

PROBLEMS IN MIXING AND STORAGE OF LONG TERM
FIRE RETARDANTS IN ALBERTA

BY

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Problems in Mixing and Storage of Long Term
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ABSTRACT

Mixing and storage characteristics of Fire-Trol 100 (1-bag and 3-bag product) and Phos-Chek XA long term fire retardants were evaluated by the Canadian Forestry Service and the Alberta Forest Service. There were two phases: (1) laboratory mixing and storage tests at the Alberta Forest Service Depot, Edmonton and (2) field mixing trials at the Edson and Rocky Mountain House retardant bases in Alberta. All retardant slurry samples settled out over the five-month storage period. Viscosity drop was evident in both products; Fire-Trol 100 regained its original viscosity upon remixing, Phos-Chek XA did not. Apparently, after prolonged storage, there is a breakdown in the guar-gum thickener in Phos-Chek XA.

Fire-Trol 100 (3-bag) was used in the field mixing trials. Comparative tests using the Alberta Forest Service batch mixer and Chemonics Industries vertical and horizontal mixers were conducted.

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The trials showed that the Chemonics Industries mixers were under-powered and an impeller of better design and construction similar to the British Columbia Forest Service impeller would improve the shear capabilities of the mixers.

Present recirculation of the large wet inventory stored annually must be improved. This large inventory should be reduced to a minimum to avoid settling-out problems with Fire-Trol 100. Adequate recirculation of all materials in storage is necessary. Quality control cannot be achieved unless the above problems are rectified.

RÉSUMÉ

Des composés d'extinction du feu à effet prolongé, en l'occurrence le Fire-Trol 100 (produits à 1 sac et à 3 sacs) et le Phos-Chek XA, furent évaluées par le Service canadien des forêts et l'Alberta Forest Service pour ce qui concerne leurs caractéristiques de mélange et d'emmagasinement. Il y eut deux phases: (1) tests de mélange en laboratoire et d'emmagasinement au dépôt de l'Alberta Forest Service à Edmonton et (2) des essais de mélange sur le terrain à Edson et Rocky Mountain House en Alberta. Il se forma des dépôts dans tous les échantillons de mixtures durant la période de 5 mois d'emmagasinement. Il y eut une baisse évidente de viscosité chez les deux produits: le Fire-Trol 100 redevint visqueux après remêlage mais le Phos-Chek XA ne le redevint pas; apparemment, après emmagasinage prolongé, l'épaississeur guar-gomme dans le Phos-Chek XA se décompose.

Le Fire-Trol 100 (3 sacs) fut utilisé lors des essais de mélange sur le terrain. Les auteurs conduisirent des tests utilisant le mélangeur en vrac de l'Alberta Forest Service et les mélangeurs vertical et horizontal de Chemonics Industries. Il fut constaté que ceux-ci ne sont pas assez puissants, et un impulseur mieux conçu et mieux construit, semblable à celui du British Columbia Forest Service améliorerait le pouvoir de cisaillement des mélangeurs.

La remise en circulation actuelle des larges stocks de produits mélangés et entreposés annuellement doit être améliorée. Un tel stock doit être réduit au minimum afin de réduire les problèmes de formation de dépôts chez le Fire-Trol 100. Une remise en circulation adéquate des mixtures emmagasinées s'avère nécessaire. Le contrôle de la qualité sera impossible si ces problèmes ne sont pas résolus.

INTRODUCTION

The use of commercial fire retardants by fire control agencies is increasing and involves large expenditures of public funds. In the Province of Alberta, a four-year average shows 261,350 gallons (1,186,529 litres) of retardant slurry are dropped annually. The average cost per gallon freight-on-board aircraft is about \$.60. This cost, combined with tanker base development and maintenance, airtanker operations and personnel presents a staggering sum to fire control managers and ultimately to the public.

Long term fire retardants contain an active chemical which, when applied to forest fuels, alters the combustion process to produce less flammable products while increasing the amount of nonflammable products. Because of this reaction both the fire spread and combustion rate are reduced (George and Blakely, 1972). Chemical formulations used at present in Alberta for these purposes are:

- (1) dry diammonium phosphate powder 21-53-0 (21% nitrogen, 53% phosphorus, 0% potassium), Phos-Chek XA, 259⁴;
- (2) ammonium sulphate powder 21-0-0 (21% nitrogen, 0% phosphorus and potassium) Fire Trol 100⁵; and
- (3) liquid diammonium phosphate 10-34-0 (10% nitrogen, 34% phosphorus and 0% potassium) Fire-Trol 931 & 934⁵.

⁴ Phos-Chek XA, 259 marketed in Canada by Monsanto Canada Ltd., Abbotsford, British Columbia.

⁵ Fire-Trol 100, 931 & 934 marketed in Canada by Chemonics Industries Ltd., Kamloops, British Columbia.

A summary of the retardants; composition, viscosities, mixing procedures and costs is presented in Table 1.

Several problem areas which need to be rectified were encountered at most fire retardant bases in the Province of Alberta. These are:

- (1) Mixers used in mixing the fire retardants are underpowered and have deficient impellers.
- (2) When the fire retardant is stored in slurry form, there is continuous settling out of the product.
- (3) Recirculation of the stored slurry does not mix the settled-out retardant ingredients in the bottom of the storage tank.
- (4) Quality control of the mixed retardant slurry is inconsistent.

This report presents findings regarding the storage and mixing of long term fire retardants, together with suggestions for overcoming problems.

1974

TABLE 1

FLAME INHIBITING (long-term) RETARDANT CHEMICALS

IN USE IN CANADA

Information noted a,b,c etc. applies to all products so marked

As adapted from various sources by the NORTHERN FOREST RESEARCH CENTRE - CANADIAN FORESTRY SERVICE, EDMONTON, ALBERTA

BRAND NAME	COMPOSITION	PERCENT	MIXING RATIO lb/gal water	MIXING RATIO lb/gal soln	MIXED DENSITY lb/gal	VISCOSITY IN CENTIPOISES	SALT CONTENT % by weight in soln	SWELLAGE % BY VOLUME	GAL. SOLN PRODUCED per ton of dry chemical	PACKAGING METHOD	MIXING PROCEDURE	APPLICATION METHOD	STORAGE PROCEDURE	1974 COST 22 TON MINIMUM	REMARKS
PHOS-CHEK XA	(NH ₄) ₂ HPO ₄ DIAMMONIUM PHOSPHATE (ORTHO 21-53-0) GUAR GUM THICKENER IRON OXIDE COLOURING CORROSION AND SPOILAGE INHIBITORS	89 8 1 2	1-37	1-28	10-6	1500-2000	10-6 DAP 5-7 P ₂ O ₅ equivalent	7	1560 (1800-7580) equivalent (1)	-57 lb. bags, continuous flow -1 ton pallets, eductor bulk -batch		aerial	- wet - dry	\$420 ⁰⁰ /ton	(a) Inhibits glowing and flaming comb. Incorporates most superior (b) fire retardant chemical Readily mixed Quality control readily maintained Corrosion inhibited for aluminum, copper, and ferrous alloys, and magnesium Good cohesive properties Viscous solution One-bag product 90-Day wet storage guarantee
PHOS-CHEK 259	AS IN X A ABOVE	94 2 1 3	1-92	1-75	10-9	50-100	15-0 DAP 8-1 P ₂ O ₅ equivalent	10	1140	-continuous flow 50 lb. bags, eductor -batch -agitation		ground	-primarily dry	\$420 ⁰⁰ /ton	(c) Low viscosity for ease of pumping for ground application Higher active salt content than XA -a,b.
FIRE-TROL 100	(NH ₄) ₂ SO ₄ AMMONIUM SULPHATE (21-0-0) ATTAPULGITE CLAY THICKENER IRON OXIDE COLOURING CORROSION INHIBITOR	63-5 35 1 5	3-34	2-78	11-3	1800-2300	15-6 (NH ₄) ₂ SO ₄	20	720	50 lb. bags-batch		aerial	-primarily wet	\$159 ⁰⁰ /ton	Viscous slurry Ammonium sulphate only 2/3 as effective as ammonium phosphate Primarily effective in retarding flaming combustion Economical, but logistically inconvenient One-bag or 3-bag product Mixing procedure slow Mixer horsepower and mixing time critical Abrasive when in motion Sodium dichromate inhibits aluminum 2024 T3 corrosion
FIRE-TROL 931	(NH ₄) ₂ HPO ₄ DIAMMONIUM PHOSPHATE (POLY N 10-34-0 liquid fertilizer) ATTAPULGITE CLAY COLOUR CARRIER AND THICKENER IRON OXIDE COLOURING CORROSION INHIBITOR	93 4 2 1	3-70 4:1 RATIO	2-96 4:1 RATIO	11-0 4:1 RATIO	50-150	15-4 DAP 8-3 P ₂ O ₅ equivalent	0	675 (670 lb/45 gal) (148 lb/gal)	-670 lb/45 gal -bulk -proportioner (blender) -agitation		aerial	-concentrate only	\$177 ⁰⁰ /ton	Non-viscous solution Minimal, and ease of handling "VARIABLENDER" provides improved control of LC and water intake New improved corrosion inhibitor Solution mixed upon discharge from loading pump Polyphosphate reverts to ortho- phosphate during long term storage of L.C. 8-3% P ₂ O ₅ in 10-34-0 is equivalent to 7-5% P ₂ O ₅ in reagent grade DAP In-line thickening agent may be available -a,b.
FIRE-TROL 934	DIAMMONIUM PHOSPHATE (POLY N 10-34-0) CORROSION INHIBITOR	98-7 1-3	3-70 4:1 RATIO	2-96 4:1 RATIO	11-0 4:1 RATIO	50-60	15-8 DAP 8-5 P ₂ O ₅ equivalent	0	675 (670 lb/45 gal) (148 lb/gal)	-670 lb/45 gal -bulk -proportioner -agitation		ground	-concentrate only	\$177 ⁰⁰ /ton	Similar to F.T. 931 but: -no clay content -non-abrasive -colourless -a,b,c.

PHASE I: LABORATORY MIXING & STORAGE TESTS

Objectives

A number of preliminary tests were conducted to determine:

- (1) the effect of mixing time on Phos-Chek XA and Fire-Trol 100 (1-bag product); and (2) the relationships between various salt and clay contents in Fire-Trol 100 (3-bag product) using various mixing time intervals.

Methods

To establish a uniform and consistent mix for fire retardants, tests were conducted to determine:

- (1) Maximum viscosity⁶ obtainable in accordance with manufacturer's recommended quantities of basic ingredients.
- (2) Optimum specific gravity as per U.S.D.A. - Forest Service specifications.
- (3) Effect of temperature increase on specific gravity and viscosity during and after mixing basic retardant ingredients.
- (4) Mixing time required to obtain an optimum viscosity for various retardant concentrations.
- (5) Mixing effect on settling-out and separation of retardant and water.
- (6) Effects of temperature and time on retardants during long term storage under a variety of conditions.

⁶ Viscosity is a measure of the thickness of a solution or the relative ability of a fluid to resist flow. It is measured in centipoises (cps).

The Mixer and Materials Tested

A 1½-gallon (6.8 litres) mixer was designed and manufactured by the Alberta Forest Service equipment development section for the laboratory tests (Figure 1). It is driven by a 1.5 horsepower (11.2 kilowatt hour) electric motor; this horsepower is required to obtain a peripheral impeller velocity of 5,000 feet per minute (1524.4 metres per minute) (Table 2).

The two impeller blades are made of stainless steel, 5 inches (12.7 centimetres) and 5-¾ inches (14.6 centimetres) in diameter, each having 16 fins. Each fin's angle is spot-welded at 12 degrees. This angle produced the best shearing effect on the clay particles of the Fire-Trol 100 retardant.

Two 1½-imperial-gallon (6.8 litres) mixing tanks were manufactured; one round tank 6-¾ inches (17.1 centimetres) in diameter, and one cloverleaf tank 7 inches (17.8 centimetres) outside diameter, and one cloverleaf tank 7 inches (17.8 centimetres) outside diameter and 5-¾ inches (14.6 centimetres) inside diameter at the innermost point.

The 5-inch (12.7 centimetre) diameter impeller produces a peripheral speed of 4458 feet per minute (1359.1 metres per minute). Both tanks were found adequate for the mixing of Fire-Trol 100 and Phos-Chek XA.

Although field mixing tanks are round, the cloverleaf-designed 1½-imperial-gallon (6.8 litres) tank was used for the laboratory tests because it provided reduced mixing time and because some major features of the field mixers could not be duplicated in the laboratory.

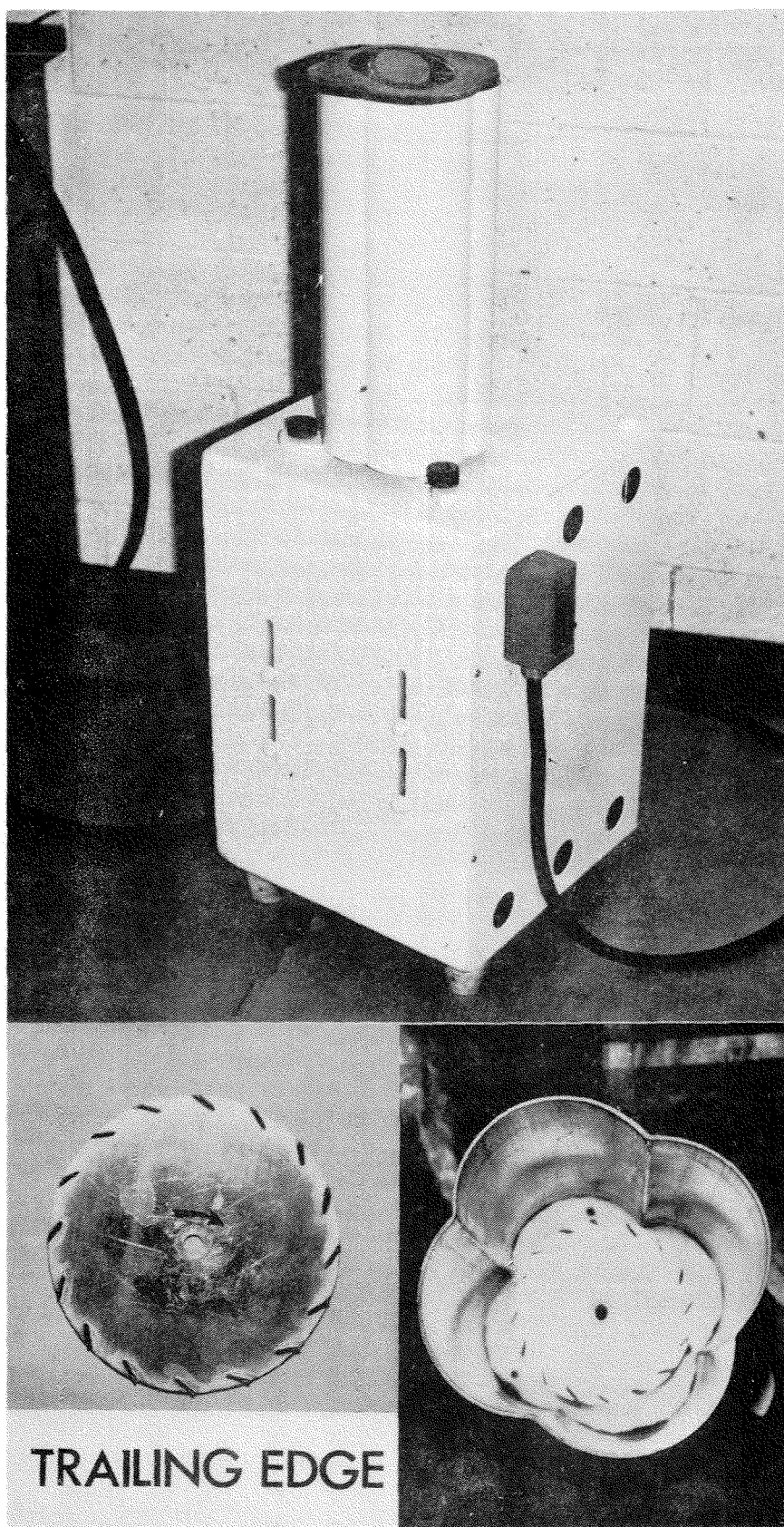


Figure 1. Laboratory Mixer, Impeller Blade and Cloverleaf Designed Tank.

TABLE 2 - REQUIRED PERIPHERAL SPEED OF THE ALBERTA FOREST SERVICE
500 GALLON (2270 LITRES) AND 1½ GALLON (6.8 LITRES) LABORATORY
MIXERS

A.F.S. MIXER 500 GALLON (2270 LITRES)

Impeller Diameter	Engine R.P.M.	F.P.M. Peripheral Speed	Metres P.M. Peripheral Speed
Lely 12 inch (30.5 cm)	1600	5034	1534.8
12 inch (30.5 cm)	1650	5192	1582.9
12 inch (30.5 cm)	1700	5349	1630.8
12 inch (30.5 cm)	1750	5506	1678.7
12 inch (30.5 cm)	1800	5664	1726.8
12 inch (30.5 cm)	1850	5821	1774.7
12 inch (30.5 cm)	1900	5978	1822.6
12 inch (30.5 cm)	1950	6136	1870.7
12 inch (30.5 cm)	2000	6293	1918.6
12 inch (30.5 cm)	2100	6608	2014.6
12 inch (30.5 cm)	2200	6922	2110.4
12 inch (30.5 cm)	2300	7237	2206.4
12 inch (30.5 cm)	2400	7552	2302.4

A.F.S. MIXER 1½ GALLON ELECTRIC (6.8 LITRES)

5 inch (12.7 cm)	3400	4458	1359.1
5-3/4 inch (14.6 cm)	3400	5126	1562.8
5-3/4 inch (14.6 cm)	3350	5051	1540.0

Fire-Trol 100, 1-Bag Packaging

Mixing & Storage

Following the manufacturer's recommended mixing specifications, 3.34 lb of retardant were added per imperial gallon (1.515 kilograms per 4.54 litres) of water⁷. One sample of Fire-Trol was mixed for one-minute periods for a total of three minutes, and during the intervals viscosity, specific gravity (salt content) and slurry temperature were measured (Table 3.)

Results

Temperature in warm storage was 72° (22°C) and cold storage temperatures varied from a high of 45°F (7°C) to a low of -25°F⁸ (-32°C). Viscosity ranged from 3295 cps after one minute of mixing to 5300 cps after three minutes of mixing. Salt content readings for all three samples was 15.6% regardless of mixing time. The viscosity readings showed that the attapulgite clay particles were being over-sheared, a direct result of over-mixing. Mixing time was decreased to 45 seconds with a resulting viscosity of 2600 cps and a salt content of 15.6%. As mixing time increased, retardant temperature increased.

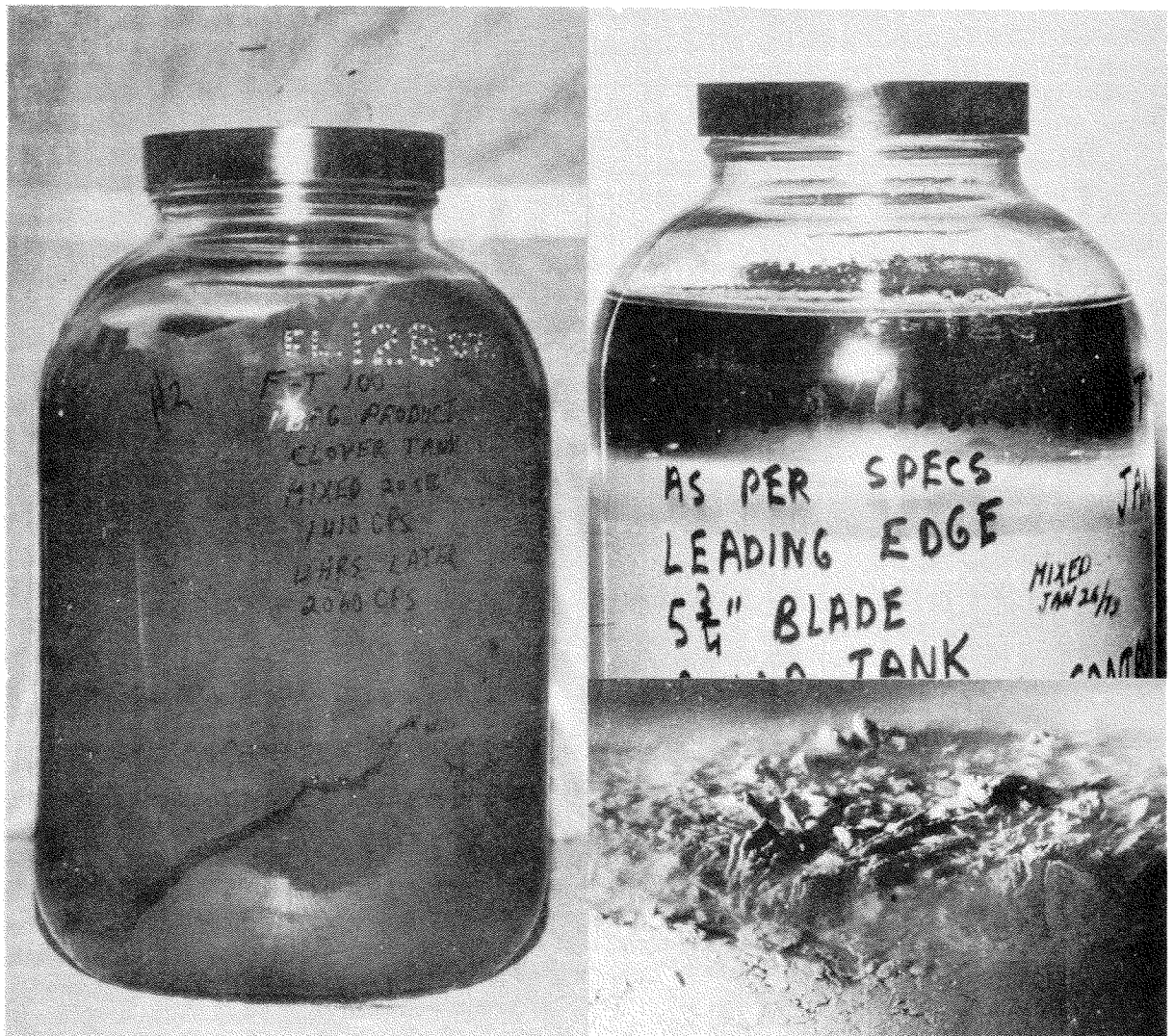
After one month of warm storage no separation or settling-out was evident in the Fire-Trol 100 (1-bag) samples. However, during the second month, a definite separation of the slurry occurred despite monthly agitation (Figure 2). Each month the samples were agitated for one minute in the laboratory mixer to attain a viscosity of 2100 cps. The clay-salt-water combination repeatedly settled out during each

⁷ Water temperature for the laboratory tests was between 53-54°F (11-12°C) (tap water).

⁸ All retardants tested were stored under these conditions.

successive month.

The cold storage Fire-Trol 100 (1-bag) samples showed complete separation of the clay from the salt-water after thawing (Figure 2). After five months in cold storage, the samples were agitated in the laboratory mixer to attain a viscosity of 2100 cps, well within the mixing specifications. Success after complete separation was mainly due to an efficient laboratory mixer plus a smaller sample volume (1 gallon or 4.54 litres).



Warm storage separation.
(Note cracks or fissures
in samples).

Cold storage separation.
(Note complete separation of
clay-salt-water combination
plus close-up of clay particles).

Figure 2. Fire-Trol 100 (1-bag).

TABLE 3. MIXING TEST RESULTS OF FIRE-TROL 100 BY 1 BAG AND 3 BAGS

Fire-Trol 100 ¹	Mixing Time	Viscosity cps	Mixed Retardant Temperature	Specific Gravity & Salt Content (% wt)
1 Bag	1 minute 2 minutes 3 minutes 45 seconds	3295 4495 5300 2600	60°F (16°C) 67°F (19°C) 74°F (26°C) 58°F (14°C)	1.103 15.6 (NH ₄) ₂ SO ₄
3 Bag	15 seconds 20 seconds <u>25 seconds</u> 2 minutes 3 minutes	1200 1500 <u>2200</u> 6500 7000	- - 54°F (12°C) 65°F (18°C) 74°F (23°C)	1.103 15.6 (NH ₄) ₂ SO ₄

¹ All mixes were at a ratio of 3.34 lb of retardant per 1 imperial gallon of water (1.515 kilograms of retardant per 4.54 litres of water). Water temperature (tap water) 53°F (11°C).

Fire-Trol 100, 3-Bag Packaging

Mixing & Storage

Various mixing times were experimented with at the manufacturer's recommended 3.34 pounds of retardant per imperial gallon (1.515 kilograms per 4.54 litres) of water to find the time interval which produced a mix between 1800 - 2300 cps (Table 4). Also, clay content reductions of 19%, 38%, 42% and 47% below manufacturer's specifications were experimented with to see if a more stable Fire-Trol slurry could be produced with viscosities between 1800 - 2300 cps.

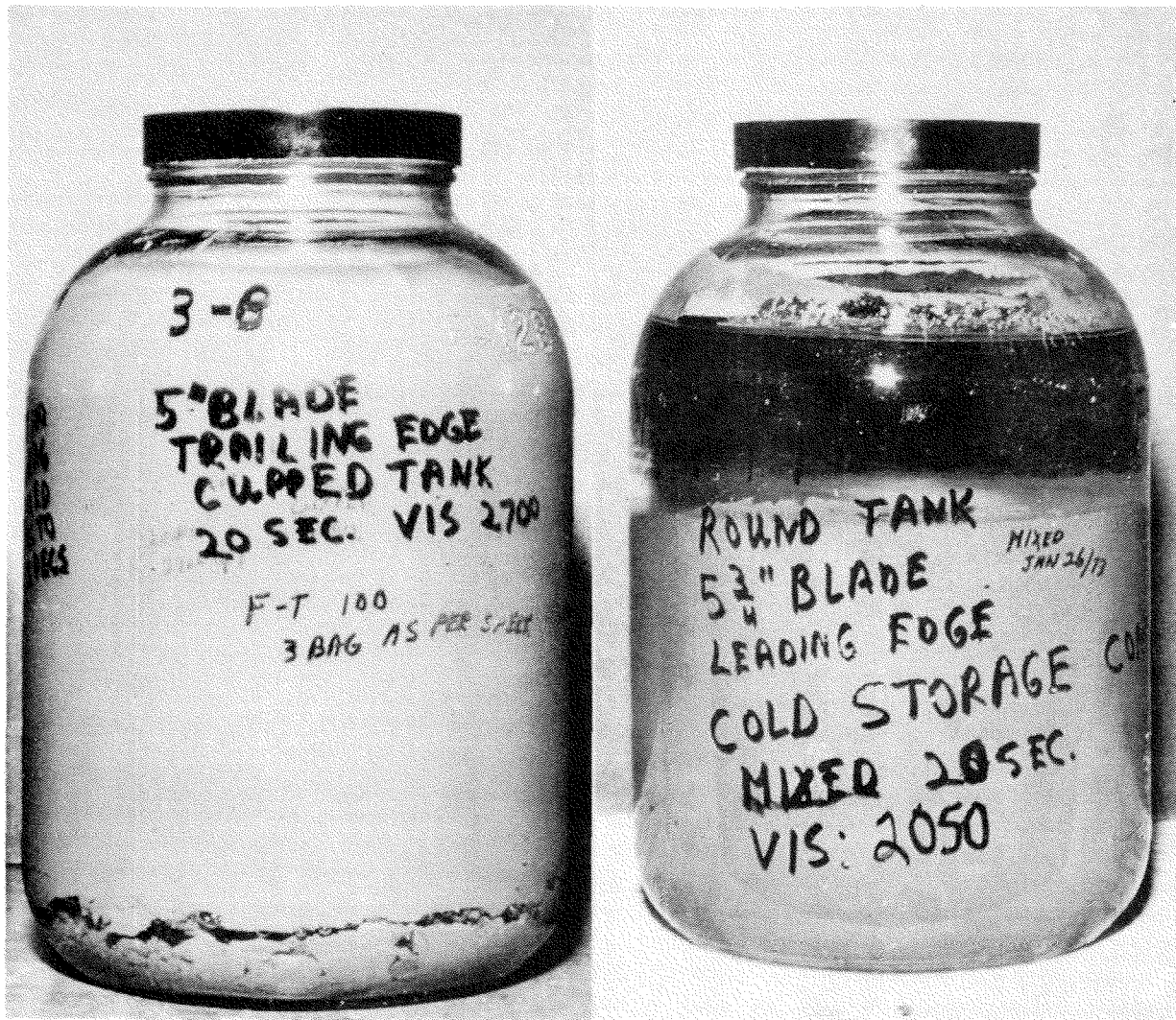
Results

With a reduction in clay content, viscosities similar to the manufacturer's recommended specifications were attained but a longer mixing time was required (Tables 3 & 4). For example, a reduction of 38% clay took 1.5 minutes to produce a mixed slurry of 2050 cps as compared with 25 seconds to achieve a viscosity of 2200 cps at the manufacturer's mixing ratio. Samples mixed according to the manufacturer's specifications showed a substantial amount of unsheared clay particles, whereas in the sample with 38% less clay, small amounts of unsheared clay particles were noted.

Results from the warm storage samples indicated that separation took place in the form of water caverns, fissures and a water filament on top of the retardant. The water caverns and fissures were likely the result of air pockets being formed after mixing, with water settling in these after prolonged storage. The water filament was a direct result of the clay beginning to separate from the salt-water combination (Figure 3). In the samples with less clay, separation took place at a slower rate over the five-month storage period. Each month the samples were agitated in the laboratory mixer for 1 minute; viscosities well

within the acceptable limits (1800 - 2300 cps) were attained.

The cold storage Fire-Trol 100 (3-bag) samples reacted similarly to the Fire-Trol 100 (1-bag) samples (Figure 3).



Warm storage separation.
(Note separation taking place
in bottom of container).

Cold storage separation showing
complete separation of clay-salt-
combination.

Figure 3. Fire-Trol 100 (3-Bag).

Table 4 MIXING RESULTS OF FIRE-TROL 100 BY 3 BAGS

Quantity	Percentage	Mixing	Mixed	Viscosity	Spec. Grav.
Water ¹ and Retardant	Clay	Time	Temp.	cps	and
	Reduction	(min.)			Salt Content
2.12 lbs. (.962 kilograms) salt	19%	1	58°F (14°C)	2200	1.115
.95 lbs. (.431 kilograms) clay		2	64°F (18°C)	3150	17.7%
.05 lbs. (.023 kilograms) dye & inhibitor		2	70°F (21°C)	3650	
3.12 lbs. 1.416 kilograms					
2.12 lbs. (.962 kilograms) salt	38%	0.5	64°F (18°C)	860	1.1115
.73 lbs. (.331 kilograms) clay		1	58°F (14°C)	1660	17.7%
.05 lbs. (.023 kilograms) dye & inhibitor		1.5	62°F (17°C)	2050	
		2	65°F (18°C)	2525	
		8	96°F (35°C)		
2.90 lbs. 1.316 kilograms					
2.12 lbs. (.962 kilograms) salt	42%	8	94°F (34°C)	1860	1.103
.68 lbs. (.309 kilograms) clay		10	103°F (39°C)	2000	15.6%
.05 lbs. (.023 kilograms) dye & inhibitor		12	111°F (44°C)	2050	
2.85 lbs. 1.294 kilograms					
2.12 lbs. (.962 kilograms) salt	47%	0.5	54°F (12°C)	460	1.098
.62 lbs. (.281 kilograms) clay		1	58°F (14°C)	1000	14.8%
.05 lbs. (.023 kilograms) dye & inhibitor		1.5	61°F (16°C)	1260	
		2	67°F (19°C)	1675	
2.79 lbs. 1.266 kilograms					

¹An imperial gallon (4.54 litres) of tap water 53°F (11°C) was used for each batch mixed.

Suspension Characteristics of Attapulgitic Clay

Upon completion of laboratory and field trials (preparation and storage), the properties of attapulgitic clay were briefly investigated to better understand its composition and factors affecting its stability while in suspension.

Attapulgitic, a hydrating clay, belongs to the fibrous group of clays because of its nap-like structure, which is distinctly different from the plate-like structure of clays like bentonite. This characteristic gives attapulgitic increased ability to remain in suspension. Each particle entraps the solvent in which it is suspended, thereby reducing the rate of settling of particles and subsequently improving stability of the suspension (colloidal). Entrapment is not as evident in the plate-like clays. This partially explains the choice of attapulgitic as a retardant thickening agent. Another important reason is the relative ease of mixing it in the presence of a retardant salt compound. Bentonite, on the other hand, will not hydrate in a diammonium phosphate (DAP) solution (Johansen and Shimmel, 1963).

Despite the favorable suspension stability characteristics of attapulgitic it will, like any colloidal suspension, eventually settle out according to Stokes law⁹. Also, introducing an electrolyte like ammonium sulphate or climatic factors such as freezing

⁹ STOKES LAW. The resistance offered by a liquid to the fall of a particle varies with the radius of the particle and not with the surface of the particle. This law is based upon several fundamental assumptions and limitations related to particle and liquid descriptions.

and thawing will augment the rate of settling of particulates¹⁰.

Bacterial decomposition of the clay was not suspected. It was verified by Johansen & Shimmel (1963) that attapulgite clay in mixed storage is not attacked by fungal or bacterial organisms.

Impurities

The Canadian Forestry Service Soils laboratory conducted a series of tests with Fire-Trol 100, both in the dry and slurry states, to define and determine the extent of impurities found in the attapulgite component of this product. The tests were also to determine how silt impurities affect the settling of mixed Fire-Trol 100 slurry.

The presence of ammonium sulphate and iron oxide prevented standard analyses of random dry samples of Fire-Trol 100 (1-bag product) from accurately indicating the percentage composition of sand and silt in the attapulgite component. However, the following acceptable results were obtained from hydrometer analyses of several random samples of raw attapulgite clay:

High total sand/silt content	= 14.8% (by weight)
Low total sand/silt content	= 6.1%

¹⁰ Personal communication with Dr. J. Baker and staff- Soils Research, Northern Forest Research Center, Edmonton, Alberta.

Weighted average total sand/silt content	= 11.0%
Weighted average total sand content	= 4.9%
Weighted average total silt content	= 6.1%
Range of percentage sand content	= 3.1% to 6.0%
Range of percentage silt content	= 3.0% to 8.8%

The test results indicate that the randomly selected 11 attapulgate samples analyzed were not within the limit of acceptability imposed by Chemonics Industries Ltd., i.e. about 7% total impurities (grit content)¹¹.

We feel that the larger and heavier sand and silt particles found in attapulgate clay will fall through a Fire-Trol 100 slurry during extended storage and accumulate at the bottom of the tank. This hampers pumping of the retardant when required, since the discharge outlet on most tanks is about 3 feet (0.91 metres) above the ground level. The rate of descent of these impurities will likely exceed the rate of settling of clay particles and serve to compound problems associated with the settling-out of Fire-Trol 100. Additional or more definitive investigations into this phenomenon would be largely redundant during an era when the use of clay-thickened retardant is being outmoded by alternative retardant compounds with superior qualities and logistical, mixing and storage advantages.

¹¹ Personal communication with Mr. M. Williston - Manager Chemonics Industries Ltd., Kamloops, British Columbia.

Phos-Chek XA

Mixing & Storage

All of the 16 Phos-Chek XA samples were mixed according to the manufacturer's specifications, 1.37 lb of retardant per imperial gallon (.622 kilograms per 4.54 litres) of water. Half of the above mixed samples were set aside as controls. Mixing time was three minutes, with resultant average viscosity of 1650 cps and a salt content of 1.072. Each month, four Phos-Chek samples were agitated with a rod for two minutes, then left for five minutes to permit aeration bubbles to escape. Viscosity was then read. The remaining samples were mixed for one minute in the laboratory mixer and left for ten minutes to allow bubbles to dissipate before viscosity was read.

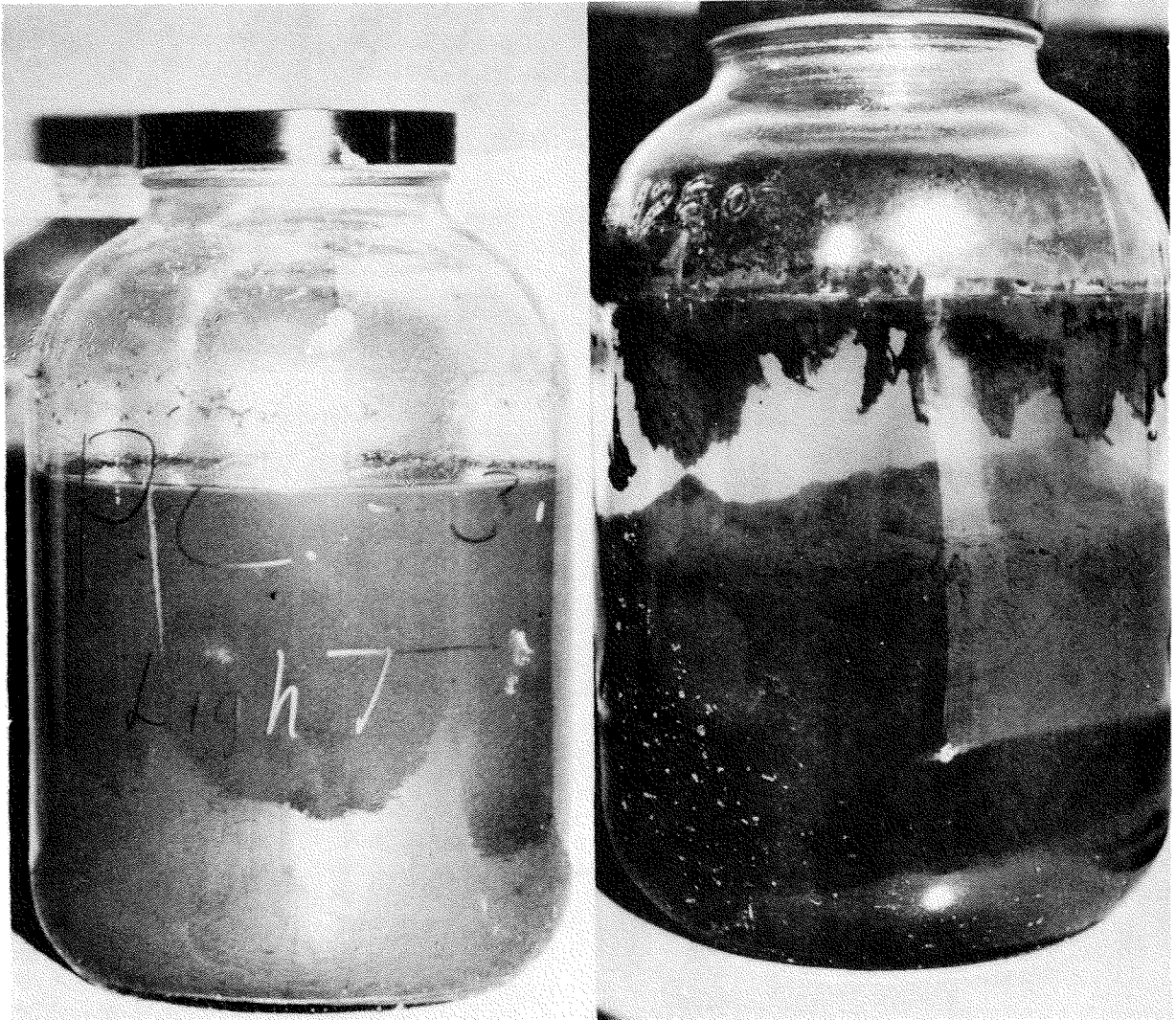
Results

After one month in warm storage, thickener, color and salt had noticeably separated (Figure 4). Also, there was a 24% (400 cps) drop in viscosity that could not be regained even after remixing. Each succeeding month resulted in a more pronounced separation and loss in viscosity until, after the five-month storage period, it dropped from 1650 to 500 cps, a 70% loss. Agitation of the slurry resulted in no viscosity increase. There was a definite degradation of the guar-gum thickener over prolonged warm storage.

All cold storage Phos-Chek XA samples completely separated during the five-month test¹². After they thawed and were remixed, a drop of 24% (400 cps) from the original 1650 cps mix was noted (Figure 4). Viscosity of cold storage samples decreased only 24% compared to a 70% (1150 cps) decrease in warm storage. The reason for this was that no

¹² This observation will be discussed under Phos-Chek Separation.

degradation of the guar-gum thickener took place while the slurry was in a frozen state.



Warm storage separation.

Cold storage separation.
Note complete separation of
gum-salt-water combination.

Figure 4. Phos-Chek XA.

Separation

Phos-Chek separated more slowly in warm and cold storage than did the Fire-Trol 100 samples. This is likely because the guar-gum thickener is more fibrous, thus stabilizing the mixed retardant samples for slightly longer (one month).

We feel that freezing temperatures greatly affect the wet storage of Phos-Chek XA, resulting in the separation of the retardant/water solution.

To check the validity of the above findings more rigorously, Dr. F. H. Wolfe of the University of Alberta conducted a series of tests to investigate viscosity changes as a function of storage temperature.

The following procedure was used:

- A. Phos-Chek XA dry powder was mixed thoroughly with water at a concentration of .32 lb per quart (153.5 grams per litre) of solution. The viscosity of the resulting solution was measured in the Brookfield rotary viscometer.
- B. The freshly prepared solution was divided into three parts, two placed in the freezer at -9°F (-20°C), third placed in cold storage at 39°F (4°C).
- C. After 24 hours one of the frozen samples was thawed, brought to 68°F (20°C) and the viscosity measured.
- D. After three weeks' time the second frozen sample was thawed, brought to 68°F (20°C) and the viscosity measured.
- E. The viscosity of the cold storage sample was also measured, after 24 hours and three weeks of storage.

The results were as follows assuming 100% viscosity on the freshly prepared sample:

	<u>24 hours</u>	<u>21 days</u>
Cold Storage	100%	100%
Frozen Storage	100%	77%

The results confirmed that a physical change and a drop in viscosity had occurred in the Phos-Chek XA solution which was frozen for 21 days.

PHASE II: FIELD TESTS

Objectives

The objectives were to: (1) evaluate stored mixed retardant for quality control, (2) evaluate recirculation techniques used on the stored slurry, and (3) test the effectiveness of the Alberta Forest Service mixer and Chemonics Industries vertical and horizontal mixers with varied quantities of attapulgite clay.

Field tests were conducted at Edson and Rocky Mountain House retardant bases (Figures 5 and 6, respectively) in Alberta.

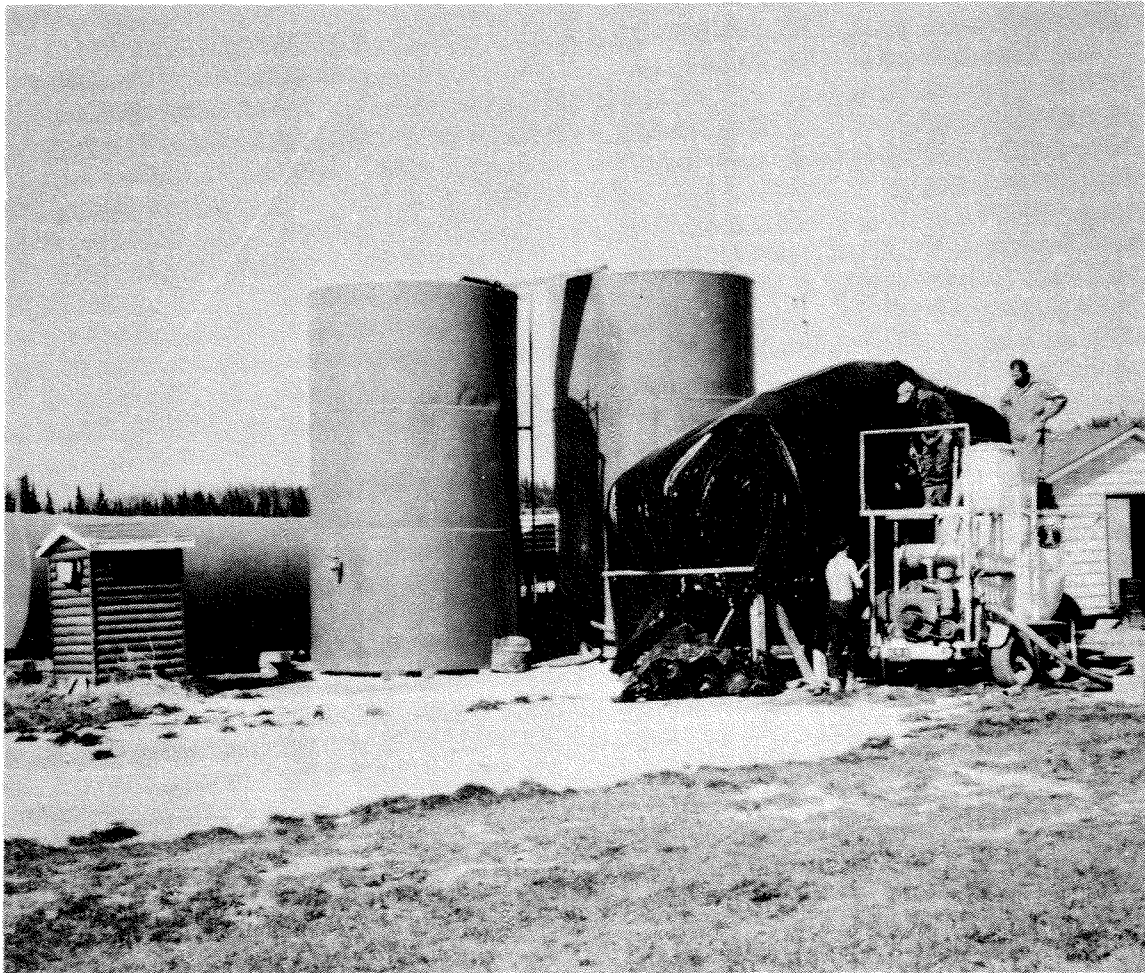


Figure 5. Edson Retardant Base.

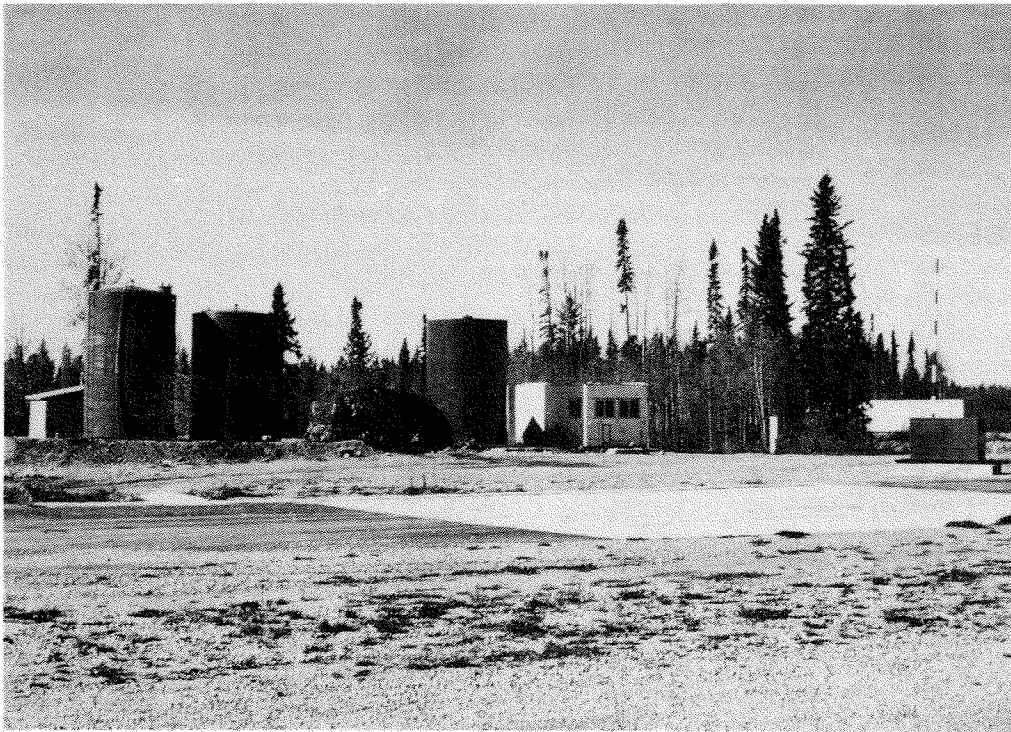


Figure 6. Rocky Mountain House Retardant Base.

Quality of over-wintered retardant

The Edson retardant storage tank contained 7,000 imperial gallons (31,780 litres) of mixed Fire-trol 100 (3-bag product). Throughout the winter months, the slurry was not recirculated (October 1972 to May 1973).

Characteristics of the retardant slurry after over-wintering and before recirculation were measured on samples collected from within the tank by means of a one-inch (2.54 cm) hollow probe rod 25 feet (7.62 metres) in length.

Results

The samples indicated differing degrees of separation at three distinct levels (Figure 7). The top 7.8 feet (2.37 metres) of the mixed slurry was mostly water (no clay) with very little salt remaining in solution. Specific gravity was 1.004 versus the recommended level of 1.101. The viscosity of the slurry at this level was 1 cps, the equivalent of water, since no clay remained in suspension.

The middle 5.7-foot (1.73 metres) layer also had a low specific gravity (1.081) and a viscosity of only 1500 cps (recommended 1800-2300 cps for field application). To bring the specific gravity of the slurry at this interval up to the recommended level, 59 pounds of ammonium sulphate (retardant salt) would be required per 100 gallons (26.79 kilograms per 454 litres) of retardant solution.

The clay and salt which did not remain in suspension in the top 13.5 feet (4.11 metres) were found in the bottom 3.0 feet (0.91 metres) of the tank. This lowest level of mixed slurry was so thick it was impossible to pump the material or obtain a viscosity reading with the modified Marsh Funnel. The specific gravity of the slurry in this layer was 1.175, well above the level recommended for field use.

Effects of Recirculation

Chemonics Industries Ltd. recirculated the 7,000 imperial gallons (31,780 litres) of over-wintered retardant slurry for 4.5 hours. A two-cylinder, three-inch (7.62 cm) trash pump drew the retardant from the discharge outlet and transferred it back into the tank through the top man-hole. After recirculation was completed, the specific gravity was 1.080 and the viscosity was 1030 cps, both well below specifications.

Following the above procedure, a 450-imperial-gallon (2043 litres) batch of recirculated slurry was pumped from the retardant storage tank into the Alberta Forest Service Mixer. This slurry was then mixed for two minutes at 1950 R.P.M. (impeller shaft speed) and subsequently for an additional three minutes and five minutes at 2300 R.P.M. for a total mixing time of ten minutes. Viscosities of 1160, 1275 and 1320 cps were obtained at the two-minute, five-minute and ten-minute intervals respectively. However the optimum viscosity range of 1800-2300 cps could not be attained.

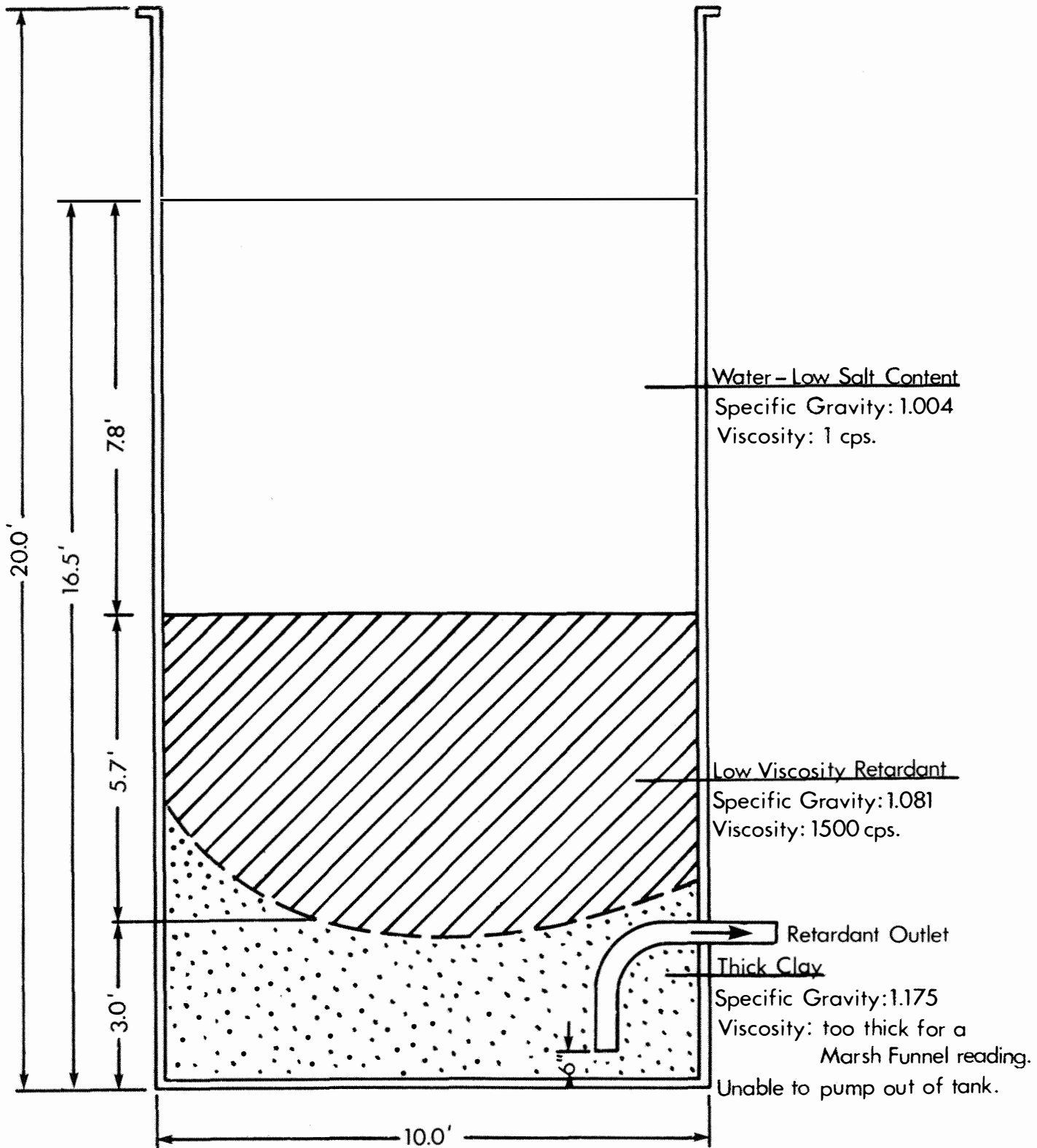


Figure 7. Retardant Storage Tank (Edson)

Mixing Trials

Several experimental 450-imperial-gallon (2043 litres) slurries of Fire-Trol 100 - 3 bag (clay, salt, dye and inhibitor) were mixed using an Alberta Forest Service Mixer and two Chemonics Industries Mixers. All mixers tested used the trailing edge of the impeller blade for mixing the retardant (Figure 1). An Alberta Forest Service retardant meter (Figure 8) was used to assure that proper quantities of water were added to each load mixed. The A.O. Smith model 5.28 meter with positive displacement, 3-inch (7.62 cm) kamlok fittings has a maximum capacity of 230 imperial gallons (1044.2 litres) per minute at a maximum pressure rating of 150 P.S.I. (6.1 g/sq cm). It has an accumulation register of 7 figures and an individual load register of 5 figures.

The meter must be installed 10 (± 1) feet (3.04 metres) from the pump with flexible hard 3- or 4-inch (7.62 or 10.16 cm) suction hose between the pump discharge and meter intake. The hose acts as a pressure dome to relieve any sudden shock loads, which occur whenever the loading valve is closed instantly while the pump is operating at full capacity. The meter should be placed in the upright position and be parallel with the intake and discharge lines. A one-way flow valve (check valve) was installed on the discharge side of the meter to prevent any fluid backup from the aircraft loading valve to the meter. Without this the flow meter could reverse, showing negative meter readings.

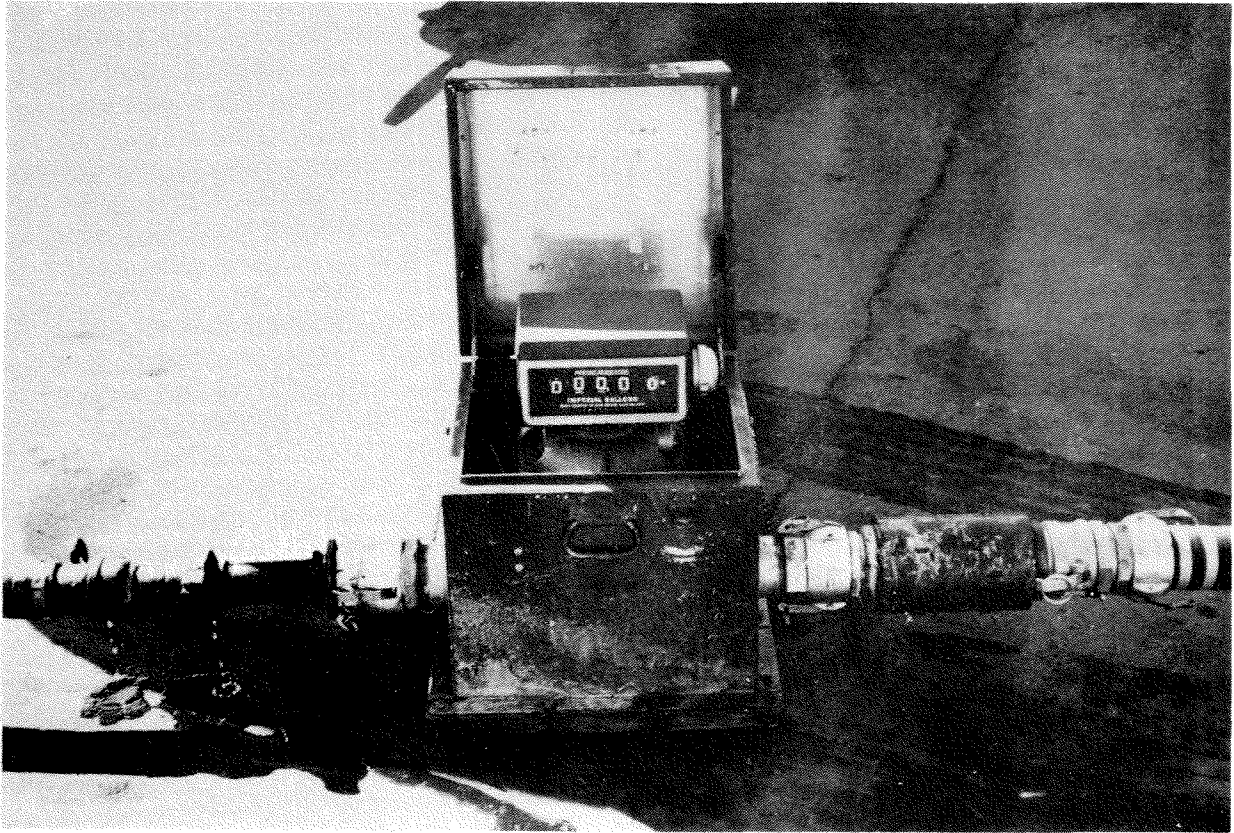


Figure 8. Alberta Forest Service Retardant Meter.

Characteristics of Mixers

The A.F.S. Mixer is powered with a 307 C.I.D. (5032 cc) V8 G.M.C. engine and has a model 435 CR Transmission connected to the impeller shaft (Figure 9).

It is possible to obtain 2300 engine R.P.M. with the 307 (5032 cc) G.M.C. engine, which results in 7237 R.P.M. (2206.4 metres per minute) peripheral speed on the 12-inch (30.48 cm) diameter impeller. With this horsepower the mixer could remain shut off until all of the retardant ingredients were added.

To obtain 5000 R.P.M. (1524.4 metres per minute) peripheral speed on the impeller, the engine must turn at 1600 R.P.M. with the transmission in direct drive (4th gear).

The A.F.S. Mixer, skid mounted, has the pump mounted beside the 307 (5032 cc) G.M.C. engine. A two-cylinder Wisconsin engine, Model TJD powers the pump.

All plumbing suction and discharge are four-inch (10.16 cm), although the pump is only three-inch (7.62 cm). These larger diameter lines increase pumping efficiency over the length of lines (storage tank to aircraft loading line) required to load aircraft.

Chemonics Industries Ltd. have two types of Fire-Trol 100 mixers:

1. Vertical Tank Mixer (Figure 10)
2. Horizontal Tank Mixer (Figure 11)

Tests were conducted with the vertical tank model in Edson and the horizontal tank model in Rocky Mountain House.

Power for the mixer and pump on both mixers is a Wisconsin engine model V465B-177 cubic inch displacement - 65 horsepower (2900 cc engine-48.490 kilowatt hours).

Maximum R.P.M. obtained when mixing Fire-Trol 100 was 1650 with the vertical mixer and 2000 R.P.M. with horizontal model.

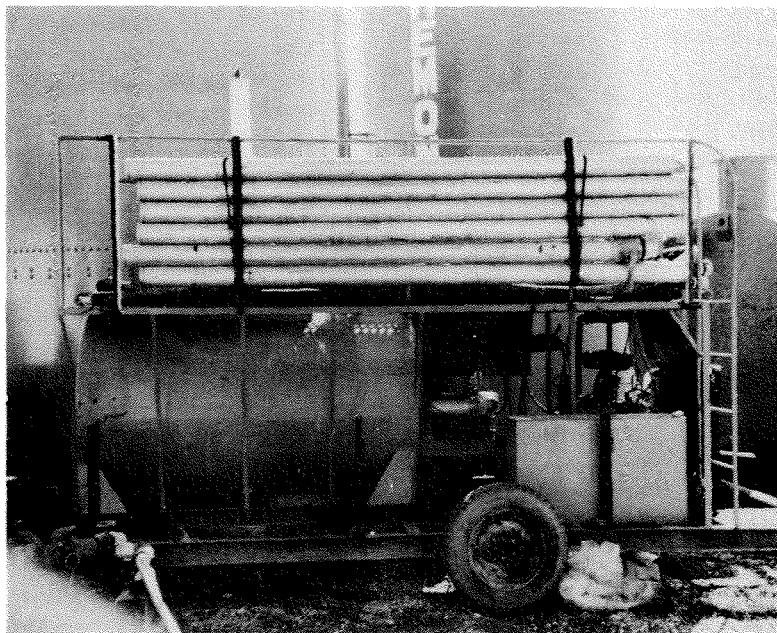


Figure 9. Alberta Forest Service Mixer.

Mixing Techniques

The standard procedure for mixing Fire-Trol 100 retardant was followed. Two minutes is required to complete each of the following:

1. adding 375 imperial gallons (1702.5 litres) of water
2. adding each of the retardant ingredients (in order of clay, dye and inhibitor, and salt) into the mixer, and
3. pumping the mixed slurry out of the mixer (note that there is 20% swellage in all Fire-Trol 100 mixes).

Mixing times and clay quantities were varied to try to produce an improved retardant slurry within the 12 minutes of efficient mixing time allotted by the manufacturers on an operational basis.

Results

Using six bags of attapulgite clay, the Alberta Forest Service mixer can provide the desired viscosity between 1800 and 2300 cps within the allotted 12 minutes. Table 5 shows that a viscosity of 1900 cps was achieved in eight minutes, using six bags of clay. An additional bag of clay was added and the 450 gallons (2043 litres) of slurry were mixed for five minutes more, giving 2420 cps (total mixing time of 13 minutes plus six for adding water, ingredients and pumping the slurry from the mixer; total: 19 minutes).

Using seven bags of clay (Table 5) and mixing for three- and two-minute sequences (total of five minutes), viscosities of 2264 and 2708 cps were achieved. In three minutes a good retardant slurry was produced which was well within an efficient operational mixing schedule. At present, Chemonics Industries Ltd. is using eight bags of clay (400 lb) per 450 gallon (181.6 kilograms per 2043 litres) slurry mix, which is 1.7 bags less than their suggested mixing ratio specification of 35% attapulgite clay. A sample batch prepared with this latter amount mixed for three minutes

resulted in a viscosity of 2140 cps (Table 5). Using seven bags for three minutes, a reading of 2264 cps was achieved. Upon checking several operation batch mixes with the experimental mixes we felt that with the extra bag of clay added, the clay particles are not sheared adequately, mainly because of the time factor; thus, a lower viscosity. After mixing the test batch for an additional three minutes, the viscosity achieved was 2660 cps. This is still less than the 2708 cps achieved using seven bags of clay for five minutes.

Mixing Technique

The same procedure employed with the Alberta Forest Service mixer was followed, except that the Chemonics' impeller blade had to be rotating while the clay-salt combination was added.

This requirement poses no problem, because during normal field mixing operations a batch mixer is running continuously.

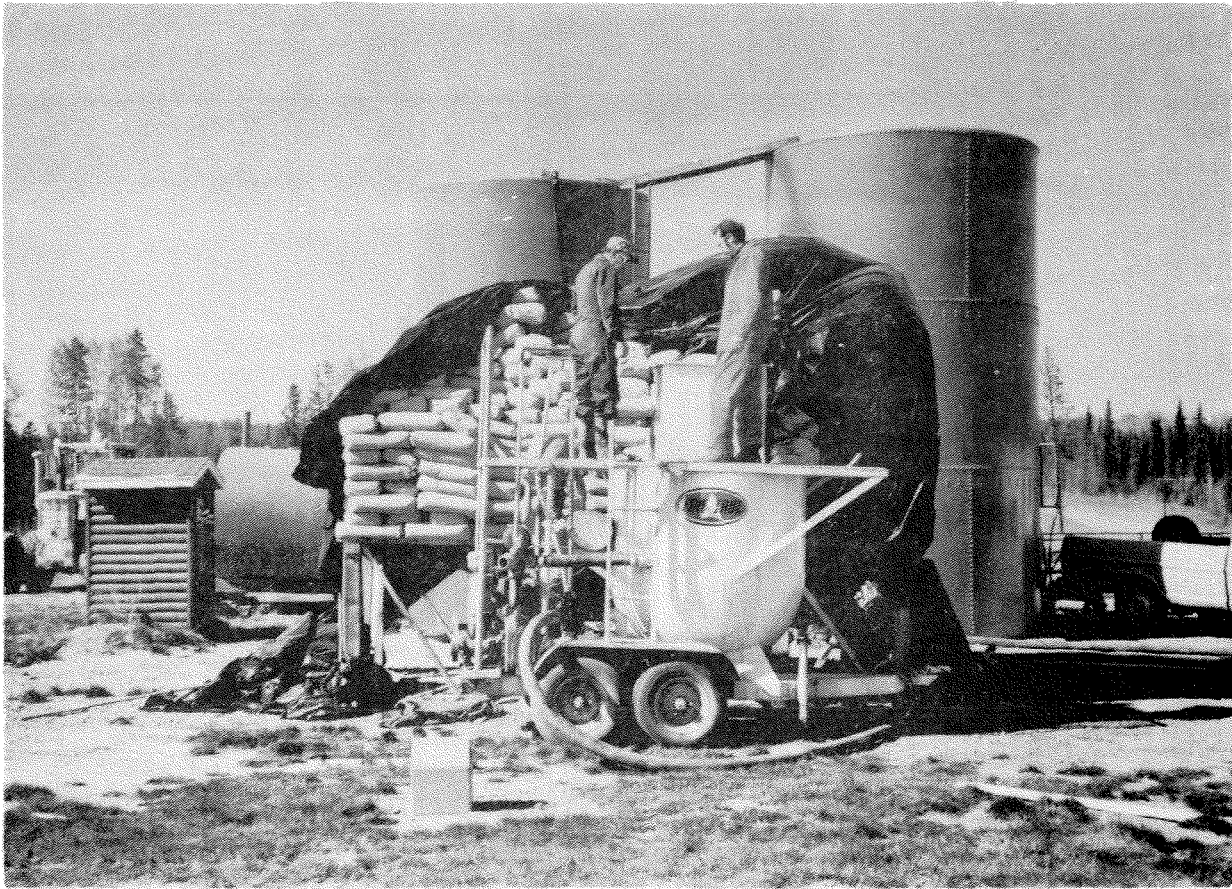


Figure 10. Chemonics Industries Ltd. Vertical Mixer in operation.



Figure 11. Chemonics Industries Ltd. Horizontal Mixer in operation.

Results

During the course of the trials conducted with the vertical mixer, viscosity readings of 1410 and 1680 cps were attained mixing six bags of clay plus the other ingredients (salt, dye and inhibitor) for three and two minutes respectively (Table 5). Then an additional 50-lb bag (22.7 kilograms) of clay was added to the slurry. However, the mixer was not capable of properly shearing the added volume of clay and subsequently it did not readily blend in with the original mix. This would indicate that the impeller speed had fallen below the maximum attainable speed of 1650 R.P.M. at this stage and agitation had declined considerably.

Another sample of slurry was prepared, this time with eight bags-400 lb (181.6 kilograms) of clay. The sample was sheared at 1650 R.P.M. for one minute, two minutes and three minutes with viscosity readings of 2000, 2480 and 2920 cps respectively being attained (Table 5). The one-minute and two-minute samples revealed that many granules of clay had not been sheared completely.

The results indicated that the Chemonics vertical mixer at 1650 R.P.M. could mix a given batch of dry ingredients including up to 8 bags of clay in a fixed volume of water, providing all ingredients were introduced at the start of a batch mix. Under these conditions the Chemonics vertical mixer at 1650 R.P.M. produced the desired slurry viscosity in less time than the Alberta Forest Service mixer at 2200 R.P.M.

Table 5. Alberta Forest Service Mixer Tests¹

<u>Quantity</u> <u>Water² & Retardant</u>	<u>Cumulative</u> <u>Mixing Time (min)</u>	<u>Mixed Retardant³</u> <u>Temperature</u>	<u>Viscosity</u> <u>(cps.)</u>	<u>Specific</u> <u>Gravity</u>
<u>6 bags</u> clay - 300 lb (136.2 kilograms)	2	54°F (12°C)	1290	1.106
<u>1 bag</u> dye & inhibitor-20 lb (9.08 kilograms) ⁴	5	58°F (14°C)	1755	1.106
<u>17 bags</u> salt - 850 lb (385.9 kilograms) ⁴	8	61°F (16°C)	1900	1.106
<u>Add 1 bag</u> clay - 50 lb (22.7 kilograms)	13	63°F (17°C)	2420	1.106
<u>7 bags</u> clay - 350 lb (158.9 kilograms)	3	63°F (17°C)	2264	1.106
	5	65°F (18°C)	2708	1.106
<u>8 bags</u> clay - 400 lb (181.6 kilograms)	1	56°F (13°C)	1460	1.106
	3	59°F (15°C)	2140	1.106
	6	61°F (16°C)	2660	1.106
<u>Chemonics Industries Vertical Mixer</u> ⁵				
<u>6 bags</u> clay - 300 lb (136.2 kilograms)	3	60°F (16°C)	1410	1.106
	5	61°F (16°C)	1680	1.106
<u>Add 1 bag</u> clay - 50 lb (22.7 kilograms)	Mixer could not mix the additional 1 bag of clay			
<u>7 bags</u> of clay - 350 lb (158.9 kilograms)	1	62°F (17°C)	2000	1.106
	3	62°F (17°C)	2480	1.106
	6	64°F (18°C)	2920	1.106
<u>Chemonics Industries Horizontal Mixer</u> ⁶				
<u>7.5 bags</u> clay - 375 lb (170.2 kilograms)	6	45°F (7°C)	1530	1.103
	7	46°F (8°C)	1640	
	9	47°F (8°C)	1825	
	11	48°F (9°C)	1900	
	14	49°F (9°C)	2044	
	16	50°F (10°C)	2178	
	18	51°F (10°C)	2216	
	1 hour setting		2330	
<u>8 bags</u> clay - 400 lb (181.6 kilograms)	6	44°F (7°C)	1900	1.103
	7	46°F (8°C)	1948	
	8	47°F (8°C)	2044	
<u>9 bags</u> clay - 450 lb (204.3 kilograms)	6	48°F (9°C)	2140	1.103
	8	--	2292	

¹ Impeller turning at 2200 R.P.M.² 375 gals. (1702.5 litres) of water was used in the A.F.S. & Chemonics Vertical mixer; 400 gals. (1816.0 litres) with the horizontal mixer.³ Water temp. 52°F (11°C) for A.F.S. mixer & Chemonics Vertical mixer; 44°F (7°C) for the horizontal mixer test.⁴ These ingredients were added to all subsequent mixes.⁵ Impeller turning at 1650 R.P.M. (maximum).⁶ Impeller turning at 2000 R.P.M. (maximum).

Mixing Technique

The horizontal Lely mixer, similar in design to the A.F.S. mixer, (Figure 11) is the most widely used for mixing Fire-Trol 100 (1-bag or 3-bag). The impeller was turning at 2000 R.P.M. while the retardant ingredients were added.

Three 450-imperial-gallon (2043 litres) batches were mixed (Table 5) varying only the amount of clay and mixing times to achieve 1800-2300 cps.

Results

Using 17 bags of salt and 9 bags of clay (manufacturer's specifications) the mixing tests indicated this slurry mix achieved the recommended viscosity more quickly than the mixes with reduced clay (Table 5). However, with more bags of clay more unsheared clay particles appeared in the final mix. Reducing the amount of clay produced less unsheared clay particles, but at the expense of longer shearing time. After five months of cold storage, the samples from the above mixes showed evidence of separation and settling similar to the laboratory trial results (Figure 3). A mixer with more horsepower is required; less clay would then be required to produce a stable mix and also help reduce the recirculation problems being encountered after prolonged storage.

A 13-inch (33.02 cm) standard British Columbia Forest Service heavy duty impeller was experimented with at the Rocky Mountain House base. This impeller has 30 fins evenly spaced about the circumference of the impeller blade, each welded on the bottom side, while the standard Lely used in Alberta has 27 fins which are unevenly spaced and welded on the top side (Figure 12).

With the B.C. impeller mounted in the horizontal mixer, the Wisconsin engine could only attain a maximum of 1500 R.P.M. in water with no retardant added. Thus, no observations could be made to determine whether or not the modified impeller increased mixing efficiency.

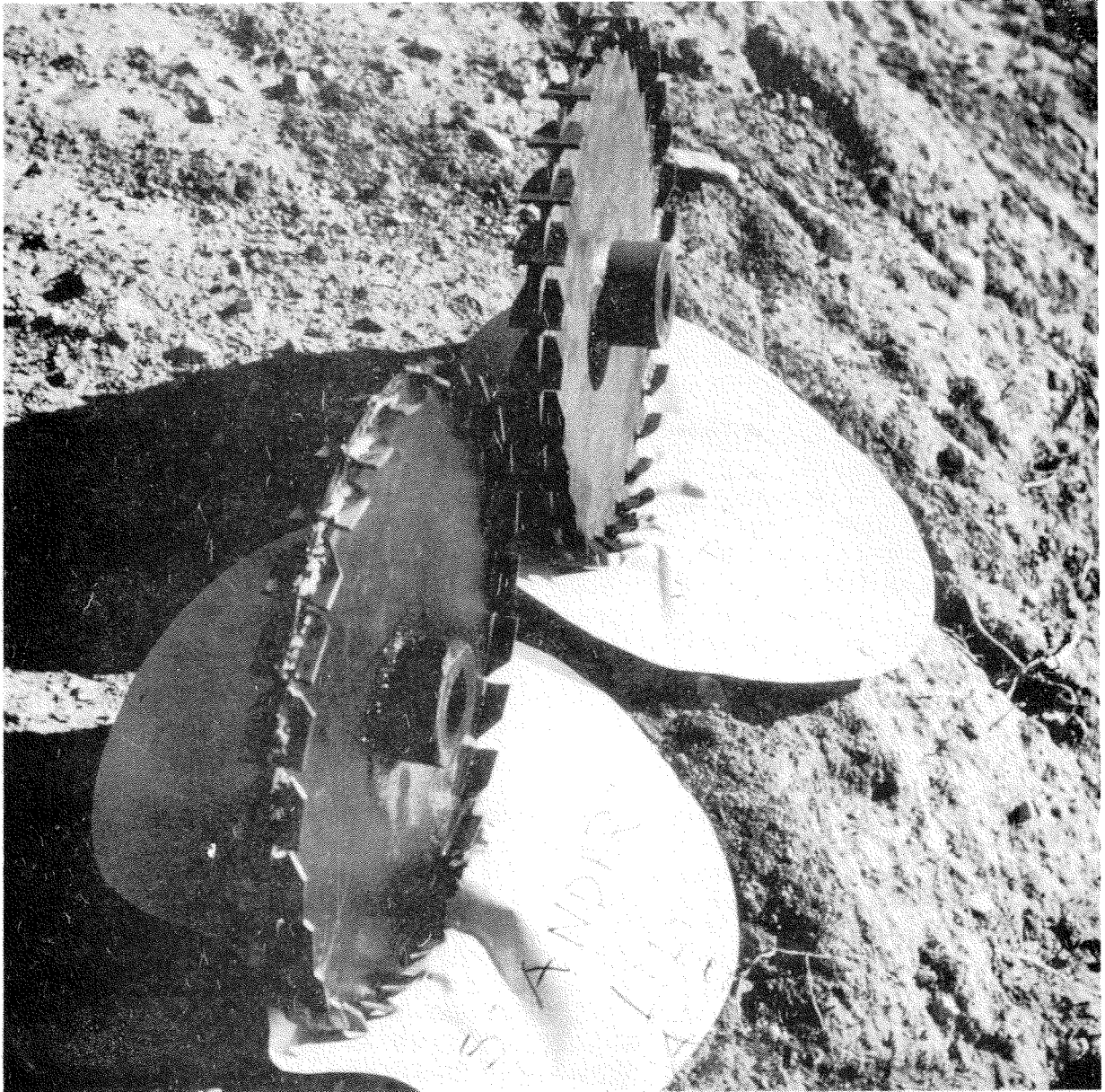


Figure 12. British Columbia Forest Service Impeller (top) and Standard Lely Impeller (bottom). Note spacing of fins and weld on each impeller blade.

DISCUSSION & CONCLUSIONS

Both the laboratory and the field tests indicated that the over-wintering of the Fire-Trol 100 slurry should be kept to a minimum or eliminated. This will reduce or eliminate the problem of settling-out and recirculation of the wet storage at each base.

The tests conducted at Edson showed that the accepted method of recirculating the over-wintered slurry each spring does not reconstitute the slurry to the recommended operational use level. After 4.5 hours of recirculation, the specific gravity of the salt and viscosity of the slurry were still very low, 1.080 (recommended 1.106) and 1030 cps (recommended 1800-2300). Shearing for an additional ten minutes in the Alberta Forest Service mixer brought about an increase of only 290 cps (1320). It may be possible to bring 10,000 gallons (45,400 litres) of over-wintered slurry within the specifications desired with the addition of some clay or salt, but what about the three to five feet (0.91 to 1.52 metres) of compacted slurry on the bottom of the tank? Furthermore, each year this problem will likely be compounded with an increase in the volume of residual slurry incapable of being recirculated. Past experience has shown that the only way to remove the compacted slurry is to shovel it out of the bottom of the tank(s).

If large volumes of wet storage of Fire-Trol 100 slurry are still anticipated, owing to the uncertainty of demand from one fire season to the next, a new method of recirculation should be developed to ensure adequate reconstitution of stored slurry prior to its use in the spring. Possible improved means of recirculation include installing a shaft with blades mounted near the bottom of each tank to two 3-inch (7.62 cm) pipes with $\frac{1}{2}$ to $\frac{3}{4}$ inch (1.27 to 1.91 cm) staggered holes in the line which

would also be placed near the bottom of each tank to improve agitation of the slurry with normal pump pressure. To properly recirculate stored slurry, an empty 10,000 gallon (45,400 litres) tank should be available at each base to permit: (1) pumping of all retardant slurry from the storage tank into the empty tank; (2) cleaning out the original tank (if settling is evident) and, if feasible, reconstitution of the settled-out slurry and pumping into the empty tank; and (3) recirculation of ingredients from the empty tank to and from the storage tank. This should alleviate the problem of poor recirculation, particularly in the bottom portion of the tank and, at the same time, produce an adequate slurry. If such an arrangement is not possible, the entire tank's ingredients should be re-sheared with a batch mixer to bring the retardant slurry back to a satisfactory level of quality. Further tests with the Chemonics vertical mixer using seven bags of clay should be experimented with, since eight bags yield 2920 cps in six minutes.

The design of the Chemonics vertical mixer contributes largely to its added efficiency. When the slurry is being mixed it is concentrated immediately above the impeller rather than ahead, behind, and overhead of the impeller, as it is in the Alberta Forest Service mixer.

RECOMMENDATIONS

It is recommended that the Chemonics Industries Lely mixers in use in Alberta should be increased in horsepower regardless of the amount of clay used per 450-gallon (2043 litres) batch, and that the mixers be equipped with better-constructed impellers. We suggest trying the British Columbia Forest Service modified Lely impeller. With these improvements, mixing efficiency coupled with a decreased amount of clay (eight bags) should improve the quality control and storage capabilities of Fire-Trol 100.

Quality control spot checks should be made by designated qualified personnel to see that mixing standards are upheld.

Finally, utilization of high capacity retardant mixing systems capable of producing large volumes of fire retardant on demand should be considered because of storage requirements.

ACKNOWLEDGEMENTS

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