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THE INFLUENCE OF POST DETONATION BURNING PROCESS ON BLAST WAVE PARAMETERS IN AIR

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Outline

- Motivation
- Non ideal blast waves
- Goal
- Model
- Simulations
- Experimental work
- Calibration
- Summary

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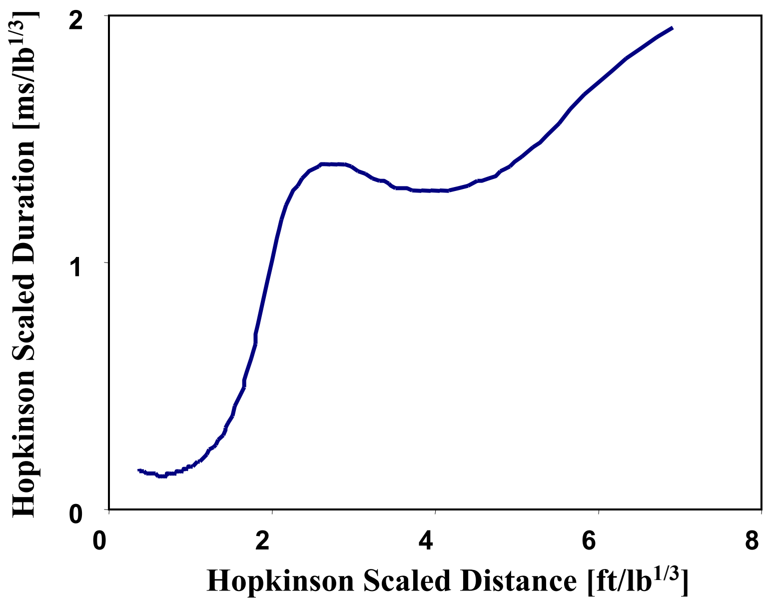
Motivation

- An unexplained non-monoticity of the scaled blast duration is evident in CONWEP data.
- A possible explanation might be related to non-ideality of the explosion (post-detonation burning).



Non-Ideal Blast Waves

Ideal Explosion	Non Ideal Explosion
All chemical energy is extracted in the detonation front	Some energy remain due to negative oxygen balance
Gas diffusion and surface turbulence are neglected.	Gas diffusion and surface turbulence taken into account
Detonation products do not burn	Detonation products burn when oxygen is supplied

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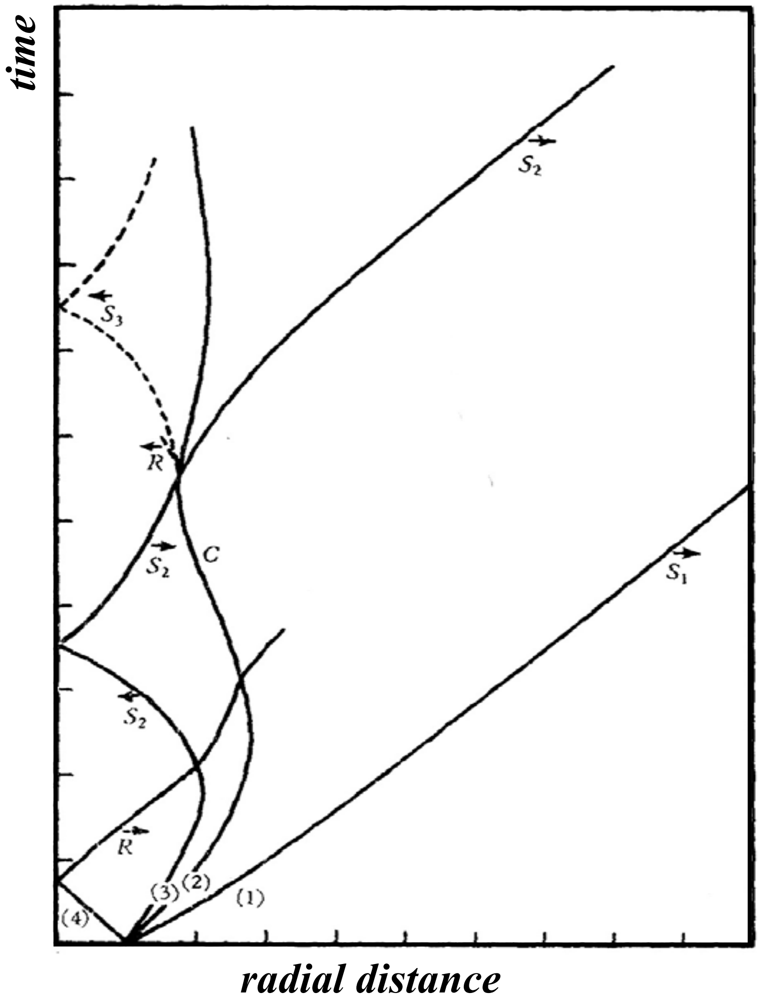
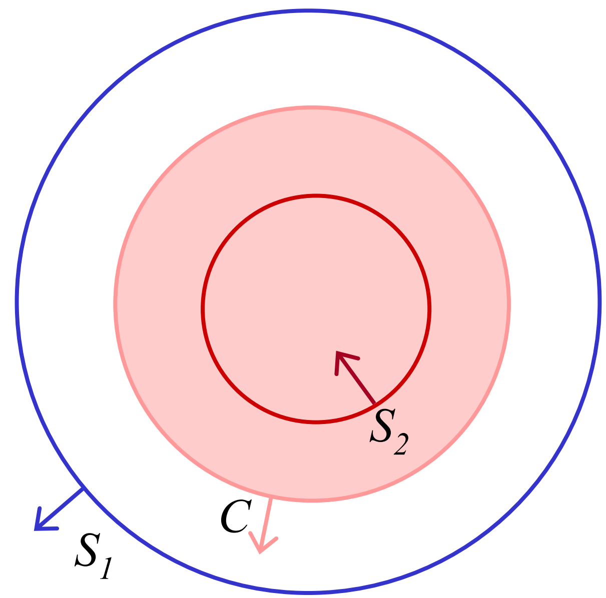
The Goal of our Study

To model effectively the non ideal blast effects (i.e. gas diffusion and burning) in order to understand their influence on the blast profile.

Spherical Explosion Shock Wave Dynamics





C – Det. products – air surface.
S_1 – Primary shock wave
R – Rarefaction shock wave.
S_2 – Secondary shock wave.

Gas Diffusion

- Classically, the diffusion of two gases controlled by three gradients:
  - Concentration
  - Pressure
  - Temperature

- Concentration estimated diffusion velocity: 500-1500 m/s

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Model Hypothesis

- All gases are ideal gases with various adiabatic constants.
- Adiabatic constant of mixed gas is a concentration weighted average.
- The burning process affects only the internal energy and the adiabatic constant of the gas.

<u>Relative concentrations inside detonation products cloud:</u>

- η - air
- ξ - Pre-burned gas
- β - burning products

$$\eta + \xi + \beta = 1$$

Energy release dynamics

Initial conditions (det. products cloud): $\eta = 0; \quad \xi = 1; \quad \beta = 0$

Diffusion: $$\eta(r,t) = \eta_0 \exp\left(-\frac{r_C - r}{ut}\right)$$

Rate of change in internal energy: $$\dot{E}_b = \min\left(\tfrac{5}{7}\eta \;, \xi\right)\cdot \dot{E}_b^0$$

Burning Products concentrations: $$\beta(t) = \frac{E_b(t)}{E_b^{final}}$$

Pre-burned gas concentration: $$\xi = 1 - \beta - \eta$$

$$\dot{E}_b = \min\left(\tfrac{5}{7}\eta(r,t), \left(1 - \eta(r,t) - \frac{E_b}{E_b^{final}}\right)\right)\cdot \dot{E}_b^0$$

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Numerical Simulation

- Simulation conducted using AUTODYN ver. 6.0.
- New EOS (based on ideal gas) was defined in order to implement the model.
- Two stages simulation:
  - Detonation
  - Blast propagation & burning
- The simulation set-up was a spherically symmetrical explosion of 5kg TNT charge.

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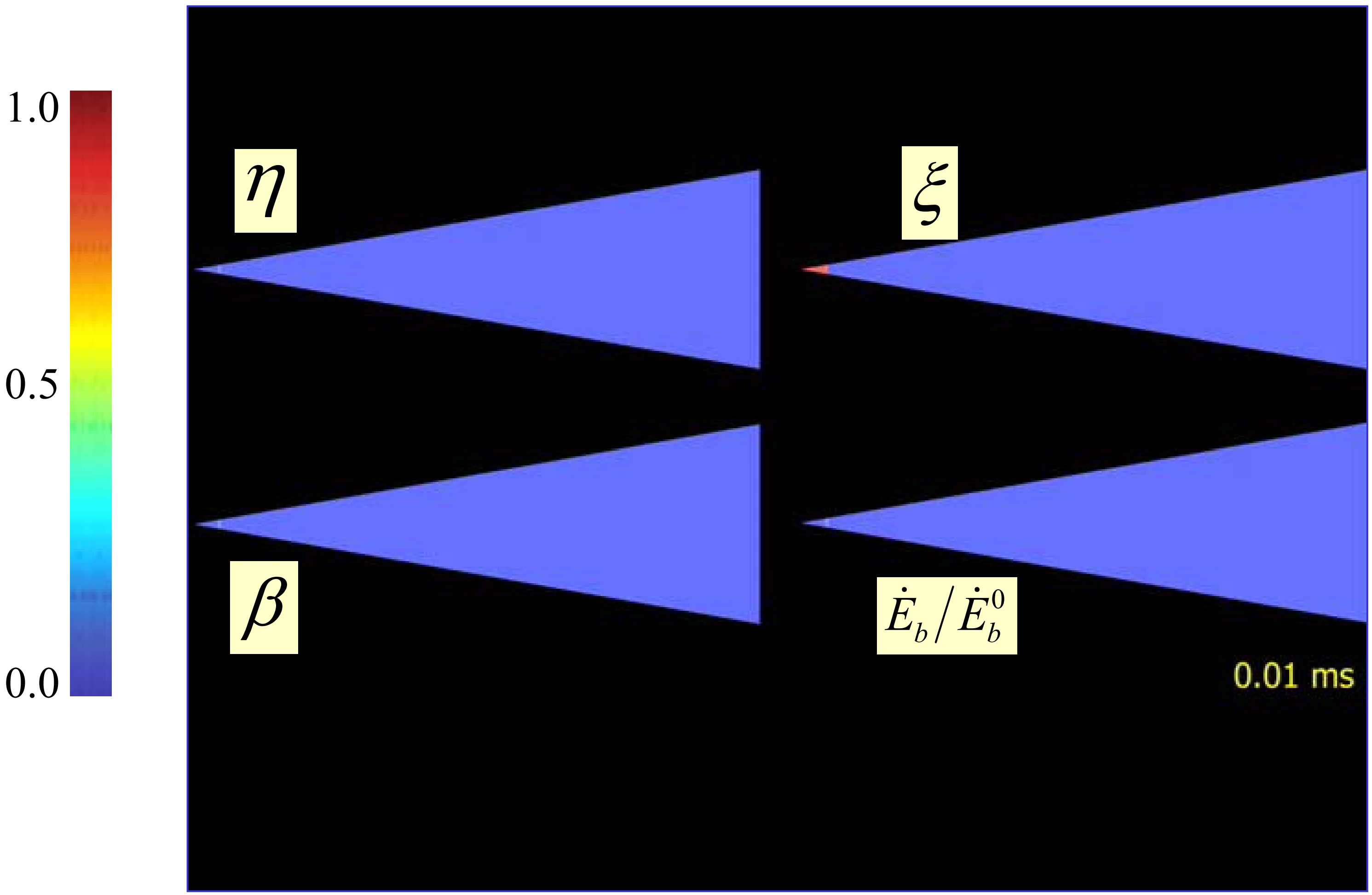
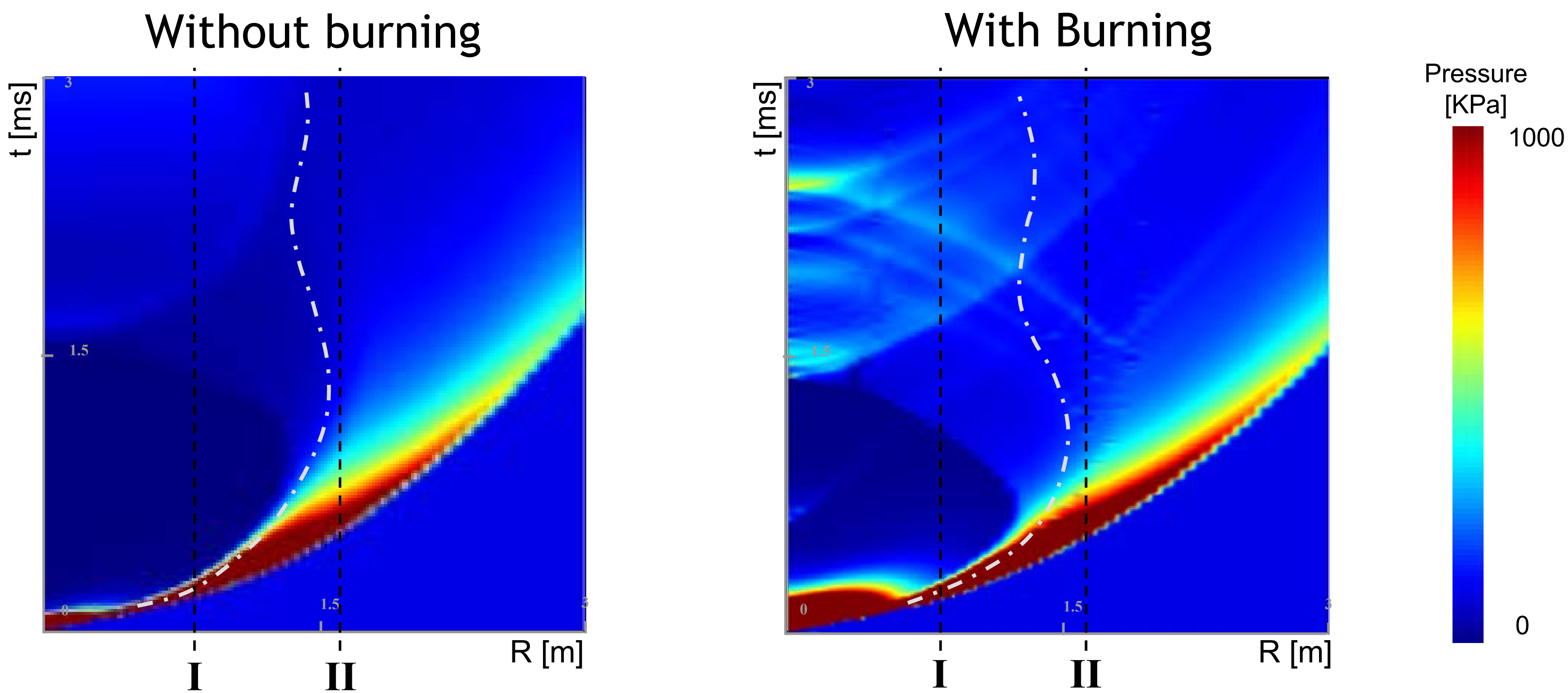
Numerical Simulation

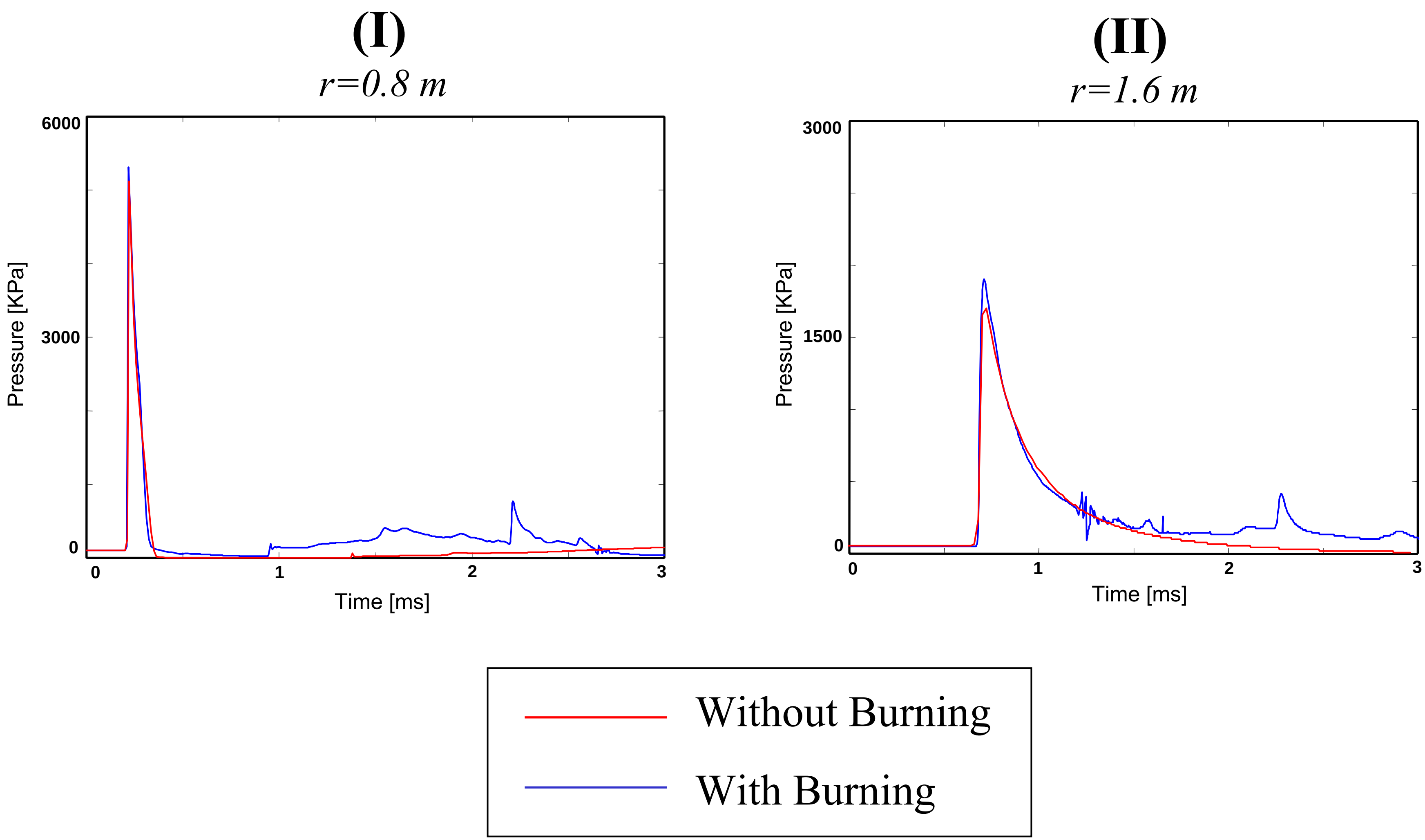
1D axially symmetrical explosion



Simulation results



Simulation Results



Experimental Set Up

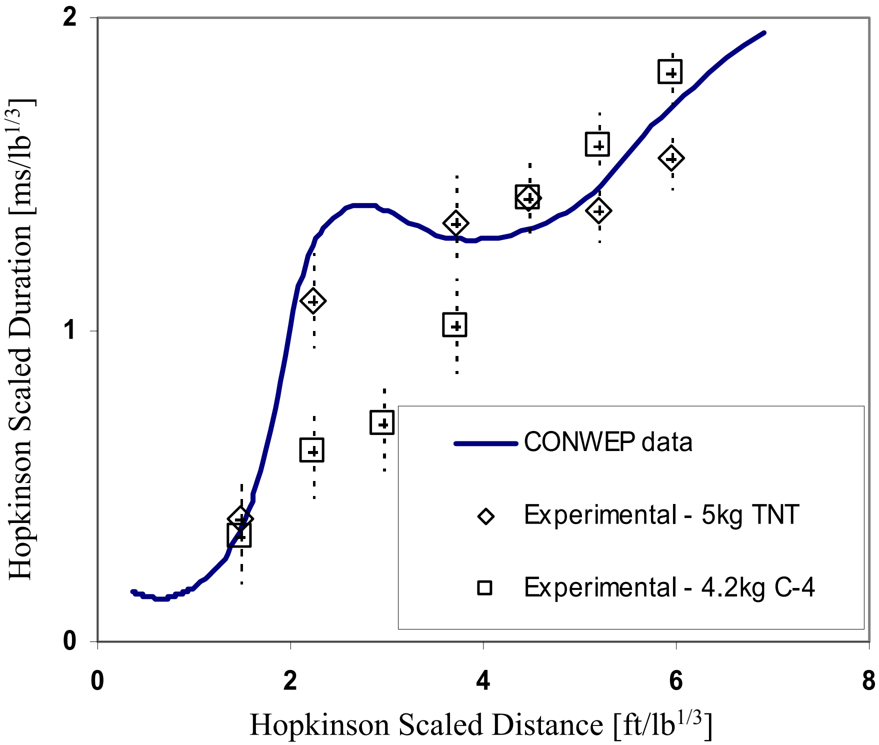
- Two energy equivalent free field explosion tests conducted:
  - 5 kg TNT
  - 4.2 kg C-4

Detonation Products of TNT and C-4

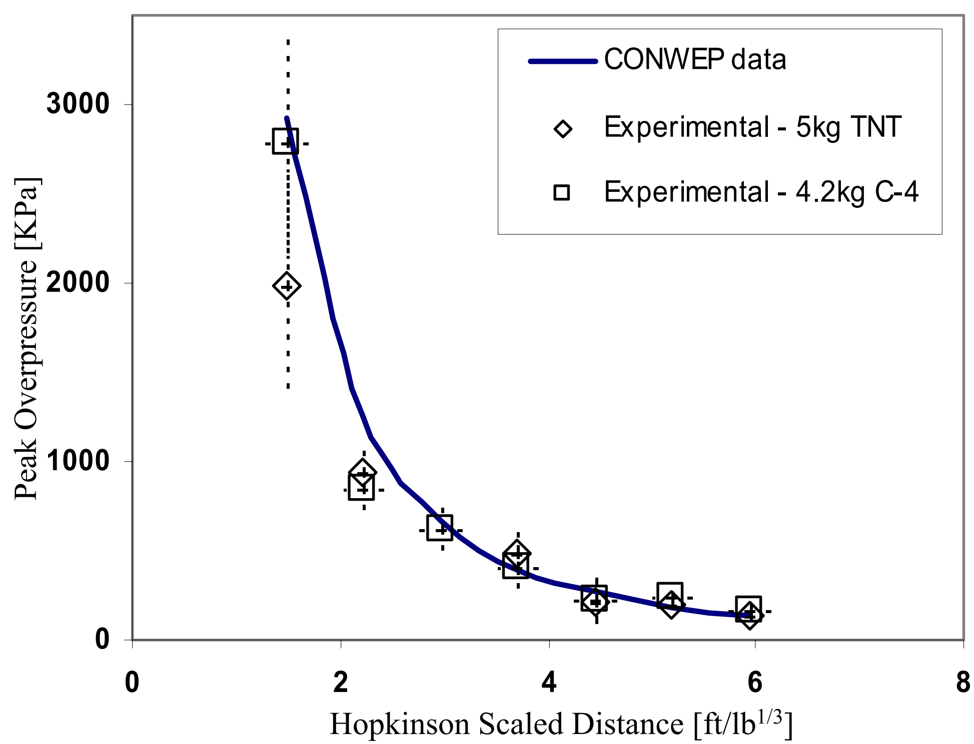
	TNT [%mole]	C-4 [%mole]
H_2	21.4	12.6
CO	54.5	22.0
CO_2	5.5	10.5
H_2O	1.5	18.0
N_2	12.5	28.0
Others	5.5	9.9
$CO+H_2$	**76%**	**35%**

Experimental Results

Pulse durations



Pulse pressure peak



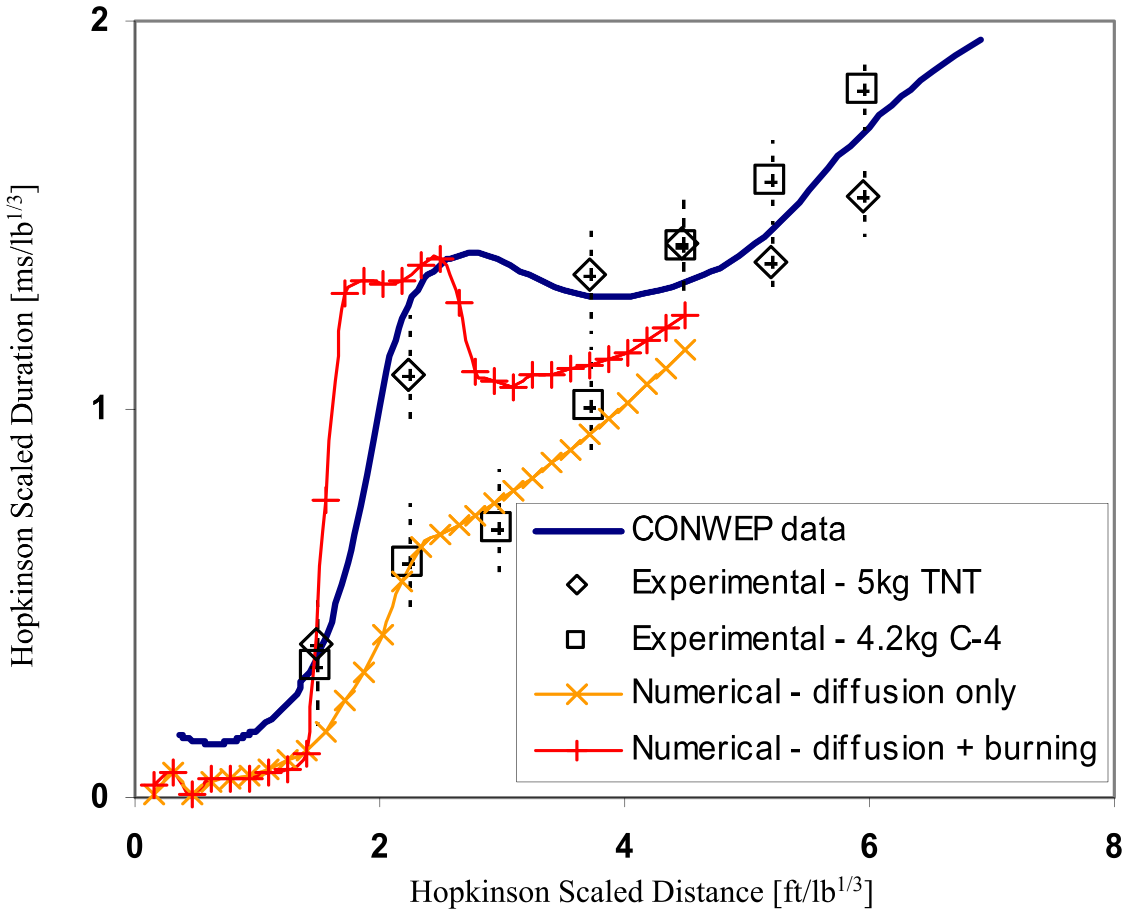
Model Calibration

- Calibration parameters:

$$u, \ \eta_0, \ \dot{E}_b^0$$

- The model was calibrated employing:
  - CONWEP data
  - Experimental results

Results


2
1
0
0
2
4
6
8
Hopkinson Scaled Duration [ms/lb^1/3]
Hopkinson Scaled Distance [ft/lb^1/3]
CONWEP data
Experimental - 5kg TNT
Experimental - 4.2kg C-4
Numerical - diffusion only
Numerical - diffusion + burning

Summary

- An effective model is proposed, capable of reproducing the burning effect on a non-ideal blast waves.
- Good agreement obtained between numerical and experimental results.
- Post detonation burning affects the blast profile in the near field (scaled distance < 4 $ft/lb^{1/3}$).
- When non ideal blast effects are important the TNT equivalence convention must be reconsidered.

Acknowledgements

- We would like to thank Dr. Eitan Hirsch for the fruitful discussions of the topic