Manfred Bohn

EMG MURAT
EUROPEAN MANUFACTURERS GROUP

Insensitivity aspects of NC bonded and DNDA plasticizer containing gun propellants

Manfred A. Bohn and Dietmar Müller

Fraunhofer-Institut für Chemische Technologie, ICT

2006 Insensitive Munitions & Energetic Materials Technology Symposium

Maintaining Performance and Enhanced and Survivability Throughout the Lifecycle

April 24-28, 2006

Bristol, UK

Fraunhofer Institut Chemische Technologie

Content

- Introduction

  Conventional GP versus new type gun propellants (NT-GP)
- LTC effect
- Formulations

  type, ingredients
- Performance data
- Results on thermal properties / sensitiveness

  adiabatic self heating – cook-off sensitivity

  ageing behaviour

  mass loss at 70℃, 80℃ and 90℃

  heat generation rate at 60℃, 70℃, 80℃ and 90℃
- Results on operational properties

  shaped charge impact

  barrel erosivity
- Conclusion

Introduction

Conventional gun propellants

NC based

single base, double base, triple base

performance enhancement by surface treatment

Semi nitramine gun propellants

NC bonded

NC, RDX, plastizicer are nitrate ester based (sort of triple base GP)

New type gun propellants

NC bonded

NC, RDX, (+ CL20, FOX7,..), non nitrate ester plasticizer

elastomer bonded (thermoplastic, GAP, CAB,...)

binder, RDX (+ any X), plasticizer

ICT's New Type Gun Propellants (NT-GP)

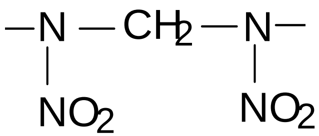
NC bonded

NC, RDX, (+ CL20, FOX7,..), non-nitrate ester plasticizer

DNDA gun propellants

DNDA

recent plasticizer based on the n,(n+2)-**D**i **N**itro - n,(n+2)-**D**i **A**za group as energetic molecular part



Content

- Introduction
  - Conventional GP versus new type gun propellants (NT-GP)
- LTC effect
- Formulations
  - type, ingredients
- Performance data
- Results on thermal properties / sensitiveness
  - adiabatic self heating – cook-off sensitivity
  - ageing behaviour
    - mass loss at 70℃, 80℃ and 90℃
    - heat generation rate at 60℃, 70℃, 80℃ and 90℃
- Results on operational properties
  - shaped charge impact
  - barrel erosivity
- Conclusion

Defining the LTC effect for gun propellants

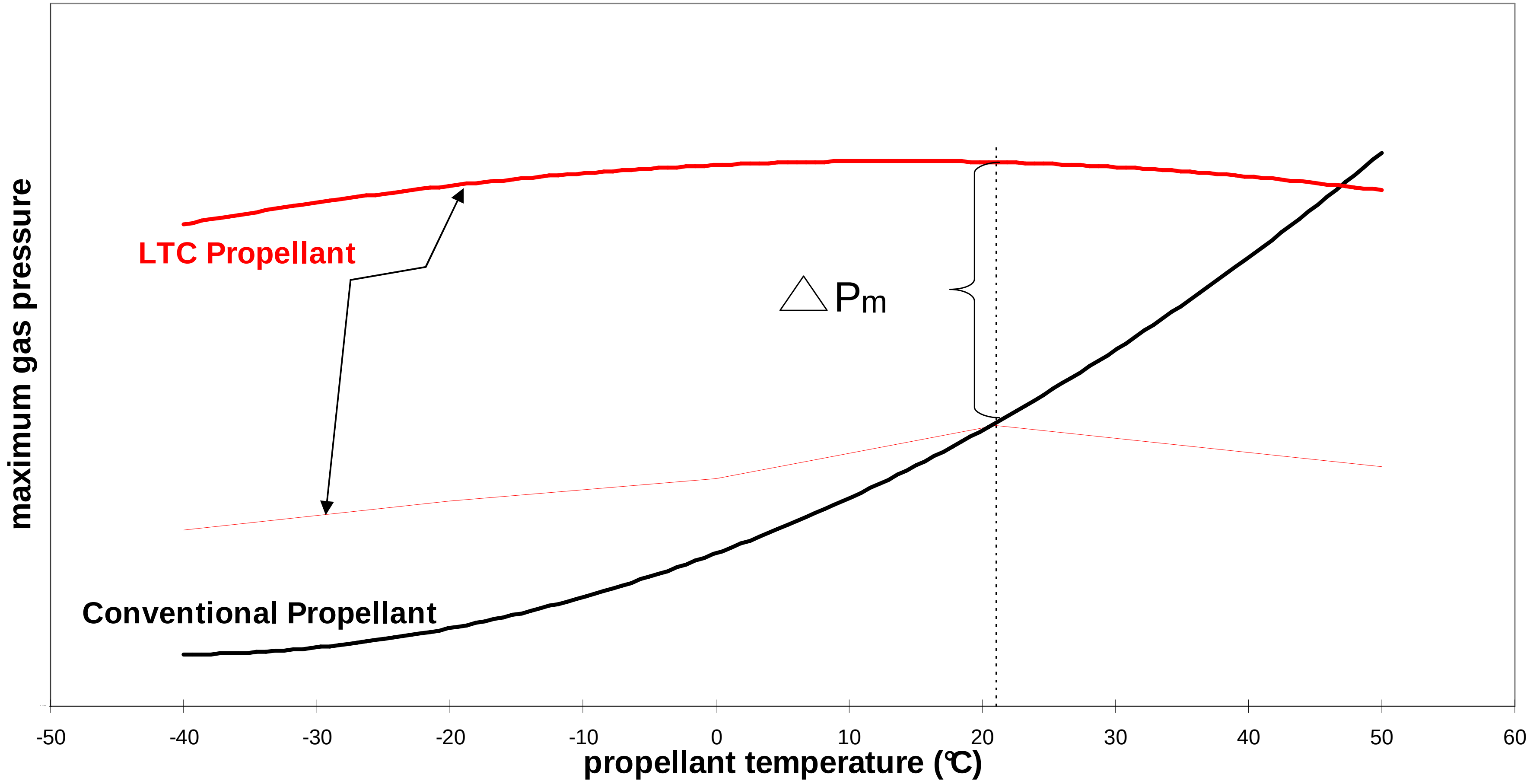
LTC: low (small) temperature coefficient

means

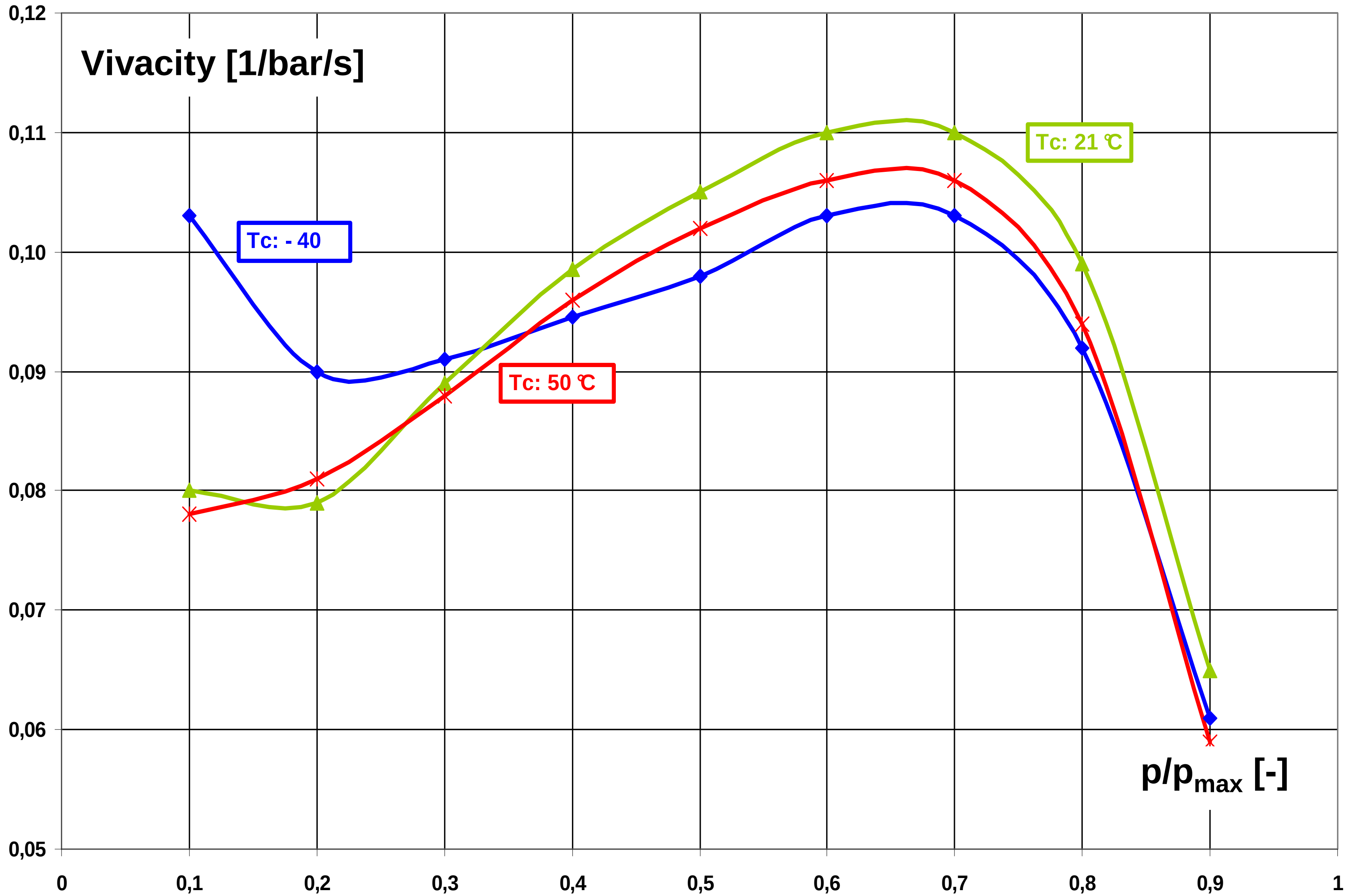
A gun propellant which shows small to very small dependence of maximum chamber pressure as function of charge temperature

temperature range of interest is from -40℃ (-54℃) to +63℃ (+71℃)

Comparison of typical gas pressure curves of conventional and LTC propellants



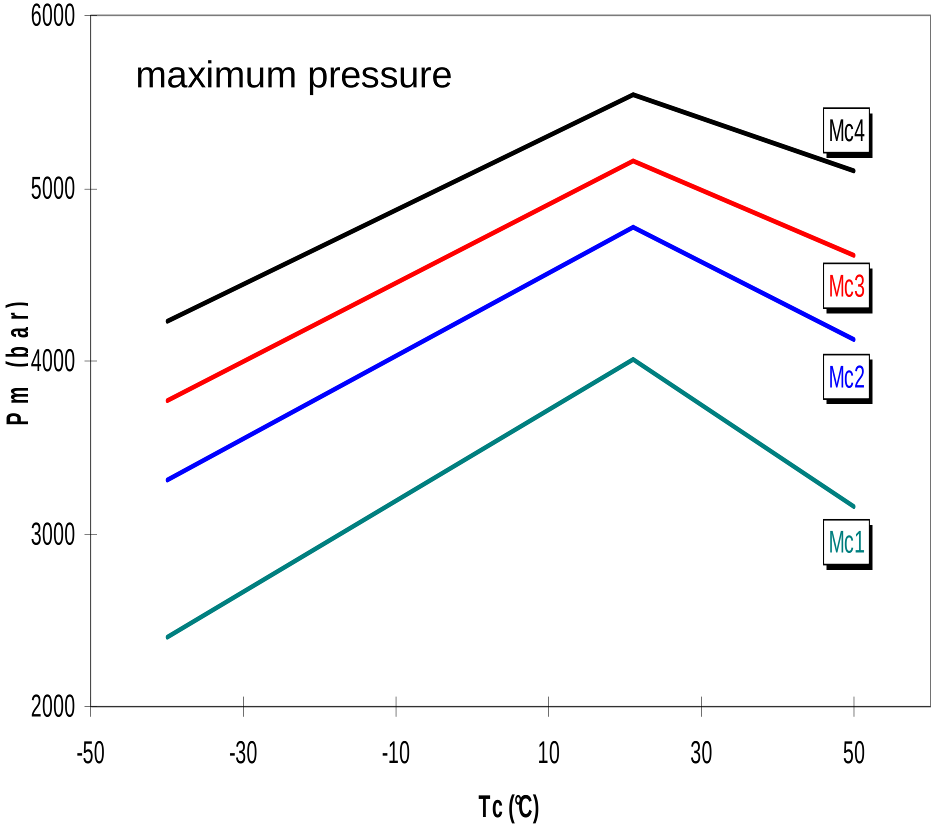
Characteristics of a LTC GP - Dynamic vivacity determined in a 200ml pressure vessel at loading density of 0.3 g/ml and at three charge temperatures Tc

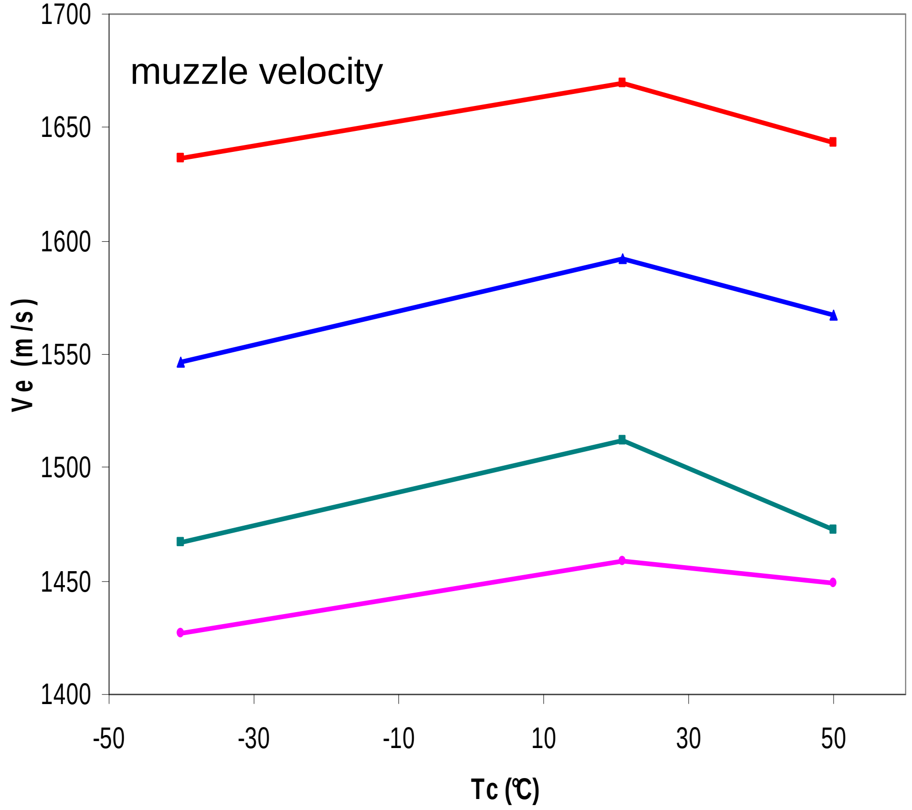


Example of chamber gas pressure courses and resulting muzzle velocities as function of charge temperature Tc with charge mass Mc as parameter

40 mm gun firing tests with variable charge mass:

temperature behaviour must be independent of loading density and pressure level





Content

- Introduction
  - Conventional GP versus new type gun propellants (NT-GP)
- LTC effect
- Formulations
  - type, ingredients
- Performance data
- Results on thermal properties / sensitiveness
  - adiabatic self heating – cook-off sensitivity
  - ageing behaviour
    - mass loss at 70℃, 80℃ and 90℃
    - heat generation rate at 60℃, 70℃, 80℃ and 90℃
- Results on operational properties
  - shaped charge impact
  - barrel erosivity
- Conclusion

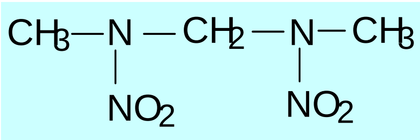
Principal components in some new type GP and two conventional GP

GP	base	Cal.	Web	Components
TLP 1N		70	7	NC, RDX, DNDA57; EC, AkII
TLP 2N		70	7	NC, RDX, DNDA57; EC, AkII
TLP 3N		70	7	NC, RDX, DNDA57; EC, AkII
TLP 4G		70	7	NC, RDX, FOX7, DNDA57; EC, AkII
TLP 5W		30	19	NC, RDX, DNDA57; with A17; EC, AkII
TLP 6		30	19	NC, RDX, DNDA57; without A17; EC, AkII
JA2 (L 5460)	double	120	7	NC, Ngl, DGDN; AkII, MgO
MRCA (Q 5560)	triple	27	19	NC, NQ, K_2SO_4, DGDN, DOP; AkII

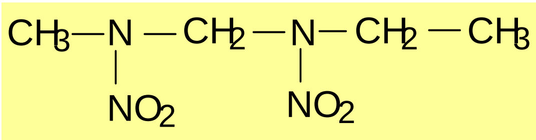
Ingredients - part 1: energetic plasticizer DNDA

DNDA 57: liquid dinitro-diaza plasticizer

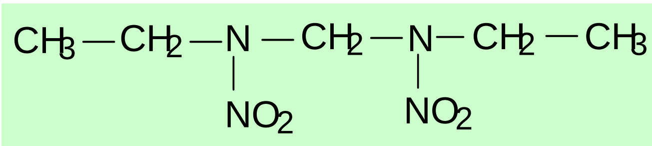
Mixture of three components: DNDA5 : DNDA6 : DNDA7, about 43 : 45 : 12 mass-%



2,4-dinitro-2,4-diaza-pentane, DNDA 5



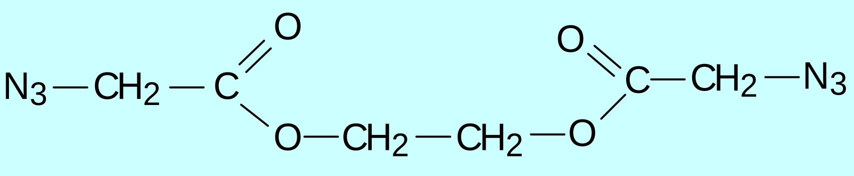
2,4-dinitro-2,4-diaza-hexane, DNDA 6



3,5-dinitro-3,5-diaza-heptane, DNDA 7

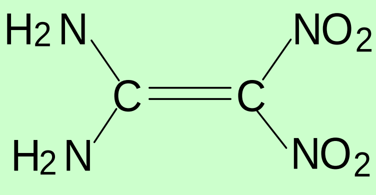
DNDA 57 gells with NC

Ingredients – part 2: used in the NT-GP formulations

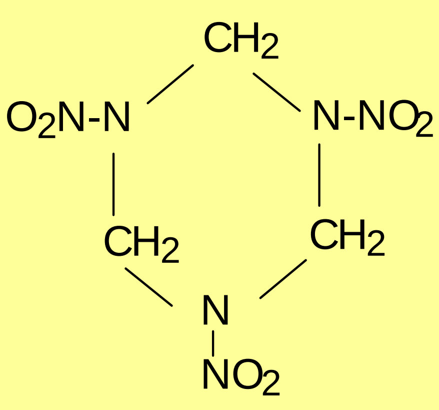


A17, EGBAA,
ethylene glycol-bis-(2-azidoacetate)
azido type plasticizer with ability for strong reduction of glass transition temperature

A17 was developed by ICT.



FOX 7,
1,1-diamino-2,2-dinitro – ethylene (DADNE)
nitro compound



RDX, Hexogen,
1,3,5-trinitro-1,3,5-triaaza-cyclohexane
nitramin compound

Content

- Introduction
  - Conventional GP versus new type gun propellants (NT-GP)
- LTC effect
- Formulations
  - type, ingredients
- **Performance data**
- Results on thermal properties / sensitiveness
  - adiabatic self heating – cook-off sensitivity
  - ageing behaviour
    - mass loss at 70℃, 80℃ and 90℃
    - heat generation rate at 60℃, 70℃, 80℃ and 90℃
- Results on operational properties
  - shaped charge impact
  - barrel erosivity
- Conclusion

Fraunhofer Institut Chemische Technologie

Some characteristic data of GP formulations

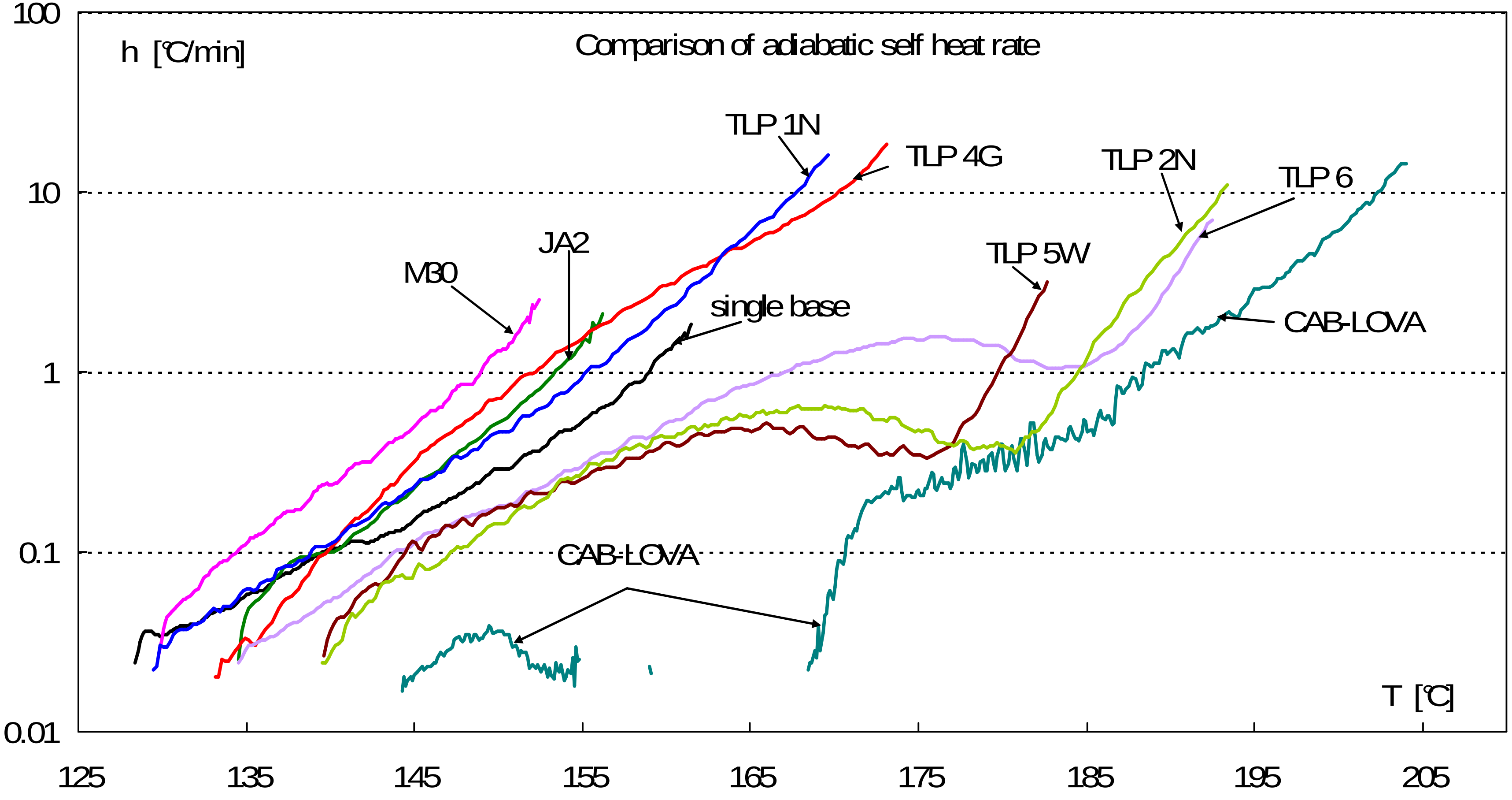
GP	web	LTC effect	autoignition temp. [°C]	adiab. flame temp. T_{ad} [K]	force [J/g]	Q_{EX} [J/g]	V_{EX} at 25°C [ml/g
TLP 1N	7	yes	185	2905	1170	3768	961
TLP 2N	7	yes	220	2906	1178	4198	939
TLP 3N	7	yes	193	2910	1180	4201	939
TLP 4G	7	yes	198	2908	1185	4071	938
TLP 5W	19	yes	189	2510	1060	4124	931
TLP 6	19	yes	199	2540	1080	4177	929
JA2 (L 5460)	7	no	168	3390	1139	4610	753
MRCA (Q 5560	19	no	172	3078	1040	3758	857

Adiabatic flame temperature T_{ad}, force, heat of explosion Q_{EX} and gas volume V_{EX} have been calculated by ICT Thermodynamic Code using the data of the ICT Thermochemical Data Base

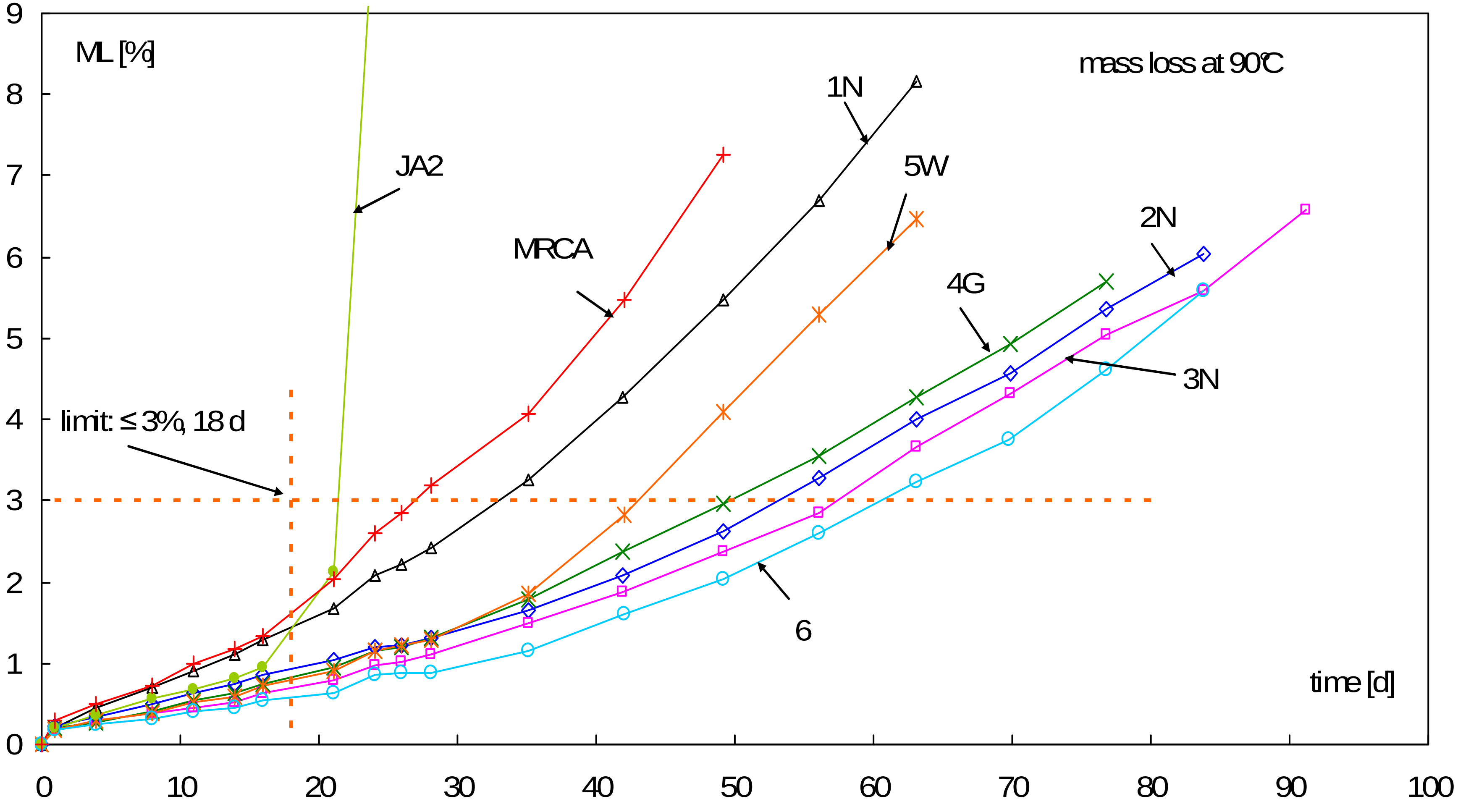
Content

- Introduction
  Conventional GP versus new type gun propellants (NT-GP)
- LTC effect
- Formulations
  type, ingredients
- Performance data
- Results on thermal properties / sensitiveness
  adiabatic self heating – cook-off sensitivity
  ageing behaviour
    mass loss at 70℃, 80℃ and 90℃
    heat generation rate at 60℃, 70℃, 80℃ and 90℃
- Results on operational properties
  shaped charge impact
  barrel erosivity
- Conclusion

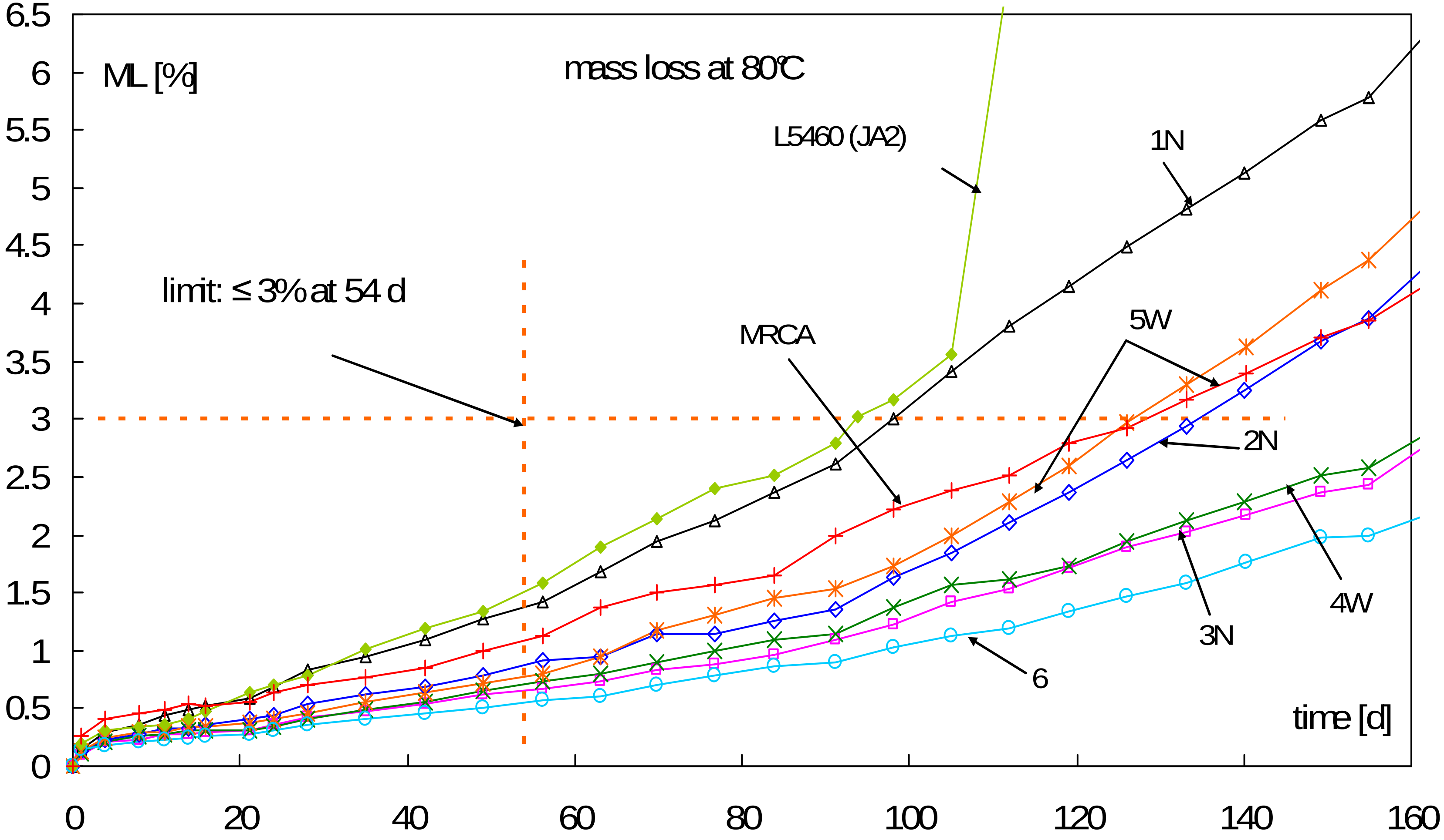
Adiabatic self heating determined by an ARC™ of typical conventional and of new type GP, including the XM39 GP with a binder based on CAB



Assessment of ageing and stability with mass loss



Assessment of ageing and stability with mass loss

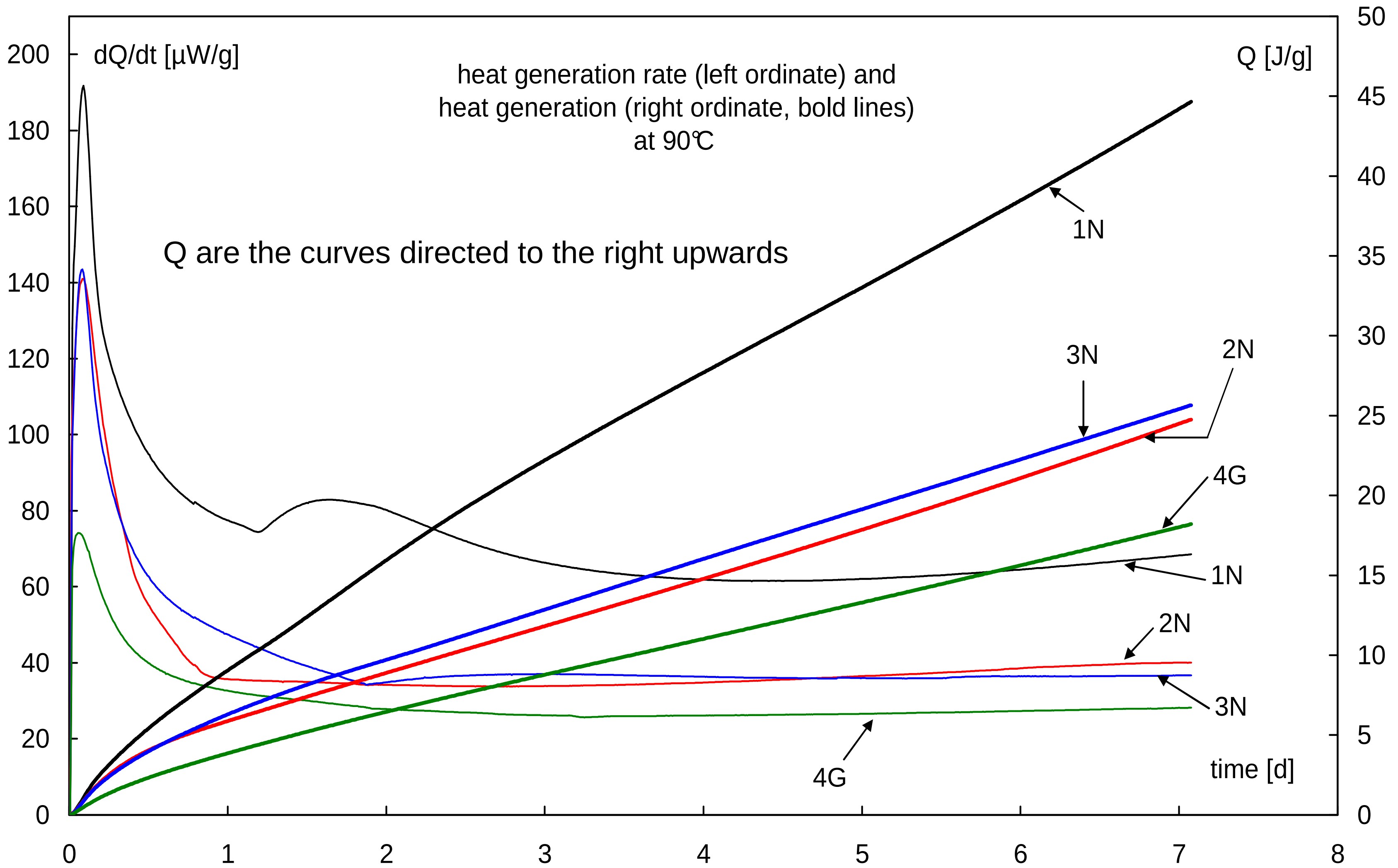


Fraunhofer Institut Chemische Technologie

Times ty_{ML} to reach 3% mass loss in years calculated with Arrhenius parameters obtained from mass loss measurements at 70℃, 80℃ and 90℃

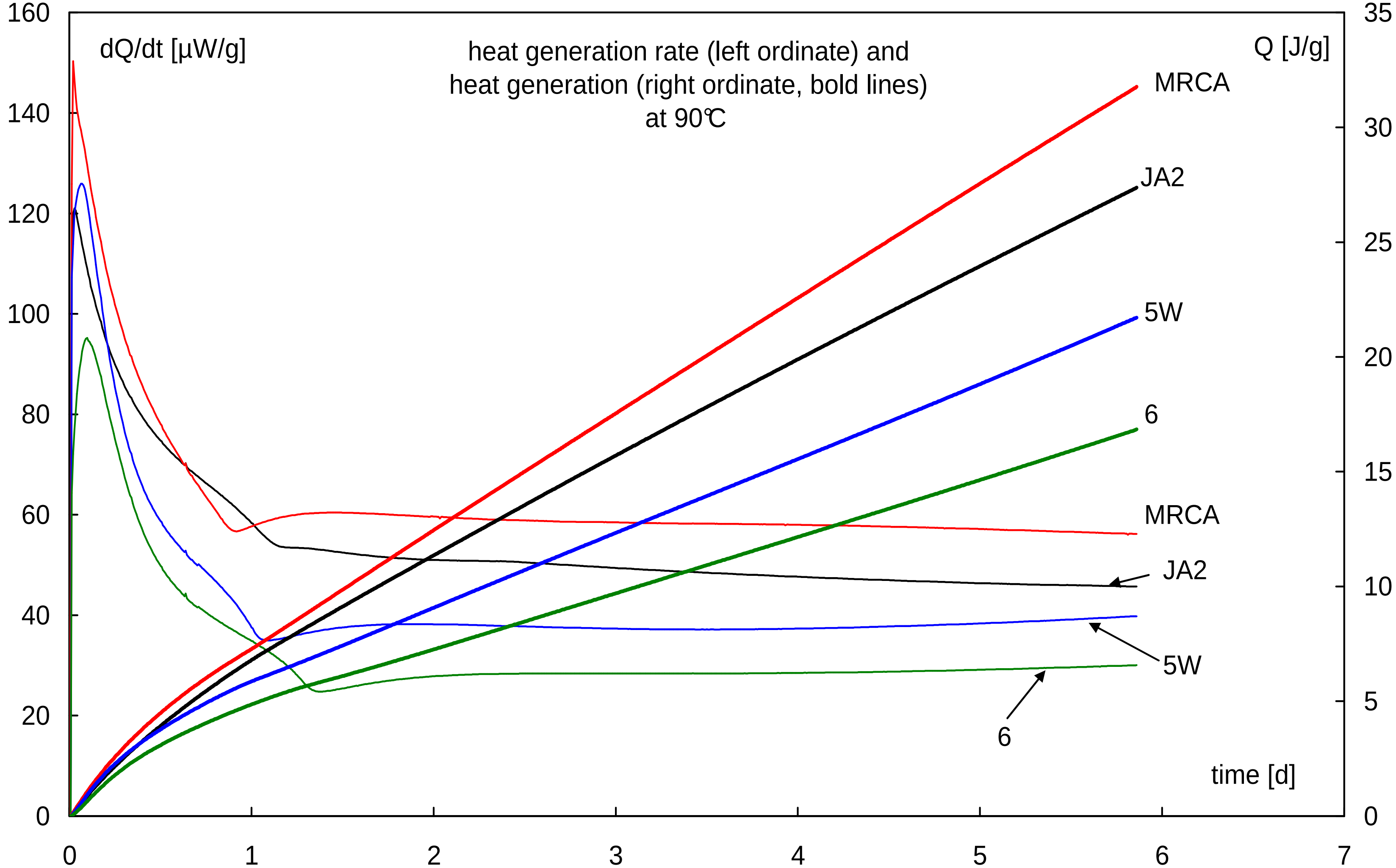
	1N	2N	3N	4G	5W	6	MRC A	JA2	JA2, HT
web	7	7	7	7	19	19	19	7	7
Ea_{ML} [kJ/mol]	116.5	104.3	101.8	105.6	105.7	102.2	147.9	102.0	149.0
$\log(Z_{ML}$ [1/d])	15.235	13.286	12.865	13.457	13.56	12.888	19.837	13.282	20.102
	time ty_{ML} to reach 3% mass loss ML in years at preset temperatures								
65°C [a]	1.6	1.8	2.0	1.9	1.6	2.2	2.8	0.8	2.2
50°C [a]	10.6	10.3	10.6	11.1	9.2	11.9	31.9	4.5	26.3
35°C [a]	87.8	68.1	67.1	75.1	62.3	75.6	465.1	28.3	391.2

Assessment of ageing and stability by heat generation rate (dQ/dt) and heat generation Q at 90℃ - Part 1: NT-GP 1N, 2N, 3 N and 4G



Fraunhofer Institut Chemische Technologie

Assessment of ageing and stability by heat generation rate (dQ/dt) and heat generation (Q) at 90℃ - Part 2: NT-GP 5W, 6 and JA2, MRCA



Fraunhofer Institut Chemische Technologie

Times ty_{EL} to reach 3% energy loss EL

Times ty_{EL} in years calculated with Arrhenius parameters obtained from heat generation rate measurements at 60℃, 70℃, 80℃ an d 90℃.
Reference quantity Q_{ref} is the individual heat of explosion Q_{EX}

	1N	2N	3N	4G	5W	6	MRCA	JA2
Q_{EX} [J/g]	3768	4198	4201	4071	4124	4177	3758	4610
web	7	7	7	7	19	19	19	7
Ea_Q [kJ/mol]	112.3	115.6	121.6	118.2	111.5	113.9	130.0	128.2
log(Z_Q [µW/g])	17.971	18.217	19.059	18.43 6	17.633	17.847	20.426	20.056
	time ty_{EL} to reach 3% energy loss EL in years at preset temperatures							
65°C [a]	0.85	1.74	2.12	2.57	1.53	2.22	1.62	2.45
50°C [a]	5.4	11.7	15.8	18.1	9.6	14.6	13.8	20.3
35°C [a]	42	95	142	154	73	115	146	207

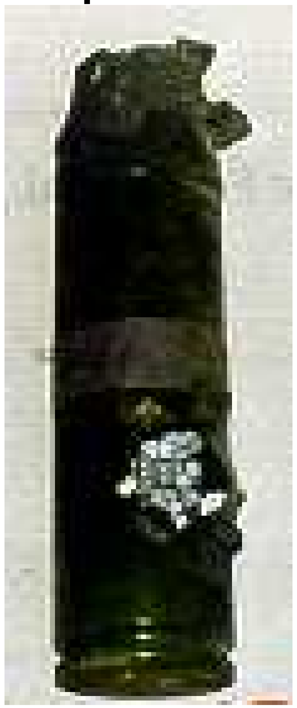
Content

- Introduction
  - Conventional GP versus new type gun propellants (NT-GP)
- LTC effect
- Formulations
  - type, ingredients
- Performance data
- Results on thermal properties / sensitiveness
  - adiabatic self heating – cook-off sensitivity
  - ageing behaviour
    - mass loss at 70℃, 80℃ and 90℃
    - heat generation rate at 60℃, 70℃, 80℃ and 90℃
- Results on operational properties
  - shaped charge impact
  - barrel erosivity
- Conclusion

Results of shaped charge jet impact (cal 44 mm) on 35 mm cartridges filled with US GP XM39 (left) and ICT's NT-GP lot 2N (right).

The XM39 propellant reacts very mild, but also ICT's NT-GP lot 2N does it

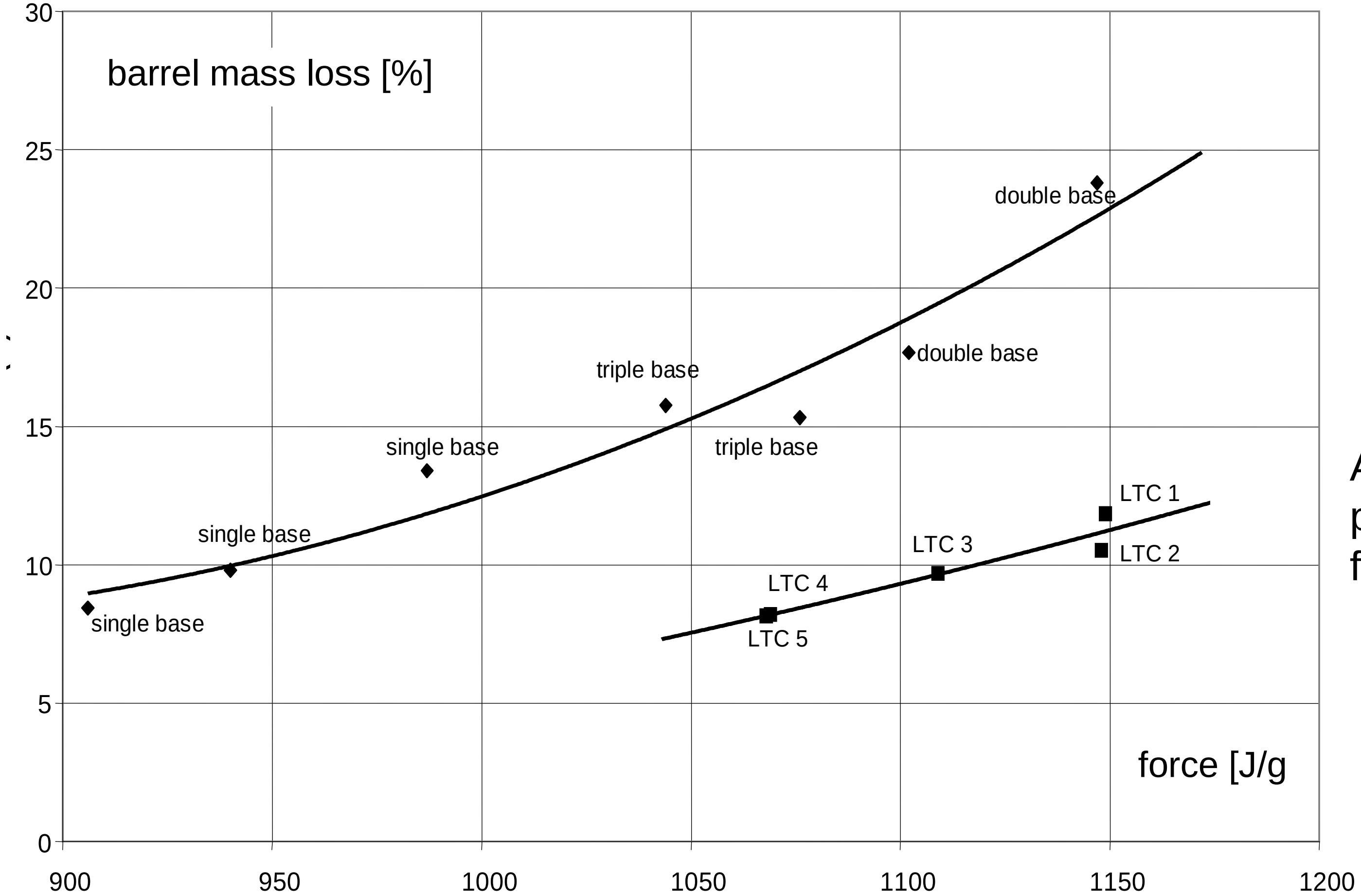
CAB -LOVA Propellant



NT-GP lot 2N with LTC

Results on erosivity - Degree of erosion as function of GP force.

The hotter the combustion gases the higher the erosion. Conventional db-GP with high flame temperatures show the highest values. Data determined with a ballistic bomb equipped with plate of weapon steel having a die. The mass loss of the plate quantifies the erosivity



All LTC propellants from ICT

Conclusion – part 1 of 2

ICT's NC-bonded New Type GP have significant advantages compared to conventional GP

- The autoignition temperature is higher: 185 to 220℃ versus 170 to 175℃
- High force values at lower flame temperature, difference in T_{ad} is about 400 to 500 K
- Higher force values in direct comparison of weapon designed lots
- Sensitivity against shaped charge (cal. 40mm) jet impact comparable with US XM39
- Barrel erosivity is much lower compared with convent. double and triple base GP

Conclusion – part 2 of 2

The most striking advantage of ICT's NT-GP is

The small temperature dependence of maximum gas pressure p_{max} from charge temperature Tc

Means these NT-GP show a real LTC (low temperature coefficient) effect

The effect is independent of loading density and pressure level

Essential criteria for LTC

The pressure p_{max} is smaller at high temperature end (50 to 63℃) tha n at 21℃

The vivacity curve lies at 50 to 63℃ below the one at 21℃