Evaluation of Firezat Protective Wrap Materials Using a Cone Calorimeter

Prepared for

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Table of Contents

List of Figures

List of Tables

Introduction

Firezat supplies composite fire barrier materials for use in the protection of structures against the radiant energy emitted by wild fires. The materials are constructed with an aluminum foil outer layer that is designed to reflect about 95% of the incoming thermal radiation. Two versions of the materials were sent for evaluation; light weight - a combination of foil laminated to a glass fiber backing and heavy weight - foil laminated to a woven fiber backing. The backing material in the heavy weight material was not identified. The unit mass of the light and heavy weight samples were xxx g/m^2 and yyy g/m^2 respectively. Figure 1 is a photograph of the two materials tested showing both the foil outer and textile inner layers.

Figure 1 Fire Barrier Materials Evaluated Using Cone Calorimeter (light weight, heavy weight)

The materials are not intended to be exposed to direct flame contact, so in consultation with Mr. Dan Hirning, President of Firezat, it was decided that a cone calorimeter would be used to expose the samples to a radiant only condition. It was further decided that the heat flux on the surface of the materials should be sufficient to result in the piloted ignition of unprotected wood samples within a 30-60 second exposure period.

Figure 2 shows the cone calorimeter used in the testing. The apparatus consists of a temperature controlled conical electrical heater that is mounted so that the energy leaving the heater is directed downward. Samples of materials to be exposed are mounted in a horizontal orientation beneath the heater with a protective shutter between the heater and the sample closed. The spacing from the heater is set to obtain a uniform exposure while the exposure heat flux is set by adjusting the temperature of the heating element. The resulting exposure energy was measured using a water cooled guardon gauge (Medtherm Corp.). At the start of a test the protective shutter blocking the sample from the radiant energy is opened and a spark ignition system moved into position over the sample. The spark ignititer was operated continuously during the unprotected wood exposures to simulate the presence of an ignition source such as an open flame or a fire brand.

Exposure Heat Flux

The range of exposures that could be produced as a result of a wild fire is tremendous and depends on the size of the flames, the separation distance between the emitting and receiving surface and whether or not there is direct flame impingement on the surface. Traditionally the flames are modeled as a black body emitter of a given size at some distance from the receiving surface. Figure 3 shows a typical simulation where the flames were assumed to be a flat plane with a fixed width. The flames were assumed to emit 100 kW/m^2 (black body at 880^{o}C, unity emissivity) and there is no hot gas contact with the surface. The receiving surface is modeled as a vertical surface facing the flames.

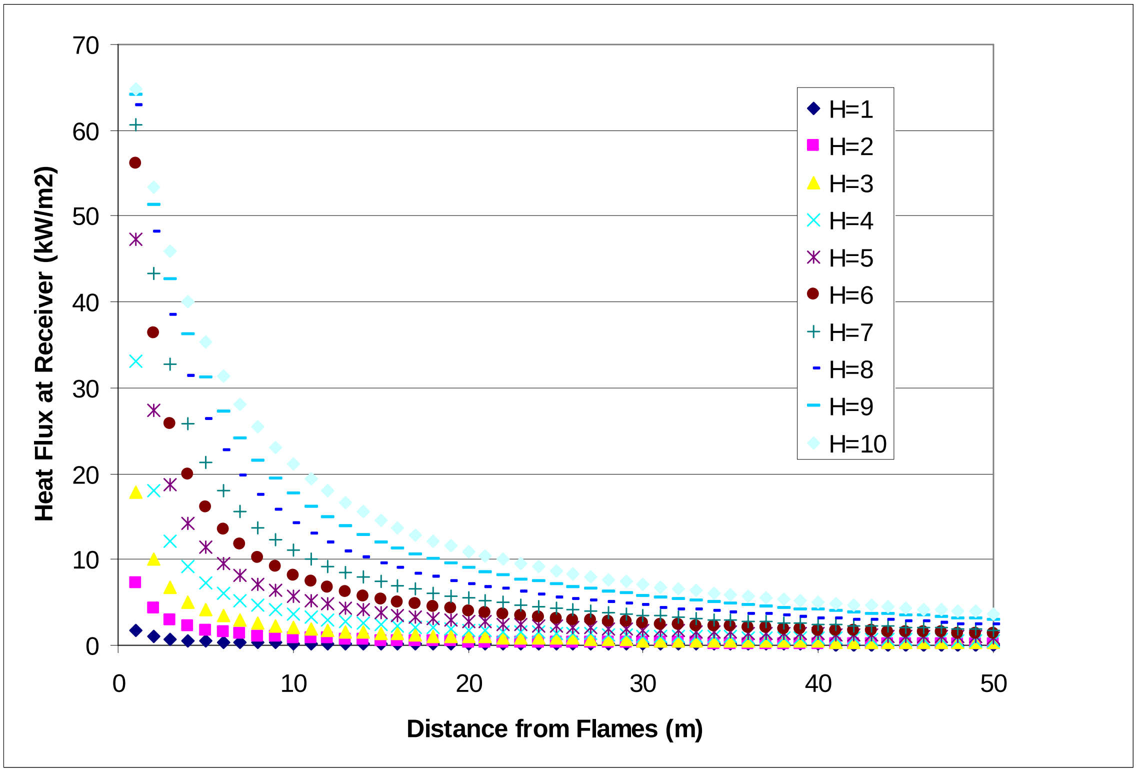


Figure 3 Simulated Heat Flux from a Planar Flame at a Distance from a Receiving Surface

What Figure 3 shows is that for an idealized emitting surface a heat flux of 10 kW/m^2 would be obtained with a 10m tall flame at a separation of approximately 20 m or a 5 m flame at a separation of 6 m.

The ignition of wood as a result of incident thermal radiation involves an energy balance between the incoming energy and the losses from the heated wood surface back to the environment. Incoming thermal radiation is absorbed at the wood surface, the surface temperature increases with time and, if high enough, the woody material begins to break down and form volatile decomposition products. These decomposition products, if present in sufficient quantity (between lower and upper flammability limits) may catch fire. Flaming may be initiated either through an auto-ignition process (where no external source of flame is necessary) or it may be piloted (where a burning brand or other open flame source) ignites the decomposition products. If the incoming energy is low the surface will come to equilibrium where the incoming absorbed energy is lost back to the environment through convection and re-radiation without the surface exhibiting any open flaming. In this case the surface may show no damage or may show some charring. If the incoming energy is of sufficient magnitude the decomposition of the wood will proceed at a high enough rate to produce flammable quantities of products and these products can either auto-ignite or be ignited through a pilot (fire brand or open flame).

To determine an appropriate exposure level a number of 4in x 4in x 3/4in samples of kiln dried cedar (8-10% moisture content) were exposed at increasing heat flux until ignition was obtained within the 30-60 second time period initially set. Once the exposure condition (33 kW/m^2) was determined the repeatability of the process was evaluated by exposing 8 samples and recording the time required for open flaming to occur. Table 2 shows the results of the trails as well as the standard deviation of the time to flaming. Figure 3 shows a typical exposure and illustrates the tests start, initiation of the decomposition resulting in gaseous products, ignition and subsequent burning of the sample. After open flaming was observed the samples were extinguished.

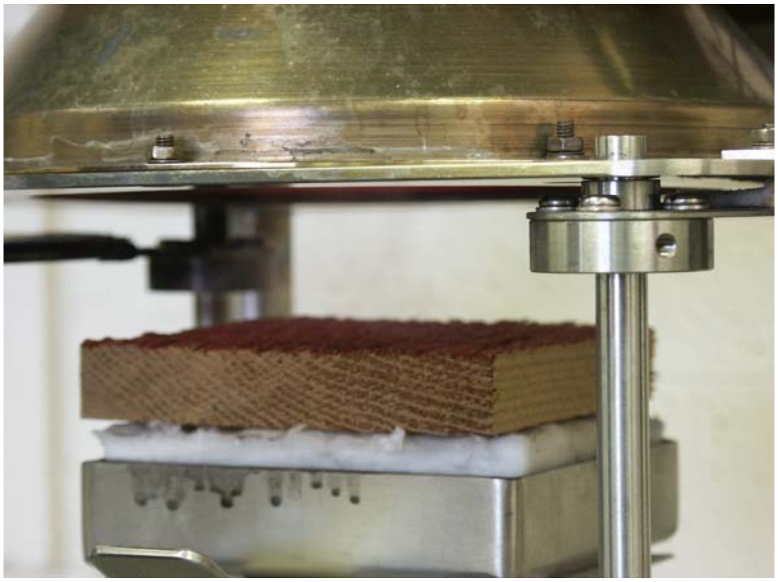
Table 1 Firezat Materials Tested using Cone Calorimeter

Material	Mass	Thickness
Lightweight Composite	240 g/m^2 (nominal 7 oz/yd^2)	0.13 mm (0.005 in)
Heavyweight Composite	610 g/m^2 (nominal 18 oz/yd^2)	0.43 mm (0.017 in)

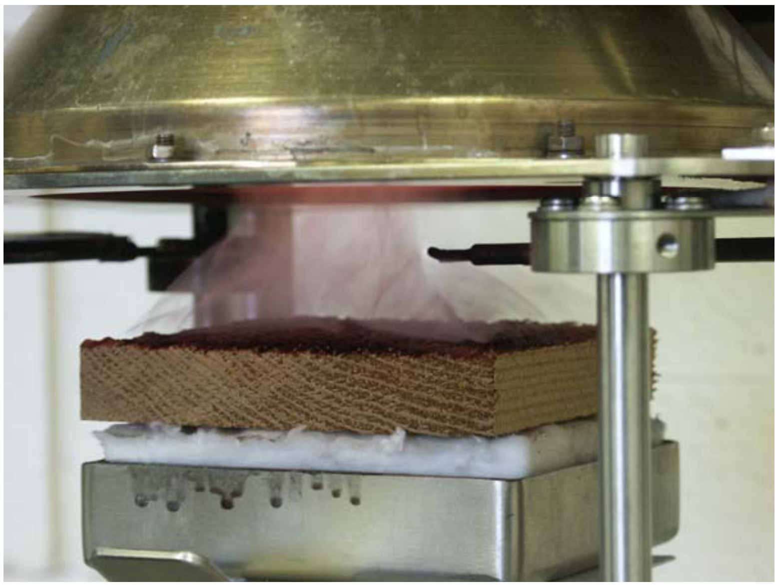
Table 2 Samples Exposed to 33 kW/m^2 Heat Flux (625^{o}C Cone Temperature)

Sample	Time to open flaming (seconds)
1	34
2	28
3	38
4	36
5	37
6	39
7	34
8	28
Mean	34.25
Standard Deviation	4.2

Figure 2 Cone Calorimeter Used for Evaluation of Firezat Samples



a) Sample exposed for approximately 10 seconds - starting to smoke



b) Sample exposed for 20 seconds, decomposition products almost in quantities sufficient for combustion

c) Sample after 30+ seconds, flaming initiated using spark pilot

Figure 3 Typical Exposure for Unprotected Wood Samples

Sample Exposures

After establishing appropriate heat flux levels to reliably obtain ignition within a 30-60 second interval, six protected samples were prepared (three light weight, three heavy weight). Each sample was prepared using an 8in x 8in piece cut from the material provided. Prior to wrapping the cedar blocks two thermocouples were placed on top to measure the temperature between the back of the protective wrap and the wood surface. These were connected to a data logger and each recorded once per second for the duration of the test. The protective foil composite material was then wrapped over the block and secured using staples. Figure 4 shows the preparation of a sample prior to exposure.

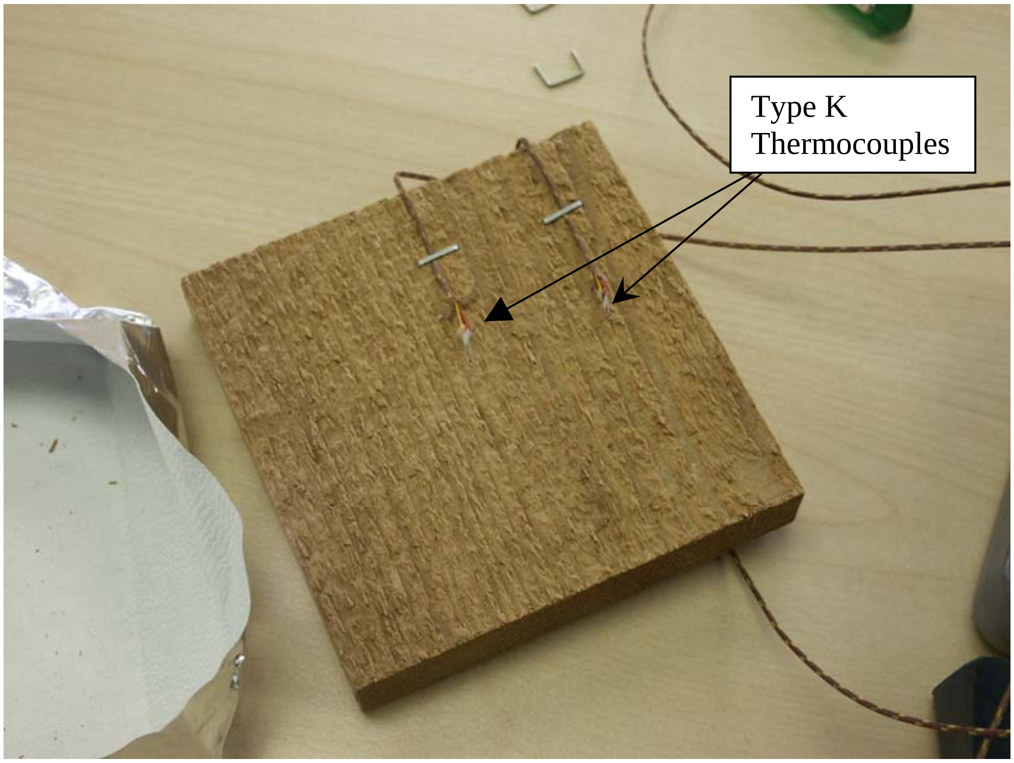


Figure 4 Sample of Cedar Wrapped Prior to Wrapping in Firezat Material

Figure 5 Shows a Sample Mounted Beneath the cone calorimeter during the exposure. The samples were placed on a load platform and the systems protective shutter (used to block thermal radiation) opened to allow the thermal radiation from the heater to impinge on the upper surface of the sample.

Figure 5 Sample Under Cone Calorimeter During Exposure

Each wrapped cedar wood sample was exposed for a period of 10 minutes while temperatures were recorded. After exposure the samples were allowed to cool and then unwrapped and examined for damage either to the material or the cedar sample.

Figure 6 shows a typical temperature trace for the light weight material tested at a heat flux of 33 kW/m^2. Thermocouples located at the sample center and half way between the center and edge show differences in temperature as would be expected given the air flow patterns over the surface of the sample.

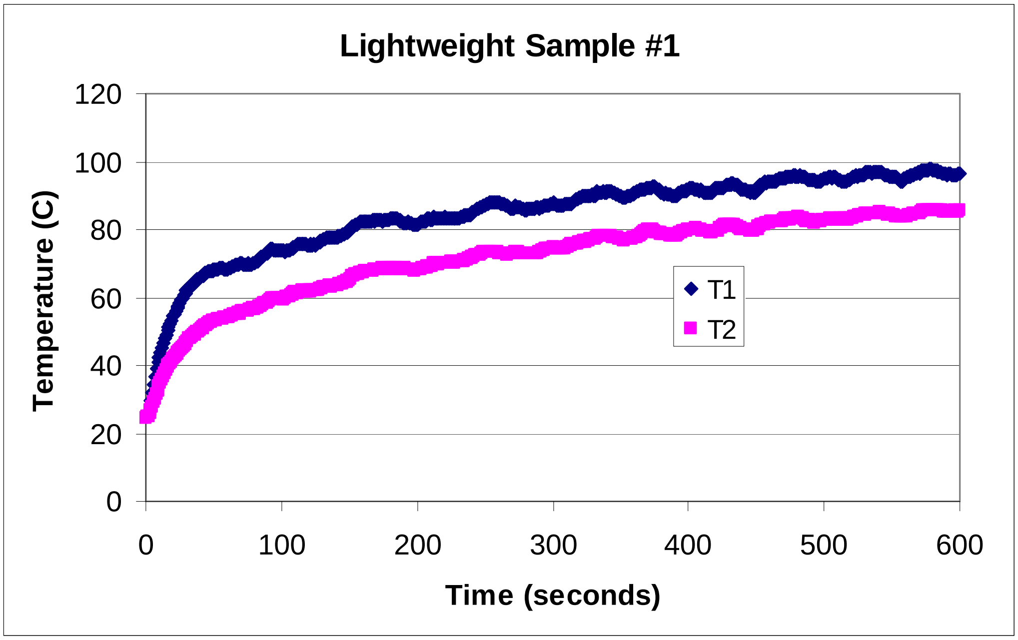


Figure 6 Lightweight Material Exposed at 33 kW/m^2 for 10 minutes

Figure 6 illustrates the behavior expected from a material that provides a reflective surface to radiation in that there is an initial rapid rise in temperature beneath the barrier material as the fraction of the incident energy that is absorbed goes into heating the air between the protective barrier and wood surface. Beyond that time (approximately 30 seconds into the test) there is a gradual increase in measured temperature as the energy absorbed is either lost back to the environment via convection or conducted through the wood sample to the back side. If sufficient time were allowed the system would come to equilibrium where the absorbed energy was lost back to the environment (from the front side of the barrier material and the back side of the wood sample) via convection. From the figure it appears that this process would require more than 20 minutes and would result in a temperature between the barrier material and wood of around 120^{o}C, well below the auto-ignition temperature of most wood species. This equilibrium process would require time scales much longer than that shown and is not really relevant given the typical residence time of wild fires.

Figure 7 shows the behavior of the barrier material and wood sample with the heavy weight material in place. What is interesting is that the response of the light weight and heavy weight materials appear to be nearly the same.

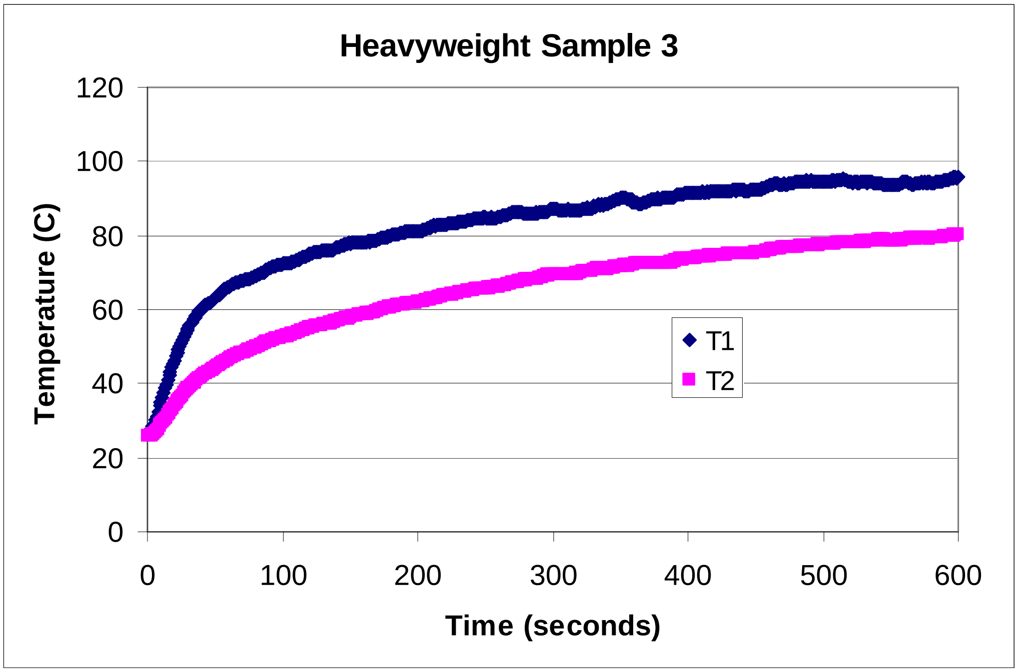


Figure 7 Response of Heavy Weight Barrier Material to Heat Flux of 33 kW/m^2.

In both cases the maximum measured temperature, after 10 minutes of exposure, was less than 100^{o}C.

Figure 8 shows a summary of all tests performed at a heat flux of 33 kW/m^2. While there is some variability within the results, the overall performance of the both materials is very close. There was no distinct difference observed between the light weight and heavy weight materials in either the shape of the time-temperature response or the maximum temperatures observed. In all cases it appears that if sufficient time were allowed the measured temperatures would eventually reach equilibrium at a temperature much lower than the auto-ignition temperature of wood. This would indicate that under the test conditions there is little difference in the protective capabilities of the two materials. This is not an unusual result in that the primary protection comes from the property of the aluminum foil to reflect the vast majority of incoming thermal radiation. The thermal resistance of the materials (resistance to conductive energy transfer) is likely quite different due to the different thicknesses but the overall thermal resistance is largely a function of the boundary layer exterior to the surface and the layer of air between the material back and the wood surface. As a result the overall energy transfer to the wood surface is similar in both cases.

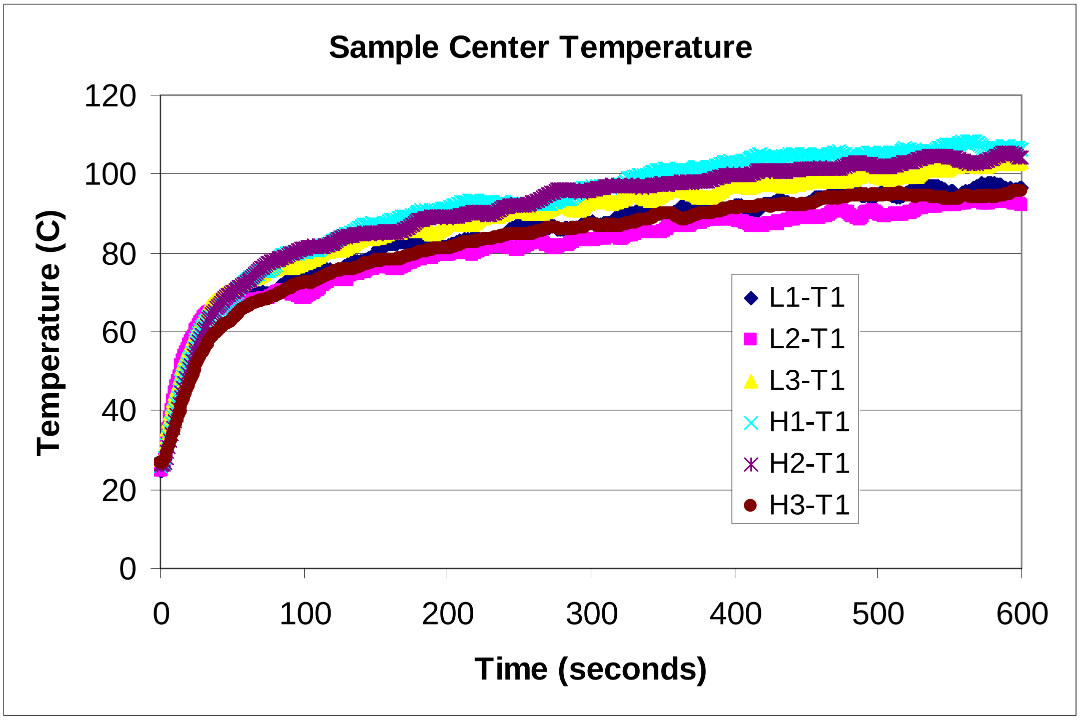


Figure 8 Summary Plot of Measured Center Temperature, Light and Heavy Weight Materials.