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Ignition and Flow Stopping Considerations for the Transmission of Hydrogen in the Existing Natural Gas Network

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Contents

This project was funded by Ofgem and led by Northern Gas Networks as part of the H21 Network Innovation Competition project. The contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.

Introduction

- Summarising some of the work from the H21 project
  - Aim of H21 is to show that the existing natural gas (NG) network can be safely repurposed for hydrogen (H_2)
  - Worked with Northern Gas Networks (NGN) who are a Gas Distribution Network (GDN) in the UK
  - https://h21.green/
- Gas groups (from BS EN ISO 80079-20-1:2019)
  - NG is Group IIA if less than 25% H_2, and IIC if above 25%
  - Possibility from MIC experiments that H_2 in NG between 16 and 25% could be IIB (Janes et al, 2017)

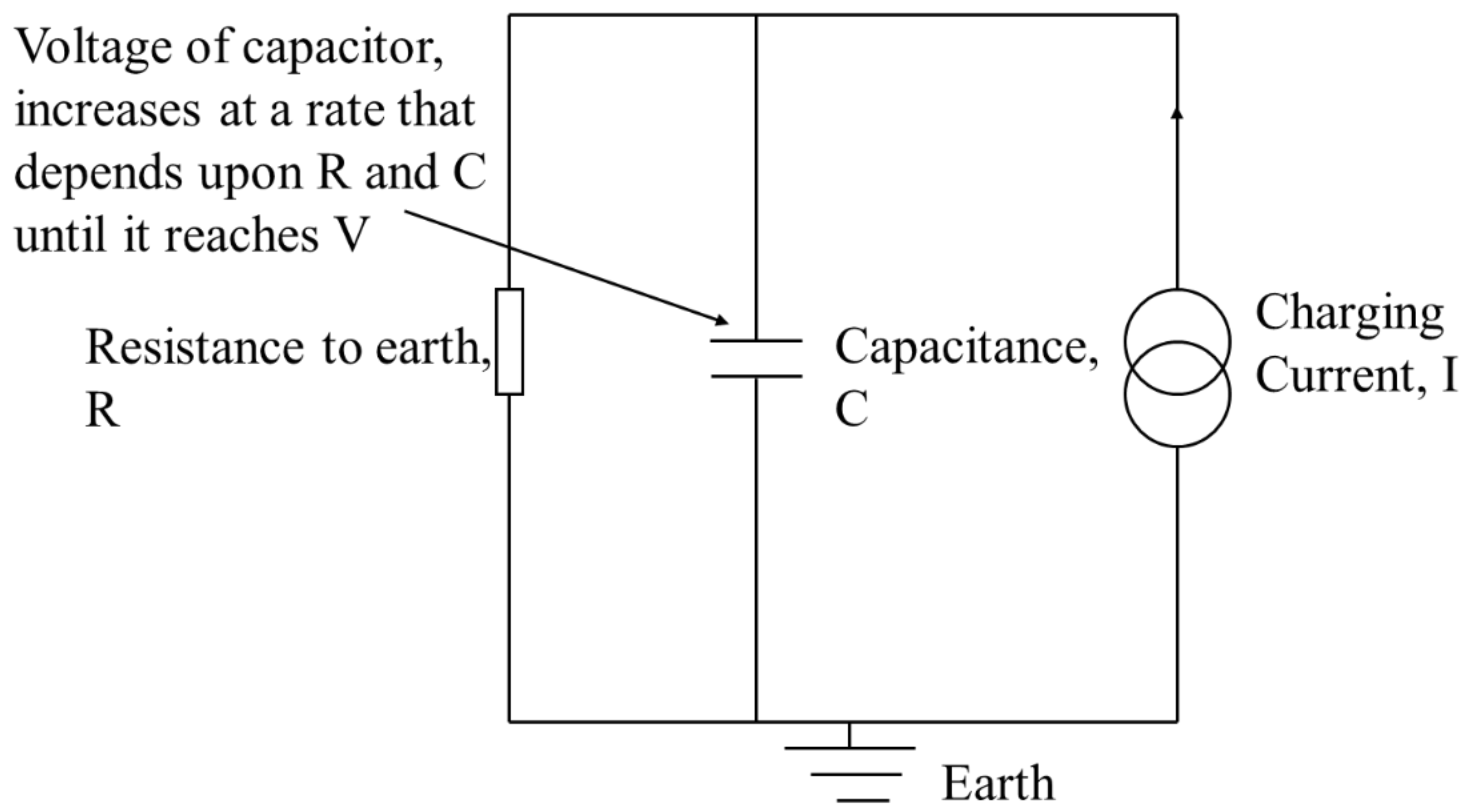
Zones and use of tools

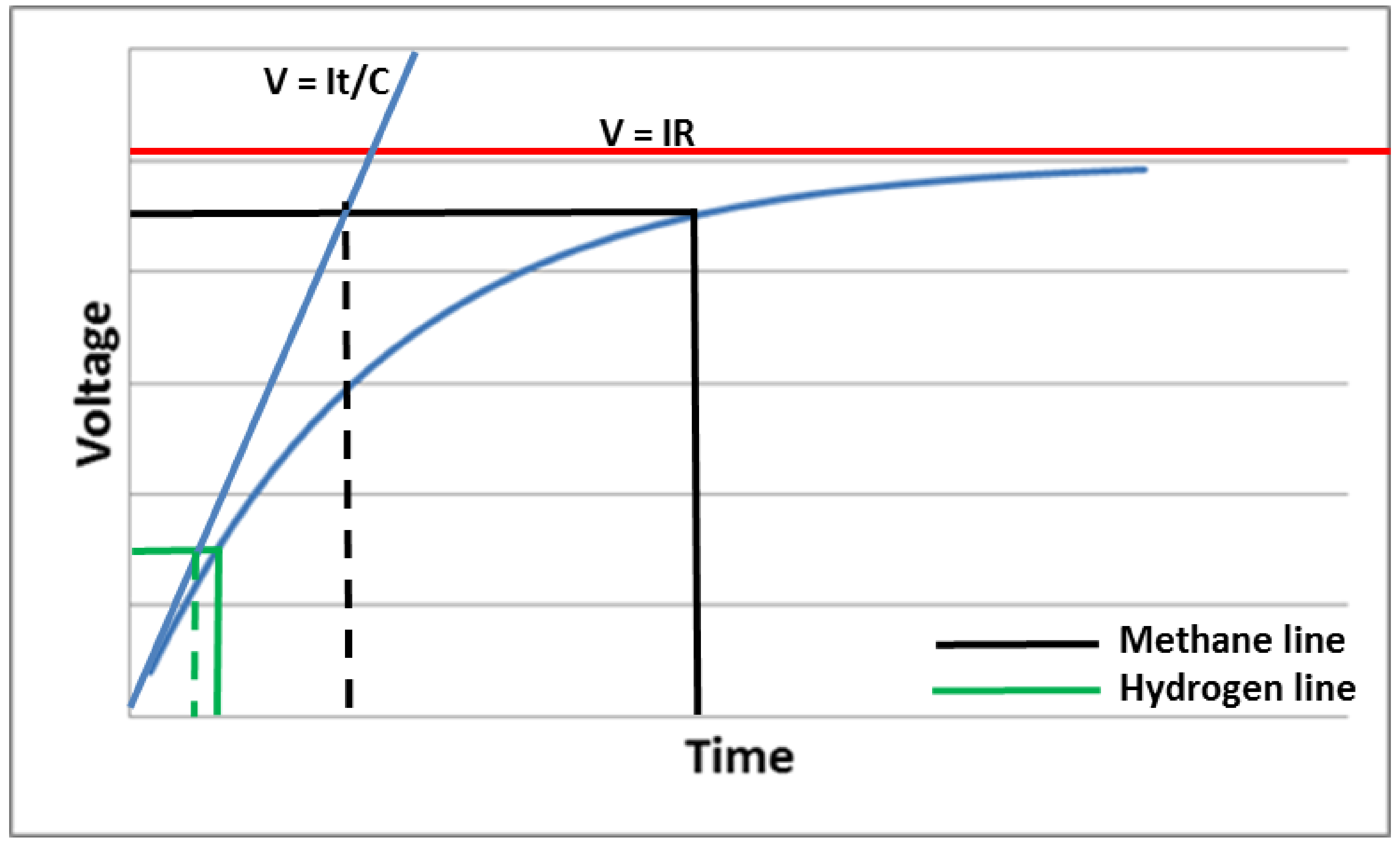
- The table applies BS EN 1127-1:2019 to network operations
    - HSE defined indictive zones to aid comparison
    - This assumes the worst case of metallic pipe, as PE melts below 200°C
- For cutting operations, risk assessments needed to consider the hazards to operatives of cutting into hydrogen containing pipes

	Zone 1	Zone 2
Definition	A flammable atmosphere created occasionally during normal operations	A flammable atmosphere that should not occur during normal operations but is foreseeable
GDN example	Cutting or drilling into a pipe containing gas* Work in the area of a leak, the size of the zone depends on the size of the leak	Work on the outside of a pipe where no breaking of containment is planned Inside a line purged to air held on a single isolation
Natural Gas	Steel tools allowed*	Steel tools allowed
Hydrogen	Steel tools not allowed	Steel tools allowed
*This is assuming hand powered tools where the potential to create multiple sparks is not considered credible.		

Electrostatics

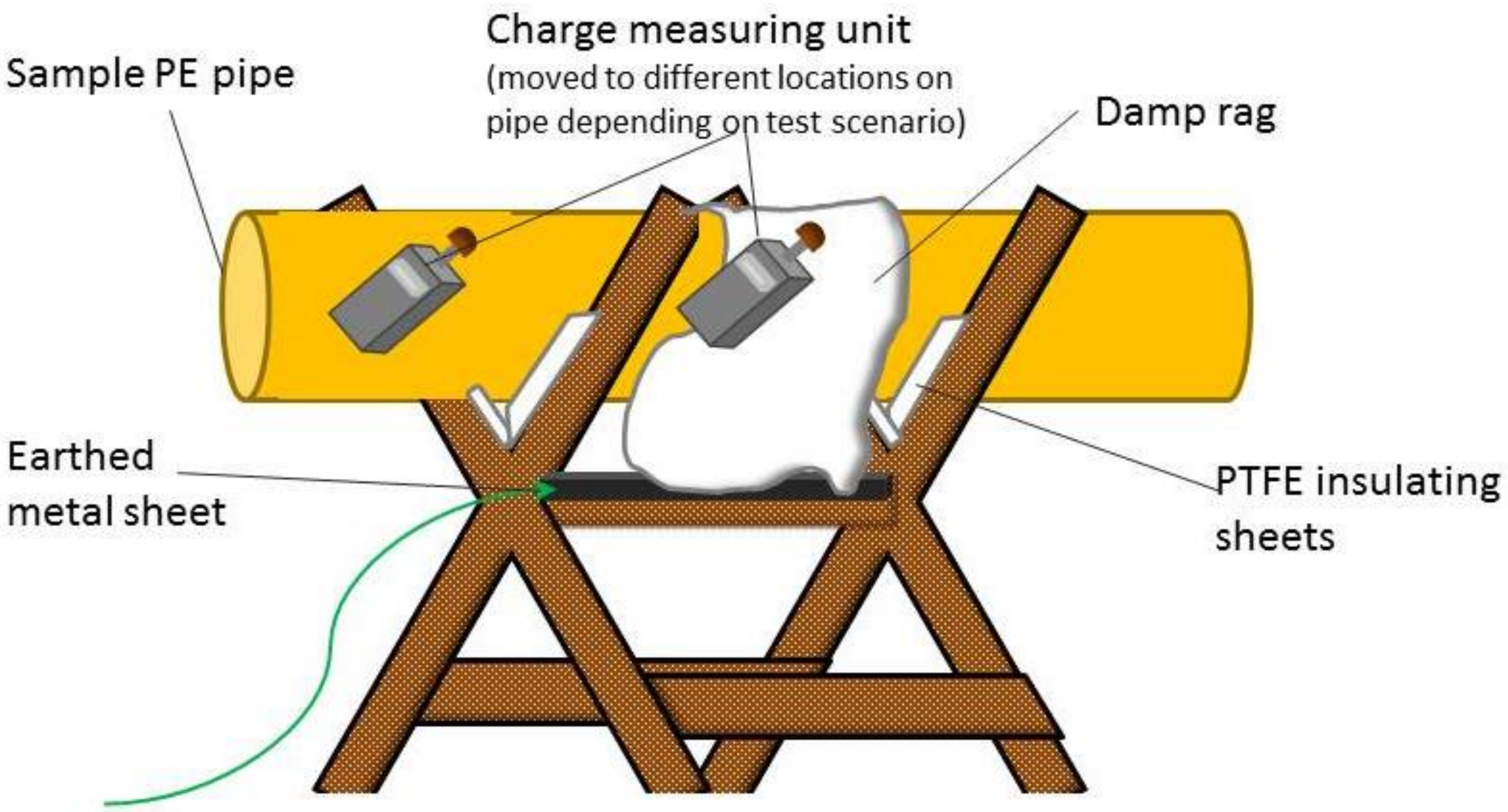
- Electrostatic discharges from conductors (such as people or small metal tools) are large enough that they can ignite both H_2 and NG (due to their large capacitances).
    - However, charging would only need to occur for 30% of the time with H_2 to get an incendive spark
    - For personnel, this risk control can be achieved via appropriate antistatic/electrostatic discharge (ESD) footwear and clothing.
- Wet rag earthing used as a safety precaution when cutting into PE pipes
    - Handling and cleaning of PE can produce large voltages (up to 14 kV) (AGA, 2001)
    - Previously shown that wet towels can reduce this voltage on the outer but not inner surface (Advantica, 2001)
    - This work tested the suitability of wet towel earthing for use with H_2





Electrostatic experiments

- PE pipes from 63 to 630 mm diameter were tribocharged following BS EN 60079-32-2:2015
- Found discharges large enough to ignite both H_2 and methane (using limits from BS PD CLC/TR 60079-32-1:2018)
  - 10 nC for H_2, 60 nC for methane
- Values also compared to Bennett (2010) which tested what size discharges from plastic containers resulted in ignition of flammable mixtures with air
  - Around 30 nC for H_2, 100 nC for methane



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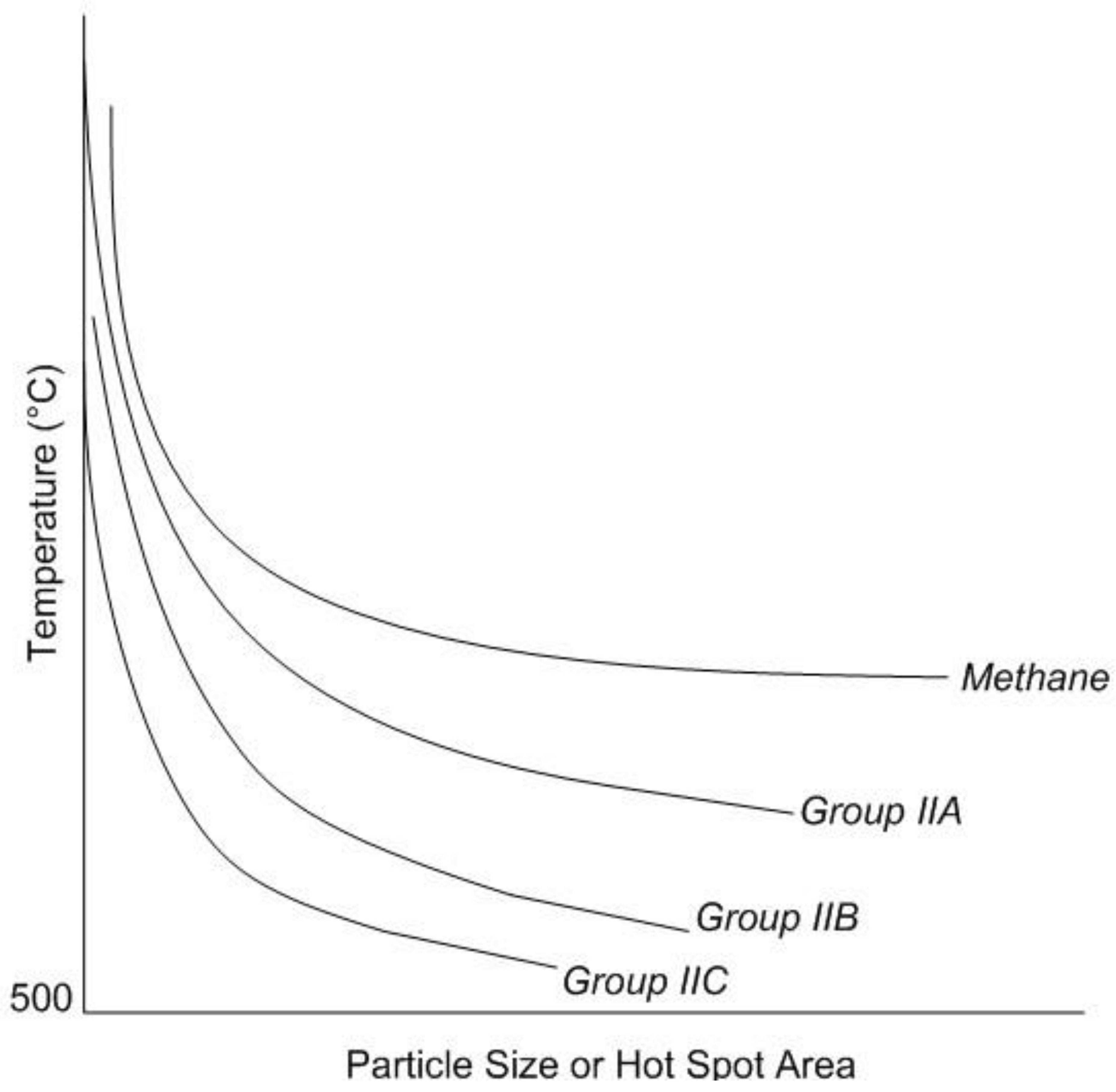
Tribocharging results

- Damp rag removed charge
  - No discharges from it or under it, discharges only observed 100 mm or more away
- Even if the damp rag was not earthed, it removed or reduced the size of the discharge

		63mm Pipe (nC)	250mm Pipe (nC)	630mm Pipe with the outer (removable) layer stripped (nC)	630mm Pipe (nC)
Typical charge obtained before earthing	Avg	-67	-55	-145	-138
	Max	-107	-106	-164	-168
Test 1: Wet rag earthed	Avg	0	0	0	0
	Max	0	0	0	0
Test 2: Wet rag not earthed	Avg	-20	-39	-20	-4
	Max	-43	-106	-69	-12

Frictional ignition

- Ease of frictional ignition linked to size and temperature of hot spot/particle generated
- Methane is more difficult to ignite by frictional ignition than Group IIA gases such as propane
- Minimum ignition energy (MIE) correlates with ease of frictional ignition
    - Expected that 20% H2-NG blend behaves like propane
- No practical difference if the 20% blend is IIA or IIB
    - BS EN 1127-1:2019 only requires different precautions for a IIC gas

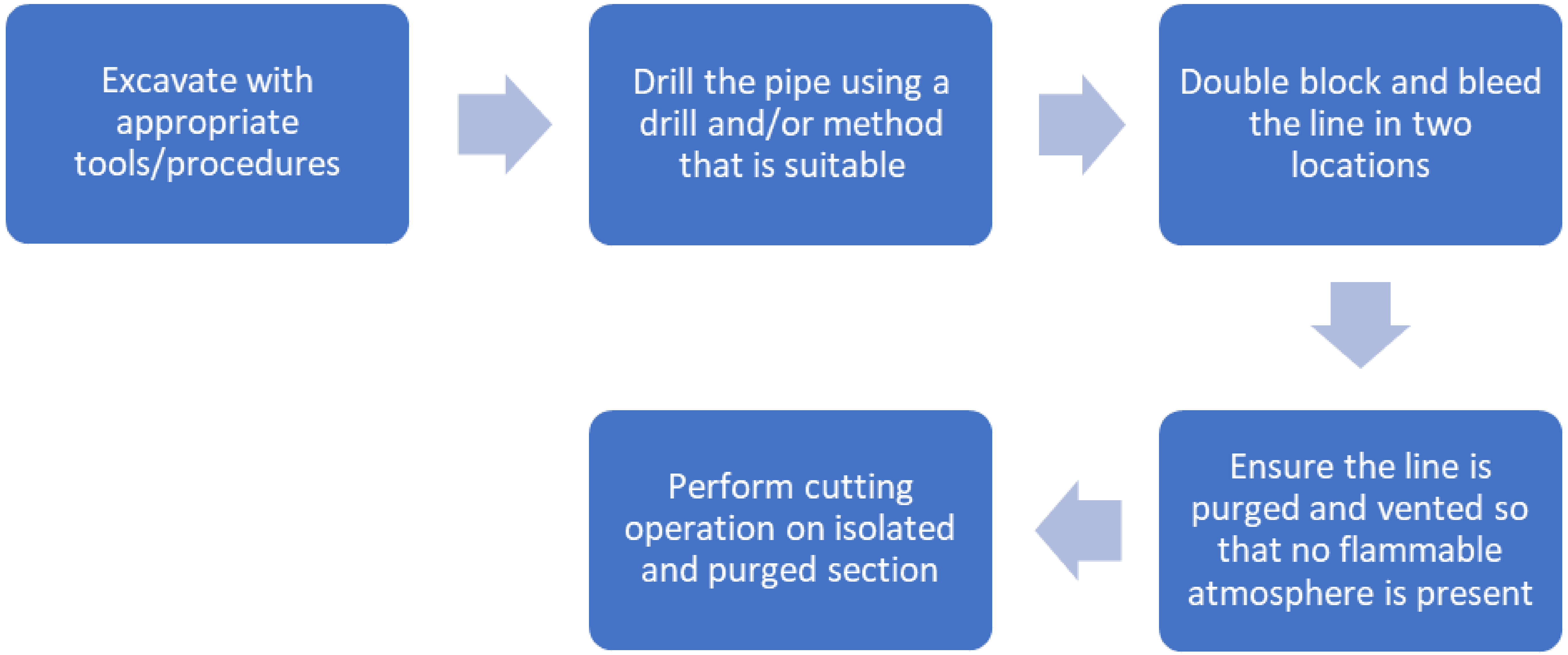


Frictional ignition precautions

- Non-sparking tools are a sensible precaution, but won't entirely eliminate the risks of igniting H_2
    - BS EN 1127-1:2019 requires non-sparking when used in a H_2 Zone 1, but steel tools could be used in a H_2 Zone 2 alongside a live pipe or on a purged section
- Cutting and drilling of pavements/barholing unlikely to generate the surface temperatures required to ignite H_2, but the internals of the equipment could be an ignition source. There are three options to avoid ignitions:
    - Have the motor outside of any flammable regions (or point on metal-metal contact for barholing)
    - Group IIC (or Group IIB + H_2) ATEX rated motors
    - Perform a Mechanical Equipment Ignition Risk Assessment (MEIRA) as per BS EN ISO 80079-36:2016 to demonstrate the suitability of the equipment

Cutting and drilling of live mains

- Proven isolations such as double block and bleed required to use multi-sparking tools
- HSG 253 is the relevant UK reference
- Cutting or drilling of live hydrogen mains in metallic pipe is prohibited by BS EN 1127-1:2019
- If the flammable atmosphere inside the drill body was considered to be of negligible extent (NE), then the use of such equipment could be allowed



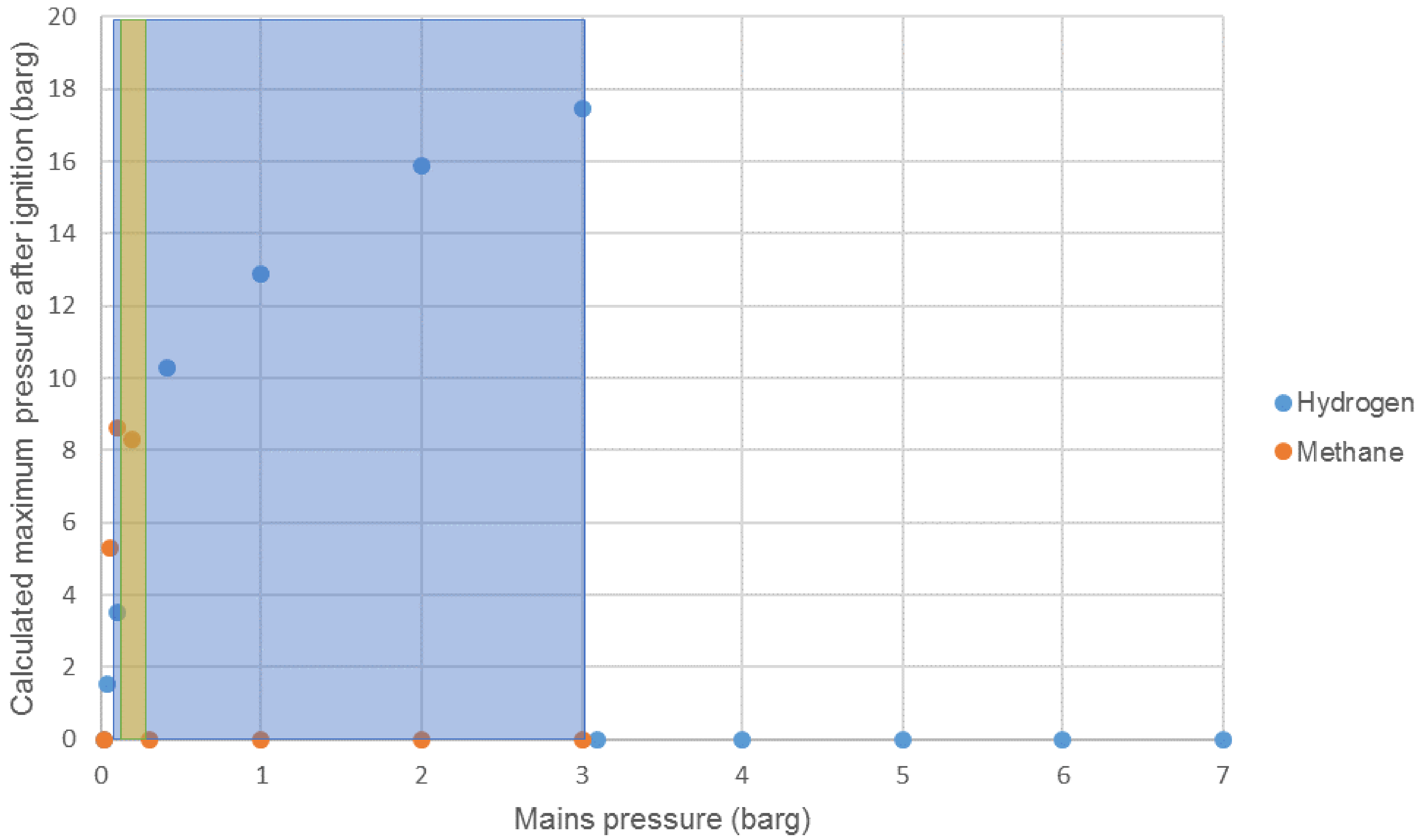
- This assumes the worst case of metallic pipe as PE will melt below 200°C
- Drilling steel can generate 550°C at very high speeds, but 200-250°C for more typical speeds

Achieving NE

- A risk assessment would be required looking at the quantity of hydrogen released
    - Both metallic and PE pipes
- BS EN IEC 60079-10-1:2021 [6] defines negligible extent (NE): “An example of zone NE is a natural gas cloud with an average concentration that is 50 % by volume of the LFL and that is less than 0.1 m^3.”
- As the LEL of H_2 is 4%, a volume of 0.002 m^3 (at ambient pressure) or less is needed for NE to be concluded

Under pressure mains drilling

- Flammable atmospheres formed in equipment between 46 to 200 mbarg for NG, but 41 mbarg to 3 barg for H_2
- To achieve NE, there are three options:
  - Create a vacuum in the drill body
  - Purge the drill with an inert gas
  - Use a drill with a MAWP that is above the overpressure that can be generated



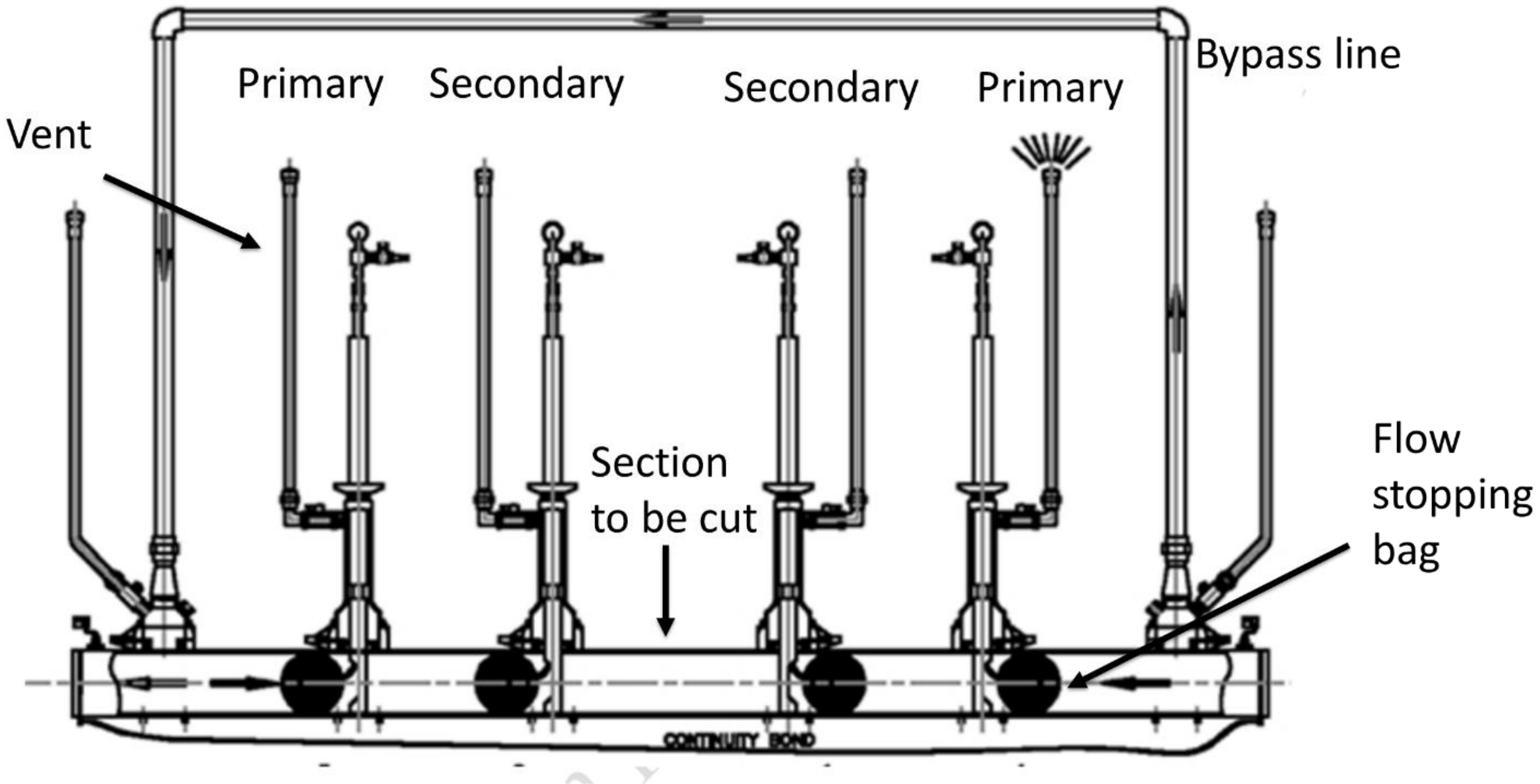
Drill speeds

- 0.7 m/s was previously found by experiment to ignite H_2 (Hawksworth et al, 2005)
    - Compare with the 1 m/s limit placed by BS EN ISO 80079-36:2016 for friction ignition
- Need to limit drill speeds to 0.7 m/s if not encapsulated

Drill size (mm)	RPM to achieve 0.7 m/s	Leak rate of hydrogen through hole at 22 mbar (g/s)	Vz (m^3)	Distance to ½ LFL (m)
3	4456	0.13	0.7	2.6
5	2673	0.37	3.4	4.3
9	1485	1.21	19.9	7.8
10	1336	1.50	27.3	8.6

Flow stopping – basis of safety

- Basis of safety should change for H_2
    - Prevent formation of an ignitable atmosphere rather than avoid re-pressurisation and/or excess losses
    - Due to increased sensitivity of H_2 to ignition
- Current UK Gas Industry Standards (GIS) look at leak rates passed one stop at maximum usage pressure
    - New criterion developed based upon differential pressure across the second stop
    - Calculated from testing this needs to be greater than 0.2 mbarg



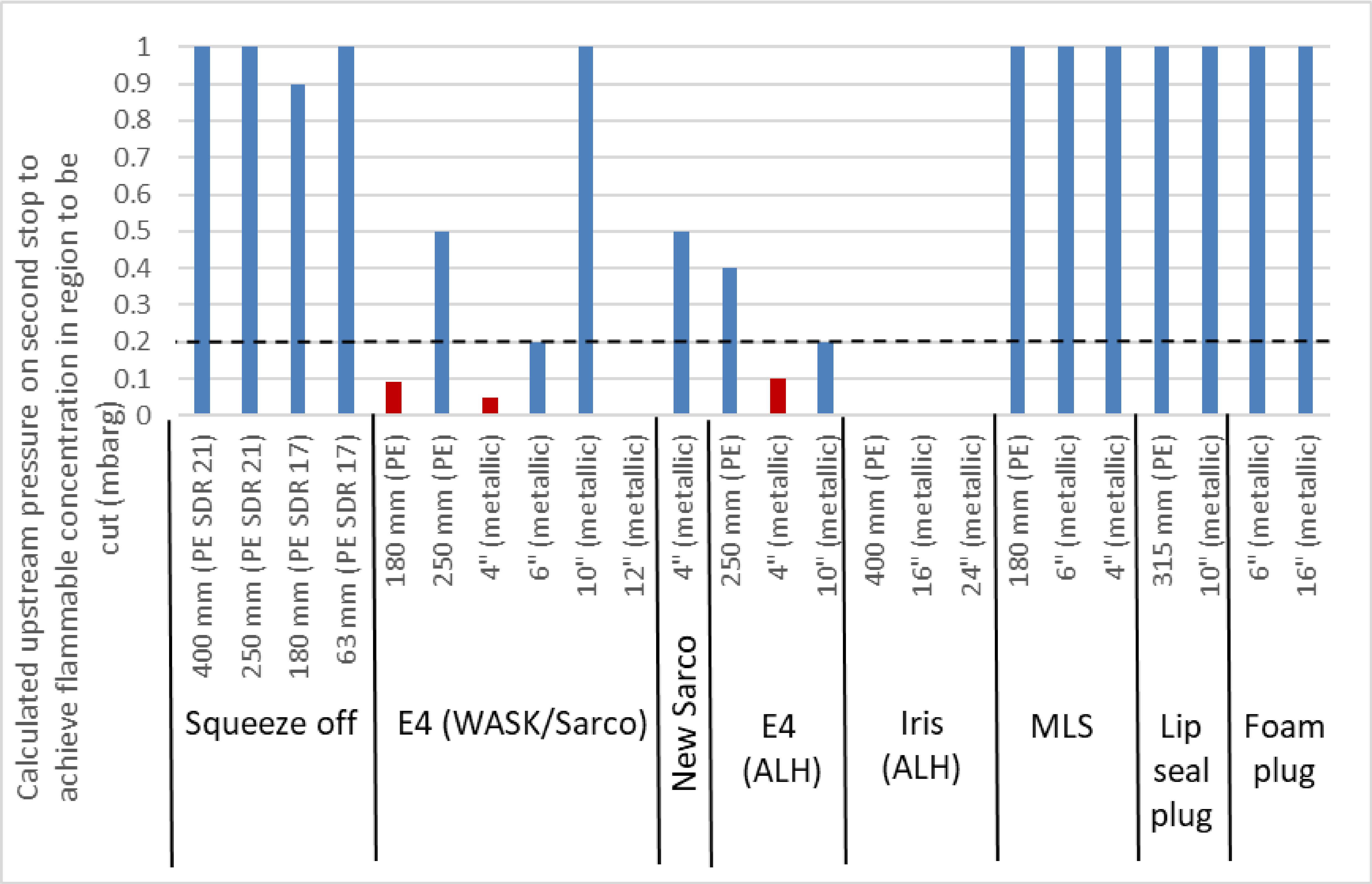
Flow stopping experiments

The following method can be used to calculate the maximum allowable flows past the secondary stop:

1. The theoretical upper limit of the time required to make a cut has been estimated
2. The flow rate to just achieve an ignitable mixture (5.5 vol% H_2, BS EN ISO 10156:2010) in the pipework volume to be cut can be calculated (permissible volume flow past the secondary stop)
3. The flows can be measured experimentally for a single stop for a range of pressures
4. The flow rates from 3 can be used to calculate the differential pressure needed across the secondary stop to achieve the maximum flows calculated in 2

Flow stopping results

- Some stopping methods performed well, others require some development
- Promoting laminar leakage leads to better performance at low pressures
- The results of this testing programme were obtained for particular samples of pipe under given ambient conditions.



Conclusions

- Electrostatics
    - Wet towel earthing has been shown to be effective
- For friction ignition
    - Non-sparking tools are a sensible precaution
    - Limits should be placed on motors
    - Under pressure drills can be used provided certain conditions are met
    - Drill speeds should be limited to 0.7 m/s when not encapsulated
    - (No significant changes for the 20% blend)
- Flow stopping
    - Basis of safety needs to change for H_2 to preventing an ignitable atmosphere
    - New criterion developed
    - Testing of commonly used methods performed

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