

VAPOUR CLOUD EXPLOSIONS FROM THE IGNITION OF METHANE/HYDROGEN/AIR MIXTURES IN A CONGESTED REGION

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INTRODUCTION

NATURALHY – potential for hydrogen distribution within existing natural gas pipeline networks

- **This work funded by Shell Hydrogen B.V.**
- **Hydrogen mixed with methane**
- **Change in explosive properties**

AIM

- **Measure over-pressures produced by premixed clouds in a repeated pipe congestion array**
- **Determine the amount of hydrogen which can be added to methane without a large increase in explosion overpressure**

EXPERIMENTAL PROGRAMME

- **Perform experiments igniting mixtures of methane, hydrogen and air in a repeated pipe congestion rig.**
- **Measure the overpressures produced by the different mixtures.**

EXPERIMENTAL PROGRAMME

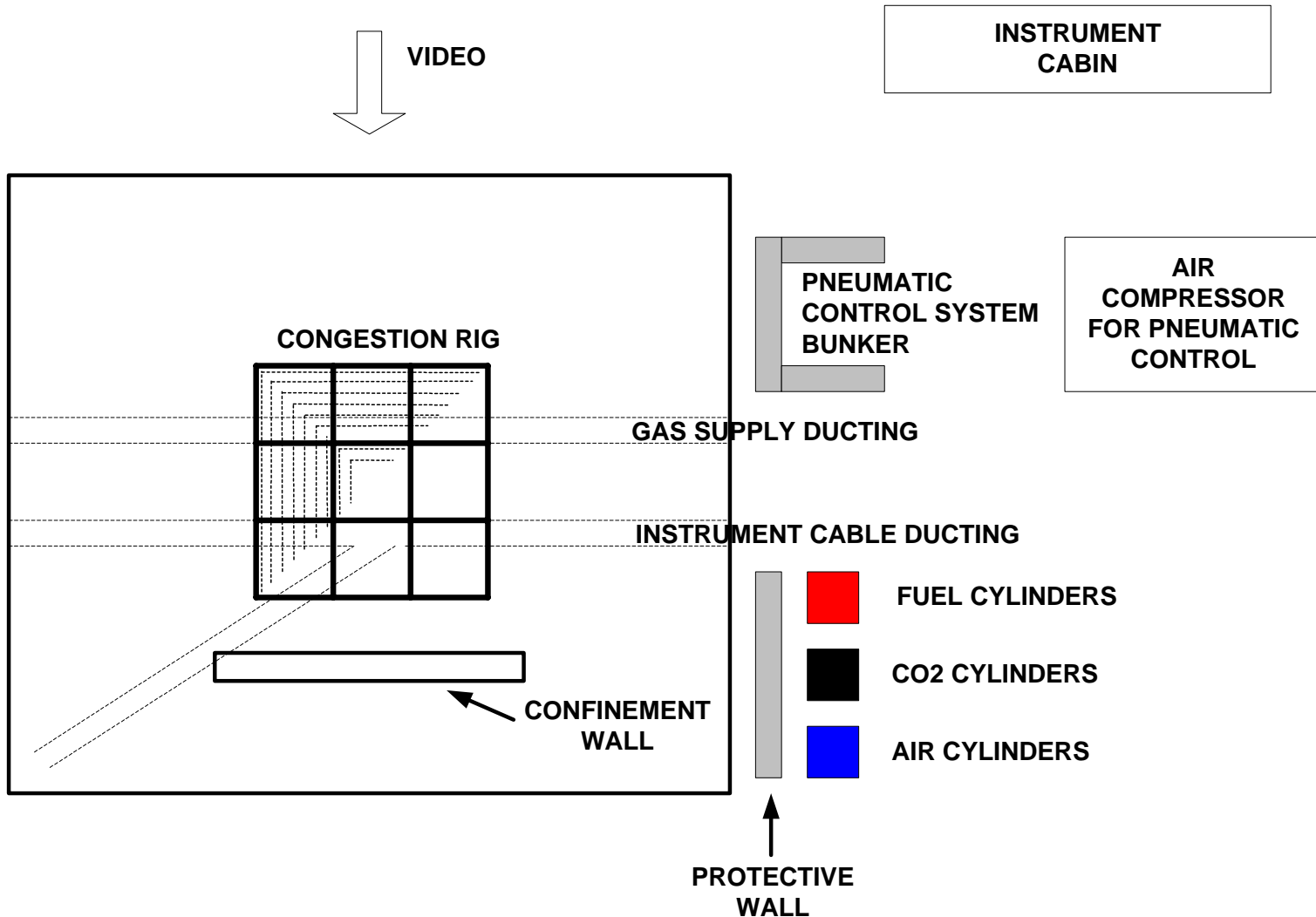
- **Mixtures chosen**
 - 100% hydrogen
 - 25% methane 75% hydrogen
 - 50% methane 50% hydrogen
 - 75% methane 25% hydrogen
 - 100% methane
- **Nominal equivalence ratio – 1.1 for methane mixtures. 1.2 for 100% hydrogen.**

CONGESTION RIG

- **3 m x 3 m x 2 m metal framework structured to consist of 18 one cubic metre units**
- **Bottom units fitted with 9 layers of vertical bars**
- **Top units fitted with 7 layers of criss-crossed horizontal bars**
- **Rig wrapped in plastic film to hold in gas**



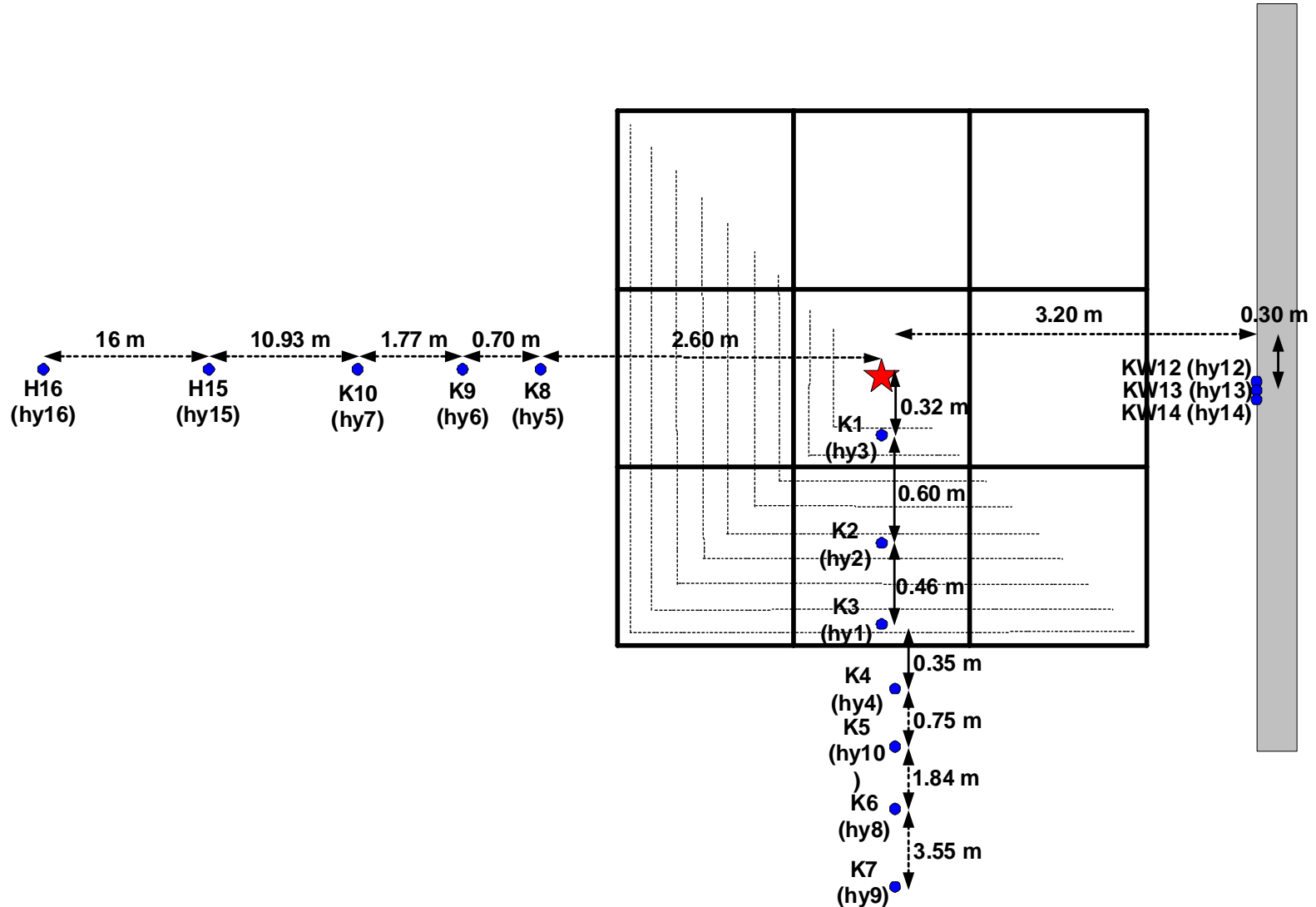
TEST FACILITY



Measurements within congestion rig

- **Temperature**
- **Humidity**
- **IR methane analyser**
- **Paramagnetic oxygen analyser**
- **8 x electro-chemical oxygen sensors**

PRESSURE SENSORS



Gas mixtures

- **Certified gas mixtures used (hydrogen / methane) made to order by BOC.**
- **Gas mixture injected into rig via air amplifiers to entrain air**
- **Oxygen and methane concentration monitored until required equivalence ratio obtained**

TRIAL EQUIVALENCE RATIOS

Test name	Certified proportion of hydrogen in mixture (%)	Nominal equivalence ratio	Actual* equivalence ratio
NATHY_01	100	1.2	1.28
NATHY_02	0	1.1	1.06
NATHY_03	50.9	1.1	1.06
NATHY_04	25.5	1.1	1.09
NATHY_05	75	1.1	1.1

* Calculated from mean depleted oxygen concentration

PHOTOGRAPHS

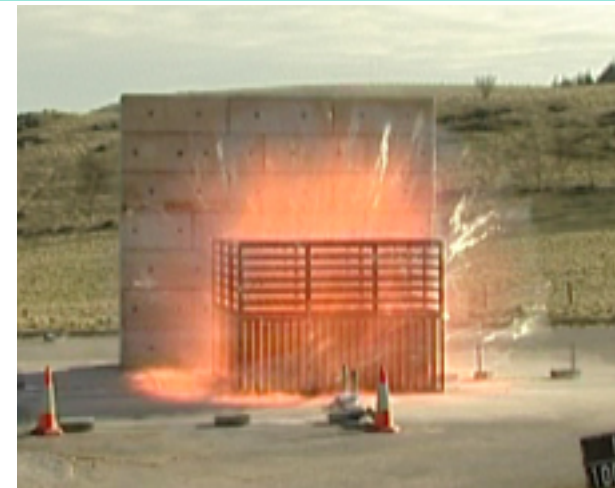
2nd frame after ignition



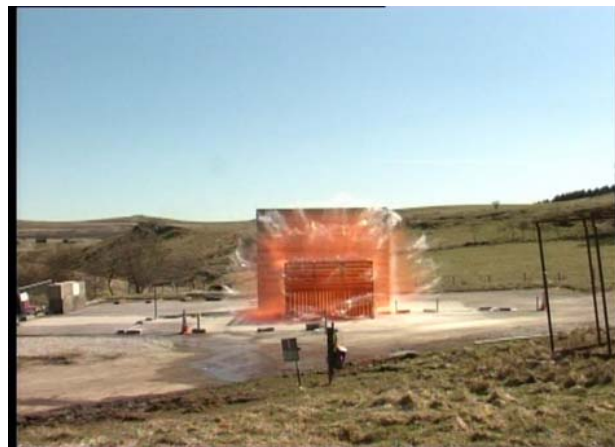
100% methane



25% hydrogen



51% hydrogen



75% hydrogen



100% hydrogen

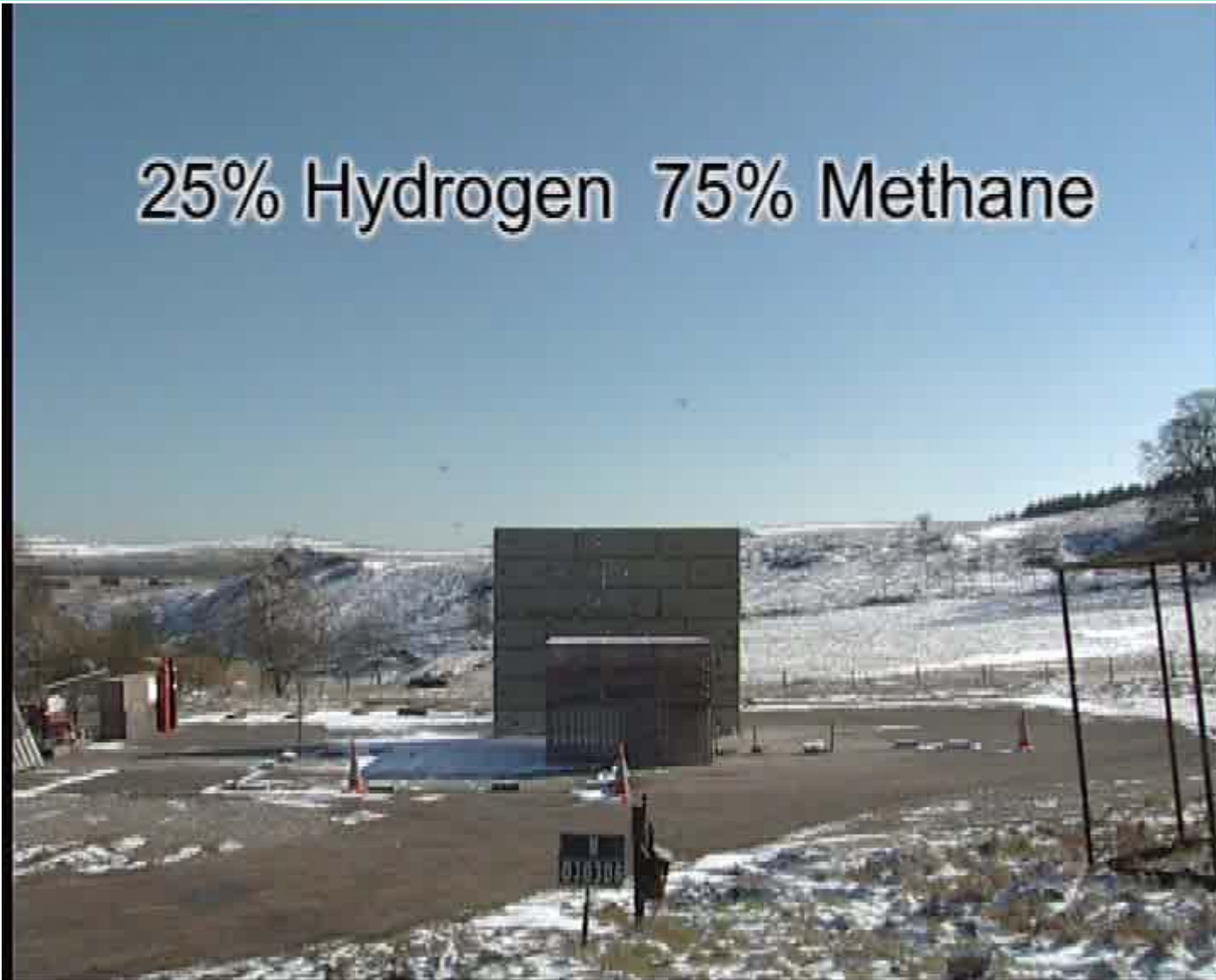


HEALTH & SAFETY
LABORATORY

100% Methane



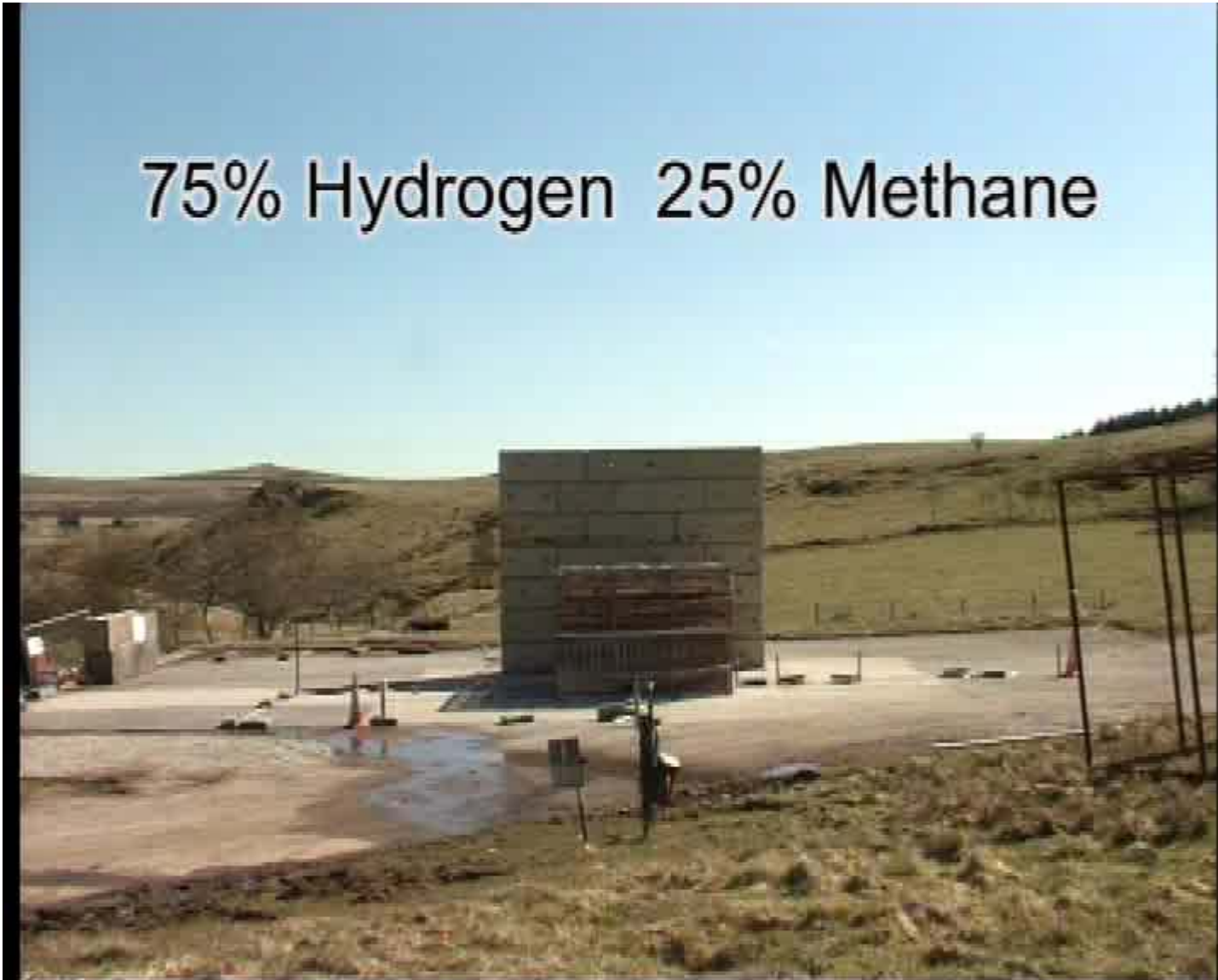
25% Hydrogen 75% Methane



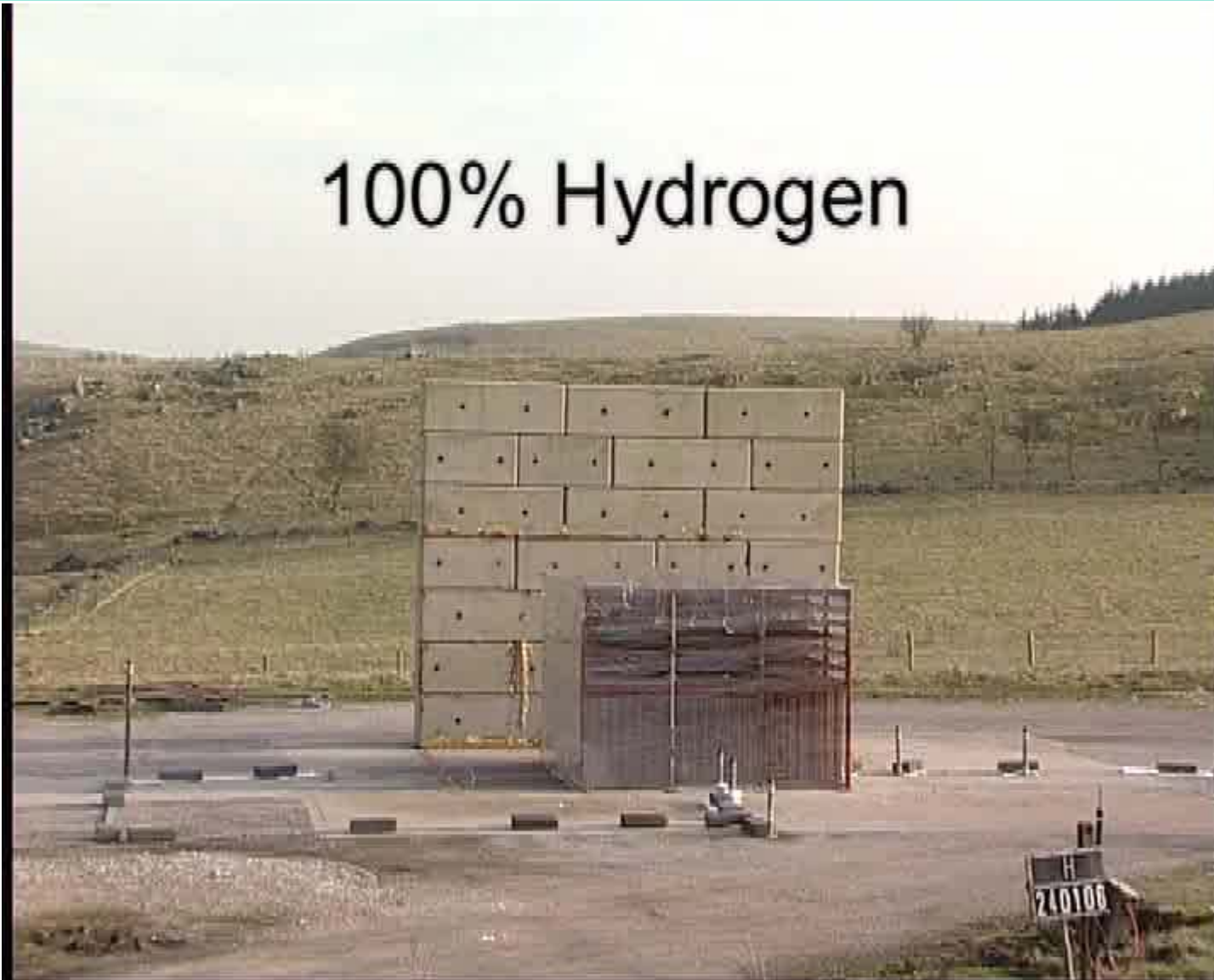
50% Hydrogen 50% Methane



75% Hydrogen 25% Methane

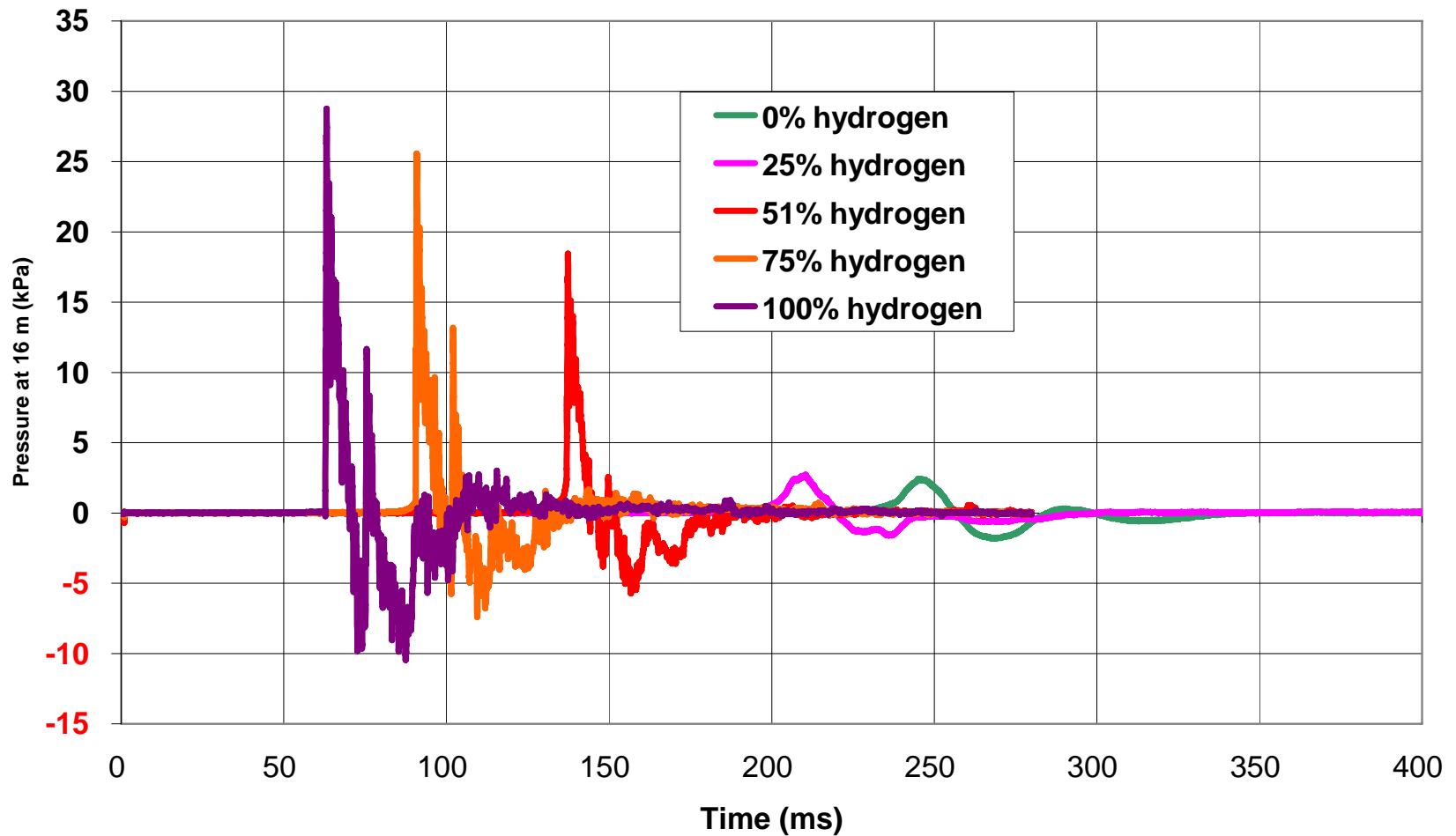


100% Hydrogen



PRESSURE DATA AT 16 METRES

Pressureat16m.xls



DETONATION OF HYDROGEN

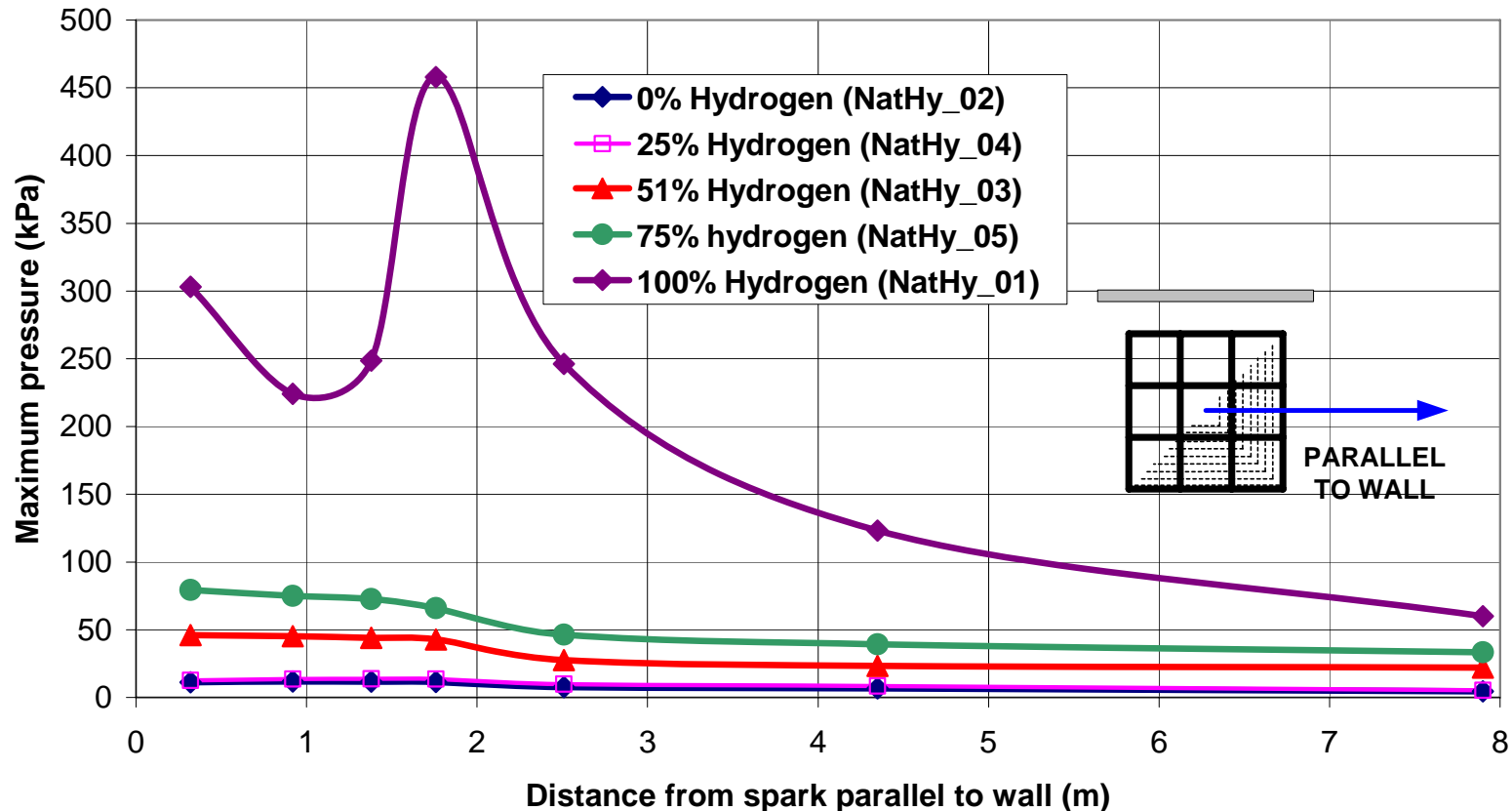
- For 100% hydrogen
 - Pressure 3.03 bar just inside and 4.58 bar just outside rig
 - Plastic shredded into narrow strips (20.5 ± 6.7 mm)
- Groethe et al. (2002) found:
 - 21 mm for a 20% hydrogen no-obstacle detonation test
 - explosive charge initiation
 - 13 mm for a 30% hydrogen with obstacle test
 - spark initiation with 10.9% volume repeated pipe blockage (c.f. 4.4%)
 - 8 mm for a 30% hydrogen no-obstacle detonation test
 - explosive charge initiation



MAXIMUM PRESSURES

Inside and near rig (parallel to wall)

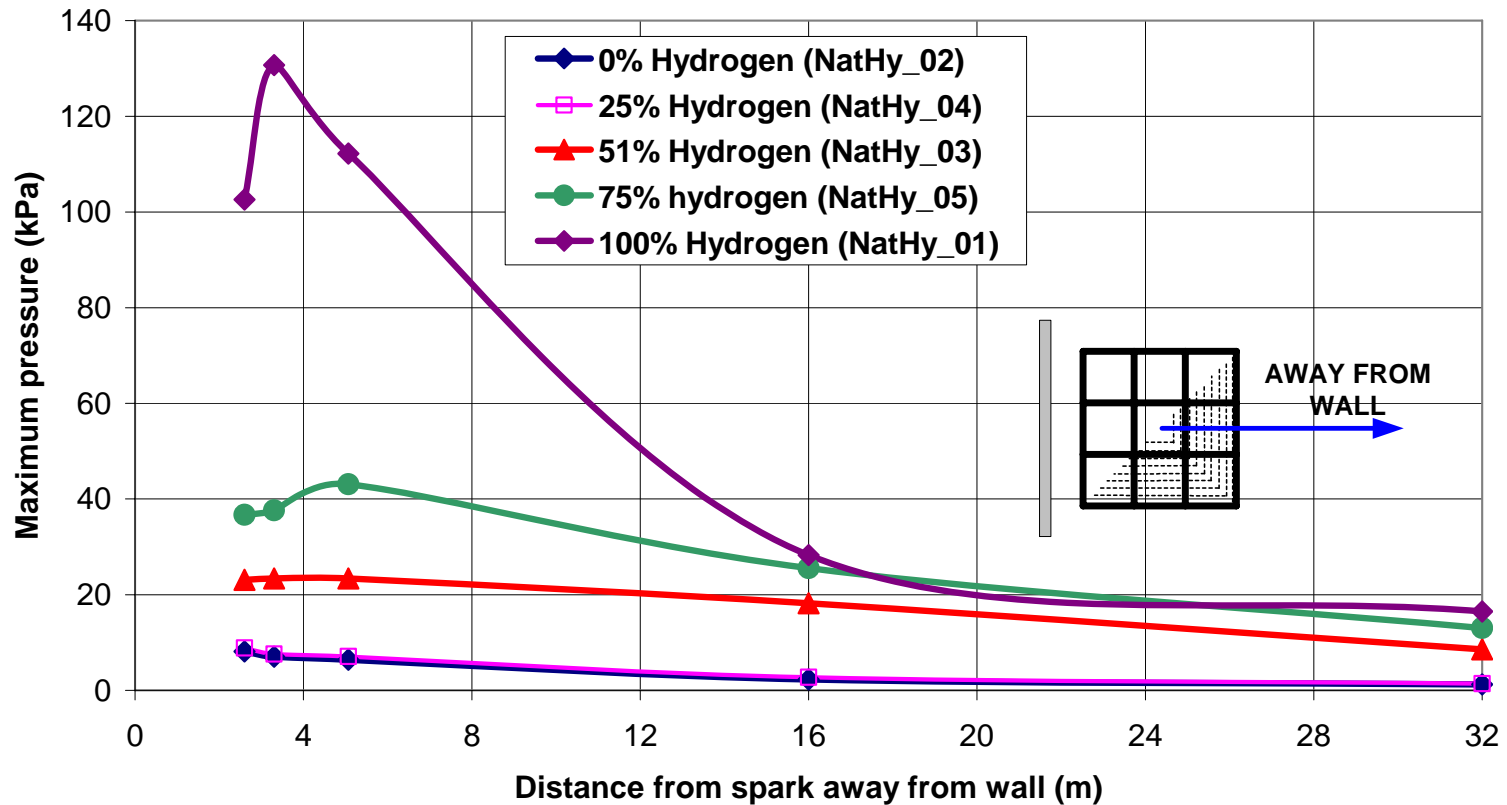
MethaneHydrogen_comparison.xls



MAXIMUM PRESSURES

Far field (away from wall)

MethaneHydrogen_comparison.xls



CONCLUSIONS

- For 100% hydrogen transition to detonation occurred at the corners of the rig
- Only 0.02 bar difference between 0% & 25% H₂
 - 0.12 bar ca. 0.14 bar
- 50% hydrogen gives ca. 3.5 times the pressure given by methane
 - 0.44 bar inside rig

CONCLUSIONS (2)

- **Explosion effects from the mixtures correlate reasonably with mass of hydrogen in the mixture.**
- **Results suggest maximum overpressures generated in large scale trials by methane hydrogen mixtures containing up to 25% (volume) hydrogen may not be much more than those generated by methane alone.**