General Description

The combustion retarding effectiveness of a mixed retardant is determined by burning treated aspen excelsior and ponderosa pine needle fuel beds. Each fuel bed is loaded in the prescribed manner with either Ponderosa pine needles or aspen excelsior to obtain even distribution of fuel. The beds, 8 feet long by 18 inches wide by 3 inches high (2.4 meters by 46.7 centimeters [cm] by 7.6 centimeters [cm]), are sprayed uniformly with the mixed retardant or a specified standard chemical.

Coverage levels of one gallon-per-hundred-square feet (GPC) and two GPC are used. Each treated bed is dried to remove the water contained in the applied retardant or the standard. The weight loss of each bed is monitored until 95 to 100 percent of the added water is lost. Then the bed is burned under controlled conditions (90 ºF [32 °C] ±5 ºF, 20 percent ±2 percent relative humidity, and 5 miles per hour [mph] ±0.25 mph wind velocity) while monitoring the fire behavior. Each day that burn tests are performed, an untreated fuel bed (control) and a fuel bed treated with 10.6 percent technical grade diammonium phosphate (DAP; standard) are burned, in the same manner as the beds treated with test product.

The rate of spread and rate of weight loss for each bed is determined. These results are compared to those rates for untreated fuel beds and for beds treated with DAP. Reductions in the rates of fire spread and weight loss calculated from these comparisons provide the basis for evaluation.

Fuels

All fuels for a test series must come from the same source; i.e., the same season's needle cast and the same site for the needle collection or the same purchase of aspen excelsior. Ponderosa pine needles are collected from natural sources in the immediate area, shortly after needle cast. Commercially available, standard grade aspen excelsior is obtained in 70-pound bales from a single source.

Both pine needles and split bales of excelsior are stored inside to equilibrate with ambient indoor conditions. The excelsior is then manually separated into individual fibers. Care is taken to remove knots, bundles, and any other collected fibers that may create non-uniformity in the fuel texture.

Fuel-Bed Building

A fuel bed is used to contain the test fuel and ensure the proper fuel structure during each test. The fuel bed, 8 feet long by 18 inches wide by 3 inches high (2.4 meters by 46.7 cm by 7.6 cm), is built on an aluminum frame. Hardware cloth with half-inch openings is used for the floor and sides of the bed to form an open-ended box. Heavy aluminum foil covers the hardware cloth. The foil floor and hardware cloth sides are covered, in turn, by ceramic paper, which serves as the test bed surface. Finally the ceramic paper is painted with a hardener to extend the life of the paper. Experience has shown that ceramic paper with three coats of ceramic hardener will remain intact, to contain fuel and limit airflow, through a 4-week burn-test period.

Fuels used for a test series are stored inside for at least 2 days to allow the fuels to equilibrate with ambient indoor conditions prior to use. After the beds are built they are taken into the combustion chamber and allowed to come to constant weight at 90 ºF (32 °C) and 20 percent humidity before the retardant is applied. The fuel for each test is spread in a uniform manner on the fuel bed.

Aspen Excelsior

Aspen excelsior is separated into individual fiber (fluffed) and weighed into tared paper bags, each containing approximately 1 pound (455 to 465 grams). This fuel is spread onto half of the 8-foot length of the fuel bed. The content of a second bag is spread on the other 4 feet of the bed. This excelsior is pulled apart and spread evenly, ensuring that no tight bundles of fibers or knots remain. At this point, the fuel is roughly 15 to 18 inches high (38 cm to 46 cm). The evenly distributed fuel is then gently compressed and kneaded to fill the width and length of the frame completely and the resulting layer is no higher than 4 or 5 inches. Two more bags, for a total of 4 pounds of excelsior fuel are spread, fluffed, and gently compressed as before. During this process, raking through the fuel with fingers penetrates through the fibers to make one bed of uniform thickness from two layers. The resulting homogeneous fuel layer is no thicker than the height of the bed walls. All loose fibers that extend from the surface are trimmed. Aspen excelsior beds can be made the day before they are used for burn tests.

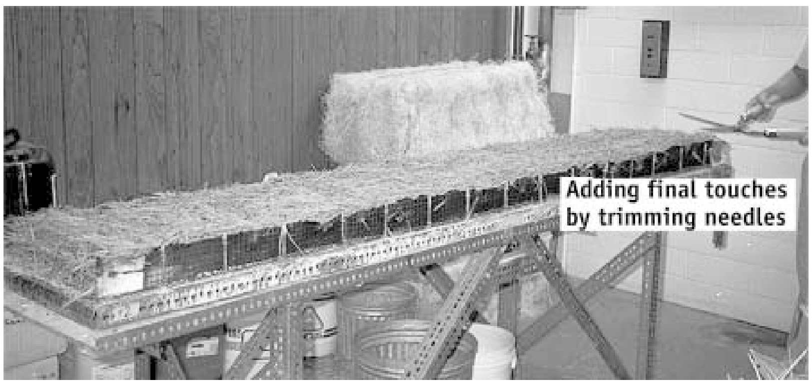

Figure 2.1—Adding final touches by trimming needles.

Ponderosa Pine Needles

Pine needles are cleaned before storing by removing any twigs, moss, cones, or other debris. As the needles are weighed for bed building, twigs or cones that were missed during the earlier cleaning are removed. The needles are weighed into paper bags, each containing approximately 1 pound (455 to 465 grams) of needles. Three bags of needles are spread evenly along the 8-foot length of the bed. Another 3 bags of weighed needles are distributed and spread evenly on top of the previous layer for a total of 6 pounds of needles on each test bed. Light trimming removes needles that extend from the ends or the top surface. See figure 2.1.

Pine needle beds are made on the morning of burning. Needles can settle and slide within the fuel layers overnight, even with no disturbance.

Starter Beds

Starter beds, 3 feet (0.9 meters) in length, are built in the same manner, with the same fuels and fuel loading, to provide an ignition source for the fuel test beds. The starter beds contain 1-1/2 pounds (0.7 Kilograms [Kg]) of excelsior, or 2-1/4 pounds (1.02 Kg) of pine needles. These 3-foot (0.9 meters) starter beds provide a developed fire across the width of the fuel bed as an ignition source for the test bed.

Mixed Retardant

Fire retardant to be tested is prepared according to the manufacturer's directions. Sufficient retardant is made (10 to 15 gallons or 38 to 57 liters) to complete the planned series of test burns. Measurements are made to determine the density, viscosity, and percent solids. These values are used to assure the retardant was mixed properly and to calculate the volumes of liquid to be applied for each coverage level.

The percent solids is determined by drying samples, 4 to 7 milliliters, of the mixed retardant to constant weight in a drying oven set to 100 °F (38 °C).

Subtracting the dry weight from the wet weight of the product and dividing the result by the dry weight calculate the percent solids. Average the results for all samples.

Thickened products must have the viscosity reduced to approximate the condition of the retardant following breakup from an aerial drop and to permit consistent spraying from the application system's nozzle onto the test bed's fuel surface. An enzyme additive obtained from the product's supplier is most commonly used to reduce the retardant viscosity.

Spray Apparatus

The spraying system, shown in figure 2.2, applies a constant and even coating of mixed retardant from a TeeJet™ Spray Systems nozzle, model number TP8030-SS with a nominal opening of 2.5 millimeters. With an applied head pressure of 12 pounds per square inch in the 4-gallon (15 liter) stainless steel tank, the nozzle produces a flat, fan-shaped spray pattern, perpendicular to the bed length, from a height of 37 inches (94 cm) above the fuel bed surface. This spray pattern, assures even coverage across the bed surface.

The volume delivered from the nozzle is determined by spraying the test product for 10 seconds onto a tared tray. The weight of retardant sprayed is measured and the volume calculated. Several trials are made and the results averaged to calibrate the sprayer.

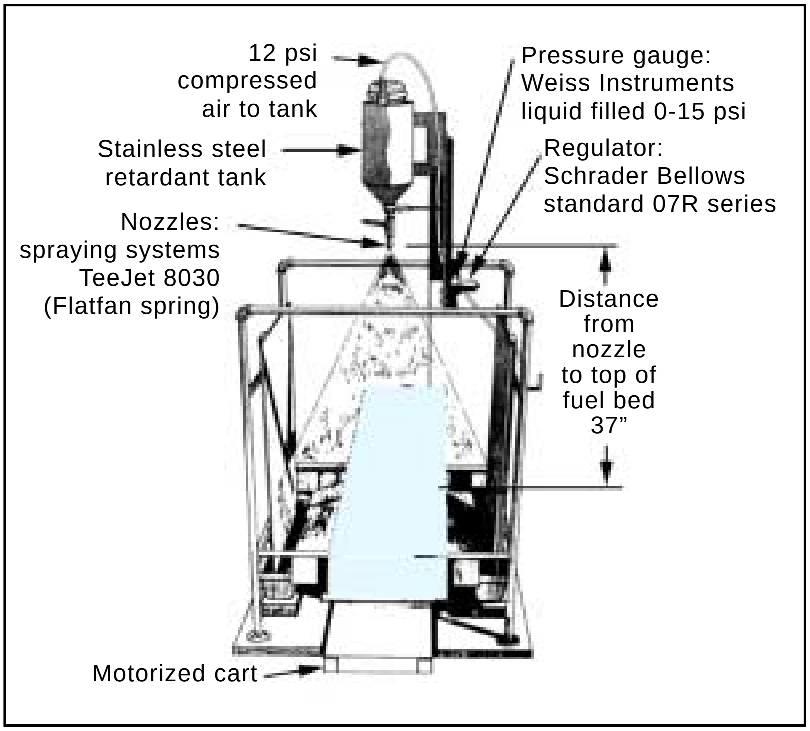

Figure 2.2—Spraying system.

The volume delivered per second is used to calculate the spray time necessary to deliver retardant equivalent to coverage of 1 GPC or 2 GPC to the test bed. In turn this value is used to set the travel time for the bed.

An electronically driven transport system is adjusted with the test bed in place to move the entire test bed under the spray apparatus in the calculated travel time.

Retardant Application

Once a fuel bed has reached a constant weight in the combustion chamber, it is sprayed with either 1 GPC or 2 GPC of mixed retardant. The bed is immediately weighed again and the difference in the treated and untreated weights used to calculate the actual retardant coverage for that bed.

The fuel beds are then dried under the standard conditions of 90 °F (32 °C) and 20 percent relative humidity until the applied moisture evaporates. Air-drying is accomplished under circulating air in these controlled environmental conditions similar to those in the wind tunnel.

The weight of each bed is checked periodically. When the treated beds have dried sufficiently that 95 to 100 percent of the water applied with the retardant had been removed, the beds are burned.

Data Collection System

The data collection system consists of a weighing system for the fuel bed; a computer that records the weighing system outputs and the flame spread data, and then calculates the rate of weight loss and rate of spread.

The weighing system, shown in figure 2.3, is located in the wind tunnel. The framework is an 11-foot-long steel structure anchored in sand to ensure a level surface. A 30 kilogram capacity balance is positioned approximately 4 feet from the downwind end of the framework. A 4-foot-long (1.2 meter) aluminum frame sits on the balance and supports the 8-foot (2.4 meter) test bed.

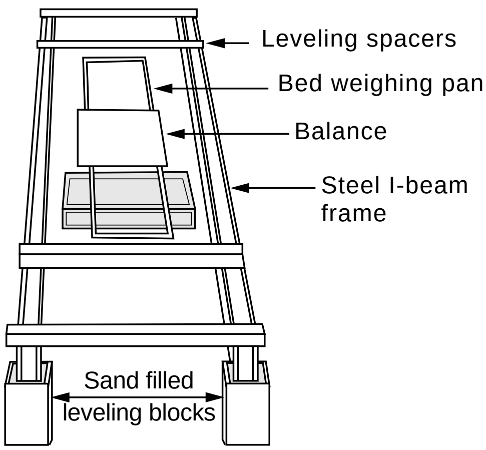

Figure 2.3—Weighing system.

Communication is established between the balance and the computer used to record data and compile results. A Tbasic computer program is used to collect the burn test data and calculate rates of spread and weight loss. The program is available from the Technology and Development Center/Wildland Fire Chemicals Systems Program in Missoula, Montana.

A video recording system of tripod, camera, and monitor is used to record each test for reference to clarify fire behavior or in case of questions.

Burning

Once the fuel bed has reached the proper weight, the bed is removed from the combustion chamber and placed in the wind tunnel where burning conditions 90 °F (32 °C), 20 percent relative humidity, and 5 mph wind) have been established. The bed is balanced on the weighing system, a final weight is recorded, and a sample of fuel, roughly 2 inches by 4 inches (5 cm by 10 cm) through the fuel depth, is cut from the downwind end of the fuel bed for a fuel moisture determination. See figure 2.4. The sample weighs approximately 15 to 25 grams.

At this point final trimming is done to remove pine needles or excelsior fibers extending over the surface. These stray fibers may spread the flame front unevenly or cause flame spotting or uneven advancement of the observed flame front. Refer back to figure 2.1.

Tables, covered with nonflammable material, are arranged on all 4 sides of the test apparatus to minimize edge effects and air whorls and their influence on the fire behavior.

The computer program is started and the starter bed is ignited by an electronically heated wire. This starter bed provides an established flame front for ignition across the entire fuel bed rather than from a single point.

As the flame front reaches each 0.5-foot point (15.2 cm), measured against a reference bar, along the test bed, the operator presses a switch connected to the computer. The computer program records the time that the switch was pressed. The weight of the test bed is recorded every 10 seconds throughout the test burn.

At the conclusion of the combustion, the rates of spread and weight loss are calculated. As a rule, the 3-foot point and the 7-foot point are chosen as the basis for calculation. This allows space for the fire to become established on the bed and eliminates end effects from the starter bed or the downwind direction. Other points can be chosen by the operator to accommodate uneven burning or unique fire behavior.

All beds burned on the same day are made from the same fuel. At least one untreated bed and one test bed treated with technical grade diammonium phosphate (21-53-0 DAP) will be burned each day along with one or more test beds treated with the product being tested.

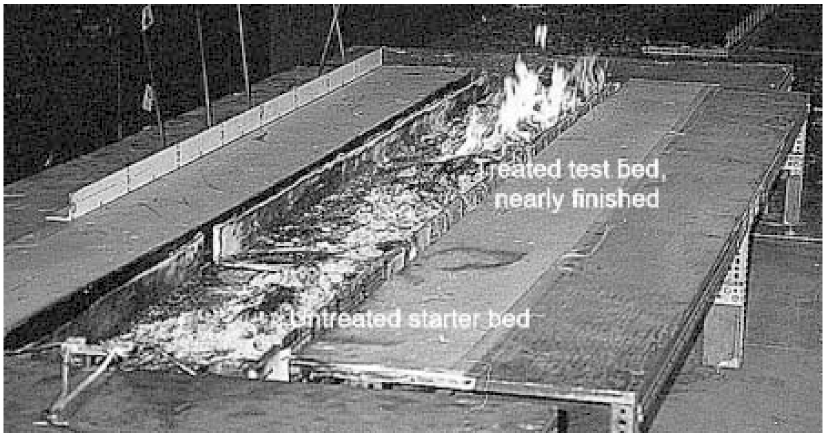

Figure 2.4. Burning bed.

Fuel Moisture Analysis

The sample cut from the end of the test bed is placed into a 500 milliliter Florence flask that has been cleaned, dried, and weighed empty. It is sealed with a rubber stopper and set-aside until the end of the day when it will be run through a xylene-distillation process to determine the fuel moisture content.

The rubber stopper is removed, the flask and fuel are weighed, and then the flask and contained fuel is placed in an electrically heated mantle. Sufficient histological grade xylene is poured into the flask to reach the middle of the flask and be visible above the edge of the heating mantle. A condensing tube with collecting column attached is connected to the flask and all seals are secured. The heated mantle applies heat for 1 hour. Water and xylene boil off and the vapor is trapped and condensed over the graduated collecting column. The water (heavier than xylene) collects at the bottom of the graduated column and the volume measured to the nearest 0.025 milliliter.

The weight of the collected water is subtracted from the weight of the fuel sample contained in the flask to give the dry fuel weight. The weight of the water collected from the distillation is divided by the dry fuel weight. This calculation will yield the percentage of fuel moisture.

Repeating Tests and Discharging Data

More than the required number of tests may be run. Additions may be used to replace other burns, to confirm results, or to reduce variations in the results. Each additional burn test will be subject to the same requirements as the original tests.

The results of individual burns can be discarded completely if the fuel and treatment fall outside of standard conditions and:

> The coverage level for a 1 GPC test must be between 0.95 and 1.05 GPC.
>
> The coverage level for a 2 GPC test must be between 1.95 and 2.05 GPC.
>
> The test bed must be between 95 and 100 percent dry.

On occasion there will be results that do not fall outside the required parameters, but also do not agree with the remaining test results. These are not discarded. Additional tests may be run to confirm that the result is an oddity. These tests may also fill in the gap so that the non-agreement no longer exists.

Calculations

Each test series consists of five fuel beds of each coverage level of the test product (1GPC and 2GPC) on each type of fuel bed (aspen excelsior and ponderosa pine needles).

The numerical data from the fuel bed tests is entered into an Excel™ spreadsheet and the rate of spread and rate of weight loss for each bed (test product, standard, and control) is calculated.

At the end of the burn test series, of the rates of spread for all untreated beds of the same fuel are averaged. Similarly, the rates of weight loss for all untreated beds of the same fuel are averaged. These four average values are used to determine reductions.

The reduction in rate of spread and rate of weight loss is calculated for each bed treated with the test product or standard chemical using the general formula:

$$\text{Reduction} = \frac{\text{Rate}_{\text{Untreated}} - \text{Rate}_{\text{Treated}}}{\text{Rate}_{\text{Untreated}}}$$

All reductions in rate of spread for the same coverage level on the same fuel with the same product are averaged. Similarly all reductions in rate of weight loss for the same coverage level on the same fuel with the same product are averaged.

The eight average reductions for the test product are added. The eight average reductions for the standard product are added. The totals of the reductions are compared. The performance of the test product is considered to be acceptable if the total of the reductions for the test product is at least as great as the total of the reductions for the standard product.