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HOUSE FIRE SPREAD, AN INVESTIGATION – GULGONG NSW

Report to
Bushfire CRC

P.A. Bowditch

CSIRO - Manufacturing and Infrastructure Technology
Fire Science and Technology Laboratory

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1. Introduction

The investigation of house fires normally takes place after the fire event.

Few occasions arise where fire scientists can observe the burning of a house under controlled conditions. NSWFB Fire Investigation and Research Unit (FIRU), in conjunction with the NSW Police Forensic Services Group and Arson Squad, carried out a series of fire scenario experiments in a soon-to-be-demolished house at Gulgong, NSW, in order to study arson/forensic related issues, and to make training videos. The series of experiments culminated in one large-scale experiment in which the house was burnt to completion. CSIRO was invited to participate in order to gather data of use to the joint CSIRO/NSWFB project on changes in life safety that may have occurred due to changes in construction techniques, materials of construction, and changes in nature and quantity of building contents in Class 1 buildings over the last three decades, and the opportunity was also taken to make radiation measurements for use in bushfire research. The details of this part of the project are described in separate report [1].

With the approval of FIRU and police, a CSIRO team involved in Bushfire CRC Project D1, Building and Occupant Protection, were also in attendance. Their goal was to study the potential of flame spread from a dwelling to other structures.

This report forms part of research initiatives being carried out under CRC Project D1, Building and Occupant Protection.

2. House details

2.1 Location and siting

The house was situated at 283 Wellington Road, Gulgong. Gulgong is located 293 km north-west of Sydney, 28 km north of Mudgee and 466 m above sea-level in central New South Wales. Figure 1 shows the location of the house outside Gulgong.

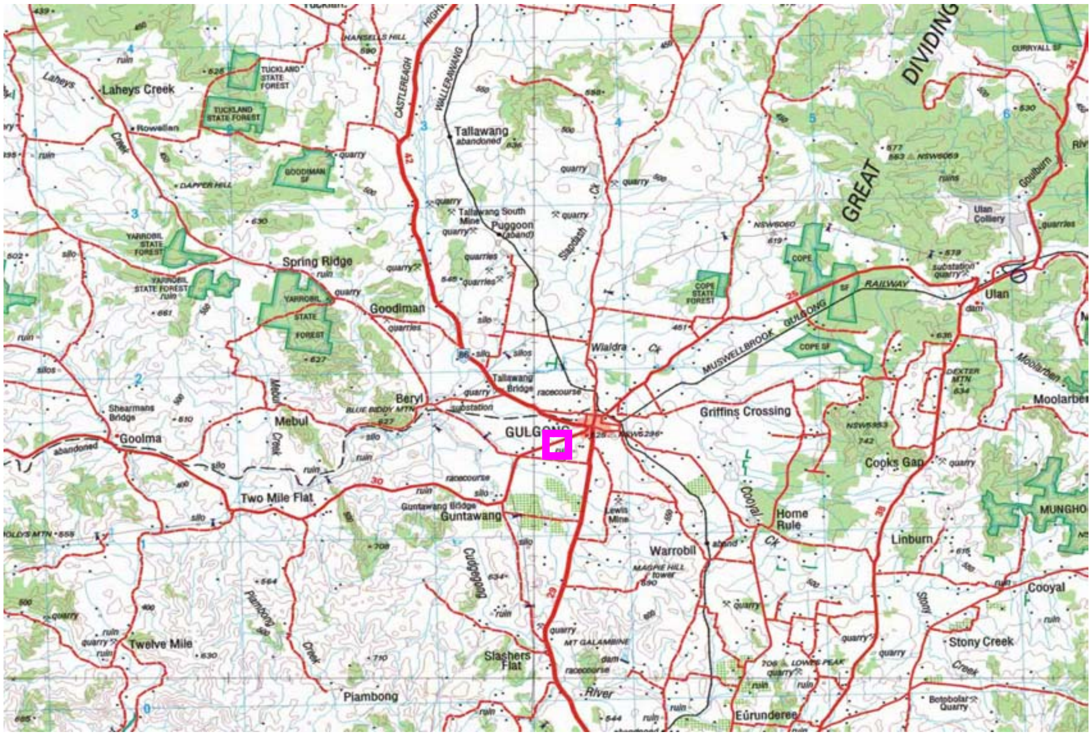

Figure 1. Location map of the Gulgong house.

The house was sited in an east-west orientation with the front door facing west towards Wellington Road.

The surrounding area was flat with mostly stubble grass vegetation. The house was surrounded by the usual outbuildings expected on a farm; stables, machinery sheds, chicken coops and rainwater tanks. The only vegetation surrounding the house of any note was a large orange tree at the rear of the house.

2.2 Construction

Built in the 1960s the house was predominately clad in weatherboards to window sill height and then asbestos reinforced cement sheet to the eaves. The bathroom and kitchen additions to the house were clad full height in asbestos reinforced cement sheet.

Wall, floor and roof framing was hardwood with member spacings typical of the era. Internal lining was predominately plasterboard. Corrugated iron roofing was pitched at 20-30 degrees.

Flooring was predominately tongue and groove timber flooring boards, most likely Baltic pine or similar. Floors in the kitchen and bathroom were partially covered with vinyl flooring, with the bathroom having a concrete slab floor under the vinyl.

The house had a corrugated iron roofed verandah around west and north sides. The verandah on the west side (front) had 19 mm thick cypress pine tongue and groove boards with Australian hardwood sub-floor framing . Flooring had been removed from a large section of the verandah.

Window glazing in Bed 1 south wall was 4mm annealed glass louvres.

The north side of the house had a concrete verandah along two-thirds of its length.

Figures 2-5 show four views of the house.

2.3 House treatment pre-burn

As the house was due for demolition, it contained minimal furniture but included fixtures such as kitchen cupboards and some window curtains.

The FIRU installed various articles of clothing and furniture including items such as beds with doonas, couches, coffee tables with magazines and various electrical appliances to add realism to the fire scenarios.

Figures 2-5 show the four views of the house.

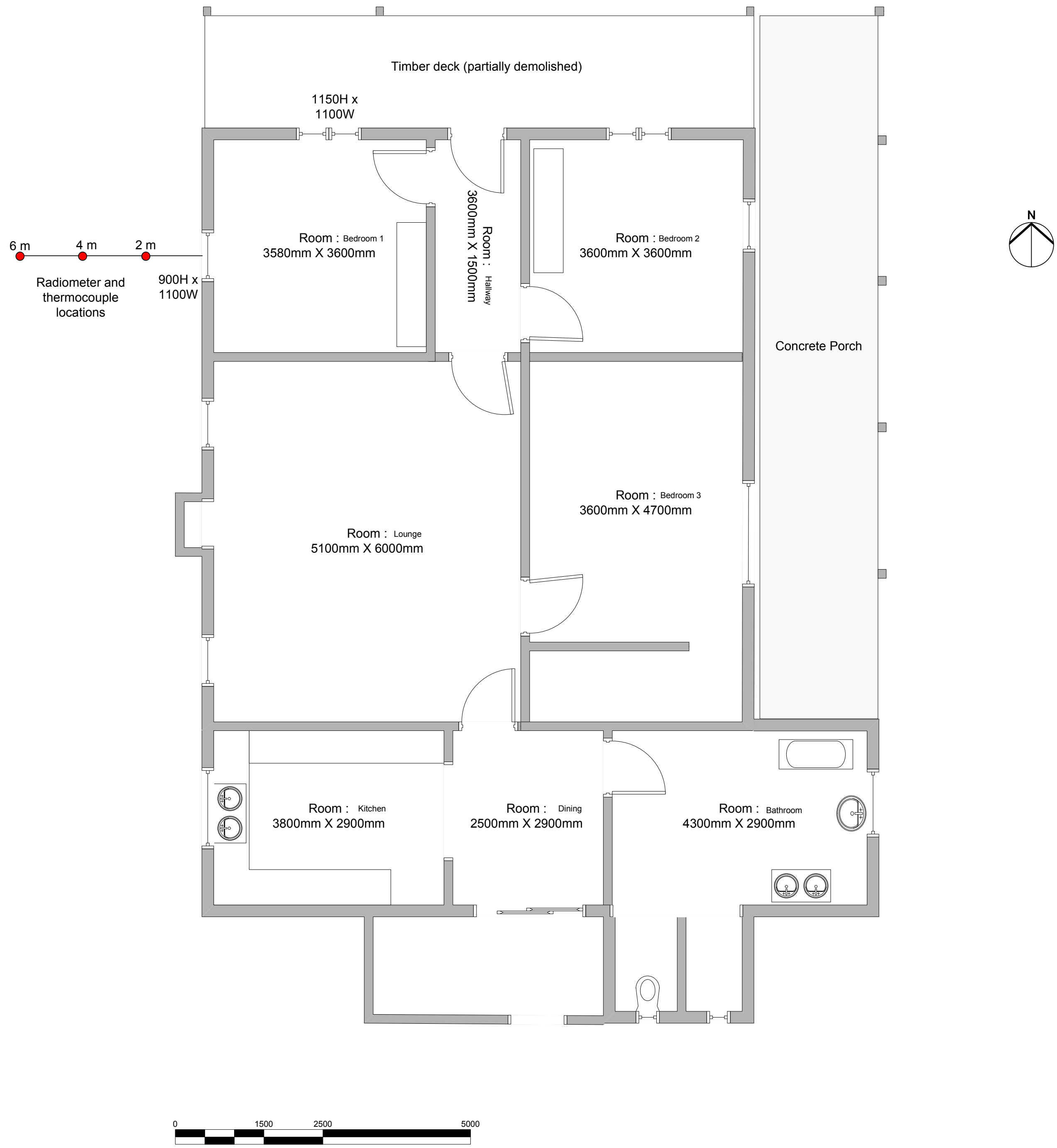

Figure 2. House plan – including radiometer and thermocouple pole locations

Figure 3. West view (front)

Figure 4. North-west view

Figure 5. North-east view

Figure 6. South-east view

Figure 7. South view. Note radiometer/thermocouple poles

3. Experimental apparatus

3.1 Environmental measurement

A hand held temperature and humidity probe was used to measure meteorological conditions, and an anemometer was used for wind speed.

Weather was mild prior to the house burn. Just prior to testing the recorded temperature was 19^{o}C with 57% R.H. A westerly breeze of 3-4 m/s was recorded.

3.2 Radiation and temperature measurement

'K' type Inconel sheathed thermocouples of 1.5 mm diameter with unearthed tips were used to measure all temperatures. These thermocouples have an operating range of 0 to 1200^{o}C.

Radiation was measured using 25mm diameter water-cooled Schmidt-Boelter radiometers with a sensing range of 0 to 100 kW/m^2. These measure total heat flux and cannot differentiate between convective, conductive and radiative forms of radiation. Water cooling was supplied by a 12 volt pump located 20 m away from the poles.

Thermocouples and radiometers are factory calibrated and their responses are checked pre-test by heating with a blow torch.

Radiometers and thermocouples were placed on poles at 2, 4 and 6 metres from the external wall on an axis central to the south window of Bedroom 1. They were placed at two heights – 1.7 m (central window height) and 2.8 m (eaves height), see Figures 2, 7 and 8.

Radiometers and thermocouples were mounted on the poles with tie wire, and all cabling was shielded with adhesive aluminium tape and aluminium foil, see Figure 10.

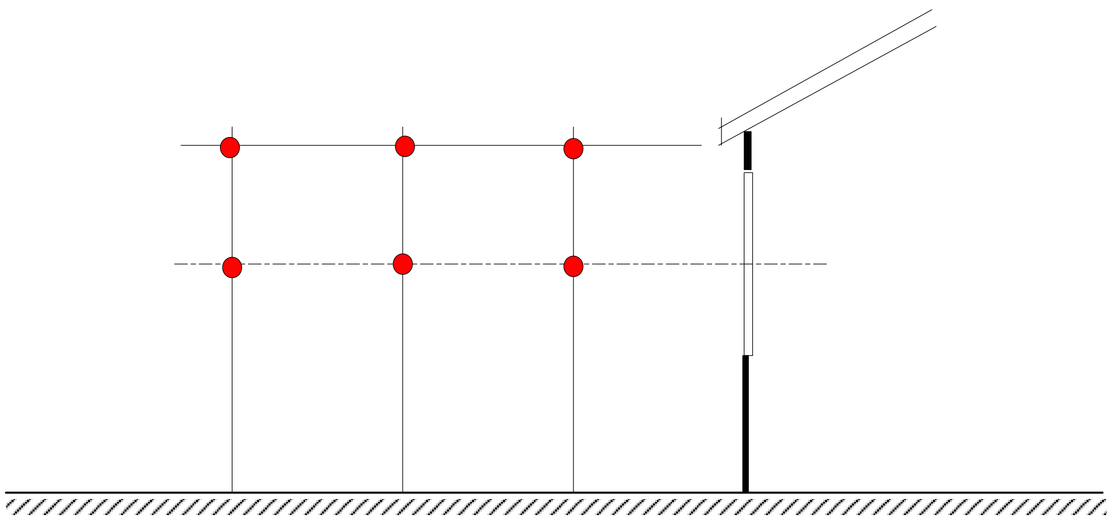

Figure 8. Radiometer and thermocouple locations

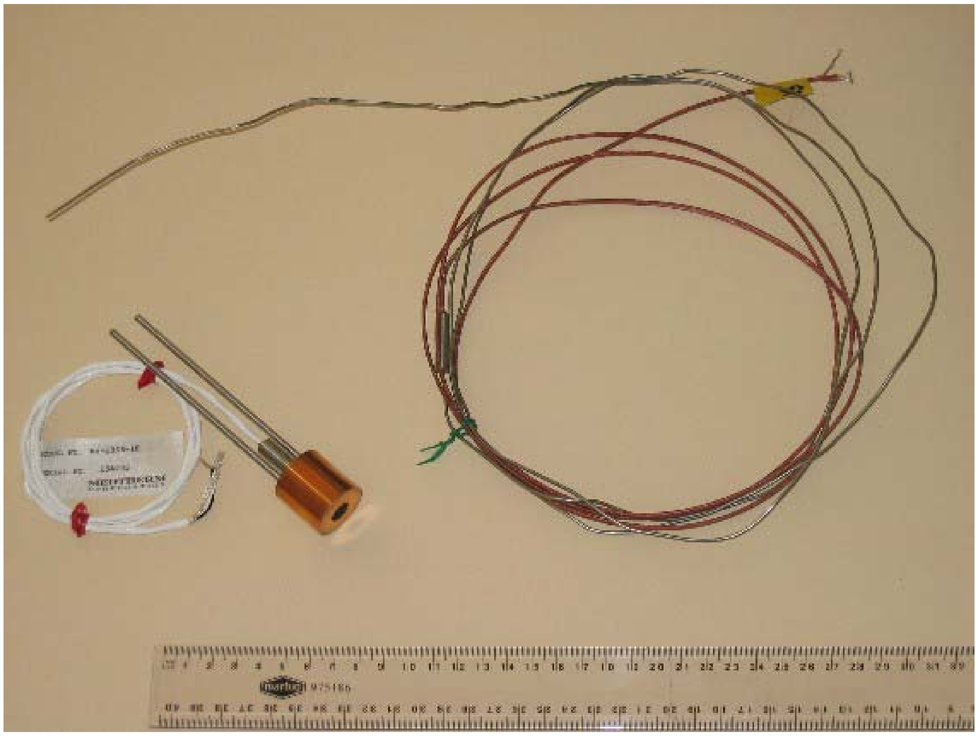

Figure 9 Radiometer and thermocouple cable

Figure 10 Typical radiometer and thermocouple mounting on poles

3.3 Data acquisition

Data from thermocouples and radiometers was logged at 5 second intervals using a DT500 Datataker datalogger and a laptop computer. Figure 11 shows the crude but effective setup of the data logging system. All equipment was covered by a heavy duty canvas tarpaulin for protection. The ‘heat sink’ was placed to create a thermal and radiative barrier against the fire.

Figure 11 Data acquisition equipment

All tests were video-taped and digital photos were taken.

All equipment was powered by batteries and water cooling of radiometers was achieved with a small submerged centrifugal water pump in a bucket of water.

4. Experimental Procedure

In the series of small experiments that were carried out prior to the house burn, some of the fuel within the house had been partially burnt and extinguished. This may have had a small effect on the ignition of the house burn. However, given that the house fire was started by an accelerant, and that there was so much fuel in the house, especially once the timber floors and framing became involved, that the overall effect of the small burns on end results would have been minimal.

There was a hole in the roof, 2 roofing sheets wide above Bedroom 2. These had been removed for previous experimentation to allow access for suppression of roof space fires should they occur.

With damage to most rooms, the best room with windows intact was chosen, Bedroom 1, outside which the radiometer/thermocouple poles were erected.

After 3-4 litres of accelerant was spilt around the interior, ignition was started with a match. The fire was started just inside the back door.

All other doors were left open to allow for flame spread from room to room. The front door was left open allowing a view of the house’s interior during the fire. This door, and the already broken windows of the house, also allowed the entrainment of fresh air into the house, thus feeding the fire. Damage to the ceiling lining in the lounge room in the form of large holes from the previous experiment also allowed fresh air access to the fire.

Fire steadily progressed through the house till involving Bedroom 1.

Datalogging of temperatures and radiation continued throughout the house burn, as did photos of its progress.

Figure 12. Fuel load of Bedroom 1 prior to house burn. Note window in background which had measurement poles on its outside.

5. Results and discussion

5.1 General

A description of the fires progress through the house is given in Table 1.

Time (min:sec)	Event
00:00	Ignition
2:25	Much flaming internally, cracking of flames could be heard indicating large flames present
4:00	Flames penetrating first lounge room window
5:19	Second lounge room window fell out and heavy smoke expelled through opening
7:46	Flames through hole in roof sheeting signifying roof space is now involved
8:41	Crack in louvre window of Bed 1, from heat no flames present in room yet
10:45	Much white smoke emitting from under eaves at front of house
16:00	All rear of house and lounge room well ablaze with no flaming yet in Bed 1
18:00	Flaming on far wall of Bed 1
18:30	Front Bed 1 (west) window fell out
19:00	Side Bed 1 (south) window fell out (window facing measurement towers
20:00	Bed 1 totally involved
20:00+	House continued to burn till razed to the ground

Table 1. Experiment time line

Fuel load in Bedroom 1 is difficult to calculate due to the randomness of furniture and clothes placement in the room. Additional heat load to the room from adjoining compartments is also an unknown factor, so fuel load is not discussed in the results of in this experimentation.

Photos of the fire’s progress can be seen in Appendix C.

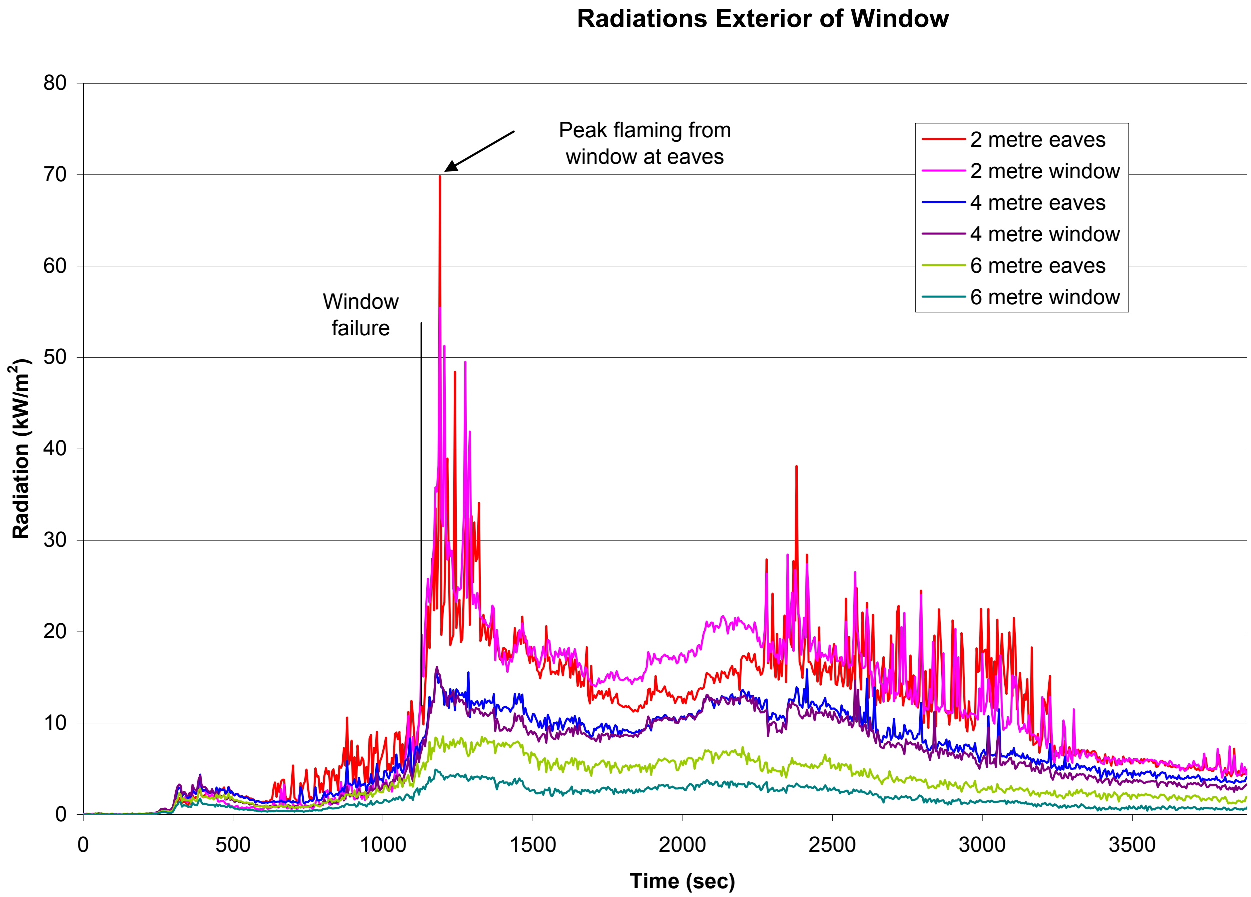

Figure 13. Radiation v. time during experimentation.

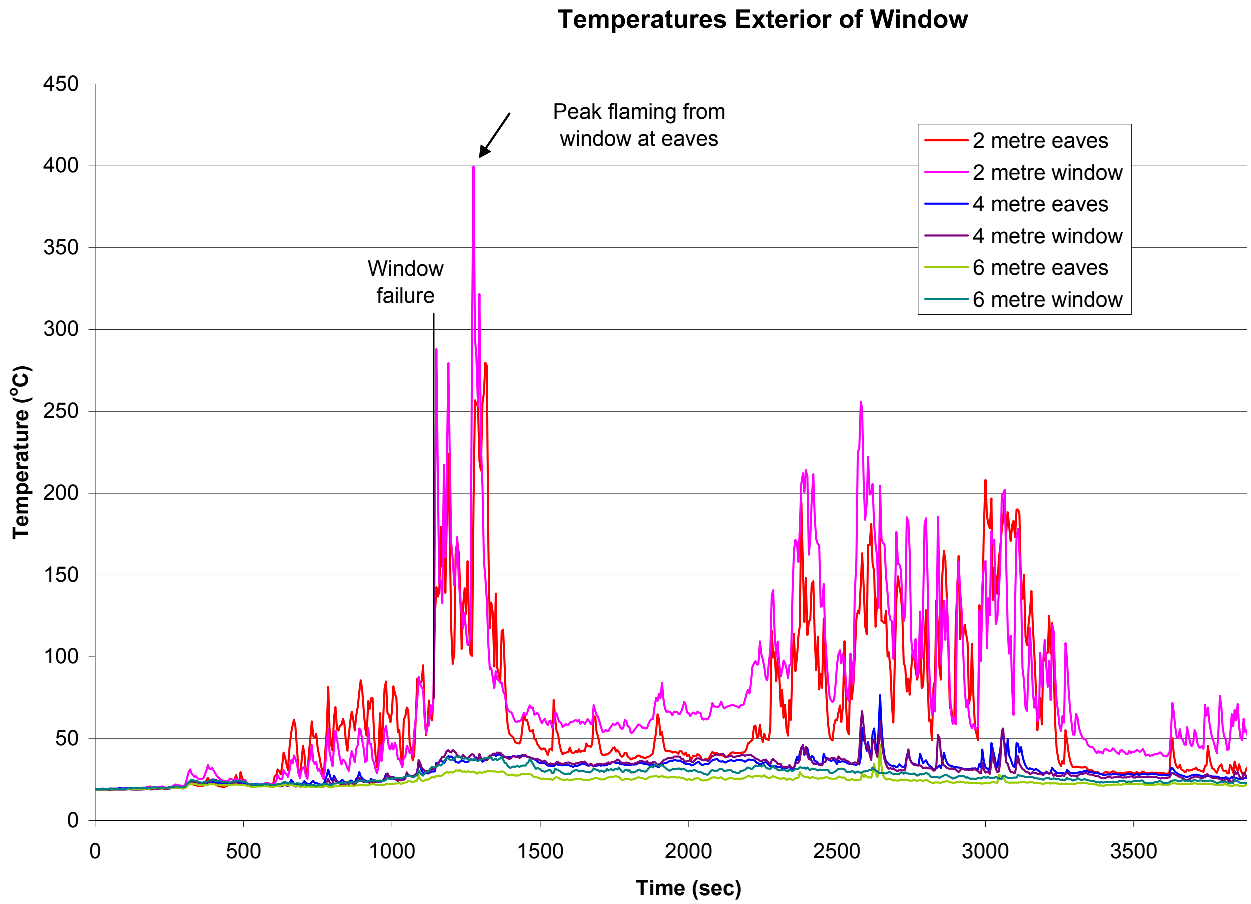

Figure 14. Temperature v. time during experimentation.

5.2 Radiation and temperature graphs

Figures 13 and 14 show radiation and temperatures measured during the experiment.

Immediate spikes in data occurred after window failure. Peak radiation and temperature occurred 80 sec later as the fire within the room intensified with the ingress of fresh air. Peak radiation 2 metres from the window centre was 55 kW/m^2 with a temperature of 223 ^oC. At this time peak radiation at eaves was 70 kW/m^2 with a temperature of 400^oC.

Radiation and temperature reduces after this peak as available fuel lessens. The rise in radiation and temperature after approximately 2200 sec occurs when the walls have burnt sufficiently to expose the internal house structure.

5.3 Potential ignition of surrounding elements and flame spread

Laboratory results from cone calorimeter experiments as part of the Bushfire CRC timber decking project (yet to be reported), have shown that common species of timber used in Australia ignited under piloted conditions at 25 kW/m^2. These experiments conducted in accordance with guidelines for fire-retarded treatments as outlined in AS 3959 [2].

Radiation measured during the experiment, see Figure 13, shows sustained periods of radiation in excess of 25 kW/m^2. The radiation measurement at 2 metres from the window exceeded 25 kW/m^2 for a duration of 145 seconds..

In laboratory experiments on timber, new Treated Pine ignited in 95 sec at 25 kW/m^2 and Mountain Ash at 135 sec when a piloted ignition was used, i.e. presence of a spark or flame.

Further to this, Drysdale [3] Pg 61, Table 2.8, states that volatiles from wood can be ignited by a pilot after prolonged exposure at 12.5 kW/m^2. This is supported by results in Appendix A where piloted ignition at 12 kW/m^2 revealed an ignition of the specimen after 495 sec.

If another house with external timber features, timber fence or other combustible material was placed at 2 metres from the window, ignition of that material would most likely occur in the presence of a pilot flame. Peak radiation was 55 kW/m^2 at this position with temperatures exceeding 300 ^oC.

At eaves height the peak radiation was almost 70 kW/m^2 which would pose potential threat to tall structures within 2 metres e.g. water tanks and power or phone lines.

Radiation levels at 4 and 6 metres from the window peaked at 16 kW/m^2 for short periods and without sustained exposure and pilot flames present it is unlikely that if a fence was present at these distances that it would ignite and flaming would occur.

Data in Babrauskas [4] pg. 269 – 271, gives minimum heat fluxes for ignition of common polmers (plastics) e.g. polyethylene and polyurethane. The maximum of these values required for ignition is 17 kW/m^2. As a result these polymers when presented within the distance of 6 metres would ignite and would potentially create secondary ignition sources. These objects would include childrens toys, play equipment, rubbish bins etc..

External radiations were in excess of 6.4 kW/m^2 a level damaging to human skin causing blistering [4] pg. 61 Table 2.8, which would limit egress or access along this side of the dwelling within 6 metres.

6. Conclusions

These real-scale experiments have given a valuable insight into radiation from house fires, and the propensity of house-to-house spread in the absence of fire-fighting activities.

The radiation measured at 2 metres from the window exceeded 25 kW/m^2 for a duration longer than necessary to cause ignition of most timber species and a variety of polymers. Whilst these experiments were insufficient to determine an appropriate spacing of houses in bushfire-prone areas, it seems apparent that a spacing of 2 m is insufficient to prevent house-to-house spread, even in the absence of combustibles between adjacent houses.

7. References

1. Bicknell A.D., Bradbury G.P, Hofstadler J., Lewis C., Dowling V.P, 2006, *Fire Growth in a Thirty Year Old House*, CSIRO CMIT Doc. No 2006-???

2. Australian Standard AS 3959–1999, *Construction of Buildings in Bushfire-Prone Areas*, Standards Australia, Sydney.

3. Drysdale D., 1999, *Introduction to fire dynamics 2nd edition*, John Wiley and Sons Ltd., West Sussex, UK.

4. Babrauskas V.,2003, *Ignition Handbook*, Fire Science Publishers – A Division of of Fire Science and Technology Inc., Issaquah, WA 98027, USA.

Appendix A - Flammability experiments

B1. Experimental method

Using a cone calorimeter [3] a series of ignitions experiments were carried out on hardwood fence palings to determine whether radiation levels achieved from the house burning would be enough to ignite a fence. Piloted and unpiloted ignition results were obtained.

Piloting of specimens with a spark igniter simulates the presence of flames or sparks which can ignite the volatiles evolving from a heated specimen.

The fence palings were left over from previous experiments and their speciation determined them as being Messmate Stringybark *(Eucalyptus Obliqua)*. This fencing had been in service for over 20 years so was well weathered.

Specimens were not conditioned as is normal practice but were tested as is after months of storage. A sample specimen was oven dried to determine a typical moisture content which was 11%.

B2. Results and discussion

Specimens were subjected to the radiation and piloting conditions listed in Table B1 to obtain ignition and critical heat flux data.

Radiation (kW/m^2)	Piloted/unpiloted	Ignition time (sec)
10	Piloted	No ignition
12	Unpiloted	No ignition
12	Piloted	495
15	Piloted	350
25	Unpiloted	No ignition
25	Piloted	83

Table B1. Ignition experiment results

From the data a radiation of 12 kW/m^2 with a piloted ignition was needed to cause flaming. As these were ad hoc experiments the data can be considered an approximate.

As discussed in [4], pg 217, this is a correct approximation. The widely accepted figure for timber ignition when piloted in [4], pg 61 Table 2.8 is 12.5 kW/m^2.

Appendix B - Photos of house burn experiment

Figure B1. Crude but effective protection of data logging equipment

Figure B2. Experimental setup pre-test

Figure B3. Depth of flames through lounge room window. These flames are much larger than that for bedroom 1, given the room is of a greater volume and has more fuel. This photo is indicative of the extent flames can protrude from a building in this case approximately 4 metres.

Figure B4. Flames beginning to emerge from bedroom 1 window, most louvres still in place.

Figure B5. Fire well established in Bedroom 1

Figure B6. House totally involved

Figure B7. Aftermath of the fire