MINUTES OF THE MEETING

TECHNICAL COMMITTEE ON
STRUCTURAL AND PROXIMITY FIRE FIGHTING
PROTECTIVE CLOTHING AND EQUIPMENT

St. Louis, MO

1-2 OCTOBER 2013

PRE- FIRST DRAFT MEETING NFPA 1971 AND 1851

1 October 2013

Agenda Items 1 and 2: Call to Order, Introduction of Members and Guests

TC Chairman Stephen King called the meeting to order at 0900. Chairman King then called for an introduction of members and guests.

The following members and guests were present:

Principal Members and Alternates (A) Present:

Stephen King, Chairman
George Berger
Steven Corrado
Paul Curtis
Tim Durby
Richard Edinger
David Fanning
Jonathan Fesik (A)
Patricia Freeman
Richard Granger
Ira Harkness
Tricia Hock (A)
John Karban
Pam Kavalesky (A)
Kim Klaren (A)
Steve Lakey
Michael Laton (A)
Karen Lehtonen
Michael McKenna
Daniel Melia
Amanda Newsom (A)
Jim Reidy
John Rihn
Wendell Robison
Marni Schmidt (A)

Special Expert
USMC/Marine Corps Systems Command
Underwriters Laboratories Inc.
L.N. Curtis & Sons
International Fire Service Training
Chesterfield County Fire & Emergency Medical Services
E.D. Bullard Company
Fire Industry Repair Maintenance Inc.
Globe Manufacturing Company
Charlotte Fire Department
US Department of the Navy
Safety Equipment Institute
FireDex
Intertek Testing Services
Fairfax County Fire & Rescue Dept.
Verified Independent Service Providers
Honeywell First Responder Products
Lion Apparel
Michael McKenna & Associates
Fire Department City of New York
Underwriters Laboratories
Texas State Association of Fire Fighters
MSA
National Volunteer Fire Council
Fire Industry Equipment Research Organization
MINUTES - PRE-FIRST DRAFT MEETING NFPA 1971 AND 1851

Kelly Sisson              Heartland Fire & Rescue
Doug Sloan                Honeywell First Responders
Jeff Stull                International Personal Protection
Tim Tomlinson             Addison Fire Department / GCS
Robert Tutterow           Fire Industry Equipment Research Organization
David Whiting (A)         IAFF
Pat Woods (A)             FDNY

Guests Present:
Brian Barton              Stedfast USA
Holly Blake               W.L. Gore & Associates
Ron Bove                  W.L. Gore & Associates
Don Bowers                Fairfax Co (VA) Fire / Rescue
A. Shawn Deaton           NCSU
Charles Dunn              Tencate Protective Fabrics
Jim Evans                 Solutions Safety Products
Matt Elmore               Bullard
Tom Flaherty              Reflexite
Tim Gardner               3M Occupational Health
Chris Gaudette            Orafol Americas
Tyler Griffith            Sturges Mfg.
Christine Habicht         Tencate Protective Fabrics
Tom Hamma                 Heartland Fire & Rescue
Earl Hayden               International Association of Fire Fighters
Diane Hess                PBI Performance Products
Donald Holman             USMC
Rick Johnson              Gear Cleaning Solutions
Shonali Nazare            NIST
Kirk Owen                 Tencate Protective Fabrics
Stephane Rousse           Innotex
Jeff Sedivec              L.N. Curtis & Sons
Richard Weise             Los Angeles County Fire (SAFER)
Mark Williams             W.L. Gore & Associates
Harry Winer               HIP Consulting
Jennifer Wise             W.L. Gore & Associates

Agenda Item 3: Staff Liaison Report.

David Trebisacci provided the NFPA Staff Liaison report. Dave reviewed the NFPA procedures applicable to the business of the pre-First Draft meeting and outlined the timeline associated with the next editions of NFPA 1971 and NFPA 1851.

Agenda Item 4: Approval of the TC Minutes of the Web Conference December 7 & 17, 2012.

The minutes of the web conference were approved by unanimous consent without amendment.
Agenda Item 5: Chairman’s Remarks

Chairman King welcomed everyone to the meeting and outlined the day’s agenda. The chairman noted that this meeting was a planning meeting for the next editions of NFPA 1971 and NFPA 1851.

Agenda Item 6: Update on FPRF Care and Maintenance Project.

Casey Grant with the Fire Protection Research Foundation (FPRF) provided an update via a conference call link on the Defining the Landscape of PPE Care and Maintenance project. This presentation can be found on the NFPA 1971 and NFPA 1851 Doc Info pages at www.nfpa.org/1971 and www.nfpa.org/1851 respectively.

Agenda Item 7: Turnout Gear Weathering Issues.

Dr. Shonali Nazare of the National Institute of Standards and Technology provided a presentation on weathering issues related to turnout gear. This presentation can be found on the NFPA 1971 and NFPA 1851 Doc Info pages at www.nfpa.org/1971 and www.nfpa.org/1851 respectively.

Agenda Item 8: Formal Interpretation Requests.

Four requests for Formal Interpretations to NFPA 1851 were discussed. FIs from Mr. Oliver and Mr. Edinger will be processed. Two FIs to NFPA 1971 were withdrawn by Mr. Winer and will not be processed.

Agenda Item 9: Stand Alone Annex Project.

Robert Tutterow suggested the development of a stand-alone Annex that would explain the purpose of each test method that is found in NFPA 1971.

Agenda Item 10: Task Group Assignments.

See attached list of task groups and members.

Agenda Item 11: NFPA 1971 and NFPA 1851 Topics.

Jim Reidy and Tim Tomlinson reviewed a list of potential items to be considered for the next editions of NFPA 1971 and NFPA 1851. Items were assigned to the appropriate task groups for further review.
Agenda Item 12: Old Business.

No old business was discussed.


Jeff Stull provided an overview of the shower test. This presentation can be found on the NFPA 1971 and NFPA 1851 Doc Info pages at www.nfpa.org/1971 and www.nfpa.org/1851 respectively.

Under New Business, a presentation prepared by Angie M. Shepherd (NIOSH NPPTL) and Michael F. McKenna (Michael McKenna & Associates, LLC), entitled Firefighter Fatality Investigation and Prevention Program – Preliminary Glove Findings and Dimensional Stability Evaluation, was presented by Mr. McKenna.

[Informational Note: While the presentation was intended to demonstrate that the test method for evaluating gloves may not be adequate, since the meeting, NIOSH has been directly informed of some concerns dealing with the content of the presentation. A revised presentation will be developed and NIOSH/NPPTL would like to present it at a future Committee meeting as input to the NFPA task group established in this area. See the attached NIOSH/NPPTL letter of January 8, 2014].

Robert Tutterow discussed an article on PPE cleaning and cancer.

Earl Hayden discussed the use of proximity gear by the U.S. Air Force.

The next meeting was scheduled for March 4-6, 2014 in San Diego.

Agenda Item 14: Adjournment.

Chairman King adjourned the meeting at 11:45 a.m. on Wednesday, October 2, 2013.
FAE-SPF TASK GROUPS

1. Glove Thermal Shrinkage Test

   Mike McKenna, TG Chair
   Jeff Stull
   Steve Corrado
   Kelly Sisson
   Karen Lehtonen
   Harry Winer
   Tricia Hock
   Rich Granger

2. Helmets

   Dan Melia, TG Chair
   Dave Fanning
   John Rihn
   Dick Weise
   Tim Tomlinson
   Tom Hamma
   Jason Allen

3. Hoods

   Jim Reidy, TG Chair
   Pam Kavalesky
   Jeff Stull
   Amanda Newsom
   Mike Laton
   John Karban
   Kim Klaren
   Pat Woods
   Diane Hess
   Ron Bove
4. Cleaning/Decontamination

   Tim Tomlinson, TG Chair
   Jonathan Fesik
   Steve Lakey
   Jeff Stull
   Paul Curtis
   Karen Lehtonen
   Jim Evans
   Dave Whiting

5. DRD

   Rick Edinger, TG Chair
   Jonathan Fesik
   Steve Lakey
   Tim Durby

6. Risk Assessment – Structural vs Proximity

   Earl Hayden, TG Chair
   George Berger
   Don Holman
   Harry Winer
   Lou Ott
   Steve Lakey
   Mike Laton

7. Annexes

   Robert Tutterow, TG Chair
   Patricia Freeman
   Jeff Stull
   Marni Schmidt
   Karen Lehtonen
   Tricia Hock
   Jeff Sedivec
   Shonali Nazare
   Tim Tomlinson
   Christine Habicht
Impact of Aging on Protective Performance of Firefighter’s Turnout Gear

October 1-2, 2013

St. Louis, MO

Technical Committee on Structural and Proximity Fire Fighting Protective Clothing and Equipment

Presenter: Shonali Nazaré, PhD
Guest Researcher, Fire Research Division

Shonali.Nazare@NIST.gov
Tele: 301-975-2499
PURPOSE
To study impact of environmental stresses on protective performance of firefighter’s turnout gear.

OUTCOMES
- Provide improved guidelines to the Standards committee for retirement of turnout gear.
- Assist manufacturers’ in developing high durability turnout gear.
## Testing of Outer Shell Fabric

### Standards for Protective Ensembles

**NFPA 1971:** Specifies test methods and performance requirements for PPE

### Testing of Outer Shell Fabrics

<table>
<thead>
<tr>
<th>Section #</th>
<th>Test</th>
<th>Performance requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.2</td>
<td>Flame resistance <strong>ASTM D 6413</strong></td>
<td>Char length &lt; 100 mm (4 in), Avg. Afterflame &lt; 2 s, No melt dripping</td>
</tr>
<tr>
<td>8.6</td>
<td>Heat/Thermal shrinkage <strong>ISO 17493</strong></td>
<td>Heat exposure: 260 °C for 5 min, Shrinkage &lt; 10%</td>
</tr>
<tr>
<td>8.12</td>
<td>Tear resistance <strong>ASTM D 5587</strong></td>
<td>Tear strength &gt; 22N (5 lbf)</td>
</tr>
<tr>
<td>8.24</td>
<td>Cleaning shrinkage resistance <strong>AATCC 135</strong></td>
<td>5 wash cycles, Shrinkage &lt; 5%</td>
</tr>
<tr>
<td>8.25</td>
<td>Water absorption resistance <strong>AATCC 42</strong></td>
<td>Water absorption &lt; 30%</td>
</tr>
<tr>
<td>8.49</td>
<td>Breaking strength <strong>ASTM D 5034</strong></td>
<td>5 wash cycles, Breaking strength &gt; 623N (140 lbf)</td>
</tr>
<tr>
<td>8.60</td>
<td>Radiant heat resistance test</td>
<td></td>
</tr>
<tr>
<td>8.53</td>
<td>Wet flex</td>
<td></td>
</tr>
<tr>
<td>8.54</td>
<td>Adhesion after wet flex</td>
<td></td>
</tr>
<tr>
<td>8.55</td>
<td>Flex at low temperature</td>
<td></td>
</tr>
<tr>
<td>8.56</td>
<td>Resistance to high temp. blocking</td>
<td></td>
</tr>
</tbody>
</table>
## Standards for Protective Ensembles
### NFPA 1851: Selection, care and retirement of PPE

<table>
<thead>
<tr>
<th>Routine inspection (after every use)</th>
<th>Advanced inspection (annual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embrittlement</td>
<td>Light evaluation test</td>
</tr>
<tr>
<td>Discoloration</td>
<td>Bucket test</td>
</tr>
<tr>
<td>Tears</td>
<td>Hydrostatic test</td>
</tr>
<tr>
<td></td>
<td>Seam strength</td>
</tr>
</tbody>
</table>
Standards for Protective Ensembles

NFPA 1851: Selection, care and retirement of PPE

- Retirement criteria for TG is based on visual inspection and economic analysis.
- No provision to evaluate compliance of TG with NFPA 1971 requirements.
- The TG can be retired if the cost of repair is more than 50% cost of new TG.
- If visual damages are absent, the TG can be used up to 10 yrs from the date of manufacturing.
- Manufacturers suggest normal useful life of 3-5 yrs.
Useful Life of Turnout Gear

- Material
- The number, duration and intensity of exposures
  - Position of firefighter in fire front line
  - Activities of firefighter
- Care, maintenance and storage
Useful Life of Turnout Gear

Evaluating protective performance of in-use TG

Test methods described in NFPA 1971 are destructive type of tests therefore assessing performance of in-use TG is difficult.

Evaluating protective performance of TG components subjected to simulated environmental stresses

Difficult to obtain ‘real’ level of damage as a result of simulated laboratory exposures.
Quantification of Relationship between Turnout Gear Performance and Environmental Stressing

Environmental stresses:
- UV exposure
- Heat exposure
- Abrasion
- Laundering

Testing:
- Tear strength
- Breaking strength
- Thermal protective performance (TPP)
- UV protection factor (UPF)
### Outer Shell Experimental Fabrics

<table>
<thead>
<tr>
<th>Samples</th>
<th>M-aramid</th>
<th>P-aramid</th>
<th>Melamine</th>
<th>PBI</th>
<th>Area density</th>
</tr>
</thead>
<tbody>
<tr>
<td>NKB</td>
<td>93</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>250-270 g/m²</td>
</tr>
<tr>
<td>KPB</td>
<td>-</td>
<td>60</td>
<td>-</td>
<td>40</td>
<td>Rip Stop</td>
</tr>
<tr>
<td>BBK</td>
<td>-</td>
<td>60</td>
<td>40</td>
<td>-</td>
<td>weave</td>
</tr>
<tr>
<td>BF</td>
<td>50</td>
<td>50</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>BK-00</td>
<td>-</td>
<td>60</td>
<td>40</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>BK</td>
<td>-</td>
<td>60</td>
<td>40</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>BK-Elite</td>
<td>-</td>
<td>60</td>
<td>40</td>
<td>PBO &lt; 1%</td>
<td></td>
</tr>
</tbody>
</table>

*LOI* = Limiting Oxygen Index

### High Performance Fibers

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Tensile strength (g/d)</th>
<th>Elongation (%)</th>
<th>LOI* (%)</th>
<th>Decomposition temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBO</td>
<td>42</td>
<td>3.2</td>
<td>68</td>
<td>1200</td>
</tr>
<tr>
<td>P-aramid</td>
<td>22</td>
<td>2.2-4.4</td>
<td>29</td>
<td>1000</td>
</tr>
<tr>
<td>M-aramid</td>
<td>5.3</td>
<td>25-40</td>
<td>29</td>
<td>750</td>
</tr>
<tr>
<td>PBI</td>
<td>3.1</td>
<td>29</td>
<td>41</td>
<td>1100</td>
</tr>
<tr>
<td>Melamine</td>
<td>2.3</td>
<td>11-18</td>
<td>32</td>
<td>660</td>
</tr>
</tbody>
</table>

*LOI = Limiting Oxygen Index*
## Laboratory Simulation of Environmental Stresses

<table>
<thead>
<tr>
<th>Environmental Stressing Factors</th>
<th>Assumed stress amount for 5 years of service life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laundering</td>
<td>5 cycles (40 ºC for 1 h)</td>
</tr>
<tr>
<td>Heat exposure</td>
<td>260 ºC for 5 min 180 ºC for 24 h</td>
</tr>
<tr>
<td>UV exposure*</td>
<td>13 d</td>
</tr>
<tr>
<td>Abrasion*</td>
<td>20,000 rub cycles</td>
</tr>
</tbody>
</table>

* Assumed stresses based on literature
Laboratory Simulation of Environmental Stresses

UV Exposure

Simulated Photodegradation via High Energy Radiant Exposure (SPHERE)

- Source of UV: Mercury lamp,
- UV flux: $15.9 \text{ kJ/m}^2$
- 32 ports receive uniform UV flux,
- Controlled temperature and humidity.

1 d on SPHERE = 7.4 d of Continuous Sun
 = 19.7 d of Natural Condition (NC)
 = 177.3 d of TGC ~ 0.5 y

13 d on SPHERE = 5.5 yrs TGC
Laboratory Simulation of Environmental Stresses

UV Exposure: Delineation of UV, temperature and humidity effects

The deterioration in physical properties is mainly due to photodegradation.
Laboratory Simulation of Environmental Stresses

Abrasion and Wear

ISO 12947-3, Martindale Test Method

Abrader: 100% wool fabric
Pressure: 9kPa
Stroke length: 60.5 mm

Abraded specimen area: 1134 mm$^2$
Laboratory Simulation of Environmental Stresses
Abrasion and Wear

Modified Assembly of Martindale Type Abrader

Abraded specimen area: 1,134 mm²

Abraded specimen area: 3,660 mm²
Performance testing

Single tear method
(ASTM D 2261)

In-plane tear

Trapezoid tear test
(ASTM D 5587)

Out-of-plane tear

Load vs Extension Plot

Easy tear propagation
Lower tear strength values

Tear propagation due to yarn pulling
Higher tear strength values
PERFORMANCE TESTING

60% of tear strength is lost after 13d exposure (~5 years of TGC) to UV radiation
Laundering, heat exposure alters fabrics properties and hence tear strength.

UV exposure causes photodegradation of constituent fibers and hence loss of tear strength.
Tear strength of OS fabrics

- Single yarn strength
- Yarn density
- Yarn mobility
- Ease of slippage
Deterioration in tensile properties is mainly due to photodegradation of fibers.
PERFORMANCE TESTING

Thermal Protective Performance

NFPA 1971 Test Standard

- 50% radiative and 50% convective heat flux
- Total heat flux = 84 kW/m²

\[
TPP \ (\text{Cal/cm}^2) = TTB \times \text{heat flux}
\]

NFPA 1971 requirement: \( TPP = 35 \ \text{cal/cm}^2 \)
Ensembles with all OS meets NFPA 1971 requirement of TPP = 35 cal/cm²
PERFORMANCE TESTING

TPP of Fabric Ensembles with Environmentally Stressed OS

Laundering < Heat exposure < Abrasion < UV exposure
HYPOTHESIS

Combined effects of Environmentally Stressing on TPP of OS fabric composites

<table>
<thead>
<tr>
<th>OS (TPP in cal/cm²)</th>
<th>Percent changes in TPP values</th>
<th>Calculated TPP value due to combined stressing (TPP in cal/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Laundering (I)</td>
<td>Abrasion (II)</td>
</tr>
<tr>
<td>BK-00 (52)</td>
<td>-8</td>
<td>-13</td>
</tr>
<tr>
<td>BK (49)</td>
<td>+2</td>
<td>-8</td>
</tr>
<tr>
<td>BKP (48)</td>
<td>0</td>
<td>-8</td>
</tr>
<tr>
<td>BBK (55)</td>
<td>-9</td>
<td>-16</td>
</tr>
</tbody>
</table>
PERFORMANCE TESTING
Ultra Violet Protection Factor (UPF)

Spectral transmittance of fabric depends on:
- Constituent fibers
- Fabric structure
- Finishing ancillaries
- Laundering conditions

UPF ratings of NKB and KPB OS fabrics

<table>
<thead>
<tr>
<th>OS fabrics</th>
<th>Control</th>
<th>UV /50 °C/50 % RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>NKB</td>
<td>43</td>
<td>25 (Very good)</td>
</tr>
<tr>
<td></td>
<td>(Excellent)</td>
<td></td>
</tr>
<tr>
<td>KPB</td>
<td>25</td>
<td>18 (Good)</td>
</tr>
<tr>
<td></td>
<td>(Very good)</td>
<td></td>
</tr>
</tbody>
</table>
SUMMARY

• Individual stressing has varied impact on protective performance of turnout gear.

• Environmental stressing has more detrimental impact on tear strength of OS than TPP of the ensemble.

• Laundry and heat exposures alter dimensional properties of OS and thereby tear resistance.

• Deterioration in tear strength of OS is mainly due to photodegradation of fiber.
Recommendation to NFPA 1851 Committee

- Redefine retirement criteria based on performance metric.
- Minimum tear strength requirements due to UV exposure.
<table>
<thead>
<tr>
<th></th>
<th>1 day</th>
<th>4 days</th>
<th>7 days</th>
<th>13 days</th>
<th>28 days</th>
<th>Washed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BK</td>
<td></td>
<td></td>
<td></td>
<td>-88%</td>
<td></td>
<td>-5%</td>
</tr>
<tr>
<td>BK-00</td>
<td></td>
<td></td>
<td></td>
<td>-93%</td>
<td></td>
<td>-36%</td>
</tr>
<tr>
<td>BK-Elite</td>
<td></td>
<td></td>
<td></td>
<td>-80%</td>
<td></td>
<td>+3%</td>
</tr>
<tr>
<td>BF</td>
<td></td>
<td></td>
<td></td>
<td>-54%</td>
<td></td>
<td>+2%</td>
</tr>
</tbody>
</table>

SUMMARY
Future work

• To study impact of novel coating method (LbL) to deposit TiO$_2$ coating on OS.

• To study impact of environmental stresses on durability of LbL coatings.

• To study impact of environmental stresses on protective performance of MB and TL.
Publications

• **Shonali Nazaré,** Shaun Flynn, Rick Davis, and Joannie Chin. Protective performance of environmentally stressed fabrics containing melamine fiber blends, Fire Technology 2013, Published on line: 26th June 2013.

• **Shonali Nazaré,** Rick Davis, and Joannie Chin, Accelerated Weathering of Firefighter Protective Clothing Containing Melamine Fiber Blends, NIST TN 1751, August 2012, National Institute of Standards and Technology, Gaithersburg MD.

• **Shonali Nazaré,** Rick Davis, and Joannie Chin, Accelerated Weathering of Firefighters’ Protective Clothing: Delineating Effects of Heat and UV Exposures, NIST TN 1746, November 2011, National Institute of Standards and Technology, Gaithersburg MD.


• Davis RD, Chin J, Lin CC, Petit S. Effect of Accelerated Ultraviolet Weathering on Firefighter Protective Clothing Outer Shell Fabrics. National Institutes of Standards and Technology Technical Note 1657 2010, National Institute of Standards and Technology, Gaithersburg MD.
Acknowledgements

Maryland Fire Equipment Corporation (ISP) - Laundering
Shaun Flynn - Summer Intern
Debbie Stanley - UV transmittance measurements

Thank you!
Accronyms

ISP  Independent Service Provider
LbL  Layer by Layer
LOI  Limiting Oxygen Index
MB   Moisture Barrier
NC   Natural Conditions
NIST National Institute of standards and Technology
OS   Outer Shell
PBI  Polybenzimidazole
PBO  Polyphenylene-benzobisoxazole
PPE  Personal Protective Ensemble
RH   Relative Humidity
SPHERE Simulated Photodegradation via High Radiant Exposure
TL   Thermal liner
TGC  Turnout gear Conditions
TPP  Thermal Protective Performance
TTB  Time to 2nd degree Burn
UPF  Ultra Violet protection Factor
UV   Ultra violet