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DROPPING FIRE RETARDANTS BY HELICOPTER: TESTS OF THREE NEW HELITANKS

By
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ABSTRACT: Late model helicopters equipped with new helitanks and adequately supplied can accurately deliver as much fire retardant as most fixed-wing air tankers at a potentially lower cost. Viscous water dropped from helicopters clung to fuel surfaces and was concentrated in a narrower pattern than plain water.

Under many conditions in the western United States, late model helicopters equipped with new accessories and adequately supplied can drop as much fire retardant as most fixed-wing air tankers, and with greater accuracy and economy.

This conclusion is based on studies held at Minter Field, north of Bakersfield, California, in April 1963. These studies included drops of fire retardant materials from three new helicopter tanks at selected combinations of heights and speeds and tests of equipment for mixing and loading fire retardant at the heliport.

The drop tests were a cooperative venture of the California Division of Forestry, Los Angeles County Fire Department, Kern County Fire Department, and three U.S. Forest Service organizations: Pacific Southwest Forest and Range Experiment Station, Arcadia Equipment Development Center, and California Region.

1/ The author is in charge of firefighting techniques research at the Pacific Southwest Station, on assignment from the California Division of Forestry.

Figure 1.--One of three assemblies of 1/2-inch pine dowels located in the target area. Rubble kept the plywood cover from sliding during the drop impact.

TEST PROCEDURES

All drops were made over a system for collecting liquid that consisted of two measuring devices:

1. A grid of 10-ounce paper cups on 121 metal holders, placed in a uniform pattern over the 400-foot long by 50-foot wide drop area.

2. Three 12- by 18-inch assemblies of $\frac{1}{2}$-inch pine dowels spaced one-half-inch apart within the assembly, placed along the center line of the drop area (fig. 1). The helicopter pilots tried to release their loads so that the three assemblies would be within the impact area.

Precise drop heights and speeds were determined from films taken of each drop sequence (fig. 2). After each drop, the cups were collected, capped to prevent evaporation, marked with their location numbers, and weighed to the nearest 0.1 gram. We subtracted dry cup weight and converted the weight of liquid to gallons per 100 square feet.

The three dowel assemblies were weighed just before and immediately after the drop. The difference in weight due to the adhering retardant was converted to grams of retardant per square inch of dowel surface.

HELITANKS TESTED

One of the chief reasons that commercial helicopters have not been more widely used as air tankers is that their low engine power has limited loads to 35 gallons or less. But within the past few years, manufacturers

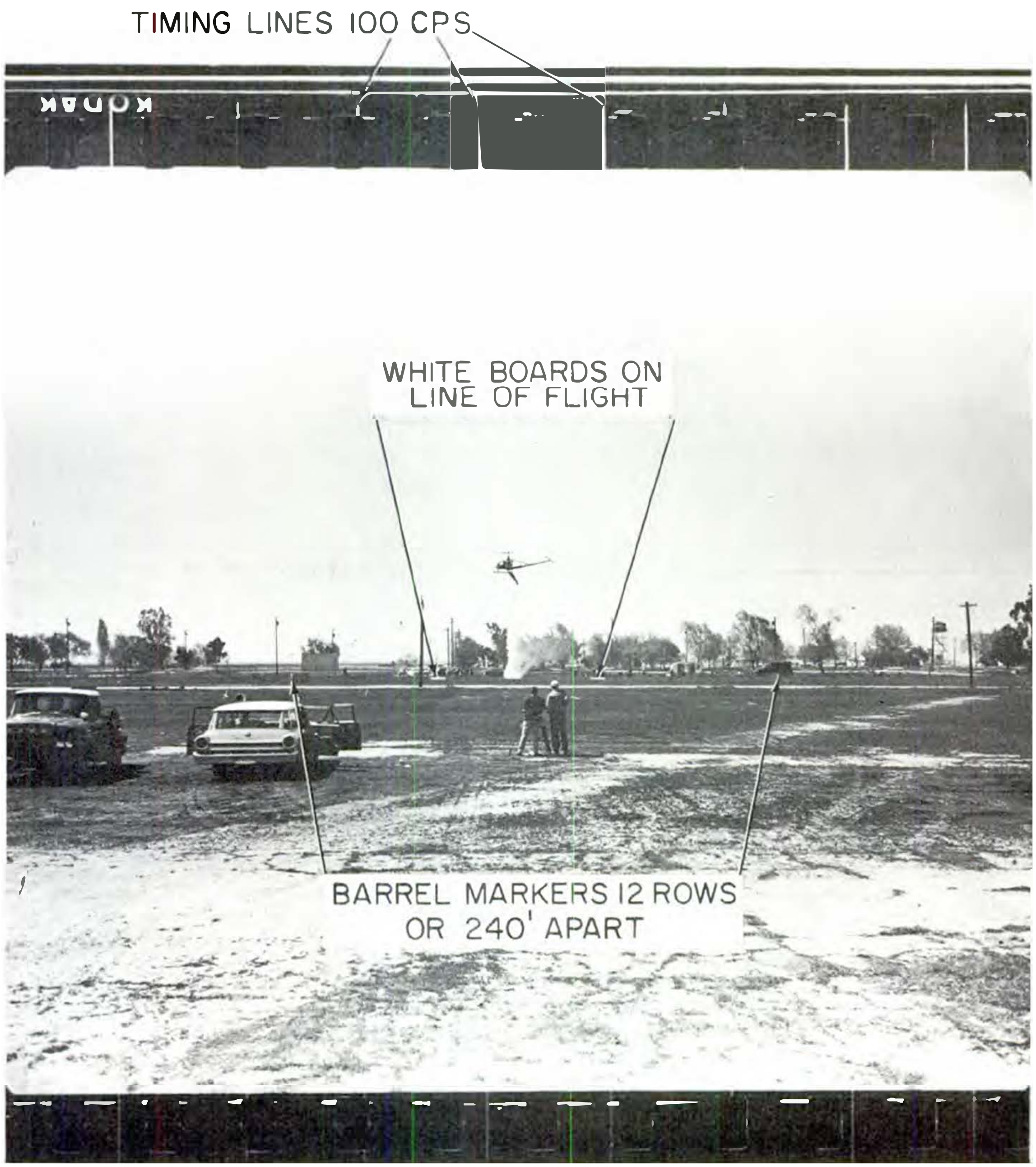

Figure 2.--Scene of the command post, drop area, and helitanker--taken with the Hulcher 70 mm. camera.

have developed more powerful helicopter engines and designed new helitanks that can carry up to 100 gallons. We tested three such helitanks --two metal and one neoprene.

Los Angeles County Fire Department tank.--This all-metal tank holds 105 gallons of water or fire retardant solution (fig. 3). With attached fittings, an empty tank weighs 50 pounds. It can be installed or removed by two men in 2 minutes.[2] The tank is clamped to the fore and aft cross tubes of the helicopter landing gear at the four saddle points. It is fitted with interior baffles. The gates can be opened and closed electrically or manually by cockpit controls, and the width of the opening can be adjusted, providing the pilot good control over the length of the ground pattern.

The tank's rigid symmetrical mounting does not affect stability because the load cannot sway from side to side. The retardant discharge pattern resembles that of fixed-wing air tankers. Costing $1,200, the tank was more complex than the other two tanks tested at Minter Field.[3]

Meade tank.--The all-metal, open-topped Meade tank is designed and stressed to carry 800 pounds (fig. 4). It should not be overloaded. Four struts connect the forward end to the fuselage of the helicopter; a manually operated catch supports the aft end. The pilot lowers the rear end of the tank by releasing the catch. After the retardant has been spilled, elastic cords automatically snap the tank back up into place. The pilot has no control over the discharge rate because the liquid drops in a mass.

The tank and release mechanisms are simple, easy, and quick to install, and cost about $600. The tank can also serve as a carrier for low density cargo, such as lunches and fire hose.[4]

Irvin Air Chute tank.--The Irvin "tank" is actually a 7-foot long, 3-foot diameter vinyl sleeve attached to an electrically actuated release mechanism that snaps up into the bomb shackle of an adapter for either Bell or Hiller helicopters (fig. 5). The lower end of the sleeve is pulled up inside itself and held in place by two bars to form a 100-gallon bag. When the bars are released, the bottom of the bag drops down, forming a tube through which the liquid flows. To keep the bag from flopping about, the pilot can retract it by operating elastic cords or an electric winch mounted on the release assembly.

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[2] Singleton, Robert C. New 105-gallon helitank. U.S. Forest Serv. Fire Control Notes 23(4): 108-109, illus. 1962.

[3] Additional information on this tank may be obtained from Keith E. Klinger, Chief, Los Angeles County Fire Department, P. O. Box 3009, Terminal Annex, Los Angeles 54, Calif.

[4] Additional information on the Meade tank may be obtained from James Meade Helicopters, Porterville, Calif.

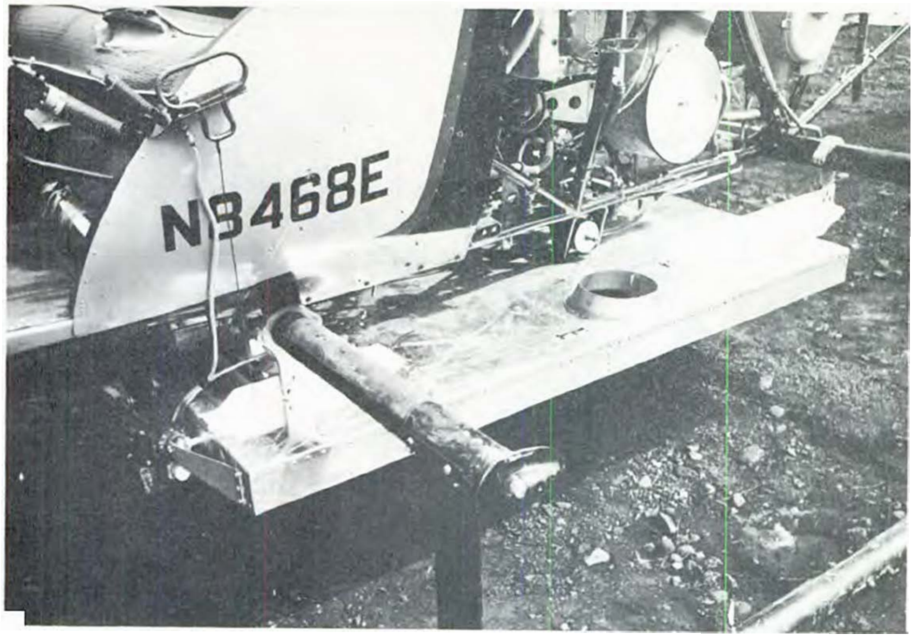

Figure 3.--Los Angeles County Fire Department tank mounted on the Fire Department's Bell 47G2 helicopter.

Figure 4.--The Meade tank installed on a Hiller 12E helicopter.

Figure 5.--Filling the Irvin Air Chute tank as it is hovering—or why fire safety officers get grey.

The ground pattern can be lengthened by increasing helicopter speed inasmuch as the sleeve somewhat restricts retardant flow. Drop height also affects pattern size. Since the bag hangs below the helicopter's landing gear, it must be attached while the aircraft is hovering, is supported by a platform, or stands over a hole in the ground. For the most efficient operation, use two bags--fill one while the helicopter is carrying another to the fire. One man can attach or detach a bag in seconds.

The tank and mechanism are comparatively simple, and can be rolled up into a small package for transportation. Costs are $155 for the release mechanism and about $175 for the tank.[5]

RETARDANTS TESTED

Recent tests have shown that the effectiveness of water for fire-fighting can be greatly increased by making it thick or viscous.[6] As a result, viscous water and gels (a very thick form of viscous water) are being widely used both from fire trucks and from fixed-wing air tankers.

Viscous water appears to be particularly applicable to helicopter operations because only a very small quantity of powder is required to thicken the liquid. Consequently, a helicopter can, if necessary, carry its own supply of chemical to a fire. We wanted to know how well viscous liquids would drop at the relatively low heights and at speeds at which helicopters fly and how effectively the material would adhere to fuel surfaces.

We tested the following materials for their mixing, handling, and drop characteristics:

CMC (sodium-carboxymethyl-cellulose-7HSP) has been used extensively in fire trucks in California. This white or buff-colored powder resembles corn meal. During the test, we mixed CMC at the rate of slightly more than 3 pounds per 100-gallon helitank load (0.4 percent) and produced a viscosity of about 300 centipoise--similar to 30-weight motor oil. The cost is about 2 cents per gallon.

Algin gel (sodium alginate-keltex FF plus calcium chloride) is a thick viscous water produced by adding a small amount of calcium chloride solution to water that has been thickened with algin at the rate of about 5 pounds per 100 gallons of water. The resulting solution is similar to gelatin--rigid and strong enough to support its own weight. Algin gel is being used successfully as a suppressant and short-term retardant from both fire trucks and fixed-wing air tankers. It costs slightly more than 5 cents per gallon.

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[5] Additional information on this tank may be obtained from Irvin Air Chute Company, 622 Rodier Dr., Glendale, Calif.

[6] Davis, James B., Dibble, Dean L., and Singer, K. L. Tests of fire retardant chemicals at Plum Creek, Calif. Calif Air Attack Coordinating Com. 14 pp., illus. 1962.

Gel-Guard is a snythetic polymer. The finely ground powder absorbs water and swells to produce tiny particles or beads rather than the fibers produced by the other two viscosity agents. Although its viscosity cannot be measured directly in centipoises, the gel is rigid enough to support its own weight. About 1½ pounds per 100 gallons will produce a thick gel, although the exact quantity varies, depending on water hardness. The cost is about 2 cents per gallon.

Water was dropped from each tank throughout the test series both as a control and as a fire retardant in its own right. Under conditions where fuels are light or penetration into leaf mold is required, plain water may be the most effective and practical retardant for helitanker use.

TEST RESULTS

EFFECT OF VISCOSITY

The test results showed that more retardant clung to or "stayed put" on the dowel grid assemblies when water was thickened (table 1). A qualitative examination made after drops on natural brush fuels showed similar retention.

Table 1.--Retention of retardants on fuel surface after helicopter drops, as related to viscosity[1]

Retardant	Viscosity	Retention on fuel surface		
		L.A. Co. test	Meade test	Irvin test
	Centipoise	- - - Grams/square inch - - -		
Water	Low (1-100)	0.18	0.24	0.16
CMC	Moderate (100-1000)	1.01	0.52	0.71
Dow	High (1000-5000)	1.68	0.39	2.00
Algin gel	High (1000-5000)	1.62	0.48	2.62

1/ Average value for three grids for a series of three or more drops.

Retention appeared to be related to degree of retardant thickness for both the Los Angeles County Fire Department tank and the Irvin Air Chute tank. Retention of algin gel dropped from the Irvin helitank was 16 times that of unthickened water. In the Meade tank test, twice as much viscous liquid was retained on the grids than plain water, but even so these results were consistently lower than in the other tank tests. The retardant falling in droplets from the other two tanks tended to adhere to the dowels better than the more or less single mass of liquid from the Meade tank.

In all tests, viscous liquids produced a somewhat smaller and denser pattern than plain water. When dropped at speeds of 20 to 40 miles per hour and from heights under 50 feet, plain water produced a wider pattern than viscous water. At these speeds and heights, the pattern length was about the same for retardants (fig. 6).

Air drops made at high elevation and high speed tended to be much less concentrated than low, slow drops. Liquids cascaded into the air from a fast moving aircraft broke into droplets, their size varying with air turbulence and viscosity. Viscous liquids, such as algin gel, formed larger droplets than plain water. Drift and evaporation rates both increased rapidly as droplet size decreased.[7]

The effects of height, speed, and viscosity became apparent when we compared patterns obtained with helicopter drops made at low speed and height to patterns of larger volume drops made by fixed-wing air tankers at greater speeds and heights (table 2). In all cases, the area covered by 1 gallon per 100 square feet was larger for the fixed-wing aircraft. However, the portion of the target receiving 2 gallons or more per 100 square feet--the minimum we estimate that is required to suppress a hot fire in heavy fuel--was actually larger for the slower flying helicopter than for such small fixed-wing aircraft as the N3N.

Table 2.--Helicopter drop patterns compared to patterns typical of fixed-wing aircraft

Aircraft	Retardant	Drop volume	Drop ht.	Drop speed	Concentration in gallons per 100 square feet: 1	2	3	4
		Gallons	Feet	M.p.h.	Area covered in square feet			
Helicopter[1/]:								
Bell 47G	Water	100	50	36	2,382	1,287	750	419
Bell 47G	CMC	100	54	30	2,256	1,487	785	175
Bell 47G	Dow	100	50	30	1,680	825	419	187
Bell 47G	Algin gel	100	57	26	1,405	985	857	579
Fixed-wing:								
N3N	Water	180	90	100	3,100	94	0	0
N3N	Borate	180	100	100	2,671	142	0	0
Twin Beech	Bentonite	300	115	100	7,839	3,089	359	0
Twin Beech	Bentonite	300	102	125	4,050	1,311	0	0
TBM	Water	400	109	100	30,172	1,840	269	0
TBM	Bentonite	400	126	75	10,542	5,106	2,838	332

1/ Equipped with Los Angeles County Fire Department tank.

7/ Reed, Wilmer H., III. An analytical study of the effect of airplane wake on the lateral dispersion of aerial sprays. U.S. Natl. Advisory Com. Aeronautics Tech. Note 3032, 46 pp., illus. 1953.

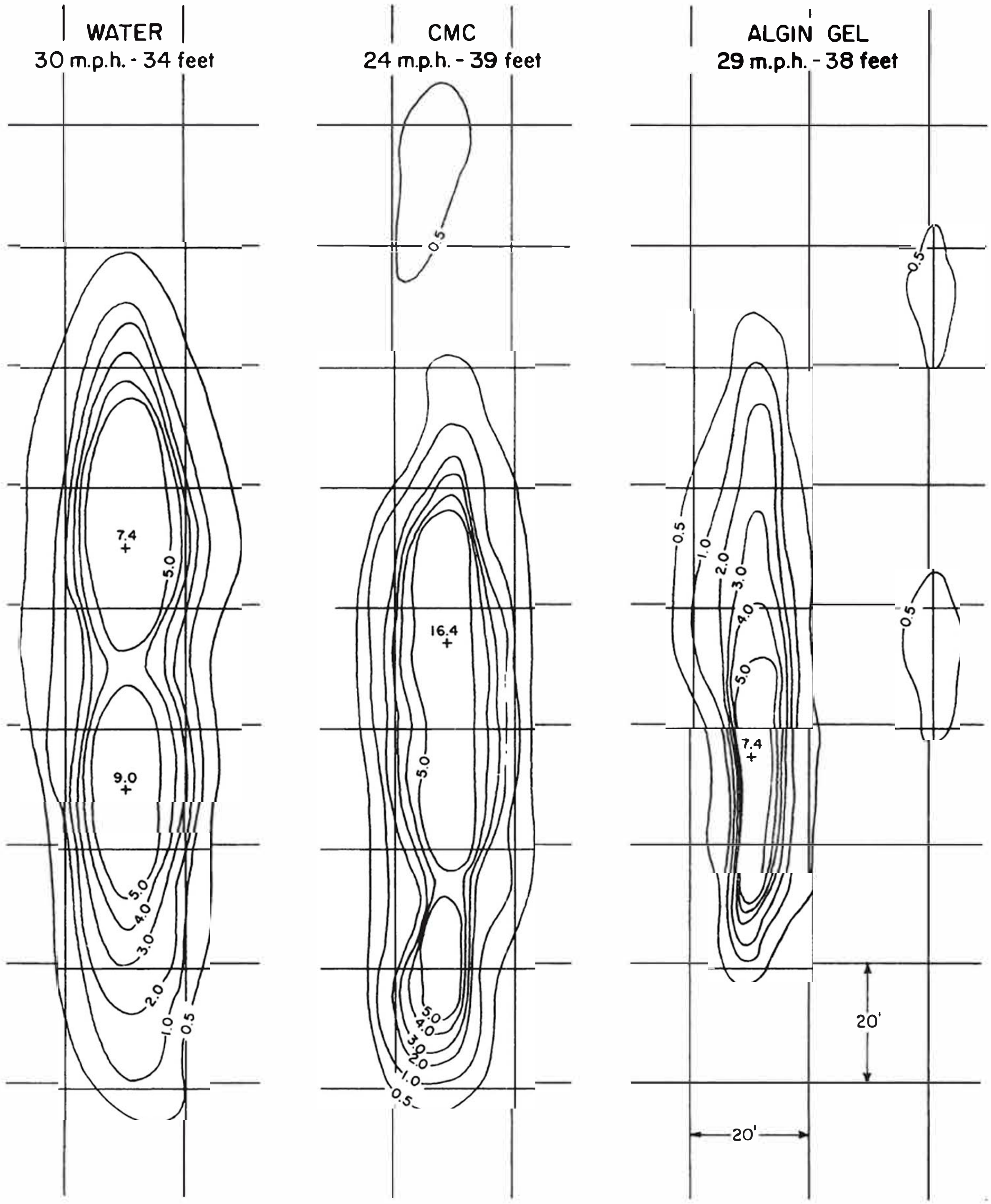

Figure 6.--Drop patterns obtained with plain water, CMC, and algin gel in tests of the Los Angeles County Fire Department tank.

Retardants for helicopter use are made as needed "on the spot." Therefore, the retardant can be tailored to the needs of the individual fire situation or "fire job." The maneuverability of helicopters enables the pilot to make his drop at the optimum height and speed. The Minter Field tests provided us optimum ranges of height and speed for each of the three helicopters tested. Table 3 suggests viscosity of the retardant, and height and speed at which the helicopter should fly to obtain the best drop pattern, according to various fuels or "fire jobs."

Table 3.--Suggested viscosity of retardant, drop height and speed of helicopter for various fuels

Fuels	Viscosity	Height	Speed
	Centipoise	Feet	M.p.h.
LOS ANGELES COUNTY FIRE DEPARTMENT TANK			
Low (grass)	Low-medium (1-1000)	35-50	35+
Medium (light brush)	Medium (100-1000)	35-50	25-30
High (heavy brush, timber, slash)	High (1000-5000)	35-	25-30
Special (snag, spot)	Medium-high (100-5000)	--	--
MEADE TANK			
Low (grass)	Low-medium (1-1000)	100-125	25-30
Medium (light brush)	Medium (100-1000)	100-125	25-30
High (heavy brush, timber, slash)	High (1000-5000)	--	--
Special (snag, spot)	Medium-high (100-5000)	100-150	10-20
IRVIN TANK			
Low (grass)	Low-medium (1-1000)	50+	25+
Medium (light brush)	Medium (100-1000)	55-65	25-30
High (heavy brush, timber, slash)	High (1000-5000)	45-55	20-25
Special (snag, spot)	Medium-high (100-5000)	--	--

ACCURACY OF HELICOPTER

During the Minter Field trials, the helicopter pilots demonstrated a consistent high level of accuracy. They were instructed to make their drops so that the three dowel assemblies set up 20 feet apart along the center line of the drop area would be in the center of the ground pattern. This area represents a 40-foot by 18-inch target. In more than 75 percent of the drops, two or more of the assemblies were within the 1 gallon or more per 100 square foot area. All drops were in line; misses were due to over-shooting or under-shooting the target. The frequency with which dowel assemblies were hit by helicopter drops was:

	Los Angeles County tank	Meade tank	Irvin tank
	(number of drops)		
Number of assemblies hit:			
All 3	10	4	6
2	7	4	7
1	2	4	1
Complete miss	0	2	2

DROP CHARACTERISTICS OF TANKS

Los Angeles County Fire Department tank.--The ground pattern obtained with this tank was largely a function of retardant viscosity and aircraft speed (fig. 7A and B). The retardant flowed through a restricted opening, and a high forward ground speed tended to distribute the chemical over a longer swath on the ground. The high speed also tended to break up the material into smaller droplets, resulting in more drift and a wider pattern. The pilot could control his application rate to meet the individual fire situation by presetting the gate opening of the tank or varying his drop speed. Variations within the normal range of drop heights did not appear to affect the pattern of drop for viscous liquids.

Meade tank.--Tests of the Meade tank showed that the area covered by 1 gallon of viscous water or more per 100 square feet was related to drop height (fig. 7 C and D). Since the retardant spilled from the tank as a single mass without restriction to its flow rate, speed did not influence drop behavior except to break up the material into smaller size droplets. But when drop height was increased, the material drifted and covered a larger area. For the best patterns, drops should be made at heights above 100 feet. While such drops permit an extra margin of safety, they also tend to be less accurate.

Irvin Airchute tank.--Both area and length of the 2 gallon per 100-square-foot pattern obtained with the Irvin tank were affected by helicopter height and ground speed (fig. 7 E and F). The pilot could vary the ground pattern to meet various fire situations by modifying his height and speed.

METHODS OF MIXING AND LOADING

A modern helitanker can cover accurately a fairly large area of vegetation with fire retardant. But the aircraft should be operated as closely to the fire line as possible if its capabilities are to be fully realized. By keeping close to the fire line, a helicopter can fly a large amount of water or retardant to a fire in a short time. In one instance, a helicopter flying from the top of a dam to a nearby fire in the canyon below made a round trip every 2 minutes and dropped water at the rate of 3,000 gallons per hour.

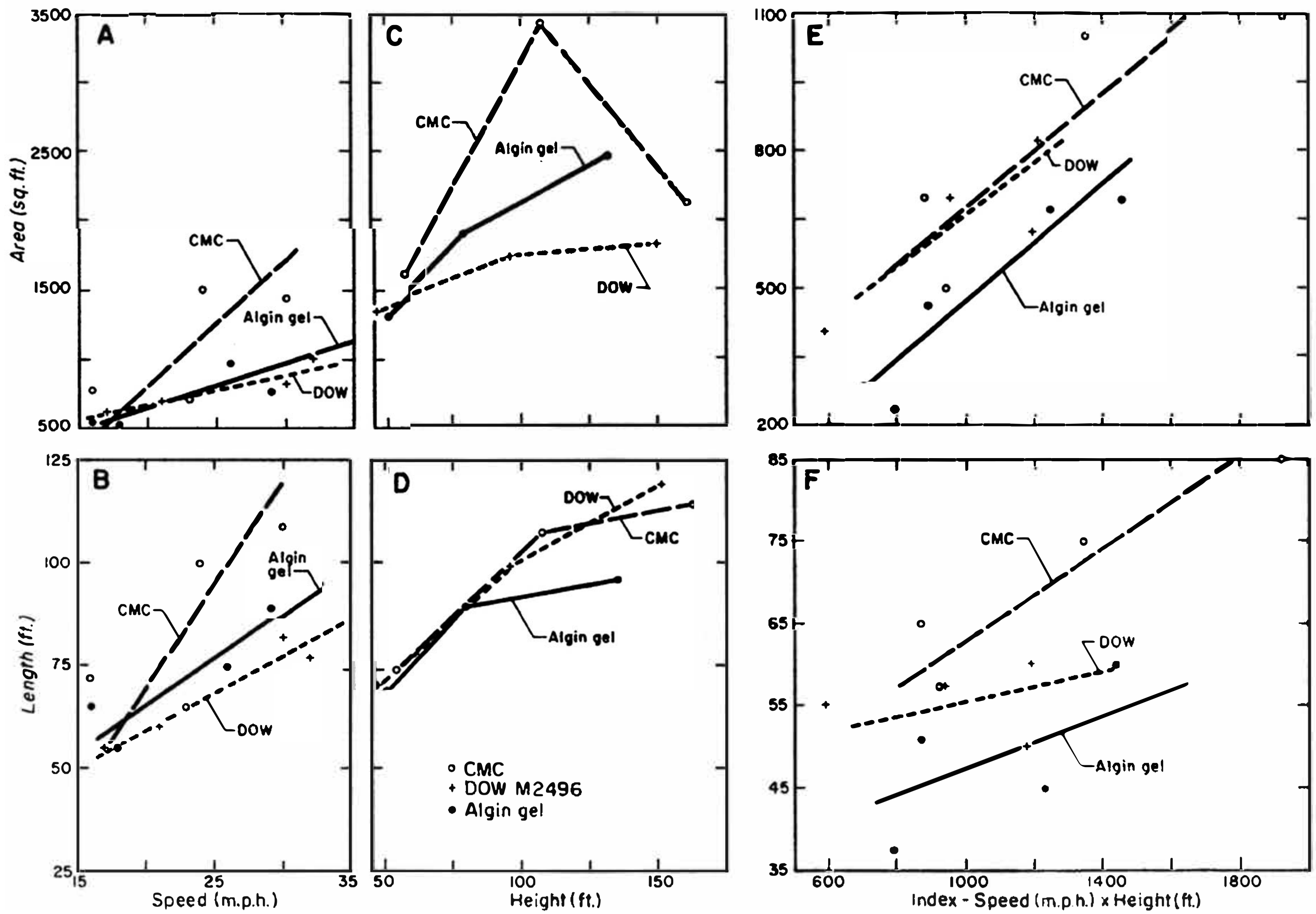

Figure 7.--In tests of three helitanks (Los Angeles County, A, B; Meade, C, D; and Irvin, E, F) dropping three types of fire retardant chemicals (CMC, Dow M2497, algin gel), increasing drop speed, drop height, or both generally resulted in greater area covered by 1 or more gallons per 100 square feet and in longer ground pattern.

Helicopter equipment for mixing retardant must be mobile, available when needed, and have an adequate capacity to serve two or more aircraft on a sustained basis. We tested two methods of mixing and loading viscous liquids at Minter Field.

Fire truck.--A standard California Division of Forestry fire truck was used as a mixing and supply base. Equipped with a 500-gallon tank, 250 gpm pump, and viscous water mixing equipment, the vehicle is typical of many located throughout California. The truck equipment could mix 500 gallons of CMC-thickened water in 2 minutes using its eductor-mixer. It then could load 100 gallons into a helitank in less than 60 seconds. With an adequate water supply, similar equipment readily available throughout California could mix and load 3,000 gallons of retardant per hour at a heliport.

Arcadia batch mixer.--This multipurpose slip-on unit developed by the Arcadia Equipment Development Center of the Forest Service can be used to mix any known forest fire retardant (fig. 8).[8]

The mixer can be transported on a heavy duty trailer or flat bed truck. It can mix up to 6,000 g.p.h., making it ideal as a mixer-loader for helicopters. The mixer consists of a 300-gallon metal mixing tank, chemical hopper, hose, engine, 300 g.p.m. pump, and pump priming tank. The mixing tank houses a side-entering impeller that mixes the chemical by agitation. To mix the algin gel, 20 gallons of a 5-percent calcium chloride solution were pumped into the mixer from a 55-gallon drum mounted on the back of the truck. Both the Gel Guard and the algin gel mixed in this unit were pumped directly into the helitankers. Mixing times of thick gels averaged about 3 minutes per 300-gallon batch, and transferring 100 gallons to the helicopter took less than 1 minute.

COMPARISON OF COSTS

The cost of delivering fire retardant chemical to the fire line by helicopter can actually be less than delivery by fixed-wing aircraft. But an efficient chemical mixing operation must be set up near the fire line.

One of the principal advantages of the helitanker is its ability to operate from temporary helispots located near the fire. Only 4 or 5 minutes are needed for a round trip. Table 4 compares operating costs for two typical helitankers and three fixed-wing air tankers. It shows that a helitank operation located close to the fire has a cost advantage over air tankers, but it also points out the need for efficiency. For example, if a helicopter required 8 minutes for a round trip because of inadequate chemical mixing facilities, the aircraft would be more costly to operate than the three fixed-wing air tankers listed.

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[8] U.S. Forest Service. A new ground chemical-mixer for forest fire fighting. U.S. Forest Serv. Fire Control Notes 24(1): 17-19, illus. 1963.

Figure 8. --Batch-type mixer developed by the Arcadia Equipment Development Center has a 300-gallon mixing tank.

Several other cost factors not mentioned in the table should be considered and balanced against each other. A helitanker operation does not require the large capital investment in manpower and in mixing, handling, and storage facilities needed by an air tanker base. But, any savings may be offset if large quantities of water must be hauled by truck to a remote heliport. Also as much as 1,000 pounds of high octane gasoline must be supplied to the helicopter each day.

Table 4.--Comparative costs of operating helitankers and fixed-wing air tankers in delivering fire retardants[1]

Aircraft	Capacity	Trips/hr.	Gals./hr.	Cost of aircraft: Per hour	Cost of aircraft: Per gal. of retardant
	Gals.	Number	Number	Dollars	Dollars
Helicopter:					
Bell 47G2	100	15	1,500	130	0.12
Hiller 12E	100	15	1,500	130	.12
Fixed-wing:					
N3N	200	2	400	90	.22
TBM	600	2	1,200	250	.21
AJ-1	2,000	2	4,000	550	.14

[1] Based on round trip of 4 minutes for the helitanker, and 30 minutes for the air tanker.

SUMMARY AND CONCLUSIONS

- The ground coverage obtained with retardants dropped from helicopters using recently developed tanks was comparable to that from small fixed-wing air tankers.
- As much as 16 times more viscous liquid than plain water was retained on fuel surfaces.
- Drop patterns made by viscous liquids are narrower and more concentrated than patterns made by plain water.
- Mobile or portable mixers can supply up to 6,000 gallons of viscous water or gel per hour.
- Each helitank tested had advantages and disadvantages. The choice of tanks will depend largely on the kind of fuels and fires anticipated.
- A helicopter "air show" can be tailored to the immediate fire situation because chemicals do not have to be mixed and stored ahead of time. If fuels are light and penetration through overstory vegetation is not required, use unthickened water or low viscosity solutions. For heavy fuels or penetration, use a thick gel and drop it at a slow speed. Use small gate openings and high speed at greater height to cover a larger area.
- The thickeners should only add from 2 to 5 cents per gallon to the cost of helicopter-delivered water, and they are used in such small quantities that their supply is little or no problem.

NOTE: Use of proprietory or brand names is sometimes necessary to report factually on available data. The Station neither guarantees nor warrants the standard of the product, and use of the name implies no approval of the product to the exclusion of others which also may be suitable.