A Report

to

Westex by Milliken

on

Characterization of Test Garments Using the PyroMan™ System

from

Textile Protection and Comfort Center (T-PACC)
College of Textiles
North Carolina State University
Raleigh, North Carolina 27695-8301

August 14, 2018

Characterization of Test Garments Using the PyroMan™ System

Ensembles were submitted by **Westex by Milliken** to the Textile Protection and Comfort Center (T-PACC) in the College of Textiles at North Carolina State University. These garments were evaluated for resistance to a simulated flash fire exposure employing procedures similar to ASTM F 1930 *Standard Test Method for Evaluation of Flame Resistant Clothing for Protection Against Flash Fire Simulations Using an Instrumented Manikin,* and *NFPA 2112: Standard on Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire*, see the "Thermal Protective Clothing Analysis" for each test found in Appendix A for details.. The purpose of this report is to describe the testing system used and to present the results.

NCSU PyroMan™ Test System

The PyroMan™ System consists of a number of components, designed to work together to measure the performance of protective clothing under full scale, flash fire exposure conditions. The most important requirements of this flash fire system are safe operation and reproducibility. The layout of system components is shown in Figure 1.

Fire Chamber: The instrumented manikin and the exposure system are housed in a flame resistant room with large viewing windows on one wall and double entrance doors on the opposite wall. The fire chamber is provided with supply and exhaust ducts and fans, which are automatically controlled to provide safe startup of the system and rapid removal of the products of combustion and degradation after a test exposure.

Gas Supply System: Pressure sensitive switches monitor the system to maintain safe operating conditions. Propane gas is supplied to the burner system through a series of valves and reducers. Electrically controlled valves prevent supply of high-pressure gas for the test exposure until all of the safety devices are satisfied and the test is ready to be run. The gas supply line is vented through solenoid valves, which are open, when the system is not in use.

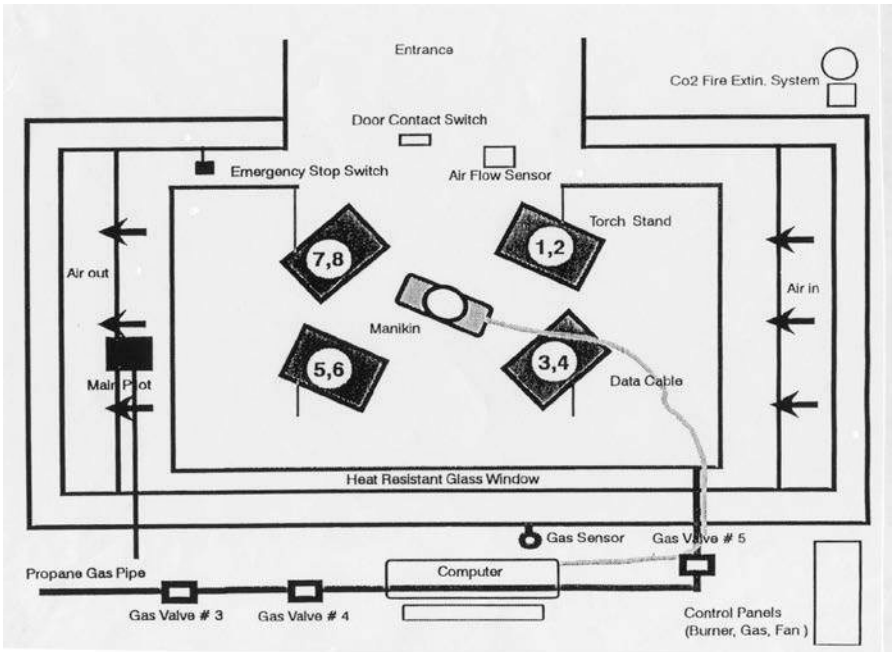


Figure 1. Fire Chamber and Gas Delivery System

Burners & Gas Control Panel: Eight industrial burners, modified to produce the flash fire, are carefully positioned to create a large volume of fire that fully engulfs

the manikin. Each burner has a pilot flame that is lighted and proven before the gas is supplied to the torch. A gas control panel monitors the state of each pilot flame to prevent opening of the exposure torch valve if there is no pilot flame present. This panel also monitors the condition of the supply line and safety devices and, in case of a malfunction, will shut the system down and vent the gas in the supply line.

Manikin: The test manikin, suspended from the ceiling of the burn chamber on an adjustable fixture, is a size 40 regular male, made from a flame resistant polyester resin reinforced with fiber glass (Figure 2). There are sockets, uniformly distributed on the surface, for 122 heat sensors. Leads from each sensor are taken to the data acquisition unit through a guarded, heat-shielded cable.

Computer System: After dressing the manikin, safe operating conditions are assured via interaction with a sophisticated computer system used to control the test procedure, to include the lighting of pilot flames, exposing the test garment to the flash fire, acquisition of data, and running the fans to vent the chamber. Data acquired by the system is used to calculate the incident heat flux, predicted burn injury for each sensor during and after the exposure, and produce a report and graphics each test.

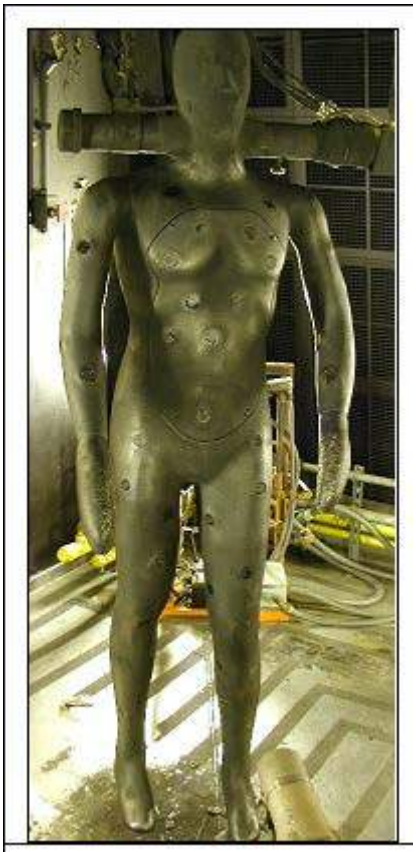


Figure 2. PyroMan™ Manikin

Test Materials

The ensembles were tested as received. For clothing and laundry specifics, see the "Thermal Protective Clothing Analysis" for each test found in Appendix A.

Test Results

Measuring the amount of heat transfer a garment allows to a manikin during a flash fire simulation can assess flash fire resistance. This transferred heat can be expressed in terms of predicted burn damage to human skin. This can be done by using heat flux measured at the manikin surface to estimate changes in the temperature throughout the layers of human skin including the epidermis, dermis, and subcutaneous layers. These temperatures can then be used to predict if a sufficient amount of energy has been transferred to produce either a second or third degree burn.

Prior to testing, a nude manikin calibration was done with a **3** seconds exposure. All test garments were evaluated with an average heat flux of 2.00 cal/cm^{2}sec ± 0.05 cal/cm^{2}sec with a flash fire exposure of **3** seconds. Test results are summarized in Table 1. Detailed data,

including test summary, comment sheet, burn injury prediction graphic, and before and after pictures, are found in Appendix A.

The extinguish time noted in test comment section reflects the time it takes for a garment to self extinguish from the end of the flame exposure.

Caveat: These data characterize the properties of materials or assemblies in response to radiant and convective energy under controlled laboratory conditions and should not be used to appraise the safety benefits or risk of materials, products, or assemblies under actual fire conditions. They are the results of specific laboratory exposures; extrapolations to other types of heat exposures or different combinations of radiant, convective and conductive assaults cannot be made. They are not presented to predict all types of field conditions where the nature of the thermal exposures can be physically complicated and unqualified. We wish to emphasize that it is not our intention to recommend, exclude, or predict the suitability of any commercial product for a particular end-use.

Table 1. Summary of Test Results

Burn (#)	**NCSU File ID**	**Flame Exposure (sec)**	**Sample ID**	**Predicted Burn (%)**		
				2nd	3rd	Overall
1	180814K	3	MPG S000107266 Coverall, Rep #1	8.197	6.557	14.75
2	180814L	3	MPG S000107266 Coverall, Rep #2	10.656	6.557	17.21
3	180814M	3	MPG S000107266 Coverall, Rep #3	9.016	6.557	15.57
			AVERAGE	**9.290**	**6.557**	**15.84**

Appendix A

PyroMan™ Test Specifications, Test Remarks, Photos, and Manikin Burn Injury Predictions

Thermal Protective Clothing Analysis

3-Layer Skin Model

File Name	180814K	Test Time	Tue, Aug 14, 2018 8:58 AM
System Identification	PyroMan™	Sponsor	WESTEX BY MILLIKEN

Garment Identification: MPG S000107266 COVERALL, REP #1

Garment size: NFPA 2112 REFERENCE

N Washes: 1 (-1 = Unknown) ✓ 100% Cotton Underwear & Tshirt

Garment/Fabric Comments:
LAYER 1: COTTON T-SHIRT AND BRIEF
LAYER 2: MPG S000107266, 6.0 OSY WESTEX SYNERGY PRO, 6.0 OSY, 93% META-ARAMID /5% PARA-ARAMID/ 2% ANTISTAT COVERALL

Pre Test Comments:
GARMENTS WERE PRECONDITIIONED BY UNDERWRITERS LABORATORIES ACCORDING TO NFPA 2112 SEC 8.5
CONDITIONED BY NC STATE UNIVERSITY AS SPECIFIED IN ASTM F1930-15
GARMENTS STORED IN CONDITIONED SPACE PRIOR TO TESTING
TESTING CONDUCTED ACCORDING TO ASTM F1930-15
TESTING CONDUCTED BY JOHN MORTON-ASLANIS, RESEARCH ASSOCIATE AND MARK MARTIN, RESEARCH TECHNICIAN

Post Test Comments:
AfterFlame: 3.79

Smoke Generation	Shrinkage	Break-Open	Embrittlement		
Light	Moderate	None	Durable	Start Room Temp (oC)	25
				Start Avg Sens. Temp (oC)	33

Vaisala RH (%): 52 Vaisala Temp (oF): 77 Grains of Water/ lb. Mass of Dry Air: 1

Total DAQ time (s): 60 Avg Expos. Heat Flux (cal/(cm^2*sec): 2.00 Scan Interval (s): 0.10

Exposure Time (s): 3.00 Torches Used: ALL ALL, or those used, separated by commas

Scrubber Time (s): 0 **Burn Calculation Time (s): 59.0**

% 2nd Degree Burns: 8.197

% 3rd Degree Burns: 6.557

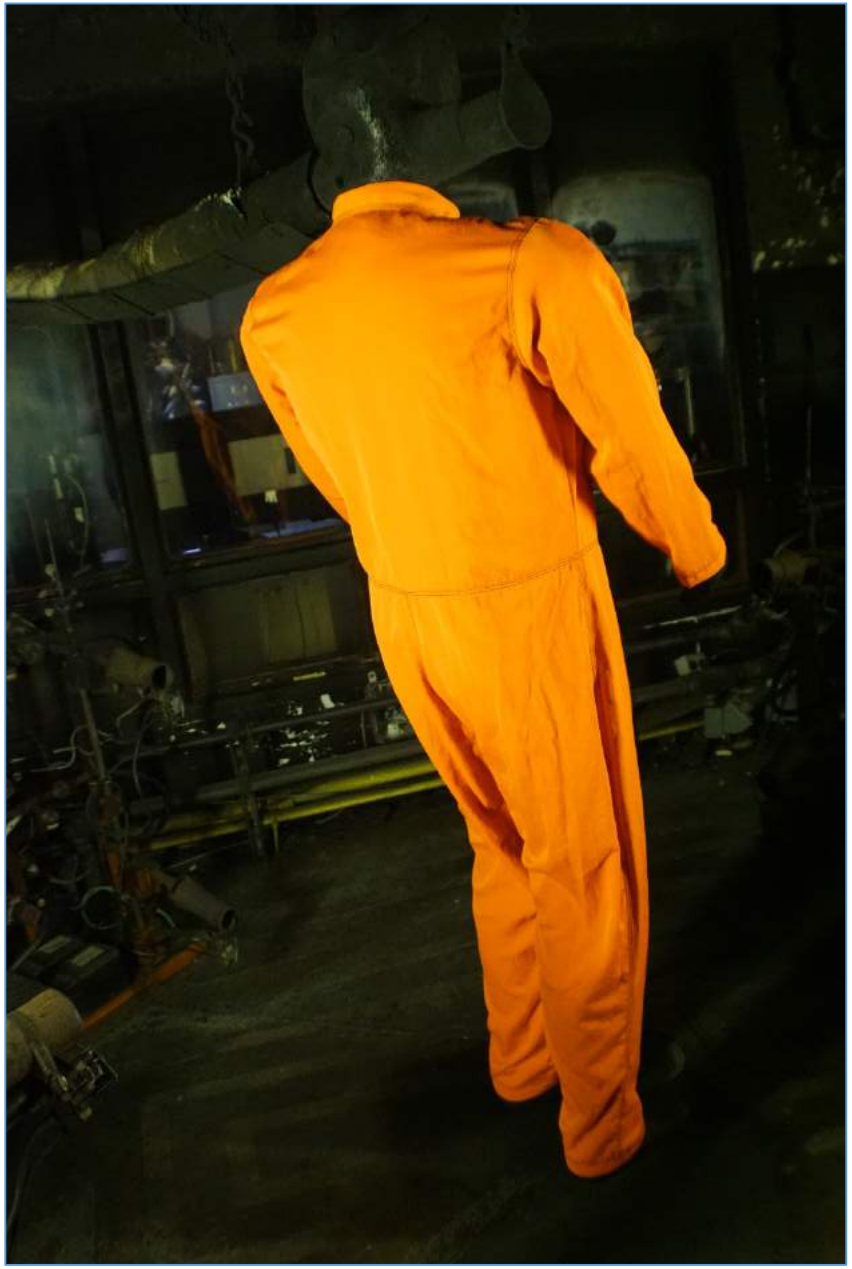
% Total Burn: 14.75

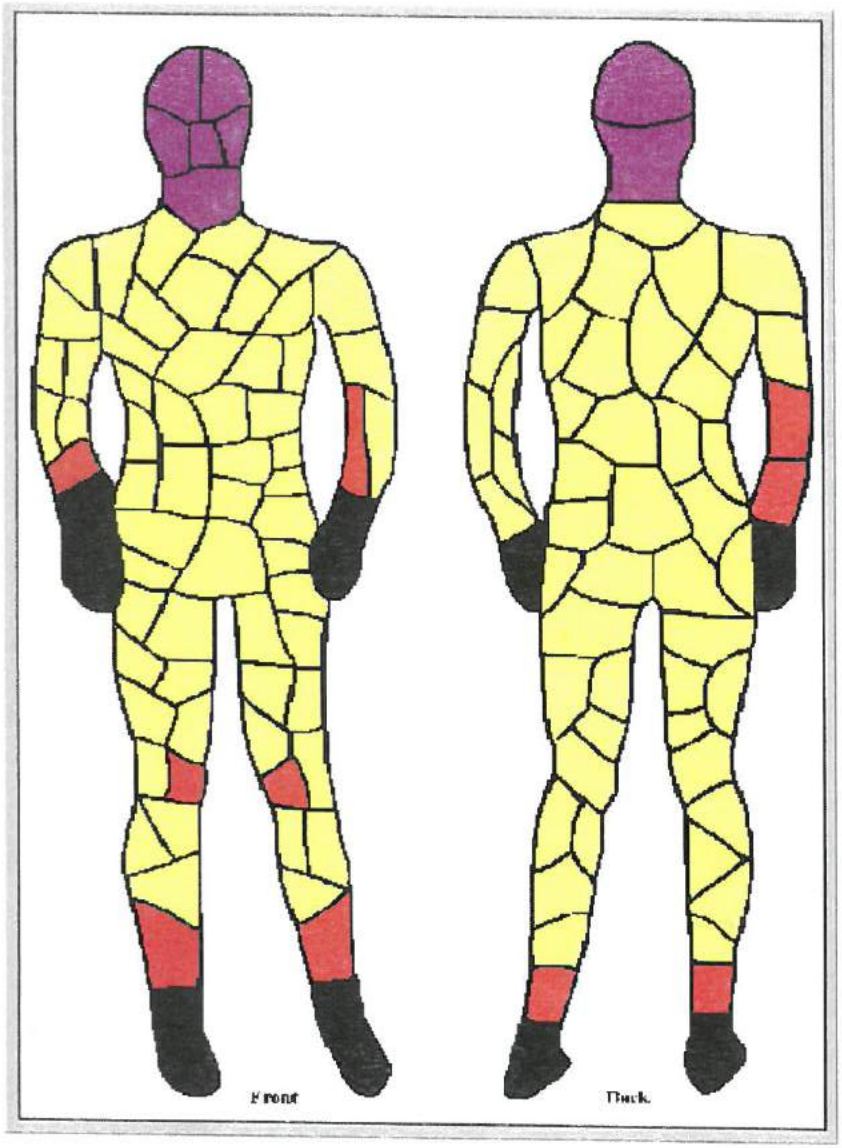
For More Information Contact:

North Carolina State University
College of Textiles
Textile Protection and Comfort Center
P.O. Box 8301
Raleigh, NC 27695-6577 USA

MPG S000107266 Coverall, Rep # 1
180814K

MPG S000107266 Coverall, Rep # 1
180814K





NCSU **PyroMan™**

3-Layer Skin Model

Thermal Protective Clothing Analysis System

Burn Injury Prediction

WESTEX BY MILLIKEN

MPG S000107266 COVERALL, REP #1

Exposure Time (s)	3.00	DAQ Time (s)	60.00	Time Step (s)	0.10

% 2nd Degree Burns	8.197	% Total Burn	14.75
% 3rd Degree Burns	6.557		

Burn Calculation Time (s) 59.0

Invalid Sensor
No Burn
2nd Degree Burn
3rd Degree Burn

180814K

PyroMan™

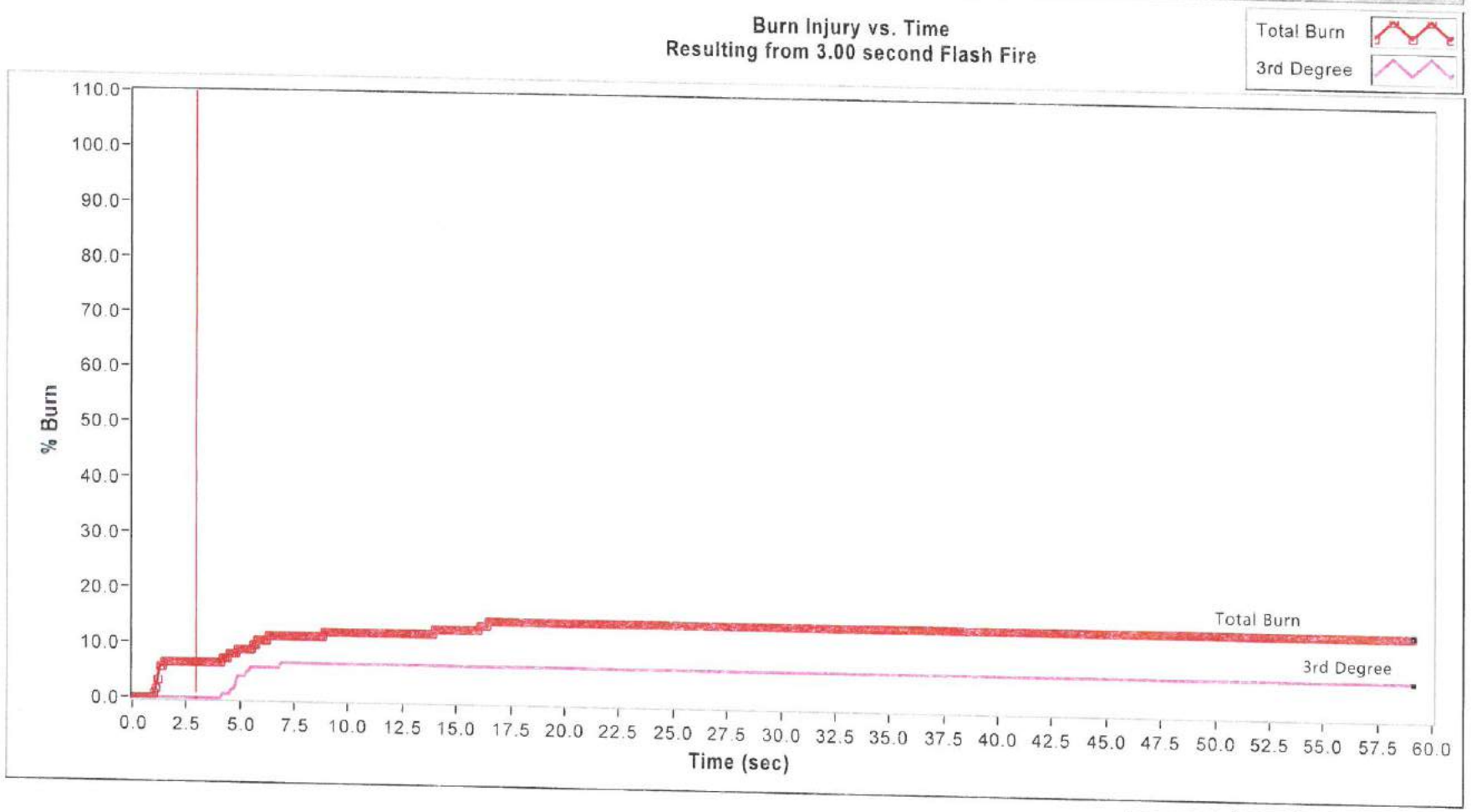
Thermal Protective Clothing Analysis System

3-Layer Skin Model

WESTEX BY MILLIKEN

MPG S000107266 COVERALL, REP #1

Burn Injury vs. Time
Resulting from 3.00 second Flash Fire



Burn Calculation Time (s) 59.0

180814K

Thermal Protective Clothing Analysis

3-Layer Skin Model

File Name	180814L	Test Time	Tue, Aug 14, 2018 9:11 AM
System Identification	PyroMan™	Sponsor	WESTEX BY MILLIKEN
Garment Identification	MPG S000107266 COVERALL, REP #2		
Garment size	NFPA 2112 REFERENCE		
N Washes	1 (-1 = Unknown) ☑ 100% Cotton Underwear & Tshirt		
Garment/Fabric Comments	LAYER 1: COTTON T-SHIRT AND BRIEF LAYER 2: MPG S000107266, 6.0 OSY WESTEX SYNERGY PRO, 6.0 OSY, 93% META-ARAMID /5% PARA-ARAMID/ 2% ANTISTAT COVERALL		
Pre Test Comments	GARMENTS WERE PRECONDITIIONED BY UNDERWRITERS LABORATORIES ACCORDING TO NFPA 2112 SEC 8.5 CONDITIONED BY NC STATE UNIVERSITY AS SPECIFIED IN ASTM F1930-15 GARMENTS STORED IN CONDITIONED SPACE PRIOR TO TESTING TESTING CONDUCTED ACCORDING TO ASTM F1930-15 TESTING CONDUCTED BY JOHN MORTON-ASLANIS, RESEARCH ASSOCIATE AND MARK MARTIN, RESEARCH TECHNICIAN		
Post Test Comments	AfterFlame: 3.44		

Smoke Generation	Shrinkage	Break-Open	Embrittlement		
Light	Moderate	None	Durable	Start Room Temp (oC)	25
				Start Avg Sens. Temp (oC)	33

Vaisala RH (%)	51	Vaisala Temp (oF)	77	Grains of Water/ lb. Mass of Dry Air	1
Total DAQ time (s)	60	Avg Expos. Heat Flux (cal/(cm^2*sec)	2.00	Scan Interval (s)	0.10
Exposure Time (s)	3.00	Torches Used	ALL	ALL, or those used, separated by commas	
Scrubber Time (s)	0			**Burn Calculation Time (s)**	**59.0**

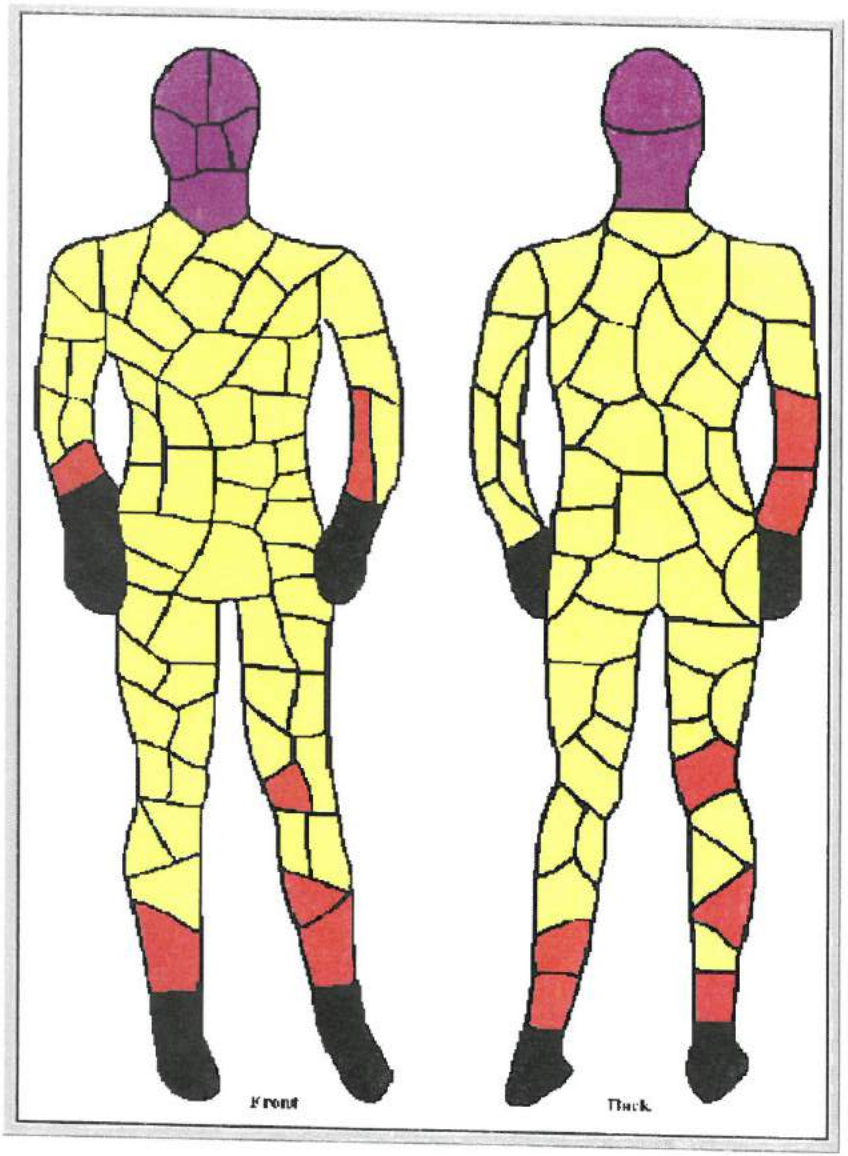
% 2nd Degree Burns	**10.656**	**% Total Burn**	**17.21**
% 3rd Degree Burns	**6.557**		

For More Information Contact:

North Carolina State University
College of Textiles
Textile Protection and Comfort Center
P.O. Box 8301
Raleigh, NC 27695-6577 USA

MPG S000107266 Coverall, Rep # 2
180814L

MPG S000107266 Coverall, Rep # 2
180814L



NCSU **PyroMan™**

3-Layer Skin Model

Thermal Protective Clothing Analysis System

Burn Injury Prediction

WESTEX BY MILLIKEN

MPG S000107266 COVERALL, REP #2

Exposure Time (s)	3.00	DAQ Time (s)	60.00	Time Step (s)	0.10

% 2nd Degree Burns	10.656	% Total Burn	17.21
% 3rd Degree Burns	6.557		

Burn Calculation Time (s) 59.0

Invalid Sensor
No Burn
2nd Degree Burn
3rd Degree Burn

180814L

PyroMan™

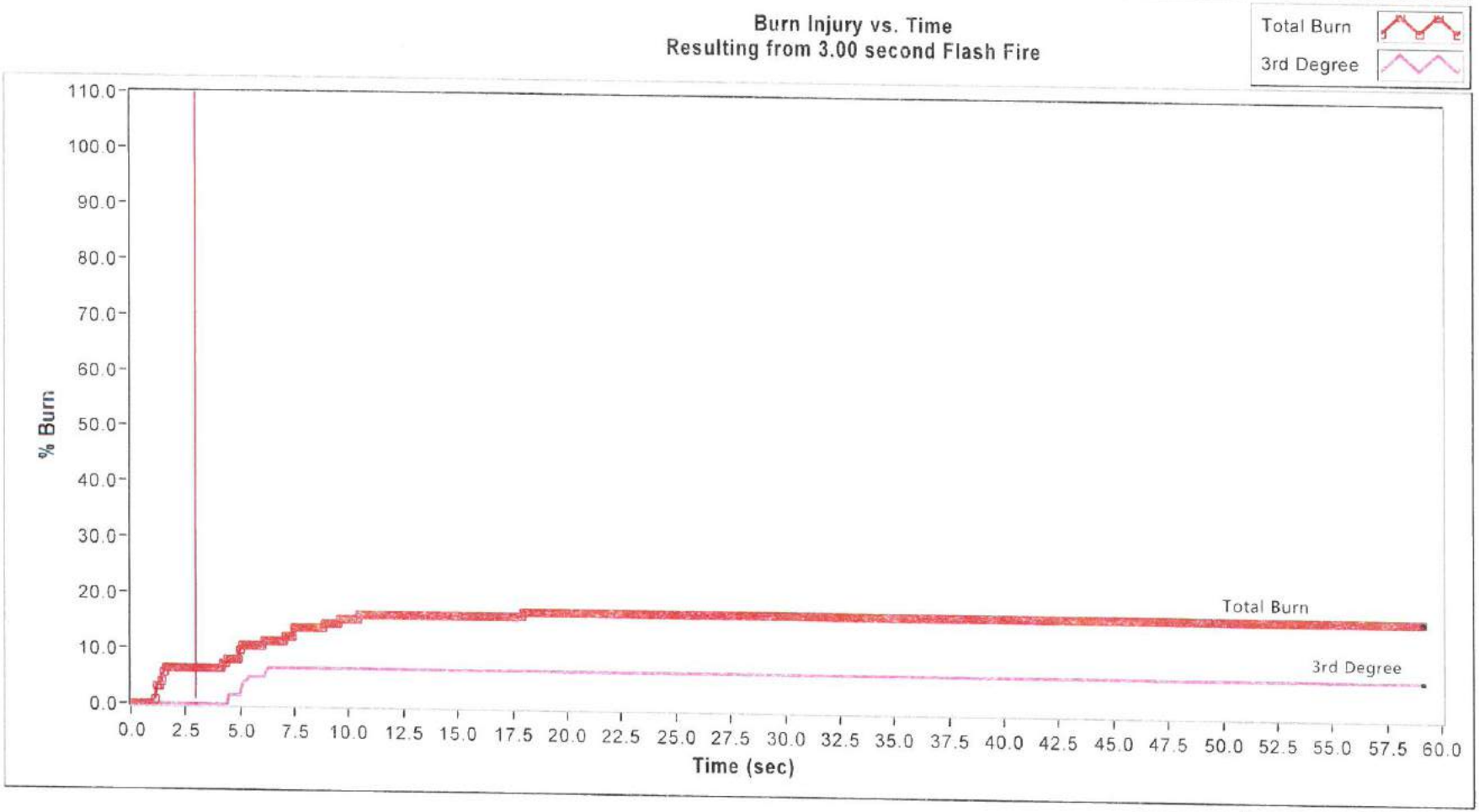
Thermal Protective Clothing Analysis System

3-Layer Skin Model

WESTEX BY MILLIKEN

MPG S000107266 COVERALL, REP #2

Burn Injury vs. Time
Resulting from 3.00 second Flash Fire



Burn Calculation Time (s) 59.0

180814L

Thermal Protective Clothing Analysis

3-Layer Skin Model

File Name	180814M	Test Time	Tue, Aug 14, 2018 9:22 AM
System Identification	PyroMan™	Sponsor	WESTEX BY MILLIKEN

Garment Identification: MPG S000107266 COVERALL, REP #3

Garment size: NFPA 2112 REFERENCE

N Washes: 1 (-1 = Unknown) ☑ 100% Cotton Underwear & Tshirt

Garment/Fabric Comments:
LAYER 1: COTTON T-SHIRT AND BRIEF
LAYER 2: MPG S000107266, 6.0 OSY WESTEX SYNERGY PRO, 6.0 OSY, 93% META-ARAMID /5% PARA-ARAMID/ 2% ANTISTAT COVERALL

Pre Test Comments:
GARMENTS WERE PRECONDITIIONED BY UNDERWRITERS LABORATORIES ACCORDING TO NFPA 2112 SEC 8.5
CONDITIONED BY NC STATE UNIVERSITY AS SPECIFIED IN ASTM F1930-15
GARMENTS STORED IN CONDITIONED SPACE PRIOR TO TESTING
TESTING CONDUCTED ACCORDING TO ASTM F1930-15
TESTING CONDUCTED BY JOHN MORTON-ASLANIS, RESEARCH ASSOCIATE AND MARK MARTIN, RESEARCH TECHNICIAN

Post Test Comments: AfterFlame: 3.21

Smoke Generation	Shrinkage	Break-Open	Embrittlement		
Light	Moderate	None	Durable	Start Room Temp (oC)	27
				Start Avg Sens. Temp (oC)	34

Vaisala RH (%)	49	Vaisala Temp (oF)	79	Grains of Water/ lb. Mass of Dry Air	1

Total DAQ time (s)	60	Avg Expos. Heat Flux (cal/(cm^2*sec)	2.00	Scan Interval (s)	0.10
Exposure Time (s)	3.00	Torches Used	ALL	ALL, or those used, separated by commas	

Scrubber Time (s)	0	**Burn Calculation Time (s)**	**59.0**

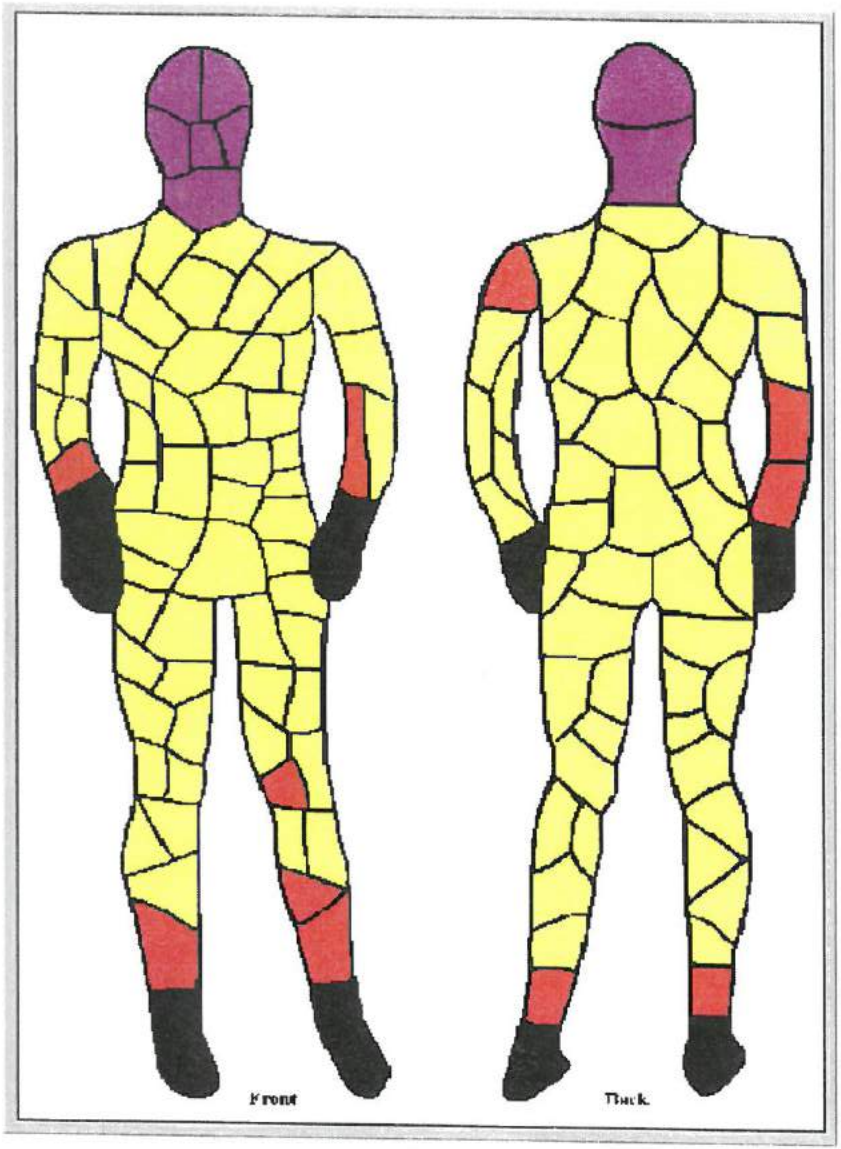
% 2nd Degree Burns	**9.016**	**% Total Burn**	**15.57**
% 3rd Degree Burns	**6.557**		

For More Information Contact:

North Carolina State University
College of Textiles
Textile Protection and Comfort Center
P.O. Box 8301
Raleigh, NC 27695-6577 USA

MPG S000107266 Coverall, Rep # 3
180814M

MPG S000107266 Coverall, Rep # 3
180814M



NCSU **PyroMan™**

3-Layer Skin Model

Thermal Protective Clothing Analysis System

Burn Injury Prediction

WESTEX BY MILLIKEN

MPG S000107266 COVERALL, REP #3

Exposure Time (s)	3.00	DAQ Time (s)	60.00	Time Step (s)	0.10

% 2nd Degree Burns	9.016	% Total Burn	15.57
% 3rd Degree Burns	6.557		

Burn Calculation Time (s) 59.0

Invalid Sensor
No Burn
2nd Degree Burn
3rd Degree Burn

180814M

PyroMan™

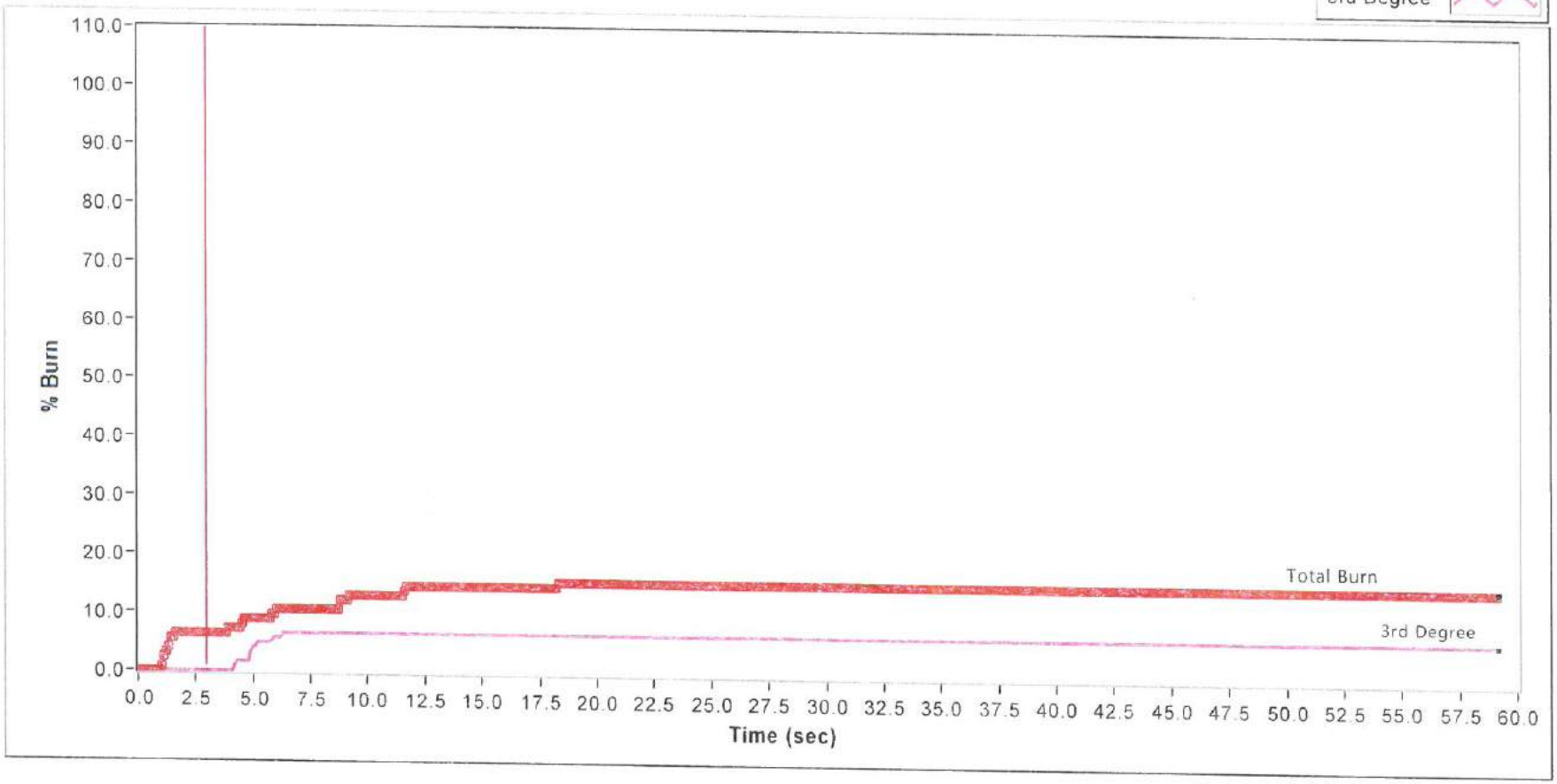
Thermal Protective Clothing Analysis System

3-Layer Skin Model

WESTEX BY MILLIKEN

MPG S000107266 COVERALL, REP #3

Burn Injury vs. Time
Resulting from 3.00 second Flash Fire



Burn Calculation Time (s) 59.0

180814M