	NS	Flow meter data
67	Chemicals	Both	0.45	0.02	4.44%	8,426	96.19%	No	NS
68	Chemicals	Both[2]	0.04	0.02	50.00%	8,760	100.00%	No	NS
69	Chemicals	Upset/MSS	0.42	NA	NA	NA	NA	NA	NA
70	Terminal	Both	0.78	0.195	25.00%	8,520	96.99%	No	Flow meter data

Table 19. Flare Survey Data Summary – Routine Flaring

Flare ID	Industry Sector	Service	Flare Design Capacity (MMscf/hr)	Average Routine Flow Rate (MMscf/hr)	Average Routine Flow Rate as a % of Design Capacity	Routine Hours of Operation (hr)	Percentage of Total Hours	Average Routine Flow Rate Contains Upset/MSS Emissions?	Average Routine Flow Rate Data Source
71	Terminal	Both	0.78	0.195	25.00%	8,664	98.90%	No	Flow meter data
72	Terminal	Both	0.78	0.195	25.00%	8,664	98.90%	No	Flow meter data
73	Terminal	Upset/MSS	0.118	NA	NA	NA	NA	NA	NA
74	Terminal	Both[2]	0.021	0.005	23.81%	8,760	100.00%	No	Flow meter data
75	Terminal	Both	0.558	0.139	24.91%	8,664	98.90%	No	Flow meter data
76	Terminal	Both	0.013	4.80E-06	0.04%	8,740	99.77%	Yes	Flow meter data
77	Terminal	Both	0.084	0.022	26.19%	8,757	99.97%	Yes	Flow meter data
78	Terminal	Both	0.035	0.014	40.00%	8,680	99.88%	Yes	Flow meter data
79	Refinery	NS	NS	NS	NA	8760	NA	NS	NS
80	Refinery	NS	NS	NS	NA	8760	NA	NS	NS
81	Chemicals	Both	NS	NS	NA	8717	99.5%	NA	NS
82	Terminal	Both	1.3	1.50E-3	0.12%	8760	100%	NS	NS

[1] Although site indicated flare service as routine only, the site categorized a number of hours as upset/MSS.
[2] Site reported zero hours of upset/MSS operation for 2008 calendar year.

Table 20. Flare Survey Data Summary - Upset/MSS Flaring

Flare ID	Industry Sector	Service	Flare Design Capacity (MMscf/hr)	Average Upset/MSS Flow Rate (MMscf/hr)	Average Routine Flow Rate as a % of Design Capacity	Upset/MSS Hours of Operation (hr)	Percentage of Total Hours	Averaging Period (Upset/MSS period or Annual)	Average Upset/MSS Flow Rate Data Source
7	Chemicals	Upset/MSS	NS	NS	NA	NS	NA	NS	NS
29	Chemicals	Both	10	0.1	1.00%	284	3.23%	Upset/MSS	Flow meter data
32	Chemicals	Both	0.325	0.049	15.08%	1,830	21.15%	NS	NS
33	Chemicals	Both[1]	0.5	0.020	4.00%	240	2.73%	Annual	Flow meter data
34	Terminal	Upset/MSS	0.1	0.1	100.00%	1	100.00%	Upset/MSS	Estimate - based on approximate Upset/MSS hours
35	Chemicals	Both[2]	0.7	NS	NA	0	0.00%	Upset/MSS	NA
36	Chemicals	Upset/MSS	7.9	0.3	3.80%	174	100.00%	Upset/MSS	Flow meter data
37	Chemicals	Upset/MSS	16.8	NS	NA	5	100.00%	Upset/MSS	NA
38	Chemicals	Upset/MSS	16.8	NS	NA	1	100.00%	Upset/MSS	NA
39	Chemicals	Both	0.1173	0.021	17.90%	48	0.59%	Upset/MSS	Flow meter data
40	Chemicals	Both	0.00387	0.003	77.52%	48	0.59%	Upset/MSS	Flow meter data
41	Chemicals	Both	3.5	0.087	2.49%	29	0.33%	Upset/MSS	Flow meter data
42	Chemicals	Both	0.0024	0.00001	0.42%	10	0.11%	Upset/MSS	Estimate - based on approximate Upset/MSS hours
43	Terminal	Upset/MSS	0.12	0.0001	0.08%	8,760	100.00%	NS	Flow meter data
44	Terminal	Upset/MSS	NS	0.0004	NA	NS	NA	NS	Flow meter data
45	Terminal	Upset/MSS	0.14	0.003	2.14%	NS	NA	NS	Flow meter data

Table 20. Flare Survey Data Summary - Upset/MSS Flaring									
Flare ID	Industry Sector	Service	Flare Design Capacity (MMscf/hr)	Average Upset/MSS Flow Rate (MMscf/hr)	Average Routine Flow Rate as a % of Design Capacity	Upset/MSS Hours of Operation (hr)	Percentage of Total Hours	Averaging Period (Upset/MSS period or Annual)	Average Upset/MSS Flow Rate Data Source
46	Polymers	Both	4.7	0.004	0.09%	1,067	12.51%	Upset/MSS	Flow meter data
47	Polymers	Both	4.7	0.004	0.09%	1,394	15.87%	Upset/MSS	Flow meter data
48	Polymers	Both	4.4	0.003	0.07%	1,642	18.69%	Upset/MSS	Flow meter data
49	Polymers	Both	0.2	0.002	1.00%	45	0.51%	Upset/MSS	Flow meter data
50	Terminal	Both	0.3	0.05	16.67%	13	0.15%	Upset/MSS	Flow meter data
51	Polymers	Both	NS	NS	NA	NS	NA	Upset/MSS	NA
52	Polymers	Both	NS	0.1125	NA	372	4.24%	Upset/MSS	Flow meter data
53	Polymers	Both	NS	0.346	NA	453	6.52%	Upset/MSS	Flow meter data
54	Polymers	Both	NS	0.0657	NA	480	5.51%	Upset/MSS	Flow meter data
55	Chemicals	Both	12.1	1.1033	9.12%	694	7.90%	Upset/MSS	Flow meter data
56	Chemicals	Both[1]	31.3	0.6732	2.15%	186	100.00%	Upset/MSS	Flow meter data
57	Chemicals	Both	26.7	0.373	1.40%	553	6.30%	Upset/MSS	Flow meter data
58	Refinery	Both	NS	0.2653	NA	1,444	99.52%	Upset/MSS	Flow meter data
59	Refinery	Both	NS	0.3619	NA	850	9.91%	Upset/MSS	Flow meter data
60	Refinery	Both	NS	0.0477	NA	35	83.33%	Upset/MSS	Flow meter data
61	Refinery	Both	NS	0.4247	NA	80	98.77%	Upset/MSS	Flow meter data
62	Refinery	Both	NS	0.1009	NA	68	68.69%	Upset/MSS	Flow meter data
63	Refinery	Both	NS	0.3179	NA	335	3.81%	Upset/MSS	Flow meter data
64	Refinery	Both	NS	0.377	NA	348	72.35%	Upset/MSS	Flow meter data
65	Refinery	Both	NS	0.0428	NA	440	8.70%	Upset/MSS	Flow meter data

Table 20. Flare Survey Data Summary - Upset/MSS Flaring

Flare ID	Industry Sector	Service	Flare Design Capacity (MMscf/hr)	Average Upset/MSS Flow Rate (MMscf/hr)	Average Routine Flow Rate as a % of Design Capacity	Upset/MSS Hours of Operation (hr)	Percentage of Total Hours	Averaging Period (Upset/MSS period or Annual)	Average Upset/MSS Flow Rate Data Source
66	Refinery	Both	NS	0.0319	NA	340	3.87%	Upset/MSS	Flow meter data
67	Chemicals	Both	0.45	0.1	22.22%	334	3.81%	NS	NS
68	Chemicals	Both[2]	0.04	0.02	50.00%	0	0.00%	NS	NS
69	Chemicals	Upset/MSS	0.42	0.0002	0.05%	10	100.00%	Upset/MSS	Flow meter data
70	Terminal	Both	0.78	0.195	25.00%	264	3.01%	Upset/MSS	Flow meter data
71	Terminal	Both	0.78	0.195	25.00%	96	1.10%	Upset/MSS	Flow meter data
72	Terminal	Both	0.78	0.195	25.00%	96	1.10%	Upset/MSS	Flow meter data
73	Terminal	Upset/MSS	0.118	0.029	24.58%	96	100.00%	Upset/MSS	Flow meter data
74	Terminal	Both	0.021	0.005	23.81%	0	0.00%	Upset/MSS	Flow meter data
75	Terminal	Both	0.558	0.139	24.91%	96	1.10%	Upset/MSS	Flow meter data
76	Terminal	Both	0.013	9.80E-06	0.08%	20	0.23%	Upset/MSS	Estimate – based on volume in loading arms for the event
77	Terminal	Both	0.084	0.022	26.19%	3	0.03%	Upset/MSS	Estimate – based on volume in loading arms for the event
78	Terminal	Both	0.035	0.014	40.00%	10	0.12%	Upset/MSS	Estimate – based on volume in loading arms for the event
81	Chemicals	NS	NS	NS	NA	43	0.5%	NS	NS

Table 20. Flare Survey Data Summary - Upset/MSS Flaring

Flare ID	Industry Sector	Service	Flare Design Capacity (MMscf/hr)	Average Upset/MSS Flow Rate (MMscf/hr)	Average Routine Flow Rate as a % of Design Capacity	Upset/MSS Hours of Operation (hr)	Percentage of Total Hours	Averaging Period (Upset/MSS period or Annual)	Average Upset/MSS Flow Rate Data Source
82	Terminal	Both	1.3	2.09E-5	0.002%	NS	NA	NS	NS

[1] Although site indicated flare service as both routine and upset/MSS, the site reported only upset/MSS hours of operation for 2008 calendar year.
[2] Although site indicated flare service as both routine and upset/MSS, the site reported only routine hours of operation for 2008 calendar year.

5.2 Flare Data Quality

As noted in the Introduction, the information contained within this report is presented as it was reported by participating industrial sites to ENVIRON. Data validation activities performed by ENVIRON were limited to email correspondence and telephone conversations with participants regarding perceived anomalies and/or clarification of projects performed. If confirmed by survey respondents as accurate, data is included in the findings and analysis presented within this report.

In a number of instances, the routine flare loading rates reported by facilities seems high. As an example, the reported “average routine” flow rate for Flare 31 is 0.79 MMscf/hour. Using the ideal gas law and assuming that all of the material flared is ethylene, the flare loading is estimated as follows:

$$M = (PV/RT) \bullet MW \qquad \text{(Equation 1)}$$

Where:

M	=	Mass		
P	=	Pressure	=	1.0 atmosphere
V	=	Volume	=	790,000 ft^3/hr
R	=	Gas Constant	=	0.7302 atm•ft^3/lbmole•°R
T	=	Temperature	=	520°R
MW	=	Molecular Weight	=	28 lbs/lbmole (ethylene)

Solving:

$$M = \{[(1\ \text{atm})\bullet(790{,}000\ ft^3/hr)]/[(0.7302\ \text{atm}\bullet ft^3/\text{lbmole}\bullet{}^\circ R)\bullet(520^\circ R)]\}\bullet(28\ \text{lbs/lbmole})$$

$$M = 58{,}256\ \text{lbs/hr}$$

$$M = 29.1\ \text{tons/hr}$$

Assuming a 99% destruction efficiency (standard assumption for flaring of ethylene), emissions from this flare would be 0.291 tons/hr or 2,461 tons/year (8,450 hours of annual operation). This value seems excessive for actual emissions from a single flare.. However, the following should be kept in mind while reviewing this report:

- Main flares at petroleum refineries, chemical plants, polymer plants and terminals can be very large sources of emissions. These sources can be permitted for routine and scheduled MSS emissions in excess of 1,000 tons/year of volatile organic compounds (VOC).
- Survey recipients were only asked to report average routine *total* flow to the flare. They were not asked to speciate the flare flows. Therefore, the reported flows will include not only HRVOC and other VOCs, but methane or refinery gas sweep, nitrogen purge gas, carbon monoxide, carbon dioxide, water vapor, and any other gases that are in the flare header. If, for purposes of illustration, the average heat content of material being routed

to Flare 31 is assumed to be 400 Btu/scf and the combustible hydrocarbon has the characteristics of ethylene, the ratio of flare gas heat content to ethylene heat content (approximately 1,600 Btu/ft^3) can be used to estimate flare hydrocarbon emissions.

$$M = [0.291 \text{ tons/hr } (@\ 1{,}600\ Btu/ft^3)] \times [(400\ Btu/ft^3)/(1{,}600\ Btu/ft^3)]$$

$$M = 0.0728 \text{ tons/hr}$$

$$M = 615 \text{ tons/year } (8{,}450 \text{ hours of annual operation})$$

Total hydrocarbon emissions of this amount, while still large, seem within the realm of possibilities.

- The purpose of the survey was to obtain an estimate of routine flow rates in relation to design capacity, not to allow estimation of emissions. The information provided by survey respondents is insufficient to allow for an accurate estimate of emissions.

5.3 Analysis

5.3.1 Flare Design Capacity

Figures 13(a), 13(b) and 13(c) present histograms that represent the frequency of occurrence for flares of a certain design capacity range and the corresponding cumulative percentage. The flare design capacities have been divided into three bins:

- “Small” flares with design capacities less than 1 MMscf/hr;
- “Medium” flares with design capacities ranging from 1 to 10 MMscf/hr; and
- “Large” flares with design capacities greater than 10 MMScf/hr.

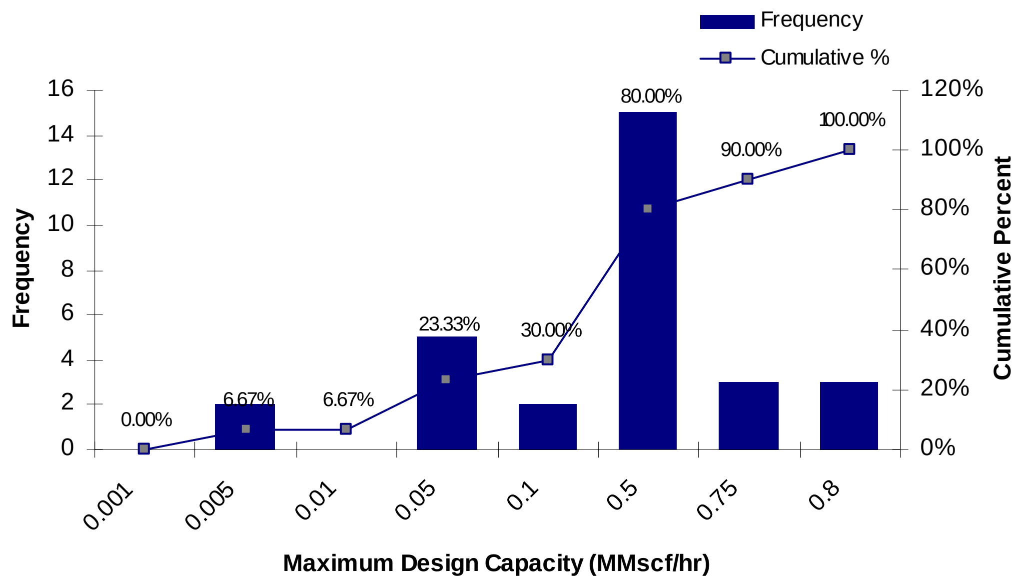

Figure 13(a). Small Flare Maximum Design Capacity - Frequency and Cumulative Percentage

Figure 13(a) shows that almost 80% of small flares have a design capacity equal to or less than 0.5 MMscf/hr and that approximately 20% of small flares have a design capacity greater than 0.5 MMscf/hr.

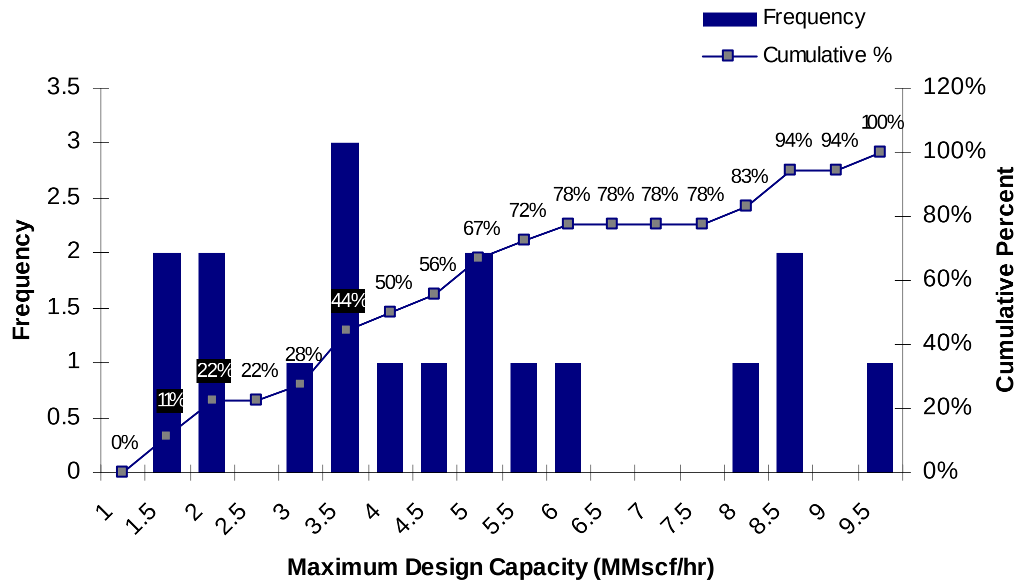

Figure 13(b). Medium Flare Maximum Design Capacity - Frequency and Cumulative Percentage

Figure 13(b) shows that almost 67% of medium flares have a design capacity equal to or less than 5 MMscf/hr and that approximately 33% of the flares have a design capacity greater than 5 MMscf/hr.

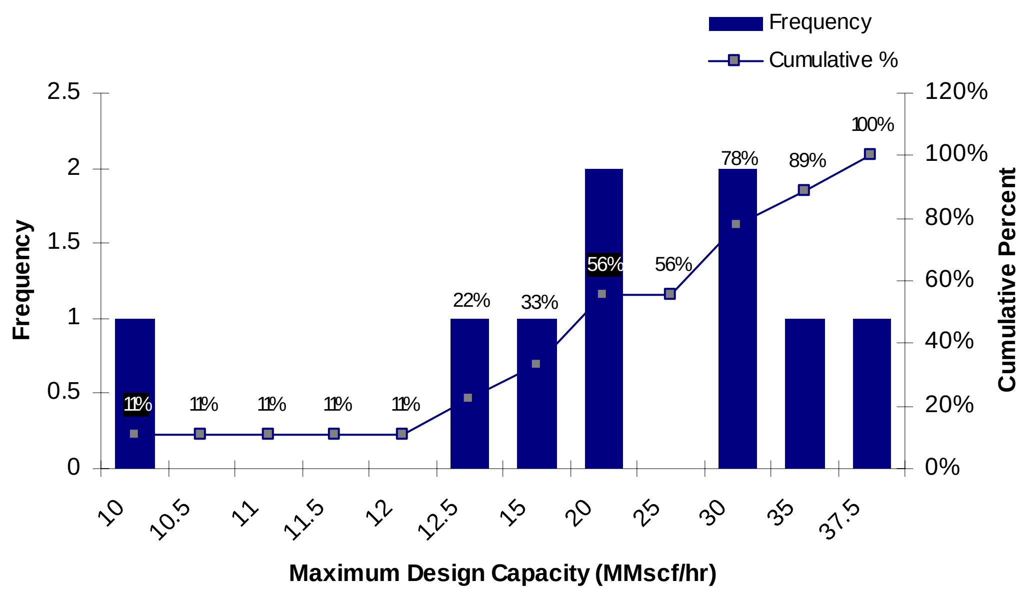

Figure 13(c). Large Flare Maximum Design Capacity - Frequency and Cumulative Percentage

Figure 13(c) shows that almost 56% of large flares have a design capacity equal to or less than 20 MMscf/hr.

5.3.2 Flare Loading

Figure 14 presents a histogram that represents the frequency of occurrence for flares of a certain routine loading and the corresponding cumulative percentage.

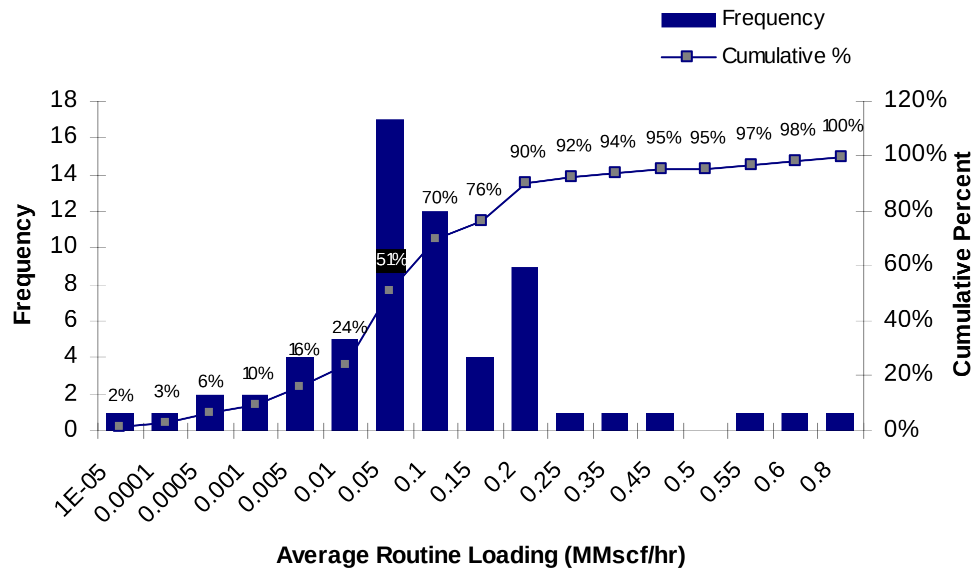

Figure 14. Average Routine Loading - Frequency and Cumulative Percentage

Figure 14 shows that 92% of flares have a routine loading equal to or less than 0.25 MMscf/hr.

Figure 15 presents a histogram that represents the frequency of occurrence for flares in emergency service and the corresponding cumulative percentage.

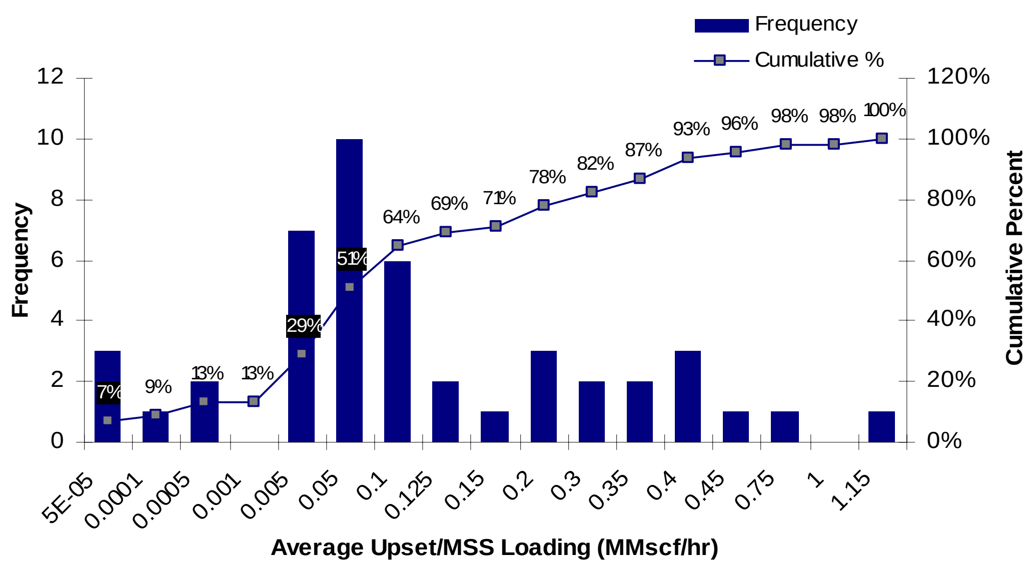

Figure 15. Average Upset/MSS Loading - Frequency and Cumulative Percentage

Figure 15 shows that 78% of the flares have an upset/MSS loading equal to or less than 0.2 MMscf/hr.

Figures 16(a), (b) and (c), present frequency histograms that represent the percentage of average routine loading to maximum design capacity for small, medium and large flares, respectively, in either routine only service or both routine and emergency service.

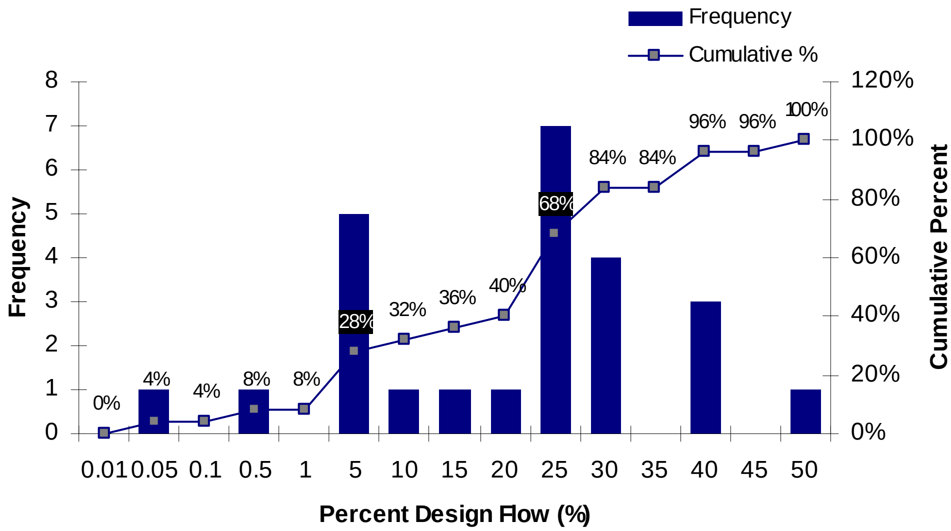

Figure 16(a). Small Flare Average Routine Loading to Design Capacity - Frequency and Cumulative Percentage

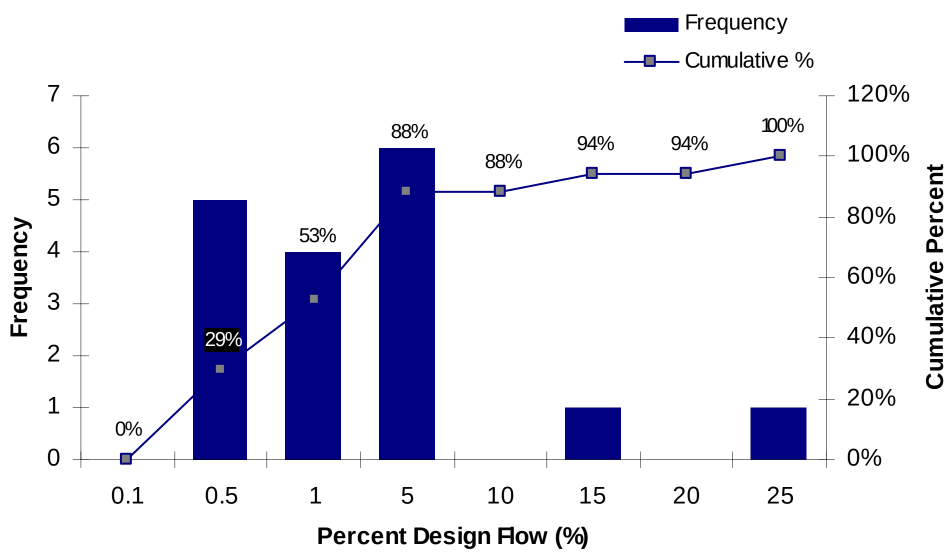

Figure 16(b). Medium Flare Average Routine Loading to Design Capacity - Frequency and Cumulative Percentage

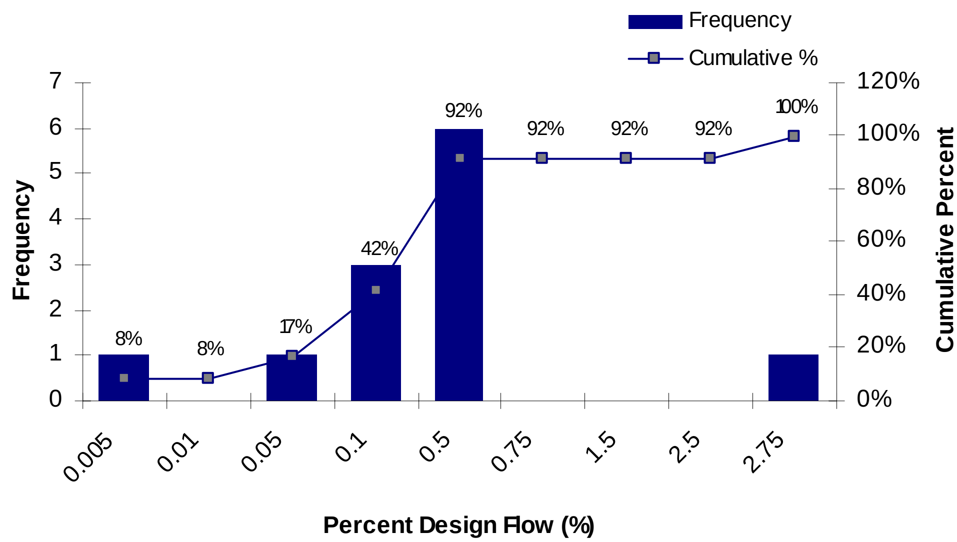

Figure 16(c). Large Flare Average Routine Loading to Design Capacity - Frequency and Cumulative Percentage

Key statistics from Figures 16(a), 16(b) and 16(c) are as follows:

- For small flares, almost 68% of the flares operate at less than or equal to 25% of the maximum design capacity. This amounts to 17 out of a total of 25 flares in this design capacity range;
- For medium flares, approximately 88% of the flares operate at less than or equal to 5% of the maximum design capacity. This amounts to 15 out of a total of 17 flares in this design capacity range;
- For large flares, 92% of the flares operate at less than or equal to 0.5% of the maximum design capacity. This amounts to 11 out of a total of 12 flares in this design capacity range;
- Out of a total 54 of flares, in either routine only or both routine and emergency service for which design capacity is known, only 1 flare operates routinely at 50% of design capacity. This is the maximum among all flares surveyed.

Figure 17(a) represents the number of flares in HRVOC service and the corresponding percent average flow, by industry sector.

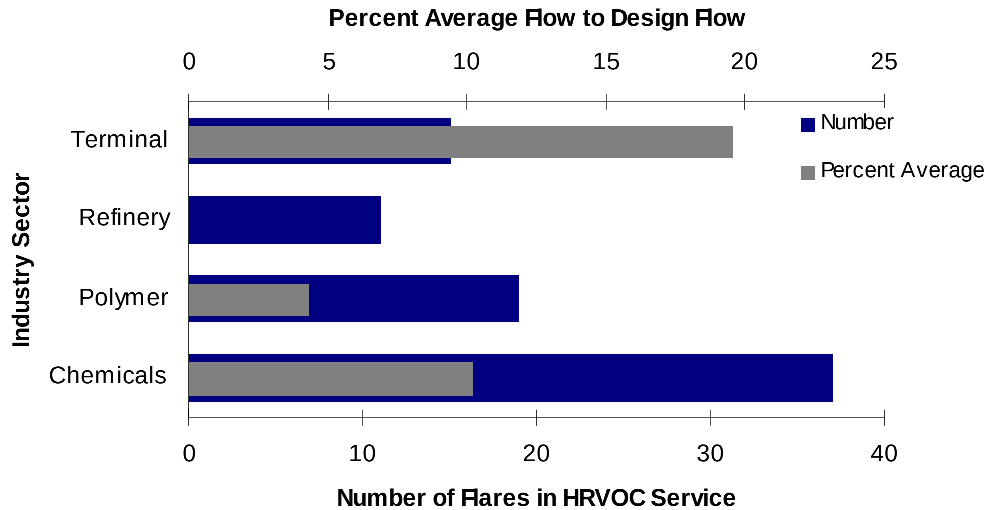

Figure 17(a). Percent Average Flow and Number of Flares Surveyed – Industry Sector

As shown in Figure 17(a), among the flares surveyed, 19 flares are in HRVOC service for polymer manufacturing facilities, 11 flares are in HRVOC service for refineries, 15 flares are in HRVOC service at terminals, and 37 flares are in HRVOC service at chemical plants. Figure 17(a) also shows the percentage of average flow to maximum design capacity for the flares in HRVOC service at different facilities. Under routine operating conditions, flares in HRVOC service at polymer plants operate at 0.08% - 40% of the maximum design capacity; flares in HRVOC service at chemical plants operate at 0.03% - 50% of the maximum design flow rate; and flares in HRVOC service at terminals operate at 0.04% - 40% of the design flow rate. The percent average flow to design flow could not be calculated for refinery flares as the maximum design flow rate for these flares was not provided by the respondents. The percentage of design flow for each industry sector was determined by calculating the average value for the flares within a particular industry sector. For the facilities that responded to this survey, the average loading across all sectors was approximately 12% of flare design capacity; the range was from less than 0.03% to 50%.

Most flares are designed to handle maximum flow rates expected during facility upsets and MSS events. Therefore, instead of having a dedicated flare for HRVOC control during emission events, most facilities use a single flare for both routine and upset/MSS operations. Figure 17(b) breaks down the flare data based on the type of service. Out of a total of 82 flares in HRVOC service, 66 flares are designed to handle routine as well as emergency flows; 4 flares are designed for routine service only; and 10 flares are dedicated to handle emergency flows only. Type of flare service was not specified for 2 flares. Figure 17(b) also shows the percentage of average flow to maximum design capacity for these flares.

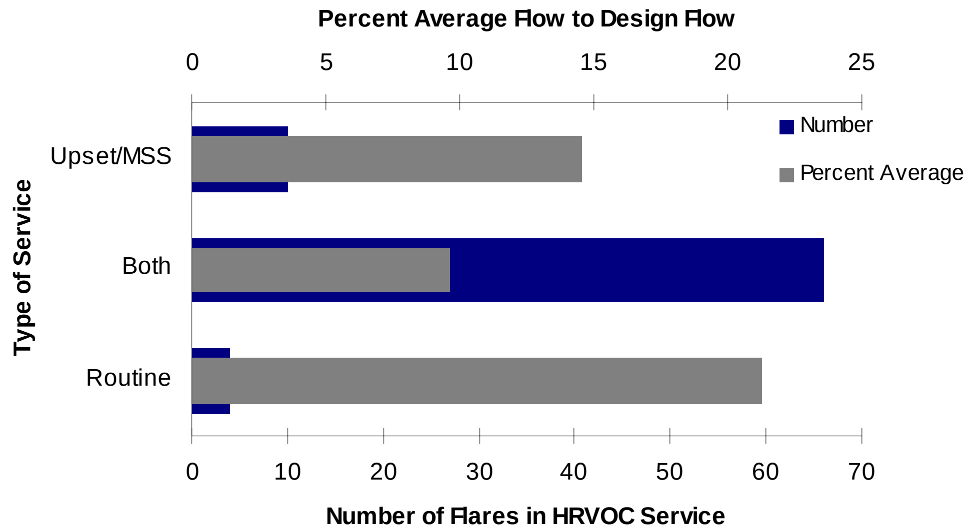

Figure 17(b). Percent Average Flow and Number of Flares Surveyed – Type of Service

Flares in both routine and emergency service operate at 0.04% - 50% of the maximum design flow rate; flares in routine only service operate at 0.03% - 37.8% of the maximum design flow rate; and flares in upset/maintenance service operate at 0.05% - 24.58% of the maximum design flow rate.

Figure 18 is a frequency histogram representing the percentage of routine hours of operation to the total hours of operation for flares in both routine and upset/MSS service.

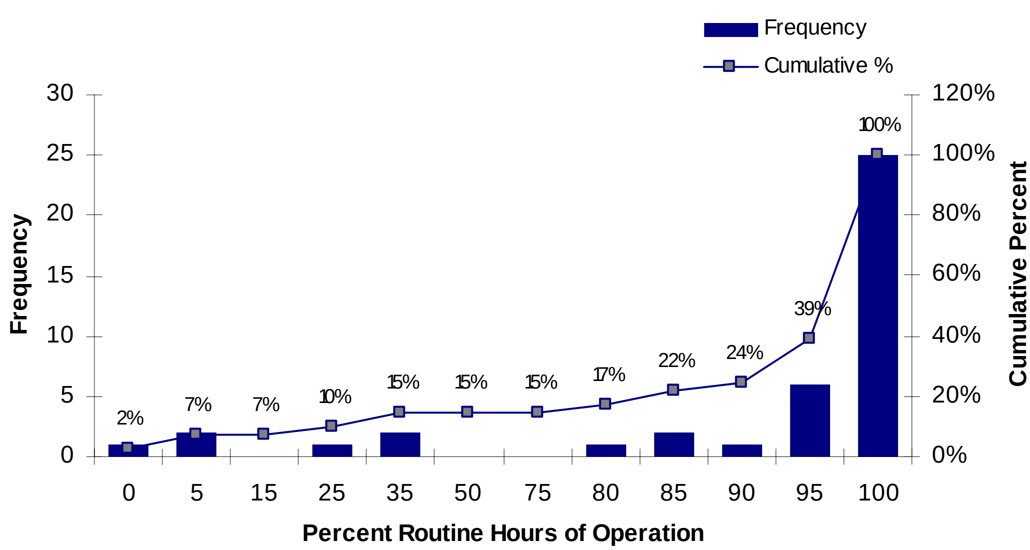

Figure 18. Percent Routine Hours of Operation – Frequency and Cumulative Percentage

Figure 18 shows that out of a total of 41 flares in both routine and upset/MSS service, 24% of flares operated in routine service less than or equal to 90% of the total hours of operation during the calendar year 2008.

Figure 19 is a frequency histogram representing the percentage of upset/MSS hours of operation to the total hours of operation for flares in both routine and upset/MSS service.

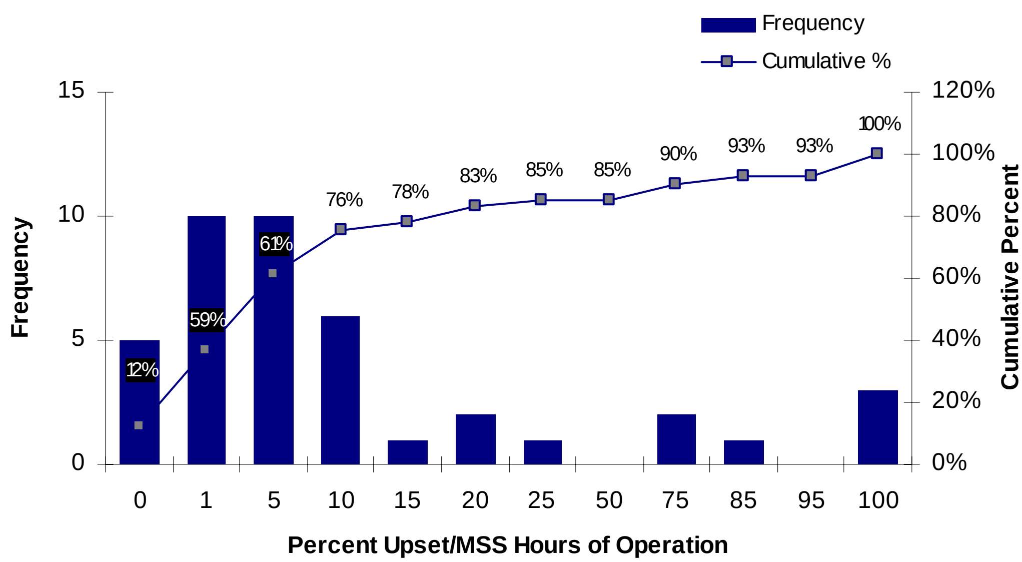

Figure 19. Percent Upset/MSS Hours of Operation – Frequency and Cumulative Percentage

Figure 19 shows that out of a total of 41 flares in both routine and upset/MSS service, 61% of the flares operated in upset/MSS service less than or equal to approximately 5% of the total hours of operation during the calendar year 2008.

It is important to note that only flares in both routine and upset/MSS service, with operating hours data provided by the respondent, were chosen for this analysis.

5.3.3 Statistical Analysis of Flare Survey Data

Table 21 lists the descriptive data analysis for the maximum flare design capacity, average routine loading and average upset/MSS loading.

Table 21. Flare Survey Data Analysis

Descriptive Statistics	Maximum Design Capacity (MMscf/hr)	Average Routine Loading (MMscf/hr)	Average Upset/MSS Loading (MMscf/hr)
Mean	4.92	0.01	0.14
Median	0.78	0.04	0.05
Mode	0.70	0.01	0.003
Standard Deviation	8.29	0.15	0.21
Minimum	0.002	4.8E-06	9.8E-06
Maximum	37.13	0.79	1.10

From Table 21, the average maximum design capacity is 4.92 MMscf/hr; the average loading to the flares is 0.01 MMscf/hr and 0.14 MMscf/hr, for routine loading and emergency loading, respectively. Half of the flares have design capacities less than 0.78 MMscf/hr and half have design capacities greater than 0.78 MMscf/hr. Similarly, half of the flares have routine loading greater than 0.04 MMscf/hr and half have routine loading less than 0.04 MMscf/hr. The median loading value for flares in emergency service is 0.05 MMscf/hr. The standard deviation indicates that almost 68% of the flare design capacities fall within 1 standard deviation of the mean (4.92+/-8.29) and about 95% fall within 2 standard deviations of the mean (4.92+/-16.58). The minimum and maximum values indicate a large variability in the design, routine and emergency flows to the flares. The design capacities vary from 0.002 MMscf/hr to 37.13 MMscf/hr; the routine loading varies from less than 0.0001 MMscf/hr to 0.79 MMscf/hr; and the emergency loading varies from less than 0.0001 MMscf/hr to 1.10 MMscf/hr.

An analysis of variance (ANOVA) statistical test was performed to determine whether variations across industry sectors in the average routine flare loading as a percent of design capacity for flares in HRVOC service are statistically significant. The average routine flare loading as a percent of design capacity for flares in different industry sectors are 11% for chemicals; 4% for polymers; and 20% for terminals. The average routine flare loading as a percent of design capacity could not be calculated for refinery flares as the design flow rate for these flares was not provided. Results from the ANOVA show that the variations are statistically significant at the 95% confidence level (p value of 0.045; see discussion in Section 4.2.3).

Comparisons of the average routine flare loading as a percent of design capacity between pairs of industry sectors were also made using a two-tail Student’s t-test with the unequal variance assumption as described in Section 4.2.3. Resulting p-values between Chemicals and Polymer ($p = 0.10$) and between Chemicals and Terminals ($p = 0.06$) are both greater than 0.05, thus indicating differences that are not significant at the 95% confidence level (although they are significant at the 90% confidence level) However, the p-value between Polymer and Terminals ($p < 0.01$) indicates a statistically significant difference between these two sectors. Figure 18 illustrates these results by showing the mean percent design capacity for each industry sector with corresponding 95% confidence intervals.

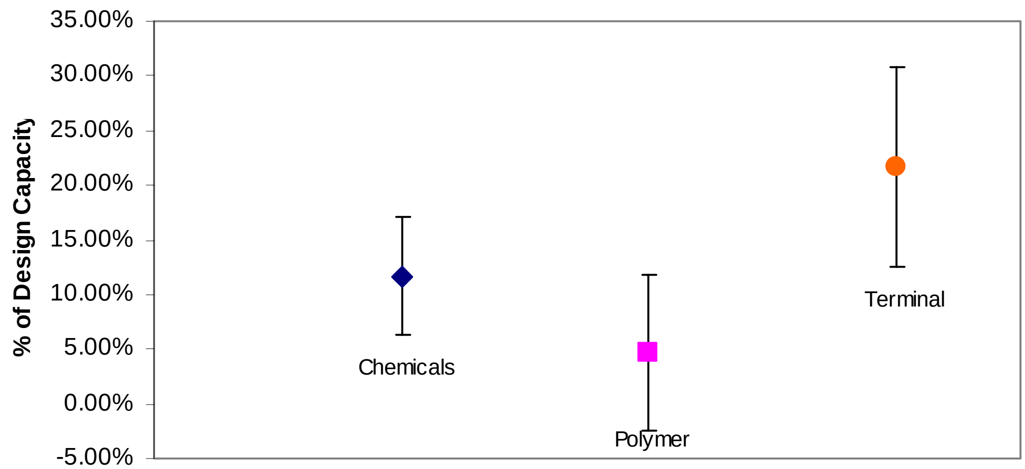

Figure 20. Routine Flare Loading as a Percent of Design Capacity by Industry Sector with 95% Confidence Interval

5.4 Summary of Flare Survey Findings

This section provides an summary of flare data that was collected and compiled as part of the Phase 1 and Phase 2 studies. Key findings are as follows:

- A total of 82 flares were analyzed. Of these, 37 were in service at chemical plants; 19 were in service at polymer plants; 11 were in service at refineries; and 15 were in HRVOC service at terminals.
- Of the flares surveyed, 66 flares (82%) are designed to handle routine as well as emergency flows; 4 flares (5%) are designed for routine service only; and 10 flares (13%) are dedicated to handle emergency flows only.
- The most frequent routine loading among all flares surveyed, represented by the mode, was 0.01 MMscf/hr.
- Flares in HRVOC service at polymer plants operate at 0.08% - 40% of design capacity; flares in HRVOC service at chemical plants operate at 0.01% - 50% of design capacity; and flares in HRVOC service at terminals operate at 0.04% - 40% of design capacity.
- On an average, flares in HRVOC service at terminals operate at approximately 20% of design capacity, followed by flares at chemical plants at approximately 11% of the design capacity.
- Flares in HRVOC service at polymer plants have the largest disparity between design capacity and actual routine loading and operate, on average, at 4% of design capacity.

- The average routine loading for all flares surveyed was approximately 11% of design capacity. Half of the flares have routine loading less than 0.043 MMscf/hr; half of flares have emergency loading less than 0.049 MMscf/hr.
- Out of all flares surveyed, 32% of flares operate at less than or equal to 0.5% of the maximum design capacity under routine operations; 62% of flares operate at less than or equal to 5% of the maximum design capacity; Almost 85% flares operate at less than or equal to 25% of the maximum design capacity.
- Only 1 flare included in the survey responses operates at 50% or more of design capacity.
- The observed differences in average routine flare loading as a percent of design capacity between all industry sectors is statistically significant.
- The observed differences in average routine flare loading as a percent of design capacity between polymers and terminals are statistically significant.
- The observed differences in the average routine flare loading as a percent of design capacity between chemicals and polymers and between chemicals and terminals are not statistically significant and could be due to chance.
- 32 flares operated in routine service for 90% or more of the total hours of operation during the calendar year 2008.
- 16 flares operated in upset/MSS service for 60% or more total hours of operation during the calendar year 2008.

6 Conclusions

6.1 HRVOC Emission Reduction Projects

Conclusions on HRVOC emission reduction projects implemented by polymer plants, chemical plants, petroleum refineries and storage terminals are as follows:

- Out of the four industrial sectors surveyed, polymer and chemical plants implemented the highest number of HRVOC emission reduction projects and achieved maximum HRVOC emission reductions. Out of the 3 refineries surveyed, only one refinery implemented one or more HRVOC emission reduction projects in response to HRVOC rules. Out of the 8 terminals that participated in the study, none indicated that they had implemented HRVOC emission reduction projects.

- Of the 36 HRVOC emission reduction projects identified by this survey, 30 involved changes in operating procedures, 17 involved flare minimization, and 7 involved installation of vent gas controls. No facility implemented a change in process to reduce HRVOC emissions.

- 76% of the total HRVOC emission reduction projects had a total annual cost less than or equal to $250,000.

- A majority of the HRVOC emission reduction projects resulted in emission reductions of 20 tpy or less.

- Polymer plants achieved the greatest reduction in HRVOC emission when compared to their HECT allowance allocation – approximately 55%. Chemical plants achieved HRVOC emission reductions equal to approximately 48% of their HECT allowance allocation and petroleum refineries achieved HRVOC emission reduction equal to approximately 16% of their HECT allowance allocation.

- Statistical analysis indicates that the differences in observed mean HRVOC emission reductions as a percent of HECT allowance allocations across different industry sectors are not statistically significant. The differences in observed means between chemical and polymer plants could be due to chance.

6.2 Flare Usage

Conclusions on flare use are as follows:

- Flares in service at polymer plants, on average, operate at approximately 4% of design capacity; flares in HRVOC service at chemical plants, on average, operate at 11% of design capacity; and flares in HRVOC service at terminals, on average, operate at 20% of the design capacity. Insufficient information was provided by survey respondents to estimate flare capacity utilization at petroleum refineries.

- Most of the flares surveyed, approximately 82%, are designed to handle routine as well as emergency flows.

- Out of all flares surveyed, 32% of flares operate at less than or equal to 0.5% of the maximum design capacity under routine operations; 62% of flares operate at less than or equal to 5% of the maximum design capacity; Almost 85% flares operate at less than or equal to 25% of the maximum design capacity. Of the flares surveyed, only one flare operates at 50% of the design capacity. This is the maximum among all flares.

- Statistical analysis indicates that the difference in the observed means of average routine flare loading as a percent of design capacity for flares across all industry sectors is significant.

7 References

Texas Commission on Environmental Quality. 2009. Flare Task Force Stakeholder Group. Presented at the March 30 and April 2, 2009, stakeholder meetings, Austin.

8 Project Team Contact Information

TCEQ Project Representative:	Dr. Bogdan Slomka +1 512.239.1709 bslomka@tceq.state.tx.us
ENVIRON Principal in Charge:	Dr. Gregory Yarwood +1 415.899.0704 gyarwood@environcorp.com
ENVIRON Principal Investigator and Project Manager:	Steven H. Ramsey, P.E., BCEE +1 713.470.6657 sramsey@environcorp.com
ENVIRON Co-Investigators:	Christopher J. Colville, P.E. +1 713.470.2647 ccolville@environcorp.com
	Dr. Shagun Bhat +1 713.470.2648 sbhat@environcorp.com

Appendix A:
Questionnaire Templates

Polymer Plant Questionnaire
Cost Analysis of HRVOC Controls on Polymer Plants and Flares
TCEQ Work Order No. 582-07-84005-FY08-12

1. What type of process is used? Please select all that apply.

- Polyethylene - low density, high pressure process
- Polyethylene - low density, low pressure process
- Polyethylene - high density, gas phase process
- Polyethylene - high density, liquid-phase slurry process
- Polyethylene - high density, liquid-phase solution process
- Polypropylene - liquid-phase slurry process
- Polypropylene - gas phase process
- Other

2. Have any projects been implemented to reduce emissions in response to HRVOC rules? Projects could include process changes, pollution prevention techniques as well as add-on control technology.

- Yes
- No

If yes, please provide the following for each project: description, capital and annual cost, and estimated HRVOC reduction.

Project 1
Description:
Capital Cost ($):
Annual Cost ($):
Estimated HRVOC Reduction (tpy):

Project 2
Description:
Capital Cost ($):
Annual Cost ($):
Estimated HRVOC Reduction (tpy):

3. Have any HRVOC emission reduction projects been considered, but not implemented?

- Yes
- No

If yes, please select from among the following potential reasons.

- High Cost (please describe what constitutes high cost)
- Technical Infeasibility (please describe what constitutes technical infeasibility)
- Other (please describe)

4. Are there emission reduction methods that would be technically feasible for new plants but not for existing plants?

- Yes
- No

If yes, how do they vary by type of production process?

Questionnaire Instructions

1. Please add responses to the yellow highlighted fields only.

2. For those questions requesting a "yes" or "no" response, please enter an "a" in the yellow highlighted field next to the appropriate response.

3. Please feel free to add additional projects for question 2, as necessary.

What is unique to your facility that would make emission reductions more difficult or more expensive?

Estimated costs and potential emission reduction?

Method 1

Description:

Capital Cost ($):

Annual Cost ($):

Estimated HRVOC Reduction (tpy):

Method 2

Description:

Capital Cost ($):

Annual Cost ($):

Estimated HRVOC Reduction (tpy):

5. Are process vents (i.e., upstream of extruder) recycled back to the process or routed to a control device (e.g., flare, thermal oxidizer, boiler, process heater)? Please select all that apply.

- Recycled to Process
- Flare
- Boiler
- Process Heater
- Thermal Oxidizer
- Other Add-on Control Device (please describe)

6. Are there VOC control devices on any finishing vents (i.e., extruder and downstream to storage and loading)?

- Yes
- No

If yes, please describe.

7. Is excess monomer removed from the pellets prior to the finishing operations (e.g., steam stripping)?

- Yes
- No

If yes, please describe how.

Flare Questionnaire
Cost Analysis of HRVOC Controls on Polymer Plants and Flares
TCEQ Work Order No. 582-07-84005-FY08-12

1. How many flares are in HRVOC service?

Please provide the average or typical flow and design capacity for each flare in HRVOC service.

EPN	Average Flow (MMscf/hr)	Design Flow (MMscf/hr)

2. Have any projects been implemented to reduce or minimize flaring?

Yes

No

If yes, please provide the following for each project: description, capital and annual cost, and estimated HRVOC reduction.

Project 1

Description:

Capital Cost ($):

Annual Cost ($):

Estimated HRVOC Reduction (tpy):

Project 2

Description:

Capital Cost ($):

Annual Cost ($):

Estimated HRVOC Reduction (tpy):

3. Have any flare minimization/reduction projects been considered, but not implemented?

Yes

No

If yes, please select from among the following potential reasons.

High Cost (please describe what constitutes high cost)

Technical Infeasibility (please describe what constitutes technical infeasibility)

Other (please describe)

4. What factors affect the cost and feasibility of flare minimization projects at your facility?

Questionnaire Instructions

1. Please add responses to the yellow highlighted fields only.

2. For those questions requesting a "yes" or "no" response, please enter an "a" in the yellow highlighted field next to the appropriate response.

3. Please feel free to add additional projects for questions 2 and 5, as necessary.

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5. Have any projects been conducted to route additional uncontrolled streams to flare?

	Yes
	No

If yes, please provide the following for each project: description, capital and annual cost, and estimated HRVOC reduction.

Project 1

Description:	
Capital Cost ($):	
Annual Cost ($):	
Estimated HRVOC Reduction (tpy):	

Project 2

Description:	
Capital Cost ($):	
Annual Cost ($):	
Estimated HRVOC Reduction (tpy):	

6. Is a flare gas recovery (FGR) system installed at the plant?

	Yes
	No

If no, has any consideration been given to FGR as a potential flare minimization project?

	Yes
	No

7. Are any HRVOC process vents routed to a thermal oxidizer for control?

	Yes
	No

Submit by Email

Facility Questionnaire

Cost Analysis of HRVOC Controls on Refineries and Chemical Plants and Control of Highly Reactive Volatile Organic Compound (HRVOC) Emissions in Flares at Low Flow Conditions

TCEQ Work Order No. 582-07-84005-FY09-15

For this project, ENVIRON will gather information on HRVOC emission reduction projects at refineries, chemical plants and other HECT-affected facilities and use the information to perform an analysis of the costs of controlling HRVOC emissions from different types of facilities. ENVIRON will also gather certain information to better understand how emergency flares are being used to control HRVOC emissions.

This interactive questionnaire contains 14 questions. ***We ask that you complete this questionnaire to the best of your ability and return it to ENVIRON by March 31, 2009*** . We realize this request may coincide with other reporting deadlines; therefore, we greatly appreciate your efforts to complete this questionnaire by the end of March. The questionnaire is compatible with Adobe Acrobat Professional or Reader. You may periodically save your responses to the questionnaire to your desktop/computer so that you do not have to complete the questionnaire all at once. When you have completed the questionnaire and are satisfied with your responses, please click the blue "Submit" button located at the top of the first page of the questionnaire. Next, select the option that best describes how you send email and click OK. Then, click "Send Data File" to send the form's data file. When the email message is generated, please send the email message. Should you have any questions regarding the questionnaire or the information sought, please contact any of the following ENVIRON personnel.

- Chris Colville, +1 713.470.2647, ccolville@environcorp.com
- Dr. Shagun Bhat, +1 713.470.2648, sbhat@environcorp.com
- Steven Ramsey, +1 713.470.6657, sramsey@environcorp.com

1) What products are manufactured at your facility?

2) Please identify which of the following source types at your facility are in HRVOC service and included in your HECT program cap:

Flares?	YES ☐	NO ☐	How Many?
Cooling Towers ≥ 8,000 gpm?	YES ☐	NO ☐	How Many?
Cooling Towers < 8,000 gpm?	YES ☐	NO ☐	How Many?
Uncontrolled Process Vents?	YES ☐	NO ☐	How Many?
Process Vents Routed to Control Device?	YES ☐	NO ☐	How Many?
Process Vents Recycled to Process?	YES ☐	NO ☐	How Many?

3) Have any HRVOC emission reduction projects been implemented at your facility for the following units for the purpose of reducing routine, MSS or event emissions?

Cooling Towers? YES ☐ NO ☐

If YES, please provide details in Table 3 (a).

Controlled Process Vents? YES ☐ NO ☐

If YES, please provide details in Table 3 (b).

Uncontrolled Process Vents? YES ☐ NO ☐

If YES, please provide details in Table 3 (c).

Flares? YES ☐ NO ☐

If YES, please provide details in Table 3 (d).

These projects could include installation of emission controls, such as routing an uncontrolled process vent to a flare header, changes in the manufacturing process, change in operating procedures, elimination of HRVOC sources, etc.

Table 3 (a). HRVOC Emission Reduction Projects - Cooling Towers

Requested Information	**Project 1**	**Project 2**	**Project 3**
Project Description:			
Estimated HRVOC Reduction (tpy):			
Capital Cost ($):			
Annual Cost ($/year):			

Table 3 (b). HRVOC Emission Reduction Projects - Controlled Process Vents

Requested Information	**Project 1**	**Project 2**	**Project 3**
Project Description:			
Estimated HRVOC Reduction (tpy):			
Capital Cost ($):			
Annual Cost ($/year):			

Table 3 (c). HRVOC Emission Reduction Projects - Uncontrolled Process Vents			
Requested Information	**Project 1**	**Project 2**	**Project 3**
Project Description:			
Estimated HRVOC Reduction (tpy):			
Capital Cost ($):			
Annual Cost ($/year):			

Table 3 (d). HRVOC Emission Reduction Projects - Flares			
Requested Information	**Project 1**	**Project 2**	**Project 3**
Project Description:			
Estimated HRVOC Reduction (tpy):			
Capital Cost ($):			
Annual Cost ($/year):			

4) Have any HRVOC emission reduction projects been considered, but not implemented?

YES ☐ NO ☐

If YES, please provide details in Table 4.

Table 4. HRVOC Emission Reduction Projects Not Implemented			
Requested Information	**Project 1**	**Project 2**	**Project 3**
Project Description:			
Source Type (e.g. process vent):			
Projected HRVOC Reduction (tpy):			
Reasons (e.g., high cost, technical infeasibility, etc) - Please explain.			

5) Are there any HRVOC emission reduction methods that would be technically feasible for new facilities that manufacture the same product as your facility, but not for existing facilities?

YES ☐ NO ☐

If YES, please provide details.

6) Is there anything unique to your facility that would make HRVOC emission reduction more difficult or expensive?

YES ☐ NO ☐

If YES, please provide details.

7) While not a part of the HECT program, control of fugitive sources is a key component of reducing HRVOC emissions. Have investments been made to reduce the fugitive release of HRVOCs at the facility?

YES ☐ NO ☐

If YES, please provide details in Table 7.

Table 7. HRVOC Emission Reduction Projects - Fugitive Releases

Requested Information	**Project 1**	**Project 2**	**Project 3**
Project Description:			
Estimated HRVOC Reduction (tpy):			
Capital Cost ($):			
Annual Cost ($/year):			

8) Have any process units been shutdown or derated as a strategy for complying with the HECT cap?

YES ☐ NO ☐

If YES, please provide details.

9) For Flares in HRVOC service, please provide details in Table 9.

Table 9. Flare Operation During Calendar Year 2008

Flare EPN	Design Capacity (MMscf/hr)	Flare Service			Average Loading - Excluding Event & MSS (MMscf/hr)	Average Loading - Event & MSS only (MMscf/hr)
		Normal Process Only	Event & MSS Only	Normal Process + Event & MSS		
		☐	☐	☐		
		☐	☐	☐		
		☐	☐	☐		
		☐	☐	☐		
		☐	☐	☐		
		☐	☐	☐		
		☐	☐	☐		
		☐	☐	☐		
		☐	☐	☐		
		☐	☐	☐		

10) For the calendar year 2008, how long (in hours) did each flare operate under normal process conditions and Emission Event and MSS conditions? Please provide details in Table 10.

Table 10. Flare Operating Hours During Calendar Year 2008

Flare EPN	Flare Operation (Hours)	
	Normal Process Only	Event & MSS Only

11) Have any Flare Gas Recovery (FGR) projects been implemented at the facility?

YES ☐ NO ☐

If YES, please provide details in Table 11 (a).

If NO, please provide reasons in Table 11 (b).

Table 11 (a). Flare Gas Recovery Projects Implemented			
Requested Information	**Project 1**	**Project 2**	**Project 3**
Project Description:			
Estimated HRVOC Reduction (tpy):			
Capital Cost ($):			
Annual Cost ($/year):			

Table 11 (b). Flare Gas Recovery Projects Considered But Not Implemented			
Requested Information	**Project 1**	**Project 2**	**Project 3**
Project Description:			
Projected HRVOC Reduction (tpy):			
Reasons (e.g., high cost, technical infeasibility, etc) - Please explain.			

12) Are any process vents in HRVOC service routed to control devices other than flares (e.g., thermal oxidizers, process heaters, etc.)?

YES ☐ NO ☐

If YES, please provide details in Table 12.

Table 12. Controlled Process Vents		
Process Vent Controlled	**Control Device**	**HRVOC Emission Reduction (tpy)**

13) Have projects, that were not specifically carried out to reduce HRVOC emissions but resulted in reducing HRVOC emissions, been implemented at the facility (e.g., construction or enhancement of a Flare Gas Recovery system by a refinery under the Global Petroleum Refinery Consent Decree)?

YES ☐ NO ☐

If YES, please provide details in Table 13.

Table 13. Other Projects			
Requested Information	**Project 1**	**Project 2**	**Project 3**
Project Description:			
Estimated HRVOC Reduction (tpy):			
Capital Cost ($):			
Annual Cost ($/year):			

14) Please provide any additional comments/information related to HRVOC control at your facility that you would like to share: