FLIR SYSTEMS – OGI

Applications and field results for Quantitative Optical Gas Imaging

FINDING PETROLEUM NOVEMBER

2018

Partnership

Optical Gas Imaging (OGI) cameras have been widely used by industries and regulators to detect and locate gas leaks for over 10 years. The FLIR GFx320 and GF320 optical gas imagers are instrumental visual tools, however, FLIR has partnered with Providence Photonics' to allow Quantification of Optical Gas Imaging (QOGI) technology in the form of the Providence QL320™. With the QL320 you can not only see hydrocarbon leaks, you can quantify the leak rates.

Content Overview

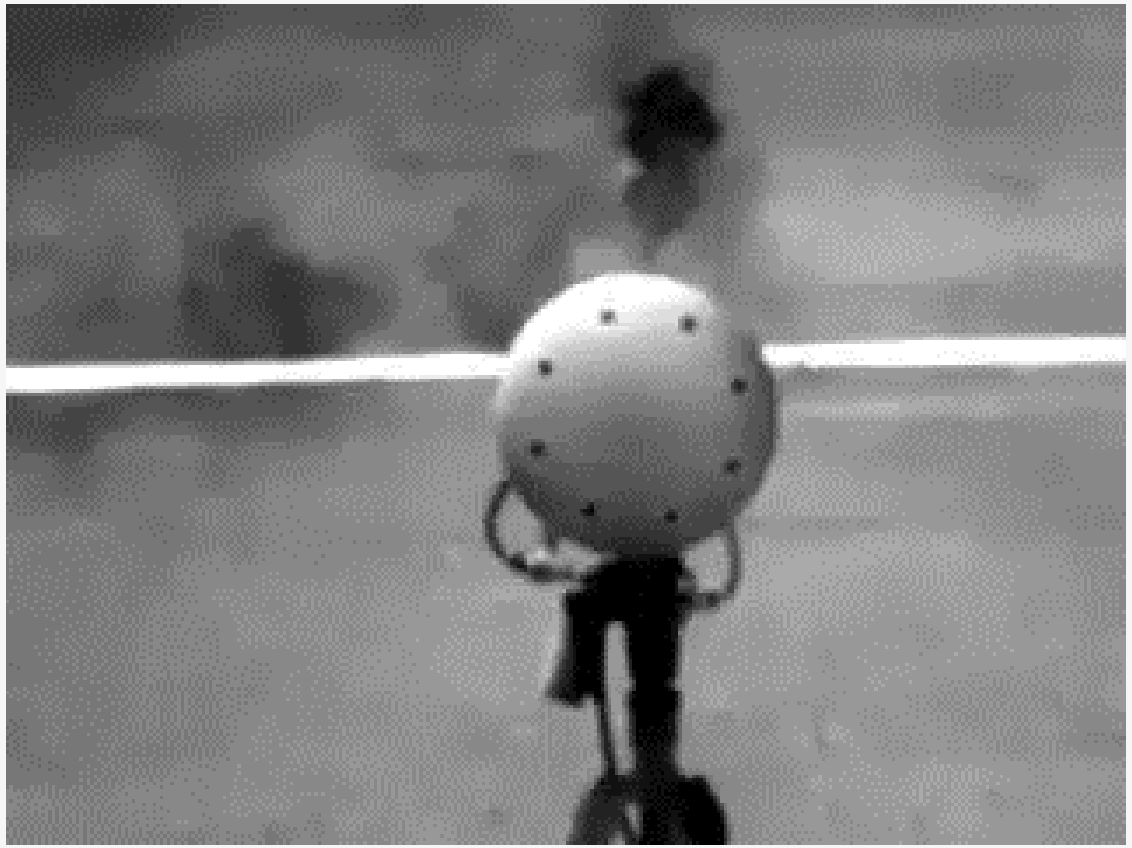
- Optical gas imaging (OGI) fundamentals
- Introduction to Quantitative OGI (QOGI)
- QL320 Field Applications
- QL320 Performance

QUANTITATIVE OGI

Optical Gas Imaging (OGI) Fundamentals

Visualize Gas Plumes with OGI

Using an infrared OGI camera you can visualize gas plumes



Absorptive plume

(Black smoke)*

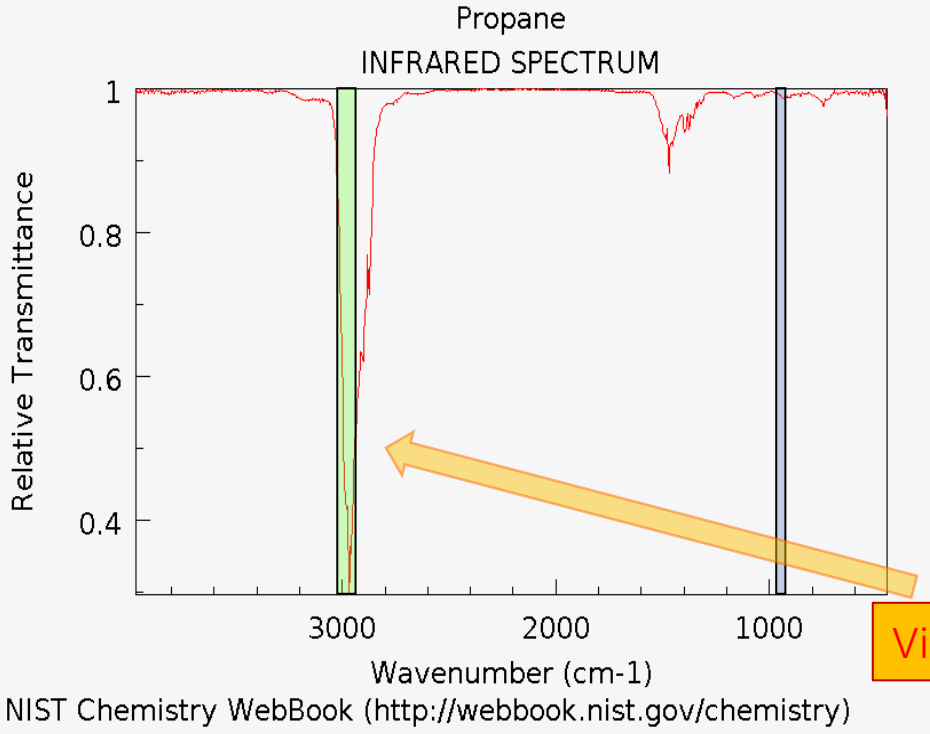
Emissive plume

(White smoke)*

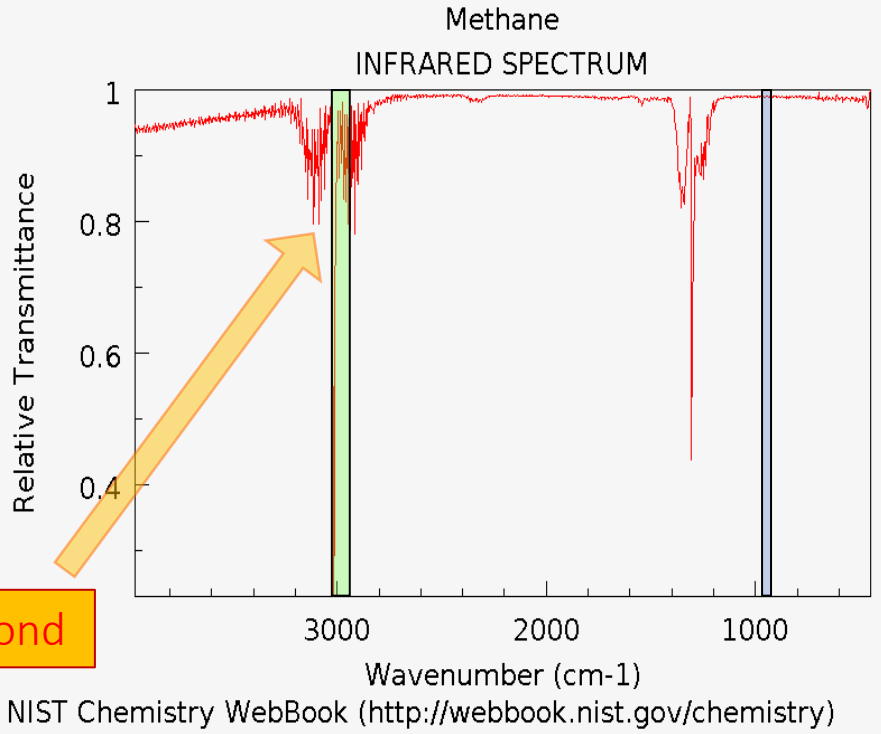
* Presumes polarity of white = hot

Hydrocarbon IR Spectra

Exploit common absorption bands of most hydrocarbons in mid-wave IR



Vibration of C-H bond

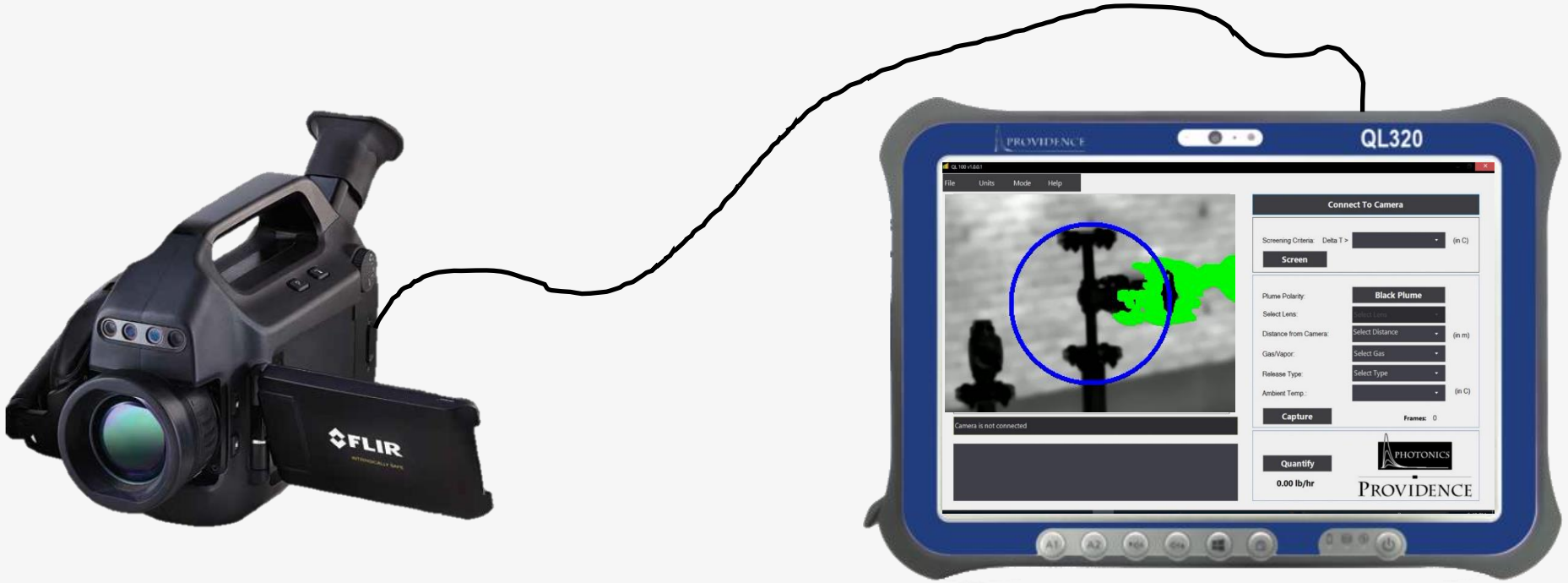


QUANTITATIVE OGI

Introduction to Quantitative Optical Gas Imaging (QOGI)

FLIR and Providence Photonics

FLIR GF320 and GFx320 cameras can be used with the QL320 from Providence Photonics to Quantify Leaks!



Quantitative Optical Gas Imaging - qOGI

Plug & Play - No Synchronization Required

Provides a remote quantitative measurement

- Mass leak rates (lb/h or g/h)
- Volumetric leak rates (cc/min or L/min)

Quantitative Optical Gas Imaging - qOGI

Opened a valve on the well head

Total Hydrocarbons: 1.05 lb/hr

Methane: 0.59 lb/hr

Leak Quantification: How?

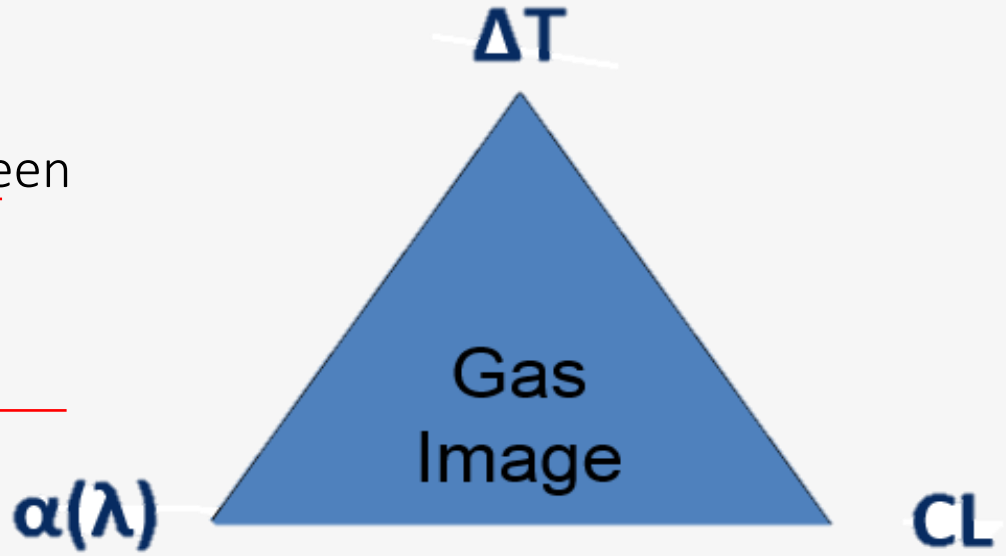
The OGI Triangle

You need three things to image a gas with an infrared camera:

1) α(λ): The gas has IR absorption peak that overlaps with the spectral window of the OGI camera

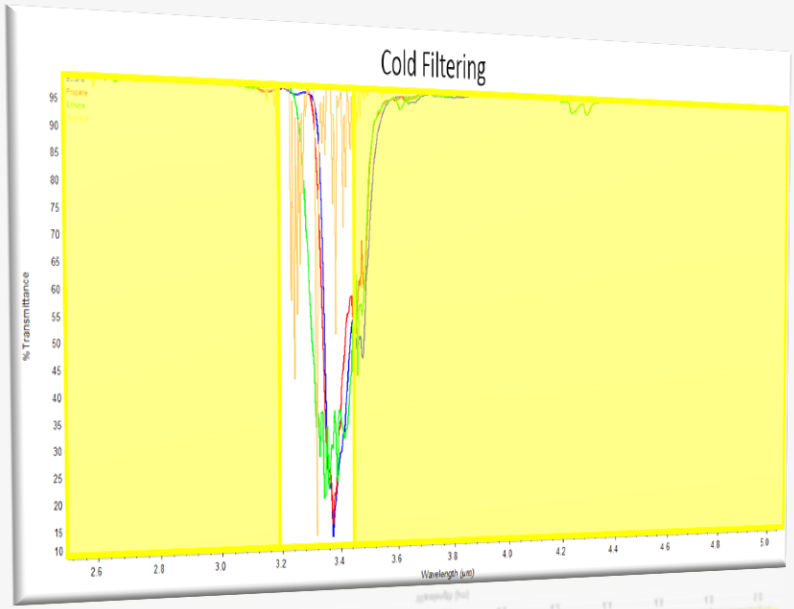
2) ΔT: There is sufficient temperature differential between the gas plume and the background

3) CL: There is sufficient concentration path-length



Leak Quantification: The OGI Triangle

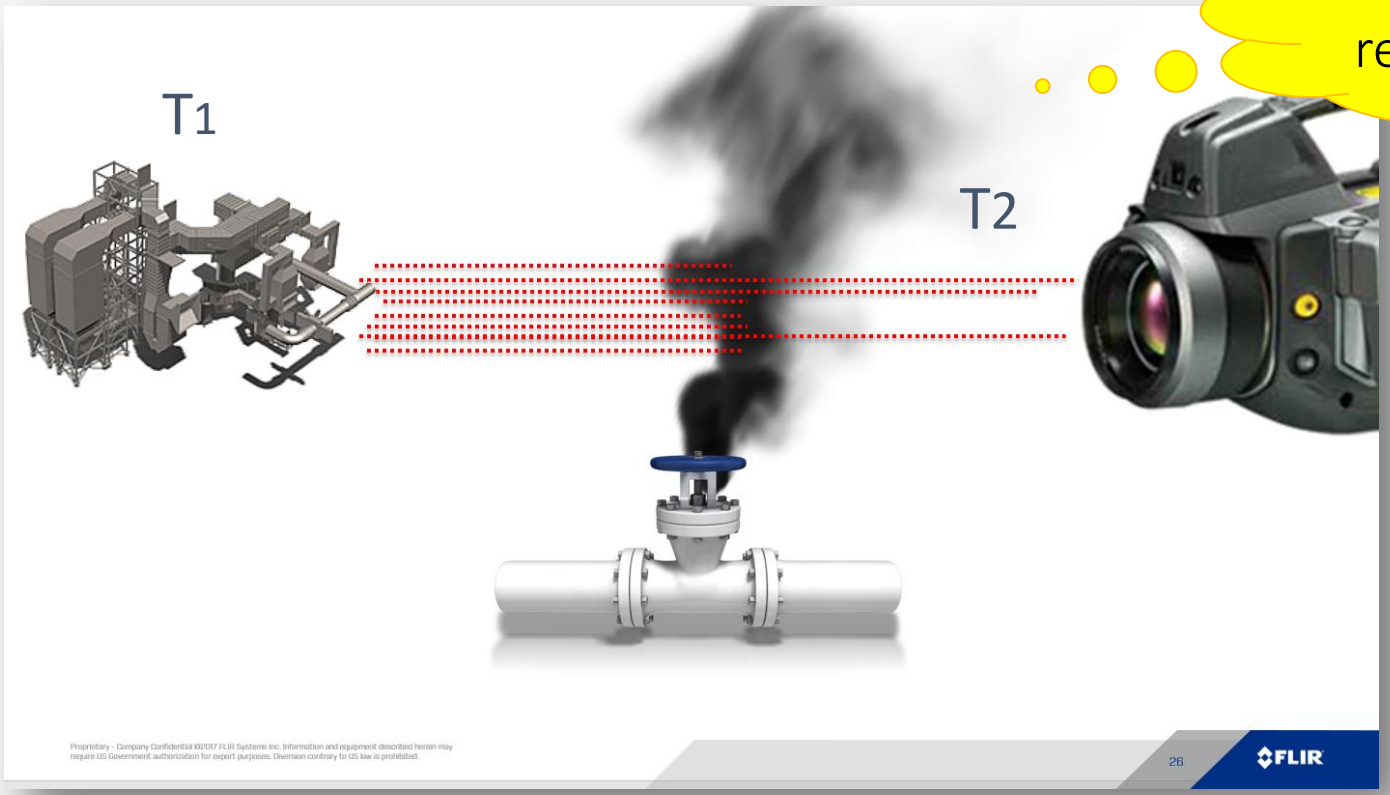
α(λ): The gas has IR absorption peak that overlaps with the spectral window of the OGI camera



How well the QL320 quantifies a specific gas is a function of how much the gas absorbs energy in the filtered wavelengths. This absorption peak value is called the Response Factor. The response factor is referenced to Propane which has a Response factor of 1.000 with the GF320 and GFx320 camera.

Leak Quantification: The OGI Triangle

ΔT: There is sufficient temperature differential between the gas plume and the background



Minimum ΔT > 2~3 °C is recommended

$$\Delta T = T_1 - T_2$$

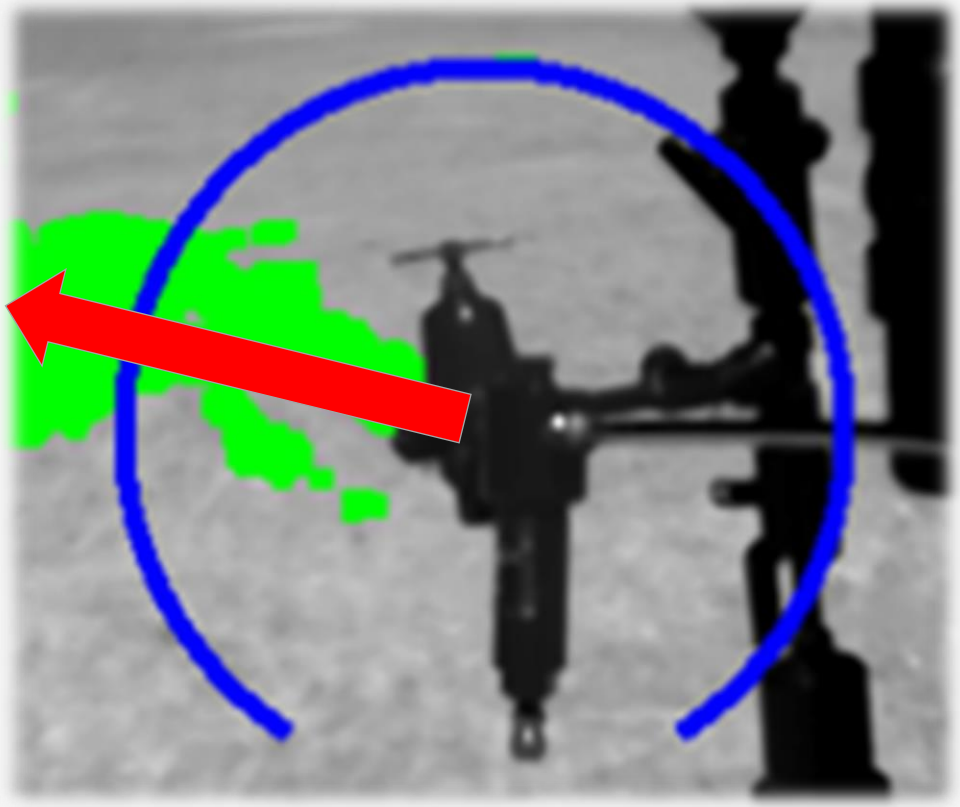
T_1: Background Temperature

T_2: Ambient Air Temperature

Leak Quantification: The OGI Triangle

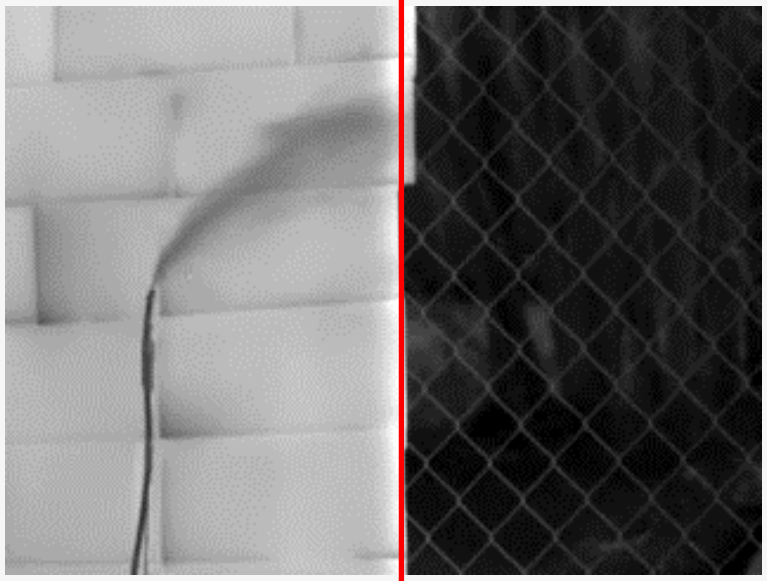
CL: There is sufficient concentration path-length

- CL Computed based on plume movement in blue circle
- Empiric model
- Automatic plume and movement recognition



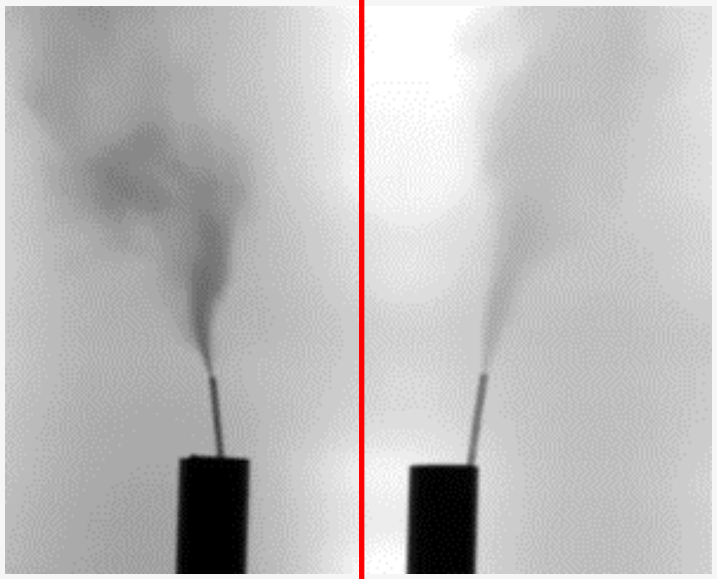
QOGI Factors

Good ΔT | Poor ΔT



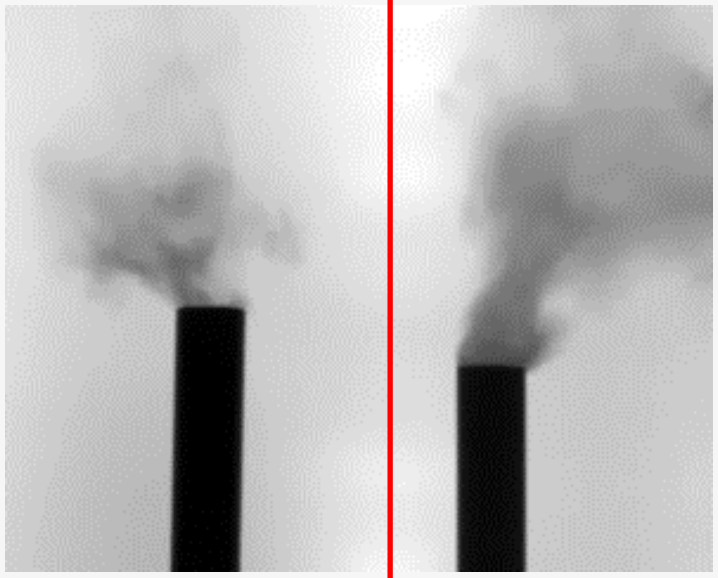
ΔT between gas and background

Propane (RF = 1.00) | Methane (RF = 0.297)



RF between different compounds

Propane (2 l/min) | Methane (16 l/min)



Concentration path-length

(this is what we want to measure)

General principle of QL320 method

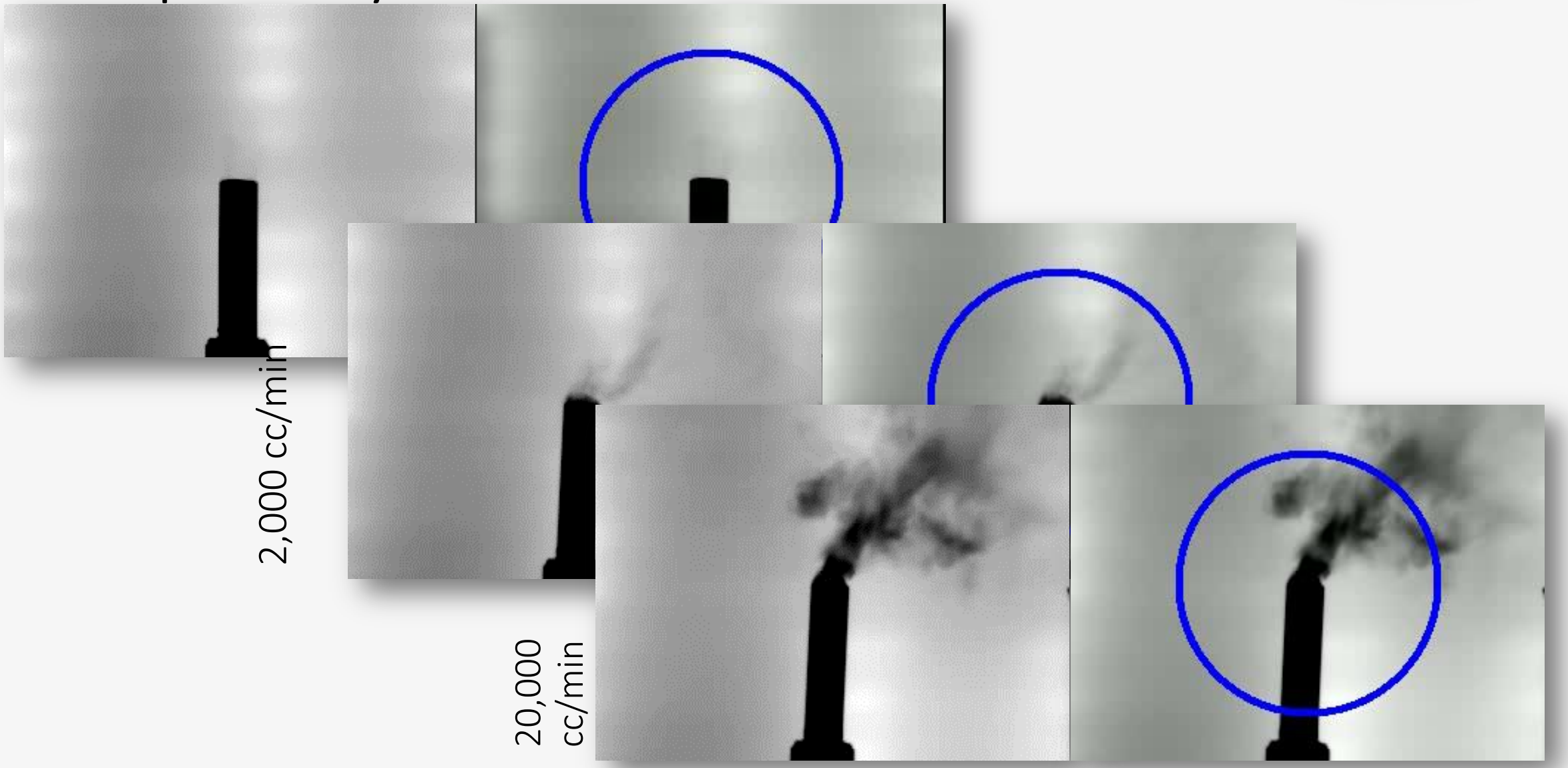
- **Extract** plume from background

- **Derive** concentration path-length measurement at the pixel level (ΔI)
    - Correct for ΔT, RF, distance, etc…

- **Aggregate** ΔI across a boundary (Signal)

- **Determine** release rate by comparing signal to empirically derived linear calibration curve (scc/min, lb/hr)

Empirically Derived Calibration Curve

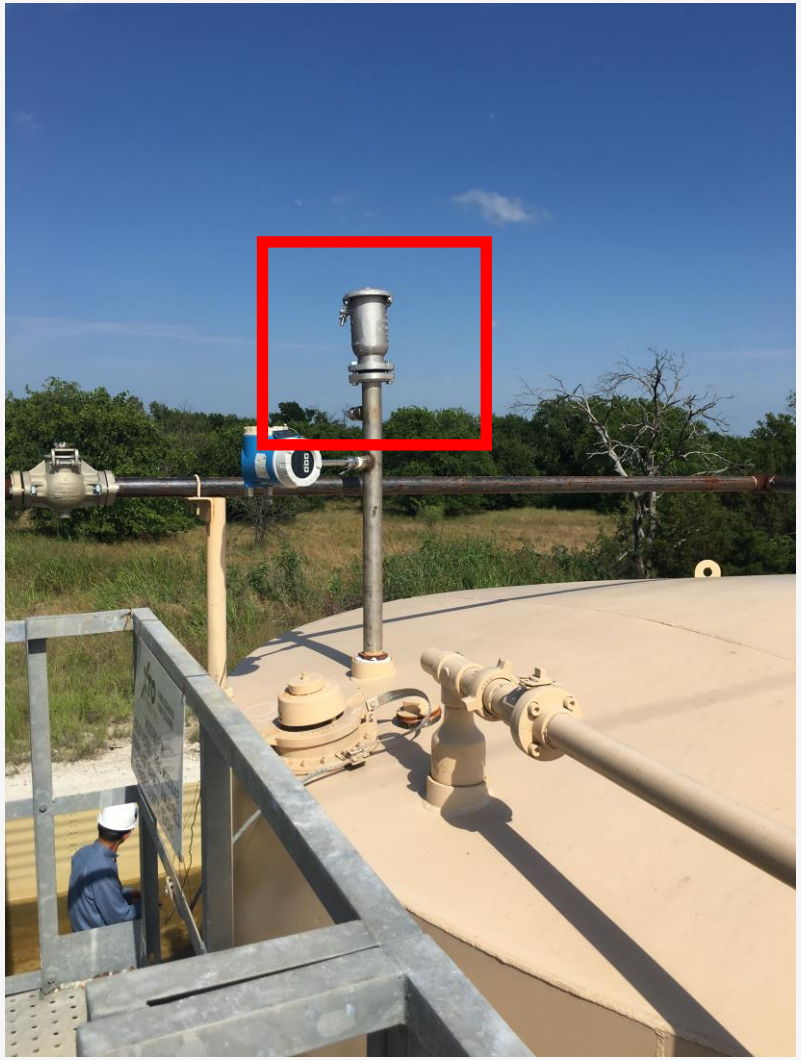


QUANTIFICATION

QL320 Field Applications

Tank Thief Hatch

Anardo Tank Valve



Difficult to Monitor (DTM)

Measured with QL320

- Difficult to monitor LDAR components (downstream)
- Distances up to 100 feet
- Eliminate need for scaffolding or manlift

QUANTIFICATION

QL320 Field and Test Results

qOGI vs TVA: an Industry Comparison

A European Industry Association study performed to compare the accuracy of the Providence system against traditional sniffer technology, US EPA Method 21

Quantitative Optical Gas Imaging - qOGI

The test data confirm that the M21 correlations cannot be used to accurately estimate individual leak rates because of the statistical method used in their development. The QOGI system, on the other hand, has been shown to be able to provide accurate quantification for individual leaks over the range 1.7 to 1000 g/h. Even where estimation is made for the total emissions from a number of leak sources (for example as would occur in an LDAR survey), the QOGI system provided a more accurate total flux value than M21. This suggests that QOGI could indeed be used for numerous applications in the O&G industry, including demonstration of LDAR compliance.

ABSTRACT

This report provides the results of a preliminary
performance of a quantitative optical gas imaging
developed to measure the mass emission rate of hy
process equipment.

Testing was performed using controlled releases in th
comparison purposes a conventional sniffing tech
detection with emission estimates determined using the correlation equations from US EPA Method 21.

Sixty one leak tests were performed. The QOGI system detected all of these leaks but it was found that quantification required a differential temperature of > 5°C between the released gas and the background.

Where leak rate quantification was achieved with the QOGI system the differences between the values determined and the known release rates were within a range of -23% to 69%, with an average difference of 6%. By comparison, where the US EPA Method 21 correlations were used to estimate leak rates these differed from the known release rates within a range of -92% to 667%, with an average difference of 31%.

Concawe Test at VITO – 06/15

- Series of tests conducted in Mol, Belgium
- Compared **QL320** vs **US EPA Method 21**
- Total of **61 scenarios** tested
- Leak rates from **1.7 to 1000 g/h**
- Backgrounds: **brick, concrete, metal, sky**
- Distance: **2 to 10 meters**
- Gases quantified:
  - Methane
  - Propane
  - Propylene
  - Mixture (33% each)
- **QL320 outperformed** Method 21

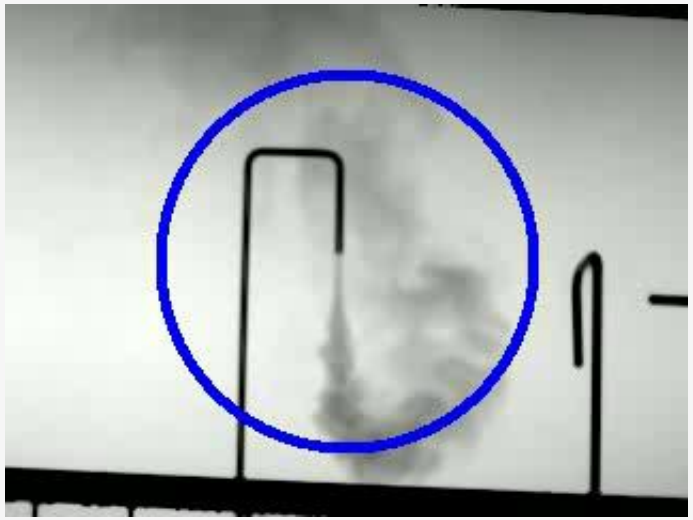
QOGI vs. Method 21 – Comparison of differences between calculated emissions and known release rates		
Difference [1]	**QOGI**	**Method 21**
Minimum	-23%	-92%
Average	6%	31%
Standard deviation	22%	155%
Median	2%	-4%
Maximum	69%	667%

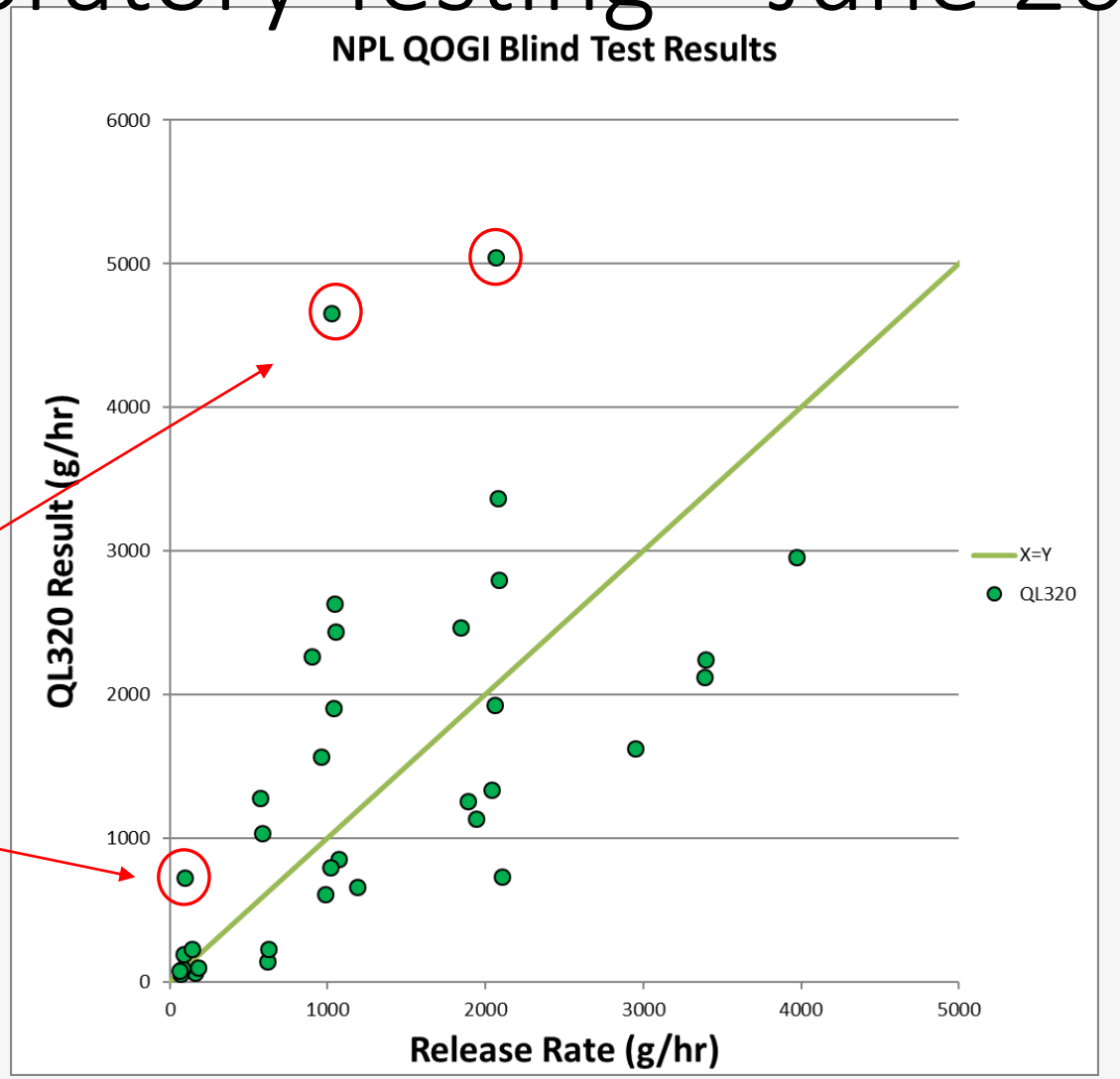
National Physical Laboratory Testing – June 2017

- Three days of **blind tests** administered by NPL in June 2017
- Raining, overcast, extreme calm wind (difficult conditions for QOGI)
- **49 individual tests** were administered by NPL
  - Methane, natural gas, propane
  - Leak rates from 0.6 g/hr up to 3972 g/hr (nearly 4 orders of magnitude!)
  - Raining, overcast, extreme calm wind conditions
  - Variety of release scenarios and configurations (release geometry, orientation)
  - Variety of background conditions (ambient, temp. controlled, sky)
- QL320 reported results for 39 tests
  - 13 tests did not have sufficient delta temperature for QL320 method (3°C)
  - Used QL320 factory calibration only (no site specific calibration)
  - Challenging conditions affected data quality

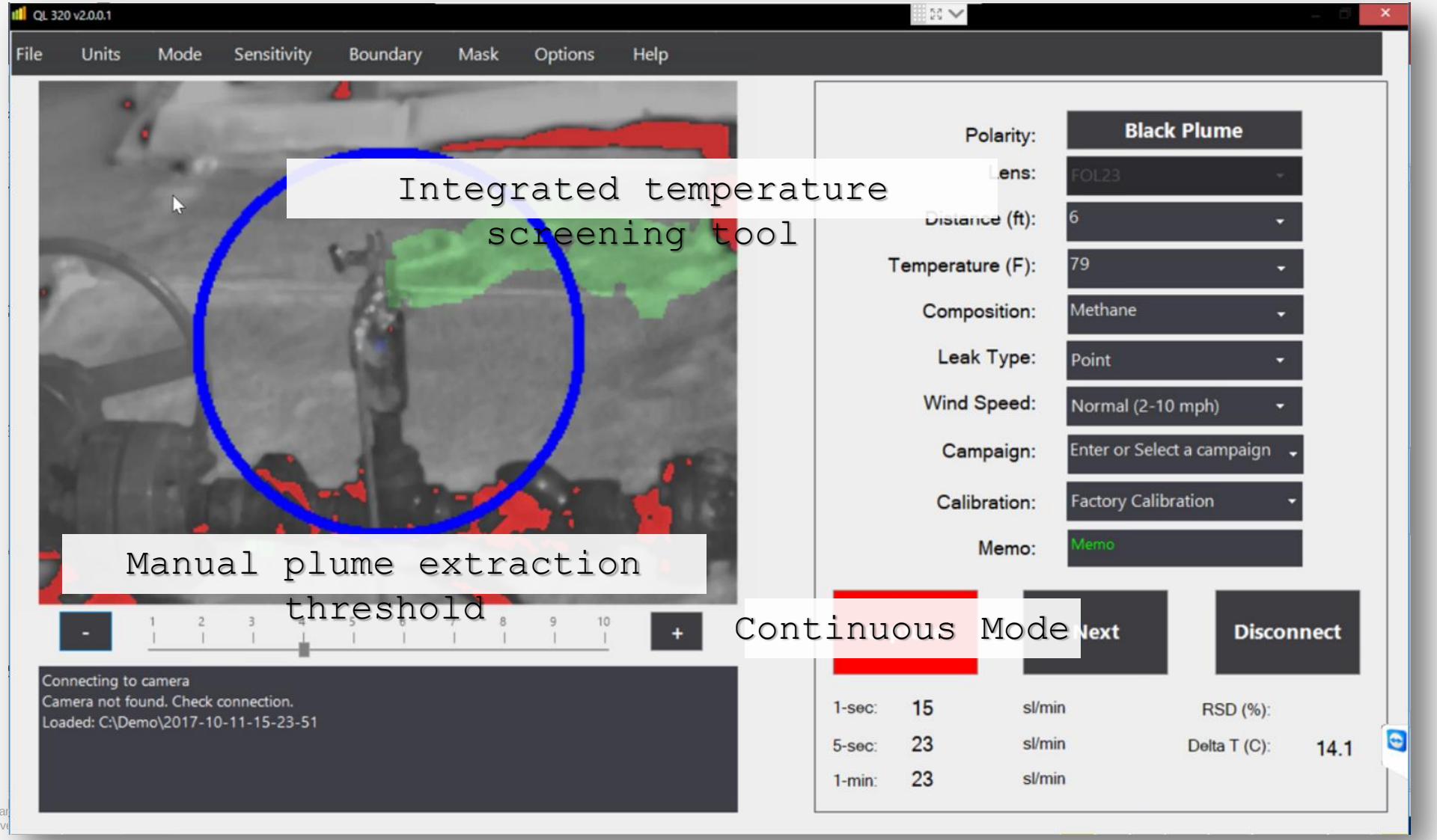
National Physical Laboratory Testing – June 2017

- 3 outliers (out of 36 results)
  - Extreme calm wind conditions
  - Caused pooling and accumulation
  - Biased QL320 result high
  - Example shown below

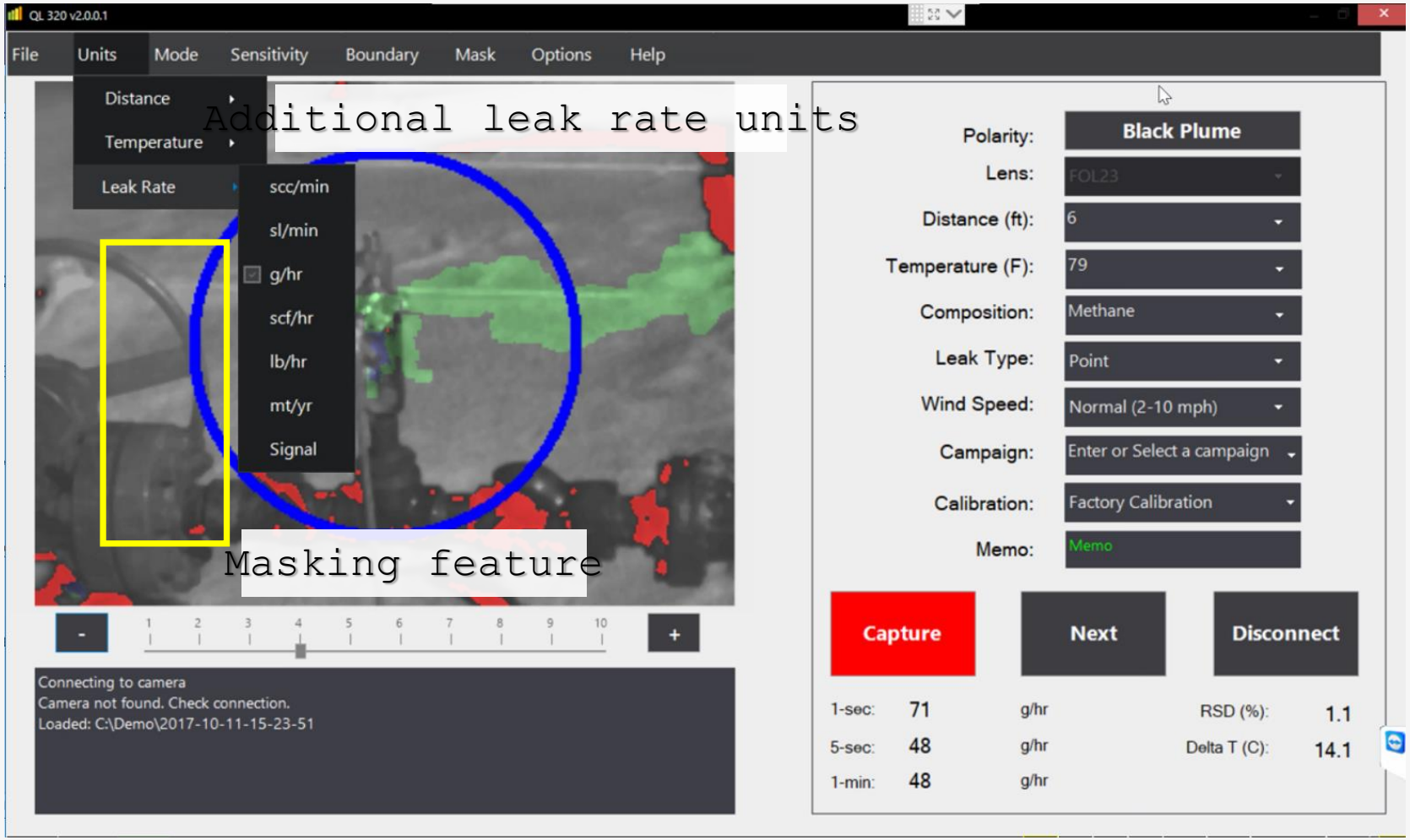




QL320 v2.0 Improved Features



QL320 v2.0 Improved Features



National Physical Laboratory Testing – June 2017

- QL320 results including all outliers
  - Average error of 46%
- QL320 results excluding the 3 outliers due to extreme calm wind condition
  - Average error of 15%
  - Correlation to release rate of 0.7
- QL320 results for leak rates < 1000 g/hr (15 of the 39 measurements)
  - Average error of -11%
  - Correlation to release rate of 0.86
- QL320 QOGI Method performed within expectations
  - Data quality was low due to challenging environmental conditions
  - Calm winds generally biased results high
  - Measured leak rates across four orders of magnitude, three different gases, variety of release geometries
  - Looking at better ways to exclude bias due to pooling and accumulation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