Hazard in the Workplace – Fire Crew Protection

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Victoria

Inaugural Bushfire CRC Conference
Perth October 2004

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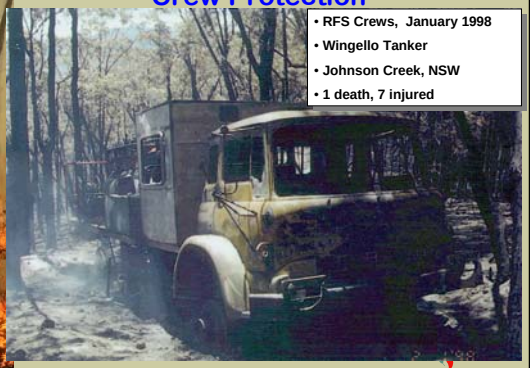

- RFS Crews, January 1998
- Wingello Tanker
- Johnson Creek, NSW
- 1 death, 7 injured

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

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Joint Initiative

Country Fire Authority
NSW Rural Fire Service
CSIRO

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Project Goal

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

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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

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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

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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

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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

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Stage 2: Establish Test Parameters

Materials Testing

Radiant Heat Panel

Oil Pan Fixture

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Stage 2: Establish Test Parameters

Wind Tunnel Test of Spray Systems

Tanker Cabin Mock-up In Wind Tunnel

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Stage 2: Establish Test Parameters

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

NSW RFS Bedford On Fire Front Simulator

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Stage 2: Establish Test Parameters

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

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Stage 2: Establish Test Parameters

Simulated Wildfire Conditions

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

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Stage 2: Establish Test Parameters

Crew Conditions

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

Gas	Time(seconds)	Quantity
CO	1450	500 ppm
HCL	600	35 ppm
HF	600 ppm	5
NO_x	350	38 ppm
HBr	600	35 ppm
HCN	140	50 ppm
SO_2	120	5 ppm

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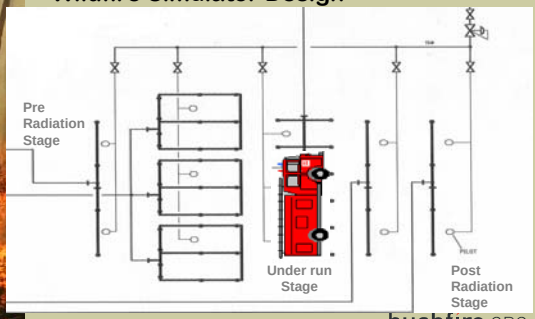
Stage 2: Establish Test Parameters

Wildfire Simulator Design



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Stage 3: Evaluate Crew Protection

CFA ACCO 610 On Fire Front Simulator Test Bed

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Stage 3: Evaluate Crew Protection

Systems

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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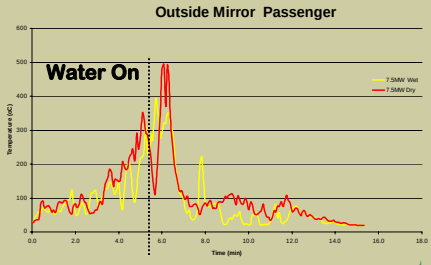
Stage 3: Evaluate Crew Protection System

Results



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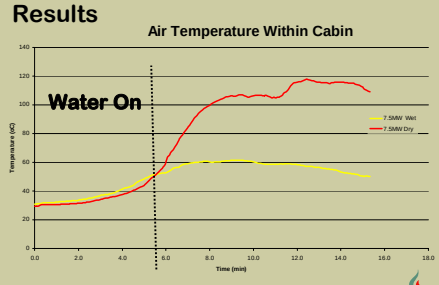
Stage 3: Evaluate Crew Protection Systems

Results



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Stage 3: Evaluate Crew Protection Systems

Results

- **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**

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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

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Stage 3: Evaluate Crew Protection Systems

Testing Prototype Crew Protection System

CFA Hino Dual Cabin Tanker With Spray System

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Stage 3: Evaluate Crew Protection Systems

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

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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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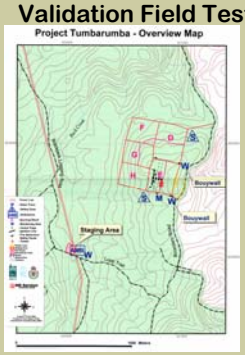
Stage 4: Field Validation Tests

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

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Stage 4: Field Validation Tests

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)

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Stage 4: Field Validation Tests

Tumbarumba Field Test Site Fuels

Plot E

25 t/ha

Plot G

26 t/ha

Predominately White Gum, Peppermint mixed forest with heavy ground fuels

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Stage 4: Field Validation Tests

Validation Field Test Site

Plot E

Plot G

NSW RFS Isuzu Tanker

CFA Dual Cabin Hino Tanker

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Stage 4: Field Validation Tests

Plot G Burning Conditions

Plot G Aerial View

Plot G

- 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°

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Stage 4: Field Validation Tests

Plot G Burning Conditions

Plot G

- 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 Conditions

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Stage 4: Field Validation Tests

Plot G Burning Results

NSW RFS Isuzu Tanker

CFA Dual Cabin Hino Tanker

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Stage 4: Field Validation Tests

Plot G Burning Results

CFA Dual Cabin Hino Tanker

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Stage 4: Field Validation Tests

	Tumbarumba Plot G	Mogo Test 25	Mogo Test 15
Tanker	Hino Dual Cab	Hino Dual Cab	ACCO
Intensity (MW/m)	5.0	5.0	5.0
Temperature: Ambient	28°C	20°C	28°C
Cabin head high	50°C	62°C	72°C
Cabin seat level	40°C	41°C	56°C
ROPS head high	63°C	38°C	45°C
ROPS seat level	56°C	32°C	39°C
Toxics:			
Cabin	Survivable	Survivable	Survivable
ROPS	Survivable	Survivable	Survivable

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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

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Stage 4: Field Validation Tests

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/m
- 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

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