Hazard in the Workplace – Fire Crew Protection

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Country Fire Authority
Victoria

- RFS Crews, January 1998
- Wingello Tanker
- Johnson Creek, NSW
- 1 death, 7 injured

- CFA Crews, December 1998
- Geelong West & Geelong City Tankers
- Linton, Vic.
- 5 deaths

Joint Initiative
Country Fire Authority
NSW Rural Fire Service
CSIRO
**Project Goal**

To research and develop vehicle crew protection systems for the safety of firefighters during wildfire suppression.

**Project Objectives**

- Identify and test existing water spray systems
- Identify and define wildfire burnover conditions
- Establish test parameters
- Develop test methods and facility
- Develop prototype crew protection system
- Test prototype crew protection systems
- Validate results and report outcomes

**Project Research Stages**

1. Identify and define crew protection issues
2. Establish test parameters
3. Evaluate crew protection systems using wildfire simulator
4. Validate wildfire simulator results

**Stage 1: Identify and Define Issues**

Crew Protection Issues

- Lack knowledge of tanker components combustion
- Various spray systems exist
- Spray systems designed without scientific base
- Effect of wind on spray systems
- No evaluation procedures exist
- Fire burnover conditions need to be identified
- Crew protection system prototype required
- Test parameters need to be defined
- Validation procedures need to be established
Stage 2: Establish Test Parameters

Experimental Requirements

- Identify and define fire burnover conditions
- Develop a model defining wildfire conditions
- Assess and test existing spray systems
- Combustion and toxicology assessment of vehicle components:
  - Burning characteristics of tires
  - Flame immersion of air brake lines
  - Analysis of cabin components
  - Analysis of window glass
- Develop and test prototype spray system
- Develop flame front simulator

Materials Testing

- Radiant Heat Panel
- Oil Pan Fixture

Laboratory Results

- Rubber materials ignited at moderate radiant levels
- Existing spray systems proved ineffective
  - Sprays affected at all wind speeds
  - Cabin hot spots without water protection
  - Irregular surfaces not covered
  - Not all glass surfaces covered with water
  - Glass could fail under burnover conditions
- Prototype spray system developed
- Prototype spray configuration provided good coverage at moderate wind velocities
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Stage 2: Establish Test Parameters

Simulator Test Facility

Simulator Test Facility
NSW RFS Bedford On Fire Front Simulator

- Flame Front Simulator Requirements
  - Simulator facility
    - Construct gas fired flame front simulator
  - Variable fire intensity: 2.0 MW/m to 12 MW/m
  - Direct flame impact for up to 1 minute
  - Large scale for complete tanker/appliance testing

- Test methods
  - Simulate radiant heat and flame impact
  - Test material degradation/toxics off gassing
  - Validate water spray protection tests - repeatable
    - 500 Litres water
    - Minimum of 5 minutes coverage

Simulated Wildfire Conditions

<table>
<thead>
<tr>
<th>Intensity (MW/m)</th>
<th>2.5</th>
<th>5</th>
<th>7.5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Loads (tonnes/ha)</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Fire Danger Index</td>
<td>20</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Wind Speed (Km/hr)</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Air Temp (°C)</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>43</td>
</tr>
<tr>
<td>Relative Humidity (%)</td>
<td>30</td>
<td>15</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Drought Factor</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Flame Depth (m)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Flame Resident Time (s)</td>
<td>11</td>
<td>11</td>
<td>12</td>
<td>14</td>
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</tbody>
</table>

Crew Conditions

- Metabolic Body Temperature must not rise by more than 1.5°C
- Toxic gases to not exceed:

<table>
<thead>
<tr>
<th>Gas</th>
<th>Time (seconds)</th>
<th>Quantity</th>
</tr>
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<tbody>
<tr>
<td>CO</td>
<td>1450</td>
<td>500 ppm</td>
</tr>
<tr>
<td>HCL</td>
<td>600</td>
<td>35 ppm</td>
</tr>
<tr>
<td>HF</td>
<td>800</td>
<td>ppm</td>
</tr>
<tr>
<td>NO_2</td>
<td>350</td>
<td>38 ppm</td>
</tr>
<tr>
<td>HBr</td>
<td>600</td>
<td>35 ppm</td>
</tr>
<tr>
<td>HCN</td>
<td>140</td>
<td>50 ppm</td>
</tr>
<tr>
<td>SO_2</td>
<td>120</td>
<td>5 ppm</td>
</tr>
</tbody>
</table>
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Stage 2: Establish Test Parameters
Wildfire Simulator Design

Stage 3: Evaluate Crew Protection Systems
CFA ACCO 610® On Fire Front Simulator Test Bed

Tests
- 25 tests conducted on 5 different vehicles
- Fire line intensities from 2.0 to 10.0 MW/m
- Base line tests conducted without water spray at each fire line intensity
- Fire duration from 14 to 17 minutes
- Over 50 data points for each test
- 5 video cameras
- Gas collection at 3 second intervals
- Various spray system configurations tested
- Various crew protection components tested
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Stage 3: Evaluate Crew Protection Systems
Results

Air Temperature Within Cabin

- Flame front simulator effective test bed
- Tanker cabins structurally sound
- Windows are durable under radiation and flame contact up to 10.0 MW/m
- External tanker fittings emit toxic gas
- Temperature stratification evident in cabin
- Limiting radiant heat in cabin/ROPS critical
- Survivability unlikely in an unprotected tanker for fire intensities greater than 5.0 MW/m
Stage 3: Evaluate Crew Protection Systems

Prototype System Features

- 24 nozzles: Cabin, ROPS, heat shielding, tyres
- Use vehicle’s reserve water supply
- Supply at least 5 minute water coverage
- Incorporate radiant heat curtains cabin/ROPS
- Removal of flammable material, i.e. mud flaps
- Increase heat shielding-ROPS, pump, batteries
- Air intake metal pre-cleaner for truck engine and pump

Testing Prototype Crew Protection System

CFA Hino Dual Cabin Tanker With Spray System

Prototype System Test Results

- Radiant heat curtains reduce cabin temperatures and can reduce flame intrusion
- Protected tanker at low to moderate fire intensities up to 10.0 MW/m
- Reduced internal cabin temperature (45 to 56°C) when compared to external temperatures (500 to 950°C)
- Radiant heat loads inside cabin above pain threshold, burns to skin likely in fire intensity >5.0 MW/m
- Mean body temperature increases exceed 1.5°C when unprotected in fire intensities >5.0 MW/m
- Toxic gas survivability acceptable with spray and heat curtains up to 10.0 MW/m

Stage 4: Field Validation Tests

Experiment Design

- Field experiment parameters
  - Fire line intensities up to 5.0 MW/m
  - Temperature in low to mid 20s °C
  - Low to moderate wind velocities, >25k/hr
  - Relative Humidity, 20%
  - FFDI, 16 (High)
  - Fuel loads, >20 t/hectare
- Site selection at Tumbarumba, N.S.W.
- Bushfire CRC participation
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Stage 4: Field Validation Tests
Validation Field Test Site

Participants
- CSIRO (CFFP, CMIT)
- NSW RFS
- CFA
- State Forests NSW
- NSW NPWS
- Dept Conservation and Land Management, WA
- Forest Research NZ
- University of Melbourne
- Dept of Sustainability and Environment Victoria
- UNSW at ADFA
- BoM (fire weather forecasting)
- Bushfire CRC

2003-2004 Work Plan
- Pre fire measurements
  - Weather (Oct- Mar)
  - Fuel (Nov-Jan)
- Truck instrumentation (Nov – Dec)
- Field instrumentation (Jan-Feb)
- Experimental fires
  - Burning experiments (Jan – Feb)
  - Post fire measurements (Jan – Mar)
- Data reduction
  - Data analysis (Mar-Jun)
  - Reports (Mar, Oct)

Tumbarumba Field Test Site Fuels
Predominately White Gum, Peppermint mixed forest with heavy ground fuels

Plot E: 26 t/ha
Plot G: 25 t/ha

25 t/ha

25 t/ha
Stage 4: Field Validation Tests

Validation Field Test Site

Plot E    Plot G

NSW RFS Isuzu Tanker  CFA Dual Cabin Hino Tanker

Plot G Burning Conditions

- Temperature: 28°C
- Relative humidity: 20%
- Wind speed: 17 km/h, gust 35 km/h
- Wind direction: SW
- FFDI: 16 (High)
- Fuel load 26t/ha
- Slope 10-20°

Plot G Aerial View

Plot G Burning Conditions

- FMC: 8.4%
- ROS: 165 – 930 m/hr
- Fire Line Intensity:
  - 1230 - 6920 kW m⁻¹
- Flame height: 1 - 4 m
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Stage 4: Field Validation Tests

Plot G Burning Results

CFA Dual Cabin Hino Tanker

NSW RFS Isuzu Tanker
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Stage 4: Field Validation Tests

**Results**
- Prototype system protected truck during tests
- Cabin temperatures at 40°C at lower levels
- ROPS temperatures at 56°C at lower levels
- Toxics levels survivable for tests
- Minor damage to truck with spray system operating
- Fuel moisture around vehicles altered with spray
- Both truck and pump engines continued operation
- Field tests longer fire duration but lower intensity
- Validation results align with simulator results at fire intensity levels tested

**Conclusions**
- Radiant heat entry into the cabin is most critical factor limiting survival
- Tyres, mud flaps, hoses exposed to radiant heat a source of toxics and flame if not protected
- Radiant heat curtains effective in reducing inside cabin and ROPS radiant heat and temperatures
- Well designed spray system will provide useful gains in firefighter safety up to 10.0 MW/m²
- Total truck protection required to promote survivable conditions for crew
- Fire fighting vehicles are not designed to provide survivable conditions in High Intensity burnovers
- Consideration of prototype components incorporation into future tanker designs

**Hazard in the Workplace – Fire Crew Protection**

Stage 4: Field Validation Tests

### Table 1

<table>
<thead>
<tr>
<th>Tanker</th>
<th>Plot G Test 26</th>
<th>Mogo Test 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensity (MW/m)</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Temperature:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient</td>
<td>28°C</td>
<td>28°C</td>
</tr>
<tr>
<td>Cabin head high</td>
<td>50°C</td>
<td>52°C</td>
</tr>
<tr>
<td>Cabin seat level</td>
<td>40°C</td>
<td>41°C</td>
</tr>
<tr>
<td>ROPS head high</td>
<td>63°C</td>
<td>39°C</td>
</tr>
<tr>
<td>ROPS seat level</td>
<td>56°C</td>
<td>32°C</td>
</tr>
</tbody>
</table>

**Toxics:**
- Cabin: Survivable
- ROPS: Survivable

**Notes:**
- CFA Crews, December 1999
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- Linton, Vic.
- 5 deaths