

ERGOS

Extended Research for Guidance on Separation Distance

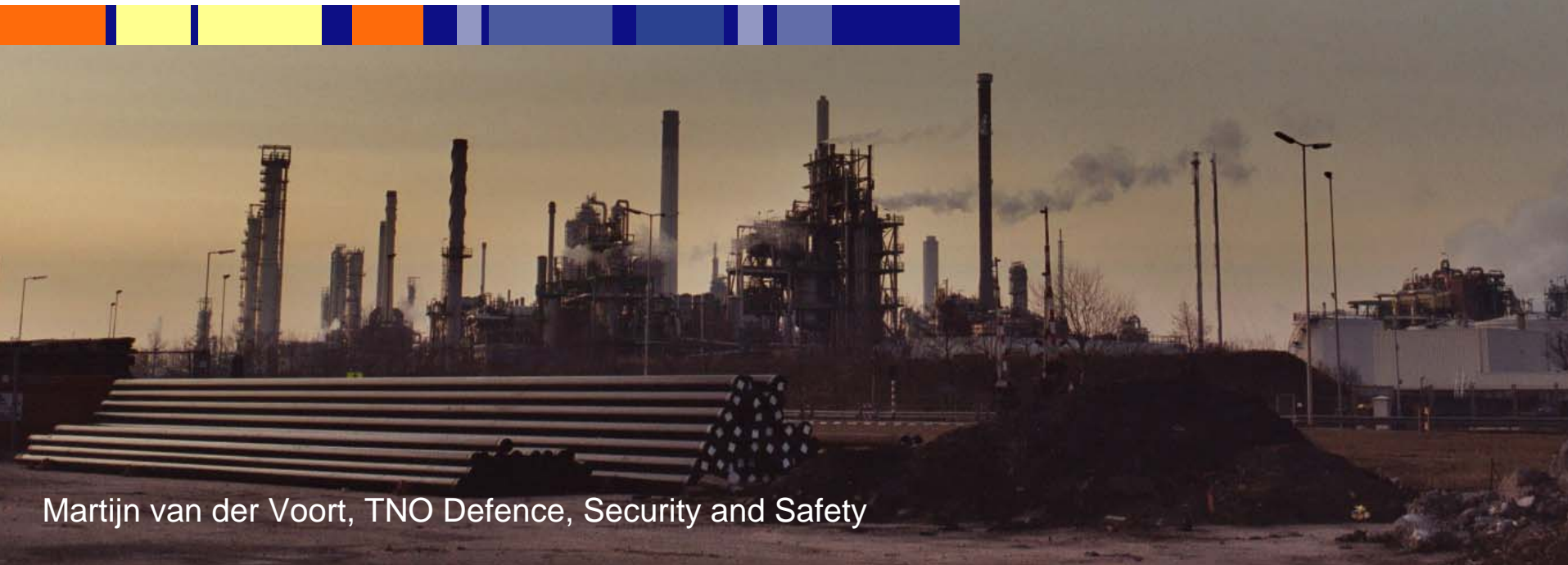
Experimental program performed by TNO and Shell Global Solutions

UKELG meeting, 30th of March 2007

TNO | Knowledge for business



Martijn van der Voort, TNO Defence, Security and Safety



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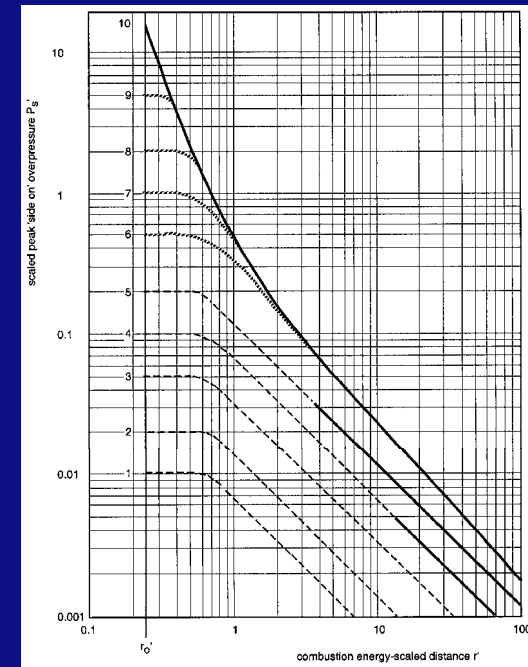
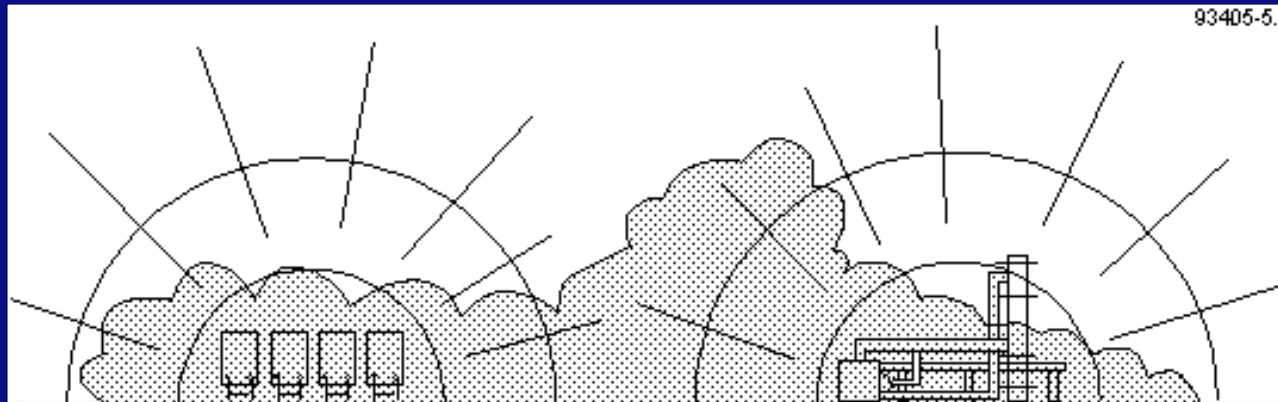


Ethylene, Rig 2



Background of the ERGOS project

- **Multi Energy Method (1984)**
 - In gas explosions overpressure is only generated in obstructed areas



- **Two important quantities (charge strength and size)**
 - Charge strength
 - Research programs MERGE (1992), EMERGE (1996)
 - Resulted in GAME correlation (1995)
 - Charge size
 - Research program RIGOS (2000 - 2002)
 - ERGOS (2003 - 2006)

Background of the ERGOS project

Separation Distance (SD) between obstructed areas is important in gas explosion scenarios



- SD in a plant is represented by a donor-acceptor configuration
- Two definitions of the **Critical Separation Distance (CSD)**
 1. The minimum distance between two areas of congestion that results in just two separate blast waves
 2. The minimum distance between two areas of congestion such that a gas explosion in one will not amplify the explosion overpressure in the other

The ERGOS objectives

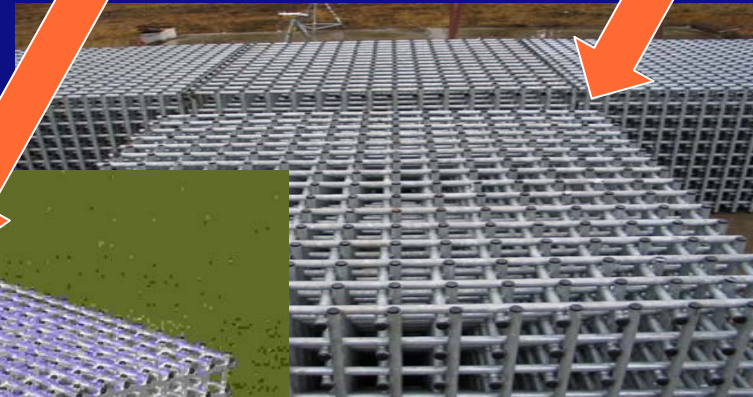
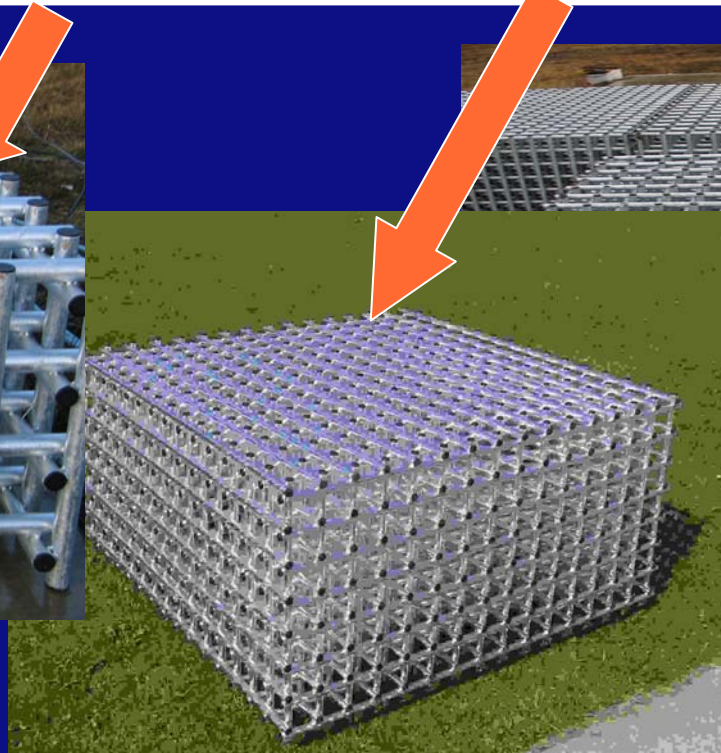
- **Experimental investigation of the CSD**
 - based on second definition
- **CSD determination for**
 - Various fuels (methane, propane, ethylene, hydrogen)
 - Various rig types (rod diameter, density)
 - Presence of a pipe rack
 - Influence of scale
- **CSD based on 2 test types**
 - A1 test (reference test with stand-alone acceptor)
 - CSD test (donor-acceptor test)



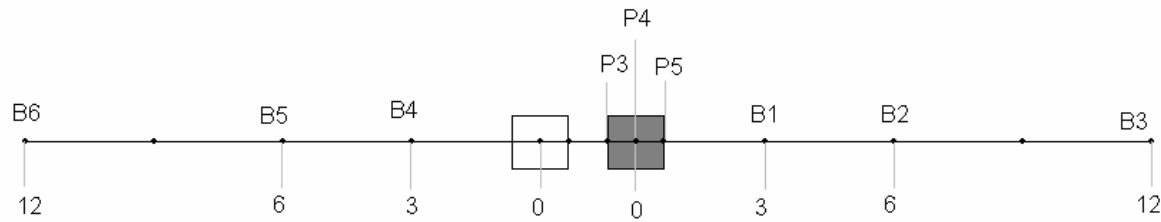
The ERGOS objectives

- Rig types

	Rig 1	Rig 5	Rig 2	Rig 3	Rig 4	Rig 6 (= 4+3+4)
Size (m ³)	1.4×1.4×0.7	1.4×1.4×0.7	1.4×1.4×0.7	1.4×1.4×0.7	1.4×1.4×0.7	4.2×1.4×0.7
Pipe diameter (m)	0.06	0.045	0.035	0.02	0.02	0.02
Number of rods	6×6×3	8×8×4	10×10×5	16×16×8	20×20×10	Combi
Pitch (m)	0.23	0.175	0.14	0.09	0.09	Combi



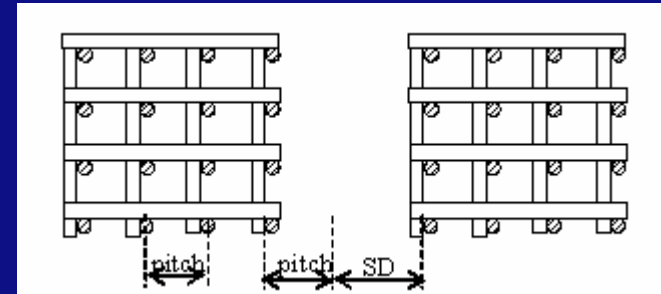
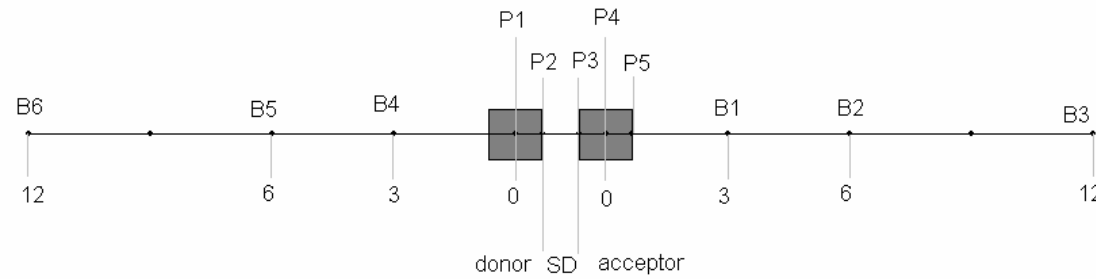
A1 – Test type



Rig 3, propane



CSD – Test type



- SD = distance – pitch
- SD varied to find CSD

Rig 3, propane

The ERGOS objectives

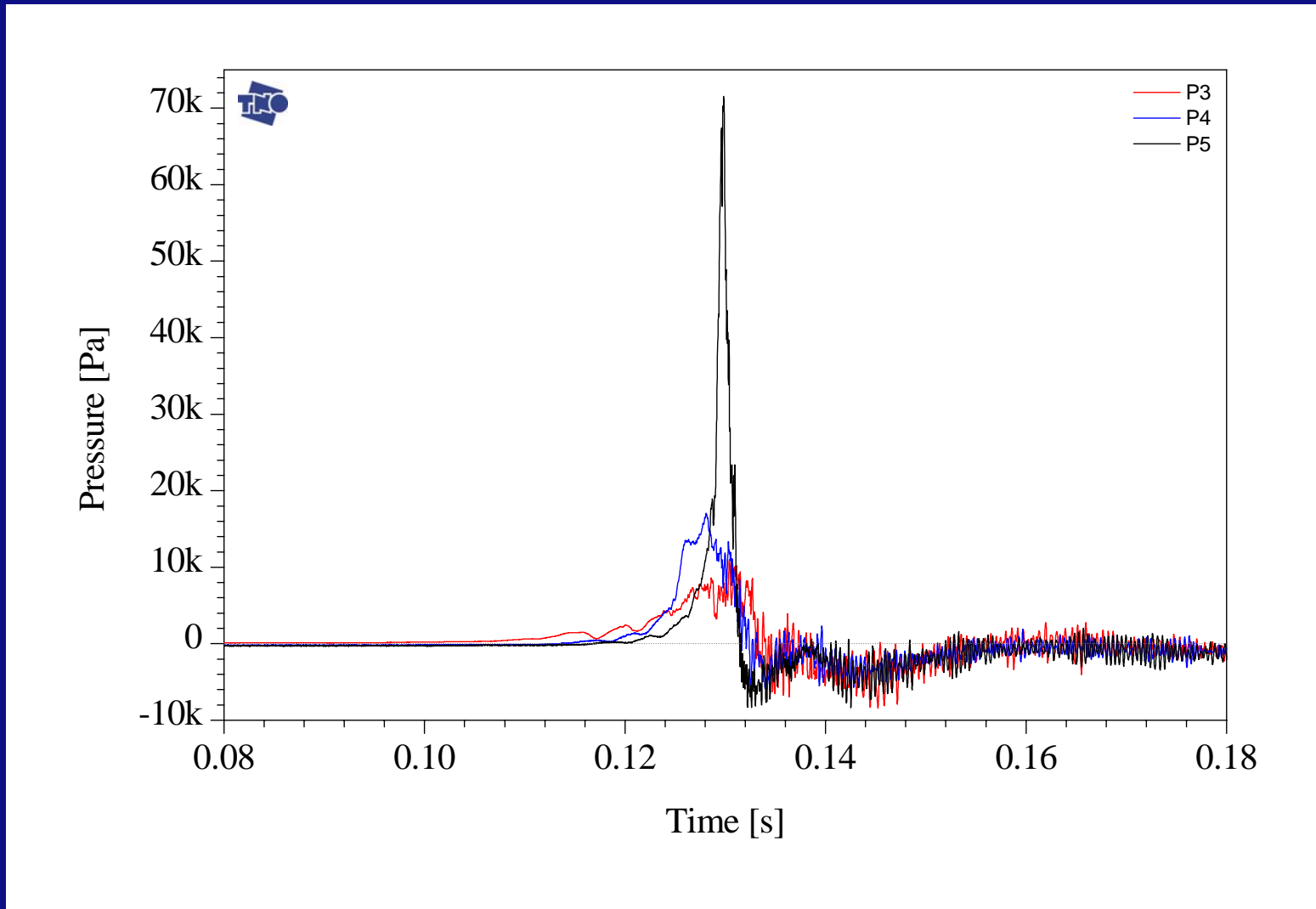
- **Measurement of explosion overpressure** (*max 5 locations*)
- **Blast recordings** (*max 6 locations*)
- **High speed camera recordings**



- **Gas preparation with fans and gas analyzers**
 - Stoichiometric concentration
 - 2 sample points
 - Katharometer used for Hydrogen
- **2 test sites**
 - Rijswijk
 - Reek

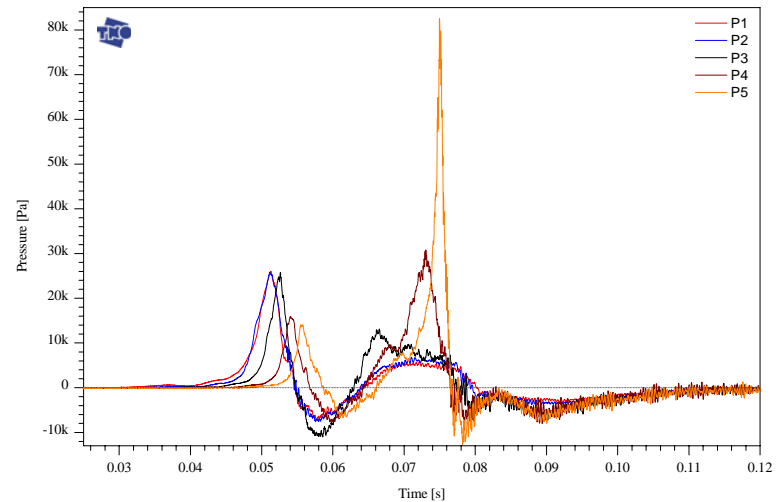
Results – Ethylene rig 2 – A1 test

- Overpressure **70 kPa**



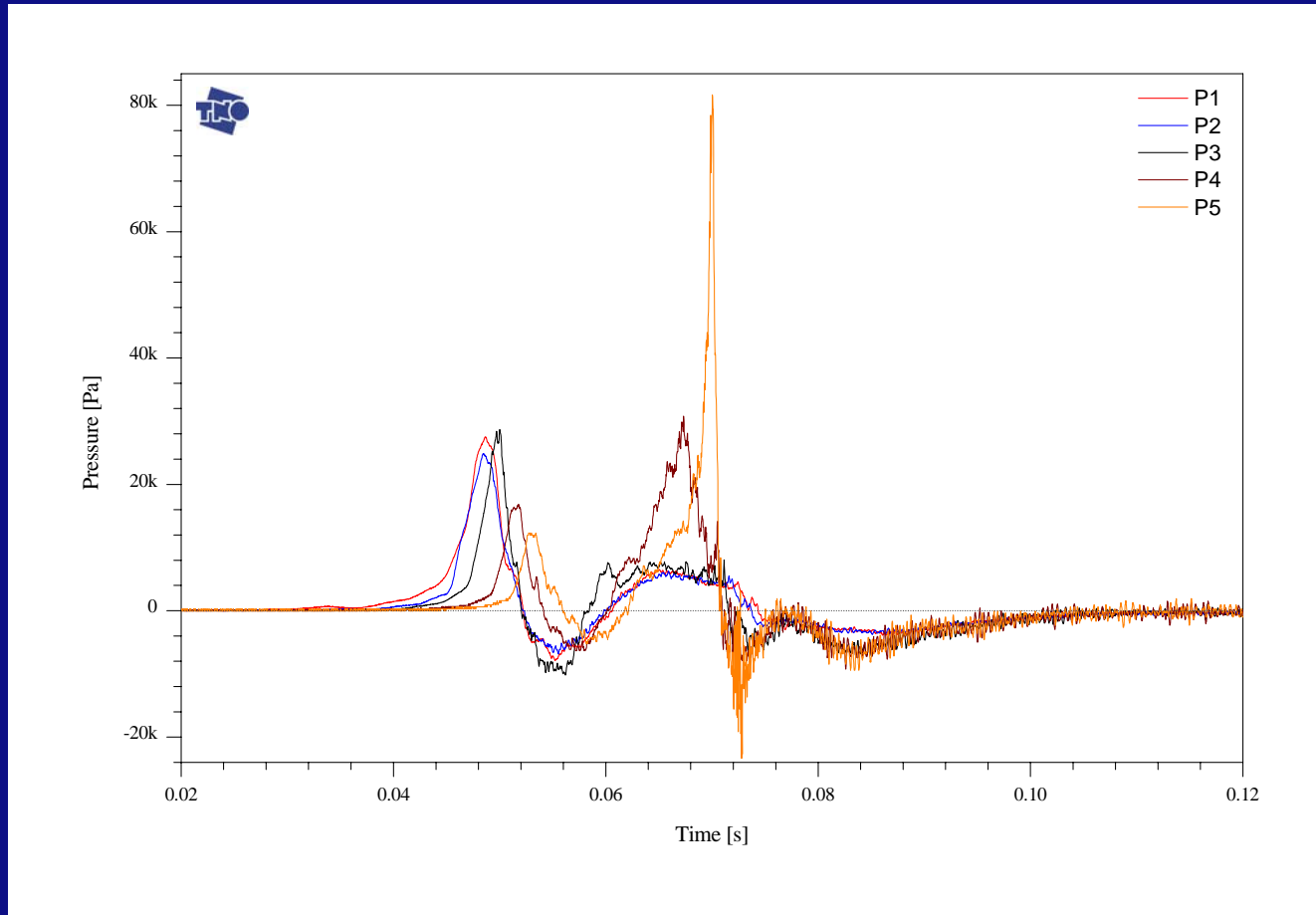
Results – Ethylene rig 2 – CSD test series

- Test with largest SD
- Overpressure **80 kPa**



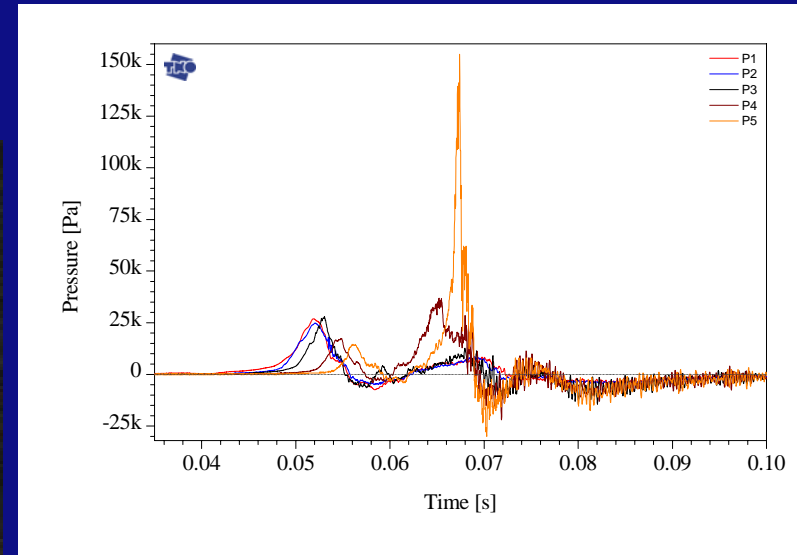
Results – Ethylene rig 2 – CSD test series

- Decreased SD (I)
- Overpressure **80 kPa**



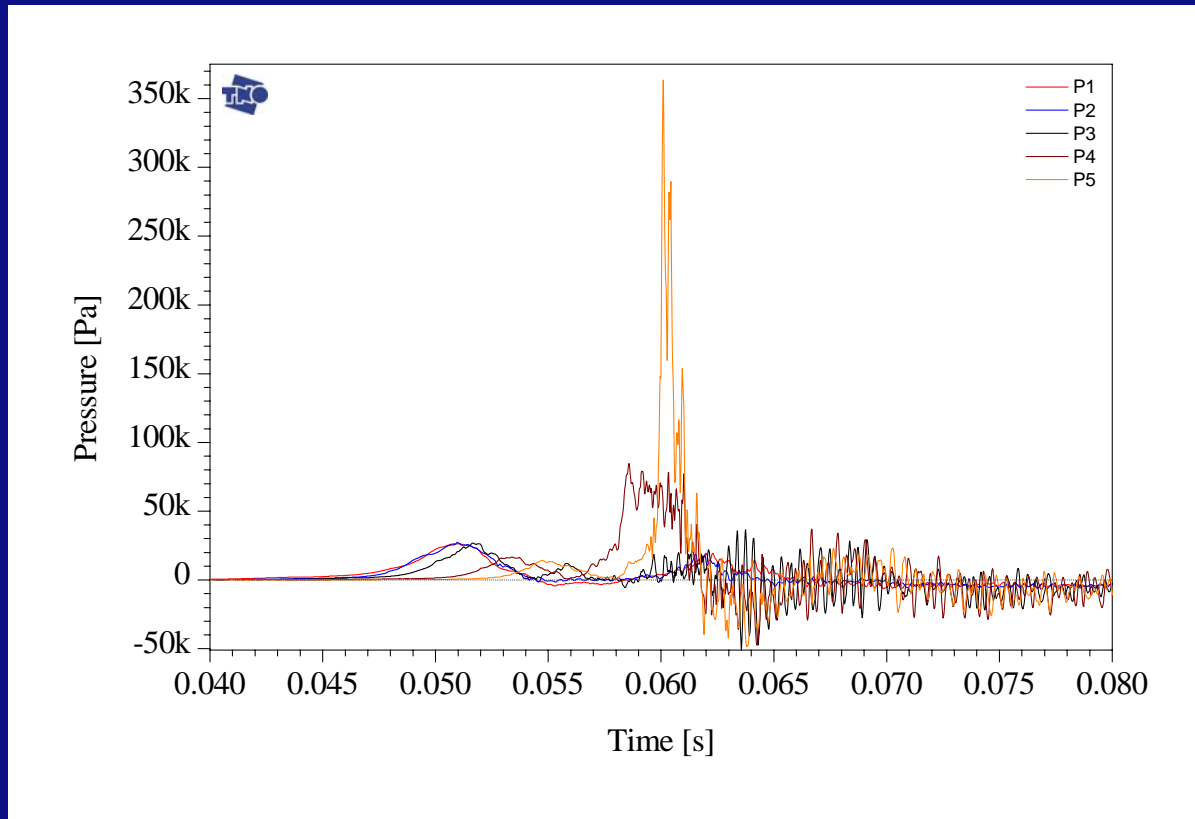
Results – Ethylene rig 2 – CSD test series

- Decreased SD (II)
- Overpressure **150 kPa**



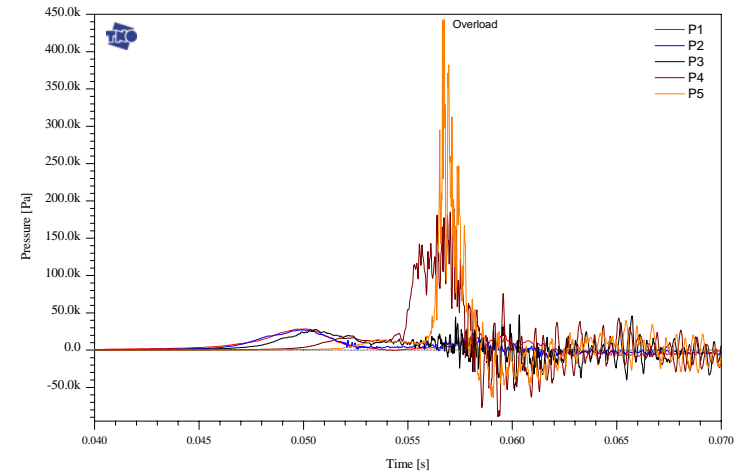
Results – Ethylene rig 2 – CSD test series

- Decreased SD (III)
- Overpressure **350 kPa**



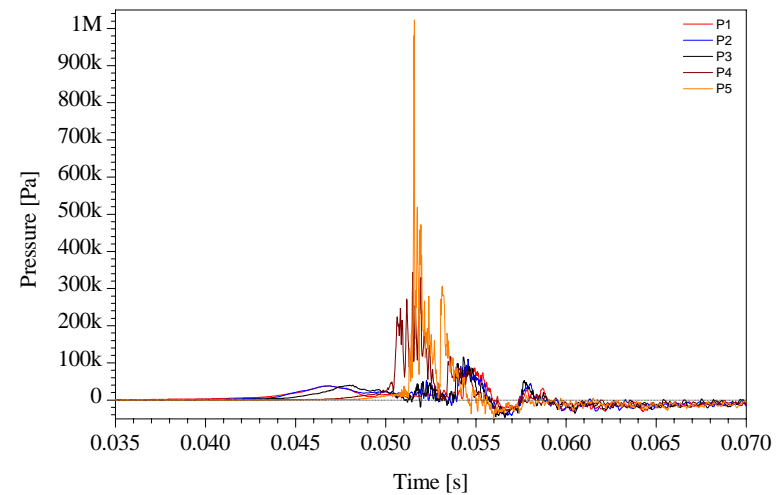
Results – Ethylene rig 2 – CSD test series

- Decreased SD (IV)
- Overpressure > 450 kPa



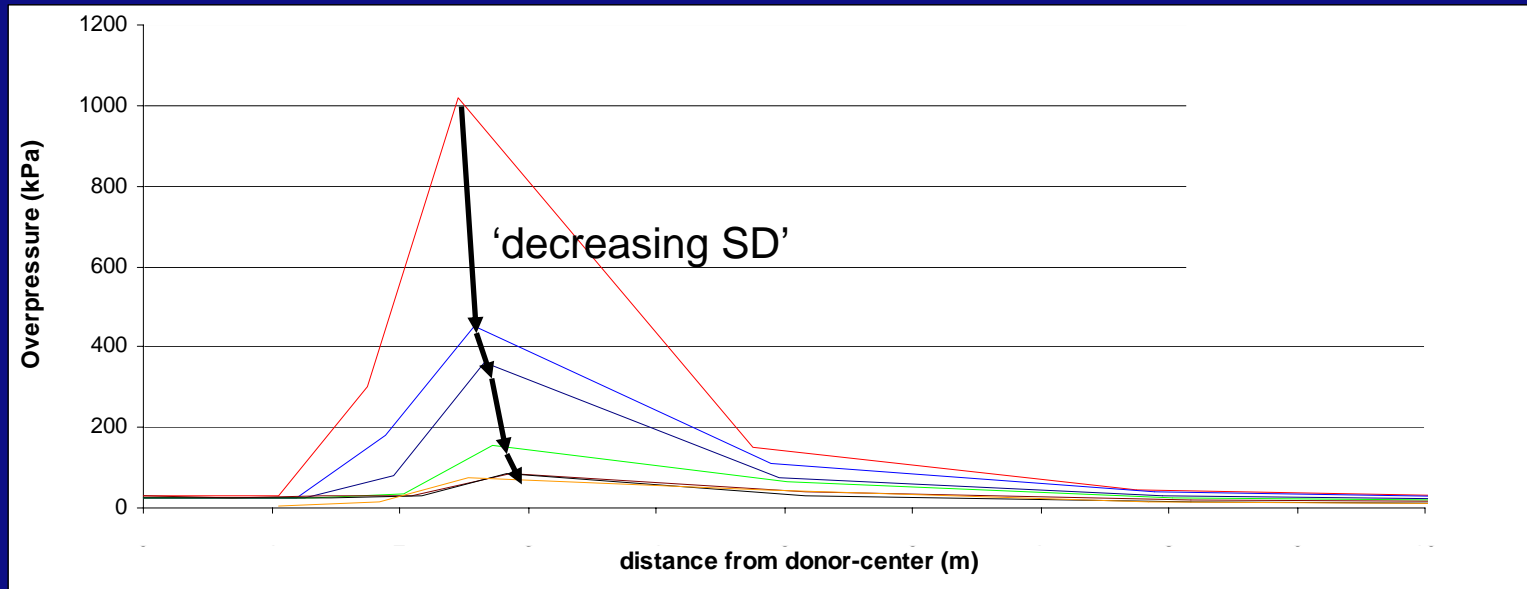
Results – Ethylene rig 2 – CSD test series

- Test with smallest SD
- Overpressure **1000 kPa**



Results – Ethylene rig 2 – CSD test series

- Overview of all ethylene rig 2 tests

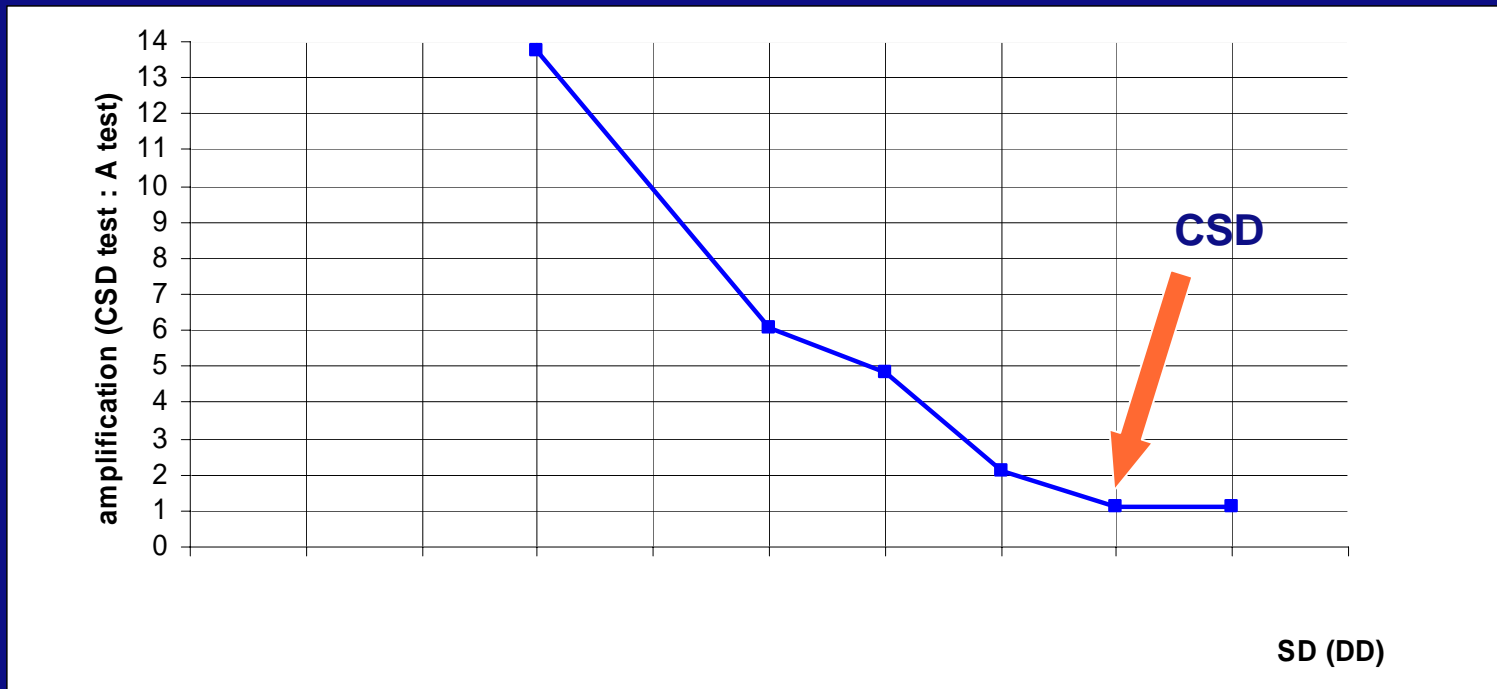


- Definition of 'Amplification'

$$Amplification = \frac{\max(CSD_{test}, acceptor)}{\max(AI_{test}, acceptor)}$$

Results – Ethylene rig 2 – CSD test series

- Amplification

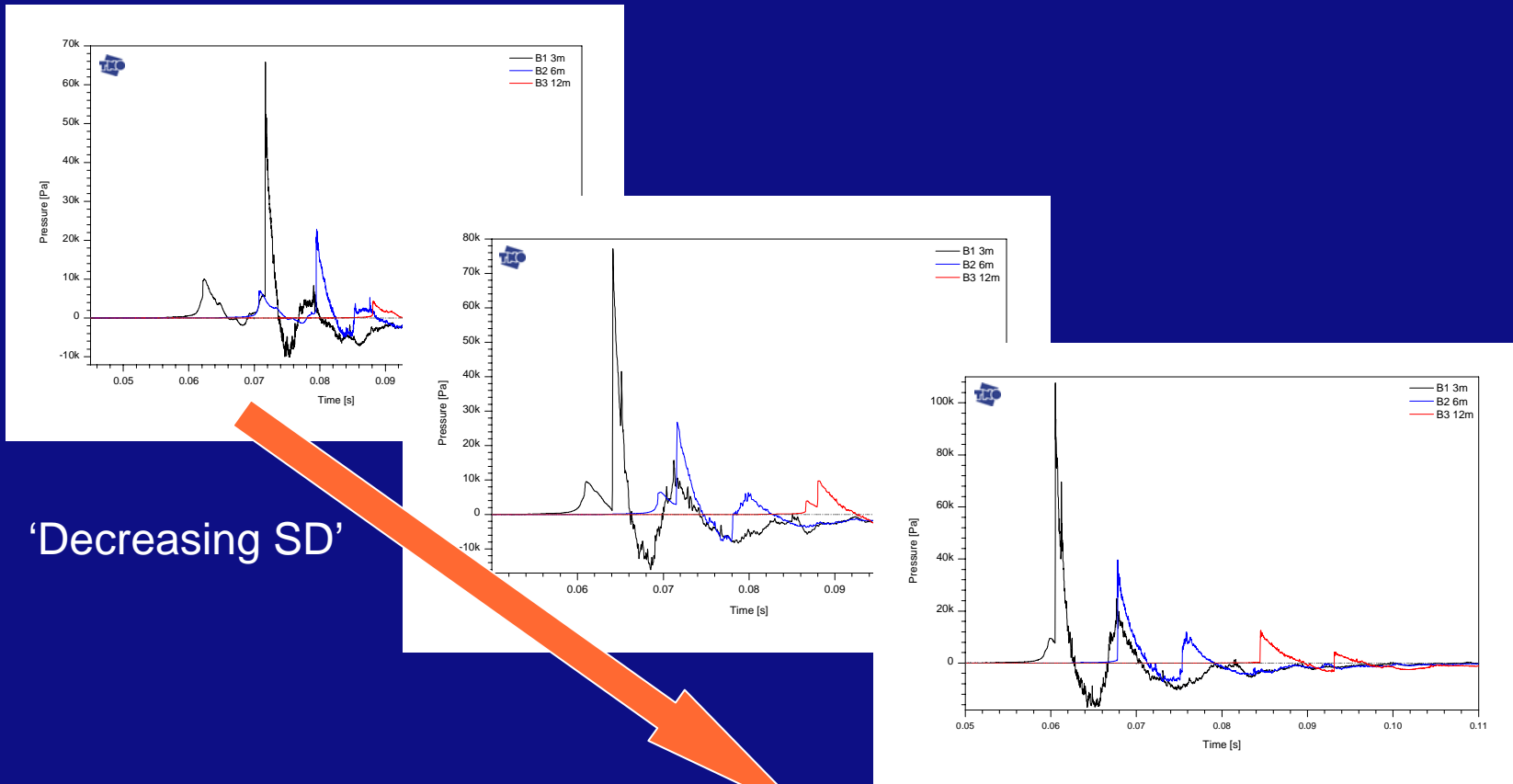


- CSD according to second definition;
 - SD at which amplification ~ 1

Results – Ethylene rig 2 – CSD test series

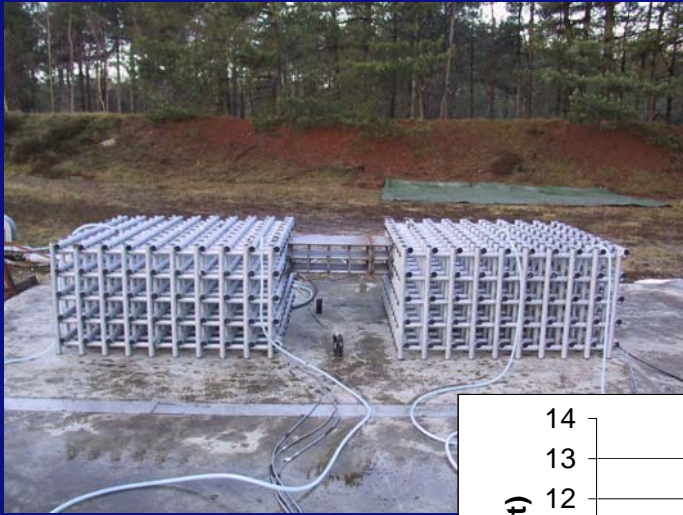
- **Blast measurements**

- In acceptor - donor direction always two separate blasts
- In donor acceptor direction one blast for small SD
- CSD according to definition 1 is somewhat smaller than CSD according to definition 2

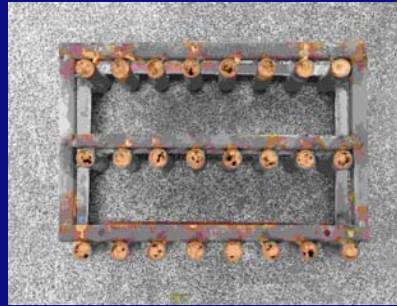


Results – Ethylene rig 2 – PR test series

- Influence of all piperack types was minor
- CSD remains unaltered



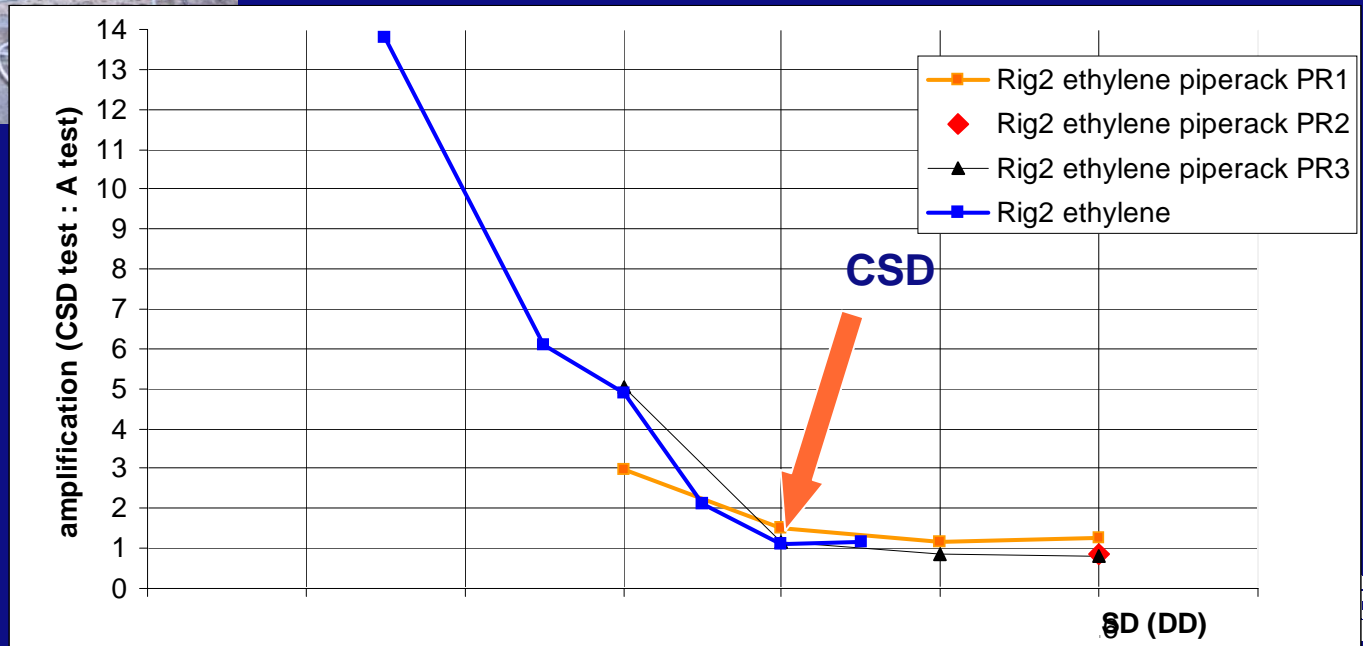
Rig 2 & Pipe rack 3



Pipe rack 1 & 3

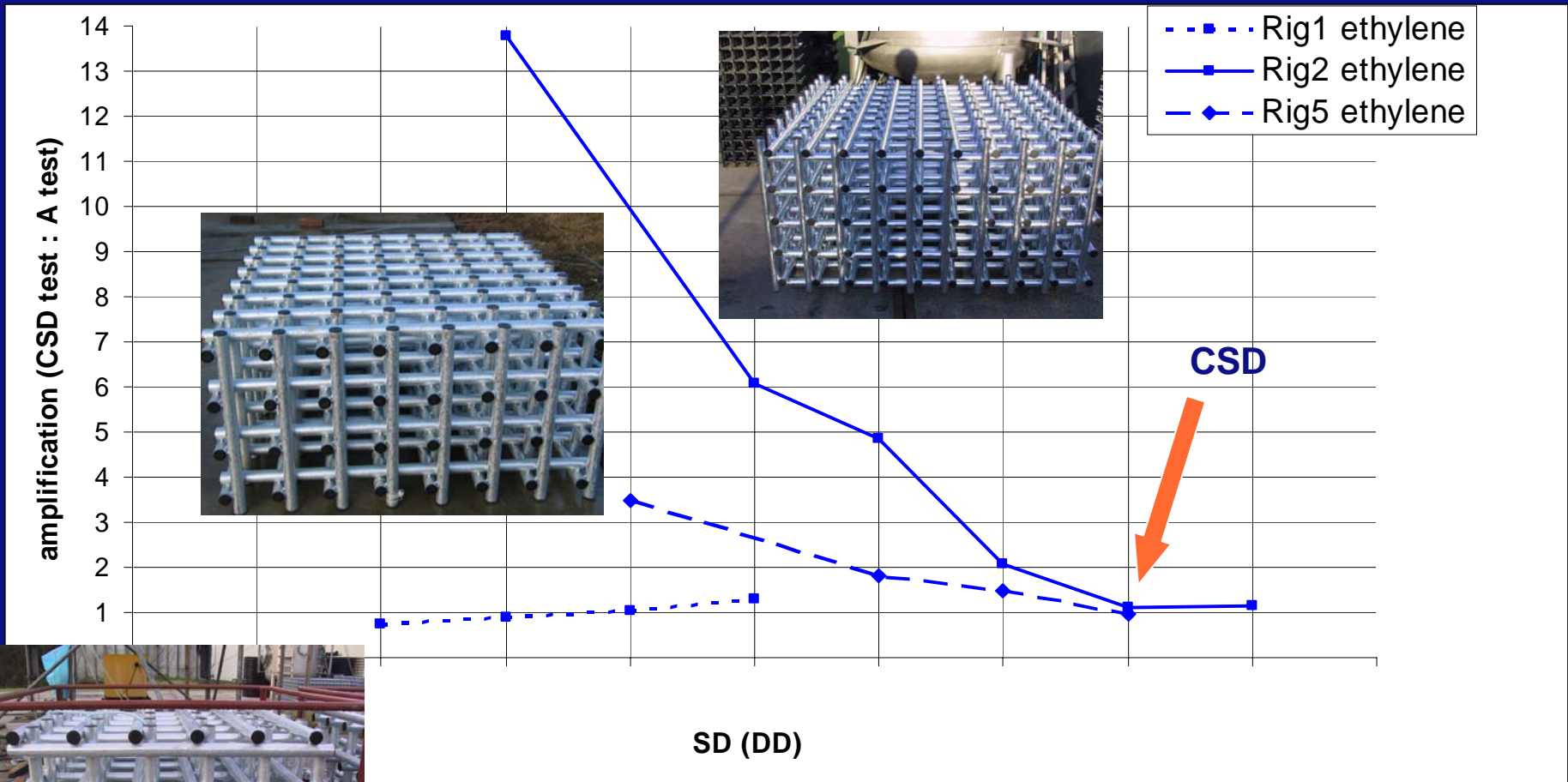


Pipe rack 2



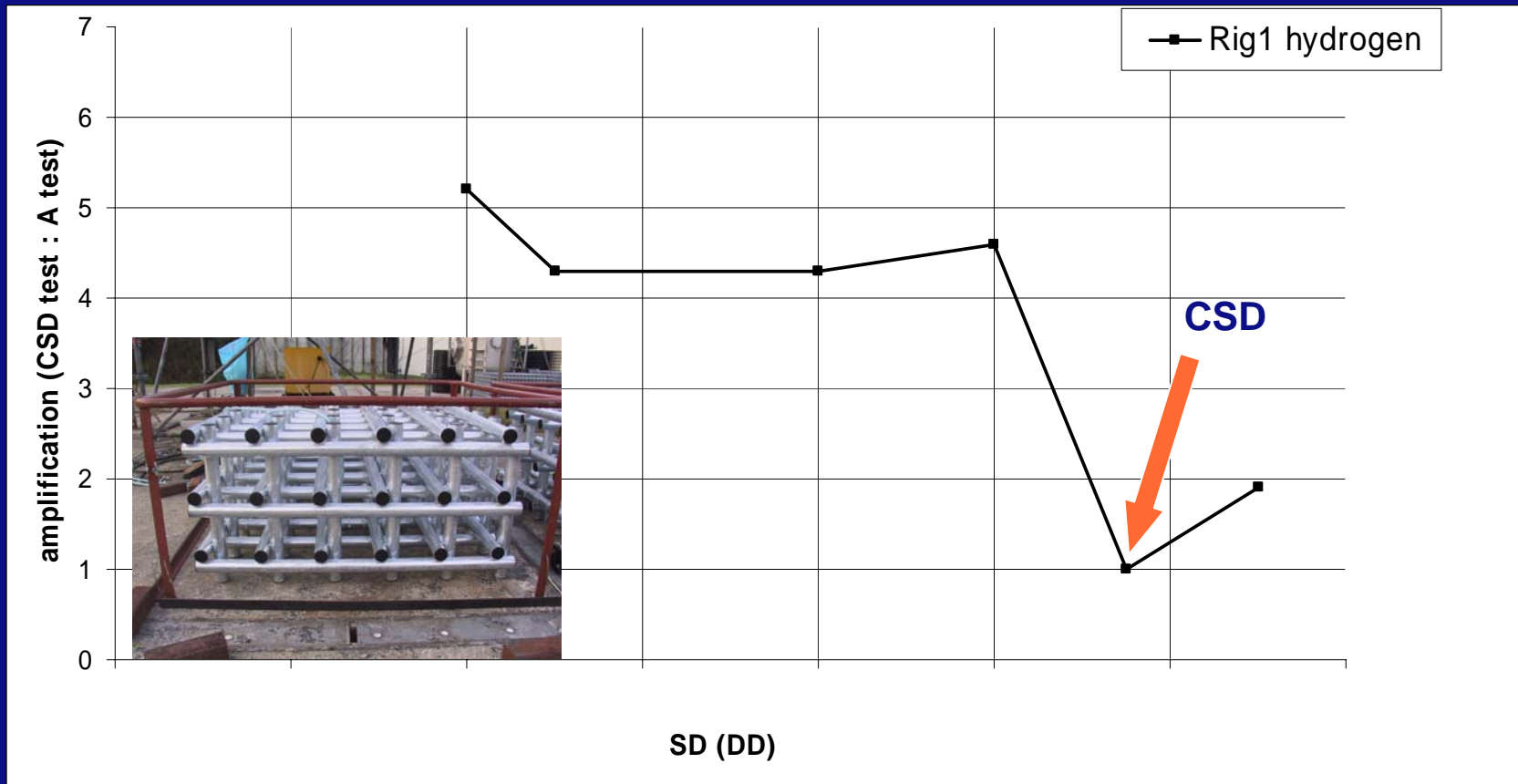
Results - Overview

- Overview of all test series (except pipe rack)
- Based on close to 100 tests
- Results for ethylene



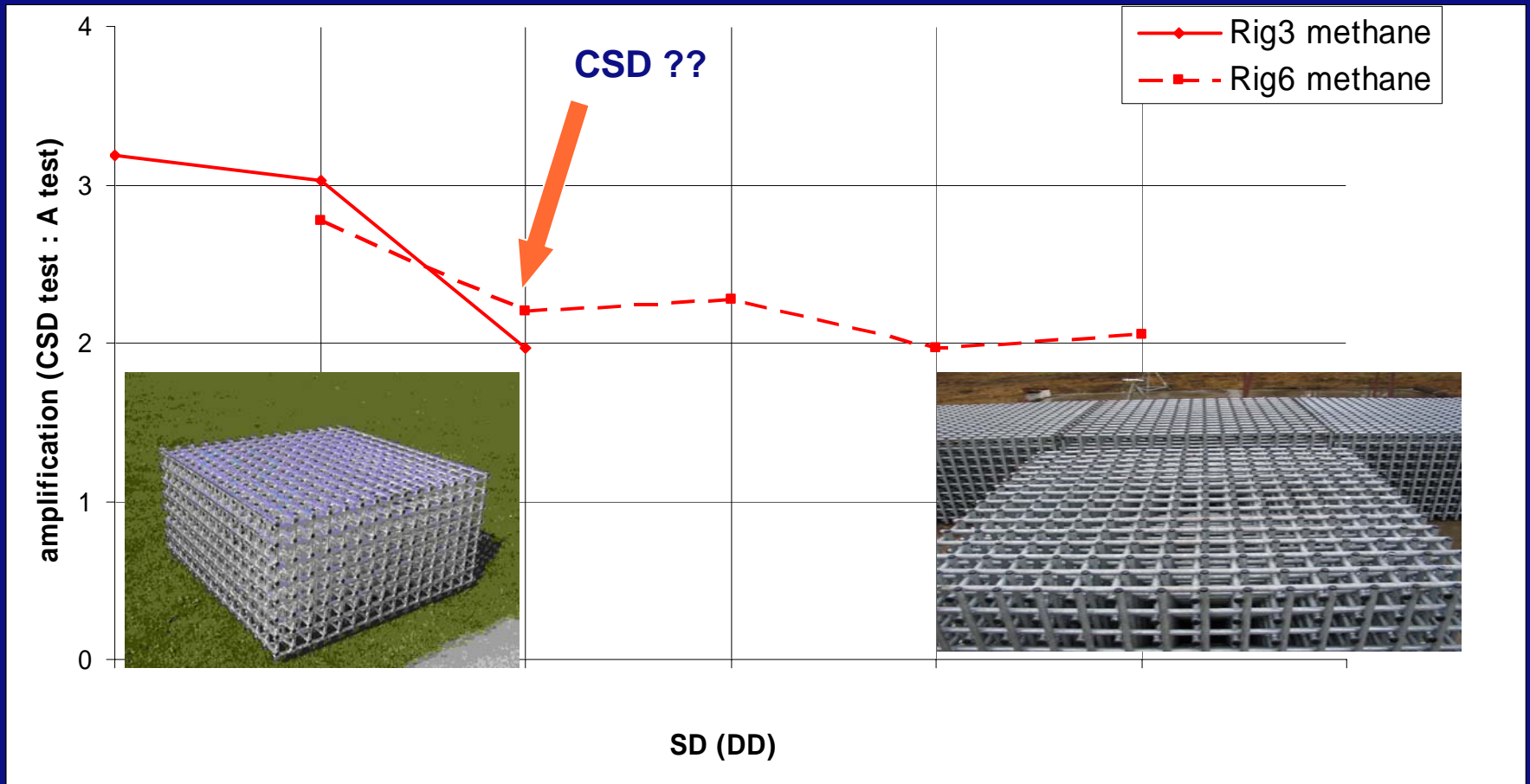
Results - Overview

- Results for hydrogen
- Behavior resembles detonation up to CSD



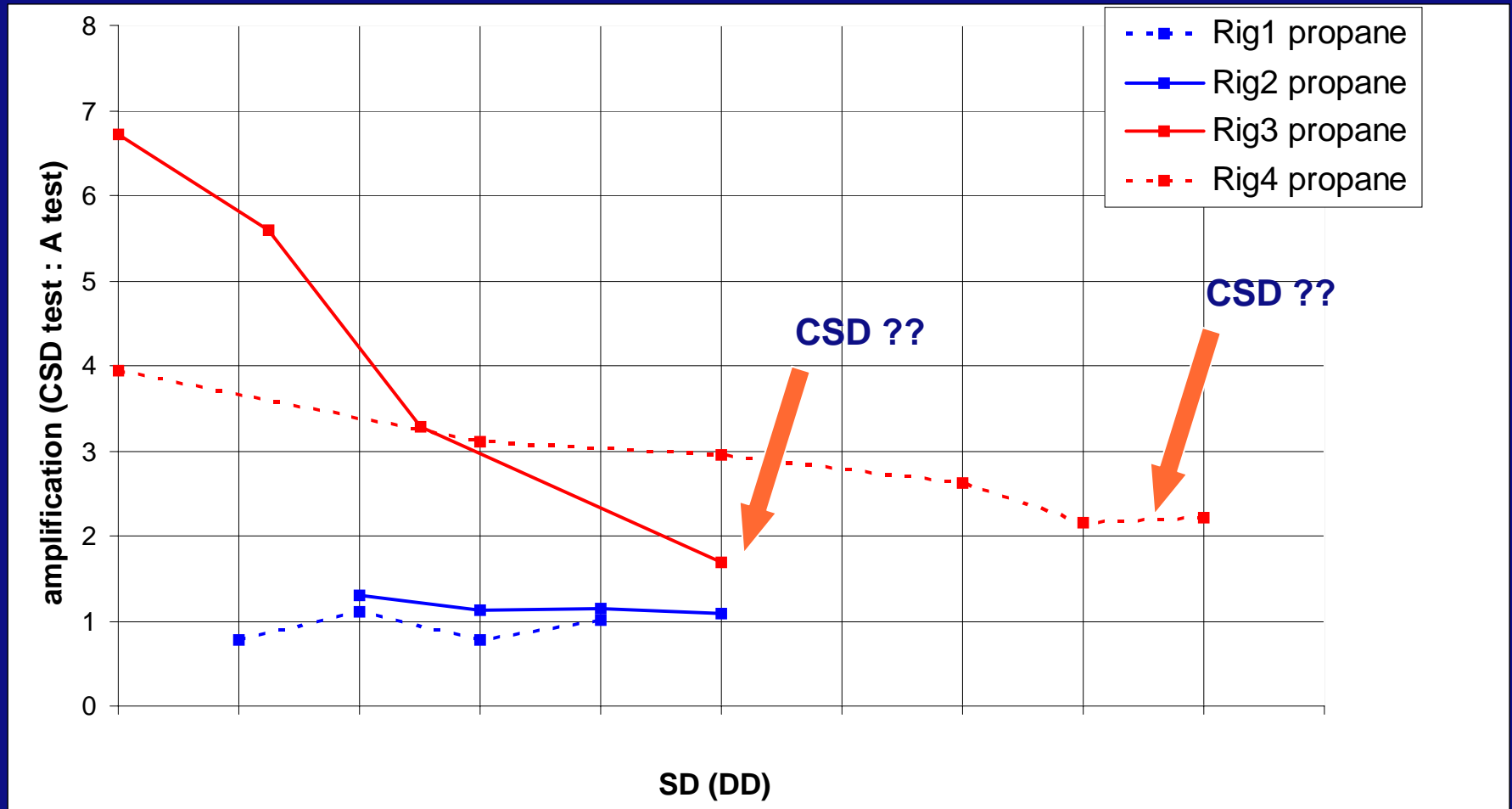
Results - Overview

- Results for methane
- CSD definition problem



Results - Overview

- Results for propane
- CSD definition problem



Conclusions

- Large differences observed between fuels and rig types; overpressure

CSD tests	Methane	Propane	Ethylene	Hydrogen
Rig 1	-	< 3 kPa	< 10 kPa	< 500 kPa
Rig 5	-	-	< 160 kPa	-
Rig 2	-	< 14 kPa	< 1000 kPa	-
Rig 3	< 25 kPa	< 80 kPa	*	-
Rig 4	-	< 80 kPa	**	-

* Rig 3, A-test 250 kPa

** Rig 4, A-test 1400 kPa

Conclusions

- Large differences observed between fuels and rig types; maximum amplification and CSD

CSD tests	Methane	Propane	Ethylene	Hydrogen
Rig 1	-	~ 1	~ 1	5
Rig 5	-	-	3.5	-
Rig 2	-	~ 1.5	14	-
Rig 3	3	4	*	-
Rig 4	-	7	**	-

* Rig 3, A-test 250 kPa

** Rig 4, A-test 1400 kPa

Suggested Future Research

- Scale

- Design of new scaled rig types;
 - Rig size
 - Rod diameter
 - VBR (Volume Blockage ratio)
- Towards realistic sizes
- Derivation of scaling laws for the CSD



'ERGOS'



Suggested Future Research

- Hydrogen
 - Hydrogen is under interest
 - TNO participates in EU network of excellence 'HYSAFE'
- Hydrogen: New test series
 - Rigs with smaller density than Rig type 1
 - Non-stoichiometric concentrations
- Proposal for follow-up project
 - Looking for consortium of several partners (multi-sponsor)
 - Experiments by TNO
 - Project program to be discussed and agreed by the consortium

Thank you !!!!



Ethylene & rig 4

14 bars overpressure