MEASUREMENT OF THE EFFECTIVENESS OF WATER AS A FIRE SUPPRESSANT

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CANADIAN FORESTRY SERVICE
DEPARTMENT OF FISHERIES AND FORESTRY
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Measurement of the Effectiveness of Water as a Fire Suppressant

Progress report on Project F-67

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Introduction

The initial work on this project was carried out by B.S. Hodgson hence the background material on his investigations into the project feasibility and on the developmental stages are outlined in his preliminary progress report for project F-67 of 1968. Although the project had been reassigned, the original guideline objectives remained basically the same. Since the tests on uniform duff layers in situ within a red pine stand proved to be a failure due to excessively high fuel equilibrium moisture content (EMC) levels, the second objective was modified to permit fuel conditioning prior to burning. The principles of the trolley system were retained, however, the rig was remodelled to permit the application of a larger amount of water over a larger fuel bed. A stationary testing site was established on Thomas' Field at Petawawa Forest Experiment Station.

Spray Rig Modification

A review of the specifications and the calibration data sheets together with discussions with E.C. Little (who had been involved in this project since initiation), indicated that the "FloodJet" nozzle best met the distribution and coverage requirements for the present phase of testing. However, since the nozzles on hand had small orifice openings, larger nozzle sizes were required to increase output. By reducing trolley speed and thus increasing the application time, the total output of the small nozzle could be substantially increased but this proved impractical hence the purchase of a full compliment of nozzle sizes was advisable. A wider range of application rates was accomplished by the installation of a dual nozzle arrangement (Figure 1).

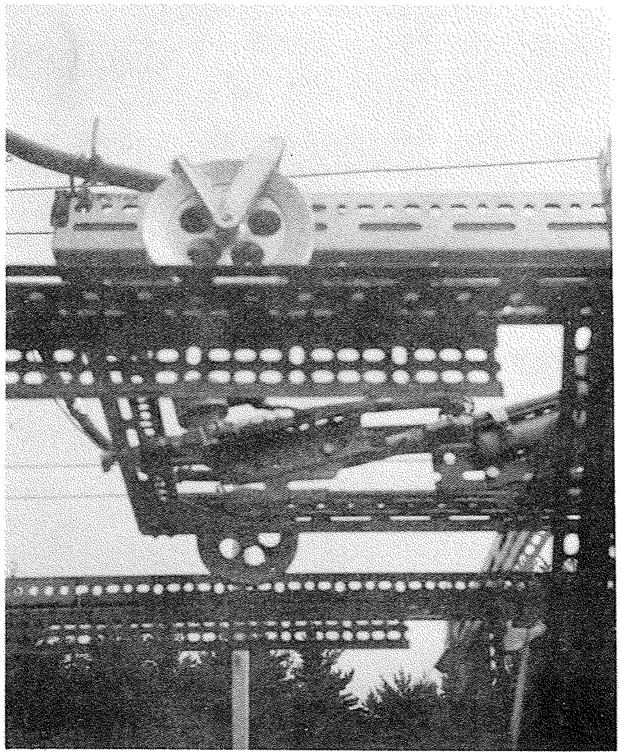


FIGURE 1 DUAL NOZZLE ARRANGEMENT ON TROLLEY.

The choice of a single or a dual nozzle combination to deliver a specified amount of water posed no problem if the mean droplet size was not significant in the suppression quality of water. Spray droplet size increased with orifice opening and decreased with pressure, therefore, should it become evident that droplet size is important, single large orifice nozzle should be replaced by an appropriate combination of two smaller nozzles.

The original spray rig (Figure 2) was modified to permit:

1. The burning of larger fuel beds
2. The change in the direction of water application relative to the fire front
3. The installation of a larger water reservoir
4. The enlargement of capacity for pressurization of the water reservoir to maintain uniform water output.

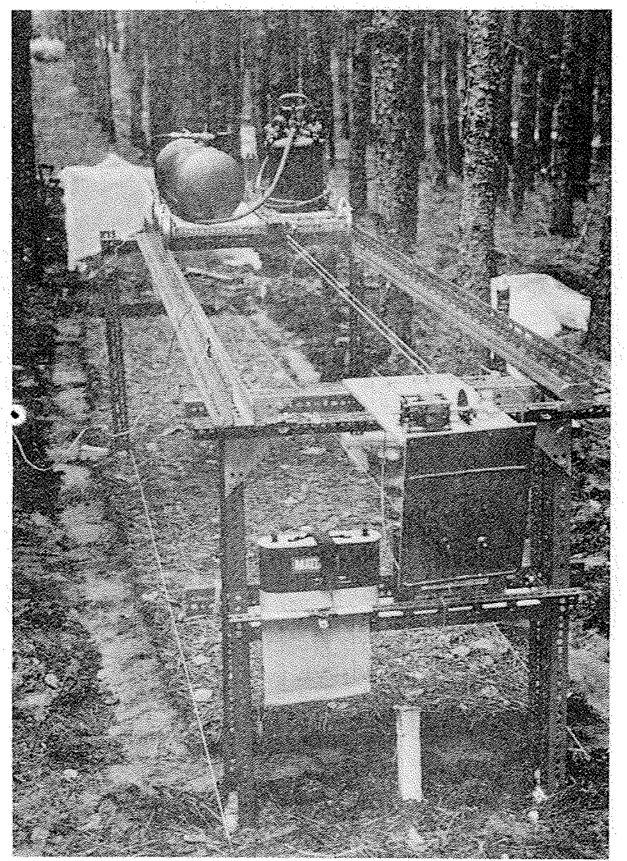


FIGURE 2 ORIGINAL AIRTANKER DROP SIMULATOR SET UP OVER RED PINE NEEDLE (IN SITU) FUEL BED.

To reduce edge effect and the merging of the entire fire front into a common convection column, it was deemed desirable to increase the fuel bed width, however, this appeared impractical since the spray rig was designed to straddle a long narrow bed. This was rectified by raising the rig (leg extensions) to provide five feet of clearance between the nozzle and the fuel and by extending the track to get a clear spraying span of ten feet (Figure 3).

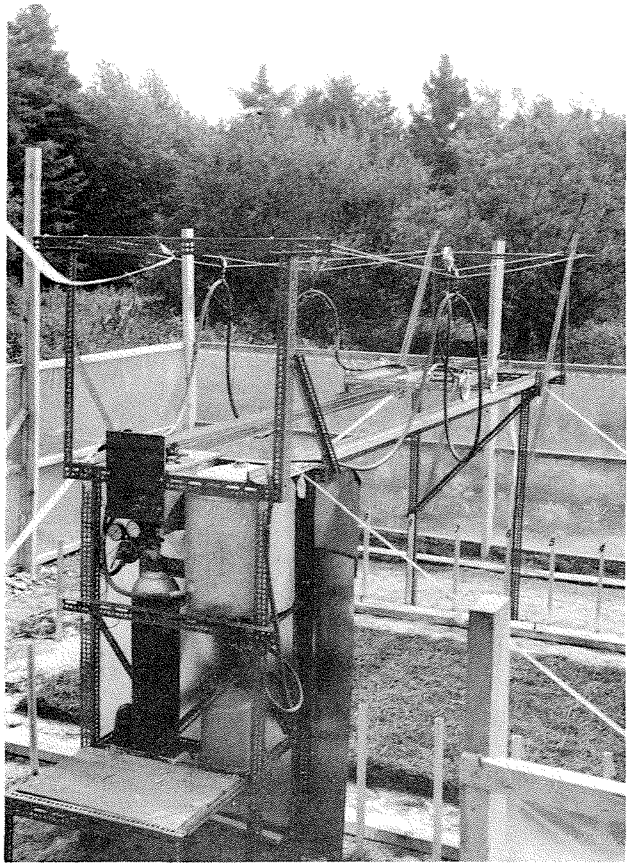


FIGURE 3 REMODELLED SIMULATOR SET AT RIGHT ANGLE TO FUEL BED.

This permitted the simulation of an airtanker flight path parallel to the fire line.

The change to a larger water reservoir and a large cylinder of compressed air was accomplished by mounting these units in a fixed position at the motor end and by installing mobile supply lines to the nozzles on the trolley.

The Fuel and Fuelbed

The unpredictability of the weather which in turn affected the EMC of the forest fuel made it impractical to burn natural fuels in situ. The red pine needles, including bark platelets, cones, and twig fragments, were raked from beneath a pure pine stand along Orange Road and were dried in a 12' x 30' plastic shelter (Figure 4) by solar radiation to a moisture content of six to ten per cent.

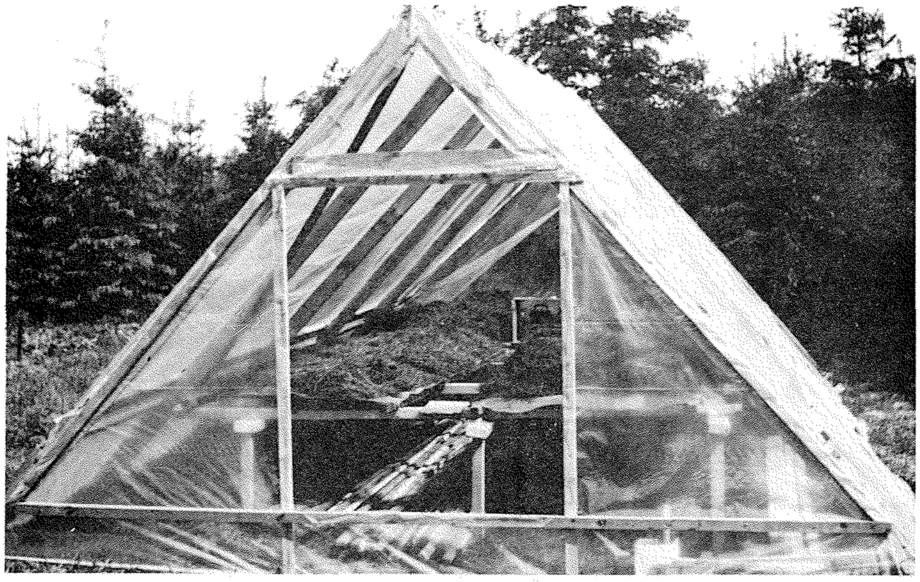


FIGURE 4 DRYING SHELTER WITH RED PINE NEEDLES ON SCREENED LATH FLATS.

After bagging in polyethylene sacks and storing for a short period in the Fire Research Workshop, the EMC of the fuel stabilized at ten to eleven percent. The fuel requirements for each test were weighed out shortly before being taken to the testing site. The fuel was laid on a fine dry sand base to form a bed six feet wide by twelve feet long (Figure 5).

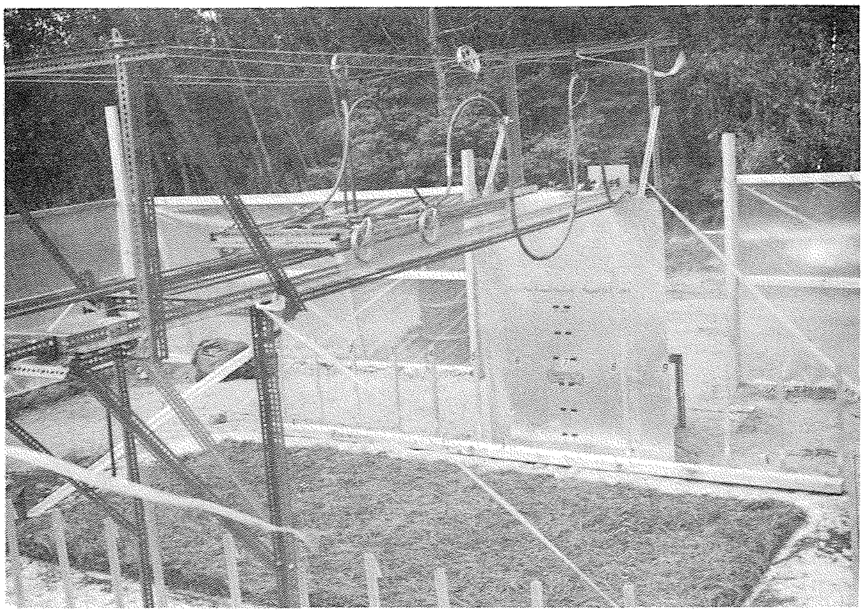


FIGURE 5 RED PINE NEEDLE FUEL BED READY FOR IGNITION. TO BE IN START POSITION TROLLEY MUST BE AT EXTREME LEFT.

positioned so that station No. 7 (St.7) (i.e. seven feet from St.0 the ignition zone) was directly below the nozzle. (Figure 6).

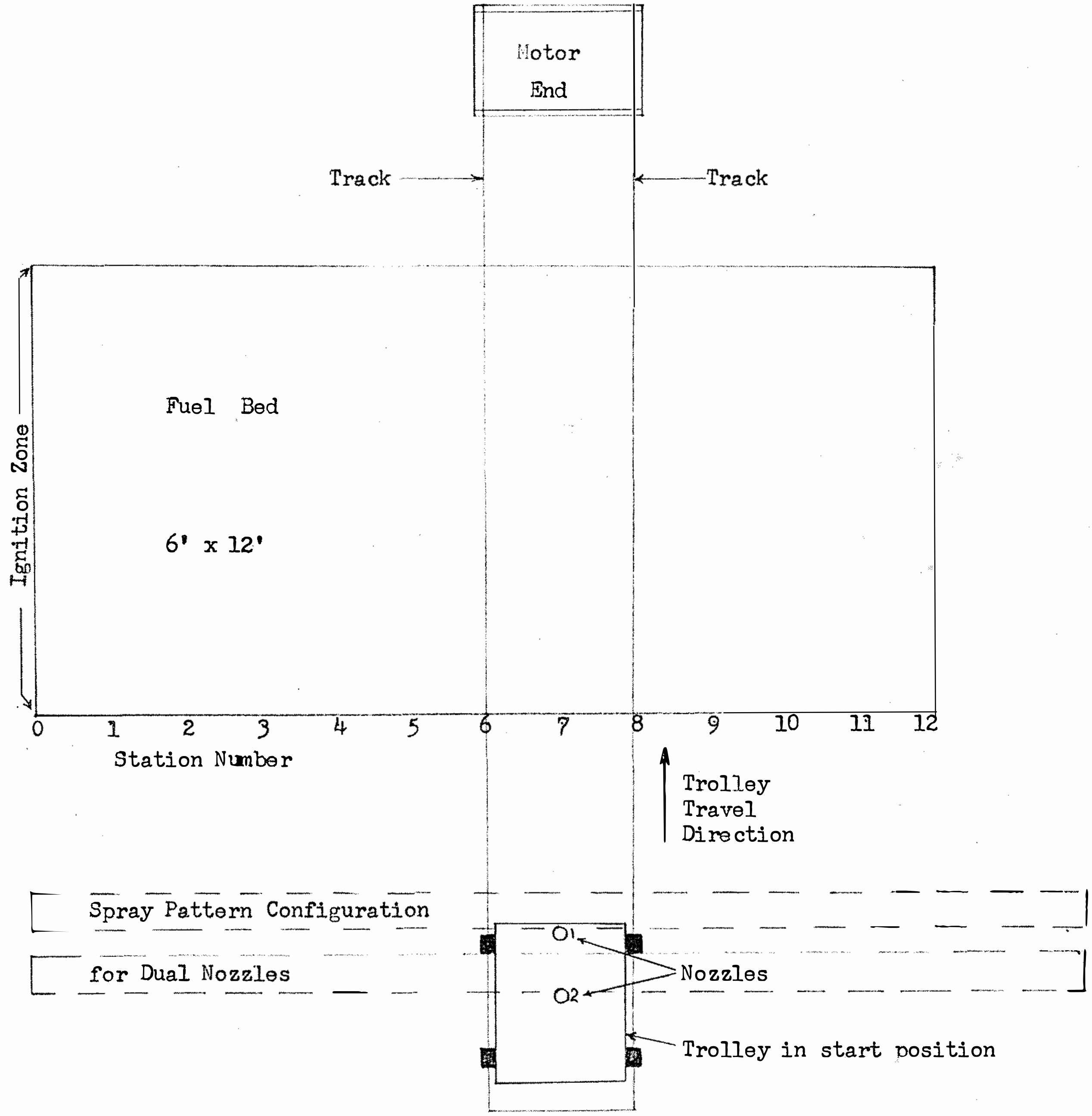


FIGURE 6 SKETCH OF FUEL BED RELATIVE TO THE SIMULATOR AND SPRAY PATTERN.

The side edges of the fuel bed were tapered down to a low angled slope to reduce edge effect during burning and to minimize the problem of reignition in this vicinity. Randomly picked fuel samples were gathered from the bed surface for moisture content determination. Fuel depths were varied to produce fires of different intensities but in each case a specified depth was laid as evenly as possible but the bed was not deliberately compacted.

The cured balsam fir slash from the cutting site had a moisture content of fifteen to eighteen percent. The limbs were clipped into twelve to eighteen inch lengths to allow the slash to lie in as compact a bed as possible. The needles were in a brown stage still intact on the twigs. A minimum of needle loss was experienced during handling.

Testing Procedure

To avoid erratic fire spread rates it was deemed advisable to restrict the tests to periods when wind velocity was less than two mph. A check of literature on wind/fire spread rate relationship revealed that beyond this wind velocity, fire spread rate increased dramatically. Simultaneous fuel bed end ignition was achieved by momentarily laying a flaming seven foot ignition board to the fuel bed at St.0. (Figure 8. Observations of fire characteristics were recorded for each station (see sample forms in Appendix A) during the pre- and post-spraying periods. When the fire front reached St.7, the fuel bed centerline, the spray system was activated and the trolley (which had been positioned at the start end of the track) was set in motion towards the motor end as indicated in Figure 6.

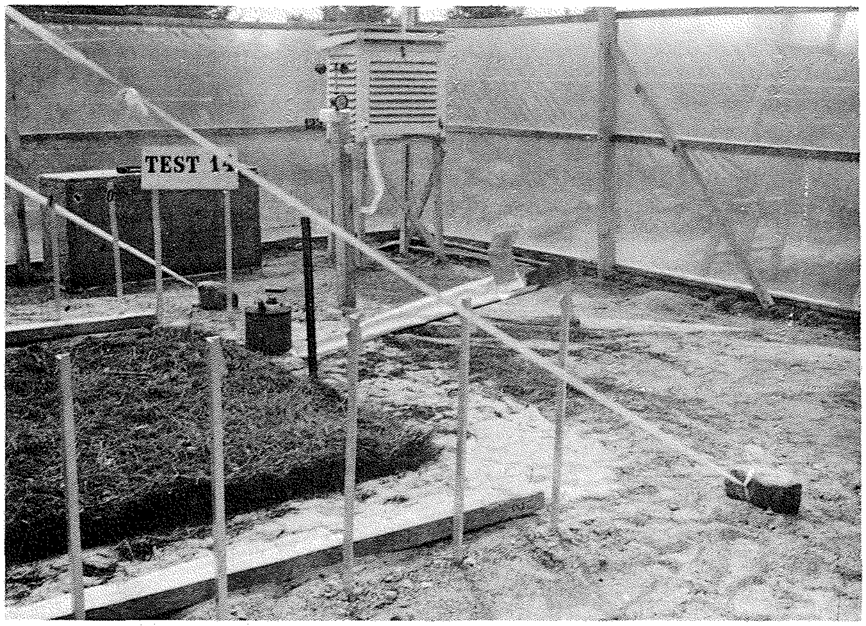


FIGURE 7 FUEL BED READY FOR IGNITION. IGNITION BOARD PROPPED ON ST. STAKE READY FOR FUEL OIL APPLICATION AND IGNITION.

FIGURE 8 SIMULTANEOUS IGNITION OF FUEL BED AT ST. 0 (IGNITION ZONE).

On completing its pass, the trolley was stopped and spraying was terminated. The demarcation between burned and unburned part of the fuel bed was immediately mapped, depth of water penetration was measured, depth of residual unburned fuel was determined, and depth of charred needles in burned area was recorded. These determinations were made for the central portion of the fuel bed from Stations 2 to 12.

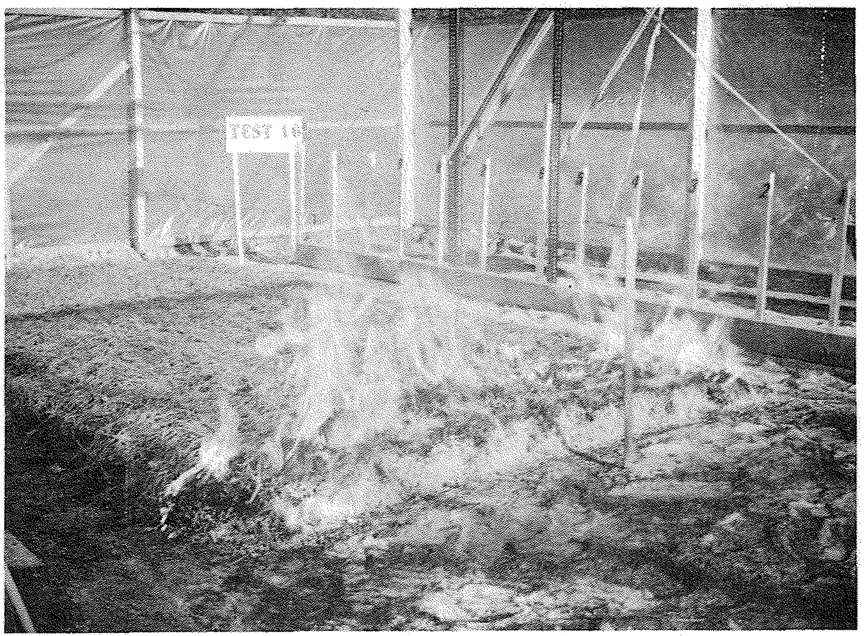


FIGURE 9 FUEL BED AFLAME (APPROXIMATELY ONE MINUTE AFTER IGNITION).

FIGURE 10 FIRE (TEST NO. 16) NOW FIVE FEET FROM IGNITION ZONE, BURNING AT 0.023 FT/SEC AT APPROXIMATE INTENSITY OF 92 BTU/FT/SEC.

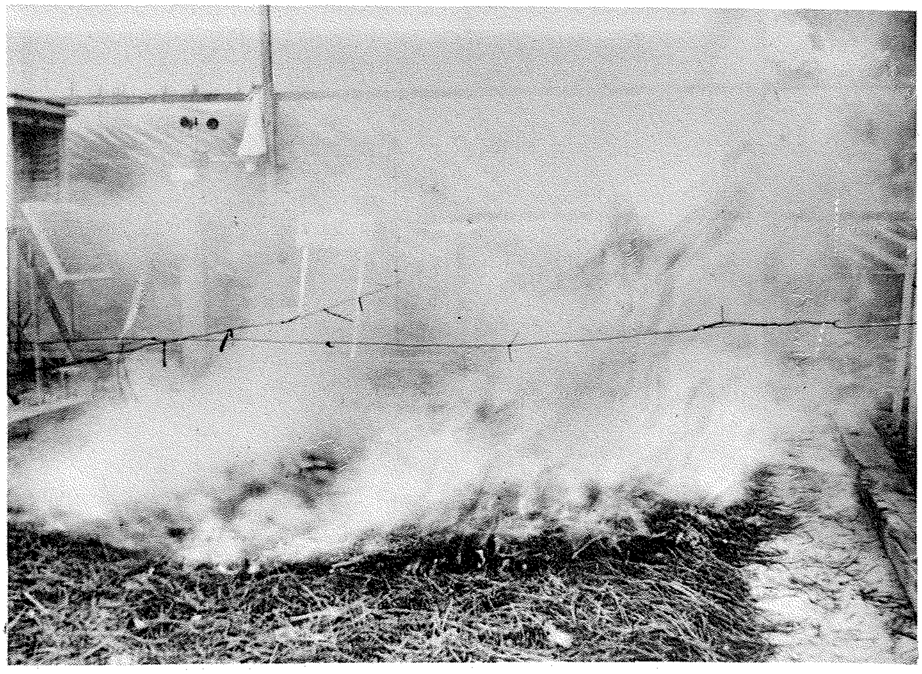


FIGURE 11 WATER APPLICATION HAS JUST PASSED THE CENTER-LINE OF THE FUEL BED. ONLY THAT PORTION OF FIRE-LINE AHEAD OF SPRAY PATTERN STILL IN FLAME.

During the post-spraying period provided the fire was not extinguished, the smoldering and flaming areas were mapped at random time intervals to indicate progression through the now moistened fuels.

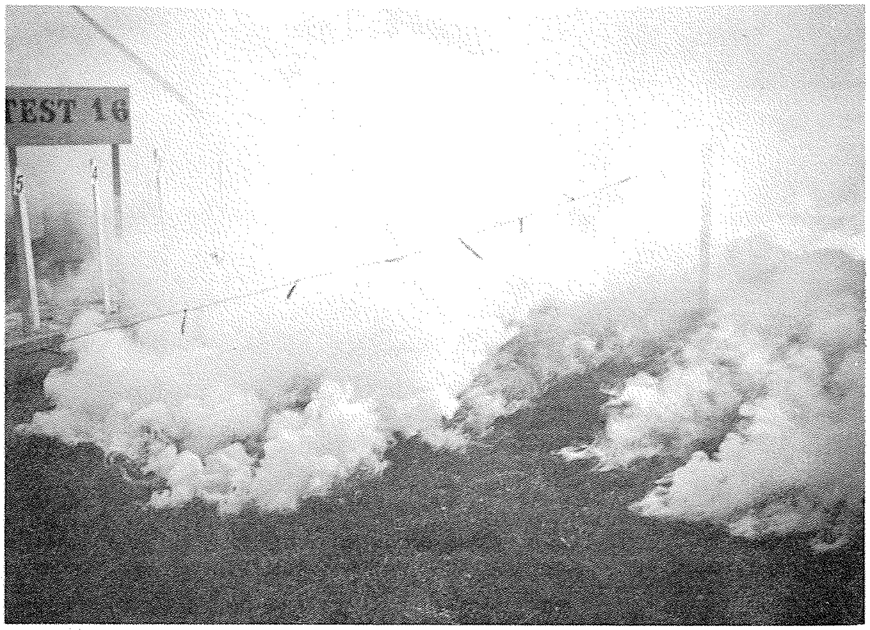


FIGURE 12 SMOKE ISSUING FROM THE FUEL BED 10 MINUTES AFTER WATER APPLICATION (0.05 INCHES ON A FIRE OF 92 BTU/FT/SEC INTENSITY).

A fuel sample was extracted vertically from the center of the bed at St.8 to determine the new fuel moisture content ten minutes after water application. The fires were permitted to burn twenty or more minutes after spraying to indicate the degree of retardation achieved.

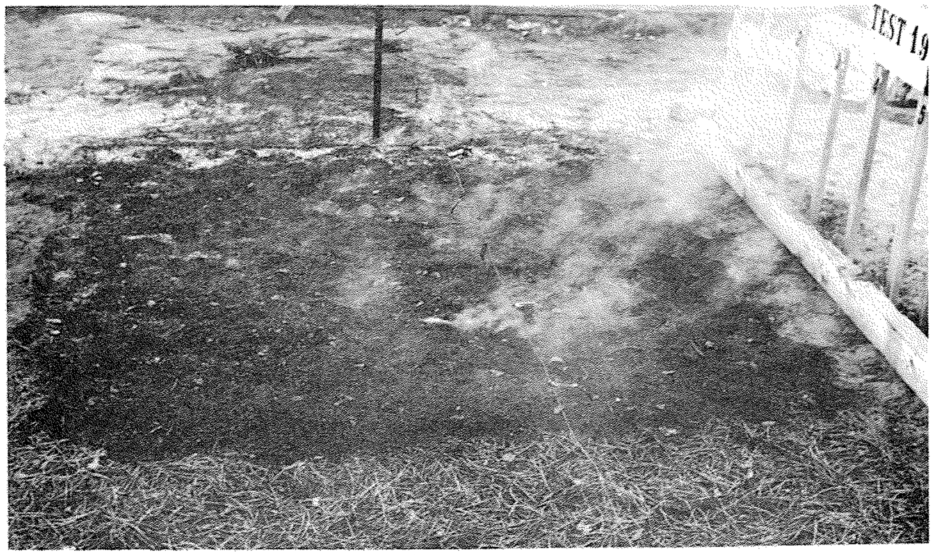


FIGURE 13 AN APPLICATION OF 0.03 INCHES (DEPTH) OF WATER EXTINGUISHED FIRE WHICH BURNED AT AN INTENSITY OF 39 BTU/FT/SEC.

The mean wind velocity during each test was calculated from the revolution count of a Casella sensitive anemometer. A sling psychrometer was used to determine the relative humidity just prior to ignition -- however a continuous record was accumulated by a hygrothermograph in the Stevenson Screen visible in the background in Figure 7.

Water Distribution Measurements

The distribution pattern and the equivalent depth of water applied by each nozzle at each particular trolley speed was determined by nozzle calibration tests.

Test Indications

Thirty-four of the thirty-six tests were successfully executed, however the magnitude of the information compiled has evaded definition. Although reasonable control was maintained over the obvious factors affecting fuel and applied water, other inherent factors were instrumental in distorting the test evidence. The graphical plot (Figure 14) of the amount of applied water versus fire intensity (I) for each test with each point symbolically representing success or failure in attaining extinguishment, denotes the diversity of the results about some undefined optimum combination. Is the relationship linear or is it curvilinear? The number of tests plotted is not sufficient since there is a clustering of points in the low intensity range and a deficiency at the required levels in the upper range.

Considering that moderate surface wildfires may have intensity ratings in the range of 100 to 1000 btu/ft/sec, the tests thus far have been confined to the lowest intensity level and can hardly be used in any extrapolation which could lead to a prediction in the water/fire intensity relationship. The plots in Figure 14 indicate that comparisons between tests for different fuels are not valid due to differences in fuel voidage. The amount of available air within the balsam fir slash beds was much greater than within those of red pine needles therefore fire intensities were substantially greater, however, the water requirements for suppression were much less. Water penetration was three to four times greater through the fir slash than through the pine needles hence the water's extinguishing qualities were enhanced. Wetting to a greater depth was facilitated by increased fuel bed voidage. There is no alternative but to regard each type of fuel as a distinct entity having a different water/fire intensity relationship. This in reality is too fine a breakdown to be of any value in actual field application, however, generalization based on the graphical plots for the various fuels can lead to valid predictions. The best that can be hoped for is a prediction denoting the deviation range in water requirements about some mean curve.

An attempt to define a break even line for the 1969 tests yielded the following relationship:

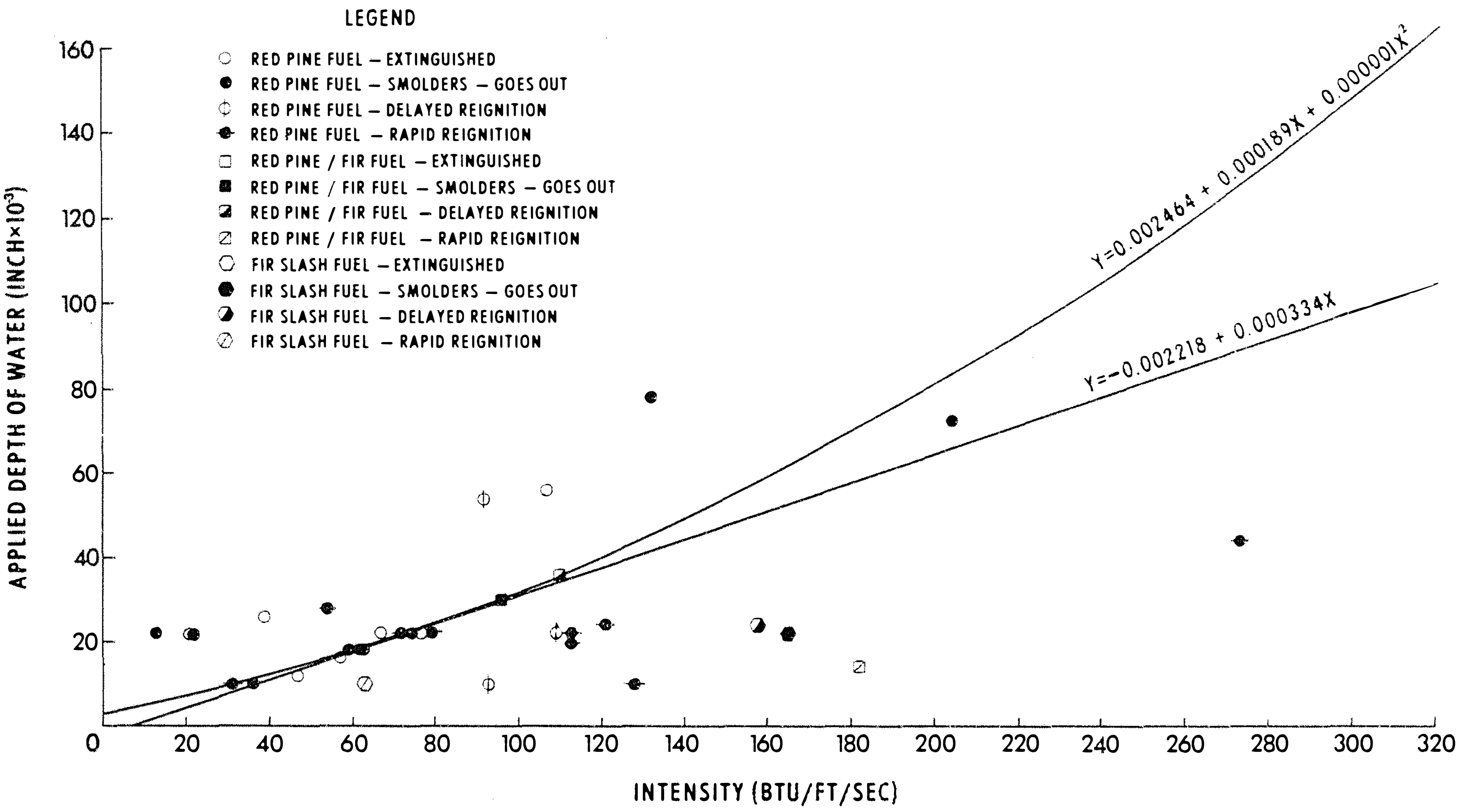
1. If the quantity of water Y varies with fire intensity X linearly, the equation is

$$Y = -0.002218 + 0.000334\ X$$

2. If the relationship is curvilinear

$$Y = 0.002464 + 0.000189\ X + 0.000001\ X^2$$

FIGURE 14 DEPTH OF WATER APPLIED VERSUS FIRE INTENSITY FOR 34 TEST FIRES WITH APPROXIMATE CURVILINEAR AND LINEAR CURVES FOR RED PINE NEEDLE FUEL BEDS ONLY.



Very rarely does one find a single fuel type in existence in a wooded area for generally there is a distinct stratification ranging from compacted duff and litter to small herbaceous plants, and from logging slash to aerial fuels. On having determined the water requirements for each specific level of forest fuel, the overall requirements for a given fuel complex will be a summation of the individual values or some allied value which incorporates some degree of surety. This is where fuel classification comes into play. However, our problem is not interpreting fuel classes and their relevance to our tests but rather relating suppression quantities of water to the fuels most prevalent, hence the need to divert to a wide range of fuels is inevitable.

The higher intensities required to give the graph some latitude may prove excessive for the present simulator set up however this could be readily rectified by extending the legs to nine or more feet. The change in height would necessitate nozzle recalibration.

APPENDIX A

WATER DROP SIMULATION PROJECT F-67

1/4

Test No. __________ Date __________ Time __________

Nozzle: Size __________ No. ______ Pulley Size __________

Trolley Speed: 5 Feet In __________ Seconds, F.P.M. __________

Fuel Moisture:

	Tin No.	M.C. %	Avg. M.C. %
(1) Before Ignition:	______ ______	______ ______	______
(2) 10 Min. After Spraying.:	______	______	______

Wind: No. Revolutions ______ Time ______ Min. ______ Sec.

Speed ______ M.P.H., ______ F.P.S., Rev./Min. ______

Psychrometer Readings: Dry Bulb ______ F, Wet Bulb ______ F

Relative Humidity ______%

Fuel: Type __________

Vol. ______ Ft.^{3}, Air Dry Wt. ____ Lb., O.D. Wt. ______ Lb.

Fuel Bed: Area ______ Ft.^{2}, Depth ______ inch, Width ______ Ft.

Length ______ Ft.

Residual Fuel Bed: Area ______ Ft.^{2}, Length ______ Ft.

Volume ______ Ft.^{3}, O.D. Weight ______ Lb.

Residual Fuel Within Burn Area: Volume ______ Ft.^{3}

O.D. Weight ____ Lb.

Fuel Consumed: Volume ______ Ft.^{3}, O.D. Wt. ______ Lb.

Burn After Spraying:

(1) In Burn Area: Spread Rate ______ inches in ______ Min. ___ Sec.

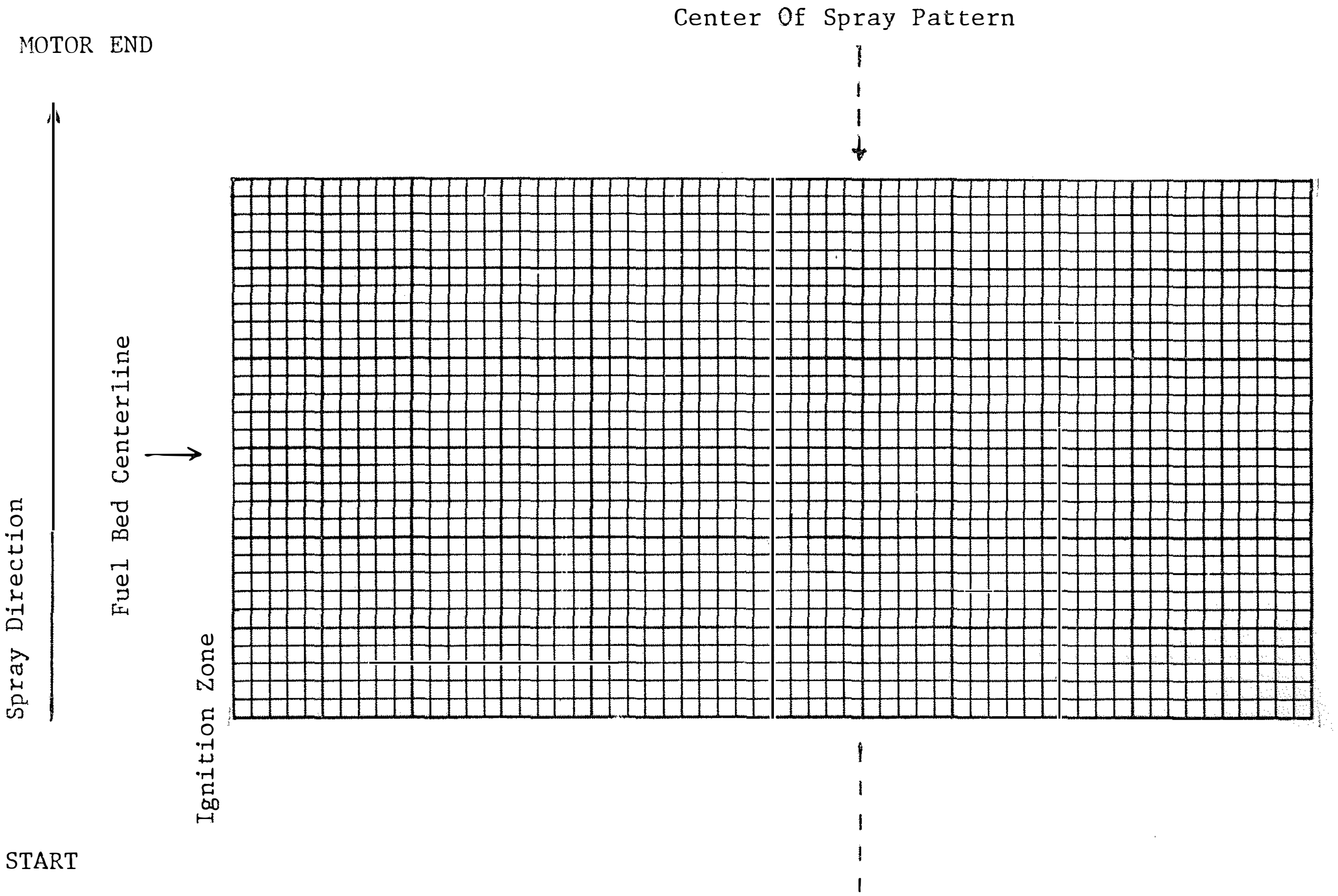
Burned Out Time ______ Min. ______ Sec.

(2) In Unburned Area:

Spread Rate _____ inches in ______ Min. _____ Sec.

Burned Out Time ______ Min. ______ Sec.

Fire Extinguished: ______ Min. ______ Sec. After Ignition.



Station No.	0	1	2	3	4	5	6	7	8	9	10	11	12
Initial (min/sec) Fire Spread													
Flame Height(ft)													
Flame Depth (ft)													
Wind Direction													
Spray Time	XXX	XXXXXX	XXXXXX	XXXXXX	XXXXX	XXXXXX	XXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXX
Smoke Volume													
Water Penet.-(in)													
Sub/Surf.Spread													
Sec/Fire Spread													
Residual Fuel Depth (in)													
Fire Spread Rate F.P.Sec.													
Charred Needle Depth(in)													

Test No. ___________

Remarks:

(1) Before Ignition:

(2) During Burning:

(3) After Spraying:

Water Drop Simulation Project F-67

Test No. ______________________

Heat Yield of Fuel ____________________________________ BTU/LB

Fuel Consumed ____ lb/ft^2

Initial Rate of Spread (Station No. 2 to No. ___) ____________ ft/sec

Fire Intensity ____ BTU/ft/sec

Equivalent Depth of Water Applied __________________________ in

Reignition Time Lapse ___________ min ____________________ sec

Final Rate of Spread (Station No. ___ to No. ___) ____________ ft/sec