New Optical Gas Imaging Technology for Quantifying Fugitive Emission Rates

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Objective and Agenda

- This presentation introduces advances in Optical Gas Imaging Technology that allows improved Leak Detection And Repair (LDAR) surveys by more efficiently identifying fugitive sources and quantifying emission rates

- Agenda
  - Overview of current LDAR methodologies
  - Uncertainties in EPA Method 21
  - Introduction to Quantitative Optical Gas Imaging (QOGI)
  - Performance and application of QOGI technology
  - Conclusions

Current LDAR Methodologies

Leak detection and quantification methods:

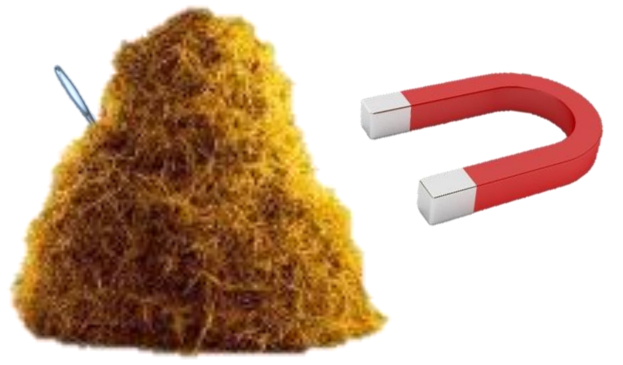
- EPA Method 21 based method
  - Used by most LDAR Programs
- Bagging test
- Optical Gas Imaging (OGI) method
  - A great visual tool, but it's currently qualitative
  - Approved as an Alternative Work Practice (AWP), but still requires Method 21 application
  - Widely used as a fast response visual tool, but very limited use for LDAR compliance

Method 21 vs. OGI for LDAR

Method 21

- Finding a leak is like looking for a needle in a haystack – and you need to inspect every "straw"!
- Inspecting hundreds of components to find one leak (or no leaks)

OGI Technology



- OGI allows for rapid screening of components – focusing on the "needle" rather than every "straw"
- Much more efficient method for finding significant leaks
- Potential to reduce the cost of LDAR compliance

Method 21 vs. OGI for LDAR (Cont'd)

Method 21

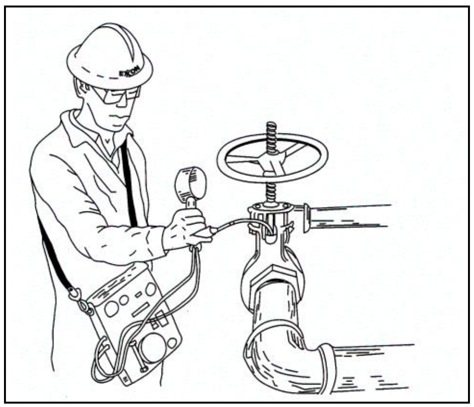
- Developed to reduce fugitive VOC emissions at time when there was no better method; contributed VOC reduction throughout decades
- Not intended for accurately quantifying emission of each leak
- Significant uncertainties
- Labor intensive

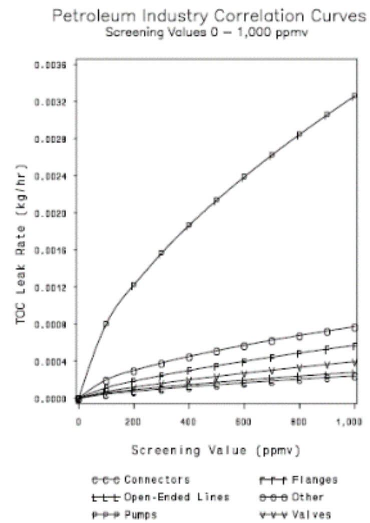
Current OGI Technology

- Higher productivity – can find significant leaks faster than M21
- Provides qualitative result only (i.e., image), no estimate of emissions

Understanding Uncertainty in Current Method 21 Based LDAR Programs

Typical LDAR Process:





ER
(lb/hr)

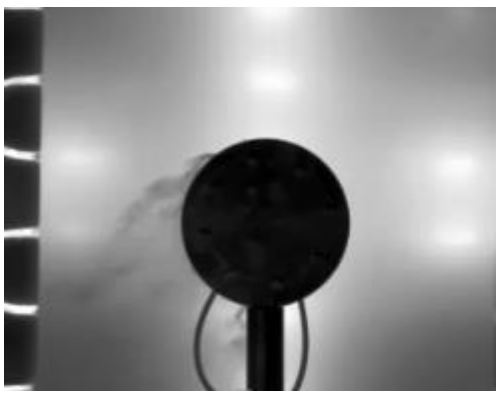
Screen components to get Screening Values (SV) in ppmv

Apply correlations to estimate emission rates (ER)

Report ER.

Understanding Uncertainty in Method 21 Screening Values

Small leak area (single point)



Large leak area (diffused leak)

Same leak rate
(500 cc/min propane)

- Only concentration is directly measured by Method 21
  - The size of the leak is not considered
  - Different leak rates could have same concentration, and vice versa
- Response Factors (RFs) applied to account for differences between calibration and measured gases
  - Instrument dependent
  - Component dependent

Response Factor Overview

- Flame Ionization Detector (FID) used in Method 21 is calibrated using one calibration gas (e.g., propane or methane)
- FID reading can differ significantly for other gases
- RF is a pre-determined ratio between the FID reading of calibration gas and the gas in question.

  Actual Conc. (ppm) = [SV (ppm) from FID] / RF.

- EPA 1995 leak detection protocol, App. D includes RF of ~200 compounds.
- RF varies from compound to compound, can be a order of magnitude different, and can be different from instrument to instrument.
  - Example: Propane RF ranges from 0.63 to 0.88
    Ethylene RF: 0.52-4.49
    Methanol: 1.88-21.73

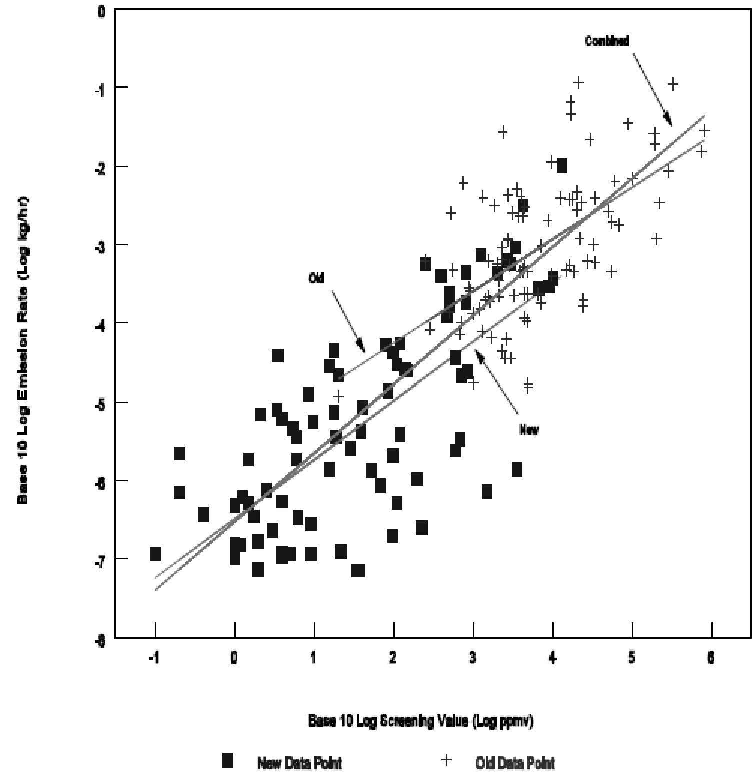
EPA Protocol Regarding RF

- EPA 1995 Protocol (Sect. 2.4.2)
  - If RF<3, no adjustment. A potential bias up to 300% (200% error).
  - If RF>3, apply RF adjustment.
  - Instrument is supposed to have RF<10 (EPA 1995 Protocol, Sect. 3.2.2.1, Table 3-1).
- If RF is not properly applied, resulting SV can have even higher error

Understanding Correlation Equations

- Empirical equations based on field data (SV vs. ER from bagging tests)
- Cannot be used above certain value (pegged value, e.g., 10,000 or 100,000 ppm)
- R^2 for these correlations range from **0.32 to 0.54** (EPA 1995 protocol, App. C, Table C-2)

Example:
Gas Valve Regression Equations

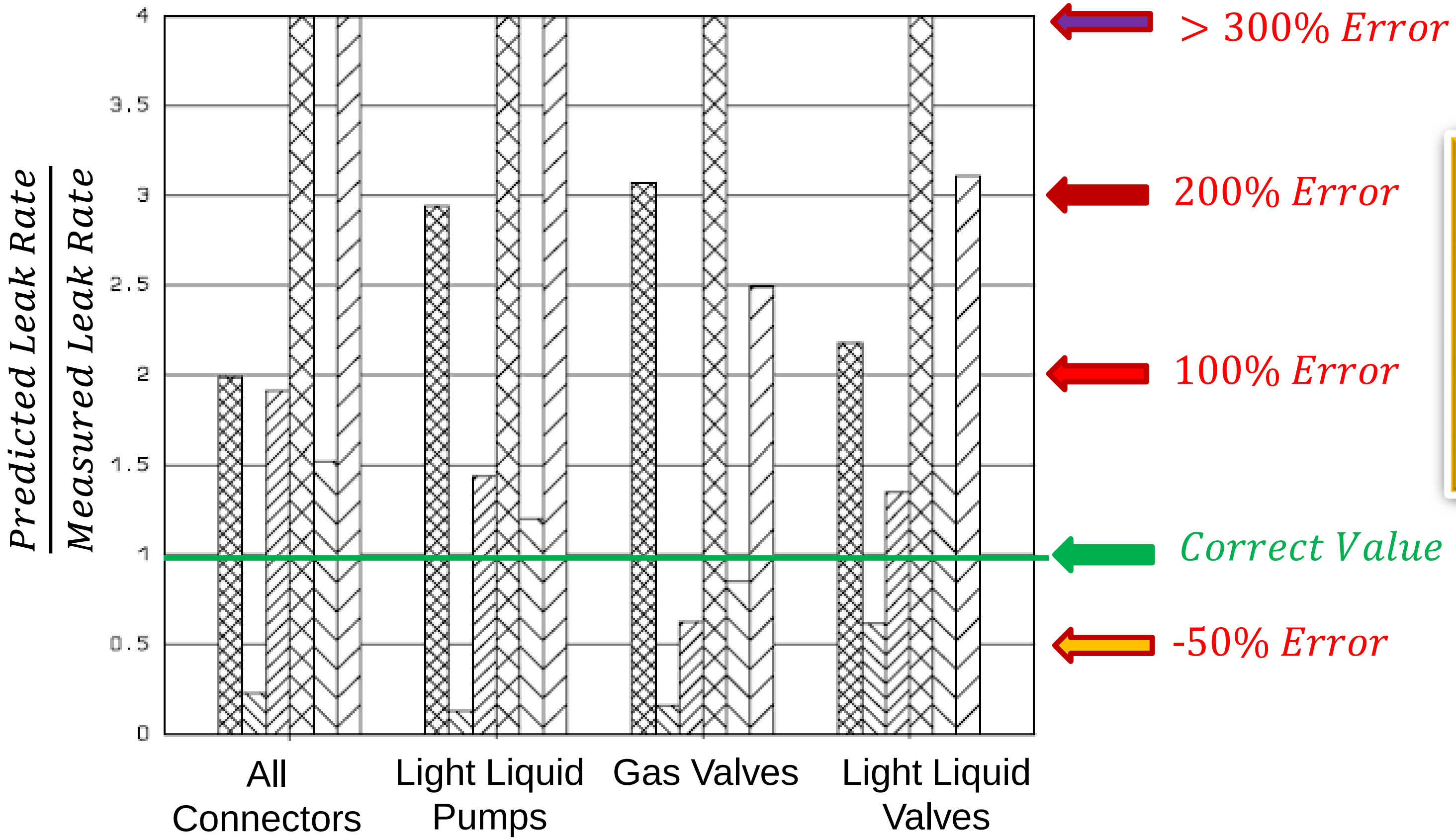


Source: EPA 1995 Leak Detection Protocol App. B, Fig. B-3

Understanding Uncertainty in Correlation Eq.

Example from 1995 EPA leak detection protocol

Three correlation equations were derived from 1980, 1993, and combined field data, and applied to 1980 and 1993 data, thus 6 sets of results (6 bars in the chart) for each of the 4 component types.

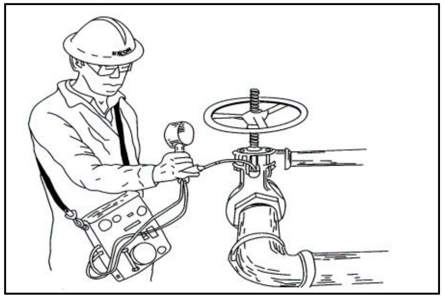


Errors range from -80% to >300%

Source: EPA 1995 Leak Detection Protocol, App. C, Fig. C-3

In Summary: Method 21 Has Uncertainties That Can Significantly Affect Leak Rate Estimates

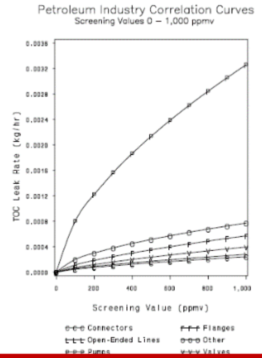
Screening Value



Uncertainty:
up to 300%

Errors up to 300% could be introduced by not correcting for RF. There are other sources of errors as discussed earlier.

Correlation Eq.



Uncertainty:
-80% to +300% or worse

Based on EPA 1995 Protocol, App. C.

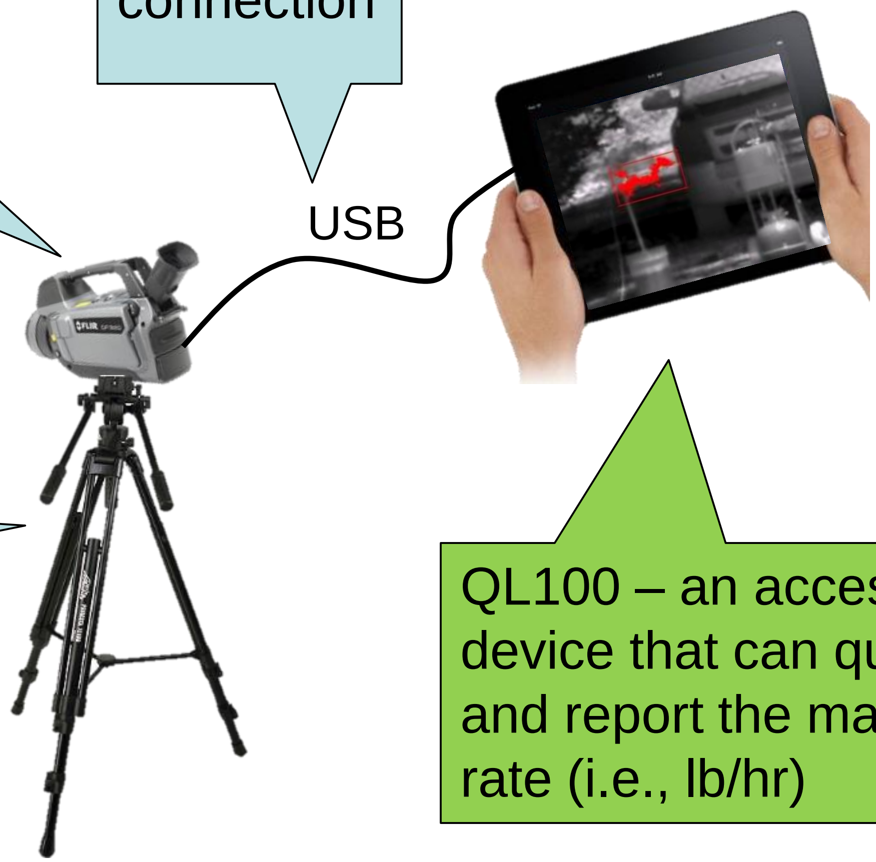
ER (lb/hr)

Combined Error?

Overcome M21 Uncertainties by Directly Measuring Leak Rate Using Quantitative OGI (QOGI)

USB or wireless connection

Infrared (IR) gas detection camera (currently available)



Tripod to steady the image

QL100 – an accessory device that can quantify and report the mass leak rate (i.e., lb/hr)

QOGI: Working Principle

- IR images of a leak are analyzed for intensity on a pixel-by-pixel basis
- Each pixel represents a column of hydrocarbon vapor between the camera and the background
  - Pixel contrast intensity is a function of temperature difference between the background and the plume (ΔT)
  - At a given ΔT, the intensity is proportional to the hydrocarbon molecules in the vapor column
- Leak rate drives both pixel intensity and number of pixels. Inversely, the combination of the two factors determines leak rate.

QOGI: How Does It Work in the Field?

- Use IR camera to survey for leaks.
- When a leak is detected, connect the QL100 device to the camera (USB or wireless).
- User enters ambient air temperature and estimated distance from the plume to the camera.
- QL100 does the rest
  - Collects images for about 30 seconds, uses proprietary algorithms to automatically calculate the mass leak rate in lb/hr
  - Provides immediate result in the field

QOGI: What Conditions Have Been Tested?

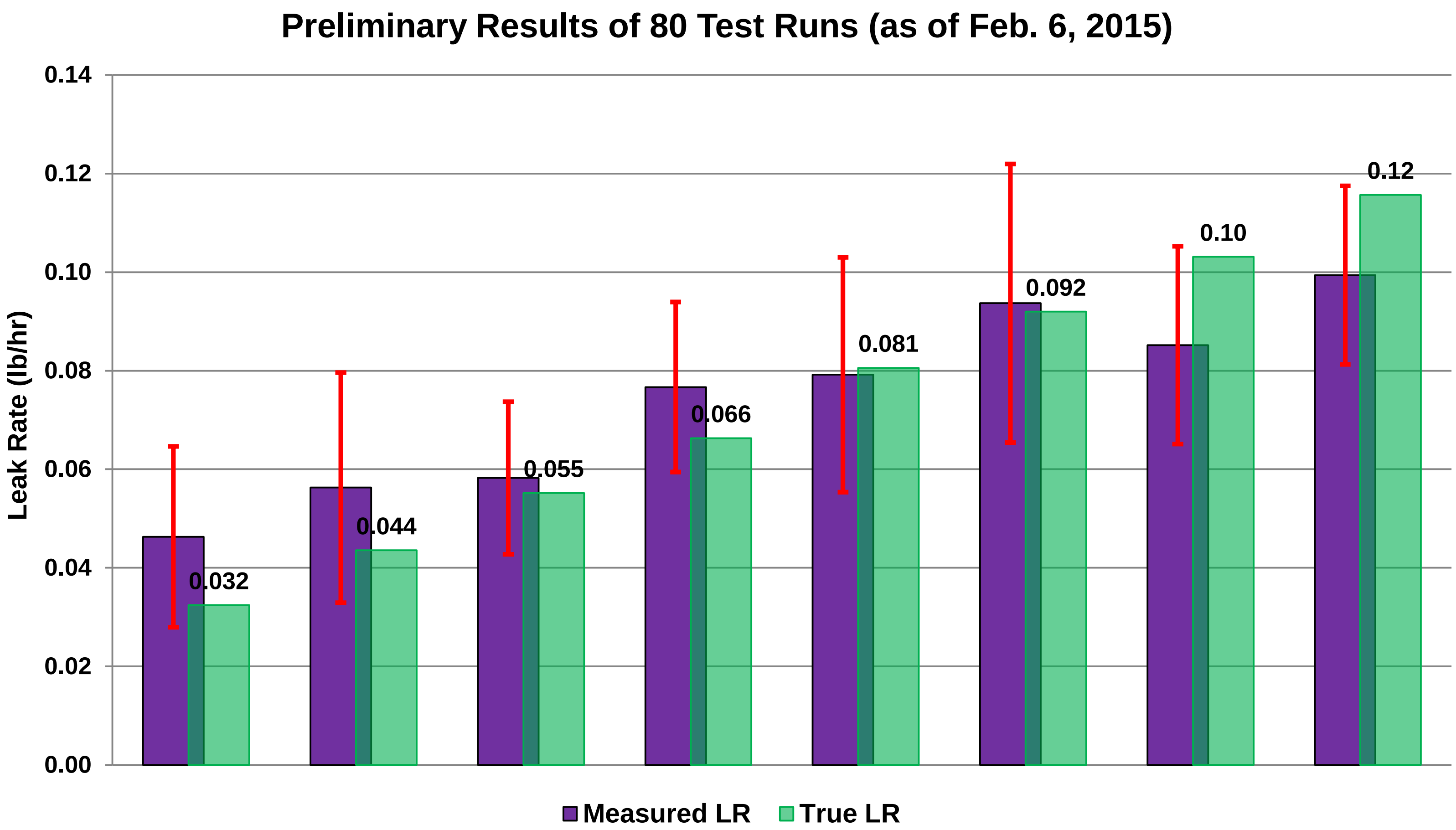
Preliminary tests have been performed (80 tests to date). More tests are underway.

The results reported here were based on propane, and included the following environmental conditions:

- Types of background: uniform temperature controlled metal board, building wall, gravel.
- Sunny and cloudy days; in sunlight and in shade.
- Ambient temp.: 37-95 ^{O}F (3-35 ^{O}C)
- Relative humidity: 50%-90%
- Wind conditions: moderate
- Distance: 10 ft.

Tests to date have indicated that QOGI is robust under a variety of environmental conditions

QOGI: How Accurate Is It?



- QOGI Accuracy: -17% to 43% across all leak rates and all 80 tests
- QOGI accuracy very promising vs Method 21

QOGI: Does It Work for Different Compounds?

Majority of tests were done using propane leaks. A limited number of tests have been done for methane and ethylene. IR Response Factors (RF) have been developed to measure different compounds accurately while maintaining the simplicity of the method. The measurement is calculated as if the gas were Propane and then scaled by IR RF. Preliminary results show this approach is viable.

Compound	Range of Leak Rates (lb/hr)	Number of Tests	Average Error %	Standard Deviation of Error %
Methane	0.12 to 0.24	25	24%	39%
Ethylene	0.03 to 0.11	20	19%	34%

QOGI: How Does the IR RF Work?

- User can select a compound, or a mixture of compounds.
- QL100 will automatically apply the proper IR RF to adjust the quantitative result
- IR RF is developed using spectral response of each compound
- Similar to Method 21 RF with two important differences
  - IR spectral response and IR RFs are less dependent on the instrument (vs. Method 21 where RF is more dependent upon the FID)
  - IR RF would be incorporated directly into software with minimal input from the user (vs. Method 21, where RFs are not always applied rigorously)
- These factors contribute to a more accurate leak rate provided by QOGI vs. Method 21 SV.

Conclusions

- It has been demonstrated, with initial but compelling data, that ***quantitative*** optical gas imaging (QOGI) is technically feasible.
- Method 21 ***estimates*** emission rates; QOGI ***directly measures*** emission rates.
- QOGI is efficient and provides mass emission rates, making it attractive as a primary LDAR technology.
- More field testing is underway to further qualify the technology and understand advantages compared to Method 21.
- QOGI is not limited to LDAR applications. It can be used for applications such as product loss, methane emissions, remote assessment of toxic gas release, etc.