Califlux4240 : a heat flux calibration tool for Fast Heating tests

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CONTEXT AND OBJECTIVES

1. IMEMG EWG

- **IMEMG gathers 21 major companies from Austria, France, Germany, Italy, Norway, Spain, Sweden and the United Kingdom within the Armament Industry**

- **Fast Heating Working Group - Goals :**
  - Harmonize Fast Heating test procedures and acceptance criteria
    - **Identify key test methodology criteria in STANAG 4240**
    - **Compare test facilities in Europe : fuel types, temperature, item position, mounting, sensors, wind barrier, …**
  - Evaluate equivalence of liquid fuel and alternative solutions
    - **Compare test methods and results : temperatures, heat fluxes, reaction results**
    - **Promote harmonized practices**

The consistency of IM test results shall be guaranteed whatever the fire test method

CONTEXT AND OBJECTIVES

2. FAST HEATING TESTS

- **= Hazard classification with respect to large liquid fuel fire**

- **Test procedure described in STANAG 4240**
  - Edition 3 recently released
  - STANAG document now supported by AOP 4240 (Edition A Version 1, Nov. 2018)

- **To reduce environmental impact an alternative procedure using gas fueled heating source has been introduced in edition 3.**

→ Three test procedures are described:
- **The Large Pool Fire (LPF)**
- **The Mini Pool Fire (MPF)**
- **The Fuel Burner Fire (FBF)** NEW

STANAG 4240 ed. 3

1. CALIBRATION

- **Alternative gas facilities need to be properly calibrated**
  - Process based on temperatures and **heat fluxes** NEW
  - Verification of **spatial heating uniformity** NEW

- **Criteria :**
  - **Min flame temperature of 800°C**
  - **Time to reach 550°C < 30s**
  - **Minimum net absorbed heat flux of 80 kW/m²**

LPG Fire
(Courtesy of WTD91, Germany)

Propylene gas burners
(Courtesy of Nexter, France)

STANAG 4240 ed. 3

2. HOW TO MEASURE FIRE HEAT FLUX ?

- **Net absorbed heat flux required in AOP 4240**
- **Which device ?**

Extract from AOP4240 :

> Appropriate heat flux measuring devices include plate thermometers, differential flame thermometers, differential heat flux sensors, and slug calorimeters.

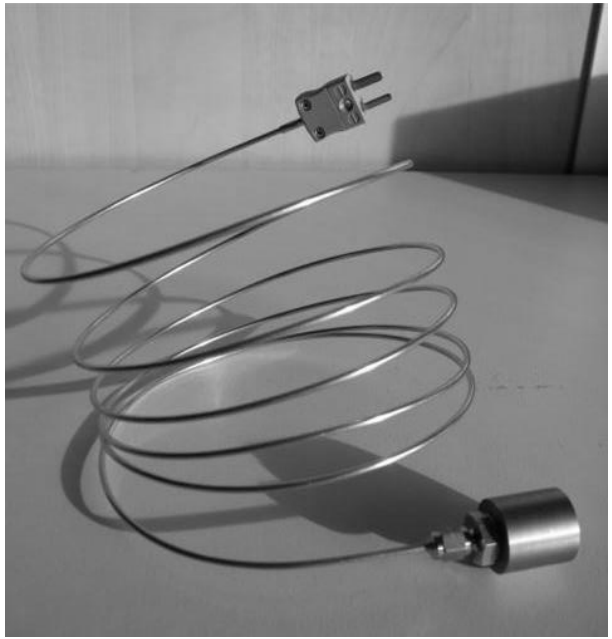
- **IMEMG EWG is recommending using a joint heat flux calibration device to evaluate heat flux as specified in AOP and get comparable measurements**

- **IMEMG EWG proposal = CALIFLUX 4240**
  - Full validation process implemented

STANAG 4240 ed. 3

2. HOW TO MEASURE FIRE HEAT FLUX ?

- **CALIFLUX 4240 :**
  - Purpose :
    - **Fast heating facilities calibration**
    - **Fire-to-fire heat flux comparison**
    - **Harmonized device for Fast Heating test facilities**
  - Key requirements :
    - **Fire heat flux measurement, as requested by AOP4240**
    - **Easy and cheap to build**
    - **Small, easy to install in fire, robust, reusable**



CALIFLUX4240

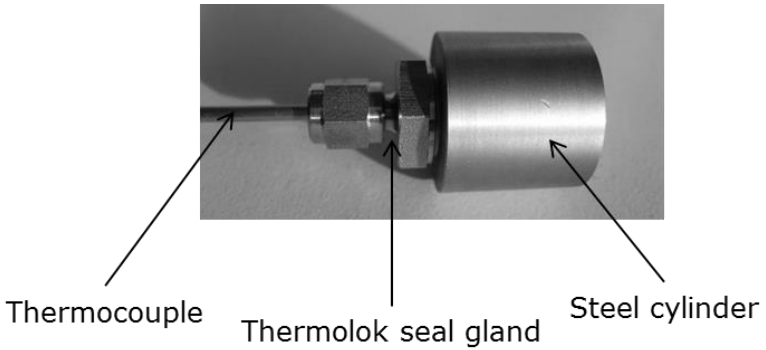
1. DESIGN

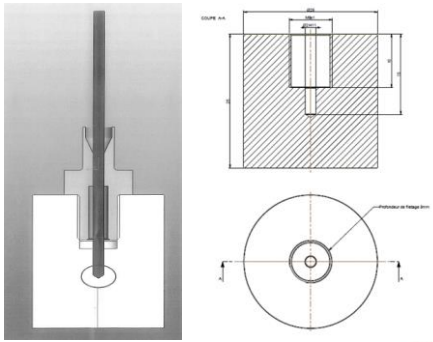
- **Full engulfment of the device in flame, no active cooling**

- **Diameter and length = 25mm**
  - Steel cylinder
  - 2mm thermocouple type K
  - Sealing ring

Elementary cost (without TC)
≤ 50€ per unit

Easy parts procurements





Courtesy of NEXTER, France

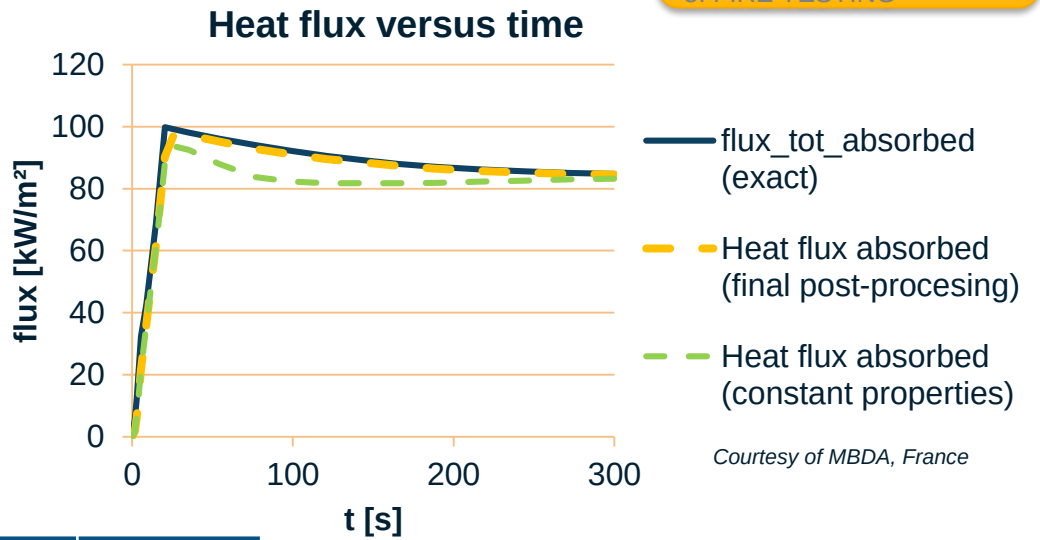
CALIFLUX4240

2. POST PROCESSING

$q_{abs} = h.(Tf-T)+\varepsilon.q_{inc} = \rho C \delta . \partial T/\partial t + \varepsilon \sigma T4$

- **Comparison with exact F.E. simulations**
- **Dimension optimization study**
- **Good sensitivity to fire conditions**

Easy post-processing :
→ *simple Excel sheet*
→ *Input data: T(t), frequency 1Hz*



Courtesy of MBDA, France

Geometry D25-L25	Fire 1	Fire 2	Fire 3
Convection (20W/m²K)	800°C	800°C	1000°C
Radiation (ε=0.9)	900°C	800°C	1000°C
Phi_abs (max) [kW/m²]	108	82	151
Phi_abs (steady state) [kW/m²]	95	68	134
% max error (flux)	**2,1**	**2,3**	**2,8**

Good correlation achieved with exact result
Max error <3%

CALIFLUX4240

1. DESIGN
2. POST-PROCESSING
3. CALIBRATION
4. ASSEMBLY CHECK
5. FIRE TESTING

3. CALIBRATION TRIALS

Objective: check correct response of the tool with well known incident heat flux conditions

→ **Cone calorimeter trials**

- Incident heat flux : 50kW/m² and 80kW/m²
- Post processing adapted to the case (1 heated side)

Courtesy of CEA, France

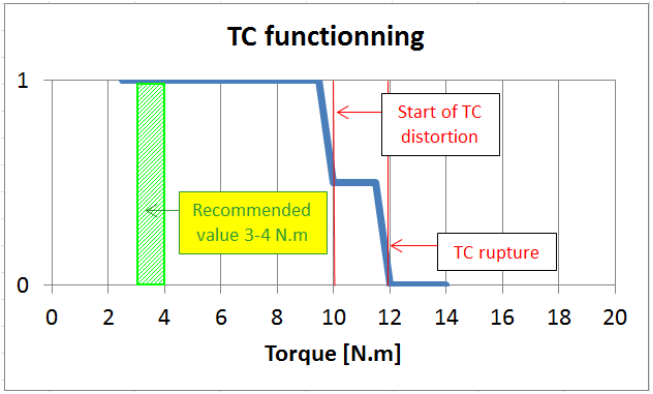
Good correlation achieved with test result
Max error <3%

Qinc (trial)	Qinc mean (approx)	Delta trial / approx
50 kW/m²	49kW/m²	-1%
80 kW/m²	82kW/m²	+3%

CALIFLUX4240

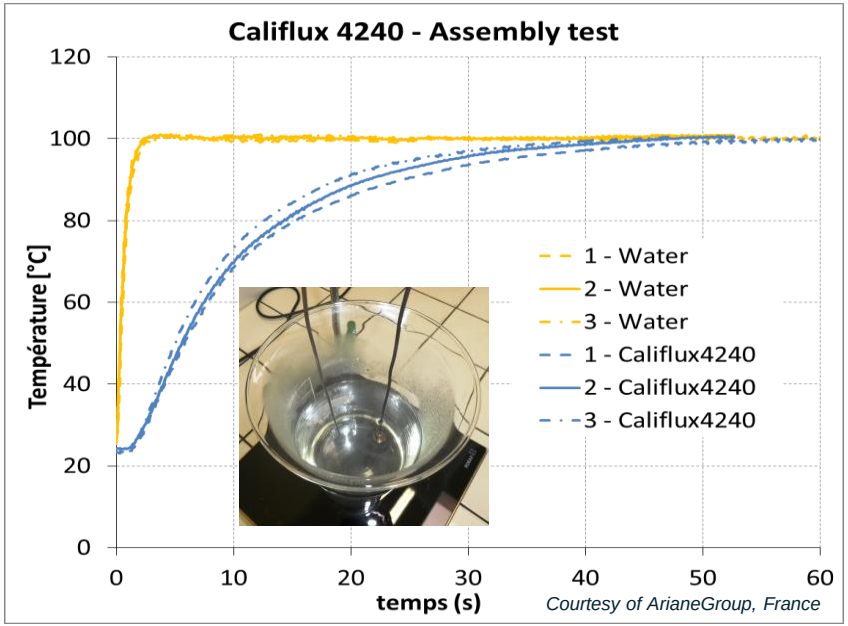
4. ASSEMBLY CHECK

- **Assembly process definition (notice of use)**
- **Torque assessment**



- **Elementary test defined in order to check the thermocouple fixing (contact)**

  → Califlux immersed in boiling water during 1min



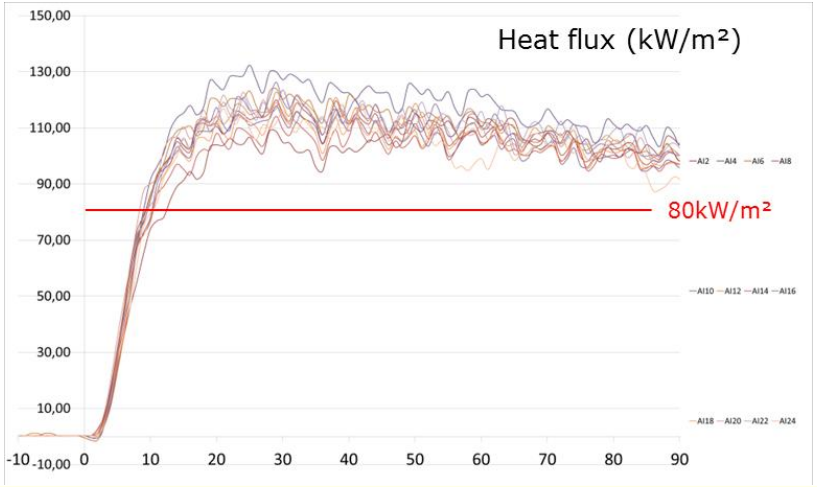
CALIFLUX4240

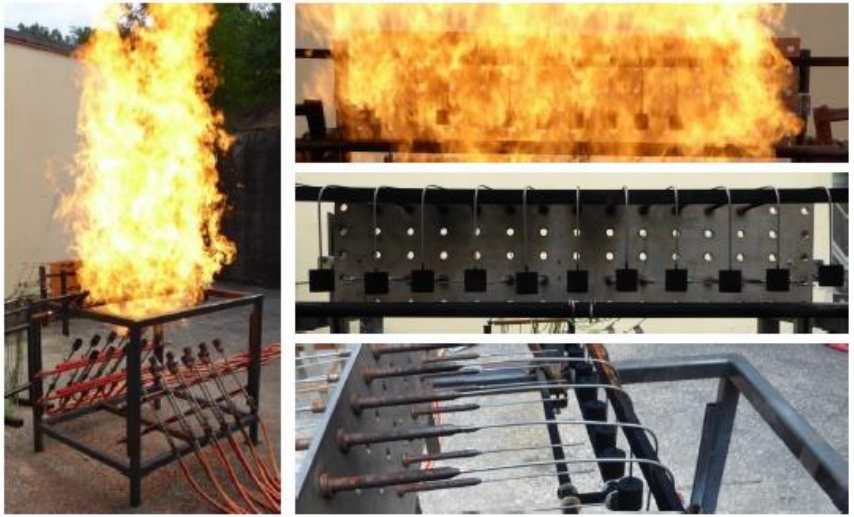
5. FIRE TESTING

- **Preliminary tests**
- **Good response of the tool**

Example 1 : DIEHL Defence test setup

Parametric setup for calibres up to 155mm





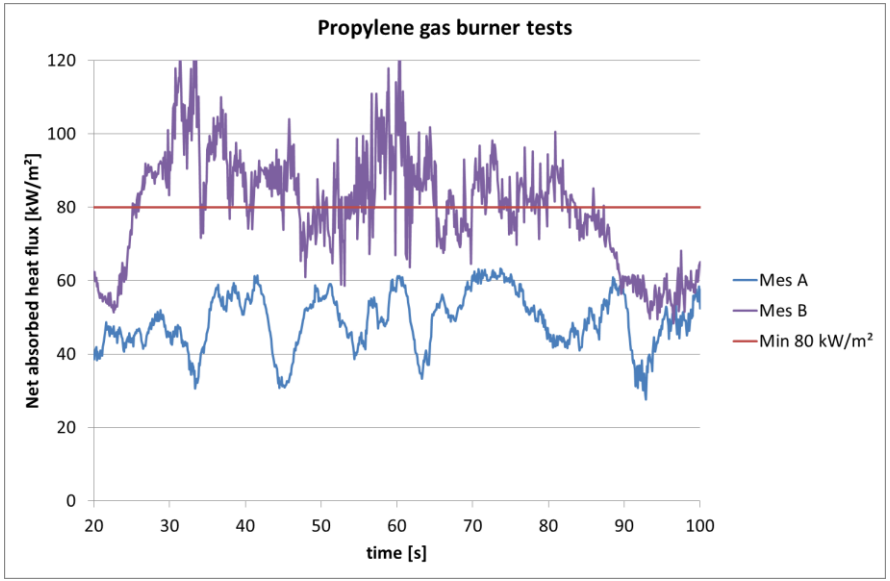
Courtesy of DIEHL Defence, Germany

CALIFLUX4240

5. FIRE TESTING

Example 2 : NEXTER propylene gas burner

- Small calibres 20-155mm (demonstrator)
- Sensitivity to burner parameters (mass flows) :



Courtesy of NEXTER, France

CONCLUSIONS

KEY OUTPUTS

- CALIFLUX4240 = heat flux measurement device developed by the IMEMG FCO expert working group in response to the need to have a better characterization of fire heat fluxes for fire trials on munition
  - **Joint effort from IMEMG companies**
  - **Operational device**
  - **Affordable, easy to use**

CONCLUSIONS

NEXT STEPS

- Fire testing
  - ➢ **Liquid / gas fires**
  - ➢ **Tests with 2 sizes of Califlux4240**
- RetEx analysis
  - ➢ **Califlux use, post-processing**
  - ➢ **Ageing effect, reuse of device**
- Data pack will be made available soon on IMEMG website

Expected in 2020 :

- ✓ 3 liquid fuel fire tests
- ✓ 3 gas fire tests
- ✓ Calibration tests up to 150kW/m²

THANK-YOU FOR YOUR ATTENTION

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