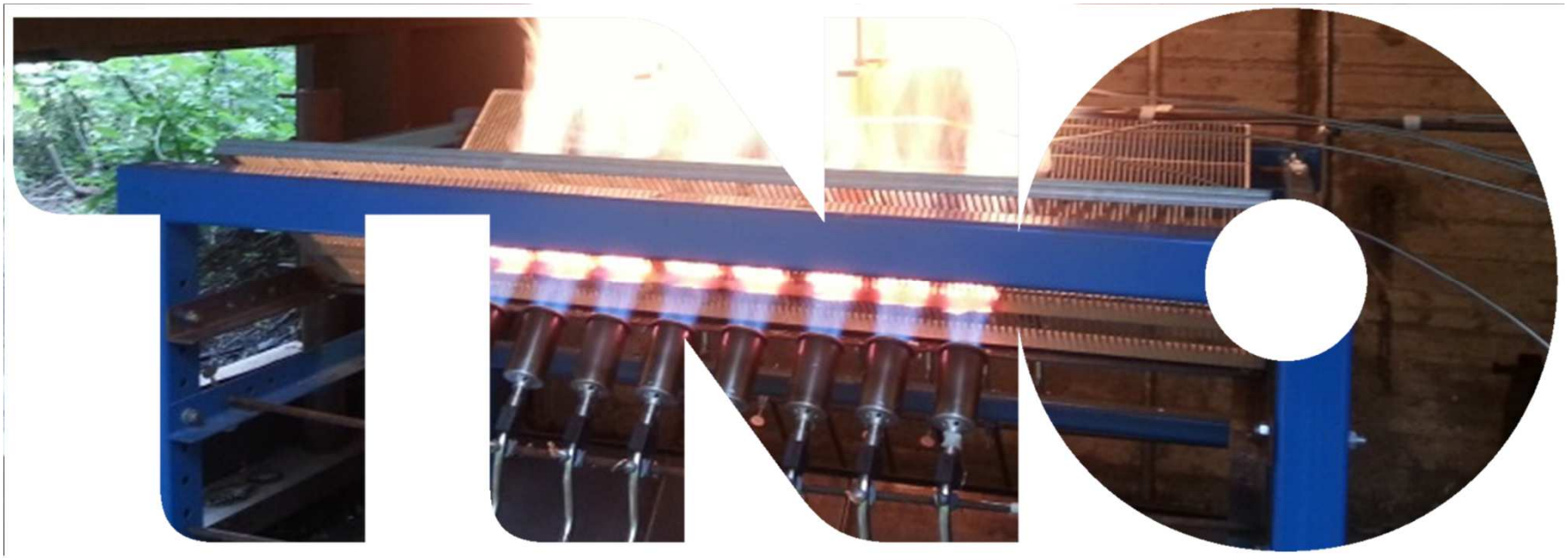
TNO innovation for life

IMPROVEMENT OF A CLEAN FAST COOK-OFF TEST IN THE NETHERLANDS

Gert Scholtes TNO and Albert Bouma Dutch MOD KC W&M,
May 2015, IMEMTS symposium Rome

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Overview

- Introduction
- Summary 2013
- Modifications and preliminary testing
- Test series at ‘t Harde with MOD
- Results of test series
- Conclusions way forward


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Introduction

- Fuel fire test in STANAG 4240
- Use of Jet Fuel/Kerosene or Wood (UN)
- Severe pollution: rising problem with future environmental legislation
- MoD The Nederlands limited use of fuel fire equipment per year
- Looking for a ‘clean’ solution


Summary of results of 2013

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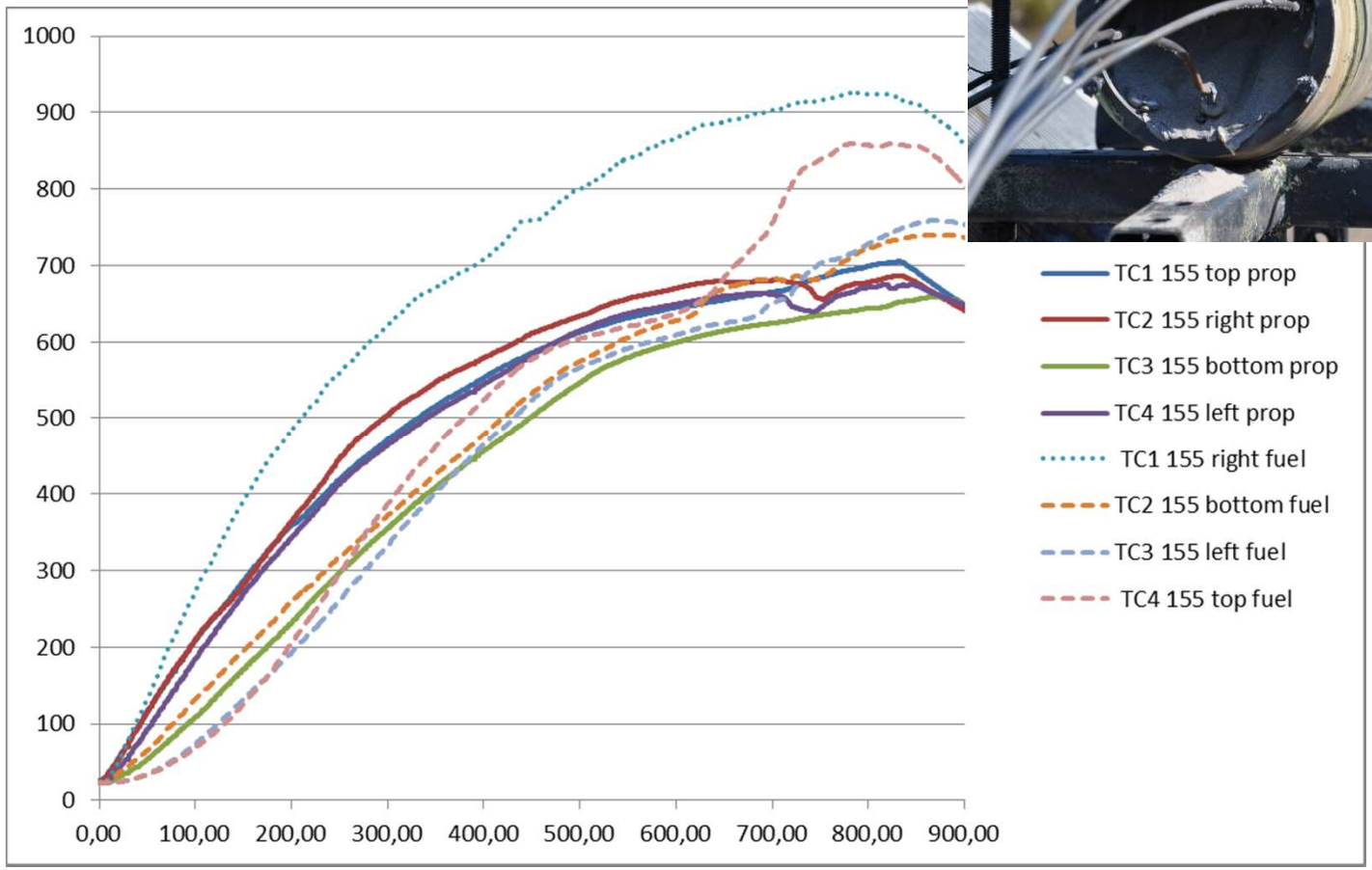
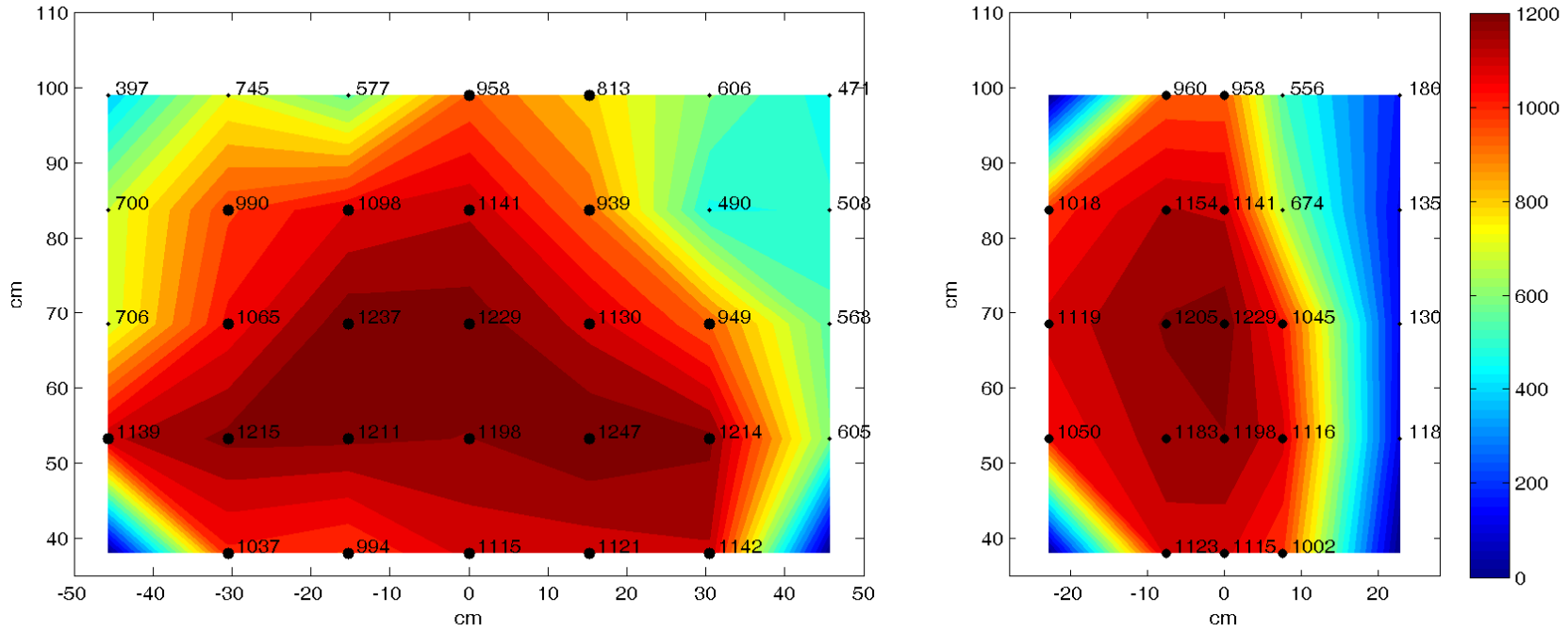
Photographs

Comparison fuel vs propane of 155 mm mock-up

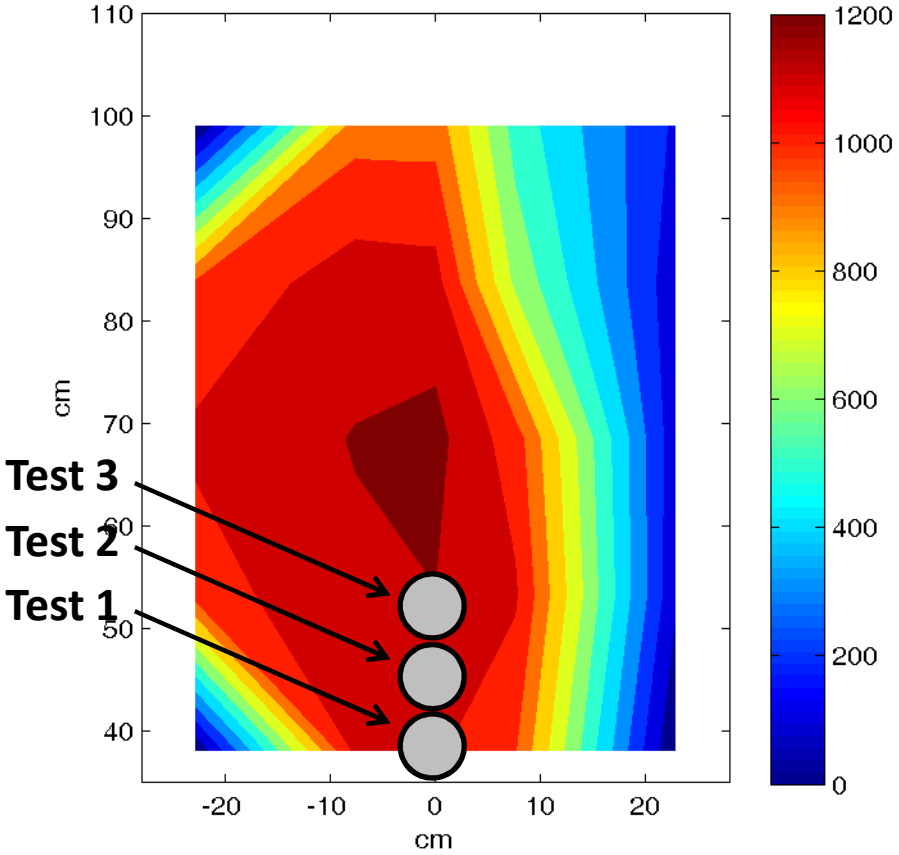


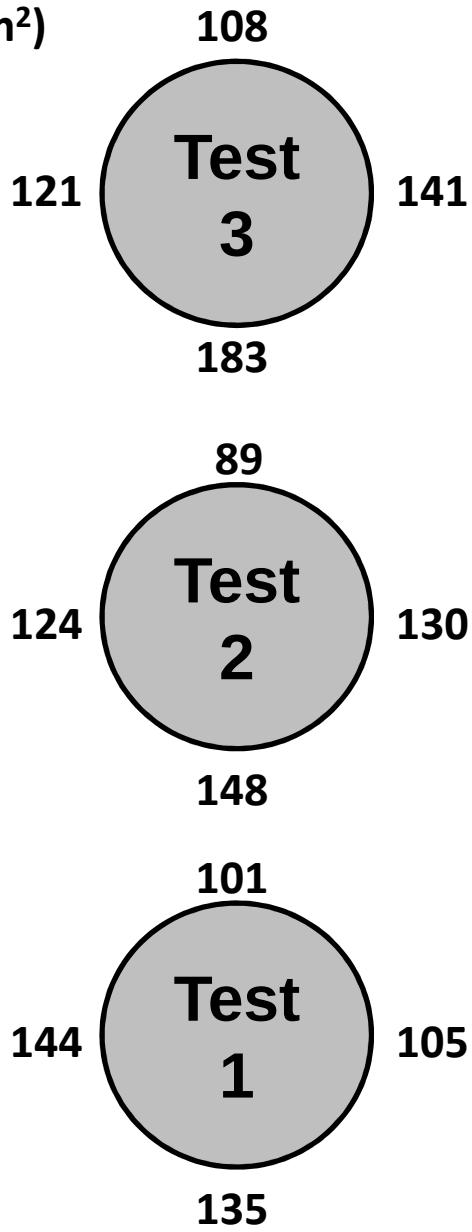
Results of temperature and Flux measurements (results from NSWC Jon Yagla and co-workers)



Average temperatures measured over the course of 4 separate tests


Measured Heat Flux (kW/m²)





The directional slug calorimeter was positioned at three different heights in three sequential tests to measure the heat flux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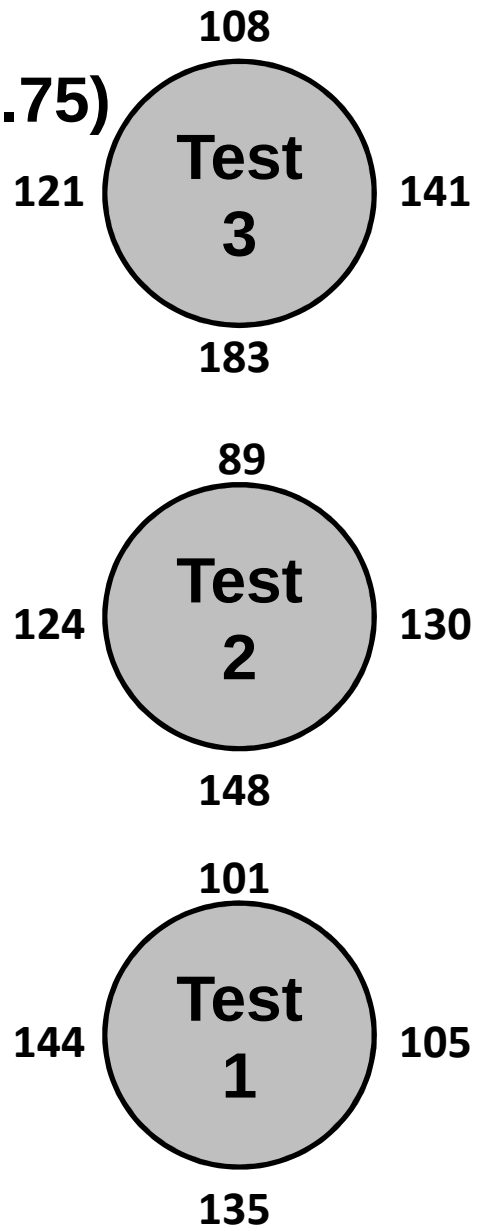
Criteria: 80-150kW/m²
Directional uniformity (AOP DU >0.75)

$$DU = 1 - \frac{\sqrt{\sum_{i=1}^{4} |\bar{x} - x_i|^n}}{\bar{x}};$$

n=1 Hubble, n=2 Scholtes

						Scholtes n=1	Hubble (NAVSEA) n=2
	108						
121	138,25	141				0,794686	0,82821
	183						
	89						
124	122,75	130				0,825714	0,862525
	148						
	101						
144	121,25	105				0,846769	0,849485
	135						
example from US test set-up							
	101						
120	115,25	112				0,913368	0,924078



Minor modificaties performed

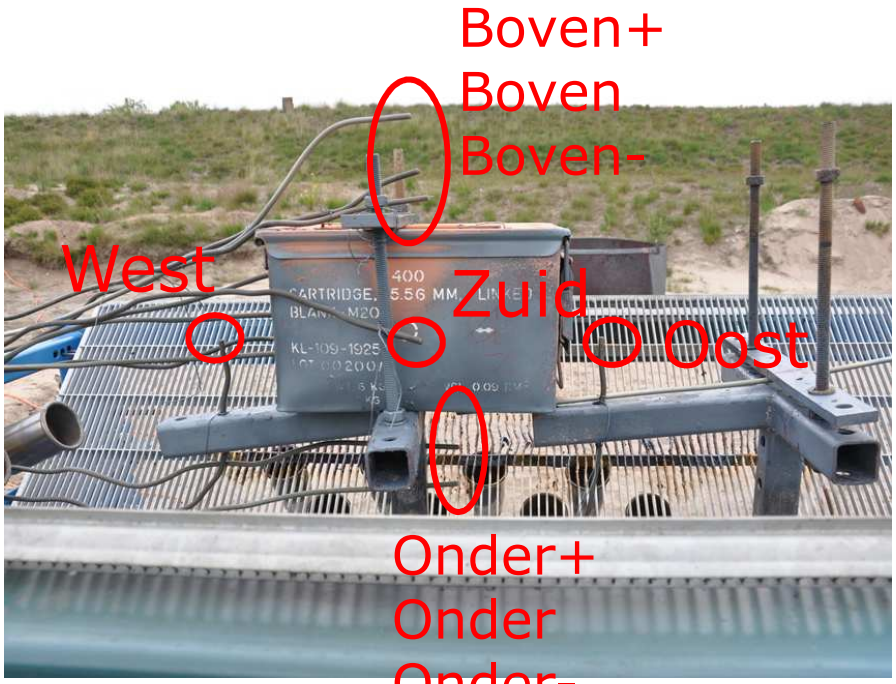
- Longer gas tubes (50m)
- Electronic gas valves and ignition safely controlled from bunker
- More burners all around (not all with piezo ignition)

Modifications/checks

- Is there pressure or performance loss due to longer tubes ?
- Do the electronic gas valves and ignition work ?
- Do the piezo burners ignite all other burners ?
- Is the heating capacity enough and uniform ?

Modifications & Pre-check

M2A1 box (filled with empty copper shells) – Setup

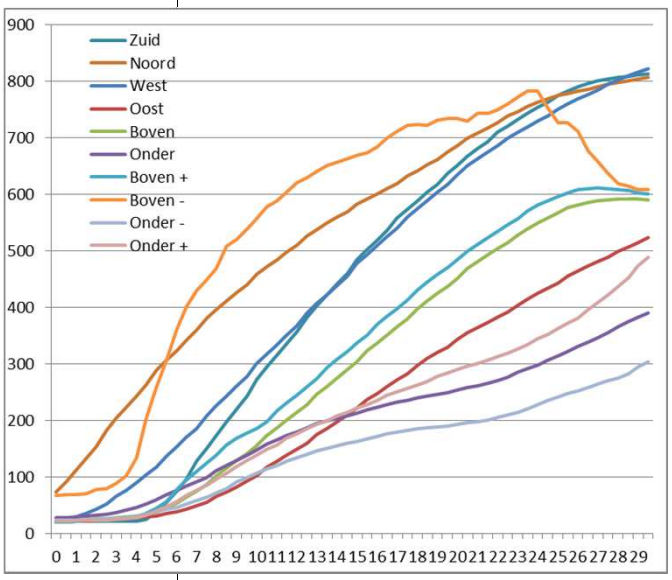


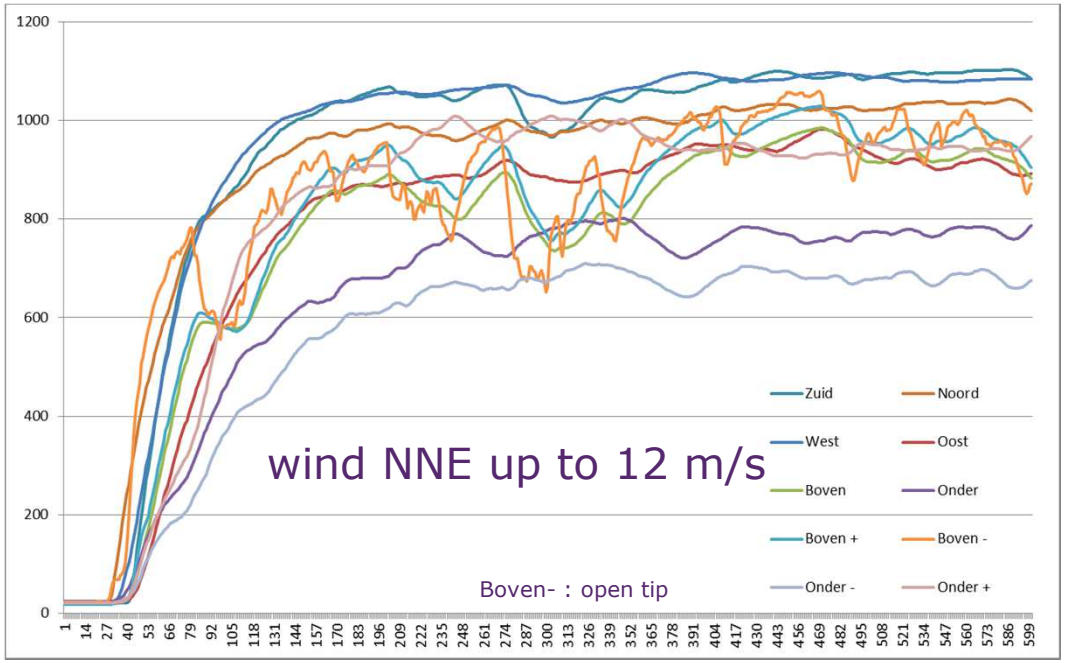
Distance top and bottom box–thermocouples > 10cm (4 inches)

M2A1 box – Results test 1(box @ lowest position)

Required heat build up (avg 800°C / 550°C < 30s)

- Insufficient average T at lowest two positions
- All three low and East TC have a slow temperature rise

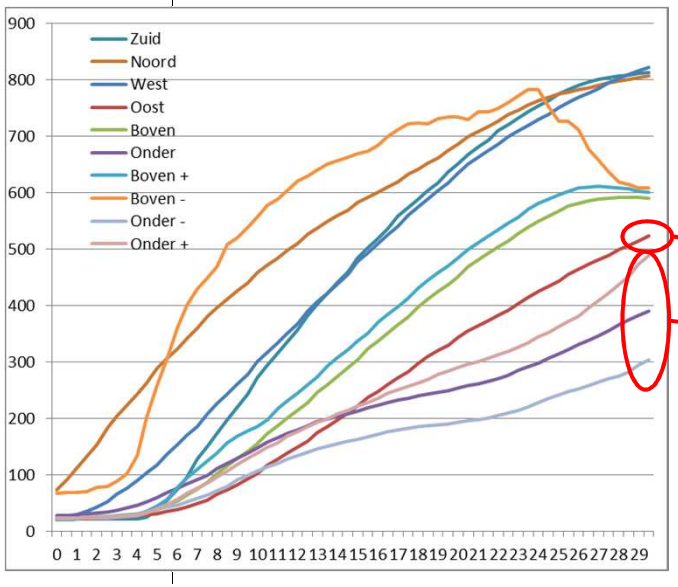


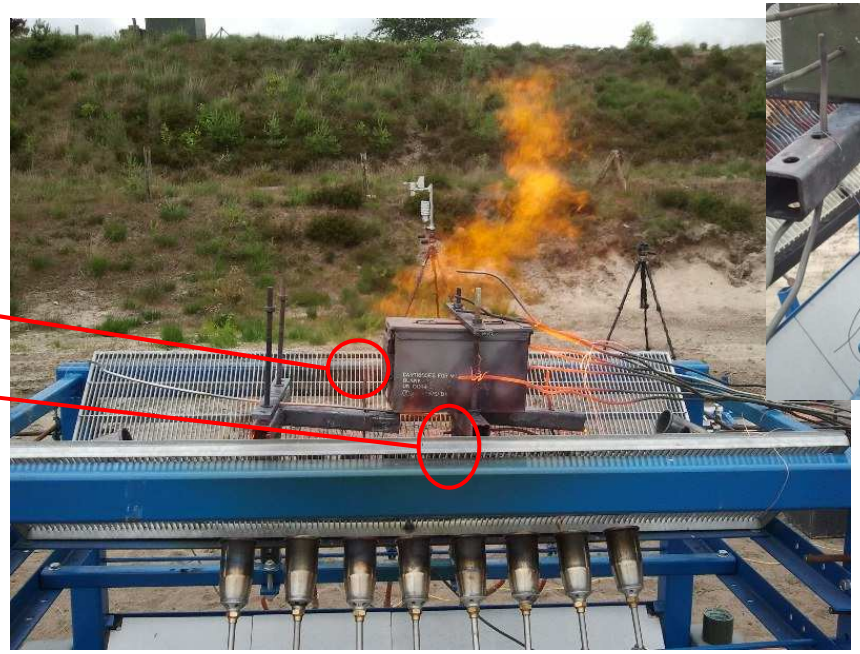


M2A1 box – Results test 1 (box @ lowest position)

Required heat build up (avg 800°C / 550°C < 30s)

- Insufficient average at lowest two positions
- All three low and East have a too slow temp rise

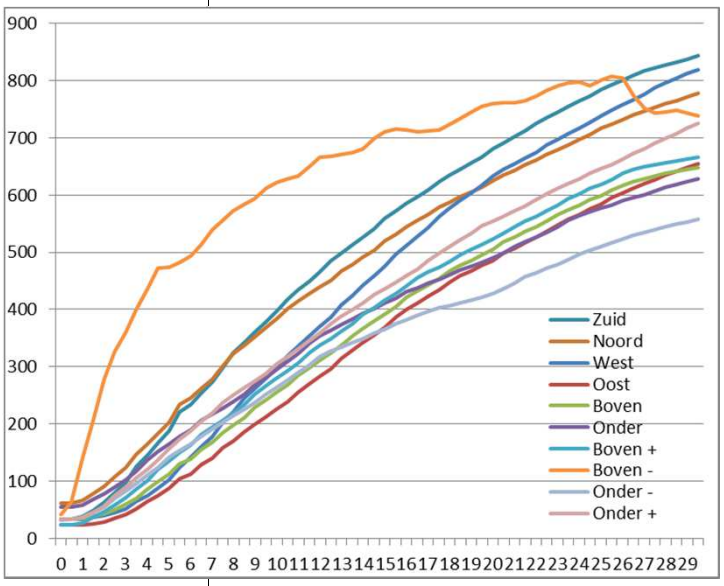


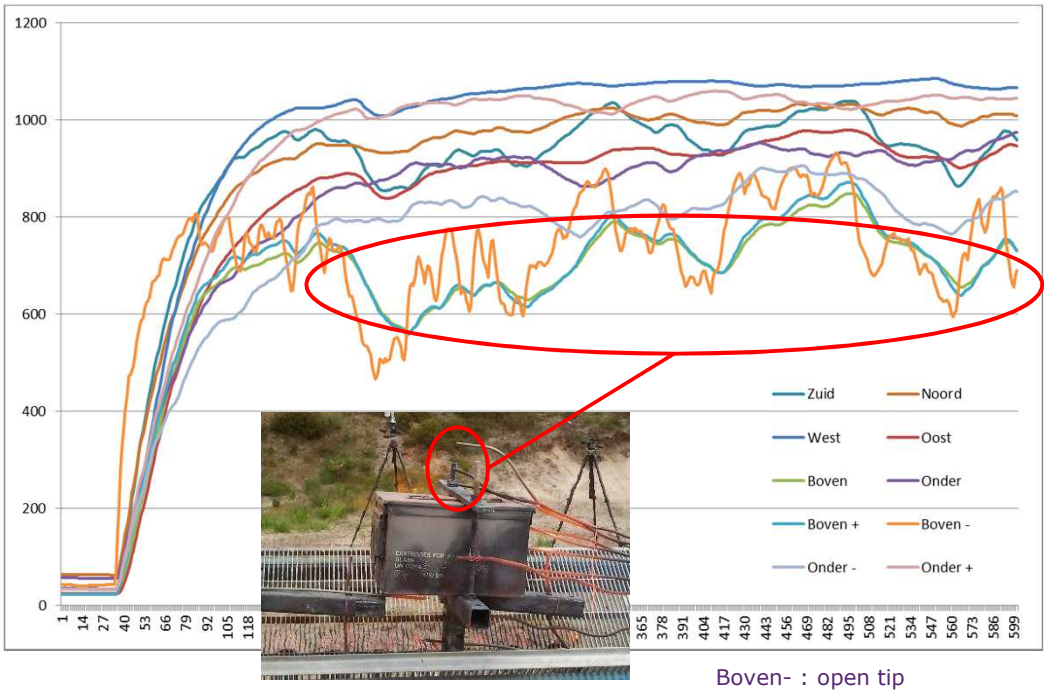


M2A1 box – Results test 2 (box 1 step higher)

Required heat build up (avg 800°C / 550°C < 30s)

- Lowest has a slower temp rise (but sufficient)
- All three upper have insufficient average (wind NNE up to 14 m/s)





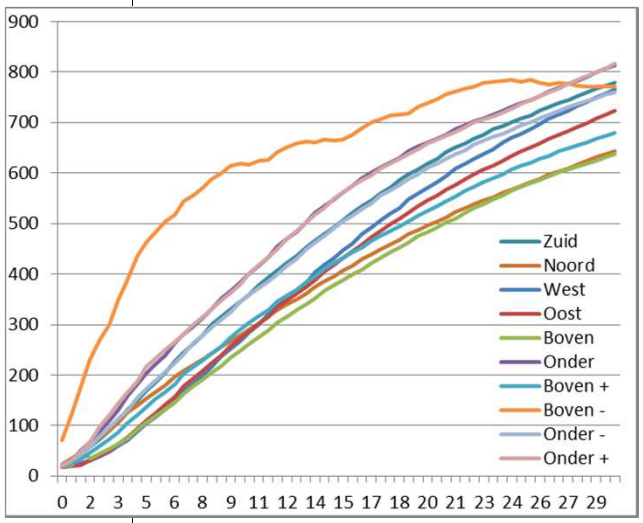
Boven- : open tip

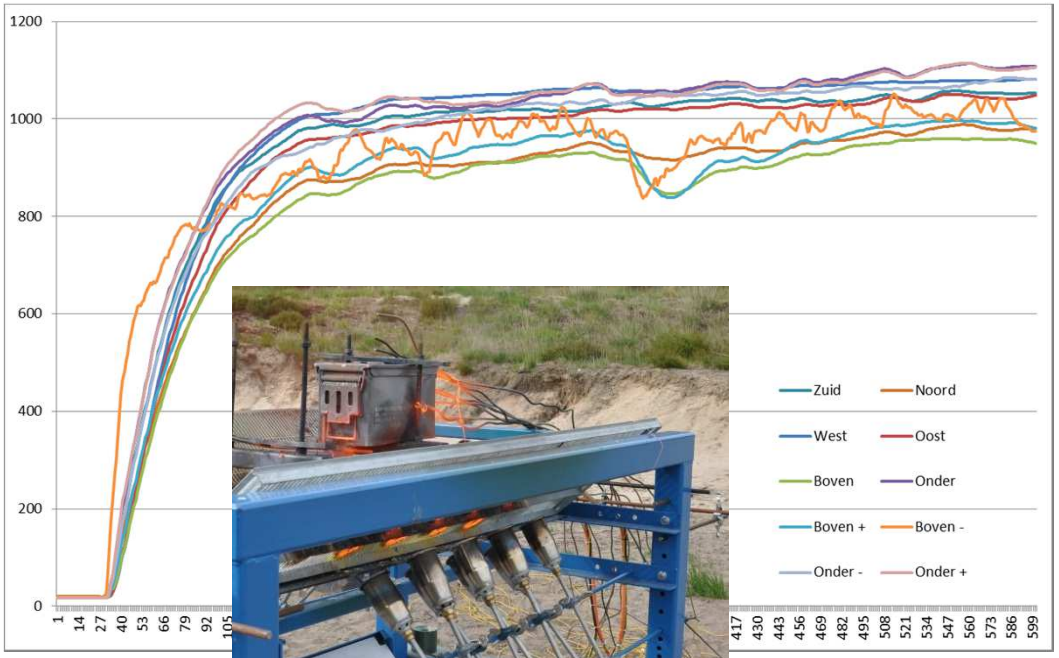
Change of burners: alternating height

M2A1 box – Results test 3
(burners high & low angle, box at lowest position)

Required heat build up (avg 800°C / 550°C < 30s) :

- All thermocoules sufficient (wind NNE up to 11 m/s).





Response time of 6 mm
TC ~ 10-15 sec.

Boven- : open tip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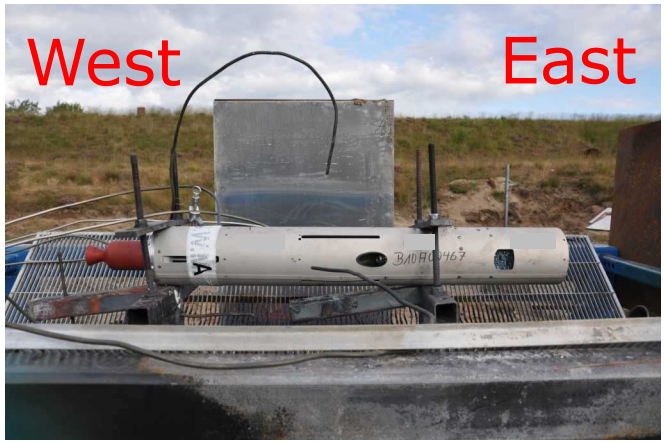
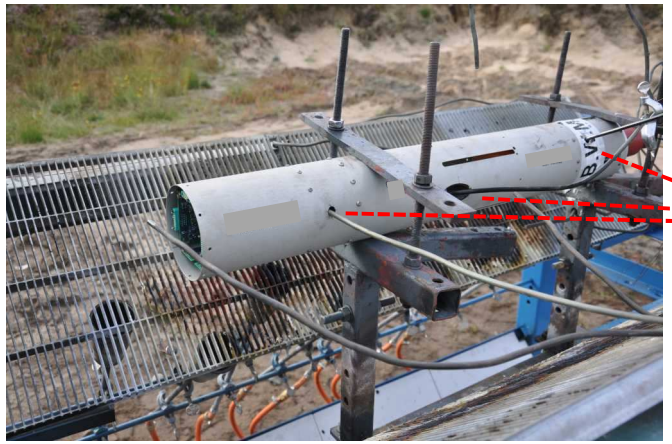
Test series with munitions

Med Range Anti Tank Rocket - Setup



Fuel Fire

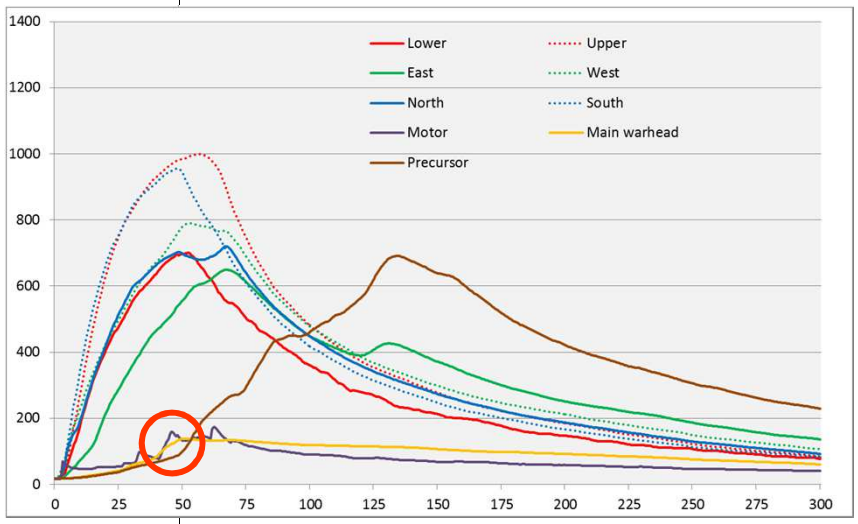


Inside

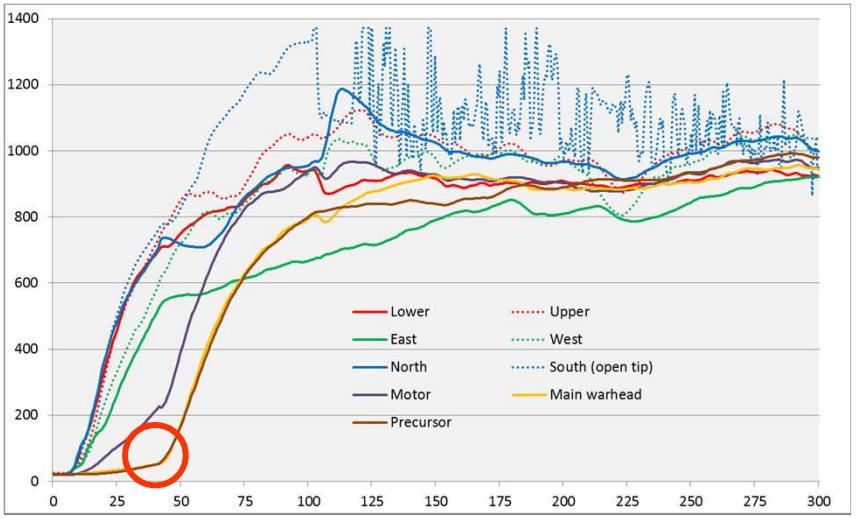
Propane-FCO

Med Range Anti Tank Rocket – Measured Temperatures

- Propane first reaction after 48 sec
  (after that several thermocouples were pushed out of the hearth)
- Fuel fire first reaction after 37 sec

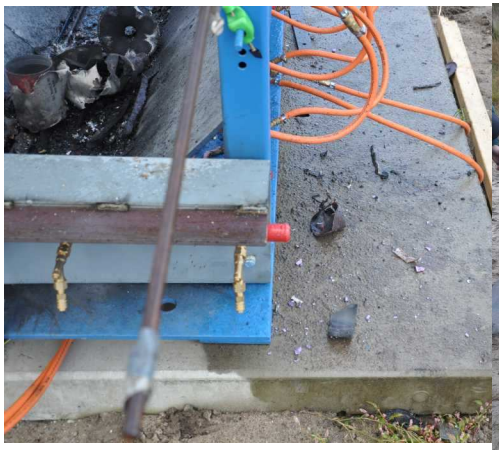


Propane-FCO



Fuel Fire

Med Range Anti Tank Rocket - Findings



Propane-FCO:

- Launching motor ignited, and pushed rocket forward against armoured plate.
- Flight motor and warhead(s) fell down out of the hearth (still burning)
- Explosion of the flight motor
- Primer cap of main warhead still intact

Med Range Anti Tank Rocket - Findings

Propane-FCO:

- Launching motor ignited, and pushed rocket forward against armoured plate.
- Flight motor and warhead(s) fall down out of the hearth (still burning)
- Explosion of the flight motor
- Primer cap of main warhead still intact

Med Range Anti Tank Rocket - Findings

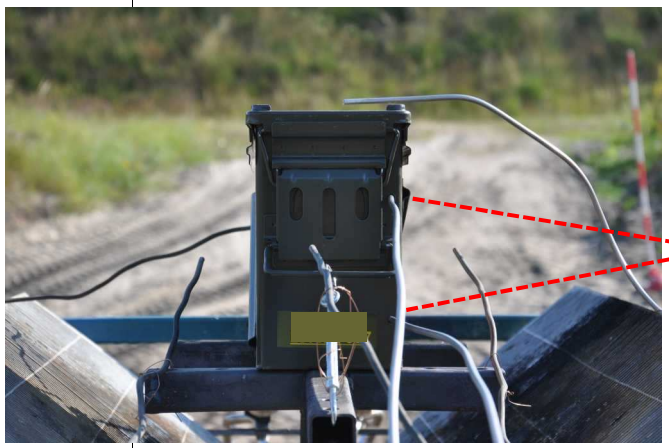
Fuel Fire:

- Launching motor ignited and ruptures
- Nitrogen cilinder releases pressure
- Explosion of the flight motor
- No reaction of the warhead(s)

Life item comparison

40mm HEDP - Setup

Fuel Fire



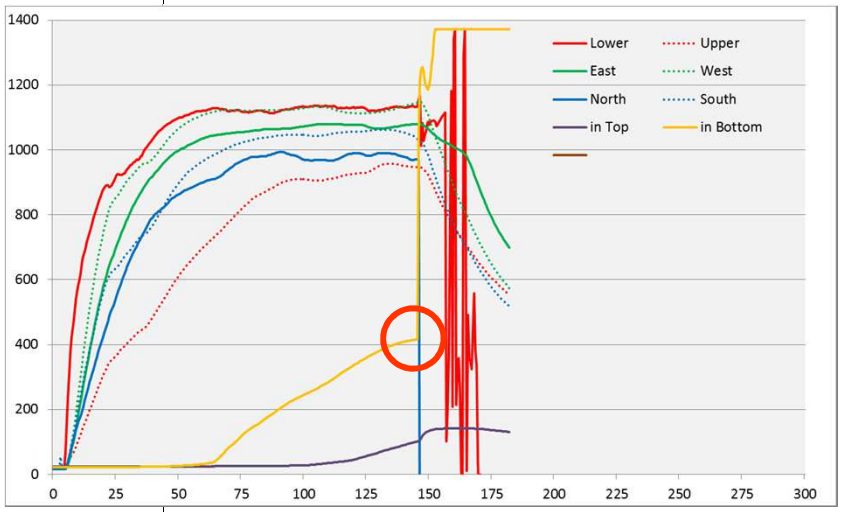
Inside

Propane-FCO

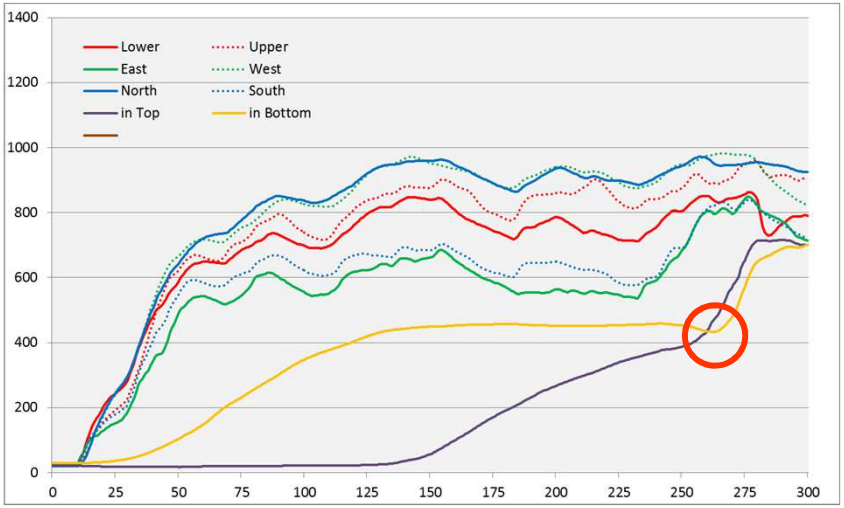
Life item comparison

40mm HEDP – Measured Temperatures

- Propane reaction after 2 min 24sec
- Fuel Fire first reaction after 4 min
- Wind velocities testing week around 10-15 m/s!!



Propane-FCO



Fuel Fire

Life item comparison

40mm HEDP - Findings

Propane-FCO (1):

- One main event : Case explodes and projects all contents. No shock wave visible.
- Ignition of (8) propellants and deflagration of projectiles (in bottom of box).
- Remains up to 35m distance

Life item comparison
40mm HEDP - Findings

Propane-FCO (2):

- One main event : Case explodes and projects all contents. No shock wave visible.
- Ignition of (8) propellants and deflagration of projectiles (in bottom of box).
- Remains up to 35m distance

Life item comparison

40mm HEDP - Findings

Fuel Fire:

- Several events over a longer timescale. Ignition of propellants
- Probable detonation of one or more projectiles. No shockwave visible.
- Remains up to 33m distance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Summary results life munitions testing

Article	Time	Test item Temperatures	Findings
76mm SMK	Comparable	@Propane: Large temp differences top-bottom in ammo box	Comparable
AtG rocket motor	@Propane: Very quick reaction	Comparable	Comparable
Med Range AT	Comparable	Comparable	Comparable
40mm HEDP	@Propane quicker reaction	Same temp rise till 400C in bottom, @Fuel first reaction after 1.5min soaking	@Propane only deflagration, @Fuel probable detonation
Naval Flare	Main reaction time comparable	@Propane faster heating, reaction temp comparable	Comparable


Lessons Learned (general Propane vs Liquid Fuel)

- Influence of the higher temperatures with propane are still questionable (MOD): However Directional unitiformity is well within the range (>82-86% old set-up, new set-up is probably higher, limit is 75%)
- With pre-mixed burners (torches) it is not the problem to reach the minimal average temperature of 800°C and heat flux >80kw/m2
- Pre-mixed gas burners with forced flow could result in a different location of the first reaction (other hot spots) which can result in more ejections of the contents.
- Do not aim burners (torches) towards or in open parts of the test item.
- The setup with premixed burners aimed from below, works only with smooth shaped items (e.g. round or square, not with fins).


Lessons Learned (Dutch P-FCO setup)

- Retain the test item and all its components in the hearth (esp. unpackaged thin walled items→ metal grid below test item).
- Very good (high speed) video possibilities.
- Current setup allows ~80% of all purchased items (by the Army & Navy) to be tested
- Burner intervals should be 8-10 cm maximum for instantatious ignition and optimal heat distribution.
- Influence of wind is less for propane burner


Proposed way forward (for KCW&M NLD)

TNO to investigate the possibilities for “less-efficient” (not pre-mixed) propane burning possibilities. Those burning possibilities will lead to :

- Lower (maximum) flame temperatures and heat fluxes
- Yellow/Orange coloured (non transparant) flames
- More natural (comparable to liquid fuel) flow of air/flames

Options to consider are:

- High pressure nozzle jets aimed from a distance at a point under the test item. (In service German WTD 91 facility)
- A bed of perforated steel pipes under the test item. (US prototype used in Karlskoga Sweden 2014)

For questions or remarks please contact :

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