ROLE OF THE HELITANKER IN FOREST FIRE CONTROL

BY

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ABSTRACT

The helitanker has proven to be an effective fire suppression tool in Canada. It applies either water or long-term fire retardant with the dip-load bucket. The retardant may be supplied from fixed, mobile, or portable mixing stations. Because of the high costs associated with a helicopter retardant operation, improved helicopter management and close supervision on the fire are required.

RESUME

L'hélitanker s'avère un agent efficace de lutte contre les incendies de forêts au Canada. Il lâche soit de l'eau ou du retardant à action prolongée au moyen d'un sceau verseur. On peut s'approvisionner de retardant depuis des stations fixes, mobiles ou portatives de mélange. Vu le coût élevé des opérations avec du retardant, il convient d'améliorer la gestion des hélicoptères et de prévoir avec plus de soin la marche des incendies.

CONTENTS

INTRODUCTION

The helicopter has proven to be a versatile tool in forest fire control in Canada. This multi-use aircraft is used to:

1. transport fire-fighters
2. carry cargo
3. provide fire-line management
4. fly reconnaissance
5. lay hose
6. aerially ignite backfires, and
7. drop water and fire retardants.

Although the transport of men, equipment, and supplies receives priority, the application of water and retardant by the helicopter is increasing. In several areas this is an accepted fire suppression tactic.

Water is abundant in most of the forested areas of Canada. Lakes, ponds, sloughs, and rivers are usually close to any fire and turn-around time for drops is short. In these areas, the helitanker[1] has proven to be an effective suppression tool. Long-term fire retardant[2] is also being applied with the helitanker. Its use has increased through the availability of both mobile and portable retardant mixing equipment, the availability and acceptance of large helicopters, and improved accessibility.

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[1] A helitanker is a helicopter equipped with a fixed tank or a suspended bucket-type container which is used for aerial delivery of water or retardant.

[2] A long-term retardant contains an active retardant chemical (e.g., diammonium phosphate), which when applied to cellulosic fuels alters the combustion process to produce less flammable products while increasing the amount of non-flammable products.

This report reviews the use of the helitanker in Canada with emphasis on the application of long-term retardants. Guidelines for the effective use of the helitanker are also presented.

BACKGROUND

The first use of a helicopter in fire control was made in California in 1946 (Jefferson 1948). Although the initial models were small and had limited lift capabilities, the potential uses of the helicopter in fire suppression were well recognized. One of these uses was the more accurate water bombing of free-burning fires.

The role of the helitanker increased following Operation Firestop, a study to find new tools, methods, and techniques to help meet the California forest fire problem (Anon. 1955). Initially, small helicopters (e.g., Bell 47G) were rigged to carry 35-60 U.S. gal[3] in a coated fabric bag attached to a cargo sling beneath the helicopter, or in two aluminum side tanks connected to an equalizing pipe equipped with three drop valves (Cobb 1961). Soon, new helitanks mounted externally as a rigid tank or as fabric containers were tested with small (e.g., Hiller 12E and Bell 47G2) (Davis 1963) and medium (e.g., Bell 204B) helicopters (Anon. 1965). All of the tanks were filled on the ground by pumps.

To permit refilling from the nearest open water source, buckets attached to the cargo hook by wire cable slings were developed. The original "monsoon buckets" were 45-gal barrels fitted with a drop gate activated by a solenoid. The success of the dip-loading technique led to the development of specially-designed buckets constructed of fiberglass

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[3] Metric conversion factors are presented in Appendix 1.

(Anon. 1967a). These buckets, initially used with smaller helicopters, contained 150 gal or less. Use of larger helicopters in fire control prior to 1968 was restricted because of limited availability and high cost (Anon. 1968). When large helicopters were used on wildfires, they were military-owned and activated during emergencies only (Dodge 1966).

In the late 1960's larger helicopters became available and were gradually utilized in the helitanker role. Numerous buckets and tanks were designed. In Canada, development of the buckets was confined to the dip-load variety.[4]

EQUIPMENT

TYPES OF BUCKETS

Buckets are specially designed and constructed of either fiberglass, aluminum, polyurethane, or fabrics. Portability is important, and several designs are collapsible to permit easy transport within the helicopter. These containers, which range in size from 45 to 350 gal or more, employ several types of drop mechanisms. The drop gate(s) are activated electrically and are operated either electrically, hydraulically, or pneumatically. The buckets used commonly in Canada are described in Table 1 and illustrated in Figures 1-5.

Since the bucket is not an integral part of the helicopter, different types can be used interchangeably within limits. The activating devices on the helicopter and bucket must be compatible. Most buckets are available in several models, each tailored to a particular range of

[4] The province of Ontario has developed a 75-gal capacity folding bucket which is attached to the belly of a small, float-equipped helicopter. The bucket is loaded by a pump on the helicopter. The drop opening is variable and is controlled by the pilot.

TABLE 1

HELICOPTER BUCKETS COMMONLY USED IN CANADA
(Anon. 1973a, Grigel et al. 1974)

MAKE AND MODEL NO.	COLLAPSIBLE DIAM. X HT.	H_2O LEVEL[1] ADJUSTMENT (GAL.)	OVERALL DIMENSIONS DIAM. X HT.	UNIT COMPLETE WEIGHT (lb)		DOOR OPERATION		
				EMPTY	FULL H_2O	NO.	TYPE	HOOKUP
Chadwick C-140	NO	40-60-75-90-115	45" x 39"	90	1,280	1	Valve	Electric
Chadwick C-450	NO	140-190-250-315-375	45" x 51"	300	4,125	3	Valve	Electric
Hawkins & Powers-110	42" x 4½"	60-90 Zipper	42" x 24"	101	1,036	2	Butter-fly	Pneumatic
Hawkins & Powers-200	48" x 4½"	105-165 Zipper	48" x 24"	104	1,804	2	Butter-fly	Pneumatic
Hawkins & Powers-300	48" x 4½"	165-250 Zipper	48" x 38"	108	2,658	2	Butter-fly	Pneumatic
Hawkins & Powers-400	48" x 4½"	250-330 Zipper	48" x 50:	111	3,511	2	Butter-fly	Pneumatic
Sims PT-150	NO	40-60-75 90-115	47" x 39"	86	1,361	1	Valve	Electric
Sims PT-450	NO	165-210-250-290-375	64" x 57½"	252	4,077	2	Butter-fly	Electric
Griffith 150	32" x 24"	Variable 125	34" x 43½"	84	1,359	1	Valve	Electric
Griffith 400	50" x 30"	Variable 330	51" x 55"	225	3,625	1	Valve	Electric
Alta. Forest Service Monsoon	NO	235-300	42" x 80"	330	3,330	2	Butter-fly	Hydraulic

All above buckets are sling-mounted to the helicopter and are open-topped.
Material: Hawkins & Powers - Canvas/Steel frame; Griffith - Polyurethane; AFS Monsoon - Aluminum; the rest are Fiberglass.

Figure 1. Chadwick C-450 bucket. Sikorsky S-58T in background.

Photo: NFRC

Figure 2. Hawkins and Powers 400 bucket. Note zipper for regulating load capacity and air hose for operating doors.

Photo: Canwest

Figure 3. Sims PT-150 bucket. Note wetting agent reservoir on top and load level adjustors.

Photo: NFRC

Figure 4. Griffith bucket series. Large bucket is Model 400.

Photo: Griffith Polymer, Inc.

Photo: NFRC

Figure 5. Alberta Forest Service Monsoon Bucket. Unit is constructed of aluminum and tapered at bottom to facilitate easy dip-loading. Insert shows the two semi-circular doors.

helicopter lift capabilities. However, most buckets are equipped with removable plugs to permit several capacities.

TYPES OF HELITANKERS

Helitankers are classified into three load-capacity ranges:

1. Small <200 gal
2. Medium 201-500 gal
3. Large >501 gal

Examples of helicopters used for dropping water and retardant in Canada are listed in Table 2 and illustrated in Figures 6-8. The helicopters listed are representative of size class and do not include all of the models used in the helitanker role.

In Canada, small and medium helitanker are used almost exclusively. Several studies have substantiated that the medium helicopter is most suitable for fire control work. Newburger (1968) concluded that helicopters in the 10,000-12,000 lb gross weight range were most effective in controlling fires. This optimum range was also substantiated in a study by Simard and Forster (1972), wherein machines with 250-350 gal capacities (8,000-9,500 lb gross weight) appeared to be more desirable than significantly larger or smaller helicopters. As the distance from the fire to retardant source increases, the larger capacity machines demonstrate increasing economies of scale up to about 450 gallons, in that costs decrease with increasing capacity. While there is no clearly defined point of maximum efficiency, it is evident that small machines with capacities of less than 100 gal are significantly more expensive to operate per foot of line held than larger capacity machines (Simard and Forster 1972).

TABLE 2

EXAMPLES OF HELICOPTERS USED TO DROP WATER AND RETARDANT IN CANADA
(Anon. 1973a)

Size Load Capacity (gal)	Model[1]	Engine Horsepower	Fuel Cap. (gal)	Fuel Cons. (gph)	Average Payload (gal water)	No. Pass.	Hover Ceiling (ft)	Cruise[2] Speed (mph)	Cost/hr ($)
Small <200	Hiller 12E	305	38[3]	15	50	2	9,500	70	140
	Alouette 11	400	127[4]	46	100	4	5,400	92	285
	Bell 206B	400	63[5]	25	100	4	11,300	133	285
Medium 201 - 500	Sikorsky S-55T	840	150[5]	35	200	10	10,000	85	350
	Bell 204B	1100	137[4]	60	250	9	8,400	120	525
	Bell 205A	1400	185[4]	70	350	14	18,200	124	625
	Sikorsky S-58T	2-900	235[5]	87	370	15	8,950	127	650
Large >500	Sikorsky S61N	2-1400	340[4]	150	600	26	8,700	139	1500

[1] Models listed are representative of load capacity category.
[2] Loaded cruise speed is normally 10-20 mph less.
[3] 100/130 fuel grade.
[4] JP-1+5 fuel grade.
[5] Turbine fuel grade.

Figure 6. Small helitanker. The Bell 206B Jet Ranger carries about 90 gallons of water. Hawkins and Powers-110 bucket is submerged below helicopter.

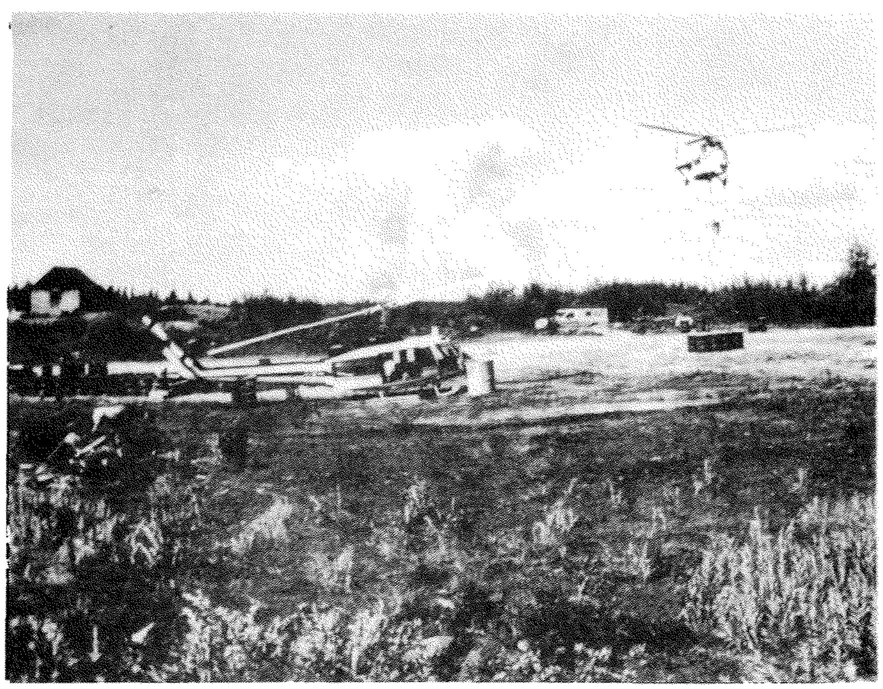

Figure 7.
Medium helitankers. Sikorsky S-55T (airborne) and Bell 205A, both with Hawkins and Powers Water Buoy buckets. Note smoke column in background.

Photo: Canwest

Photo: NFRC

Figure 8. Medium helitanker. Sikorsky S-58T with Chadwick C-450 bucket.

The costs per foot of line held exhibit relatively little response to changing tank capacities ranging from 40 to 720 gal as the flying distance approaches zero (Simard and Forster 1972). Operational assessment substantiates this finding. In 1968, a Hiller 12E with a 55-U.S. gal monsoon bucket could make one round trip per minute and compete costwise on very short haul distances (1,000 ft) with a large Sikorsky S61 carrying twin PT-450 buckets and delivering 900 U.S. gal per trip (Percival and Noste 1973). In 1969, however, the trend was away from these small and large helicopters towards the medium-size helicopters like the Bell 204B (Percival and Noste 1973).

ROLE OF HELITANKERS

Initial Attack and Support

The availability of portable, collapsible buckets with simple attachment devices allows the helicopter to quickly convert to a helitanker which can perform in either the initial attack or the support role.

For initial attack the helitanker can be dispatched from a retardant base within minutes. It can drop its load of retardant and return for additional loads; or, if advantageous, it can also be dispatched to the fire with a partial load of retardant and several men, then return to base for more retardant and men. Or, the helicopter can proceed to the fire with an empty bucket and a helitank crew, off-load the crew, convert to a helitanker, then support the crew using water from the nearest source. In the support role on larger fires, the helicopter can be quickly diverted from delivering men and supplies to drop water or retardant on a flare-up or to aid the ground crews in mop-up.

Comparison with Fixed-Wing Airtankers

Helitankers supplement rather than compete with fixed-wing airtankers. Airtankers, with their high speed, large load capacity, and greater range are generally considered to be more effective for initial attack. Although the helitanker's capability in the initial attack role is limited, it is nevertheless an important suppression tool.

The retardant fire-line building capability of medium helitankers (e.g., Bell 204B--235 gal and Sikorsky S58T--325 gal) is comparable with that of airtankers releasing between 285 and 450 gal per drop (Grigel et al. 1974). A comparison of line lengths and widths established by these helitankers and fixed-wing airtankers is presented in Table 3. Although the airtanker data refer to partial loads, the helitanker lines are comparable at the .04-in. application level and are longer at the .07-in. level (Table 3).[5] A study by Simard and Forster (1972) indicates that medium helitankers would be more advantageous than fixed-wing aircraft for short fire-to-retardant-source distances only (<9 miles for water-based aircraft and <17 miles for land-based aircraft).

The great manoeuvreability of the helicopter allows accurate drops and close support of ground personnel. Helitankers can often operate more effectively and safely than fixed-wing airtankers during smoky, windy, and turbulent conditions and in rough topography. The relatively small load capacity of even the large helitankers, as compared to fixed-wing airtankers, is often offset by their ability to operate from water or

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[5] The .04-in. level corresponds to 2.1 Imp gal or 2.5 U.S. gal per 100 sq ft; .07-in. corresponds to 3.6 Imp or 4.4 U.S. gal/100 sq ft. For long-term retardants, between 2 and 4 U.S. gal/100 sq ft are required to slow or stop fires in most fuel types (Anon. 1967b).

TABLE 3

RETARDANT FIRE-LINE ESTABLISHED WITH HELITANKERS
AND FIXED-WING AIRTANKERS
(Grigel et al. 1974)

Aircraft	Retardant	Drop Vol. (gal)	Drop Speed (kn)	Drop Height (ft)		Retardant depth (in.) .01	.02	.04	.07
Sikorsky S58T	Phos-Chek 259				length	230	205	182	130
(Chadwick)	(100 cps.)	325	20	100	width	35	32	28	22
Bell 204B	Phos-Chek 259/XA				length	250	230	200	160
(AFS Monsoon)	(400 cps.)	235	20	95	width	40	35	22	12
Thrush	Fire-Trol 100				length	203	141	101	70
	(2083 cps.)	310	85	85	width	50	45	35	25
PBY5A					length	275	250	165	95
Canso	Gelgard	400	85	90	width	50	40	30	15
B-26					length	320	290	170	10
(4-door)	Fire-Trol 931	450	120	90	width	64	42	20	10
B-26	Fire-Trol 100				length	270	220	180	78
(4-door)	(2600 cps.)	450	120	90	width	42	33	30	15
TBM	Phos-Chek XA				length	330	260	200	40
Avenger	(1250 cps.)	285	120	140	width	38	30	25	15

retardant-mixing stations close to the fire. Little time is wasted in ferrying, and the helitanker can accurately drop greater quantities than fixed-wing airtankers from distant bases.

FIRE SUPPRESSANTS

WATER VERSUS RETARDANTS

Water is often used on helitanker operations because of its availability, economy, and effectiveness[6]. The cost of the operation is limited to the cost of flying. Water is an effective suppressant that can reduce rate of fire spread and intensity, control spot fires, and facilitate mop-up and burning out (Figure 9). It can also be used to construct temporary and permanent lines (Percival and Noste 1973). Water dropped with helitankers has been effective in holding fires in light surface fuels at the edge of a grass sedge meadow but the line was overrun by a relatively intense front travelling through adjoining willow brush (Noste and Percival 1972). A problem with the use of water for permanent line construction is escape of the fire when mop-up is not complete (Noste and Percival 1972).

The effectiveness of water is relatively short-term and either additional drops or immediate ground action is mandatory to prevent rekindling of the fire. In areas where travel by foot is slow and tiring (e.g., muskeg or mountains) and roads are limited, immediate ground action is often difficult to achieve.

Long-term retardant decreases the urgency for ground action; unlike water, which evaporates quickly and permits rekindling, the

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[6] Several helibuckets (e.g. Sims, Rainmaker and Chadwick) are equipped with reservoirs for wetting agent. The agent is injected into the water after loading. A wetting agent reduces the surface tension of the water and permits deeper penetration of fuel.

retardant forms an effective fire barrier when wet or dry. A permanent retardant fire line can be built by applying retardant at or adjacent to the fire edge or at some strategic location. The retardant is especially effective during potential blow-up conditions and when numerous inaccessible spot fires are burning (Figure 10). Application of retardant minimizes the successive drops so often required with water. When retardant is used, the helicopter is usually not totally committed to the helitanker role and thus is available to transport and support ground crews.

An operation employing long-term retardant, however, is more complicated than one with water. Unless the fire is located close to a permanent retardant base, mixing facilities must be established near the fire. This requires time and a specialized crew equipped with a retardant mixing unit. Accessibility to the fire site may be limited and the transportation difficult and costly. Logistics may thus prevent application of retardant, even though it is desirable.

The use of retardant with helicopters is accordingly limited primarily to the support role on established fires. An established fire may be one acre, 1,000 acres or 10,000 acres in size. The decision to use long-term retardant is dependent upon the behavior and potential of the fire(s).

RETARDANTS

Two types of long-term retardant are available for use with helitankers: Fire-Trol 931, a liquid concentrate (LC) and Phos-Chek 259, a powder. Composition and mixing data for these retardants are presented in Appendix II.

Figure 9. Water is an effective suppresant. A Bell 205A helitanker drops 370 gal of water onto a spot fire with a Chadwick C-450 bucket.

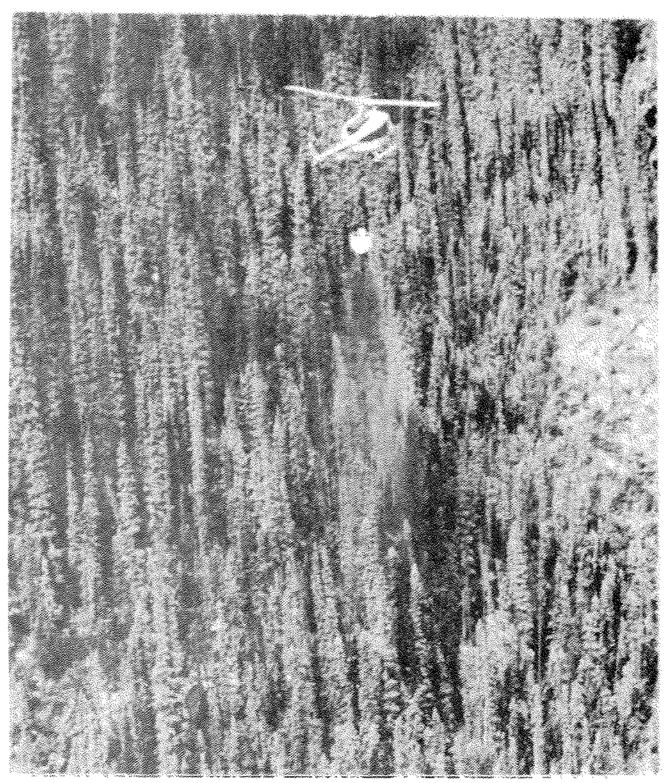

Figure 10. Retardant is effective in suppressing inaccessible spot fires and preventing blow-ups. A Bell 205A drops a load of retardant on an inaccessible spot fire.

Mixing Equipment

Mobile Base. A mobile retardant base can be used where accessibility to a fire is good. The mobile equipment consists of a large tanker-trailer unit modified to store both water and retardant, either in the mixed or unmixed state.

With Fire-Trol 931 LC, the tank is compartmentized to hold both water and the concentrate (Figure 11)[7]. A Variblender or similar blending device is used to proportion the LC at the desired mixing ratio of one part LC to four parts water. The retardant is blended (mixed) by the pump at 200-300 gal/min, depending on the size of pump, during the proportioning; it is either loaded directly into the helibucket or transferred to a pit or holding tank from which the helicopter dip-loads. Each trailer unit can carry 3,800 gal of LC, enough to mix 19,000 gal of Fire-Trol 931.

With Phos-Chek 259, the tank is compartmentized to hold water and mixed retardant. The Phos-Chek Hamp Mixer (Model 200), a continuous-flow eductor which mixes about 200 gal/min, is mounted on the retardant compartment. Water is pumped from the water compartment and through the eductor. A vacuum is created and retardant powder is entrained at a calibrated flow rate and mixed. A powder supply must be transported with the mobile base[8]. The mixed retardant is pumped from the unit either directly into the helibucket or into a holding tank.

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[7] A tanker-trailer unit may be used to haul only Fire-Trol 931 LC. A pump and blending unit can either be mounted on the unit or be transported separately. Water must be obtained from an outside source.

[8] In the United States, a Mobile Phos-Chek Base (MPB) consists of a trailer which contains 20 tons of dry retardant and a Hamp Mixer mounted on a tank strapped to the side of the unit. It is capable of producing around 22,150 gal of Phos-Chek 259. The trailer can return to the base plant for reloading, or can be filled by a bulk truck at the mix site or any convenient location (Anon. 1971).

Both types of mobile bases are self-contained units. However, a readily available water supply is essential for both. The water storage compartments must be filled by additional pumping equipment. The mobile bases are confined to accessible roads and water supply, and thus are somewhat restricted in use.

Portable Base. A portable retardant base can be transported by either trucks, fixed-wing aircraft, or helicopters. The portable unit is usually a modified mobile base capable of being used where access is limited or in remote areas.

A Fire-Trol 931 portable base consists of a blending unit, light-weight pump, hoses, and one or two portable tanks (Figure 12). Where access is limited, the LC is transported in small tanks or 45-gal barrels. The retardant is mixed with the portable blending unit and is pumped directly into the helibucket or into a holding tank. The size of pump used determines the rate of mixing (and loading); a 3-in. pump mixes about 180 gal/min.

A Phos-Chek 259 portable base consists of a Model 100 Hamp Mixer and accessories (Figure 13). The base is unitized into a 1,000-lb kit that can be transported in a half-ton truck, slung under a Bell 206B Jet Ranger helicopter, or carried inside the cabin of a Bell 204B or larger helicopter.

The powder, which comes in 50-lb bags, is mixed at a rate of approximately 100 gal/min into a reservoir tank. The pump is equipped with wyes to permit pumping of either water (i.e. for mixing) or retardant (i.e. for transferring directly to helibucket or to pit or holding tanks).

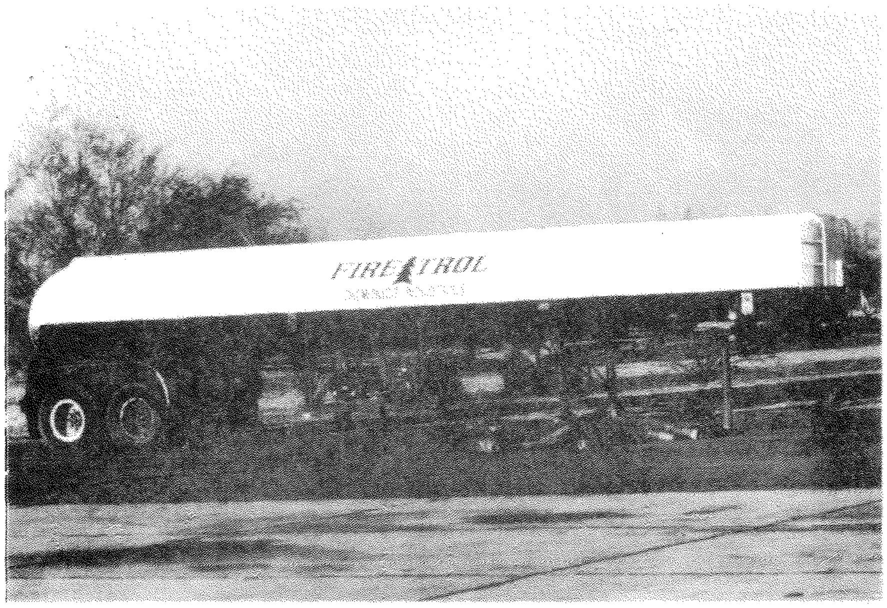

Figure 11. A mobile retardant base for Fire-Trol 931 LC. The 5,200 gal tanker trailer is compartmentized to hold 3,800 gal of LC, and water. The unit can supply 19,000 gal of mix with this LC supply. Variblender and pump are mounted on bottom of tank.

Figure 12. A portable retardant base for Fire-Trol 931. The blending system includes an "on-off" valve for both water (right) and LC (centre), a proportioning valve for the LC (left-partially open) and one-way check valves. The pump mixes the entrained water and LC and transfers the retardant to a pit or holding tank.

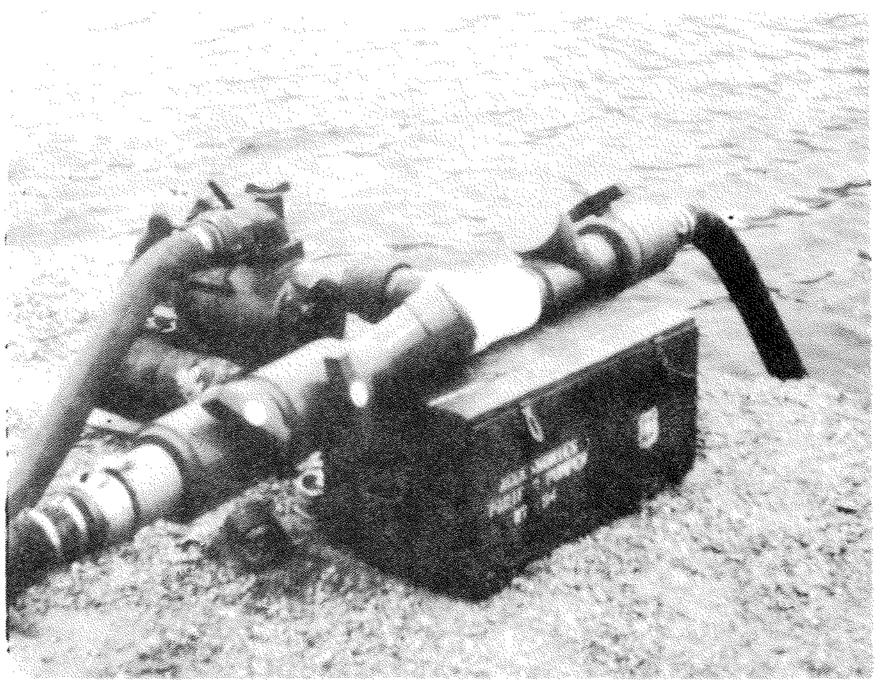

Photo: Canwest

Figure 13. A portable retardant base for Phos-Chek 259. The Model 100 Hamp Mixer can mix 6,000 gal/h or mix and load 4,000 gal/h with the 2½-in. pump. The pump is equipped with wyes which either supply water for mixing or transfer the mixed retardant from the mixing reservoir to a portable tank, pit or helibucket. A Bell 212 Twin is loaded with 320 gal of retardant in approximately 2 min.

Fire-Trol 931 Versus Phos-Chek 259

Logistics. The logistics of each retardant are important because of the requirements of the helitanker operation. Transportation of both the mixing equipment and retardant supply is required. The type and amount of mixing required is also important. As the remoteness of the helitanker operation increases and accessibility decreases, the logistics become increasingly significant.

The Fire-Trol 931 mobile base carries enough concentrate (3,800 gal) to mix 19,000 gal of retardant. A similar weight (28 tons) of Phos-Chek 259 powder, which must be transported separately, mixes 32,000 gal of retardant. One ton of Fire-Trol 931 LC mixes 675 gal; one ton of Phos-Chek 259 mixes 1,140 gal at the manufacturers' recommended mixing ratios. The Fire-Trol 931 base must be resupplied by a specialized tanker while the Phos-Chek 259 base can be supplied by almost any type of carrier.

As the overland accessibility to the fire decreases and portable bases are established, the retardants must be transported in smaller amounts. The Fire-Trol 931 concentrate must be carried in bulk by smaller tank trucks (e.g., 1,000 gal or less) or in 45-gal barrels; since each barrel weighs approximately 700 lb, bulk handling appears more favorable. The Phos-Chek 259 powder is available in 50-lb bags palletized into a 1-ton poly-wrapped unit[9].

In remote areas where the mixing equipment and retardant supply must be transported by air, Fire-Trol 931 concentrate may be carried in fuel bladders, 45-gal barrels, or 5-gal containers. A 5-gal container

[9] Phos-Chek 259 may also be available in a 2,000-lb or smaller container called a "Phos-Bin". The semi-bulk container eliminates bag-breaking; however, it decreases the portability of the powder supply once it is unloaded (Anon. 1973b).

weighs approximately 80 lb and mixes 25 gal of retardant. The Phos-Chek 259 bags can be easily transported in a cargo net, as can the Fire-Trol 931 in the barrels or containers. The barrels, however, are difficult to handle manually. Both the barrels and the containers, if not disposable, must be returned to the base for refilling, while the Phos-Chek 259 bags can be disposed of at the mixing site.

Mixing. Fire-Trol is prepared by blending one part LC with four parts water (2.96 lb LC/gal of mix). Phos-Chek 259 is prepared by mixing 1.75 lb of powder per gallon of mixed retardant. Although vigorous agitation can mix both products in small quantities, rates of 100 gal/min or more require specialized mixing equipment (i.e. Variblender or proportioner for Fire-Trol 931 and Hamp Mixer for Phos-Chek 259). The Hamp Mixer also requires a reservoir to store the mixed product.

Cost. One tone of Fire-Trol 931 concentrate costs $197.00, or 29.2¢/gal of mix, f.o.b. Kimberly, B.C. One ton of Phos-Chek 259 powder costs $516.00, or 45.3¢/gal f.o.b. Abbotsford, B.C.[10] On this basis, Fire-Trol 931 is significantly cheaper than Phos-Chek 259. The difference in cost between the two products diminishes somewhat, however, when both initial cost and logistics are considered (Table 4).

The difference between the cost of the two products decreases further when the retardant supply is transported into areas of limited or no road access. When air freight by either fixed-wing aircraft or helicopter is required, the logistics alone favor Phos-Chek 259 since the

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[10] Costs given are effective for 1974 and do not reflect the 1975 prices.

same weight of Fire-Trol 931 mixes only .6 times the retardant (Table 5). A 12-mile flight to a fire with a Bell 204B helicopter slinging 3,500 lb or retardant costs $126.00, or 10.7¢/gal for Fire-Trol 931 and 6.3¢/gal for Phos-Chek 259. (Note that the Bell 206B is about twice as expensive as the Bell 204B for air cargo.)

If the retardants had been transported 400 miles by truck, then airlifted 12 miles with the Bell 204B, the cost per gallon for material alone would be 44.2¢ for Fire-Trol 931 and 54.1¢ for Phos-Chek 259 at the fire (Tables 4 and 5). If the retardants had been transported 1,000 miles by truck, then airlifted 16 miles with the Bell 204B, the cost per gallon would be 54.2¢ for Fire-Trol and 60.0¢ for Phos-Chek 259 at the fire.

Mixing costs are assumed to be equivalent. However, the capital cost of the mixing units differs. A Model 100 Hamp Mixer portable unit costs approximately $6,500 while a Fire-Trol 931 portable blending unit costs approximately $4,000.

Effectiveness. Fire-Trol 931 and Phos-Chek 259 contain approximately the same quantity of retardant salt (i.e., 15.4% DAP, 8.3% P_2O_5 equivalent; and 15.0% DAP, 8.1% P_2O_5 equivalent, respectively) (Appendix II). Approximately one U.S. gal/100 sq ft of 15% DAP solution extinguishes a head fire in the highly flammable palmetto-gallberry fuel type (Johansen 1967). Additional field application studies indicate that one U.S. gal/100 sq ft controls fires in light-medium grass, 1½ U.S. gal/100 sq ft in heavy grasses-light brush, and 2 U.S. gal/100 sq ft in heavy brush-slash and trees (Anon. 1969). Observations of helicopter drops using Pyro (11-37-0) LC in light fuels indicate that there is no apparent difference in the effectiveness of the retardant mixed at the recommended 5:1 ratio or at 10:1 water:LC ratio (Cobb 1961).

TABLE 4

COST OF FIRE-TROL 931 AND PHOS-CHEK 259 AT VARIOUS DISTANCES
FROM SAME POINT OF ORIGIN
(exclusive of additional off-loading and trans-shipment costs)
AUGUST, 1974

	Distance (miles)[2]													
	0		100		200		300		400		500		1000	
Retardant[1]	$/ton	$/gal	$/ton	$/gal	$/ton	$/gal	$/ton	$/gal	$/ton	$/gal	$/ton	$/gal	$/ton	$/gal
Fire-Trol 931	197	.292	204	.301	211	.313	219	.324	226	.335	233	.346	270	.400
Phos-Chek 259	516	.453	523	.459	530	.465	538	.472	545	.478	552	.484	589	.516

1 Fire-Trol 931 = 675 gal/ton material;
Phos-Chek 259 = 1,140 gal/ton at recommended mix ratio.

2 Truck Freight Rate: $1.60/mile for 22-ton load minimum.
Base Cost/Ton : Fire-Trol 931 - $197.00
: Phos-Chek 259 - $516.00
: Provincial & Federal Sales Tax not included in prices.

TABLE 5

COST OF FREIGHT PER GALLON FOR FIRE-TROL 931 AND PHOS-CHEK 259
TRANSPORTED BY DIFFERENT HELICOPTERS; RETURN FLIGHT COST

Helicopter[1]	Average Speed (mph)	Load (lb)[2]		One-Way Distance (miles) 2	8	12	16	20
				Total Freight Cost ($ per gallon)[3]				
Bell 206B	110	900	Fire-Trol 931	.034	.136	.201	.273	.341
			Phos-Chek 259	.020	.081	.121	.162	.202
Bell 204B	100	3,500	Fire-Trol 931	.018	.071	.107	.142	.178
			Phos-Chek 259	.010	.042	.063	.084	.105
Sikorsky S-58T	90	4,220	Fire-Trol 931	.020	.081	.122	.162	.203
			Phos-Chek 259	.012	.048	.072	.096	.120

[1] Cost per h: Bell 206B - $285.00;
Bell 204B - $525.00;
Sikorsky S-58T - $650.00.

[2] 1½ h fuel (plus reserve).

[3] Cost of flying ÷ gallons of retardant per load.

It may be possible to effectively use either Fire-Trol 931 or Phos-Chek 259 at less than the recommended mix ratio under certain fire conditions[11]. If these dilutions are made on a relative basis, the two products should still be equally effective.

MANAGEMENT OF HELITANKERS

The efficient use of the helitanker depends on trained and qualified key fire personnel who have a working knowledge of helicopter operations (Anon. 1973a). At present, helicopter management tends to be inefficient because of a shortage of qualified people. The rapid escalation in the use of helicopters, particularly in the medium-sized category, has largely contributed to inadequate management.

Medium helitanker use became established during severe fire seasons. Numerous helicopters engaged in mining and oil exploration were readily available, especially in Canada's northern region. During severe seasons, when the fire incidence and work load exceeded the capabilities of the available airtankers, helicopter fleet, and ground crews, these helicopters were often mobilized as helitankers. Most helicopters were equipped with attachments for buckets and usually carried or had immediate access to helibuckets.

Initially, water was used exclusively. Its abundance permitted short turn-around and thus rapid water delivery. Many pilots became experienced in the application of water with the helibucket. However, close coordination between helitankers and ground crews was rarely

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[11] Corrosion inhibitors are added to these proprietary products on the basis of the recommended mix ratios. Since corrosion is a function of the total fluid volume, dilution of the retardant solution may encourage corrosion.

practised, and when it was, in many instances it was initiated by the helicopter pilot. As a result, the helitanker operation was often divorced from the fire organization and controlled by the pilot. Helicopter costs were consequently high and comprised a major portion of the suppression costs.

The lack of efficient helitanker management was usually recognized after the accounts were submitted because the helicopter costs generally constituted a significant portion of the overall suppression costs. In several areas their use was minimized as a result; in other areas, however, it was apparent that the management principles developed for the small helicopter were inadequate for the larger helicopters. New principles were developed and helitanker management for waterdropping improved.

The application of long-term retardant with medium helicopters has further increased the need for efficiency in helitanker management. With larger capacity helicopters it has become practical to dispatch helitankers from retardant bases in the initial attack role[12]. Improved accessibility and availability of mobile and portable retardant mixing units have permitted the retardant mixing operation to be moved near the fire, eliminating time-consuming and costly flights. In either case, the cost of retardant material (between \$.30 and \$.50 per gallon) necessitates close supervision of both the helitanker and retardant operation.

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[12] Distance from base to fire, availability of airtankers and ground crews, fire hazard and behavior, accessibility, and type of helicopter available determine whether initial helitanker attack is a suitable alternative.

GUIDELINES FOR USE OF RETARDANTS

The selection of the retardant mixing site is critical to the success of a helitanker operation. Unsuitable location of the site can result in an inefficient and costly operation. Sufficient water should be readily available.

A clear level area suitable for safe takeoffs, landings, and loading is desirable. The surface of the mixing site should be sod or a ground cover which prevents dust formation. If dust is a problem, the area should be wetted down.

Selection of the site for a mobile base may be difficult because of the limited accessibility of the tanker-trailer unit. Heavy equipment (e.g., bulldozers) is usually available to prepare the area. The site for a portable base should be selected by both the retardant supervisor and helitanker pilot. This is mandatory if the mixing equipment and retardant supply are airlifted by the helicopter, since manual movement of the materials once they are dropped is difficult. If the equipment or the original and additional retardant supply is transported by float plane, the logistics of transferring the materials from the docking point to the mixing site should be considered beforehand.

The mixing station should be located as close to the fire as possible. It is less expensive to haul 1.75 lb of Phos-Chek 259 powder or 2.96 lb of Fire Trol 931 concentrate--the amount required for mixing one gallon of product--than it is to haul 11 lb/gal of mixed retardant. However, a natural site that is close to both the fire and an adequate water supply is sometimes difficult to lcoate. The maximum hauling distance should be 3 miles, approximately a 5-min turn-around. On large fires, the base should be located nearest the areas of expected heavy retardant use.

The mixing unit and loading area should be at least 100 ft apart for small helicopters and 150-200 ft apart for medium helicopters (Figure 14). The force of the rotor blast at the mixing unit is thus minimized. All loose articles should be secured and in the case of the empty Phos-Chek bags should be quickly disposed of.

Loading is facilitated through either a pit or holding tank (Figure 14). Direct loading into the bucket is not recommended for both safety and cost reasons (Figure 13). On operations where a bulldozer is available, a pit can be easily dug and then lined with polyethylene after all sharp objects have been removed from the bottom of the pit. The pit should be large enough to facilitate easy dip-loading, yet small enough to prevent excessive waste of mixed retardant when the operation is terminated. Where a holding tank is used, rocks or other heavy objects should be placed in the corners of the tank to prevent the rotor blast from upsetting it when it is partially full. The pit or holding tank should be located to permit the helitanker to dip, load, and takeoff facing the wind. The mixing unit should be situated outside of the helitanker's flight path.

A man trained in helitanker use should be stationed at the mixing site to supervise loading and to enforce safety regulations. All personnel associated with the retardant operation, particularly those in the loading area, should wear hard hats with chin straps. Face masks and goggles should be worn by retardant mixing personnel. The supervisor should coordinate the movements of other helicopters and aircraft (float planes) in the vicinity of the mixing site. He should also be equipped with a portable radio to communicate with the helitanker.

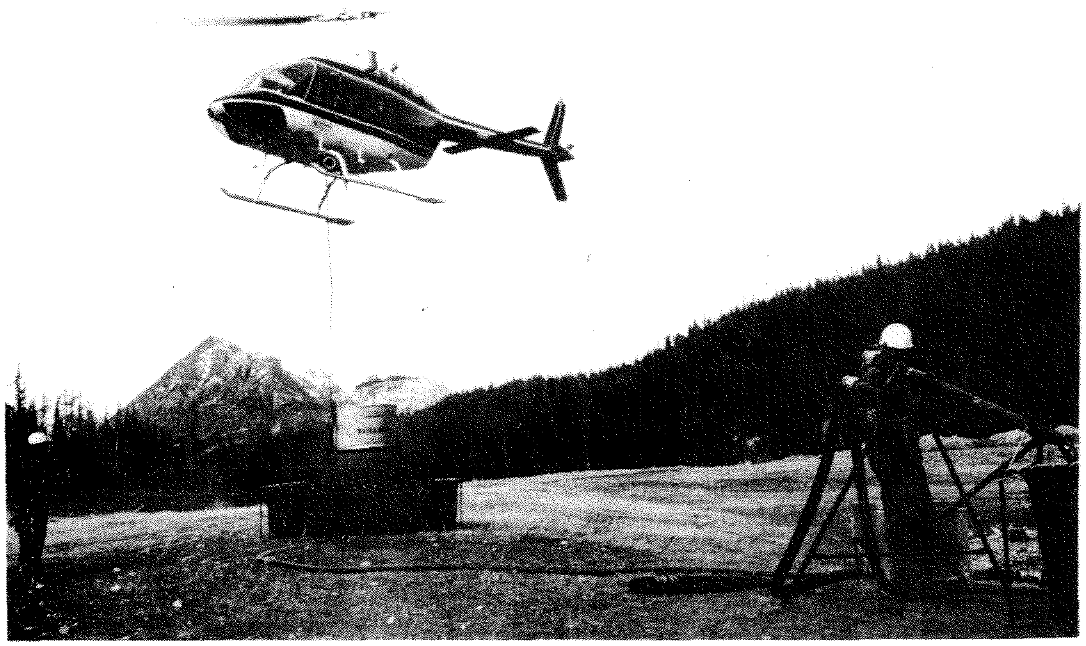

Photo: NFRC

Figure 14. The holding tank for retardant should be located away from the mixing unit (lower right). A Bell 206B Jet Ranger equipped with a Hawkins and Power Water Buoy-110 dip-loads from the holding tank. The helitanker operation is coordinated by a supervisor.

APPLICATION OF WATER AND RETARDANT

The methods of applying water and long-term retardant with the helitanker differ. Water, primarily used as a suppressant, is usually applied directly onto the burning fuel. Heavy concentrations are required and the entire bucket is normally released at one time. Long-term retardant is used as either a suppressant or retardant, and is usually applied on the perimeter or adjacent to the fire edge, although for small spot fires it is generally applied directly. Less retardant than water is required and several individual drops may be made with one bucket load. Since this retardant has a long term effect, its use must be integrated into the fire suppression strategy[13].

A helitanker pilot experienced in the application of water is not necessarily experienced in the use of costly retardant. It is advantageous, if not essential, to have a suppression supervisor control the application of retardant. A medium helicopter such as the Sikorsky S58T costs $650 per h, or about $11 per minute; it carries 350 gal of retardant which costs at least $.50/gal, or $175 per load, and therefore must be efficiently managed. The cost of mixing the retardant can easily equal the cost of the material[14]. If possible, the supervisor, who is likely paid $7.50 per hour, or approximately 1% of the cost of operating the helicopter, should accompany the helitanker or otherwise direct the drops.

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[13] Although retardant often extinguishes fire in light fuel and prevents rekindling in fine fuels, it does not prevent smoldering in subsurface fuels, especially in deep duff. The fire often burns underneath a retardant line. Follow-up with ground crews is almost always essential.

[14] Because of the many variables which occur with a helitanker operation a cost analysis of a "typical" operation is difficult.

The experience of the helicopter pilot affects the efficiency of the helitank operation. The time for dip-loading water can vary between 4 and 30 sec depending upon the pilot's technique. Dip-loading retardant from a holding tank is equally variable; an experienced pilot can obtain a load in 7 to 15 sec while an inexperienced pilot takes considerably longer and can easily damage the tank. During mop-up, the helitanker drops must be precise. When the helitanker supports a ground crew, radio contact between the crew boss and pilot permits accurate and effective drops. Close coordination permits optimum utilization of both the helitanker and ground crew.

The wide range of drop speeds and heights available with the helicopter and the variable discharge rates of most helibuckets makes the helitanker a versatile delivery platform. For example, with a medium helicopter, a heavy concentration of retardant (or water) over a small area to either douse an ignited snag or penetrate a tree canopy to stop a surface spot fire can be obtained with a high hovering drop, a medium concentration along a wide swath to treat the perimeter of a moderate intensity logging slash fire can be obtained with a slow high drop, and a light concentration along a narrow swath to stop a fast-spreading fire in light surface fuel can be obtained with a fast, low drop using a controlled gate opening.

Minimum helitanker drop heights and speeds are necessary. The downwash from helicopters, particularly the large models with 300-1000 gal buckets, can fan a fire and increase its intensity and rate of spread. However, guidelines for minimizing the effects of downwash vary. Results of tests with the Bell 204B showed that the aircraft should make fly-bys at speeds of 35-40 knots and at heights above 50 ft under average 10 mph wind conditions. Under zero wind conditions, the height should be increased to 100 ft to eliminate the effects of the rotor wake (Shields, 1969). The hovering downwash from the Bell 204B is potentially dangerous up to 300 ft. In the vicinity of a fire, drops at 20 knots should be made at a height above 200 feet, drops at 40 knots at a minimum height of 100 ft, and drops at 60 knots at a minimum height of 50 ft from medium-size helicopters (Grigel et al., 1974). Drops from large helicopters should be made from a hovering elevation above 300 ft; at elevations below 300 ft the drop should be made with at least 15 mph forward speed (Wilson, 1973). With small helicopters carrying 50-150 gal buckets, downwash is not a serious problem when the hover is only for a few seconds and at least 75 ft above the fire (Wilson, 1973).

Various techniques have been developed to reduce the effects of downwash on fire behavior. Several operators approach the target at high speed and height, then "float" through the area during the drop. With the larger helitankers, the pilot can approach the target from the side and, using the centrifugal force developed in the swinging bucket, "fling" the retardant towards the target; the rotor blast is thus minimized.

When drops are made into a forest stand tree cover usually affects downwash depending on the shape of the tree crowns and density and height of the stand. Usually tree cover helps to dissipate downwash, although observations in white spruce stands have shown that the downwash effect from the helicopter can be augmented. The conical crowns of the spruce trees form funnels which appear to increase the turbulence on the ground. Although not all drops with helitankers are made in the vicinity of the fire front (e.g., often a retardant fire-line is established parallel to the fire), careful consideration should be given to the effect of drop height and speed on wildfire control operations.

DISCUSSION

Helitanker programs, especially those using retardant, are at present comparable to the early fixed-wing air attack operations. Helicopters are not always readily available for bombing, and retardant support facilities and crews are generally inadequate. Qualified supervisory personnel are usually committed to other fire suppression duties and are unavailable when required. Close coordination of the helitankers with ground suppression crews and other suppression equipment is often lacking. These factors combine to create the general impression that helitankers are ineffective and uneconomical for applying retardant.

Until helitanker programs are developed to the level of current fixed-wing air attack programs--realizing that the initial attack capability of helicopters is limited--efficient retardant operations with helitankers will not be possible. Separate funds must be allocated to both fixed-wing airtanker and helitanker programs. Integration of the two attack systems is essential for optimum efficiency.

The acceptance of long-term retardant will promote the operational use of large helicopters. Tests with a H-MAFFS (Helicopter-Modular Airborne Fire Fighting System) mounted in a Chinook (C-47) helicopter have recently been carried out; a 1500-U.S. gal retardant system has been tested for drop characteristics and general operational performance (Anon. 1974). Use of these large helicopters for dropping retardant, however, will likely be limited to missions where the high cost can be easily justified. Development of retardant programs will primarily center around the medium helicopter. The availability of the medium helicopter and its multi-use function on wildfire operations will promote this development.

The helicopter is in the process of replacing many of the conventional modes of transportation, including the wheeled vehicle, floatplane, all-terrain vehicle, and foot-travel. It is thus more available for use as a helitanker. Use of the helitanker to establish suitable retardant control lines from which to anchor aerially-ignited backfires and burnouts and to control resulting spot-fires has been operationally tested in northern Canada (Lait and Taylor 1972). Operational tests of the helicopter to rappel initial attack crews into remote, inaccessible fires are also underway (Anon. 1973c). The helicopter can then convert to a helitanker and support the crew from the nearest water source. These modifications to current suppression methods and techniques to integrate the helicopter will increase its use as a helitanker in the future.

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LITERATURE CITED

Anon. 1955. Aerial fire fighting--The helitanker. Operation Firestop Prog. Rep. No. 10, Pac. Southwest For. Range Exp. Sta., 5pp., illus.

Anon. 1965. Bell 204B helitank evaluation (modified 300 gallon). USDA For. Serv., Arcadia Equip. Develop. Cent., Spec. Rep. ED and T-1139, 11pp., illus.

Anon. 1967a. A fiberglass helicopter sling bucket. Oreg. Dep. For. Activ. Fire Contr. 13, 3pp., illus.

Anon. 1967b. Chemicals for Forest Fire Fighting. A report of the NFPA Forest Committee. 2nd ed. (Boston: National Fire Protection Association). 112pp., illus.

Anon. 1968. Large helicopter use in fire suppression. USDA For. Serv., Fire Contr. Notes 29(3):13-14.

Anon. 1969. User guide--Phos-Chek fire retardant by Monsanto. Monsanto Company, St. Louis, Missouri.

Anon. 1971. A mobile mixing base for Phos-Chek fire retardants. USDA For. Serv., San Dimas Equip. Develop. Cent., Spec. Rep. ED and T-712, epp., illus.

Anon. 1973a. Interagency Helicopter Management Training Guide: TT-78 (5100). USDA and USDI, February, 1973.

Anon. 1973b. The Phos-Bin Bulk System. Monsanto Company, St. Louis, Missouri, 1pp., illus.

Anon. 1973c. Fire Down Below. Truck Logger, May, 1973, p.27.

Anon. 1974. H-MAFFS Modular Retardant System. North American Forestry Commission, For. Fire News, January 1974, pp.16.

Cobb, S.S. 1961. Pennsylvania's initial attack operations - Spring, 1960. USDA For. Serv., Fire Contr. Notes 22(3):90-100.

Davis, J.B. 1963. Dropping fire retardants by helicopter: Tests of three new helitanks. USDA For. Serv., Res. Note PSW-27, 16pp., illus.

Dodge, M. 1966. Mass helitack on large fires in California. USDA For. Serv., Fire Contr. Notes 27(4):4-5, 16, illus.

Grigel, J.E. et al. 1974. Air drop tests with helitankers. Environ. Can.,Can. For. Serv.,North. For. Res. Cent. Inf. Rep. NOR-X-77. 78pp., illus.

Jefferson, F.J. 1948. The helicopter - a new factor in fire control. USDA For. Serv., Fire Contr. Notes 9(1):1-9, illus.

Johansen, R.W. 1967. A new approach to fireline construction. USDA For. Serv. Fire Contr. Notes 28(1):6-7, illus.

Lait, G.R. and W.C. Taylor. 1972. Backfiring and burnout techniques used in the Yukon, 1972. Environ. Can., Can. For. Serv., North. For. Res. Cent. Inf. Rep. NOR-X-43, 12pp., illus.

Newburger, A. 1968. Study into the Use of Aircraft in the Control of Forest Fires - Summary. United Aircraft of Canada Ltd., Longueuil, Quebec.

Noste, N.V. and R.M. Percival. 1972. Alaska's extra ace: water dropping. USDA For. Serv., Fire Contr. Notes 33(2):9.

Percival, R.M. and N.V. Noste. 1973. Helicopters and helibuckets used to control interior Alaska wildfires. USDA For. Serv., Fire Contr. Notes 34(1):16-18.

Shields, H.J. 1969. Helicopter rotor downwash effects. USDA For. Serv., San Dimas Equip. Develop. Cent., Spec. Rep. ED and T-1818, 13pp., illus.

Simard, A.J. and R.B. Forster. 1972. A survey of airtankers and their use. Environ. Can., For. Fire Res. Inst. Int. Rep. FF-17, 152pp., illus.

Wilson, K.O. 1973. The helicopter bucket...a versatile tool. USDA For. Serv., Fire Manage. 34(3):15.

APPENDIX I

Metric Equivalents

1 gallon (Can.)	=	4.546 litres
1 gallon (U.S.)	=	3.785 litres
1 pound	=	0.454 kilograms (kg)
1 ton	=	0.907 tonne (t)
1 inch	=	2.54 centimetres (cm)
1 foot	=	0.304 metres (m)
1 mile	=	1.609 kilometres (km)
1 acre	=	0.405 hectare (ha)
1 square foot	=	0.093 square metres (m^2)
1 mile per hour	=	0.868 knots (kn)

1974

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 chem/ton	PACKAGING METHOD	MIXING PROCEDURE	APPLICATION METHOD	STORAGE PROCEDURE	JULY 1974 COST 22 TON MINIMUM	REMARKS
PHOS-CHEK XA	$(NH_4)_2HPO_4$ 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_2O_5 equivalent	7	1560 1180 (● 7·5 P_2O_5 equivalent) ①	● 57 lb. bags - 1 ton pallets - bulk ■ 1 ton Phos-Bin	continuous flow eductor - batch	aerial	- wet - dry	● $516.00/ton ■ $526.00/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 XA ABOVE	94 2 1 3	1·92	1·75	10·9	50-100	15·0 DAP 8·1 P_2O_5 equivalent	10	1140	50 lb. bags	- continuous flow eductor - batch - agitation	ground	- primarily dry	$516.00/ton	(c) Low viscosity for ease of pumping for ground application Higher active salt content than XA a,b.
FIRE-TROL 100	$(NH_4)_2SO_4$ 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 $(NH_4)_2SO_4$	20	720	50 lb. bags	- batch	aerial	- primarily wet	$163.00/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	$(NH_4)_2HPO_4$ 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_2O_5 equivalent	0	675 (14·8 lb/gal)	- 670 lb/45 gal - bulk	- proportioner (blender) - agitation	aerial	- concentrate only	$197.00/ton	Non-viscous solution Minimal, and ease of handling "VARIBLENDER" provides improved control of L.C. and water intake New improved corrosion inhibitor Solution mixed upon discharge from loading pump Polyphosphate reverts to orthophosphate during long term storage of L.C. ① 8·3 % P_2O_5 in 10-34-0 is equivalent to 7·5 % P_2O_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_2O_5 equivalent	0	675 (14·8 lb/gal)	- 670 lb/45 gal - bulk	- proportioner - agitation	ground	- concentrate only	$197.00/ton	Similar to F.T.-931 but: -no clay content -non-abrasive -colourless a,b,c.

'gn 72-74 F-2062