THE SAND BED BURNER AND THE ADIABATIC SURFACE TEMERATURE PROBE

– THE FUTURE EQUIPMENT FOR FAST COOK OFF TESTING

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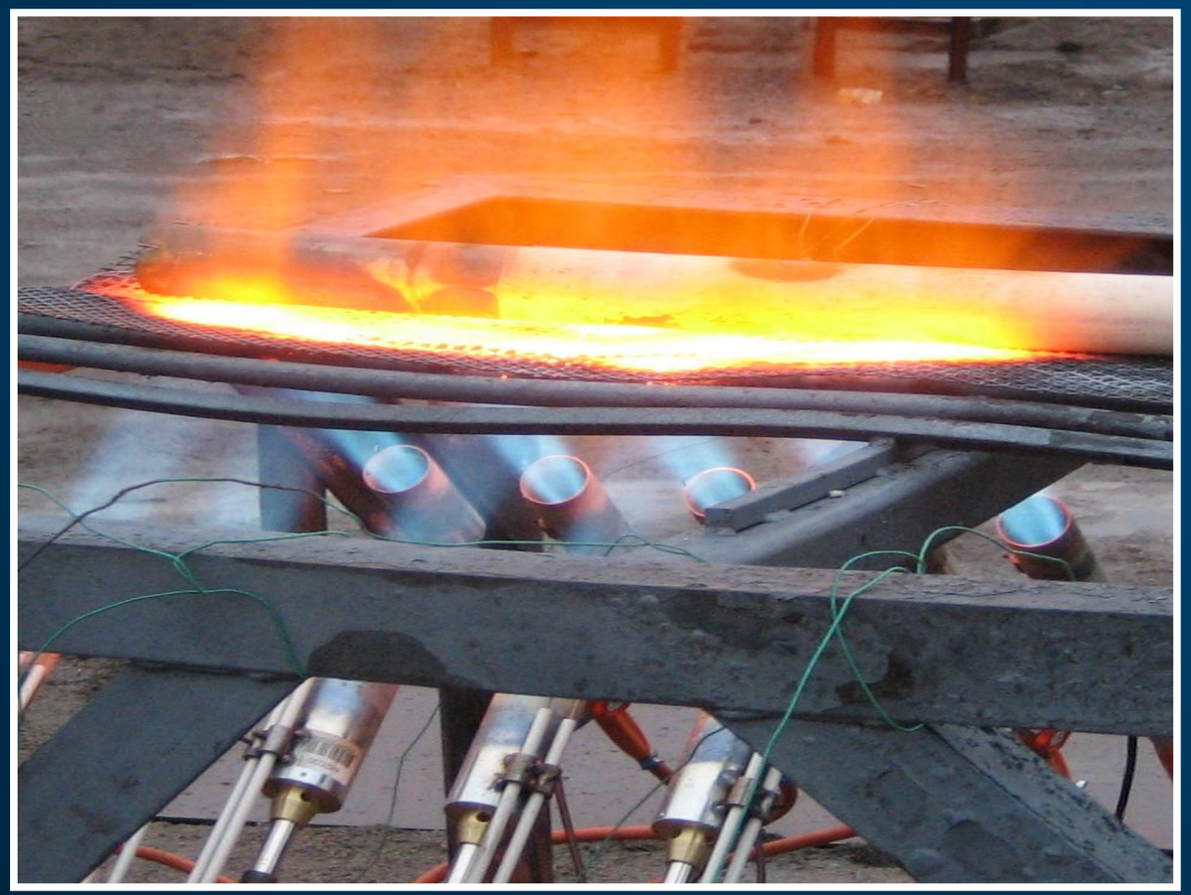
WHAT WE ARE FACING

+ STANAG 4240 compatible

- Environmental Impact
- Costs
- Working Environment
- Weather Conditions



+ Low Environmental Impact
+ Low Costs
+ Improved Working Environment
+ Weather Conditions
+ Assessment
+ Test Results
+ Temperatures

- Not STANAG 4240 compatible
- Heat flux?

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THEORY OF HEAT TRANSFER

or

- What the f*** is Heat Flux?

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$\dot{q}_{inc}$
T_g
ρ
χ
$\varkappa$
A
h_c
ε
c
σ
α
Γ
β
d
K
τ
T_{AST}
ΔH_c
u_∞
$\dot{m}$
Re
I CANNOT COUNT THEM ALL

THE INCIDENT HEAT FLUX

$$\dot{q}''_{inc}$$

The total energy supplied to the test object

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$$\dot{q} = A_f \dot{m}_f \chi \Delta H_c \rightarrow u = 6.8\left(\frac{z}{\dot{q}^{2/5}}\right)^{1/2} \dot{q}^{1/5} \rightarrow$$

Heat release rate

McCaffery's plume equation

$$\rightarrow \Gamma = \frac{u_\infty d}{T_f^{1.67}} \rightarrow \mathrm{Re} = \frac{1}{1.13 \cdot 10^{-9}} \cdot \Gamma \rightarrow$$

Reynolds number

A, C, n (Tabulated)

$$h_c = A \cdot C \cdot \frac{T_f^{0.92-1.67n} u_\infty^n}{d^{1-n}}$$

Heat transfer coefficient

σ

Stefan-Boltzmann constant

ε

Surface emissivity

T_g T_{AST}

Measured values

$$\dot{q}''_{inc} = \sigma T_{AST}^4 - \frac{h_c}{\varepsilon}\left(T_g - T_{AST}\right)$$

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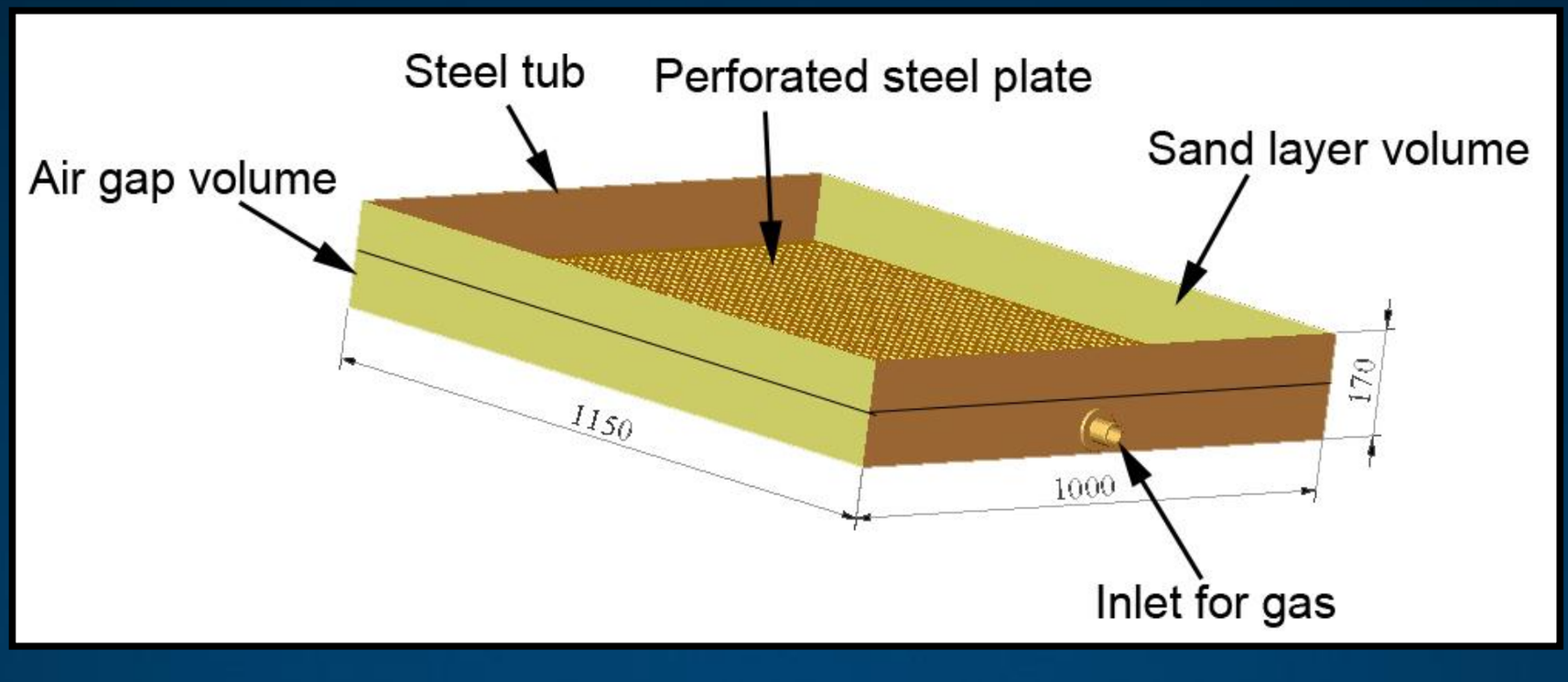
THE SAND BED BURNER



Propane will diffuse through a bed of sand

↓

Thicker diffusion flames with higher radiation than premixed flames

- Manufactured in modules
- One module = 1.15 m^2
- Sand particle size 4 – 8 mm
- Sand layer thickness 100 mm
- Required flow of propane: 0.044 kg/s

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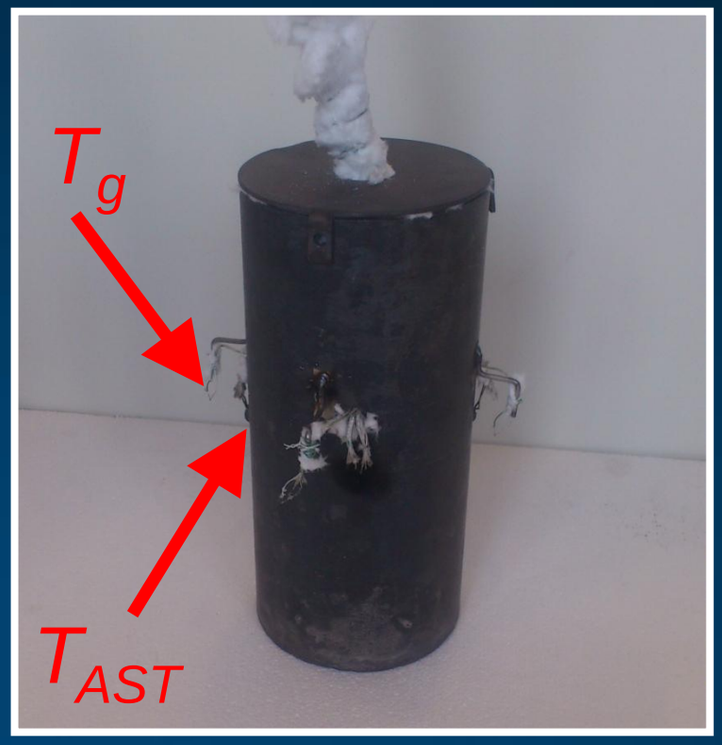
THE ADIABATIC SURFACE TEMPERATURE PROBE

Requirements for an accurate probe

1. A similar shape as the actual test object
2. Similar surface properties as the actual test object
3. An insulated surface
4. A short response time



- Has a similar shape as a bare round
- Made of 2 mm thick steel pipe
- $Ø_{outer}$ 110 mm, Length 240 mm
- Has a constant surface emissivity, ε
- Insulated with fire insulation
- 4 + 4 thermocouples
- Measure T_g and T_{AST}

(Gas Temperature and Adiabatic Surface Temperature)

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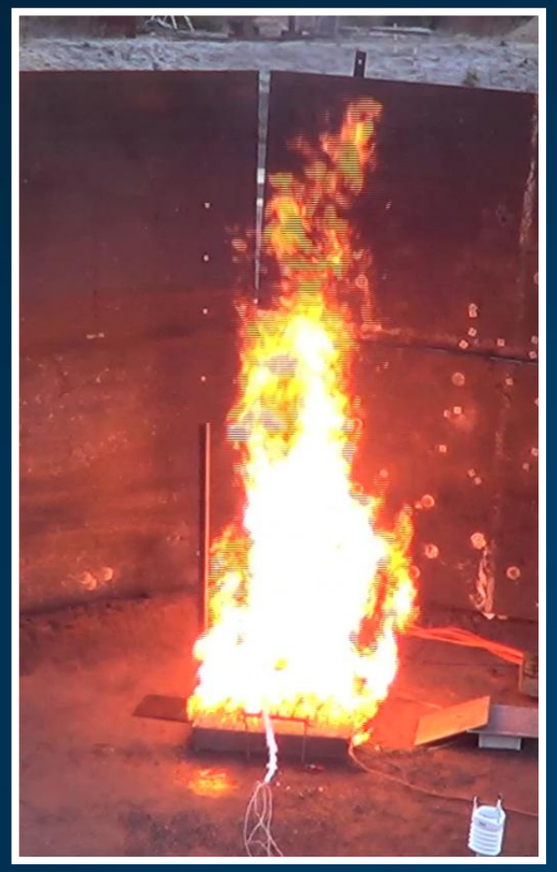
COMPARISON TESTS



Sand Bed Burner

SBB

Small Scale Test

Jet A-1

Bofors Test Center

LPG

System

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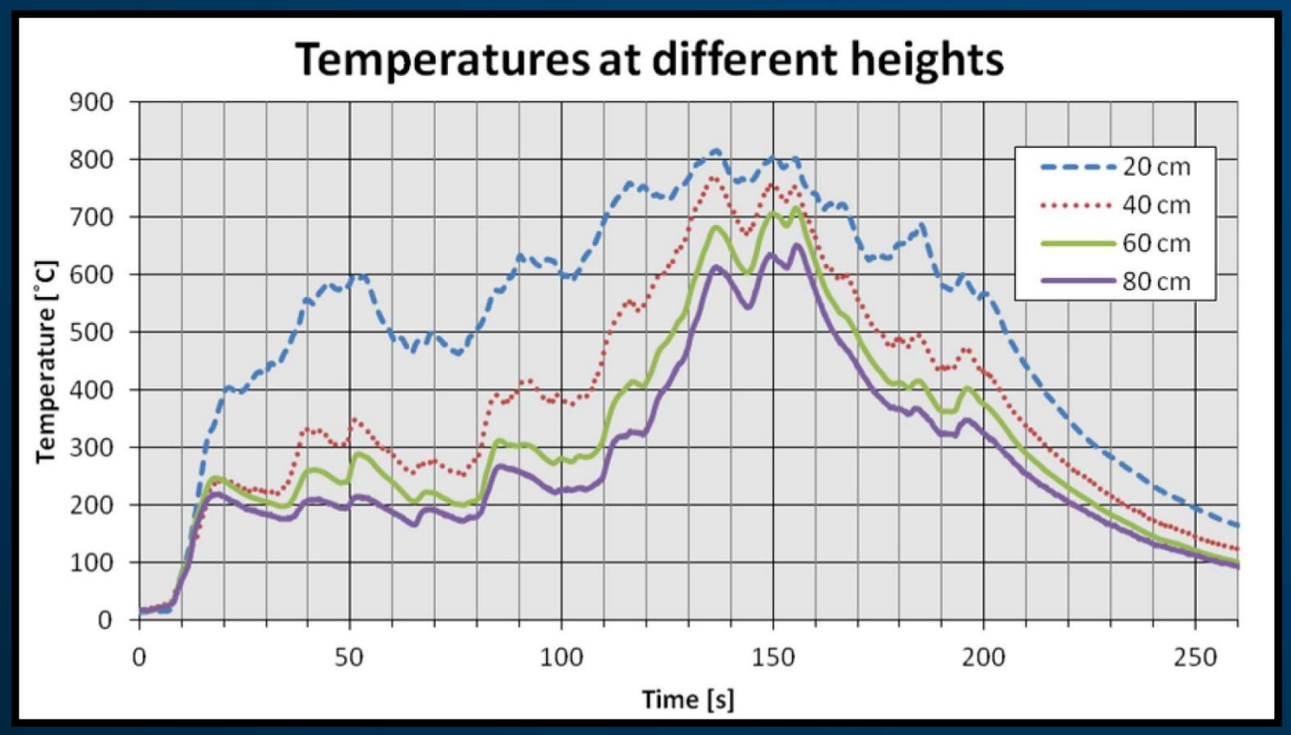
SAND BED BURNER TESTS

Test 1

- Determine the most effective height to place the probe
- 4 different heights were tested



Chosen height: 20 cm

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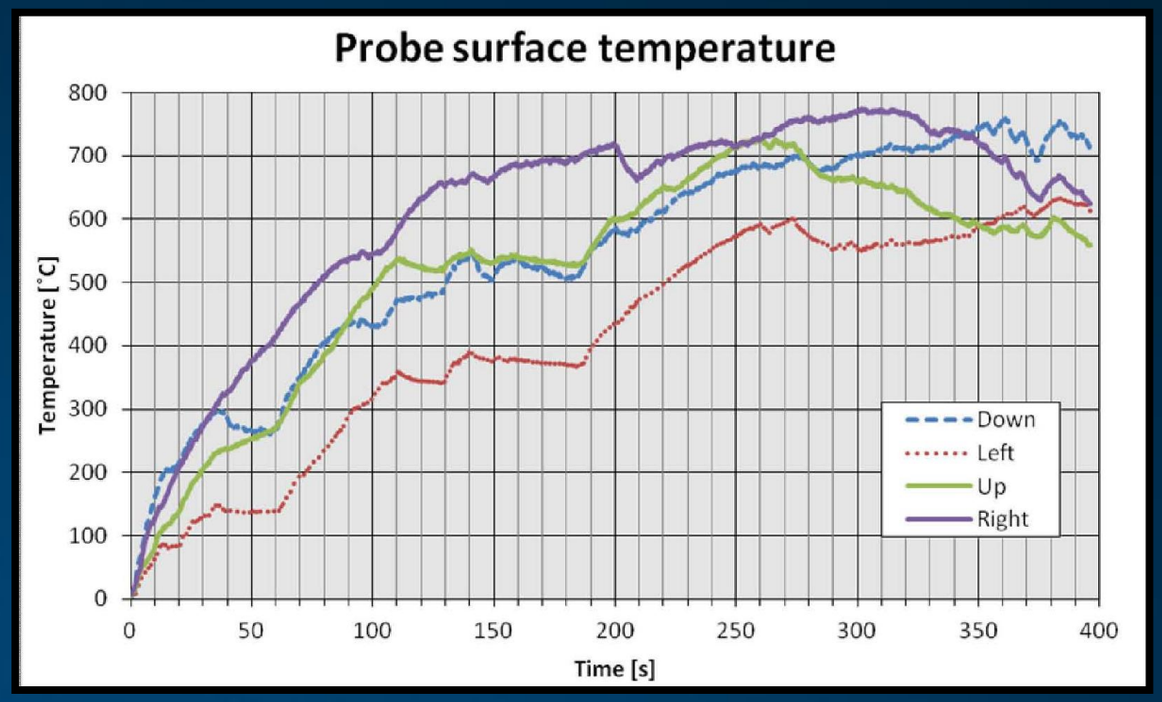
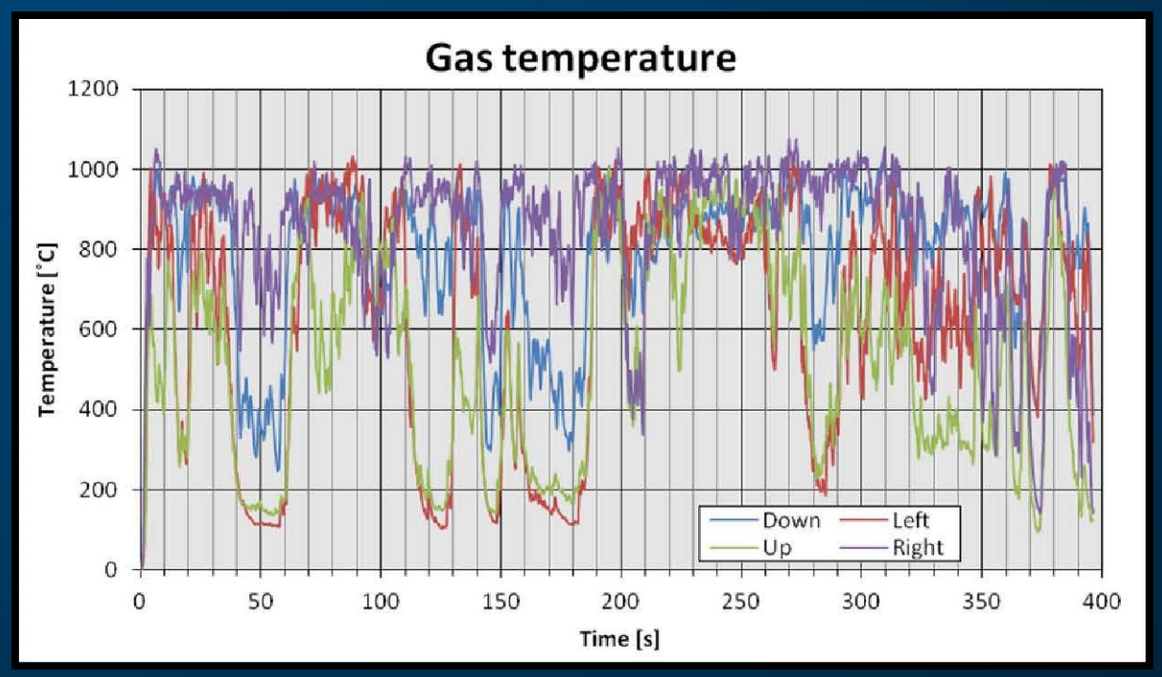
SAND BED BURNER TESTS

Test 2

Mean gas flow: 0.038 kg/s

(0.044 kg/s required)





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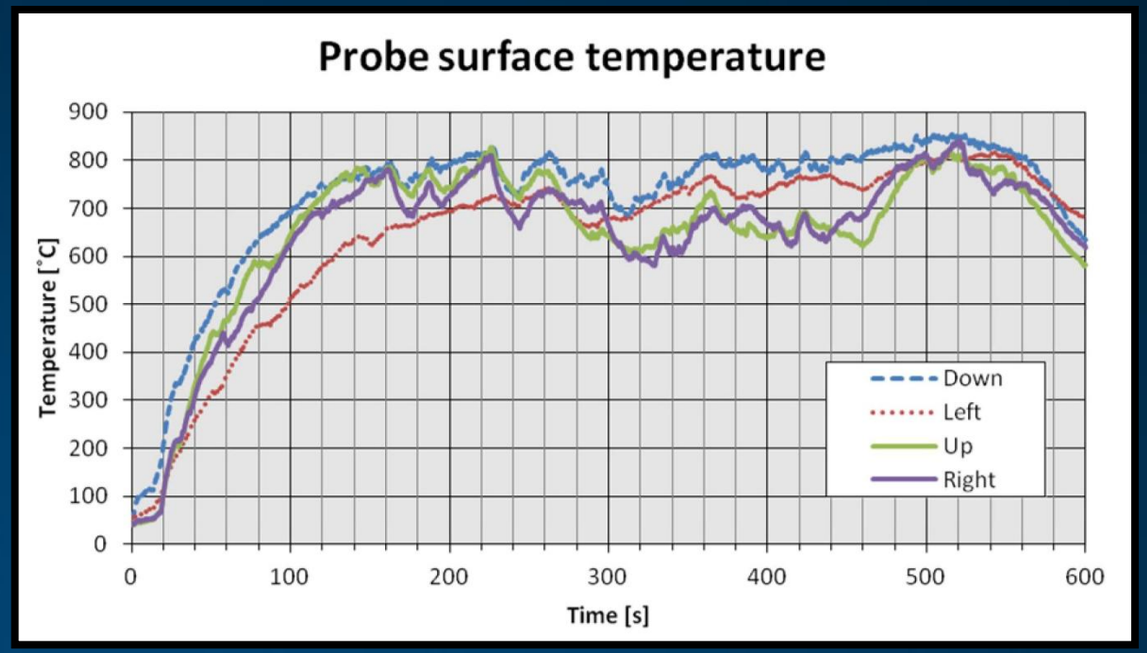
SMALL SCALE TEST, JET A-1

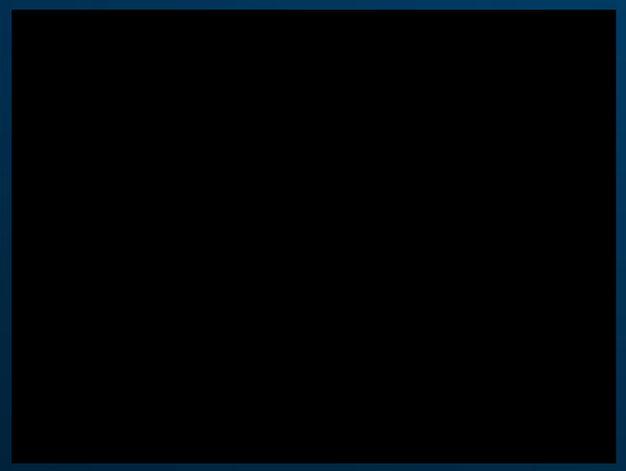


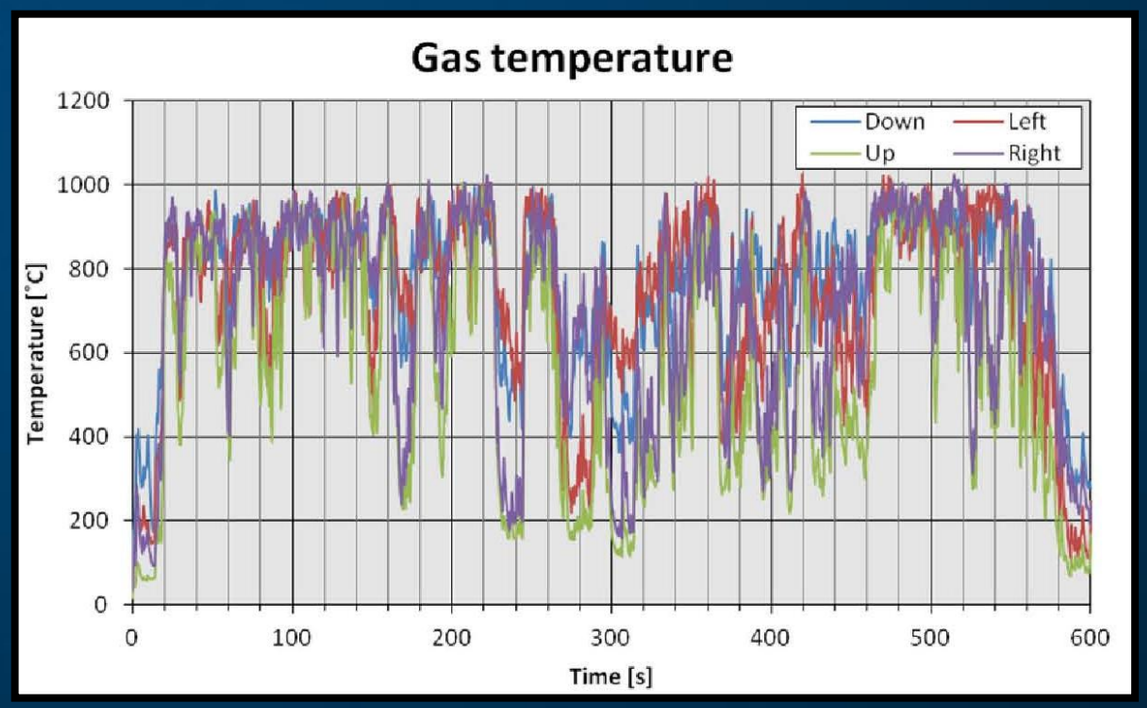
Size of the tub: 1.15 m²

(same as the Sand Bed Burner)

30 liters of Jet A-1 and

4.5 liters of flight petrol





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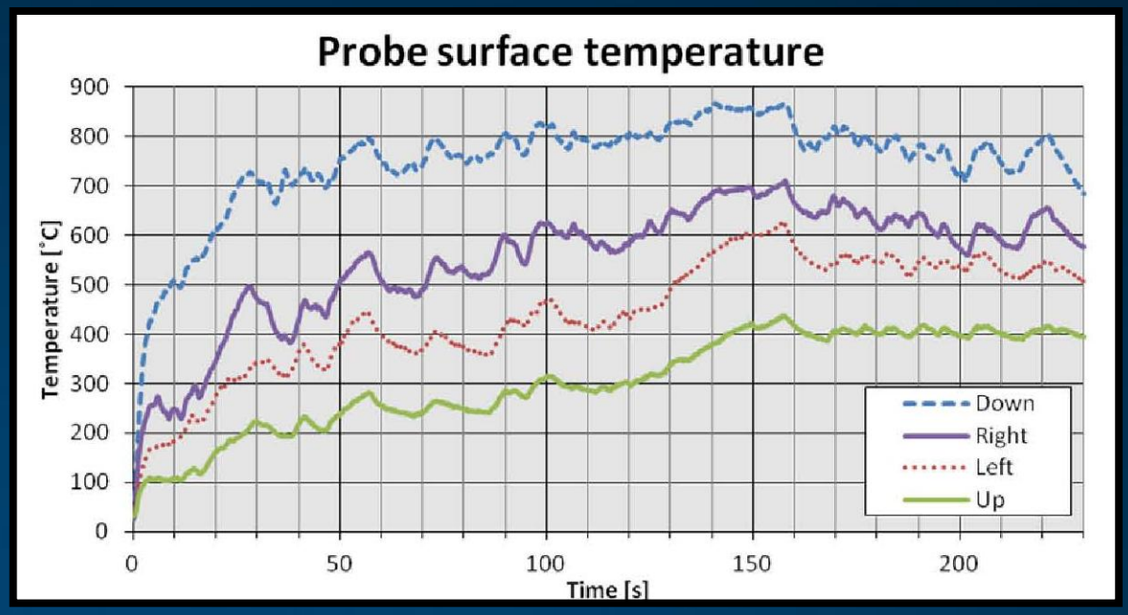
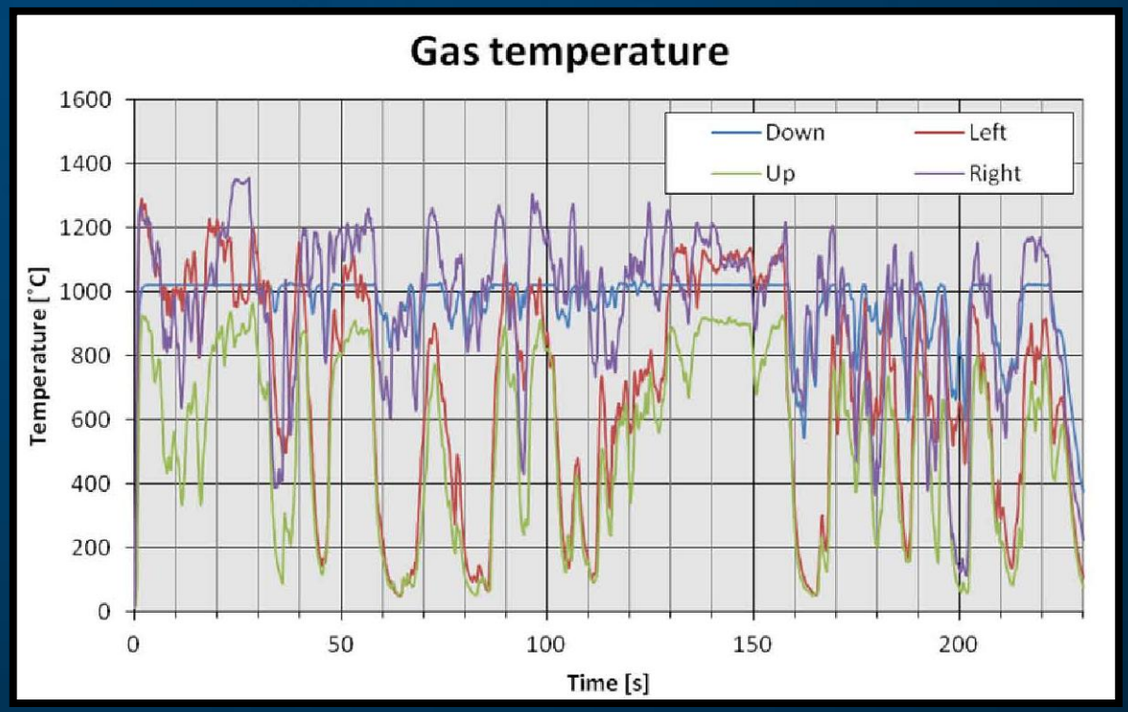
BOFORS TEST CENTER LPG SYSTEM TEST



Mean gas flow: 0.016 kg/s



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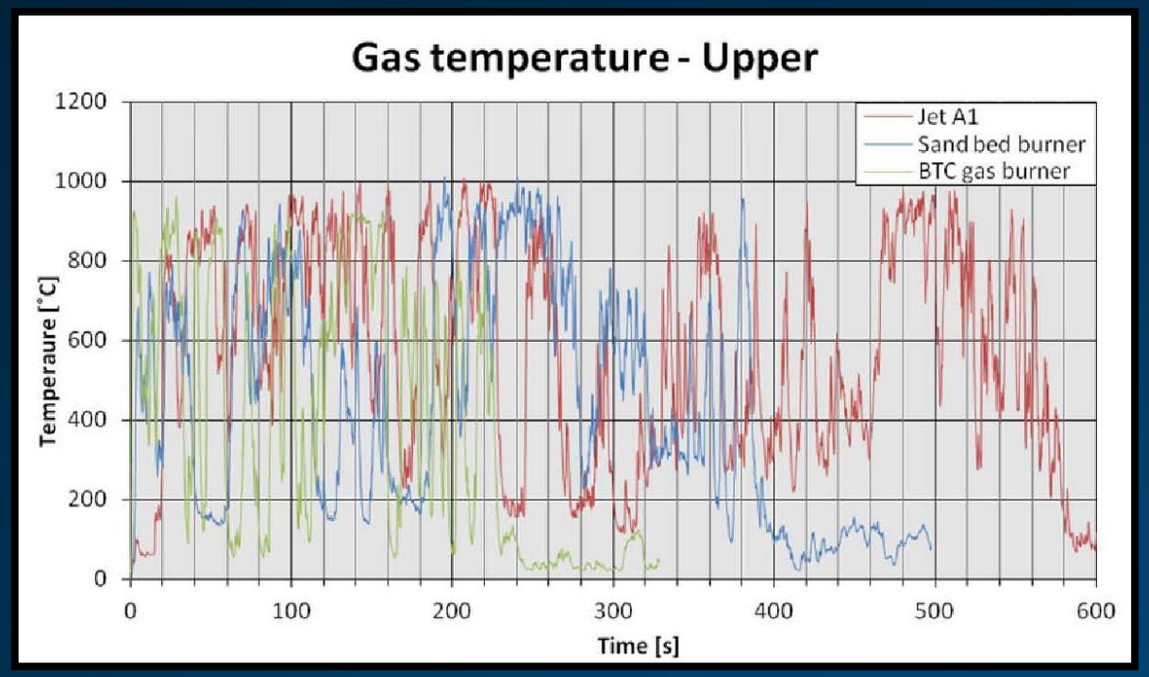
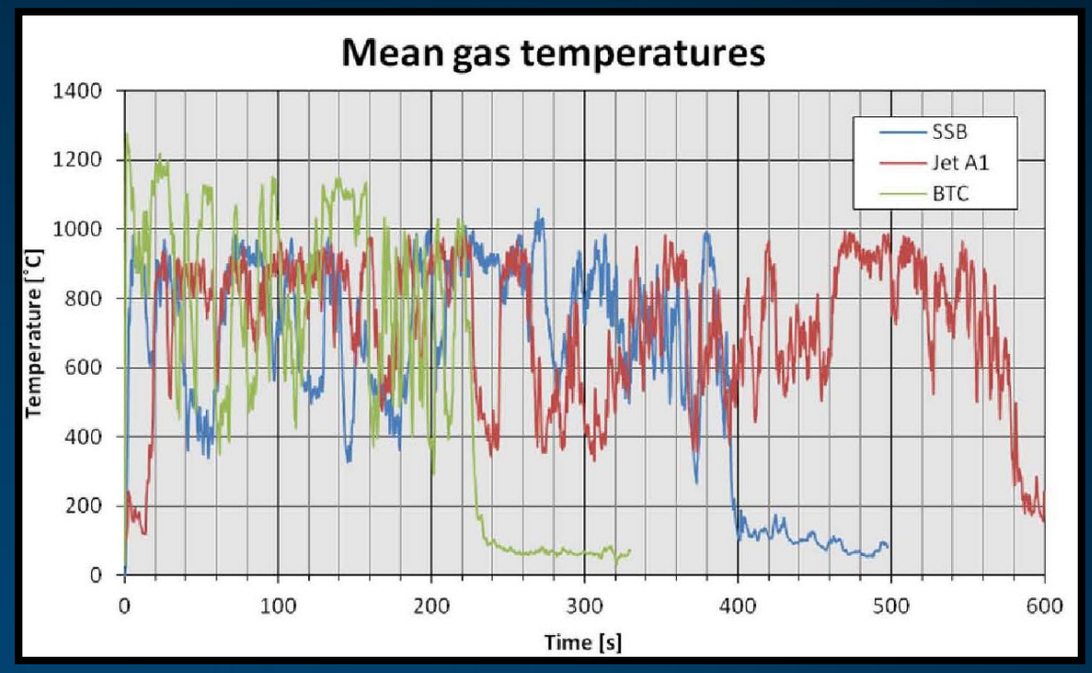
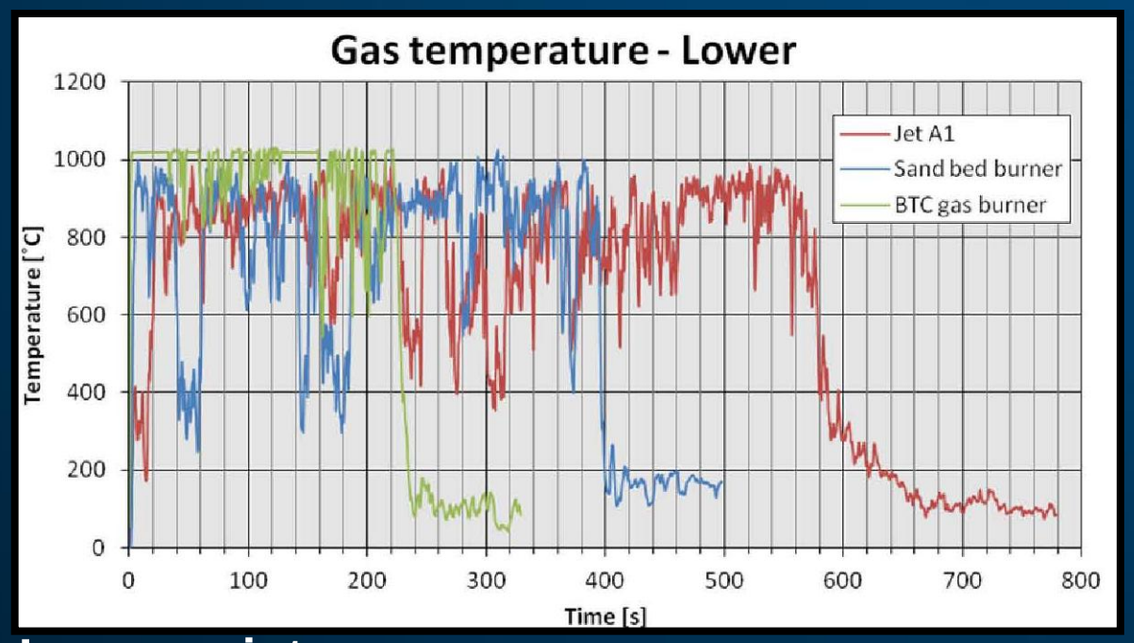
GAS TEMPERATURES



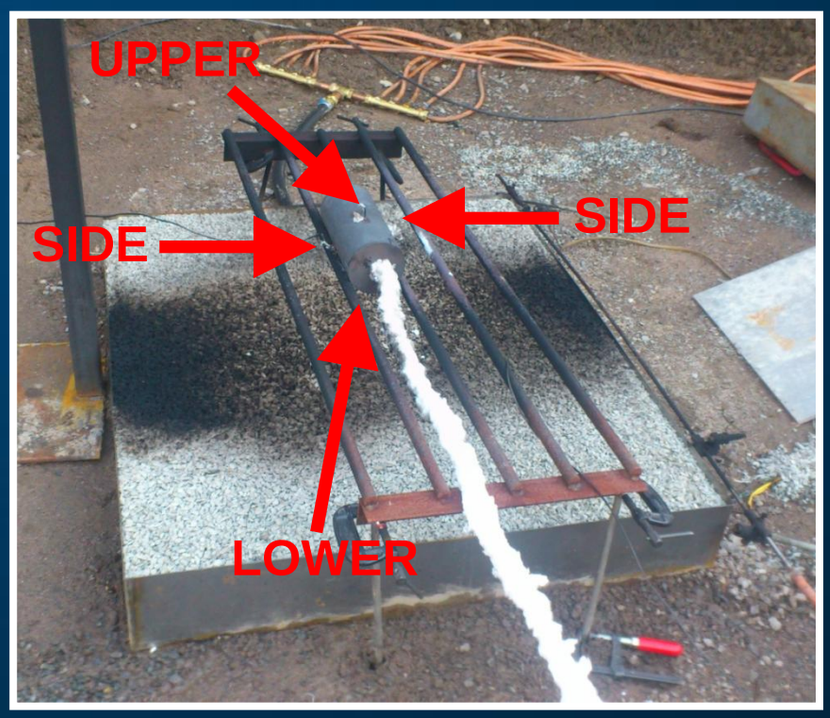
Upper point



Side points



Lower point



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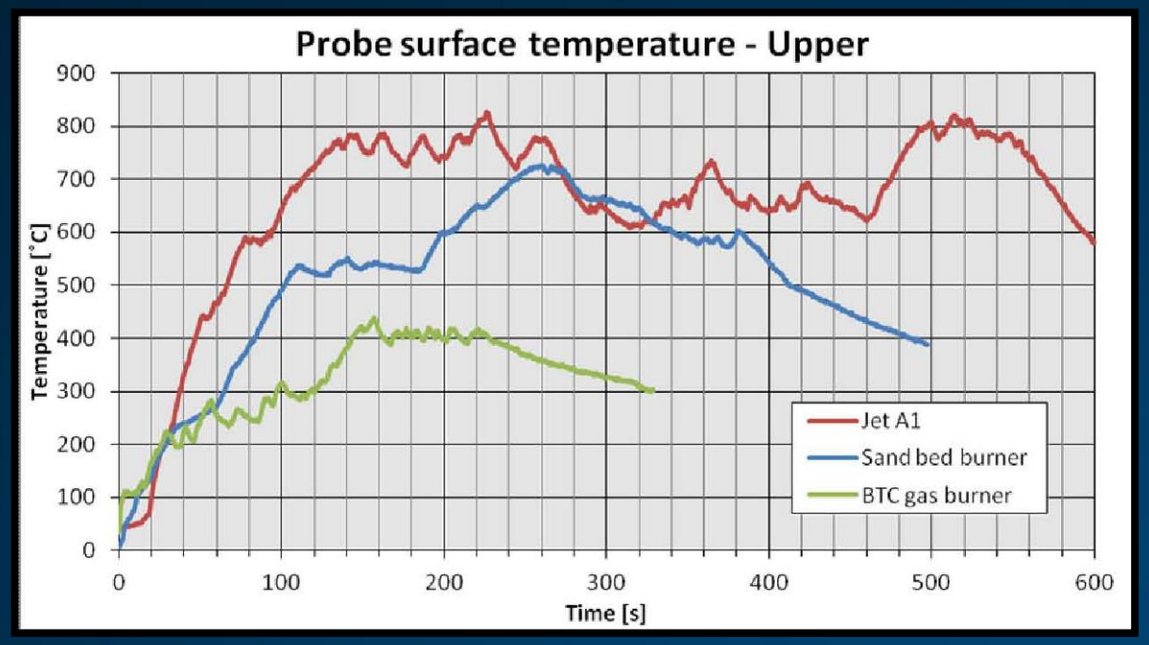
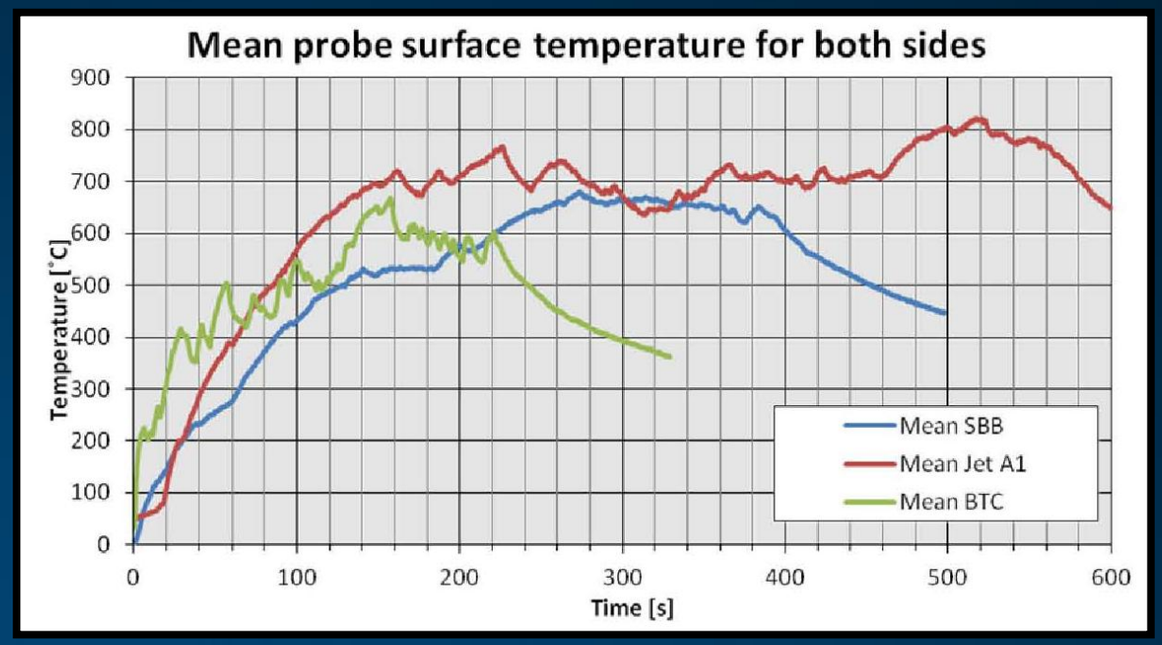
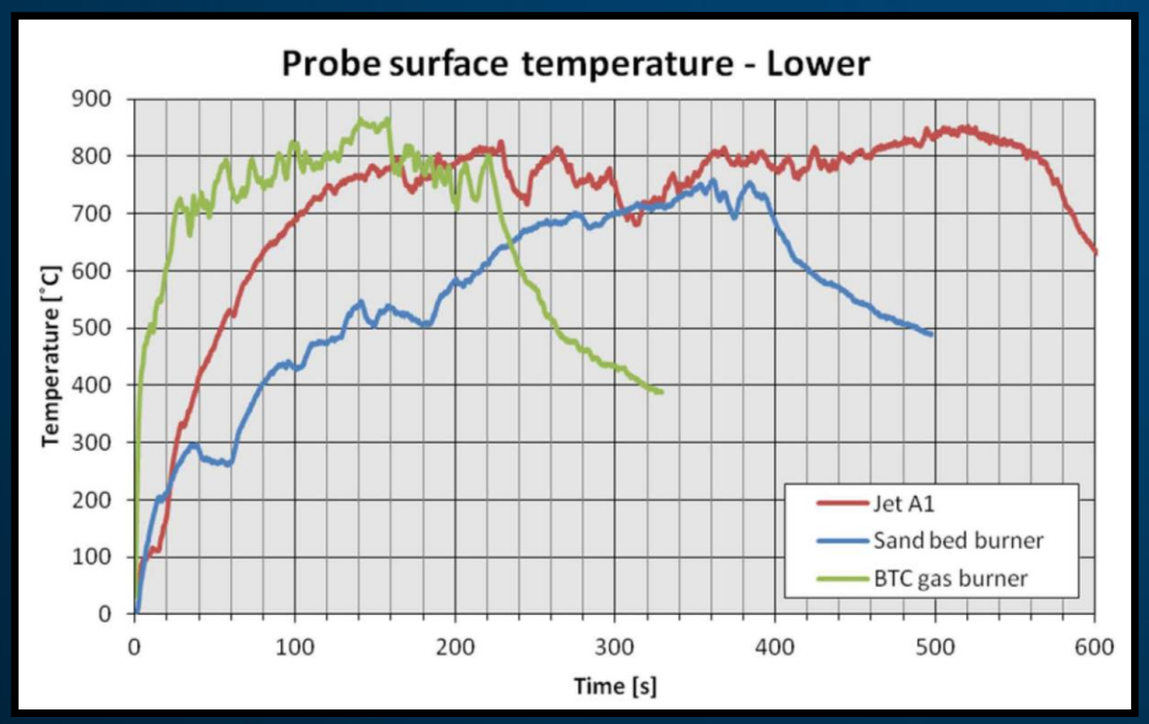
ADIABATIC SURFACES TEMPERATURES



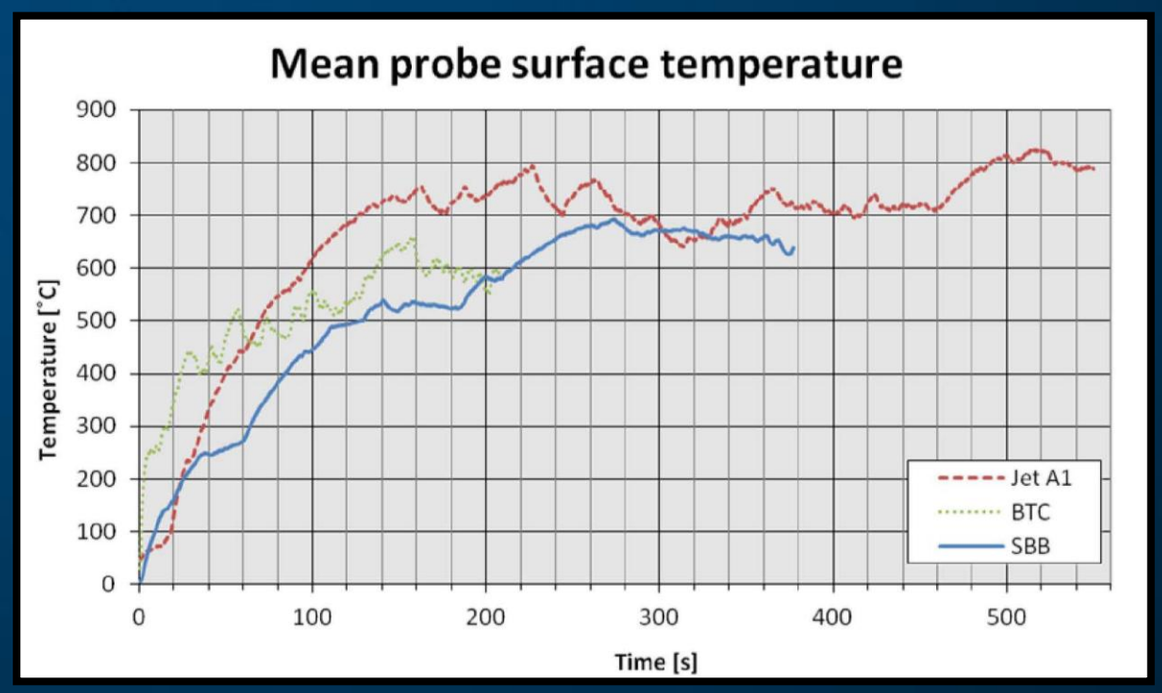
Upper point



Side points



Lower point



All points

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INCIDENT RADIATION

$$\dot{q}''_{inc} = \sigma T_{AST}^4 - \frac{h_c}{\varepsilon}\left(T_g - T_{AST}\right)$$

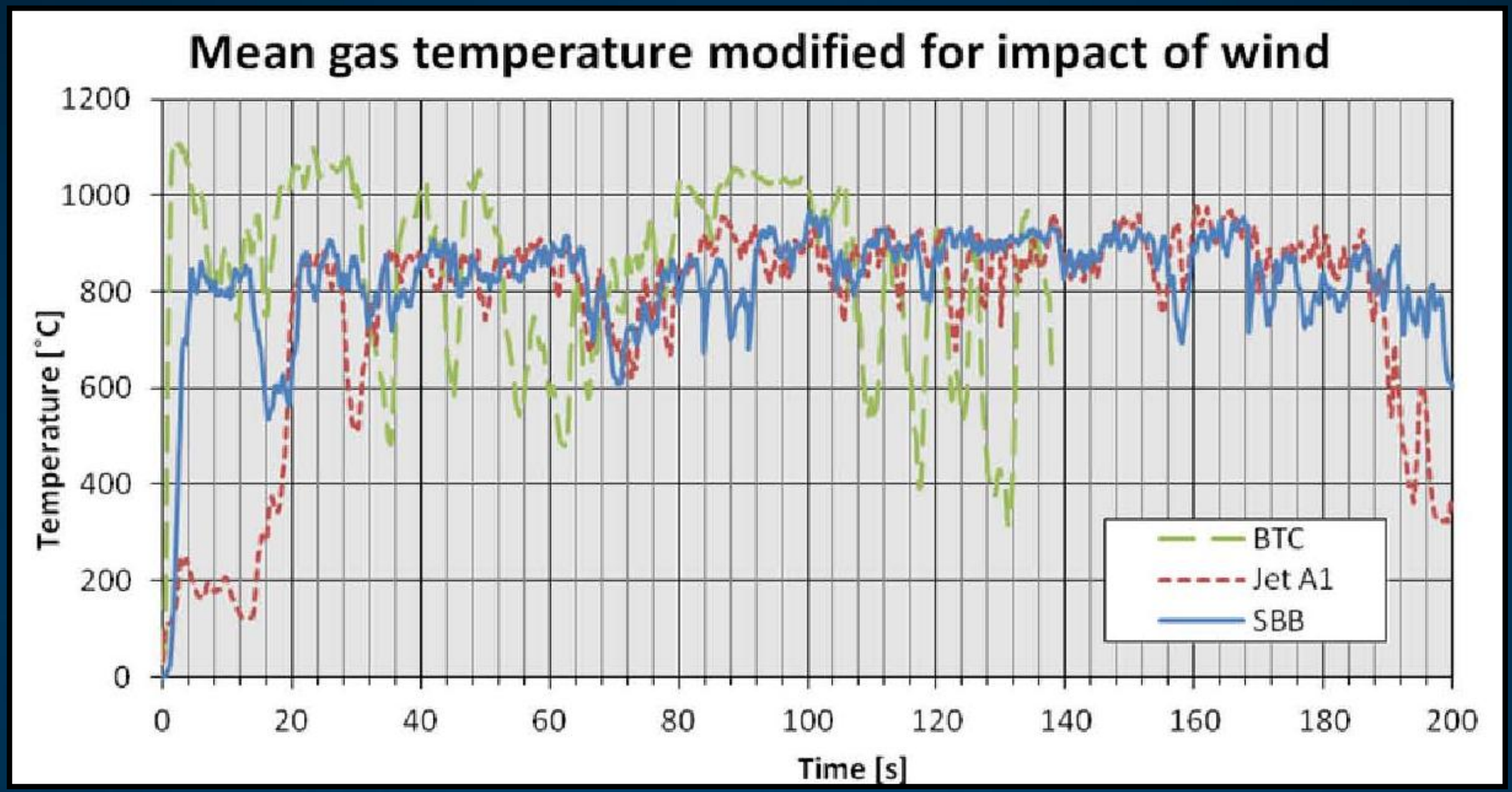
Sand Bed Burner

$$\dot{q}''_{inc} = \sigma T_{AST}^4 - \frac{h_c}{\varepsilon}\left(T_g - T_{AST}\right) = 5.67 \cdot 10^{-8} \cdot 943^4 - \frac{18.0}{0.9}\left(983 - 943\right) = 44036 W/m^2$$

Small Scale Test, Jet A-1

$$\dot{q}''_{inc} = \sigma T_{AST}^4 - \frac{h_c}{\varepsilon}\left(T_g - T_{AST}\right) = 5.67 \cdot 10^{-8} \cdot 988^4 - \frac{17.8}{0.9}\left(923 - 988\right) = 55315 W/m^2$$

WIND



One of the most important things to consider!

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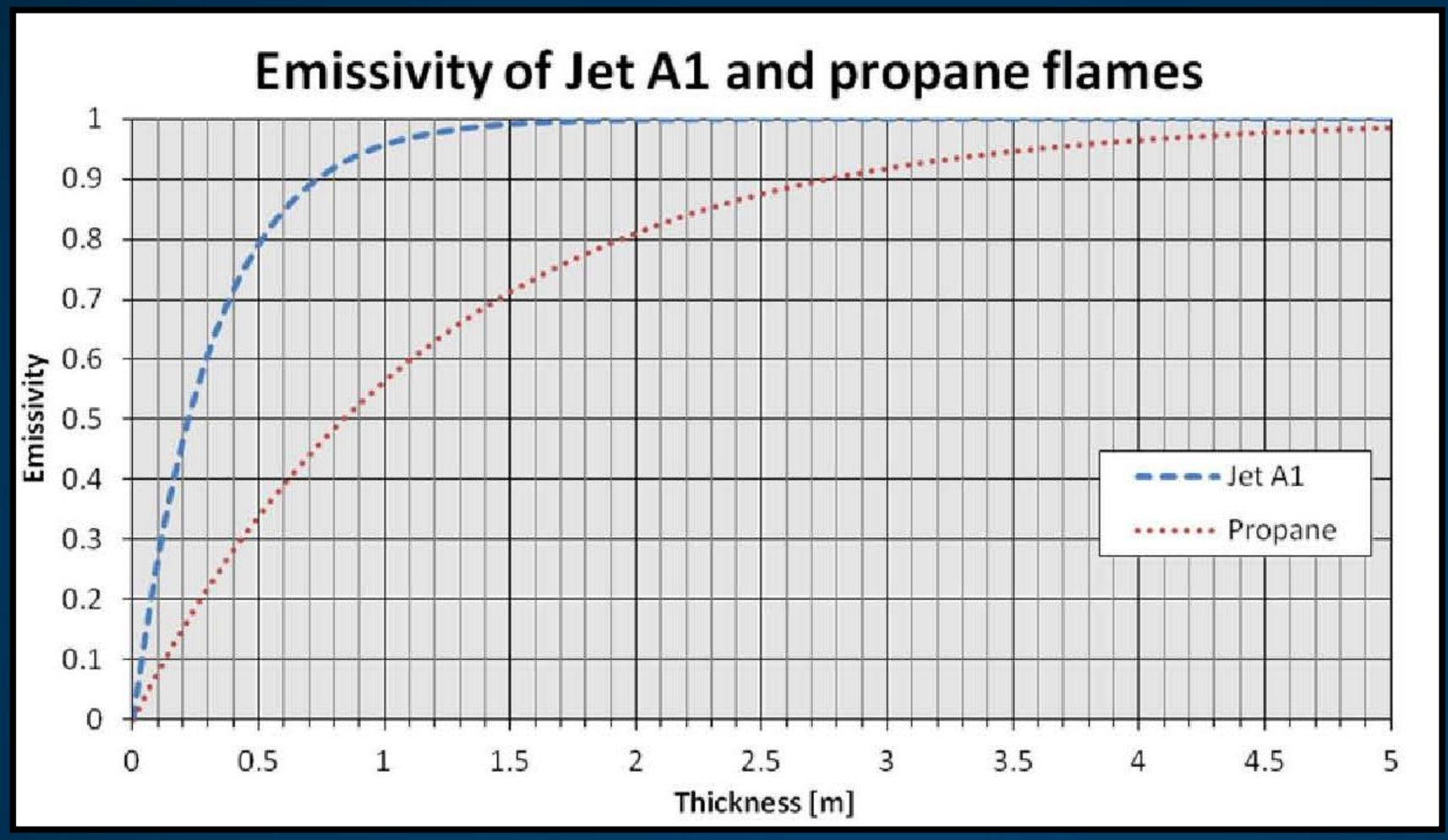
HOW TO IMPROVE THE SAND BED BURNER

Make it bigger!



A larger fire will result in higher flame emissivity and thereby higher radiation

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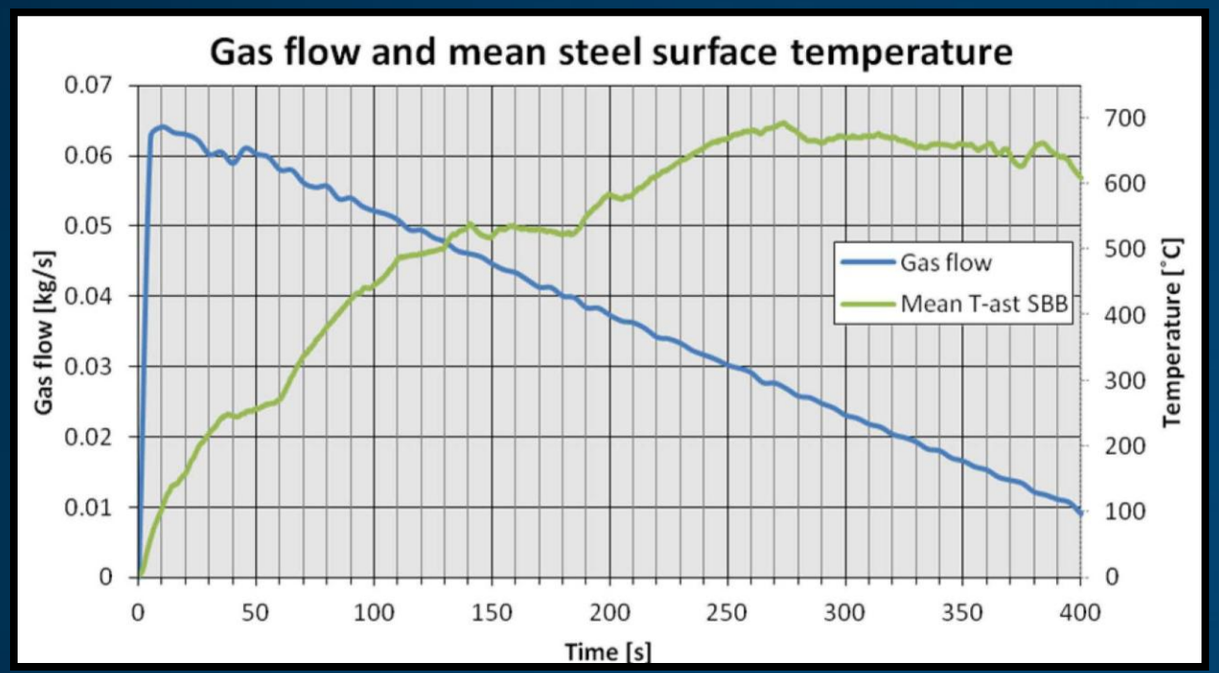
HOW TO IMPROVE THE SAND BED BURNER

Get a better gas flow! Needs to be constant.

Required flow of propane: 0.044 kg/s
Mean gas flow: approx. 0.038 kg/s



Preheat the LPG using an evaporator to prevent freezing inside of the tubes

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HOW TO IMPROVE THE SAND BED BURNER

Solve the problems with the area were no combustion occurred!

The amount of gas?

Gas not distributed uniformly?

Uneven gas flow?

The sand fraction?

Top priority to solve this problem!

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CONCLUSIONS

THE SAND BED BURNER:

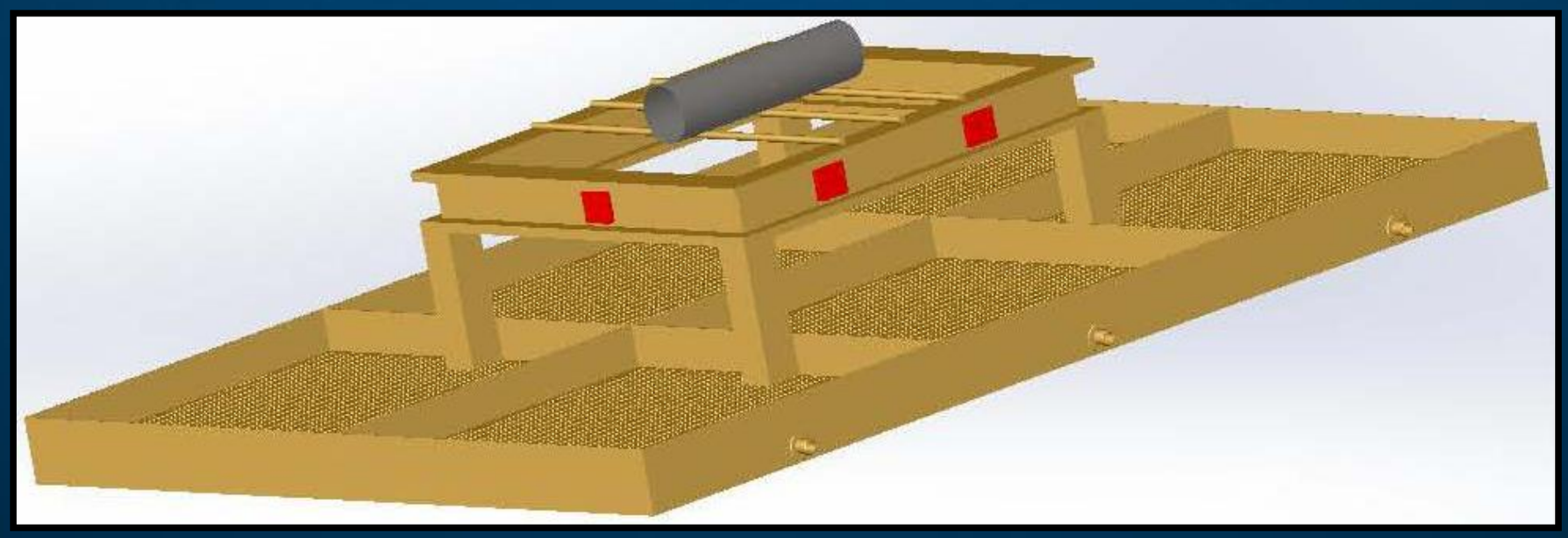
- Some children’s diseases needs to be solved
- Gives a more uniform heating than conventional LPG systems
- Will deliver roughly the same heating in every test (if the wind conditions are the same and gas flow is constant)
- Is a very cost efficient solution
- Is easy to manufacture and handle
- ***Could definitely be a future alternative to liquid hydrocarbon fuel***

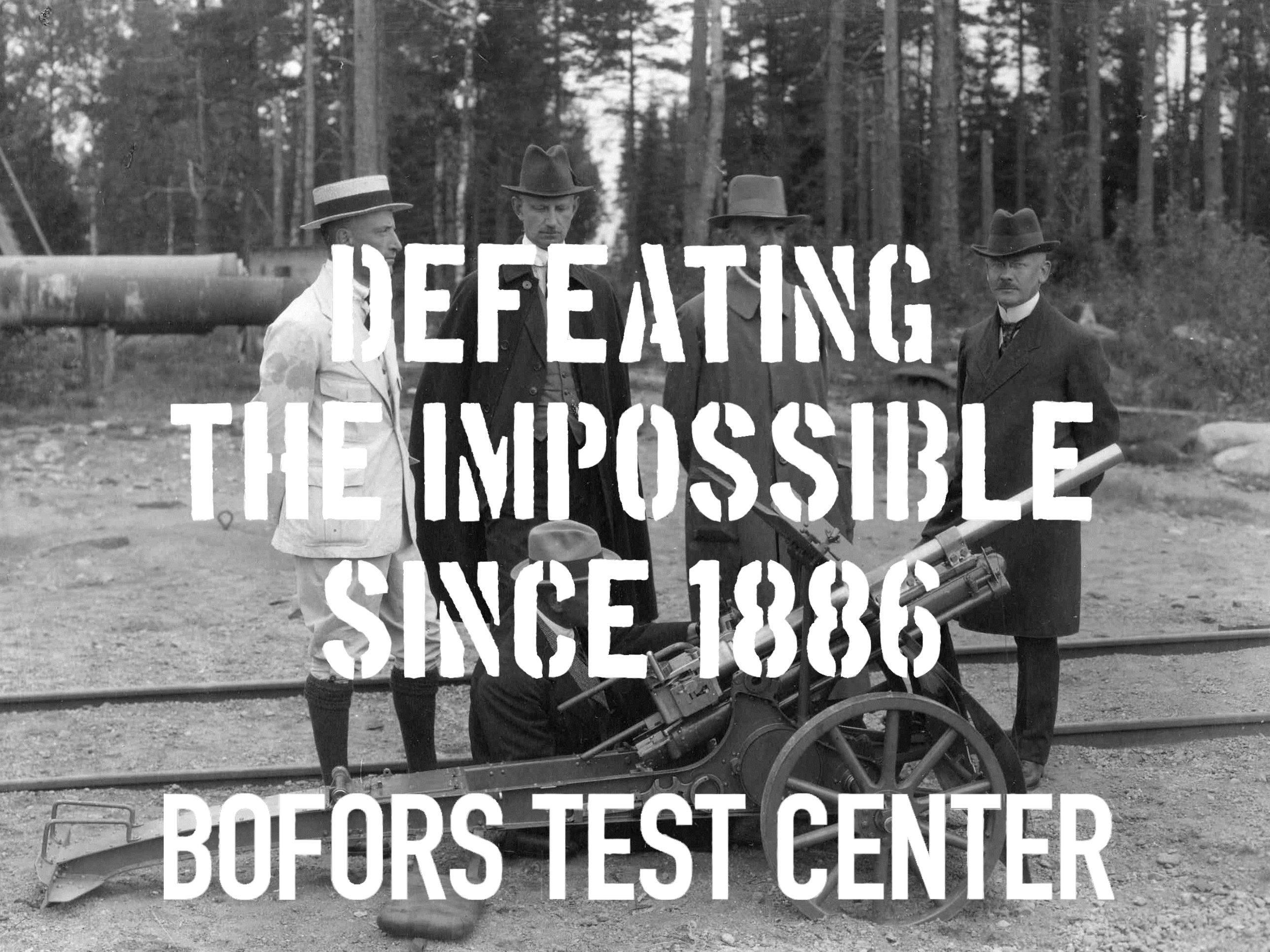
THE ADIABATIC SURFACE TEMPERATURE PROBE:

- Should not be used in live tests
- Measure influences of heat, both T_g and T_{AST}, from different directions
- Gives input data for a lot of further analyses
- The incident heat flux can easily be calculated
- Can be manufactured to simulate all kinds of test objects

PROPSED NEW TEST METHOD

- Perform a calibration test with the Adiabatic Surface Temperature Probe prior to the live test in order to calibrate the gas flow required
- Use that gas flow in the live test
- In both tests (calibration and live); include a number of Plate Thermometers and Thermocouples placed at the same positions
- If required; use the Adiabatic Surface Temperature Probe data from the calibration test to calculate the incident heat flux





DEFEATING THE IMPOSSIBLE SINCE 1886

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