UiT

THE ARCTIC
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Cold Technology Applications of Infrared Thermography (IRT)

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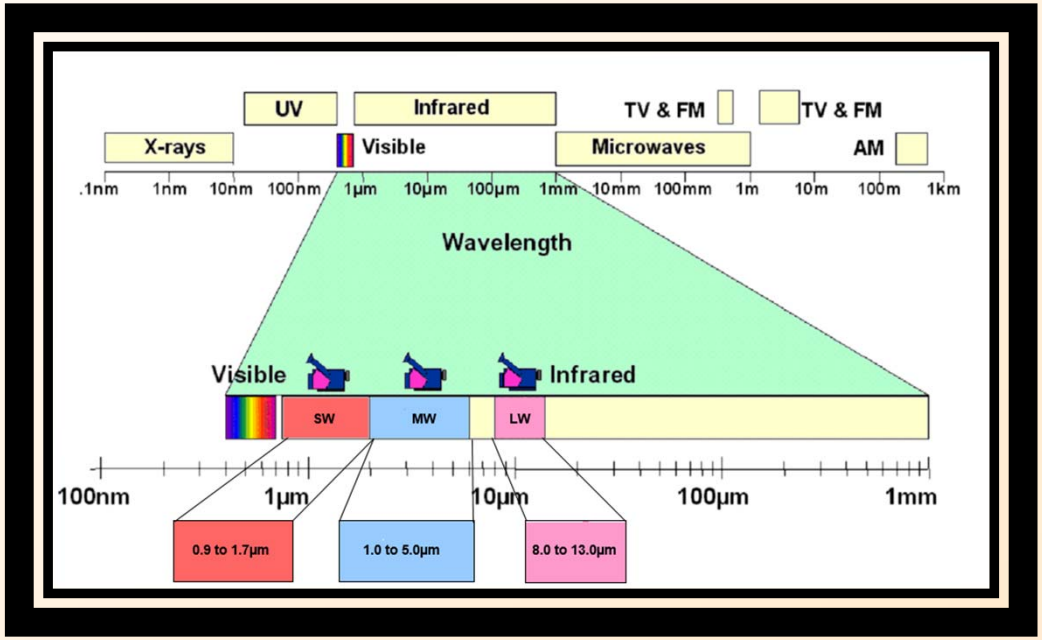
Infrared Themography

- Infrared Thermography Cameras
  - Shortwave Infrared Camera (SW)
  - Midwave Infrared Camera (MW)
  - Longwave Infrared Camera (LW)



Infrared Camera

- FLIR® T1030sc Camera Specifications
  - 1024 X 768 Thermal Pixels
  - High Speed Interface (30Hz, 120Hz, 480Hz)
  - NETD <20mK
  - LW Spectral Range (7.5 -14 micrometer)
  - Uncooled Microbolometer Detector
  - Cost: Around 50,000 USD

Working Principle

- Plank's Law

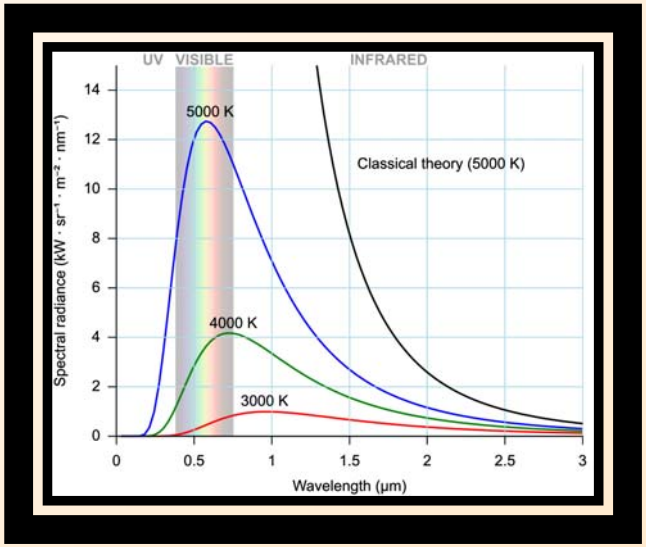
$$B_\lambda(Watt.sr^{-1}.m^{-3}) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda k_B T}}-1}$$

- Wien's Law (Differentiating Plank's Law)

$$\lambda_{max}(\mu m) = \frac{2898}{T}$$

- Stefan Boltzmann's Law (Integrating Plank's Law)

$$W(Watt.m^{-2}) = \epsilon\sigma T^4$$



Working Principle Cont.

- Infrared Radiation Sources (Absorbtion/Emittance, Reflection, & Transmission)

$$\alpha_\lambda + \varphi_\lambda + \tau_\lambda = 1 \quad \text{OR} \quad \varepsilon_\lambda + \varphi_\lambda + \tau_\lambda = 1$$

- Black Body (only theoretical)

$$\alpha_\lambda = \varepsilon_\lambda \quad \text{OR} \quad \epsilon_\lambda = 1$$

- Gray Body (only theoretical)

$$\epsilon_\lambda = \alpha_\lambda = constant$$

- White Body (only theoretical)

$$\varphi_\lambda = 1$$

- Real Body

$$0 < \epsilon_\lambda/\alpha_\lambda < 1 \quad \text{AND} \quad 0 < \varphi_\lambda < 1 \quad \text{AND} \quad 0 < \tau_\lambda < 1$$

Industrial Applications & Advantages

Thermography Applications:

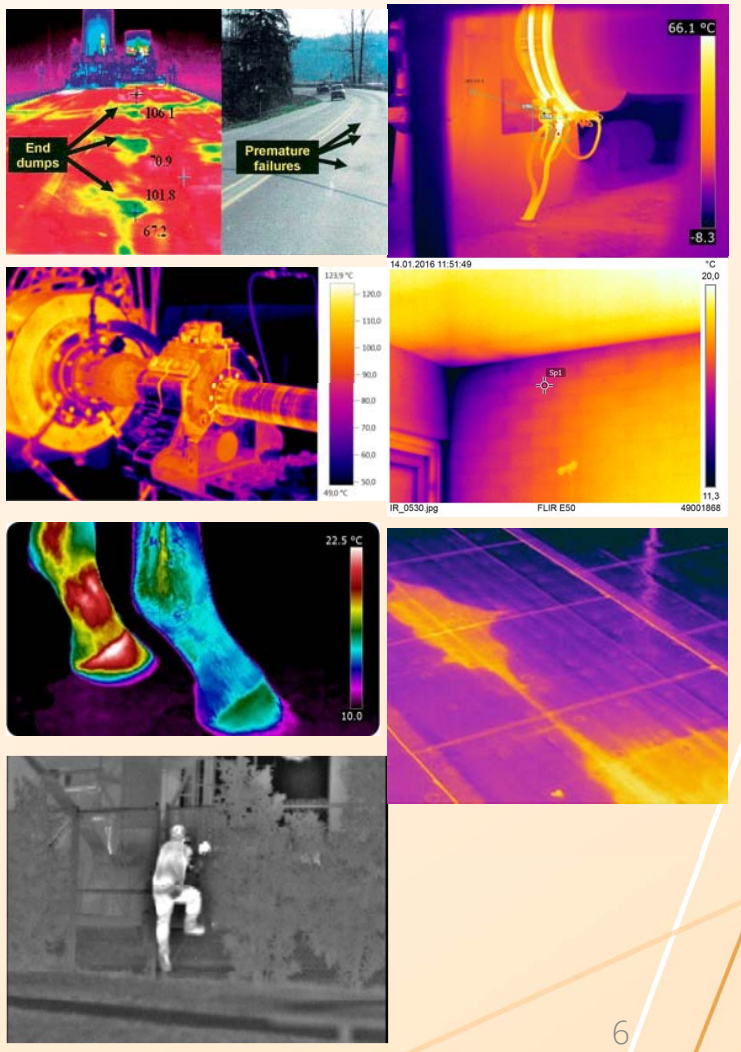
- Electrical Equipment
- Civil Structures (e.g. insulation, water leaks, etc.)
- Boilers and Steam Systems
- Engines and Power Production
- Mechanical Equipment (e.g. gears, bearing, etc.)
- Surveillance and Security
- Medical and Veterinary

Advantages:

- Non-contact
- Non-intrusive
- Pre-emptive maintainance
- Fast and detailed

Certified Thermographer (category I, II, III):

- ANSI/ASNT CP-105 and CP-189
- DIN EN ISO 9712



Application 1: Ice Thermal Conductivity

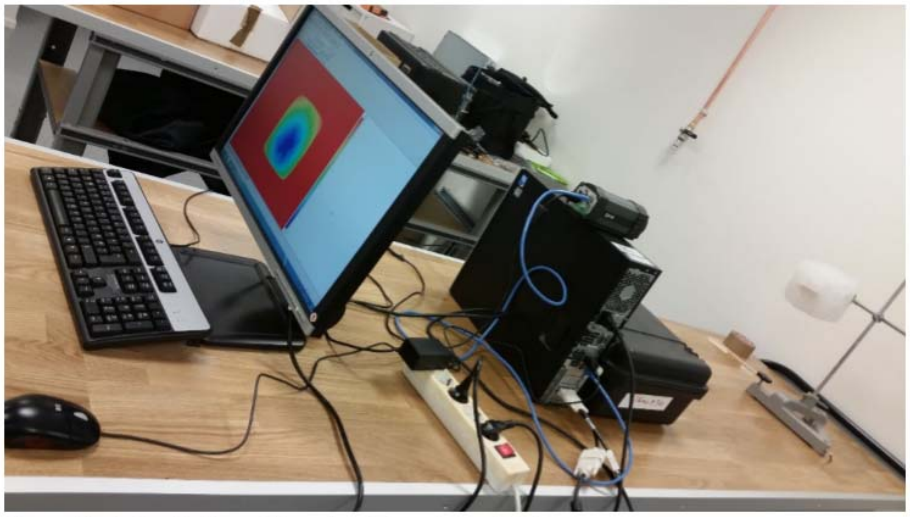


Figure 5: Actual Infrared Imaging Experiment Setup

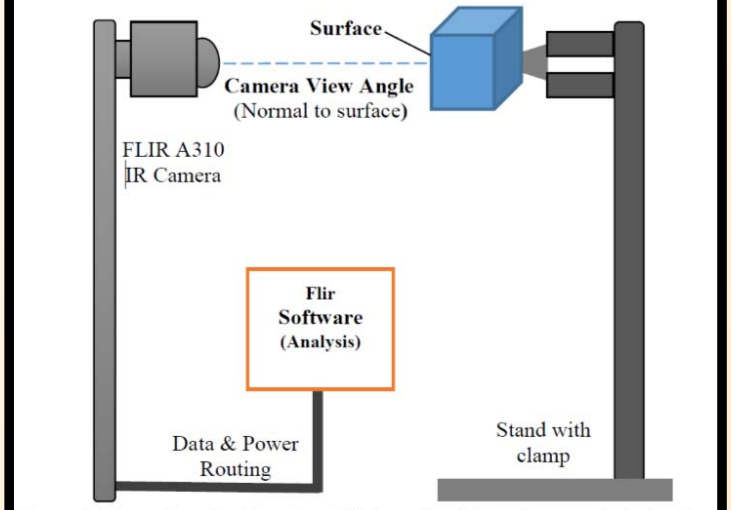


Figure 4: Infrared Imaging Experiment Schematics. Infrared camera is facing the surface of ice block [22, 23].

Application 1: Ice Thermal Conductivity Cont.

- Thermal Diffusion is governed Heat Equation

$$\frac{\partial T}{\partial t} = \frac{k}{\rho c}\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right) + \frac{\dot{q}}{\rho c}$$

- Forward Time Central Space (FTCS) Discretization using Finite Difference Method can be used to solve the above equation.

Application 1: Ice Thermal Conductivity Cont.

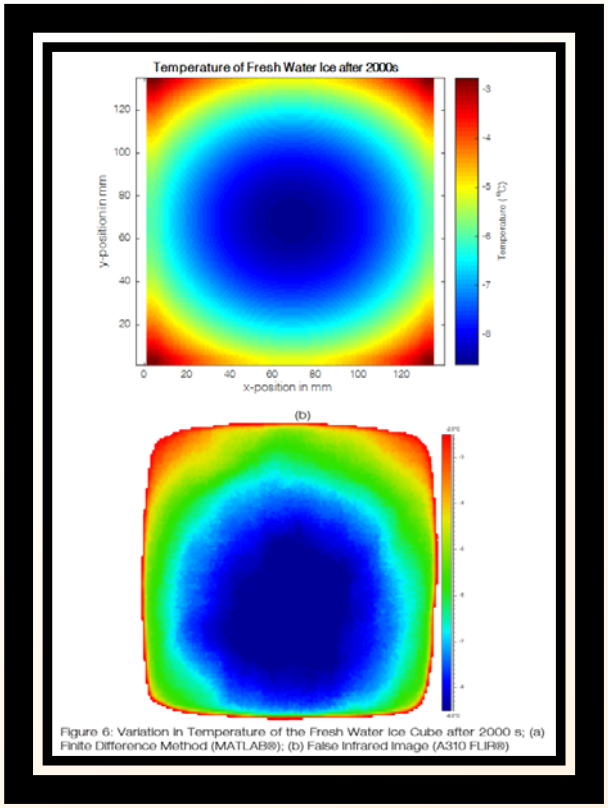


Figure 6: Variation in Temperature of the Fresh Water Ice Cube after 2000 s; (a) Finite Difference Method (MATLAB®); (b) False Infrared Image (A310 FLIR®)

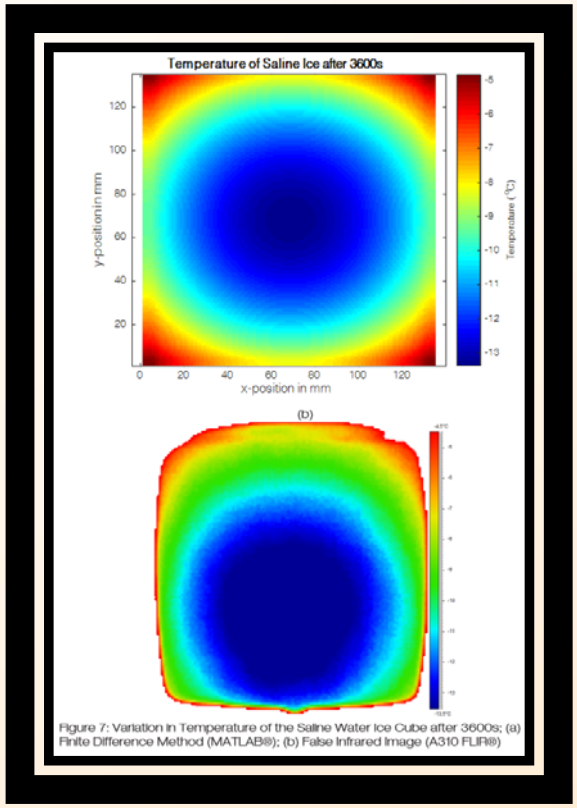
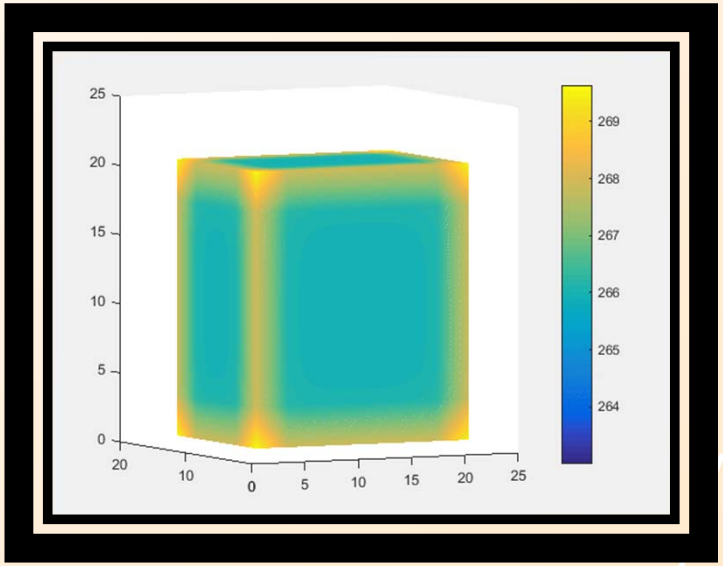
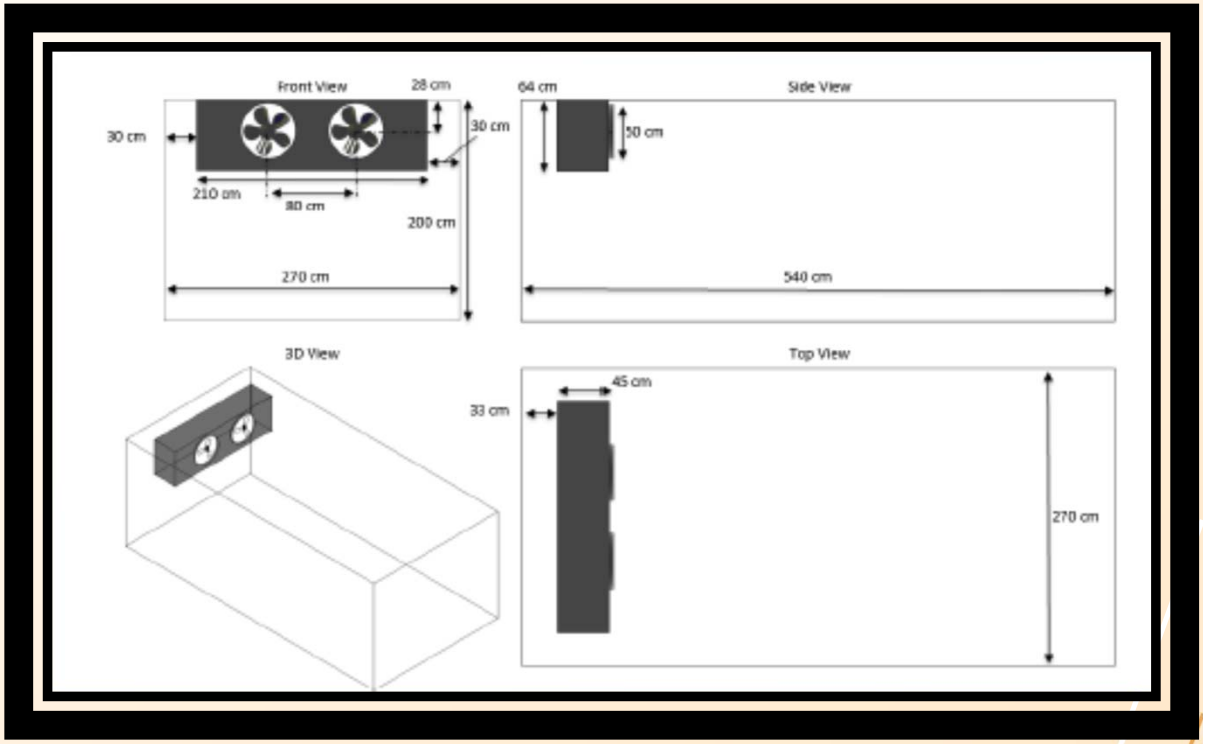


Figure 7: Variation in Temperature of the Saline Water Ice Cube after 3600s; (a) Finite Difference Method (MATLAB®); (b) False Infrared Image (A310 FLIR®)

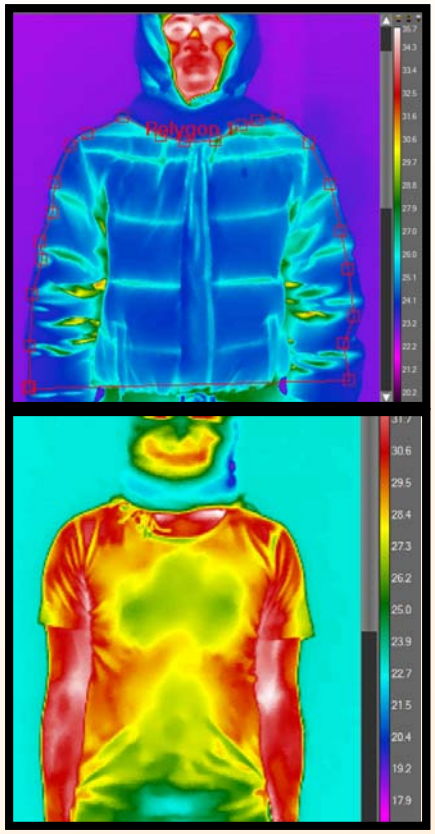


Application 2: Required Insulation index (IREQ)

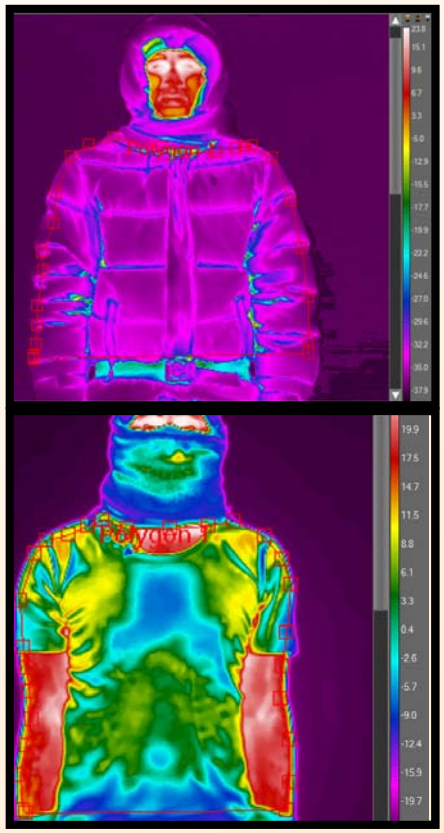


Application 2: Req. Insulation index (IREQ) Cont.

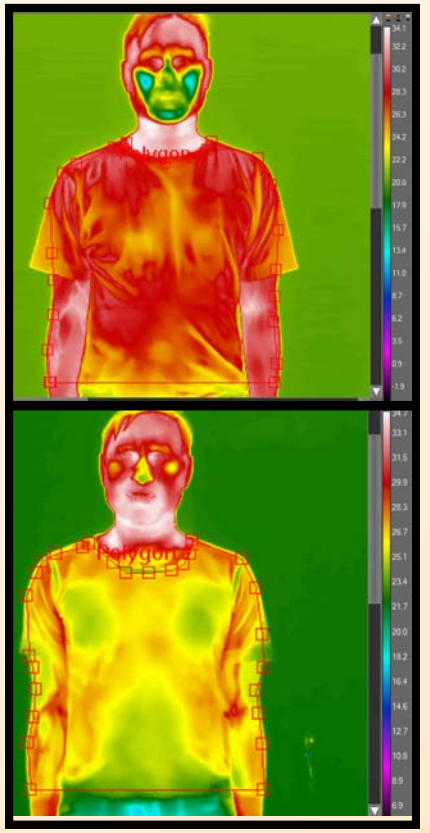
Before Cold Room



Insider Cold Room T_{cl}



After Cold Room T_{sk}



Application 2: Req. Insulation index (IREQ) Cont.

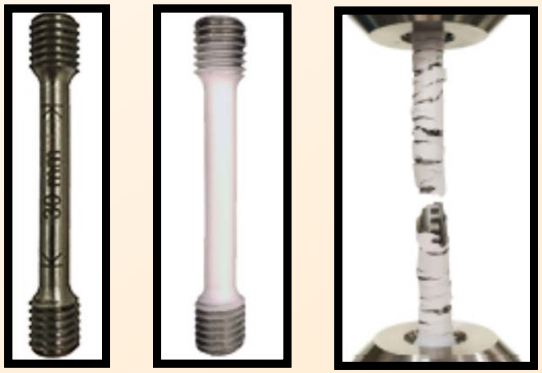
- Required Clothing Insulation index (IREQ)

$$\frac{\overline{T}_{sk} - T_{cl}}{R + C} = IREQ$$

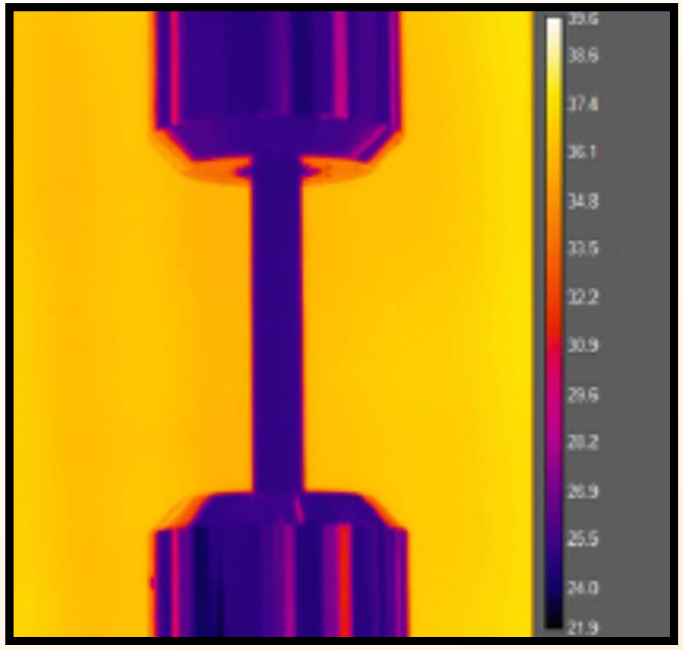
- *IREQ Value of Winter Jacket = 392 Clo
- *IREQ Value of Summer Jacket = 276 Clo
- *IREQ Value of Sweater = 224 Clo
- *IREQ Value of T-Shirt = 125 Clo

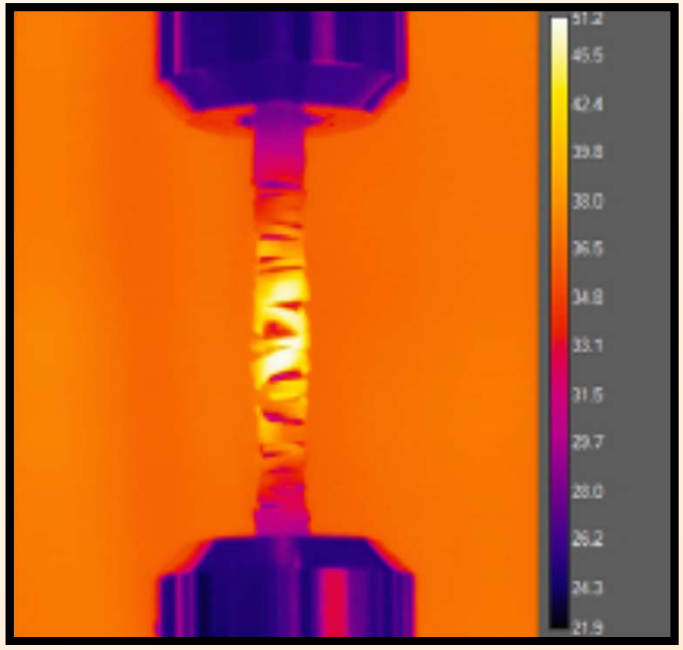
*relative required clothing insulation index

Application 3: Tensile Tests of Steel



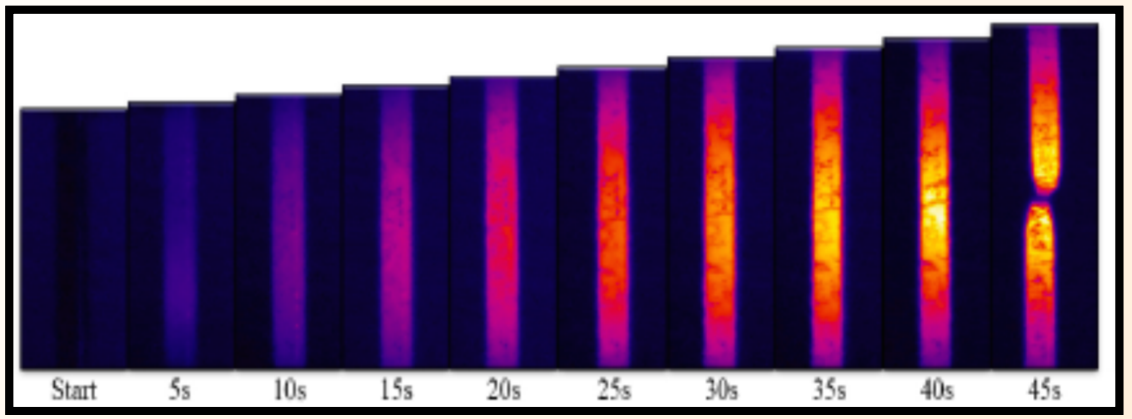
Application 3: Tensile Tests of Steel Cont.



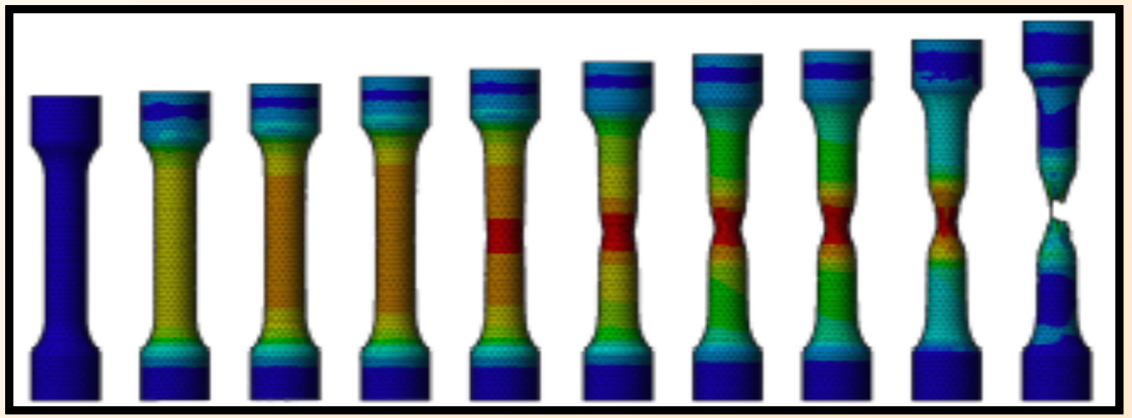


Application 3: Tensile Tests of Steel Cont.

Thermography



Finite Element Analysis



Special Thanks to Students

Even Stange
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Taimur Rashid

References

Ahmad, Tanveer; Rashid, Taimur; Khawaja, Hassan Abbas; Moatamedi, Mojtaba. **Study of the required thermal insulation (IREQ) of clothing using infrared imaging.** The International Journal of Multiphysics 2017; Volum 11 (4). ISSN 1750-9548.s 413 - 426.s doi: 10.21152/1750-9548.11.4.413.

Rashid, Taimur; Khawaja, Hassan Abbas; Edvardsen, Kåre. **Determination of Thermal Properties of Fresh Water and Sea Water Ice using Multiphysics Analysis.** The International Journal of Multiphysics 2016; Volum 10 (3). ISSN 1750-9548.s 277 - 291.s doi: 10.21152/1750-9548.10.3.277.

Thanks

"The sun was warm but the wind was chill.

You know how it is with an April day.

When the sun is out and the wind is still,

You're one month on in the middle of May.

But if you so much as dare to speak,

a cloud come over the sunlit arch,

And wind comes off a frozen peak,

And you're two months back in the middle of March."

By Robert Frost