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Fire Tests at the Interface between Timber Decks and Exterior Walls

Report to
Bushfire CRC

L. Macindoe
A. Sargeant
P. A. Bowditch
J. Leonard

CSIRO - Manufacturing and Materials Technology
Fire Science and Technology Laboratory

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Please address all enquiries to:
The Chief
CSIRO Manufacturing & Materials Technology
P.O. Box 56, Highett, Victoria 3190

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Executive Summary

This report forms part of the work undertaken for the Bushfire CRC to reduce the risk of building loss and injuries to occupants due to bushfires. It investigates the parameters which control the ignition of timber decks and the subsequent propagation of the fire to the external wall of the house. This was achieved through testing small samples of deck/wall and varying the parameters to determine their effect.

The parameters varied included:

- External radiation
- Size and type of ignition source
- Airflow
- Position of ignition source
- Type of deck
- Material conditioning
- Application/timing of the ignition source, radiation and air flow

Even though over 60 tests were conducted it equates to only a few comparative tests for each set of parameters considered. It does however give a good overall indication of what parameters are critical and what needs to be considered in future decking design guides for bushfire areas.

Some interesting outcomes include:

- Small gaps (<1mm) in the cladding, too small for embers to get through are susceptible to air driven fire attack particularly if the orientation of the wall is likely to channel the air into the gaps such as occurs at a recess or corner. These gaps can appear due to the drying out and distortion of the cladding during the bushfire.
- The radiation on a component such as a wall is approximately the sum of the radiations from the contributing sources. Hence a 15 kW/m^2 radiation load from the radiant panel plus the radiation from the ignition source can result in a combined radiation load of 20 kW/m^2, i.e. enough to ignite cedar weatherboards within 2 - 3 minutes.

- Durable hardwood timber decking tends to burn slowly, each board separately, resulting in a heat load on the wall similar to a medium sized ignition source such as 0.5 kg of tree litter.
- Airflow, simulating wind, has a major influence on the fires behaviour and whether the deck or wall will continue to burn or go out. It increases the rate of combustion and the likelihood of continued combustion or spread of fire. It also changes the heat profile on the wall from an adjacent ignition source, driving the temperatures up near the ignition source and dispersing or reducing the heat further away from the ignition source.
- The heat load on the wall is greatly affected by the timing of the application of the various components, e.g. allowing the ignition source to burn for a period prior to applying the radiant heat can result in a higher peak load on the wall.
- The gaps in a timber deck provide greater airflow to an ignition source on the deck resulting in a higher flame height. This is also likely to be the case for non-combustible surfaces such as steel grating as well. However for timber decks the gaps also segment the fire and disperse the heat which reduces the fires impact of the deck burning.
- Using better detailing such as separating the combustible parts of the deck from the wall and using a non combustible subfloor (e.g. steel joist, bearer and stumps) could make durable hardwood timber decks significantly safer in terms of the potential heat loading on the wall.

The report also shows that the relatively simple test procedure used is able to provide good performance data on a number of the parameters that affect the way timber decks and building walls interact when exposed to fire. It does however have limitation and these include:

- the size of the radiant panel which limits the size of the test specimen and gives a radiation profile which varies from 40 kW/m^2 at the front of the deck to 20 kW/m^2 at the back
- the applied airflow is limited to a small vertical band just above the deck although this could be improved by using a grid of outlets to apply the compressed air onto the test specimen

Contents

1. Introduction

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The parameters varied included:

- External radiation
- Size and type of ignition source
- Airflow
- Position of ignition source
- Type of deck
- Material conditioning
- Application/timing of the ignition source, radiation and air flow

An understanding of the effect of these parameters is necessary in order to:

- make a realistic comparison between the performance of timber decks and alternative non-combustible deck surfaces
- determine how timber decks/walls can be designed to reduce the fire spread between the deck and the house

This work adds to existing work already completed for the CRC for Bushfires:

- Reference [1] which looked at under-flame tests on timber decks using the American Urban Wildland Interface Building Test Standard, 12-7A-5, Fire Resistive Standards for Decks and Other horizontal Ancillary Structures, Part A Under-flame test.
- References [2,3] which looked at the fire behaviour of different decking timber species through tests carried out using the cone calorimeter. These tests provided information on how different timber species performed when subjected to external radiation and small, ember type ignition sources.

Although over 60 test were conducted, much of the individual analysis relies on a relative small number of tests. Hence this report aims to identify the overall relationships between the various parameters investigated with consolidation of these relationships completed in later work.

2. Test Procedure

2.0 Literature Review

A literature review was carried out to identify existing data and test procedures that could be used or modified for determining the fire performance of the typical types of domestic decking used in Australia. The following main sources [4-13] were identified.

- The American Urban Wildland Interface Building Test Standard, 12-7A-5, Fire Resistive Standards for Decks and Other horizontal Ancillary Structures.

- Draft AS 3959-2005, Construction of Buildings in Bushfire-Prone Areas, Standards Australia.

- Draft AS 1530.8.1, Method for fire tests on Building Materials, Components and Structures, Part 8.1: Tests on Elements of Construction for Buildings Exposed to Radiant Heat and Small Flaming Sources during Bushfires, Standards Australia.

- Poon SL and England JP, Literature review of Bushfire Construction materials and proposed test protocols for Performance Assessment, Report 20551 for the National Timber Development Council, Warrington Fire Research Victoria, 2002.

- England JP, Performance of Timber buildings in Bushfire-Prone Areas, Warrington Fire Research Victoria, 2002.

- McArthur NA, Bradbury GP, Bowditch PA and White N, Preliminary Investigations into Radiant Heat Effects on External Building Elements and Test Methods for

Fire-retardant Treaded Timber on Buildings in Bushfire-prone Areas, CSIRO BCE Doc 00/314b, 2000.

- McArthur NA and Lutton P, Ignition of Exterior Building Details in Bushfires: An Experimental Study, CSIRO.

- Babrauskas V, Ignition of Wood: A Review of the State of the Art, pp. 71-88 in Interflam 2001, Interscience Communications Ltd., London 2001.

- McArthur NA and Leonard J, investigation of Bushfire Attack mechanisms involved in House Loss in the October 2002 Engadine Bushfire, CMIT Doc 02/304, CSIRO, 2003.

- Dowling V. P., Ignition of Timber Bridges in Bushfires. Fire Safety Journal, 22 (1994) pp145-168.

- Various photos, interviews, web sites covering information on bushfire attack on houses.

The main outcomes of the review were:

- In the American test procedure:
  - The above deck flame test used timber cribs as an ignition source and an airflow of 5m/s (12mph)
  - The below deck flame test used a 80kW sandbox burner as the ignition source with ambient airflow from the ventilation hood. The flame is applied for 3 minutes.
  - No external radiant is applied.
  - The size of the decks are approximately 700mm x 600mm with Douglas-fir joists. Typically 5 (2x6 inch) deck boards would be use.

- Materials conditioned to 6% Equilibrium Moisture Content (EMC) prior to test
- Gap between boards = 5mm
- For the below deck flame test, the wall end decking is butted up against a plinth board with the last decking board overlaying it by 1 inch.
- Conditions of Acceptance are no flaming or glowing after 40mins, no structural failure and <25 kW/ft^2 (for below deck test only)

o In the Draft AS 1530.8.1

- A radiant panel is used to simulate external radiation profiles, cribs to simulate burning litter and a gas torch to simulate embers.
- The specified crib (Class A) is much smaller than that used in American standard (250g compared to 2000g) due to the assumption that the area will be kept tidy prior to bushfire.
- No airflow (wind) is applied
- Deck size 750mm x 1800mm and constructed adjacent to a specified alcove wall.
- Materials conditioning: Cribs 40-50°C for 12 hours, Materials 25°C and 45% RH for 1 week prior to test
- Gap between boards < 5mm (from AS 3959)

o Ember attack of decks during bushfires is well documented by photos and interviews but information on the type of materials (timber species, treatment, etc) involved and how the fires start and spread is not well known. Often appears to start near a joist, post or where litter has accumulated. However many decks are completely destroyed and the evidence is gone.

2.1 Test Procedure Summary

As discussed in the introduction there were a number of parameters to be investigated which the test procedure needed to account for. To achieve this a modified test procedure using ideas from both the American and Australian standards was used. The procedure was kept simple for time and resource reasons mainly due to the number of tests that needed to be performed and the size of the available radiant panel which as 1.5m by 1.5m. The basic apparatus, shown in *Figure 2-1*, consisted of a 0.75m x 0.75m deck positioned against a 0.8m wide by 1200mm high wall. The wall and deck were on a carriage that could be positioned relative to the radiant panel by a motor allowing a radiant profile to be applied. Airflow using compressed air was applied via a steel pipe positioned in front and slightly above the deck. A single radiometer recorded the heat flux on the wall while 6 thermocouples in a inverted T formation, (see *Figure 2-2*), measured the temperature distribution on the exposed side of the wall.

A complete description of the test procedure is given in Appendix A.

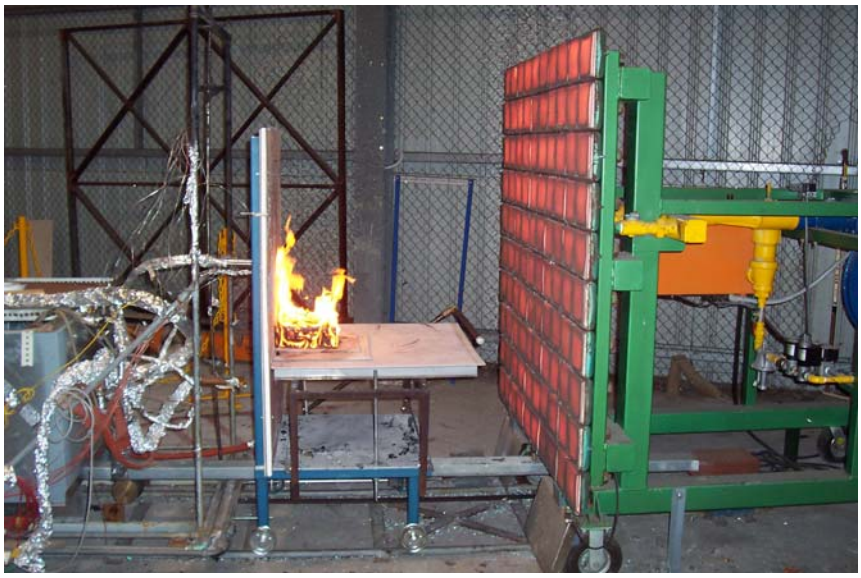


Figure 2-1 Test Rig

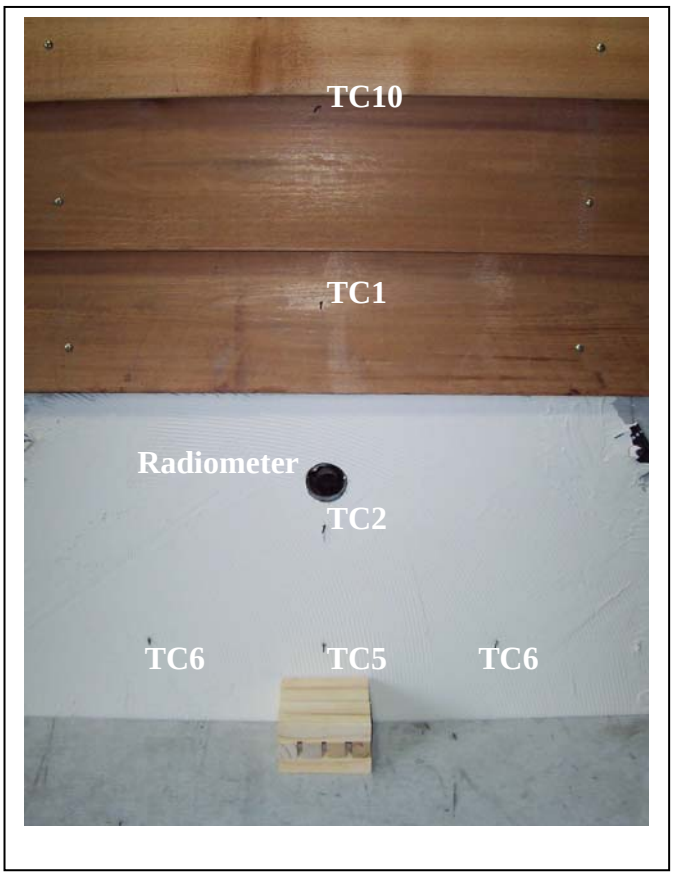


Figure 2-2 Radiometer and thermocouple positions

3. Test Parameters

3.0 External Radiation

This is an important factor in the Australian standard but not used in the American standard. The Draft AS 1530.8.1 gives a number of radiation profiles to be used depending on the likely bushfire exposure. In simple terms the profiles represent a peak 2 minute exposure followed by a controlled decrease in radiation over time to simulate the fire front moving passed the building. The peak levels of radiation are 12.5, 19, 29 and 40 kW/m^2.

In this study it was assumed that the peak radiation level would occur at the front edge of the deck or 750mm from the wall. As a result the radiation level along the deck and on the wall will be lower than the peak, as shown in *Figure 3-1*. The vertical radiation at the centre of the deck and at the wall is half the peak radiation applied at the front of the deck. Also the horizontal radiation at the centre of the deck is a quarter of the peak radiation.

It should be noted that the radiation distribution is related to the size and intensity of the radiant panel. If a larger radiant panel were used it is likely that the drop off in radiation across the deck would be reduced.

As a result of this radiation distribution it was decided to conduct the majority of the tests at the 40 kW/m^2 peak radiation level. The main reasons being:

- Using the highest radiation level would provide an upper bound on the influence the radiation level has when compared with the other parameters being looked at, particularly the size, position and type of ignition source and the airflow.
- Even at the 40 kW/m^2 peak radiation, the radiation on the horizontal surface of the deck between the wall and the centre of the deck would be less than 10 kW/m^2. This is the

region where the ignition source (crib or litter) was to be placed and where the influence of the radiation on the deck was likely to have the greatest influence.

- The vertical edge of the deck boards, particularly the one closest to the radiant panel would experience up to 40 kW/m^2 and were likely to burn particularly under piloted ignition from a flame.
- The radiation level on the wall at the 40 kW/m^2 peak radiation would be 20 kW/m^2. This is mid range of the levels recommended for different bushfire exposures and hence provides a reasonable basis from which to examine the influence the various parameters have on influencing the propagation of a fire from the deck to the wall.

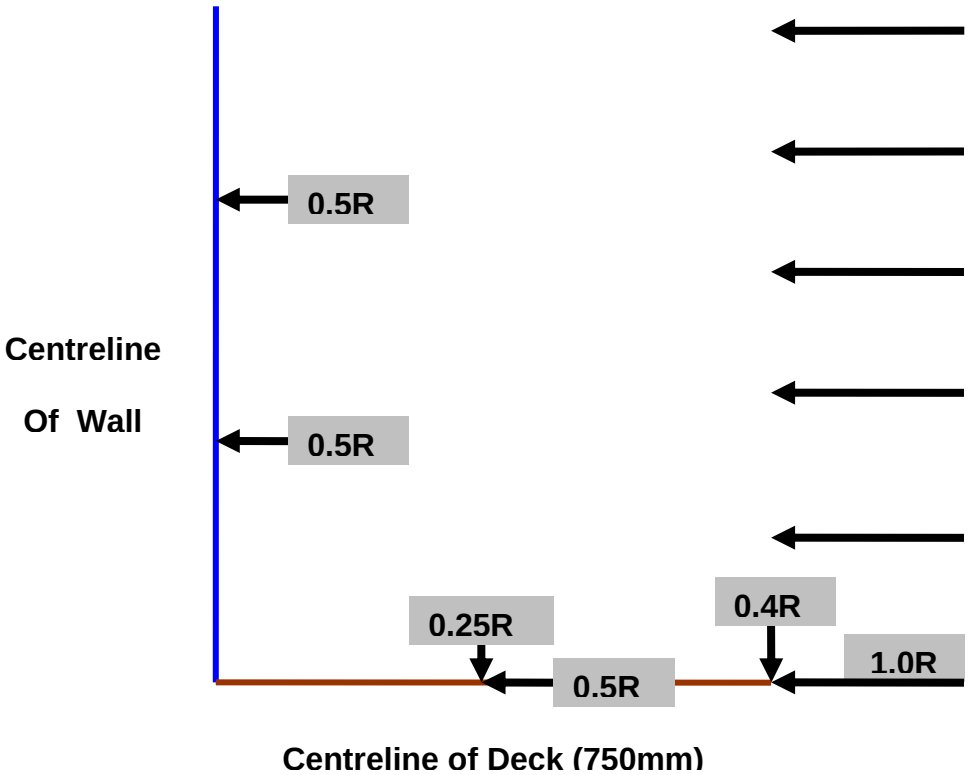


Figure 3-1 Approximate radiation distribution across the deck and at the wall

The radiation profile used during the testing approximately followed that given in the Draft AS 1530.8.1 except the shape of the tail of the profile was kept constant irrespective of the peak radiation level. The tail shape used was similar to that given in AS 1530.8.1 for the 19 kW/m^2 profile. A plot of a typical radiation profile is shown in *Figure 3-2*. The radiation profile was achieved by moving the test specimen relative to the radiant panel. The reasons for using a different tail shape than in Draft AS 1530.8.1 where the drop off in radiation is much sharper for the higher peak radiations were:

- Even when a 40 kW/m^2 peak radiation is applied to the front of the deck, the wall experiences a radiation profile with a peak of about 20 kW/m^2 which is similar to the 19 kW/m^2 profile given in the Draft AS 1530.8.1.
- Keeping the shape of the tail constant eliminates another variable and the radiation profile can be define by reference to the peak radiation level used.
- The radiation profile used was simply achieved by moving the test sample at a constant speed away from the radiant panel.

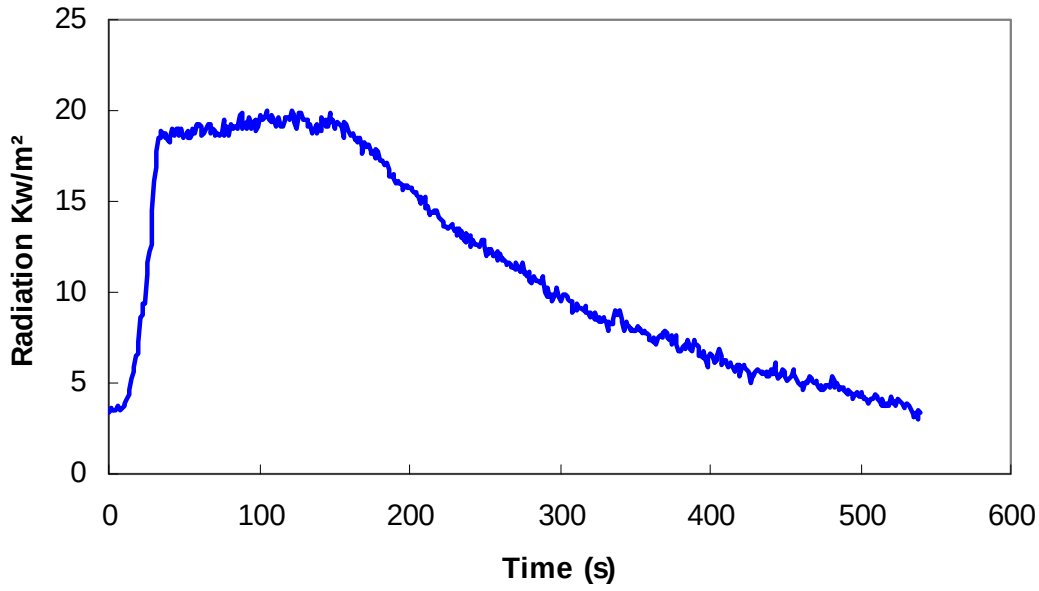


Figure 3-2 A Typical Radiation Profile (for a 19kW/m^2 peak)

3.1 Size and Type of Ignition Source

Only larger ignition sources representative of burning debris or litter were considered. This was because:

- Previous work [2] had examined ember type ignition sources.
- Larger ignition sources are more consistent and repeatable
- Larger ignition sources are a worst case scenario of ember ignited litter.
- Litter deposition rates vary greatly in different bushfire scenarios, human controls can not guarantee minimisation of the debris during all stages of the bushfire attack.

Two large ignition sources are considered.

- Timber cribs constructed from Radiata Pine
- Tree litter consisting of leaf matter, twigs and seed pods collected from under local gum trees.

A comparison of heat release values for the ignition sources are given in *APPENDIX C – Heat Release Tests*

Note: While a gas burner used for the under flame deck test in the American standard is simple to use and very repeatable it was not suitable for the tests to be conducted because of safety issues and the fact it cannot be used in all locations. Some of the differences between using the cribs, gas burner and litter as ignition sources are:

- For the same mass, cribs burner longer but with a lower flame height than the litter
- The gas burner fire used as an ignition source in Part A of the American standard burns for a relatively short time, 3 minutes, compared to a crib fire, particularly one with a similar flame size, which may burn for 10 - 20 minutes. A 1 kg litter fire is a closer match to the gas burner fire than the crib fire in terms flame height and period.

- Cribs and gas burner fires are less variable than litter fires. This is due to difficulties in sourcing litter that is consistent and placing it on the specimen.

3.1.1 Timber Cribs

The Draft AS 1530.8.1 recommends using the smaller Class A crib as representative of the likely litter ignition sources as it is assumed that the premises will have been kept reasonable tidy leading up to the bushfire. It does provide two larger Class B and C cribs that can also be used if required. The American standard uses a crib (referred to as "A" brand) that is larger than the Class C crib (2000g for the "A" brand compared to 1250g for the C Class crib).

To provide a range, two sizes of cribs were selected to be used in the testing . They are given in *Table 3-1*. The cribs represent the largest and smallest crib sizes given in the Draft AS 1530.8.1.

Table 3-1 Cribs used as ignition sources

Crib	Stick Thickness (mm)	Length (mm)	No. Sticks per row	No of Rows	Approx. Mass (g)
Class A	20	100	4	3	250
Class C	20	230	9	3	1250

For practical reasons a modification to the procedure given in the Draft AS 1530.8.1 was used in the construction of the cribs and the method of igniting them. To allow the cribs to be ignited and then placed in position it is necessary for the cribs to be held together. The standard recommends stapling the sticks together but this was found to be time consuming and less effective than using PVA glue. Also to make the gluing easier two additional sticks were added to the crib at the top, one along each edge. The cribs used are shown in *Figure 3-3*. Another modification involved the method of igniting the cribs. Rather then use the recommended method of a hand held gas torch, the cribs were placed on a 3 ring gas burner and rotated using tongs. The gas burner proved an easier, safer and more consistent method. A full description is given in the test procedure in Appendix A.

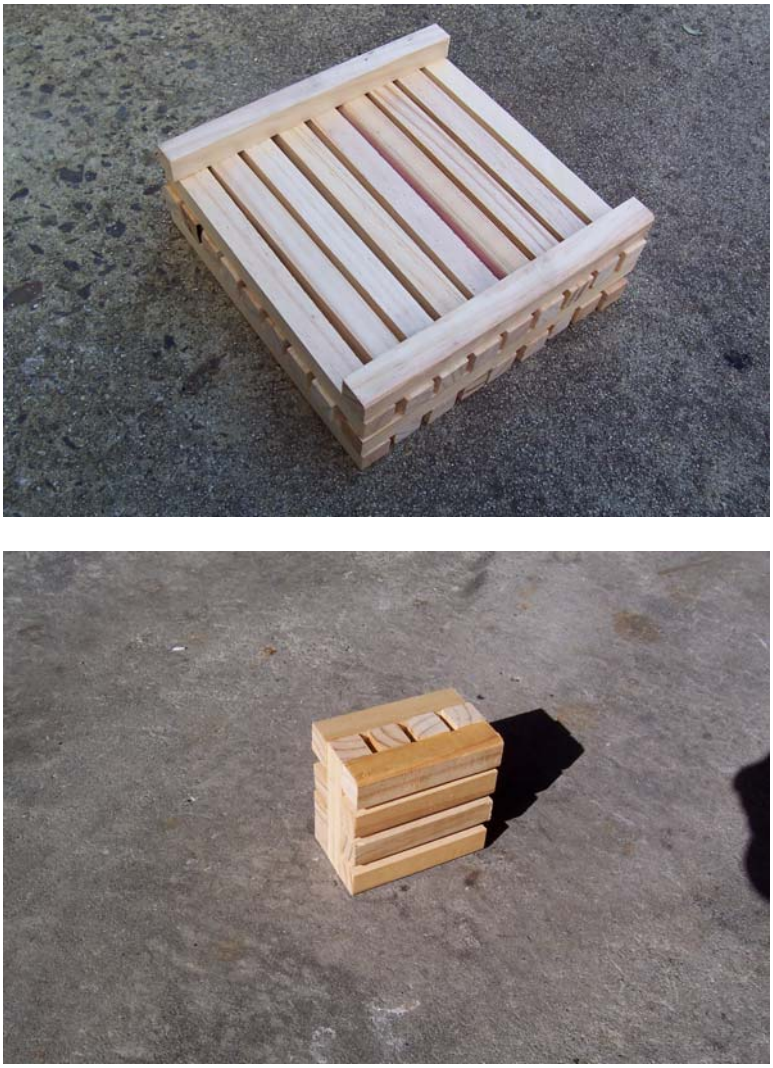


Figure 3-3 Cribs used as ignition sources

3.1.2 Litter

To provide data that is more realistic to what occurs during a bushfire two types of Eucalyptus tree litter were selected as an ignition sources. The first source consisted almost entirely of dried leaves. The second which had approximately twice the density consisted of dried leaves, twigs and gum nuts. In both cases a 1 kg mass of litter was used as the ignition source. Typical photos of the litter ignition sources are shown in *Figure 3-4*. In addition, a number of tests were conducted to determine the effect of varying the mass of litter used for the ignition source.

The denser litter was used in the following sizes:

- 1000g
- 500g
- 250g
- 125g

Unlike the cribs the litter ignition sources could be placed in position and ignited by simply using a match or flame.

(a) 1 kg of dried eucalyptus leaves (33 kg/m^3)

(b) 1 kg dried eucalyptus leaves, twigs and gum nuts (76 kg/m^3)

Figure 3-4 Litter Ignition Sources

3.2 Airflow

Airflow here refers to simulated horizontal wind being applied to the specimen to model the effects that the wind would have on the ignition and burning of the test specimen. There are other airflows that affect how the specimen will burn and are commonly determined by geometry, gaps or the general ambient conditions in the lab. An example is the effect that gaps in the deck have on the airflow around the ignition source sitting on the deck. This and other examples were noted during testing and have been included in the general results.

Airflow of 12 mph (5m/s) is used in Part B (Burning brand exposure) of the American standard but is not included in the Draft AS 1530.8.1. In the American standard a small rectangular wind tunnel is used to provide a uniform airflow across the specimen. However because of the position of the radiant panel this could not be used and a solution of a single pipe in front and slightly above the deck spraying compressed air onto the deck through 5 outlet holes was used.

This had the advantages that:

- it provided little interference to the radiation being applied to the specimen
- the airflow could be easily controlled using a valve and pressure gauge

The disadvantage was that the airflow was concentrated in a small band just above the surface of the deck. The airflow at approximately 30mm above the deck was calibrated using a hand anemometer as shown in *Figure 3-5*. Airflow of 5 m/s (18 km/h) was generally used when wind was to be simulated during a test. While only a rough approximation to the actual wind conditions that might occur during a bushfire the effect that the airflow had was still useful in determining wind effects, particularly as it helped offset some of the artificial airflows generated by the radiant panel and general lab conditions.

Figure 3-5 Anemometer used to measure airflow above deck

3.3 Position of Ignition Source

Four positions were used for the ignition sources:

- On the deck adjacent to the wall
- On the deck in the centre of the deck
- Below the deck adjacent to the wall
- Below the deck under the centre of the deck.

These positions were selected because:

- The wind will tend to blow embers and litter against the wall.
- The wall is likely to experience a more severe fire load when the ignition source is adjacent to it.
- Positioning the ignition source in the centre of the deck was used to provide a comparison with the source being placed at the wall. It was also useful in indicating if the fire might spread along the deck to the wall.
- the front edge of the deck would generally ignite under a pilot flame when exposed to 40 kW/m^2 without the need for an ignition source.

For the majority of below deck ignition source tests the height between the ignition source/ground and the underside of the deck was 300mm. This was arbitrarily selected to give a similar flame interaction with the deck as occurs with the under-flame test in the American Urban Wildland Interface Building Test Standard (ie using the sandbox burner). Additional tests to determine the effect of the height above the ignition source were also conducted. The height was varied to determine the limit at which the deck would catch alight and continue to burn.

3.4 Type of Deck

In general two types of decks were used:

- A timber deck consisting of nominally 20mm thick x 90mm wide boards attached to two steel joists (30mm wide x 75 mm deep x 1mm thick C channels) with a 5mm gap between boards. A typical timber deck is shown in *Figure 3-6*.
- A cement sheet deck consisting of 6mm cement sheet supported on two steel joists. Additional pieces of cement sheet were used under the ignition source to ensure the thickness of the deck was approximately the same as for the timber deck so the ignition source was at the same height relative to the wall. A typical cement sheet deck is shown in *Figure 3-7*.

The choice of steel joists for the majority of the tests was made for the following reasons:

- Previous testing [1] indicated that using steel joists would reduce the risk of the deck burning or to continue to burn once the ignition source has died down.
- Using a non combustible joist will reduce the likelihood of the deck collapsing, resulting in damage to the building facade or more rapid spread of the fire.
- Commonly available joists such as Radiata Pine, Treated Pine, Cypress Pine or manufactured pine joists are much more combustible than durable hardwood decking and would significantly increase the fire risk and spread to the building.
- Steel joists are uniform, reusable and reduce the variability in the test procedure.

All decks were 750mm x 750mm in size. This size was chosen because:

- Similar to the size (approximately 700mm x 600mm) used in the American standard.
- Allowed sufficient coverage by the radiant panel. Requirement in Draft AS 1530.8.1 for the panel to be 400mm wider and 400mm higher than the sample being tested.
- Sufficiently larger than the ignition source so that the size does not influence the results.
- A square shape allows the deck to be rotated 90° and tested to compare the influence of the board orientation.
- Could be easily handled by one person

Due to time and resource constraints the majority of timber decks were constructed using Merbau with a small number constructed from Spotted Gum and Radiata Pine. Addition information on the type of decking used in Australia is provided in [14-17]. The Merbau was use for the following reasons:

- Commonly available locally (Melbourne) having good consistent material properties
- Commonly used for domestic and commercial decking locally.
- Identified in previous work [2, 3] as having better performance in terms of resistance to ignite and burn compared with other timber species.

The cement sheet deck was tested to represent a non combustible horizontal surface adjacent to the wall of the house. Examples being a concrete pavement, dirt, tiled patio or a cement sheeted deck.

The cement sheet deck as chosen because it had the following properties:

- Smooth flat surface
- Non combustible
- No holes or gaps to allow airflow to the ignition source from below.
- Could be placed close enough to the wall to leave a negligible gap

A non combustible deck representative of a fire retarded timber deck or steel mesh surface which would allow airflow to the ignition source from below was not able to be tested. Hence the effect that airflow through the deck has on the combustion of the ignition source and propagation of the fire to the wall was not fully investigated.

A small number of decks were modified to investigate the influence of:

- Pine joists
- Placing a barrier between the last board and the wall
- Tapering the edge of the boards to reduce the heat build up between adjacent boards
- The width of the gap between the deck and the wall.

Figure 3-6 Typical Timber Deck

Figure 3-7 Typical Cement Sheet Deck

3.4 Material Conditioning

The following materials were conditioned prior to testing:

- The deck including deck boards and joists
- Weatherboards used in later tests which were fastened to the wall prior to testing
- Ignition sources, i.e. cribs and litter

Two types of conditioning were used :

- Room conditions, 22° C and 47% RH
- Bushfire conditions, 45° C and 18% RH (represents the limit of the conditioning room available, but typical of civic fires involving significant house loss, eg Canberra)

The bushfire conditions were selected because preliminary tests on exposure samples during January 2006 indicated that on bushfire days (windy, high 30 - 40° C maximum temperatures over 2 - 3 days) moisture contents in samples of spotted gum and merbau could drop to around 7 - 9%. This is simular to what is achieved if the timber (at ~12% initial MC) is conditioned in the room at 45° C and 18% RH for 2 - 3 days. Recent data taken on 12/10/06 after 2 days of bushfire conditions has confirmed this. A summary of the data is given in Appendix B.

The ignition sources were all conditioned at 45° C and 18% RH until equilibrium moisture content was reached. For the Radiata Pine cribs this required at least 2 days. For the litter at least 3 weeks of conditioning was used. This was due to material being wet initially and the need to periodically turn it over to allow it to fully dry.

Note: In the Australian Standard the cribs are conditioned at room conditions. A comparison of the effect of the conditioning could be undertaken in future work.

The decks were all conditioned at 22° C and 47% RH for at least 1 week prior to testing. This was used for the following reasons:

- To be consistent with the recommendations in AS1530.8.1
- Previous work [1] had investigated the effect of different deck conditionings on the ignition and burning of the deck.
- Using only one conditioning environment reduced the number of variables being covered
- Investigating the effect of the conditioning of the wall cladding was seen as being more important than that of the deck

For the weatherboards some comparison tests were conducted using both types of conditions to see if the conditioning of the material had any effect on the outcome.

3.5 Application/timing of the ignition source, radiation and airflow

The timing of when the ignition, radiation and airflow occur can greatly affect the outcome of a test. For example:

- The interaction between the ignition source and the external radiation profile can be timed to produce a maximum heat load on the deck and wall.
- The proximity of the radiant panel can disrupt the natural airflow around the ignition source reducing the flame height. If the ignition source is allowed to burn initially before the external radiation is applied the initial heat profile up the wall due the ignition source will be different.
- Similarly the applied airflow (wind) will also affect the way the ignition source will burn. Horizontal airflow will tend to drive the heat into the wall adjacent to the ignition source and disperse the heat which is further away from the ignition source.
- If the airflow is applied too early it may cases the fire to die down or go out. If it is applied too late the fire may have already gone out.

In general the ignition source was ignited just prior to applying the radiation profile. If airflow was used it was usually applied in the later half of the ignition source fire. Only in a few cases was the timing varied to determine any effect. This was because:

- The significance of the interaction only became apparent towards the later part of the testing when the weatherboard walls were included.
- To compare the effect of other parameters, the timing of the ignition and radiation was kept constant.
- Applying airflow to the ignition source, particularly as it starts to burn has a dramatic effect. For the litter ignition source the material could be dispersed before it has fully ignited.
- To measure the effect of changing the application/timing of the ignition source, radiation and airflow together is more difficult than changing a single parameter and would be easier once the results of the effects of changing the other single parameters were determined.

4. Discussion of Test Results

4.0 General

In total 60 tests were performed. In approximate chronological order they covered:

- Simple tests focused on the ignition and burning of the deck alone.
- Comparison of fires on timber decks and fires on a cement sheet deck (representing a non combustible horizontal surface such as a concrete patio)
- Interaction between the deck fire and a cement sheeted wall
- Propagation of the deck fire onto a combustible wall cladding
- Propagation of the deck fire onto a combustible wall cladding at an internal corner

The order reflects the increasing complexity from looking at the timber deck in isolation to comparing timber decks with non-combustible surfaces to finally looking at how the timber deck interacts with the wall of the building. To simplify the analysis of the data, each parameter investigated is reported separately in the following sections.

4.1 External Radiation

4.1.1 Effect on the Ignition of the Timber Deck

The influence of the external radiation level on the ignition of the timber deck was greatly reduced because the horizontal surface of the deck was parallel to the radiation being applied. As shown in *Figure 3-1*, the radiation perpendicular to the surface at the centre of the deck is only one quarter the level of the external radiation being applied. However the edges of the decking boards facing the radiant panel experience a much higher radiation level. For the edge board closest to the radiant panel the leading edge experiences the full external radiation. For the decks tested, at 40 kW/m^2 this edge could easily be ignited using a pilot flame (see *Figure 4-1*). However the edge fire ceased once the peak radiation level passed except for the Radiata

Pine deck which continued to burn for longer or when airflow was applied across the surface of the deck (see *Figure 4-2*).

The influence of the external radiation on the ignition of the deck is also reduced because the peak radiation is only applied for 2 minutes while the ignition source, particularly the crib, may burn for 10 to 20 minutes. At the margin the external radiation may tip the balance of a deck burning or not. To determine this would require constructing a test where the ignition of the deck was marginal, ie. by reducing the ignition source or varying its position. It was decided not to do this because:

- the external radiation has a much bigger influence on the ignition of the wall
- the variability in conditions (airflow, temperature of rig, materials, etc) between tests
- other factors such as size and position of the ignition source appear more critical than the level of external radiation in determining the ignition of the deck.

Figure 4-1 Piloted ignition of leading edge of deck

Figure 4-2 Edge of decking boards continuing to burn when airflow is applied

4.1.1 Effect on the Ignition of the Wall

The effect of the external radiation on the ignition of the wall is simpler to measure compared to that of the deck because it has a relatively large effect. The level of the radiation at the wall was half that applied at the front of the deck. Hence for a 40 kW/m^2 peak radiation test, 20 kW/m^2 was applied to the wall. This is sufficient to cause piloted ignition of Western Red Cedar in a cone calorimeter within 2 to 7 minutes (see *Table 4-1*). Note the reduction in ignition time if a flame from a match is placed near the surface of the specimen. This would be the case for a weatherboard wall where the flame from burning litter contacts the wall.

Table 4-1 Cone Calorimeter Data on Western Red Cedar Tested at the CSIRO

Heat Flux (kW/m²)	Ignition Time (s)	Average Ignition Time (min)
Piloted Ignition - spark igniter above specimen		
15	>600	>10
19	337	6.5
19	414	
19	426	
22	139	2.7
22	171	
22	250	
22	93	
Piloted Ignition – flame from match on specimen		
19	172	2.9
20	151	2.5

To measure the influence of the deck, ignition source and level of external radiation on the ignition of the wall a series of wall tests were undertaken. A section of straight wall 800mm wide having a non combustible cladding for the first 400mm of height then Western Red Cedar weatherboards for the remaining 400mm of height (see *Figure 4-3*) was tested using the procedure given in Appendix A. Two types of ignition sources, Class C and Class A cribs and two types of decks, cement sheet and timber, were used. The radiation level was varied to find the threshold level required to cause the wall to ignite.

The reasons for selecting this test procedure were:

- Cedar weatherboards are commonly used for cladding on domestic housing
- The ignition times and radiation levels for piloted ignition of cedar in the cone calorimeter was achievable with the current radiant panel test setup
- The 400mm height of non-combustible material is a requirement in AS3959 for external walls in medium and high bushfire attack categories.

  The performance thresholds given in AS3959 for these categories are:

- Medium < 12.5 kW/m^2
- High 12.5 - 19 kW/m^2. Note the upper end of the high category is in the range of heat flux values given in *Table 4-1*.

o The number of ignition sources and deck types was restricted by the resources available. Hence the selection of a large and small ignition source, and a continuous non-combustible deck and a permeable combustible deck.

Figure 4-3 Western Red Cedar Weatherboard Wall Test using a Class A Crib

The results of the tests have been summarised in

Table 4-2 below. Individual test results are shown in the table by a YES or NO (9 tests in total). Interpolated results are shown in grey and are based on:

- Ignition of the weatherboards are more likely for timber decks than for cement sheet deck because the gaps in the timber deck allows air to the ignition source and hence a higher flame height. This is discussed in detail in the test result section – 4.7.6 Effect of Gaps in Deck.
- Ignition of the weatherboards are more likely for a Class C Crib than for a Class A Crib because it is a larger ignition source.
- Ignition of the weatherboards are more likely for 45°C 18% RH condition weatherboards then for 22°C 47% RH conditioned weatherboards.

Table 4-2 Conditions for which Western Red Cedar Weatherboards Ignited during Wall Tests

(interpolated values shown in grey)

Radiation at Wall	Type of Deck	Conditioning of Cedar Weatherboards			
		45°C 18%RH		22°C 47%RH	
		Crib (ignition source)			
		Class **A**	Class **C**	Class **A**	Class **C**
20 kW/m^2	Cement Sheet	**YES**** **1**	**YES** **2**	**NO** **3**	**YES** **4**
	Timber	YES	YES	?	YES
15 kW/m^2	Cement Sheet	NO	**YES** **5**	NO	**NO/YES** **6** **7**
	Timber	**NO** **8**	YES	NO	**YES** **9**

** Weatherboards ignited manually using a burning stick

Numbers in boxes are used for identification of test

The observations during the tests indicated that a 15 kW/m^2 peak external radiation load with a Class C Crib ignition source was sufficient to cause the ignition of the cedar weatherboards either during or shortly after the application of the peak radiation (i.e. within 2 - 4 minutes of commencement of the test). This compares with the data in *Table 4-1* in which Cedar is ignited with a heat flux 19 kW/m^2 in a similar time provided the ignition is piloted by a flame from a match. The actual radiation load on the wall due to both the radiant panel and the crib will depend on the profile of the radiation, size of the crib and the timing between the ignition of the crib and the application of the radiation profile. The radiation measured at the top of the lower weatherboard (approximately 500mm above the deck) for various types of ignition sources is given in section 4.2.2 - Radiation and Temperature Profiles (on the wall) due to various Ignition Sources.

A comparison of the individual components making up the radiation on the wall for a typical case (Class C crib and 15.5 kW/m^2) is given in *Figure 4-4*. In the plot the various lines represent:

- red - the radiation from the radiant panel (15.5 kW/m^2 at the wall)
- blue - the radiation from a Class C crib placed on the deck against the wall with no external radiation applied
- green - the radiation from a Class C crib placed on the deck against the wall with 15.5 kW/m^2 (at the wall) from the radiant panel
- black - the summation of the red and blue lines

This indicates that the total radiation is approximately equal to the sum of the radiations due to the radiant panel and the ignition source. Hence if it is assumed from *Table 4-1* that 20 kW/m^2 over a 2 - 3 minute period is sufficient for the cedar weatherboards wall to ignite when exposed to a flame, then some possible combinations of radiation/ignition sources that may produce ignition of the weatherboards are:

- 15.5 kW/m^2 + Class C crib, with ignition of crib just prior to application of the radiation
- 10 kW/m^2 + Class C crib, with ignition of crib 2 minutes prior to the application of the radiation
- 1000g litter with no radiation
- 10 kW/m^2 + 500g litter, with ignition of the litter half a minute prior to application of radiation
- 15 kW/m^2 + 250g litter, with ignition of the litter half a minute prior to application of radiation

The timing is critical because it is important that the ignition source is near its average peak heat release during the 2 minute peak of the radiation profile. The combination of radiation and ignition source selected to achieve 20 kW/m^2 are based on the data given in section 4.2.2.

The weatherboards are assumed to be conditioned at 22°C 47% RH. Additional testing is needed to confirm the above predictions.

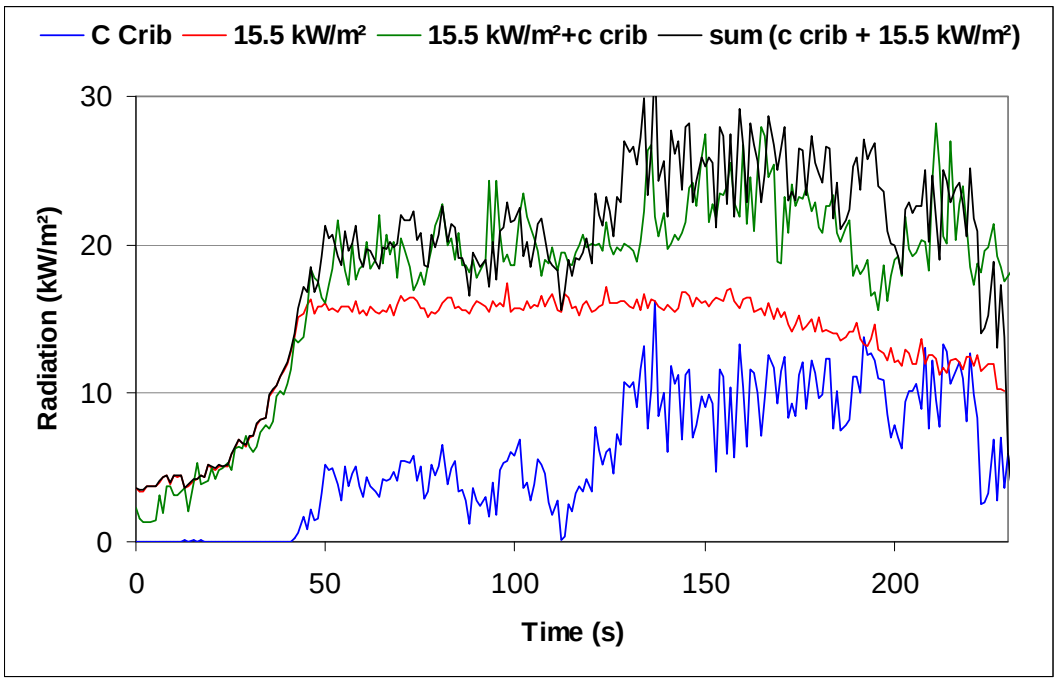


Figure 4-4 Example of Summing Radiation Components on the Wall

Finally the plots of the wall temperature for the wall tests are given in *Figure 4-5*. It can be seen that a surface temperature just above 200ºC is the threshold at which the weatherboards ignite and appears to be fairly independent of how the weatherboards were conditioned prior to testing. Hence the extra moisture contained in the timber for the milder conditioning level may assist in delaying the onset of ignition but not the critical temperature of ignition. Hence short test exposures and high moisture levels may give a no ignition during a test while in reality they may resent a significant risk to the structure and occupant.

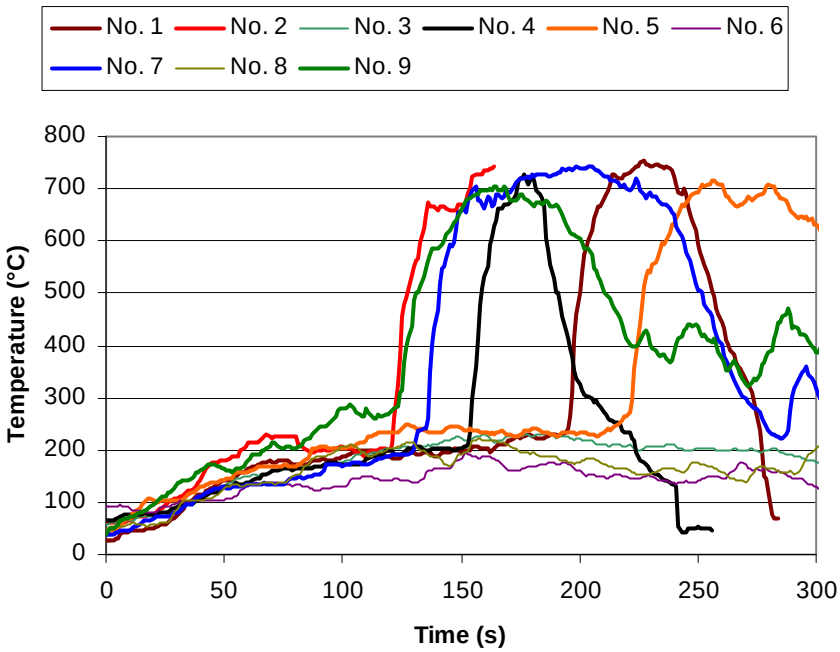


Figure 4-5 Wall Temperatures for Western Red Cedar Weatherboard Wall Tests (for the series numbers refer to

Table 4-2)

4.1.3 Effect of External Radiation on below Deck Fire

An example of the difference that external radiation can make can be seen in the comparison of two tests in which a Class C crib is placed against the wall under a Merbau deck. In Test A a 40 kW/m^2 external radiation is applied while in Test B no radiation is applied. The plots of the temperature and radiation readings are shown in *Figure 4-6* and *Figure 4-7*. The labels in the legend refer to the thermocouples and radiometer shown in *Figure 2-2*. Also some photos taken during the tests are shown in *Figure 4-8* and *Figure 4-9*. A number of observations can be made.

For Test A (40 kW/m^2):

- The ignition source burns hotter and more rapidly.
- A much greater portion of the deck is ignited
- At the end of the test all boards have been burnt but none have been completely burnt through

For Test B (0 kW/m^2):

- The ignition source burns steady with a smaller flame than for the first test, i.e. lower temperatures over the first few minutes.
- Only the 3 boards closest to the wall are badly damaged, however the two closest are completely burnt through resulting in higher temperatures on the wall.

The conclusion is that applying an external radiation doesn't necessary result in a worst case scenario.

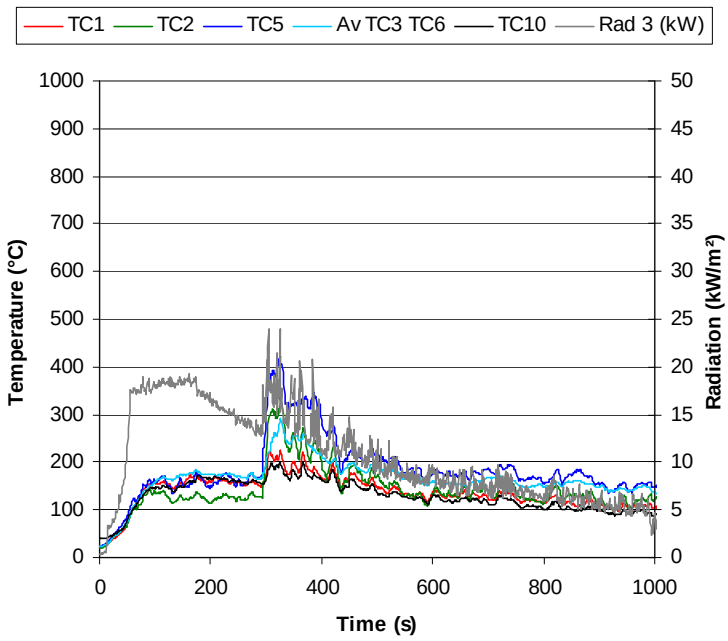


Figure 4-6 Temperature and Radiation Plots for Test A

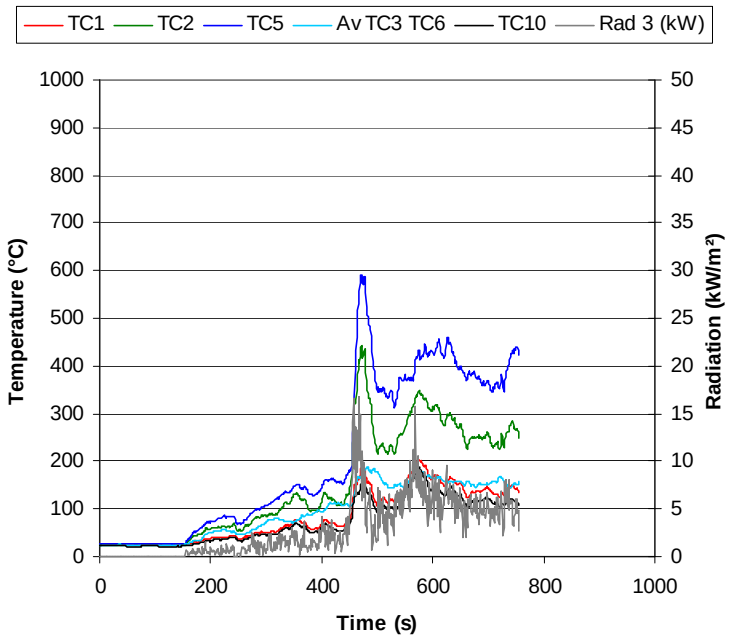


Figure 4-7 Temperature and Radiation Plots for Test B

Figure 4-8 Photos from Test A

Figure 4-9 Photos from Test B

4.2 Size and Type of Ignition Source

Two series of tests were undertaken to look at the effect of different ignition sources:

- The first series compared the effect two different types of ignition sources had on causing sustained burning in a timber deck when the sources were placed below the deck.
- The second series looked at the effect of the size of ignition source had on the radiation and temperature profiles on a wall when the sources were placed on a deck against the wall.

4.2.1 Sustained Burning of a Deck due to Ignition Sources placed Underneath.

Two ignition sources, Class C crib and 1 kg litter (dried eucalyptus leaves, twigs and gum nuts, 76 kg/m^3) were placed below a Merbau deck, against the wall with a 40 kW/m^2 external radiation applied (see *Figure 4-10*). The distance below the deck of the ignition source was varied so the threshold distance could be determined at which sustained burning was developed in the deck for both of the ignition types. A comparison of the results is given in *Table 4-3*. The results show that the threshold distance for the Class C crib is approximately 400mm while for the 1 kg litter it is approximately 650mm. This is as expected since the litter burns much hotter with a higher flame height, although it burns for a much shorter period. Another way to compare the two ignition sources would have been to vary the size of the litter so that sustain burning of the deck occurred at the same threshold distance as for the Class C crib. Other ignition sources such as dried grass, paper, etc, along with different deck timbers and conditioning could be used to provide a more complete picture.

Table 4-3 Distances of Ignition Sources below the Deck to cause Sustained Burning of the Deck

Distance Below Deck (mm)	Class C crib	1 kg Litter
300	yes	
380	yes	
415	no	yes
450	no	
500		yes
600		yes - just

Figure 4-10 Below Deck Test using 1 kg Dried Eucalyptus Leaves, Twigs and Gum Nuts (76 kg/m^3)

4.2.2 Radiation and Temperature Profiles (on the wall) due to various Ignition Sources

The measurements of the radiation and temperature (rise above ambient) on the wall due to various ignition sources were made using a previously burnt weatherboard wall (see *Figure 4-11*). The measurements were made at approximately 550mm and 500mm above the deck (at the top of the lower weatherboard) for the radiation and temperature respectively. The ignition sources were placed on the deck against the wall.

This configuration was chosen because the burnt weatherboards provided:

- protection to the wall support frame
- gave a realistic profile to the wall

The ignition sources used were the Class C and Class A cribs and 1000, 500, 250 and 125 grams of litter consisting of leaf matter, twigs and gum nuts with a lose density of 76 kg/m^3.

Plots of the radiation and temperature (rise above ambient) measurements with time are given in *Figure 4-12*. There is good correlation between the radiation and Δ temperature (rise above ambient) values:

$$\text{Radiation} \approx \Delta\text{Temperature} / 20$$

A summary of the average peak values are given in *Table 4-4*. This indicates that while the Class C crib and 500g of litter produce a similar average peak heat loading on the wall, the Class C crib maintains these values for 4 times longer. The Class A crib produces a very small heat loading on the wall, approximately a quarter of that from the 125g litter source.

Table 4-4 Average Peak Radiation and Temperatures (on the wall) due to various Ignition Sources

Ignition Source	Average Peak Radiation (kW/m^2)	Average Δ Temperature (°C)	Peak Time Period (s)
Class C Crib	15	300	400
Class A Crib	1	20	300
1000g litter	30	500	200
500g litter	15	300	100
250g litter	7.5	200	100
125g litter	3.5	100	100

Figure 4-11 Weatherboard wall used to measure radiations from various ignition sources

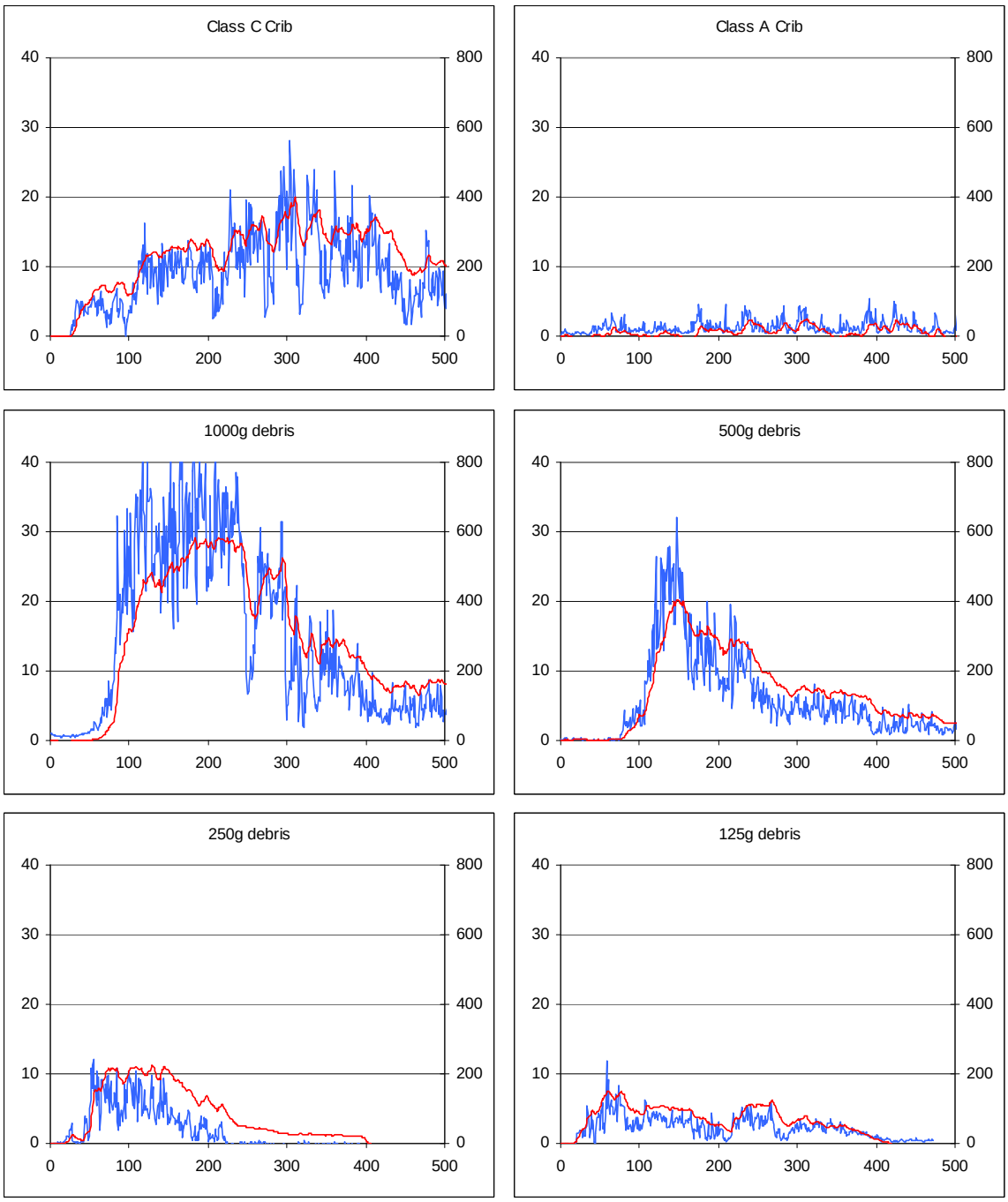


Figure 4-12 Radiation (in blue, LHS axis kW/m^2) and Temperature rise above ambient (in red, RHS axis °C) on the wall due to various ignition sources.

(horizontal axis is time (s))

4.3 Airflow

Although the test procedure only allowed the airflow to be directed towards the wall in a thin band close to the surface of the deck, its effects on the combustion of the materials are likely to be similar to that of wind blowing against a building.

Four general types of airflow effects were observed:

- maintains/increases combustion that would under ambient conditions go out
- spreads the fire, e.g. across the deck or wall
- accelerates the burning and alters the heat profile around the ignition source
- wind driven spread of fire through small gaps (less than 1mm)

An example of the dramatic effect of applying airflow is shown in *Figure 4-13*. When airflow is applied between 450s and 700s the temperatures and radiation on the wall becomes steady.

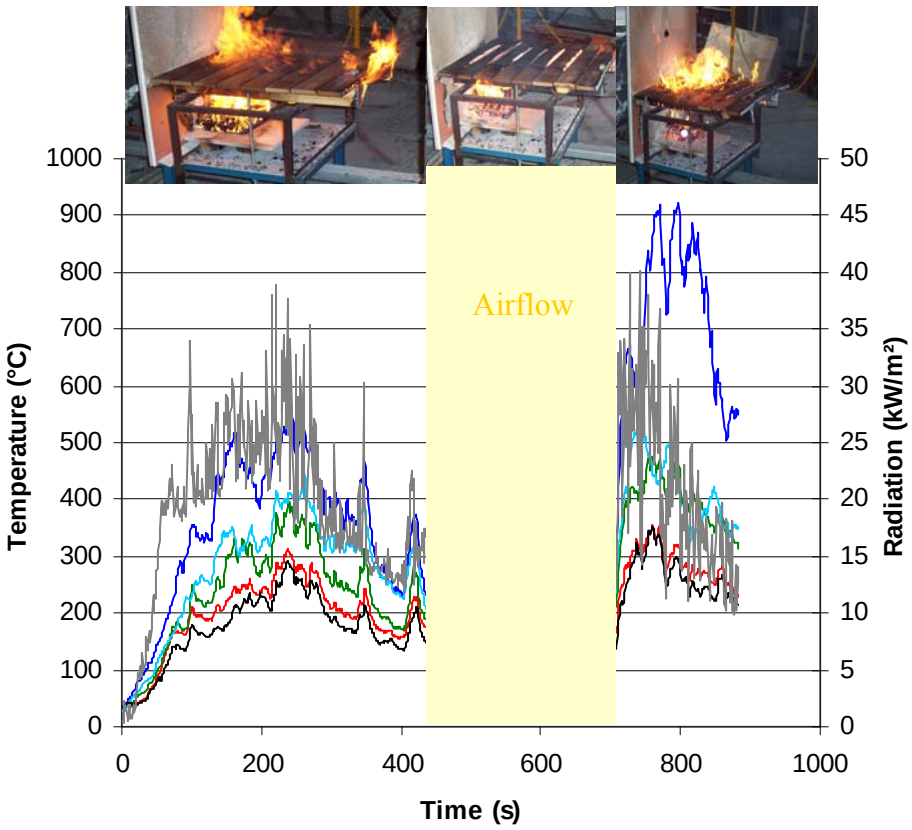


Figure 4-13 Example of the effect of airflow on temperature and radiation on the wall (Radiation in grey, other colors are wall temperatures at various heights)

4.3.1 Maintenance/Increase of Combustion, Spread of Fire

A commonly used test success/failure criterion is whether the specimen continues to burn after a period of time from the start of test or when the ignition source has been turned off as is the case with the below deck flame test in the American Standard. A number of comparison tests were conducted where the effect using airflow on the combustion of the decking boards was observed.

A typical example where airflow is used is shown in *Figure 4-14*. In this case a Class C crib is placed at the centre of the deck with a 40 kW/m^2 radiation applied. The airflow spreads the fire across the deck leaving a line of burnt out boards. A similar test in which no airflow is used is shown in *Figure 4-15*. With no airflow the deck stops burning once the ignition source has died out leaving a hole slightly larger than the ignition source.

Another example, this time with the Class C crib placed under the deck and against the wall, is shown in *Figure 4-16* and *Figure 4-17*. In *Figure 4-16* the airflow causes the edge of the deck boards to glow red, followed by the boards burning completely through. In *Figure 4-17* without any airflow the boards at the end of the test are still in one piece although badly burnt.

A final example is a case of a cedar weatherboard wall that has caught alight and burnt. Typically when there is no wind and the heat source is removed the weatherboards will eventually stop burning leaving a charred façade (see *Figure 4-18*). When airflow is applied to the still glowing weatherboards the combustion continues and the weatherboards can burn through and/or catch alight again (see *Figure 4-19*).

Figure 4-14 Merbau deck, Class C Crib Ignition Source located centrally on the deck, 40 kW/m^2 External Radiation, Airflow (5m/s)

Figure 4-15 Spotted Gum deck, Class C Crib Ignition Source located centrally on the deck, 40 kW/m^2 External Radiation, No Airflow (0m/s)

Figure 4-16 Merbau deck, Class C Crib Ignition Source located below against the wall, 40 kW/m^2 External Radiation, Airflow (5m/s)

Figure 4-17 Merbau deck, Class C Crib Ignition Source located below against the wall, 40 kW/m^2 External Radiation, No Airflow (0m/s)

Figure 4-18 Charred Weatherboards Left after Heat Source is Removed. No applied airflow.

Figure 4-19 Airflow onto Burnt but still Glowing Weatherboards

4.3.2 Accelerates the burning and alter the heat profile around the ignition source

When airflow is applied to the ignition source it has a dramatic effect as can be seen in *Figure 4-14*. The effect of airflow on the temperature profile on the wall can be seen by comparing *Figure 4-21* and *Figure 4-20*. In *Figure 4-21* which doesn't have airflow applied the peak

temperatures for the thermocouples (TC5, TC2 and average of TC3 and TC6) near the ignition source are lower while the temperatures of the higher thermocouples above the ignition source (TC1 and TC10) are higher than in *Figure 4-20* in which airflow is applied. Also the peak temperatures last for a shorter time when airflow is used. Airflow also shortens the time it takes for the crib to burn out (1200s without airflow and 700s with airflow). In general the airflow drives the heat in towards the wall adjacent to the ignition source but disperses the heat further away or higher above the ignition source.

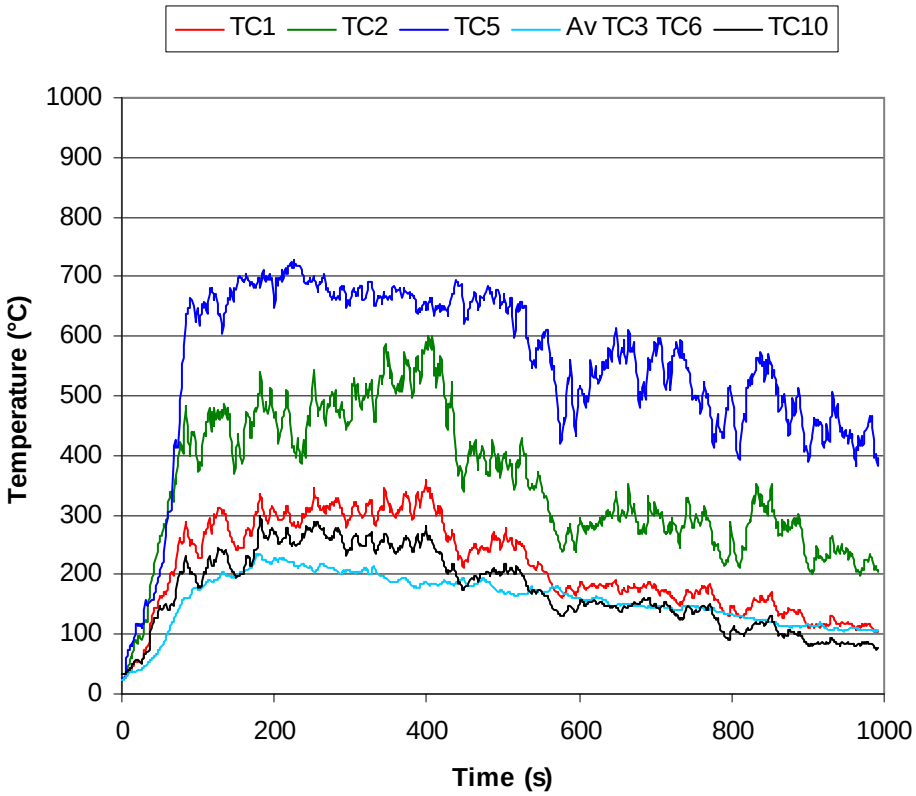


Figure 4-20 Temperature plots for cement sheet deck, Class C Crib on the deck against the wall, 40 kW/m^2 External Radiation, No Airflow (0m/s)

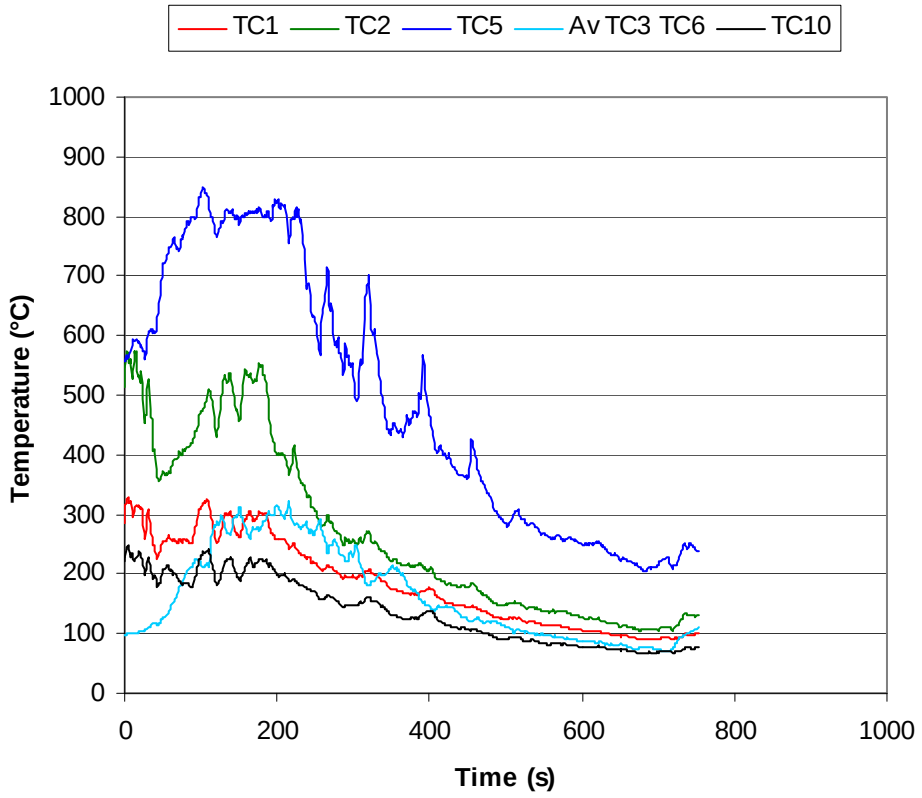


Figure 4-21 Temperature plots for cement sheet deck, Class C Crib on the deck against the wall, 40 kW/m^2 External Radiation, Airflow (5m/s)

4.3.3 Spread of fire through small gaps

A case where the application of airflow resulted in rapid spread of the fire through a small gap in the wall occurred during the test on a corner of a weatherboard wall. The test was conducted using a Class A crib and a 16 kW/m^2 external radiation. Airflow was added once the ignition source began to die down and full ignition of the weatherboards appeared unlikely even though the bottom corner edge of the weatherboards were burning slowly (see *Figure 4-22*). Once the airflow was added the weatherboards quickly ignited and the fire rapidly spread through a small gap in the bottom corner of the weatherboard wall onto the back face of the weatherboards (see *Figure 4-23*). The wall had been constructed to ensure that all gaps

were kept as small as possible (less than 1 mm, see *Figure 4-24*), although these could have widen as the weatherboards were heated.

It appeared unlikely that the fire would have spread as quickly, if at all, to the back face of the weatherboards without the airflow being applied, even if the weatherboards had been fully ignited by the ignition source and radiation alone. Further testing could confirm this as well as determining what detailing (e.g. gap fillers, insulation) could be used to prevent the spread of fire through gaps.

Note: Cavity fires as observed in *Figure 4-23* have been noted in a number of bushfire survey cases and is a common location for flames to spread to the inner furnishing of the structure.

Figure 4-22 Corner of weatherboard wall prior to applying 5m/s airflow

Figure 4-23 Corner of weatherboard wall after applying of 5m/s airflow

Figure 4-24 Corner of weatherboard wall prior to testing

4.4 Position of Ignition Source

Three variables were examined:

- Above or Below the deck
- Horizontal position from the wall
- Vertical position below the deck

4.4.1 Above or below the deck

Comparative tests were performed using Class C cribs placed above and below the deck. The setup of the below deck tests were chosen to insure that the decks caught alight. For the above tests both timber (Merbau) decks and cement sheet decks were used (see *Figure 4-25*). For below deck only timber decks were used (see *Figure 4-26*). The cribs were placed against the wall and the temperature and radiation measurements on the wall recorded (see *Figure 4-27* and *Figure 4-28*).

The following points can be noted:

- For the below deck fires, the deck contributes around about the same to the temperature rise on the wall as the Class C crib ignition source placed 380mm below the deck (see *Table 4-5*).
- When the crib was placed above the deck the temperature and radiation profiles on the wall when the timber deck was used were slightly higher than for the cement sheet (e.g. 7% or 750ºC compared to 700ºC for TC5 with 40 kW/m^2 of radiation applied). This could be due to the gaps in the timber deck allowing better airflow to the crib or to the burning of the deck or both.
- The temperature and radiation profiles were much higher for the above deck fire than for the below deck fire (eg. ~60% higher or 750ºC compared to 450ºC for TC5 with 40 kW/m^2 of radiation applied).
- For the below deck fires the 0 kW/m^2 test produced higher temperatures on the wall than the 40 kW/m^2 test (eg. 400ºC compared to 350ºC for TC5). This may be due to the particular decks used. More tests would be needed to confirm this trend.
- The heat load on the wall for the above deck fire using a Class A crib ignition source is higher than for the below deck fires (eg 20% higher or 500ºC compared to 400ºC for TC5).

In general the results indicate that the above deck fire places a much higher heat load on the wall than the below deck fire. Also for above deck fires the heat from the ignition source had a greater effect on the heat load on the wall than the heat from the burning deck.

Figure 4-25 Typical above Deck Tests

Figure 4-26 Typical Below Deck Test

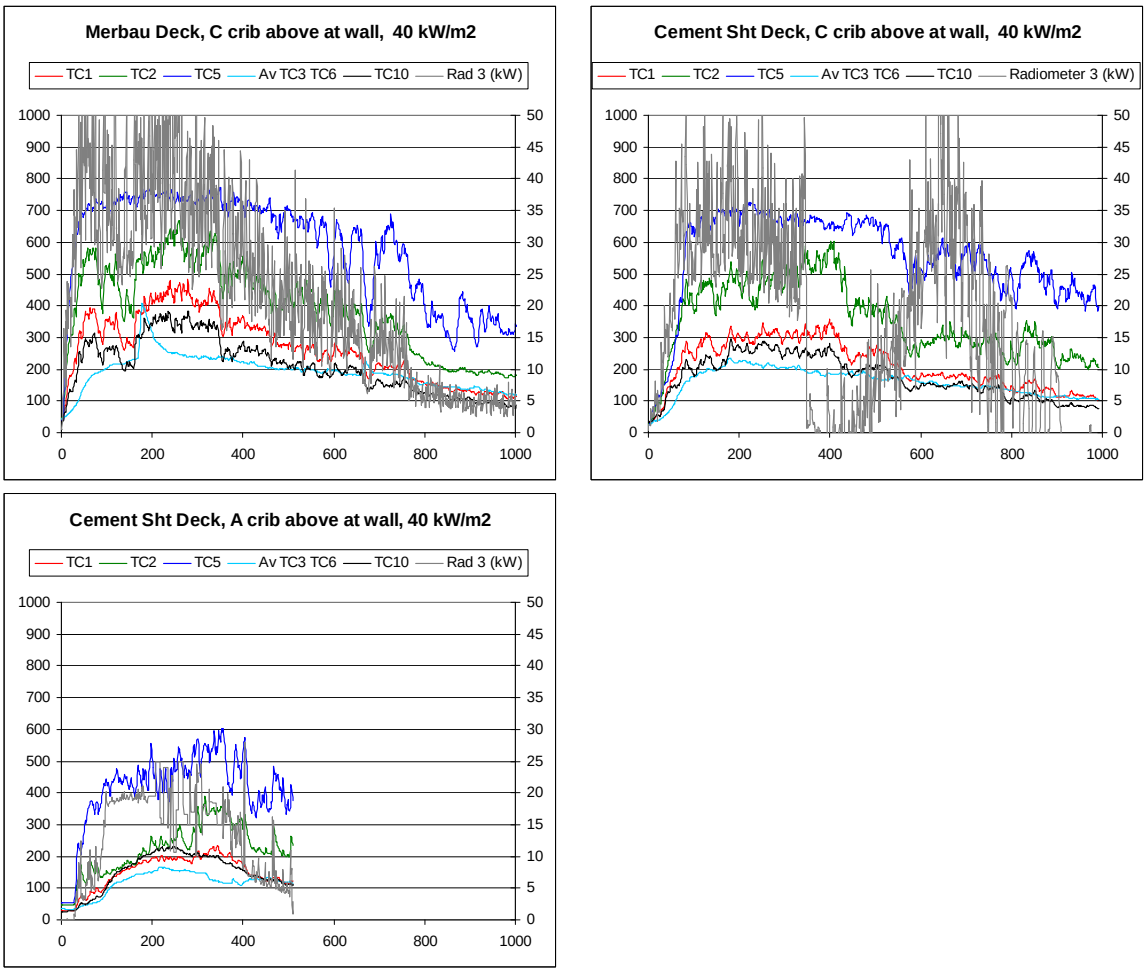


Figure 4-27 Above Deck Tests

{Axes: RHS- Temperature (ºC), LHS- Radiation (kW/m^2), Horizontal- Time(s)}

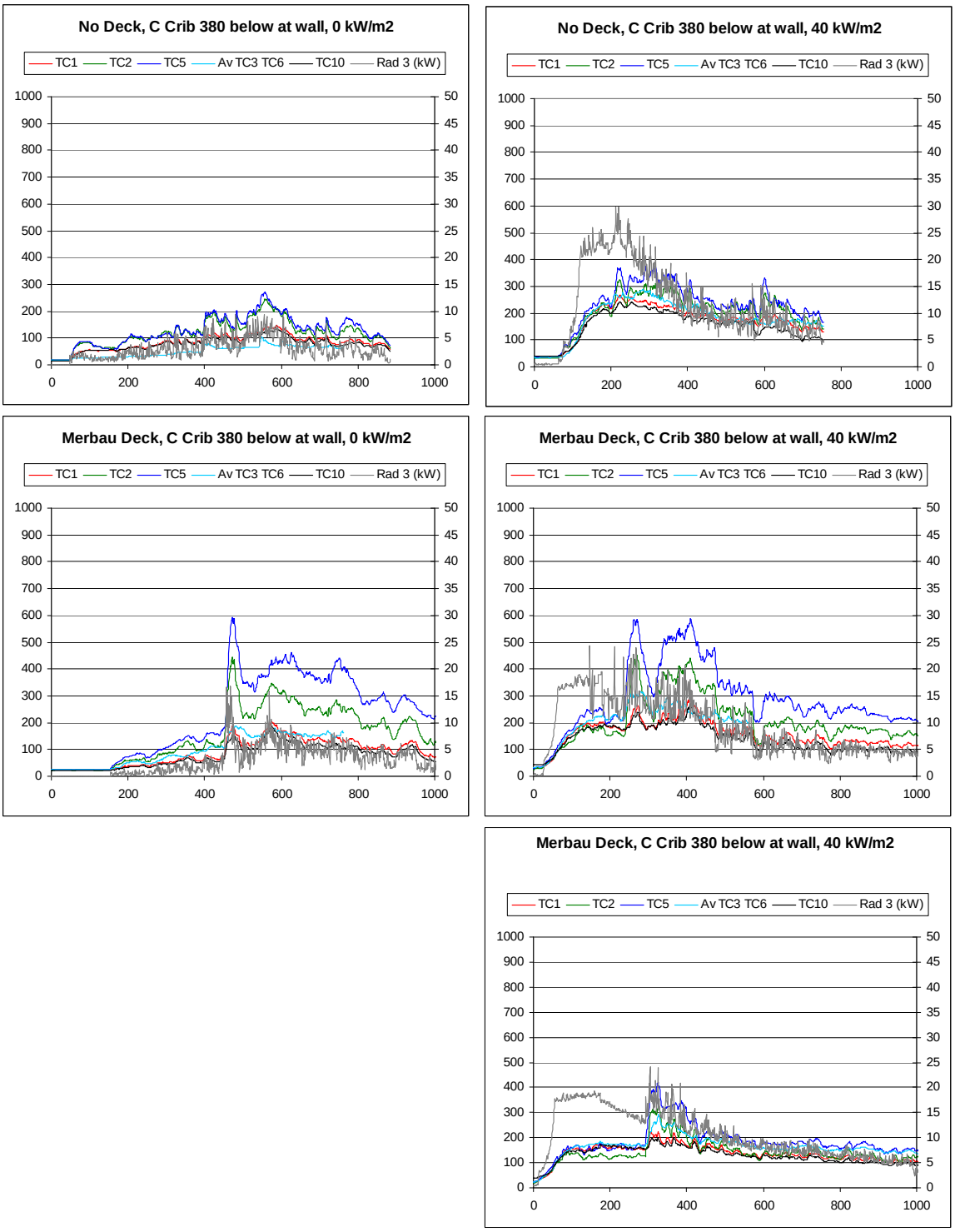


Figure 4-28 Below Deck Tests

{Axes: RHS- Temperature (°C), LHS- Radiation (kW/m^2), Horizontal- Time(s)}

Table 4-5 Temperature on Wall near Crib for Below Deck Tests given in Figure 4-28

Contributing Components	External Radiation	
	0 kW/m^2	**40 kW/m^2**
Class C Crib + Radiation	175	325
Class C Crib + Deck + Radiation	400	350, 475
Due to Radiation	0	150
Class C Crib Only	175	175
Deck Only	225	25, 150

4.4.2 Horizontal position from the wall

In previous tests a number of observations were noted that indicated that the heat load due to the ignition source may be more critical on the wall than the heat from the burning deck. Hence the horizontal position of the ignition source relative to the wall is important. The main points observed were:

- Correct detailing can reduce the propagation of the fire from the decking to the wall e.g. replacing the last timber deck board with a non-combustible board, placing a barrier between the decking and the wall. In the below deck flame test [1] in *Figure 4-29* the gap between the plinth board (fastened to the wall) and the last decking board (on top of the plinth board) acts as a channel for the fire.
- Using non-combustible (e.g. steel) joists and durable hardwood decking boards results in a deck that burns slowly and produces a peak heat load on the wall which is lower than that from a Class A crib ignition source placed against the wall. In *Figure 4-30* the temperature plots for the deck shown in *Figure 4-14* are given. These show that after 400 s when most of the crib has burnt the temperature on the wall due to the heat from the decking is approximately 250°C. This compares with over 400ºC for the Class A crib shown in *Figure 4-25*. It should be noted that to assist the deck to burn, airflow had to be applied. Without airflow the temperature on the wall due to the decking burning is

likely to be even lower as the airflow tends to drive the heat into the wall near the deck. A better understanding of the heat load due to the decking could be gained by igniting the decking using a gas burner and then turning it off and measuring the residual heat load on the wall from the deck alone.

Figure 4-29 Poor Detailing can Result in the Propagation of Fire from Deck to Wall

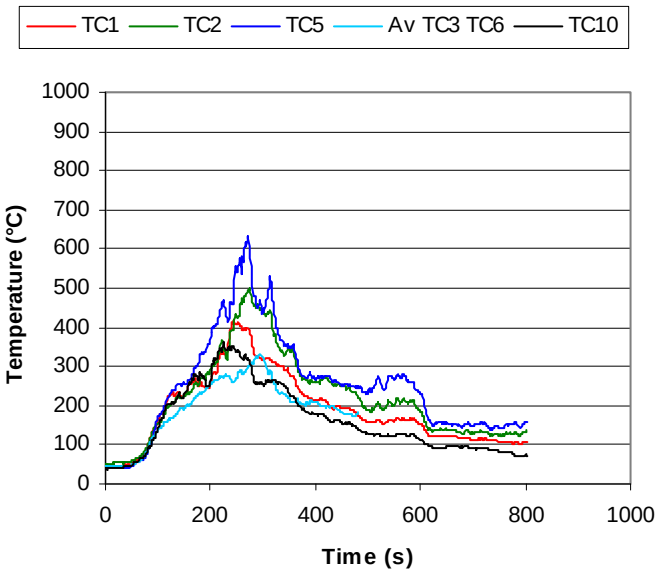


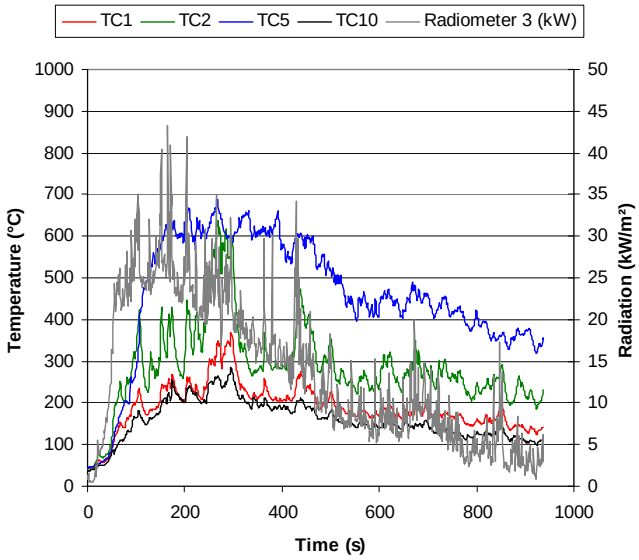
Figure 4-30 Temperature Plots for Merbau Deck, Class C crib Ignition Source Located Centrally on the Deck, 40 kW/m^2 External Radiation, Airflow (5m/s)

Providing a gap between the ignition source and the wall is a possible way of reducing the heat on the wall. This could be achieved using a barrier along the wall/deck or offsetting the deck from the wall. To investigate having a gap between the deck and the wall, two comparative tests were performed using a cement sheet deck and a Class C crib placed on the edge of the deck near the wall as shown in *Figure 4-31*. In one test a 50mm gap was left between the deck and the wall while in the other the deck was flush against the wall. The temperature and radiation plots for the decks are shown in *Figure 4-32*. As can be seen the gap reduces the temperatures on the wall by up to half. It should be noted that this reduction is due to two factors:

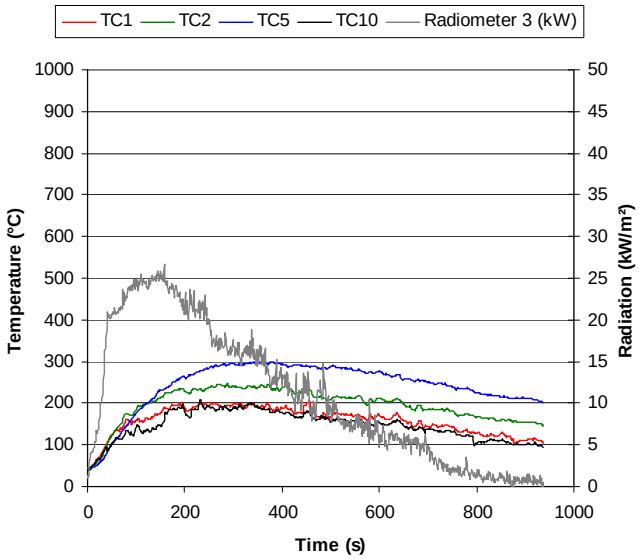
- the increased distance the crib is from the wall
- the change in airflow with cooler air flowing from beneath the deck up between the wall and the crib.

If airflow was applied to simulate wind blowing across the crib towards the wall the effect the gap has on the temperatures on the wall would be reduced.

Figure 4-31 Testing the Effect of a Gap between the Deck and the Wall



(a) No gap between deck and wall



(b) 50mm gap between deck and wall

Figure 4-32 Comparative Plots showing the Effect of a Gap between the Deck and the Wall

4.4.3 Vertical position below the deck

This work is presented in the previous section: 4.2.1 Sustained Burning of a Deck due to Ignition Sources placed Underneath.

Two different ignition sources, Class C crib and 1 kg litter were position against the wall at various heights below a Merbau timber deck and the height determined at which the ignition source would cause the deck to ignite and continue to burn. No airflow was used. Table 4-3 shows that for the Class C crib the height required was approximately 400mm while for the 1 kg litter (dried eucalyptus leaves, twigs and gum nuts, 76 kg/m^3) the height was approximately 600mm. It was observed that at these heights the fames from the ignition source are just licking through the decking.

Additional work is needed to determine heights for small cribs and litter piles.

4.5 Type of Deck

The variations in the type of deck covered were:

- Timber deck vs Cement sheet deck
- Radiata Pine vs Merbau decking
- Radiata Pine vs Steel joists
- Tapered edge boards vs Square edge boards
- Gap between wall and deck vs No gap
- Effect of gaps in deck

4.5.1 Timber deck vs Cement sheet deck

A number of above deck tests were performed to determine what effect using a timber deck had over a cement sheet deck (representing a non-combustible horizontal surface) on the heat profile on the wall. A typical timber deck consisting of Merbau decking and steel joists was used with a Class C crib ignition source (see *Figure 4-33*).

The major differences between the timber and the cement sheet decks are:

- timber is combustible and will add to the heat load on the wall and also provide embers
- timber decks have gaps which will alter the airflow to the ignition source and wall.

Figure 4-33 Timber Deck / Wall Test using a Class C crib and 20 kW/m^2 radiation (at the wall)

A summary of the tests undertaken is given in *Table 4-6*. The temperature values are approximate only and represent the average peak temperature held for a period of at least 100s. This eliminates any short term peaks while indicating a sustained heat load on the wall.

It can be noted that compared with the cement sheet deck the timber deck:

- has a small effect (roughly <12% increase) on the temperature on the wall near the crib.
- has a larger effect on the temperature higher up the wall (roughly 30% increase).
- produces a longer period of elevated temperatures (up to 50% longer)

It should be noted that the majority of the temperature increase on the wall is due to the applied radiation and the crib. These were selected to give a realistic scenario for high bushfire risk conditions. It may be that the effect of the timber deck is greater when the bushfire risk conditions are lower as a greater proportion of the temperature rise on the wall will be due to the timber deck.

To better compare the timber deck with an alternative non combustible surface would require:

- Determination of the relative effect on the heat load on the wall that the gaps in the deck have compared to the heat generated from the burning of the deck
- Undertake comparative tests using smaller ignition sources, lower radiation levels, air flow, different wall configurations, etc

Table 4-6 Comparison between Tmber and Cement Sheet Decks

Type of deck	Temperature near crib:TC5 (ºC)	Temperature at wall:TC1 (ºC)	Time (s) TC1>200ºC	Time (s) TC1>300ºC
Cement sheet wall, Class C Crib at wall, 20 kW/m^2 at wall				
Timber	750	400	800	400
Cement Sheet	700	300	500	300
Cement sheet wall, Class C Crib at wall, 20 kW/m^2 at wall, 5 m/s air				
Timber	900	350	400	100
Cement Sheet	800	300	300	100
Weatherboard wall above 400mm, Class C Crib at wall, 15.5 kW/m^2 at wall				
Timber	650	600 (wall burnt)	(wall burnt)	(wall burnt)
Cement Sheet	600	600 (wall burnt)	(wall burnt)	(wall burnt)
Burnt weatherboard wall above 400mm, Class C Crib at wall, 0 kW/m^2 at wall				
Timber	600	450	700	400
Cement Sheet	600	350	700	200

Note: Temperatures values are approximate and represent a average peak over a period of at least 100s

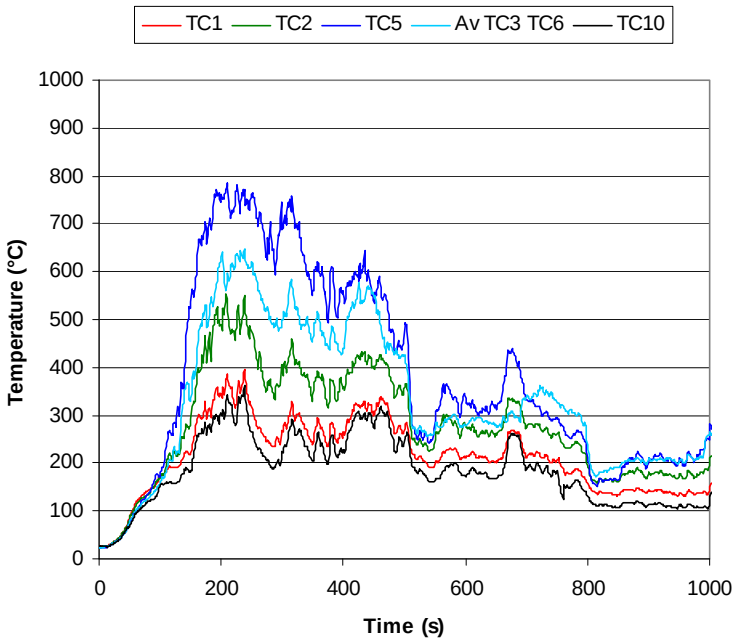
4.5.2 Radiata Pine vs Merbau decking

A comparative test was undertaken using pine decking to check previous work [1] that indicated pine decking performed much worse than the durable hardwood decking in terms of the intensity of the heat released and the damage to the deck. The test used a 1 kg litter ignition source placed under the deck and against the wall. The boards used for the Radiata Pine deck were thicker than the Merbau boards (35mm compared to 20mm). This was due to the stock available. In general the thick boards of the same wood would be expected to burn slower. The temperatures on the plasterboard wall were measured. Comparisons of the type of fire produced and the temperature profiles on the wall are given in *Figure 4-34* and *Figure 4-35*. It can be seen that the Pine puts a higher heat load on the wall particularly near the deck

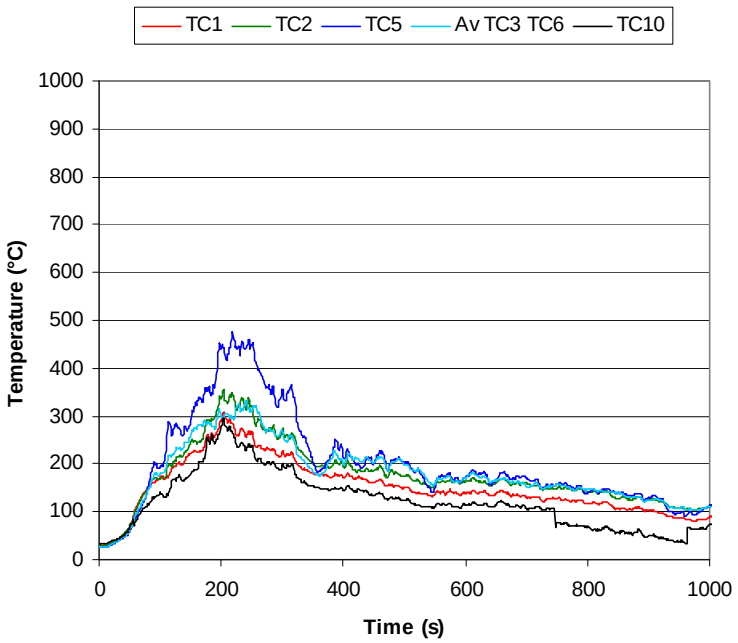
(temperature TC5) with temperatures up to 70% higher than for the Merbau deck and occurring over a much longer time frame. Also the pine deck is fully engulfed in flames resulting in the deck being almost completely burnt at the end.

Note: In *Figure 4-41* the dip in temperatures between 500s and 700s for the Pine deck is due to 5m/s airflow being applied.

Figure 4-34 Comparison of Pine (top) and Merbau (bottom) decking fires



(a) Pine decking



(b) Merbau decking

Figure 4-35 Wall temperatures for pine and Merbau decking tests

4.5.3 Pine vs Steel joists

One comparative test was undertaken to compare pine and steel joists to confirm previous observations [1] showing that pine joists increased the likelihood of the deck burning from an ignition source placed below the deck.

The test involved:

- Class C crib placed below the deck at the wall
- 40 kW/m^2 radiation
- 5 m/s airflow between 450s and 700s
- Merbau 90 x 20 decking boards

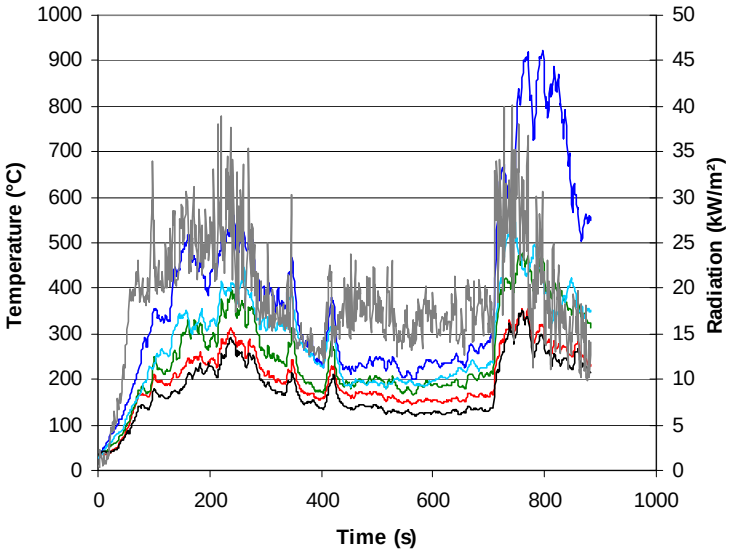
Comparisons showing the spread of fire across the deck and the temperature profiles on the wall are given in *Figure 4-36* and *Figure 4-37*. It can be seen that the pine joist deck puts a 10-15% higher heat load on the wall than the steel joist deck. It was also observed that the steel joists acted as a barrier to help prevent the fire spreading along the decking boards. Also the pine joists continued to burn, particularly if airflow is applied ultimately resulting in loss of structural integrity.

The other interesting point was the rapid increase in the heat load on the wall when the airflow is turned off at 700s as the fire again flares up. While this occurred for both decks the pine joist deck resulted in the biggest rise.

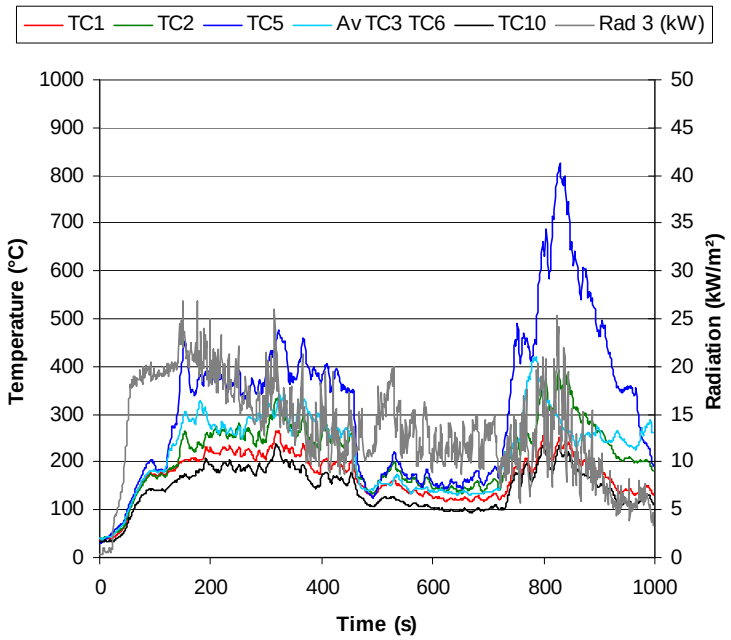
(a) Pine joists

(b) Steel joists

Figure 4-36 Comparison of Pine and Steel joists



(a) Pine joists



(a) Steel joists

Figure 4-37 Wall temperatures and radiations for pine and steel joist decking tests

4.5.4 Tapered edge boards vs Square edge boards

A comparison between tapered edge and square edge decking boards was undertaken because previous work [1] had indicated (based on a single test) that tapered edge boards may perform better for below deck fires. A possible reason for this may be that square edged boards exposed to below deck fires tend to initially burn at the bottom corner of the boards until the edge is effectively tapered (see *Figure 4-38*). Having an initial taper on the edge would reduce the amount of heat trapped in the gap between the edges of the boards.

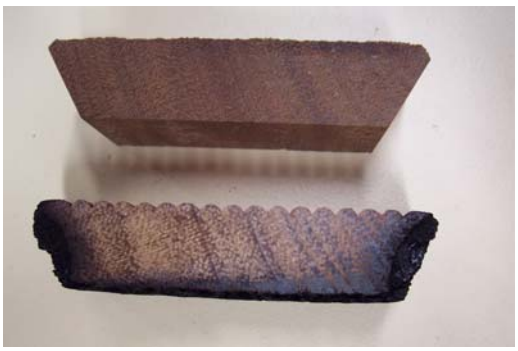


Figure 4-38 Tapered Edged Board Compared with a Square Edged Board Removed from a Burnt Deck

One comparative test was undertaken to compare the tapered (20º) and square edge decking boards exposed to a below deck fire.

The test involved:

- Class C crib placed below the deck at the wall
- 40 kW/m^2 radiation
- Merbau 90 x 20mm decking boards with square or tapered edges

The crib was placed at 380mm below the deck. This is chosen because it had been previous found, (see *Table 4-3*), to cause the deck to catch alight and burn but just short of the distance (approximately 400mm) at which the deck can survive. Hence if the tapered edge increased the resistance of the deck burning, the deck was likely to survive at this distance.

The results of the comparative tests are shown in *Figure 4-39* and *Figure 4-40*. The results indicate that both decks burned to a similar amount but the tapered edge deck performed worse in terms of producing higher temperatures on the wall. Another test, using the tapered edge but without the external radiation, resulted in a similar outcome.

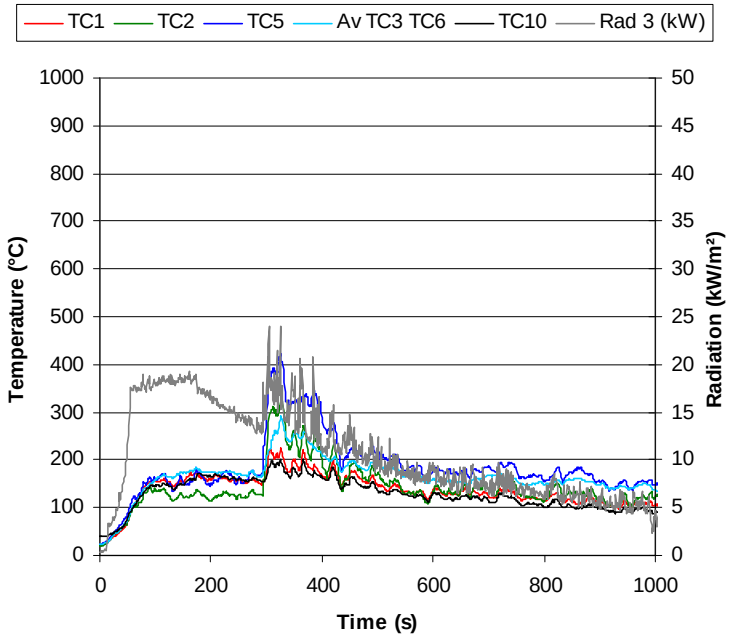
It was concluded that the tapered edge did not improve the performance. Reasons why the under deck flame test had indicted an improvement in the performance which wasn't repeated here are:

- The Class C crib burns for much longer than the 3 minute gas burner used in the under deck flame test.
- The airflow from the pilot flame used in the under deck flame test could have affected the flame from the main burner, making single test comparisons unreliable.

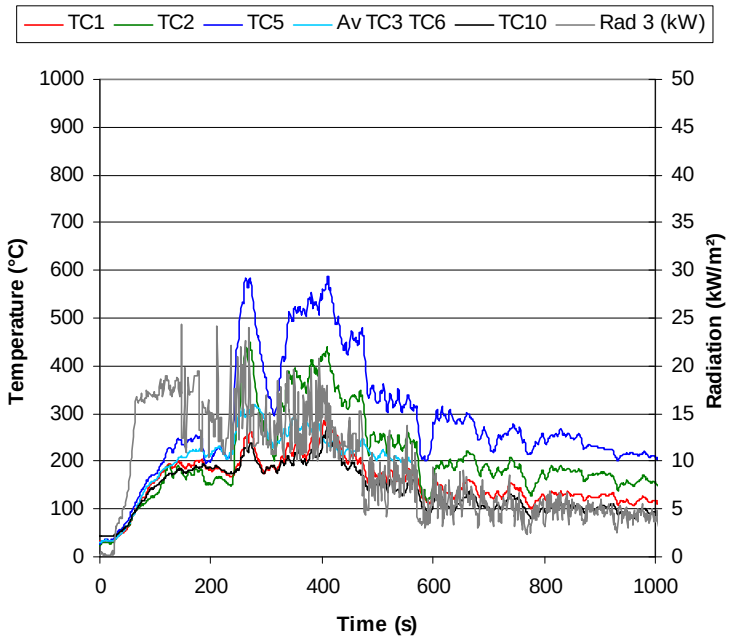
(a) Square edged

(b) Tapered edged

Figure 4-39 Comparison of Square and Tapered edged decking boards



(a) Square edged



(b) Tapered edged

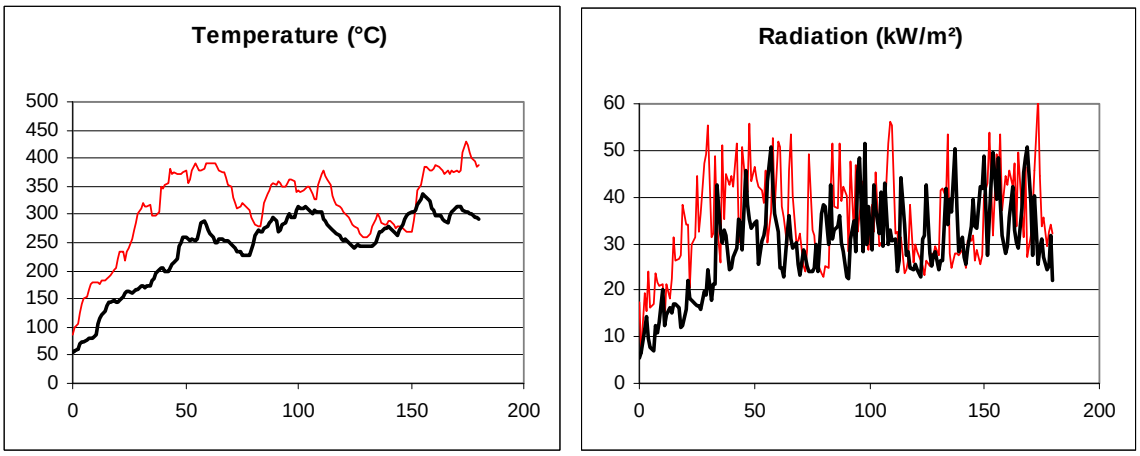
Figure 4-40 Wall temperatures and radiations for square and tapered edged decking tests

4.5.5 Gap between wall and deck vs No gap

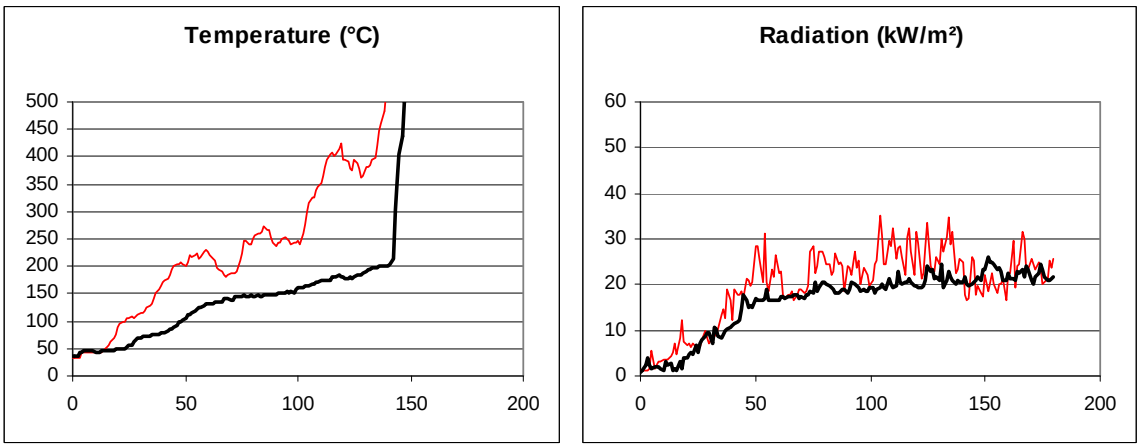
This has already been covered in the previous section, 4.4.2 Horizontal position from the wall.

4.5.6 Effect of gaps in deck

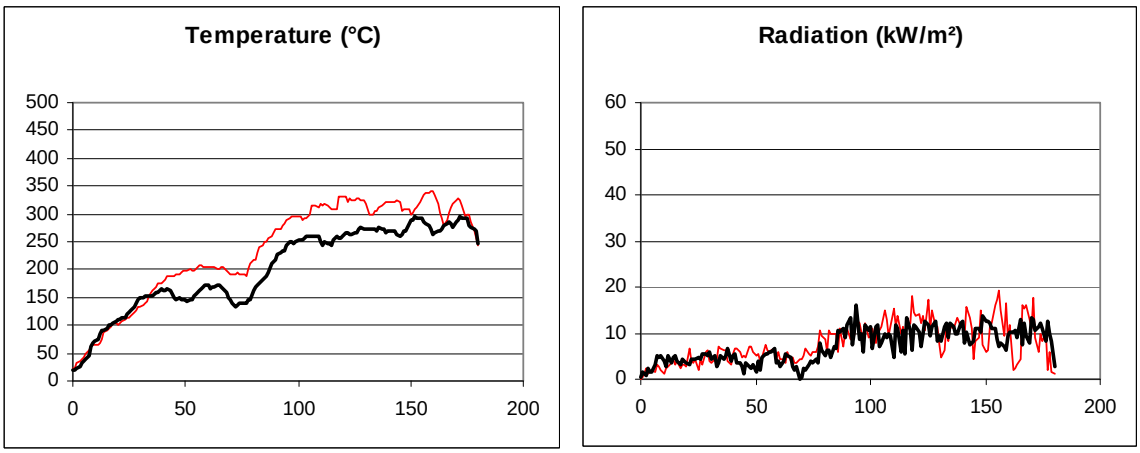
Besides the combustible difference between the cement sheet deck and a timber deck the later also allows air into the ignition source from below. It was noticed during the initial stages (1 to 3 minutes) of some tests that the flame height appeared to be higher when a timber deck was used than for the cement sheet deck. During this stage the timber deck hasn't fully ignited, so the reason may be due to the extra airflow to the ignition source. Analysis of some of the tests shows that in these early stages the timber deck produces higher temperatures and radiation levels at the wall. Typical plots are shown in *Figure 4-41*.



40 kW/m^2 cement sheet wall



15.5 kW/m^2 cedar weatherboard wall



0 kW/m^2 burnt weatherboard wall

Figure 4-41 Comparison of Temperature (on wall, 500mm above deck) and Radiation (on wall, 300 above deck) between Timber (red) and Cement Sheet (black) Decks with a C Class Crib Ignition Source against the Wall.

4.6 Material Conditioning

The comparative tests involving material conditioning were limited to the weatherboards used to clad the wall. The effect of conditioning of the decking material wasn't investigated. This was partly because other parameter such as size and placement of ignition source, radiation and airflow will often control the outcome.

In a weatherboard wall test there is a relationship between the conditioning of the weatherboards and the level of radiation applied. The result of the test conducted have been reported in section 4.1.1 Effect on the Ignition of the Wall. It can be seen in Table 4-2 that only in two cases could a difference be identified:

- using a Class A crib and a 20 kW/m^2 radiation at the wall the weatherboards ignited when conditioned at 45° C and 18% RH but didn't ignite when conditioned at 22° C and 47% RH
- using a Class C crib and a 15 kW/m^2 radiation at the wall the weatherboards ignited when conditioned at 45° C and 18% RH but ignited only 1 in 2 tests when conditioned at 22° C and 47% RH

This is an expected outcome as the dryer boards are more likely to ignite.

As with the decking boards it is hard to obtain a qualitative measure of the effect that the conditioning has and relative influence of the conditioning compared to the other parameters investigated. To do this would require many more tests and as previously stated it was assumed that the effort be better placed investigating parameters which are assumed to have a bigger influence. Future work could investigate the effect of conditioning the decking boards at 45° C and 18% RH to avoid under prediction of the combustibility outcomes. The completion of current work monitoring the moisture content in timber samples exposed to the weather over summer will provide data on what conditions are relevant for decking exposed to bushfire conditions.

4.7 Application/timing of the ignition source, radiation and air flow

Two cases were investigated to determine what effect the timing of ignition, radiation and airflow had on the likelihood of fire propagating from the deck to the wall.

These were:

- Time of application of airflow
- Time of application of radiation following lighting of the ignition source.

4.7.1 Time of application of airflow

As already mentioned in section 4.3.2, airflow causes the ignition source to burn quicker, driving the heat into the wall near the ignition source and dispersing the heat that is further away from it. For the deck wall tests where the weatherboards are placed 400mm above the deck it was found that the weatherboards were more likely to ignite if the airflow was not applied until the ignition source had substantially burnt. This was because the ignition source without any airflow burnt with a higher flame height and was more likely to set fire to the weatherboards. It was also found that if airflow was applied while the weatherboards were only partly burning (glowing) they could fully ignited (see *Figure 4-42*) or in the case of burnt weatherboards reignited.

(a) before airflow

(b) airflow applied, corner glowing

(c) weatherboards ignite and burn

Figure 4-42 Airflow applied after weatherboards are burning.

4.7.2 Time of application of radiation following lighting of the ignition source

A comparative test was performed to compare the effect of increasing the time between lighting the ignition source and applying the external radiation. A corner weatherboard wall test with a Class A crib ignition source was used as shown in *Figure 4-43*. In the first test a 16 kW/m^2 external radiation was applied immediately after the burning ignition source was placed on the deck. In the second test the application of the external radiation was delayed by 1 minute and the radiation reduced to 12 kW/m^2. In *Figure 4-43* the photos show the test walls just as the peak radiation is being applied. The second test crib which was allowed to burn for 1 minute prior to applying the radiation profile has a flame height which is touching the base of the weatherboards. However the first test crib doesn't achieve this flame height until towards the end of the peak radiation profile.

Plots of the radiation and temperatures on the wall for the two tests are shown in *Figure 4-44*. It can be seen that the temperatures close to the crib (TC5 and TC2) are higher in Test 2 than in Test 1 during the initial minutes of the test as the crib in Test 2 is more advanced in its burning cycle. However the temperatures on the wall further above the cribs (TC1 and TC10) are higher in Test 1 due to the higher external radiation being applied. It is interesting to note that the average radiation measured at the wall during this time is similar for both tests. This is due to the combining in Test 2 of the lower external radiation with the higher radiation from the crib.

In the end it is Test 2 with the lower external radiation but with a crib that has been allowed to burn prior to the radiation being applied that result in the weatherboards igniting and burning. This occurs at 220 s into the test while for Test 1 the weatherboards only ignite after airflow is introduced at 630 s as shown in *Figure 4-42*.

It should be noted that at 380 s airflow was also introduced into Test 2. This had little effect on the temperatures except for TC2 which is positioned near the radiometer, half way up the wall between the deck and the bottom of the first weatherboard. The temperature behind the crib (TC5) continues to climb as the airflow drives the heat from the crib into the wall while

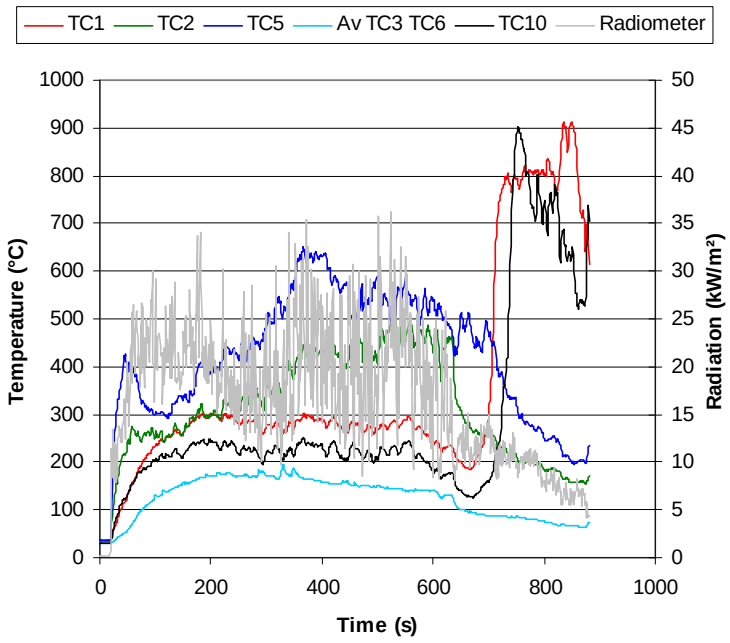
the temperatures on the weatherboards also stay high as the burning of the weatherboards are fanned by the airflow. The drop in temperature of TC2 may be due to the airflow creating a zone of air between the wall and the flames from the crib.

In conclusion the tests demonstrate that the timing sequence is important because it is the summation of the various parameters contributions at is crucial.

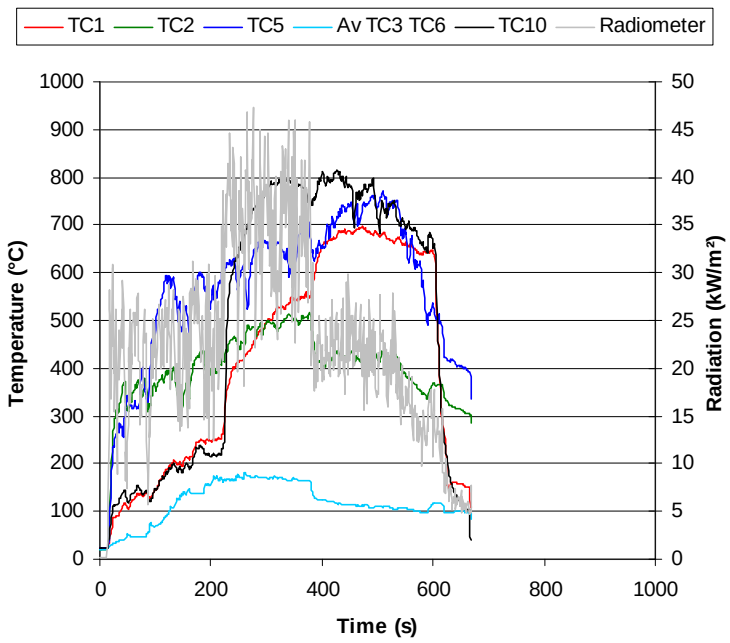
(a) Test 1

(b) Test 2

Figure 4-43 Corner weatherboard wall test using Class A crib ignition source



(a) Test 1



(b) Test 2

Figure 4-44 Temperature and Radiation Plots for Tests Comparing Timing of Application of Radiation after Lighting Ignition Source

5. Conclusions

This report covers only a preliminary investigation into what affects the propagation of fire across the interface between a timber deck and the external wall of a building. Even though over 60 tests were conducted it equates to only a few comparative tests for each parameter considered. It does however give a good overall indication of what parameters are critical and should be studied further.

Some interesting outcomes include:

- Small gaps (<1mm) in the cladding, too small for embers to get through are susceptible to air driven fire attack particularly if the orientation of the wall is likely to channel the air into the gaps such as occurs at a recess or corner. These gaps can appear due to the drying out and distortion of the cladding during the bushfire.
- The radiation on a component such as a wall is approximately the sum of the radiations from the contributing sources. Hence a 15 kW/m^2 radiation load from the radiant panel plus the radiation from the ignition source can result in a combined radiation load of 20 kW/m^2, i.e. enough to ignite cedar weatherboards within 2 - 3 minutes.
- Durable hardwood timber decking tends to burn slowly, each board separately, resulting in a heat load on the wall similar to a medium sized ignition source such as 0.5 kg of tree litter.
- Airflow, simulating wind, has a major influence on the fires behaviour and whether the deck or wall will continue to burn or go out. It increases the rate of combustion and the likelihood of continued combustion or spread of fire. It also changes the heat profile on the wall from an adjacent ignition source, driving the temperatures up near the ignition source and dispersing or reducing the heat further away from the ignition source.

- The heat load on the wall is greatly affected by the timing of the application of the various components, e.g. allowing the ignition source to burn for a period prior to applying the radiant heat can result in a higher peak load on the wall.
- The gaps in a timber deck provide greater airflow to an ignition source on the deck resulting in a higher flame height. This is also likely to be the case for non-combustible surfaces such as steel grating as well. However for timber decks the gaps also segment the fire and disperse the heat which reduces the fires impact of the deck burning.
- Using better detailing such as separating the combustible parts of the deck from the wall and using a non combustible subfloor (e.g. steel joist, bearer and stumps) could make durable hardwood timber decks significantly safer in terms of the potential heat loading on the wall.

The report also shows that the relatively simple test procedure used is able to provide good performance data on a number of the parameters that affect the way timber decks and building walls interact when exposed to fire. It does however have limitation and these include:

- the size of the radiant panel which limits the size of the test specimen and gives a radiation profile which varies from 40 kW/m^2 at the front of the deck to 20 kW/m^2 at the back
- the applied airflow is limited to a small vertical band just above the deck although this could be improved by using a grid of outlets to apply the compressed air onto the test specimen

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APPENDIX A – Test Procedure

A.1 Summary

The test is performed on a section of external wall and deck to measure the propagation of fire from the deck to the wall. Exposure to a number of elements including radiant heat, ignition sources such as cribs and debris and airflow are used. Typical test setups are shown in *Figure A 1*.

(a) Straight weatherboard wall

(b) Corner weatherboard wall

Figure A 1 Typical Test Setups

A.2 Apparatus

A.2.1 General

The test apparatus consists of a computer controlled carriage which supports the test specimen and allows it to be moved in and out from a stationary radiant panel. The carriage has radiometers and thermocouples for measuring radiation and temperatures as well as a compressed air line for blowing compressed air onto the test specimen. A computer and data acquisition system is linked to the carriage for recording the test data and controlling the carriage position.

Other pieces of equipment include:

- Test Specimens including timber or cement sheet decks and cedar weatherboard or cement sheet walls
- Timber crib and leaf litter ignition sources
- 3 ring gas burner for igniting the cribs
- time display
- air compressor and associated gauge and valve for regulating the airflow
- camera or video recorder
- safety/protective equipment

A.2.2 Radiant panel

The radiant panel is a 1.5m by 1.5m grid of gas radiant heaters. The panel is stationary and runs at a fixed gas flow rate.

A.2.3 Carriage

The carriage runs on tracks and its position relative to the radiant panel is controlled by a computer via a motor and drive chain. The front of the carriage is “L” shaped. The vertical section consists of two steel supports onto which is fastened a 6mm thick cement sheet. The test wall and any wall mounted radiometers and thermocouples are fixed to this section. The horizontal section consists of a steel frame onto which is also fixed a 6mm thick cement sheet which is the floor of the carriage. A support frame for the deck is fixed to this section and allows the height of the deck to be adjusted. The floor of the carriage is inline with the bottom edge of the radiant panel.

A.2.4 Test Specimen

Two test specimens (see *Figure A 1*) are used:

- Straight Wall
- Corner Wall

A.2.4.1 Straight Wall Test Specimen

The straight wall test specimen consists of a1200mm high by 800mm wide wall section and a 750mm by 750mm deck surface. The deck surface can be position at a set height above the floor of the carriage.

A.2.4.1.1 The Wall

Two types of walls are used:

- Plasterboard Wall
- Weatherboard Wall

A.2.4.1.1.1 Plasterboard Wall

The plasterboard wall comprises a 1200mm x 800mm sheet of 16mm fire resistant plasterboard fixed to the vertical section of the carriage. This wall is used for calibration runs and tests where a non combustible wall is required. e.g. below deck tests where the height of the deck above ignition source is to be varied. An elevation view of the wall is shown in *Figure A 2*.

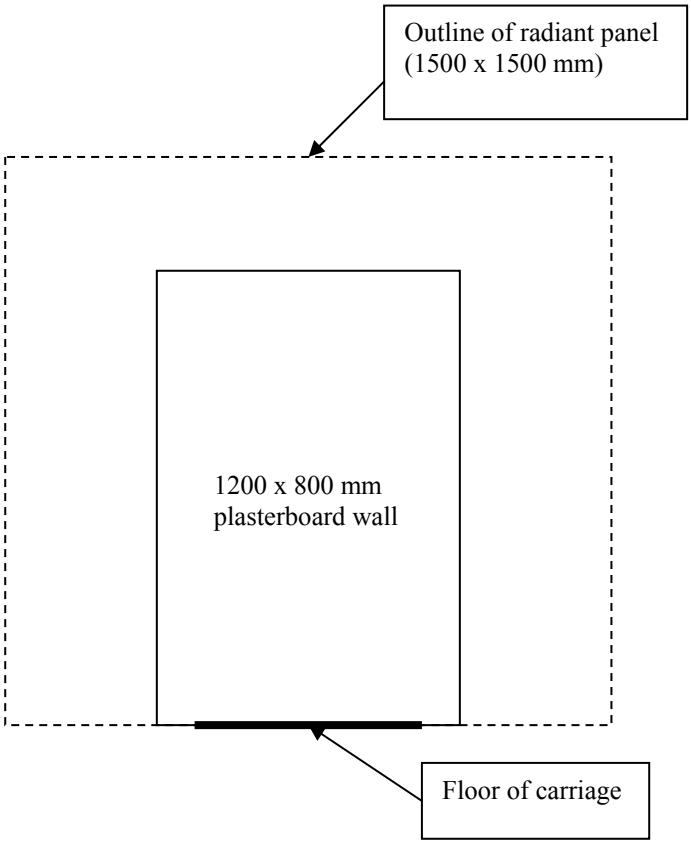

Figure A 2 Elevation View of Plasterboard Wall

A.2.4.1.1.2 Weatherboard Wall

The weatherboard wall comprises a 800mm x 800mm sheet of 6mm cement sheet fixed to the bottom part of the vertical section of the carriage with 3 cedar weatherboards fixed to the top part. The bottom weatherboard sits directly on the top edge of the cement sheet. The deck is positioned at a height of 400mm above the floor of the carriage and 400mm below the bottom edge of the lowest weatherboard. At this height the surface of the deck is 400mm above the bottom edge of the radiant panel. This wall is used for testing the performance of a typical weatherboard in a high bushfire risk environment. The dimensions of the wall are given in *Figure A 3*. The weatherboards are installed using standard industry practice. The weatherboards used were 185mm wide with a 35mm overlap. i.e. the total height of the 3 weatherboards was 485mm. Hence the top weatherboard extend above the wall by 85mm.

The use of cement sheet for the lower 400mm of the wall below the weatherboards was to refect what might be used in practice. However one drawback in using cement sheet was that it cracks after a couple of tests and needs repair or replacing. Figure A 8 shows one attempt to protect the cement sheet using mesh and plaster with little success.

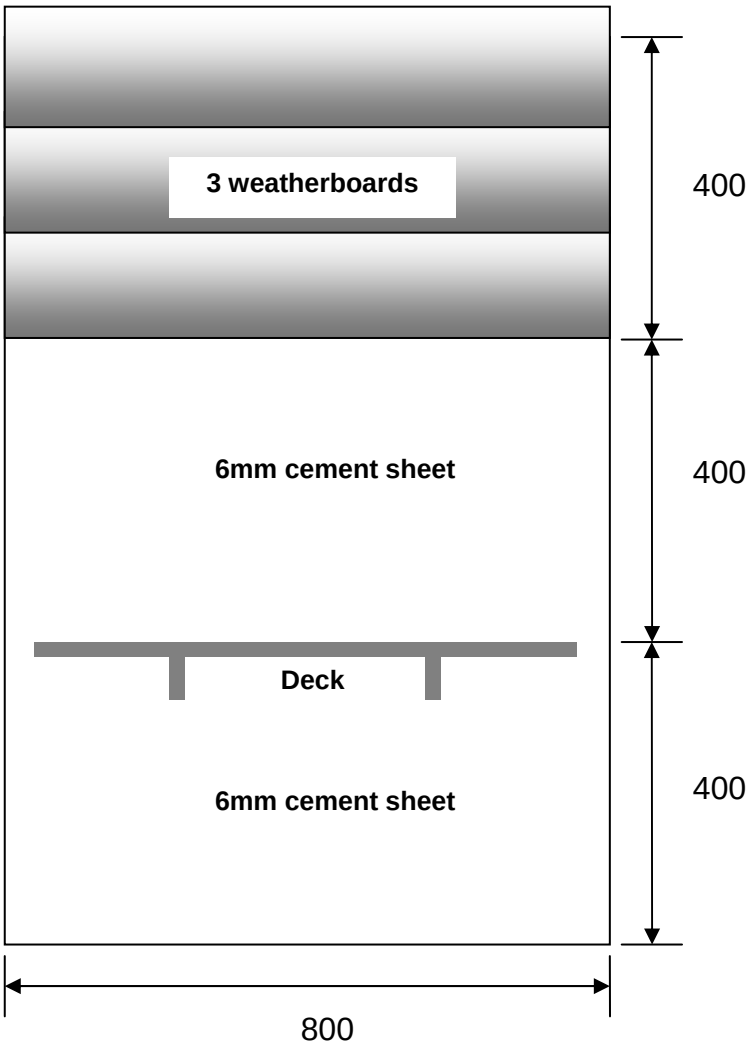

Figure A 3 Weatherboard Wall Dimensions

A.2.4.1.2 The Deck

Two test specimens are used:

- Cement Sheet Deck
- Timber Deck

The dimensions of the deck are given in Figure A 4.

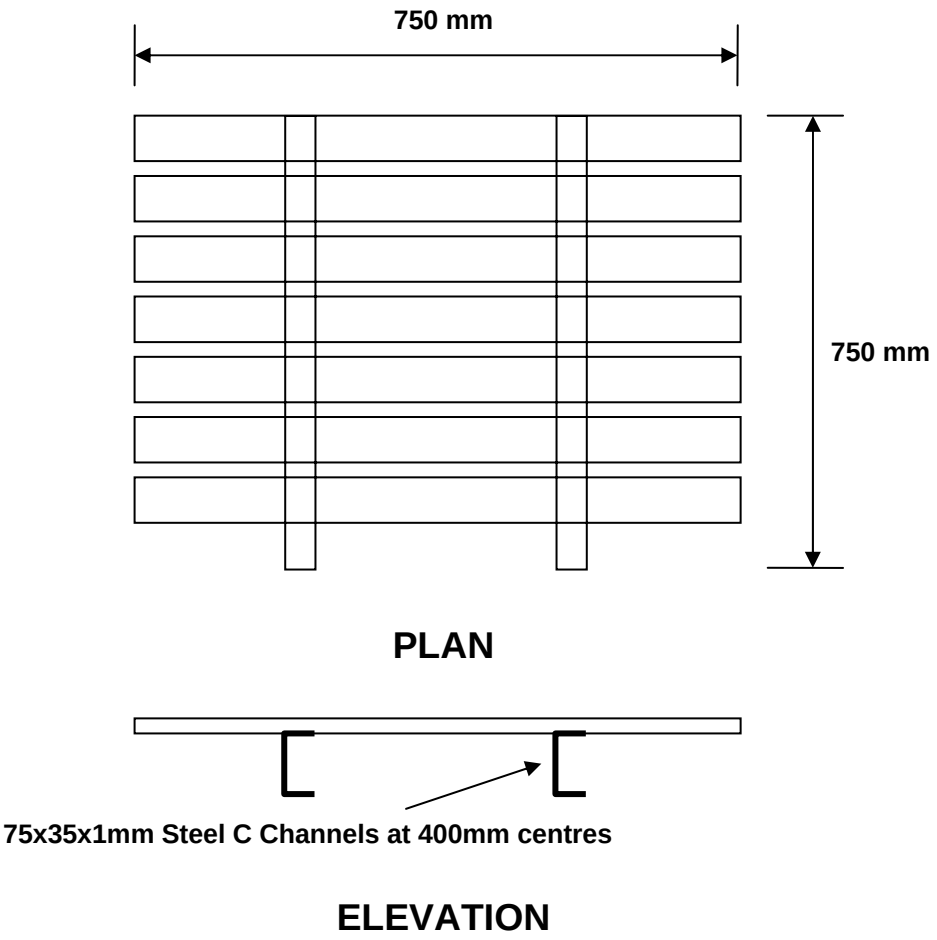

Figure A 4 Deck Dimensions

A.2.4.1.2.1 Cement Sheet Deck

The deck consists of a 750mm x 750mm x 6mm cement sheet screw fastened to two steel C channel joists. For comparative tests, packing is used under the ignition sources to raise the surface of the cement sheet deck to the same level as the timber deck (see *Figure A 1*).

A.2.4.1.2.2 Timber Deck

The deck consists of 750mm long timber decking boards screw fastened to two steel C channel joists 750mm long.with 5mm gaps between the boards (see *Figure A 5*). At the wall

end the first decking board is placed flush with the end of the joist and the remaining boards separated by a 5mm gap. The last board must sit completely on the joist without overlapping the end. Hence there will often be a small length of joist sticking out past the last board.

Figure A 5 Timber Deck

A.2.4.2 Corner Wall Test Specimen

The corner wall test specimen is constructed in a similar manner to the straight wall test specimen. Two 1200mm high by 500mm wide walls are joined at a 90º angle to form the corner. A 500mm x 500mm deck is placed into the corner at the required height above the floor of the carriage.

However for the tests reported in this report a modified specimen was used as described below.

A.2.4.2.1 Modified Corner Wall Test Specimen

The modified corner test specimen is for above deck fire tests and consists of only the above deck portion of the wall which is placed on the same decking used for the straight wall test. This allows quick interchange between the corner and straight wall test setups.

The modified corner wall test specimen is constructed using two 900mm high by 500mm walls joined at a 90º angle to form the corner as shown in *Figure A 6*.

The following details are used:

- The bottom 400mm of the wall is constructed from 6mm thick cement sheet
- The top of the wall is constructed from three 185mm wide by 480mm long western red cedar weatherboards
- The corner of the weatherboard wall is constructed using a 20mm x 20mm square piece of cedar with the end of the weatherboards butting flush against it.
- A 40mm x 0.8mm thick aluminium angle flashing strip is placed in the corner between the timber studs and the cladding.
- The bottom edge of the lowest weatherboard is 400mm above the deck surface (including any packing pieces used under the ignition source).
- The bottom weatherboard overlaps the top of the cement sheet by 10 mm. The weatherboard is screwed to the frame so it sits tight against the cement sheet.
- A number of holes in the cladding are made to accommodated the radiometer and 6 thermocouples
- The wall is placed on the carriage so the centreline of the corner is normal to the radiant panel as shown in *Figure A 7*.

Figure A 6 Modified Corner Wall Test Specimen

Figure A 7 Modified Corner Wall Test Specimen Orientation

A.2.5 Radiometer

The radiometer should have the following minimum characteristics:

- Range 0-100 kW/m^2
- Accuracy 0.5 kW/m^2
- Mounted so that it's face is within 5º of the required alignment
- for measuring the heat flux on the wall it should be mounted along the vertical centreline of the wall.

For the tests in this report the wall radiometer was mounted at a height of 300mm above the deck , (see *Figure A 1*), except for a few tests where it was mounted 550mm above the deck to measure the radiation at the level of the weatherboards (see *Figure A 8*).

Figure A 8 Radiometer Mounted in the Weatherboards

A.2.6 Thermocouples

The thermocouples should have the following minimum characteristics:

- Range 0-1000 ºC
- Accuracy +/- 10 ºC

For the tests in this report six thermocouples were used to measured the temperature profile on the wall. They were positioned in an inverted "T" formation as shown in *Figure A 9*. The thermocouples were pushed through holes drilled in the wall so that they extended 10mm past the surface of the wall. For the corner wall the centreline thermocouples were positioned in

the corner of the wall with the lower two off centreline thermocouples positioned 200mm from the corner along each wall.

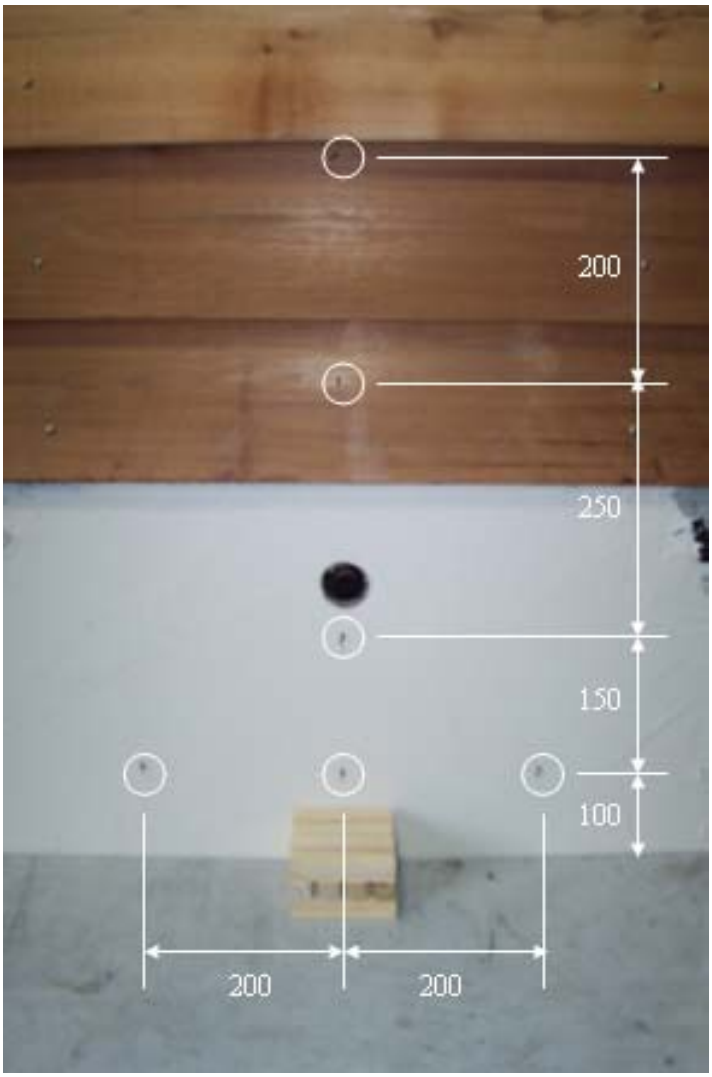

Figure A 9 Thermocouple Positions

A.2.7 Airflow/Wind

The airflow apparatus consists of an air compressor, hose, gauge, valve and a pipe mounted on one side of the carriage (see *Figure A 10*). The air compressor must have sufficient capacity to deliver the required air for the duration of the test. The one used for the tests in this report had a capacity of 175 l/min free air.

The air is delivered via a pipe that is parallel to the front edge of the deck and approximately 75mm in front and 60mm above the front edge. The pipe used for the tests in this report had an internal diameter of 13mm. The pipe has five 1mm diameter holes, 100mm apart, centred about the centreline of the deck that direct the air towards the wall as shown in *Figure A 11*.

The airflow at approximately 30mm above the centre of the deck was measured using an anemometer as shown in *Figure A 12* and calibrated against the pressure in the air hose using a pressure gauge and value. For the tests in this report airflow of approximately 5 m/s (18 km/h or 12mph) was used to simulate wind conditions.

Figure A 10 Compressed Air Pipe Mounted on Side of Carriage

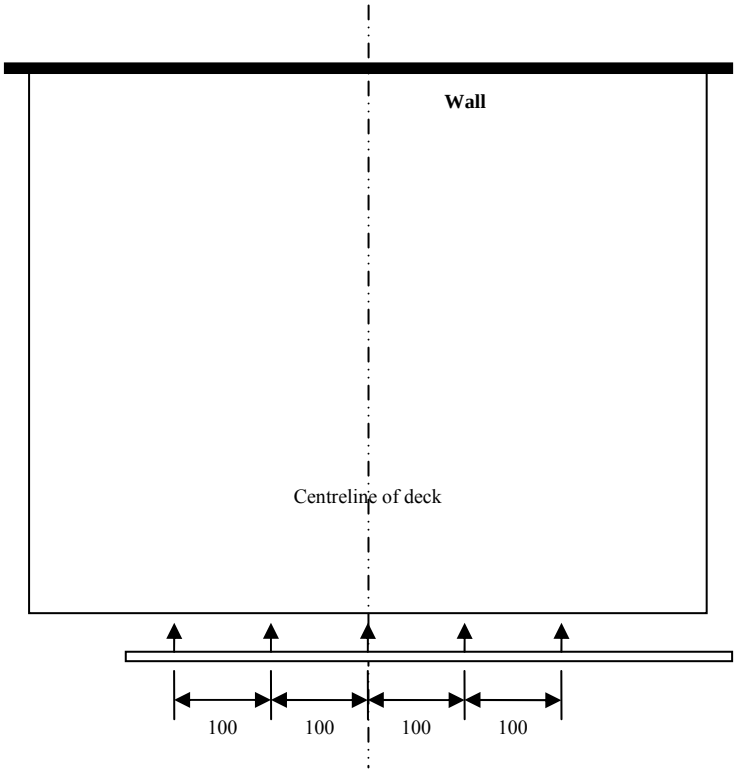

Figure A 11 Plan View of Airflow Outlets

Figure A 12 Anemometer for Measuring the Airflow Above the Deck

A.2.8 Ignition Sources

Two types of ignition sources are used;

- Timber cribs
- Tree litter

A.2.8.1 Timber Cribs

The timber cribs, (see *Figure A 13*), are used as ignition sources to simulate the burning of a pile of litter or debris. They are constructed from clear sticks of seasoned radiata pine timber which are glued together using PVA glue to form a crib (see *Figure A 14*). The two sizes of cribs recommended are given in *Table A 1*.

Table A 1 Timber cribs

Crib	Stick Thickness (mm)	Length (mm)	No. Sticks per row	No of Rows	Approx. Mass (g)
Class A	20	100	4	3	250
Class C*	20	230	9	3	1250

* Two extra sticks are used to glue the top row together.

For the Class A crib, only the two end sticks of the second row and all of the top row are glued to the row below. For the Class C crib, only the two end sticks are glued to the row below. For this reason two extra sticks are required to glue the top row of the Class C crib together.

The cribs are ignited using a 3 ring gas burner as shown in *Figure A 15*. Each of the faces are exposed to the burner for about 30 second. The crib is then held just above the burner using tongs to allow the flames to fully engulf the crib before being placed onto the test specimen.

Note: The tongs should grip the ends of the second row of sticks to prevent the crib falling apart.

(a) Class A

(b) Class C

Figure A 13 Cribs used as ignition sources

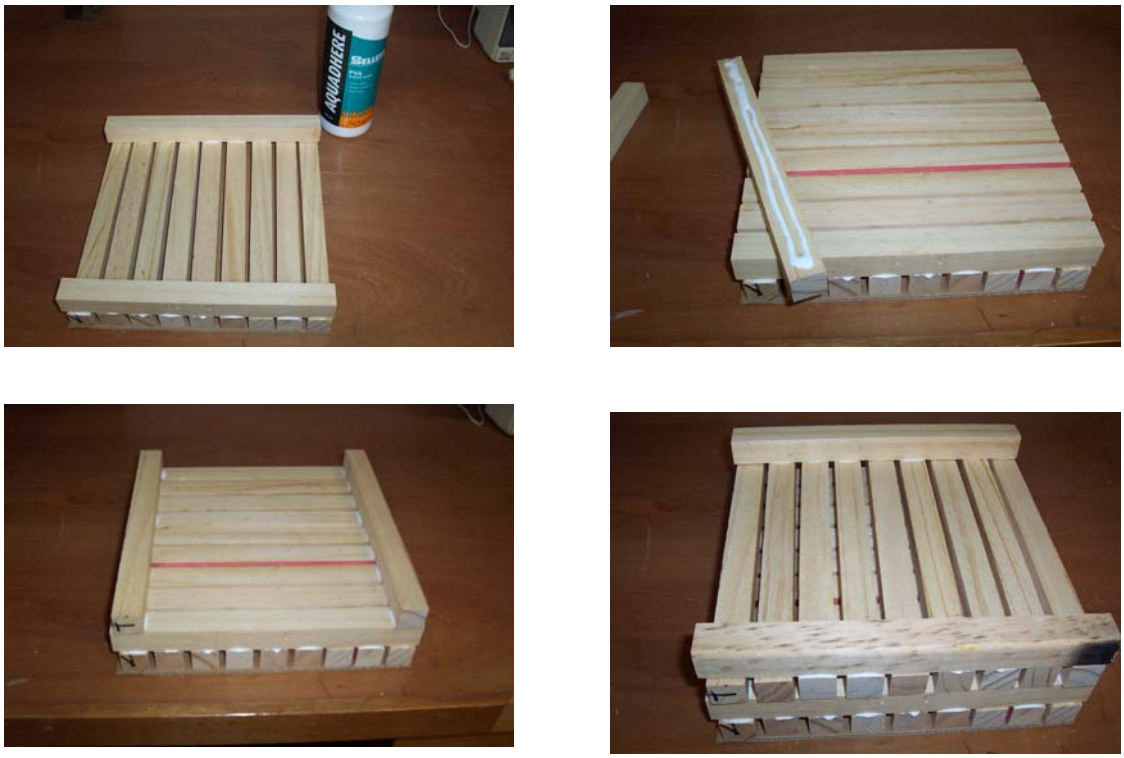

Figure A 14 Construction of the Class C Crib

Figure A 15 Lighting a crib

A.2.8.2 Tree Litter

Piles of tree litter are used to provide actual ignition sources that could occur in a bushfire environment. For the tests in this report two types of Gumtree litter was used The first source consisted almost entirely of dried leaves (*Figure A 16*a). The second which had approximately twice the density consisted of dried leaves, twigs and gum nuts (*Figure A 16*b). In both cases a 1 kg mass of litter was typically used as an ignition source although other sizes can also be used.

The tree litter can be ignited on the test specimen using the flame of a fire lighter.

(a) 1 kg of dried eucalyptus leaves (33 kg/m^3)

(b) 1 kg dried eucalyptus leaves, twigs and gum nuts (76 kg/m^3)

Figure A 16 Litter Ignition Sources

A.3 Conditioning

Two types of conditions are available :

- Room conditions: 23° C +/- 2° C and 50% +/- 5% RH
- Bushfire conditions: 45° C +/- 2° C and 20% +/- 5% RH

The materials are conditioned until equilibrium moisture content (EMC) is reached. The test is to commenced within 1 hour of the materials removal from the conditioning environment.

A.3.1 Ignition Sources (Timber cribs and Tree litter)

The ignition sources are conditioned for bushfire conditions

A.3.2 Test Specimens (Cedar Weatherboards and Timber Decking)

The cedar weatherboards and timber decking can be conditioned using either the room or bushfire conditions.

For the tests in this report the decking was conditioned at room conditions while both types of conditions were used for the weatherboards.

A.4 Radiant Panel Calibration

Prior to use the radiant panel is preheated until steady state conditions occur.

Before testing is undertaken the test apparatus is to be checked to determine the repeatability of the radiation loading on the test specimen from the radiant panel. The variation should be less than either 10% or +/-1 kW/m^2. If the variation from day to day is higher than this, the test apparatus is to be calibrated at the start of each day.

The calibration runs are performed using a test specimen where any timber decking or weatherboards are replaced with cement sheeting. A single radiometer positioned along the centreline of the wall and 300mm above the deck is used for the calibration.

A.2.5 Procedure

Once the test apparatus has been calibrated and checked with the radiation profile programmed in, then the test procedure is as follows.

1. Record test parameters
2. Ensure carriage is at the home position
3. Install test specimen on to carriage.
4. Check sensors are installed correctly
5. Check data acquisition and control software and hardware is operating correctly.
6. Place shield between radiant panel and the test specimen if radiant panel is to be used
7. Start air compressor if airflow is to be used.
8. Get ignition source from conditioning room
9. Start radiant panel and wait for steady state conditions if radiation profile is required
10. Light the ignition source and place it on the test specimen
11. Start data acquisition
12. Start display timer
13. Start airflow when required
14. Start carriage motion when the radiation profile is required.
15. Remove shield
16. Monitor test recording any significant observations as well as taking photos or video.
17. Apply flame to induce ignition on surfaces showing signs of volatile gases if required
18. End the test when goal has been achieved eg. combustion finished, ignition source smouldering, weatherboards fully ignited, etc.
19. Record final comments and observation

APPENDIX B – Timber Exposed to Bushfire Weather Conditions

This appendix summarizes the data of moisture contents in timber decking specimens placed on exposure rack at the CSIRO in Melbourne, (see *Figure 6-1*), during 2006. Only a limited amount of data was available due to:

- The relative infrequency of bushfire conditions occurring over the summer months. In general only 2 or 3 of these periods occur in Melbourne each summer.
- Temperature drift in the load sensors meant only manual measurements could be used.

It is expected that greater data will be available over the coming summer.

Moisture contents measured on two days of high bushfire weather conditions are given below. The values were obtained from oven dried moisture content measurements of timber specimens left on the wire mesh surface of the exposure rack that was fully exposed to the weather (ie. on the right hand side of the exposure rack in *Figure 6-1*).

Figure 6-1 Exposure Rack for measuring timber moisture contents at the CSIRO in Melbourne (looking south-west)

Data recorded on 3rd March 2006

This was the last of 3 high bushfire periods/days that occurred during the summer of 2005-2006. The previous two occurred during December and January. Unfortunately on both these occasions it was not possible to measure the moisture contents of the timber specimens. While the weather conditions leading up to the 3rd March 2006 represented high bushfire conditions they were not extreme as the temperatures only just reached 40°C over two of the days and the relative humidity at night return to quite high values. The graph of the temperature and humidity values at the exposure rack over the three days prior to the moisture measurements being taken are shown in *Figure 6-2*.

On the 3rd March 2006 the timber specimens were removed from the exposure rack and weighted in the morning at 10:15 am and again at 4 pm. They were then placed in an oven and dried so their oven dried moisture contents could be determined. The results are given in *Table 6-1* .

The moisture contents for the Cypress Pine, Spotted Gum and Merbau lie in a range between 7 and 9%. The Mountain Ash is lower between 5- 8% while the Blackbutt is higher at 9-11%. This is simular to what is achieved if the timber (at ~12% initial MC) is conditioned at 45° C and 18% RH for 2 to 3 days. This is based on oven dry moisture contents obtained from measurements of the change in mass of timber specimens placed in a 45° C and 18% RH conditioning room over a 3 week period. A plot of the average values is given in *Figure 6-3*.

Table 6-1 Moisture Contents of Exposure Rack Timber Specimens on 3rd March 2006

Species	Moisture Content		Nominal Dimensions (mm)		
	10:15 am	4:00 pm	Length	Width	Thickness
Blackbutt	11.7	**9.3**	100	85	20
Blackbutt	11.2	**10.5**	300	85	20
Cypress pine	8.7	**8.0**	300	70	20
Cypress pine	8.9	**8.3**	300	70	20
Cypress pine	10.3	**9.2**	100	70	20
Merbau	8.9	**8.3**	300	90	20
Merbau	11.3	**8.8**	100	90	20
Mountain Ash	11.7	**5.4**	100	100	10
Mountain Ash	9.8	**7.0**	100	100	20
Mountain Ash	10.0	**7.9**	300	100	10
Spotted Gum	10.0	**7.6**	100	100	10
Spotted Gum	9.0	**8.1**	100	85	20
Spotted Gum	8.9	**8.3**	300	85	20
Spotted Gum	8.8	**8.4**	300	85	20
Spotted Gum	N/A	**8.4**	175	50	17
Spotted Gum	10.2	**8.6**	100	85	20
Treated Pine	10.9	**7.5**	300	90	20

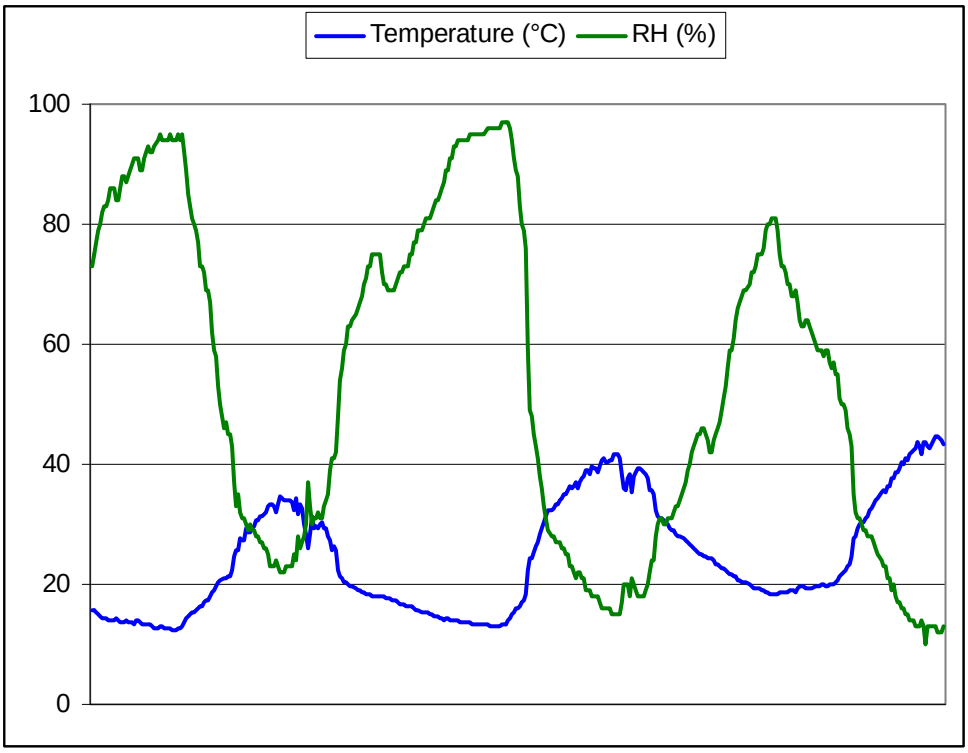

Figure 6-2 Temperature and Humidity at Exposure Rack 1/3/6 – 3/3/6

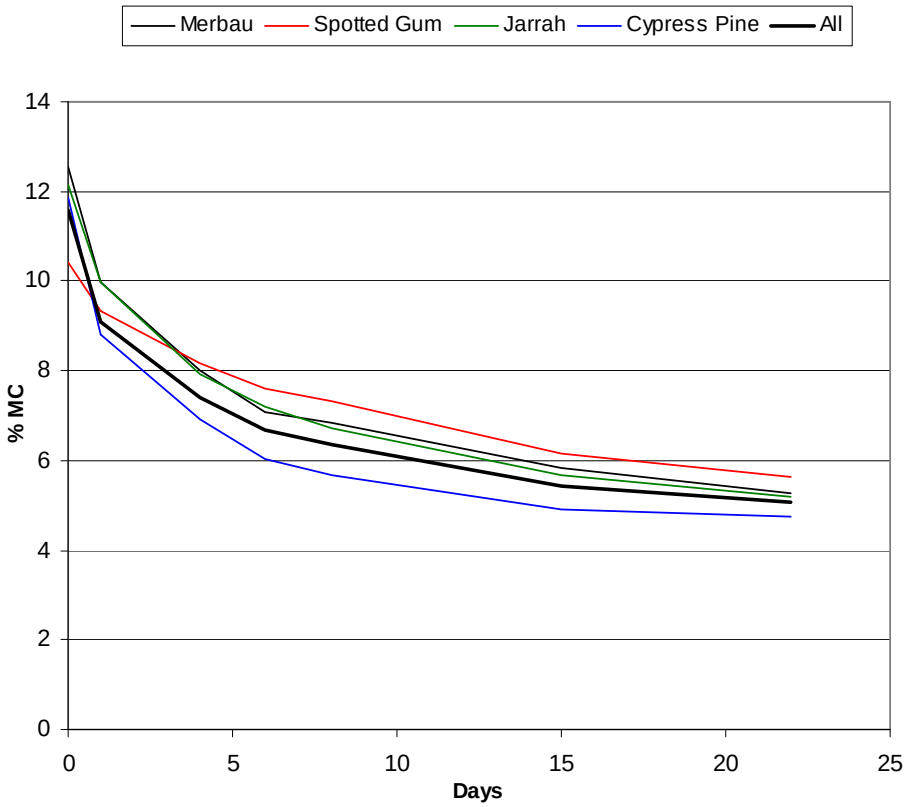

Figure 6-3 Moisture Contents of Timber Specimens Conditioned at 45° C and 18% RH

Data recorded on 12th October 2006

On the 12th October 2006, Melbourne, along with the rest of Victoria, experienced unusual (for this time of the year) bushfire conditions. While the temperature didn't reach 40°C, there were hot dry winds during the proceeding days resulting in a low relative humidity which remained low even overnight. The relative humidity/temperature sensor at the exposure rack had failed and was being repaired at this time so the values at the nearest Weather Bureau station at Moorabbin Airport have been given. These are shown in *Figure 6-4* .

The timber specimens were removed from the exposure rack and weighted in the afternoon at 2:30 pm and again at 4:30 pm. Three were then placed in an oven and dried so their oven dried moisture contents could be determined. The results are given in *Table 6-2*. The remain specimens were returned to the exposure rack. Their moisture contents will be determined at a later date.

The range of moisture contents given in *Table 6-2* are in the range 8.6-8.8%. This is simular to what is achieved if the timber (at ~12% initial MC) is conditioned at 45° C and 18% RH for 2-3 days.

Table 6-2 Moisture Contents of Exposure Rack Timber Specimens on 12th October 2006

Species	Moisture Content (%)		Nominal Dimensions (mm)		
	2:30 pm	4:30 pm	Length	Width	Thickness
Spotted Gum	8.8	8.7	124	50	18
Spotted Gum	8.7	8.6	300	90	19
Merbau	-	8.6	300	85	19

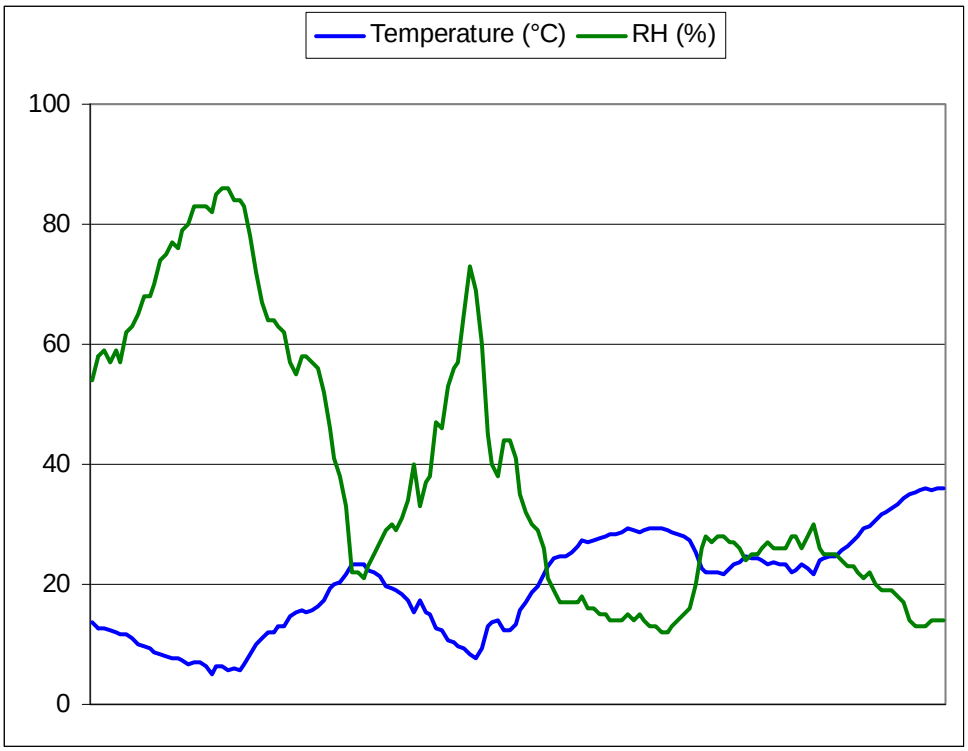

Figure 6-4 Temperature and Humidity at Moorabbin Airport 10/10/6 – 12/10/6

APPENDIX C – Heat Release Tests

This appendix contains the Test Record Sheets for the heat release tests performed on the following:

- Class C crib
- 4 x Class A cribs
- 1kg Gumtree Litter
- 0.5kg Gumtree Litter
- Below deck flame test using 80kW propane burner for 3 minutes on a Spotted Gum deck of approximately 0.5 m^2 in Area.

Photos of the tests are shown in

Figure 6-5.

A summary of the results are given in the table below:

Ignition Source	**Mass (g)**	**Peak Heat Release (kW)**	**Total Heat Release (kJ)**
Class C crib	1250	22	14000
Class A crib	750	5	3000
1kg Gumtree Litter	1000	60	16000
0.5kg Gumtree Litter	500	30	7200
Material	**Density (kg/m^3)**	**Average Heat Release (kW)**	
Spotted Gum Decking (85x 20)	1000	20	

Note: All material was conditioned at 45° C and 18% RH. The decking used steel joists. Values are approximate and are based on an average of 2 tests except for the 0.5 kg Gumtree Litter which is based on a single test.

The average heat release for the decking was obtained from the heat release readings for the below deck flame test after the burner had been turn off. Observation of other tests indicated Merbau and Spotted Gum to have similar heat release values for the below deck flame test.

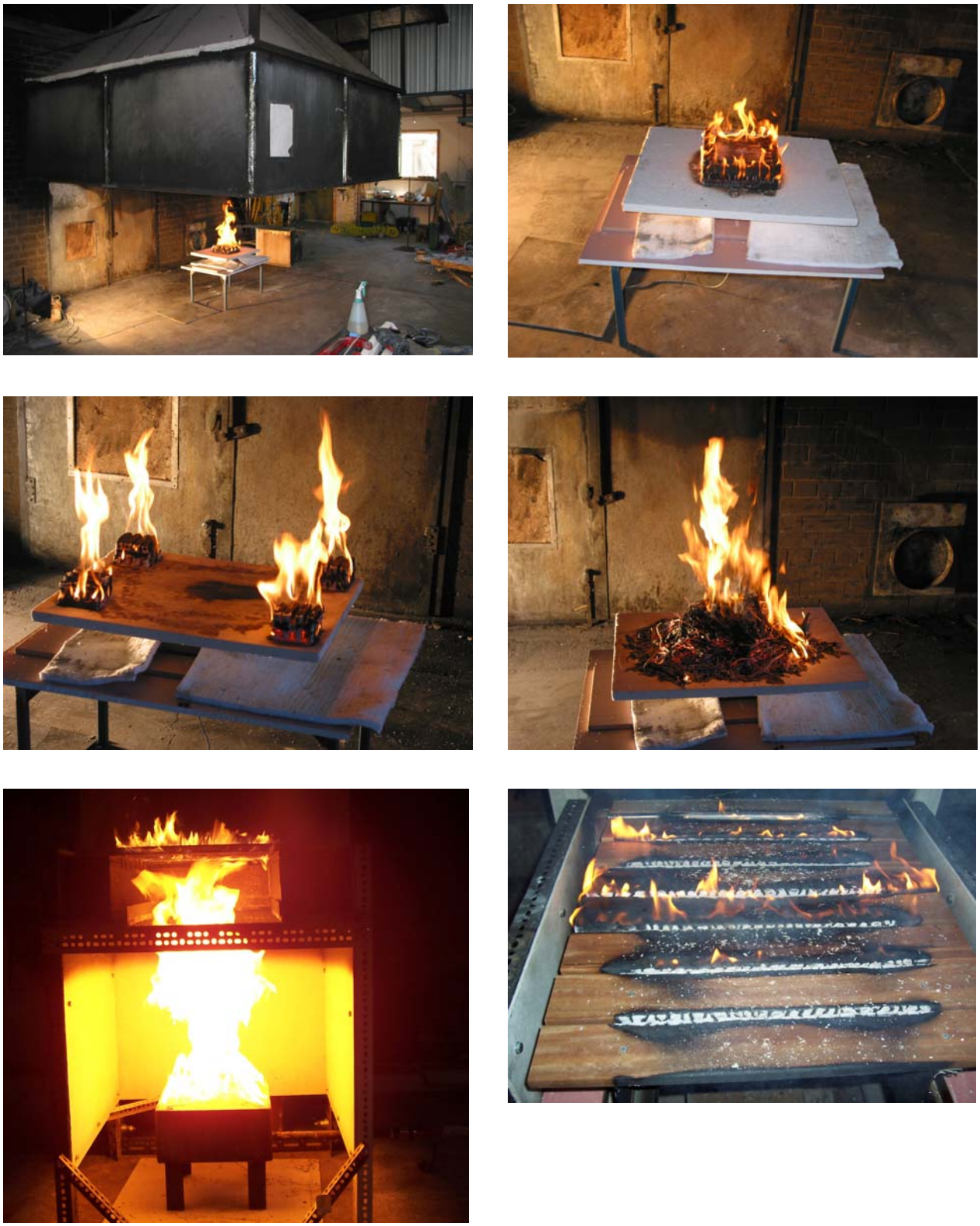

Figure 6-5 Heat Release Tests (clockwise from top left: Class C crib under hood, Class C crib, 4 x Class A cribs, 1kg Gumtree litter, Below deck flame test, Spotted Gum deck after burner has been turned off.

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Fire Science and Technology Laboratory

Graham Road, (PO Box 56), Highett, Vic. 3190, Australia
Phone: (03) 9252 6000 Fax: (03) 9252 6244

TEST RECORD SHEET

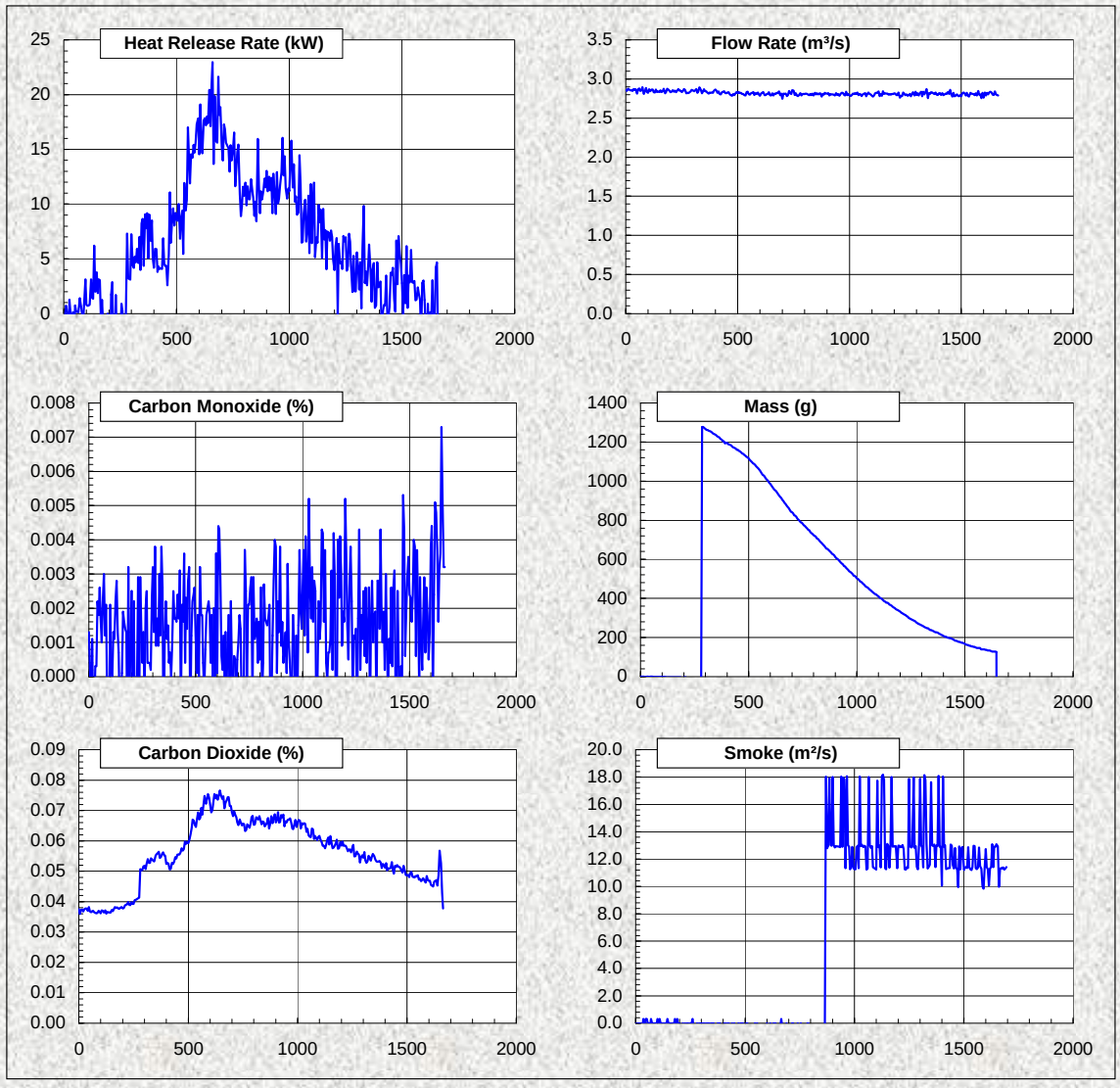
Client	
Test Number	J1449
Title	Room Burn Test
Date	28/Nov/06

Test Code	Flow	Sampling Interval (s)	Baseline Interval (s)	Ignition Time (s)	A M Fration H20
J1428	50% flow	5	100	0	0.014

Calibration Factor		Av Flow Rate (m3/s)	Total Smoke 1 (m²)	Total Smoke 2 (m²)	Total Heat Release (kJ)
1		2.82	10208	N/A	11122

Material No.	Comments
Class C crib	baffle 0.5 open

Heat Release Rate - Time Plot



Bushfire Ignition Source HRR and MLR.trd

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TEST RECORD SHEET

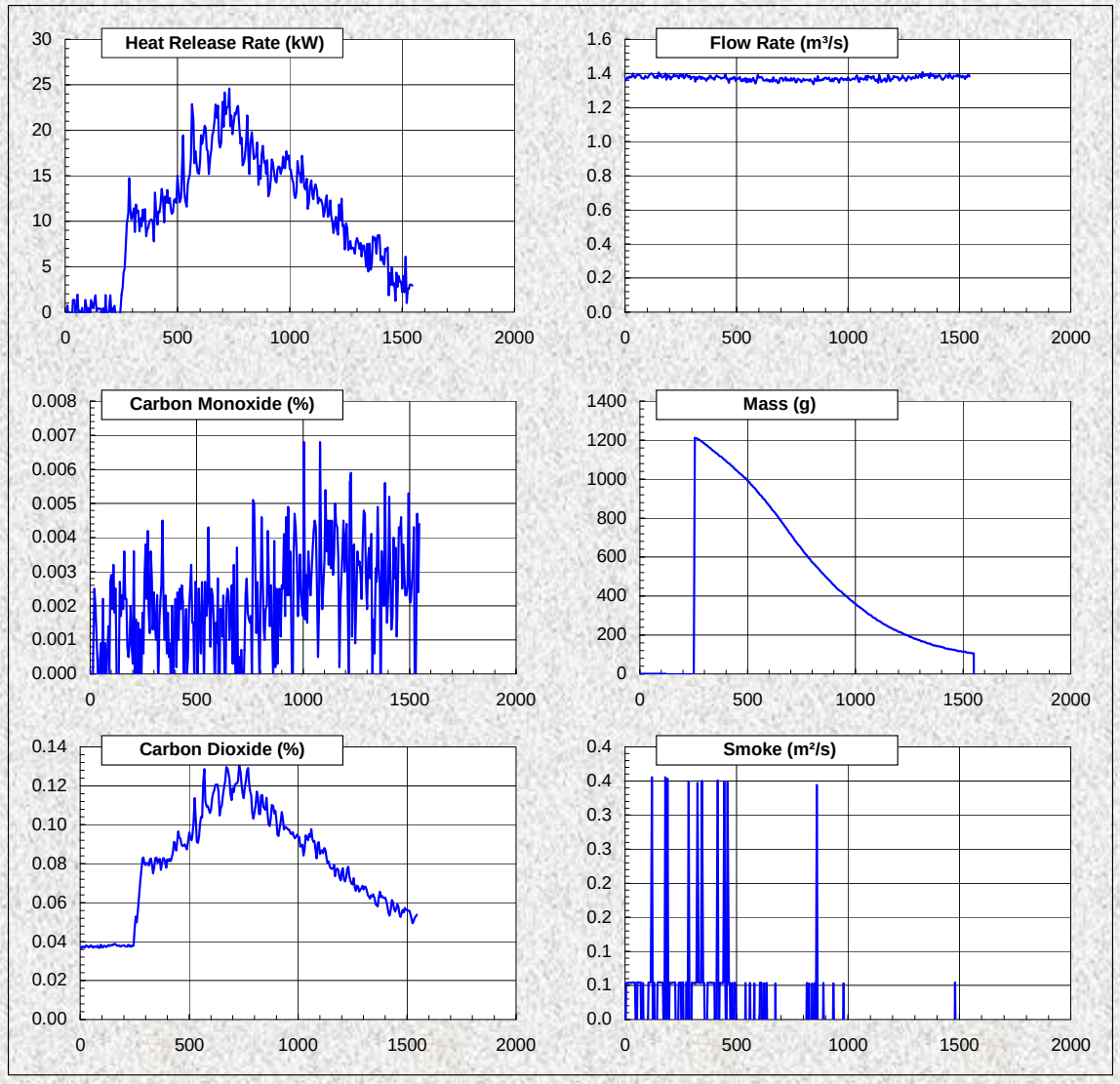
Client	
Test Number	J1448
Title	Room Burn Test
Date	28/Nov/06

Test Code	Flow	Sampling Interval (s)	Baseline Interval (s)	Ignition Time (s)	A M Fration H20
J1427	25% flow	5	100	0	0.014

Calibration Factor		Av Flow Rate (m3/s)	Total Smoke 1 (m²)	Total Smoke 2 (m²)	Total Heat Release (kJ)
1		1.37	-132	N/A	16256

Material No.	Comments
Class C crib	baffle 0.25 open

Heat Release Rate - Time Plot



Bushfire Ignition Source HRR and MLR.trd

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Phone: (03) 9252 6000 Fax: (03) 9252 6244

TEST RECORD SHEET

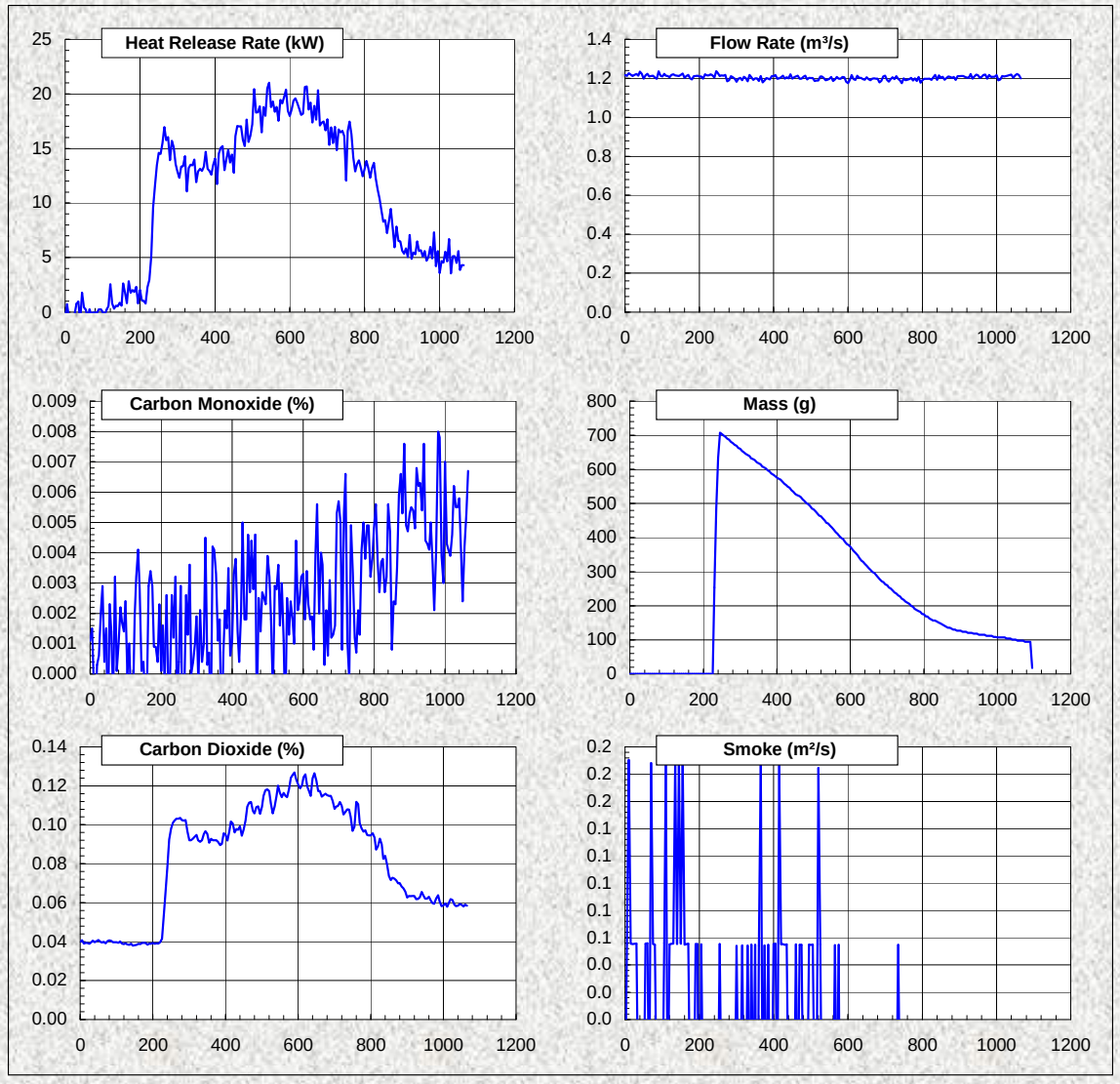
Client	
Test Number	J1453
Title	**Room Burn Test**
Date	28/Nov/06

Test Code	Flow	Sampling Interval (s)	Baseline Interval (s)	Ignition Time (s)	A M Fration H20
J1432	25% flow	5	100	0	0.014

Calibration Factor		Av Flow Rate (m3/s)	Total Smoke 1 (m²)	Total Smoke 2 (m²)	Total Heat Release (kJ)
1		1.21	-98	N/A	11099

Material No.	Comments
4 x Class A cribs	

Heat Release Rate - Time Plot



Bushfire Ignition Source HRR and MLR.trd

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Phone: (03) 9252 6000 Fax: (03) 9252 6244

TEST RECORD SHEET

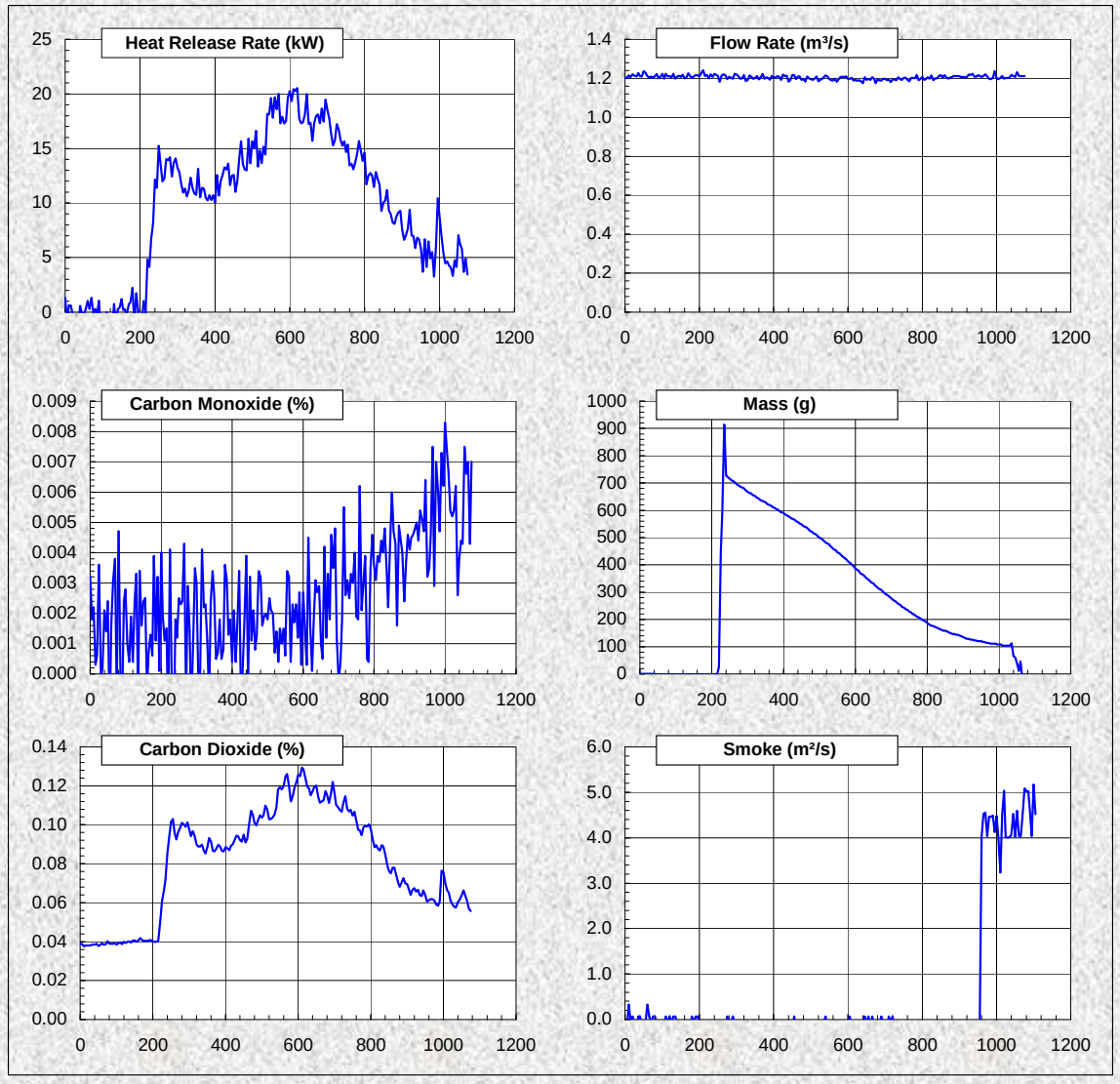
Client	
Test Number	J1452
Title	Room Burn Test
Date	28/Nov/06

Test Code	Flow	Sampling Interval (s)	Baseline Interval (s)	Ignition Time (s)	A M Fration H20
J1431	25% flow	5	100	0	0.014

Calibration Factor		Av Flow Rate (m3/s)	Total Smoke 1 (m²)	Total Smoke 2 (m²)	Total Heat Release (kJ)
1		1.21	435	N/A	10527

Material No.	Comments
4 x class A cribs	

Heat Release Rate - Time Plot



Bushfire Ignition Source HRR and MLR.trd

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TEST RECORD SHEET

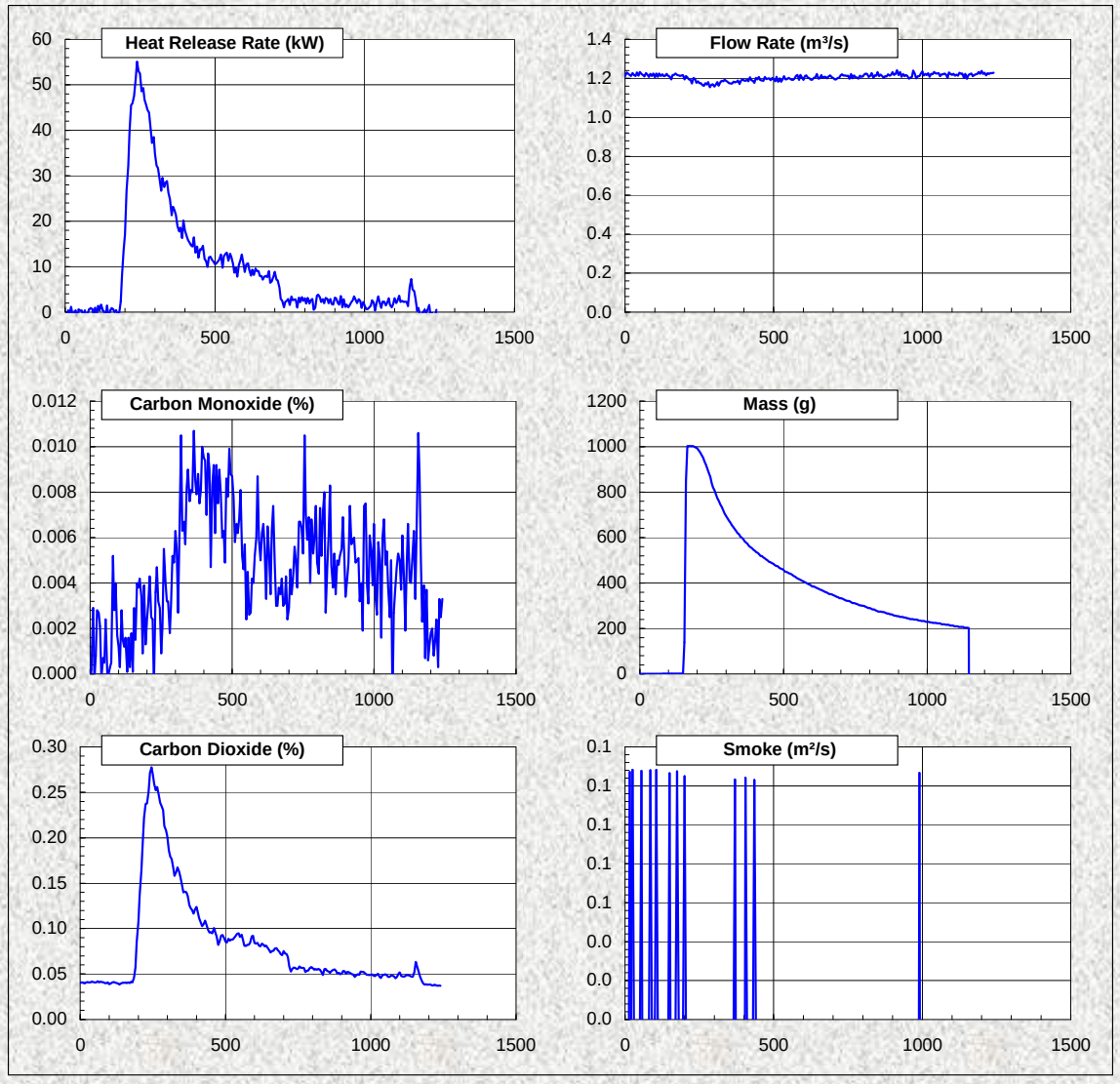
Client	
Test Number	J1454
Title	Room Burn Test
Date	28/Nov/06

Test Code	Flow	Sampling Interval (s)	Baseline Interval (s)	Ignition Time (s)	A M Fration H20
J1333	25% flow	5	100	0	0.014

Calibration Factor		Av Flow Rate (m3/s)	Total Smoke 1 (m²)	Total Smoke 2 (m²)	Total Heat Release (kJ)
1		1.21	-160	N/A	11503

Material No.	Comments
1 kg Gumtree Litter (76kg/m3)	

Heat Release Rate - Time Plot



Bushfire Ignition Source HRR and MLR.trd

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TEST RECORD SHEET

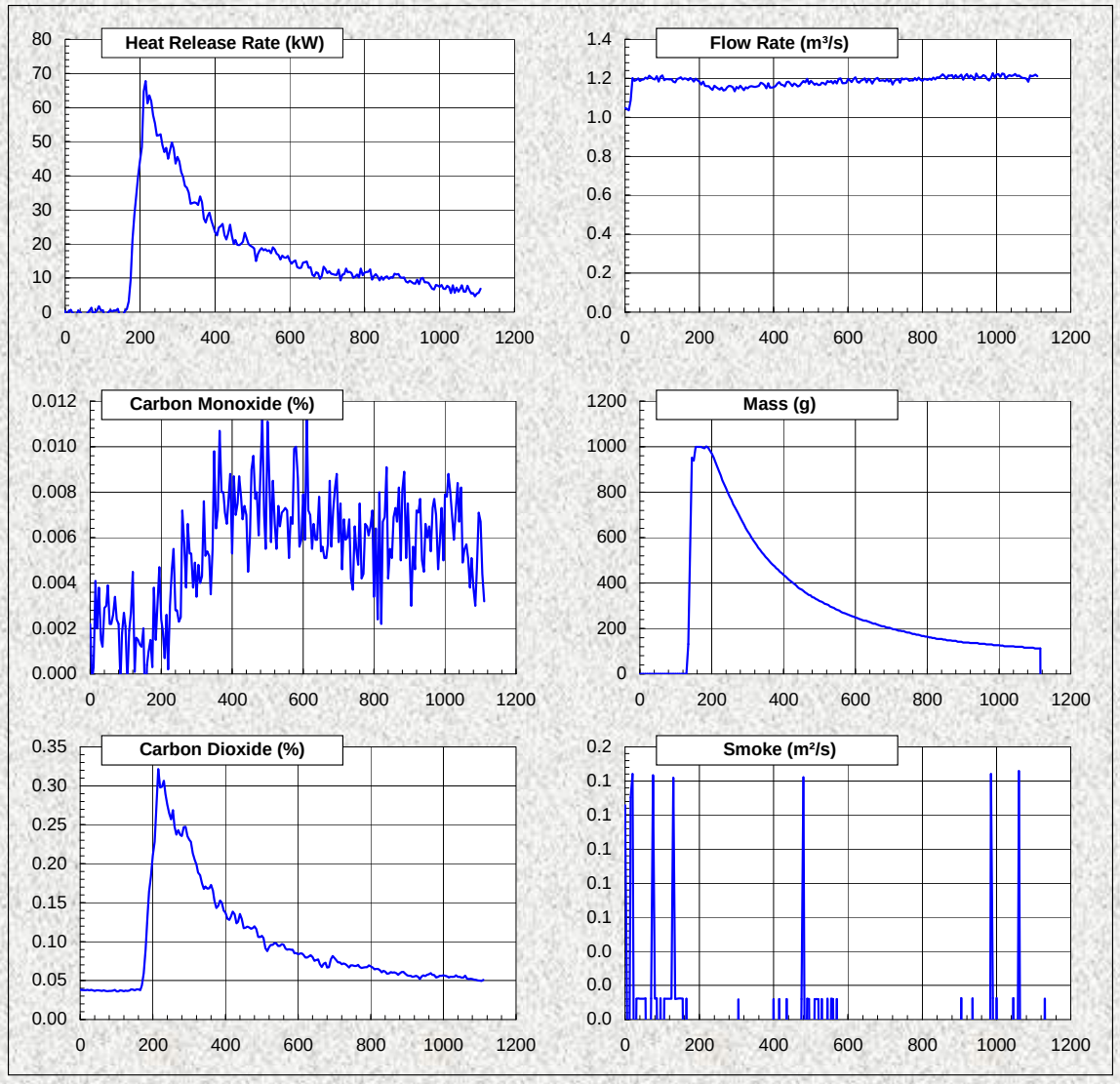
Client	
Test Number	J1450
Title	Room Burn Test
Date	28/Nov/06

Test Code	Flow	Sampling Interval (s)	Baseline Interval (s)	Ignition Time (s)	A M Fration H20
J1429	25% flow	5	100	0	0.014

Calibration Factor		Av Flow Rate (m3/s)	Total Smoke 1 (m²)	Total Smoke 2 (m²)	Total Heat Release (kJ)
1		1.19	-131	N/A	18375

Material No.	Comments
1kg Gumtree Litter (76kg/m3)	

Heat Release Rate - Time Plot



Bushfire Ignition Source HRR and MLR.trd

CSIRO

Manufacturing & Infrastructure Technology

Fire Science and Technology Laboratory
Graham Road, (PO Box 56), Highett, Vic. 3190, Australia
Phone: (03) 9252 6000 Fax: (03) 9252 6244

TEST RECORD SHEET

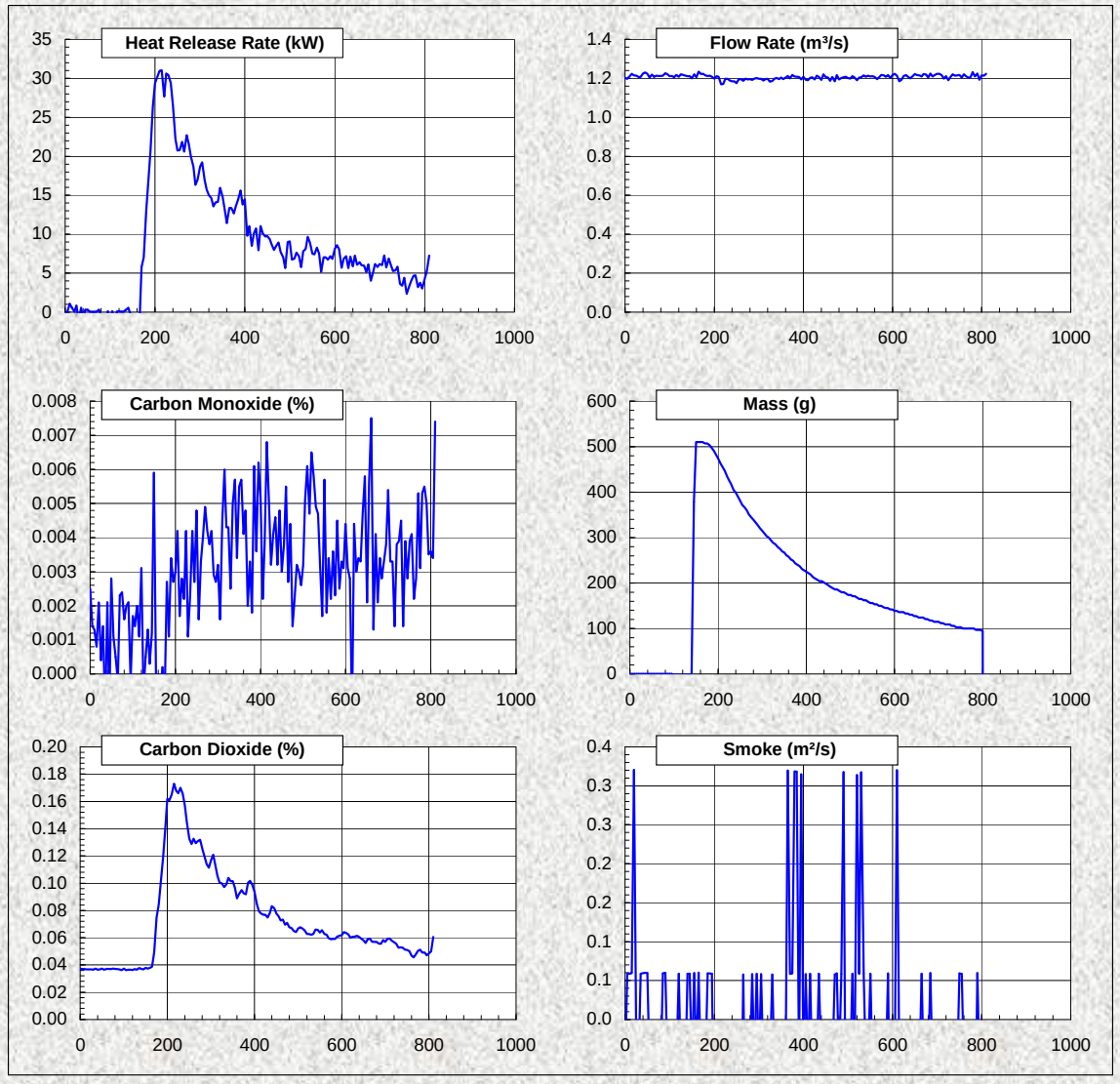
Client	
Test Number	J1451
Title	Room Burn Test
Date	28/Nov/06

Test Code	Flow	Sampling Interval (s)	Baseline Interval (s)	Ignition Time (s)	A M Fration H20
J1430	25% flow	5	100	0	0.014

Calibration Factor		Av Flow Rate (m3/s)	Total Smoke 1 (m²)	Total Smoke 2 (m²)	Total Heat Release (kJ)
1		1.21	-25	N/A	7210

Material No.	Comments
0.5kg Gumtree Litter (76kg/m3)	

Heat Release Rate - Time Plot



Bushfire Ignition Source HRR and MLR.trd

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TEST RECORD SHEET

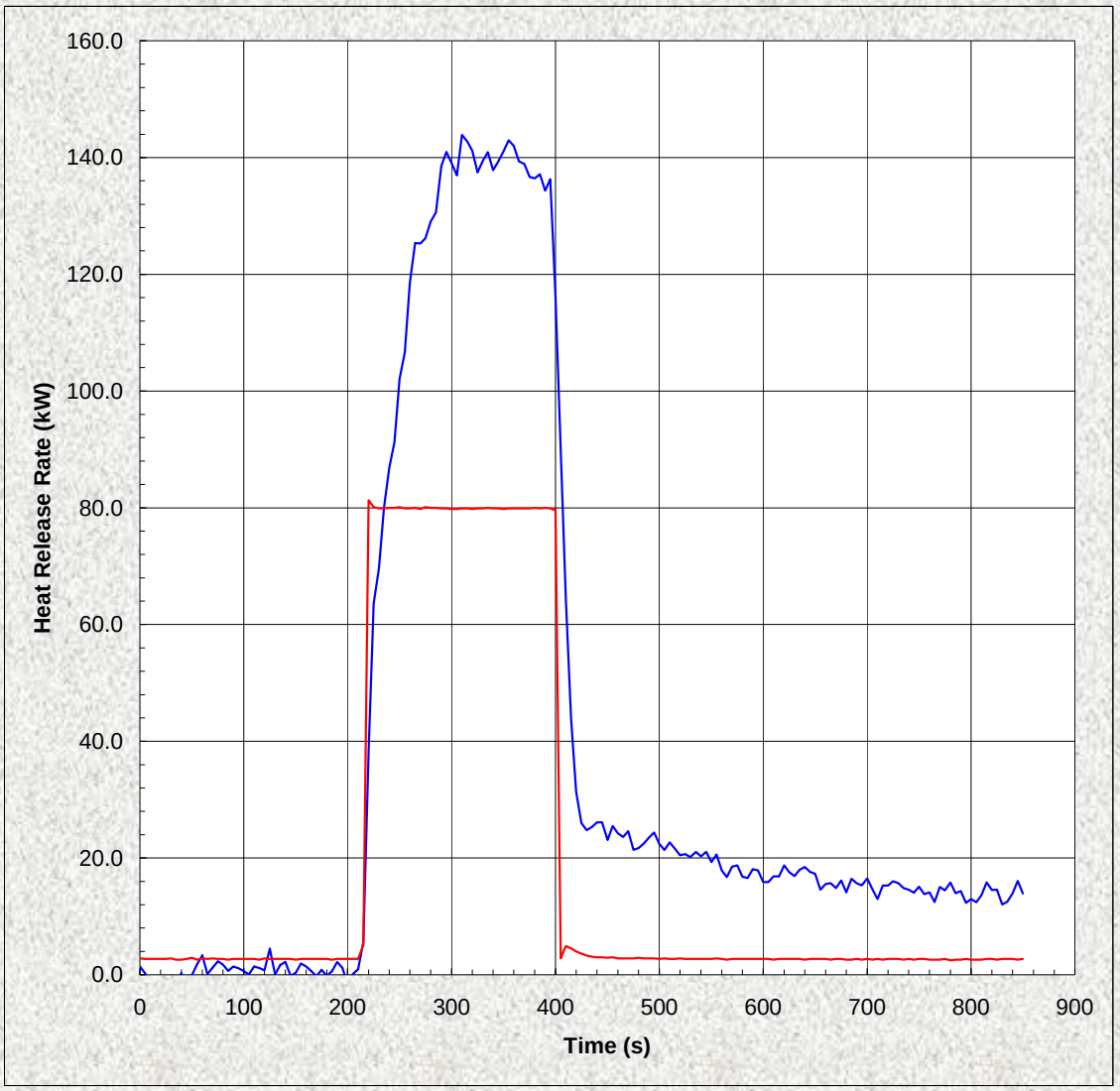
Client	
Test Number	J1369
Title	Below Deck Flame Test using Sandbox Propane Burner
Date	12/May/06

Test Code	Ignition Source	Sampling Interval (s)	Baseline Interval (s)	Ignition Time (s)	A M Fraction H20
MISC 06/42	ASTM propane	5	100	0	0.014

Exist. Calib. Factor	Av Flow Rate (m3/s)	% differ. in HR at 100kW-	% differ. in HR at 300kW	% differ. in HR at 100kW+	Total Heat Release (kJ)
1	1.24	N/A	N/A	N/A	31777

Material	Description
SPG 85 5 45C 18%RH	80kW

Heat Release Rate - Time



Calibration using Sandbox Propane Burner 21-1-2005.trd

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