Lessons Learned in Developing and Testing Advanced Prototypes for Protective and Performance Applications

Synthetic Yarn and Fabric Association Conference 2019

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Textile Protection and Comfort Center (TPACC)

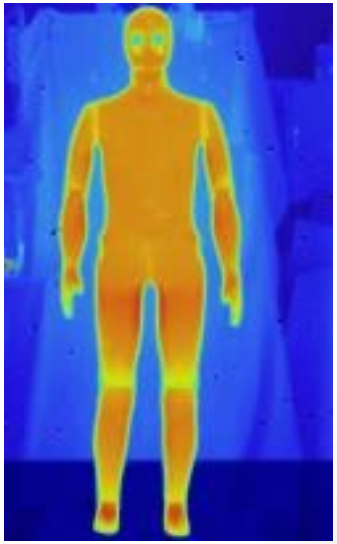
- The only center in the U.S. that incorporates in one location the capabilities to research, test, and evaluate the comfort and protective performance of textile materials, garments, and ensemble systems

TPACC has expertise and comprehensive lab capabilities for:

- Developing /prototyping new protective or performance clothing
- Demonstrating product protective or comfort performance

Experience in applying methods for diverse applications

- Firefighters
- Athletic wear
- Medical applications

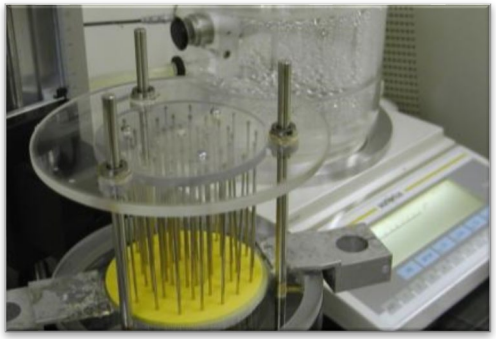


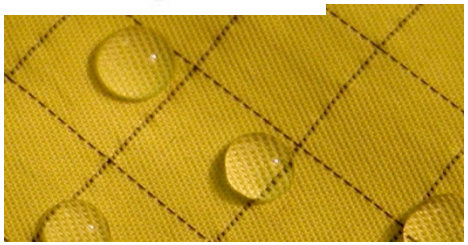
Lessons Learned

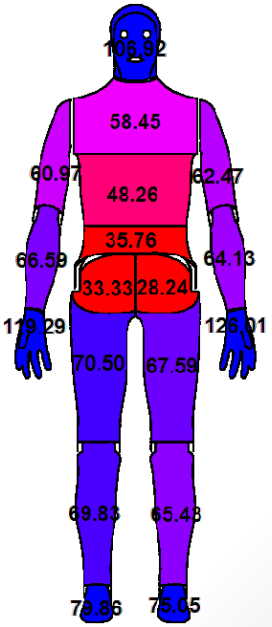
- Importance of understanding product end use requirements and expectations(purpose driven design)
- Limitations of exclusive reliance on component level product performance tests
- Beware of tradeoffs and unintended consequences in product development
- Importance of user driven, scientifically qualified lab tests and standardized performance requirement for product validation

KEY: Develop technical understanding of properties that determine optimum comfort/ protection or functional balance.

TPACC: 25+ Years Experience in Clothing Comfort Testing&Evaluation







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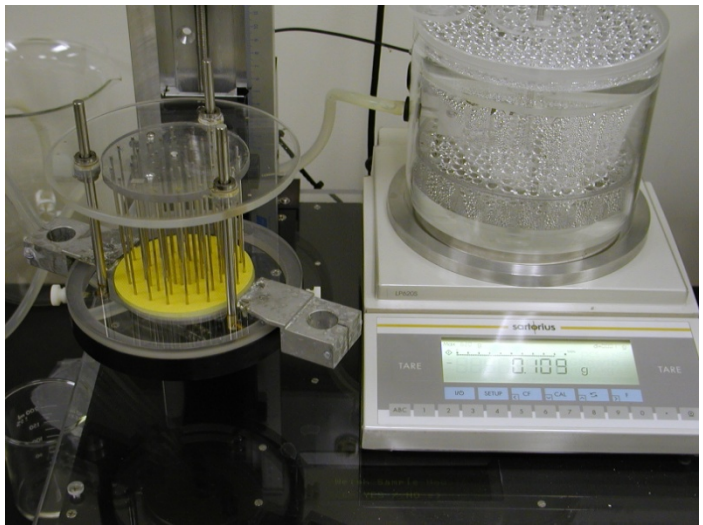
Advance the state-of-the-art of scientifically based and validated test methods for outdoor and sports performance products

What's the best comfort testing approach?

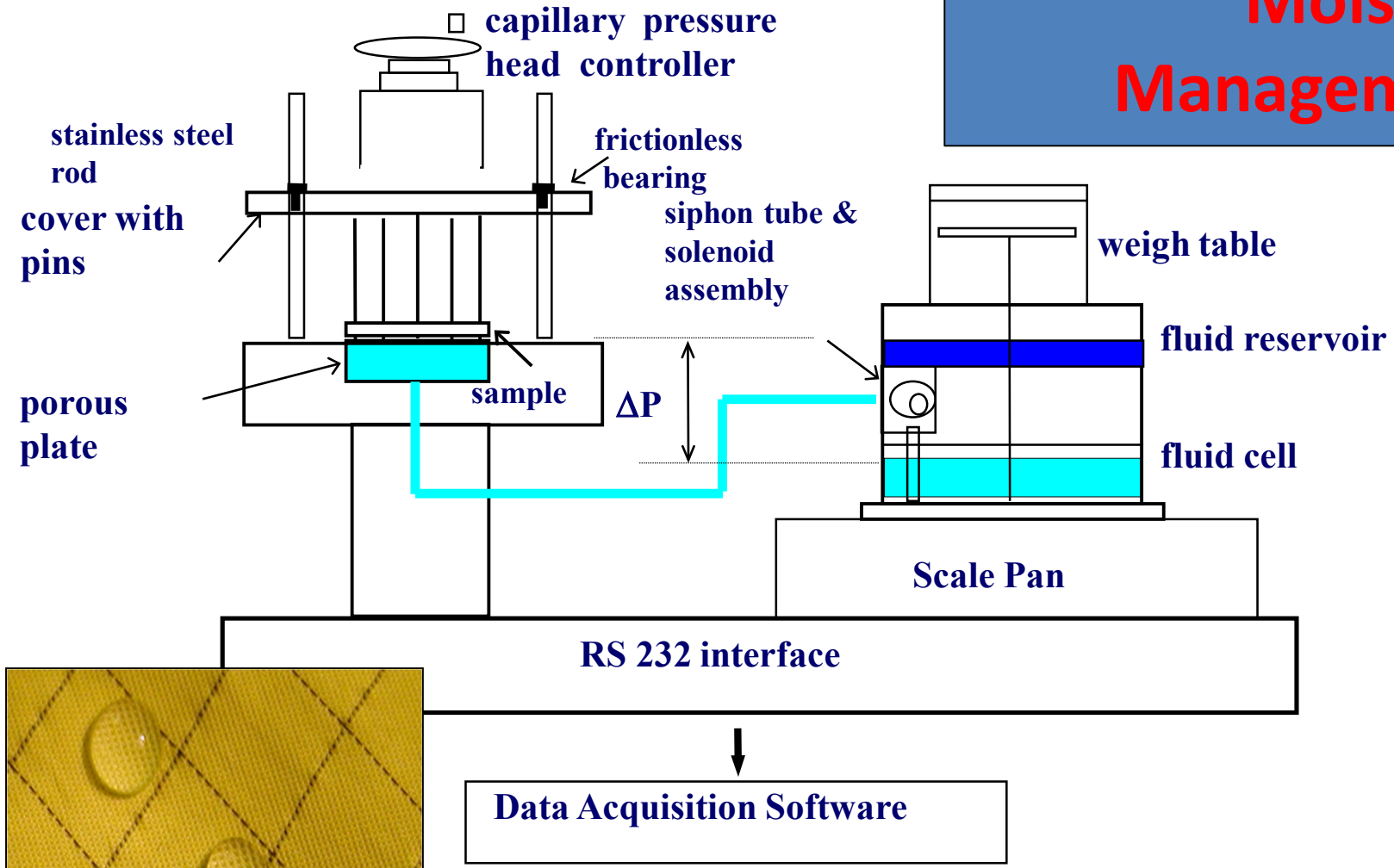
- What sequence of testing would you recommend to compare clothing comfort technologies?
- What is best way to identify best validated tests and support market claims based on scientific approach?

Moisture Management
Testing Options

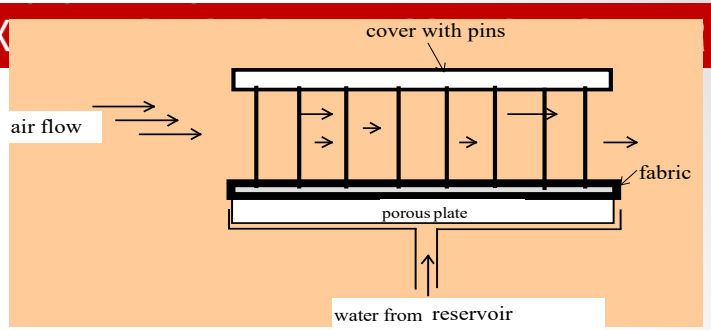
- Vertical wicking
- Horizontal wicking
- MMT-multi directional wicking
- TPACC GATS - demand wettability

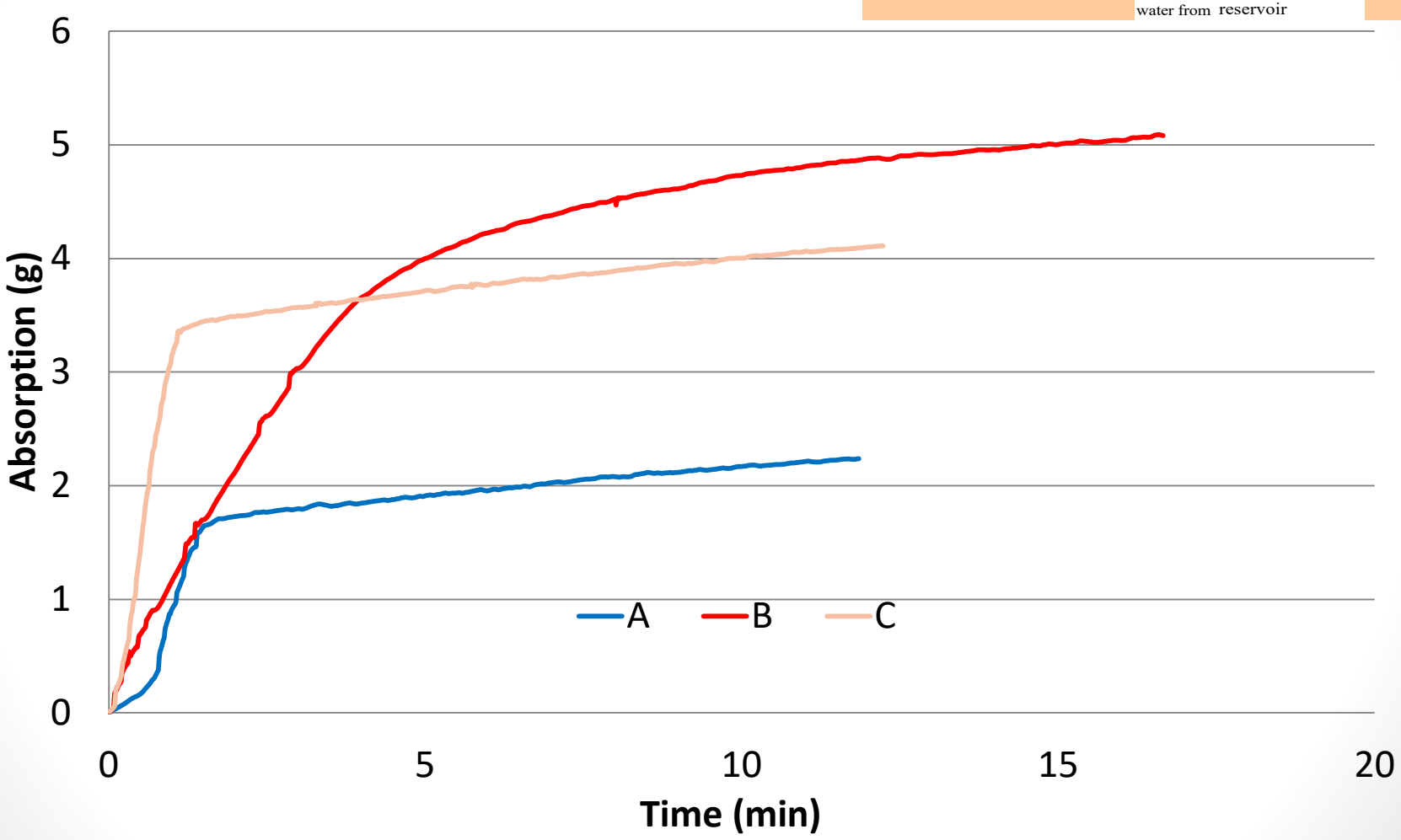


Liquid Moisture Management



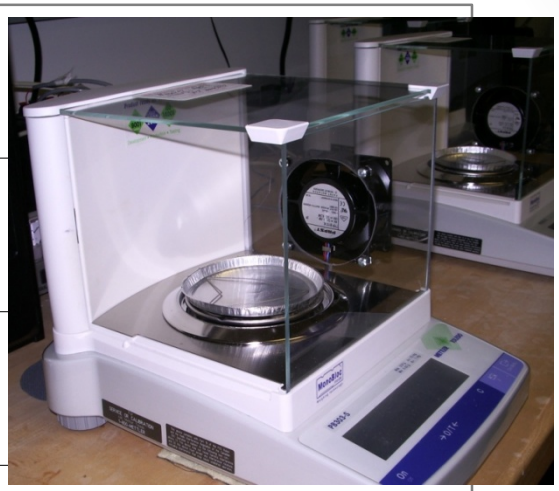
- Absorbent capacity
- Absorbent rate
- Ratio: Evaporation/absorption



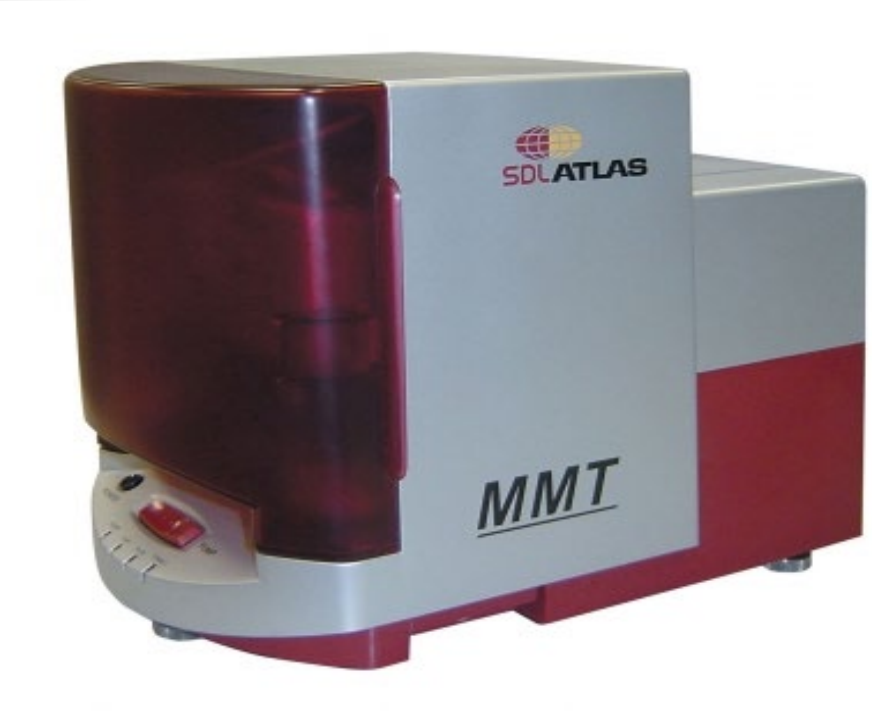


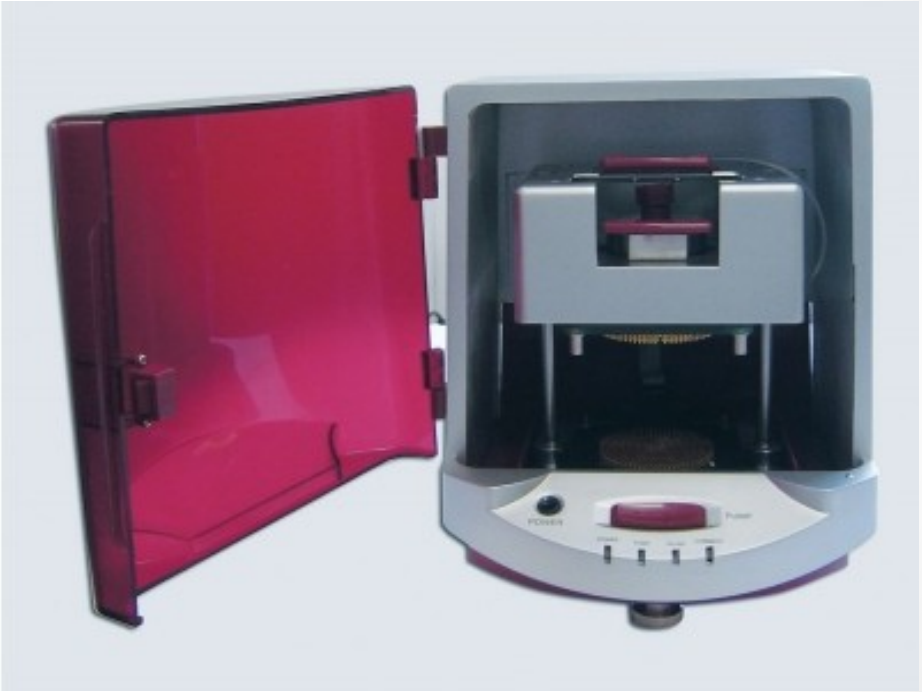
Absorption Behavior

Drying



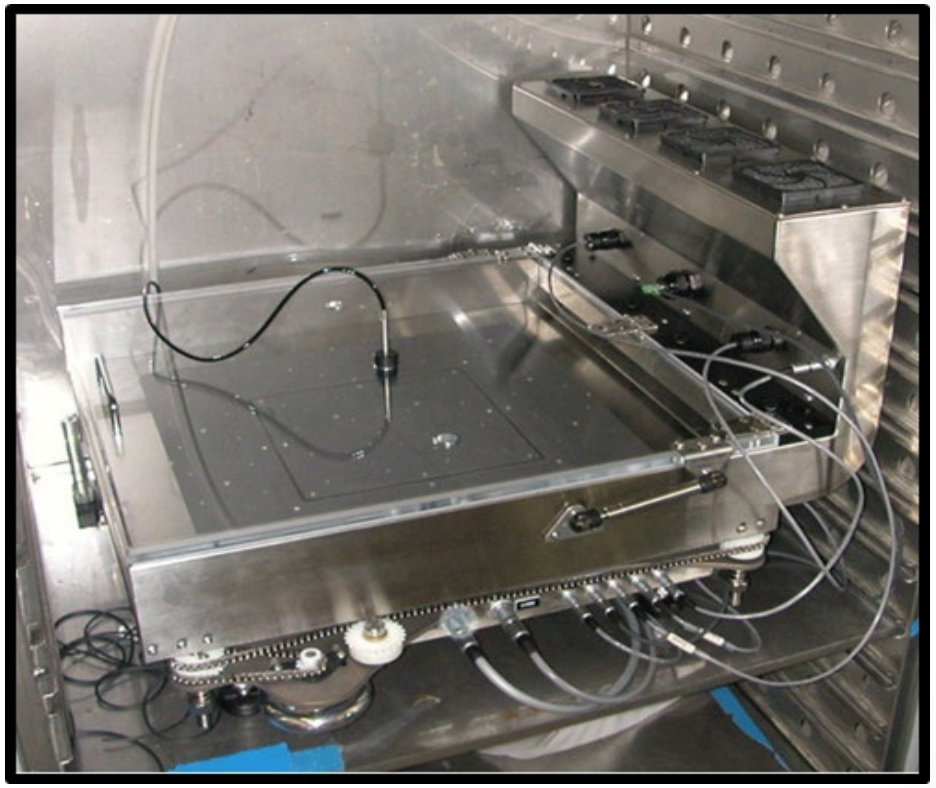
MMT





Guarded Sweating Hot Plate

- American Society for Testing and Materials (ASTM) F-1868 Standard Test Method
- 25°C; 65% RH; wind speed: 1 m/s

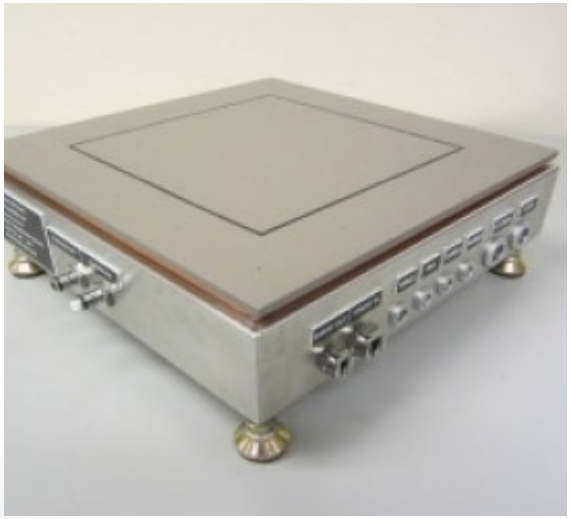


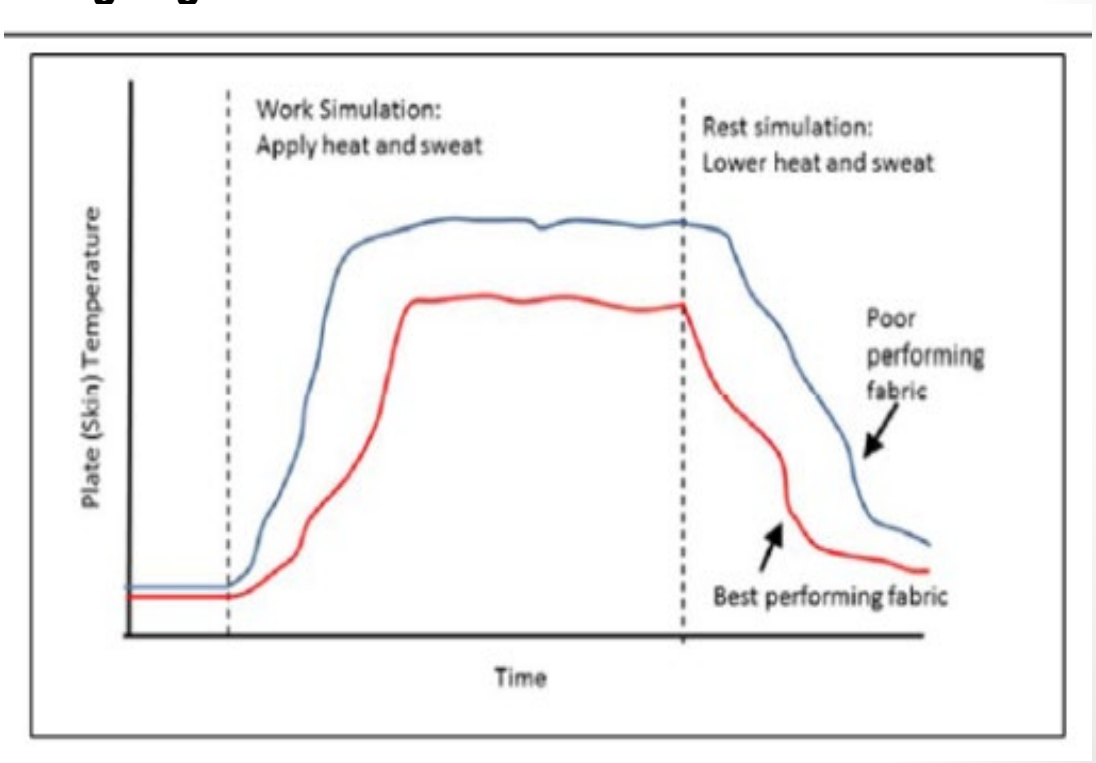
$$Q_t = \frac{T_s - T_a}{R_{cf} + K_c} + \frac{P_s - P_a}{AR_{ef} + K_e}$$

Dynamic Hot Plate Method

Measurements made with:

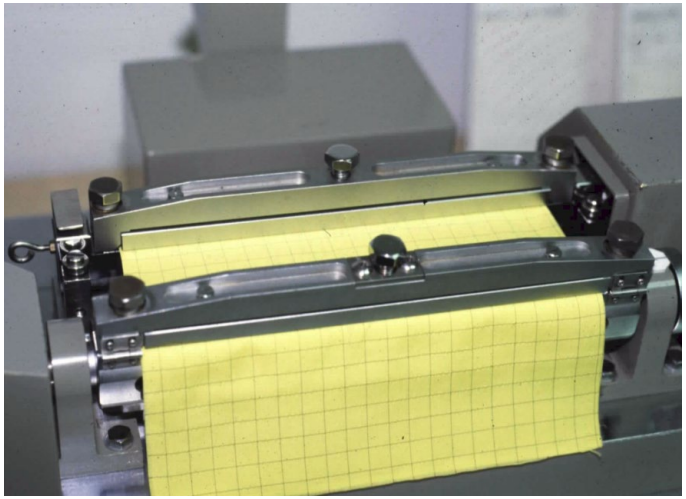
- **Hotter temperatures(water cooled)**
- **Measures incoming and outgoing heat flux**
- **Radiant loads**
- **Varying power**
  - **Work rates**





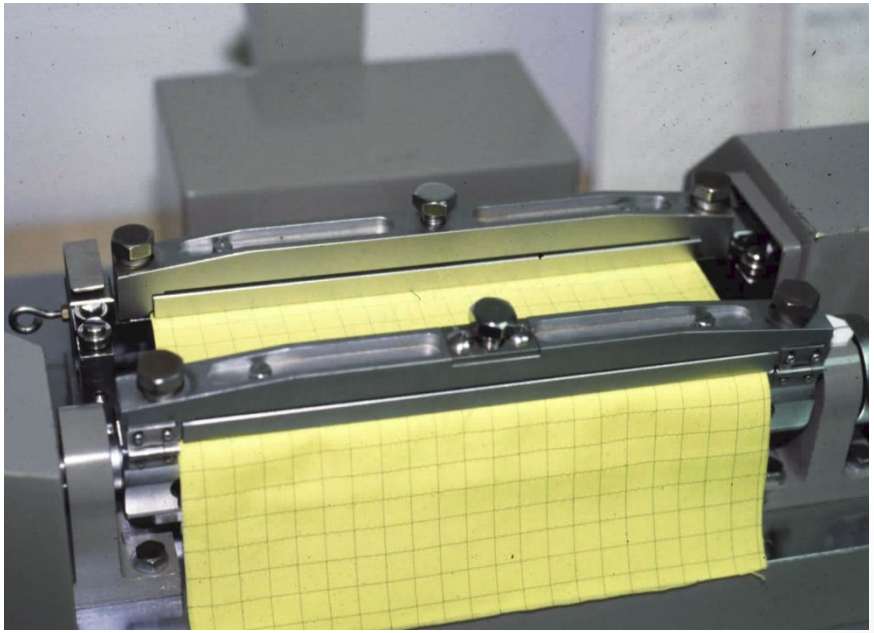
Haptics

- The study of the sense of touch—pressure, heat and cold, texture….



Kawabata Evaluation System (KES)

- Tensile
  - relates to elasticity
- Bending
  - relates to flexibility
- Shear
  - relates to flexibility
- Surface roughness
  - relates to scratchiness



Qmax-transient heat transfer from warm skin and cooler fabric. It indicates instantaneous cool-feel touch. It is best to see it not as an index of steady-state thermal insulation of fabrics.

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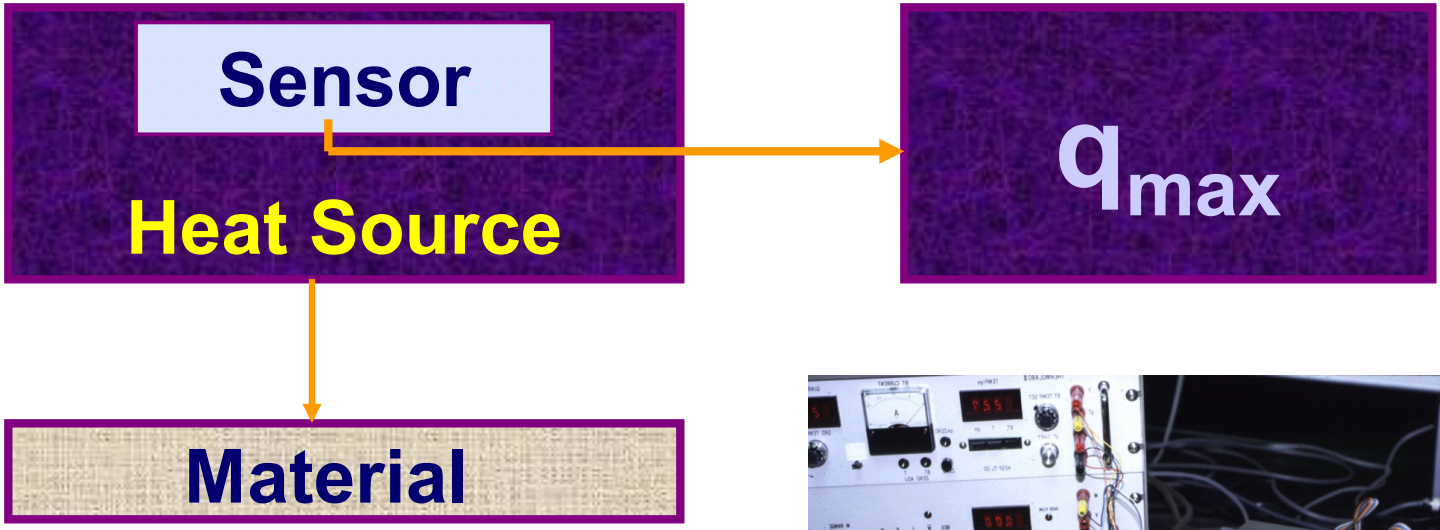
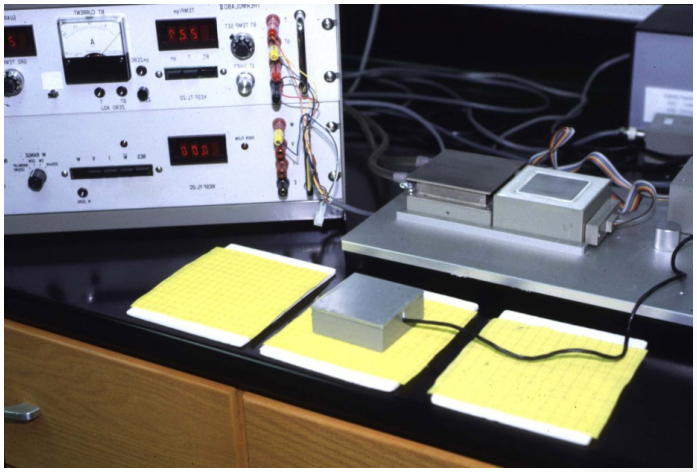
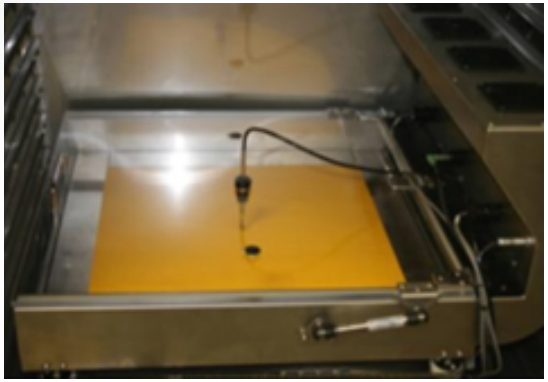
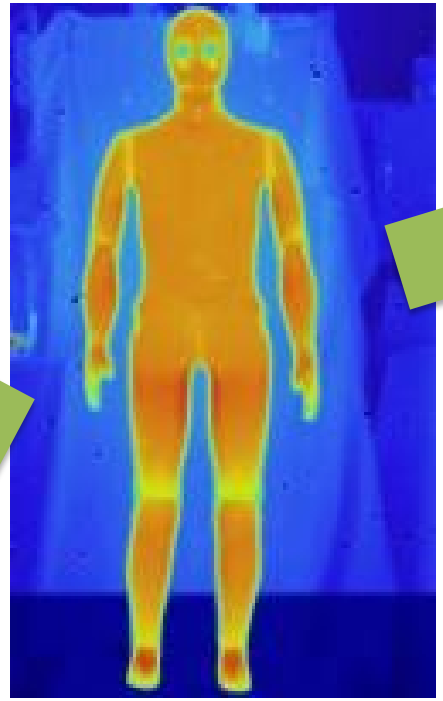




Multi-level heat strain studies:

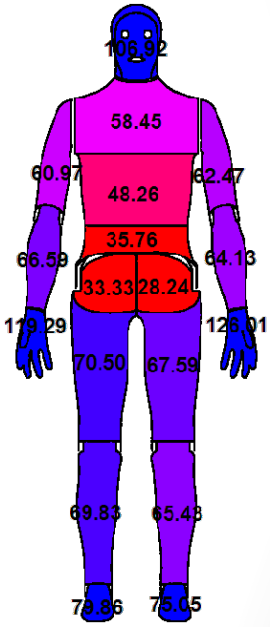




http://www.thermoanalytics.com

NCSU Sweating Manikin System

- 50th percentile male body form (178 cm, 72 kg morphology)
- 34 Zone "Newton" Manikin
  - Zonal heat and sweat control
  - Individual and overall measurements of garment insulation and breathability
  - Simulated walking motion
- Specialty Environmental Chamber
  - -7°C to 60°C
  - ~20 to 90% RH
  - 0 to 5 m/s wind
  - 0 to 1300 W/m^2 solar load



Raw Dry Heat Flux

Raw Wet Heat Flux

Rct

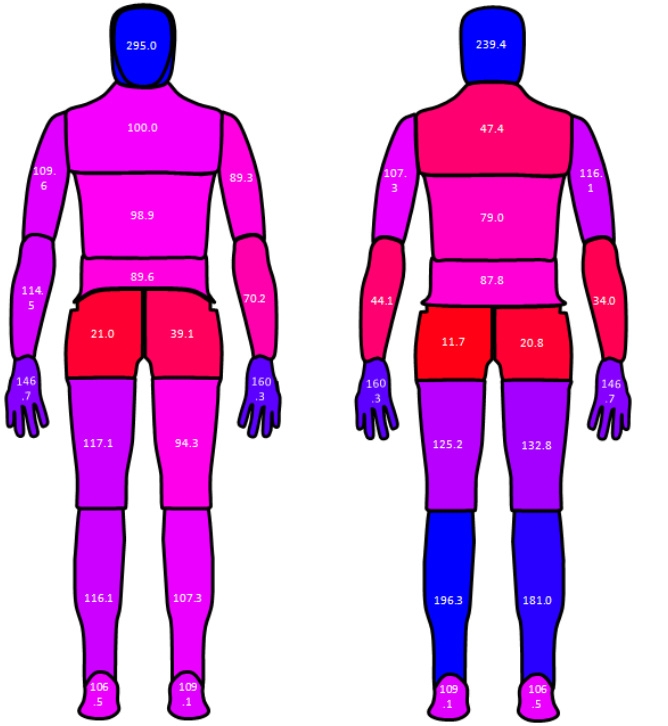
Ret

THL - Like Conditions

THL - Isothermal

THL - Predictive

Capture



Dry Component - Like Conditions

Dry Component - Isothermal Conditions

Dry Component - Predictive Conditions

Wet Component - Like Conditions

Wet Component - Isothermal Conditions

Wet Component - Predictive Conditions

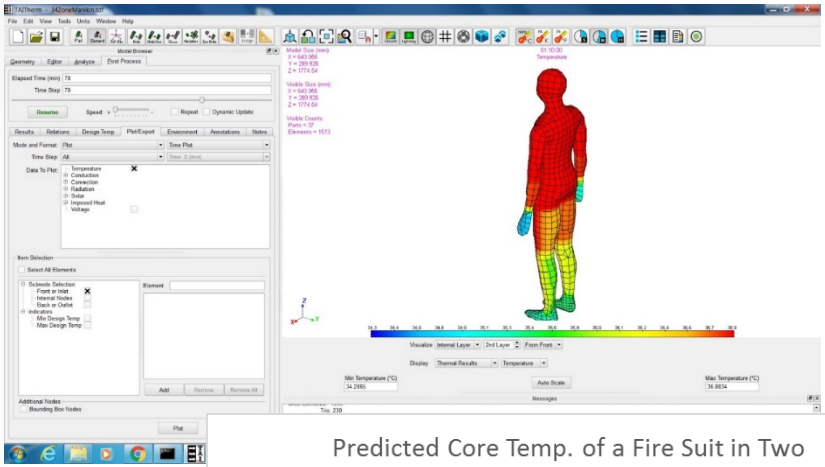
0 Total Heat Loss (W/m2) 200

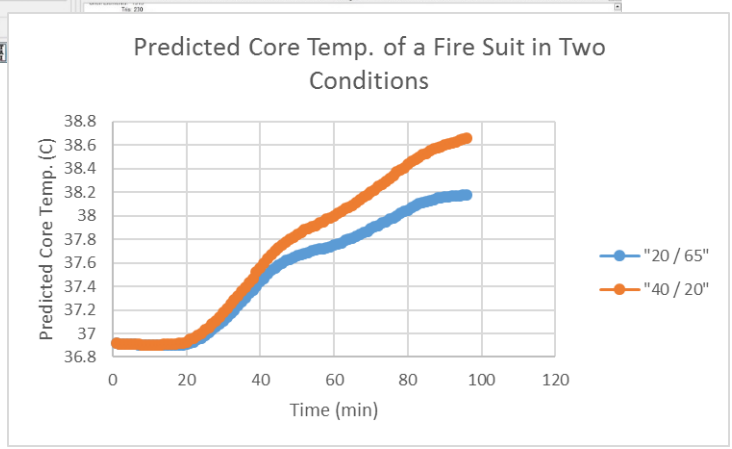
Dry Heat Flux 0		200
Wet Heat Flux 0		200
Rct 0		1
Ret 0		1000
THL 0	0 Total Heat Loss (W/m2) 200	200
Dry Component of Heat Loss 0		200
Wet Component of Heat Loss 0		200

Prediction Conditions

Temperature	16.70
Humidity	42.00

Use Physiological model to predict human heat strain response based on:



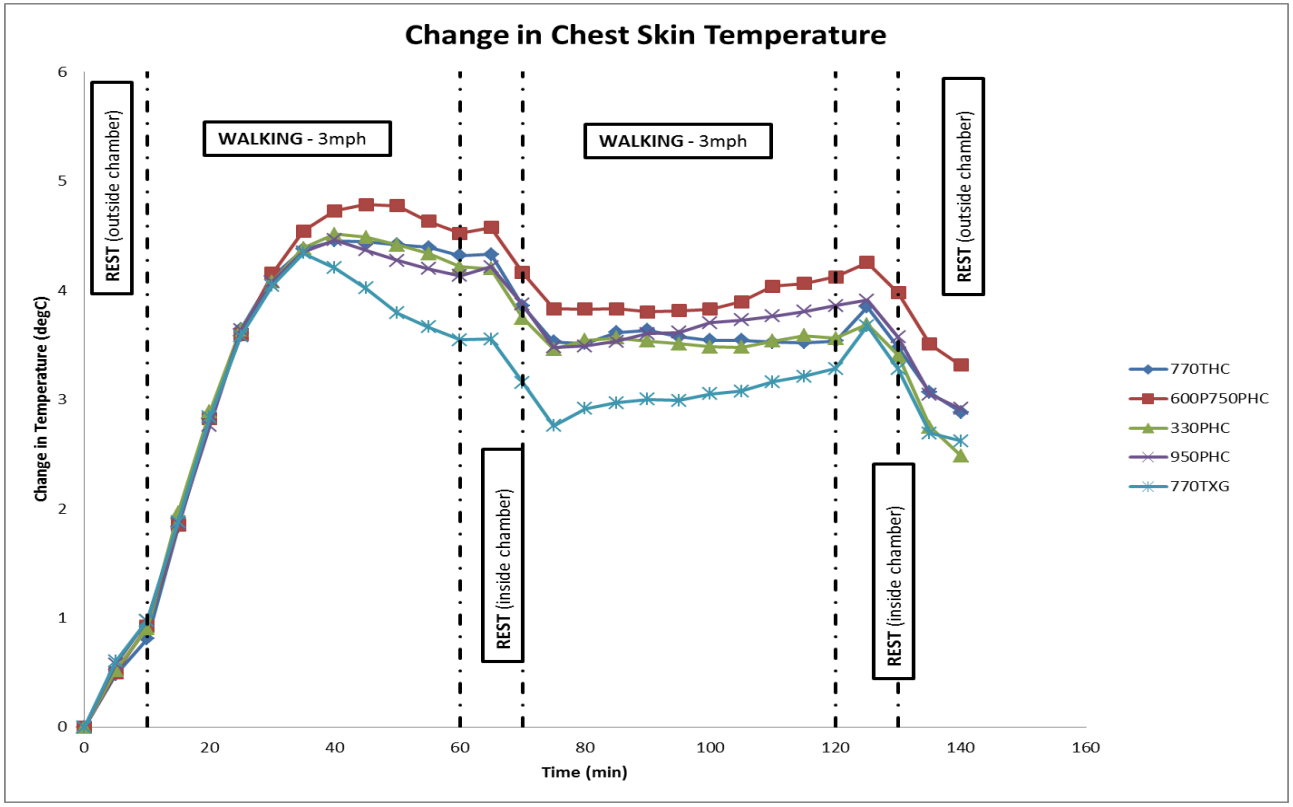


- **Inputs needed for Modeling**
  - **Clothing properties**
  - **Work Rates**
  - **Environmental Conditions**
  - **Time**

- **Outputs**
  - **Predicted physiological parameters**

We will model multiple end-use scenarios and environmental conditions

Chest Skin Temperature



Comfort Myths and Traps

- Not understanding the importance of wear conditions and consumer product expectations
- Singular focus on one performance aspect to support marketing claims
- Relying too much on not validated test methods in the absence of true performance criteria
- Forgetting about the importance of fabric tactile properties
- Its all about breathability-whatever that means?
- Its all about moisture management-whatever that means?
- Getting carried away with bench fabric property differences.
- Not recognizing the importance of garment fit and design.
- Negating a fabric level comfort advantage with poor garment design

Evolution of Fire Protection Testing Technology

ASTM D6413

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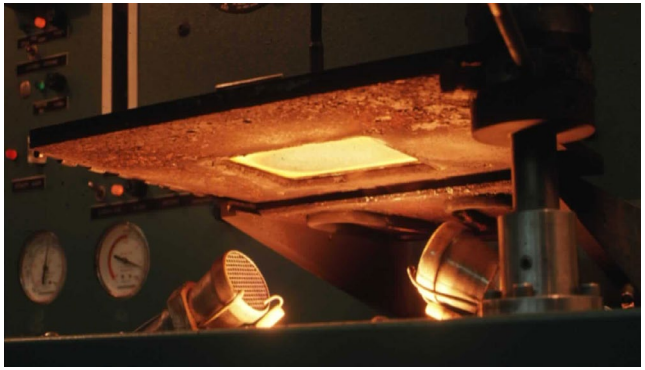


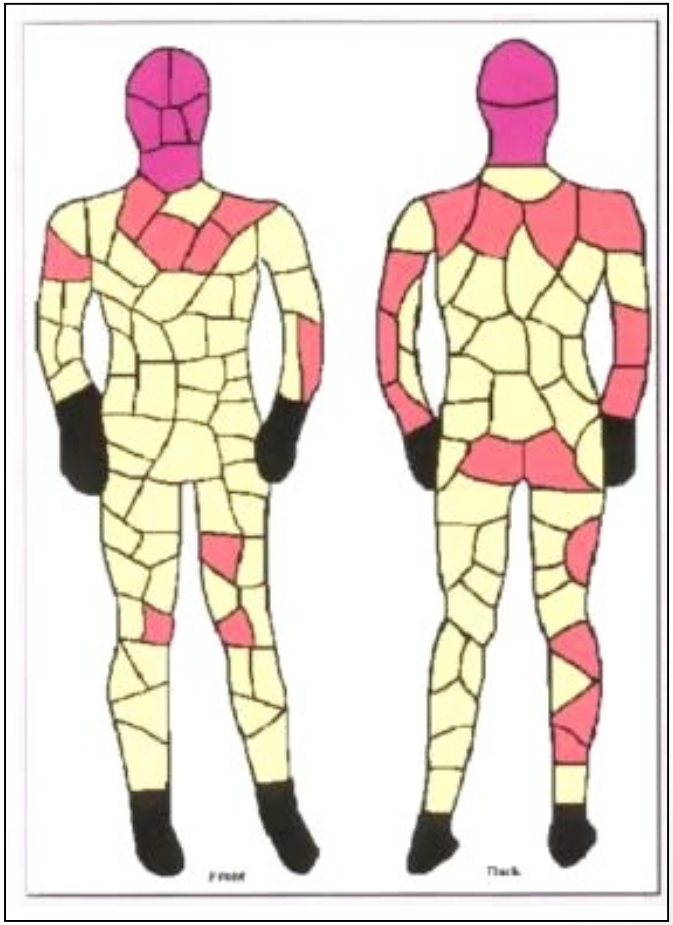
ASTM F2700 & ASTM F2703

ASTM F1930 & ISO 13506-1

Why Perform Flash Fire Testing
Does flame retardant mean Flash Fire Protection*?

*http://tyndaleusa.com/fr-clothing-safety-library/standards-and-test-methods/general-fr-clothing-standards/astm-f2302/

NCSU PyroMan



Standard Test Methods Developed or Improved by T-PACC

- Total Heat Loss
- Manikin Heat Loss
- Flashfire Manikin
- Stored Energy Test
- Thermal Protective Performance
- Radiant Protective Performance
- Glove Grip Test
- Glove Dexterity Test
- Man-in-Simulant Test
- Chemical Permeation Test
- PyroHand and PyroHead*
- Off-gassing Under Thermal Exposures*

* Method under final development and consideration

Take Away

TPACC is celebrating the 25th anniversary of education, research and service!

How can TPACC help you customize a *comprehensive* testing program for your product comfort and/or protection performance!

Thank You!

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