IGNITION OF SOME BUILDING MATERIALS BY RADIATION

by

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INTRODUCTION

Canadian fire loss statistics draw attention to the need for a more intensified research program in the field of farm fire prevention and control. Expressed as a percentage of the yearly construction budget, fire losses in rural areas are more than triple those in urban areas. The relatively high rural fire losses are due in part to the fact that in many cases fires in farm buildings burn unnoticed and that in most cases the fire brigade does not arrive until the fire is well advanced. Conflagrations that destroy the complete farmstead can occur if the buildings are closely spaced and the fire can spread from building to building unchecked.

The usual mechanism of fire spread between two adjacent buildings consists of two distinct processes: (1) the heating of the exposed building by radiant and convective heat transfer from the flaming building, and (2) the ignition of the flammable volatiles given off by the heated building materials. The heat transfer from the burning building to the exposed building is mainly by radiation except when the buildings are very close together. The volatiles are ignited spontaneously, or more probably, by pilot ignition from flaming brands, sparks or flames.

Consideration of the factors affecting the fire spread processes indicates the following potential control methods. (1) Increasing building spacing to reduce the heat transfer and the probability of pilot ignition by flaming brands, sparks or flames. (2) Reducing the radiant energy absortivity and the combustability of exposed building materials to reduce the probability of pilot ignition. (3) Constructing buildings so that they will contain fire and thereby reduce radiant energy transfer to adjacent buildings. (4) Using building materials that produce a minimum number of flaming brands and sparks. Of these four methods, building spacing is the one most commonly used by farmers.

In order to estimate the spacing between buildings required to prevent the spread of fire, it is necessary to know the intensity of radiation from an assumed burning building and the radiation intensity which will produce ignition of common building constructions. The National Research Council measured radiation intensities, amongst other things, in the well known St. Lawrence Burns (4). Most of these buildings were of brick construction. To obtain radiation measurements for constructions typical of farm service buildings, Scott (3) burned three derelict wood frame buildings.

Moysey (2) used the data on radiation intensities from burning buildings combined with existing information on radiation intensities requred to ignite some species of wood in order to predict recommended minimum spacings between wood-covered buildings of common sizes and shapes. It was found that the pilot light ignition properties of many building materials were not available.

This paper preports on the first phase of the work to determine for some common building materials the relationships between radiation intensity and pilot ignition.

LITERATURE REVIEW

Lawson and Simms (1, 5) investigated the pilot ignition properties of a number of species of wood using a gas fired radiant panel. Small samples (5 cm. square) of oven-dried wood were exposed to various levels of radiation intensity and a pilot flame was provided to ignite the volatile gases. In order to correlate their results, Lawson and Simms developed a simplified heat transfer equation:

$$\theta = \frac{I}{h}\left[1 - \frac{1}{h}\left(\frac{kps}{\pi t}\right)^{1/2}\right]$$

where θ = temperature difference, sample surface to surrounding air

I = the intensity of radiation on surface

h = the co-efficient of heat loss per degree temperature difference per unit area

t = the time required to produce ignition

k, p & s = the thermal conductivity, density and specific heat of the sample

If the critical intensity, I_0 is the radiation intensity required to maintain the surface at the ignition temperature, then $I_0 = \theta h$. If these two equations are combined it can be seen that a graph of I vs. $I/\sqrt{t}$ should give a straight line. The I-axis intercept will give the theoretical critical intensity required to produce ignition after an infinitely long time, assuming that the surface temperature required for ignition is constant for any one material.

Values of critical intensity for ignition of six species of wood as determined by Lawson and Simms (1) are given in Table I. The values shown are 20 percent higher than given in their paper because Simms (5) stated there had been a 20 percent error in radiation measurement.

TABLE I. CRITICAL INTENSITIES FOR IGNITION OF VARIOUS SPECIES OF WOOD

(Lawson and Simms, 1952)

Material	Intensity required for pilot ignition (cal/cm² sec)
Western Red Cedar	0.42
American Whitewood	0.42
Freijo	0.43
African Mahogany	0.36
Oak	0.43
Iroko	0.43
Fibre Insulating Board	0.18

APPARATUS AND PROCEDURE

The radiant energy source used for the experiments consisted of a propane fired panel 45.7 cm high by 30.3 cm wide. The propane was premixed with air supplied by a centrifugal blower. The mixture passes through the porous refractory panel and burns on the panel surface, producing a well defined rectangular radiant energy source which can be controlled to a constant temperature. This panel was chosen because it is similar to the one used by Lawson and Simms (1) except that their's was 30.3 cm by 30.3 cm. Also the same type and size of panel is prescribed for the ASTM Tentative method for surface flammability of materials, ASTM E 162-60T.

The sample to be tested was placed on a vertical bar attached to a carriage running on an overhead track above the panel. The sample could be moved into position in front of the panel quickly and accurately. The time to pilot ignition was measured with a stop watch. The samples were cut 16 cm high by 8 cm wide with the wood grain, if any, running vertically. The samples were stored in a constant humdity chamber maintained at 30% relative humidity and 70°F. For this size of sample and at a distance of 30 cm from the panel, (0.471 cal/cm²sec) the radiation intensity at the surface of the sample had a maximum range of variation of 7%, expressed as a percent of the average radiation intensity.

The pilot flame apparatus consisted of ⅛" copper tube bleed-off from the main propane line. The pilot flame length of 2.5 cm was controlled by a valve in the ⅛" line. The copper tube was clamped so that the bottom of the end of the tube was 0.5 cm above the face of the sample when in test position.

The effective temperature of the radiant panel was monitored with a total radiation pyrometer. The effective temperature is the temperature of a blackbody which emits the same intensity of radiation. The indicated effective temperature of the panel was kept constant by adjusting a constant pressure valve in the propane line. The radiation intensity at the centre of the sample was calculated using the measured effective temperature and the appropriate configuration factor.

TABLE II. PILOT IGNITION PROPERTIES OF SOME BUILDING MATERIALS

Material	Actual thickness (Inches)	Moisture content %	Critical intensity (cal/cm²sec)	Minimum intensity (cal/cm²sec)
Spruce	¾	7.9	0.34	0.38
Cedar	¾	5.5	0.34	0.36
Fir	¾	7.0	0.33	0.38
Fir Plywood	½	4.6	0.27	0.35
Fir Plywood	¼	4.9	0.28	0.36
Hardboard	¼	4.2	0.21	0.27
Fibre Insulation Board	½	5.1	0.16	0.22
Asphalt Shingles	—	—	0.19	0.30

RESULTS

Figures 1 to 3 show typical graphs of some of the test results. The intercept on the radiation intensity axis gives the critical intensity for pilot ignition. This theoretical intensity is less than what would produce ignition within fifteen minutes during an actual test. It is probable that the period of high radiation intensity from a burning farm building will not exceed fifteen minutes. In Table II the values for minimum intensity refer to the radiation intensity at which pilot ignition did not occur within fifteen minutes in at least 75 percent of the tests.

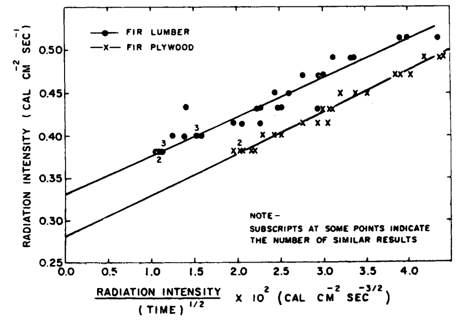

Figure 1. Pilot Ignition of Plywood and Fir.

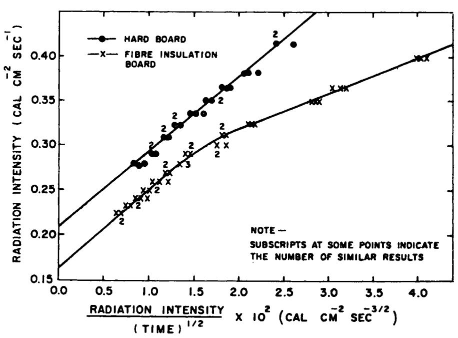

Figure 2. Pilot Ignition of Fibre Boards.

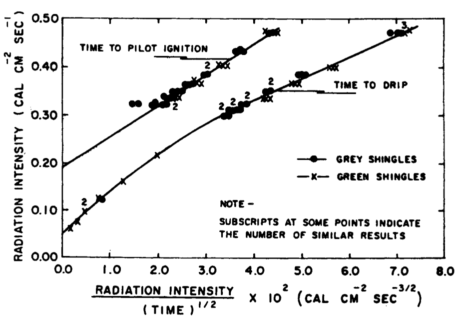

Figure 3. Asphalt Shingles.

The spruce, fir and cedar samples were cut from clear boards, 1 x 4 nominal size. The asphalt shingles tested were 210 lb. grade and were all of the same brand. They were cut to sample size and nailed to ¾ inch thick spruce for the tests.

As the asphalt shingles were heated, the asphalt melted and slid off the felt backing. Figure 3 shows the radiation intensity required to cause asphalt to drip from the sample as well as the intensity required for ignition. Figure 3 also indicates that there is little difference in the results for green and grey shingles.

DISCUSSION OF RESULTS

The critical intensities for woods tested by Lawson and Simms, as shown in Table I, are considerably higher than the results obtained in these tests. This difference could be due to variations between the test methods. Lawson and Simms used a smaller sample size which increases the surface temperature at which the volatile stream becomes turbulent and therefore increases the radiation intensity required for ignition. Preliminary tests on the position of the pilot flame indicated that ignition time was lowest with the pilot flame directly above the face of the sample, while Lawson and Simms located the pilot flame 1.25 cm in front of the sample. Lawson and Sims worked within the radiation intensity range that gave pilot ignition times of 4 to 400 seconds while in these tests lower radiation intensities were used giving pilot ignition

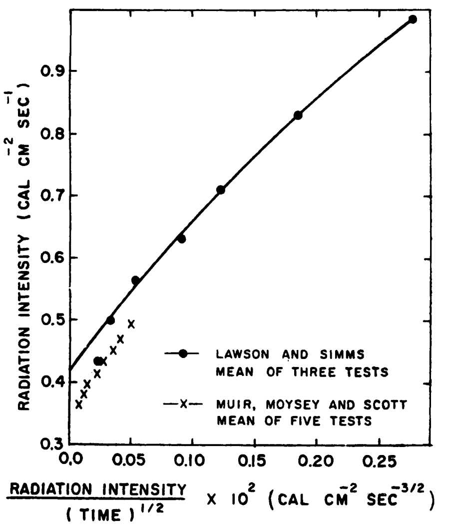

Figure 4. Comparison with Lawson and Simms Data for Pilot Ignition of Cedar.

times ranging from 125 to 1200 seconds. This is illustrated in Figure 4. The longer time interval is representative of the marginal situation where the exposed surface is almost far enough from the burning building to prevent ignition. The longer time interval may have also resulted in a greater self-heating effect. Lawson and Simms did test fibre insulation board at the lower intensities where ignition occurred in about 1000 seconds. They obtained a value of 0.18 cal $m^{-2}sec^{-1}$ for the critical intensity while in the tests reported here, a similar value of 0.16 cal $cm^{-2}sec^{-1}$ was obtained.

The two plywoods tested had similar critical and minimum intensities for pilot ignition. Differences in heat transfer through the samples and in loss of heat from the back of the samples were apparently minor for the two thicknesses tested. The values obtained for plywood were somewhat lower than for fir board and for other species of wood.

Both types of manufactured fibre board had considerably lower minimum and critical intensities than plywood or sawn lumber. This may possibly be due to differences in thermal properties or chemical composition.

Asphalt shingles ignite at somewhat lower intensities than sawn lumber but the asphalt will melt and slide off at as low an intensity as 0.06 cal cm^{-2} sec^{-1} after 15 minutes exposure. In comparison, plywood exposed for 15 minutes to a radiation intensity of 0.16 showed only very slight discoloration.

CONCLUSIONS

In calculating the spacing between buildings necessary to prevent the spread of fire, the following values of radiation intensity at the receiving surface may be permitted:

Unpainted sawn lumber and plywood
0.35 cal $cm^{-2}sec^{-1}$

Unpainted manufactured hardboard
0.25 cal $cm^{-2}sec^{-1}$

Asphalt shingles
0.30 cal $cm^{-2}sec^{-1}$

For particular situations, somewhat larger or smaller values could be used, depending on the margin of safety desired. It is most unlikely that pilot ignition of these materials will occur when exposed to the above radiation intensities for 15 minutes. However, materials exposed to these intensities would be seriously discolored or otherwise damaged.

The pilot ignition properties of painted wood products and of wood protected by non-combustible claddings is currently being investigated.

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. . . DEEP TILE DRAINS

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