

# PERFORMANCE OF SOLID TIMBER EXTERNAL WALLS UNDER SIMULATED BUSHFIRE ATTACK

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## ABSTRACT

With the increasing threat of climate change there is a need to use renewable and green materials such as timber for house constructions. Current Australian standards for the construction of homes in bushfire prone areas do not consider the use of timber as a suitable material. However, our understanding of fire performance of solid timber wall constructions is still very limited. A new test standard has been drafted recently to set a special test protocol emulating Australian bushfire conditions. The objective of this research was to conduct a pilot study of experimental testing of a solid timber wall system utilising the basic principles of the Draft Standard AS 1530.8.1 to assess the wall performance under extreme bushfire attack. The experimental work showed that solid log wall assemblies are resistant to extreme bushfire threat and timber can be a suitable material for building in bushfire prone areas if sufficiently thick and well sealed.

**KEYWORDS:** bushfire, char, performance, radiant heat flux, timber.

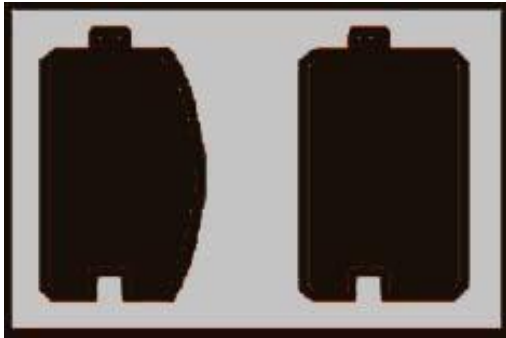
## INTRODUCTION

With the current focus on global climate change and the increasing focus on cataclysmic bushfires in Australia, the use of a renewable resource such as timber as a building material creates a quandary. Timber is an environmentally advantageous building material; timber has low embodied energy, it contributes to the carbon balance, it reduces CO<sub>2</sub> emissions when replacing other energy intensive building materials and it is a renewable resource. Timber is also a combustible material, and current and proposed Australian standards for building in bushfire prone areas discriminate heavily against the use of timber.

The fire performance of solid timber wall construction in Australian bushfires is an area with very limited research. Current Australian standards for the construction of homes in bushfire prone areas do not consider the use of timber as a suitable material in high to extreme bushfire risk areas unless it is rated as fire-retardant (treated or naturally) timber. This form of construction refers to timber cladding (15 – 20 mm) on timber stud walls. There is some consideration of solid timber wall construction, such as tongue and groove logs, which is mentioned in the Australian Standard AS 3959-1999<sup>1</sup>, however it appears that the standard is referring to the treated pine log construction commonly referred to as “log homes” found in Australia. Current proposed changes to the standard (DR 05060<sup>2</sup>) limit the use of timber entirely in the category of extreme bushfire attack, and preclude the use of timber log construction (even if a fire retardant timber is used) for very high bushfire attack category.

In North America there has been a surge in popularity of machined timber log homes referred to as “engineered log” homes over the past twenty-five years. These homes use various profiles of log. Presented in FIGURE 1 are two profiles which have a tongue-and-groove (T&G) configuration. These logs vary in thickness from 90 mm to 200 mm and are usually sealed in the tongue and groove with compressible PVC closed cell foam sealant tape. Timber species also vary from softwoods such as Western Red Cedar or Pine through to hardwoods such as Oak. This form of building has been

growing in popularity in Australia, using 90 mm thick logs of Australian White Cypress, over the past eighteen years.



**FIGURE 1.** Engineered T&G log profiles.

In Australia the “log homes” most people are familiar with are Copper Chrome Arsenic (CCA) treated round log panels which are considerably different than the North American counterpart. The main differences are that the round log panels do not have a tongue-and-groove (T&G) joints as shown in FIGURE 1, have minimal surface contact between logs, are not load bearing, and are of a timber that develops heavy checks (cracks) up to 10 mm. The wall system studied in this research has a wide contact surface between the logs, has through-bolts (threaded rod) from the top to the bottom log, which are tensioned progressively, and therefore has load-bearing capacity.

The Australian white cypress timber is prone to fine surface checking as it dries, however the checks are generally less than 1 mm, and will close up entirely once the heartwood has dried. Once the roof is constructed and load applied the wall does not have gaps at any point, and corners are morticed and tenoned and fitted with seals ensuring a tight fit. A single skin wall system means that these homes must be well sealed to prevent water penetration. The smallest (less than 0.5 mm) unsealed joint will be highly noticeable as daylight will be clearly visible through it.

The fire performance of heavy timber depends on the charring rate of the particular timber, and the exposure (one to four sides). If the timber is sufficiently thick, as in the case of a log wall construction, the progress of the combustion is slowed by the growth of the char layer which shields the unburnt layer. The charring rates in the order of 0.8 mm/min for light dry wood, 0.6 mm/min for medium density softwood and 0.4 mm/min for heavy moist wood have been cited in the literature<sup>3</sup>. A log wall construction would have single sided exposure to fire, and given a thickness of 90 mm with a charring rate in the order of 0.6 mm/min, it follows that a log wall construction should have adequate resistance to survive the passing of a fire front. The formation of char provides an insulating layer protecting the underlying solid wood, slowing the rate of burning and contributing to the tendency for heavy timbers to self-extinguish. Intuitively, it follows that solid timber wall construction should be resistant to ember ignition, to ember ignition of adjacent combustibles, as well as radiant heat and flame impingement from the passing fire front.

Testing of wall assemblies in Australia has been limited to those for fire resistance ratings, which are designed for enclosure fires rather than the endurance against a passing fire front (flame impingement, radiant heat and ember ignition of adjacent combustibles) that is associated with bushfires. The fire front of Australian bushfires is known to travel at a considerable speed through the bush, with peak levels of radiant heat of quite short duration (in the order of two minutes of peak temperatures recorded from Project Vesta<sup>4</sup>). Ember attack on the other hand is well known as the cause of most property loss, causing adjacent combustibles to ignite and spread to the building<sup>5</sup>. Test protocols for performance assessment of a wall assembly are being developed<sup>8</sup> to address the current lack of performance provisions for alternate construction methods in AS 3959 - 1999<sup>1</sup>. A draft Australian standard DR 06598 (to be AS 1530.8)<sup>2</sup> for testing of materials for bushfire resistance has recently been released for public comment.

The hypothesis for this research is that a solid timber wall can perform as a bushfire resistant wall assembly and meet the performance requirements of the Building Code of Australia (BCA) 2006<sup>7</sup>. The objective of this research is to conduct a pilot experimental study to assess the performance of solid cypress T&G log wall systems under a condition emulating severe bushfire attack.

## BACKGROUND

A limited amount of research has already been carried out in the area of fire resistance level (FRL) of solid timber walls, mainly in Europe and the USA, using local timbers and the “scribe-fit handcrafted” large logs with various sealant methods. The main source of literature in this area is a PhD dissertation by Dalibor Houdek<sup>11</sup> and a journal paper summary of this PhD Thesis<sup>10</sup> where a scribe-fit log wall was tested under ASTM E-119 conditions to achieve a fire resistance rating. The results of Houdek’s<sup>11</sup> testing confirmed that the “wall withstood 180 minutes from its integrity and insulation viewpoint and 172 minutes from the point of its load-bearing capacity”.

Bob Phillips<sup>12</sup> wrote an article based on an anecdotal case study of a log home originally built in 1819, and restored in the 70’s only to suffer an electrical fault resulting in a large scale fire. This article describes a 30 hour battle to extinguish the fire, with the resulting maximum 25 mm of charring of the 171 year old log walls simply sandblasted away and restored, while the internal modern framed walls and roof structure were lost.

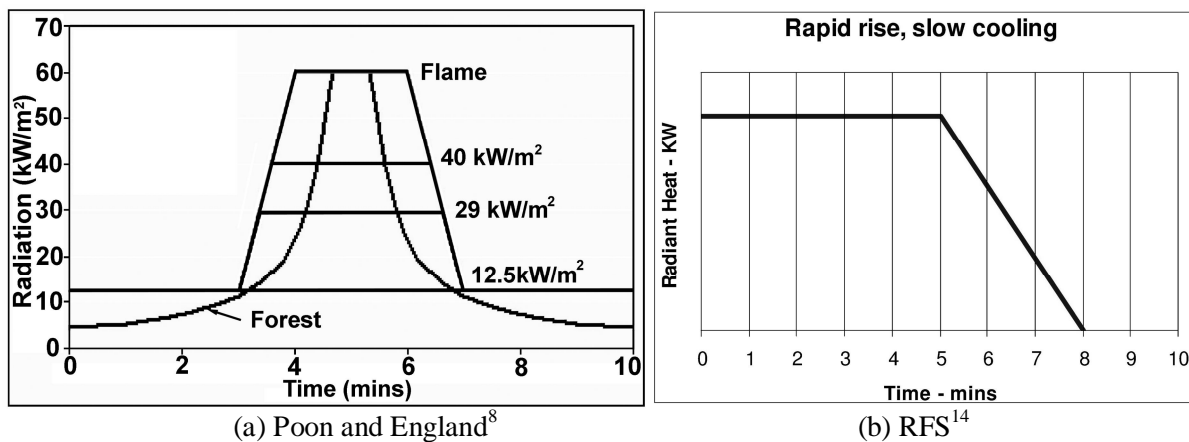
A catastrophic bushfire in Canberra, Australia on 18 January 2003 caused extensive property damage and significant house loss, and resulted in an inquiry conducted by the municipal Coroner. The CSIRO investigated the fire damage to clarify the mechanisms of bushfire attack and recently reported the findings<sup>13</sup>. One particular suburb, Duffy, was particularly impacted with 219 houses lost and was surveyed for this report. It was shown that 47% of the homes in this suburb were destroyed, 18% untouched and the balance had only superficial or light damage. Significantly, 99% of the house external wall materials were brick. In summary, the findings were that the mechanisms of bushfire attack were 50% via embers only and 35% via embers and radiant heat from surrounding vegetation and other structures. There were no houses found to have been directly impacted by flames from the fire front. The report concludes that in every survey of major bushfires by CSIRO Manufacturing & Infrastructure Technology (CMIT) ember attack has been the key mechanism for bushfire building losses.

The New South Wales Rural Fire Service (RFS) have prepared a document known as “Planning for Bushfire Protection 2001”<sup>14</sup>. This document sets out categories of bushfire attack based on a radiant heat model developed by the CSIRO for the RFS in 2000. While this document acknowledges that ember attack is the most prevalent cause of house fires in bushfire incidences, the focus is on radiant heat and flame impingement. The radiant heat flux (RHF) model described in Appendix 3 of the document has been criticised for its inaccuracy due to its broad assumptions made to implement the radiative heat transfer equation and its inability to reflect the complexity of bushfire flames<sup>15</sup>. New semi-transparent models are being developed by CSIRO<sup>16</sup> to address the shortcomings of these opaque-box models.

Poon and England of Warrington Fire Research (WFR) conducted a literature review<sup>8</sup> of bushfire construction materials and proposed test protocols for performance assessment. This report highlights the range of bushfire attacks to include ember access, ember accumulation, firebrand impact, radiant heat and flame contact. It also develops a time dependant radiation exposure profile for representing extreme bushfire conditions and finally a set of exposure conditions for bushfire hazards is derived. WFR also developed a guideline<sup>9</sup> for evaluation and specification of bushfire resistant building elements which provides a means of characterising the exposure conditions required (a radiant heat flux level and distance) along with information for testing procedures according to the fire category.

Further development of this guideline by Independent Fire Test Laboratories<sup>17</sup> resulted in specific test procedures for simultaneous radiant heat and burning brand (ember) exposure.

Independent Fire Test Laboratories have developed a test method for evaluating traditional and innovative construction in Bushfire Prone areas known as FSE 027 Part 1 Version 1.3<sup>17</sup>. The test provides an assessment of the performance of building elements when exposed to radiant heat, burning embers and burning debris as a means of simulating bushfire conditions. The imposed radiant heat flux profile simulates the transient peak from the fire front, a pilot ignition source is used to simulate ember attack, and timber cribs are imposed to simulate burning debris. There are three radiant heat profiles nominated for the test, a generic profile and two NSW Rural Fire Service profiles. The generic profile shown in FIGURE 2 is based on research work by Poon and England<sup>8</sup>. The NSW Rural Fire Service (RFS) profiles<sup>8</sup> are (i) slow rise and rapid cooling to a selected peak radiant heat flux and (ii) rapid rise and slow cooling to a selected peak radiant heat flux [see FIGURE 2(b)].



**FIGURE 2.** Radiation profiles for bushfire tests.

The timber cribs used in FSE 027 have been developed from tests conducted at WFR<sup>8</sup> of various accumulated debris pile sizes. The class of crib relates to the expected size of accumulated debris. Three classes of brands (embers) are used, Class A which applies to small surfaces close to the horizontal such as window sills, Class B which simulates areas such as decks and gutters and Class C which simulates underfloor areas where access is difficult.

The test procedure in the new draft standard DR 06598<sup>6</sup> describing the fire testing method for bushfire resistance of elements of construction is very similar to FSE 027<sup>17</sup> with the only significant differences being that the crib size for recommended for testing is Class A, the crib placement is at the beginning of the test only, the radiant heat profile is based on a rapid rise/ slow cooling profile, the categories of bushfire attack relate to the DR 05060 for the proposed new AS 3959 -1999 standard, and the failure criteria modified to include a limited temperature of internal faces. The reporting of Bushfire Resistance Level (BRL) is of the form BRL followed by the class of crib and the peak radiant heat flux used. For instance BRL A40 translates to bushfire resistance level using a Type A crib and a peak radiant heat flux of 40 kW/m<sup>2</sup>. This level relates to the Very Severe level of bushfire risk in the proposed Draft AS 3959, or extreme in the current standard.

## MATERIALS AND METHODS

Experimental work was designed as a pilot study involving the testing of several medium scale log wall construction assemblies. This experimental work was designed as a preliminary evaluation for the purpose of developing the foundation for a future and more comprehensive study. The basic principals of the test procedure detailed in DR 06598<sup>6</sup> were used to test a series of panels with various

finishes, however the sample size was smaller than the prescribed 3×3 m size. A pilot flame was not used because the burning crib provided a pilot flame from the beginning of the test.

The available radiant heat source was a 1320×1320 mm gas fired radiant heat panel at the CSIRO North Ryde Fire Testing Facility. In accordance with DR 06598 Clause 11.1, the samples were required to be 400 mm less wide and 400 mm less high than the radiant panel. Panels 850 mm wide by 7 logs high (910 mm) were constructed using logs naturally seasoned for two years to a moisture content of 10% or less as required by Clause 12. Moisture content was measured using a probe type moisture meter on the surface and inside a freshly drilled hole which was used to install a radiometer for heat flux measurement. A PVC sealant tape known as Willflex was used in the tongue and groove to emulate the real construction. Logs were held together with standard 10 mm threaded rod tightened to 40 Nm. This torque was applied to emulate the normal roof load existing on the log wall system. The fire side (external side) was finished with various external clear finishes typically used on log homes, and two test samples were finished with fire retardant products. Details of the samples are given in TABLE 1.

Three samples (#1, #6 and #9) were constructed with a small section to emulate decking material directly in contact with the log wall. The samples were fitted with a decking board on the base to provide a flat surface to balance the panel. A sheet of fibre-cement was used to form a ledge for crib placement when a deck was not used.

**TABLE 1.** Test sample panels.

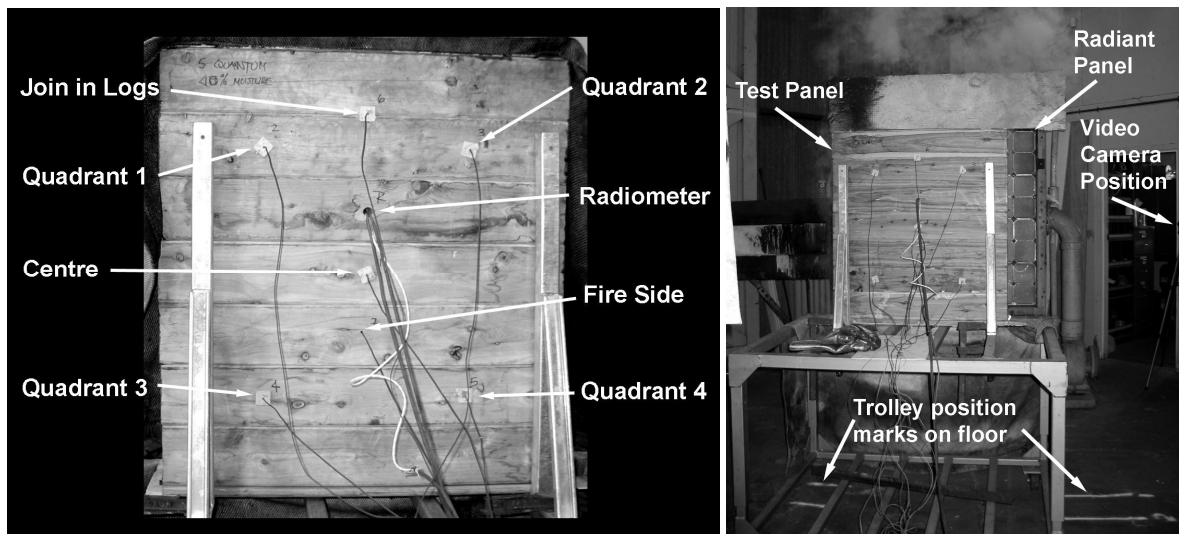
Sample #	Moisture Content	Details
1	<10%	Painted with Quantum and fitted with “deck” assembly
2	<10%	Painted with Matador FR Clear (intumescent coat)
3	<9%	Painted with primer coat and top weather coat
4	<8%	Painted with Feast Watson Woodshield (oil- based)
5	<10%	Painted with Quantum (oil-based water-borne)
6	<9%	Painted with Protim Raincoat UV Plus with “deck” assembly
7	<8%	Painted with Protim Raincoat UV Plus (oil-wax based)
8	<8%	No coating
9	<9%	No coat with “deck” assembly
10	<12%	No coating – Calibration run

Samples were mounted on a moveable trolley using two steel brackets on the inside face to stabilise the panels. The trolley on wheels enabled heat flux to be regulated as specified. Mineral fibre blankets were used to shield the samples from radiant heat until the commencement of the tests. The experimental setup is shown in FIGURE 3.

Type K thermocouples were mounted in seven positions including the centre surface, each quadrant, on a join in the logs and fire-exposed face as shown in FIGURE 3. The fire exposed thermocouple was mounted by drilling through the third log along the centreline and packing with mineral wool insulation. A total heat flux meter was used to measure the heating profile. This meter was installed along the centre line of Log 5 by drilling a hole to allow the face of the meter to be flush with the outside wall. The hole was packed with mineral wool to protect the edges formed. Data logging with a Datalogger DT800 was used to record both the heating profile and the temperature profile of the wall section.

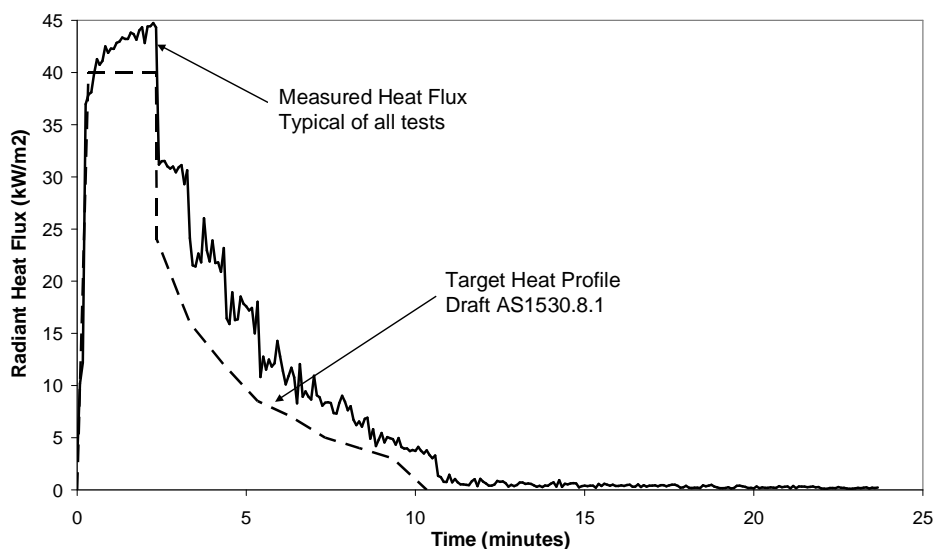
Simulation of burning debris via cribs was designed to comply with Class A of DR 06598. This class of crib was chosen to represent the expected accumulation of debris for occupied buildings with reasonable levels of maintenance on or adjacent to the building as recommended in the standard. Cribs were conditioned for 24 hours at 55°C and removed from conditioning oven 60-120 minutes

prior to testing. Cribs were ignited using a gas torch on each exposed face for 30 seconds for a total of three minutes. The bottom face was not ignited for handling reasons. Cribs were applied centrally on the deck or directly on the ledge of fibre cement sheeting with one face against the sample within 15 seconds of exposure to radiant heat.



**FIGURE 3.** Experiment setup and instrumentation.

The standard radiant heat profile prescribed in Draft AS 1530.8.1 (shown as the dash line in FIGURE 4) with a peak flux of  $40 \text{ kW/m}^2$  was utilised. The radiant heat exposure by the sample panels was regulated by physically moving the trolley with sample mounted towards and away from the radiant heat panel. The radiant heat fluxes at various distances to the radiation panel were calibrated in a calibration test using the radiometer mounted at the central location of the panel and lines were marked on the floor indicating the required trolley position to achieve the correct radiant heat flux. During the experiment, the specimen was positioned at various distances for short periods so that an approximation of the standard radiant heat flux profile could be achieved as shown by the solid line in FIGURE 4. It is noted that the measured heat flux included the convective heat transfer component. Extracting the latter, the remaining radiant heat flux component would be even closer to the prescribed standard profile.



**FIGURE 4.** Radiant heat flux profiles.

Temperature data and radiant heat flux were recorded at five second intervals from commencement of the test for at least the sixty minutes. Visible events were recorded via a video camera positioned near the radiant heat panel and with digital photography for the full sixty minutes of the test.

Performance criteria were extracted from Table 14.3 of DR 06598<sup>6</sup> and are summarised in TABLE 2. The radiant heat flux for criterion No. 4 was not measured. The intention of this criterion was to address the potential need for people to pass by the panel 10 minutes after the passage of the fire front to evacuate the building or undertake intervention. Based on the know tenability limit of 2.5 kW/m<sup>2</sup> radiant heat flux by human skin<sup>19</sup>, a rather simple test method of placing a hand at the specified position and holding it there for 30 seconds was utilised.

**TABLE 2.** Performance Criteria Extracted from Table 14.3 of DR 0659.

No.	Performance Criteria	Time to Failure (min)	Position of Failure
1	Formation of through gaps greater than 3 mm	No Failure	
2	Sustained flaming for 10 seconds on the non-fire side	No Failure	
3	Flaming on the fire exposed at the end of the 60 minute test period	No Failure	
4	Radiant heat flux 365 mm from the non fire side exceeding 15 kW/m <sup>2</sup>	No Failure*	
5	Mean and maximum temperature rises greater than 140K and 180K	No Failure	
6	Radiant heat flux 250 mm from the specimen, greater than 3 kW/m <sup>2</sup> between 20 and 60 minutes	No Failure	
7	Mean and Max temp of internal faces exceed 250 °C and 300 °C respectively between 20 and 60 minutes after commencement of test	No Failure	

\* There appeared to be an error in the original document which says “Not Applicable” for this criterion.

Collation of the experimental data was carried out in three stages. First, video footage and photos were examined to note the performance of the panels against the performance criteria. Second, temperature and radiant heat data were extracted from the data logger files, imported into spreadsheets and converted to graphical representations for analysis. Finally, panels were sectioned, photographed and image analysis used to record char depths.

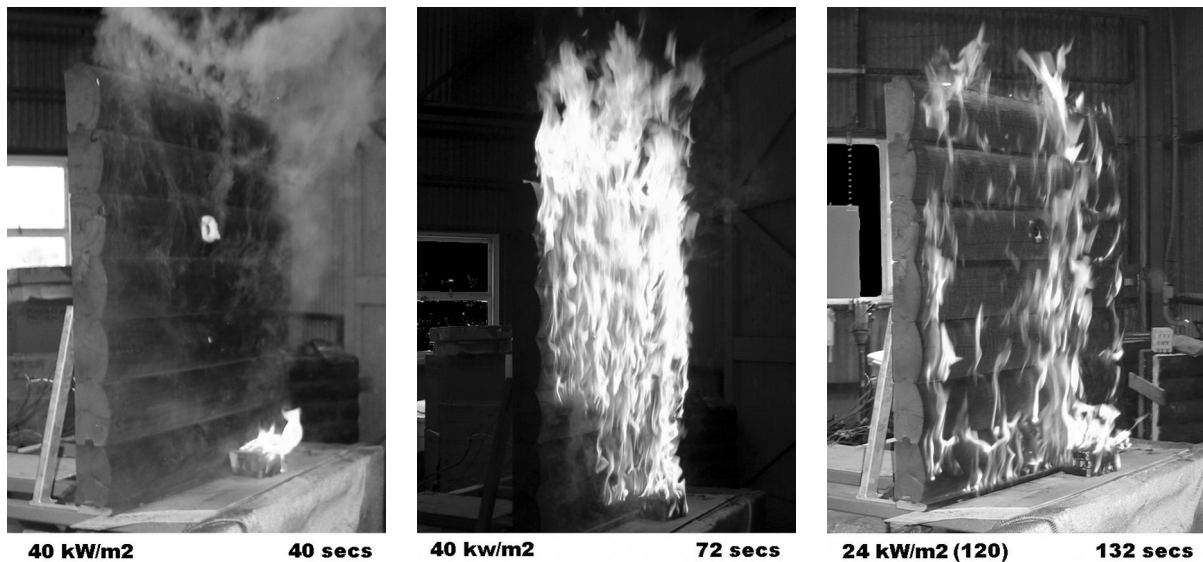
Each panel was labelled with log row numbers from 1 at the bottom to 7 at the top. The logs of four of the samples were sectioned along the vertical centre line of the panels, in quadrant one and in quadrant two after the tests. Other panels to be analysed were only sectioned along the vertical centreline, except for the Matador FR panel (Sample #2) which was simply photographed. Each section was marked with the panel number, the log number and CL, Q1 or Q2 for easy identification. Using a white background, each sectioned log sample was recorded using high resolution digital photography. The original log profile was marked with 9 positions perpendicular to the affected surface. Image J<sup>18</sup> software was utilised to then measure the char depth at each of these positions. Chars depths were then converted to spreadsheets and represented graphically.

## RESULTS

### General Observation

A series of photographs of the Sample #4 test provides a typical time line for significant events and can be found in FIGURE 5. As expected, the panel began to pyrolyse almost immediately once radiant heat was imposed. The pyrolysis or the charring pattern was somewhat uneven due to the

uneven radiant heating and the induced natural convective heat transfer. It was noted that quadrant 1 was subjected to slightly higher radiant heat than quadrant 2. The bottom section of the panel appeared to be affected by the presence of the crib fire. There was a V-shaped semi plume centred at the crib (40 sec shot). The hot air plume assisted the char formation at the surface of the panel. It was also noted that the presence of the decking board under the panel created an additional “crib” effect to the panel.



**FIGURE 5** – Pre-heating, ignition and flaming processes with Feast Watson Panel (Sample #4)

Flaming on the Sample #4 panel was significantly reduced when the imposed radiant heat flux was reduced from 40 kW/m<sup>2</sup> maximum to 24 kW/m<sup>2</sup>. Within seconds of radiant heat reduction, there was a dramatic reduction in flaming. The flaming of the logs ceased soon after the imposed radiant heat flux was reduced to 16 kW/m<sup>2</sup>. The sole source of flaming for the remainder of the test was the crib, and a small amount of flaming from the decking board under the panel. After 20 minutes from the beginning of the test there was no flaming on the fire side of the sample (including the crib which stopped flaming after 13 minutes). Heat flux from the log panel was low and it was possible to walk up to and remain within 250 mm of the panel comfortably 20 minutes after beginning the test.

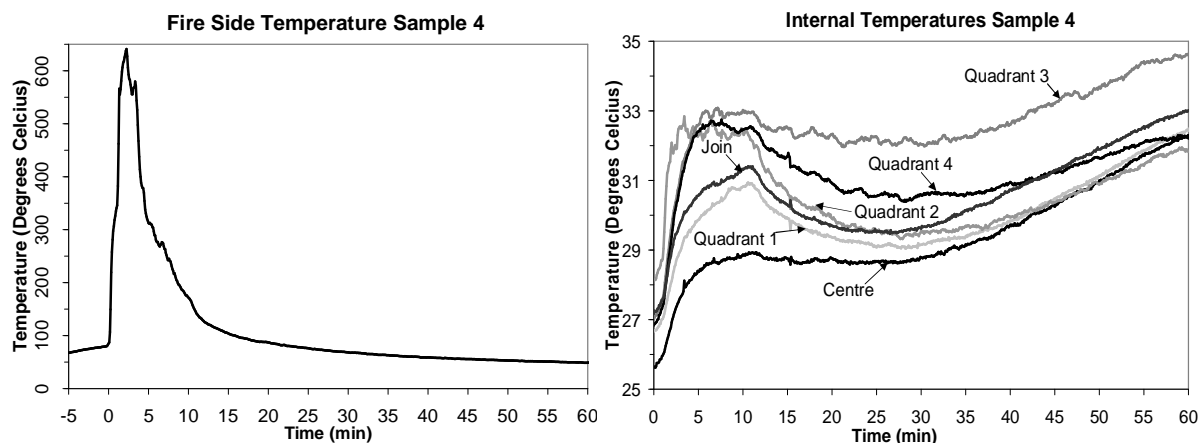
The performances of other panels, except for Sample #2 and Sample #6, were similar to that of Sample #4 as described above. Sample #2 had an intumescent coating which protected the panel effectively and prevented charring and flaming on the surface of the sample. The decking attached to Sample #6 was involved in the flaming and glowing combustion generated moderate radiant heat flux within 250 mm distance from the sample after the removal of the external radiation source.

### **Temperature Measurement**

The results of temperature monitoring for Sample #4 test showed that external temperature peaked at 641°C and was maintained above 150 °C for 10 minutes during imposed radiant heating (see FIGURE 6). The corresponding temperature increase on the inside of the panel (which is influenced by an increase in ambient temperature as the sample was manoeuvred close to the radiant panel) was approximately 4 °C. The lag time for heat transfer through the panel can be seen after the imposed radiant heat is reduced (at 10 minutes) where ambient temperature drops, and surface temperatures increase by an average of 3 °C over the ensuing 50 minutes. An overall increase of approximately 10 °C from the start of the test was measured. The temperature results of this test were typical of all other tests.



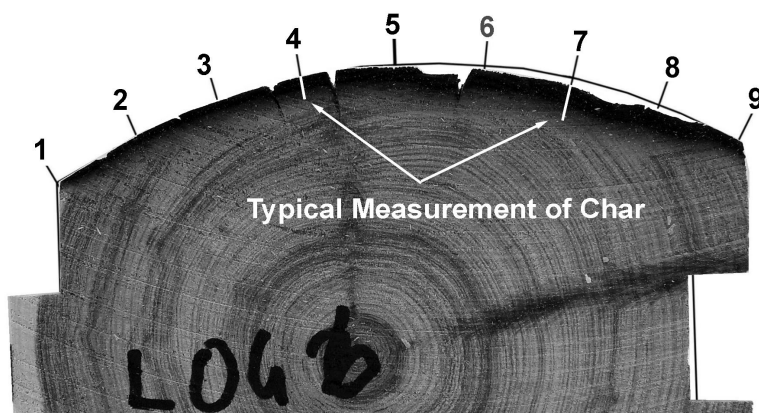
The external temperature of the panel responds to the flaming of the panel, and is also influenced by the burning crib located near the thermocouple. The external temperature also reflects the sudden reduction in flaming when the radiant heat was reduced to 24 kW/m<sup>2</sup> dropping from 580 °C to 378 °C in one minute, and dropping a further 80 °C in one minute following a reduction to 16 kw/m<sup>2</sup>.



**FIGURE 6.** Fire side and non-fire side temperature profiles of Sample #4 test.

### Charring

Analysis of char depths provides excellent insight into the performance of solid log walls and a typical char result adjacent to the crib is shown in FIGURE 7. Four panels were sectioned and analysed carefully. Results of char analysis are summarised in TABLE 3. As supported by visual monitoring, char depth analysis confirms that coating influences the fire performance of the log panels. The No Coat Panel (Sample #10) performs best among the four samples, and the Raincoat Panel (Sample #7) performs significantly worse. Nonetheless, even the worst performance has extremely low char depth. All the coatings are penetrating coatings and contain oils and pigment to protect the timber from weathering. The Raincoat product contains an oil-and-wax mixture and seemed to create stronger flaming which is supported by deeper char penetration. The Quantum Panel (Sample #5) was subjected to slightly higher and longer radiant heat flux (using radiometer to regulate heat flux without benefit of floor markings used later) and the results are conservative for this panel.



**FIGURE 7.** Typical char results

**TABLE 3.** Summary of char depths of four sample panels.

Sample # and Name	Mean Char Depth (mm)			Average Char Depth (mm)
	C/L	Quadrant 1	Quadrant 2	
4 Feast Watson	3.68	2.78	2.98	3.15
5 Quantum	3.10	3.31	2.69	3.03
7 Raincoat	4.38	3.56	3.28	3.74
10 No Coat	2.53	2.94	2.19	2.55

### Bushfire Resistance Level Assessment

The log wall samples were assessed against the bushfire resistance performance criteria (TABLE 2) to achieve a BRL A40. A summary of the assessment results is shown in TABLE 4. Difficulties with design of the decking samples and time constraints meant that only the panels with a small deck attached could be properly tested. The design of the original deck allowed flames to pass under the wall section, which was corrected by installing a timber blocking on the samples. Sample #6 failed Criterion 6 in TABLE 2 due to radiant heat generated by the burning deck material being higher than 3 kW/m<sup>2</sup> at 250 mm from the specimen.

**TABLE 4.** Summary of test results for BRL A40

Sample #	Sample name	BRL A40	Comment
1	Quantum deck	N/A	Incomplete, difficulties with deck configuration
2	Matador	Pass	Did not ignite, intumesced to 20 mm
3	FR	Pass	Primer coat and top weather coat
4	Feast Watson	Pass	Flaming occurred and self-extinguished
5	Quantum	Pass	Flaming occurred and self-extinguished
6	Raincoat deck	Fail	Deck caused criterion 6 failure
7	Raincoat	Pass	Flaming occurred and self-extinguished
8	No Coat	Pass	Flaming occurred and self-extinguished
9	No Coat deck	N/A	Incomplete

### DISCUSSION

The present experimental work showed remarkable performance by the solid log wall system subjected to a test condition emulating that of extreme bushfires. Although the experimental work was a pilot study it is possible to extrapolate the findings from the performance of the samples and combine these with the findings of case studies reported in the literature to show that the T&G log wall assembly was exceptionally resistant to bushfire attack. The current study provided insights into the mechanisms of bushfire attack and destruction of homes. It would assist a discussion of current standards as well as proposed standards and test procedures that related to bushfire behaviour and its interaction with houses. Experience with the new test procedure DR 06598<sup>6</sup> highlighted some deficiencies and possible improvements to the procedure.

The present experimental work demonstrated both the heavy dependence of flaming of T&G log walls on the presence of intense radiant heat source and the strong tendency for the walls to self extinguish once radiant heat was reduced. This result indicated that the log walls may not contribute significantly to flame spread to other components of a house after the passage of fire front and consumption of adjacent combustibles.

The current study also demonstrated the performance of T&G log walls in maintaining stability and integrity of the building envelop and preventing ember entry. Char depths were exceptionally low in the experimental testing, being less than 4% of the original wall thickness. Such a low degree damage

can be simply repaired with surface treatment and using environmentally renewable resources. The significance of easily restored damage to the structural component of a house cannot be underestimated with considerations for insurance as well as environmental issues. Buildings damaged in a fire are normally completely (including footings) removed to landfill, and rebuilt from foundations upwards using energy intensive materials.

Temperature measurements during the current experimental work show the very high thermal resistance of solid timber. Faced with external temperatures in excess of 600 °C and sustained temperatures above 150 °C for more than 10 minutes, internal temperatures increased by only 10 °C. This temperature increase was partly attributable to an increase in ambient temperature during testing. This makes a log wall a very efficient radiant heat shield.

The test procedure has several areas of potential improvement before being implemented. The radiant heat profile requires review in light of the lack of evidence to suggest such high levels and long exposure times of radiant heat attack on buildings. The rapid heating regime and long duration of imposed radiant heat flux does not replicate the true fire situation<sup>4</sup>, and this area remains a contentious issue<sup>20</sup>. The requirement for a pilot flame is redundant considering a burning crib is utilised. Crib placement requires review given that in most cases burning debris would not exist directly against a building element, for instance a non-combustible subfloor is usually a minimum of 400 mm in height on which the wall construction is built. More flexible or a range of placements can be prescribed. The performance criteria for less than 3 kW/m<sup>2</sup> radiant heat within 250 mm of the element being tested after 20 to 60 minutes requires clarification to allow the performance criteria to be assessed.

The focus by the proposed test regime on the impact of the fire front, specifically the radiant heat and flame attack from a bushfire and the materials of external construction may be misguided. The literature shows that in more than 20 years of research evidence of radiant heat and flame attack from a fire front causing building fires has not been identified. Some evidence of radiant and flame attack from adjacent burning buildings has been identified, but not from the fire front. The evidence for ember attack is very strong, and supports many of the prescribed requirements in the current AS 3959<sup>1</sup>. Scientific evidence also strongly supports the fast speed and short duration of such attacks, contrary to current prescribed documents such as Appendix III of Planning for Bushfire Protection<sup>14</sup>. The undue focus on radiant heat and flame attack may add unnecessary additional costs to new building stock without significant benefit. A considerable amount of research may be required to develop suitable models for accurate estimates of radiant heat flux from bushfires.

## CONCLUSIONS

The performance of T&G log wall assemblies of Australian white cypress were evaluated by subjecting to a newly developed test regime and assessment criteria. Most of the wall assemblies passed the test which emulates extremely severe bushfire attack in terms of radiant heat exposure and ember ignitions. The walls were found to develop initial flaming combustion but self extinguish quickly after exposure to the prescribed radiant heat flux profile. Charring to timber logs was found to be less than 4 percent of the original thickness, allowing a simple means of restoring fire impacted buildings without complete rebuilding and obvious implications for insurance and the environment.

The outcomes of the current research provided further evidence that if assembled properly, timber materials can achieve adequate fire resistance capability. The excellent performance of solid timber walls in bushfire conditions provides a means to utilise an environmentally advantageous building material, timber, in a country beset by bushfires in urban and rural areas.

Based on a literature review, the current pilot study and field engineering practice, opinions were offered for the improvement of the newly developed test standard. It was envisaged that more reasonable radiant heat flux profiles and flexible or variable placement of crib ignition source could be introduced.

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