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InfraRed (IR) Thermal Cameras for Clothing Evaluations – Scientific tool or just a toy?

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1

Human Heat Exchange - Radiation

- Radiant heat exchange between humans and their environment has not received a lot of attention.
- Some basic models have been developed
  - Lotens, EU research project (ThermProtect) - effects of color and heat reflective clothing.
- New technologies allow engineering of emissive, reflective and even transmissive properties of clothing
- IR Cameras are often used to evaluate products

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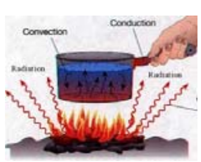
Radiant Heat Exchange

- All objects emit radiation, travels through vacuum and air,
- clothing "intercepts" (absorbs) usually at least 90-95%
- Frequency/wavelength depends on temperature of the object

Object	Peak Wavelengths (µm)
Sun	0.3-1.5
IR lamp	1.0-10
Human body	4.0-10
Environment	5.0-20



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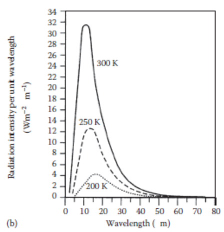
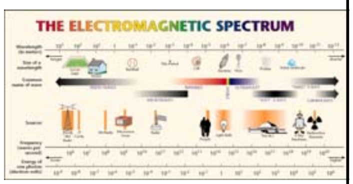
Radiant Heat Exchange

- Radiation: $\sigma \cdot \varepsilon \cdot (T_{sk}^4 - T_{rad}^4)$





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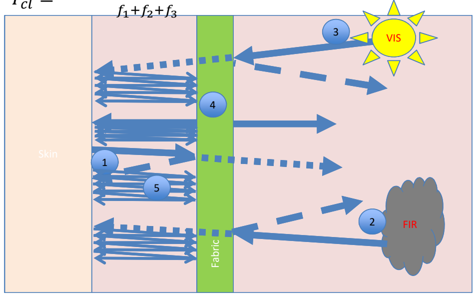
Simplified (!) Theory for Novel Fabrics

- $T_{cl} = \frac{(T_{sk}f_1 + T_{rad}f_2 + T_{air}f_3)}{f_1+f_2+f_3}$



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Simplified Theory for Novel Fabrics (1)

- Radiant Heat Loss from any object is given by:
- $E_{rad}(\lambda) = \sigma\, \varepsilon(\lambda)\, T_s^4$
  - σ is Stefan-Boltzmann Constant
  - ε(λ) the emissivity of the surface at a specific wavelength.
- Fabric interferes with radiant heat exchange between skin and environment
- Fabric may absorb (α), reflect(ρ) or transmit (τ): α+ρ+τ = 1
- Emissivity (ε) taken equal to absorption (α)
- Each component may have a strong dependence on wavelength
- Incident heat load in theory:
- $E_{rad}(\lambda) = \int_{\lambda} \varepsilon(\lambda) \cdot E_{rad}(\lambda)$

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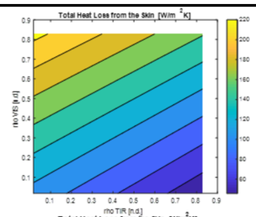
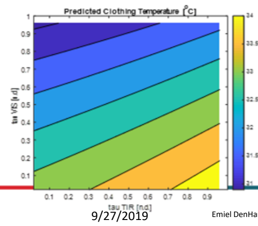
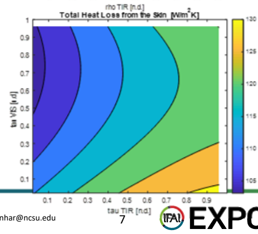
Some Results

- With external heat source (fire, sun)
- VIS & TIR







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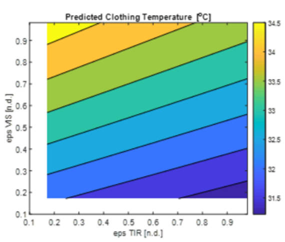
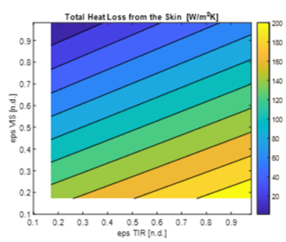
Fiber/Fabric Emissivity Effects





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Wait there's more

- Use of IR Cameras for temperature and heat loss assessments
- Some caveats
- Applications in Hot Plates and Thermal Manikins → combined wicking and heat loss

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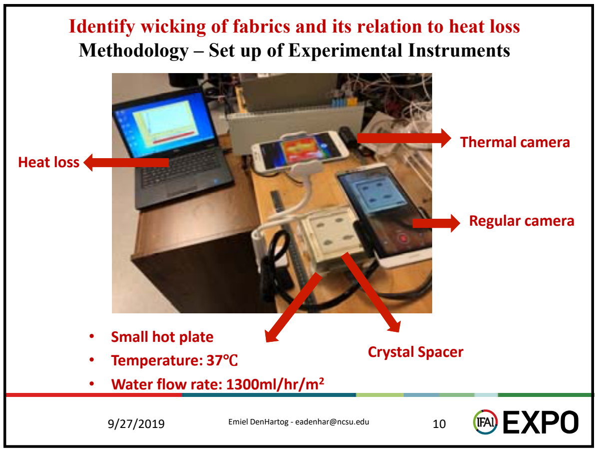
Identify wicking of fabrics and its relation to heat loss
Methodology – Set up of Experimental Instruments
Heat loss
Thermal camera
Regular camera
Small hot plate
Temperature: 37°C
Water flow rate: 1300ml/hr/m²
Crystal Spacer
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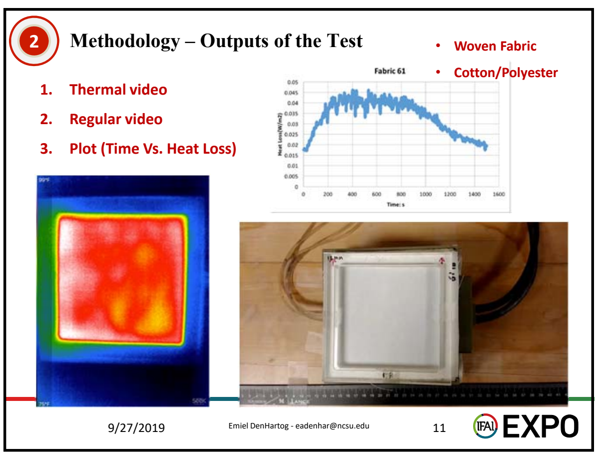
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Methodology – Outputs of the Test
Woven Fabric
Cotton/Polyester
1. Thermal video
2. Regular video
3. Plot (Time Vs. Heat Loss)
Fabric 61
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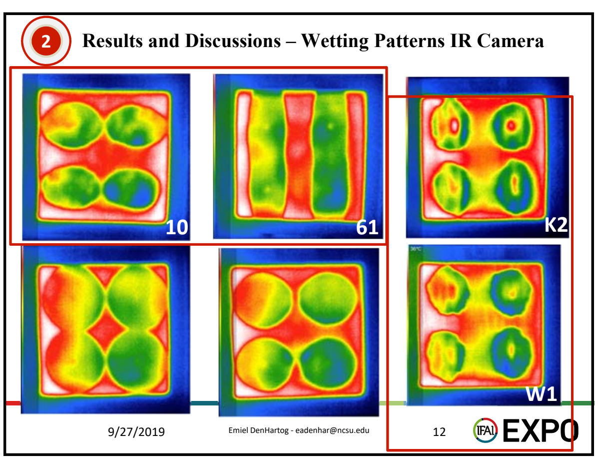
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Results and Discussions – Wetting Patterns IR Camera
10
61
K2
W1
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12
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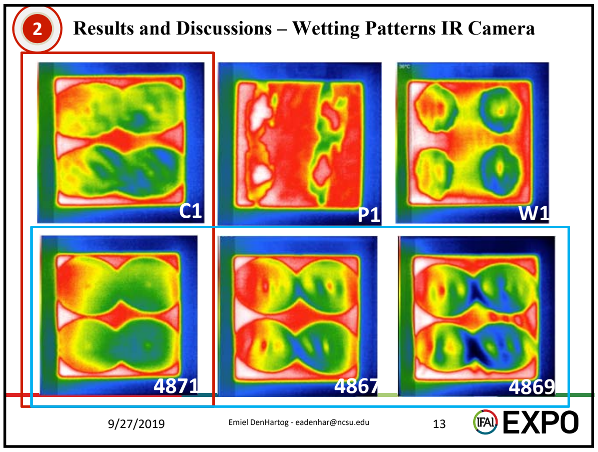
12


2
Results and Discussions – Wetting Patterns IR Camera
C1
P1
W1
4871
4867
4869
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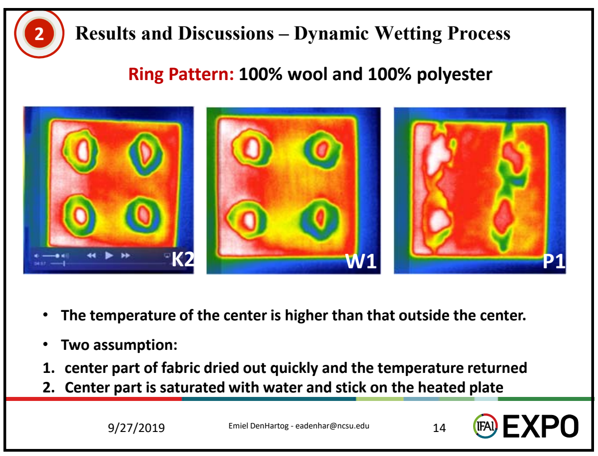
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Results and Discussions – Dynamic Wetting Process
Ring Pattern: 100% wool and 100% polyester
K2
W1
P1
• The temperature of the center is higher than that outside the center.
• Two assumption:
1. center part of fabric dried out quickly and the temperature returned
2. Center part is saturated with water and stick on the heated plate
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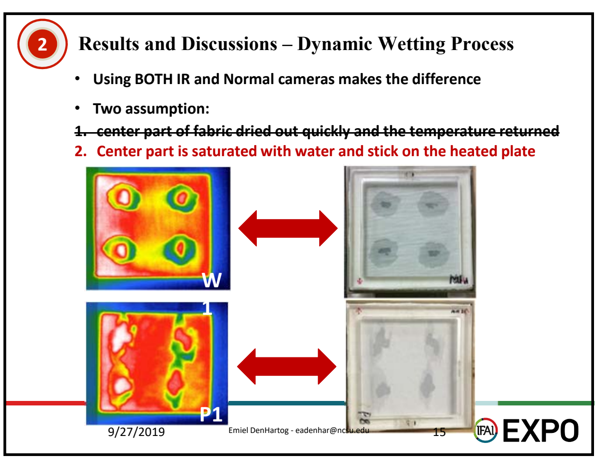
2
Results and Discussions – Dynamic Wetting Process
• Using BOTH IR and Normal cameras makes the difference
• Two assumption:
~~1. center part of fabric dried out quickly and the temperature returned~~
2. Center part is saturated with water and stick on the heated plate
W1
P1
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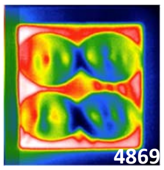
Results and Discussions – Dynamic Drying Process

- Deformation: thickness, tightness
- Combining IR and normal camera clearly shows effects of deformation, not cooling!



Natural Fiber 1

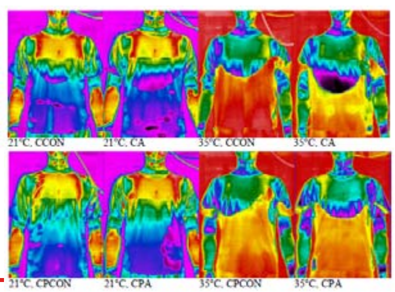
deformation

16

Results – Sweating Manikin

IR Images – Sometimes pictures do say more than numbers

Significant, but also Relevant?



17

Brief Conclusions on IR camera use

- IR Camera can be a great measurement of surface temperature
- It usually **only** measures surface temperature
- But some parameters must be know for correct interpretation of the data:
  - Emissivity, reflection and transmission of the surface
  - Any air layers (differences) between skin and fabric
- Keep in mind (additional info must be obtained):
  - A low surface temperature does NOT have to indicate a cooling of the fabric
  - A high surface temperature of the fabric does NOT have to indicate the fabric is dry

18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Thanks for your attention
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19