Advances in FR Test Method Development

ADVANCED PLANNING BRIEF TO INDUSTRY
May 12, 2011
Springfield, VA

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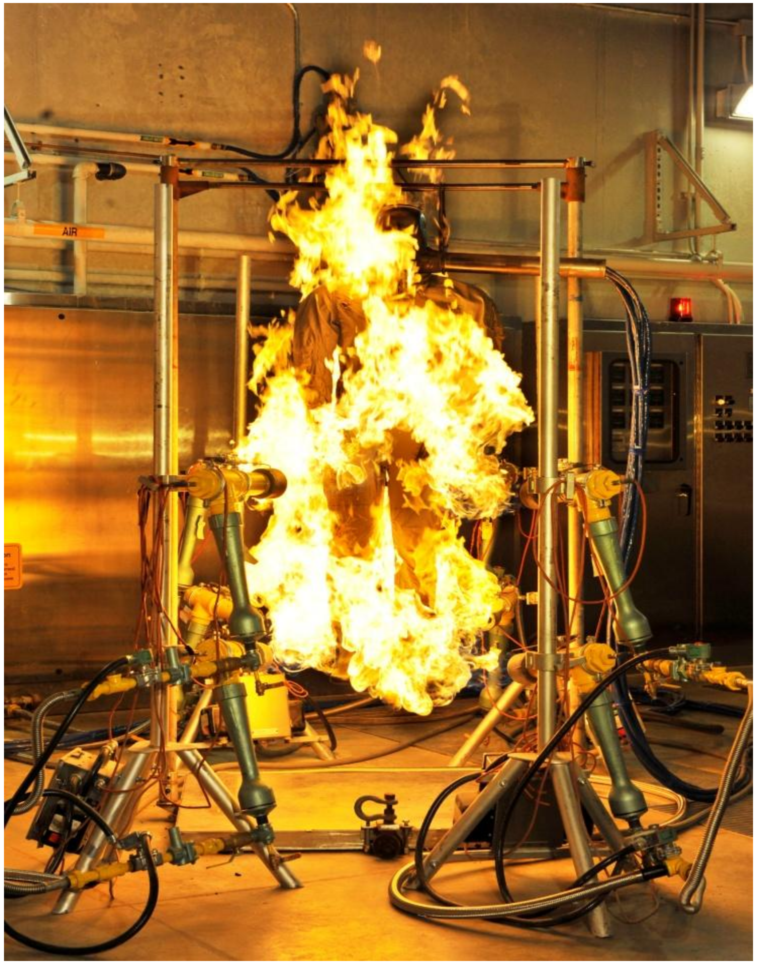
US ARMY RDECOM

US ARMY NATICK SOLDIER RD&E CENTER

Full- Scale - ASTM F1930

Calibration Burn



Clothing Burn

US ARMY RDECOM

Development of Mid-Scale FR Test System and Related Test Methodologies

US ARMY NATICK SOLDIER RD&E CENTER

Total $1.3M

Schedule & Cost

MILESTONES	FY11	FY12	FY13	FY14
Determine most needed small scale systems test				
Design and build test apparatus				
Evaluate small scale systems.				
TOTAL 62786/H98 S&T $M	0.5	0.4	0.4	

Milestone Indicators: TRL or SRL: ◆ Milestone Timeline: ▬

Purpose:

To develop a mid- scale FR test apparatus and cost effective test method capable of assessing multiple aspects of performance, such as durability or resistance to combined blast/high heat flux, in new FR materials & constructions.

Results/Products:

- New mid-scale test apparatus and method for assessing durability and FR
- Mock up garment constructions/systems that can be tested on a smaller scale prior to or in place of full-scale ASTM F1930 testing.
- Orientation and configuration of materials in the prototype system will be similar to actual wear conditions and performance should correlate to full scale testing.
- Multiple conditions can be evaluated.

Payoff:

- More rapid and cost-effective evaluation of clothing having multiple components than current manikin testing
- More reproducible results and better correlation of testing to actual use conditions than small-scale fabric testing

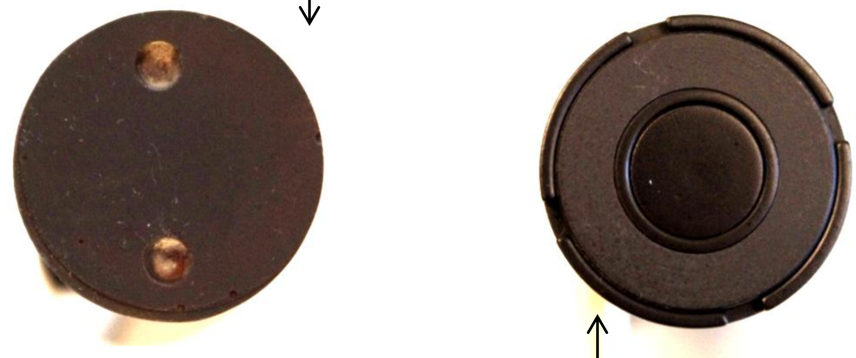
Mid-Scale FR Test System

Burners

Propane Torch - 400K BTU

Sensors

Embedded Thermocouple



Insulated Copper

Cylindrical Form- Candidate Materials

High performance thermoset composite materials

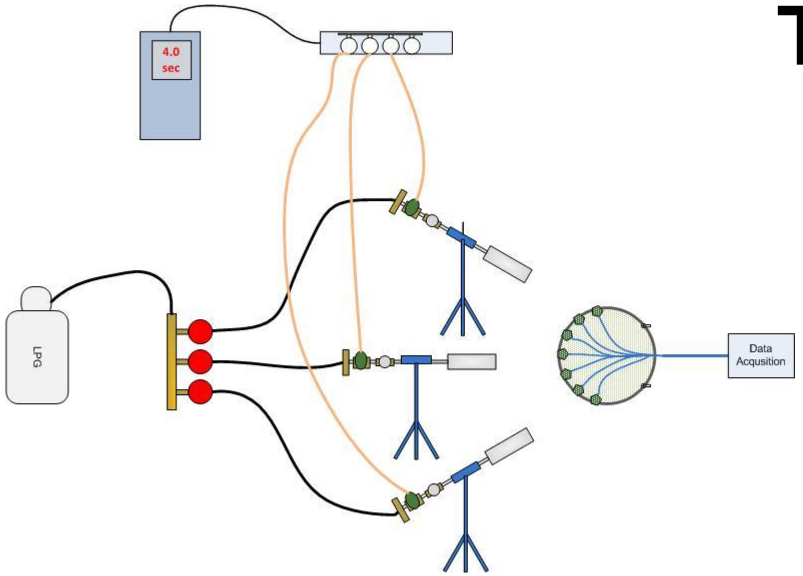
glass reinforced with FR resins

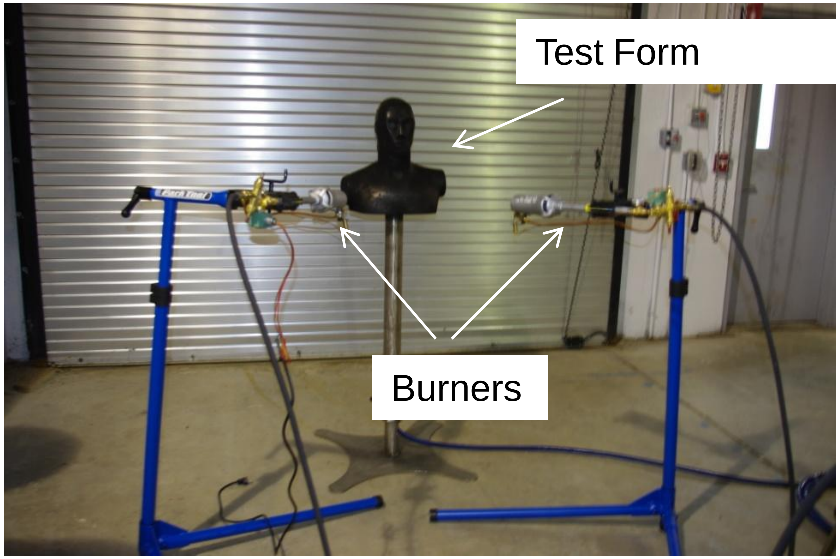
silicone resin

phenolic resins

flexible ceramics

Mid-Scale FR Test System





Test Parameters

Heat Flux

2 cal/cm^2/sec or 84 kW/m^2

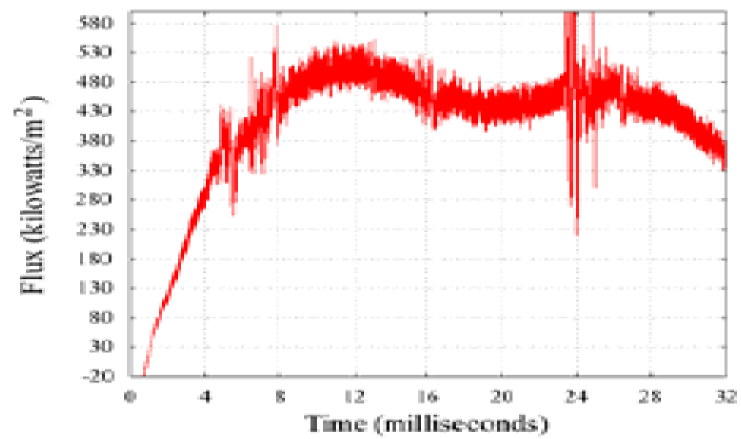
Duration

4 - 20 seconds

Test Form

Flexible- tube (torso)
head
hand

Thermal Effects of Explosive Devices



Fireball

High flux Short duration thermal radiation

Pressure Wave

CO_2 Laser as Radiant Heat Source

CHALLENGES

Thermal Threat

Even heat distribution during short intense heat flux exposure

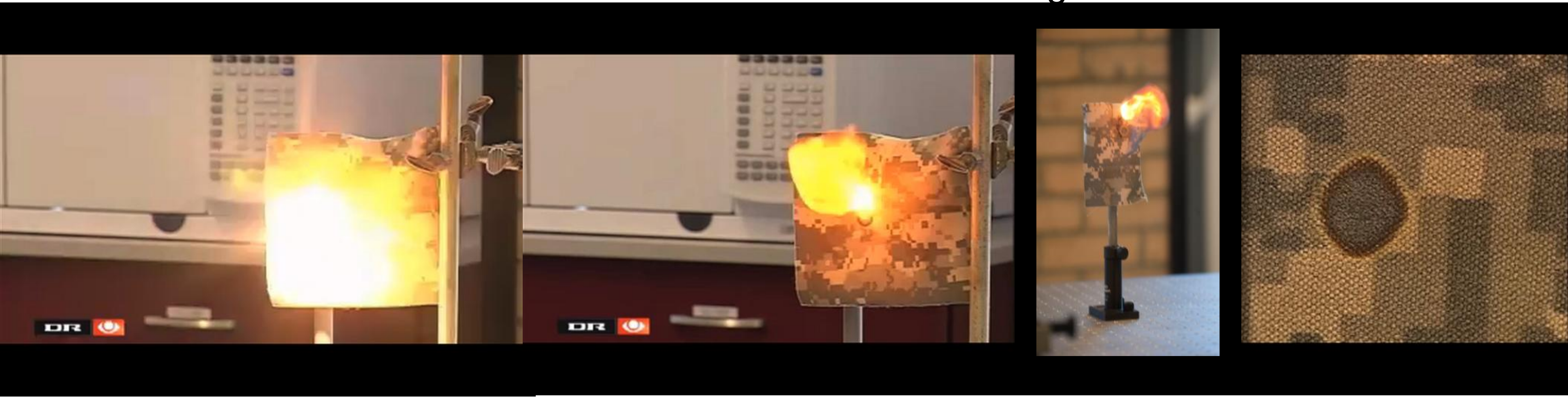
Sensors/Data Acquisition

Fast response (millisecond)

Burn injury model

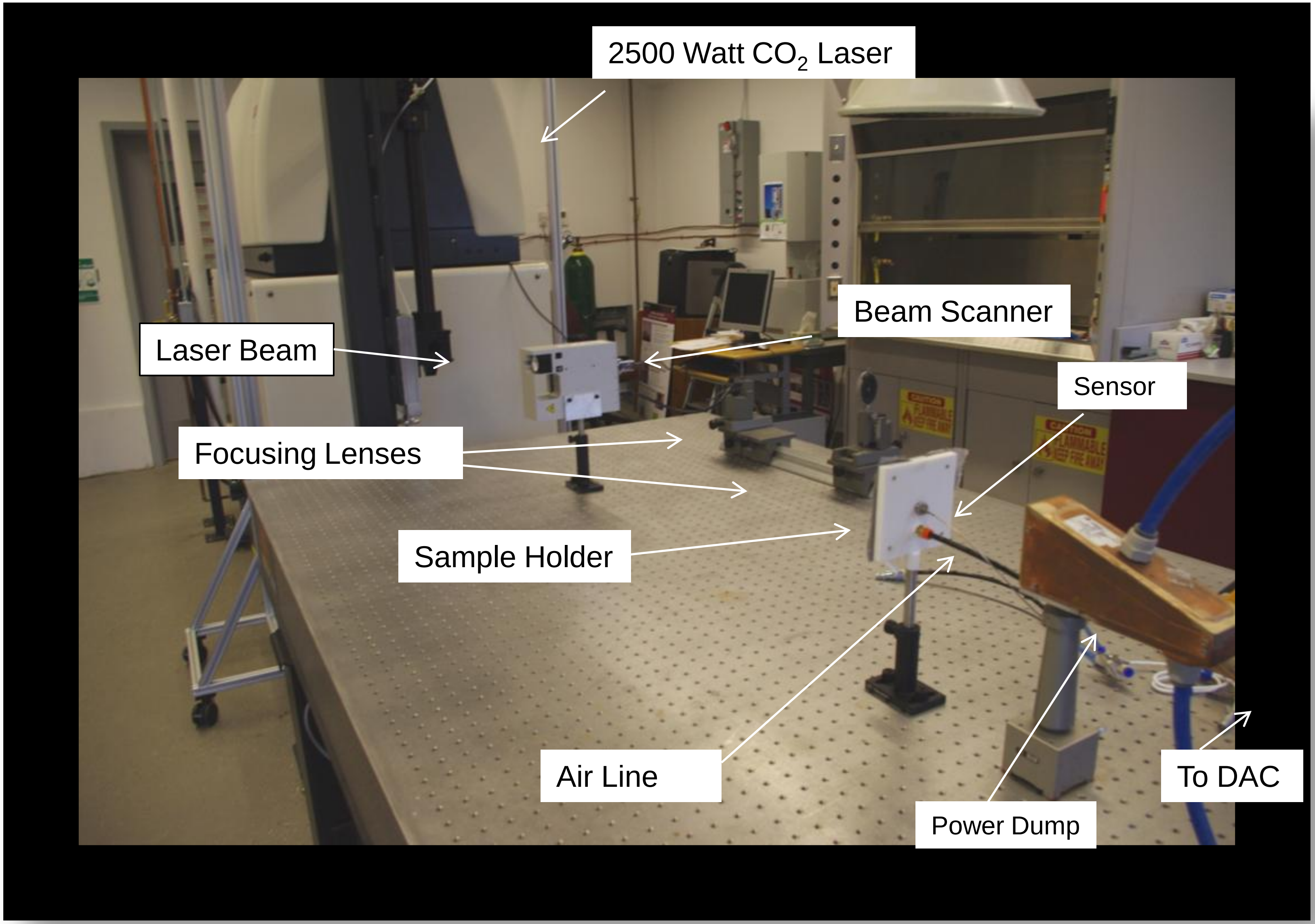
Modifications may be required

Testing of Plastic Block

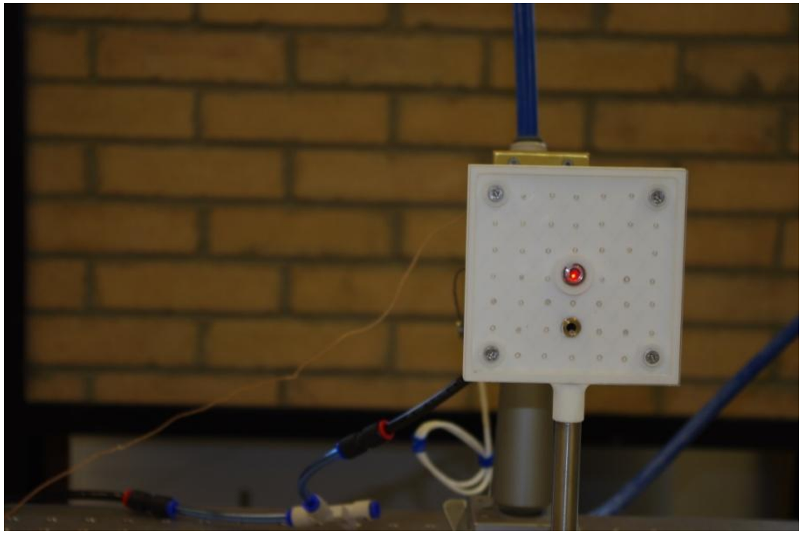


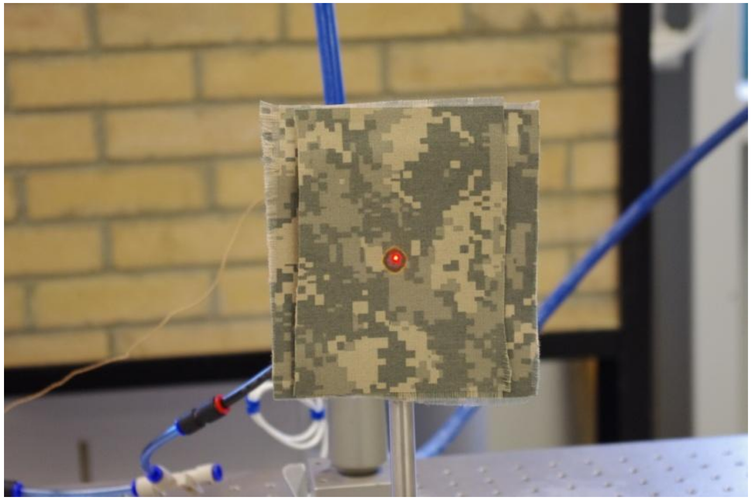
Testing of FR fabrics

CO_2 Laser Fabric Swatch Test

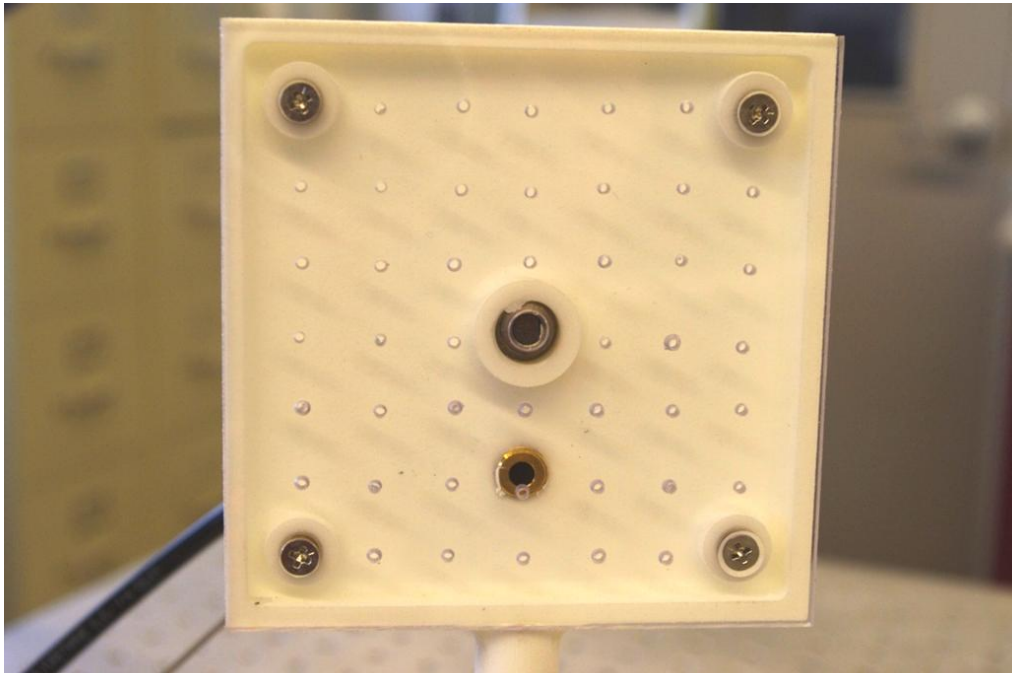


CO_2 Laser Fabric Swatch Test

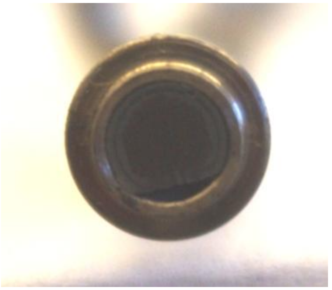




Sample Holder



Sensor



Development of Realistic Burn Injury Predictions

- Prediction of third degree burns is not within the precision of the existing ASTM burn injury prediction models.
- No real human third degree burn data exists, and test cases to verify the ASTM F1930 standard burn injury prediction model deal only with second degree burns.
- Prediction of third degree burns is a significant concern, a better understanding of the significance of these predicted values is required in order to address these limitations in the mid-scale test.

Development of Realistic Burn Injury Predictions

NSRDEC will work with the medical community to provide realistic burn injury predictions to include 3rd degree burns.

- BURNSIM
- Skin thickness in various locations of body
- Human physiology

Summary

NSRDEC is working on developing:

- Mid-Scale FR Test System
- CO2 Laser Fabric Swatch Test Method
- More realistic Burn Injury Model
  - 3rd degree burn injury

Backup Slides

The Ouellette Thermal Test Facility

Facility Facts:

8,100 sq. ft. joint Army/Navy Facility

Four laboratories and Propane Test Cell

Purpose:

To evaluate and characterize the effect of flame and thermal threats on materials under defined flame and thermal conditions.

Assist in the development of improved materials.

Develop new test methods

THERMAL BARRIER TEST APPARTUS (TBTA)

Sample Size: 5" x 7"

Heat Source: Radiant (above sample)
(up to 3.0 $cal/cm^2/sec$)

Test Method: NSRDEC

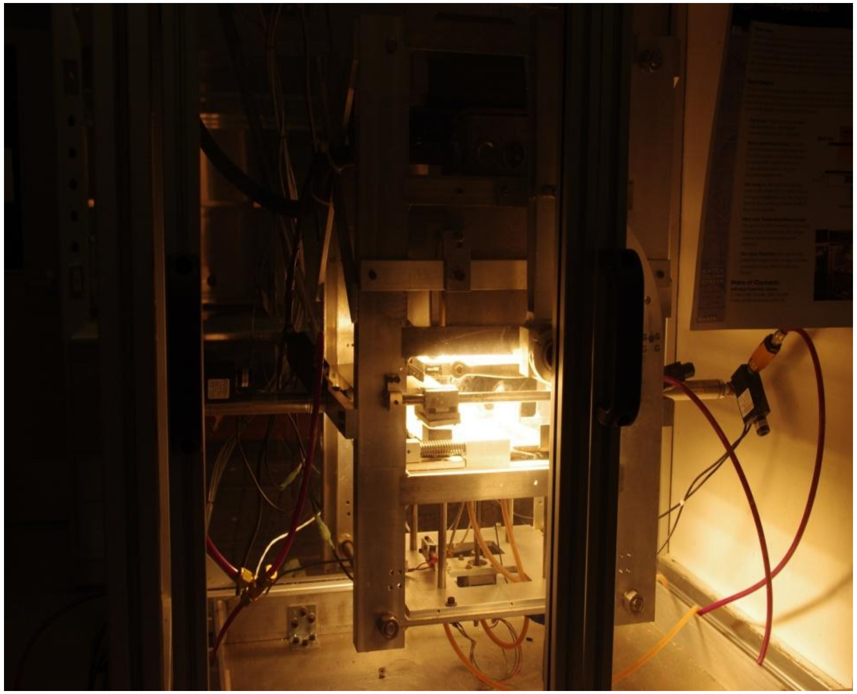
Sample Orientation: Horizontal
Device rotates(0,30,60, 90,deg)

Evaluation Criteria:
Skin Simulant Sensor
Heat Flux Gage

Test Results: Burn Injury Prediction &
Thermal Protection

Test Duration: User Defined

Dwell Times: User Defined



Burn Pit

Size: 8 ft x 12 ft
Burners: 9 – 7 foot ribbon burners 6 inch below floor level

Simulates:
A fire moving across the grass and under a tent.
Thermal effects of explosive device originating under an object.

NSRDEC Biotechnology

Eco-friendly FR materials

Human and Environmentally Safe Flame Retardant (FR) Materials

NSRDEC has developed significant capabilities in the study of "eco-friendly" methods for developing FR materials

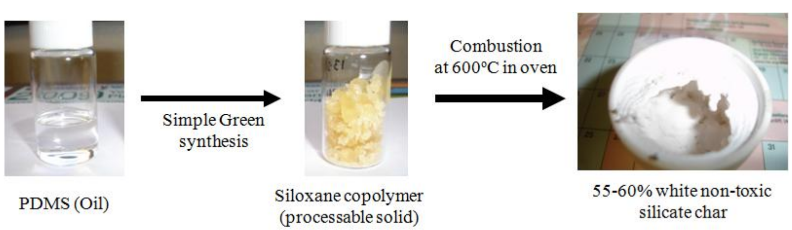
Objective: Synthesize and understand the thermal degradation mechanisms responsible for the flame retardancy of novel polyborosiloxane terpolymers and understand the synergistic effects of nanoclays/fillers on polysiloxane FR properties

Scientific Impact: This work represents an opportunity for the synthesis of novel human and environmentally friendly FR polysiloxane copolymers and blends through the incorporation of boron, nanoclays, and fillers.

Outcomes:

- Novel siloxane based polymers with enhanced thermal and flame retardant properties
- New environmentally benign processes for synthesizing siloxane based polymers that do not have any toxic combustion by-products

Synthesis and combustion of a siloxane copolymer



SOLVENT FREE synthesis

Enhanced Thermal and Flame Retardant Properties

Potentially Cost-effective FR material

Development of Flame and Thermal Resistant Fibers and Coatings for Soldier Protection

NSRDEC has developed capabilities for producing "eco-friendly" flame and thermal resistant fibers and coatings

Objective: Utilize polyborosiloxane terpolymers and polysiloxane copolymer blends to prepare novel coatings and fibers for FR textiles

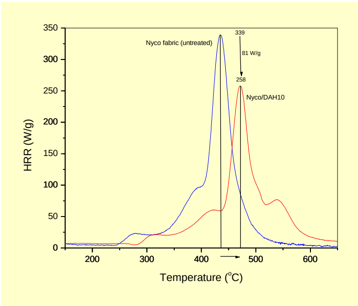
Scientific Impact: This work represents an opportunity for the preparation of fibers and fabric coatings from novel human and environmentally friendly FR polysiloxane copolymers, nanocomposites and blends

Outcomes:

- Novel siloxane based polymer coated fabrics and fibers with enhanced thermal and flame retardant properties
- New environmentally benign processes for synthesizing siloxane based polymers that do not have any toxic combustion by-products

Polysiloxane coatings and fibers

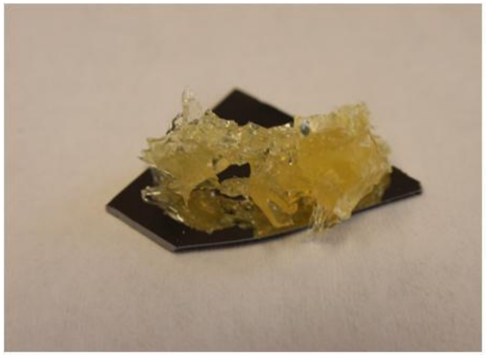
PS coated fabric



PCFC curves of DAH10 coated NyCo Fabric

Extruded thick fiber

Char Images and Elemental Analysis



Before burn

After burn

(a)

Before burn

After burn

(b)

Char images of (a) PBS-DAH (no boron) and (b) PBS-DAH-9 (3.9 wt% PBA feed or atomic B=0.5%, from Elemental Analysis).

Char images

- A dense carbonaceous char was observed when no boron was present in the polymers (a).
- Boron content (<1%) is primarily responsible for improving the FR properties (through catalyzing the formation of an intumescent glassy char (b).

Elemental Analysis

- Elemental analysis on the PBS-Oxy-3 and PBS-DAH-9 samples before and after burning confirmed the presence of boron and silicon in the polymers as well as their chars.
- Si:B ratio in these two polymers are 1:0.03 and 1:0.12 respectively. The higher boron content in PBS-DAH-9 compared to PBS-Oxy-3 is presumably responsible for the enhanced thermal and FR properties.

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