The Performance of Insensitive Blast Enhanced Explosives

Werner Arnold, Ernst Rottenkolber (*)
TDW - Gesellschaft für verteidigungstechnische Wirksysteme mbH
Schrobenhausen, Germany

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(*) NUMERICS

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Outline

- Motivation
- Yield of an Explosive
- Test Setup
- Test Results
- Numerical Simulations
- Conclusions

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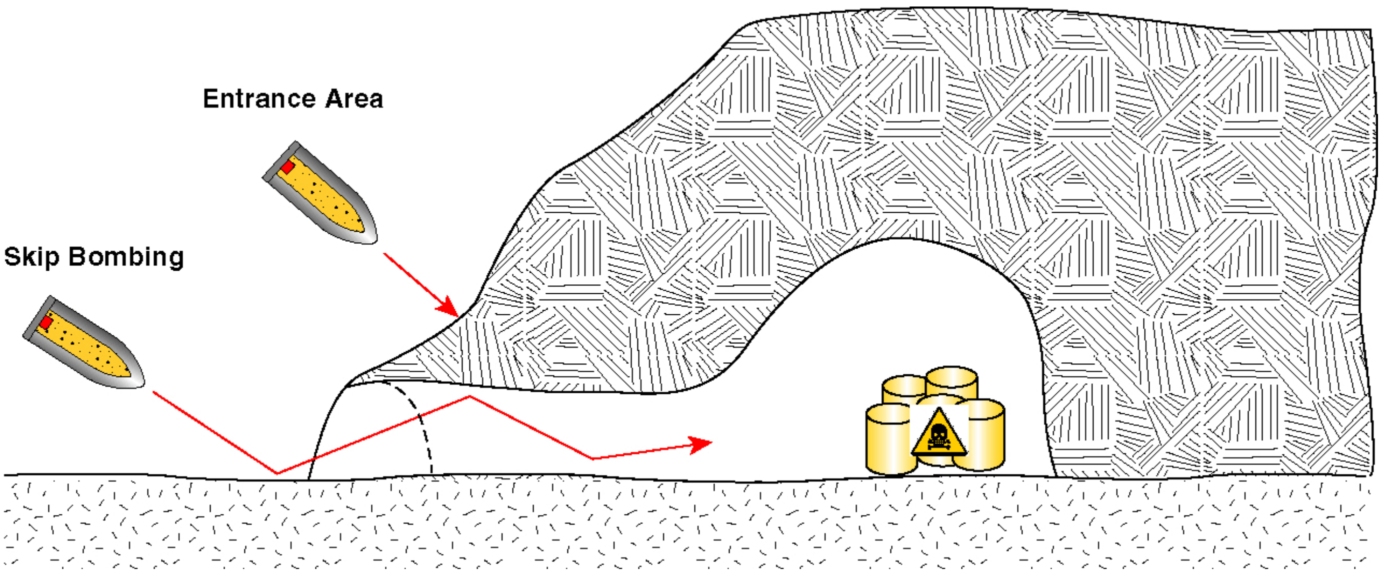
SIBEX: Shock Insensitive Blast Enhanced High EXplosives



IMEMTS 06, Bristol, UK: **"What Influences the Shock Sensitivity of High Explosives ?"**

IMEMTS 07, Miami, FL, USA: **"SIBEX: Modelling and Testing"**

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What characterizes the Yield of an Explosive

Conventional HE

SIBEX

6 msec

6 msec

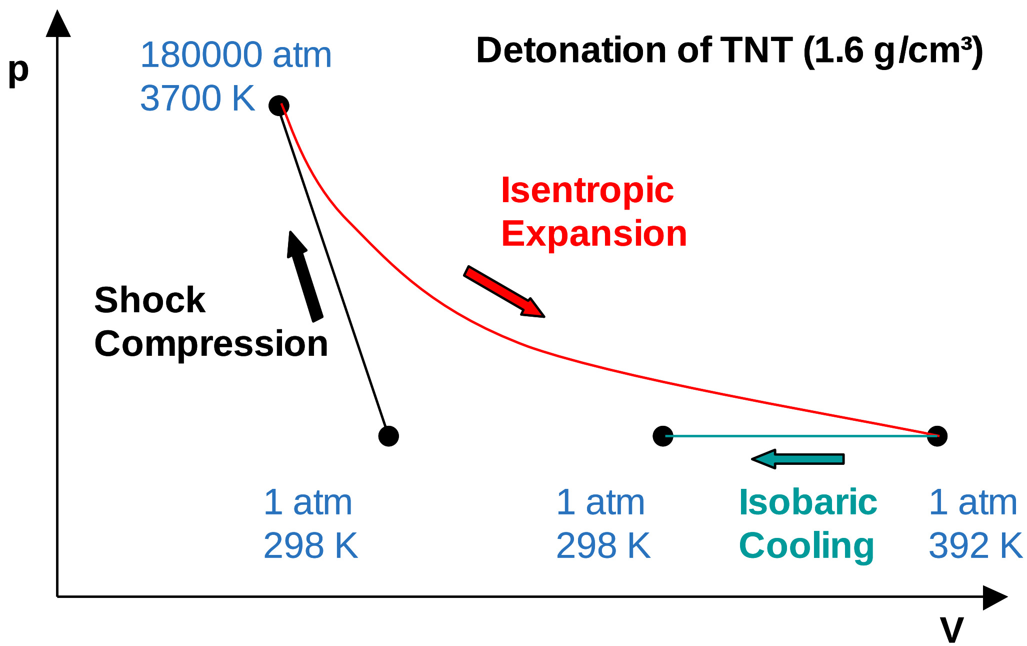
30 msec

30 msec

60 msec

60 msec

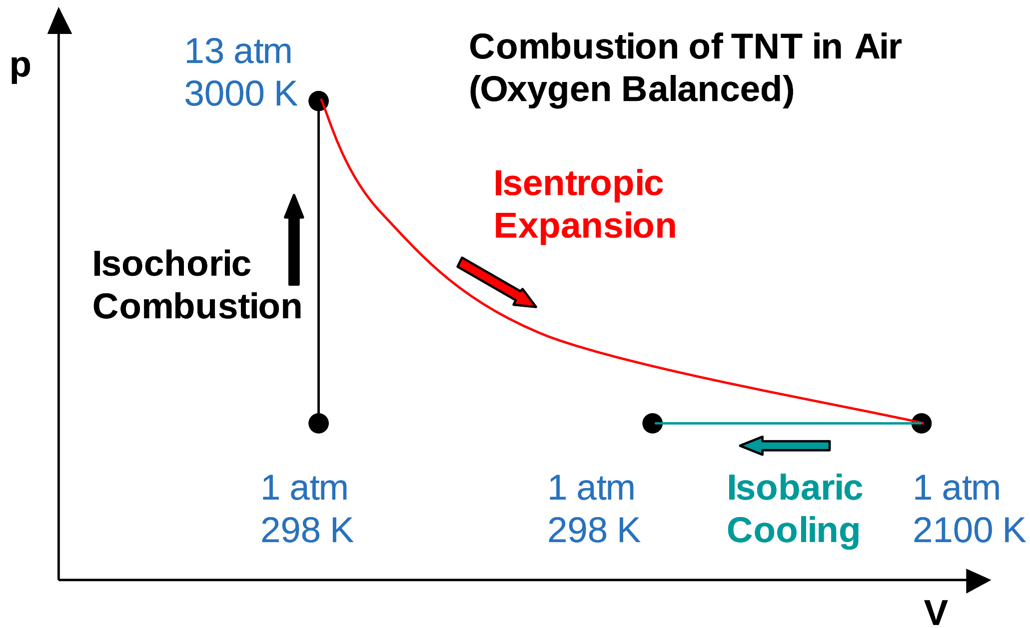
„Heat of Detonation“ (= Energy of Detonation): TNT



Process	Energy [kJ/g]		
Shock Compression	-1.41		
Isentropic Expansion	5.94		
	4.53	4.53	Mechanical Energy of Detonation
Isobaric Cooling		0.08	Thermal Energy of Detonation
		4.61	Total Energy of Detonation

„Useful Work“
Ficket & Davis „Detonation“, 1979

„Heat of Combustion“ (= Energy of Combustion): TNT



Process	Energy [kJ/g]		
Isochoric Combustion	0.0		
Isentropic Expansion	6.4		
	6.4	6.4	Mechanical Energy of Combustion
Isobaric Cooling		8.1	Thermal Energy of Combustion
		14.5	Total Energy of Combustion

„Mechanical Work“

Heat of Combustion vs Mechanical Energy (Useful Work)

Fuel	*Net Heat of Combustion (calculated) [kJ/g]*	*Volume of Air [m³/kg]*	*Mechanical Energy of Combustion [kJ/g]*	*O_2-Balance [Mass-%]*
B	58.7	35	23.2	-222
Fuel-Oil	46.9	15	21.2	-333
HTPB	42.0	15	19.0	-319
DOA	33.9	13	15.3	-263
C	32.8	12	14.5	-266
Si	32.3	16	13.3	-114
Al	31.0	15	12.9	-88.9
PMMA	27.6	9	12.5	-191.8
Mg	24.7	13	10.1	-65.8
IPN	17.2	5	7.98	-99.0
TNT	14.6	4	6.72	-74.0

For Example: TNT-Equivalent of Aluminum

- **Mechanical Energy of Combustion TNT = 6.72 kJ/g vs Al = 12.9 kJ/g: TNT-Equ ~ 2**

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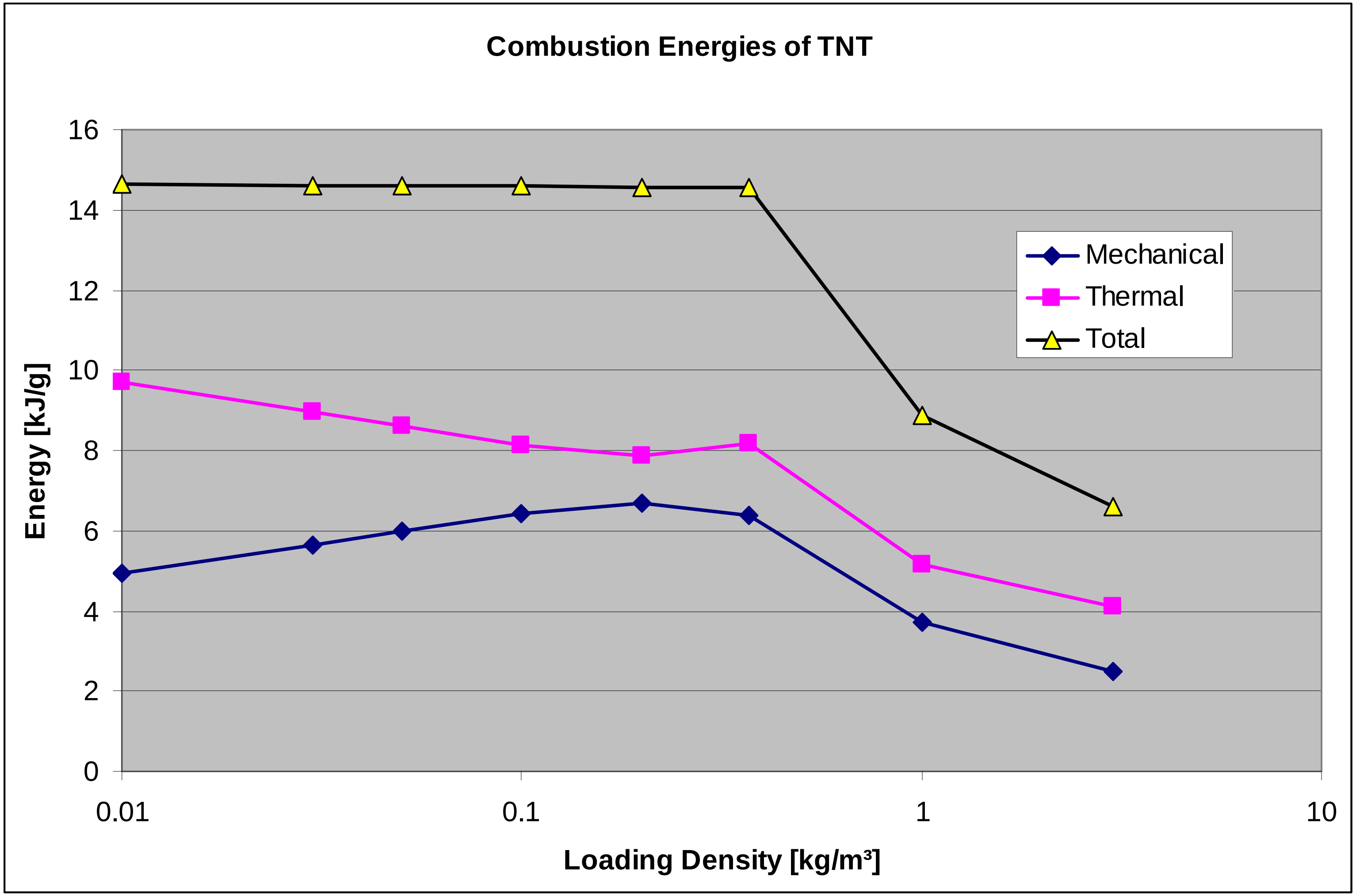
TNT: Energy of Combustion vs Loading Density



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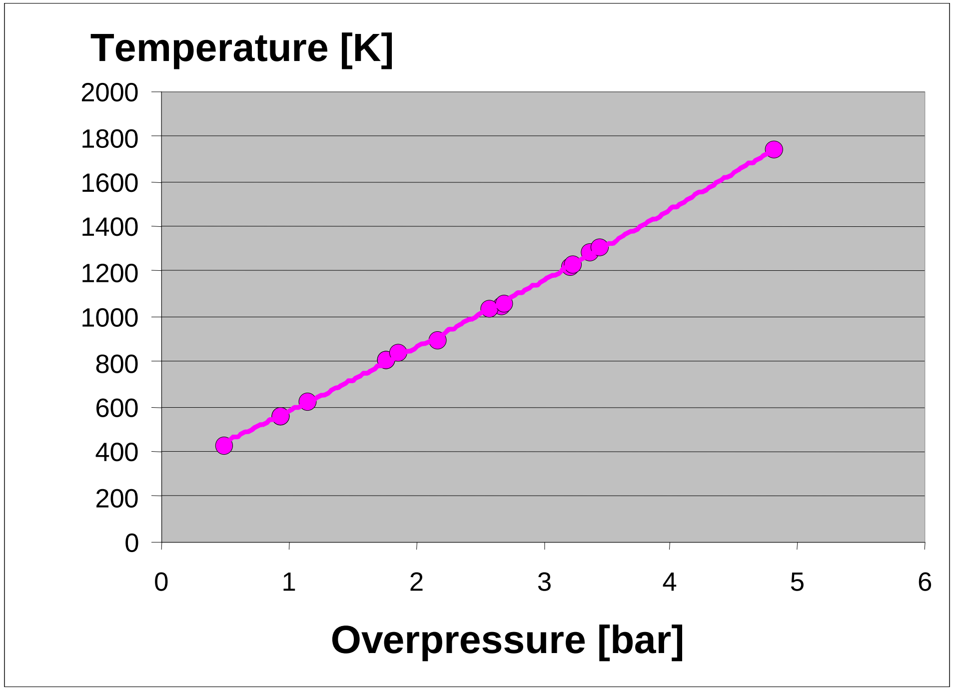
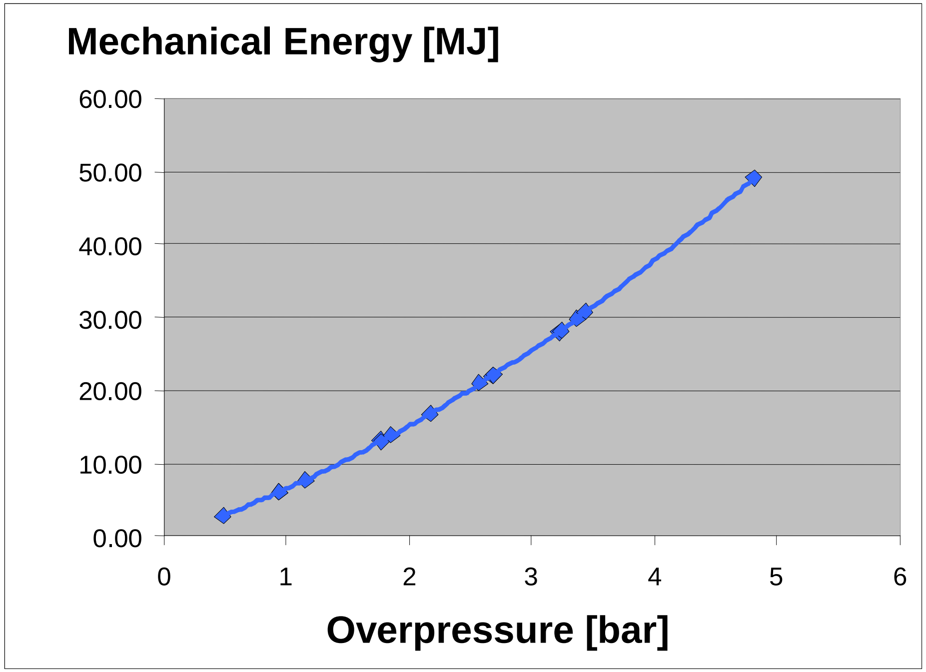
Correlation: Mechanical Energy & Equilibrium Pressure (QSP)





Simulations for a variety of HEs
PETN …. highly metallized Formulations

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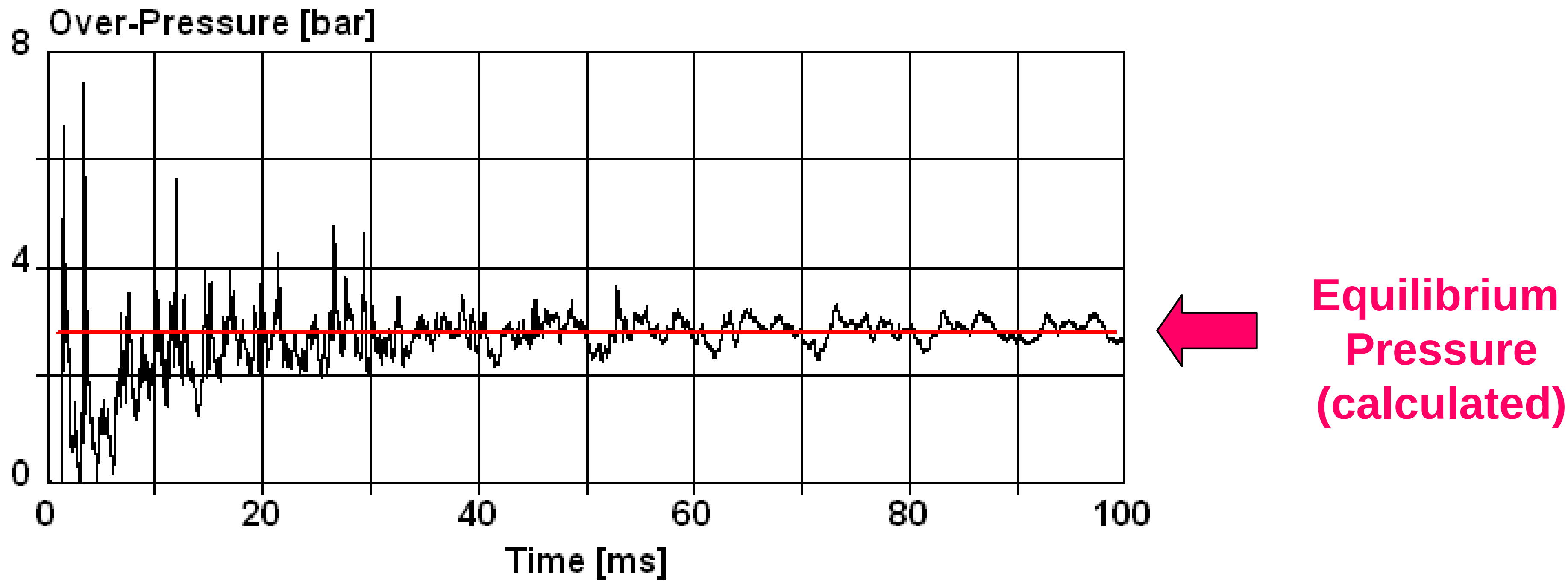
Measurement of Quasi-Static Pressure (QSP)



- Shock Reverberations within Detonation Chamber
- Energy & Mass Losses due to Heat Transfer & Openings

$QSP_{exp}(t)$
t = 50, 100 ms
& QSP_{max}

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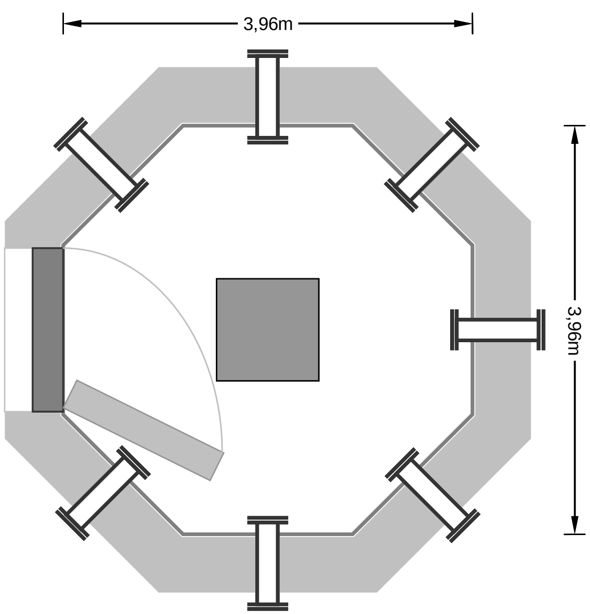
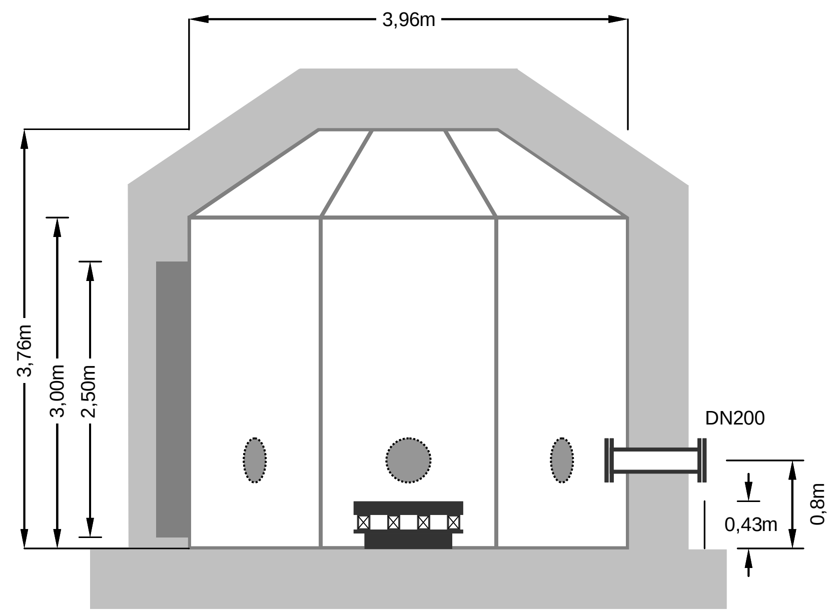
ICT Test Chamber (Constant Volume)

- **ICT Fraunhofer Institute, Karlsruhe, GE**
  Closed detonation chamber, 45 m^3, regular octagon
- **SIBEX: 2 kg cylindrical shape, Dia 104 mm**
- **1.50 m above ground in center of chamber**
- **Initiation from top**
- **Several pressure gauges**





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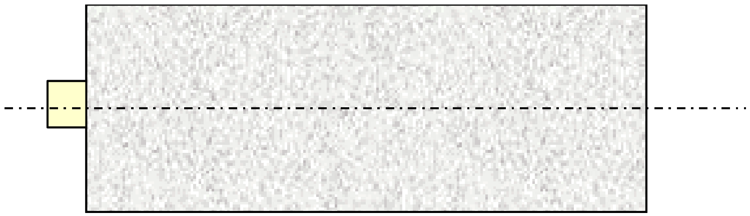
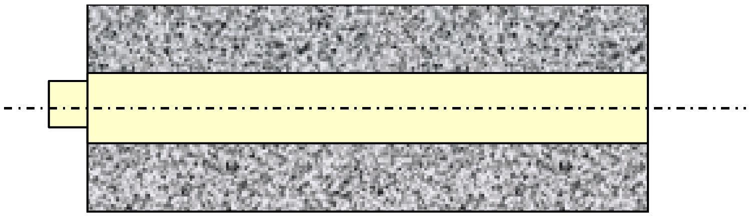
Test Charges: Composite & SDF Charges

Designation	***Components***	***Type***	***Oxygen Balance [%]***
KS22a	RDX/Al/HTPB	composite	-77
PBX-4	RDX/B/HTPB	composite	-146
BM-I	HMX/HTPB + B/DOA	SDF	-148
TB1 D	HMX/HTPB + Al/B/DOA	SDF	-116



Single body composite charge



SDF-charge (Shock Dispersed Fuel)

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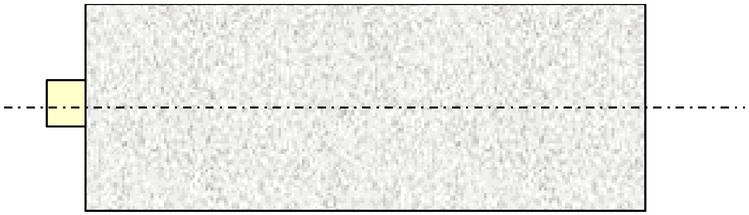
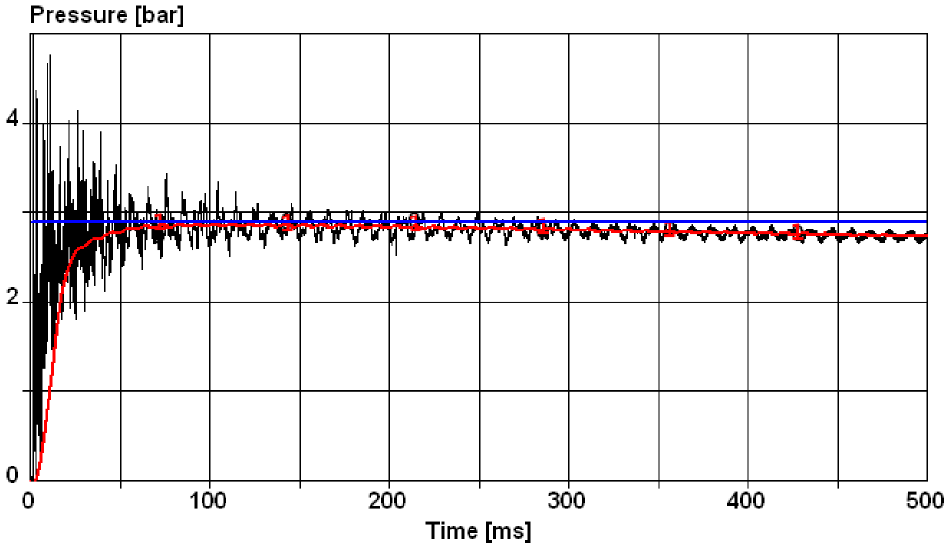
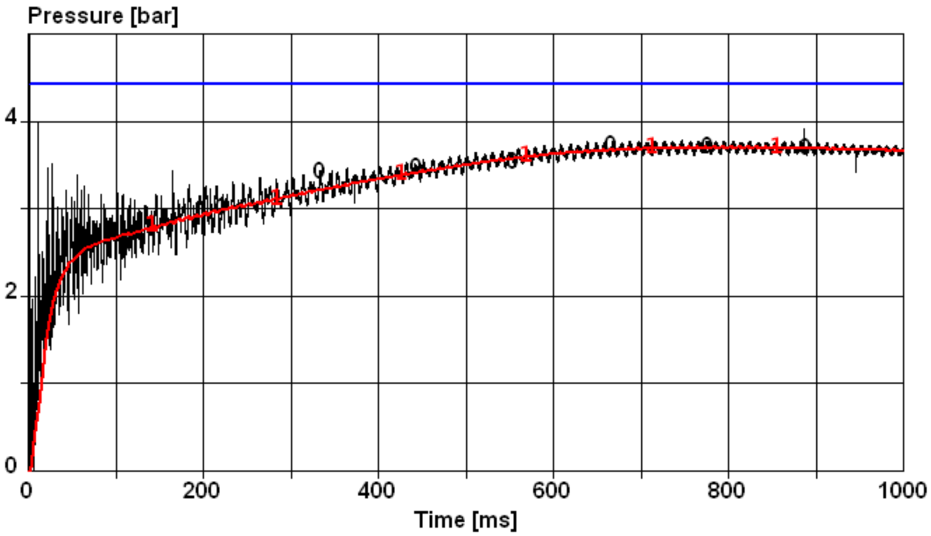
Test Results: Single Body Composite Charges



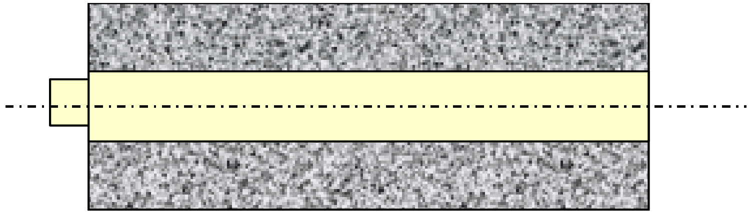


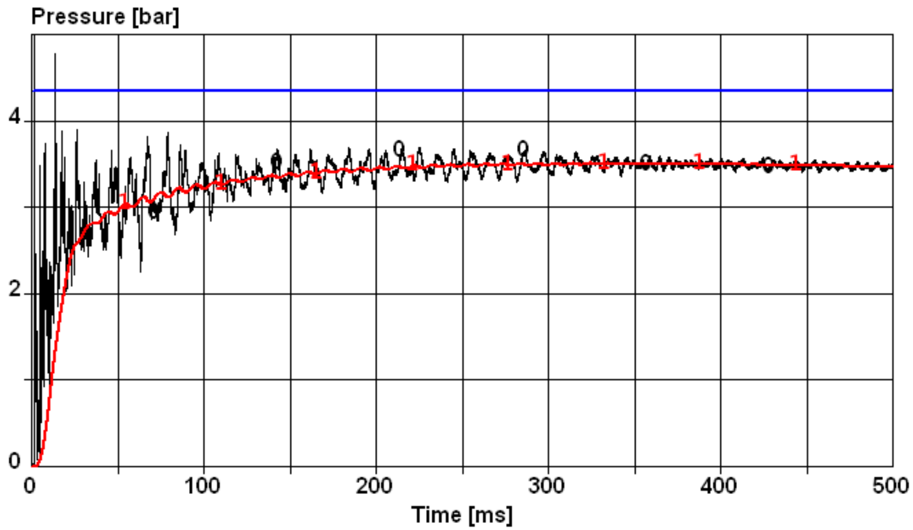


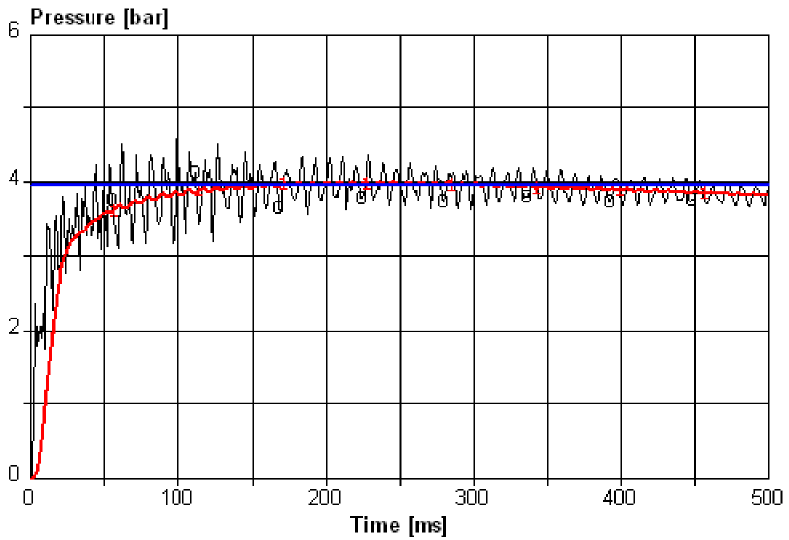
KS22a (Reference)
RDX/Al/HTPB

PBX-4
RDX/B/HTPB

Test Results: Shock Dispersed Fuel (SDF) Charges







BM-I
HMX/HTPB + B/DOA

TB1 D
HMX/HTPB + Al/B/DOA

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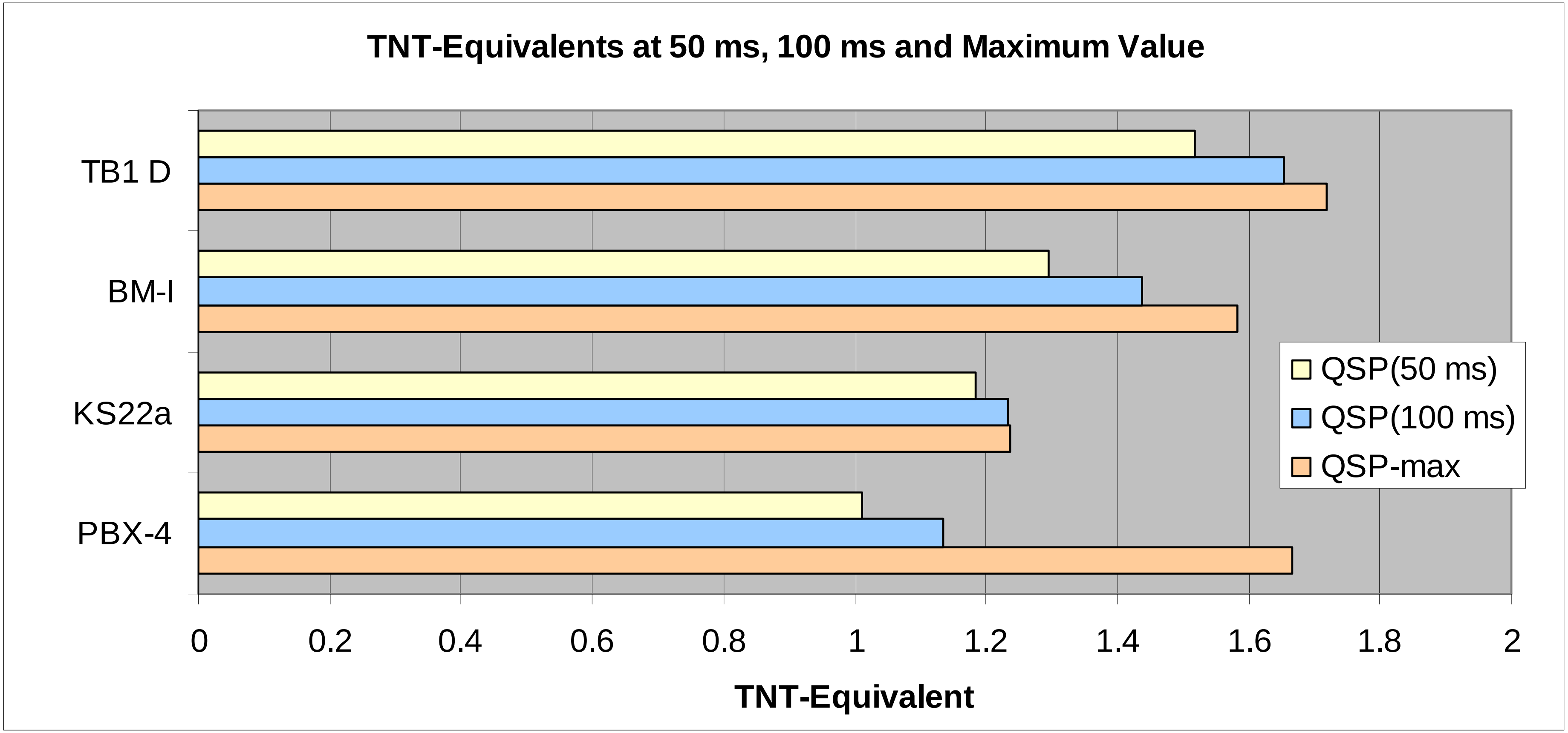
TNT-Equivalents of QSP(t)



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The Thermodynamic Model of Combustion

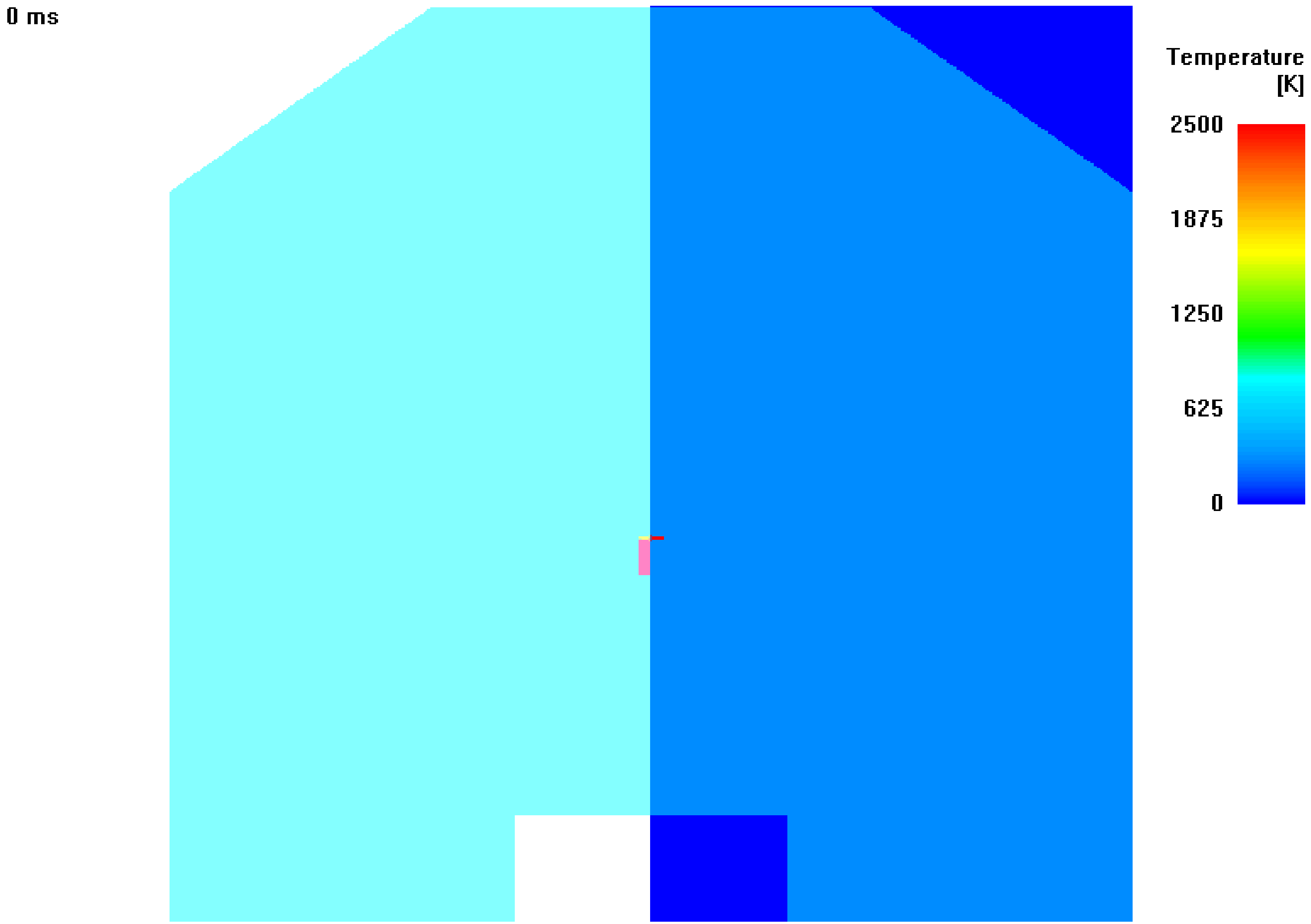
Turbulent Mixing Controlled Combustion

- Kuhl et al. (LLNL): 34th ICT Conference 2002
- Application: TNT & PETN (conv. CHNO-explosive)

W. Arnold, E. Rottenkolber
Combustion of an Aluminized Explosive in a Detonation Chamber
39th International Annual Conference of ICT
June 24 – June 27, Karlsruhe, 2008

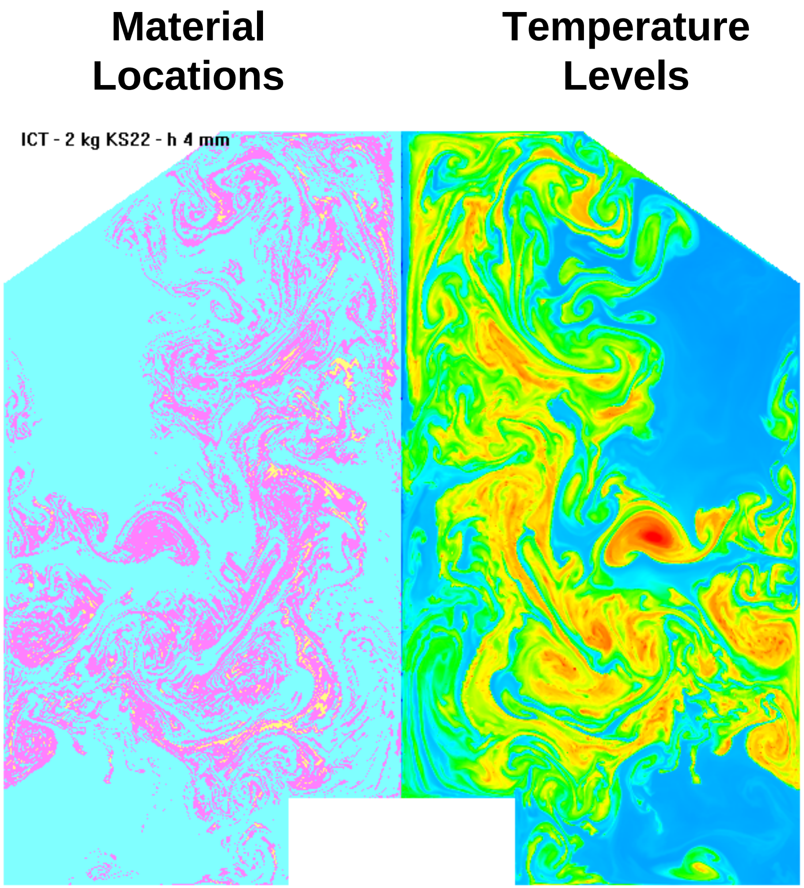
- Application: KS22a (Al-powder containing explosive)
- Modifications & extensions:

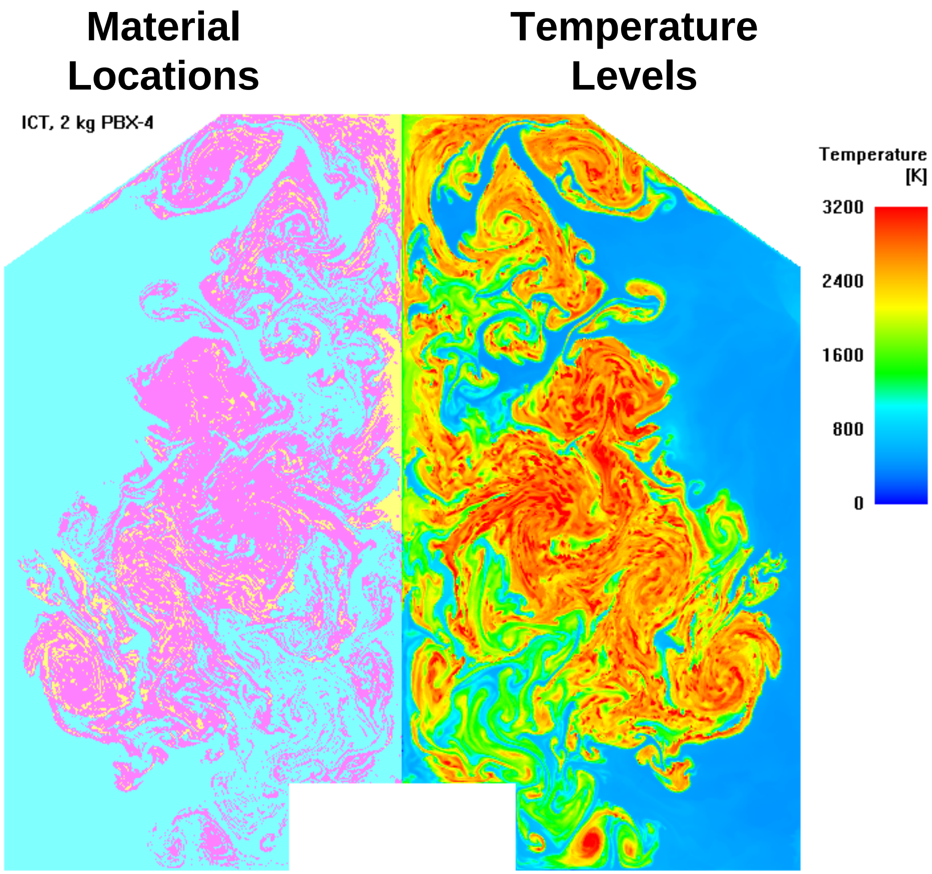
Numerical Simulation: Video Clip



Comparison: Material Location & Temperature KS22a vs PBX-4

t = 20 ms

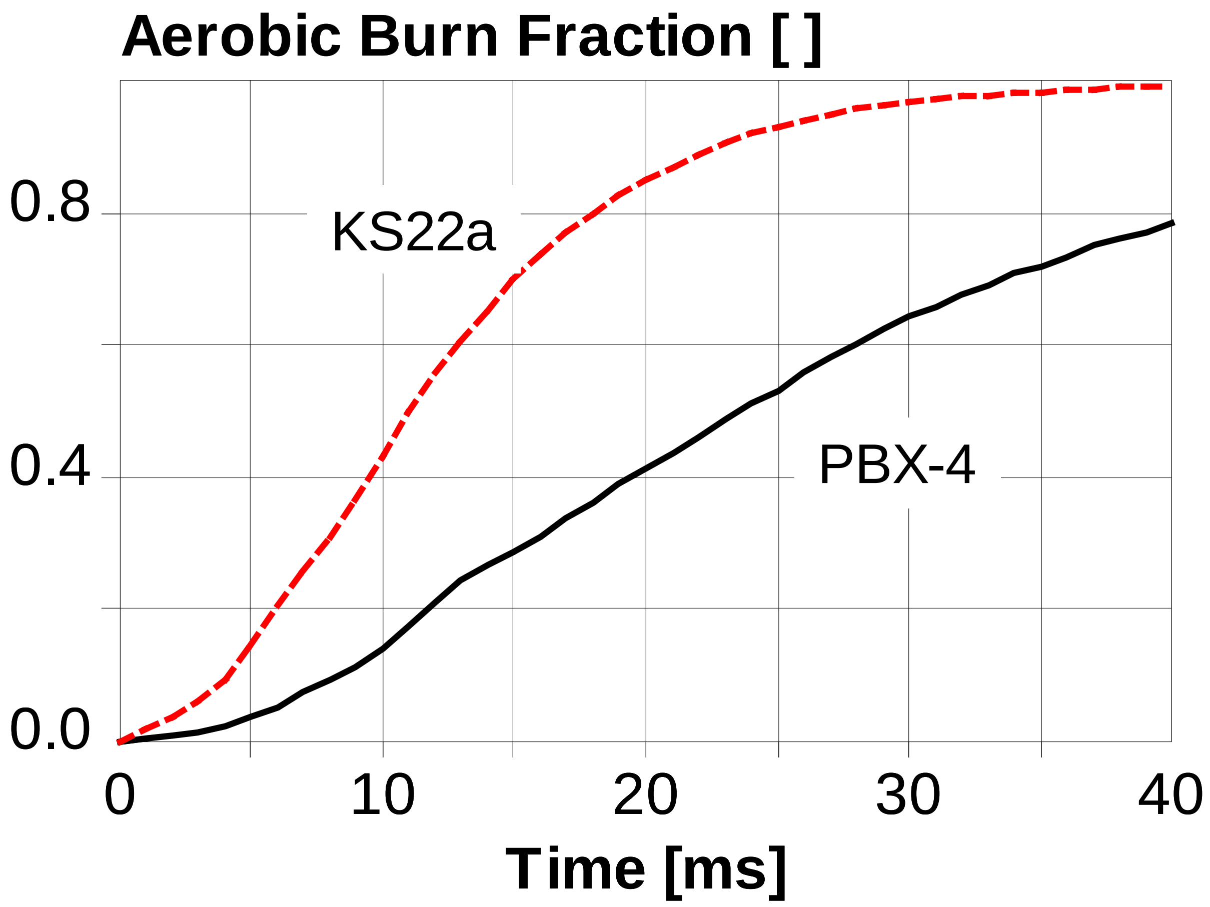




KS22a
-77% O_2 Deficit

PBX-4
-146% O_2 Deficit

Aerobic Burn Fraction: KS22a vs PBX-4



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Conclusions

- **Good correlation between mechanical energy and quasi-static pressure.**

- **Combustion of composite charges with an extremely high oxygen deficit is slowed down by the difficulty to mix the detonation products with air.**

- **Shock dispersed fuel (SDF) charges with an equally high oxygen deficit have a higher overall burn rate compared to composite charges.**

- **The best charges achieved TNT-equivalents between 1.5 and 1.7**

- **Future enhancements:**
  - **faster reacting metal particles**
  - **means to accelerate mixing of fuel with air**

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Thank You for

Your Attention !

Any Questions ?

Your Contact:
Dr. Werner Arnold
Phone: +49 8252 99 6267
Email: werner.arnold@mbda-systems.de