Evaporative Air Conditioner Bushfire Ember Protective Screen

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Abstract

It is not uncommon for houses with evaporative air conditioners situated near bush-land areas to catch fire during a bushfire due to embers (or firebrands) carried through the air. Embers are burning combustible materials which are carried ahead of a bushfire by the wind and fire convection currents. Many homes have been burnt down due to fires starting from an "ember attack" on evaporative air conditioners. This is where embers get carried though the air and into the cooling system, igniting the filter pads. Once the air conditioner catches fire it tends to fall though the roof into the homes and can cause the whole house to catch fire. The filter pads in an evaporative air conditioner are generally made of wood fibres and so are flammable. Although there has been some work into low-combustible filter pads, the build up of dust and pollen would always be flammable. Furthermore, to date Australian Standards have not addressed non-flammable pads in their regulations. This study aims to use an ember screen to block off dangerous embers from reaching the filter pads without inhibiting the effective operation of the air conditioner.

1.0 Introduction

Fire and Emergency Services Authority of Western Australia (FESA) together with the University of Western Australia aims at preventing fires from starting through an ember attack on a home's roof-mounted evaporative air conditioner (EAC). The component on an EAC most prone to ignition is the filter pads. This will not be an analysis on better ways to improve the filter pads to make them non-flammable but on ways to prevent dangerous embers reaching the pads itself.

The most probable solution and area of research to be focussed on will be a steel mesh design to shield the air cooler and prevent embers entering the cooling cabinet. The likely consequence of having a mesh screen covering the air conditioner is that airflow will drop as static pressure increases. This will hinder the efficiency and operation of the system and therefore needs to be measured for analysis. Having mesh with a smaller aperture will reduce airflow but will prevent more potentially hazardous embers getting though. Conversely, increasing the mesh aperture will increase airflow but will allow more embers to get through. Therefore a balance between mesh aperture size and possible ember penetration needs to be analysed whilst taking into account set standards.

Ultimately the goal of the research is to have a fully tested design that can be sold or provided to the market for people who want to protect their air conditioners from an ember attack. This design must also not adversely affect the performance of the cooling system and meet Australian regulations.

2.0 Background

The aftermath of bushfires have shown many homes could have escaped fire had they been better protected. People staying in bush-land areas have learnt to allow a debris-free safety zone around their house as a barrier against bushfires. As a result today, the majority of house fires during a bushfire are caused by an ember attack and not direct flame or radiant heat. The house requires an ignition point and often this is found in the form of untreated verandas, uncleaned gutters, accumulated leaves and debris around the house, doormats, flyscreens and evaporative air conditioner filter pads.

Australian fire authorities have found that it is not uncommon for houses with evaporative air conditioners situated near bush-land areas to catch fire during a bushfire due to an ember attack. This is where flying embers get trapped into the cooler's filter pads and starts a fire. Once the air conditioner catches fire, they tend to collapse though the roof into the house and can cause the whole house to catch fire.

3.0 Bushfire and Ember Issues

A thorough understanding of bushfire and ember issues is needed to understand their behaviour and create a realistic test environment. Embers or firebrands are fundamentally burning combustible materials carried through the air by wind and convection currents. Ellis (2004) describes that fibrous or flaky bark from trees are the prime source of embers. In Australia this tends to implicate the Eucalyptus variety of trees. In Western Australia, Jarrah (*Eucalyptus marginata*) is the variety most potent in spot fires and ember attacks. The most hazardous however, are bark varieties such as stringybark and ribbon bark found mostly in the eastern parts of Australia. These embers have been known and recorded to travel distances up to several kilometres and start other fires. More commonly however, they have the highest ember concentration at about 50 metres downwind (Ellis 2004). In large intense bushfires, residents have described the situation as a rain of embers in their backyard, even when their homes are hundreds of metres from the fire front.

3.1 Fuel Bed Ignition by Embers

Ignition of fuels due to embers has been investigated but a limited number of laboratory studies are available in the open literature. Some studies try to test the probability of ignition of fuel beds by embers under varying conditions. Manzello *et al.* (2004, 2005) demonstrates that moisture content is important in order to ignite shredded paper, pine needles and shredded hardwood mulch beds. Based on his findings, the flux of embers, the size of the embers as well as the degree of air flow were important parameters in determining the ignition propensity of a surface. It has been understood now that many variables affect the probability of ignition. These include:

- ember size
- multiple ember ignition
- combustion state of the ember - whether the ember is glowing or flaming
- amount of wind/airflow provided to the ember after contact
- type of fuel bed
- moisture content of fuel bed
- meteorological conditions

4.0 Evaporative Air Conditioners

Evaporative Air Conditioners or Swamp Coolers work by the natural process of evaporation. A fan draws air from the outside and discharges it though a duct into the house. As the hot air is drawn inside the cooler, it passes wet filter pads and evaporates some of the water. The pads are kept continuously wet by a pump and distributor system. The evaporation process lowers the temperature of the air and has a cooling affect. If the air is too humid it is unable to evaporate much of the water and hence evaporative air conditioners are ineffective during humid days. The main aspects of the EAC that this research is concerned with are the filter pads and the fan.

4.1 Filter Pads

There are fundamentally only two types of filter pads used in the EAC. These are the older type of Aspen pads and the newer range of honeycomb shaped pads made of cellulose. Aspen pads are made of timber shreds encased in some sort of mesh. The honeycomb shaped pads, such as the popular CELdek range, are made from cellulose wood fibres in paper form. They are treated with small amounts of chemicals and adhesive to give them stiffness, structure and a longer life. Essentially both types of pads are made from wood fibres and are therefore flammable.

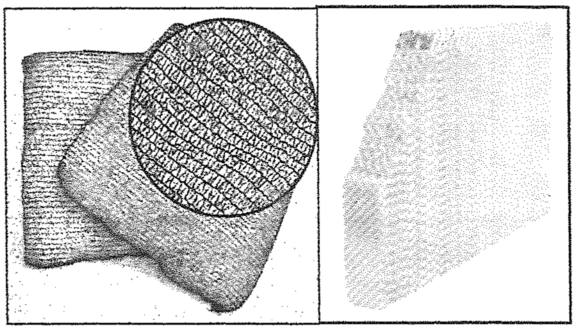


Figure 1: Aspen pad (left) and CELdek pad (right)

4.2 Fan System

The fan is an area of concern because if it does not have sufficient power to draw the air into the cabinet and discharge it though the duct it will stall. The ducting system in the roof, together with the house itself adds a back pressure to the cooler's fan. EAC systems can not operate effectively if some doors or windows in the house are not open. There are generally only two categories of fan systems used in EAC and many variations of them. These are Axial-flow fans and Centrifugal fans. These fans are driven by electric motors, either through a belt or direct drive.

5.0 Statutory Requirements

In developing an ember attack proof screen for the EAC there are set statutory requirements in Australia. The *Australian Standards AS3959-1999 Construction of buildings in bushfire-prone areas* classifies bushfire attacks into four distinct categories with three having set construction requirements. These are Medium, High and Extreme Category of bushfire risk. The key factors that determine a bushfire category type are predominant vegetation type, distance from vegetation and the average slope of surroundings.

The current requirements for roof-mounted evaporative coolers in bushfire-prone areas have also been defined in *Australian Standards AS3959-1999* (3.9.1.6, 3.9.2 and 3.9.3) and the *Building Code of Australia* (Section 3.7.4.3). For a Medium bushfire category, *"roof-mounted evaporative cooling units can only be used if openings to the unit are encased in corrosion-resistant steel or bronze mesh with a maximum aperture size of 1.8 mm"* (AS3959-1999). This aperture size of 1.8 mm (1.8 x 1.8mm) has not been empirically tested as was discovered through conversations with the *Australian Standards Committee.* This aperture size was chosen based on a committee acceptance that it is small enough to prevent dangerous embers getting through and the size of readily available mesh. The committee has also encouraged and have taken interest in a set of ember tests to be carried out to justify this figure.

6.0 Testing Procedure

Two air conditioners were chosen for testing based on their differences in fan system and filter pad material (Figure 2). One system runs on a more powerful centrifugal fan which is expected to give a stronger

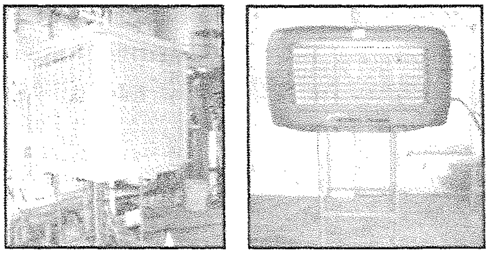


Figure 2: Cooler A (left) and Cooler B (right)

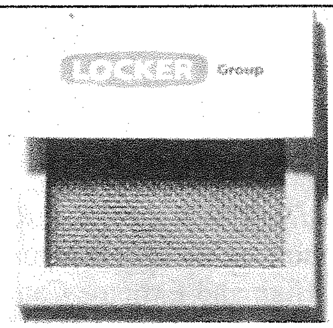
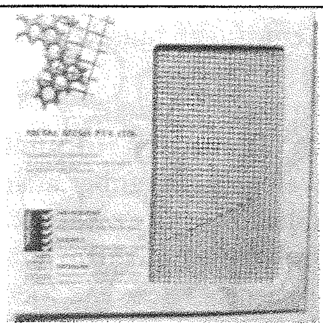
force than the other cooler's axial-flow fan. It also uses the older style of Aspen pads as compared with the other cooler's honeycomb style of cellulose pads. Table 1 shows the differences between the two coolers used for testing.

Table 1: Test cooler specifications

	Cooler A	**Cooler B**
Model Type	Breezair EA 150D	Celair LP 500
Cooler Brand	Seeley International	Climate Technologies
Filter Pad	Aspen/Woodwool	CELdek (Cellulose)
Fan System (drive type)	Centrifugal fan (belt pulley system)	Axial-flow fan (direct drive motor)
Motor Watts	1500	600

Two mesh screens were chosen as close to a 1.8 mm aperture size as possible without exceeding the size. These mesh designs not only meet current statutory requirements (Level 1: Medium bushfire category) but meet the current draft changes to prevent it from becoming an obsolete design. The mesh were installed flush with the surface of the filter pads and their specifications are shown in Table 2.

Table 2: Mesh specifications

Mesh Type	**1.66 mm stainless steel woven mesh**	**1.50 mm stainless steel mosquito gauze**
Photo		
Wire Diameter (mm)	0.457	0.315
Open Area Percentage	61.4%	68%
Price	$27.90/m (width 1525 mm) (Quote from Locker Group) *(Note: this is the same mesh used by Climate Technologies in their ember screen)*	$24.10/m (width 1000 mm), $29.50/m (width 1220 mm) (Quote from Metal Mesh)

6.1 Airflow and Static Pressure Testing

Testing focussed on the effects adding a mesh to the cabinet will have on the performance of the cooler. Any mesh arrangement added to shield the pads will make drawing air into the cooler harder and raise the fan's static pressure. As mentioned earlier if the static pressure becomes too high the fan may not be able to push the air through the duct and will stall.

The cooler is mounted on its side but with all pads accessible. Attached to the discharge of the cooler is a steel-box transition piece which is then attached to 4.5 metres of insulated ducting. The air that is discharged from the fan whirls and so needs to be straightened to accurately make the necessary measurements. Large straws tightly packed together and positioned half way along the ducting are used as the flow straightener. This test rig is shown as a schematic in Figure 3.

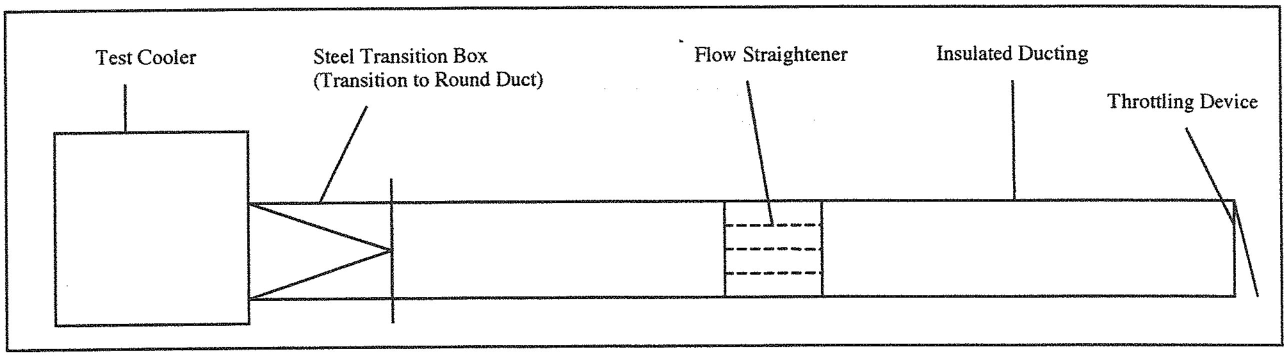


Figure 3: Schematic diagram of airflow and static pressure test rig

Static pressure and airflow measurements were done at full cooler capacity. Airflow measurements were taken at the filter pad panels using an anemometer. Static pressure were measured across the fan using a micro-manometer.

The set up was adjusted by adding different degrees of back pressure and taking airflow and static pressure measurements. Back pressure was applied to the fan by blocking off the cross section of the ducting. This was done using a throttling gate.

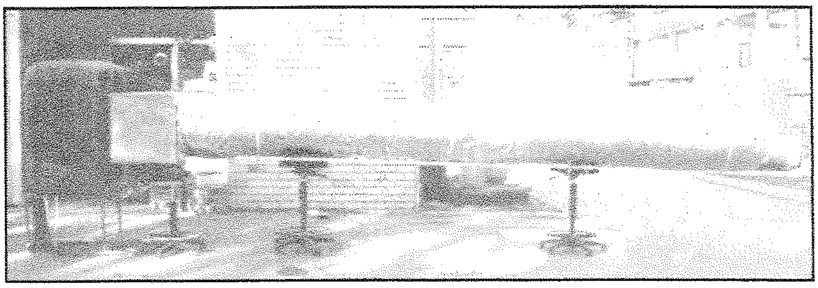


Figure 4: Test rig for airflow and static pressure testing

6.2 Ember Testing

Due to fire regulations all fire and ember testing was restricted to the FESA Training Academy in Forrestfield. Ember testing was heavily delayed due to the summer fire restrictions and timetabling issues at the training academy. Several methods were tested to generate embers, with a few failing. These failed attempts showed the difficulties involved in generating a stream of embers that appropriately simulate bushfire conditions. The ember test must provide a stream of embers that are dangerous enough to set an unprotected filter pad on fire and last for a sufficient period of time. Several preliminary ember tests were carried out solely to investigate ember production and intensity. Two preliminary trials and the final ember test are discussed below.

6.2.1 Preliminary Trial 2

The second attempt involved lighting a 2 _ 2 metres square base steel container full of wood material and allowing the wind to expel embers from it (Figure 5). Some of the wood material used had been partially burnt

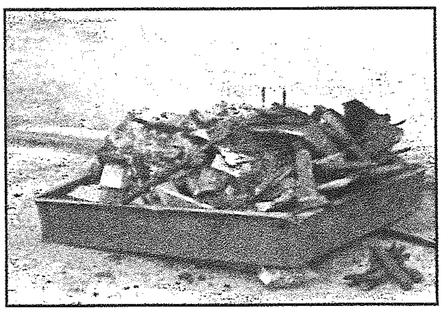


Figure 5: Preliminary trial 2 fuel

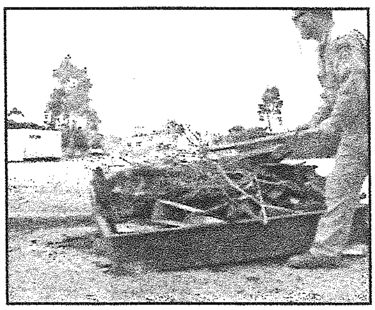


Figure 6: Agitating fire with steel bar

before, however this test was simply to give an idea of the amount of embers that could be generated from a small scale burn. From this test it was realised that insufficient embers were generated. A large steel bar was used to disturb the burning material by beating it and stirring it, resulting in a greater amount of airborne embers. This scenario is shown in Figure 6. Embers generated were still inadequate and believed to be the result of improper fuel and not enough air getting underneath the burning debris to lift the embers up.

6.2.3 Preliminary Trial 3

Loose leaf litter and dry debris were placed at the bottom of the steel container used in trial 2. It was then loaded with some old crates to hold the material down and dosed with kerosene to help get the fire started (Figure 7). A high powered industrial fan was positioned facing the fire and in a similar direction to the wind. Total wind speed measured at the edge of the fire ranged from 4 – 9 m/s. An unprotected CELdek filter pad was positioned 2.5 metres horizontal distance from the edge of the fire and hung at a height of approximately 1.6 metres. This setup, as shown in Figure 8, managed to produce a light flow of embers. To increase the ember flow the fan was brought closer to the fire and directed beneath the burning rubble. This was done occasionally and managed to drive out a greater proportion of embers in the direction of the filter pad.

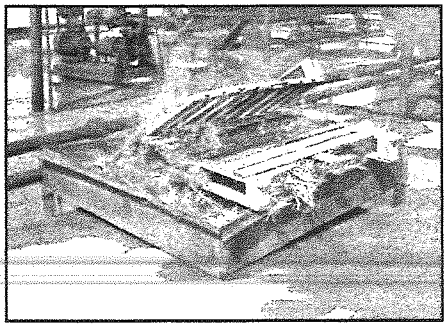


Figure 7 Preliminary trial 3 fuel

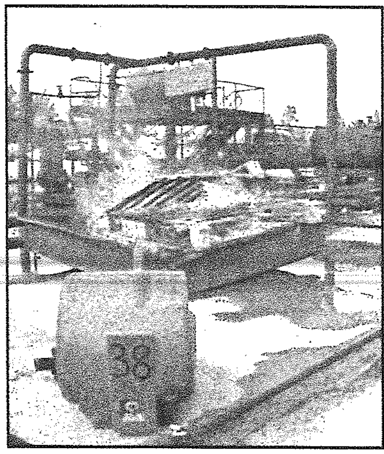


Figure 8: Setup in preliminary trial 3

The fire took about 5 minutes to properly get ablaze. After approximately another 5 minutes the filter pad caught fire from the airborne embers (Figure 9). This preliminary and successful trial set the foundation for further ember testing.

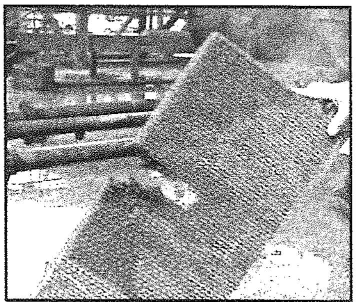


Figure 9: Cellulose pad catches fire

6.2.3 Final Ember Test

Protected pads and unprotected pads were hung on an aluminium frame 2.7 m from edge of the burning container. The industrial fan was used to drive embers airborne and in the direction of pads (Figures 10), similar to preliminary trial 3.

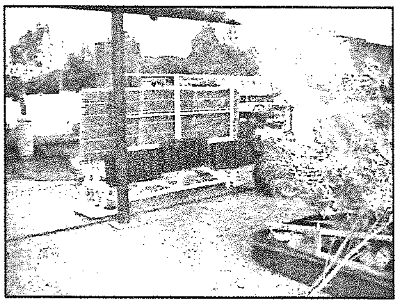


Figure 10: Test setup

7.0 Results and Discussion

7.1 Fan Performance Testing Results

Given the budget of the project and the nature of the setup, the results provided can only estimate that there is a small degree of performance reduction with the added mesh. The main result however, is that no stalling was observed within the operating range of the coolers. The experimental errors associated with such a setup include: the accuracy of the measuring devices used, errors caused by wind and environmental disturbance on readings, inconsistencies in the setup as well as human errors. These errors were best calculated for the setup. Figure 11 displays the fan performance curves for Cooler A when using no mesh, 1.50 mm mesh and 1.66 mm mesh. These curves have the error bands included which shows that to determine a precise performance reduction figure is not possible on the setup.

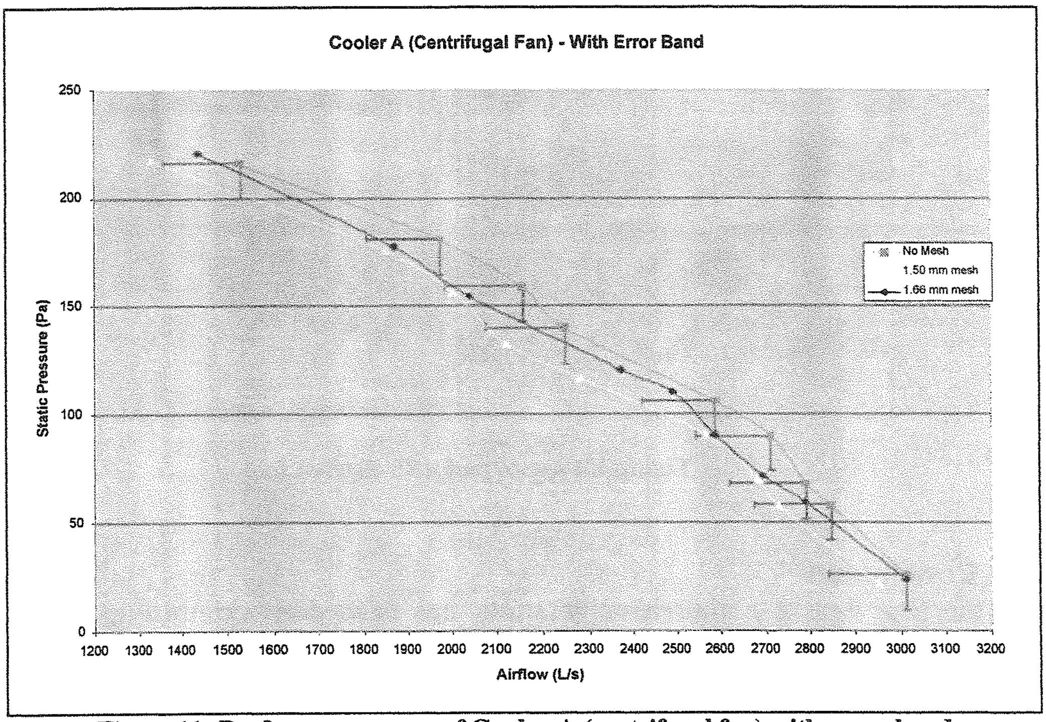


Figure 11: Performance curve of Cooler A (centrifugal fan) with error band

7.2 Ember Testing Results

Cellulose Pads

The two protected Cellulose pad ignited in very similar points after a few minutes. These ignition points occurred on a part of the filter pads that were unprotected. This is shown in Figure 12.

There was no flaming ignition event for the unprotected pad, however it received several smoldering ignition spots (where a charred spot is observed). The most likely reason for this is that the wind had tipped the pad in an awkward position, so embers were not hitting the surface of the pad as readily.

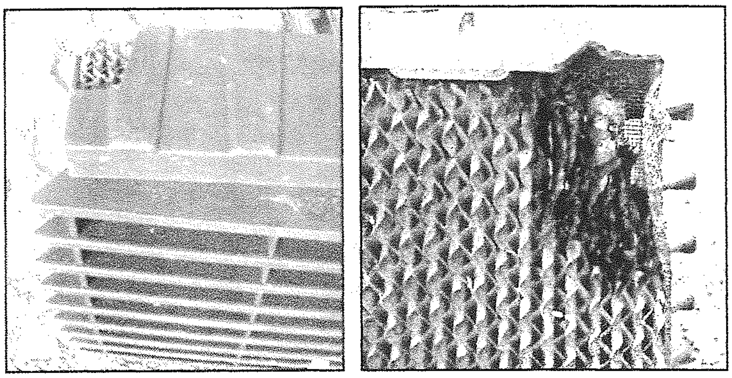


Figure 12: Unprotected part of Cellulose pad that ignited

Aspen Pads

No flaming ignition was observed for any Aspen pad. The mesh arrangements were again effective in preventing dangerous embers through. The unprotected pad however, had six spots of smoldering ignition and three of which appeared to be significantly large as shown in Figure 13. It appeared that there were four spots that ignited for a short period and self extinguished. These results showed how moisture content played an important role in the ignition probability.

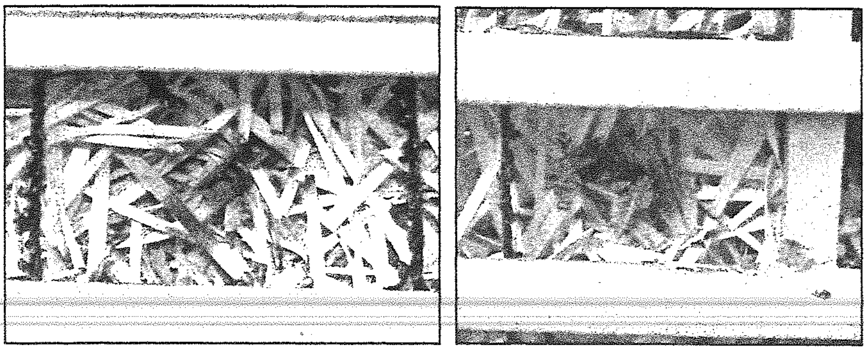


Figure 13: Aspen pad with charred spot

8.0 Conclusion

This is the first time a comprehensive study has been done combining ember attacks and evaporative air conditioners. Consequently, these findings are significant not only to fire authorities but to EAC companies and the Australian Standards. This study sought not only to develop an ember screen for the EAC that would meet Australian statutory requirements but one that has been properly ember tested.

Based on the observations from the final set of ember tests it was shown that the mesh arrangements were successful in preventing dangerous embers igniting the filter pads. Furthermore, there does not appear to be any significant performance reduction on the EAC caused by the addition of the selected mesh arrangements. This has been a successful project with a positive outcome.

9.0 References

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