CFD Simulation of Flare Gas System to Reduce Environmental Impact of Flaring and Improve Safety

Marc Laing (marc.laing@tuv-sud.co.uk)
Sandy Black (sandy.black@tuv-sud.co.uk)

National Engineering Laboratory

Contents

NORTH SEA FLOW MEASUREMENT WORKSHOP
measuring for the energy transition

Flare Gas Meter Correction

Presented by Marc Laing
marc.laing@tuv-sud.co.uk

Why Is Accurate Flare Gas Measurement Important?

In recent years flaring has come under increased scrutiny by regulators who are tasked with reducing pollution. Accurate flare gas metering is therefore important because:

- Sanctions and/or punative fines can be applied to operators who exceed their flare consent

- Hydrocarbon production can be limited by flaring i.e. Increasing production would lead to the operator exceeding their flare consent

- Emissions

Why Is Flare Gas Metering So Challenging?

Accurately metering flare gas is a challenging application for the following reasons:

- Extremely high turndown ratio (ratio of max to min flow)
- Complex pipework; where generally there is no suitable location for a flow meter
- Any flow meter must provide no resistance to flow (safety requirement)
- Flare gas is a waste product and therefore it is desirable to find a cost effective solution (eg low cost flow meter).

What Meter Can I Use?

As mentioned previously there are many requirements for flow meters installed in flare gas metering systems. The result of this is that the only type of flow meter that can be used is an Ultrasonic Flow Meter (USM) for the following reasons:

1. Non intrusive (other than transducers), therefore no resistance to flow is added.

2. Can handle the high turn down ratio required (often this can reach 10,000 to 1)

3. Single (or in some cases dual) path meters are very cost efficient.

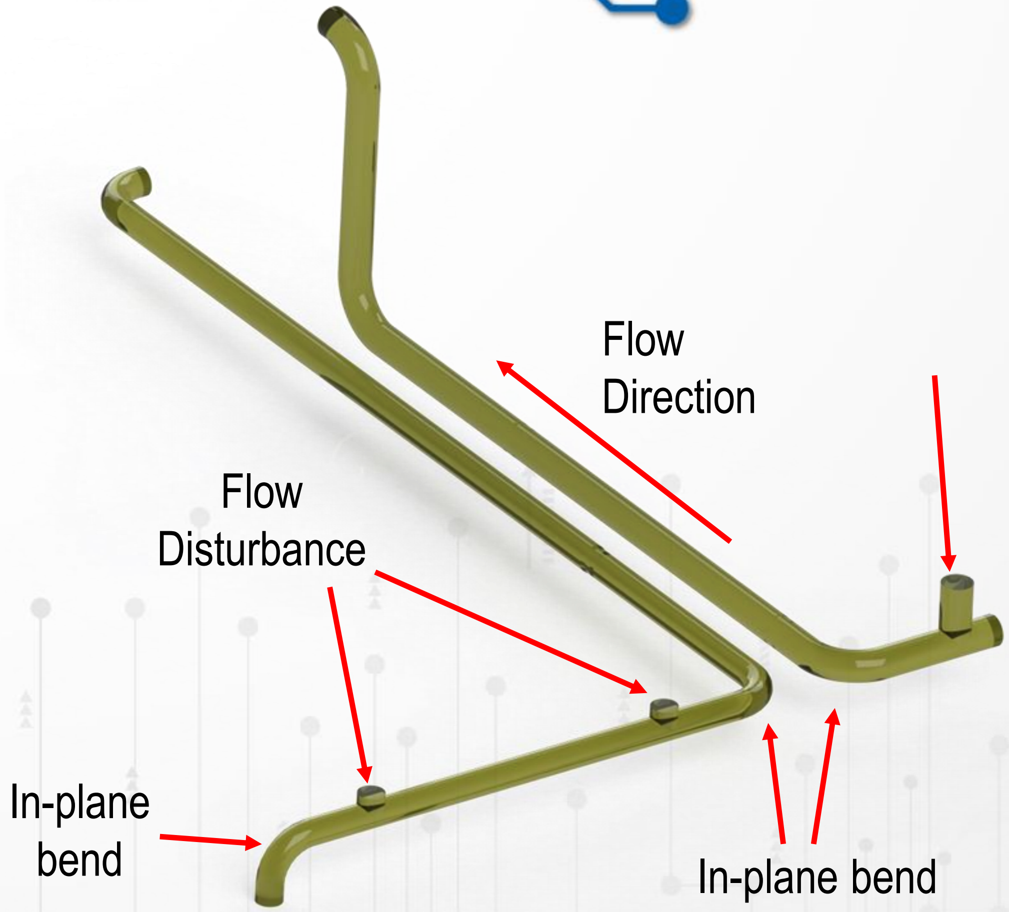
4. USMs can be corrected by supplying a k-factor to account for installation effects as well as Reynolds number effects.

Best Case Flare Metering System

The image on the right shows a flare metering installation.

In general the guidelines for installing USMs is that they must have 20D upstream and 5D downstream of straight pipework.

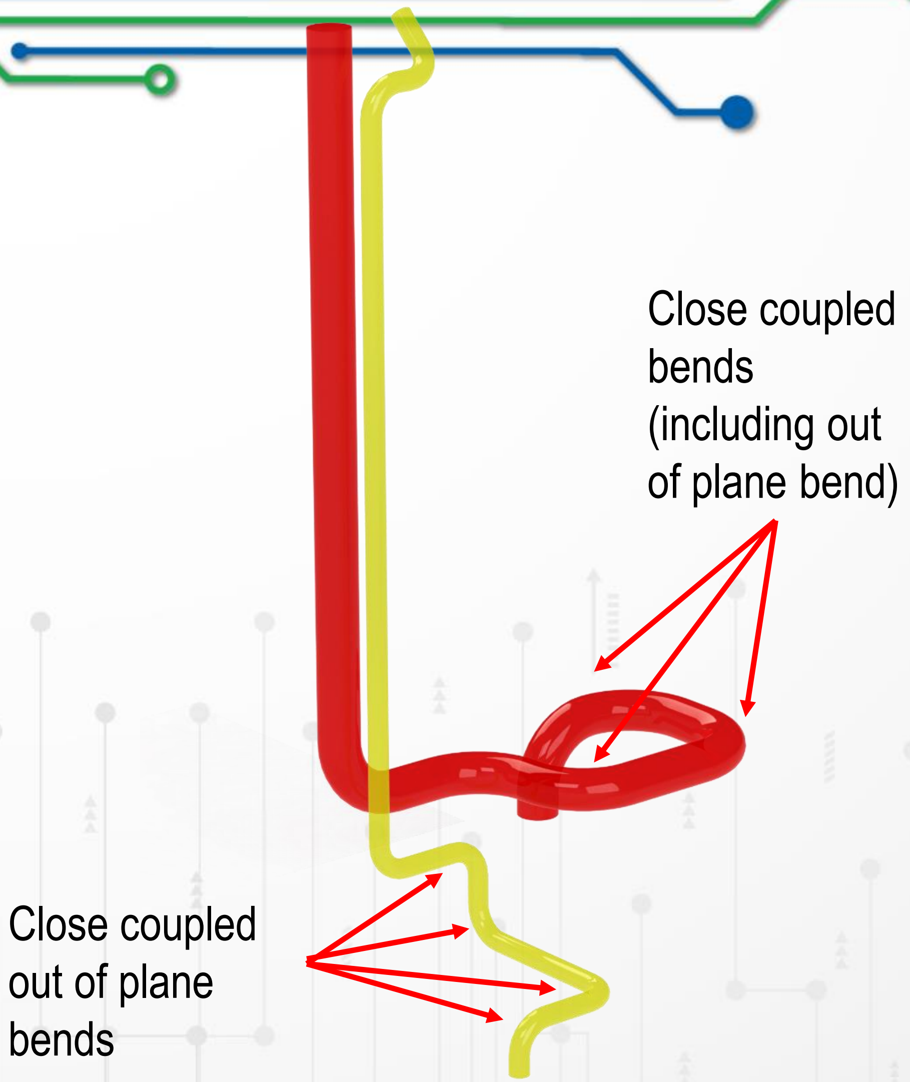
Although this metering system has many flow disturbing elements it is actually not as complex as many other systems in use today.



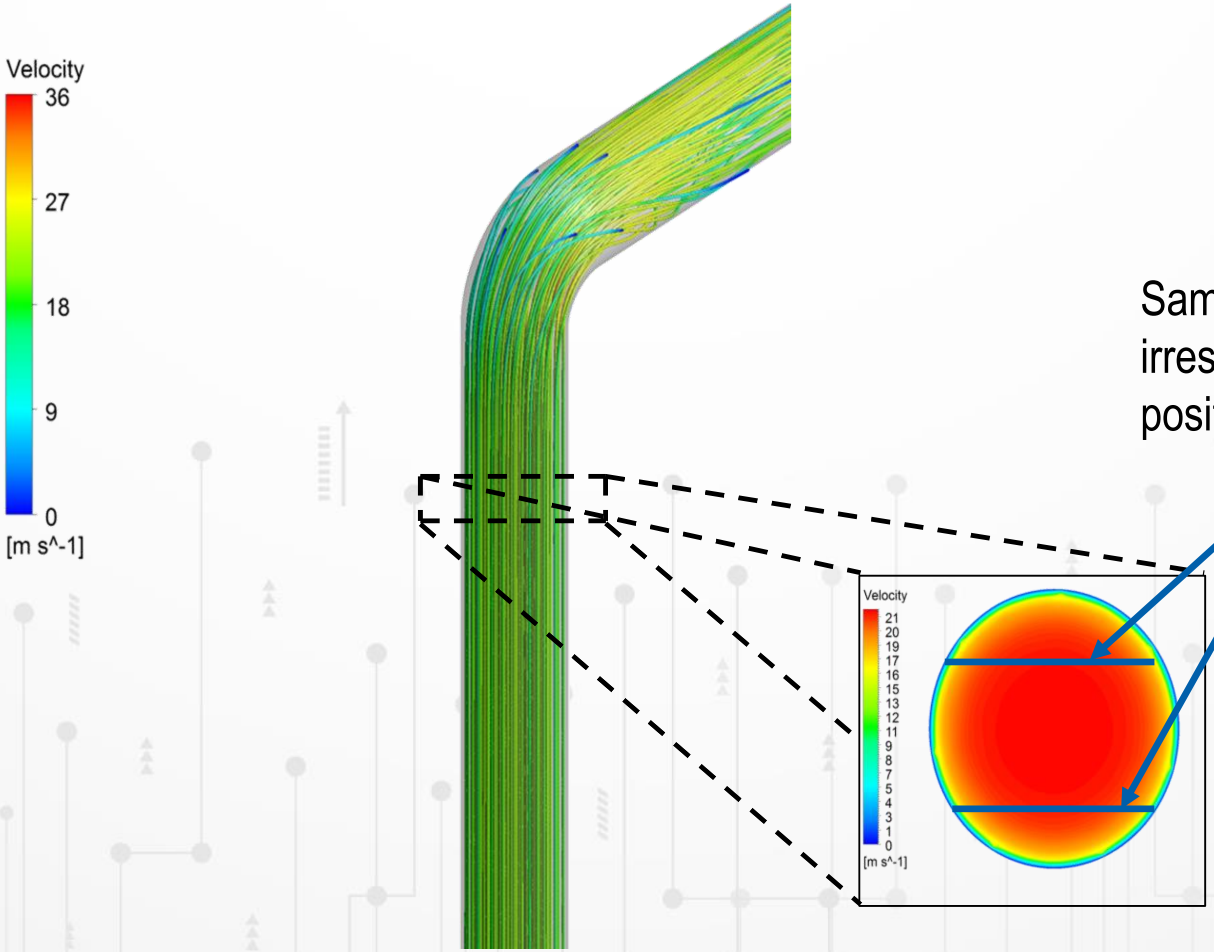
Challenging Flare Metering System (from a metering perspective)

The flare metering system shown on the right is a more challenging metering application for the following reasons:

- Swirl – Swirl is produced by out of plane bends (and is worse for close coupled out of plane bends)
- No ideal location to place a meter given that swirl will persist to a degree throughout the longer straight sections.

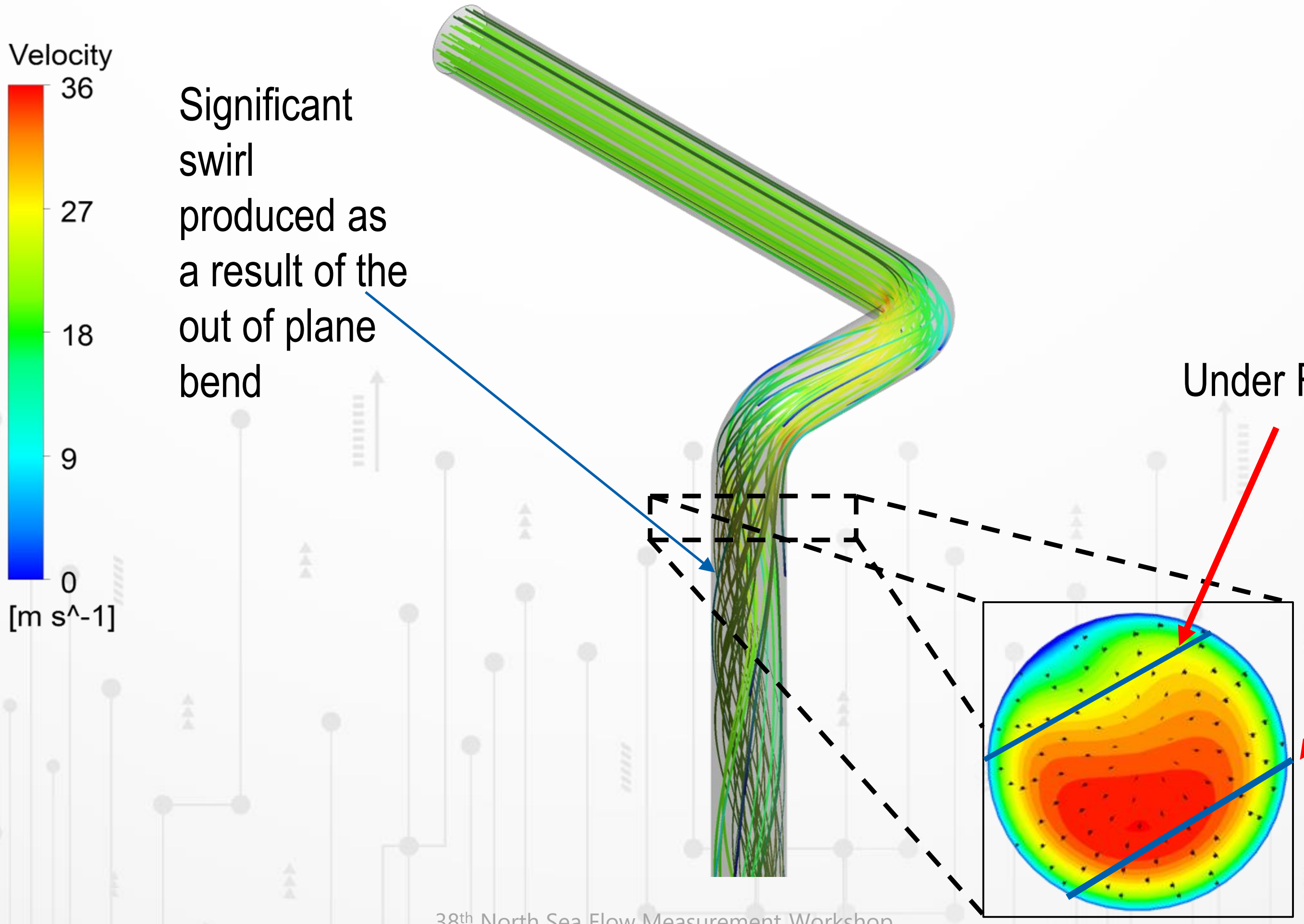


In Plane Bend – Velocity Streamlines



Same average velocity irrespective of transducer position

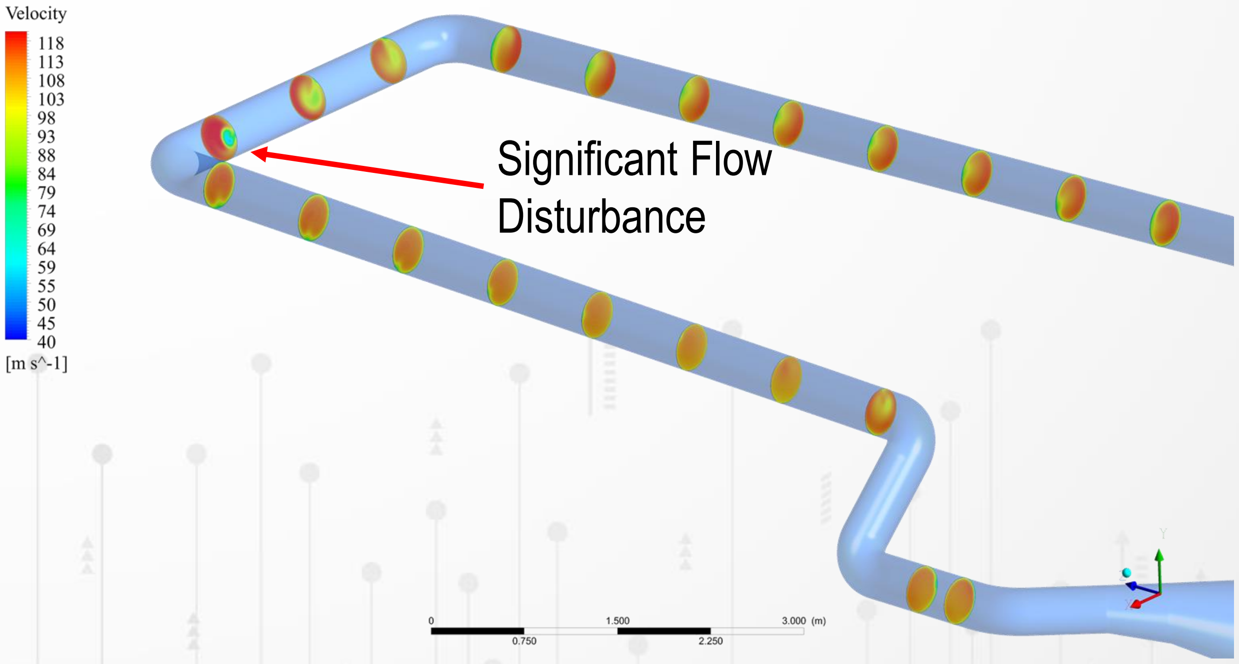
Out Of Plane Bend (Swirl) – Velocity Streamlines



Example Of Recovery Time For Flow Profile

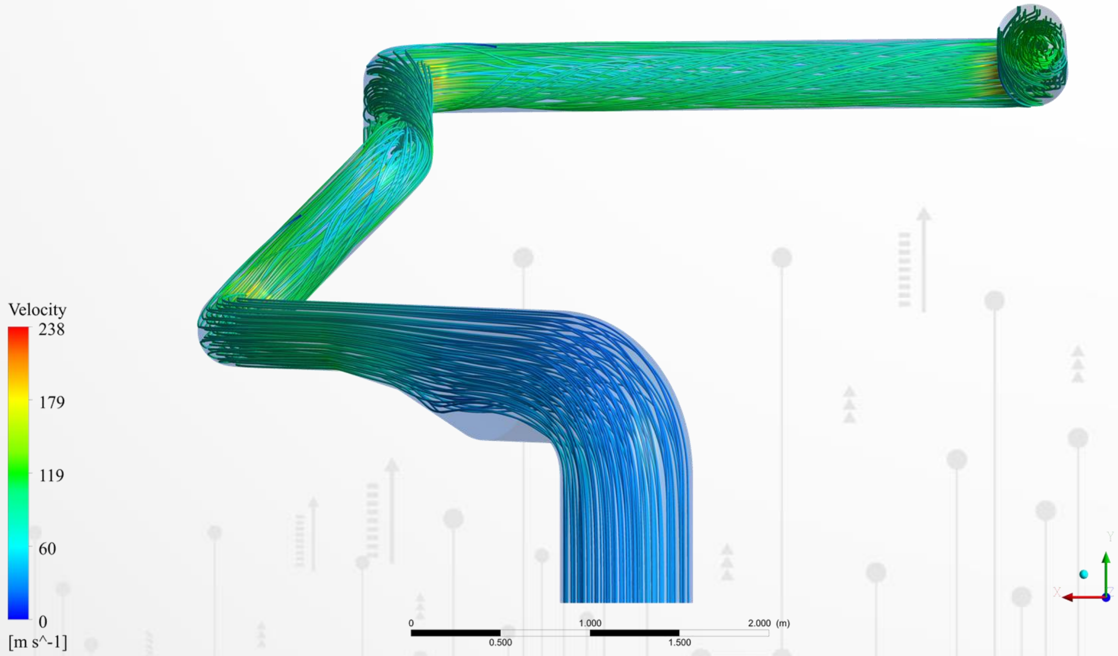
- The flow path shown on the right does not contain any “severe” bends

- Even still it can be seen that the flow profile remains disturbed for a significant distance downstream of each disturbance.

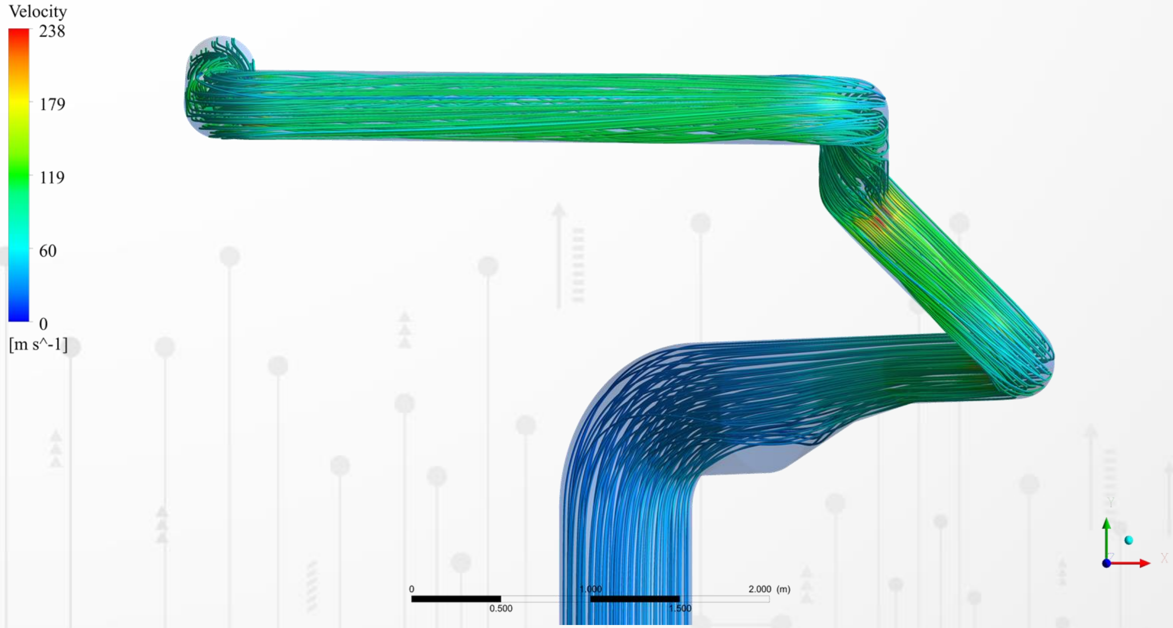


Streamlines Coloured by Velocity Showing Swirl

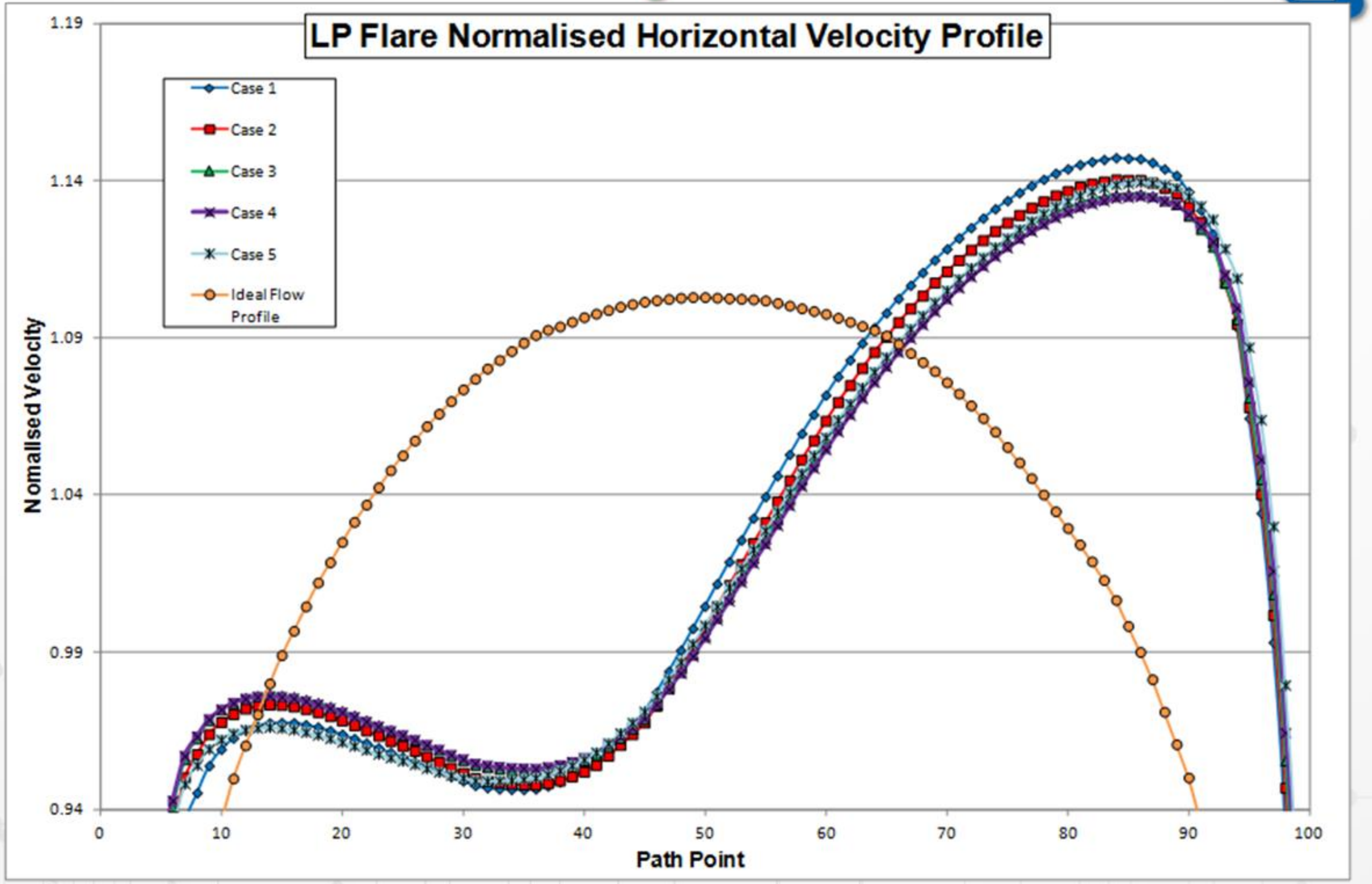
Front View



Rear View



Ideal Flow Profile vs As Installed Flow Profile



Measurement Error Trends

After having undertaken numerous CFD simulations to predict the measurement error and provide the relevant correction factors the following trends have become apparent:

- In general the flare meters tend to over read when installed in flare lines (although this is not always the case)
- Errors are generally in the 10% to 40% band, however some errors have been greater than this

Summary – Meter Correction

- In order to comply with regulators and avoid financial penalties it is necessary to have accurate flare gas measurement.
- Metering flare gas is challenging due to the turn down ratio required.
- Often there is no 'ideal' location to install a meter within a flare gas line
- The most common metering technology used for flare gas applications is Ultrasonic.
- CFD is a very powerful tool to improve the accuracy of flare gas metering

Flare Tip Combustion Analysis

Presented by Dr Sandy Black

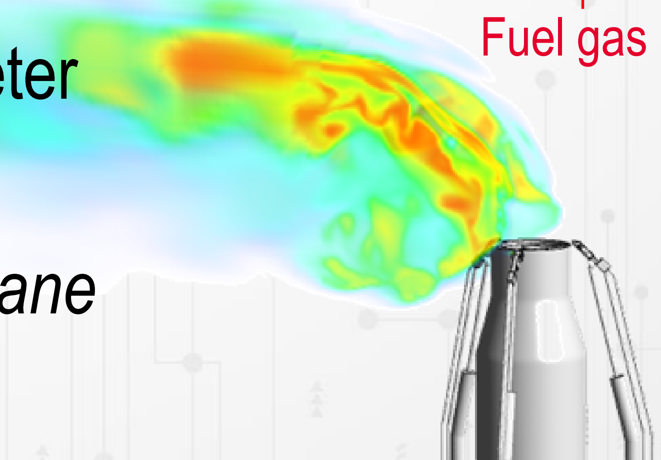
Flare Gas Emissions

- **Safety critical component**

- **<u>But</u> an environmental issue**
  - CH_4 has a 25 x greater greenhouse effect than CO_2
  - Combustion is more “environmentally friendly”

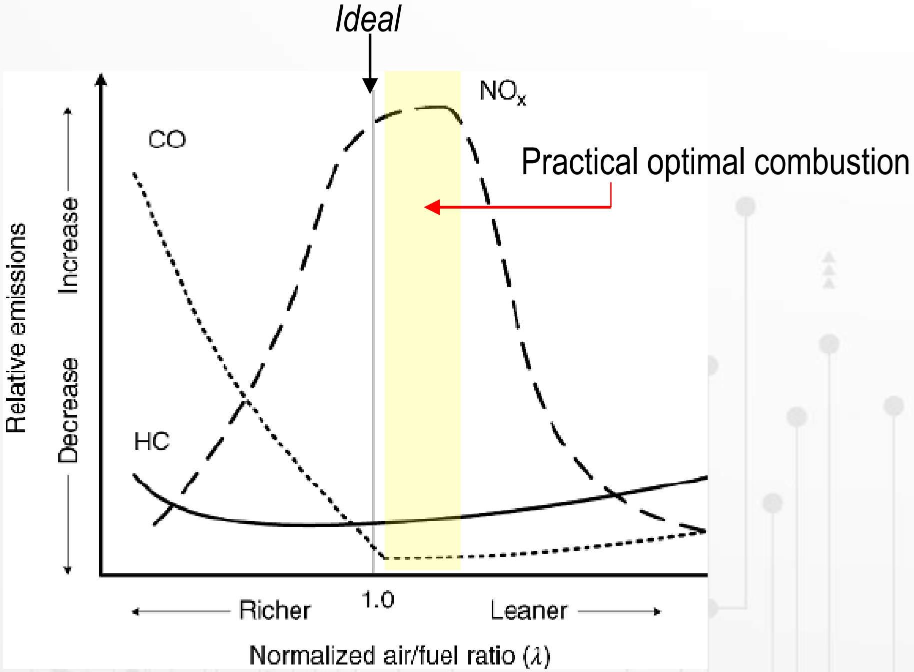
- Reduce flow rates **<u>but</u>** need to know flow rates from meter

- *Reduced flow rate : Inefficient combustion, higher methane emrission & safety concerns*



Flare Gas Emissions

- To minimise **unburnt hydrocarbons**, ‘good’ combustion efficiency is required
- However, combustion efficiency and pollutant emissions are at odds with each other



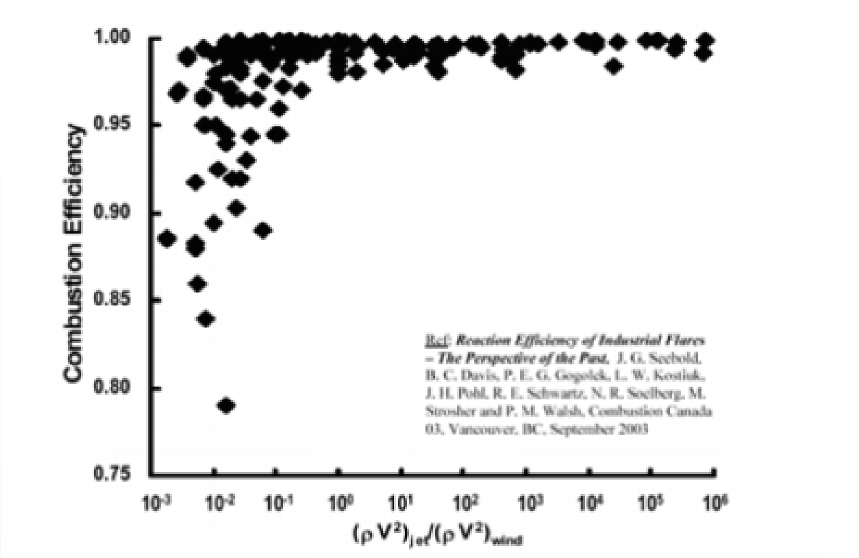


Figure 5-5. Combustion Efficiency vs. Momentum Flux Ratio, Seebold Data Source: (Seebold et al., 2004)

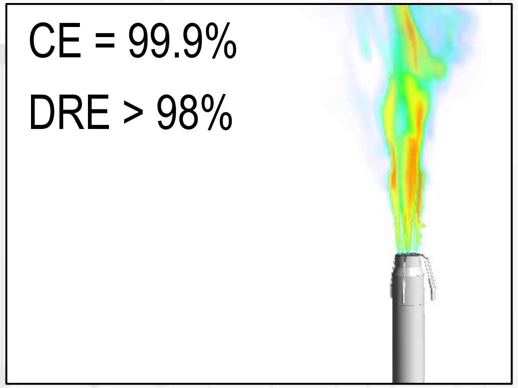
How can this be determined?

- **Flare testing**
  - Limited tests (steady state conditions only)
  - Typically smaller scale
  - Sampling (low resolution information)
  - Environmental influences

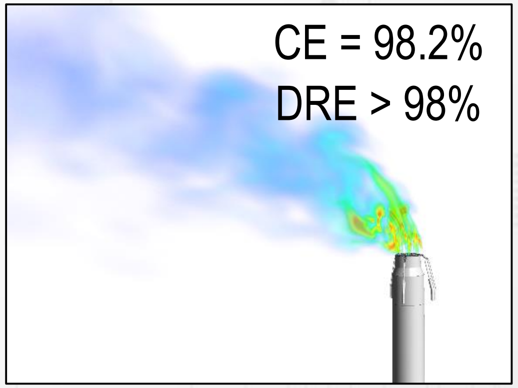
Sampling system on test facility

Flare monitoring camera

- **CFD analysis**
  - Alternative approach compared to flare testing
  - Validated models exist (from flare / experimental testing)
  - Model actual installation
  - 3D map of combustion performance
  - Parametric studies can be conducted easily:
    - *Investigate / establish trends*

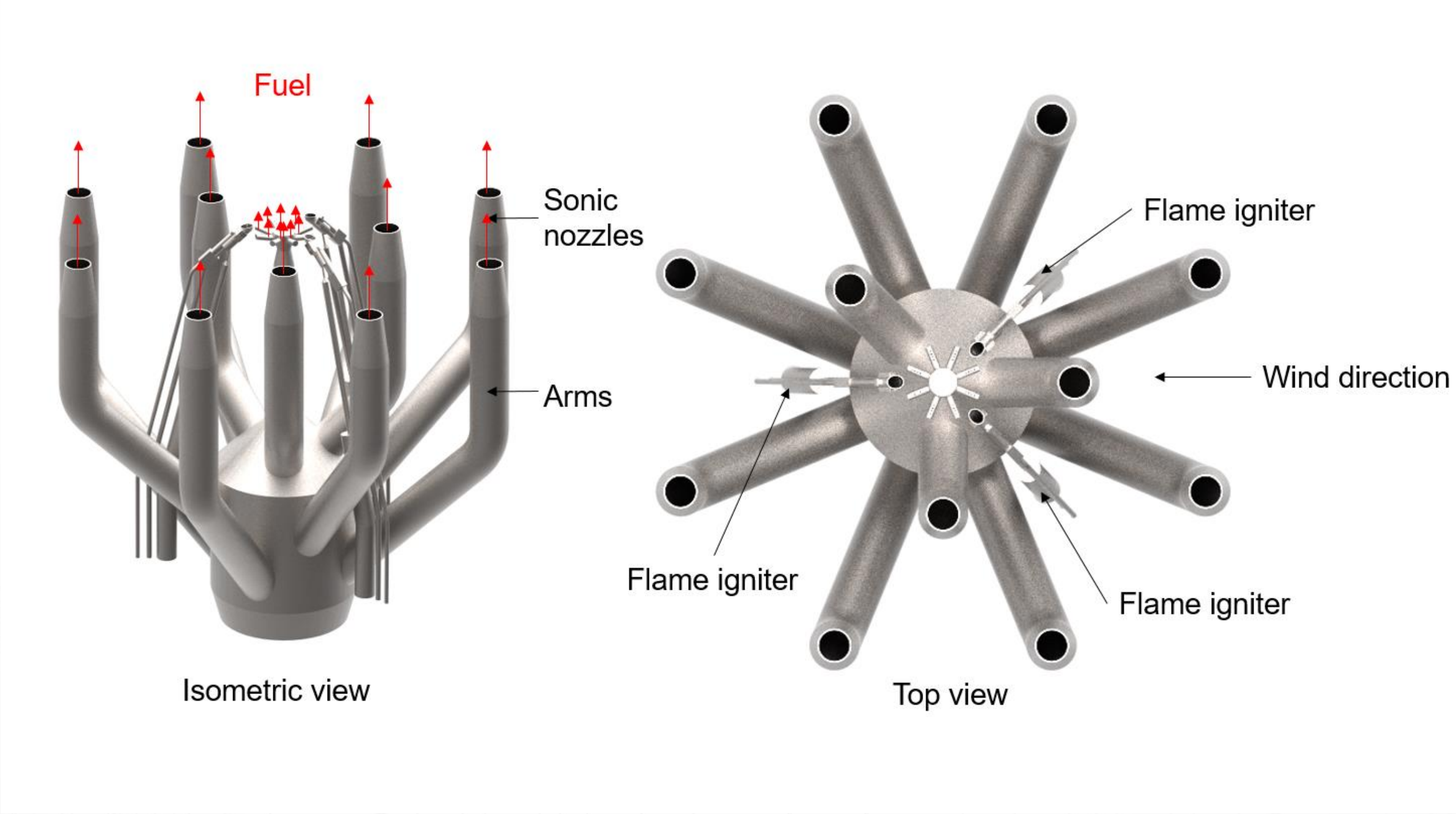


0.5 m/s

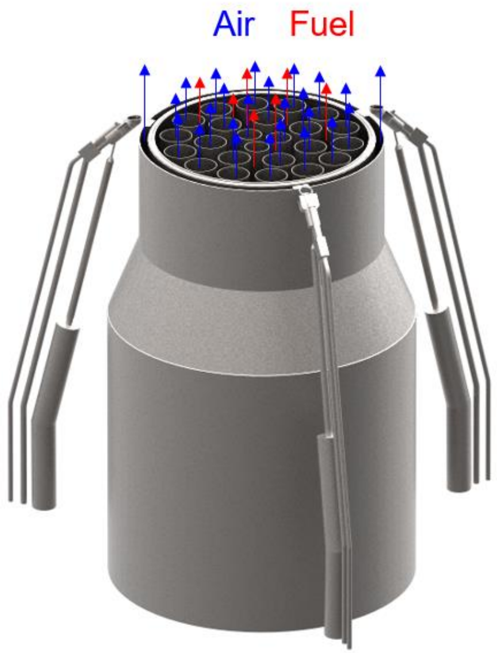


6.0 m/s

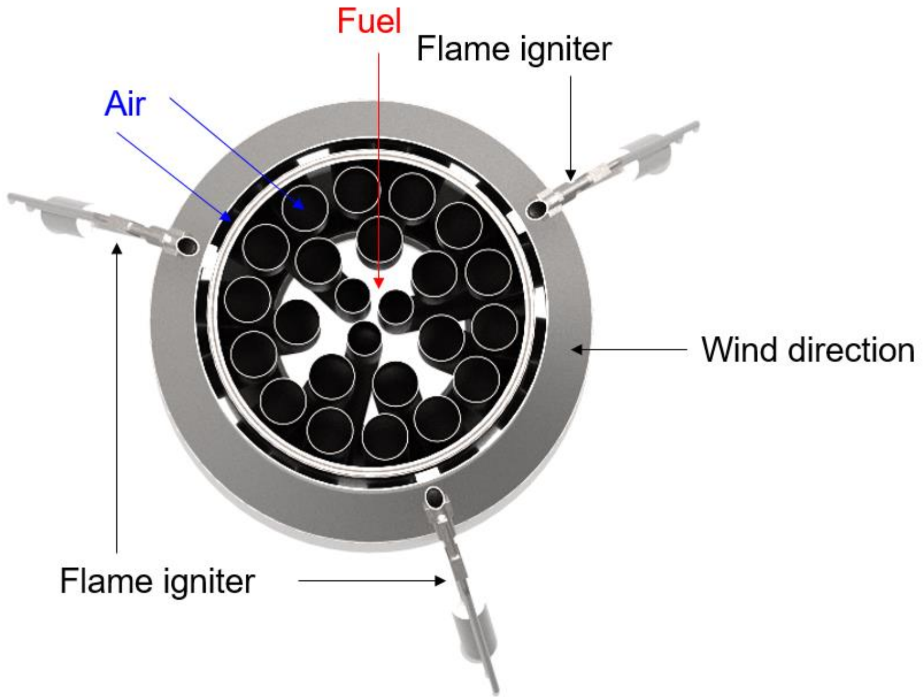
Typical Example of Flare Tip Model



Typical Example of Flare Tip Model



Isometric view



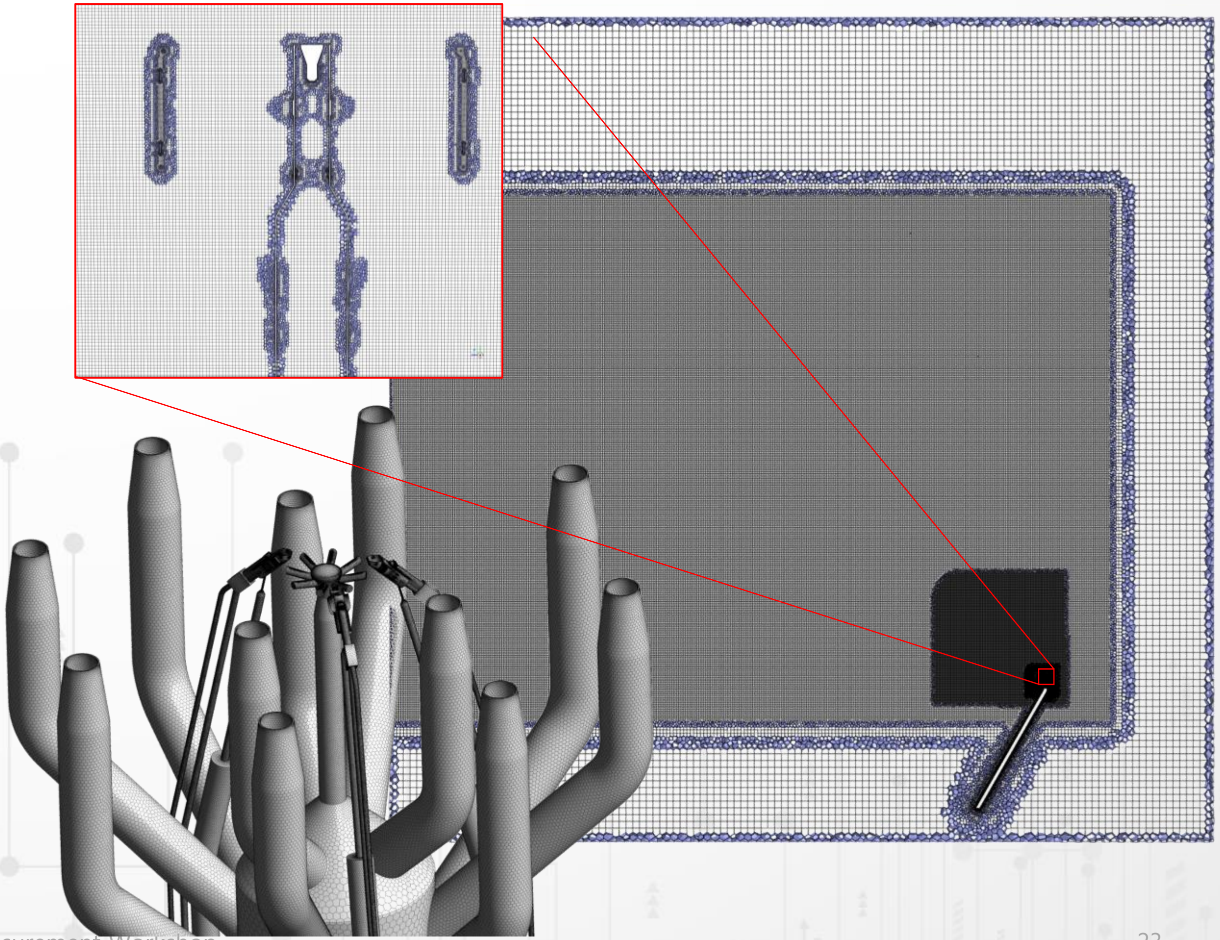
Top view

Mesh resolution

Capture complex geometry and near burner flame dynamics through high quality surface mesh and local refinement

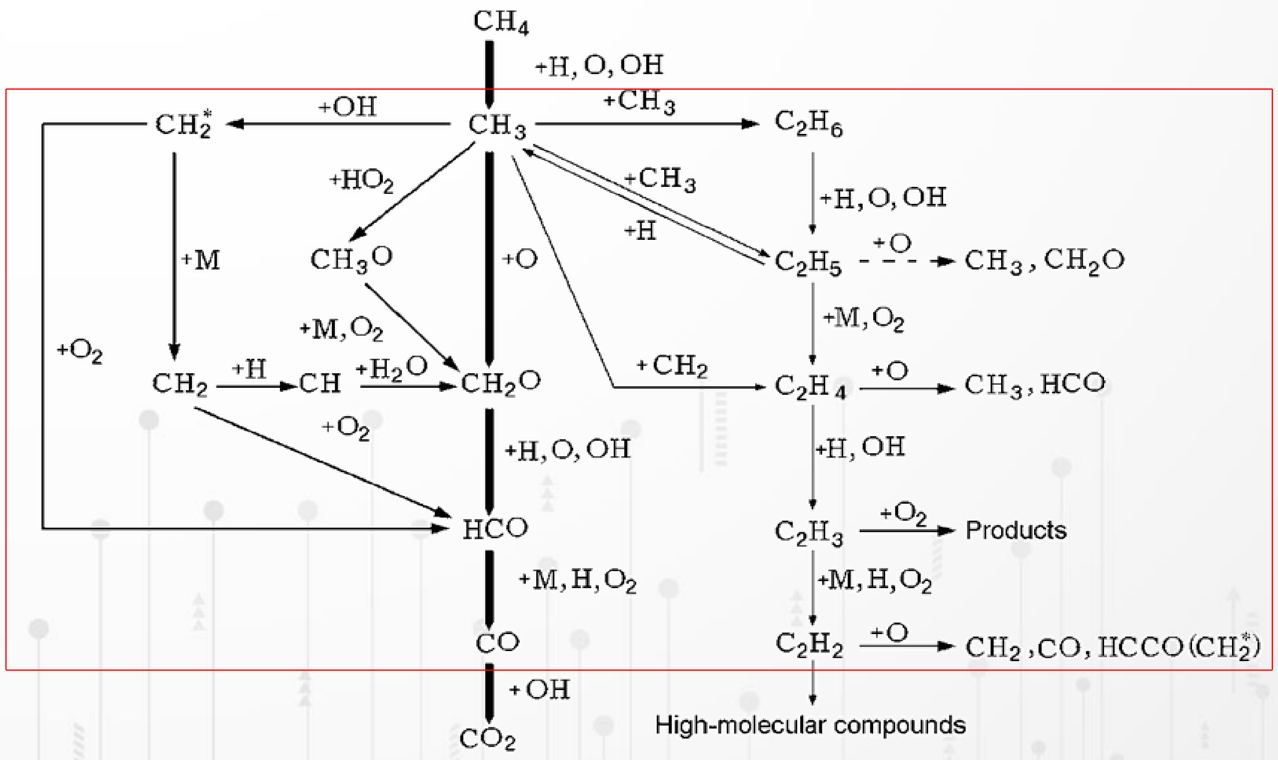
- High quality poly-hexcore meshes between 200 – 400 million cells

- Highly parallelised simulation solved on 1000s of cores



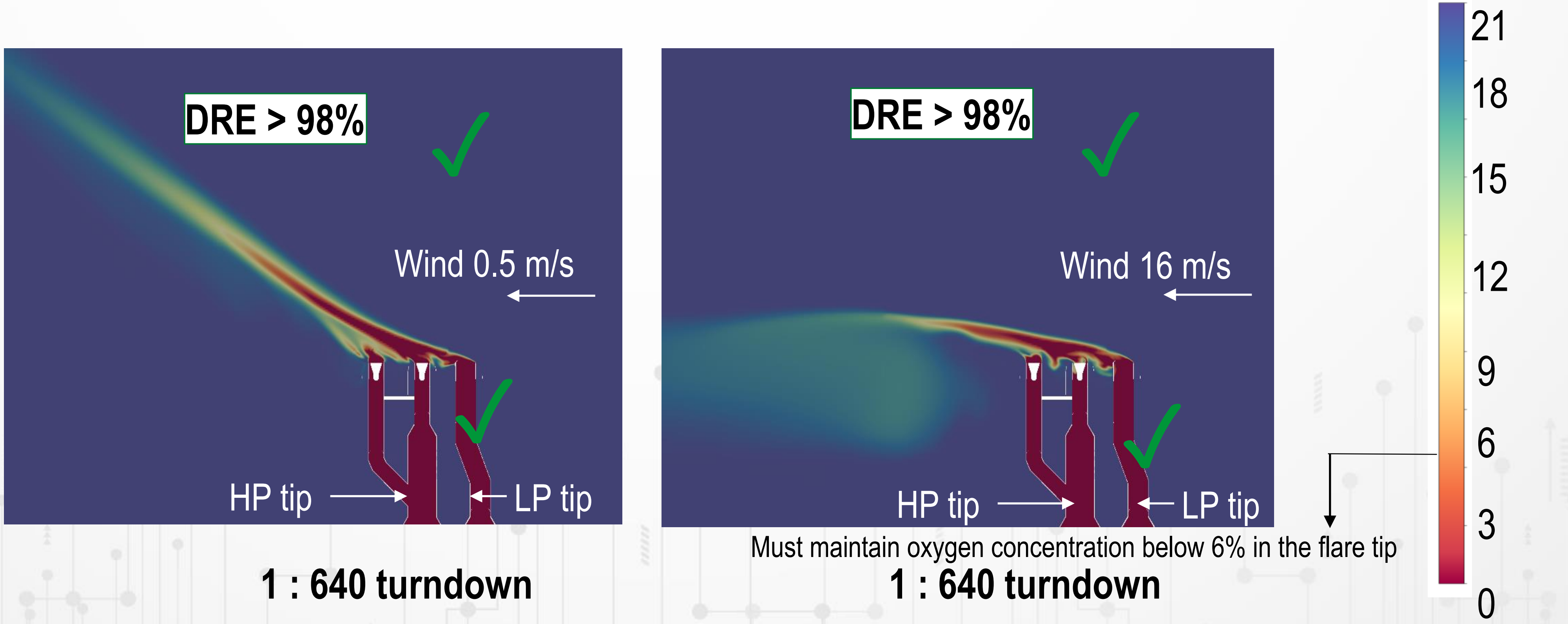
Combustion chemistry

- Detailed combustion mechanisms suited for natural gas and heavier hydrocarbon combustion are utilised
  - 10,000s of reactions
  - ~400 chemical species
- Combustion efficiency, methane destruction efficiency calculation and other pollutants (e.g. CO, NOx) can be calculated



Example | Current operation

Aim: Determine lowest flow gas to purge and DRE > 98%

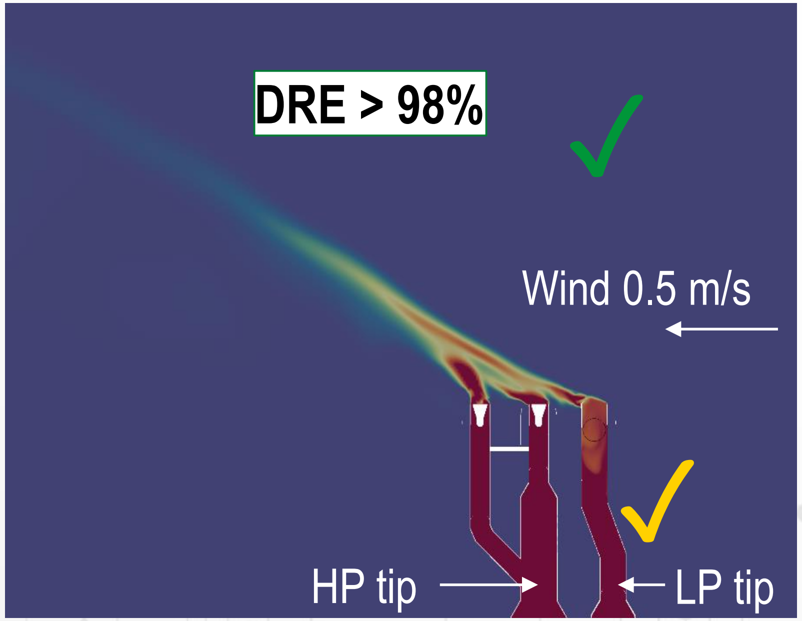


1 : 640 turndown

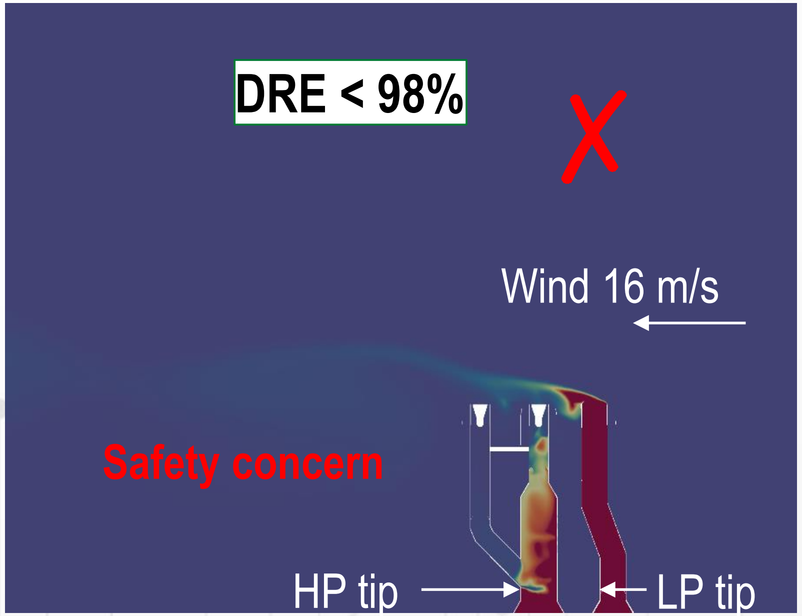
1 : 640 turndown

Example | Turndown

Aim: Determine lowest flow gas to purge and DRE > 98%

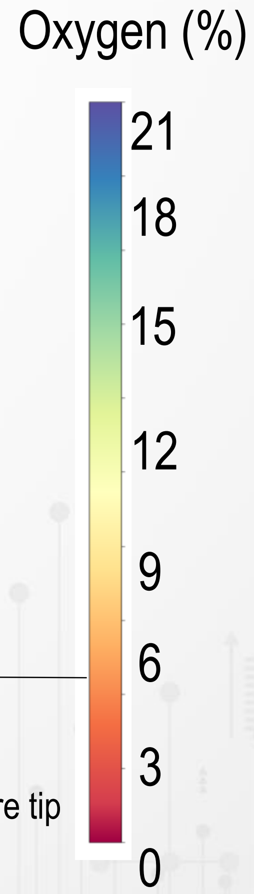


1 : 3200 turndown



Must maintain oxygen concentration below 6% in the flare tip

1 : 3200 turndown



Conclusion

- Reduce the operators overall GHG emissions
- Improved understanding of flare flow rates and emissions
- Parametric studies
  - Reduce flow rates
  - Effect of wind
  - Effect of fuel compositions
  - Highlight potential safety / operation concerns

NORTH SEA FLOW MEASUREMENT WORKSHOP
measuring for the energy transition

TÜV SÜD
National Engineering Laboratory

Contact Us

Marc Laing & Sandy Black
TÜV SÜD National Engineering Laboratory
East Kilbride
Glasgow
G75 0QF
www.tuv-sud.co.uk/nel
Marc.Laing@tuv-sud.co.uk
Sandy.Black@tuv-sud.co.uk
+44(0)1355 593700