URBAN/WILDLAND FIRES: IGNITION BY EMBERS*

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ABSTRACT

An experimental apparatus has been built to investigate the ignition of surfaces as a result of impact with burning embers. Embers were simulated by machining wood (*pinus ponderosa*) into small disks of uniform geometry. Ember simulation was necessary since it is difficult to capture and characterize embers from an actual burning object. The ember ignition apparatus was installed into the Fire Emulator / Detector Evaluator (FE/DE) to investigate the influence of an opposed airflow on the ignition propensity of a surface. The operation of the ember ignition and release apparatus is described.

INTRODUCTION

Urban-wildland fires have plagued the United States for centuries. Recent urban-wildland fires include the 1991 Oakland Hills Fire[1], the 2000 Los Alamos Fire, and the 2002 Hayman Fire. The devastation caused by these fires is massive; the Hayman Fire in Colorado burned 137,000 acres and destroyed over 600 structures. As a consequence, fires in the urban wildland interface can have a devastating effect on human life, property loss, and local economies.

Urban-wildland fires result in the deployment of firefighting resources (federal, state, and local) in an unpredictable, sporadic fashion designed to minimize losses. A more thorough understanding of the fire spread dynamics in the urban-wildland interface would allow for more accurate predictive capabilities that could be used in firefighting resource management, and rational code and ordinance requirements for land use in fire prone areas.

Embers or fire brands are produced as trees and other objects burn in urban-wildland fires. These embers are entrained in the atmosphere and may be carried by winds over long distances. Hot embers ultimately come to rest and may ignite surfaces far removed from the fire, resulting in fire spread. This process is commonly known as spotting. Understanding how these hot embers can ignite surrounding surfaces is an important consideration in mitigating fire spread in communities.

A dearth of information is available in the open literature regarding the ignition propensity of surfaces in contact with burning embers. To the author's knowledge, the only detailed study

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that exists was performed by Waterman and Takata[2]. The lack of specific knowledge on the ability of embers to ignite remote objects limits the utility of detailed computation fluid dynamic models (CFD) that could be used to predict fire spread by fire brands.

The goal of this study is to understand how lofted embers created by urban-wildland fires impact upon surfaces and ultimately ignite the impacted surface. To this end, this paper describes an apparatus that has been constructed to investigate the ignition propensity of materials due to the impingement of embers. The apparatus was designed to be implemented into the fire emulator / detector evaluator (FE / DE). The FE / DE will be used to investigate the influence of an opposed airflow on the ignitability of surfaces.

EXPERIMENTAL DESCRIPTION

Figure 1 is a schematic of the experimental apparatus. The ember ignition apparatus consists of a butane burner and ember mounting probe. The butane flowrate is controlled by a metering valve coupled to a solenoid valve. The ember is held into position by hand and the air pressure is activated, which moves the actuator and clamps the ember into position.

The motion of the butane burner is displayed in figure 1. The butane torch is mounted on a sliding bracket that is coupled to a linear actuator. After the ember is mounted, the spark is activated and the fuel solenoid is opened. The butane burner is ignited and through the use of another linear actuator, the entire assembly is moved into position under the ember. A picture of the apparatus is displayed in figure 2. The retraction of the burner upon ignition and the free-burn time are computer controlled which insures repeatability.

Figure 3 displays the ember ignition apparatus installed in the duct of the FE / DE. The FE / DE is described elsewhere[3-4] and is used here as an opposed air flow source for the experiments. The FE / DE allows for opposed air flow rates up to 4 m/s. These velocities have been verified thru laser Doppler velocimetry measurements.

Embers have been simulated by machining wood into sections of uniform geometry. Ember simulation is necessary since it is difficult to capture embers from burning objects[2]. An important consideration in simulating embers is the size and shape[5-6]. Both the size and shape are important factors as it is these properties that determine the lofting characteristics and burn time of the embers.

For the present study, embers were simulated as disks of two different sizes. The first size produced was 25 mm in diameter with a thickness of 8 mm. The second size used was 50 mm in diameter and 6 mm thick. Disks are believed to be a representative shape that can easily be generated from shingles of burning homes in urban-wildland fires[6]. In addition, disks of this size range are capable of being lofted over long distances[6].

Ponderosa Pine (*pinus ponderosa*) was selected as the wood type for these experiments. This wood was selected since it is abundant in the Western United States and it is here that urban-wildand fires are most prevalent. Prior to machining the disks, the ponderosa pine planks were stored in a conditioning room at 21 °C, 50 % relative humidity. After the disks were machined, they were stored in the conditioning room prior to the experiments.

Figure 4 displays the imaging system developed to capture ember impact and ignition of the test surfaces. The imaging system consists of a CCD camera coupled to a zoom lens. The zoom lens is used to obtain the required spatial resolution to resolve the surface ignition due to ember impact.

DISCUSSION

Prior to performing ember ignition studies with surfaces, it is important to determine the burning history of the simulated embers as a function of disk size and opposed air flow. Specifically, embers were ignited for a fixed duration (*e.g* 30 sec) and were allowed to free burn. The embers were then released onto a load cell and the burning history of the embers was obtained from the gravimetric measurements. Figure 5 displays results obtained for *pinus ponderosa* disks (25 mm in diameter, 8 mm thick). Each data point is the average of five measurements and the error bars display the standard deviation.

Two conditions are shown in the figure, no air flow and low air flow (0.5 m/s). Under low air flow, the embers were ignited under zero flow conditions and the air flow was ramped up as soon as the ignition process was over. Under zero air flow conditions, the ember remained in a flaming state. When air flow was introduced at 0.5 m/s, the air flow blew off the envelope flame from the leading edge of the ember and gradually blew the flame off the back side of the ember. This produced a glowing ember at ≈ 70 sec. after ignition. Figure 6 displays an example of an ember burning under these conditions. The burning rate was similar under zero air flow and low air flow conditions.

It has been demonstrated that embers fall at or near their terminal settling velocity. As such, when embers contact ignitable surfaces, they are in a state of glowing combustion, not open flaming[2,5]. From figure 6, it is important to see that glowing combustion of the simulated embers is obtainable using the ember ignition apparatus.

FUTURE WORK

The burning history of simulated embers has been determined under a limited set of flow conditions and additional measurements are required at higher air flow rates. The final step will be the impingement of embers upon the test surfaces. Cohen[7] has suggested that there are two main fuel sources found at homes that are most susceptible to ignition by embers. These are: (1) shingles and (2) leaves and needles in gutters. An additional consideration for shingle ignition is the trapping of embers within crevices created by shingle overlap. Consequently, wood shingles and forest litter will be used as test surfaces and the moisture content of these surfaces will be varied from 2 % to 25 %. Crevices will be constructed using wood shingles and the influence of ember trapping on shingle ignitability will be determined.

CONCLUSIONS

An experimental apparatus was built to investigate the ignition of surfaces as a result of impact with burning embers. Embers were simulated by machining wood (*pinus ponderosa*) into small disks of uniform geometry. The ember ignition apparatus was installed into the

Fire Emulator / Detector Evaluator (FE/DE) to investigate the influence of an opposed airflow on the ignition propensity of a surface.

ACKNOWLEGMENTS

The support of Dr. D. Evans, Dr R. Rehm, Mr. N. Bryner, and Dr. W. Grosshandler of BFRL-NIST is appreciated.

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FIGURE CAPTIONS

Fig. 1 Schematic of ember ignition apparatus.

Fig. 2 Picture of ember ignition apparatus.

Fig. 3 Picture of ember ignition apparatus installed in the FE / DE.

Fig. 4 Imaging system developed to capture ignition of surfaces from impinging embers.

Fig. 5 Ember mass loss as a function of opposed air flow.

Fig. 6 Ember burning under opposed air flow (0.5 m/s)

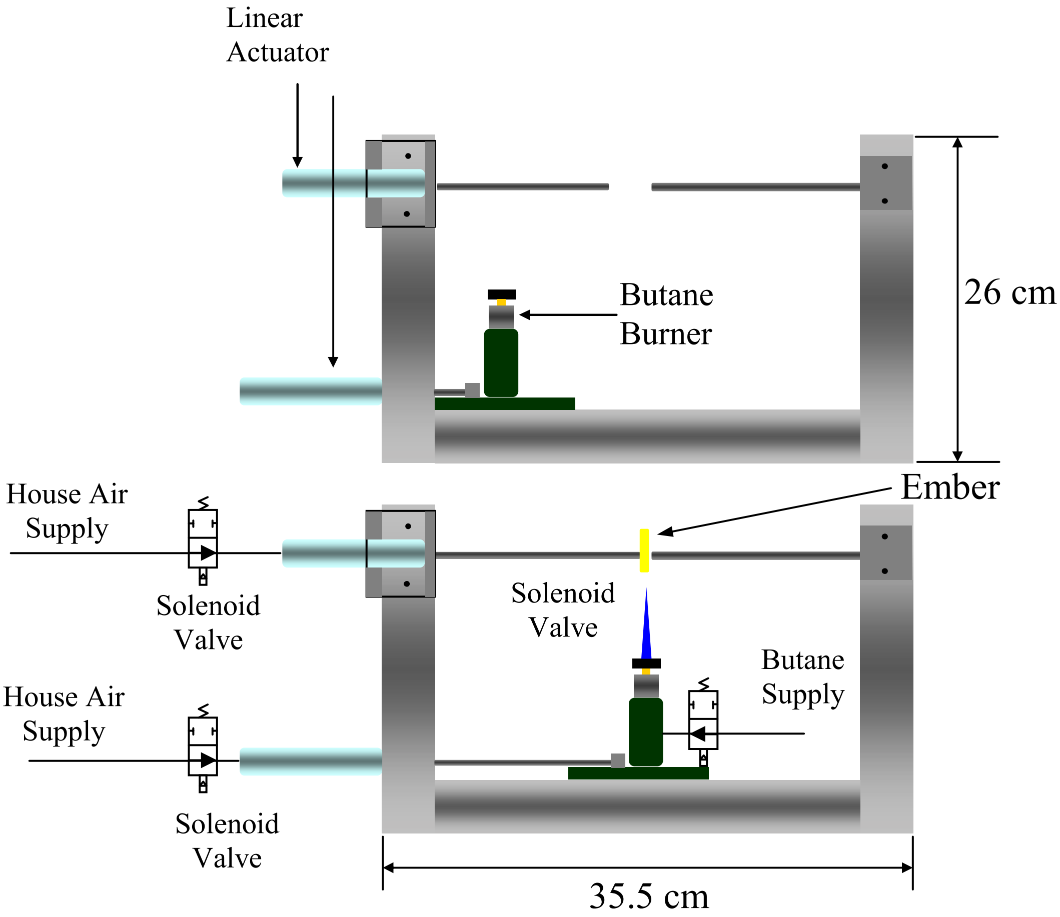

Fig. 1

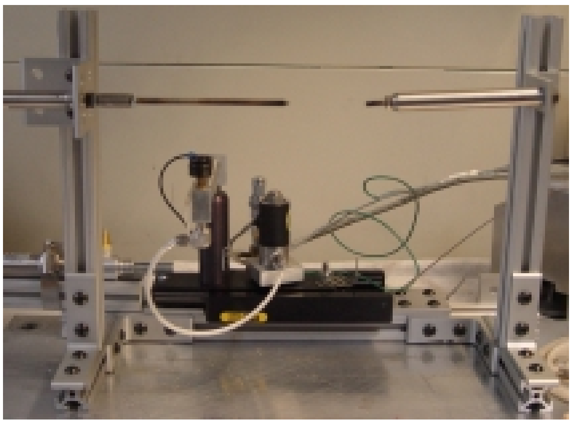

Fig. 2

Fig. 3

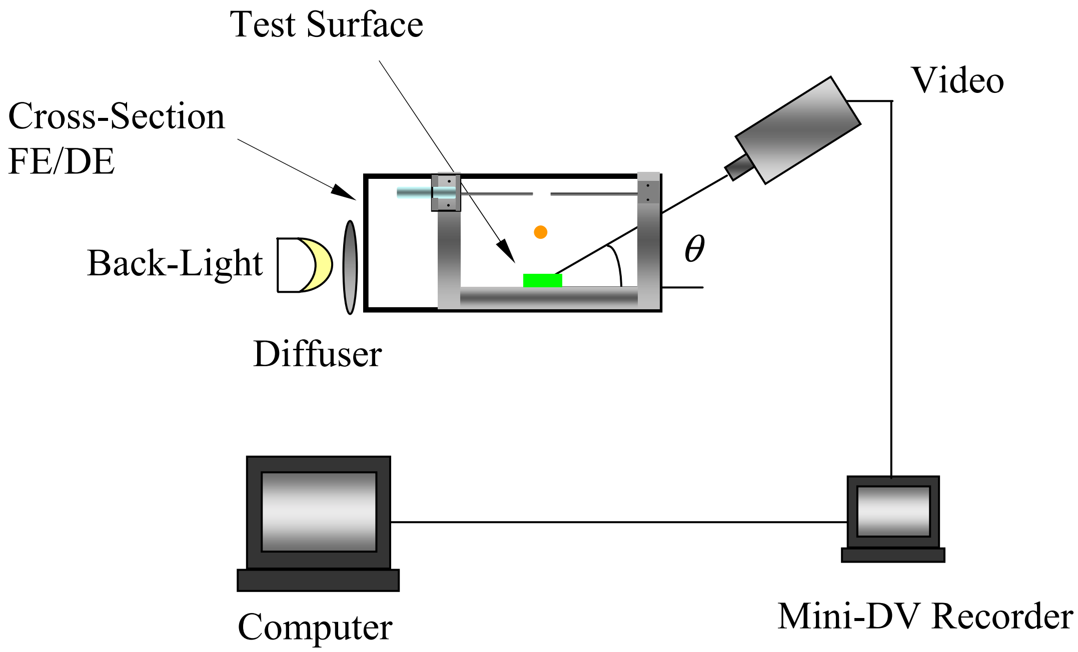

Fig. 4

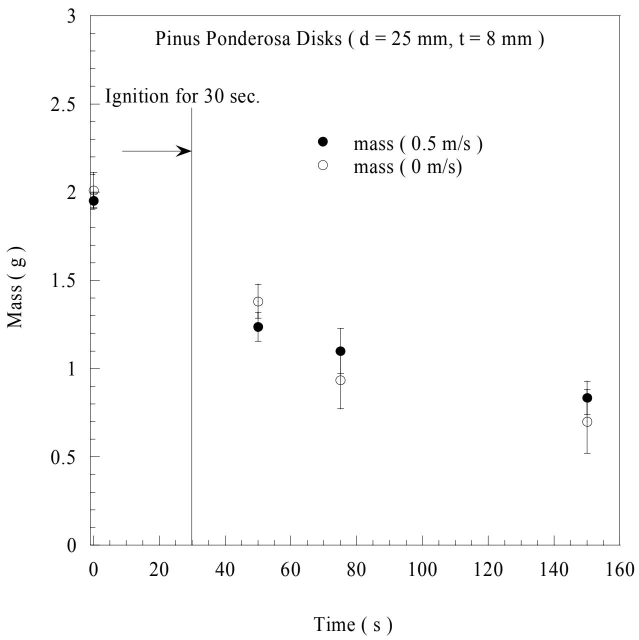

Fig. 5

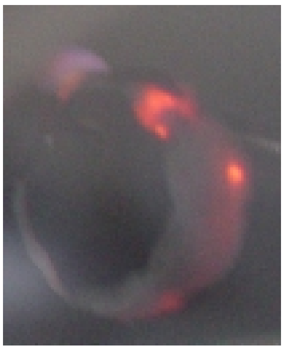

Fig. 6