2002

EVALUATION OF HEAT TRANSFER COEFFICIENTS WITH THERMOCAMERA

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Aim:

Determine heat transfer coefficients

for use in cooling calculations

to verify and improve the cooling effectiveness

$$a = \frac{q}{T_{\mathrm{surface}} - T_{\mathrm{coolingflow}}} \quad [\mathrm{W/m^2K}]$$

$$Nu = \frac{a \cdot l}{l}$$

INTRODUCTION

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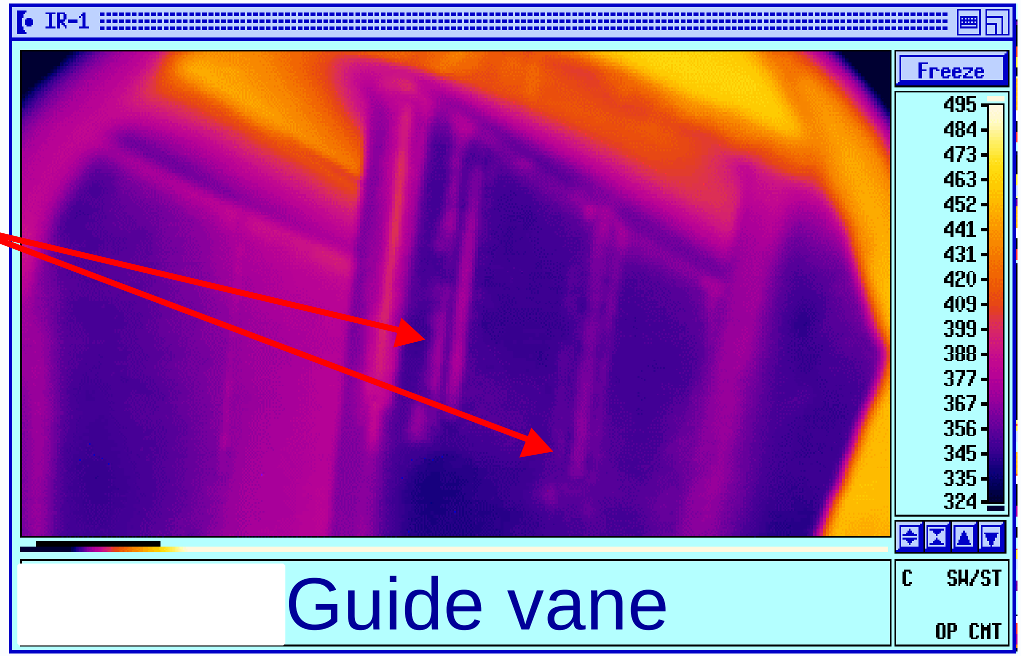
- The technique has been used since 1997 at ALSTOM Power to investigate heat transfer coefficients for tests at near engine conditions (500 - 700 deg C) and with engine parts
- More recently been used in scaled perspex models at room temperature

Temperature mapped with a thermocamera

Thermocouple



THERMOCAMERA

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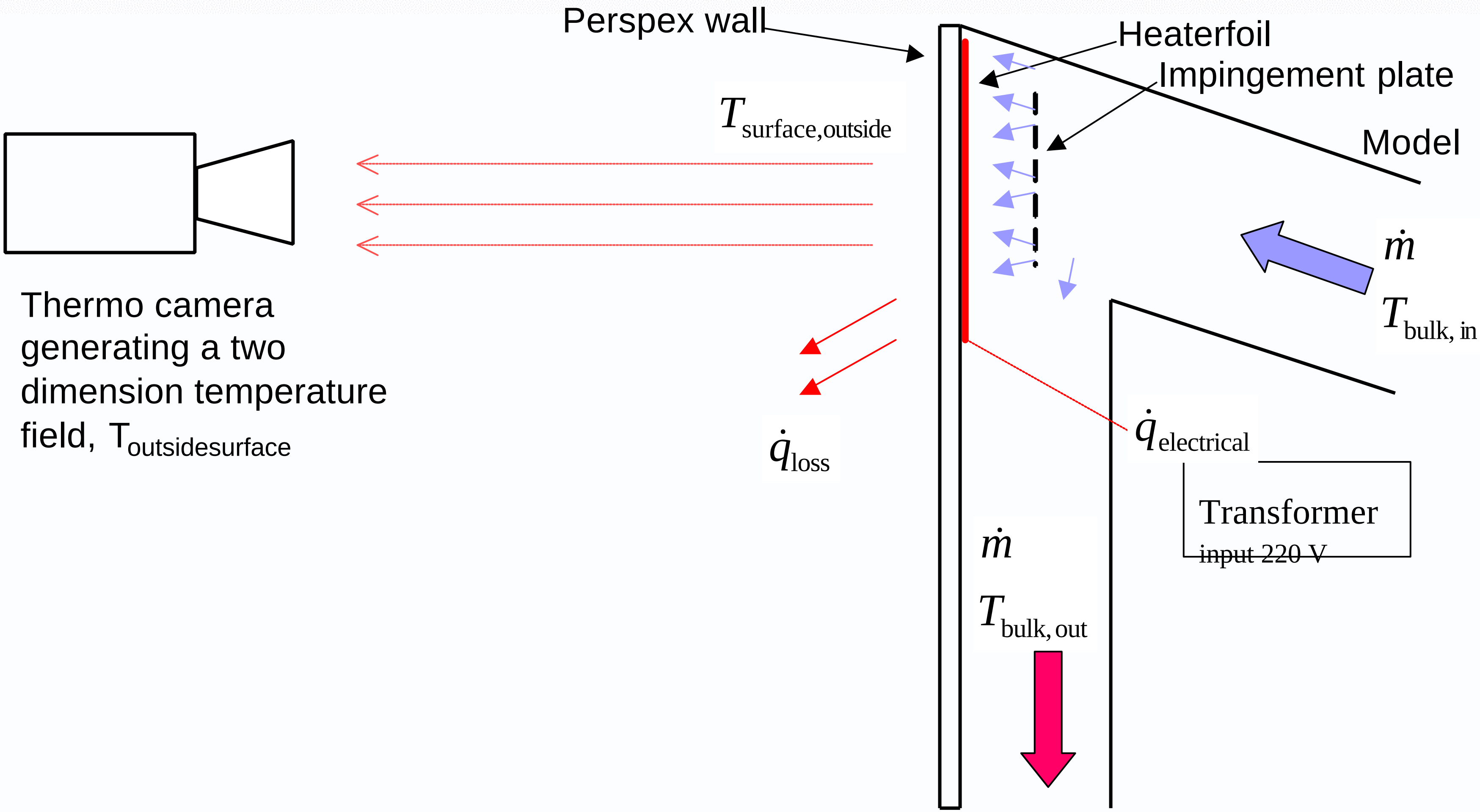
Thermovision 900 system
AGEMA 900SW/ST

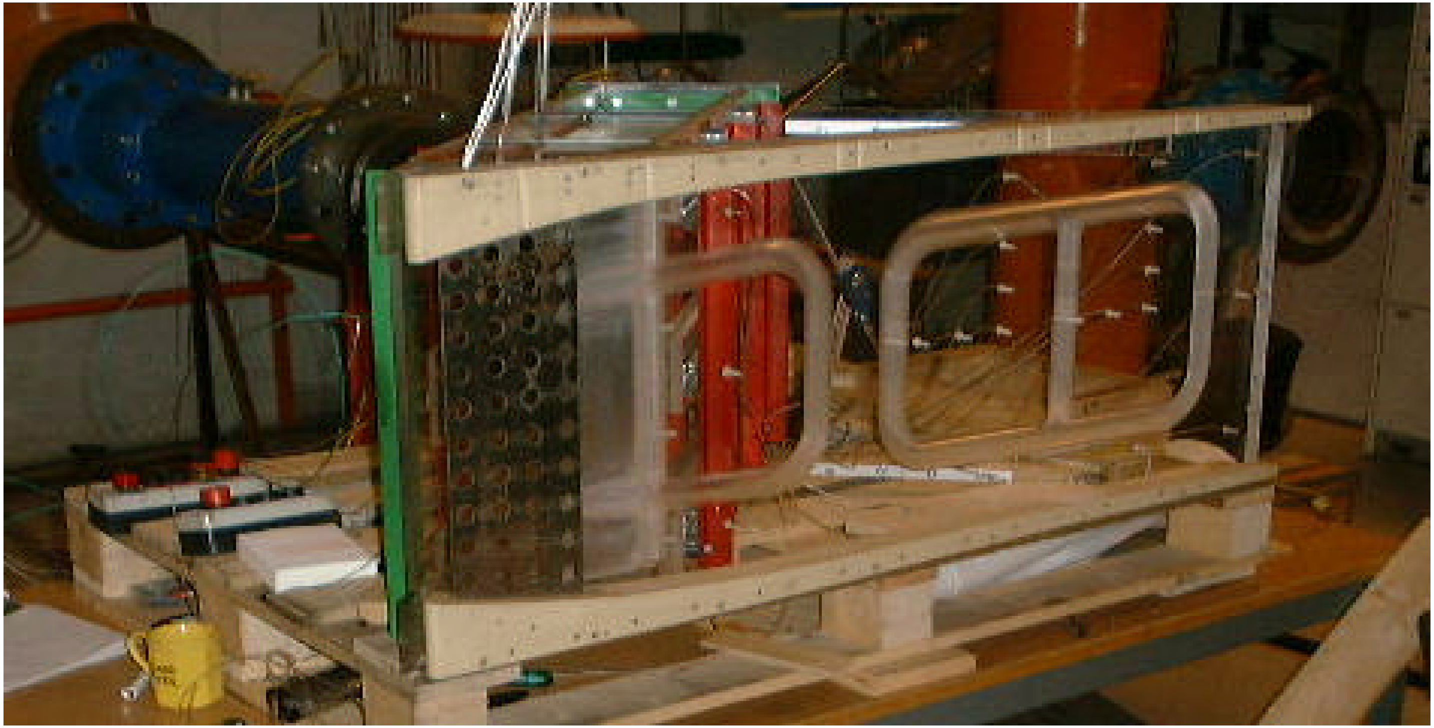
Spectral response

2.0 – 5.6 micron

SCHEMATIC DESCRIPTION

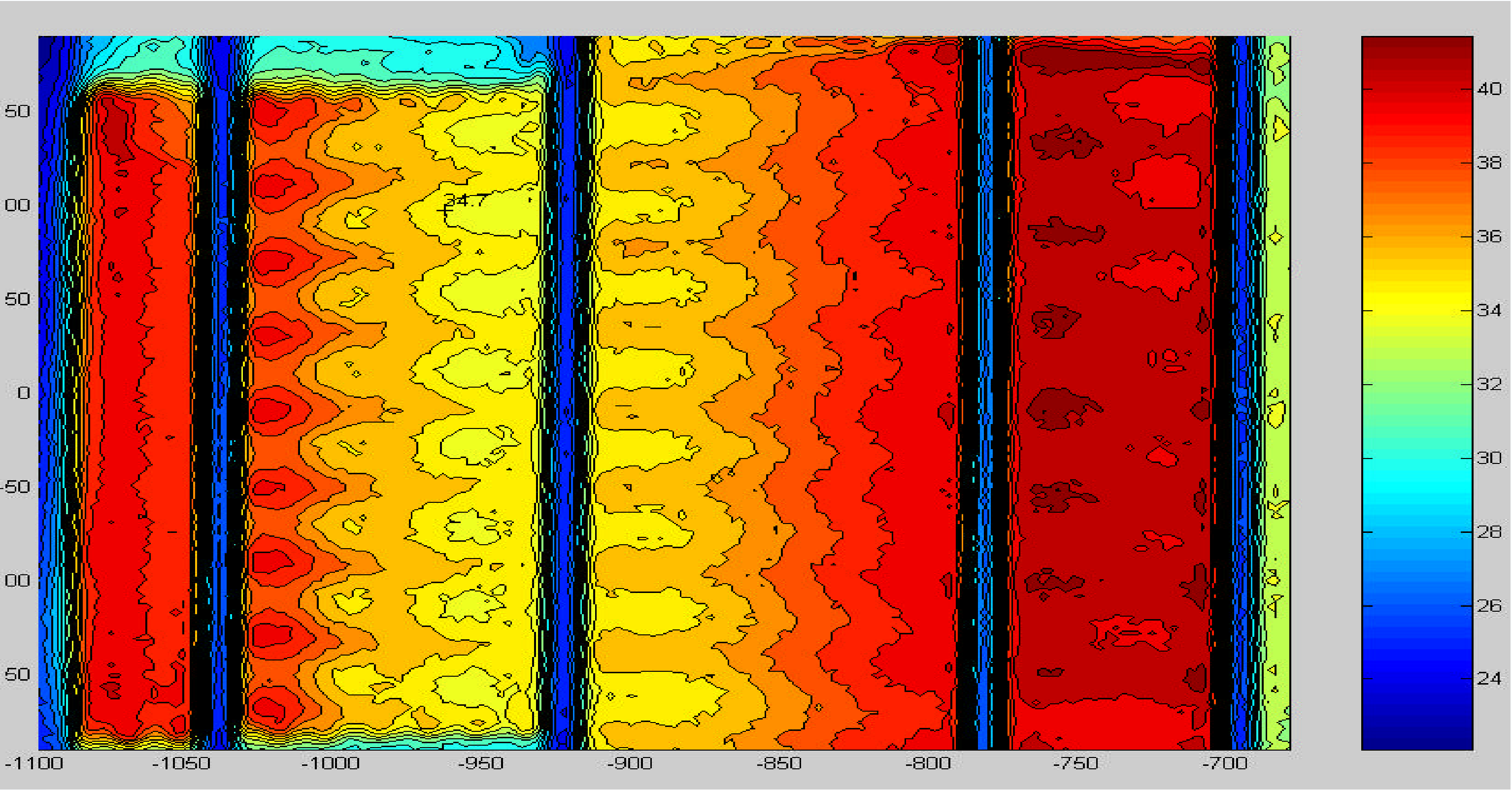


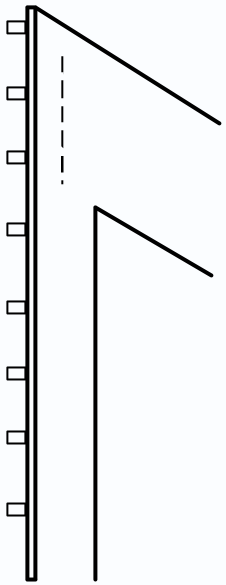
BURNER CHAMBER LINER



No heaterplate mounted

Thermo camera field



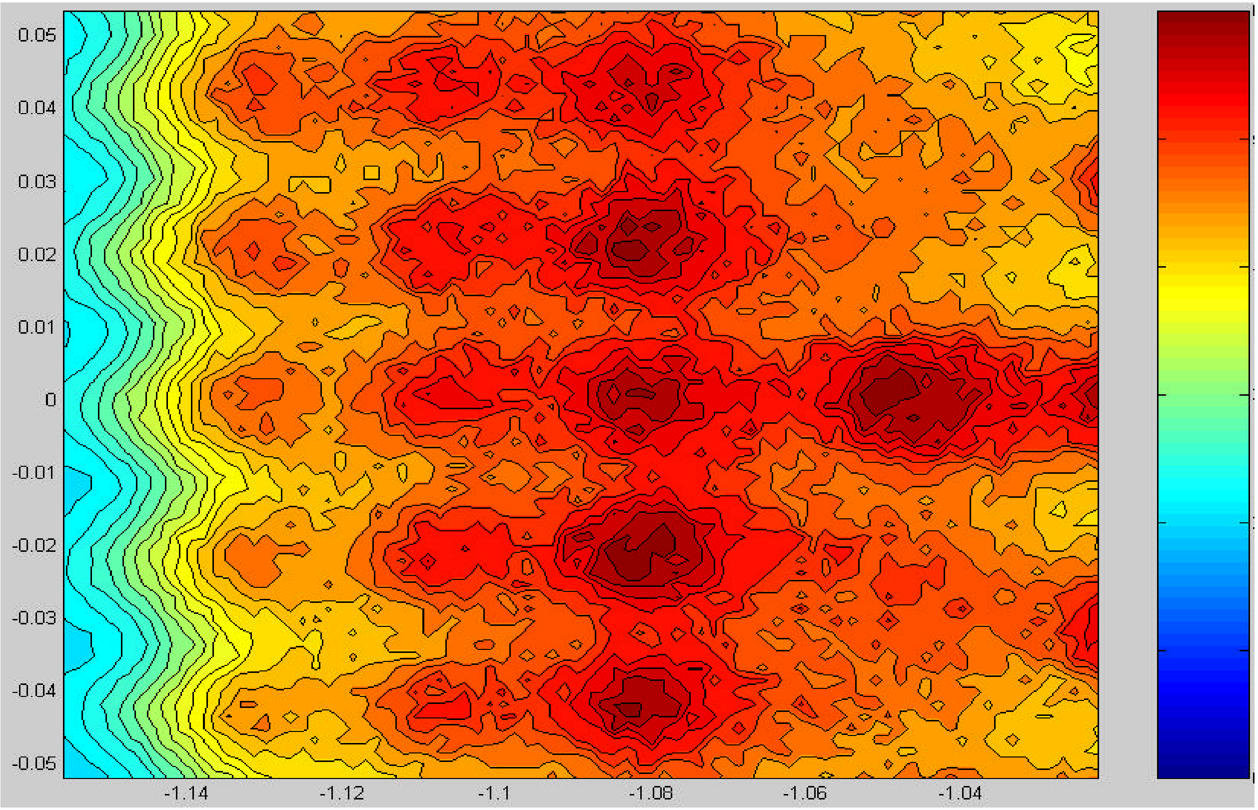


Resolution 10º x 5º at min, 1 m (176 x 87 mm)

Number of pixels 200 x 136

(this field ~400 x ~300 mm, 200 x 136 pixels)

Thermo camera field



A piece of the impingement cooled, Alfa number

REFERENCE TEMPERATURE

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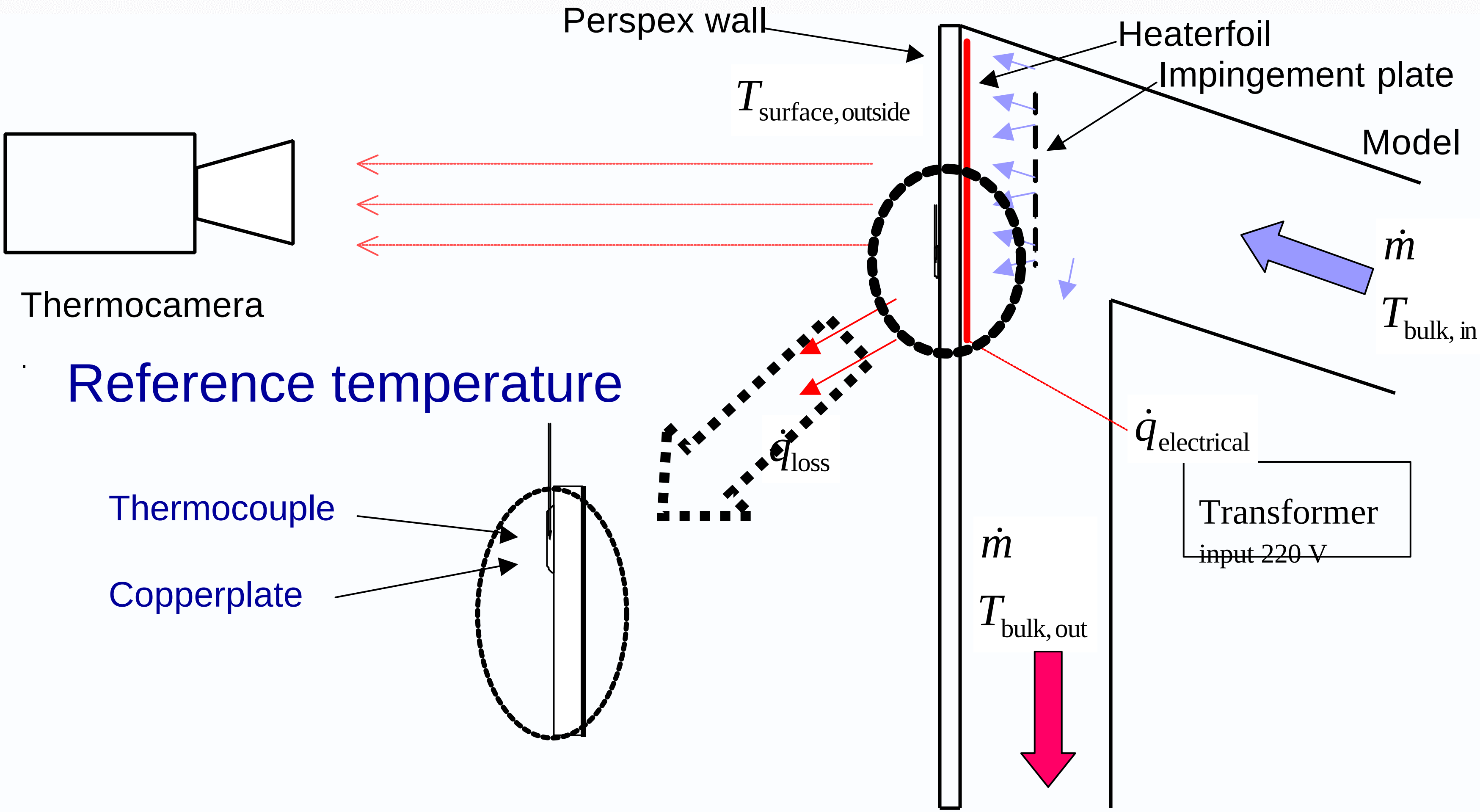


Geometric and dynamic scaling

$$n = \frac{l_{\text{model}}}{l_{\text{engine}}}$$

$$\text{Re} = \frac{\dot{m}\, l_c}{m\, A}$$

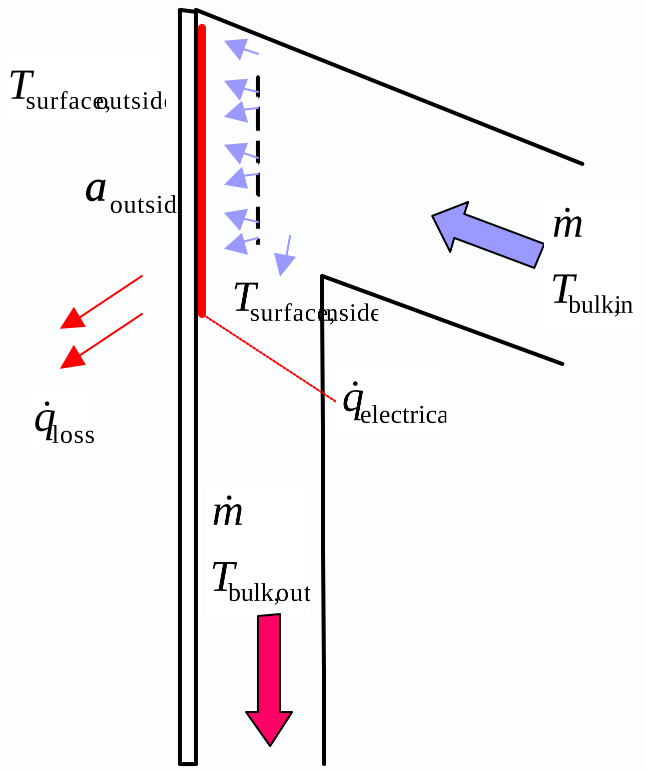
Equations for heat transfer

$$a_{\text{inside}} = \frac{q_{\text{absorbed by bulk}}}{T_{\text{surface, inside}} - T_{\text{bulk}}}$$

$$Nu_{\text{surface,inside}} = \frac{a_{\text{surface,inside}} \cdot l_{\text{c}}}{l_{\text{bulk}}}$$

$$q_{\text{absorbed by bulk}} = q_{\text{electrical}} - q_{\text{loss}}$$

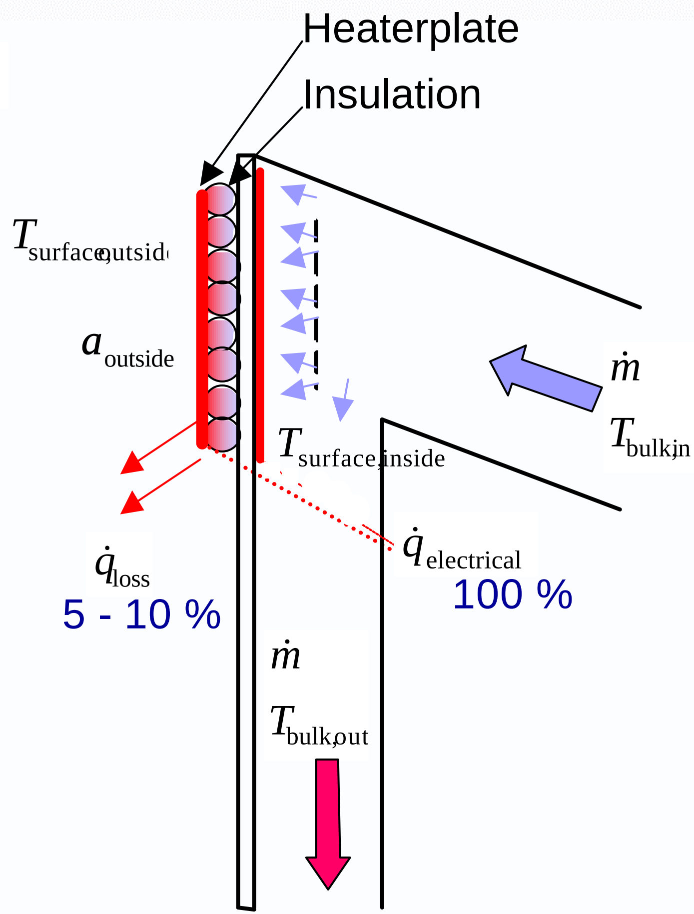
(local values, pixel by pixel)



Losses to ambient

$$q_{\text{loss}} = a_{\text{outside}} \cdot \left(T_{\text{surface,outside}} - T_{\text{ambient}} \right)$$

$$a_{\text{outside}} = \frac{q_{\text{electric}}}{T_{\text{surface,outside}} - T_{\text{ambient}}}$$



(local values, pixel by pixel)

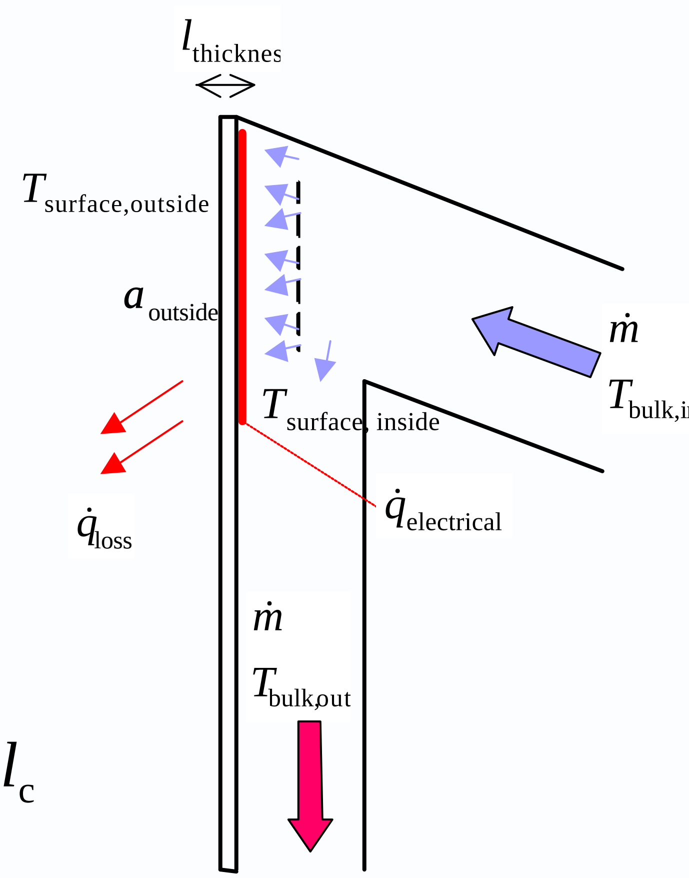
Final evaluation

$$T_{\text{surface,inside}} = T_{\text{surface,outside}} + \frac{q_{\text{loss}}\, l_{\text{thickness}}}{l_{\text{perspex plate}}}$$

$$\boxed{a_{\text{inside}} = \frac{q_{\text{absorbed by bulk}}}{T_{\text{surface,inside}} - T_{\text{bulk}}}}$$

$$Nu = \frac{\left(q_{\text{el}} - a_{\text{outside}} \cdot \left(T_{\text{surface,outside}} - T_{\text{ambient}}\right)\right)}{\left(T_{\text{surface,inside}} - T_{\text{bulk}}\right) \cdot l_{\text{bulk}}} \cdot l_{c}$$

(local values, pixel by pixel)



THEORETIC DESCRIPTION

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One remark

If there are large temperature fluctuations over the heater area the power is not uniform distributed

One example

Nickel-iron foil

40 ^{o}C	1.193 ohm
60 ^{o}C	1.297 ohm

ACCURACY

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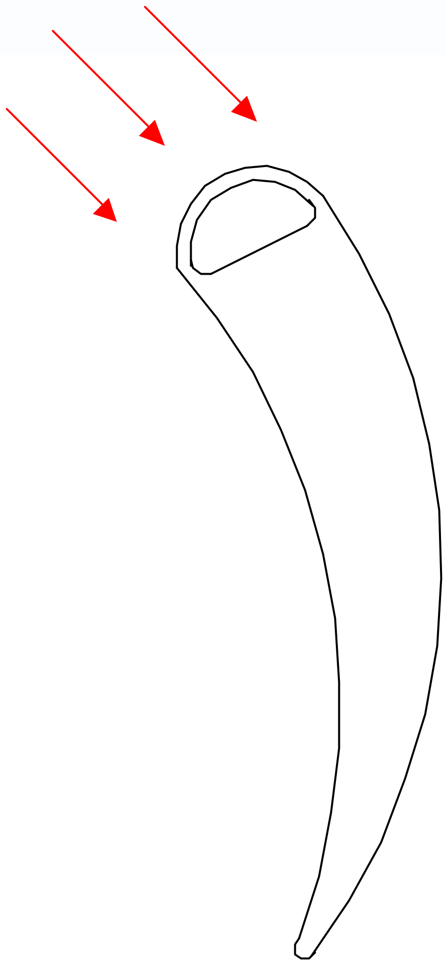
For the first example the inaccuracy is estimated to be below 5 %

The temperature measurements have most impact:

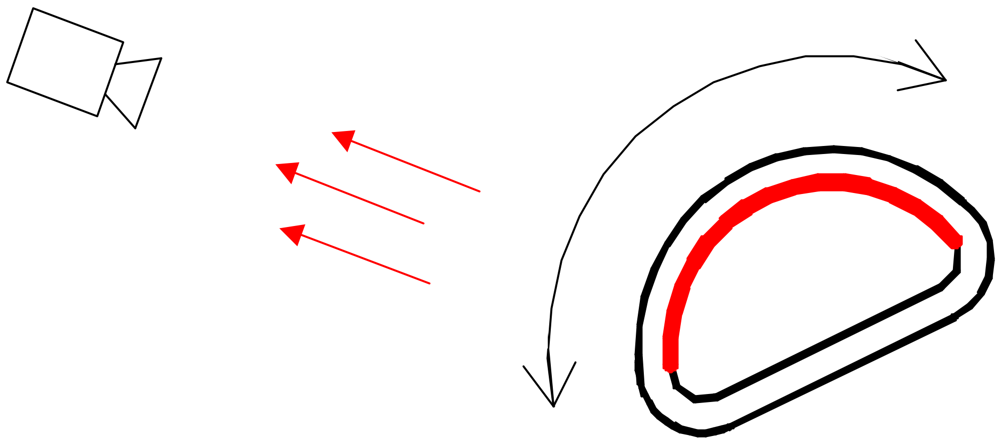
$$\left|\frac{\Delta(\overline{T}_{\text{surface,inside}} - T_{\text{bulk}})}{\overline{T}_{\text{surface,inside}} - T_{\text{bulk}}}\right| \qquad \frac{1}{45-25} = 5\,\% \qquad \frac{1}{50-10} = 2{,}5\,\%$$

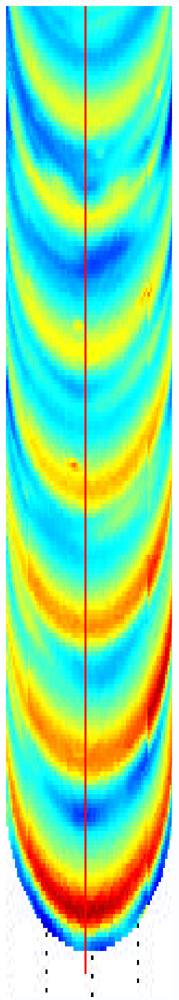
AVERAGE VALUES

TURBINE BLADE INTERNAL COOLING



TURBINE BLADE INTERNAL COOLING





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