Stave 2R Thermal Shock Test

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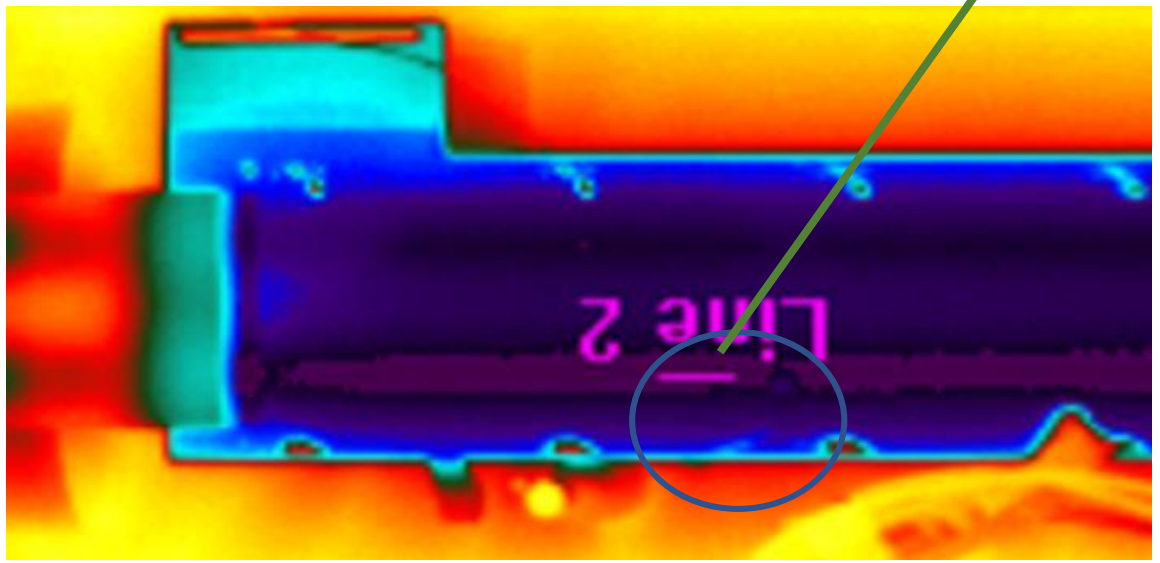
Stave 2R thermal shock 10 Cycles

Test Configurations:

- Chiller Set T -60C, Bypass wait time 10mins, shock time 10mins (10/01)
- -60C, 15mins, 8mins (09/28)
- -55C, 15mins, 10mins (09/27)
- -55C, 10mins, 5mins (09/26)
- Thermocouple taped on stave surface, close to inlet pipe (10/01)



Avg T on line 2 for comparison with thermocouple reading

IR image basic

From FLIR camera user manual: total power received by camera is

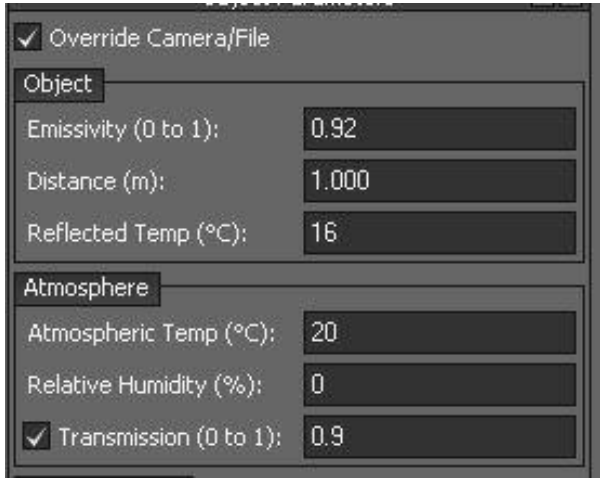
$$W_{tot} = \varepsilon \cdot \tau \cdot W_{obj} + (1 - \varepsilon) \cdot \tau \cdot W_{amb} + (1 - \tau) \cdot W_{atm}$$

Emission from the object $= \varepsilon \cdot \tau \cdot W_{obj}$, where ε is the emissivity of the object and τ is the transmittance of the atmosphere.

Emission from the atmosphere $= (1 - \tau) \cdot W_{atm}$, where $(1 - \tau)$ is the emissivity of the atmosphere.

Reflected emission from ambient sources $= (1 - \varepsilon) \cdot \tau \cdot W_{amb}$, where $(1 - \varepsilon)$ is the reflectance of the object. (It is assumed that the temperature T_{amb} is the same for all emitting surfaces within the half sphere seen from a point on the object's surface.)

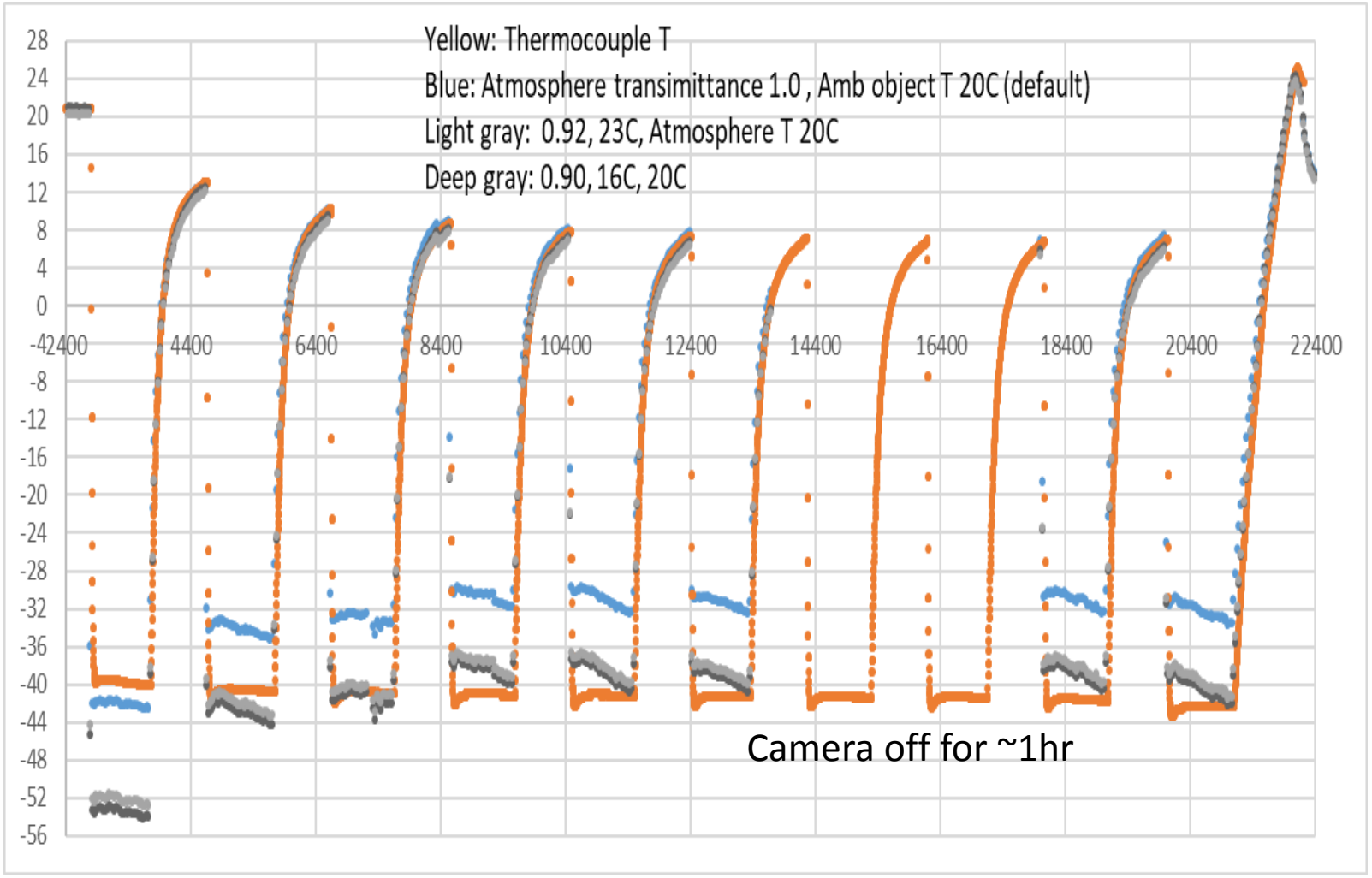
From the equation, the atmosphere transmittance τ has a large impact on measurement accuracy, τ depends heavily on radiation wavelength.



Adjustable parameters in Research IR software: Reflected object T, Atmosphere T, object-camera distance, atmosphere transmission

Thermocouple/ IR camera reading comparison

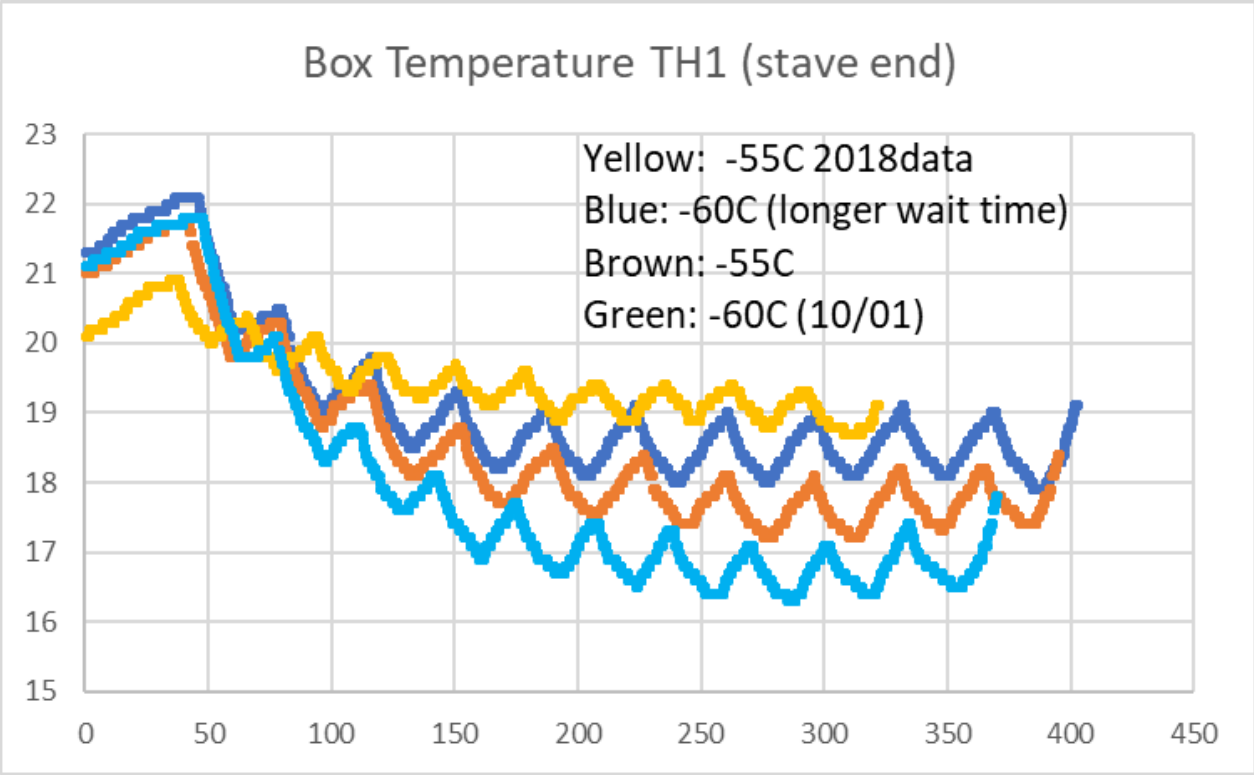
- Averaged T of Line 2 is compared with thermocouple T
- IR camera temperature with different configuration values
- Amb T , Reflect T increase -> surface T decrease; transmission decrease -> surface T decrease



Possible reason:

1. Camera was calibrated 3 years ago, recommend calibrate annually
2. Atmosphere T close to stave decreases -> density increases-> lower transmission
3. Different object reflection T, box, cable
4. Camera preload calibration range -40 - 150C
5. Sensor overheating (unlikely)

Box atmosphere temperature



Minkina W. Modeling of Atmospheric Transmission Coefficient in Infrared for Thermovision Measurements

The user`s manual of AGEMA 880 LW and AGEMA 470 Pro SW gives simplified formula that describes the atmospheric transmission in infrared, using the LOWTRAN model [2]:

$$P_{atm}(d) = exp\left[-\alpha \cdot \left(\sqrt{d} - \sqrt{d_{cal}}\right) - \beta \cdot (d - d_{cal})\right] \quad (1)$$

where: P_{atm} - atmospheric transmission; d, m - camera – object distance; d_{cal}, m - camera-object distance (in calibration process – the value of 1 m); α, β - coefficients specified for normal conditions: atmospheric

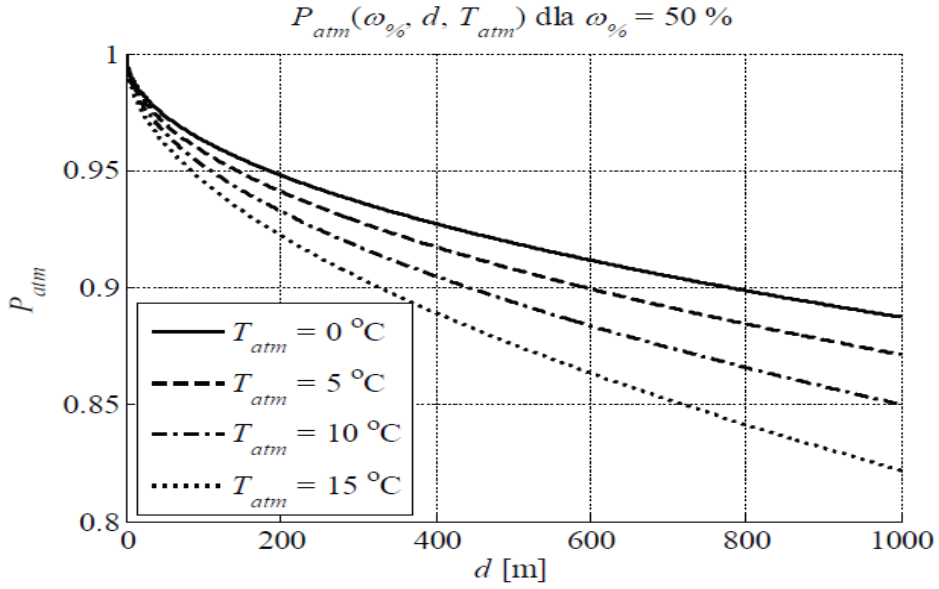
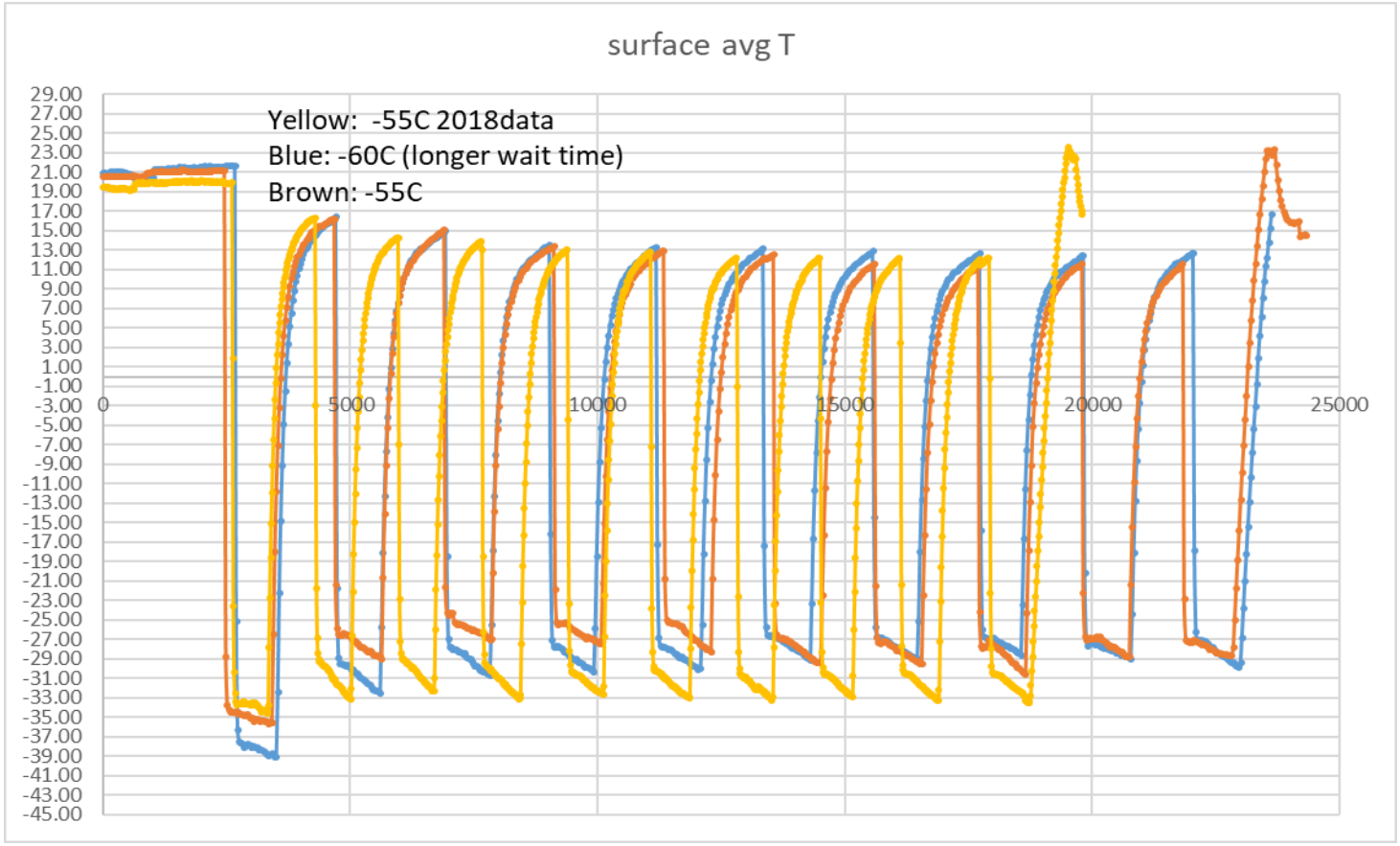


Fig. 3 Characteristics of atmospheric transmission coefficient $P_{atm}=f(d)$ for long way band LW ThermaCAM PM 595 camera as a function of the temperature of the atmosphere T_{atm}.

Back up: compare with June 2018 data

Stave surface average T



For June 2018 data, the temperate rising with cycle times is not significant

Back up: compare with June 2018 data