# Flash Emissions Model Evaluation

## Quantifying Volatile Organic Compound Emissions from Upstream Oil and Gas Storage Tanks

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# Outline

- Project Overview
- Direct Measurement of Storage Tanks
- Project Status
- Project Results and Conclusions

# Project Overview

- Study purpose: to evaluate methods and models for estimating volatile organic compound (VOC) flashing emissions from upstream oil and gas storage tank batteries
- TCEQ partnered with Eastern Research Group, Inc., and Hy-Bon Engineering
- Evaluation performed by comparing measured VOC flash emissions to VOC flash emissions determined by conventional emissions estimation methods

# Project Background

- Houston Advanced Research Center (HARC) Project 51C completed in 2006
  - Collaborative project between HARC, TCEQ, and Texas Environmental Research Consortium
  - Determined emissions factors for upstream oil and condensate storage tanks
  - Significant emissions from upstream oil and gas tanks
  - http://projects.tercairquality.org/AQR/H051C
- Project results indicated potential for subsequent research to improve emissions inventory estimates

# Project Design

- Two phases:
  - Directly measured VOC emissions from 36 upstream oil and condensate storage tank batteries
    - HARC 51C provided project template for direct measurement
  - Quantified VOC emissions using traditional methods and models
    - Process and operational data obtained directly from site
    - Site identifying data was anonymous except for county location
- Additional objective:
  - Evaluated images of **hydrocarbon** plumes from storage tank batteries taken from various standardized distances using passive infrared (IR) GasFindIR cameras

# Direct Measurement

- Measurement Procedure
  - Daniel's 2" turbine meter secured to thief hatch or vent system for 24 hours
    - Obtained daily flow rate
    - High resolution meter
    - High repeatability
  - GasFindIR camera monitoring
    - Image tank(s) before and after flow meter installation to ensure all emissions captured
    - Leaking components addressed and repaired, if necessary

# Direct Measurement

Example of Metering Equipment Installed in Thief Hatch

# Direct Measurement

- Measurement Procedure
  - Sample collection
    - Pressurized liquid
    - Separator gas
    - Tank vapor
      - Pressurized to 60 pounds per square inch
    - Tank liquid
    - Liquid samples stored below 50 degrees Fahrenheit
  - Samples performed using 300 cubic centimeter evacuated stainless steel canisters
    - Constant volume and pressure cylinders investigated, but not used
  - API gravity determined on-site using hydrometers
  - Sample analysis performed using Gas Processor's Association Method 2286
    - Compounds included C2 through C12 alkanes, benzene, toluene, ethylbenzene, isomers of xylene

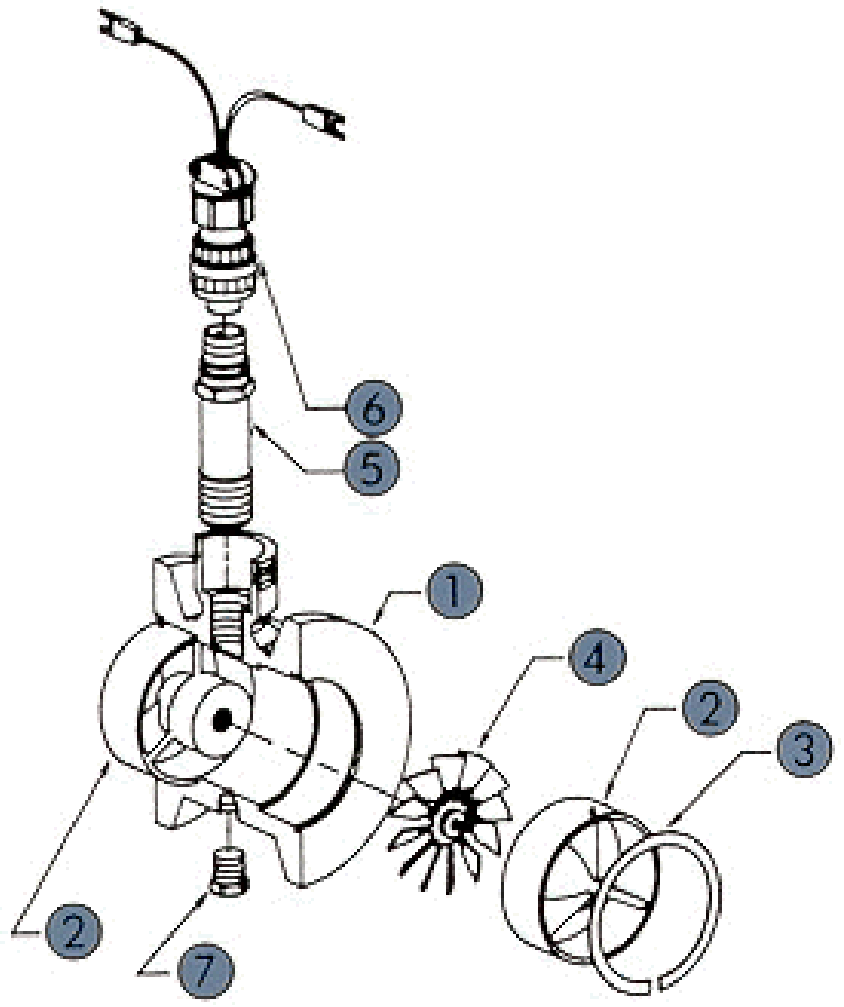
# Direct Measurement

- Measurement challenges
  - Securing site participation
    - Majority of sites tested had low vent volumes
    - Impact on study
  - Lack of standardized measurement protocol for fixed roof storage tanks
    - No EPA protocol exists
    - TCEQ rule for Houston-Galveston-Brazoria ozone nonattainment area, 30 Texas Administrative Code, Section 115.115(c)

# Direct Measurement

- Measurement challenges
  - Selection of flow meter
    - Design: thermal mass flow meter
    - Actual: Daniels 2” Model 3000 gas turbine meter
      - Rated for minimum flow of 593 standard cubic feet (SCF) per hour or 14,200 SCF (14.2 MSCF) per day
      - Confidence in flow measurements
    - Concerns existed regarding accuracy and/or performance limitations of available flow meters
  - Adequate characterization of flashed tank gases
    - Sampling
  - Selection of analytical procedure for gas analysis
    - Design and actual: Gas Processor’s Association Method 2286
    - Focus on gas component of samples

# Direct Measurement




| ITEM | DESCRIPTION |
|---|---|
| 1 | Meter Body |
| 2 | Flow Diffuser |
| 3 | Retaining Ring |
| 4 | Rotor Shaft Ass'y |
| 5 | Pickup Coil |
| 6 | Coil Cable Ass'y |
| 7 | Pipe Plug |

Metering Equipment: Exploded View

# Flash Models and Methods

- Hy-Bon collected process and operational data necessary to estimate emissions using various methods and models
  - 30 of 36 sites provided sufficient data inputs
  - Data gathered from sites included:
    - Liquid and vapor samples
    - API gravity
    - Production data
    - Temperature
    - Separator pressure and temperature
    - Tank capacity
  - Samples analyzed to determine VOC composition

# Flash Models and Methods

- For each method or model, emissions determined using site process, operational, and sample analysis data
- Models or methods evaluated included:
  - HYSYS process simulator
  - Exploration and Production TANK model (E&P Tank)
  - Gas-to-oil (GOR) ratio
  - Vasquez-Beggs correlation, including Gas Research Institute's Hazardous Air Pollutant (HAP)-Calc program
  - Valko-McCain correlation
  - Environmental Consultants and Research (EC/R) equation
  - *Note: When necessary, the TANKS 4.09d was used to estimate working and breathing losses*

# Flash Models and Methods

- For each method, results compared as set to direct measurements to assess:
  - Accuracy
  - Whether a method or model would predictably under- or over-estimate emissions
- Vasquez-Beggs (VB) correlation presented unique challenge
  - Most sites' separator pressures fell outside the correlation constraints
  - Due to numerous requests received to use VB correlation in similar circumstances, performed analysis to assess accuracy in these cases

# Flash Models and Methods

- TCEQ performed additional statistical analysis to correlate measured emissions to predicted emissions
  - Ordinary least squares (OLS) regression analysis
    - Square of correlation coefficient ($R^2$): degree of correlation between variables
    - Trend line slope: indicates how well model/method predicted emissions
- Only GOR method had strong correlation to measured values for sites measuring below 200 tons/year
  - $R^2 = 0.90$; GOR slightly overestimates emissions in these cases
- All other models had weaker correlation
  - Slope values indicate these models predicted emissions with less accuracy

# Summary of Regression Analysis
## Measured Emissions Versus Modeled Emissions*

*Outlier Values Removed

**Courtesy John Jolly, TCEQ**

| Emissions Model | N | $R^2$ | Slope | Intercept | Equation for estimating direct measurement (DM) (tons/yr) |
|---|---|---|---|---|---|
| Vasquez-Beggs Correlation + 4.09 | 25 | .11 | 0.13 | 15 | VBE = .13(DM) + 15 |
| Gas-Oil Ratio + 4.09 | 25 | .90 | 1.13** | 15 | GOR =1 .13(DM) + 15 |
| Valko-McCain + 4.09 | 25 | .02 | 0.11 | 31 | VM = .11(DM) + 31 |
| Hysys | 22 | .03 | 0.74 | 94 | Hysys = .74(DM) + 94 |
| E&P Tank – RVP | 22 | .10 | 2.8 | 218 | EP_RVP = 2.8(DM) + 218 |
| E&P Tank – GEO/RVP | 24 | 0 | 0 | 33 | Not possible to estimate |
| E&P Tank – AP-42 | 22 | .15 | 2.3* | 112 | AP42 = 2.3(DM) + 112 |

N represents number of tanks used in statistical analysis. $R^2$ is correlation coefficient. "Slope" is the slope of the linear regression estimate, when modeled emissions are plotted against measured emissions. One asterisk after slope indicates correlation is statistically significant at alpha=.10 (90% confidence interval); two asterisks, significant at alpha=.05 (95% C.I.). Note caveats in these estimates in Discussion section in Final Report.

# Passive Infrared Camera Imaging

- Hy-Bon imaged hydrocarbon vapors from tank batteries using GasFindIR cameras
  - Image types obtained include (distances are approximate):
    - Close range view
    - Mid-range view
    - Long range view
  - Images were informally evaluated to determine whether image intensity correlated to VOC emissions rate
    - Although informal, no correlation appears to exist

# Project Status

- TCEQ report being finalized; will be published at: http://www.tceq.state.tx.us/implementation/air/airmod/project/pj_report_ei.html
- Study results were posted on Web for six weeks for informal comment
  - Comments received by deadline will be posted on same TCEQ website with final report
  - No formal TCEQ response will be published
  - However, technical comments will be addressed within the report itself

# Project Status

- Final report will be revised to address technical comments as well as study limitations
  - Corrections
  - Additional statistical analysis will be published
  - Quality assurance project plan will be included
- Goal: transparency
  - All data will be published
- Anticipate posting finalized version of report by December 2009
- Will distribute notification

# Project Results and Conclusions

- Study results indicate emissions predictions from methods and models vary considerably, based upon inputs
- No one method correlates well to direct measurements under all test conditions
  - Site sample for study could influence
  - However, complex models or methods based upon measurements appear to over-predict emissions compared to direct measurements
  - Simpler equations or models using default data appear to under-predict emissions compared to direct measurements
    - Design
    - Assumptions

# Project Results and Conclusions

- Based upon study results, certain methods have questionable value as flash emissions determination methods for storage tanks
  - EC/R equation appears invalid
  - VB correlation designed to estimate emissions from **separator**, not storage tanks
- Hysys model exhibited weak correlation, but reasonable slope
  - Not generally used to estimate vent gas volumes in low separator pressure conditions

# Project Results and Conclusions

- E&P TANK exhibited weak correlation and slope values greater than 2, indicating emissions over-prediction
  - Estimates using defaults in geographic database have questionable value as flash emissions determination methods for storage tanks
- GOR method did correlate well for sites where measured emissions were less than 200 tons/year
    - No regulatory procedure for GOR method
    - GOR methods are established, but variability does occur

# Project Results and Conclusions

- TCEQ considering revising emissions inventory guidance based upon study results
- Wealth of data collected
  - Encourage additional analysis and interpretation of results
- Additional research appears warranted
  - Challenges presented in study may impact feasibility of additional research
- Protocol and standardization necessary
  - Tank testing
  - GOR method

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