
USS Forrestal - 1958

Fire protection in ammunition storage spaces

An evaluation of the water application rate

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Presentation Overview

- Introduction FiST project
- Aim of the experiments
- Experiment set-up
- Results
- Conclusions/Follow up

FiST – Project

- Cooperation between Ministry of Defense of
  - Canada, Sweden and The Netherlands

New Fire Suppression Technologies on board naval craft (FiST)

Problem definition

It is unclear how **existing** commercial fire fighting systems will react on **battle damage**, and what the **residual capacity** will be.

Objective

To **develop knowledge** on design and specification of fire suppression technologies specifically for naval vessels that operate in **hostile environments**, i.e. where **damage** from energetic weapons like anti-ship missiles can be expected.

FiST – Project partners

- FireTech Engineering
- SP Technical Research Institute Sweden
- FOI - Swedish Defence Research Agency
- FMV - Swedish Defence Materiel Administration
- Defence R&D Canada (DRDC)
- Netherlands' Ministry of Defence – Defence Materiel Organisation
- TNO - Dutch Organization for Applied Scientific Research

Experimental program (Jan-Feb 2012)

- Evaluate the necessity of the prescribed water discharge density (24-32 ℓ/m^2 per minute)
  - ANEP-77 Naval Ship Code
  - Class regulations (like DNV)
  - The U.S. Navy's handbook on magazine sprinkling
- High flow rates are a burden on system design
- Rapid flooding decreases ship stability
- Assess the feasibility of reducing flow rate
  - If necessary/advantageous in conjunction with low pressure WMS

How much is 32 litres/m² per minute?

Ship compartment (10x10x3m)

32 cm of water after 10 minutes

Nearly 1 meter of water after 30 minutes

In a 10 × 10 m² compartment, this is 3200 kg or two midsized cars <u>every minute!!</u>

Experimental program

Total of 27 tests at SP in Sweden

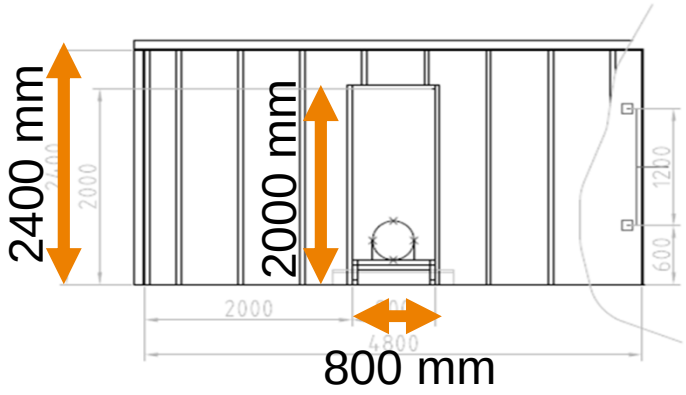
Fire suppression configurations

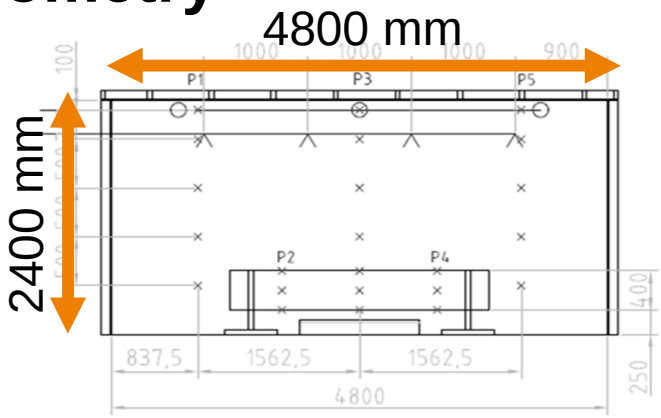
- WMS at ~6 ℓ/m^2/min
- Drencher at 10 ℓ/m^2/min
- Drencher at 32 ℓ/m^2/min
- Dual system: WMS at ~6 ℓ/m^2/min + Drencher 5 ℓ/m^2/min

Obstructions

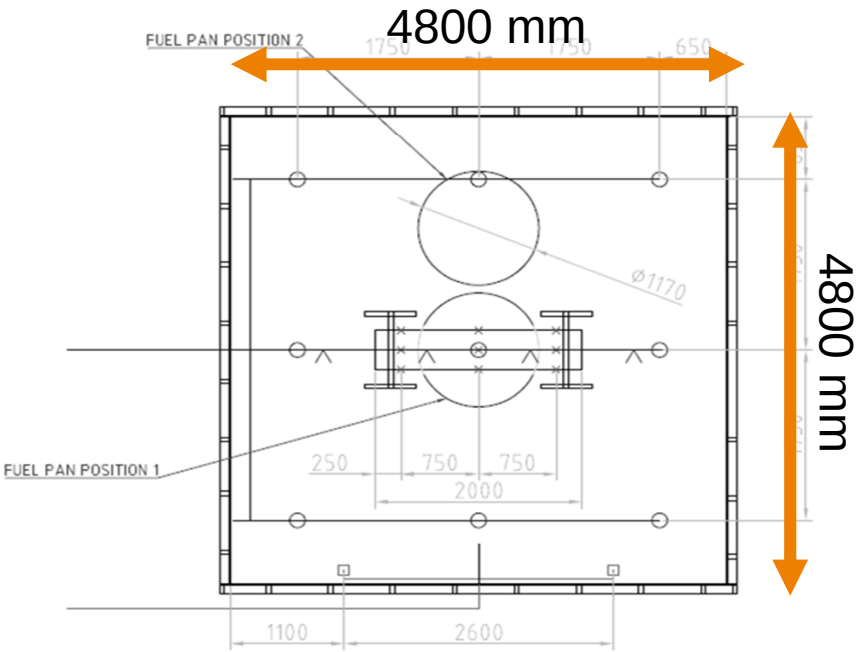
- None: Free burning
- Dummy torpedo
- Dummy torpedo + Promatect sheet

Experimental set-up - Geometry

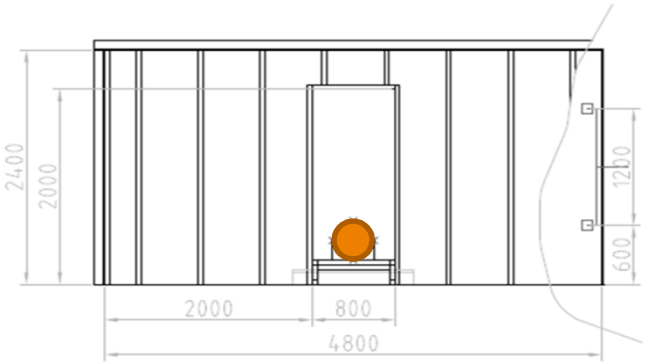


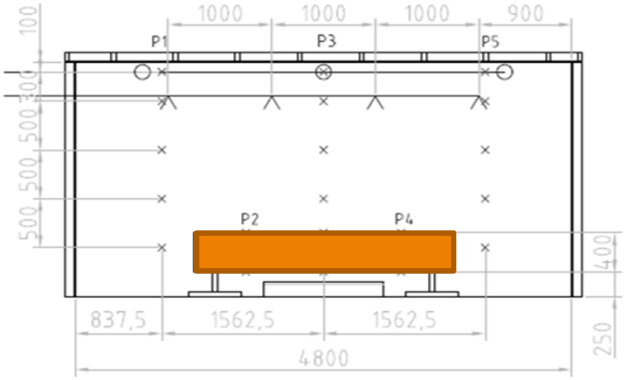


Promatect board walls
- 12 mm thick
- Calcium Silicate

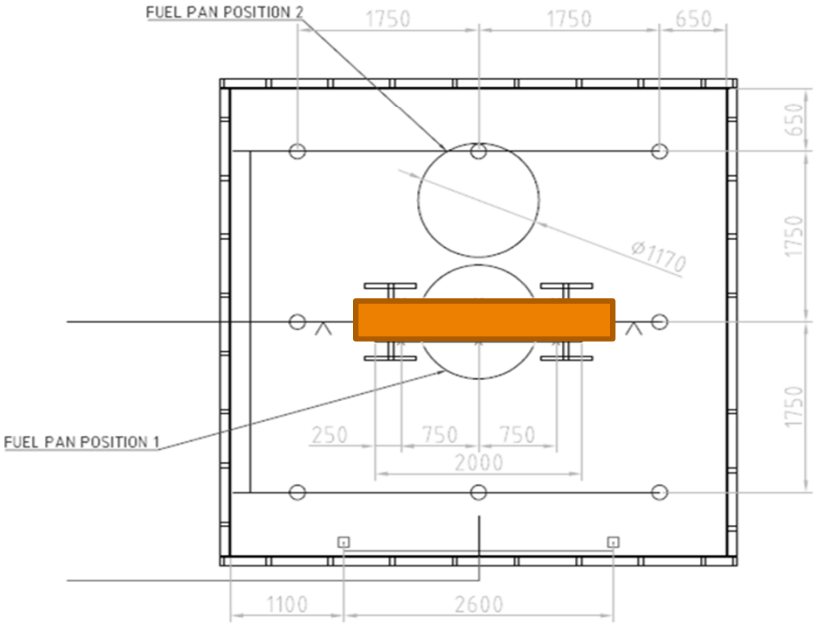


Experimental set-up – Dummy torpedo





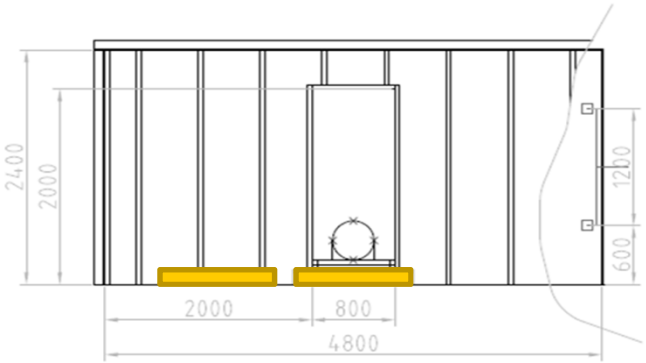
Dummy torpedo
- 3 mm steel (65 kg)
- Ø 350 mm x 2000 mm
- Filled with dry sand

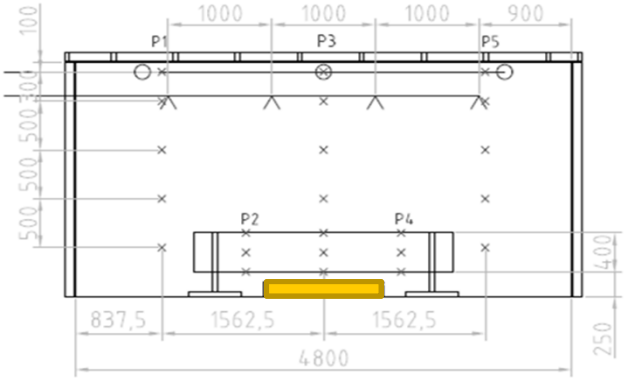


Experimental set-up – Dummy torpedo

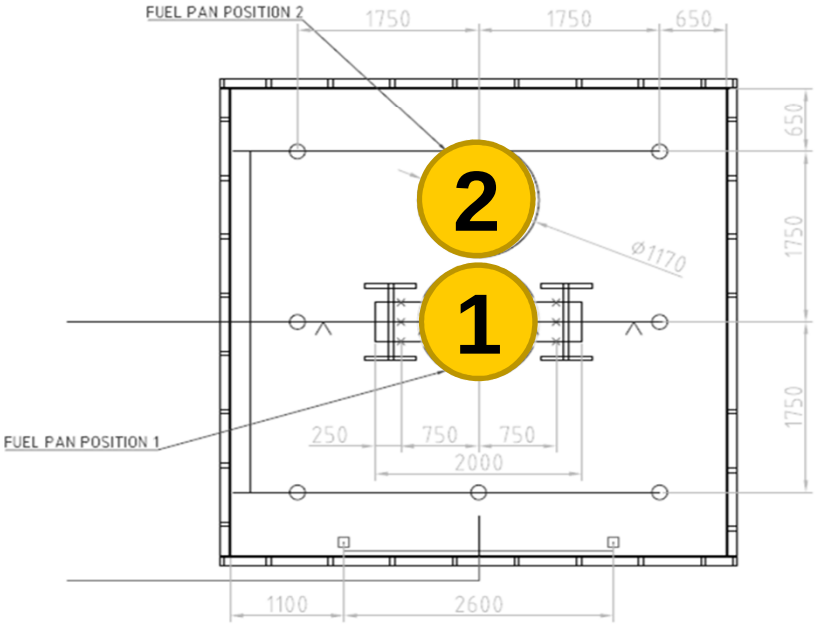
Dummy torpedo over fuel pan #1

Experimental set-up – Fuel pan locations

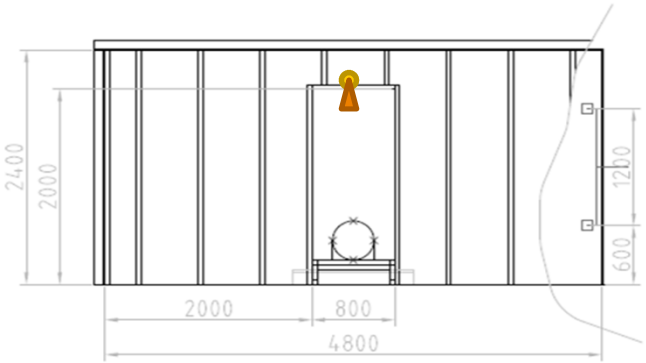


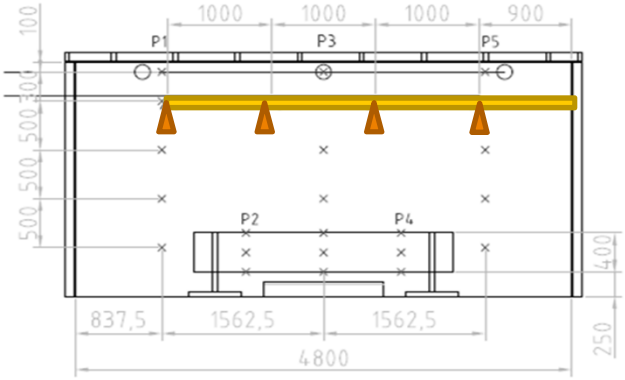


Fuel pan parameters
- Ø 1170 mm
- 15 mm Diesel
- HRR of 1.3 MW

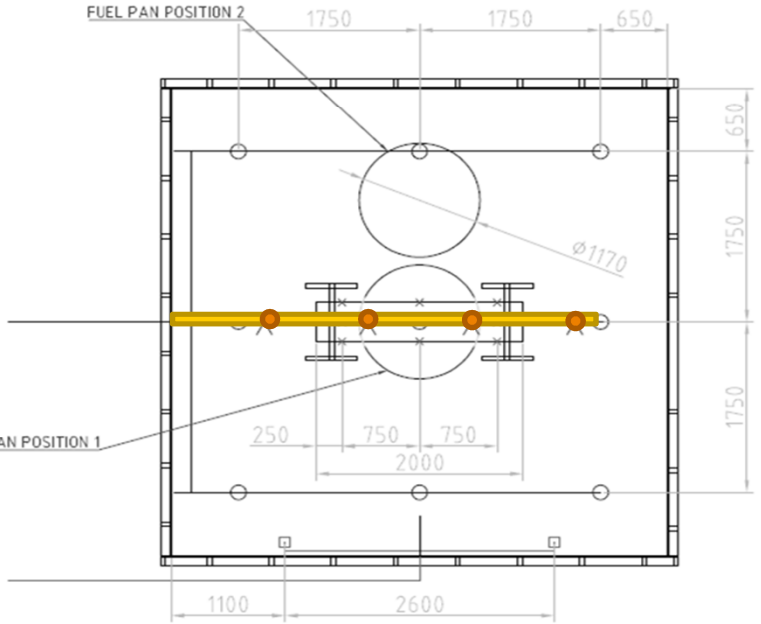


Experimental set-up – Drencher system

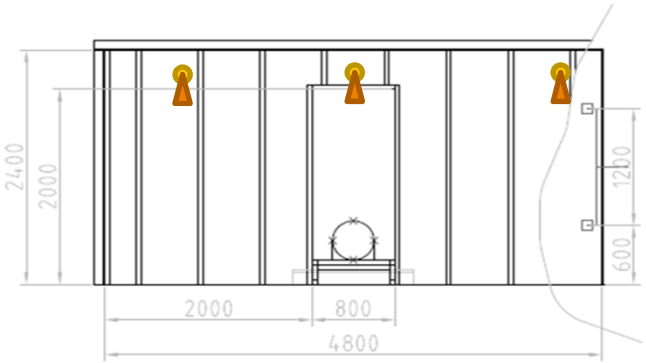


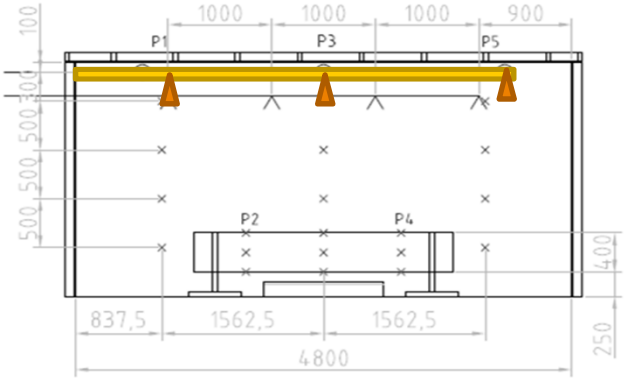


Drencher system
- 4x LECHLER nozzles
- Tests with 3 different types (5, 10 and 32 ℓ/m^2/min)

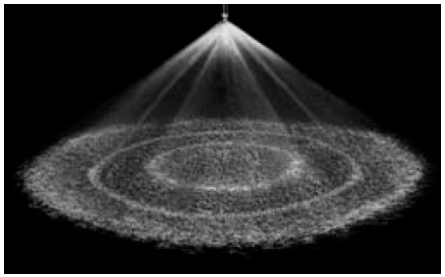


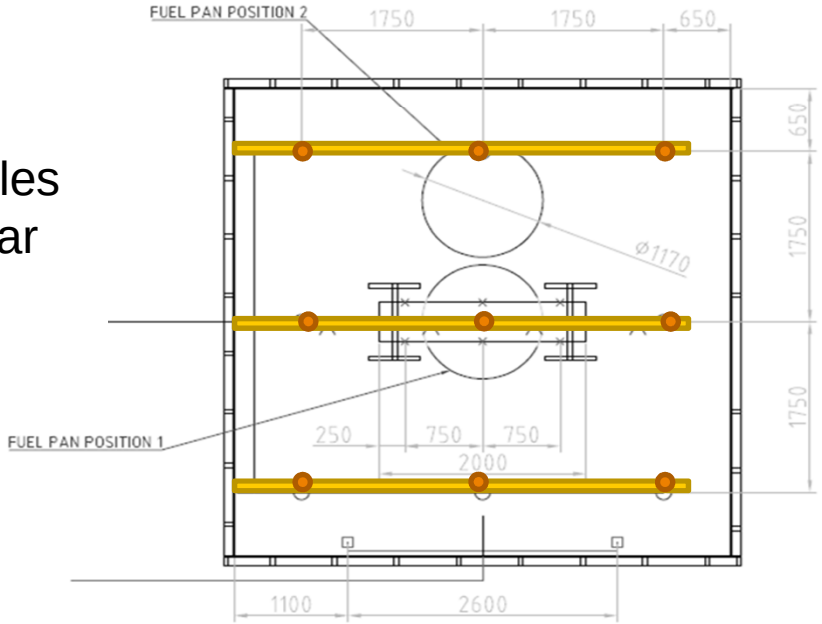
Experimental set-up – Water Mist System



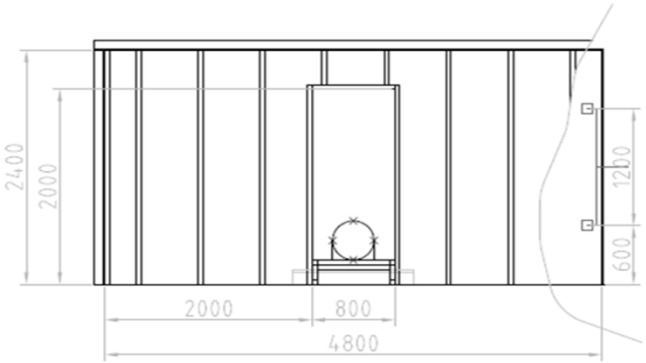


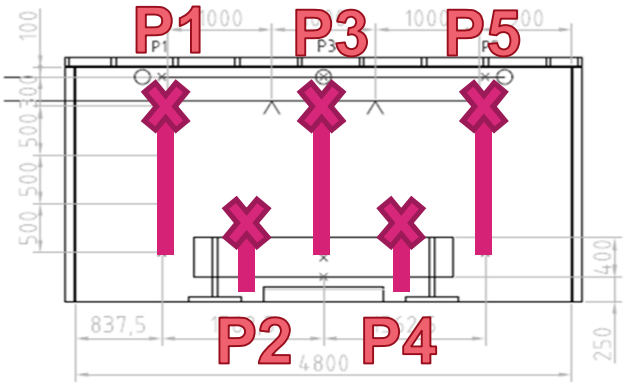
Water Mist system
- Low pressure (10 bar)
- 9x BETE TF8-170° nozzles
- K-factor of 5.93 ℓ/min/√bar
- Est. drop size: 133 µm





Experimental set-up - Instrumentation

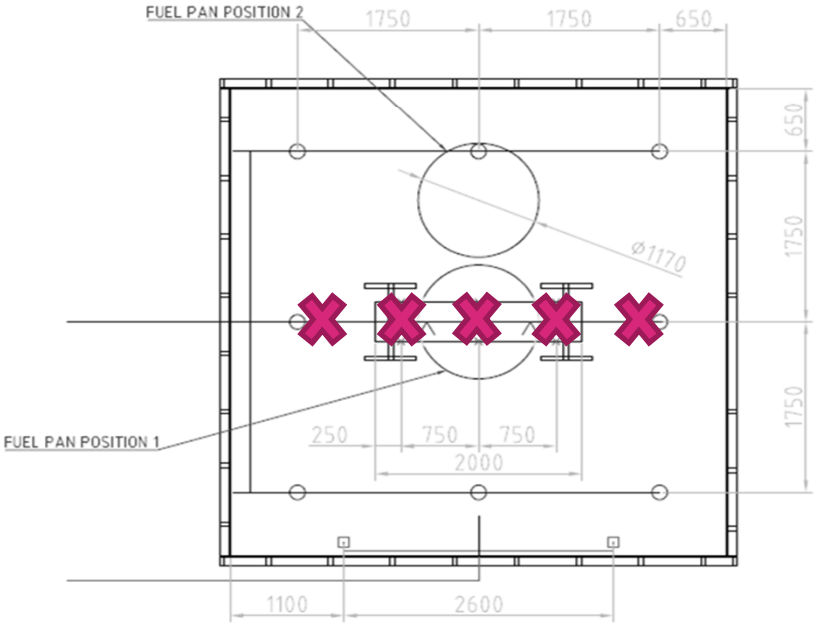




Thermocouple trees
- 5 positions (P1-P5)
- K-type

Oxygen measurement
- 2 heights at P5

Water flow rate
- In pipe
- At pump



Experimental performance criteria

- The maximum outside surface temperature of dummy torpedo must not exceed 200 °C.
- One minute after activation the outside surface temperature must not exceed 150 °C.
- Temperature on the inside of the dummy torpedo must not exceed 150 °C at all times.
- In this research: **No** criteria for extinguishment of flames!

Video Test 14 – free burning

Your Expert opinion required!

Will the drencher system (32 litres/m²/min) extinguish the 1,3 MW fire?

Yes: ☐ **No:** ☐

Test 16: Drencher Fuel pan #1
[32 litres/m²/min.]

Test 22: Drencher Fuel pan #2
[32 litres/m²/min.]

Expert opinion required!

Will the drencher system (32 litres/m²/min) extinguish the 1,3 MW fire?

Yes:  **No:** ☐

Will the WaterMist System (6 litres/m²/min) extinguish the 1,3 MW fire?

Yes: ☐ **No:** ☐

Video Test 15 – Water Mist

Expert opinion required!

Will the drencher system (32 litres/m²/min) extinguish the 1,3 MW fire?

Yes: ☐ 

No: ☐

Will the WaterMist System (6 litres/m²/min) extinguish the 1,3 MW fire?

Yes: ☐

No: ☐ 

Which system extinguishes the 1,3 MW fire the fastest?

Dual System: ☐ (WMS+Drencher: 6+5 l/m²/min)

Drencher: ☐ (10 l/m²/min)

Test 17: Drencher
[10 litres/m²/minute]

Test 18: Drencher + WMS
[5 + 6 litres/m²/minute]

Expert opinion required!

Will the drencher system (32 litres/m²/min) extinguish the 1,3 MW fire?

Yes: ☐ 

No: ☐

Will the WaterMist System (6 litres/m²/min) extinguish the 1,3 MW fire?

Yes: ☐

No: ☐ 

Which system extinguishes the 1,3 MW fire the fastest?

Dual System: ☐ 

(WMS+Drencher: 6+5 l/m²/min)

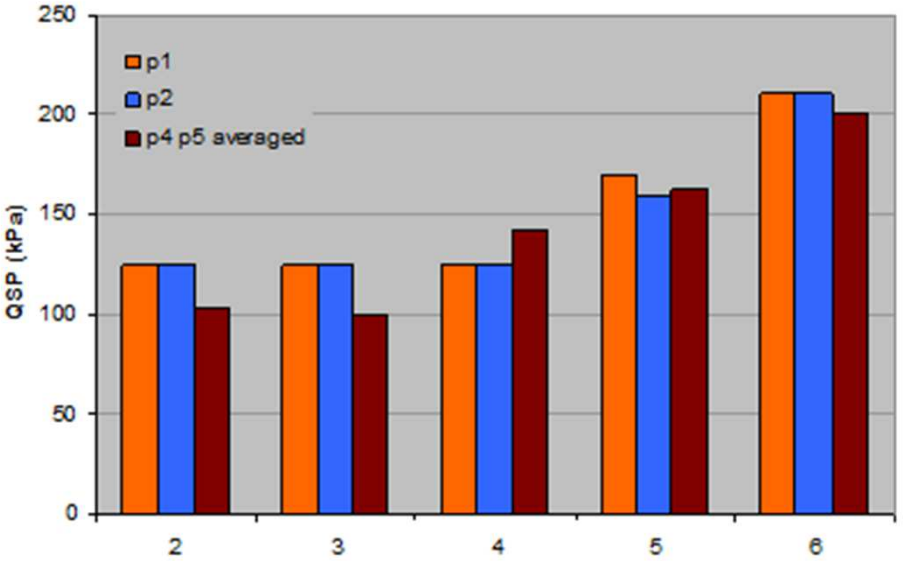
Drencher: ☐ 

(10 l/m²/min)

Added water mist effect: Explosion suppression

- Full scale explosion trials in TNO bunker

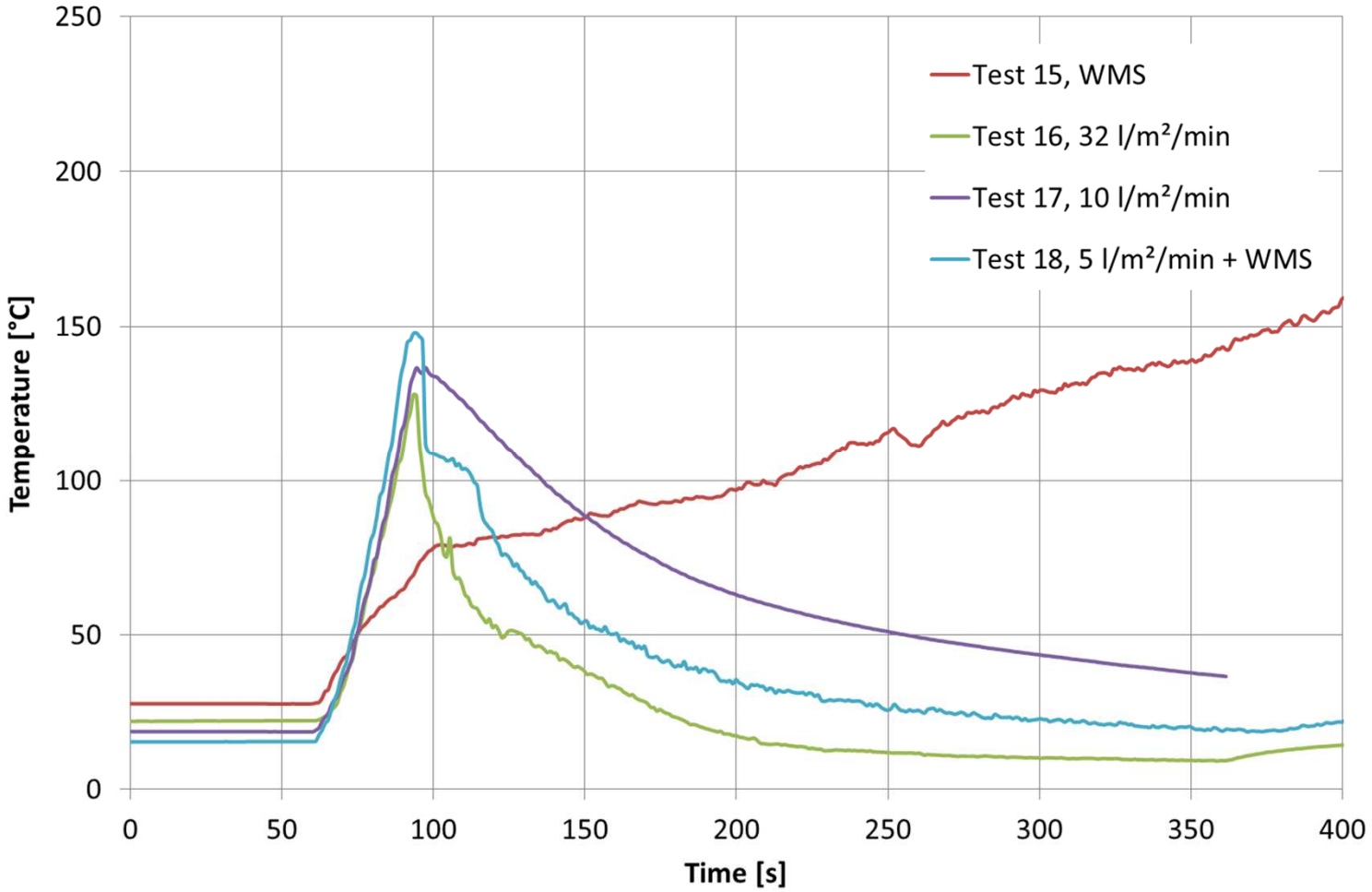
- Dispersion of water mist prior to the explosion:
  - Reduced peak pressure effects by up to 50 %
  - Greatly reduced temperatures inside the compartment (from 600 °C to 100 °C)



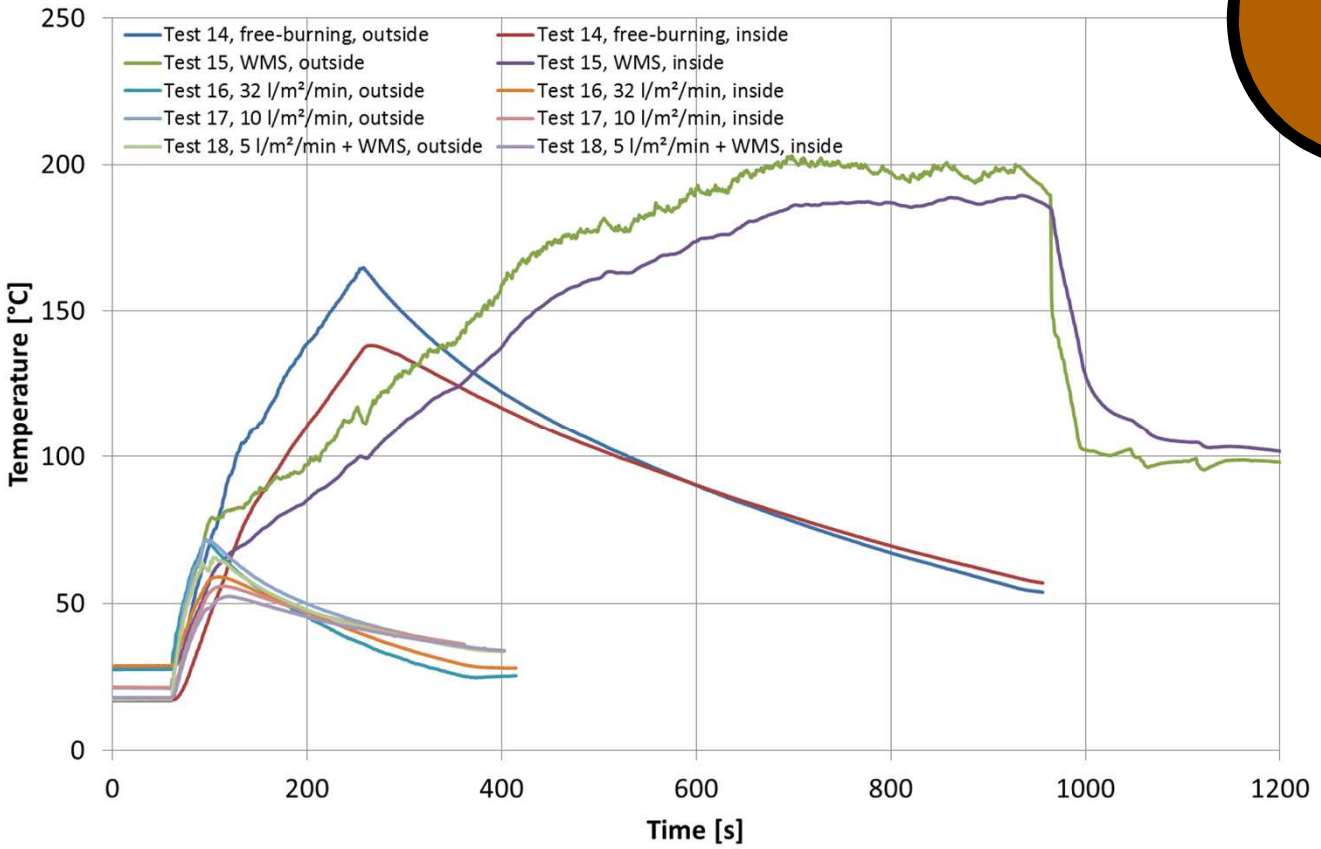
Test results (overview)

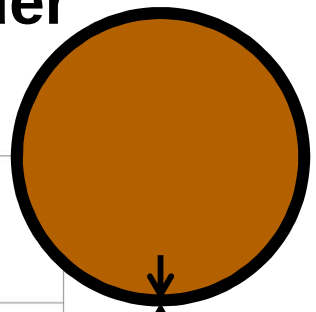
Test	Drencher ℓ/m²/min	WMS ℓ/m²/min	Fuel pan position	Obstruction	Peak surface T [°C]	Peak surface T > 1 min [°C]	Time to ext. [s]	O2 conc. at ext. [vol%]
14	-	-	1	-	550[1]	-	-	Data not available
15		6	1	Ordinance	203	203	Did not extinguish	17.9[2]
16	32	-	1	Ordinance	128	39	24	20.2
17	10	-	1	Ordinance	138	89	45	19.9
18	5	6	1	Ordinance	148	92	53	19.7
19	5	6	2[3]	Promatect lined up with ordinance	150	81	Did not extinguish	13.5[2]
20	32	-	2[3]	Promatect lined up with ordinance	113	35	27	20.3
21	32	-	2[4]	Promatect lined up with ordinance	77	30	7	20.5
22	32	-	2[4]	-	50	31	7	20.9
23	32	-	2[4]	Vertical 460 mm Prometect board	40	27	15	20.9
24	10	-	2[4]	-	65	38	160	19.2
25	10	-	2[3]	Promatect lined up with ordinance	162	82	Did not extinguish	18.2[2]
26	5	6	2[3]	Promatect lined up with ordinance	151	105	Did not extinguish	14.0[2]
27	-	-	2[3]	-	604[1]	-	-	15.5[2]

Maximum temperature of dummy torpedo – Fuel pan #1



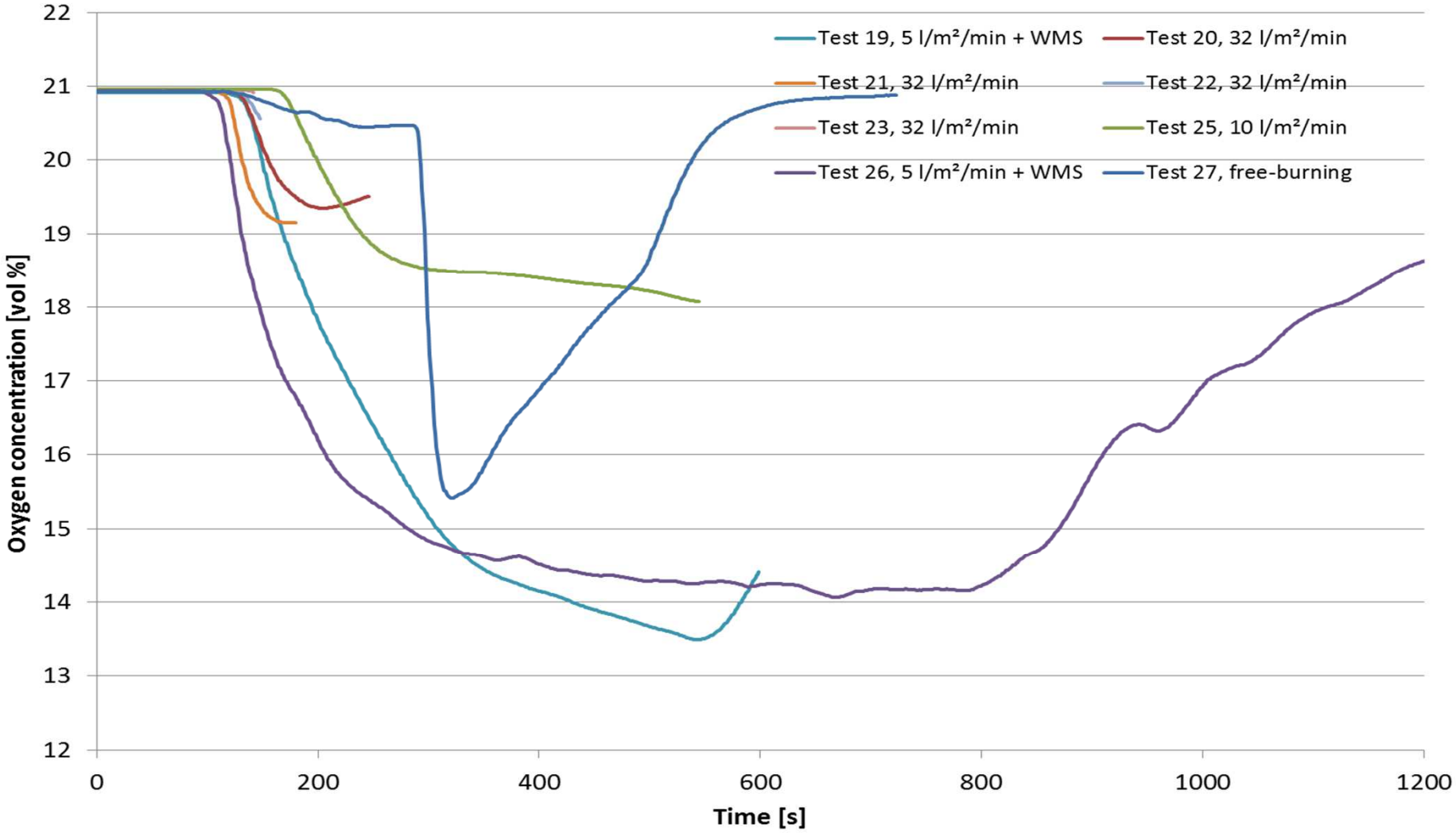
Temperature difference across the cylinder





ΔT across the cylinder

Oxygen concentration @ 500mm height

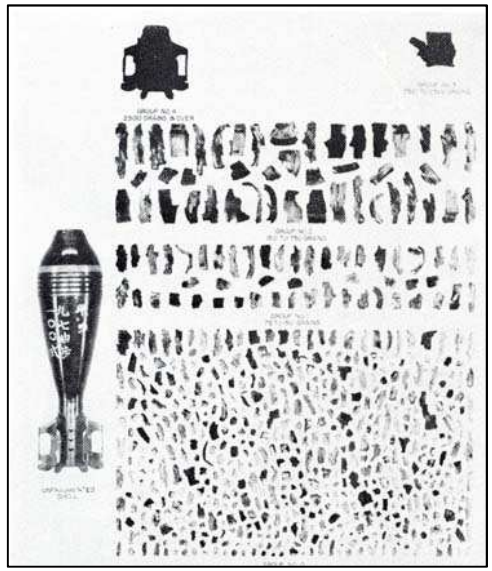


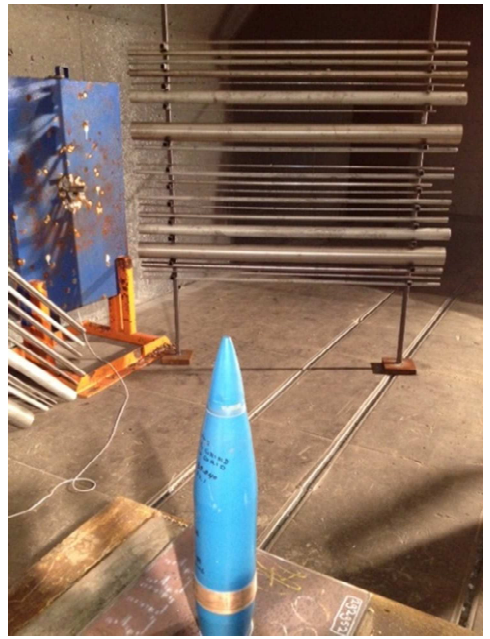
Conclusions

- Configurations with drencher capacity well below 32 ℓ/m²/min fulfilled the performance requirements
- Results of a 5 ℓ/m²/min drencher system in conjunction with a 6 ℓ/m²/min WMS are comparable to a 10 ℓ/m²/min drencher system
- WMS at 6 ℓ/m²/min is insufficient to fulfil the assumed performance requirements and the peak surface temperature exceeds 200 °C.
- A dual system may show increased survivability due to inherent redundancy
- A dual system may be costly and complex to implement
- A dual system of which one is a water mist system could be designed for explosion suppression

Follow up / Questions

- Damaged system tests January 2013
  - Damaging of piping is done <u>today</u> at TNO
- Different obstructions
- Different configurations





Questions???

Thank you for your attention!