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Study Of Wind Chill Effect and Thermal Insulation Using Infrared Imaging

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Objective

1. To prove the wind chill factor
2. Safety and Reliability

- Protective measures
- Calculate the required thermal insulation

Wind chill factor

"It is the cooling sensation due to the exposure of wind temperature environment"

Factors

- *1) air temperature 2) wind velocity 3) humidity*

Effects of Cold Weather on Human Body

- heat loss from human body (body cooling)
- health hazard (hypothermia/frostbite)

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Wind Chill Equivalent Temperature Chart

$$WCT = 13.2 + 0.6215\,T_{air} - 11.37\,V_s^{0.16} + 0.3965\,T_{air}\,V_s^{0.16}$$

Wind Speed (km h⁻¹) \ Air Temperature (°C)	Calm	10	5	0	−5	−10	−15	−20	−25	−30	−35	−40	−45	−50
10	9	3	−3	9	−15	−21	**−27**	**−33**	**−39**	**−45**	**−51**	**-57**	**−63**
15	8	2	−4	−11	−17	−23	**−29**	**−35**	**−41**	**−48**	**−54**	**−60**	**−66**
20	7	1	−5	−12	−18	−24	**−31**	**−37**	**−43**	**−49**	**−56**	**−62**	**−68**
25	7	1	−6	−12	−19	−25	**−32**	**−38**	**−45**	**−51**	**−57**	**−64**	**−70**
30	7	0	−7	−13	−19	−26	**−33**	**−39**	**−46**	**−52**	**−59**	**−65**	**−72**
35	6	0	−7	−14	−20	−27	**−33**	**−40**	**−47**	**−53**	**−60**	**−66**	**−73**
40	6	−1	−7	−14	−21	**−27**	**−34**	**−41**	**−48**	**−54**	**−61**	**−68**	**−74**
45	6	−1	−8	−15	−21	**−28**	**−35**	**−42**	**−48**	**−55**	**−62**	**-69**	**−75**
50	6	−1	−8	−15	−22	**−29**	**−35**	**−42**	**−49**	**−56**	**−63**	**−70**	**−76**
55	5	−2	−9	−15	−22	**−29**	**−36**	**−43**	**−50**	**−57**	**−63**	**−70**	**−77**
60	5	−2	−9	−16	−23	**−30**	**−37**	**−43**	**−50**	**−57**	**−64**	**−71**	**−78**
70	5	−2	−9	−16	−23	**−30**	**−37**	**−44**	**−51**	**−59**	**−66**	**−73**	**−80**
80	4	−3	−10	−17	−24	**−31**	**−38**	**−45**	**−52**	**−60**	**−67**	**−74**	**−81**

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Literature Review

- **Review of Wind Chill Factor Models**

i. Siple and Passel's Wind Chill Experiment

ii. Osczevski Wind Chill Model

- **British Standard-EN 342**
- **ISO 11079:2007**
- **Review of the Phenomenon of Heat Transfer**

i. Conduction

ii. Convection

iii. Radiation

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METHODOLOGY

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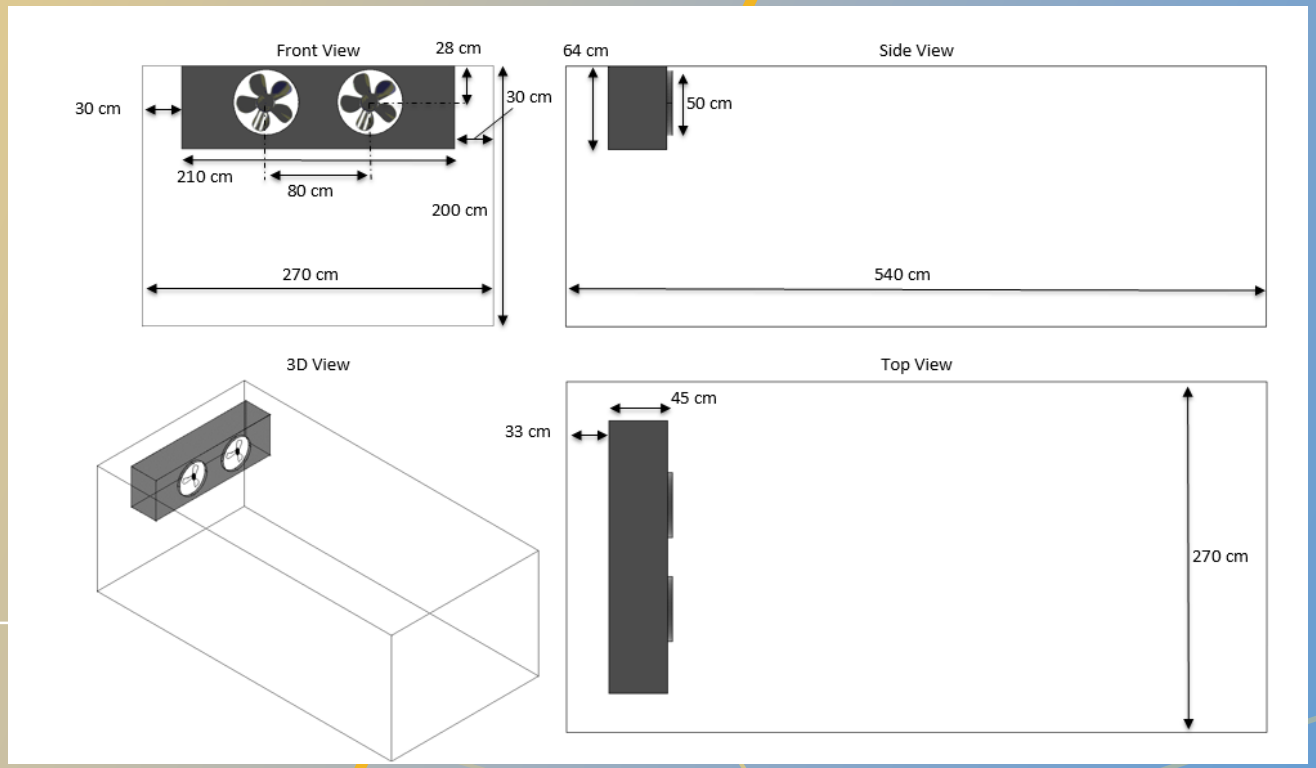
- Cold Room
- Anemometer
- IR Camera



TSI® Velocicalc

Flir® T1030sc

Fluke® Ti55

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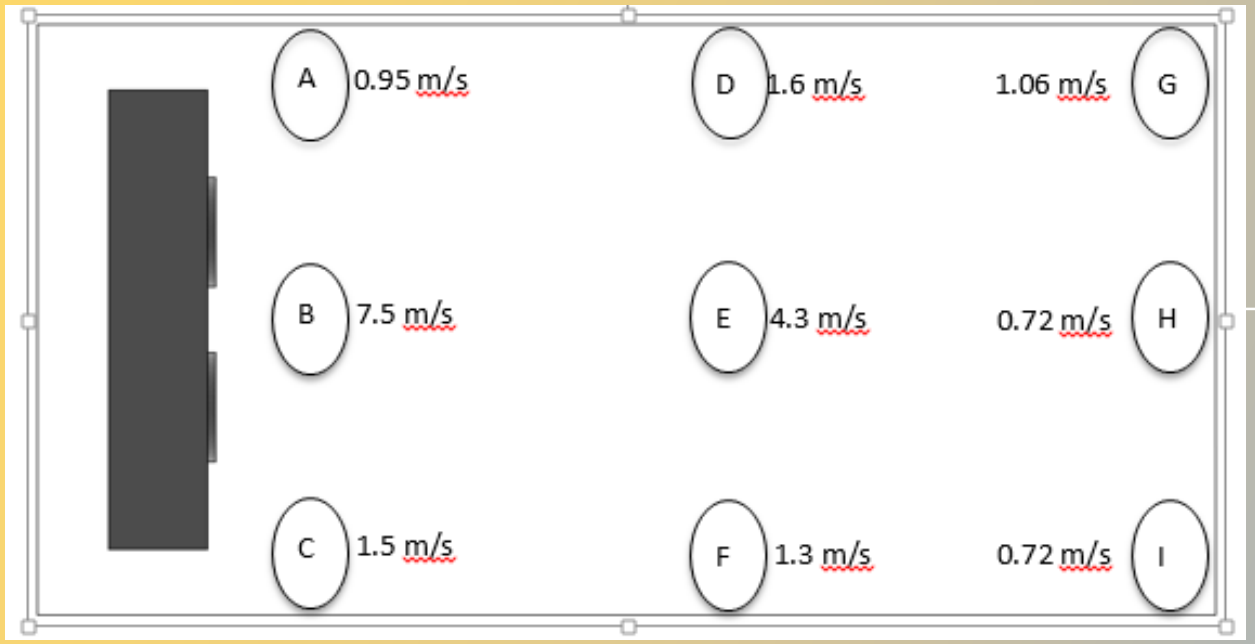
Infrared Imaging Results



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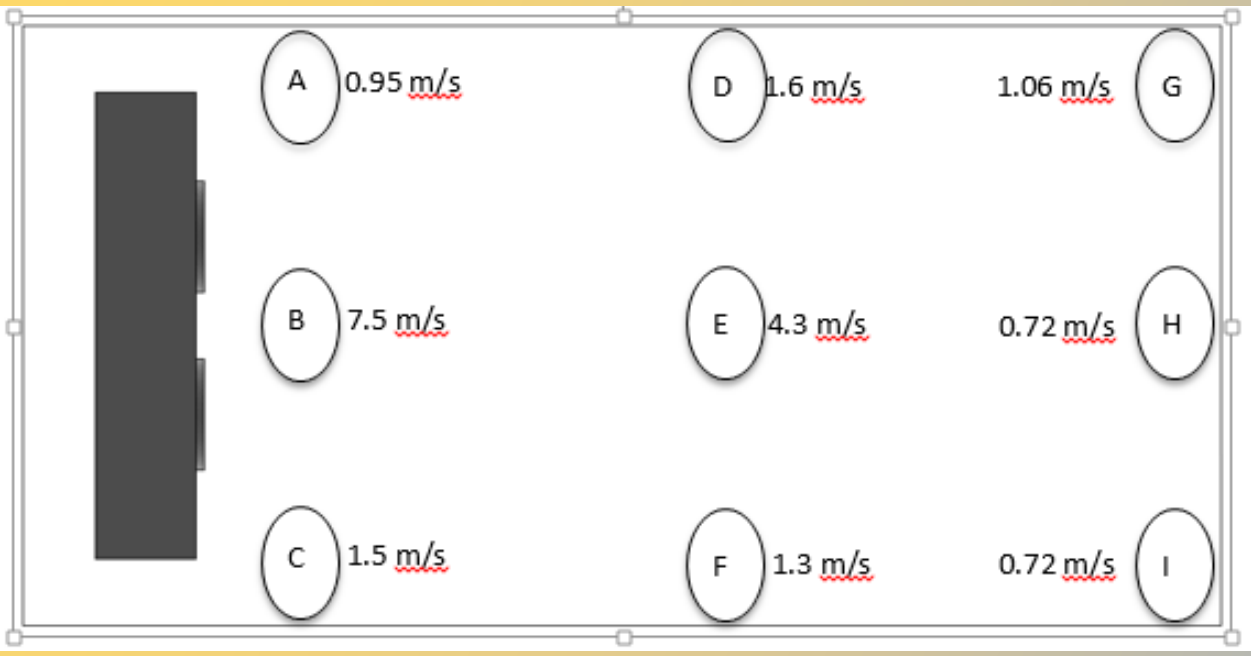
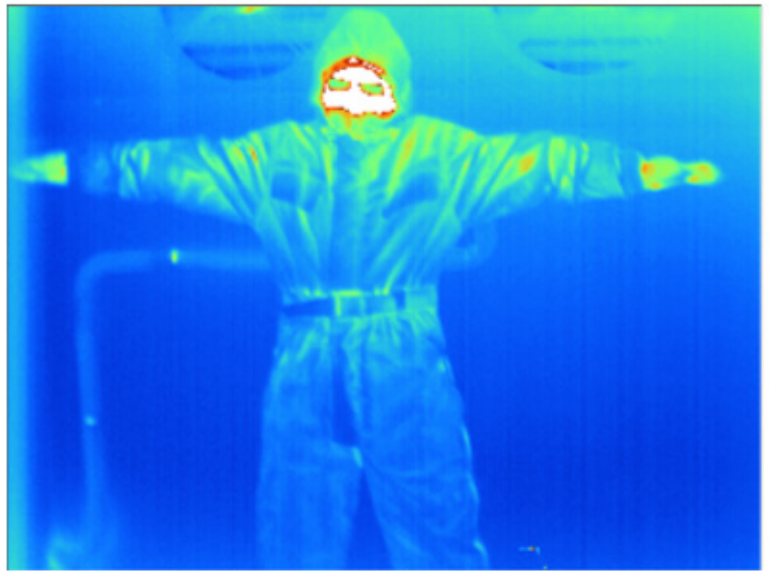
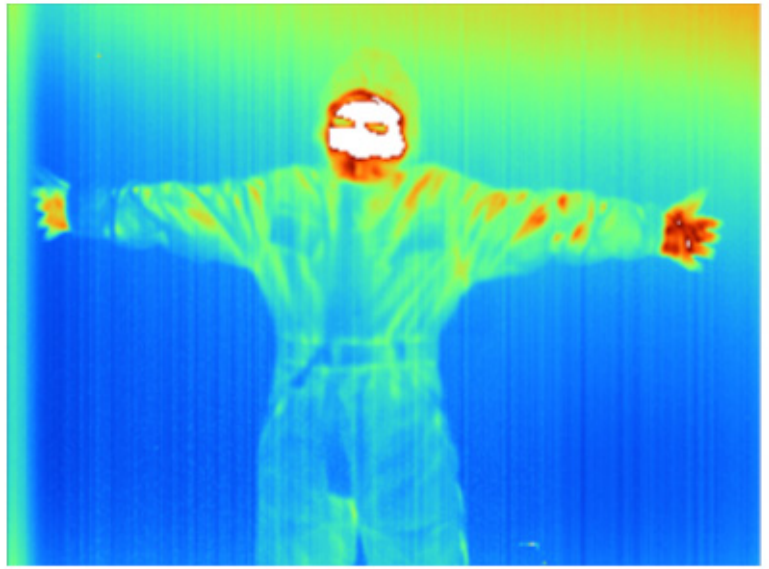




Subject 1, Position B



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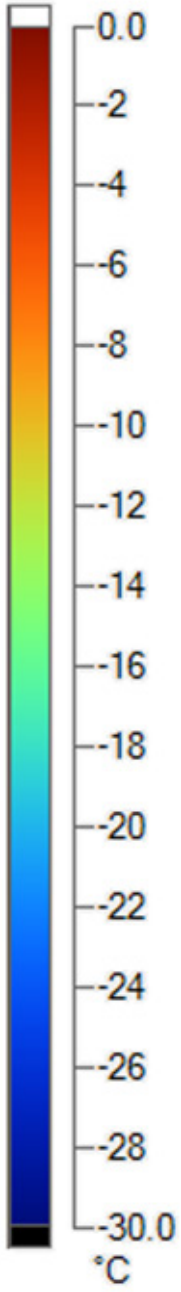

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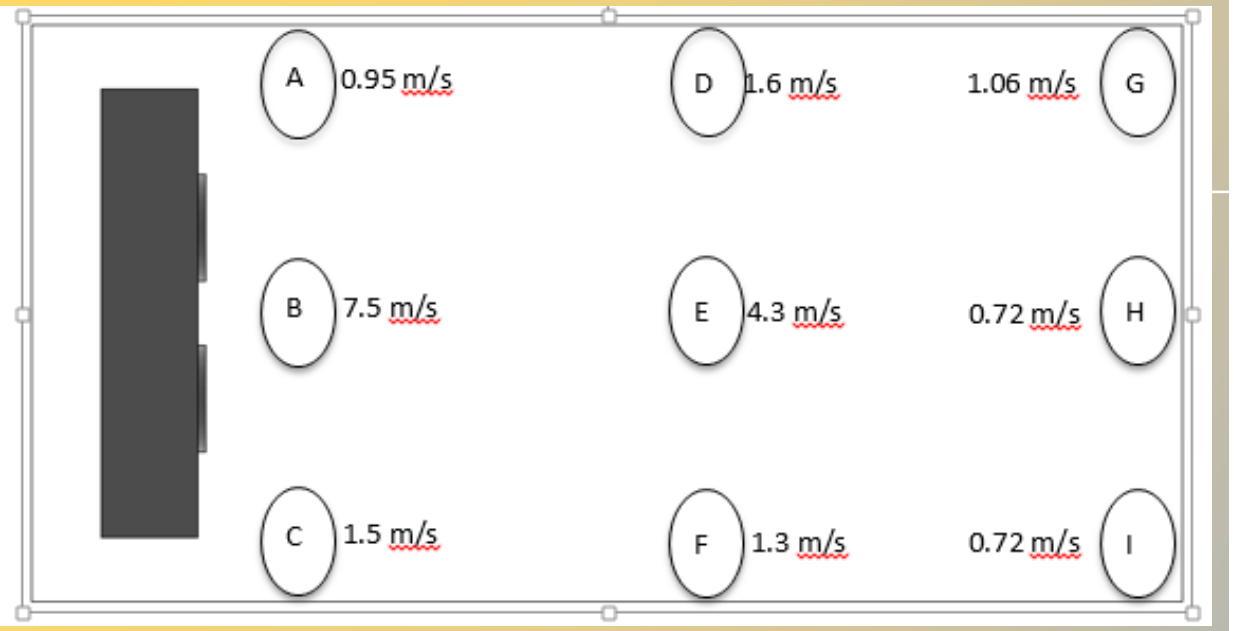

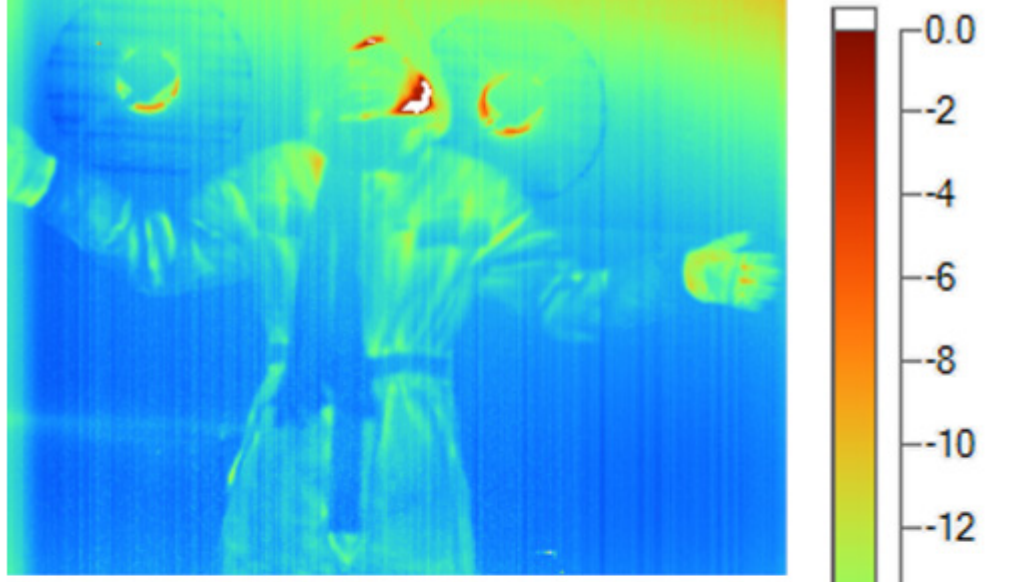

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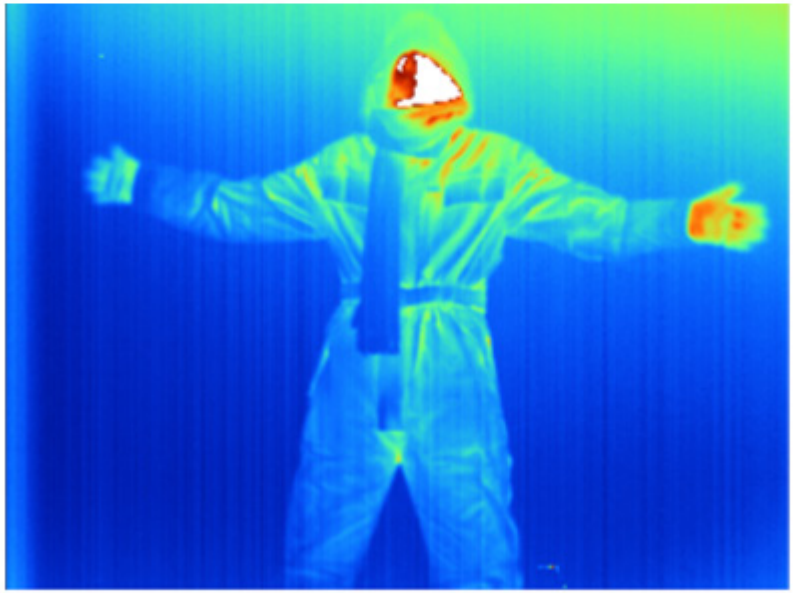

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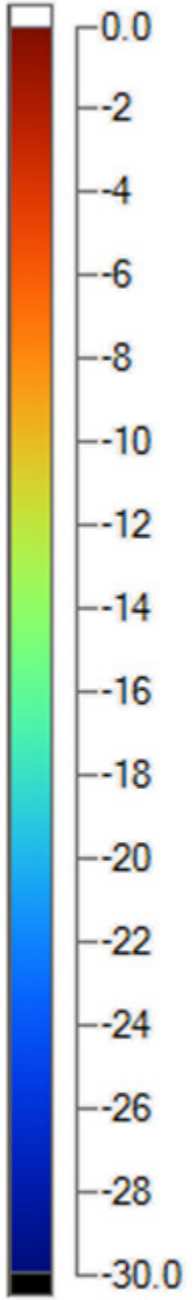

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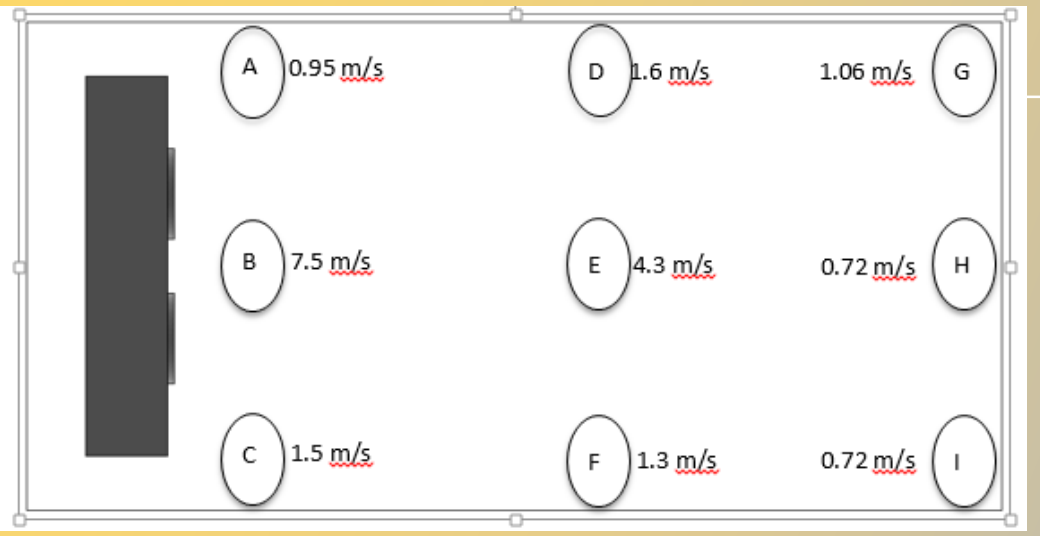
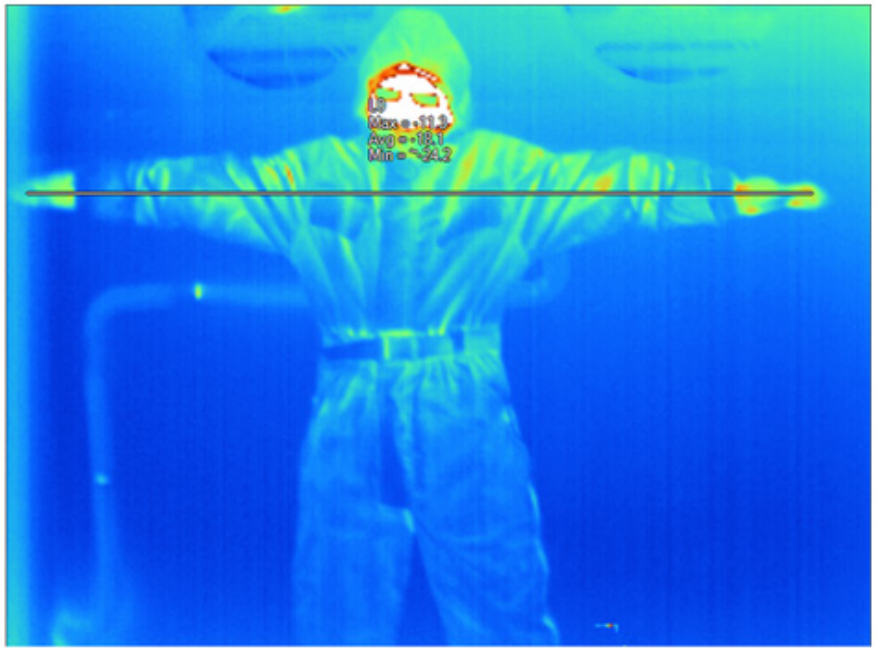




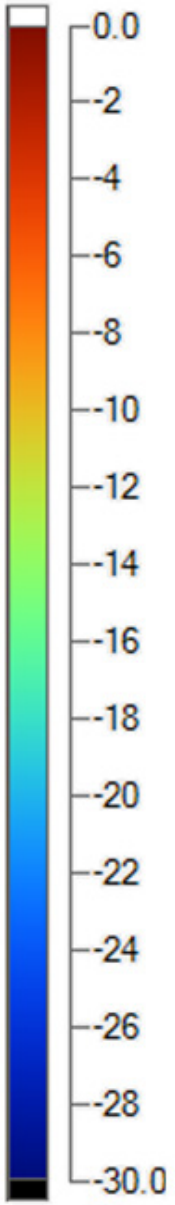
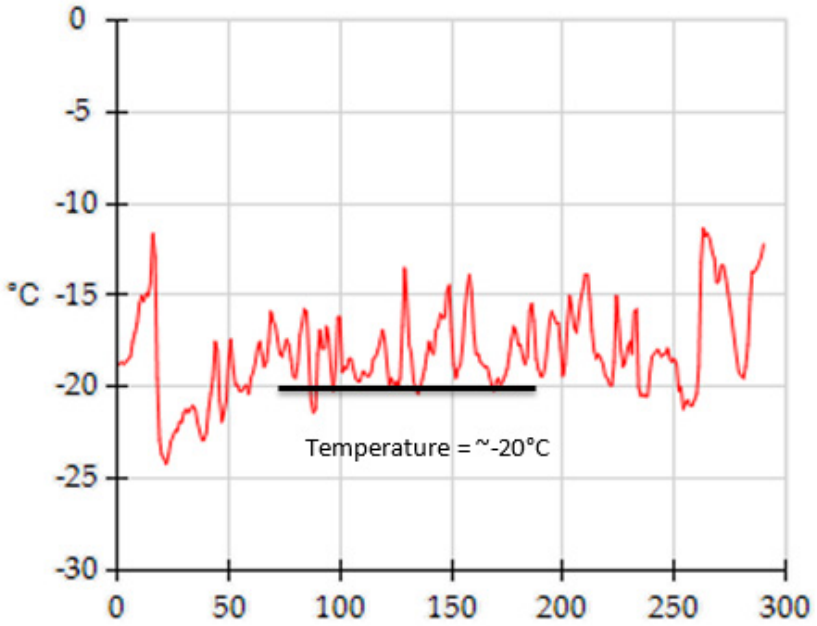


Illustration of hand to hand line at position B



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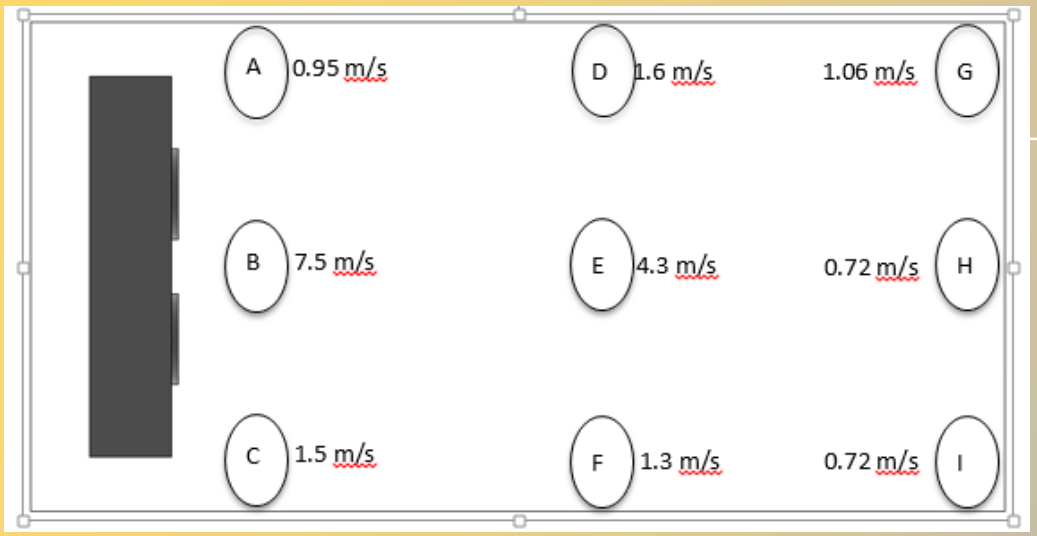

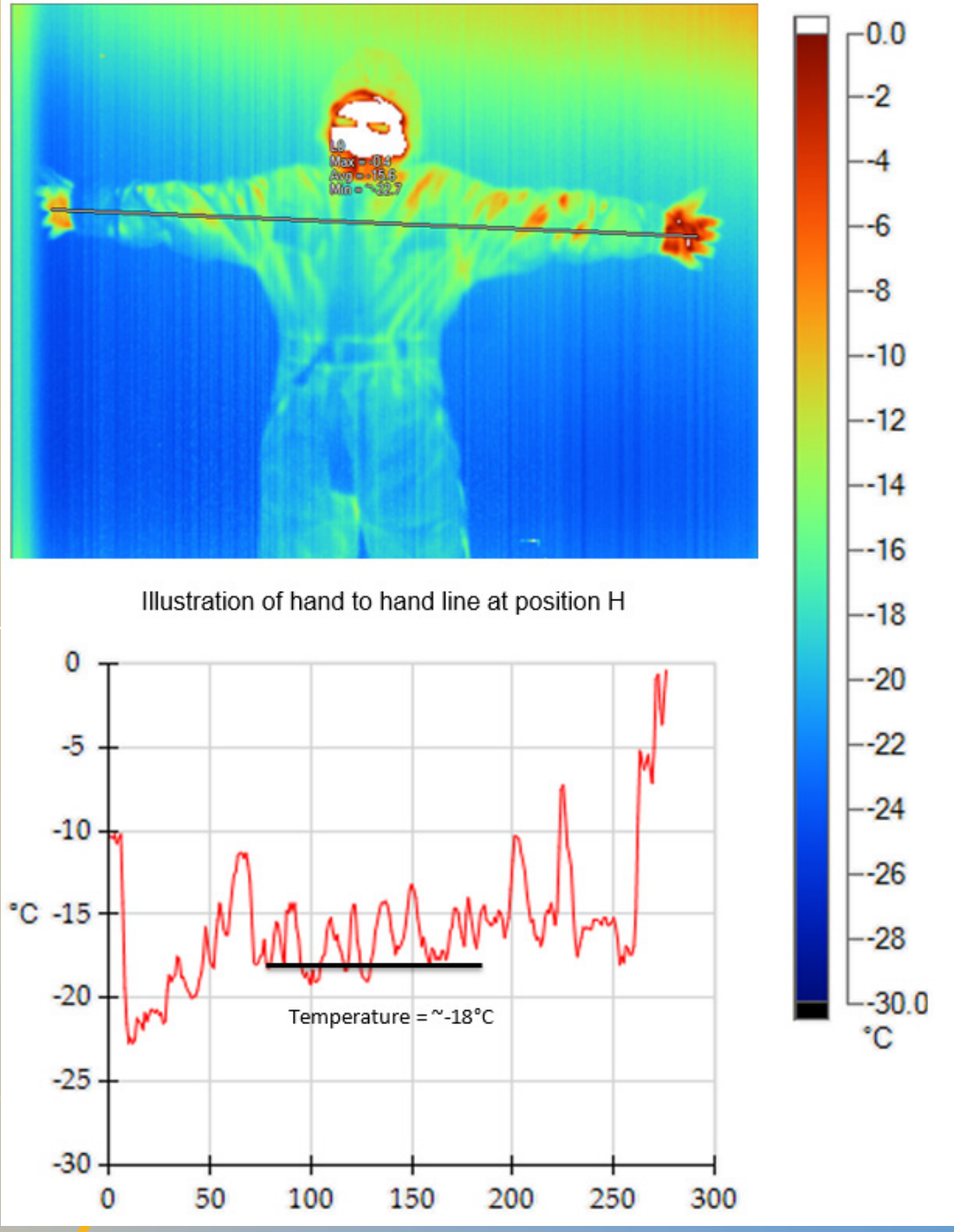

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Conclusion

- It is evident from the infrared imaging results that the recorded temperatures are different with different wind drifts.
- Under higher wind drift, the recorded temperatures are lower and vice versa. Therefore, higher wind velocity results in higher heat loss and stronger wind chill factor.

Positions	Wind Speeds	Temperatures (hand to hand line)
B	7.5 m/s	-20°C
H	0.72 m/s	-18°C

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Risk Management

Required Clothing insulation using IR Imagery

It represents the resultant clothing insulation required in cold environment to maintain the body in a state of thermal equilibrium at acceptable level of body and skin temperatures.

$$\boldsymbol{IREQ} * = \frac{\boldsymbol{T_s - T_c}}{\boldsymbol{R + C}} \left(\boldsymbol{K\, m^2 W^{-1}}\right)$$

Where

$\boldsymbol{IREQ}*$ Relative Required clothing insulation, $m^2.K.W^{-1}$

$\boldsymbol{T_s}$ Mean surface temperature with basic clothing, C°

$\boldsymbol{T_c}$ Mean surface surface temperature with additional clothing, C°

R is the radiative heat exchange

C is the convective heat exchange

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Infrared images of the subject wearing winter jacket

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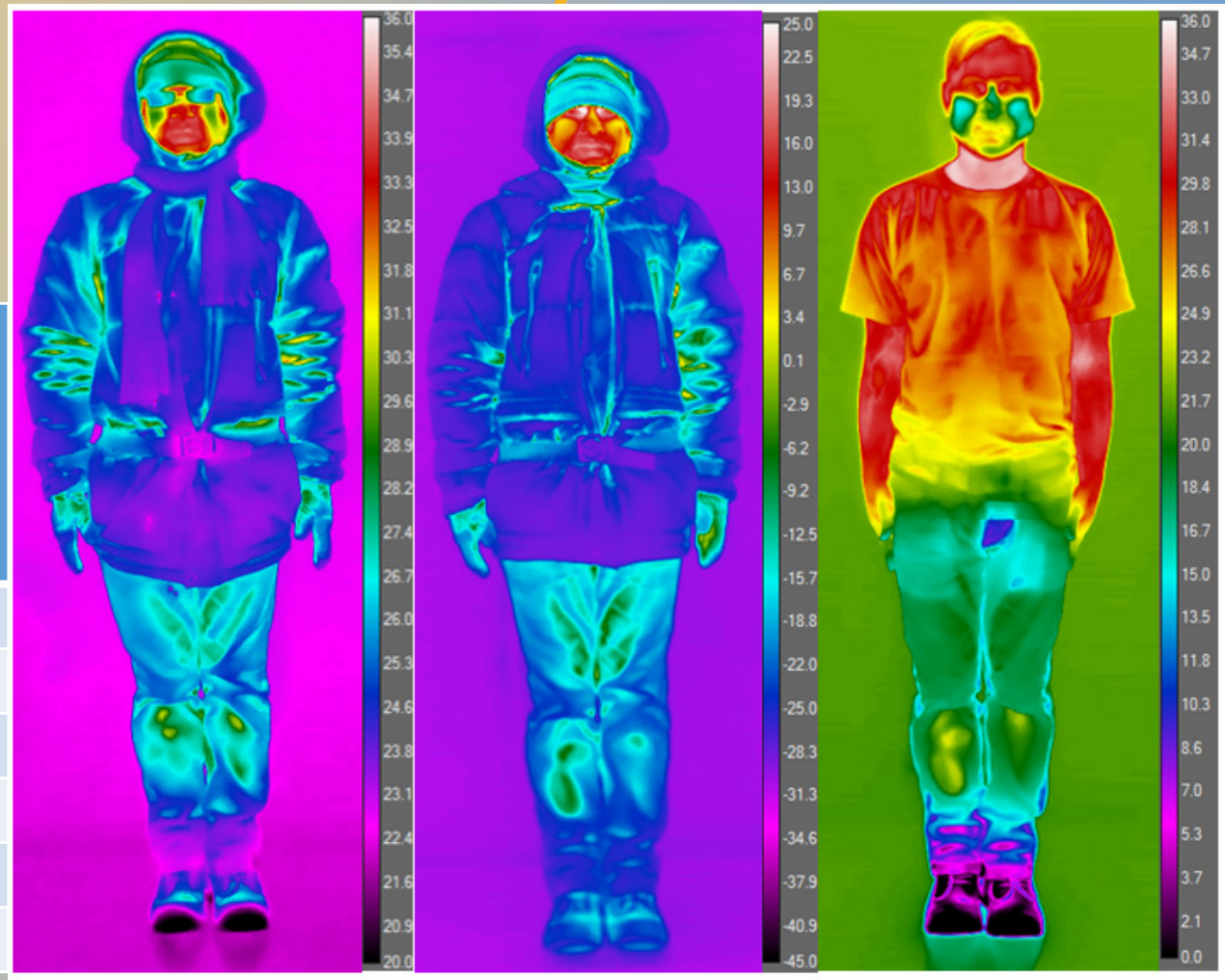
Table 4.2: Surface temperature with and without winter jackets and their respective IREQ*.

Additional clothing type	Surface temperature without additional clothing – T_s (K)	Surface temperature with additional clothing – T_c (K)	IREQ* (K m² W) $IREQ* = \frac{T_s - T_c}{55}$
Levi's®	28.0	-24.7	0.958
Stormberg®	27.3	-33.6	1.107
Kraft®	29.1	-28.5	1.047
Jean Paul®	27.9	-24.1	0.945
Fjell Raven®	28.0	-26.8	0.996
WJ-Average	**28.0**	**-27.54**	**1.01**



(a) Outside Cold Room (b) Inside Cold Room (c) Without Jacket

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Infrared images of the subject wearing Summer Jacket

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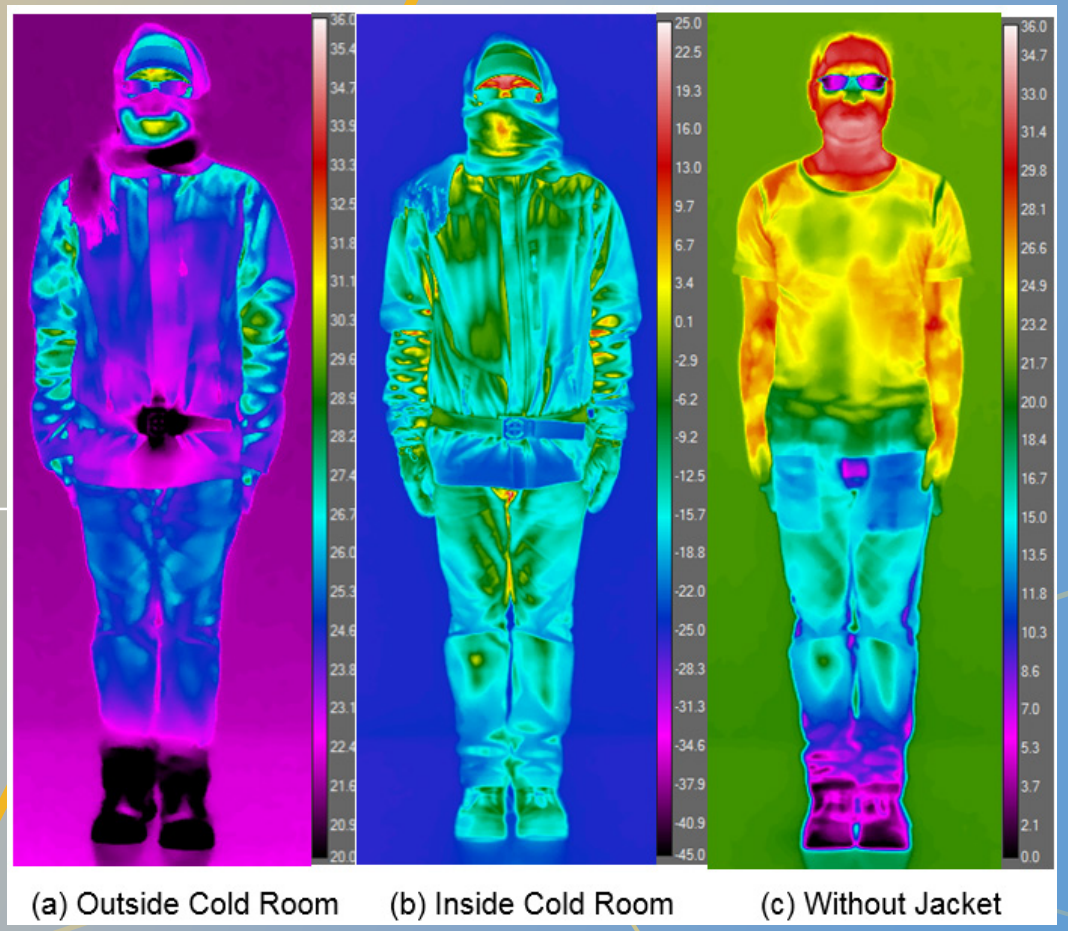
Surface temperature with and without summer jackets and their respective IREQ*.

Additional clothing type	Surface temperature without additional clothing – T_s (K)	Surface temperature with additional clothing – T_c (K)	IREQ* (K m² W) $IREQ * = \frac{T_s - T_c}{55}$
RR®	25.7	-17.1	0.778
Springfield®	26.1	-13.2	0.715
Greenwood®	26.3	-15.7	0.764
Chill Factor®	24.9	-12.0	0.671
Helly Tech®	25.7	-14.2	0.725
SJ - Average	25.7	-14.4	0.731



(a) Outside Cold Room (b) Inside Cold Room (c) Without Jacket

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Infrared images of the subject wearing sweater

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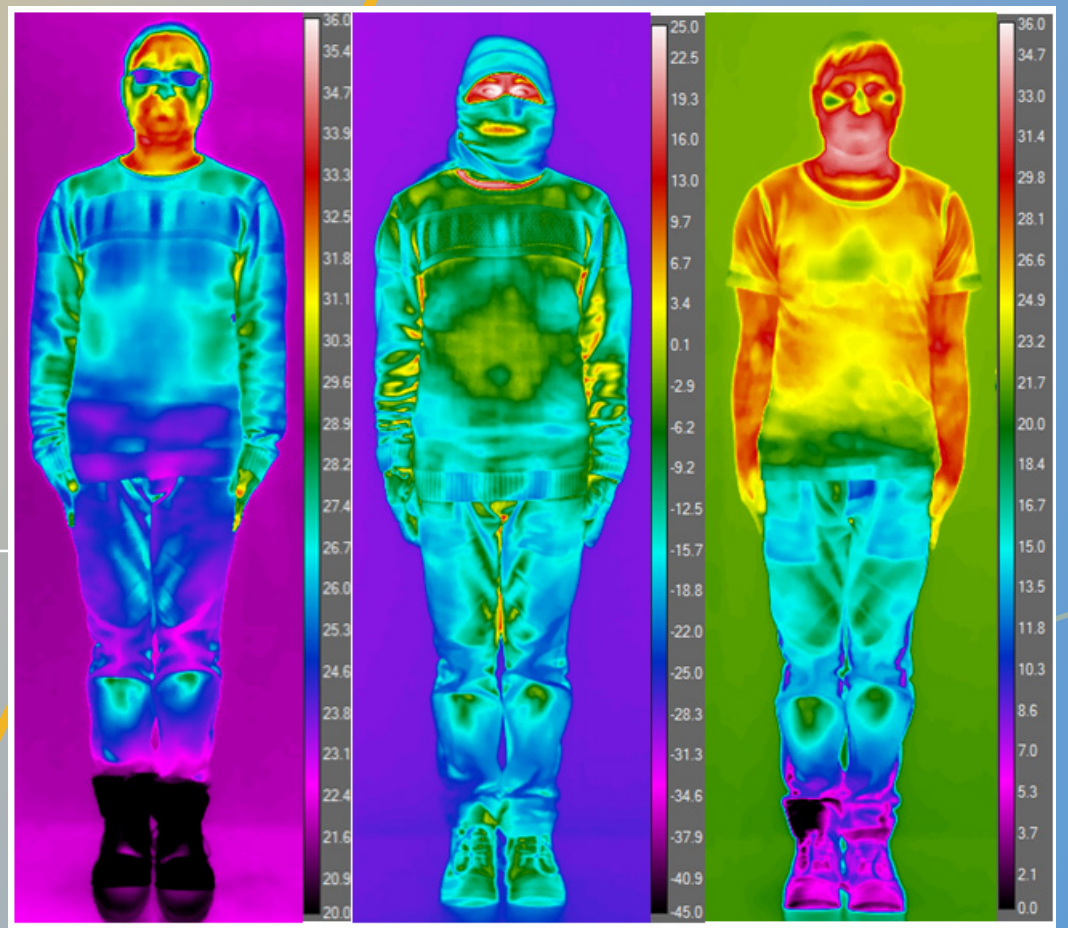
Surface temperature with and without sweaters and their respective IREQ*.

Additional clothing type	Surface temperature without additional clothing – T_s (K)	Surface temperature with additional clothing – T_c (K)	IREQ* (K m² W) $IREQ* = \frac{T_s - T_c}{55}$
Twentyfour®	26.7	-13.0	0.722
Lerros®	26.5	-8.6	0.638
NATO	27.5	-12.9	0.735
i Solid®	26.0	-8.8	0.633
Kaatiko®	26.6	-10.1	0.667
SW-Average	**26.7**	**-10.7**	**0.679**



(a) Outside Cold Room (b) Inside Cold Room (c) Without Jacket

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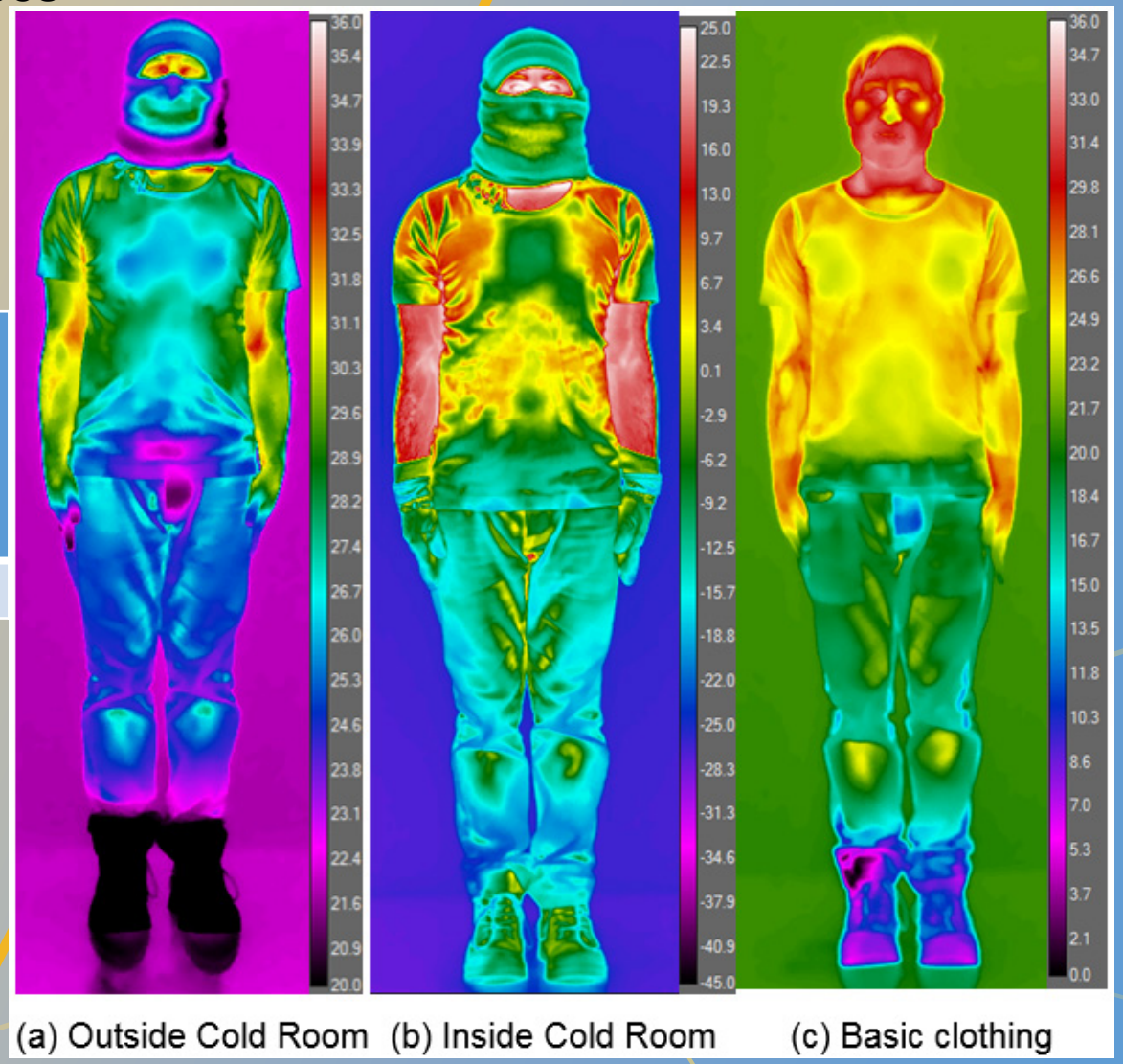
Infrared images of the subject wearing basic clothing of t-shirt, jeans, underwear, socks, and shoes

Surface temperature with basic clothing and respective IREQ*.

Additional clothing type	Surface temperature without additional clothing – T_s (K)	Surface temperature with additional clothing – T_c (K)	IREQ* (K m² W) $IREQ * = \frac{T_s - T_c}{55}$
Basic clothing	25.1	5.7	0.353



(a) Outside Cold Room (b) Inside Cold Room (c) Basic clothing

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Comparison of basic clothing, winter jackets, summer jackets, and sweaters.

Additional clothing type	Surface temperature without additional clothing – T_s (K)	Surface temperature with additional clothing – T_c (K)	IREQ* (K m² W) $IREQ* = \frac{T_s - T_c}{55}$
Winter Jacket (Average)	28.0	-27.54	1.01
Sumer Jacket (Average)	25.7	-14.4	0.731
Sweater (Average)	26.7	-10.7	0.679
Basic clothing	25.1	5.7	0.353

Results clearly distinguish between different clothing types based on evaluated IREQ* values.

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“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.”

Robert Frost

Thank You for Your Attention