Roscommon Equipment Center Program

Project No. 41-B

AN ANALYSIS OF FOAM, LONG AND SHORT TERM RETARDANTS

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Northeast Forest Fire Supervisors

In Cooperation with

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DISCLAIMER

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INTRODUCTION

In recent years many forest fire agencies have used trial and error to determine the effectiveness of new fire chemicals on the market. It appears that tighter budgets have spurred a desire to evaluate or, in some cases, re-evaluate chemicals in order to reduce cost. Some looked to reduce cost by substituting less expensive chemicals for those chemicals they had been using. Others wished to reduce operational costs by substituting chemical use for other suppression methods. Regardless of reason, two trends have clearly resulted:

- Short term retardants have caused considerable interest as one way to reduce the cost of chemicals.

- Attempts to utilize foams have occurred several times in fire control history, but the latest interest is more intensive.

Considerable research and field use has substantiated the effectiveness of long term ammonia salt retardants. Their relatively high cost makes it reasonable to look at less costly alternatives. Before cost can be evaluated, a chemical's performance must be known. Further, the cost must consider needs for special delivery equipment. In fact, the cost and performance evaluation must consider a host of variables of which the following is a partial list:

- Effect upon environment
- Handling and mixing needs
- Flash point of substance
- Fuel types
- Health affect on handlers
- Delivery equipment
- Duration of effectiveness
- Supply logistics
- Weather conditions
- Effective application rate
- Corrosiveness

It becomes obvious that a chemical's effectiveness cannot be judged quickly or by a simple demonstration. Ineffective chemicals, or ineffective application rates, will be costly regardless of the initial volume cost of the chemical.

On June 3-5, 1986, several fire agencies gathered at the Forest Fire Experiment Station in Roscommon, Michigan, to study various categories of fire chemicals. The joint study was carried out by personnel from the Michigan Department of Natural Resources, the Petawawa National Forestry Institute, and the Ontario Ministry of Natural Resources, to evaluate long term and short term retardants, foams, and water. Also involved in the

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demonstration were chemists and sales personnel from various chemical companies, as well as other interested parties. The major objectives of the study were:

A. Compare various categories of fire chemicals in terms of building effective fireline. Categories were long term retardants, short term retardants, foams, and water.

B. Allow equipment developers to “field use” fire chemicals to anticipate equipment needs and costs.

C. Compare the cost of building an effective fireline with various types of fire chemicals.

D. Allow field operation personnel from different agencies to become acquainted, and have first hand experience with controlled fire chemical usage.

TEST METHODOLOGY

Chemical Selection

Representative chemicals used during the trials were selected from several companies. It was decided that two products would represent each chemical group: two long term, two short term, and two foams. Further, “Soapskim,” a paper manufacturing by-product which has received considerable interest from some fire agencies as a possible foaming agent, was included with the chemical foam products. Water served as the control chemical. Table 1 lists the selected chemicals. Time allowed us to include several other foam products; these were not originally chosen or scheduled. They are listed in Table 2.

With the rush by chemical manufacturers to bring foam products to market, changes in formulations have occurred since these tests. What effect these changes have made is anybody’s guess.

Table 1

CHEMICALS ORIGINALLY SELECTED FOR TRIALS

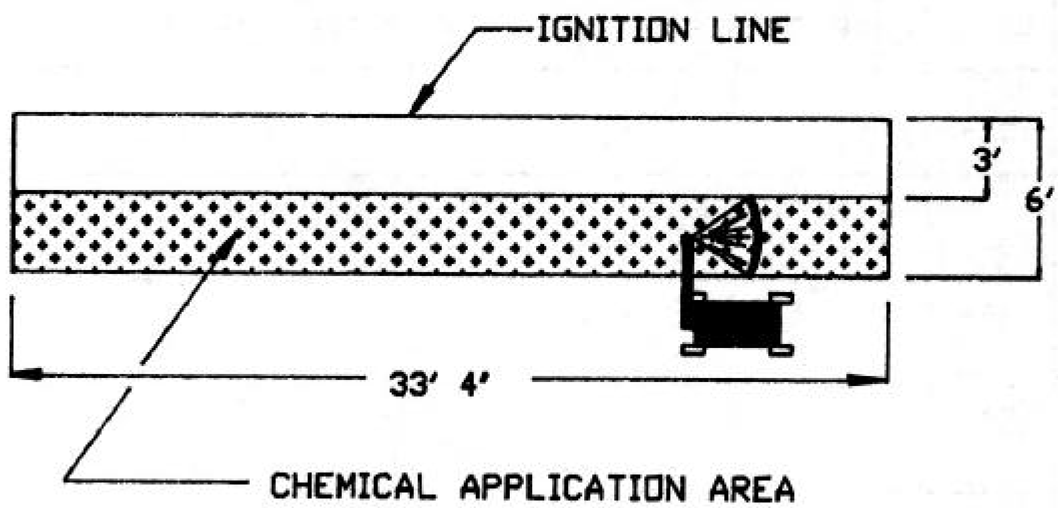
Chemical	Type	Manufacturer
Firetrol 936L	Long Term Ammonia Salt	Chemonics Ind.
PhosChek G75	Long Term Ammonia Salt	Monsanto
Checkmate	Short Term Gelling Agent	Carbontec
Firelock 5000	Short Term Gelling Agent	World Wide Waste, Inc.
Silv-Ex	Foam	Wormald
3M Foam	Foam	3M Canada
Soapskim	Foam	Paper Mfg. Byproduct
Water		

Table 2 CHEMICALS ADDED TO TRIALS DURING TEST WEEK		
Chemical	**Type**	**Manufacturer**
Firetrol Firefoam	Foam	Chemonics
Phos-Chek	Foam	Monsanto
Ansul Regular Protein 3%	Foam	Ansul

Test Plot Construction

A standard plot design was selected for each trial during the outdoor tests. Hay served as the fuel for the plot construction. The hay was all cut at one time from the same field. It had cured approximately eight months. Each hay bale weighed approximately 43 pounds (19.5 KG); one hay bale was spread over each plot. The standard plot dimensions were 6 feet (1.8m) x 33.3 feet (10.1m) or 200 square feet (18.6 sq. m). The fuel depth averaged about 5 inches (13 cm). This resulted in a fuel loading of about 4.7 tons/acre (1,935 kg/hectare). Figure 1 illustrates the typical hay plot, which ran north-south lengthwise.

FIG 1. FUEL PLOT



Chemical Mix Rates

All the chemicals tested were concentrates diluted by water. For the long term and foam chemicals, the mix rates used were those recommended by the manufacturer. The consistency of the short term retardants used in the trials was highly dependent on the mineral content and temperature of the mixing water. Laboratory work was performed to determine proper mix rates for Firelock 5000 and Checkmate, utilizing water from the well at the Forest Fire Experiment Station. The laboratory tests measured the percentage by volume of "ungelled" water in the mix. The water used on test day had a hardness measured by calcium carbonate (CaCo3), of 103 ppm CaCo3. The water temperature used for tests and to determine the mix rate, was 65 degrees F. (18 degrees C.).

Little research has been done to determine the amount of "ungelled water" desirable in the mix. For our work we aimed for 25 percent to 30 percent ungelled water. This was an educated guess, particularly based on a Dow Chemical recommendation for a similar product once marketed by Dow for forest fire use. Gelling agent mix rates is a complex subject that will be addressed in the conclusion. For these trials the mix rates used are shown in Table 3.

Table 3

MIX RATES FOR CHEMICAL TRIALS

Chemical	Type	Mix Rate
Firetrol 936L	Liquid ammonia salt	20% chem. by volume
PhosChek G75	Powder ammonia salt	1.12# Chem./1 gal. H_20
Checkmate	Powdered gel	1# Chem./36 gal. H_20
Firelock 5000	Powdered gel	1# Chem./36 gal. H_20
Silv-Ex	Liquid foam agent	1% Chem. by volume
3M Foam	Liquid foam agent	1% Chem. by volume
Firetrol Firefoam	Liquid foam agent	1% Chem. by volume
Phoschek Foam	Liquid foam agent	1% Chem. by volume
Ansul	Liquid protein foam	3% Chem. by volume
Soapskim	Paper by-product	1.5% Chem. by volume*

* The chemical composition of Soapskim will vary both by paper mill and within the mill process. For fire use Soapskim is typically cut 50 percent with water. This mixture is then mixed at 3 percent in the water tanker. This procedure was used during the trials.

Chemical Application Rates

Each chemical was applied at three different coverage rates. These were 3, 5, and 7 gallons per 100 square feet (this corresponds to 12.2, 20.4, and 28.5 liters/10 sq. meter). These rates were chosen from analysis of data from Roscommon Equipment Center Report #41A. It will be difficult to support ground units with application rates greater than these volumes.[1]

[1] Analysis of Ground Application of Retardants. Roscommon Equipment Center Report #41A, Michigan

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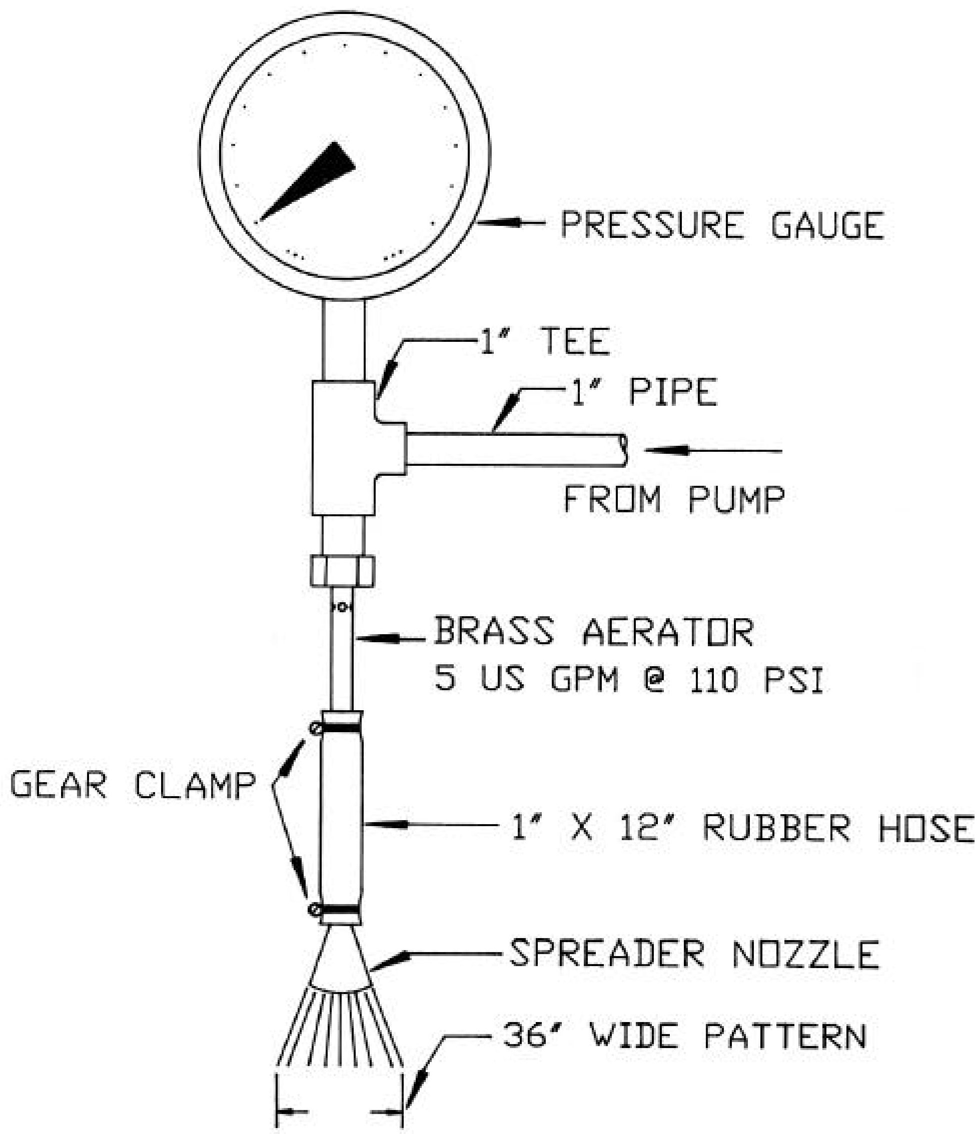
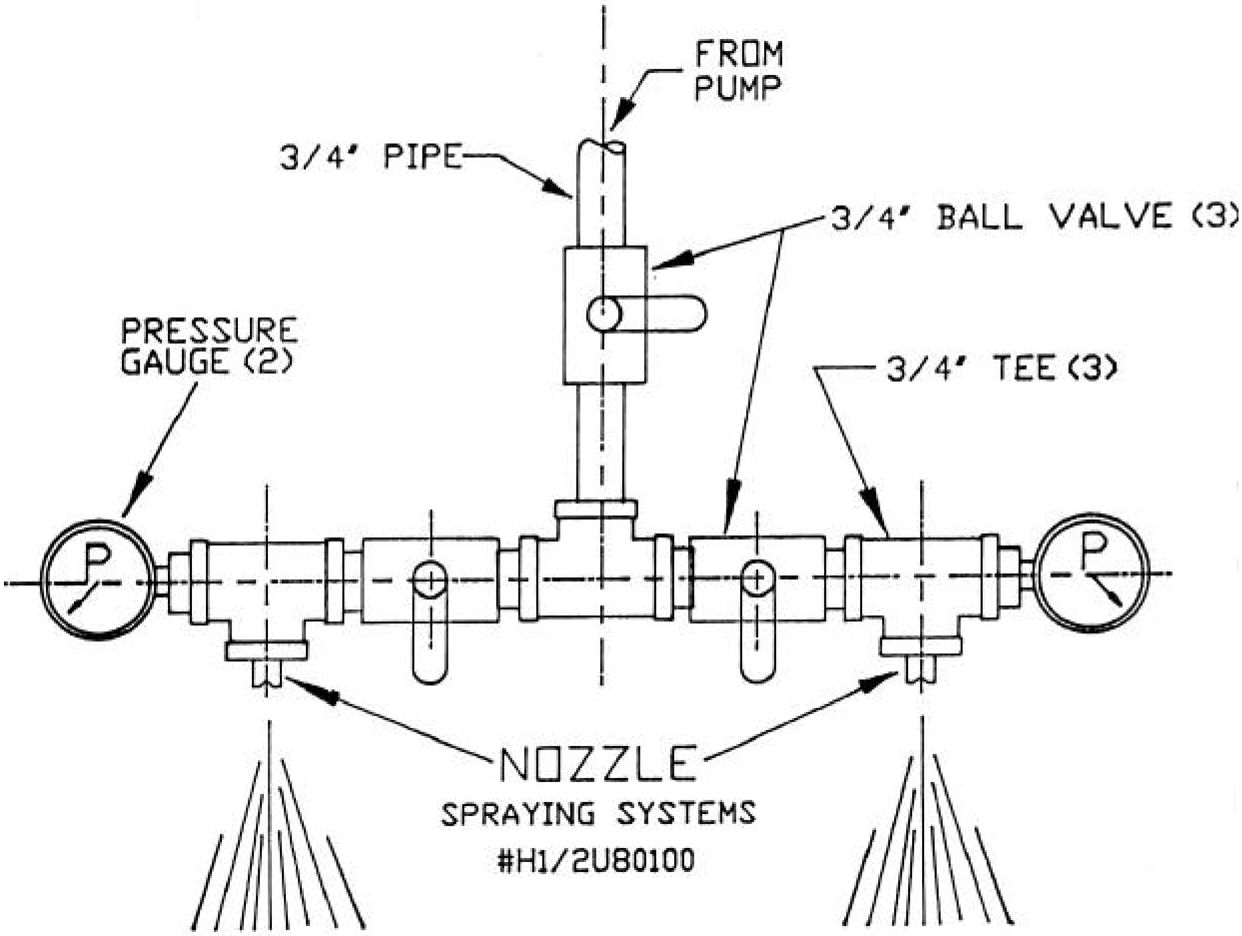
Foams were applied through the use of a prototype 5 U.S. gpm (@110 psi) brass foam aerator as indicated in the diagram. A 12 inch section of rubber hose was used to adapt a spreader nozzle to the foam nozzle, thus providing an even 3 foot spray path. The foam nozzle was calibrated to deliver a known flow rate for any given nozzle pressure, in this case 125 psi to 135 psi. This apparatus was mounted to the front of a garden tractor which had been calibrated to travel at known repeatable speeds. A 100 gallon pre-mix solution was prepared and stored on a truck equipped with a slip-on tanker. The truck system also included a Pacific Pumper Mark III used in pumping the solution to the garden tractor/foam nozzle system. Nozzle pressure was adjusted using a standard water thief. Figure 2 shows the nozzle assembly used.

FIG. 2 FOAM APPLICATION NOZZLE



For the long and short term chemicals, the Forest Fire Experiment Station assembled a nozzle manifold consisting of two Spraying Systems nozzles. Calibration charts were made for each chemical by measuring flow rates at various pressures for one or two operating nozzles. An M-715 4x4 5/4 Ton pickup carried the manifold assembly and the tank and pump. Speeds of the truck were calibrated and charts drawn up so that the amount of chemical application was known. A Wajax-Pacific WGC-4 pump powered the chemical application system. Figure 3 shows the nozzle assembly used.

FIG. 3 – TEST NOZZLE FOR LONG & SHORT-TERM CHEMICALS



Chemical applications were 36 inches (91 cm) wide by 33.3 feet (10.1m) long, placed along the downwind side of the plot. The chemical application area was 100 square feet ($9.3m^2$) of the 200 square foot ($18.5\ m^2$) plot.

Cure Times and Ignition

For each chemical tested, applications were made approximately 45 and 120 minutes prior to ignition. This was defined as the “cure time.” After the assigned cure time was reached, the plot was ignited on the outside edge, burning across the width until reaching the chemical-applied side. The tests were not devised to measure the chemical’s ability in direct suppression. The chemical’s effectiveness was judged by its ability to make fireline.

Table 4 lists the chemicals, with the data and time of application and ignition. On June 3, 1986, and June 4, 1986, the trials were randomized.

Table 4

ROSCOMMON CHEMICAL TESTS – JUNE 1986

		Mix Rate									
		U.S.		Metric		Application Rate		Time			Cure
Plot	Chemical	#/Gal.	Fl Oz/Gal	G/L	mL/L	Gal/100SF	L/10 m^2	Appl	Ign	Day	(Min)
1	Phos G75	1.12		134.22		3.00	12.21	11.02	13.02	6/3	120
2	Silvex		1.28		10.00	7.00	28.49	11.08	13.08	6/3	120
3	Firetrol 936		25.60		200.00	7.00	28.49	11.13	13.13	6/3	120
4	Silvex		1.28		10.00	5.00	20.35	11.18	13.18	6/3	120
5	Firetrol 936		25.60		200.00	5.00	20.35	11.23	13.23	6/3	120
6	Phos G75	1.12		134.22		5.00	20.35	11.30	13.30	6/3	120
7	Silvex		1.28		10.00	3.00	12.21	11.35	13.35	6/3	120
8	Flock 5000	0.03		3.33		5.00	20.35	11.40	13.40	6/3	120
9	Water		0.00		0.00	7.00	28.49	14.10	14.55	6/3	45
10	3M Foam		1.28		10.00	3.00	12.21	14.15	15.00	6/3	45
11	Firetrol 936		25.60		200.00	7.00	28.49	14.20	15.05	6/3	45
12	3M Foam		1.28		10.00	7.00	28.49	14.25	15.10	6/3	45
13	Cmate	0.03		3.33		5.53	22.51	14.50	15.21	6/3	45
14	3M Foam		1.28		10.00	5.00	20.35	14.41	15.26	6/3	45
15	Cmate	0.03		3.33		3.28	13.35	15.12	15.57	6/3	45
18	Firetrol 936		25.60		200.00	3.00	12.21	11.08	13.10	6/4	122
20	Flock 5000	0.03		3.33		3.00	12.21	11.13	13.15	6/4	122
21	Flock 5000	0.03		3.33		7.00	28.49	11.18	13.18	6/4	120
22	Phos G75	1.12		134.22		7.00	28.49	11.26	13.26	6/4	120
23	Cmate	0.03		3.33		7.67	31.22	11.34	13.34	6/4	120
17	3M Foam		1.28		10.00	5.00	20.35	11.47	13.47	6/4	120
19	3M Foam		1.28		10.00	7.00	28.49	11.52	13.52	6/4	120
16	3M Foam		1.28		10.00	3.00	12.21	11.58	13.58	6/4	120
31	Cmate	0.03		3.60		5.53	22.51	12.03	14.03	6/4	120
32	Cmate	0.03		3.60		3.28	13.35	12.08	14.08	6/4	120
24	Water		0.00		0.00	7.00	28.49	14.10	14.56	6/4	46
25	Silvex		1.28		10.00	5.00	20.35	14.15	15.00	6/4	45
26	Flock 5000	0.03		3.33		3.00	12.21	14.20	15.05	6/4	45
27	Phos G75	1.12		134.22		3.00	12.21	14.25	15.10	6/4	45
28	Silvex		1.28	10.00		3.00	12.21	14.30	15.15	6/4	45
29	Firetrol 936		25.60		200.00	3.00	12.21	14.35	15.20	6/4	45
30	Silvex		1.28		10.00	7.00	28.49	14.40	15.25	6/4	45
41	Phos G75	1.12		134.22		7.00	28.49	14.45	15.30	6/4	45
42	Flock 5000	0.03		3.33		7.00	28.49	14.52	15.37	6/4	45
C	Silvex		1.28		10.00	5.00	20.35	14.02	14.47	6/5	45
D	Phos Foam		1.28		10.00	5.00	20.35	14.14	14.59	6/5	45
E	Firetrol Foam		1.28		10.00	5.00	20.35	14.20	15.05	6/5	45
H	3M Foam		1.28		10.00	5.00	20.35	14.31	15.16	6/4	45
K	Water		0.00		0.00	7.00	28.49	14.39	15.24	6/5	45
G	Soapskim		1.92		15.00	7.00	28.49	14.46	15.31	6/5	45
F	Ansul		3.84		30.00	5.00	20.35	14.54	15.39	6/5	45

Weather Data

Because the tests were done outdoors during several days, different burning conditions resulted with each plot. Weather observations were made from 9:00 a.m. to 5:00 p.m., EDT. The chemical applications normally were made from 11:00 a.m. to 3:00 p.m., EDT. Burning occurred from 1:00 p.m. to 4:00 p.m., EDT. General weather data was taken on-site hourly and included:

- Wind speed
- Wind direction
- Relative humidity
- Air temperature
- Ground temperature
- Cloud cover
- 10 hour fuel moisture

Additionally, the oven dry fuel moisture of the hay was measured at every plot at ignition. This was measured for both the chemical applied side and the non-applied side.

The fire weather on June 3, 1986, and June 4, 1986, was generally high with relative humidity low and temperature and sun exposure high. The weather on June 5, 1986, was very damp with early morning rain, low temperatures and overcast skies. Only foam trials were conducted on June 5, 1986. Fire behavior estimate were made using the "**BEHAVE**" fire behavior prediction model developed by the U.S. Forest Service. A fuel model was developed to approximate the hay used during the test. Hourly predictions developed by this model are shown in Appendix A. Fire characteristics estimated by this model include rate of speed, heat per unit area, fireline intensity, flame length, reaction intensity and effective wind speed.

Chemical Delivery and Handling

A subjective analysis of user desirable chemical mixing and handling equipment was made during trials and pretests. These observations are included in the "Conclusion."

Results

Tables A, B, and C, tabulate the results of the trials.

Table A lists the results in chronological order.
Table B lists the results by chemical. (For example, all Firelock 5000 trials are grouped together.)
Table C groups the trials by analyzing the chemical's effectiveness during the trial. Note that the weather on June 5, 1986, resulted in much lower fire indices than on June 3 or 4, 1986.

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Heading abbreviations for the data tables are found in Appendix B.

Figure 4 graphs information gathered from laboratory tests mixing Firelock 5000 gelling agent with water. It shows the relationship between Firelock 5000 powder and the hardness of the mixing water. This information was used to determine the mix rate of the gelling agents during burning tests. **Checkmate samples were not received in time to do similar laboratory work before the tests.**

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Table A

CHEMICAL TEST RESULTS – CHRONOLOGICAL ORDER OF TEST BURNS

		Mix Rate																										
		U.S.		Metric		Application Rate		Time			Cure	Unit Cost		Application Cost		Grd Temp		Air Temp				Wind			Fuel Moistures			SUC
Plot	Chemical	#/Gal	Fl Oz/Gal	G/L	mL/L	Gal/100SF	L/10 m²	Appl	Ign	Day	Min	$US	$Can	$us/100SF	$Can/10 m²	F	C	F	C	RH	Sky	Dir	MPH	KM/Hr	Cont	Ap	10Hr	CD
1	Phos G75	1.12		134.22		3.00	12.21	11.02	13.02	6/3	120	0.48	0.62	1.51	1.83	104	40	65	18	25	CLR	SW	5	8	8.9	N/A	10	3
2	Silvex		1.28		10.00	7.00	28.49	11.08	13.08	6/3	120	N/A	N/A	N/A	N/A	104	40	65	18	25	CLR	SW	5	8	6.5	N/A	10	4
3	Firetrol 936		25.60		200.00	7.00	28.49	11.13	13.13	6/3	120	4.30	5.59	5.02	6.06	104	40	65	18	25	CLR	SW	5	8	6.5	13.6	10	1
4	Silvex		1.28		10.00	5.00	20.35	11.18	13.18	6/3	120	N/A	N/A	N/A	N/A	104	40	65	18	25	CLR	SW	5	8	6.1	21.5	10	1
5	Firetrol 936		25.60		200.00	5.00	20.35	11.23	13.23	6/3	120	4.30	5.59	3.58	4.33	104	40	65	18	25	CLR	SW	5	8	6.1	15.3	10	1
6	Phos G75	1.12		134.22		5.00	20.35	11.30	13.30	6/3	120	0.48	0.62	2.52	3.05	104	40	65	18	25	CLR	SW	5	8	5.5	38.3	10	3
7	Silvex		1.28		10.00	3.00	12.21	11.35	13.35	6/3	120	N/A	N/A	N/A	N/A	112	44	68	20	24	CLR	SW	6	10	6.1	15.4	9.5	4
8	Flock 5000	0.03		3.33		5.00	20.35	11.40	13.40	6/3	120	2.50	3.25	0.35	0.42	112	44	68	20	24	CLR	SW	6	10	5.8	61.8	9.5	3
9	Water		0.00		0.00	7.00	28.49	14.10	14.55	6/3	45	N/A	N/A	N/A	N/A	111	44	69	21	24	TS	S	10	16	5.8	36.9	8.5	3
10	3M Foam		1.28		10.00	3.00	12.21	14.15	15.00	6/3	45	N/A	N/A	N/A	N/A	111	44	69	21	24	TS	S	10	16	6.5	34.6	8.5	4
11	Firetrol 936		25.60		200.00	7.00	28.49	14.20	15.05	6/3	45	4.30	5.59	5.02	6.06	111	44	69	21	24	TS	S	10	16	7.6	20.8	8.5	1
12	3M Foam		1.28		10.00	7.00	28.49	14.25	15.10	6/3	45	N/A	N/A	N/A	N/A	111	44	69	21	24	TS	S	10	16	5.6	32.4	8.5	4
13	Cmate	0.03		3.33		5.53	22.51	14.50	15.21	6/3	45	4.90	6.37	0.75	0.91	111	44	69	21	24	TS	S	10	16	4.9	150.00	8.5	1
14	3M Foam		1.28		10.00	5.00	20.35	14.41	15.26	6/3	45	N/A	N/A	N/A	N/A	111	44	69	21	24	TS	S	10	16	5.5	40.6	8.5	3
15	Cmate	0.03		3.33		3.28	13.35	15.12	15.57	6/3	45	4.90	6.37	0.45	0.54	112	44	70	21	23	TS	SSW	8	13	5.2	95.1	8.5	3
18	Firetrol 936		25.60		200.00	3.00	12.21	11.08	13.10	6/4	122	4.30	5.59	2.15	2.60	120	49	84	29	41	SUN	S	6	10	7.5	14.2	10	2
20	Flock 5000	0.03		3.33		3.00	12.21	11.13	13.15	6/4	122	2.50	3.25	0.21	0.25	120	49	84	29	41	SUN	S	6	10	7.2	71.8	10	4
21	Flock 5000	0.03		3.33		7.00	28.49	11.18	13.18	6/4	120	2.50	3.25	0.49	0.59	120	49	84	29	41	SUN	S	6	10	8.0	106.0	10	1
22	Phos G75	1.12		134.22		7.00	28.49	11.26	13.26	6/4	120	0.48	0.62	3.53	4.27	120	49	84	29	41	SUN	S	6	10	6.7	22.4	10	1
23	Cmate	0.03		3.33		7.67	31.22	11.34	13.34	6/4	120	4.90	6.37	1.04	1.26	120	49	84	29	41	MC	SE	7	11	5.8	60.8	10	3
17	3M Foam		1.28		10.00	5.00	20.35	11.47	13.47	6/4	120	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SE	7	11	6.4	15.9	10	4
19	3M Foam		1.28		10.00	7.00	28.49	11.52	13.52	6/4	120	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SE	7	11	5.6	20.7	10	4
16	3M Foam		1.28		10.00	3.00	12.21	11.58	13.58	6/4	120	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SE	7	11	5.5	18.1	10	4
31	Cmate	0.03		3.60		5.53	22.51	12.03	14.03	6/4	120	4.90	6.37	0.81	0.98	120	49	84	29	41	MC	SE	7	11	6.1	140.0	10	4
32	Cmate	0.03		3.60		3.28	13.35	12.08	14.08	6/4	120	4.90	6.37	0.48	0.58	120	49	84	29	41	MC	SE	7	11	6.7	34.4	10	4
24	Water		0.00		0.00	7.00	28.49	14.10	14.56	6/4	46	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SW	6	10	6.8	69.4	10	3
25	Silvex		1.28		10.00	5.00	20.35	14.15	15.00	6/4	45	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SW	6	10	5.9	57.3	10	2
26	Flock 5000	0.03		3.33		3.00	12.21	14.20	15.05	6/4	45	2.50	3.25	0.21	0.25	120	49	84	29	41	MC	SW	6	10	6.9	130.0	10	2
27	Phos G75	1.12		134.22		3.00	12.21	14.25	15.10	6/4	45	0.48	0.62	1.51	1.83	120	49	84	29	41	MC	SW	6	10	6.9	59.6	10	2
28	Silvex		1.28		10.00	3.00	12.21	14.30	15.15	6/4	45	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SW	6	10	6.6	41.9	10	4
29	Firetrol 936		25.60		200.00	3.00	12.21	14.35	15.20	6/4	45	4.30	5.59	2.15	2.60	120	49	84	29	41	MC	SW	6	10	6.6	59.2	10	1
30	Silvex		1.28		10.00	7.00	28.49	14.40	15.25	6/4	45	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SW	6	10	6.3	79.5	10	2
41	Phos G75	1.12		134.22		7.00	28.49	14.45	15.30	6/4	45	0.48	0.62	3.53	4.27	120	49	84	29	41	MC	SW	6	10	6.7	94.6	10	1
42	Flock 5000	0.3		3.33		7.00	28.49	14.52	15.37	6/4	45	2.50	3.25	0.49	0.59	120	49	84	29	41	MC	SE	3	5	7.1	171.0	10	1
A	Soapskim		1.92		15.00	7.00	28.49	11.25	13.25	6/5	120	N/A	N/A	N/A	N/A	73	23	60	16	68	CLD	E	7	11	13.1	63.6	14	3
C	Silvex		1.28		10.00	5.00	20.35	14.02	14.47	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	9.6	99.0	13.5	2
D	Phos. Foam		1.28		10.00	5.00	20.35	14.14	14.59	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	9.3	126.0	12.5	1
E	Firetrol Foam		1.28		10.00	5.00	20.35	14.20	15.05	6/5	45	15.00	19.50	0.74	0.90	99	37	66	19	53	3OC	ENE	7	11	8.7	76.4	12.5	2
H	3M Foam		1.28		10.00	5.00	20.35	14.31	15.16	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	10.8	65.1	12.5	3
K	Water		0.00		0.00	7.00	28.49	14.39	15.24	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	10.5	56.5	12.5	3
G	Soapskim		1.92		15.00	7.00	28.49	14.46	15.31	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	11.3	43.7	12.5	4
F	Ansul		3.84		30.00	5.00	20.35	14.54	15.39	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	10.0	60.8	12.5	3

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Table B

CHEMICAL TEST RESULTS – GROUPED BY FIRE CHEMICAL BRAND

		Mix Rate																										
		U.S.		Metric		Application Rate		Time			Cure	Unit Cost		Application Cost		Grd Temp		Air Temp				Wind			Fuel Moistures			SUC
Plot	Chemical	#/Gal	Fl Oz/Gal	G/L	mL/L	Gal/100SF	L/10 m²	Appl	Ign	Day	Min	$US	$Can	$us/100SF	$Can/10 m²	F	C	F	C	RH	Sky	Dir	MPH	KM/Hr	Cont	Ap	10Hr	CD
27	Phos G75	1.12		134.22		3.00	12.21	14.25	15.10	6/4	45	0.48	0.62	1.51	1.83	120	49	84	29	41	MC	SW	6	10	6.9	59.6	10	2
1	Phos G75	1.12		134.22		3.00	12.21	11.02	13.02	6/3	120	0.48	0.62	1.51	1.83	104	40	65	18	25	CLR	SW	5	8	8.9	N/A	10	3
6	Phos G75	1.12		134.22		5.00	20.35	11.30	13.30	6/3	120	0.48	0.62	2.52	3.05	104	40	65	18	25	CLR	SW	5	8	5.5	38.3	10	3
41	Phos G75	1.12		134.22		7.00	28.49	14.45	15.30	6/4	45	0.48	0.62	3.53	4.27	120	49	84	29	41	MC	SW	6	10	6.7	94.6	10	1
22	Phos G75	1.12		134.22		7.00	28.49	11.26	13.26	6/4	120	0.48	0.62	3.53	4.27	120	49	84	29	41	SUN	S	6	10	6.7	22.4	10	1
18	Firetrol 936		25.60		200.00	3.00	12.21	11.08	13.10	6/4	122	4.30	5.59	2.15	2.60	120	49	84	29	41	SUN	S	6	10	7.5	14.2	10	2
29	Firetrol 936		25.60		200.00	3.00	12.21	14.35	15.20	6/4	45	4.30	5.59	2.15	2.60	120	49	84	29	41	MC	SW	6	10	6.6	59.2	10	1
5	Firetrol 936		25.60		200.00	5.00	20.35	11.23	13.23	6/3	120	4.30	5.59	3.58	4.33	104	40	65	18	25	CLR	SW	5	8	6.1	15.3	10	1
11	Firetrol 936		25.60		200.00	7.00	28.49	14.20	15.05	6/3	45	4.30	5.59	5.02	6.06	111	44	69	21	24	TS	S	10	16	7.6	20.8	8.5	1
3	Firetrol 936		25.60		200.00	7.00	28.49	11.13	13.13	6/3	120	4.30	5.59	5.02	6.06	104	40	65	18	25	CLR	SW	5	8	6.5	13.6	10	1
26	Flock 5000	0.03		3.33		3.00	12.21	14.20	15.05	6/4	45	2.50	3.25	0.21	0.25	120	49	84	29	41	MC	SW	6	10	6.9	130.0	10	2
20	Flock 5000	0.03		3.33		3.00	12.21	11.13	13.15	6/4	122	2.50	3.25	0.21	0.25	120	49	84	29	41	SUN	S	6	10	7.2	71.8	10	4
8	Flock 5000	0.03		3.33		5.00	20.35	11.40	13.40	6/3	120	2.50	3.25	0.35	0.42	112	44	68	20	24	CLR	SW	6	10	5.8	61.8	9.5	3
21	Flock 5000	0.03		3.33		7.00	28.49	11.18	13.18	6/4	120	2.50	3.25	0.49	0.59	120	49	84	29	41	SUN	S	6	10	8.0	106.0	10	1
42	Flock 5000	0.3		3.33		7.00	28.49	14.52	15.37	6/4	45	2.50	3.25	0.49	0.59	120	49	84	29	41	MC	SE	3	5	7.1	171.0	10	1
15	Cmate	0.03		3.33		3.28	13.35	15.12	15.57	6/3	45	4.90	6.37	0.45	0.54	112	44	70	21	23	TS	SSW	8	13	5.2	95.1	8.5	3
32	Cmate	0.03		3.60		3.28	13.35	12.08	14.08	6/4	120	4.90	6.37	0.48	0.58	120	49	84	29	41	MC	SE	7	11	6.7	34.4	10	4
13	Cmate	0.03		3.33		5.53	22.51	14.50	15.21	6/3	45	4.90	6.37	0.75	0.91	111	44	69	21	24	TS	S	10	16	4.9	150.00	8.5	1
31	Cmate	0.03		3.60		5.53	22.51	12.03	14.03	6/4	120	4.90	6.37	0.81	0.98	120	49	84	29	41	MC	SE	7	11	6.1	140.0	10	4
23	Cmate	0.03		3.33		7.67	31.22	11.34	13.34	6/4	120	4.90	6.37	1.04	1.26	120	49	84	29	41	MC	SE	7	11	5.8	60.8	10	3
16	3M Foam		1.28		10.00	3.00	12.21	11.58	13.58	6/4	120	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SE	7	11	5.5	18.1	10	4
10	3M Foam		1.28		10.00	3.00	12.21	14.15	15.00	6/3	45	N/A	N/A	N/A	N/A	111	44	69	21	24	TS	S	10	16	6.5	34.6	8.5	4
14	3M Foam		1.28		10.00	5.00	20.35	14.41	15.26	6/3	45	N/A	N/A	N/A	N/A	111	44	69	21	24	TS	S	10	16	5.5	40.6	8.5	3
17	3M Foam		1.28		10.00	5.00	20.35	11.47	13.47	6/4	120	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SE	7	11	6.4	15.9	10	4
H	3M Foam		1.28		10.00	5.00	20.35	14.31	15.16	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	10.8	65.1	12.5	3
19	3M Foam		1.28		10.00	7.00	28.49	11.52	13.52	6/4	120	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SE	7	11	5.6	20.7	10	4
12	3M Foam		1.28		10.00	7.00	28.49	14.25	15.10	6/3	45	N/A	N/A	N/A	N/A	111	44	69	21	24	TS	S	10	16	5.6	32.4	8.5	4
28	Silvex		1.28		10.00	3.00	12.21	14.30	15.15	6/4	45	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SW	6	10	6.6	41.9	10	4
7	Silvex		1.28		10.00	3.00	12.21	11.35	13.35	6/3	120	N/A	N/A	N/A	N/A	112	44	68	20	24	CLR	SW	6	10	6.1	15.4	9.5	4
C	Silvex		1.28		10.00	5.00	20.35	14.02	14.47	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	9.6	99.0	13.5	2
25	Silvex		1.28		10.00	5.00	20.35	14.15	15.00	6/4	45	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SW	6	10	5.9	57.3	10	2
4	Silvex		1.28		10.00	5.00	20.35	11.18	13.18	6/3	120	N/A	N/A	N/A	N/A	104	40	65	18	25	CLR	SW	5	8	6.1	21.5	10	1
2	Silvex		1.28		10.00	7.00	28.49	11.08	13.08	6/3	120	N/A	N/A	N/A	N/A	104	40	65	18	25	CLR	SW	5	8	6.5	N/A	10	4
30	Silvex		1.28		10.00	7.00	28.49	14.40	15.25	6/4	45	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SW	6	10	6.3	79.5	10	2
A	Soapskim		1.92		15.00	7.00	28.49	11.25	13.25	6/5	120	N/A	N/A	N/A	N/A	73	23	60	16	68	CLD	E	7	11	13.1	63.6	14	3
G	Soapskim		1.92		15.00	7.00	28.49	14.46	15.31	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	11.3	43.7	12.5	4
24	Water		0.00		0.00	7.00	28.49	14.10	14.56	6/4	46	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SW	6	10	6.8	69.4	10	3
K	Water		0.00		0.00	7.00	28.49	14.39	15.24	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	10.5	56.5	12.5	3
9	Water		0.00		0.00	7.00	28.49	14.10	14.55	6/3	45	N/A	N/A	N/A	N/A	111	44	69	21	24	TS	S	10	16	5.8	36.9	8.5	3
D	Phos. Foam		1.28		10.00	5.00	20.35	14.14	14.59	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	9.3	126.0	12.5	1
E	Firetrol Foam		1.28		10.00	5.00	20.35	14.20	15.05	6/5	45	15.00	19.50	0.74	0.90	99	37	66	19	53	3OC	ENE	7	11	8.7	76.4	12.5	2
F	Ansul		3.84		30.00	5.00	20.35	14.54	15.39	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	10.0	60.8	12.5	3

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Table C

CHEMICAL TEST RESULTS – ORDERED BY SUBJECTIVE SUCCESS OBSERVATION

		Mix Rate																										
		U.S.		Metric		Application Rate		Time			Cure	Unit Cost		Application Cost		Grd Temp		Air Temp				Wind			Fuel Moistures			SUC
Plot	Chemical	#/Gal	Fl Oz/Gal	G/L	mL/L	Gal/100SF	L/10 m^2	Appl	Ign	Day	Min	$US	$Can	$us/100SF	$Can/10 m^2	F	C	F	C	RH	Sky	Dir	MPH	KM/Hr	Cont	Ap	10Hr	CD
11	Firetrol 936		25.60		200.00	7.00	28.49	14.20	15.05	6/3	45	4.30	5.59	5.02	6.06	111	44	69	21	24	TS	S	10	16	7.6	20.8	8.5	1
3	Firetrol 936		25.60		200.00	7.00	28.49	11.13	13.13	6/3	120	4.30	5.59	5.02	6.06	104	40	65	18	25	CLR	SW	5	8	6.5	13.6	10	1
13	Cmate	0.03		3.33		5.53	22.51	14.50	15.21	6/3	45	4.90	6.37	0.75	0.91	111	44	69	21	24	TS	S	10	16	4.9	150.00	8.5	1
5	Firetrol 936		25.60		200.00	5.00	20.35	11.23	13.23	6/3	120	4.30	5.59	3.58	4.33	104	40	65	18	25	CLR	SW	5	8	6.1	15.3	10	1
41	Phos G75	1.12		134.22		7.00	28.49	14.45	15.30	6/4	45	0.48	0.62	3.53	4.27	120	49	84	29	41	MC	SW	6	10	6.7	94.6	10	1
42	Flock 5000	0.3		3.33		7.00	28.49	14.52	15.37	6/4	45	2.50	3.25	0.49	0.59	120	49	84	29	41	MC	SE	3	5	7.1	171.0	10	1
21	Flock 5000	0.03		3.33		7.00	28.49	11.18	13.18	6/4	120	2.50	3.25	0.49	0.59	120	49	84	29	41	SUN	S	6	10	8.0	106.0	10	1
29	Firetrol 936		25.60		200.00	3.00	12.21	14.35	15.20	6/4	45	4.30	5.59	2.15	2.60	120	49	84	29	41	MC	SW	6	10	6.6	59.2	10	1
22	Phos G75	1.12		134.22		7.00	28.49	11.26	13.26	6/4	120	0.48	0.62	3.53	4.27	120	49	84	29	41	SUN	S	6	10	6.7	22.4	10	1
D	Phos. Foam		1.28		10.00	5.00	20.35	14.14	14.59	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	9.3	126.0	12.5	1
25	Silvex		1.28		10.00	5.00	20.35	14.15	15.00	6/4	45	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SW	6	10	5.9	57.3	10	2
26	Flock 5000	0.03		3.33		3.00	12.21	14.20	15.05	6/4	45	2.50	3.25	0.21	0.25	120	49	84	29	41	MC	SW	6	10	6.9	130.0	10	2
30	Silvex		1.28		10.00	7.00	28.49	14.40	15.25	6/4	45	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SW	6	10	6.3	79.5	10	2
27	Phos G75	1.12		134.22		3.00	12.21	14.25	15.10	6/4	45	0.48	0.62	1.51	1.83	120	49	84	29	41	MC	SW	6	10	6.9	59.6	10	2
18	Firetrol 936		25.60		200.00	3.00	12.21	11.08	13.10	6/4	122	4.30	5.59	2.15	2.60	120	49	84	29	41	SUN	S	6	10	7.5	14.2	10	2
E	Firetrol Foam		1.28		10.00	5.00	20.35	14.20	15.05	6/5	45	15.00	19.50	0.74	0.90	99	37	66	19	53	3OC	ENE	7	11	8.7	76.4	12.5	2
C	Silvex		1.28		10.00	5.00	20.35	14.02	14.47	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	9.6	99.0	13.5	2
1	Phos G75	1.12		134.22		3.00	12.21	11.02	13.02	6/3	120	0.48	0.62	1.51	1.83	104	40	65	18	25	CLR	SW	5	8	8.9	N/A	10	3
15	Cmate	0.03		3.33		3.28	13.35	15.12	15.57	6/3	45	4.90	6.37	0.45	0.54	112	44	70	21	23	TS	SSW	8	13	5.2	95.1	8.5	3
6	Phos G75	1.12		134.22		5.00	20.35	11.30	13.30	6/3	120	0.48	0.62	2.52	3.05	104	40	65	18	25	CLR	SW	5	8	5.5	38.3	10	3
9	Water		0.00		0.00	7.00	28.49	14.10	14.55	6/3	45	N/A	N/A	N/A	N/A	111	44	69	21	24	TS	S	10	16	5.8	36.9	8.5	3
14	3M Foam		1.28		10.00	5.00	20.35	14.41	15.26	6/3	45	N/A	N/A	N/A	N/A	111	44	69	21	24	TS	S	10	16	5.5	40.6	8.5	3
8	Flock 5000	0.03		3.33		5.00	20.35	11.40	13.40	6/3	120	2.50	3.25	0.35	0.42	112	44	68	20	24	CLR	SW	6	10	5.8	61.8	9.5	3
24	Water		0.00		0.00	7.00	28.49	14.10	14.56	6/4	46	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SW	6	10	6.8	69.4	10	3
23	Cmate	0.03		3.33		7.67	31.22	11.34	13.34	6/4	120	4.90	6.37	1.04	1.26	120	49	84	29	41	MC	SE	7	11	5.8	60.8	10	3
K	Water		0.00		0.00	7.00	28.49	14.39	15.24	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	10.5	56.5	12.5	3
A	Soapskim		1.92		15.00	7.00	28.49	11.25	13.25	6/5	120	N/A	N/A	N/A	N/A	73	23	60	16	68	CLD	E	7	11	13.1	63.6	14	3
H	3M Foam		1.28		10.00	5.00	20.35	14.31	15.16	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	10.8	65.1	12.5	3
F	Ansul		3.84		30.00	5.00	20.35	14.54	15.39	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	10.0	60.8	12.5	3
7	Silvex		1.28		10.00	3.00	12.21	11.35	13.35	6/3	120	N/A	N/A	N/A	N/A	112	44	68	20	24	CLR	SW	6	10	6.1	15.4	9.5	4
4	Silvex		1.28		10.00	5.00	20.35	11.18	13.18	6/3	120	N/A	N/A	N/A	N/A	104	40	65	18	25	CLR	SW	5	8	6.1	21.5	10	1
12	3M Foam		1.28		10.00	7.00	28.49	14.25	15.10	6/3	45	N/A	N/A	N/A	N/A	111	44	69	21	24	TS	S	10	16	5.6	32.4	8.5	4
2	Silvex		1.28		10.00	7.00	28.49	11.08	13.08	6/3	120	N/A	N/A	N/A	N/A	104	40	65	18	25	CLR	SW	5	8	6.5	N/A	10	4
10	3M Foam		1.28		10.00	3.00	12.21	14.15	15.00	6/3	45	N/A	N/A	N/A	N/A	111	44	69	21	24	TS	S	10	16	6.5	34.6	8.5	4
19	3M Foam		1.28		10.00	7.00	28.49	11.52	13.52	6/4	120	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SE	7	11	5.6	20.7	10	4
32	Cmate	0.03		3.60		3.28	13.35	12.08	14.08	6/4	120	4.90	6.37	0.48	0.58	120	49	84	29	41	MC	SE	7	11	6.7	34.4	10	4
20	Flock 5000	0.03		3.33		3.00	12.21	11.13	13.15	6/4	122	2.50	3.25	0.21	0.25	120	49	84	29	41	SUN	S	6	10	7.2	71.8	10	4
17	3M Foam		1.28		10.00	5.00	20.35	11.47	13.47	6/4	120	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SE	7	11	6.4	15.9	10	4
31	Cmate	0.03		3.60		5.53	22.51	12.03	14.03	6/4	120	4.90	6.37	0.81	0.98	120	49	84	29	41	MC	SE	7	11	6.1	140.0	10	4
16	3M Foam		1.28		10.00	3.00	12.21	11.58	13.58	6/4	120	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SE	7	11	5.5	18.1	10	4
28	Silvex		1.28		10.00	3.00	12.21	14.30	15.15	6/4	45	N/A	N/A	N/A	N/A	120	49	84	29	41	MC	SW	6	10	6.6	41.9	10	4
G	Soapskim		1.92		15.00	7.00	28.49	14.46	15.31	6/5	45	N/A	N/A	N/A	N/A	99	37	66	19	53	3OC	ENE	7	11	11.3	43.7	12.5	4

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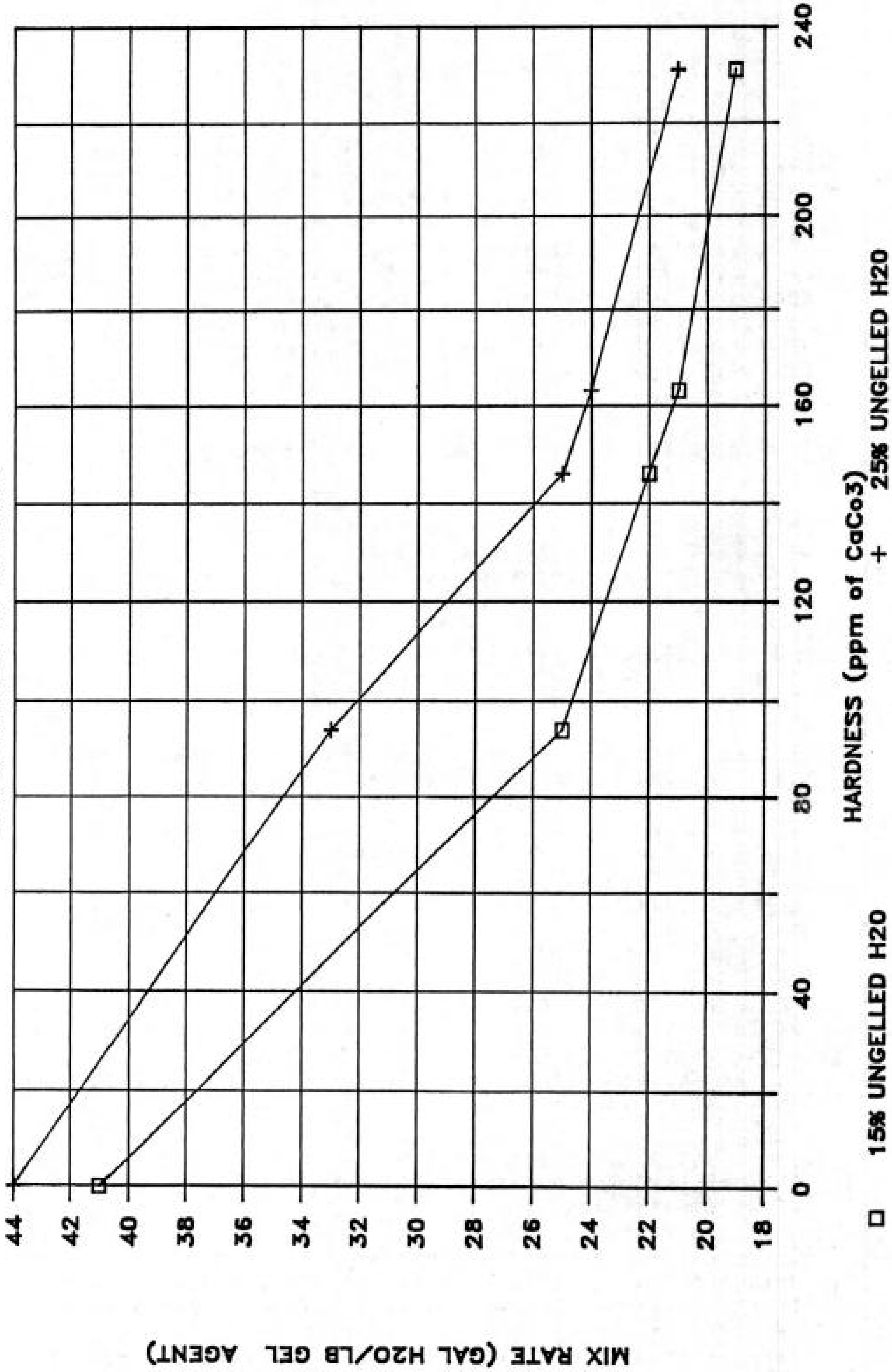
FIG. 4 WATER HARDNESS vs GEL MIX RATE

FIRELOCK 5000 AT 65 DEG. F



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CONCLUSIONS

For several important characteristics, Figure 5 summarizes the advantages and disadvantages of the chemical types tested. The reader is advised not to simply add the scores of the various chemical types shown to come up with the “best” fire chemical. Users should determine which characteristics are most important for their situation, then consider a fire chemical that matches those characteristics. For example, if it is important to create a fireline that will be effective for 2 hours, then foams or water are not good choices. On the other hand, if the user cannot afford special mixing equipment or delivery systems, and has a relatively light fire load, then water or foam through an aerated nozzle may be a better choice. One chemical may not fit all agencies needs.

The following are definitions of characteristics used in Figure 5.

Mixing Equipment – Reflects the need for special equipment to mix the chemical into the water. This score is a subjective measure of the complexity and cost of equipment used for the task.

Special Nozzle – Does the application of the chemical require a nozzle different from the typical forestry nozzle? The measurement looks mostly at the cost of the hardware.

Special Delivery System – Does the use of the chemical require special delivery equipment compared to that normally used on forest fire pumpers that handle plain water? This includes special pumps, compressors, heavy duty fittings or hose; it does not include nozzles.

Chemical Cost – The relative cost of the chemical itself, not including any special delivery system or mixing equipment needs.

2 Hour Effectiveness – Relative measure of the effectiveness of the chemical, based on mix and application rates used in the Roscommon tests. Two hour effectiveness is the measure of a chemical’s ability to hold a fireline 2 hours after the application.

45 Minute Effectiveness – Similar to 2 hour effectiveness: the ability of the chemical to hold a fireline 45 minutes after application.

Corrosion – The corrosive effect of a chemical on normally used materials, especially carbon and galvanized steel (also brass, aluminum or other metals). This includes chemical reaction or abrasion. **The reader should refer to test results conducted by and for the U.S. Forest Service for specific corrosion problems by chemical and material.**

Handling Hazard – A relative measure of precautions needed in order to protect personnel while mixing, using or otherwise handling a chemical.

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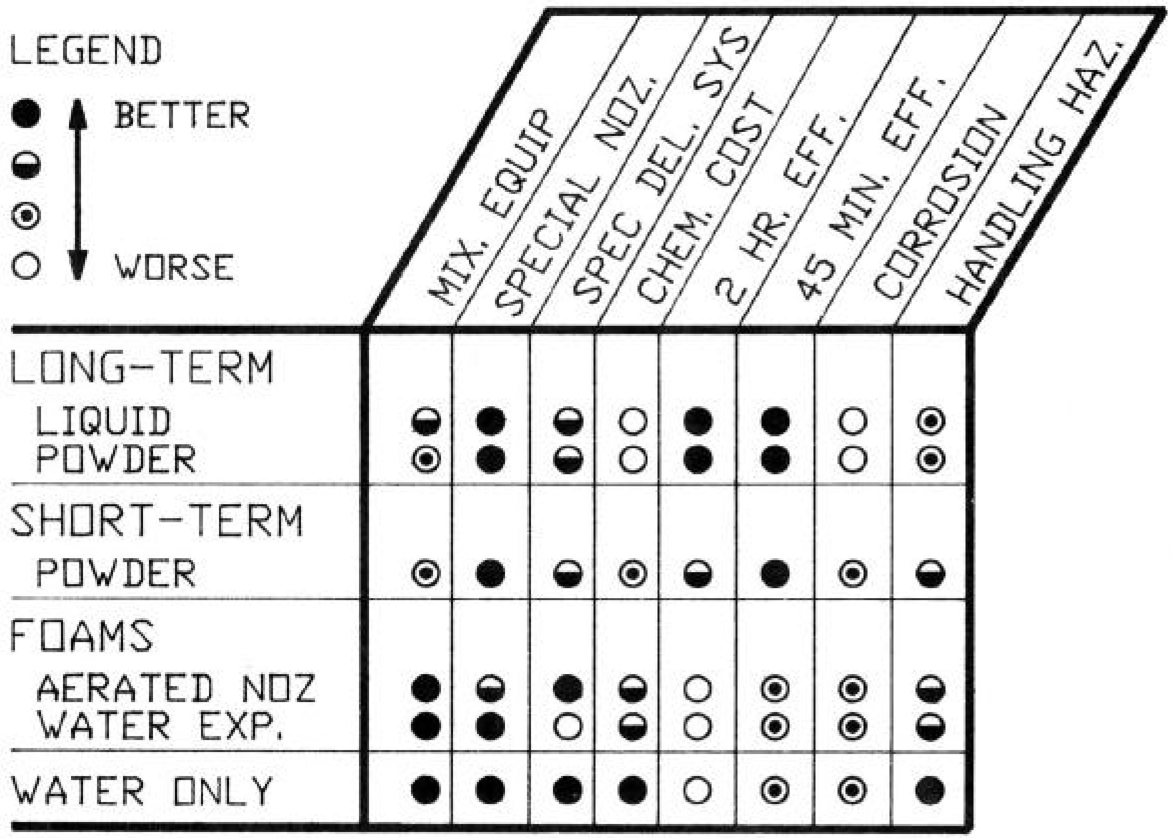
FIG. 5
CHEMICAL TESTS – INTERPRETIVE SUMMARY



The effectiveness of ammonia based retardants is unquestioned. These tests serve to help compare cost of other chemical alternatives to long term retardants and water. The cost of the long term chemicals appears to exceed that of short term chemicals. This conclusion disregards costs for mixers, blenders, corrosion protection and other delivery and handling needs. Special equipment to handle various chemicals outweigh the cost of the chemical itself. Although the chemical cost of the foams is relatively inexpensive, it may not be logistically practical to apply enough foam to compete effectively with other short term or long term chemical on a high fire day. Water appears to be a very close competitor to foams. It would be wise for agencies to analyze their situation thoroughly before committing themselves to foam products. Analysis of each product type follows.

<u>Foams</u>

Trials show that foams may have a brief retardant characteristic. During the test there was little difference between the success of foam applied areas and that of water

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applied areas. In only two trials did the fuel moisture measured at ignition of the foam applied plot significantly exceed the fuel moisture on the control plots applied with water. Other delivery systems and nozzles may have produced a better quality foam.

Foams may allow more absorption of moisture to vertical fuels because foam tends to cling to these fuels longer than water.

Compared to other chemical products, foams are relatively inexpensive.

For ground application, foams will require special nozzles or water expansion systems. No conclusive evidence exists to support that water expansion systems (informally referred to as the “Texas Snow Job”) create more effective foam than foam nozzles.

If foams show meaningful effectiveness utilizing special foam nozzles, the cost of developing or modifying special delivery equipment will not be necessary. On the other hand, the cost of water expansion systems, using compressors and high pressure lines and fittings, will add a significant cost of the use of foam products with ground delivery systems. Except for Soapskim, this study did not evaluate water expansion system (WES) produced foam. Using a WES system may provide a product that “stretches” the user’s water. Foam agent mixtures will also foam during air drops. Some agencies are evaluating foam drops now; air drop application was not part of this study.

The foam products exhibit slightly more corrosiveness than water on mild steel and also pose minimal health hazards to the handler. The user should refer to the material handling data sheets for handling and health considerations.

The logistics involved in using foam are relatively simple. For ground use the chemical can simply be poured in the tank and mixed about 1 percent. Because of the small mix ratio, the need for special mixing systems will be minimal.

Soapskim exhibited poor fire retardant characteristics compared to the wildfire foams. Soapskim’s main advantage, low chemical cost, is outweighed by the need for high cost water expansion equipment to make it foam and special concerns about handling this caustic and nauseous substance.

Foams appear to offer little advantage over water in long term use. They may have merit in making fireline for immediate backfiring. You can see the foam line well and as long as some foam remains on top of the fuels, you can reduce the chance of flash-over. These tests did not judge retardability shortly (less than 45 minutes) after application. On horizontal fuels, do not expect much more retardability than water 45 minutes after application. However, compared to water, a foam may increase absorption of moisture in vertical fuels. This was not measured by our tests.

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Long Term Retardants

Ammonia salt long term retardants have proven their effectiveness both in laboratory and field use for some time. Their chief advantage is that they do not depend on water for their retardability and, hence, when adequate application is made, the retardant can be expected to do its job until washed off. The chief drawback is the relatively high expense. The expense does not stop with the cost of the chemical itself; special equipment is needed for delivery systems. This includes special materials to prevent corrosion (aluminum, fiberglass, stainless steel). Special mixing systems are needed, especially for the powdered types. Health considerations include possible skin irritation and powder inhalation. The logistics of operating ground units with long term retardants is complex. A lot of chemical must be moved in order to support the fire engines. This is simplified with air use by setting up central mixing bases.

Long term ammonia salts are the most effective retardants available, but special mixing and delivery systems, chemical cost and support systems mean high cost. Training is essential; using these chemicals is specialty work. Their effectiveness is not disputed. Cost is the motivator for looking for other alternatives. Roscommon Equipment Center Report #41A compares these retardants versus water in greater detail.

Gelling Agents

Short term retardant gels depend on water to retard fire. Essentially, these agents gel water so it does not readily run off or evaporate. Depending upon the application rate, these short term products can be nearly as effective as long term retardants for a long period. The cost of chemicals to produce an effective line is usually lower than with long term products. The long term effectiveness is dependent on the evaporation rate. Special mixing equipment would be highly desirable when using these chemicals. Presently, no equipment is designed specifically for this use. Current evidence indicates minimal corrosion problems with these chemicals.

As previously noted, the consistency of the gelling agents is affected by the characteristics of the water with which it is mixed. Determining the mix rate is one of the most important considerations when using these products in fire situations. In order to establish the mix rate, the user must decide what percentage of water they wish to gel. Too thick a mixture will be difficult to pump. Too thin a mixture will show little difference from water. For the trials we used an educated guess that the mixture should be 25 percent ungelled water and 75 percent gelled. This was partially determined from suggestions made by the Dow Chemical Company concerning a similar product that they once marketed for forest fire. We also reasoned that it is desirable to have some ungelled water in the mixture to penetrate the fuel initially. The gelled portion would then protect the water from rapid evaporation. Pretrial work makes us believe this was a reasonably good guess, but an in-depth study of this variable was not conducted.

Water temperature and mineral content are two characteristics of the water that greatly affect gelling agents. For various water samples, holding the water temperature at

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about 65 degrees F., known amounts of the gelling agent Firelock 5000 were added to known amounts of water. Water hardness was measured in parts per million of calcium carbonate. A plot was made of the percentage of ungelled water by volume versus mix rate for various water hardness. Some of the results are shown in Figure 4. Because we did not receive the other gelling agent product, Checkmate, until shortly before the tests, we were unable to do the extensive laboratory work that we did for Firelock 5000. During the trials, Checkmate was mixed at the same rates that were used for Firelock 5000; this appeared to be too thick. The thick consistency of the Checkmate gel may have affected the readings on pressure gauges used to set the application rate. The data collected for Checkmate burns show some inconsistencies in performance. These are likely to have been caused by the mix rate problems and its affect on flow rate calibrations.

Another variable affecting the mix rates of the gelling agents is the quickness at which the gel sets up. Some agents gel very fast; some continue to gel over a 15 to 20 minute period. The quick gelling material is more difficult to mix because it does not disperse homogeneously through the water before gelling. On the other hand, a disadvantage of a slower gelling time is that it takes longer to learn if you have a reasonably good mix rate. In fact, one could premix the gel, believe it had good consistency, then find out 15 minutes later that the gel mixture is difficult to pump.

Short term gels appear to pose minimal health hazards. The chemical gel, after applied, can be slippery to walk on and care must be taken, especially on the step surfaces of fire engines. These chemicals provide moderate logistic problems. Mixing is necessary. The amount of chemical that must be supplied to ground units will be determined by the characteristics of water. If used in air drops, some type of mixing station (permanent or portable) will be needed. At permanent mixing bases the water characteristics can be analyzed and mix rates will be easier to determine.

It is difficult to find all the answers on gelling agents. Data is needed on water hardness and temperature versus mix rate. More importantly, we need to establish how much ungelled water is needed for optimal fuel penetration. This is now an unknown. These chemicals could compete with long term products; it would be cheaper to deliver and nearly as effective. At this point there is no good system for determining the best mix rate; without a system, efficient field use will be difficult.

SUMMARY OF NEEDED RESEARCH

The test week helped to clarify differences between long and short term retardants. Much more is known about long term ammonia based retardants than the short term retardants we tested during this project. The U.S. Forest Service and others have done extensive studies concerning the corrosiveness of long term retardants, their effectiveness, and their environmental effect. On the other hand, the gelling agents and

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foams have not undergone much rigorous research evaluation; this will become even more apparent when looking at our list of research needs.

1. Short term retardants depend primarily on affecting fuel moisture. It is important to know the amount of fuel moisture that can be expected at various cure times and for various fuel types. Although the gels and foams may also have some insulating value, the effectiveness of gels, foams and water could largely be determined by a fuel moisture study. A fuel moisture study would be relatively east to control within a laboratory and eliminate many fire behavior variables.

2. Characteristics of the mixing water, such as temperature and hardness, appear to affect the mix rates of gelling agents and foams. It is important to control the mix rate of the gel, but we found this is not easily or quickly determined. For the field user to effectively use gelling agents, fire personnel may have to be supplied with water test kits and laboratory produced charts to decide the correct mix.

3. Most of the research experience in delivering fire chemicals has revolved around air operations. Many attempts have been made in recent years to develop good ground retardant delivery systems. With most effective fire chemicals, the delivery equipment is a major cost. While some gains have been made, research and development will be necessary to design fire engine packages that will meet the needs of the user. It appears that for any given formulation there is a range of water temperatures at which it foams effectively, and some ranges at which it will make poor foam. Fire agencies may need to use cold water from northern lakes in the spring, or warm streams or ponds during the summer. It is quite important to understand these temperature affects.

APPENDIX

Key for Headings for Data Tables

Plot: The plot number or letter assigned to each trial.

Chemical: Several abbreviations are used in the tables: Firelock is abbreviated "FLOCK", Firetrol 9361 is abbreviated "FTROL", Checkmate is abbreviated "CMATE."

Mix Rate: The mix rates are given in both U.S. and metric units. The U.S. gallon equals 4 quarts. For powders the mix rate is given as pounds/chemical per U.S. gallon and grams/chemical per liter of water. Liquid chemicals are given as "FL OZ/GAL" (Fluid ounces per gallon of water) or "mL/L" (milliliters of chemical per liter of water).

Application Rate: Application rates are given as volume of chemical per coverage area of application. These are shown as gallons per 100 square feet "GAL/100SF" or liters per 10 square meters "L/10 m^2."

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Application Time (Time Appl.): The time and hour of day (hours and minutes) the chemical was applied.

Ignition Time (Time Ign.): The time in hours and minutes that the plot was ignited.

Day: The month and date the trial was conducted.

Cure: The time in minutes between time of chemical application to the plot and the time of igniting the plot.

Unit Cost: The cost of 1 pound of powdered chemical (or 1 gallon of liquid chemical) as furnished by the manufacturer. This is given in U.S. dollars; a conversion is also given for Canadian dollars. Conversion used was $1.00 U.S. to $1.36 Canadian, the exchange rate at time of writing. The unit cost does not include shipping; for a true cost assessment, the reader is urged to get up-to-date figures from the manufacturers.

Application Cost: The cost of the chemical in each mixture as applied per 100 square feet. In the metric version this is given as dollars Canadian per 10 square meters. In the U.S. version it is also the actual cost of the chemical applied to the plot, as each plot application was 100 square feet.

Ground Temperature (Grd. Temp): Ground temperature measured to the nearest hour from ignition time of the plot, is given in Fahrenheit and Celsius degrees.

Air Temperature (Air Temp): Temperature of air recorded at nearest hour to ignition time. Given in Fahrenheit and Celsius degrees.

RH: Relative humidity, recorded at nearest hour to ignition.

Sky: The abbreviations here refer to cloud cover recorded at nearest hour to ignition:

CLD	Cloudy
30C	30 percent cloud cover
CLR	Clear
TS	Thin strato clouds
MC	Mostly cloudy

Wind: Three columns show wind data, which gives direction/speed of wind to nearest hour of plot ignition. DIR is direction; MPH is wind speed in miles per hour; KM/HR is wind speed in kilometers per hour.

Fuel Moistures:

CONTL: Control fuel moisture; this is moisture of hay measured just prior to plot ignition.

APPL: Fuel moisture taken from sample of hay on chemically applied side of plot just before ignition.

10HR: The 10 hour fuel moisture as defined from U.S. National Fire Danger Rating System. Measured from fuel sticks at closest hour from point of plot ignition.

Success Code (SUC CD): Interpretation of effectiveness of fire chemical during trial. Success rated as follows:

1. Chemical judged to have made effective fireline for conditions and fuel. No burnover or flashover of any significance shown on applied side of plot.

2. Chemical moderately effective. Less than 25 percent of fuel on applied side was burned.

3. Poor effectiveness. Chemical prevented some applied side fuels from burning; however, there was no significant retardant action in terms of holding line or slowing the fire front. Twenty-five (25) percent to 90 percent of surface fuels on applied side were burned.

4. The chemical action did not retard the fire; in general, the total plot was consumed.

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