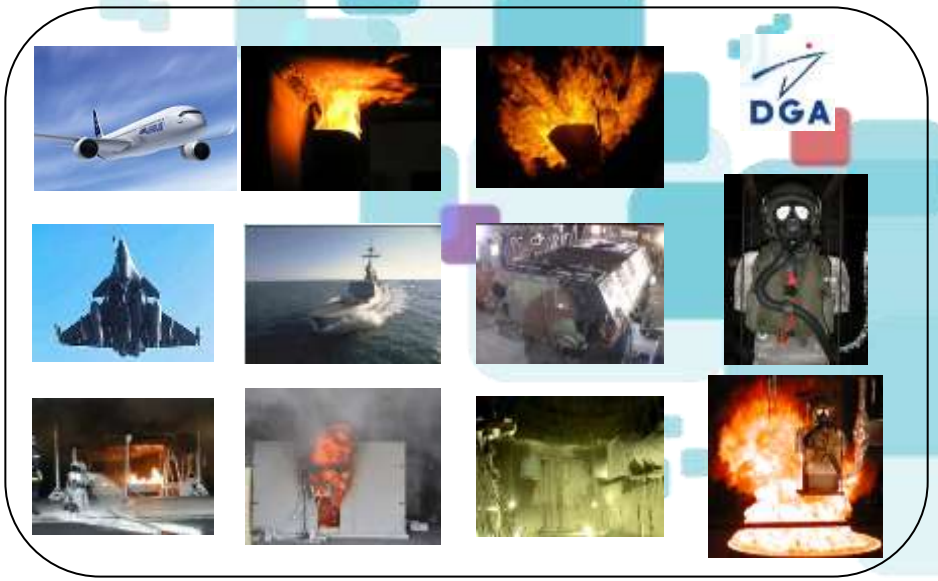
DGA Aeronautical Systems

Fire Safety Department

POWERPLANT Fire tests

Assessment of the ability of plate thermocouples to check a burner flame



Serge LE NEVE
Presented by Camille RIERA

IASFPF meeting (EASA – May 2018)

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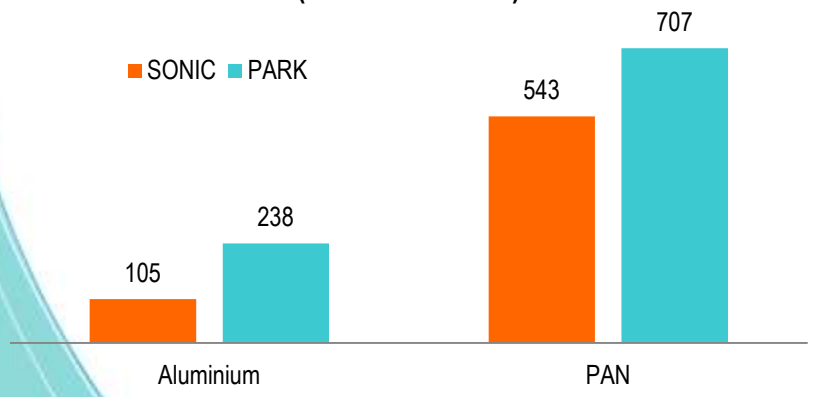
BACKGROUND

RR 2014

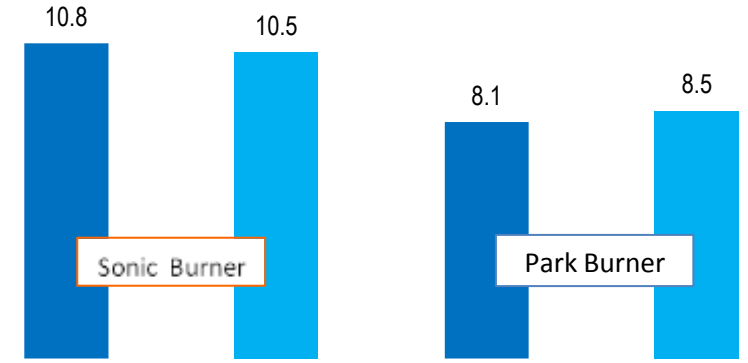
Significant differences on Burnthrough times
=> Sonic settings produced more sever flame than Old Generation Burners

DGA Test results

Burnthrough time (s)
(SONIC vs. PARK)



T° Slopes (°C/s)
(slug calorimeter)

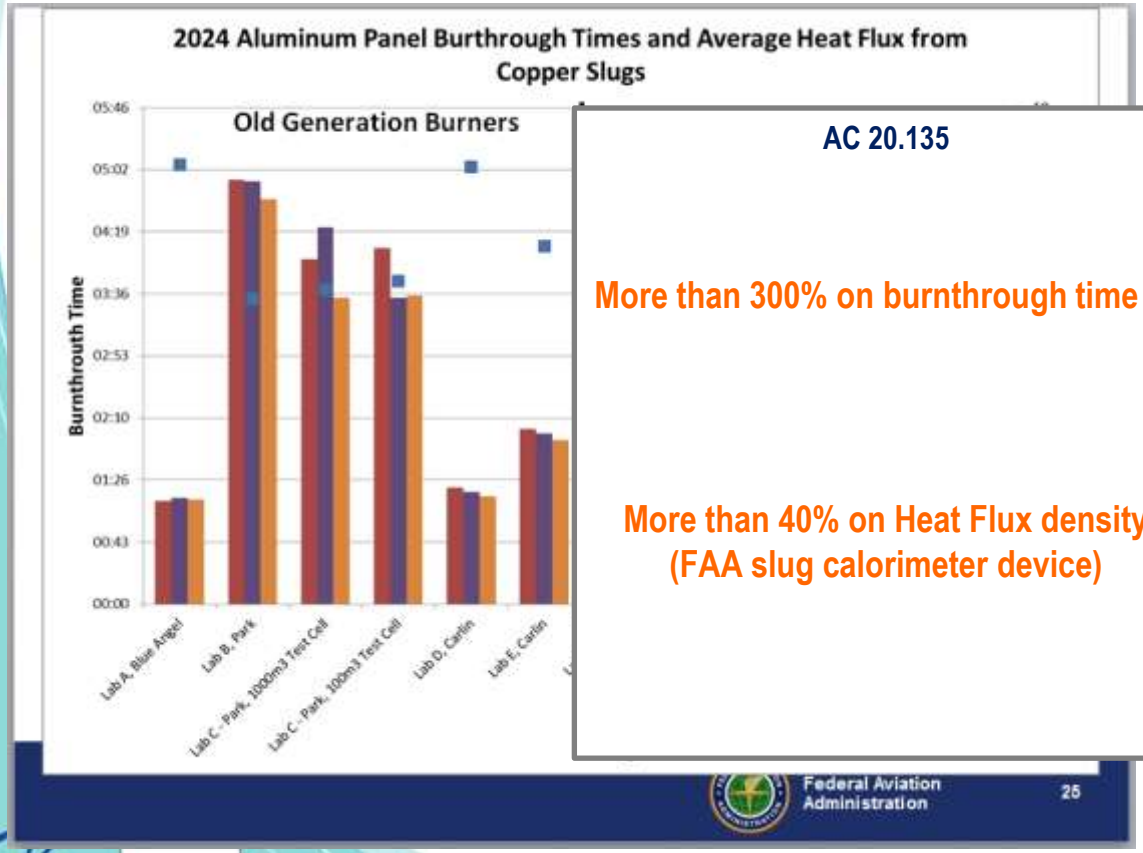


Up to 30% higher

BACKGROUND

RR 2014

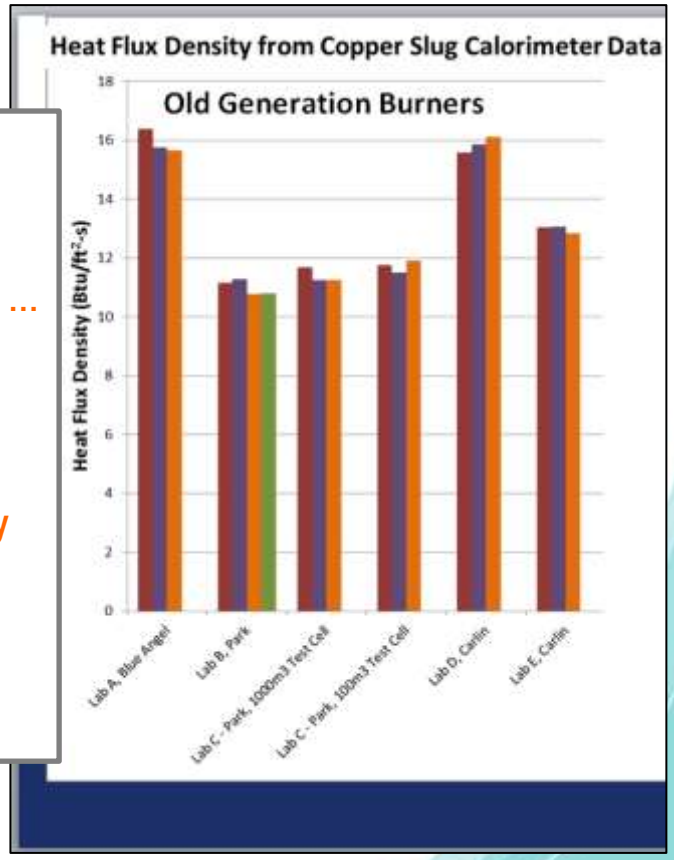
Comparison Sonic Burner vs Old generation burners
=> Important discrepancies in lab results



AC 20.135

More than 300% on burnthrough time …

More than 40% on Heat Flux density
(FAA slug calorimeter device)



DGA MINISTÈRE DES ARMÉES

BACKGROUND

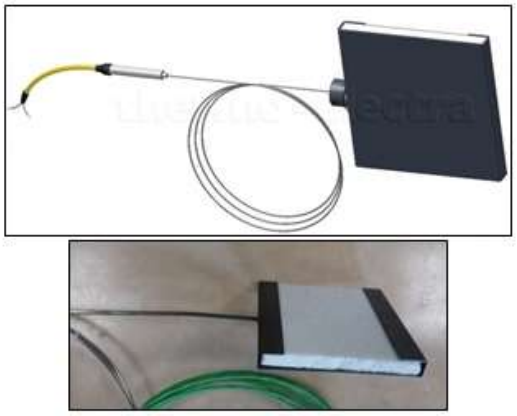
DGA 2016

Following that round robin, two conclusions

- ➔ **Copper tube calorimeter is not reliable to check or calibrate a flame intended to be applied on large plate sample or equipment,**
- ➔ **“Slug type” measurement methods are more appropriate to characterise, calibrate or just check the thermal power of burner flames**

FAA Copper Slug Calorimeter

Plate thermocouple



DGA

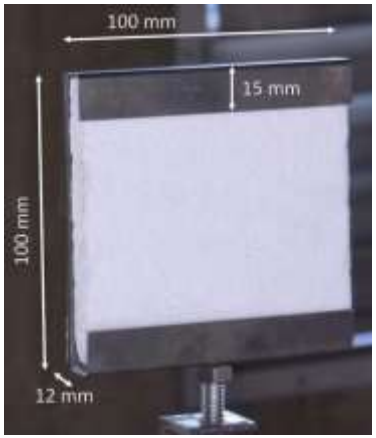
MINISTÈRE DES ARMÉES

BACKGROUND

DGA 2016 : Evaluation of another kind of Slug thermometer

Plate Thermocouple

- Commonly used to control T° in Fire Resistance Furnaces according to naval and building regulations (Bulkhead and door Fire Resistance Tests),
- Widely studied by SP Technical Research Institute of Sweden to calculate incident heat-flux

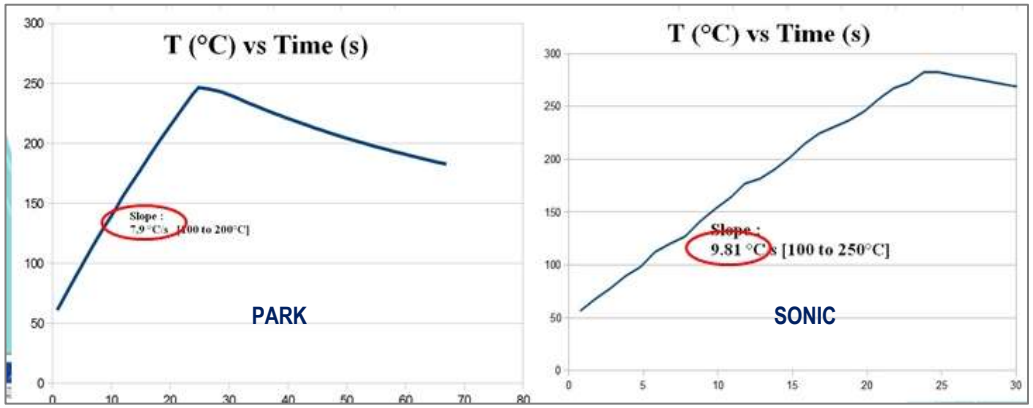


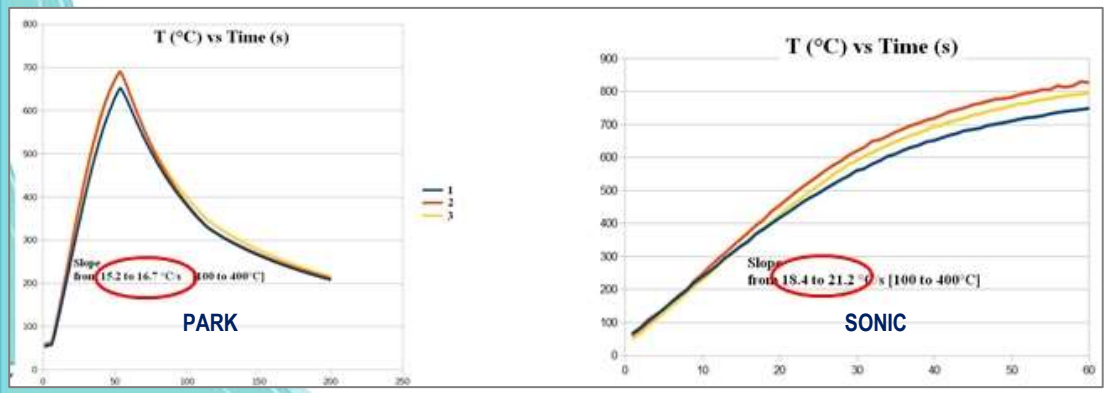
Design	
Application	Fire testing
Requirements	According to ISO 834 EN 1363 Part 1
Material	Special treated heat resistant Plate
Dimensions	100 x 100 x 10 mm
Center part	Specially treated for optimal cosine sensitivity
Connection	1/4 BSP female
Sheath	
Construction	Mineral insulated
Material	Inconel 600
Insulation	MgO
Diameter "D"	1 mm
Length "L"	2000 mm
Lead wire	
	PTFE insulated flexible thermocouple wire, braiding 260 °C
Wire length "K"	1000 mm
Element	
Calibration	Type K thermocouple
Accuracy	According IEC 584-1 / DIN 43710
Thermocouple	Pre-aged
Hot junction	Insulated
Testing	Tested at 500 Volt/20 °C
Insulation resistance	Minimum 100 M ohm

BACKGROUND

DGA 2016

- Flame measurements with FAA slug calorimeter and Plate thermocouples conducted to good agreement





=> Higher Slope in T° increase for the Sonic Burner (+24%)

WORK IN PROGRESS

Objective: Assess the ability of Plate Thermocouples (PTc) to compare oil burner flames

- **Reference: Park burner with AC 20.135 settings**
- **Repeatability of measurements : 15 tests conducted**
- **Correlation (or not) with**
  - **BTU heat transfer device (Copper tube calorimeter)**
  - **Water-cooled calorimeter (Gardon)**
  - **Rack of 7 thermocouples**
- **Effect of test configurations: 2 configurations**
  - **Free flame / Free PTc**
  - **Impacting flame / 3 embedded PTc**

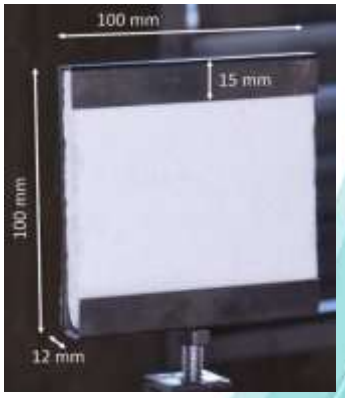
MEASUREMENT DEVICES

- **Rack of 7 thermocouples**

- **Copper Tube Calorimeter**

- **Water-cooled Calorimeter**

- **Plate Thermocouples** *(6 PTc tested)*



TEST / PROBE CONFIGURATIONS

- **Free surrounding space (1 or 3 probes)**





Plate Thermocouples

Water-cooled Calorimeter

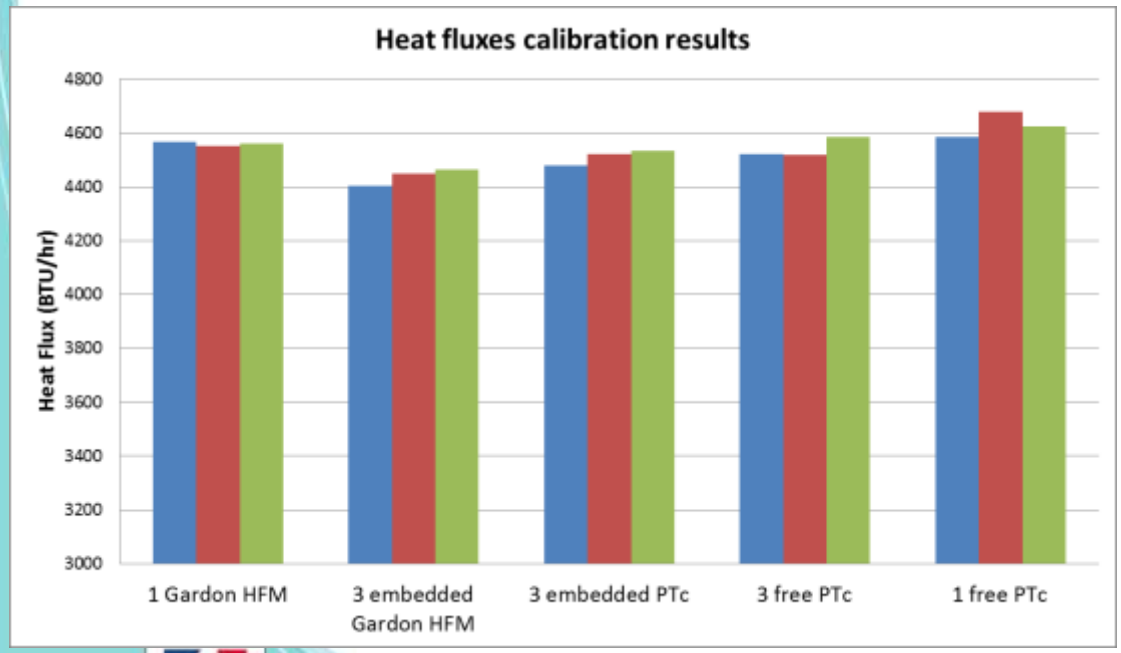
- **3 embedded probes**

Plate Thermocouples

Water-cooled Calorimeter

CALIBRATIONS

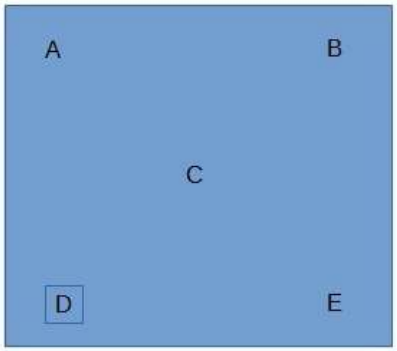
- Tests conducted with Park burner – calibration with copper tube or Gardon HFM
- Settings according to AC 20.135
- Calibration :
  - Heat Flux (Copper Tube) : before each test
  - Temperature : once a day

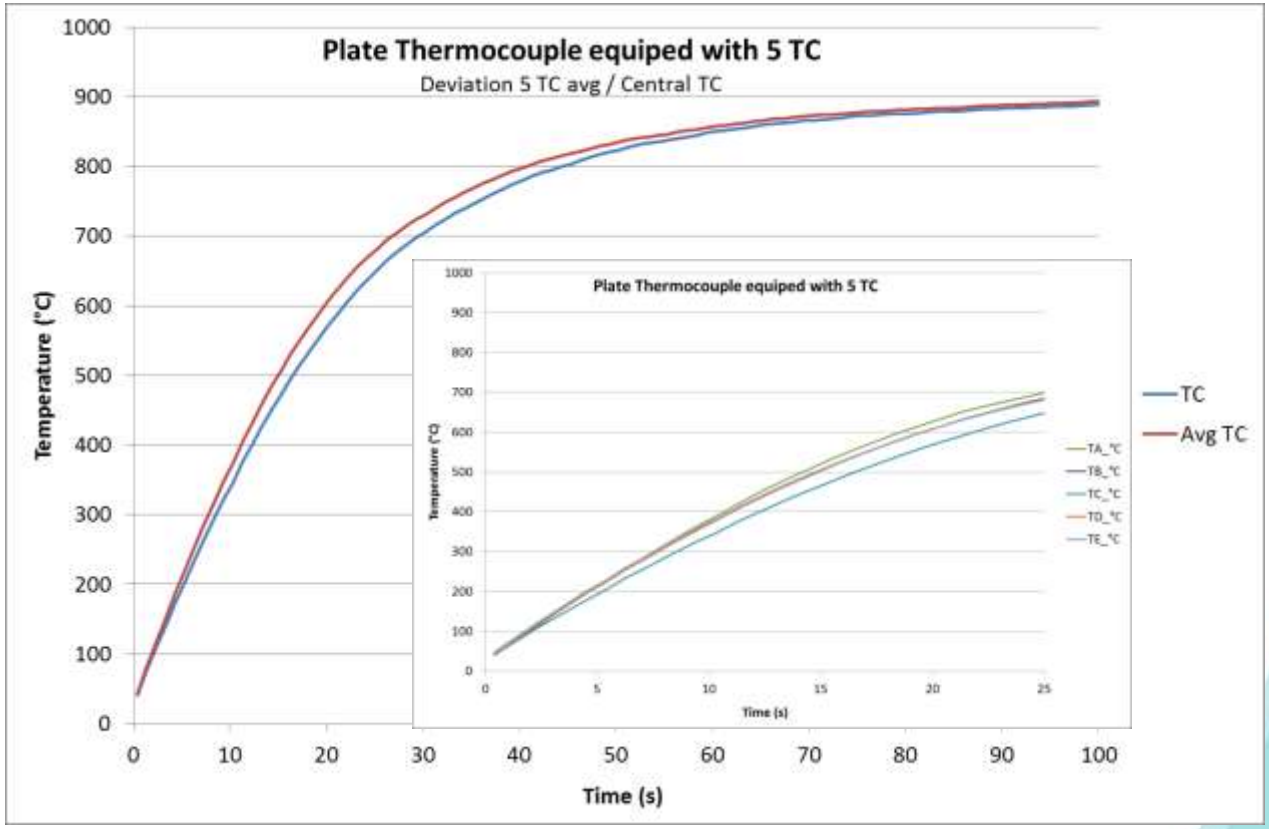


- **Average HF : 4541 BTU/h**
  Standard deviation : 1,5% (68 BTU/h)
- **Average T° : 1069 °C (1957 F)**
  Standard deviation : 1% (11 °C / 20 F)

TEST RESULTS

PTc equipped with 5 Thermocouples on back side to assess temperature homogeneity



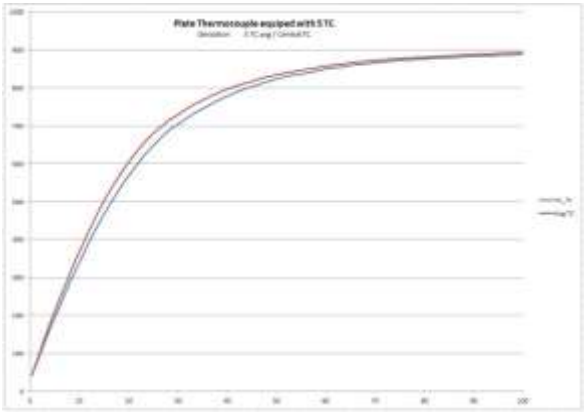


- T° stabilisation around 900 °C
- Lower slope of T° on central Tc
- Average T° of 5 Tc is up to 5% to 8% over central T°

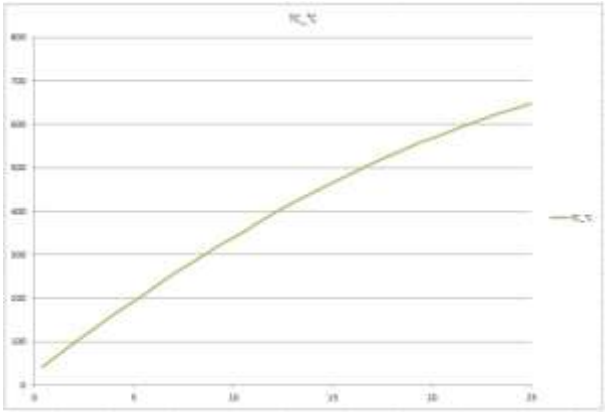
TEST RESULTS

PTc Temperature Data :

Temperature Slope Analysis

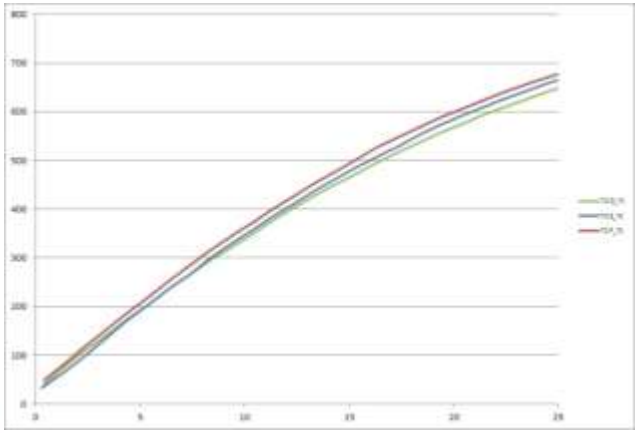


T° recording



- **Increase of T° is function of PTc thermal balance**
- **In the 1st time of flame exposure** *(before T° becomes significant)*, **slope of increasing Temperature mainly depends on flame thermal power**

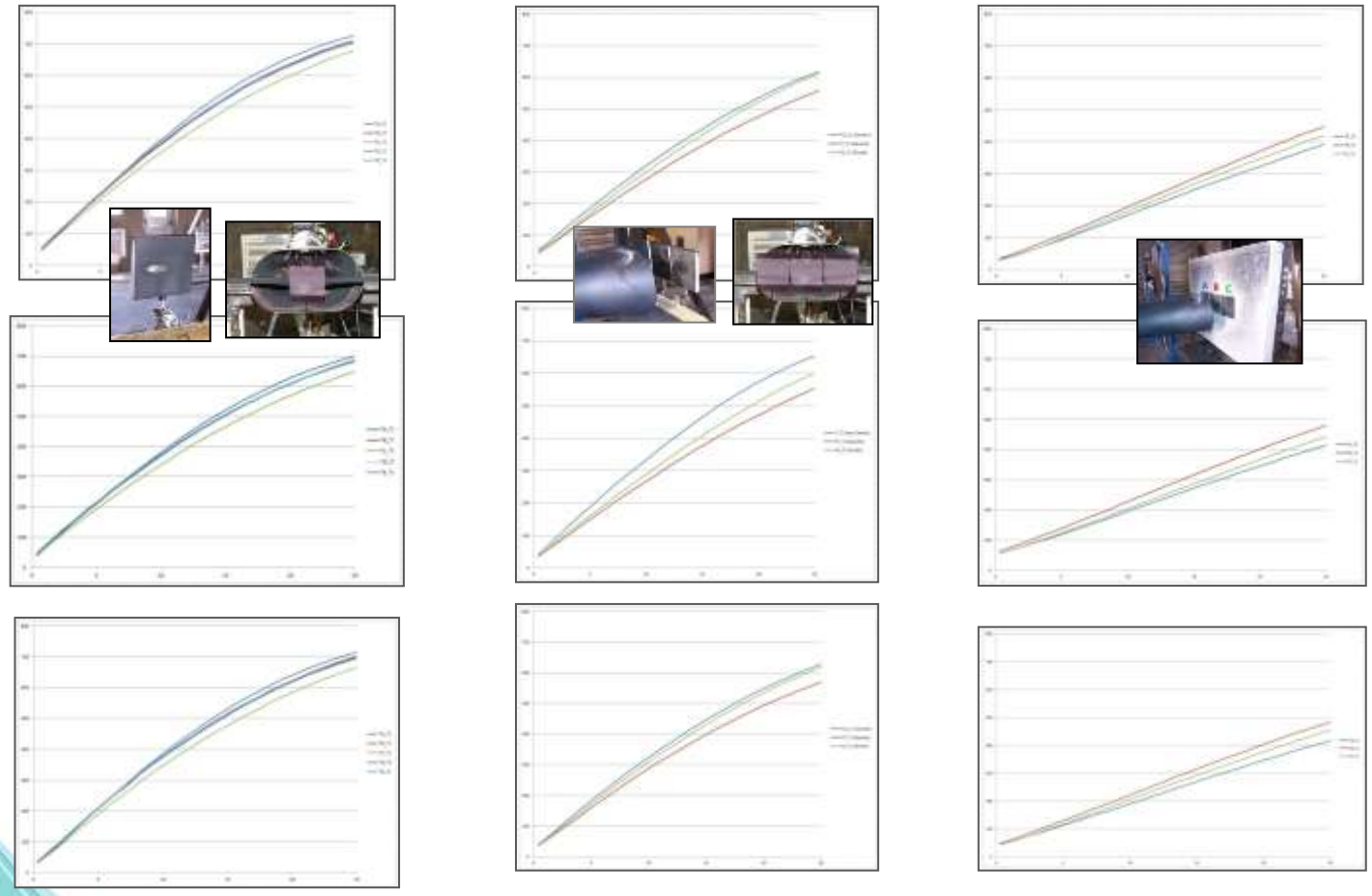
- **Good linearity on the 1st 15 seconds (up to 350 / 400°C)**



TEST RESULTS

PTc Temperature Data :

Temperature Slope Analysis



- Measurements show good repeatability for each test configuration
- With significant differences depending on the various test configurations

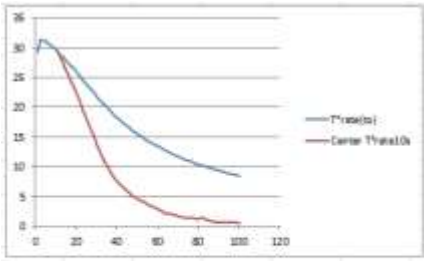
(good indicator of discriminating ability)

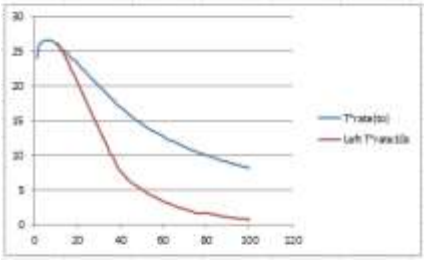
TEST RESULTS

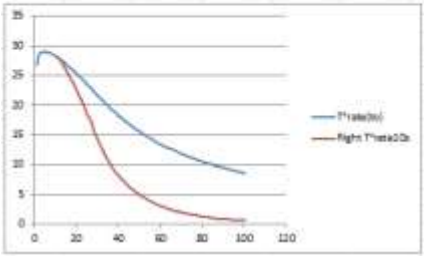
PTc Temperature Data :

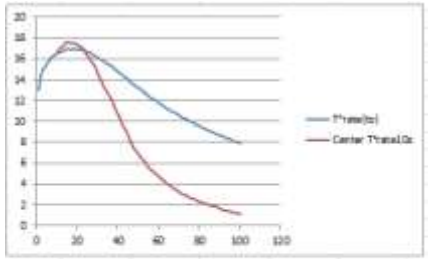
Temperature Slope Analysis

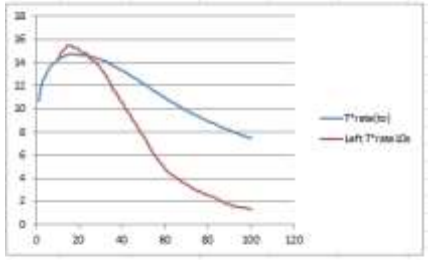
- **Configurations with 3 PTc both show a peak of Slope T°**

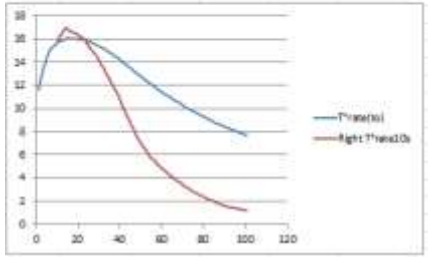








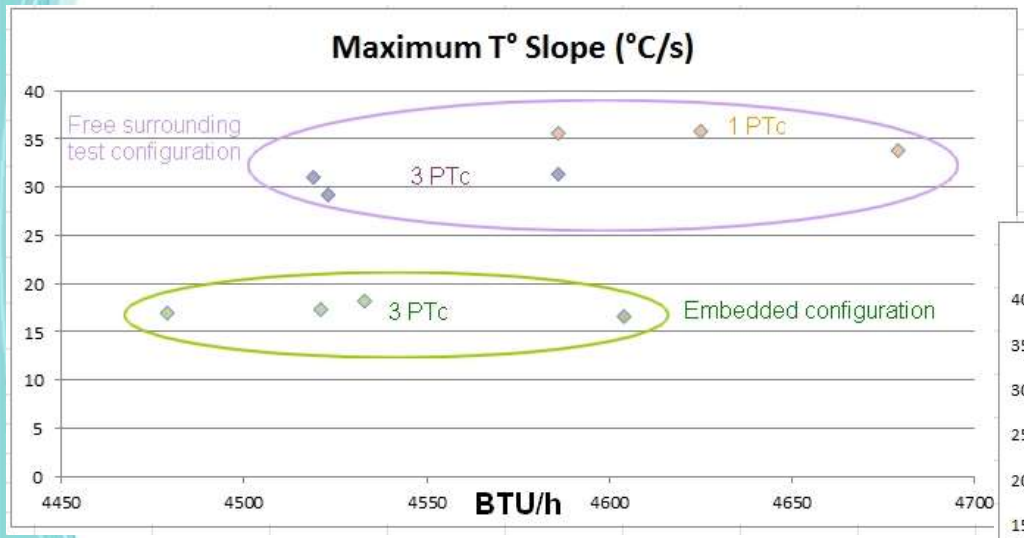


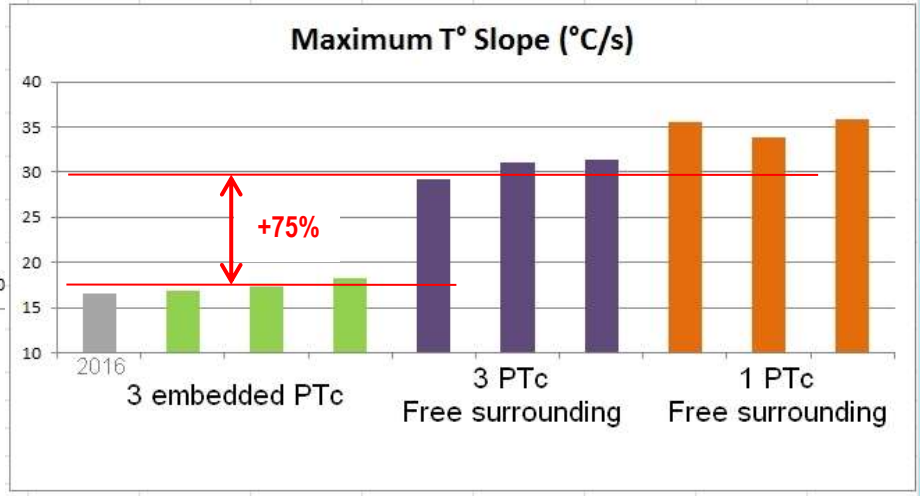


- **Idea is to compare $(T° \text{ slope})_{max}$ from all configuration tests**

TEST RESULTS

$(T° \text{ slope})_{max}$ vs BTU/h *(Thermal Power from Copper Tube)*



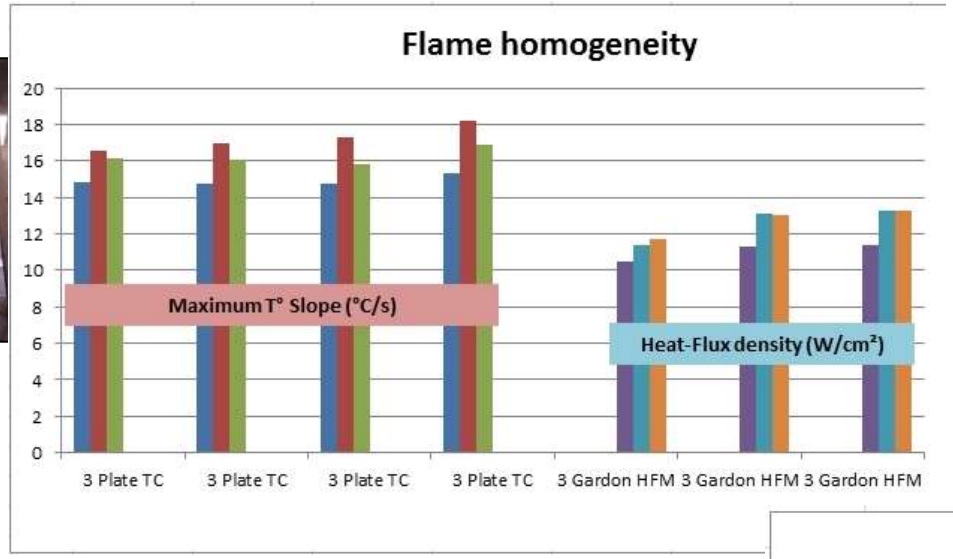


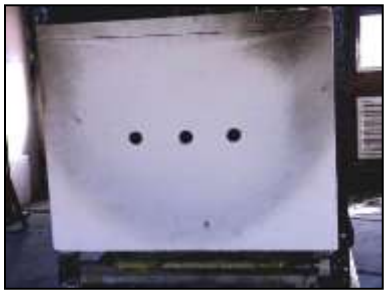
- No correlation T° slope / BTU/h
- PTc T° Slope : Potentially good discriminating ability

- "Wall effect" on flame flow ? (Impacting flame)
- Housing effect on measurement ?

TEST RESULTS

Flame homogeneity

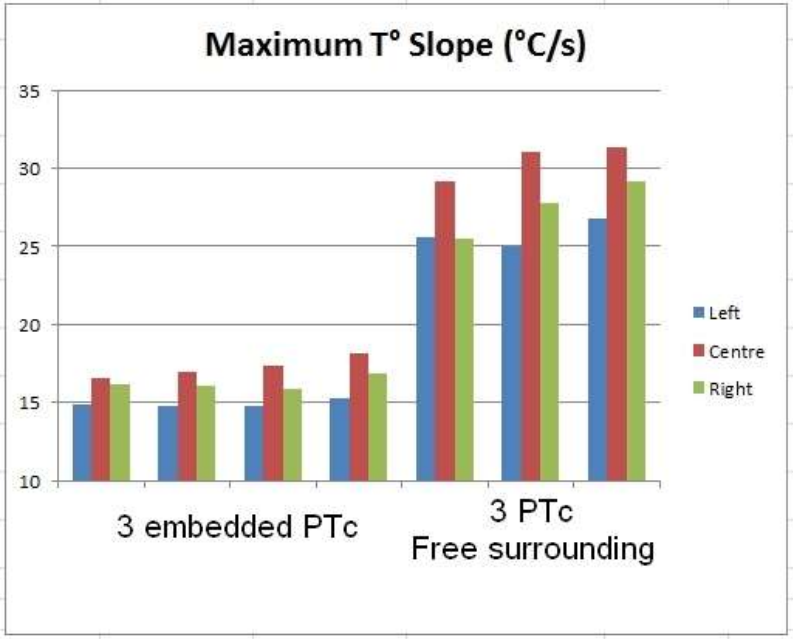




Water-cooled Calorimeter measurements:

- ➔ **Confirm a "lower" thermal power on left side**
- ➔ **But not the highest power at the centre**

(note that exposed surface of PTc is significantly higher and can reflect a hot spot not detected by the calorimeter)



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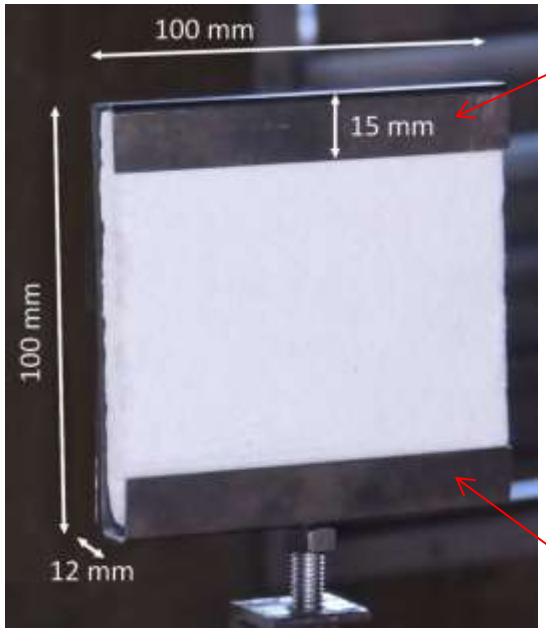
MINISTÈRE DES ARMÉES

TEST RESULTS

Edge effect on measurement



<u>Still to be investigated</u>
(in progress)

Effect of heat exchange on measurement?
(edges and rear metallic parts of PTc)

CONCLUSIONS

Plate Thermocouples have been tested under two configurations (free surrounding space or embedded into insulation).
Temperatures were compared to calibration data from copper tube calorimeter and Gardon water-cooled calorimeter.

- **More appropriate to assess flame setting on a large surface**
  (3 PTc aligned = 320 mm x 100 mm)
- **Able to check flame homogeneity** *(horizontal symmetry)*
- **More representative of the flame exposure of most of the specimens to be tested**
  - **Especially sheet/plate specimens**
  - **Except hoses**

➢ *Additional tests needed to refine and validate the choice of criteria to be used in order to check a burner flame (sensibility to flame variations)*

NEXT TESTS

- **Test data from embedded & free PTc (in progress)**
  (effect of metallic edges on temperature measurement)

- **Define PTc's criteria to check the flame**
  (check sensibility of criteria to flame variations)

- **Intentional bad flame settings**
  - Flame check
  - Burnthrough tests
  - Find / Confirm correlation "Burnthrough time / PTc data"

or

- **Check other DGA PARK burners**
  - Cargo liner test
  - Seat Cushion test
  - Burnthrough test

  9.1 to 18.2 W/cm² (8.0 to 16 BTU/ft².s)
  927 °C to 1038 °C (1700 to 1900 F)

- **Any other ideas ???**

NEXT STEPS

- **Supply and evaluate PTc commercially available from different suppliers**
  (our currents PTc have been built on demand)

- **SONIC / PARK Burners :**
  - **Find SONIC settings providing same PTc response as Park burner**
  - **Realize burnthrough fire tests to compare burnthrough times for the 2 burners**

- **SONIC Burner Round Robin (if new settings lead to same burnthrough times)**

- **Plate Thermocouple Round Robin:**
  - **Any participating lab would buy PTc**
  - **PTc flame characterisation**
  - **Burnthrough fire tests**

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Thank you

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