Implementation of OOOOa Testing, Lessons Learned and the Development of a Testing Platform to Enable the Assessment of the Performance of Camera Operators

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Overview

- About NPL
- Introduction to OGI
- NPL’s OGI Validation Work
- Experience with OOOOa and other OGI performance tests
- Newly developed test rig and PT tests
- Conclusions

About NPL

- NPL is the UK's National Metrology Institute.
- NPL responsible for developing and maintaining UK’s primary measurement standards.
- NPL is part of the **National Measurement System** (NMS) which provides the UK with a national measurement infrastructure and delivers the UK Measurement Strategy on behalf of BEIS.
- ~750 staff; 550+ specialists in Measurement Science plus 200 visiting researchers per year
- State-of-the-art laboratory facilities
- 388 Laboratories (35,746 sq. metres)

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Emissions and Atmospheric Metrology Group Activities

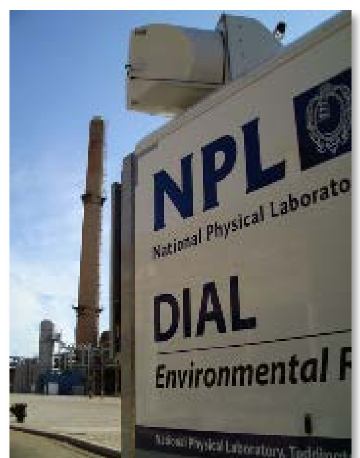
Method development in our stack simulator facilities.

Stack emissions monitoring for our industrial clients

Instrument and sensor validation

Measuring atmospheric composition

Monitoring for leaks at natural gas compressor sites



Remote emissions surveys of industrial sites

Operation and data QC of national air quality networks

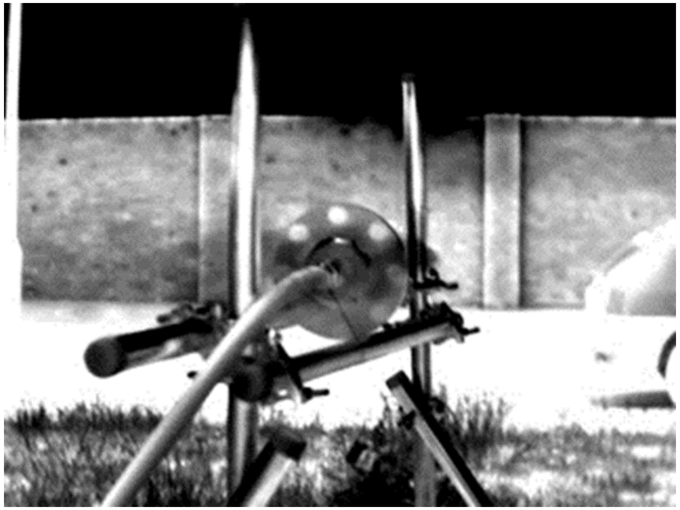
Optical Gas Imaging (OGI)

- OGI is now a well established technique.
  - Widespread uptake on oil and gas installations
- At NPL it is used to supplement other techniques and measurement services.
  - Such as DIAL and sniffing
- Number of studies investigated use, for example:
  - Concawe 2015 – study comparing OGI/sniffing/ hi-flow
  - Norway NEMS reports on use of OGI

Note: other makes of camera are available

Issues with OGI Technology

- No universally accepted protocol for camera use.
  - There is a Dutch guideline, NTA 8399:2015.
- No standard definition of sensitivity of cameras to the gases, making is difficult to prepare performance.
  - Minimum detectable leak rate.
  - Although metrics such as Noise Equivalent Concentration Length (NECL) have been proposed.
  - And EPA's OOOOa performance standard.
- Performance of the camera in the field is dependant on many factors:
  - ΔT between gas and background.
  - Background material
  - Distance from gas
  - Gas flow rate
  - Gas concentration
  - Weather conditions



- At NPL we have developed bespoke instrumentation to validate various sensing techniques, including OGI.

Performance Validation of OGI

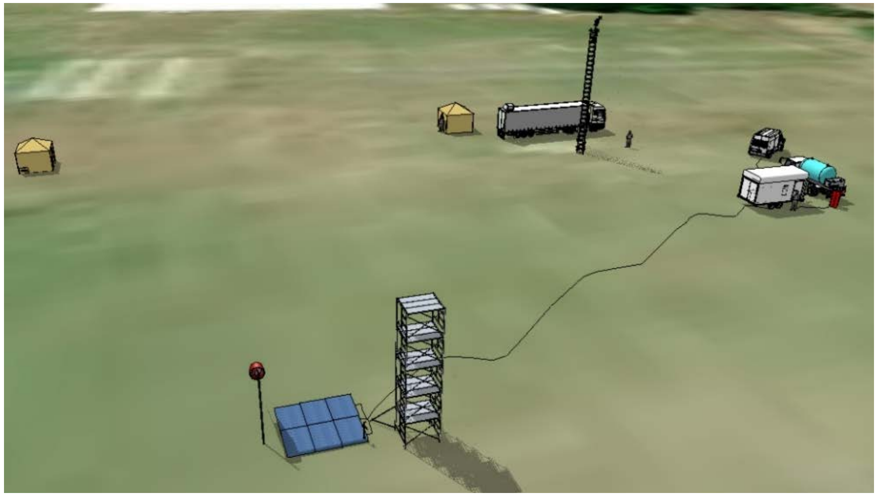
- Since 2014, NPL has carried out performance validation of OGI cameras using pioneering NPL equipment: CRF, MiniCRF and now the ‘midiCRF’.
- This work includes new European standards and validating OGI cameras for manufacturers.

Instrument Validation: Controlled release facility

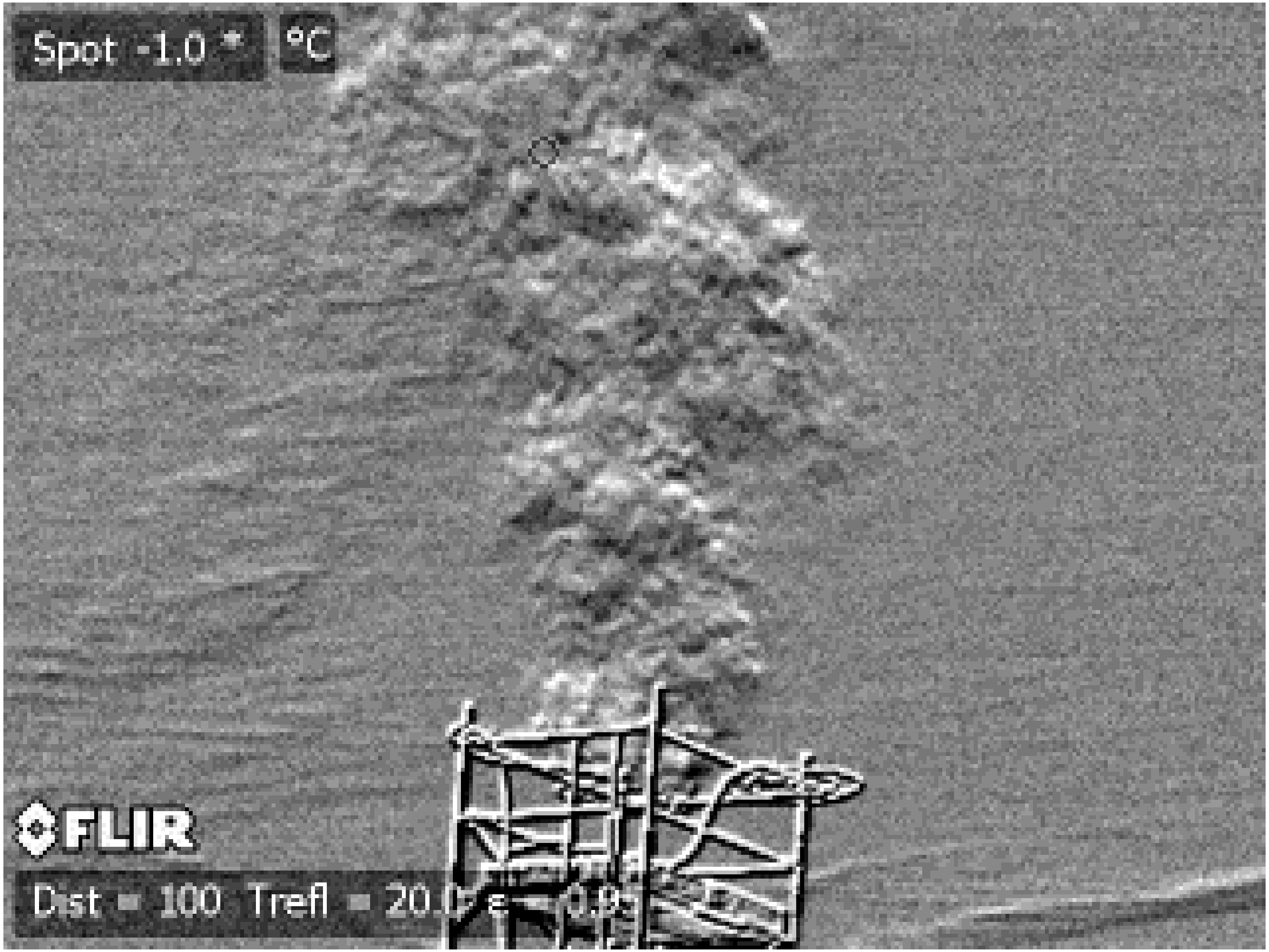
- Developed in 2014, a portable facility to test and validate techniques used for fugitive emissions monitoring.

- Able to reproduce a wide range of emission characteristics
  - Traceable emission rates up to 55 kg/h of methane.
  - Pure or mixed ratio gases with different emission nodes (line, point, area sources) can be combined.

- Used in validation of European standard/protocols, as well as OOOOa.



Elevated Methane Emissions from a tower

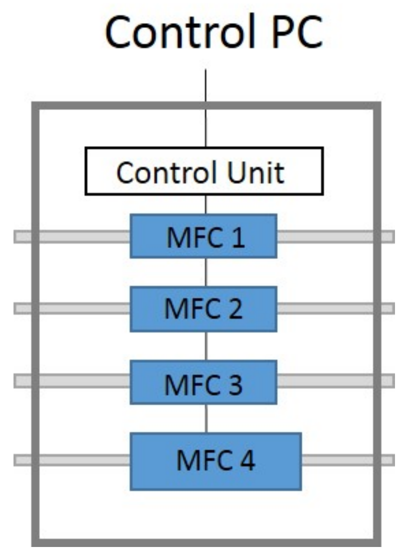


Validation trials for European standard

- CRF used in initial validation trial for European standard. Technique included DIAL, SOF, Tracer as well as OGI.
- OGI operated by trained operators.
- QA protocol included daily check with propane release to define maximum viewing distance.
- Operator experience and training was important
  - Particularly with diffuse plumes
- OGI was able to identify a ‘leak’ corresponding to almost all plumes identified using.
- However, it was operator dependent!

MiniCRF

- **Lesson learned:** CRF flow controllers too large for work at low flow rates, leading to increased uncertainty.
- In 2018, NPL developed the miniCRF to produce the test gas mixtures specifically OOOOa testing and lower magnitude flows.



- MiniCRF is comprised of four MFCs – two 500 ml/min devices for methane and propane, one 10 l/min for methane and one 100 l/min air/nitrogen. MFCs are controlled and logged via PC.

Understanding Performance OOOOa Criteria

In 2016 NPL confirmed with EPA the test conditions as:

- A gas mix of nominally:
  - 5000 µmol/mol methane, 5000 µmol/mol propane, 99% air.
- Mass flow of these two gases combined **<u>should not exceed 60 g/h</u>**.
- The internal diameter of the release orifice should nominally measure ¼”.
- Using the standard molar volume at 0°C (32°F) and 101.325kPa, 22.414 litres/mol:
  - Each hydrocarbon - 22.414 litres/hour (0.374 litres/min)
  - Total flow of all components 4482.8 litres/hour (74.713 litres/min)
- **<u>Flow rate / exit velocity is significant!</u>**

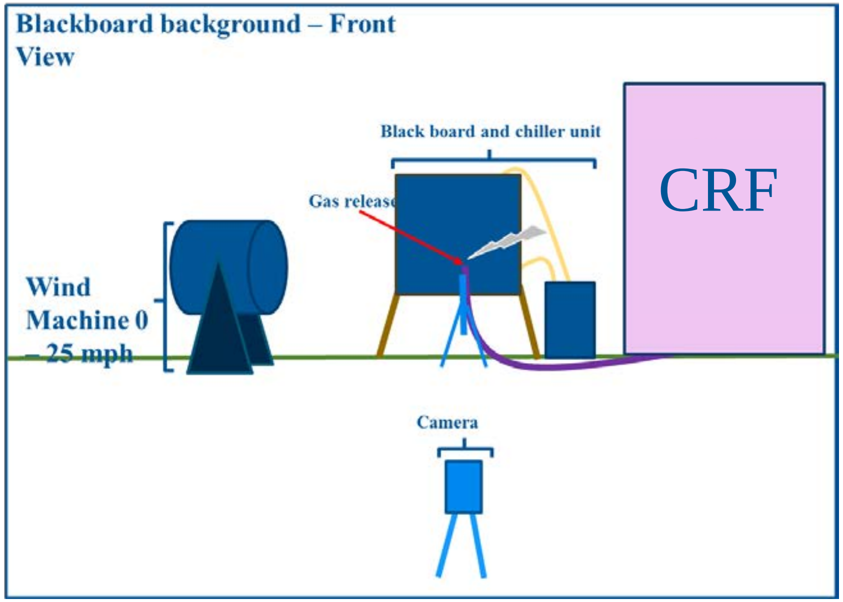
OGI Testing

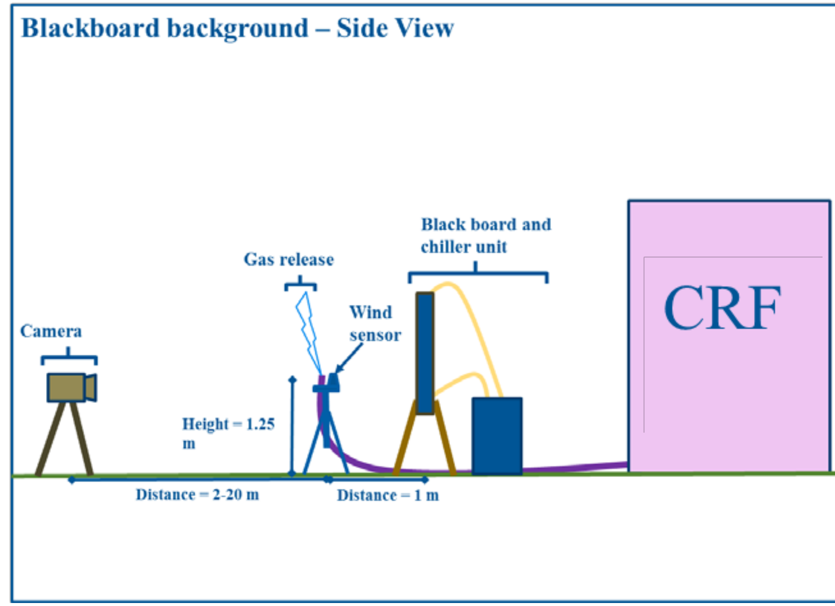
- Using the miniCRF we are able to reliably create traceable gas matrices with low uncertainty.
  - For OOOOa conditions the miniCRF the mass flow rate has an expanded uncertainty of, repeatably, less than 0.5% for the hydrocarbon components.
  - MiniCRF also capable of creating low flow rates (<1 g/h) for investigated LOD.

Parameters investigated:

- Leak rate: LOD tests
- Wind speed (mph): 0-5, 5-10, 10-15,15-20, >20;
- Temperature difference (^{o}F): <4.5, 4.5-9.0, 13.5-18.0;
- Range from release (m): 2.5, 5, 10, 20. For sky background – up to 25 m range.
- Gas composition: Response Factors

Basic OGI Test Configuration

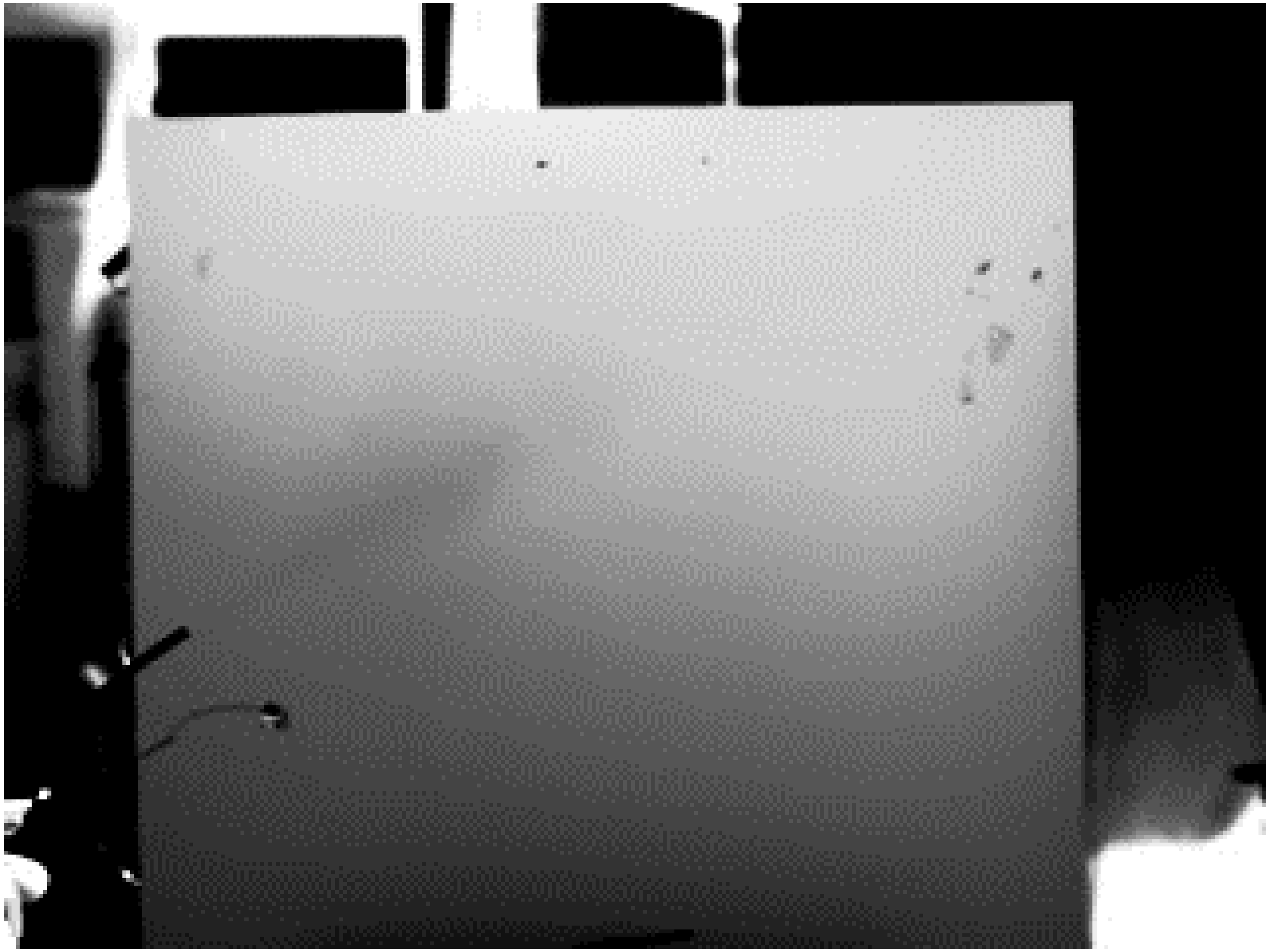




Parameters	Conditions			
ΔT (°C)	2	5	10	
Distance (m)	2	5	10	20
Flow rate (ltr/min)	15	45	60	74.8
Image mode	Auto	manual	enhanced	
wind speed (m/s)	0-5	5-10	10-15	
wind direction	with flow	towards camera	against flow?	

Example set of tests

Example of OOOOa Data



Test Conditions

- Distance: 6m
- Wind: ~5 mph
- Flow: 74.8 l/m
- ΔT: ~8 ^{o}C

*shown with permission of FLIR

NPL Assessment Methods

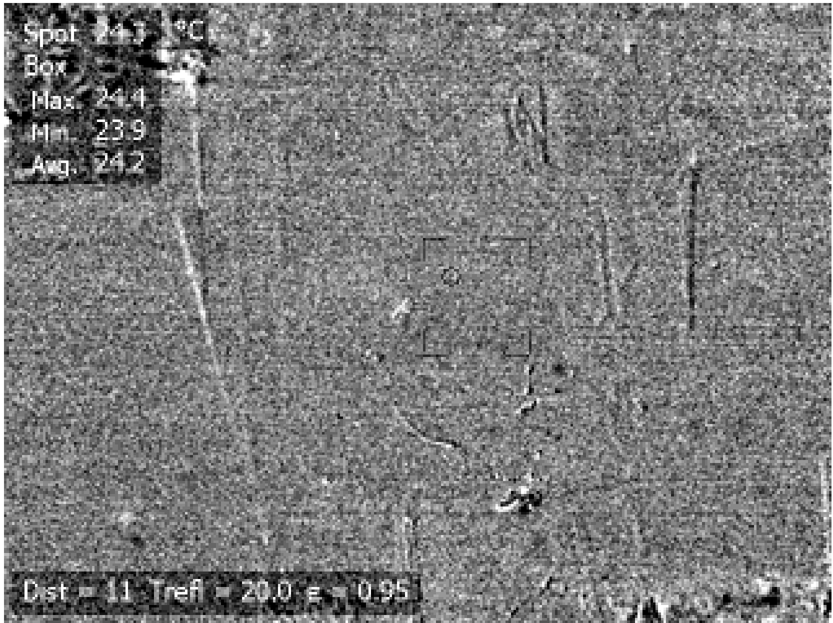
- Pass is defined as when plume is ‘visible’ in at least one of the camera modes.

- Internal protocol used:
  - Initial assessment made ‘live’.
  - Note: some cameras compress videos, so quality is lower.
  - Marginal cases reviewed by expert panel of 3 operators – unanimous decision.

- Investigated use of algorithms to define ‘visible’ plume.
  - Existing motion detection algorithms generally not as effective as eye
  - Confused by background movements
  - Machine learning not traceable
  - Issues with camera modes and image settings

General Observations from Testing

- Camera sensitivity is operator / camera mode dependent.
- Results consistent with fall off of sensitivity with range.
- The eye is most sensitive to plumes which have movement in them.
- In general as expected visibility decreases with high wind speeds.
  - However – it has been noted with very still conditions that this can lead to little plume movement – making detection harder
- Frame subtraction modes help but can be very noise depending on background.
- Need to be careful as frame subtraction sensitive to all movement!



Issues with current testing

- Uncertainty in test conditions, which can be exploited.
  - e.g. extreme ΔT could be used to enable OGI to pass OOOOa testing.
- Need for objective definition of 'visible plume'
  - Term 'visible plume' is subjective and operator dependent
- Uniformity of in-house testing:
  - Differences in implementation
  - Verification of test facilities/procedures
- Operator dependent: proficiency testing needed.
- Real-world relevance of test conditions.

Test rig for camera operator assessment

- Currently NPL are in the process of developing a new PT scheme and 'real world' test rig for standardising operator performance
- Refurbished fuel gas skid from compressor donated by UK National Grid.
- Engineered known leak points, with leak rates traceable to national standards.
- Leaking components and magnitudes to be based upon data obtained in the field.
- 5%-50%. Brandt et al.
- Named the 'midiCRF'

MFC 1 - 25 ml/min
MFC 2 - 25 ml/min
MFC 3 - 100 ml/min
MFC 4 - 100 ml/min
MFC 5 - 250 ml/min
MFC 6 - 250 ml/min
MFC 7 - 500 ml/min
MFC 8 - 1 l/min
MFC 9 – 5 l/min
MFC 10 - 50 l/min

Development of a PT scheme

- Scheme will be a blind test for operators and their equipment applying their FE protocol.
- A set of leaks in known locations, and with a range of known sizes will be created on the test rig.
- Reference environmental data will be recorded.
- Participants will be asked to survey the test rig, identify leaking components (and quantify if operating QOGI). Tag / photograph as per protocol. Report findings to NPL.
- PT report issued back to participants will give individual participant test performance and anonymised performance of the cohort (if sufficient numbers of participants).

Future developments

- Standardised protocols for use and performance testing
  - What is best way to certify/approve OGI instruments?
  - Noise equivalent concentration length NECL?
  - Image settings and software
- Protocols for use of OGI in different roles
  - Future European standard for OGI in leak detection?
  - Increased QA/QC
- Training – practical / realistic situations – certification?
- Proficiency Test scheme
  - Verify performance of test teams
- Testing and validating QOGI and automated plume detection

Thank you for listening…

Any questions?

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Department for Business, Energy & Industrial Strategy

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