STEAM AND HOT LIQUID PROTECTIVE FABRIC SYSTEMS

5th Annual DTS (USA) Inc.: Protective Clothing Systems for Safety ‘13
Presented By: Lelia Lawson, MSc
Overview of Project

University of Alberta (PCERF): Research Developments

Project start date: September 2003

- Quantifying different properties and parameters for steam and hot liquid exposures

Objectives:

- Develop criteria for hot water/steam protection
- Publish data and safety alerts (PSAC and CAPP)
- Provide guidance on choosing workwear
- Recommendations for outerwear/underwear systems
Overview of the Hazards

Individuals working in the oil and gas industry are at risk of being exposed to:

- Flash fires
- Hot liquids (e.g., water, oil, mud)
- Steam at both low and high pressures
Hot Liquid Exposures

- 80 to 90 °C
- Condensation of steam:
  - Assessment of steam quality (value opening)
  - Spraying wellheads to prevent overheating
  - High pressure valves; steam pipe ruptures
- Hot Liquids:
  - Drilling mud (oil or water based)
  - Heated water (vehicle tanks)
Steam Exposures

- Up to 375 °C
- 13,500 kPa(g)
- Boilers for steam generation:
  - SAGD
  - Process plants (heat exchangers)
  - Steam turbines (power; driver)
- Steam pipe ruptures (water hammer effect; pipe fatigue)
- Valve ruptures
American Burn Association (2012 Annual Report):

Nature of steam and hot liquid injuries:
• Skin Burn: 1st, 2nd, and 3rd degree
• Amputation: muscle and bone damage
• Death: severe dermal and respiratory burn injury
• Age influences recovery from injury

EXPOSURE | INDUSTRIAL
--- | ---
Fire/Flame | 4,208 (n = 58,200)
Scald | 3,154 (n = 45,710)

*Based on hospital medical reports.

Current Protection

Current Systems:
- Coverall or shirt/pant ensemble - meets the requirements of CAN/CGSB 155.20 & NFPA 2112
- IFR and FR treated
- Rainwear: coated (impermeable)
- Designed for protection against steam and hot liquids: IFR w/MBM (micro-porous breathable membrane – semi-permeable)
Research performed by numerous graduate students at the University of Alberta:
• Rohit Sati, Ghulam Murtaza, Yehu Lu, Indu Sunder, Sihong Yu

Outcome of completed research project (2012):
• CAPP proposal: recommendation and criteria for 2 levels of protection
• Development of test equipment (hot liquid and steam)
• Development of testing procedures and evaluation; draft test method
• Ongoing Research
• Funded by: CAPP, Imperial Oil, DuPont Canada, NSERC, Nexen, Davey Textile Solutions
## System Level Recommendations

<table>
<thead>
<tr>
<th>Criterion:</th>
<th>Time to 2\textsuperscript{nd} Degree Burn</th>
<th>Absorbed Energy</th>
<th>Typical Material Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 Steam Recommendation:</td>
<td>&gt; 5 seconds</td>
<td>&lt; 300 kJ/m\textsuperscript{2}</td>
<td>IFR or FR w/MBM (i.e., PTFE films)</td>
</tr>
<tr>
<td>Level 2 Steam Recommendation:</td>
<td>&gt; 20 seconds</td>
<td>&lt; 200 kJ/m\textsuperscript{2}</td>
<td></td>
</tr>
<tr>
<td>Level 1 Hot Water Recommendation:</td>
<td>&gt; 5 seconds</td>
<td>&lt; 200 kJ/m\textsuperscript{2}</td>
<td>Coated (e.g., aramid scrim with PVC or neoprene); Tri-laminates Insulation layer required.</td>
</tr>
<tr>
<td>Level 2 Hot Water Recommendation:</td>
<td>&gt; 20 seconds</td>
<td>&lt; 100 kJ/m\textsuperscript{2}</td>
<td></td>
</tr>
</tbody>
</table>

HOT LIQUIDS:
- Modified ASTM F2701
  - 85 °C; flow rate (low pressure): 100 mL/s
  - Also tested with hot drilling mud (oil-based)

- Combined hot liquid and steam apparatus
  - 60 – 95 °C; flow rate 100 – 200 mL/s
  - Water and oil experiments

- Full-scale mannequin
  - Direct water spray to torso via 12 water nozzles
  - 85 °C and 250 kPa(g)
Combined Apparatus

COMBINED STEAM AND HOT LIQUIDS

- Small-scale apparatus modified to allow for hot liquid exposure


www.ales.ualberta.ca
Full-Scale Mannequin

- Hot liquid exposure
- 12 water nozzles
- 20 L / 10 sec
- 60°C, 80°C, 90°C

Hot Liquid Exposure

The University of Alberta
Protective Clothing and Equipment Research Facility
Flash Fire Facility

Wednesday, Jan 5 2011
Test Type: Hot Fluid Spray
Fabric: Regular Coverall
Series: 35 psi 81°C Water
Exposure Time: 10.08 sec
Measurement Time: 60.00 sec
Second Degree Burn: 28.65%
Third Degree Burn: 17.90%
Total 2nd and 3rd Degree Burn: 46.55%
Burn Number: 00003
Hot Liquid Exposure

THE UNIVERSITY OF ALBERTA
Protective Clothing and Equipment Research Facility
Flash Fire Facility

Wednesday, Jan 5 2011
Test Type: Hot Fluid Spray
Fabric: Hot Liquid Protective Garment
Series: 35 psi 81°C Water
Exposure Time: 10.08 sec
Measurement Time: 60.00 sec
Second Degree Burn: 4.15%
Third Degree Burn: 0.00%
Total 2nd and 3rd Degree Burn: 4.15%
Burn Number: 00002
HOT LIQUIDS

• Contact exposure – increased heat transfer
• Garment: pockets / openings fill with water – increased heat transfer
• Affects of internal moisture (low $D_m$ and air permeability) on heat transfer?
Methods of Evaluation

STEAM

- Small-scale apparatus
- Boiler unit for steam generation
- 69 to 210 kPa(g) (could withstand up to 620 kPa(g))
- 95 – 150 °C

Steam – Data Analysis

![Graph showing temperature over time](graph.png)
Methods of Application

STEAM (FIELD TRIAL)
- Cylindrical torso apparatus
- 69 to 620 kPa(g)

Picture courtesy Mark Ackerman.
Video courtesy Mark Ackerman.
Steam: System Implications

- Extreme pressure exposures
- Effects of $D_m$ and insulation on heat transfer (i.e., compression, density)
- Material deformation
Steam: System Implications

Pictures courtesy Mark Ackerman.
Steam: System Implications

Pictures courtesy Mark Ackerman.
Conclusions

• Evidence that protection against steam and hot liquids is just as relevant flash fire
• Preliminary stage of research
• Continual advancement and refinement of evaluation and test equipment
• Industry development of novel materials and garment design
• Examination and characterization of material properties (development of a model?) – process of investigation.
Acknowledgements

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Publications to Date

Thank-you!