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F O R E S T   F I R E   R E S E A R C H   I N S T I T U T E

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CONTENTS

Section 1

HISTORY OF THE DEVELOPMENT OF AIRTANKERS

One of the most dramatic technological breakthroughs in forest fire suppression in recent years has been the development and use of airtankers. Although the modern airtanker and air attack techniques have largely evolved during the last decade, the first attempt at dropping water on a fire from an aircraft dates back to 1931. At that time, C. J. Jensen flew sorties against forest fires in Butte County, California, in a World War I Hispano Suisa modified with two small exterior mounted water tanks (Reinecher and Phillips, 1960). Five years later in 1936 a series of projects were initiated in California to determine the effectiveness of not only dropping water but fire retardants. These experiments lasted until 1939 at which time it was concluded that aircraft currently available were not capable of an effective airtanker role (Reinecher and Phillips, 1960, Clepper, 1969).

The next chapter in the development of airtankers occurred during the years following World War II. In 1945, the Ontario Department of Lands and Forests installed valves in the floats of a Norsman which enabled part of the float to be filled while the plane was on the water and dumped by the pilot while over the fire. Because of the limited capacity, the aircraft was not considered effective (Fraser, 1962). In 1947 and 1948 the U.S. Air Force dropped surplus fuel tanks filled with water from military bombers (P-47 Thunderbolts, B-29 Super Fortresses and B-25 Mitchells) on fires in Montana. These experiments were abandoned because of the extreme hazard to ground personnel (Reinecher and Phillips, 1960). In 1949, the Ontario Department of Lands and Forests developed a technique of dropping a salvo of 3 gallon latex lined paper bags of water through the cargo hatch. Although evaluated as successful, on a limited basis, this system was not adopted outside the province (Anonomous, 1958).

The next step in the development of airtankers took place in California in 1954. In a series of experiments called Operation Fire Stop, a TBM was equipped with a 500 Imp. gallon tank mounted in the bomb bay. The plane was used to drop both water and retardants at various heights, and the first drop patterns were developed (Reinecher, 1958). The experiments with this plane ushered in an era which is currently with us today; the conversion of World War II fighter-bombers and bombers to airtankers. In 1955 tests were conducted with a modified N2S Stearman bi-plane which had been converted to a crop sprayer (Ely, Jensen, Chatten and Jori, 1957). The PBY and the C-82 were modified and used on forest fires in California in 1956.

The turning point, where airtankers ceased to be a hopeful dream and became an accepted firefighting tool seems to have taken place in 1957. In that year the Ontario Department of Lands and Forests attached external tanks to the floats of an Otter. These tanks could be filled with a probe while the aircraft skimmed the surface of a lake, thus permitting a non-stop water bombing capability which could deliver up to 3400 gallons of water per hour to a fire if a suitable lake was within one mile of the fire. These tanks proved so successful that they were mounted on all of the Provincial Air Service Otters. A smaller version was mounted on the floats of Beavers (Fraser, 1962). In the same year, two Avengers and one Canso were converted and used for fire suppression in California. The results were so impressive that five more Avengers and another Canso were converted the following year.

The airtanker had arrived. It was finally accepted as a valuable addition to forest fire suppression systems. World War II surplus aircraft were available at a modest cost and many forest fire protection agencies developed an airtanker capability which suited its particular needs. Between 1958 and 1970 numerous conversions have been attempted, some have been highly successful, others, for one reason or another, were less successful. Most of these less successful attempts have been replaced. While experiments are still being carried out to develop more efficient equipment and techniques, the airtanker has become an integral part of most forest fire suppression programs.

Section 2

SURVEY OF AIRCRAFT USE BY FIRE CONTROL AGENCIES IN CANADA

In an earlier survey, Williams et al (1968) summarized the use of airtankers in Canada during the year 1967. Their data disclosed that 111 aircraft had been used as airtankers, 43 of these being used exclusively in this role. In 1970, 131 fixed wing aircraft and 12 helicopters were employed as airtankers, with at least 67 aircraft having had no other use (Anon, 1971). The growth in the total number of aircraft utilized as airtankers has been 27 per cent over three years, or 9 per year. How long this growth is likely to continue is difficult to say, since two points are hardly sufficient to establish a trend.

Another interesting difference between the two samples is the changing capacity of aircraft being used. Not only is a greater percentage of large aircraft being employed (Table 1), but also helicopters constitute a significant percentage of the smallest capacity class. In 1970, 16 per cent of the small capacity aircraft were helicopters. This percentage is likely to increase in the future since, despite higher operating costs per capacity, helicopters have more versatility, greater accuracy, and faster turn-around times than fixed wing aircraft for certain types of missions.

Table 1. Comparison of Average Aircraft Capacity

	1967		1970	
	Number	Percent	Number	Percent
Small (less than 400 Imp. gallons)	78	70	77	55
Medium (400 to 750 Imp. gallons)	20	18	27	18
Large (more than 750 Imp. gallons)	13	12	39	27

There are no data available for the number of hours flown in 1967. In 1970, the total for all aircraft was 55,000 hours, with airtanker operations totalling 17,000 hours. Thus, an average of 120 hours were flown by each of the 143 airtankers, as compared with 142 hours per aircraft for all uses combined. These averages are composed of owned, leased and casually operated aircraft. The leased aircraft operated for an average of 215 hours each, those owned by fire control agencies, 116 hours each, and the casually leased, 85 hours each. It would appear that guarantees of a minimum number of flying hours per season, for seasonally leased aircraft may have influenced the choice of aircraft to use when such a choice could be made. Table 2 lists the average number of hours flown per aircraft by use.

Table 2. Average Number of Hours Flown per Aircraft (1970)

USE	HOURS
Detection and/or light transport	136
Command and Supervision	220
Airtankers	157
Airtankers and/or transport	50
Transport	312
Helicopters	194

There are no data available for the quantity of retardants dropped in 1967. In 1970, a total of 10.7 million imperial gallons of water and short-term retardant, and 3.1 million gallons of long-term retardants were dropped. In all probability, the coming years will witness an increase in the use of long-term retardants due to their greater effectiveness. Whether this increase will be in addition to water or in place of it remains to be seen, as both types of retardants have a role to play in fire control. Many current operating policies use long-term retardants in the first load carried by water dropping aircraft. The effects of these and other practices make predictions of future trends very difficult.

If an average hourly cost of $200 for small, $400 for medium and $600 for large airtankers are assumed, a total of 6 million dollars was spent delivering water and retardants in 1970. Assuming an average cost of 18¢ per imperial gallon, a total of $540,000 was spent on long-term retardants. Approximately 4 million additional dollars were spent on the use of aircraft in other fire control roles bringing the total cost of air operations for all fire control agencies across Canada in 1970 to $10.5 million.

Table 3. Use of Aircraft by Fire Control Agencies in 1970

PROVINCE	HELICOPTERS								FIXED-WING								OVERALL TOTAL	
	OWNED		LEASED		CASUAL*		TOTAL		OWNED		LEASED		CASUAL*		TOTAL			
	No.	Hours	No.	Hours	No.	Hours	No.	Hours	No.	Hours	No.	Hours	No.	Hours	No.	Hours	No.	Hours
NEW BRUNSWICK											11	1,975	1	60	12	2,035	12	2,035
NOVA SCOTIA			1	1			1	1	6	740					6	740	7	740
NEWFOUNDLAND			3	175			3	175	9	415					9	415	12	590
QUEBEC			5	1,620			5	1,620	7	950			5	100	12	1,050	17	2,670
ONTARIO			5	1,325			5	1,325	40	1,755	11	2,585			51	4,340	56	5,665
MANITOBA			3	805			3	805			18	2,090	7	80	25	2,170	28	2,975
SASKATCHEWAN			2	500	3	250	5	750			6	1,980	6	760	12	2,740	17	3,490
ALBERTA	3	2,000	4	2,435	4	1,420	11	5,855	4	2,195	12	2,985	12	4,300	28	9,480	39	15,335
BRITISH COLUMBIA			1	235	25**	4,695	26	4,930			36	8,000	2	160	38	8,160	64	13,090
N.W.T.			2	675	13	1,300	15	1,975			2	615	57	2,125	59	2,740	74	4,715
YUKON			2	445	5	125	7	570			2	190	6	85	8	275	15	845
NATIONAL PARKS					19	1,390	19	1,390			3	185	13	720	16	905	35	2,295
TOTALS	3	2,000	28	8,215	64	9,180	100	19,395	66	6,055	101	20,605	109	8,390	276	35,050	376	54,445

* Some of these aircraft are known to have operated for more than one agency. The amount of duplication in the number of aircraft is not known.

** Estimated.

Table 4. Use of Airtankers by Fire Control Agencies in 1970

PROVINCE	HELICOPTERS				FIXED WING				TOTALS			
	No.	Hours	Water*	Retardants*	No.	Hours	Water*	Retardants*	No.	Hours	Water*	Retardants*
NEW BRUNSWICK					4	275	-	125	4	275	-	125
NOVA SCOTIA					3	45	30**	-	3	45	30	-
NEWFOUNDLAND					5	275	1,000	-	5	275	1,000	-
QUEBEC					12	1,050	2,600	-	12	1,050	2,600	-
ONTARIO					44	1,920	1,320	37	44	1,920	1,320	37
MANITOBA					4	460	541	-	4	460	541	-
SASKATCHEWAN					7	1,440	1,972	-	7	1,440	1,972	-
ALBERTA					18	4,825	209	349	18	4,825	209	349
BRITISH COLUMBIA	2**	170	-	100**	23	3,885	2,000	2,500	25	4,055	2,000	2,600
N.W.T.	5	355	110	-	5	1,555	89	5	10	1,910	199	5
YUKON	1	10	-	2	1	5	10	-	2	5	10	2
NATIONAL PARKS	4	500	650**	-	5	350	200**	23	9	850	850	23
TOTALS	12	1,035	760	102	131	16,085	9,971	3,039	143	17,120	10,731	3,141

* In thousands of Imperial Gallons.
** Estimates.

Table 5. Use of Aircraft by Type in 1970*

Detection and/or Light Transport	No.	Hours
** DHC-2 Beaver	31	3080
Beech 18	3	30
Cessna 170's, 180's	51	7290
Piper Super Cub	12	2800
	97	13200
Command and Supervision		
Cessna 320, 337	6	2010
Helio Courier	1	505
Maule Rocket	1	80
Piper Twin Commanche Astec, Apache	10	1050
	18	3645
Airtankers		
A-26 Invader	9	1520
Ag Commanders	6	635
B-25 Mitchell	4	565
PBY5A Canso	24	5220
CL-215	1	5
G-164A Super AG-cat	2	110
TBM, TBF Avenger	18	2220
JRM-3 Mars	2	210
N2S Stearman	1	35
	67	10520
Airtanker and/or Transport		
DHC-3 Otter	30	1865
DHC-2 Mark II Turbo Beaver	30	1090
DHC-6 Twin Otter	7	410
	67	3365
Transport		
DHC-5 Buffalo	2	540
DC-3	4	1225
Dornier	3	1285
Norseman	2	365
	11	3415
Helicopters		
Alouette II	1	25
Bell 47G	36	9715
Bell 204B	5	265
Bell 205A-1	3	340
Bell 206A	7	540
Hiller 12E, SL-4	5	1640
Hughs 300	1	5
	58	12530

* Note - The totals do not agree with the totals of previous Table, because some of the aircraft were not listed by name.

** 6 used as airtankers.

Section 3

SELECTING THE RIGHT AIRCRAFT FOR THE JOB

A. Background

Forest fire protection budgets are not bottomless pits. They have always been limited, and in today's atmosphere of tight money and a multitude of new demands, the prospect of additions to budgets have never looked bleaker. Costs of fire protection, on the other hand, are constantly increasing. Aircraft are by far the most expensive single forest fire suppression tool. It is essential therefore, in developing a balanced forest fire protection program, which includes airtankers, that all of the characteristics, costs and benefits of available airtankers be known in order to make a rational decision on their use in a forest fire protection program.

The airtanker is a tool which can be effectively deployed under favourable conditions to hold a forest fire until ground forces arrive and bring it under control. Except in the case of spot fires or in an extraordinarily ideal situation, airtankers would not normally be depended on to extinguish forest fires. They are usually used in anticipation of the arrival and in support of ground forces.

The most effective use of airtankers is in an initial attack role. Within this role it is not uncommon that success or failure of a suppression action depends on the timely arrival of an appropriate number and type of aircraft at the scene of a fire. Since the operating conditions for each fire are in a sense unique to that specific fire, selection of the appropriate aircraft to dispatch is an exceedingly complex problem. Some of the more important variations which may be encountered are:

1. The size and intensity of fires which, at the time of attack, can vary from a camp fire to an uncontrollable holocaust.

2. The distance from the base to the fire which can vary from 0 to more than 100 miles.

3. The distance to the nearest large body of water which can be anywhere from 0 to 100 miles from the fire.

4. The arrival of ground crews who may be at the scene before the aircraft arrives or might be delayed for several days.

5. The distance to and condition of the nearest airport which might range from a grass strip to a paved runway, one to 100 miles away.

To complement this almost limitless variety of operating conditions, a wide variety of aircraft types are available as airtankers. Some of the more important options are:

1. Tank capacity, which varies from 40 to 6000 Imp. gallons.

2. Cost of acquisition, which ranges from $30,000 to several million dollars.

3. Costs of operation, which varies from $200 to more than two thousand dollars per hour.

4. A choice between new aircraft specifically designed as airtankers or converted military and commercial aircraft.

5. A choice between types of aircraft: land based, water-based, amphibious and helicopters.

6. A choice of mixing and dropping systems.

7. A choice of retardants, the effectiveness of which can range from nil to complete extinguishment, depending on fire intensity as well as the retardant used.

It is impossible to consider the ramifications of all of the parameters which effect airtanker operations without using complex simulation models and computer processing. Such analytical tools are currently under development. Between now and the time these tools become operational, it is possible to gain some insight into the problem through the use of simplified analytical procedures. In the following section a set of average conditions is assumed, cost and production data for each aircraft type are summarized with respect to the assumed set of conditions, and some conclusions are drawn from these summaries.

B. Assumptions

The first step in the analysis of available airtankers is to establish a set of assumptions which limits the variables to those which are considered to be most important. The assumptions used in this study are:

1. The quantity of retardant sufficient to establish a holding line is .04 inches in depth[1] and 20 feet wide. The length of line established in a single drop is assumed to be the total length of the .04 contour plus one half of the difference between the .04 and the .02 contour minus an error factor (trail drop when possible, tip to tip)[2]. One half of the distance

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[1]Results of recent trials conducted by Stechishen indicate that applications of about .07 inches of water, .05 inches of short-term retardant and .03 inches of long-term retardant insured a reasonable chance of success in holding low to moderate intensity surface fires (75 to 200 BTU/ft./sec., depending on fuel type). Since the only purpose of this report is a preliminary comparison of aircraft types rather than techniques of use, an average retardant depth of .04 inches was used. Future computerized in depth analyses will consider the ramifications of varying the required application depth.

[2]Making two single drops with partial loads (split drop) doubles the length of the individual loads, whereas trail drops (delays between tank openings on a single pass) increase the salvo pattern length by 25% to 50%. The additional complication of multiple passes was not considered in this analysis. The maximum pattern length attainable in a single pass is used as the standard for all aircraft.

between the .02 and .04 contour is included because with proper overlapping of successive drops, the amount of retardant in this region can be doubled, thus establishing a line of appropriate width and depth. Except for those machines which can handle two of the largest buckets, helicopters must make more than one pass to establish a 20 foot wide line.

2. The average turn-around time for land-based operations is assumed to be 9 minutes. This was derived as follows:

Approach and landing time		1.5 min.
Taxi in time[1]		2.5 min.
Taxi out time[1]		3.5 min.
Take off and climb time		1.5 min.
	Total	9.0 min.

The average turn-around time for water-based operations is assumed to be 3.0 minutes (the sum of the landing and take-off time given above). The average for helicopters is assumed to be 1.0 minutes.

3. Land-based loading is assumed to take place at 250 Imp. gal./min. In addition, 0.5 minutes is added for connecting and disconnecting the retardant hose. Water-based and helicopter loading is assumed to take 0.5 minute.

4. Average drop time is assumed to be five minutes for land and water-based operations and two minutes for helicopters.

5. Costs include both fixed and variable costs. The hourly percentage of fixed costs is computed assuming that the aircraft will be flown 200 hours during the fire season. These costs include pilot's salary, depreciation, insurance, seasonal maintenance, etc. Variable costs include fuel, oil, hourly maintenance, landing fees, etc. These costs are described in detail in Section 4 of this paper. Fixed costs are included because this paper is concerned with comparisons between aircraft and not with dispatch decisions. Once a commitment has been made to acquire an aircraft, it should be dispatched to fires on the basis of variable costs only, with fixed costs being considered as a capital expense.

C. Estimation of Drop Accuracy

The length of line held per drop is one of the most meaningful measures of aircraft production which could be analyzed. It is a function of retardant tank capacity, drop system efficiency, drop accuracy and penetration. Retardant tank capacity and drop system efficiency are reflected in the contour patterns given in Section 4 of this paper. Penetration is a function of vegetation height and density, wind speed and slope. For this simplified analysis penetration is assumed to be 100%.

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[1]From Maloney (1972).

An estimation of drop accuracy is possible by comparing data obtained by Maloney (1972) for five airtanker types with the contour patterns shown in Section 4. Maloney defined an aircraft relative efficiency function such that:

(1) $$Z_j = A_j \times C_j$$

where:

Z_j = relative efficiency for airtanker type j (per gallon capacity)

A_j = drop accuracy for airtanker type j

C_j = integrated relative effect of tank capacity, drop efficiency and penetration (per gallon capacity).

Rather than determining A_j and C_j individually for each aircraft he determined the integrated effect of both parameters by use of game simulation wherein several aircraft experts were asked to estimate the number of drops that would be required by various aircraft to do a standard job. Applying standard regression techniques to the data thus obtained he was able to derive the relative efficiency for five aircraft types. The values he obtained for landform No. 1 (level terrain, no wind and no slope) were: AF-2 = .75, B-17 = .76, F7-F = .75, PBY5A = .69, TBM = .75.

By using the above values of Z (where penetration equals 100%) and defining C_j as the relative length of line held per drop per gallon capacity, the relationship:

(2) $$A_j = \frac{Z_j}{C_j}$$

would yield the average drop accuracy for each aircraft type. Values thus obtained for the above aircraft types are: AF-2 = 82%, B-17 = 76%, F7-F = 86%, PBY5A = 77%, TBM = 78%. In order to apply this data to other aircraft types, a drop accuracy function had to be defined relative to the available data for the aircraft in this study.

Intuitively, drop accuracy should be a function of aircraft maneuverability and size of the drop pattern. The first factor governs the aircraft's ability to be positioned at a precise spot in space, while the second factor is a measure of the allowable tolerance in aircraft positioning and drop release, in that as pattern size increases, the required delivery accuracy decreases since only a portion of the pattern is used. The maneuverability is related to a considerable number of aircraft characteristics, many of which are difficult to obtain data for. For the purposes of this study, a relatively simple function was defined which appears to yield a reasonably good relative measure of maneuverability:

(3) $$MF = \frac{10G}{Wl + PL + 0.5\ SS + 0.05GW};\ G \leq 4.5$$

where:

MF = maneuverability factor

G = design load factor (maneuver)

WL = wing loading (at GW, lbs./ft.^{2})

PL = power loading (at GW, 75% power setting, lbs./hp.)

SS = stall speed (mph)

GW = gross take-off weight (lb.)

The main purpose of the coefficients in the denominator is simply to reduce SS and GW to values whose magnitude are comparable to WL and PL. The 4.5 G restriction is used because pilots cannot be expected to function beyond this point without special pressurization equipment. Values of MF were computed for each aircraft in this study and they are listed in Table 6.

Consideration of the effect of pattern area required a function which decreased with increasing pattern area. The considerable range of pattern areas coupled with a requirement for compatability with MF necessitated the use of a relative rather than absolute function for simulating the effect of pattern size. It was found that the function:

$$(4) \qquad PF = 1 - \frac{1}{.0005AP}; \quad AP \geq 2,500$$

where:

PF = pattern factor

AP = area of useful pattern (ft.^{2})

yielded results that were both reasonable and compatible with MF. Values of PF were computed for each aircraft in this analysis and are listed in Table 6.

The cross product of MF and PF for each aircraft yields a relative accuracy factor (AF). AF values computed for each aircraft are also listed in Table 6. Plotting the five AF values thus obtained against the A_j values obtained by Maloney (Figure 1) permits the derivation of A_j as a function of AF. From Figure 1 the total range of drop accuracy for fixed wing aircraft appears to be relatively narrow (75% to perhaps slightly in excess of 90%). The reverse in the curve at the upper end is a reflection of intuition rather than the data itself. An infinitely good aircraft cannot have an accuracy greater than 100%. AF values for each aircraft were plotted on the curve in Figure 1 and the corresponding accuracy percentages were determined graphically. These values are listed in Table 6.

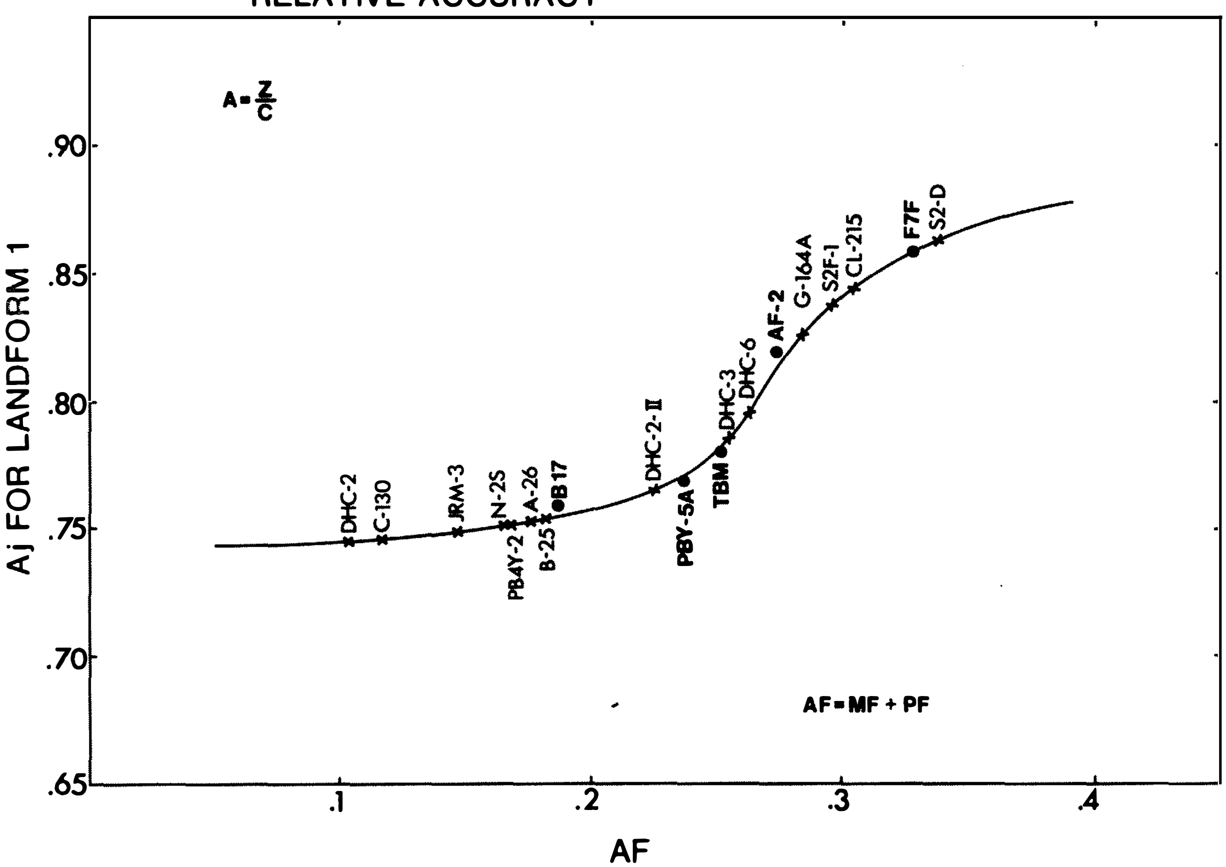
Table 6. Summary of Accuracy Percentage Determination

AIRCRAFT	+G	WL	PL	.5SS	.05GW	T**	MF	AP (1000's)	PF	AF	A%
A-26	2.8	63.5	10.7	50.0	17.5	141.7	.198	20.0	.900	.178	75.5
AF-2	3.5	44.5	13.9	41.5	12.5	112.3	.312	15.5	.871	.271	82.0
B-17	2.8	45.2	18.0	42.0	32.5	138.0	.201	31.5	.936	.188	76.0
B-25	2.6	55.0	13.1	42.5	16.7	127.3	.204	17.1	.883	.180	75.5
C-130	2.8	83.8	12.8	57.5	72.5	226.6	.124	43.0	.953	.118	74.5
CL-215	3.25	25.4	13.6	36.5	21.2	96.7	.336	23.4	.914	.307	84.5
DHC-2	3.5	20.4	15.1	30.0	2.5	68.0	.515	1.2	.200	.103	74.5
DHC-2-II	3.5	21.5	12.3	30.0	2.7	66.5	.526	3.5	.429	.226	76.5
DHC-3	3.5	21.4	17.8	29.0	4.0	72.2	.485	4.2	.524	.254	78.5
DHC-6	3.5	29.8	14.4	38.5	6.2	88.9	.394	6.0*	.667	.263	78.0*
F7F	4.2	47.5	6.9	45.0	11.8	111.3	.359	15.5	.871	.328	86.0
G-164A	4.75	18.5	13.5	33.5	2.2	67.7	.665	3.5	.429	.285	82.5
JRM-3	2.8	42.5	25.0	38.5	81.0	187.0	.150	86.2	.977	.147	75.0
N2S	7.0	10.9	12.0	29.0	1.8	53.7	.838	2.5	.200	.167	75.0
PBY5A	2.7	24.3	18.1	38.0	17.0	97.5	.277	15.2	.867	.240	77.0
PB4Y2	2.8	59.2	18.0	46.5	32.5	156.2	.179	31.5	.936	.168	75.0
S2D	10.0	21.1	15.3	37.5	3.5	77.4	.581	4.8	.583	.339	86.5
S2F-1	3.25	18.8	11.3	43.5	12.9	86.5	.376	9.3	.785	.295	83.5
TBM	3.0	36.2	13.9	38.0	8.8	96.9	.310	10.5	.810	.251	78.0

* 9.0 and 81.5 for water-based.

** Total of WL + PL + .5SS + .05GW.

FIGURE 1 PERCENTAGE ACCURACY AS A FUNCTION OF RELATIVE ACCURACY



In general, the curve in Figure 1 indicates that the larger aircraft have lower overall accuracies, implying that lack of maneuverability more than offsets the increased coverage of larger patterns. The most accurate aircraft couple fairly good maneuverability with medium capacity loads. When aircraft loads are very small the effect of pattern size becomes most important, thus dropping these aircraft into the same accuracy range as the large relatively unmaneuverable aircraft.

D. Rate of Production

In a continuous operation, the rate at which an aircraft can lay a holding line is of considerable importance. The length of line that an aircraft can hold per hour depends on the length of line held per drop and the drop interval. The drop interval is the sum of the turn-around, loading, dropping and flying times. The first three factors are related to the aircraft chosen while the fourth depends upon the fire to retardant source distance, and flying speed.

Since aircraft differ in their handling characteristics, they also differ with respect to the time required to perform each of the above functions (Newman, 1971). Use of an average value for any of the above functions would introduce a certain amount of error into the analysis. To compensate for time differences between aircraft, it was assumed that the time required for each aircraft would be inversely related to aircraft maneuverability (MF). In other words, as maneuverability increases turn-around and drop times would decrease. It was found that the function:

$$T_j = \frac{X}{.376 + MF_j} \qquad (5)$$

where:

T_j = actual time required for aircraft j

X = 6.77 for land-based turn-around (9 min. average)

X = 3.76 for drop times (5 min. average)

X = 2.26 for water-based turn-around (3 min. average)

yielded satisfactory results in that the ranges were:

5.6 to 13.5 minutes for land-based turn-around time

3.1 to 7.5 minutes for drop time

1.9 to 4.3 minutes for water-based turn-around time.

The specific results for each aircraft are listed in Table 7.

Table 7. Summary of Aircraft Cost and Production Data

AIRCRAFT		PRODUCTION								COST			
		RETARDANT TANK CAPACITY (Imp. Gal.)	CRUISING SPEED (mph)	LOAD TIME (min.)	TURN AROUND TIME (min.)	DROP TIME (min.)	CIRCUIT TIME (min.)	IDEAL DROP LENGTH (feet)	ACTUAL DROP LENGTH (feet)	COST PER HOUR ($)	COST PER MILE ($)	COST PER DROP ($)	LONG-TERM RETARDANT COST PER FOOT OF LINE HELD ($)
A-26		1,000	280	4.5	11.8	6.6	22.9	400	300	467	1.67	178	1.00
AF-2		800	245	3.7	9.8	5.5	19.0	315	260	391	1.60	124	.92
B-17		1,600	170	6.9	11.7	6.5	25.1	575	435	696	4.09	291	1.10
B-25		950	210	4.3	11.7	6.5	22.5	380	285	445	2.12	167	1.00
C-130		3,000	335	12.5	13.5	7.5	33.5	860	640	5,840	17.43	3,260	1.41
CL-215	Land	1,200	184	5.3	9.5	5.3	20.1	360	305	1,630	8.86	546	1.18
	Water	1,200	184	0.5	3.2	5.3	9.0	360	305	1,630	8.86	244	1.18
DHC-2	Land	90	130	0.8	7.6	4.2	12.6	60	45	200	1.54	42	.60
	Water	90	125	0.5	2.5	4.2	7.2	60	45	200	1.60	24	.60
DHC-2-II	Land	140	163	1.1	7.5	4.2	12.8	100	75	267	1.64	57	.57
	Water	140	160	0.5	2.5	4.2	7.2	100	75	267	1.67	32	.57
DHC-3	Land	180	125	1.2	7.9	4.4	13.5	140	110	244	1.95	55	.48
	Water	180	120	0.5	2.6	4.4	7.5	140	110	244	2.03	30	.48
DHC-6	Land	400	185	2.1	8.8	4.9	15.8	300	235	790	4.27	208	.52
	Water	450	175	0.5	2.9	4.9	8.3	200	165	790	4.51	109	.82
F7-F		800	330	3.7	9.2	5.1	18.0	315	270	461	1.40	138	.88
G-164A		240	105	1.5	6.5	3.6	11.6	100	80	205	1.95	40	.90
JRM-3	Land	6,000	153	24.5	12.9	7.1	44.5	1,025	770	1,620	10.59	1,202	2.33
	Water	6,000	153	0.5	4.3	7.1	11.9	1,025	770	1,620	10.59	321	2.33
N2S	Land	120	100	1.0	5.6	3.1	9.7	100	75	174	1.74	28	.48
	Water	120	95	0.5	1.9	3.1	5.5	100	75	174	1.83	16	.48
PB4Y2(S)		2,080	180	8.8	12.2	6.8	27.8	705	535	714	3.97	331	1.17
PBY5A	Land	800	145	3.7	10.4	5.8	19.9	310	240	553	3.81	183	1.00
	Water	800	145	0.5	3.5	5.8	9.8	310	240	553	3.81	90	1.00
S2D		250	124	1.5	7.1	3.9	12.5	120	105	219	1.73	45	.71
S2F-1		800	200	3.7	9.0	5.0	17.7	310	260	482	2.41	142	.92
TBM		500	215	2.5	9.9	5.5	17.9	215	170	330	1.53	98	.88

Since, for an individual aircraft, the major remaining source of variation in calculating the rate of production is the distance between the fire and the retardant source, that distance was used as the major variable in this analysis. In conjunction with the data listed in Table 7 the following equations were used to calculate the length of line held per hour:

(6) $$\text{Trip time} = \text{turn-around time} + \text{loading time} + \text{drop time} + \frac{60 \times \text{round trip distance}}{\text{cruising speed (mph)}}$$

(7) $$\text{Length of line held per hour (ft.)} = \frac{60}{\text{trip time}} \times \text{feet held per drop}$$

where:

all times are in minutes and distances are in miles.

The resulting values are plotted in Figures 2 (land-based) and 3 (water-based).

From the information provided in Figures 2 and 3 some observations on rate of production can be made. For both land and water-based missions the rate of production decreases at a decreasing rate with increasing distance travelled. The slope of the curve is partially dependant on aircraft speed, in that production for slower aircraft is affected to a greater degree by distance than faster aircraft. For example, the rate of production for the PBY5A (145 mph) decreases faster than that for the TBM (215 mph) with increasing distance (Figure 2).

Plotting producting against aircraft speed will result in a set of curves inversely related to those in Figures 2 and 3, in that as aircraft speed increases production increases at a decreasing rate, asymptotically approaching the limit of production at zero distance. This is governed by the sum of the turn-around, loading and dropping times. The fact that these relationships are not linear is significant when planning aircraft operations, because changes in the base to fire distance or aircraft speed at the upper end of the scale result in a proportionally smaller increase in production than similar changes in these factors at the low end of the scale. The slope of the curve is also important, since the greater the aircraft speed, the less will be the reduction in production due to increasing fire to base distance. Thus, faster aircraft should be employed in areas where the expected flying distances are long.

While it is possible to compare aircraft with each other from the data presented in Figures 2 and 3, an aircraft should be compared with other aircraft under similar circumstances. For comparison purposes, a land-based mission with a 25-mile fire to base distance was assumed. The rate of production for each land-based aircraft was calculated for this mission. These values (rates of production) were then plotted as a function of retardant tank capacity and a curve showing the average rate of production as a function of aircraft capacity was determined by the least squares method and plotted in Figure 4.

FIGURE 2 AVERAGE RATES OF PRODUCTION FOR LAND BASED OPERATIONS

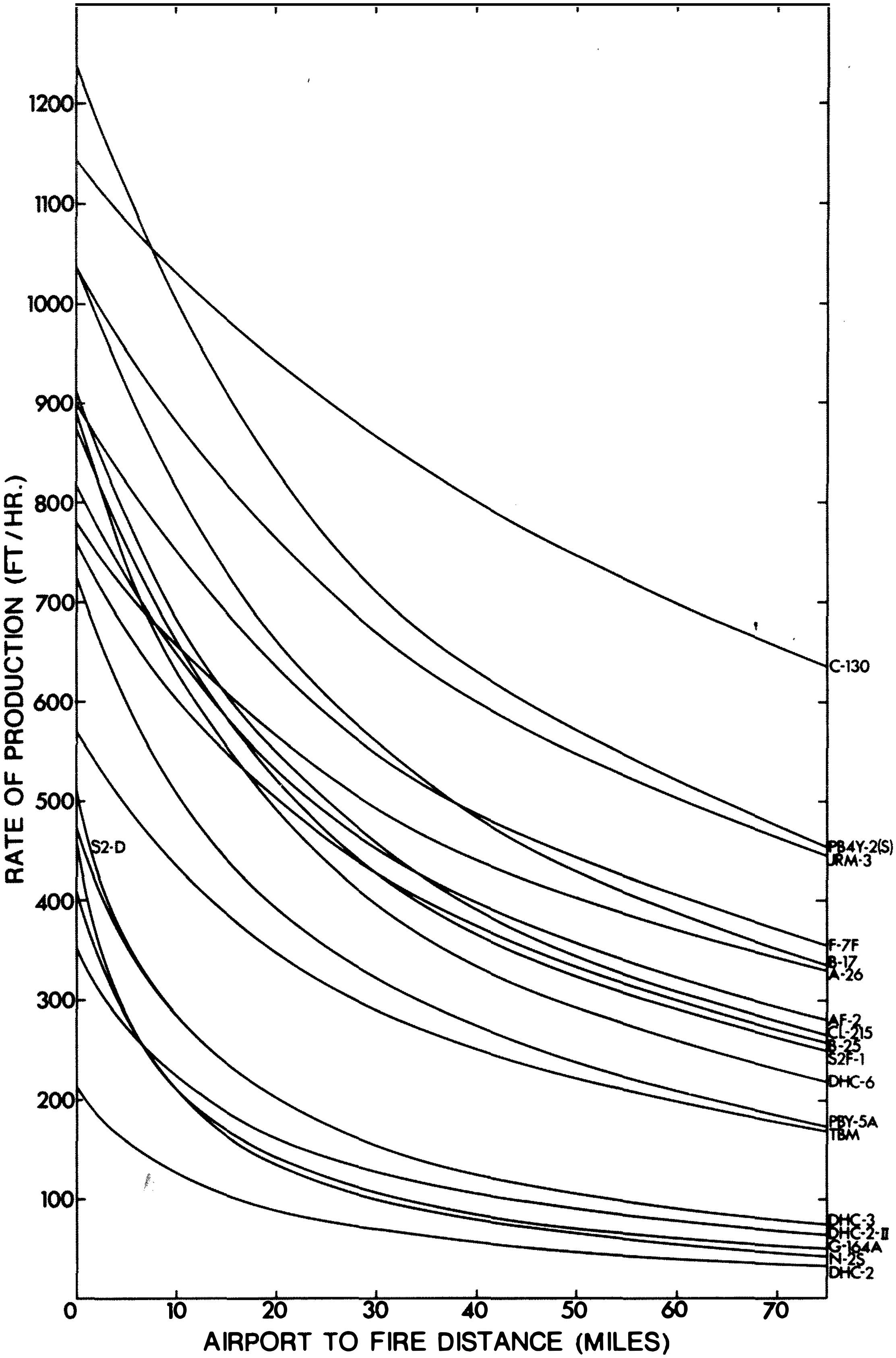


FIGURE 3 AVERAGE RATES OF PRODUCTION FOR WATER BASED OPERATIONS

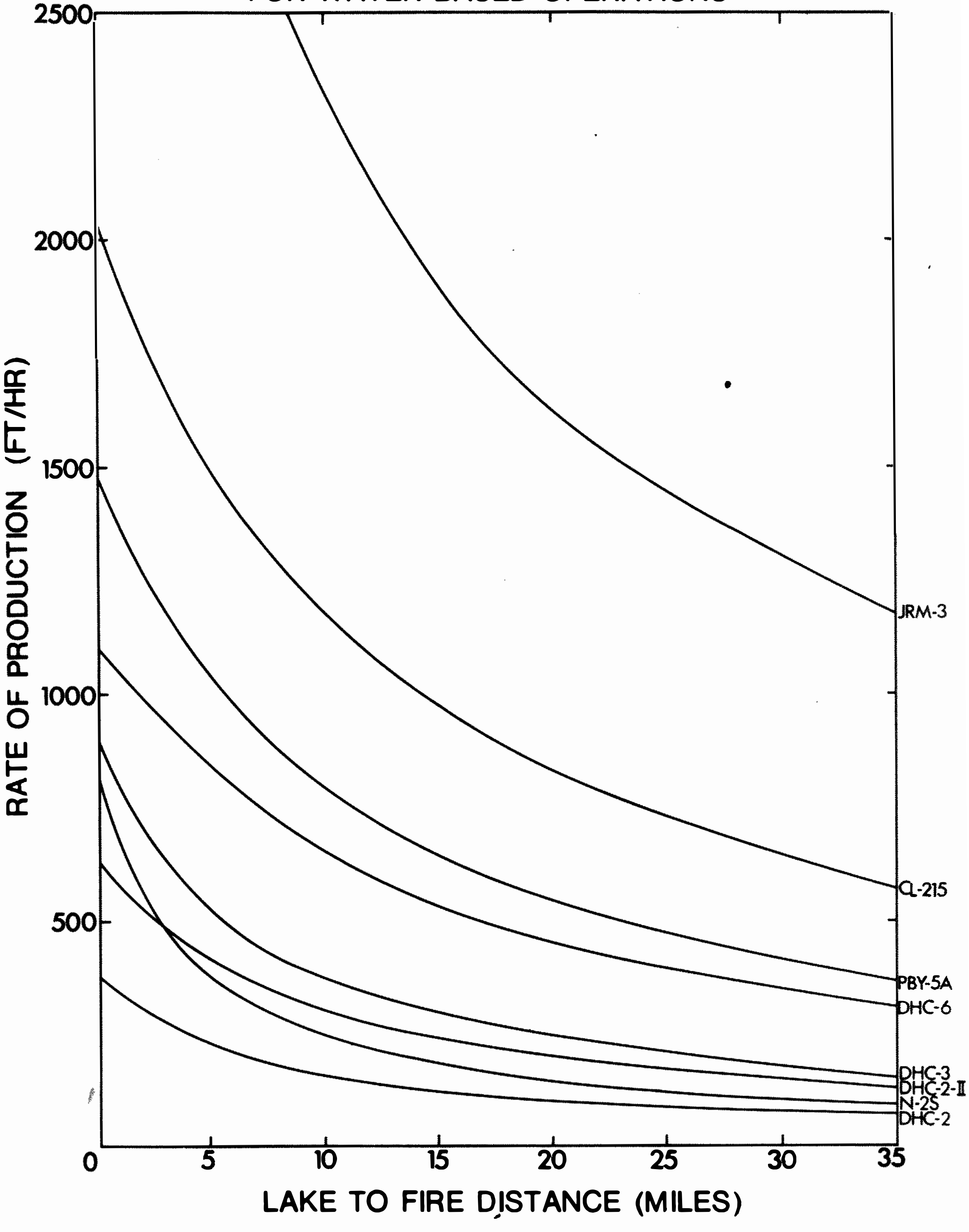


FIGURE 4 AVERAGE RATE OF PRODUCTION AS A FUNCTION OF RETARDANT TANK CAPACITY

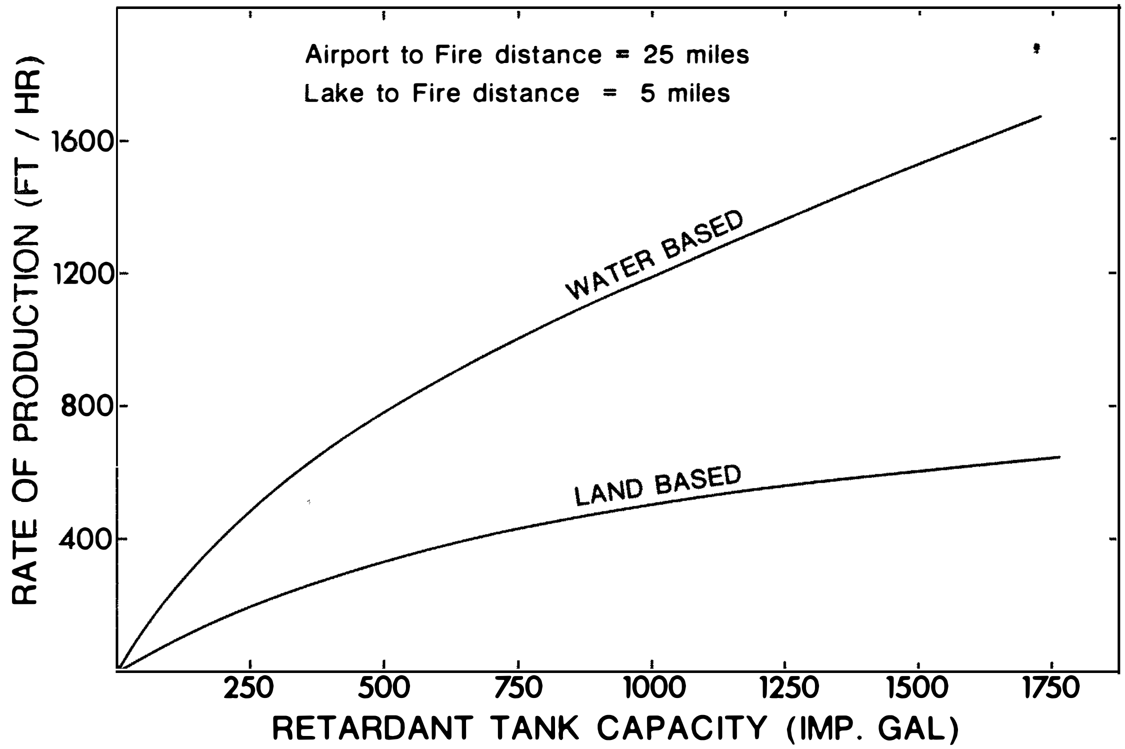
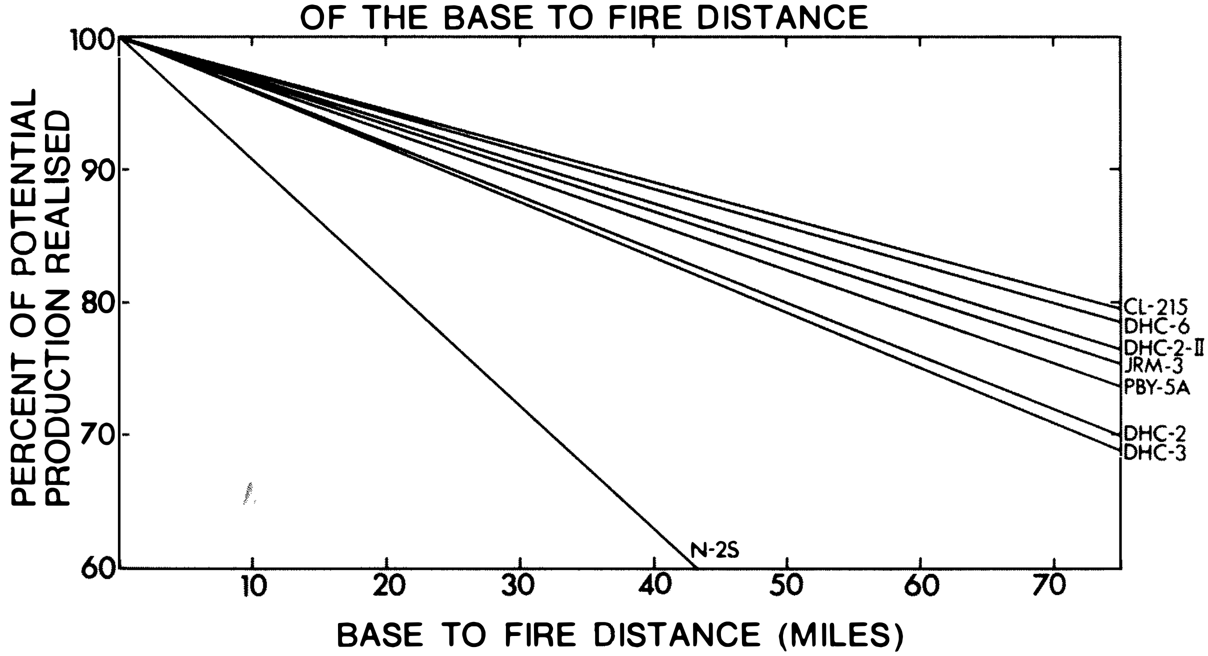


FIGURE 5 PERCENT OF AVERAGE WATER BASED RATE OF PRODUCTION REALISED AS A FUNCTION OF THE BASE TO FIRE DISTANCE



As seen in Figure 4, the land-based rate of production increases nearly linearly with increasing retardant tank capacity. Using values interpolated from Figure 2, it is now possible to determine whether a specific aircraft has a significantly greater or lower rate of production than the average aircraft of it's capacity. For example, the rate of production for the F7F (610 feet per hour) is greater than the average for a 800 gallon aircraft (440 feet per hour). It should be pointed out, however, that there is a great deal of variation between aircraft of similar capacity and that only broad generalizations can be drawn from comparing individual rates of production with averages.

The water-based production rates shown in Figure 3 do not consider the initial flight from the base to the fire and the return trip upon completion of the mission. While the aircraft is making this flight it is not dropping retardants and therefore its overall average rate of production will be reduced. While the reduction will be negligible when the base to fire distance is short, its significance increases as the distance increases.

One of the simplest ways of compensating for the effect of the base to fire distance when evaluating water-based missions would be to develop an adjustment factor to be applied to the production rates shown in Figure 3. Since aircraft flying speed is not directly related to the length of line held per drop, a separate adjustment factor is needed for each aircraft. In developing these factors, a maximum mission time of four hours (in consideration of pilot fatigue) was assumed. If the endurance of the aircraft with 45 minutes of reserve fuel is less than four hours endurance was used instead. The percentage reduction in the rate of production resulting from increases in the base to fire distance was computed by dividing the round trip flying time by the total mission time for each aircraft. These values are plotted in Figure 5. Thus, actual water-based rate of production (P) for any specific mission is given by:

(8) $$P_{1,b} = P_{1,0} * R_b$$

where:

$P_{1,b}$ = average rate of production in feet per hour for the fire to lake distance 1 and fire to base distance b.

$P_{1,0}$ = potential rate of production for lake distance and 1 and zero fire to base distance (from Fig. 3).

R_b = percentage of potential rate of production realized at fire to base distance b (from Fig. 4).

For example, with a five mile fire to lake distance, and a 25-mile fire to base distance the actual rate of production for the PBY5A would be:

(8a) $$P_{5,25} = 1035 \text{ X } .91 \text{ or}$$

$$P_{5,25} = 942 \text{ feet/hour}$$

Using the data from Figures 3 and 5, the rate of production for each water-based aircraft was calculated for a mission with a 5-mile fire to lake distance and a curve showing the average rate of production was plotted as a function of retardant tank capacity in Figure 4. This figure indicates that the rate of production for water-based operations increases at a decreasing rate with increasing retardant tank capacity. While the curve does not have a sharp breaking point which would indicate a minimum desirable size, the generalization can be made that aircraft with tanks of less than 200 to 250 Imp. gallons are not particularly efficient if used in a continuous water-based operation, relative to aircraft with larger capacity tanks. This conclusion is based on physical capacity and production only. Costs of operation will be discussed in next section.

One final consideration with respect to the rate of production is the effect of using a split drop technique, wherein two or more individual drops are made with partial loads. This technique increases the length of line held per aircraft loading at the cost of one or more extra dropping run per circuit. With the use of break-even analysis[1] it is possible to determine the flying distance at which a split drop is more efficient than a trail drop. Essentially the process involves calculating the rate of production for each technique, and the increase in production per mile flown by using the split drop technique. The break-even distance is that distance where the two rates of production are equal.

Examination of the drop patterns in Section 4 disclosed that there were nine land-based and three water-based aircraft which could, under some circumstances, increase their production rates by using split drops. The break-even flying distance was calculated for each of these aircraft. These values are listed in Table 8. In addition, the percentage increase in production per mile flown attainable by using the split drop technique was also calculated, and listed in Table 8.

Table 8. Split Drop Break-Even Summary

Aircraft	Land-Based	
	Break-Even distance (miles)	percentage increase in production per mile flown
A-26	-120.0	.00127
AF-2	13.3	.00520
B-17	20.0	.00625
B-25	- 53.0	.00197
F-7F	13.8	.00426
JRM-3	- 75.3	.00721
PBY5A	- 8.3	.00414
PB4Y2	27.0	.00498
TBM	15.0	.00684
	Water-Based	
DHC-6	11.8	.01883
JRM-3	7.5	.02416
PBY5A	9.6	.01701

[1]See Part F of this section for a brief discussion of the technique.

From Table 8, it can be seen that for the AF-2, trail drops should be used at distances less than 13.3 miles, and split drops at greater distances under the assumptions used in this analysis. To determine the increase attainable by using split drops, the percentage increase per mile flown (.00520) is multiplied by the distance flown beyond the break-even point. As an example, for a flying distance of 25 miles, the increase would be: 11.7 X .00520 or 6.1%. This value is multiplied by the rate of production shown in Figure 2 for a 25-mile flying distance (560 feet per hour) to yield the actual production increase attainable by using split drops (34 feet per hour). The total production would therefore increase to 594 feet per hour. This same technique can be used to adjust delivery costs. Some of the break-even distances listed in Table 8 are negative. This implies that at all flying distances, the split drop technique improves production. The same procedure is followed as for positive break-even distances. For example, for the B-25 at a 25-mile flying distance, the percentage increase would be 78 X .00197, or 15.4%.

E. Delivery Cost

In a continuous operation, a common economic denominator by which all airtankers could be compared is the delivery cost per foot of line held. Cost per foot of line held is calculated by dividing the length of line held per hour by the aircraft cost per hour. As with rate of production, the aircraft costs are constant[1], so that the most important factor governing the cost per foot of the line held is the fire to retardant source distance. Using data from Table 7, the aircraft delivery cost per foot of line held was calculated as a function of the fire to retardant source distance. The resulting values are plotted in Figures 6 (land-based) and 7 (water-based).

Since land-based operations normally use long-term retardants the cost of the retardant should be included if a more accurate approximation of actual costs is desired. Assuming an average cost of $.30 per mixed Imp. gallon, the retardant cost per foot of line held was calculated for every aircraft. These values are listed in Table 7. To determine the total cost per foot of line held, the retardant cost per foot of line held is simply added to the delivery cost shown in Figure 6. As was the case for rate of production, the water-based costs have to be adjusted (in this case increased) by the percentages shown in Figure 5.

These figures show that the cost per foot of line held increases linearly with increasing capacity. The slope of the line is partially dependent on aircraft speed. As with rate of production, the data from Figures 6 and 7 could be used to compare aircraft with each other. A more useful comparison would be the costs of a specific aircraft vs. the average cost of all aircraft of corresponding capacity. Again assuming a 25-mile fire to base distance, and a five mile fire to lake distance, the delivery cost per foot of line held was computed for each aircraft in a land and in a water-based operation. In the case of water-based aircraft, all values were adjusted by the percentage values shown in Figure 5 to account for the 25-mile fire to base distance. Using these values as dependent variables of capacity, the average delivery cost per foot of line held as a function of retardant tank capacity was computed. These functions are plotted in Figure 8.

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[1]Cost per hour decreases as total hours flown increase because fixed costs are constant. One assumption of this analysis states that total hourly costs are based on 200 flying hours per year, thus hourly costs are constant.

FIGURE 6 AVERAGE DELIVERY COST PER FOOT OF LINE HELD FOR LAND BASED OPERATIONS

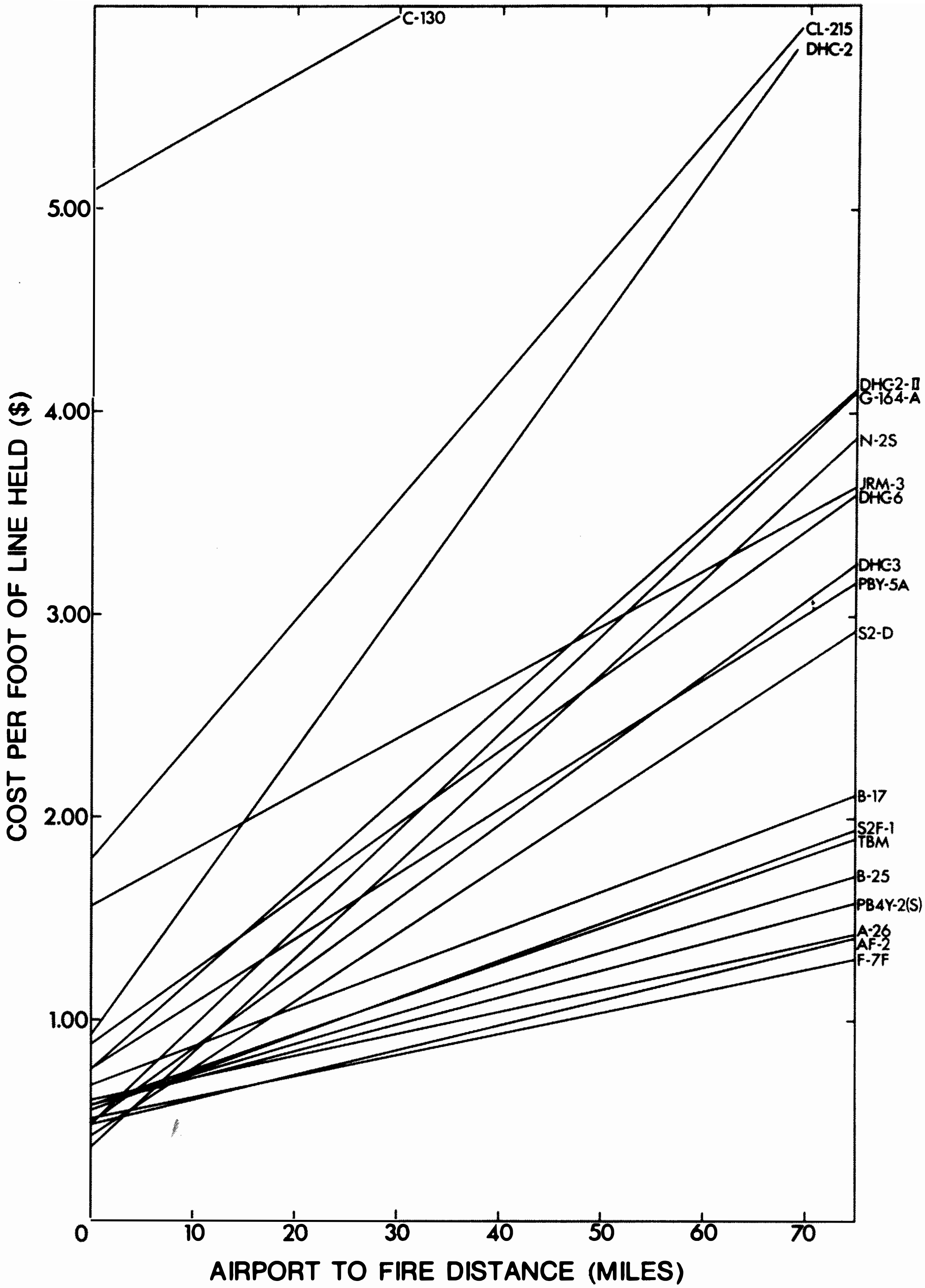
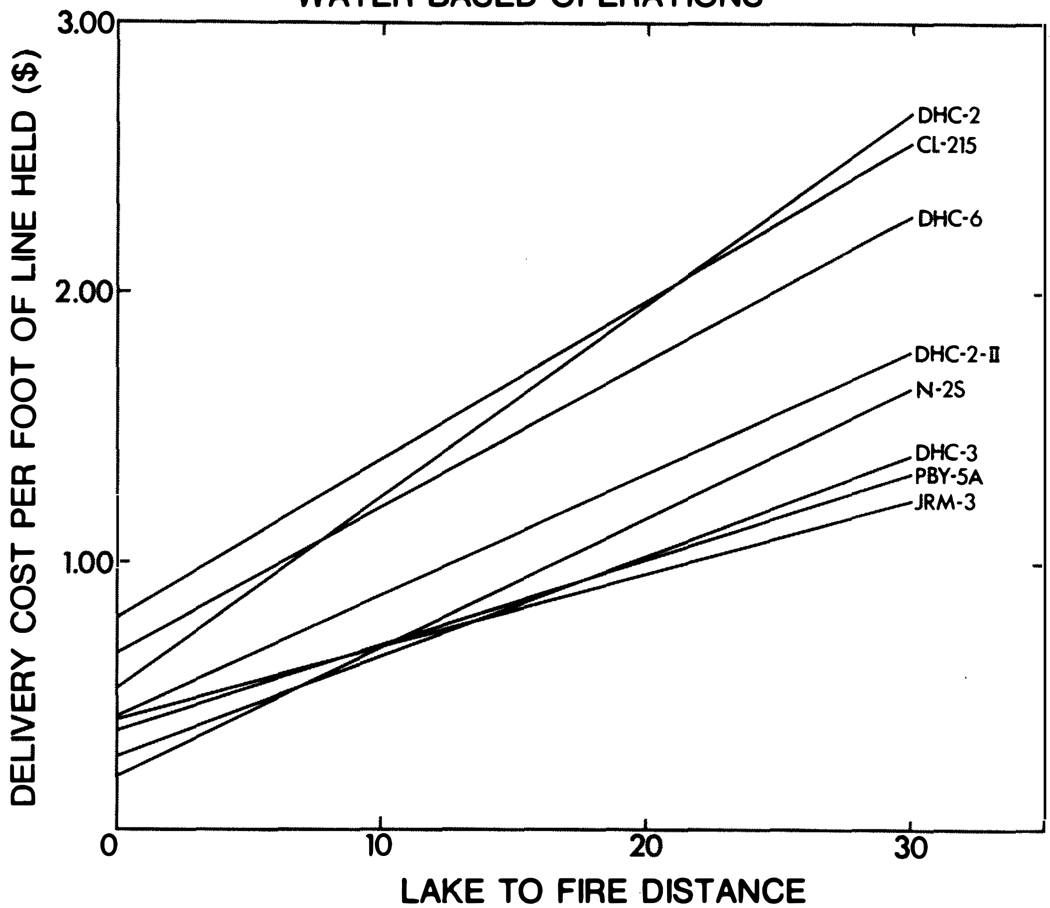


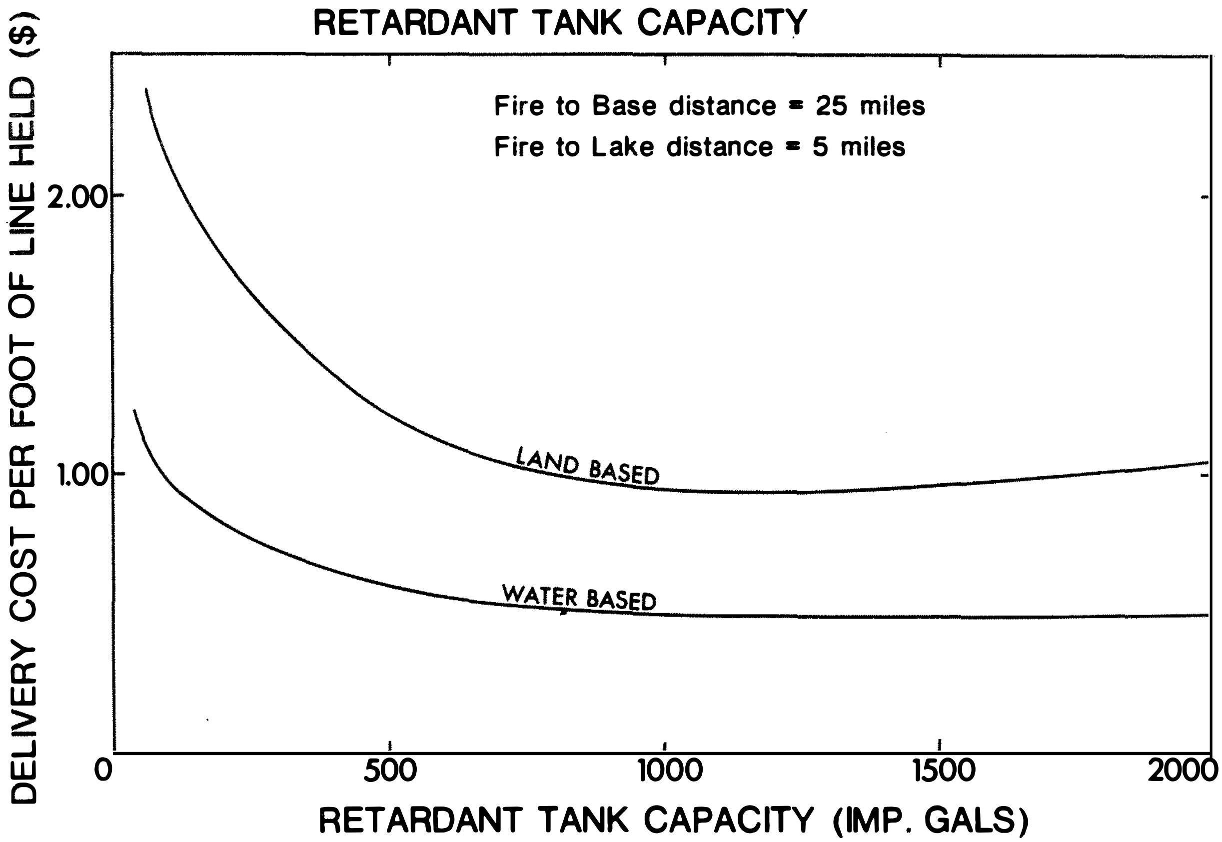
FIGURE 7 AVERAGE DELIVERY COST FOR WATER BASED OPERATIONS



For both water and land-based operations, the delivery cost per foot of line held decreases with increasing retardant tank capacity, indicating that economies of scale are obtainable through the use of aircraft with larger capacities. Furthermore, the rate of decrease in costs is much greater for small capacity aircraft than for large capacity aircraft.

When confronted with a continuous function denoting costs or any process which is not accompanied by quantified benefits of carrying out the process, it is impossible to denote a specific point where costs are greater than benefits. Generalizations, however, can be made about efficiencies gained by increasing scale. A cursory examination of Figure 8 indicates

FIGURE 8 AVERAGE DELIVERY COST AS A FUNCTION OF RETARDANT TANK CAPACITY



that increasing tank capacity for small capacity aircraft yields considerably larger gains than similar increases for large capacity aircraft. In water-based operations, aircraft with capacities below 200 Imp. gallons have considerably higher costs per foot of line held than those with greater capacities. For example, increasing capacity from 100 gallons to 200 gallons reduces the cost from $1.00 to $.82 or $.18 per foot. To achieve a similar reduction, a 200 gallon capacity would have to be increased to 400 gallons. Increasing capacity from 400 to 1,000 gallons only reduces the cost per foot of line held by $.14. There appears to be no significant cost reduction beyond capacities of 1,000 Imp. gallons. A similar argument could be made for land-based operations at approximately 400 gallons. Increasing capacity from 200 gallons to 400 gallons reduces costs by $.42 per foot. Increasing capacity from 400 to 1,000 gallons reduces costs by the same amount.

There are no significant trends in the water-based cost or production functions obtained through this analysis which would indicate a maximum desirable capacity aircraft to use. Land-based delivery costs per foot of line held appear to be at a minimum at capacities between 1,000 and 1,500 Imp.

gallons. This reflects the fact that loading time begins to become significant with very large capacity aircraft. Presumably, increasing the rate of loading with additional pumps or larger units would flatten the curve in the 1,000 to 2,000 Imp. gallon range. Practical loading limitations suggest, however, that little, if any significant delivery cost reduction can be expected beyond 2,000 Imp. gallons. Expected hours of utilization and the amount of capital that the user is willing to tie up for aircraft acquisition are important considerations in deciding the maximum capacity aircraft to use. In other words, a decision on the maximum desirable aircraft capacity will not be based entirely on either production or cost efficiency but to a large extent on other factors not considered in this abbreviated analysis.

F. A Comparison of Water and Land-Based Operations

One method of comparing water and land-based operations is break-even analysis. Break-even analysis usually assumes that one alternative has a higher initial or fixed cost and a low variable cost while the other has a low initial cost and a high variable cost. The break-even point occurs when the total cost is equal. Below this point the best alternative is the one with the low initial cost and above this point, the best alternative is the one with the high initial cost.

It is possible to compare water-based aircraft with land-based aircraft using break-even analysis if one assumes that, at a zero fire to lake distance, the cost per foot of line held is the initial or fixed cost for both land and water-based aircraft. In general, at zero distance from the lake to the fire, water-based aircraft can lay a holding line at less expense than land-based aircraft. As the lake to fire distance increases, assuming a constant airport to fire distance, the water-based aircraft's advantage gradually disappears, as it has an additional variable cost which the land-based aircraft does not encounter. Eventually, a distance is found where line is held by both types of aircraft at equal cost. This is the break-even distance, above which it is more advantageous to use a land-based aircraft and below which a water-based aircraft is more economical.

Coming into play in this relationship are two primary variables, the distance from the airport to the fire, which effects both land and water-based aircraft, and the distance from the lake to the fire which effects only water-based aircraft. To be realistic, the relative effects of using various retardants should also be considered. Therefore, the effects of using long and short-term retardants relative to water must be known. Preliminary results of tests conducted by Stechishen indicate that short-term retardants are about 1.5 times more effective as a suppressant than water and long-term retardants are about 2.5 times more effective[1].

[1] Personal communication, based on preliminary analysis of data on file at the Forest Fire Research Institute. Field observations which suggest that long-term retardants are 10 or 20 times more effective than water may stem from the fact that in many cases a single load of water is insufficient to hold a fire, whereas a similar load augmented by long-term retardants produces an effective barrier. In reality the effect of adding long-term retardants may simply be one of causing load effectiveness to cross a minimum threshold requirement. Without additives, a load may be insufficient to hold a fire, thereby resulting in only a very brief reduction in rate of spread whereas with the additives, the same load may be capable of holding the same fire for several hours. Presumably, higher concentration of water obtained through repeated drops would have the same effect.

With the information presented in this paper it is possible to compare any water-based aircraft with a land-based aircraft. Two aircraft combinations were chosen as an example of the procedure and the conclusions which can be drawn from the analysis. The two combinations are the PBY5A compared with itself in a land and water-based role, and a PBY5A as a water-based aircraft compared with the A-26 in a land-based operation.

With the values extracted from Figures 6 and 7 and corrected by the percentages given in Figure 5 for the PBY5A, Tables 9a and 9b were developed. From these tables, break even distances for the two aircraft types at the three airport to fire distances can be computed. For example, the total cost per foot of line held by the A-26 using long-term retardants at an airport to fire distance of 20 miles is $1.77. From this value is subtracted the corresponding value of using a PBY5A in a water-based role with short-term retardants at zero fire to lake distance ($.75). The difference ($1.02) is divided by the increase in cost per foot per mile from the lake ($.057) and the quotient is the break-even point (17.9 miles). By following this procedure, a set of break-even fire to lake distances were calculated for six aircraft/retardant combinations. These are listed in Table 10. The break-even distances for each combination are plotted in Figure 9.

It should be emphasized that this analysis was not constrained by either time or aircraft availability. It was assumed that an adequate supply of aircraft would be available to attain a rate of production sufficient to hold whatever fire was encountered. When such is not the case, i.e., either the rate of spread is very fast, or insufficient aircraft are available, dispatch decisions must be made on the basis of containing the fire. An otherwise efficient operation becomes worthless if the fire is not contained.

Within the limits imposed by the assumptions discussed above, examination of Figure 9 discloses a number of interesting points. Probably the most important is that both types of operations have a wide range of conditions under which one is more economical than the other. For example, comparing the A-26 with long-term retardants and the PBY5A with short-term retardants (combination No. 3) at a fire to base distance of 20 miles, a land-based operation would be more economical if the fire were more than 17.9 miles from a usable lake and less economical if the fire were less than 17.9 miles from a usable lake.

The most important variable affecting the break-even distance at short fire to airport distances is the cost of the long-term retardants. At $.30 per Imp. gallon ($.18 for material[1], and $.12 for mixing and storage) the retardant costs are greater than the aircraft delivery costs per foot of line held at zero fire to airport distance. This fact is reflected in Figure 9a wherein water-based operations are always more desirable at short flying distances. At longer flying distances, where the retardant costs become a smaller proportion of the total costs, their use becomes increasingly worthwhile. This analysis only considered the benefits of using long-term retardants as a suppressant. Presumably when used as a retardant in advance of a fire their effectiveness rate is greater than 2.5. If this is the case, then the break-even distances would be shifted downward, thus favouring land-based operations.

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[1]N.F.P.A., (1967).

Table 9A. Land-Based Operating Costs

AIRCRAFT	AIRPORT - FIRE DISTANCE (miles)	DELIVERY COST PER FOOT OF LINE HELD			TOTAL COST[2] PER FOOT OF LINE HELD		
		Long-Term	Short-Term	Water[1]	Long-Term	Short-Term	Water
PBY5A	0	.76	1.27	1.90	1.76	1.34	1.90
	20	1.40	2.33	3.50	2.40	2.40	3.50
	50	2.36	3.93	5.90	3.36	4.00	5.90
A-26	0	.57	.95	1.42	1.57	1.02	1.42
	20	.77	1.28	1.92	1.77	1.35	1.92
	50	1.09	1.82	2.72	2.09	1.89	2.72

Table 9B. Water-Based Operating Costs for the PBY5A

BASE TO FIRE DISTANCE (miles)	FIRE TO LAKE DISTANCE (miles)	DELIVERY COST PER FOOT OF LINE HELD		TOTAL COST PER FOOT OF LINE HELD		INCREASE IN COST PER FOOT PER MILE FROM THE LAKE	
		Water[3]	Short-Term[2]	Water	Short-Term	Water	Short-term
0	0	.95	.63	.95	.70		
	30	3.32	2.22	3.32	2.29	.079	.053
20	0	1.02	.68	1.02	.75		
	30	3.56	2.39	3.56	2.46	.085	.057
50	0	1.15	.76	1.15	.83		
	30	4.02	2.69	4.02	2.76	.096	.064

[1]This reflects the fact that more drops have to be made with water and short-term retardants to achieve an effectiveness comparable to that achieved with long-term retardants. The actual delivery cost per drop is, of course, the same. The absolute values of the costs used in this determination are of little consequence. Only the relative differences are important. The long-term retardant costs are taken directly from Figure 6. The short-term costs are 1.667 times the long-term costs, and water is 2.5 times as great.

[2]Includes the cost of the retardant - from Table 7 for long-term, and .07 per foot for short-term.

[3]On the same relative basis as the costs in Table 8A.

Table 10. Break-even Fire to Lake Distances for six aircraft/retardant combinations.

COMBINATION	AIRCRAFT	OPERATION	RETARDANT	FIRE TO BASE DISTANCE (miles)	BREAK-EVEN FIRE TO LAKE DISTANCE (miles)
1	PBY5A	land	long-term	0	20.0
		vs.		20	28.9
	PBY5A	water	short-term	50	39.5
2	PBY5A	land	long-term	0	10.2
		vs.		20	16.2
	PBY5A	water	water	50	23.0
3	A-26	land	long-term	0	16.4
		vs.		20	17.9
	PBY5A	water	short-term	50	19.7
4	A-26	land	long-term	0	7.8
		vs.		20	8.8
	PBY5A	water	water	50	9.8
5	A-26	land	short-term	0	6.0
		vs.		20	10.5
	PBY5A	water	short-term	50	16.6
6	A-26	land	short-term	0	0.9
		vs.		20	3.9
	PBY5A	water	water	50	7.7

FIGURE 9a BREAK EVEN FIRE TO LAKE DISTANCE USING LONG-TERM RETARDANTS FOR LAND-BASED OPERATIONS

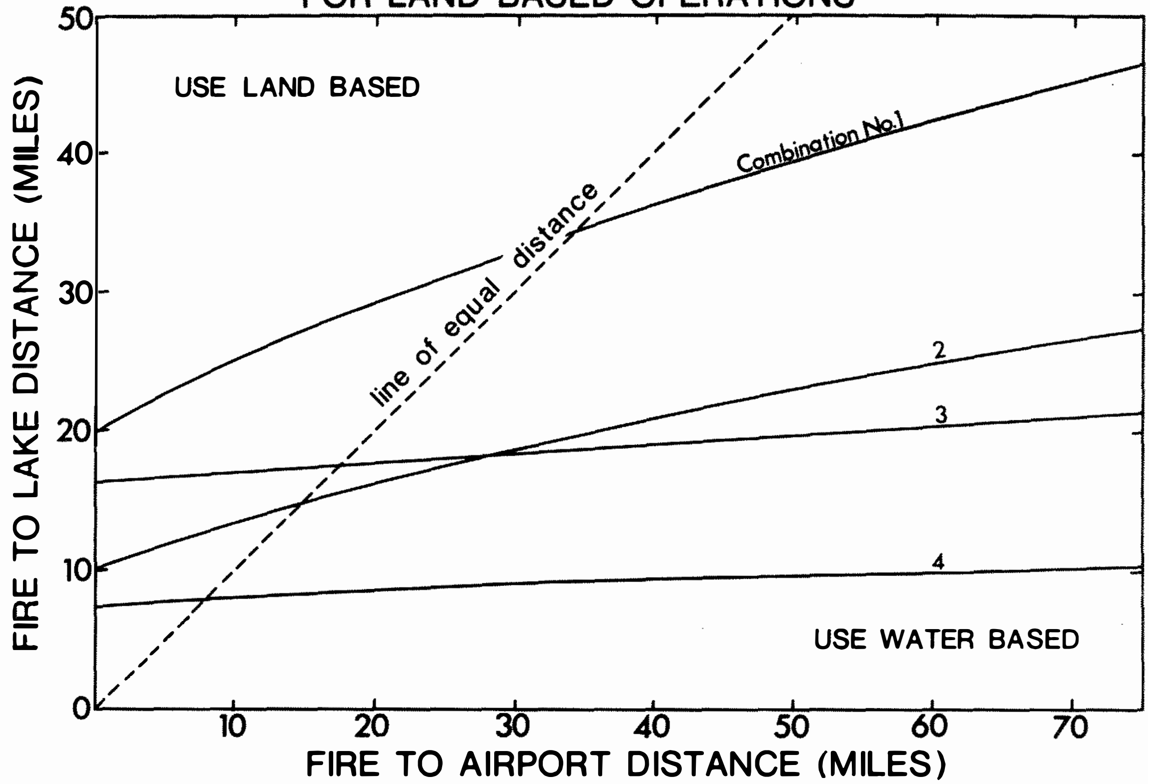
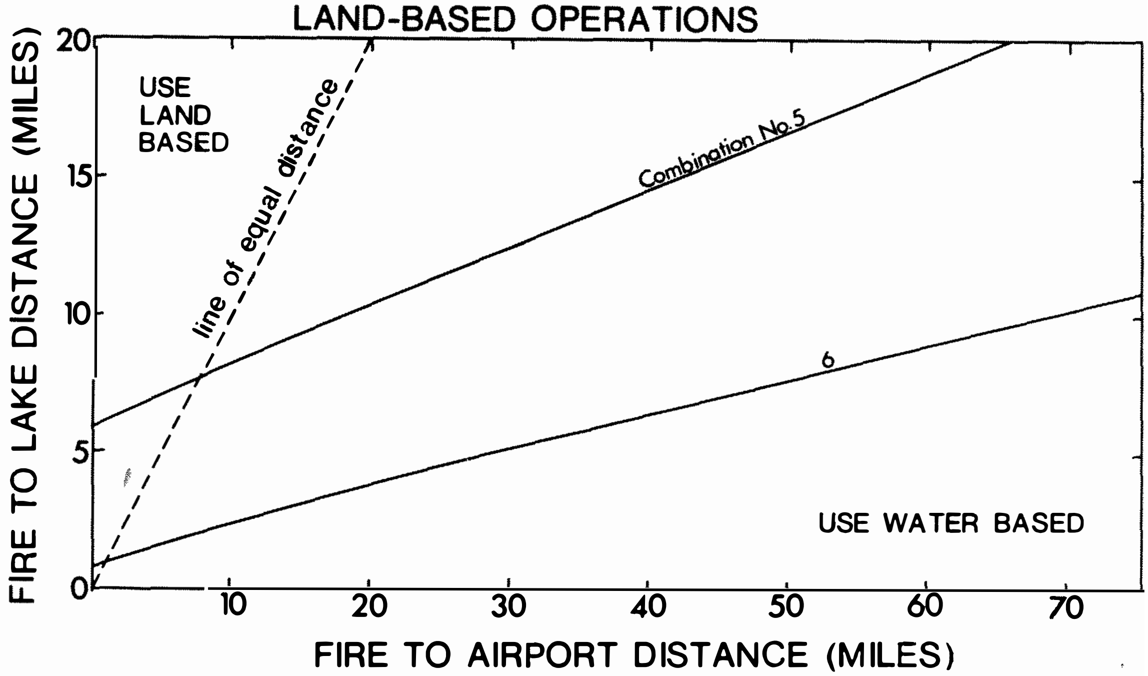


FIGURE 9b BREAK EVEN FIRE TO LAKE DISTANCE USING SHORT-TERM RETARDANTS FOR LAND-BASED OPERATIONS



The use of short-term retardants in the water-based operation greatly decreases the break-even fire to lake distance in all of the combinations tested in this analysis. In all probability this would be true for any combination considered. The use of short-term retardants for the land-based operations (combinations 5 and 6) increases the slope of the break-even lines (relative to Nos. 3 and 4). The use of short-term retardants at fire to airport distances less than 70 miles reduces the break-even distance so that land-based operations are more efficient under a wider range of conditions. At distances longer than 70 miles, the break-even distance becomes greater so that water-based operations are more efficient over a wider range of conditions. This behaviour results from a combination of two factors. At short to medium distances, reduction or elimination of the retardant costs has the most important effect while at longer distances, the loss of retardant effectiveness becomes more important. A cursory examination of the use of water in land-based operations with either aircraft or short-term retardants in the PBY5A indicated that neither of these options appear to be particularly desirable, in that under no circumstances was the range of conditions for land-based operations increased.

The functions presented in Figure 9 have a significant implication. While this analysis was limited to a specific set of circumstances, the fact that short-term retardants were more economical than long-term up to a fire to base distance of 70 miles raises serious doubts as to the general applicability of the commonly accepted adage that "whenever an aircraft returns to a base, it might as well fill up with long-term retardants". Such a policy is certainly not desirable under the conditions of this analysis. It is suspected that more detailed analyses which are currently under way will disclose a wide range of conditions where short-term retardants are more desirable than long-term.

The effect of aircraft speed is evident in that use of the faster A-26 (Nos. 3 and 4) significantly reduces the break-even fire to lake distance relative to the PBY5A (Nos. 1 and 2), and this reduction increases with increasing flying distance. This is consistent with previous findings that as flying distance increases, aircraft speed becomes increasingly significant. Presumably use of a faster water-based aircraft would have the opposite effect.

In summary, it can be seen that break-even distances are dependent on the specific combination of aircraft and retardants considered. Within the limitations imposed by the assumptions in the foregoing analysis some general tendencies are indicated. First and most important, both types of operations have a wide range of conditions under which one will be more advantageous than the other. Second, the use of short-term retardants for land-based operations at short to medium flying distances is more economical than long-term, under the conditions imposed on this analysis. Third, the use of short-term retardants for water-based operations increases the range of distances wherein they are more efficient than land-based operations.

G. Limited Operations

The most effective way of using airtankers is in initial attack. Under favourable circumstances airtankers can hold a fire until ground forces arrive. If a fire is small enough, a holding line may be established with only a few well placed drops. To account for situations where less than a continuous operation is sufficient to hold a fire, a limited operation was analyzed. A limited operation is one where a fire can be contained by a few drops, after which the aircraft returns to base or is deployed on another fire. The number of drops depends upon the size of the fire at the time of the final drop and the length of line held by each individual drop. The final size of the fire is a function of the fire size at the time of the initial drop, the length of each drop, the time between drops, and rate of growth of the fire. The length of drop is a function of each individual aircraft.

The main factor in determining whether an airtanker operation can be successfully concluded with a limited drop mission dispatch is the expected size of the fire at the time of control. While a distribution of such data is not available, it can be conservatively approximated by using the distribution of fire sizes at the time of detection which were determined from an analysis of more than 14,000 fires from three provinces. This distribution is listed in Table 11.

Table 11. Distribution of Fire Size at the Time of Detection*

Size Class (acres)	Percent of Fires	Accumulative Percent
0.0 - .01	20	20
0.01 - .1	16	36
0.1 - .5	20	56
0.5 - 1.0	12	68
1.0 - 5.0	21	89
greater than 5.0	11	100

* Data obtained from individual reports on 14,600 forest fires in the Provinces of New Brunswick, Ontario, and Saskatchewan.

This analysis shows that more than 50 percent of the fires were one-half acre or less in size at the time of detection. With efficient dispatch of airtankers, the size would not be significantly larger at the time of the initial drop for a majority of these fires. Using the feet of line held per drop values listed in Table 7, and assuming that a fire grew in the shape of a circle, the area of a circle which could be enclosed by a polygon having three to ten sides, each the length of a drop, was computed. These areas are plotted in Figure 10. It should be noted that whereas the curves in Figure 10 were plotted as continuous function, for the sake of clarity they are in fact discrete, in that drops must be made as whole units whose size is not less than the smallest tank. When the area of a fire exceeds the area which can be surrounded by a specific number of drops, an additional drop must be made, some of which may be overlapped and thus wasted[1].

[1] A certain amount of excess capacity is normally desirable as insurance against unanticipated problems and imperfect knowledge at the time of dispatch.

In a continuous operation, the cost per foot of line held is the relevant parameter by which aircraft are compared. In a limited operation, the cost per foot of line held is not as important as the total cost of establishing a holding line around the fire. There are two basic cost components of an airtanker mission: the cost of flying (dollars per mile) and the cost of dropping retardants (dollars per drop). These two costs are listed in Table 7 for each aircraft. Using these data, and the area which can be contained by a predetermined number of drops from Figure 10 the cost per acre of containing a fire was computed for each aircraft.

The equation for computing land-based mission cost is:

(9) Total cost = ((50 X cost per mile) + cost per drop) X number of drops[1].

The equation for computing water-based mission cost is:

(10) Total cost = (50 X cost per mile) + cost per drop + ((10 X cost per mile) + cost per drop)) X (number of drops) - 1)[1].

As with Figure 10, these values are plotted as continuous functions for the sake of clarity in Figures 11 (land-based) and 12 (water-based).

Examination of Figures 11 and 12 discloses a number of interesting points. First, as expected, total delivery costs increase with increasing fire size. The increase is not quite linear, because as the number of drops increases, the total drop length more closely approximates the perimeter of the fire. It would appear that with respect to limited missions and for the example chosen, there are three broad classes of aircraft: those suited to fires whose size is 0.5 acres or less, those suited to fires larger than 0.5 acres and those not suited to limited operations. This classification is particularly evident in Figure 12 (all aircraft are limited to 10 drops for this analysis).

The relationship is somewhat more difficult to discern in Figure 11 (land-based operations). Therefore, a specific comparison of two aircraft, the S2D and the AF-2, has been made in the inset with the use of a more accurate discrete function. It can be seen that for the specific example chosen the S2D is significantly more economical on fires less than 0.2 acres in size, the two aircraft are approximately equivalent between 0.2 and 0.5 acres, with the AF-2 being more advantageous on larger fires. Therefore, in the above example between one third and one half of all fires can be more economically controlled with the S2D than with the AF-2.

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[1]For continuity with the previous example it was assumed that the base was 25 miles from the fire and that a suitable lake was 5 miles from the fire.

FIGURE 10 CIRCULAR AREA WHICH CAN BE CONTAINED BY UP TO TEN DROPS

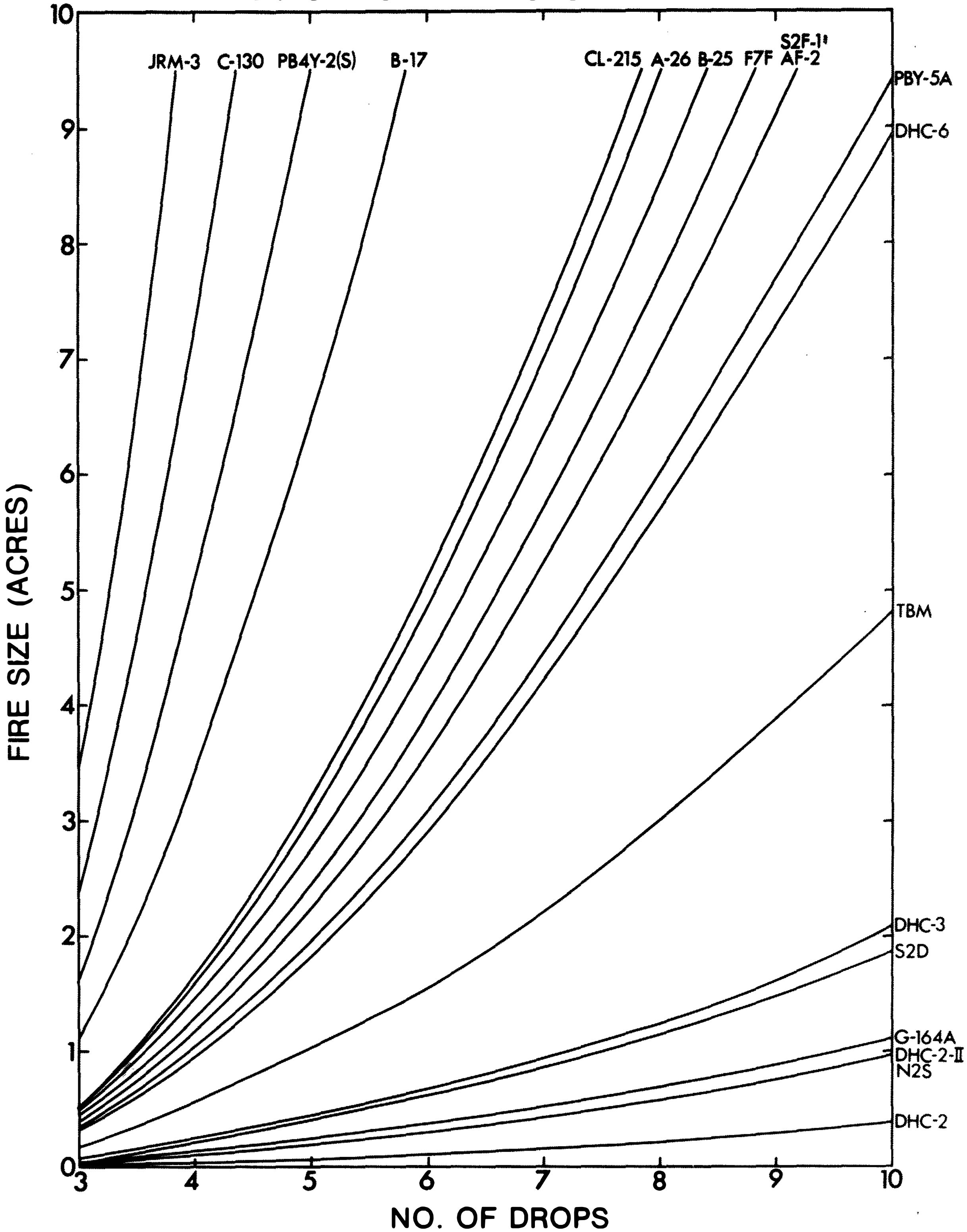


FIGURE 11 TOTAL DELIVERY COST FOR LAND BASED OPERATIONS

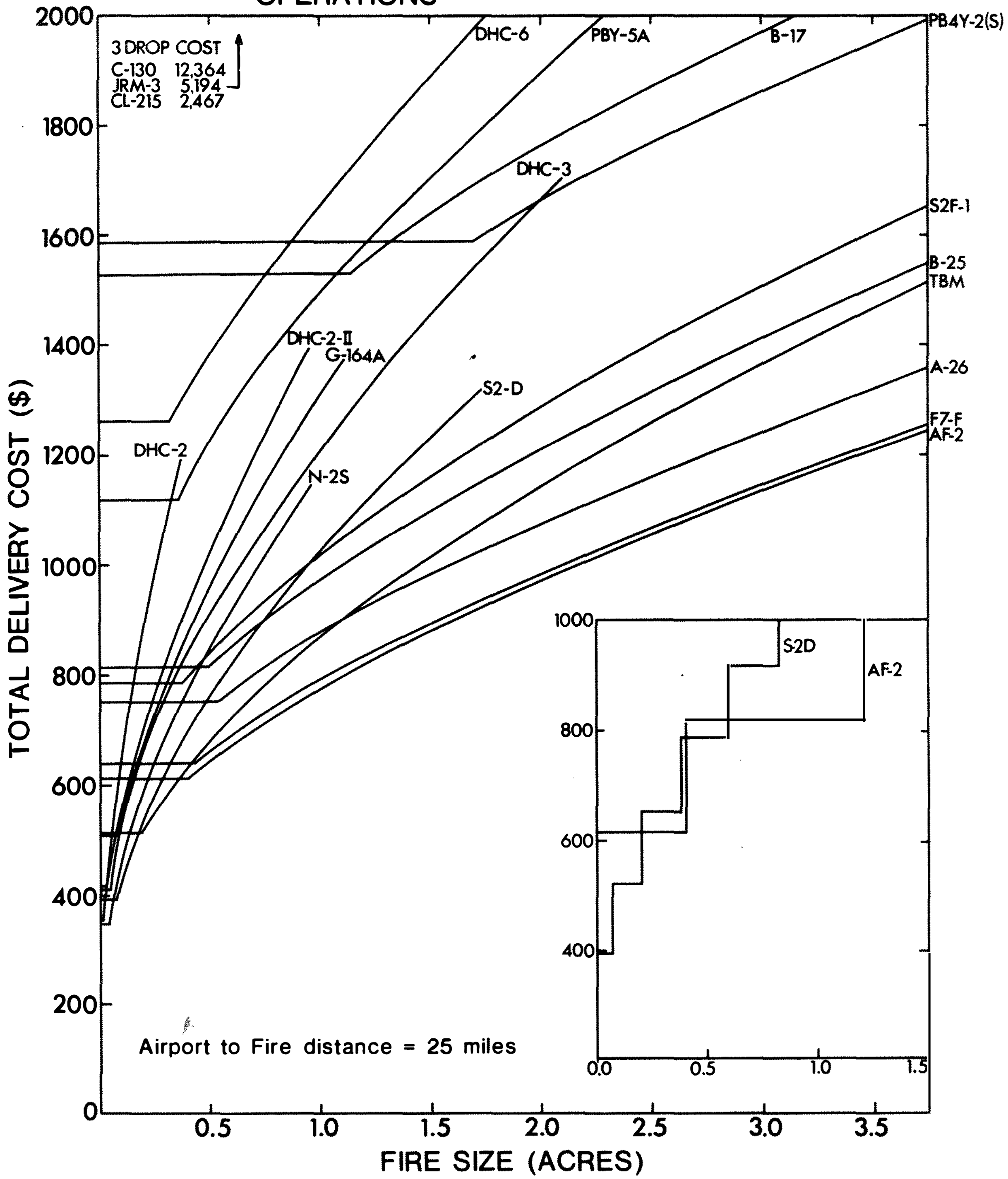
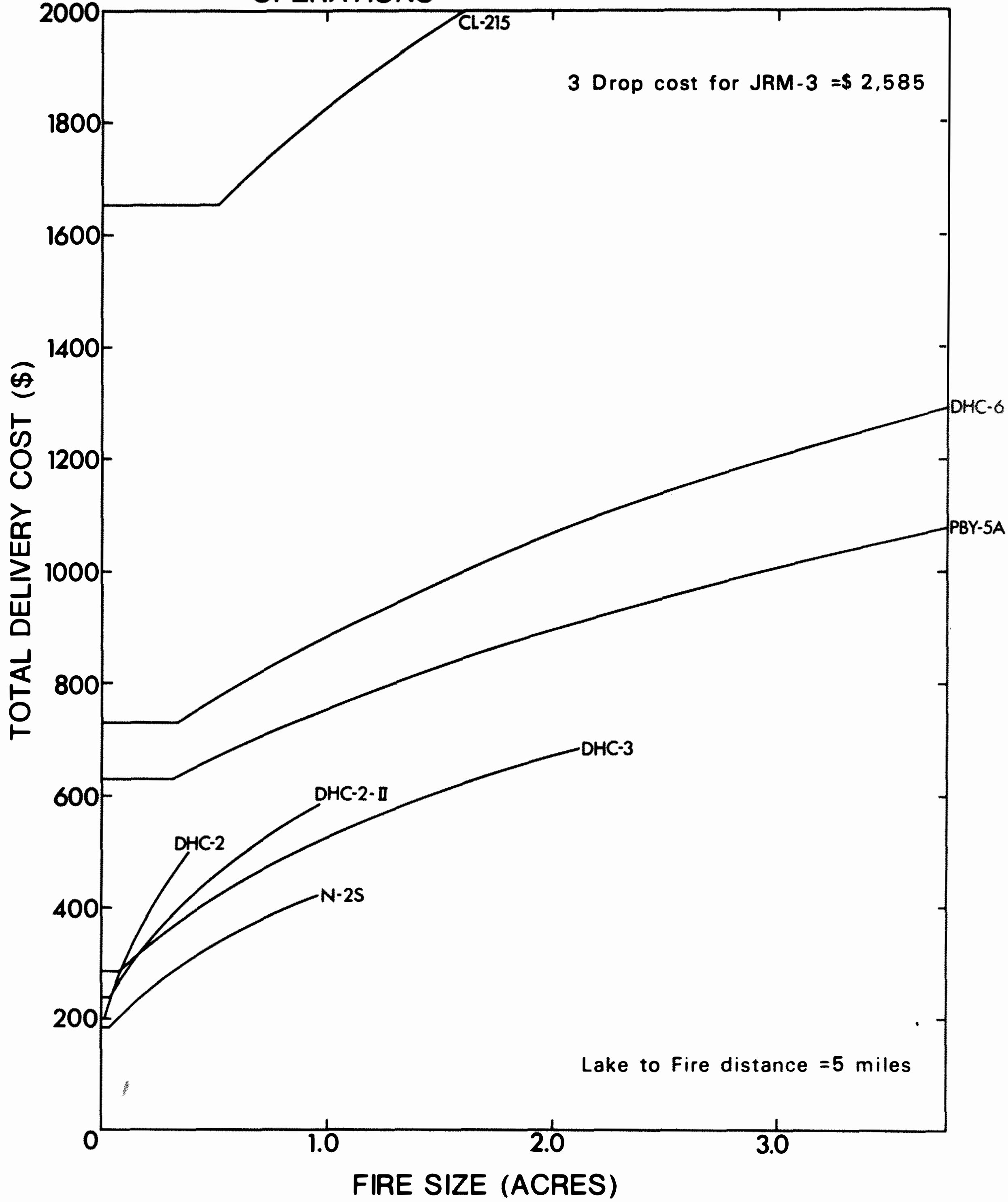


FIGURE 12 TOTAL DELIVERY COST FOR WATER BASED OPERATIONS



Thus, an individual charged with the organization of a rational forest fire protection program is faced with a dilema. For continuous operations, aircraft with larger capacities have a distinct advantage in being able to lay holding line at a rate which is substantially greater than smaller aircraft. Smaller aircraft on the other hand are more economical on between 30 and 50 percent of the fires to which they would be dispatched.

To increase production efficiency by maintaining a fleet composed entirely of large capacity aircraft increases total costs on a significant number of limited operations. Conversely, a fleet composed entirely of small to medium capacity aircraft will have higher costs on continuous operations. A fleet composed entirely of medium capacity aircraft will not incur the excessive costs on missions poorly suited to their capacity as described above, but such a fleet could not achieve the compensating economies stemming from well matched missions and capacities. Thus, it is apparent that to be efficient on a variety of missions, a fleet should consist of more than one type of aircraft (probably with capacities between 200 and 2,000 Imp. gallons), each of which should be dispatched on the type of mission best suited to it's characteristics and capacity. The number of different types of aircraft and capacities will be governed by the range of conditions likely to be encountered on a significant number of missions as well as by practical and operational consideration such as efficiency of maintenance.

H. Helicopters

Unlike airtankers, helicopters generally employ an external retardant tank or bucket. This tank is independent of the specific make and model helicopter being used except that the total load must not exceed the lifting capacity of the machine in question. There is considerable flexibility possible in the choice of load size so that the lifting capacity of each machine can be fully utilized.

Since lifting capacity is the primary concern, helicopters will not be discussed by individual make and model. Instead, a sample of helicopters will be selected such that one machine in each of several lifting capacity classes is considered. The fact that only a very few drop patterns are available for helicopters necessitated a considerable amount of extrapolation and estimation in order to develop expected patterns for each lifting capacity. Extrapolation of drop patterns was based on the assumption that patterns are linearly related to tank capacity, with a slight adjustment to compensate for decreasing efficiency with increasing capacity. Estimated rates of production are plotted as a function of retardant tank capacity for a variety of fire retardant source distances in Figure 13. Increases in the fire to retardant source distance cause considerable decreases in the rate of production at short distances and progressively smaller decreases in production rates at longer distances (Figure 13). Thus, helicopters are most productive at short fire to retardant source distances.

In Figure 14. delivery costs per foot of line held are plotted as functions of tank capacity and fire to retardant source distance. Interestingly, as the flying distance approaches zero, the costs per foot of line held exhibit relatively little response to changing tank capacities throughout the range of available data (40 to 720 Imp. gallons). As

FIGURE 13 AVERAGE HELICOPTER RATES OF PRODUCTION AS A FUNCTION OF RETARDANT TANK CAPACITY

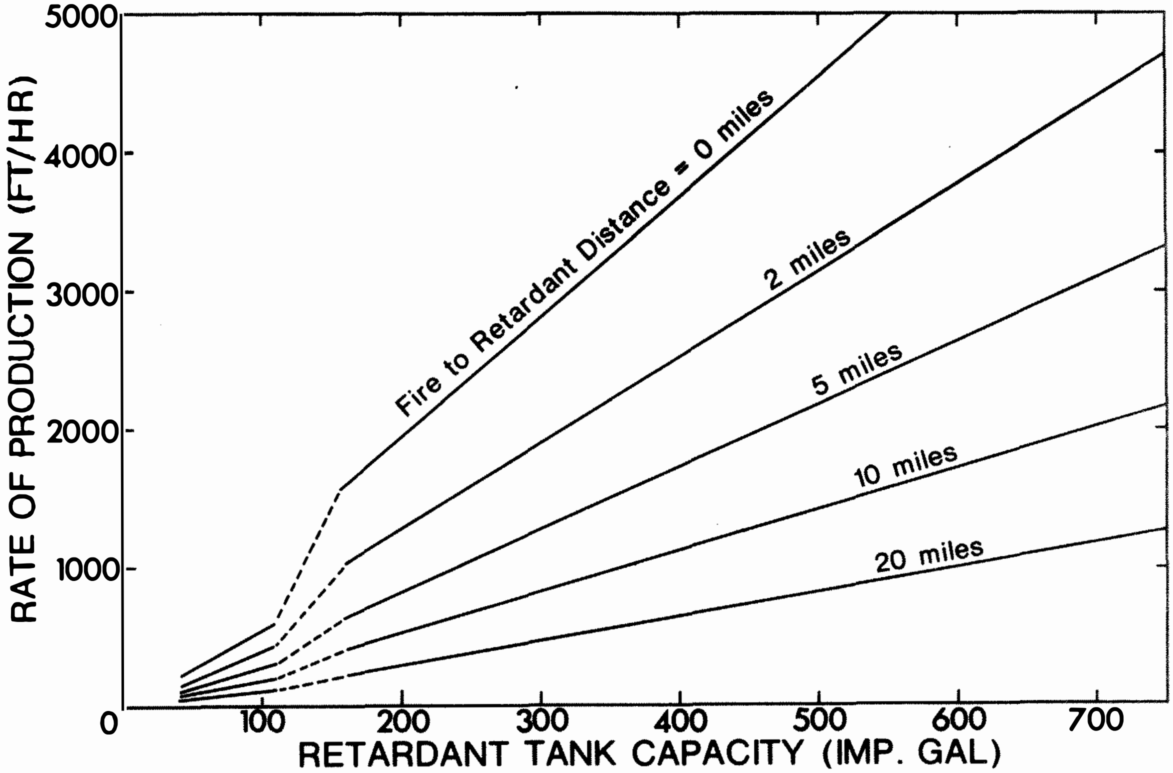
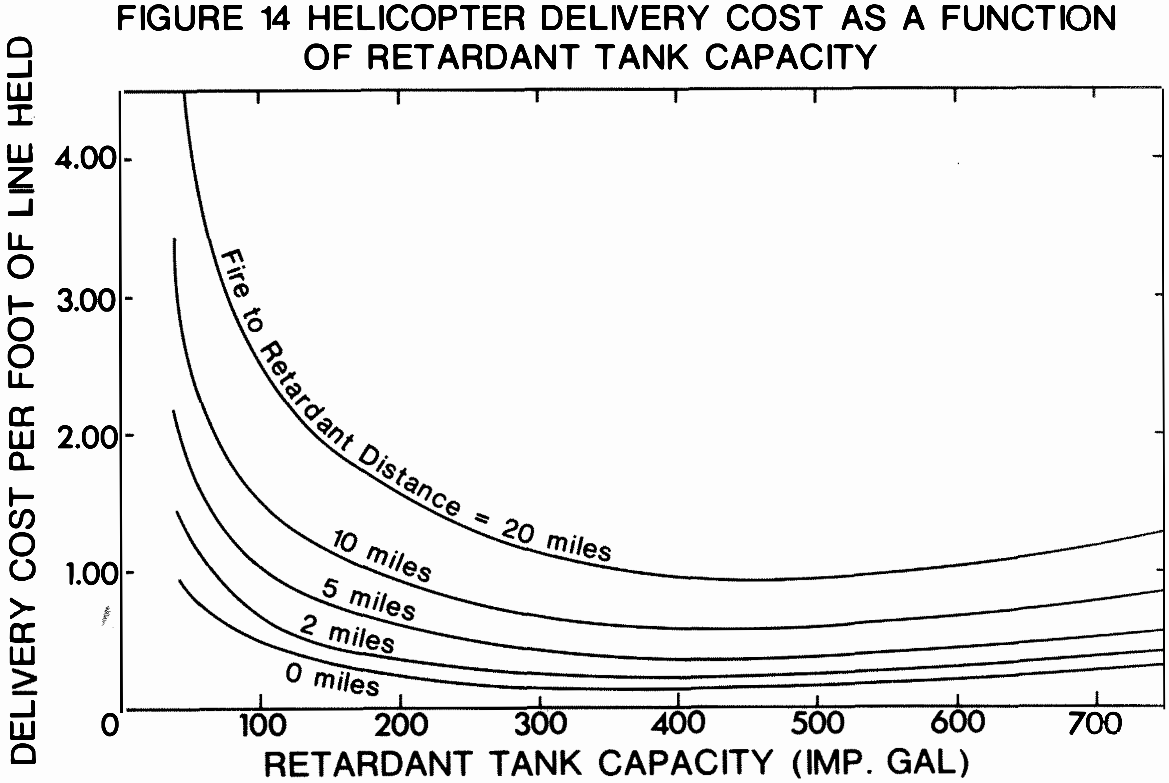


FIGURE 14 HELICOPTER DELIVERY COST AS A FUNCTION OF RETARDANT TANK CAPACITY



distance increases, the larger capacity machines demonstrate increasing economies of scale up to about 450 Imp. gallons, in that costs decrease with increasing capacity. While there is no clearly definable breaking point, it is evident that small machines with capacities of less than 100 Imp. gallons are significantly more expensive to operate per foot of line held than larger capacity machines. In addition, decisions on a minimum desirable capacity machine will have to consider other criteria such as passenger carrying capacity and versatility for other roles.

As was the case when comparing water- with land-based operations, a precise comparison of the use of helicopters with fixed wing airtankers must be limited to a single aircraft combination. A different result can be obtained for almost every airtanker-helicopter-distance combination analyzed. Although only a simplified comparison is made in this study, it is possible to draw some general conclusions which can be used as guides for the fire protection manager.

The average rates of production and costs per foot of line held for all fixed wing aircraft and helicopters were calculated for a number of fire to retardant source distances. The results are plotted in Figures 15 (production) and 16 (delivery cost). It should be emphasized that each of these curves is the average of a range of expected values. In other words, at any given distance both higher and lower costs and rates of production occur for each type of aircraft.

The curves in Figure 15 indicate that at fire to retardant distances less than nine miles, the average rate of production for helicopters exceeds the average for water-based fixed wing aircraft. At distances less than 17 miles, helicopters have a higher average production rate than land-based fixed wing aircraft. This high comparative production rate is due to the fact that at very short distances, the helicopters' rapid loading and dropping rates enable it to make far more drops per hour than fixed wing aircraft. As travel distances increase, however, the helicopters' relatively slow speed (120 mph average versus 145 for water-based aircraft and 181 for land-based aircraft) results in lower production rates relative to fixed wing aircraft.

A similar effect occurs when considering cost per foot of line held. Initially, helicopters have the lowest average cost per foot of line held but at a distance of just under 1 mile, the water-based aircraft become less expensive, and at 3.5 miles, the land-based aircraft cost less. If it is assumed that both production and costs are equally important, helicopters would appear to be more desirable up to about a 5-mile fire to retardant distance relative to water-based fixed wing aircraft, and up to a distance of 10 miles relative to land-based fixed wing aircraft. Again, the above conclusions are based on averages, and therefore only serve to indicate general trends. A specific aircraft combination must be compared in order to achieve specific results.

As is the case for water-based operations, helicopters must make one round trip from the base to the fire. For the water-based analysis, a reduction of the potential rate of production at zero fire to base distance was calculated as a function of the actual fire to base distance. Since the reduction depends on the characteristics of the specific aircraft being used, detailed calculations were not made for each helicopter. Values were calculated for typical helicopters in each class and an average value was determined. The combination of slower speeds and shorter endurance times

FIGURE 15 COMPARISON OF HELICOPTER AND FIXED WING AVERAGE RATES OF PRODUCTION

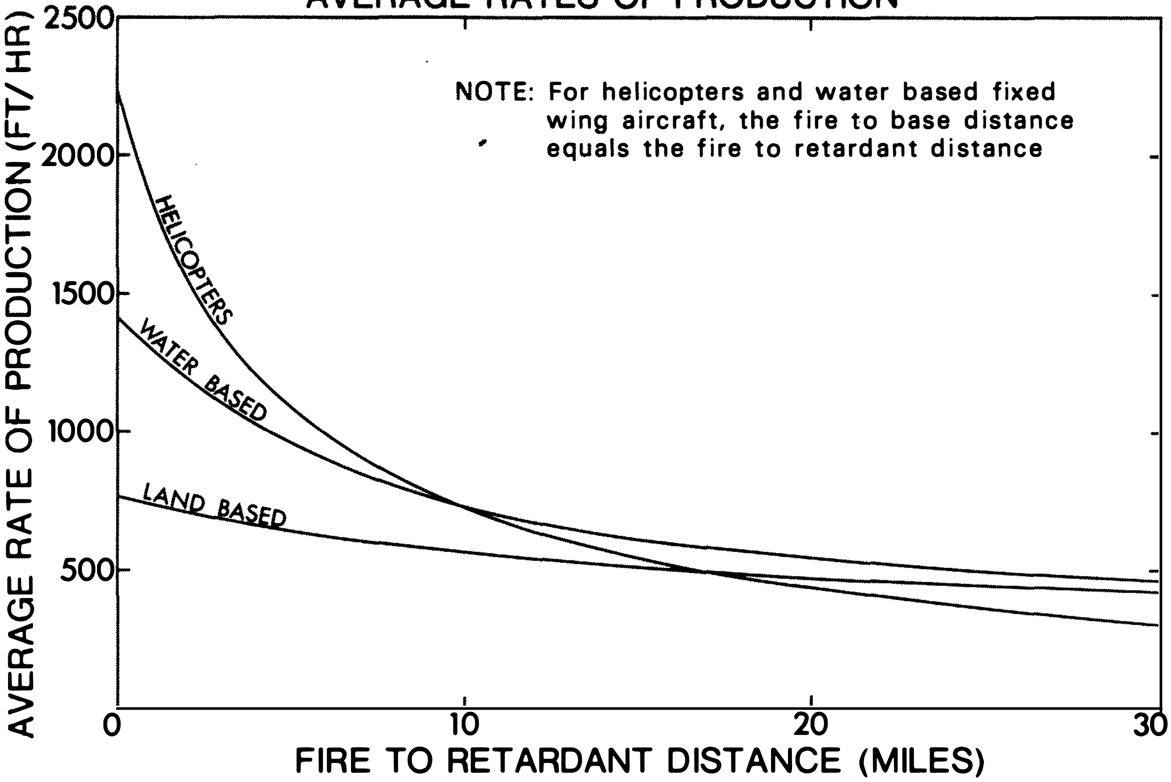
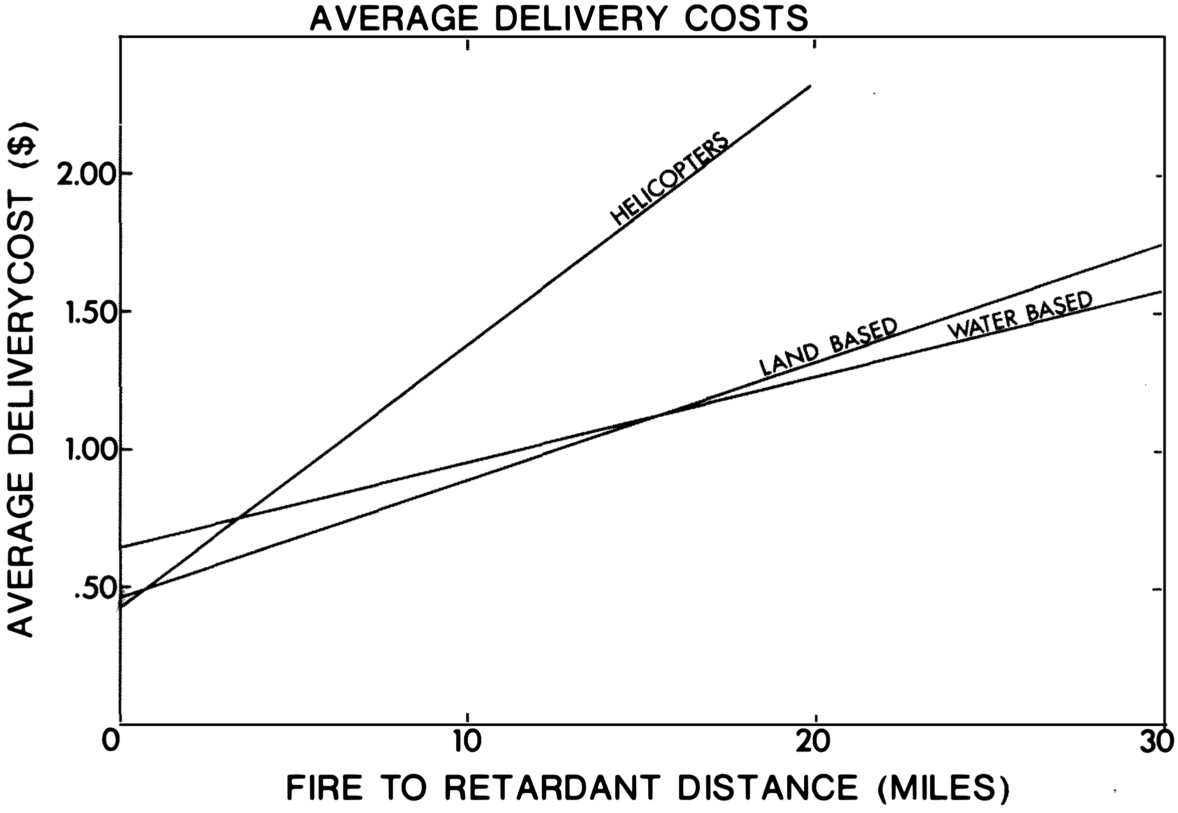


FIGURE 16 COMPARISON OF HELICOPTER AND FIXED WING AVERAGE DELIVERY COSTS



result in a reduction of the potential rate of production of approximately twice that for water-based aircraft for all fire to base distances. For example, from Figure 5 at a fire to base distance of 25 miles, water-based fixed wing aircraft will produce about 92 percent as much line as at a distance of zero miles, a reduction of 8 percent. For helicopters at this same distance, the reduction is about 16 percent, or an actual production of 84 percent of the potential at a fire to base distance of zero. Applying this correction to the curves in Figure 15 shifts the break-even distance to about 4.5 miles for water-based operations vs. helicopters and nine miles relative to land-based operations.

The above analysis could lead to the conclusion that helicopters appear to have a very narrow range of operating conditions wherein they are best suited to dropping retardants on forest fires. In all probability, comparisons of specific aircraft would not materially alter this conclusion because even doubling the break-even distance still leaves a relatively narrow range of operating conditions best suited to helicopter airtanker operations. It should be pointed out however that this analysis has not considered the usefulness of helicopters in transporting men and equipment to a fire. That topic, while certainly significant, is considered outside the scope of this discussion, which is being limited to airtanker operations only. If helicopters were to be used in a dual role, their relative attractiveness would be significantly increased.

The ability of a helicopter to load from a point source also increases their attractiveness. Up to this point, all analyses have assumed that aircraft would be used in an initial attack situation. That is, a fire is detected and reported to a dispatcher, who then deploys airtankers and ground forces from established base locations. While aircraft yield the greatest returns when deployed in initial attack, they are also frequently used in support operations to assist ground forces on large fires. In a support operation, the initial travel time is often of little consequence, so that the slow speed of the helicopter may be discounted. More important, with the removal of the requirements for immediate response inherent in an initial attack situation, ground personnel have time to establish helicopter servicing and reloading facilities close to the fire. Under such a situation, helicopters have a distinct advantage in that not only are they operating under conditions to which they are well suited, but also quite often at distances considerably less than the fixed wing aircraft which have to return to landable lakes or fixed bases.

Comparison of the above results with earlier work by Newburger (1968) discloses partial agreement with his findings. He concluded that helicopters in the 10,000 to 12,000 lb. gross weight range were most suitable for fire control work. His optimum range is substantiated by the foregoing analysis, wherein machines with 250-350 Imp. gallon capacities (8,500-9,500 lbs. gross weight) appear to be more desirable, for a variety of reasons, than significantly larger or smaller helicopters. On the other hand, his conclusions that such helicopters would be more advantageous than fixed wing aircraft appears to be valid for short fire to retardant source distances only.

I. Summary

In the preceeding section, costs and production for various aircraft were compared under a variety of operating conditions. As a result of the analysis two significant conclusions can be drawn:

1. No single type of aircraft or operation is, or in fact could ever be well suited for all use conditions, and

2. If either the aircraft or type of operation is poorly suited to mission requirements substantially decreased production and/or increased costs could result.

Perhaps even more important than the specific comparisons considered is the description of the methodology by which they were made. Because the analysis is greatly simplified many assumptions are necessary. Some may fit expected operating conditions for a specific region while others may not. The reader is invited to change those assumptions not applicable to his area of interest, and follow the procedures used in this section to reach his own specifically applicable conclusions which may or may not parallel those reached here. All the necessary basic aircraft data is available in the next section, although even some of that could readily be altered if specific modifications render an aircraft's characteristics significantly different from the listed averages, for example, as in the case of a super PBY rather than the regular version used in this report.

In developing the techniques used in this section emphasis was placed on applicability by field personnel without advanced training in mathematics or computer operations. All that is needed is a knowledge of the expected operating condition likely to be encountered, a desk calculator, and an ability to draw and interpret graphs. While solutions obtained through this procedure can in no way be considered exact, they should provide the forest fire protection manager with reasonably good estimates of solutions applicable to his area which can be used in the interim until more precise results become available.

Section 4

AIRCRAFT CHARACTERISTICS

The following section describes aircraft which have been, or are currently being used as airtankers. Because of the multitude of sources from which information was taken, specific references are not listed on each page. The primary sources are:

1. Janes "All the World's Aircraft"
2. manufacturer's specification sheets
3. Canadian Forestry Service publications
4. personal communications with:
   a. United States Forest Service
   b. manufacturers
   c. contractors who lease airtankers
   d. companies who carry out airtanker conversions
   e. private forest fire protection agencies
   f. Aeronautical Engineering Branch, N.R.C.
   g. Civil Aviation Branch, M.O.T.

Suffice it to say that there is no original data in the following listing. All of the information has come from outside sources. The only contribution of this section is a compilation under a single cover.

Aircraft Characteristics

There is a great deal of conflicting information written about airtankers. These conflicts arise, not necessarily as a result of error but because each airtanker is, in a sense, a prototype. Conversions are not identical. Capacities are not identical and certainly operating characteristics and drop patterns are not identical even when the aircraft type is the same. In addition, different models of the same aircraft can differ considerably in their characteristics. The Ag Cat, for example, can be equipped with any of six engines ranging from 200 to 600 horsepower. Even manufacturer's specification sheets have been found to be inconsistent. When conflicting information was encountered, those data which seemed to be most representative (or average) were chosen. Therefore, much of the performance and cost data should be considered as the mid-point of a range which could vary as much as plus or minus 20 percent.

It should be emphasized that inclusion or exclusion of any make or model aircraft or helicopter does not in any way imply an endorsement or lack thereof. The authors have simply compiled information about a variety of aircraft types. It was considered redundant to include descriptions of variations which differed only slightly from the one listed. This is particularly applicable to the section on helicopters.

This section is divided into two parts. The first part describes in detail the characteristics of a number of fixed wing aircraft which have been converted to airtankers. The second part describes the characteristics of a few helicopters which have been or could be used as airtankers.

Explanatory Notes for Aircraft Characteristics

Wherever possible performance data is for a standard atmosphere at sea level.

1. Primary Purpose

The function which the aircraft was originally designed to perform.

2. Manufacturer

The primary contractor who built the aircraft.

3. Dimensions

In the three point attitude. The width for helicopters assumes the rotor parallel to the airframe, or removed.

4. Weights

(a) Empty

Without fuel, crew or avionics. Often, modifications to World War II Aircraft may decrease the empty weight by the removal of ordinance and other items not required for airtanker operations. This will naturally increase the load carrying capacity.

(b) Maximum Load

With crew, avionics and full fuel load (decreasing the fuel load will naturally increase the payload but does so at the expense of endurance).

(c) Certified gross take off weight.

5. Engine(s)

Number, horsepower and manufacturer of the most commonly used engine(s).

6. Fuel

(a) Capacity

Capacity of the fuel tanks (the actual operating load may be less).

(b) Consumption

Total consumption for all engines.

7. Speeds

(a) Maximum

At cruising altitude.

(b) Cruising

Normally at about 70 to 75 percent power setting.

(c) Stall

At gross take off weight. N/A for helicopters.

(d) Rate of Climb

At gross take off weight.

8. Loadings

(a) Normal Power

Gross take off weight divided by horsepower at 75 percent setting.

(b) Wing (fixed wing)

Gross take off weight divided by the wing area.

(c) Design Load Factor (fixed wing)

Maneuver G's of stress that the airframe is designed to tolerate.

(d) Disc (helicopters)

Gross take off weight divided by the area of the circle described by the rotors.

9. Endurance

(a) Hours

With 45-minute reserve for fixed wing, 10 percent reserve for helicopters. If not directly available it is calculated from full fuel load and consumption. Reduction in fuel load will reduce endurance.

(b) Ferry

With full fuel load and no pay load, with reserves.

(c) Fully Loaded

With full retardant tanks and in some cases a reduced fuel load, with reserves.

10. Minimum Take Off Run (Fixed Wing)

Either land or water; at gross take off weight; does not include distance required for 50-foot obstacle clearance.

10. Hovering Ceiling (Helicopters)

At gross take off weight, both outside and inside ground effect.

11. Retardant Tank Capacity

(a) Total

Capacity of the retardant tank(s). This may be greater than the certified load capacity of the aircraft in some instances. For helicopters the capacity of the bucket to be used:

S-100:	40 to 80 Imp. gal.	wt. 75 lbs.
S-140:	40 to 112 Imp. gal.	wt. 80 lbs.
S-450:	160 to 360 Imp. gal.	wt. 244 lbs.

(b) With Full Fuel Load

Amount of water the aircraft is certified to lift with a full fuel load (based on 10 pounds/Imp. gallon). Retardants with greater densities than water will reduce this figure if the total exceeds the gross take off weight.

12. Retardant Loading

(a) Time Required

Land-based: tank capacity divided by 250 gal./min.
Water-based and helicopter: 0.5 min.

(b) Lake Length Required (water-based)

For a safe pickup in a water-based operation.

13. Retardant Distribution Patterns

On the ground, in the open, with light winds, drop height of 75 to 100 feet and drop speeds of 80 to 120 mph (helicopters at 20 to 40 mph). These patterns are for water (or unthickened retardants only). There is insufficient information available to develop patterns for thickened retardants. Field observations indicate that thickened retardant patterns tend to hold together more than water. With fast drop speeds or high drop altitudes the effect becomes particularly noticeable. The dimensions are at the widest points (length and width) of the generally elliptical patterns. In a series of tests recently reported by Griegel[1] it was found that pattern lengths for the Thrush were reduced by between 1/3 and 2/3 when dropping through forest canopies. This is in contrast to Maloney's (1972) findings for larger aircraft which had an average reduction of 17 percent under approximately comparable conditions.

Distribution patterns for helicopters are based on a linear extrapolation of patterns for a 360 Imp. gallon load. Patterns for the small buckets are also partially based on subjective observations of actual test drops.

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[1] Grigel, J.E. 1971. Air drop tests with Fire-Trol 100 and Phos-Check 205 fire retardants; Northern Forest Research Center, Edmonton, Alta., Inf. Rept. NOR-X-8.

Aircraft Costs

There are as many types of financial arrangements as there are individuals who lease or contract airtankers. Leases can include a retainer, a guaranteed minimum number of hours or standby charges. Hourly charges may be different for time to and from fires and time actually dropping. Even if a fire control agency owns an aircraft it may be leased to a contractor who, in turn, supplies pilot, maintenance and operational experience and leases the service back to the agency. Agencies which own their own aircraft may reduce the true costs through bookeeping procedures and policies. In such cases the true cost may not be considered in making decisions concerning an aircraft's operations since the forest fire protection budget absorbs only the actual costs.

Thus the descriptions and costs which follow may not precisely describe the actual characteristics or cost of the available aircraft. They are intended as a general guide for comparative purposes, to assist in the evaluation of aircraft types and relative costs. In any particular situation the best answer can be achieved only by using the actual characteristics of the available aircraft and the actual costs of utilizing them.

It should be noted that actual costs may not be real costs in an economic sense. Actual costs are costs which are actually paid by the organization using the aircraft. If the aircraft is rented or leased, actual cost will include not only the variable and fixed costs described in this section but also a margin for profit, risk and uncertainty. If the aircraft is allocated to the organization by another department of a public agency, actual costs may include only operating costs.

Explanatory Notes for Aircraft Costs

I. Fixed Costs

These are costs which have to be paid regardless of the number of hours flown. Acquisition cost includes the installation of retardant tanks and drop system as well as avionics. Old aircraft should have at least half-life engines. Spares are not included. The cost includes sales tax and import duties to Canada where applicable.

1. Pilots' Salary

Pilots' salaries are divided into two components - a base salary which is paid regardless of the number of hours flown and an hourly bonus such that for a 200 hour season the totals are: $13,000 for a single engine aircraft, $15,000 for a twin engine aircraft and $17,000 for a multi-engine aircraft. For comparison purposes all single and twin engine aircraft are assumed to require only one pilot and all multi-engine aircraft are assumed to require a co-pilot. The use of a co-pilot for a twin engined aircraft would increase the crew's salary by 80 percent and personnel costs by $4,000.

2. Personnel

Personnel costs are benefits, such as insurance, sick leave, vacation etc. and per diem expenses for the pilot and mechanics (assuming 100 days at $20.00 per day). The per diem allowance should be deleted if the base is also the operator's principal place of business.

3. Hangar Space

This rent is the cost for inside storage of the aircraft over the winter months. If the aircraft is stored outside, this cost should be eliminated.

4. Yearly Maintenance

This cost includes required annual maintenance; unscheduled maintenance; repainting the aircraft, dismantling, inspecting, cleaning retardant tanks and drop mechanisms; general re-fitting and refurbishing; the additional cost of performing hourly maintenance before it is due to prevent down-time during the active season.

5. Cost of Remote Operations

This expense includes the cost of establishing a supply of parts, equipment and fuel at a location removed from a home base; costs of transportation; etc. If the base is also the operators' principal place of business this cost should be deleted.

6. Depreciation

Depreciation is assumed to be straightline, 15 years to 20 percent residual.

7. Insurance

Insurance costs are calculated at 8 percent for land based, 15 percent for amphibious aircraft and 12 percent for helicopters. Aircraft are assumed to be insured for 100 percent of their depreciated value at the halfway point in the depreciation schedule.

8. Interest on Fixed Assets

The alternative rate of return which could be earned by the capital funds invested in the aircraft. This value is assumed to be 5-1/2 percent of the depreciated value of the aircraft at the halfway point in the depreciation schedule. If the aircraft is publicly owned, the original purchase may have been justified by predicted benefits and a return on investment is not usually included as a cost.

9. Total Fixed Costs

Total fixed costs are the sum of all of the above. Because of the many unknowns, this value is only an approximation and is most useful as a guide for comparing aircraft. As previously mentioned, use of a co-pilot for the twin engine aircraft will increase the total fixed cost by about $16,000. Since the original purpose of computing these values is for comparison of aircraft types, fleet administration costs were not included, for they do not affect the relative differences between aircraft. Fleet administration costs will probably add $50,000 to $100,000 to the total cost of operation, depending on the size and complexity of the fleet. Deletion of the costs of hangar space, remote operations, and interest on fixed assets can reduce the fixed costs by as much as 45 percent.

II. Hourly Costs

These are expenses which are exclusively a function of the number of hours that the aircraft is flown. These costs include:

1. Fuel and Oil

   The costs of fuel and oil changes per hour of flying time.

2. Maintenance

   (a) Engine overhaul - total cost of engine replacement (labour and materials) divided by the number of hours of flight allowed between replacements.

   (b) Labour - mechanics salaries divided by 200 hours of flying time per year. This is actually a fixed cost, as is the pilots salary, but since most companies list this cost on a per hour basis as part of a total for engine overhaul, labour and maintenance, it is listed under hourly costs for comparison purposes.

   (c) Materials - the total cost of engine and airframe parts which have to be replaced divided by the number of hours allowed between replacement.

3. Pilot per Hour

   Discussed previously under the pilot's base salary.

4. Landing Fees

   An average of $20.00 per hour for all land based aircraft.

5. Total Hourly Costs

   A total of all of the above.

6. Cost per Hour

   Total fixed cost divided by 200 hours plus total hourly cost. Note that any use in excess of 200 hours will reduce the hourly cost proportionally. The greater the versatility of the aircraft or helicopter, the greater is the possibility of other uses.

7. Cost per Hour per Gallon Capacity

The overall cost per hour divided by the capacity of the retardant tanks.

CONVERSION FACTORS USED IN THIS SECTION

1 foot (per minute)	=	0.305 metres (per minute)
1 Imperial gallon	=	1.201 U.S. gallons = 4.546 litres
1 Imperial gallon of aviation fuel	=	7.2 lbs.
1 Imperial gallon of water	=	10.0 lbs.
1 inch	=	2.54 centimetres
1 inch of water depth	=	62.34 U.S. gallons/100 sq. ft.
1 pound	=	0.454 kilograms
1 statute mile (mph)	=	.869 nautical miles (knots) = 1.609 kilometres (kph)

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SECTION 4

AIRCRAFT CHARACTERISTICS

(a) Fixed Wing Aircraft

AIRCRAFT	A-26 INVADER

General Characteristics

PRIMARY PURPOSE World War II Medium Bomber	
MANUFACTURER Douglas	
DIMENSIONS length 50 ft.9 ins. wing span 70 ft. height 18 ft.6 ins.	WEIGHTS empty 20,000 lbs. maximum load 10,000 lbs. gross take off 35,000 lbs.
ENGINE(S) Two 2,000 HP. Pratt & Whitney R 2800-71	FUEL capacity 640 imp. gal. consumption 150 imp. gal./hr.

Performance Data

SPEEDS maximum 345 mph. cruising 280 mph. stall 100 mph. rate of climb 650 ft./min.	LOADINGS normal power 10.7 lbs/hp. wing 63.5 lbs/sq. ft. design load factor+ 2.8 G (est)
ENDURANCE hours 3.5 hours ferry range 1030 miles fully loaded range 925 miles	MINIMUM TAKE OFF ROLL 4150 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY total 1000 imp. gal. with full fuel load 1000 imp. gal.	RETARDANT LOADING time required 4.5 min. lake length required N/A

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02*	.04	.07 *
Single Tank	125 X 25	90 X 20	50 X 15
2 Tank Salvo	250 X 40	180 X 30	120 X 20
2 Tank Trail	340 X 25	250 X 20	160 X 15
4 Tank Salvo	360 X 75	260 X 60	200 X 50
4 Tank Trail	450 X 60	350 X 50	260 X 40

* Extrapolation based on patterns for other aircraft with comparable loads.

Costs

COST OF ACQUISITION (including conversion to an airtanker) $70,000 (used)			
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$10,000	fuel & oil	$50.00
personnel	9,000	engine overhaul	
hangar space	5,000	labour	$150.00
yearly maintenance	5,000	materials	
cost of remote operation	6,000	pilot per hour	$25.00
depreciation	3,700	landing fees	$20.00
insurance	3,400		
interest on fixed assets	2,300		
Total Fixed Cost	$44,400	Total Hourly Cost	$245.00
Cost per Hour $467.00			
Cost per Hour per Gallon Capacity $0.47			

Remarks

The main advantages of the A-26 are a high flying speed and an above average retardant capacity, as well as a low delivery cost per foot of line held. The only significant disadvantage is a requirement for a long paved runway. The A-26 is generally considered to be one of the more successful airtanker conversions. It is well suited to continuous operations particularly at long flying distances. It is also suited to limited operations where fire size at the time of attack is moderately large. The Martin B-26 Marauder is often confused with the Douglas A-26 Invader as they are similar in both dimensions and appearance. The main difference between the two is the slower speed (287 mph) and greater gross take-off weight (30,200 lbs) of the B-26.

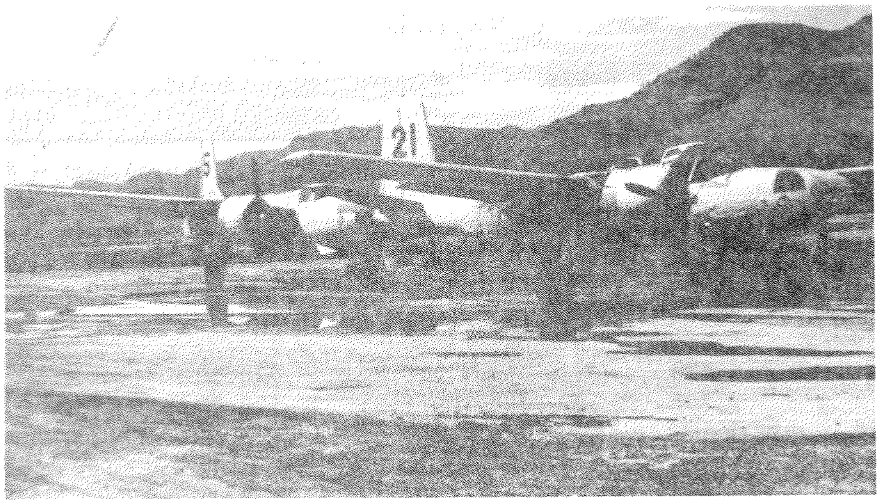

Figure 17. A-26 Invader (Photo: Author).

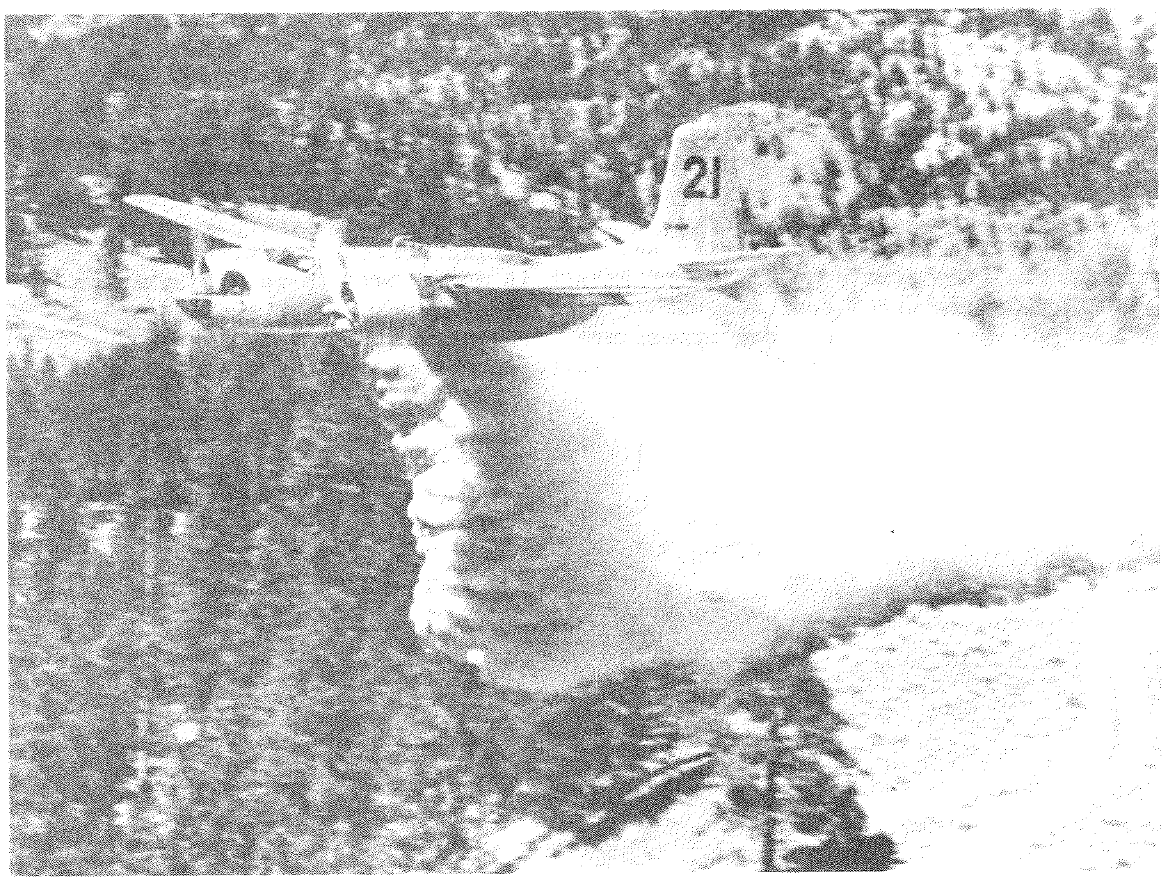

Figure 18. A-26 Invader (Photo: British Columbia Forest Service).

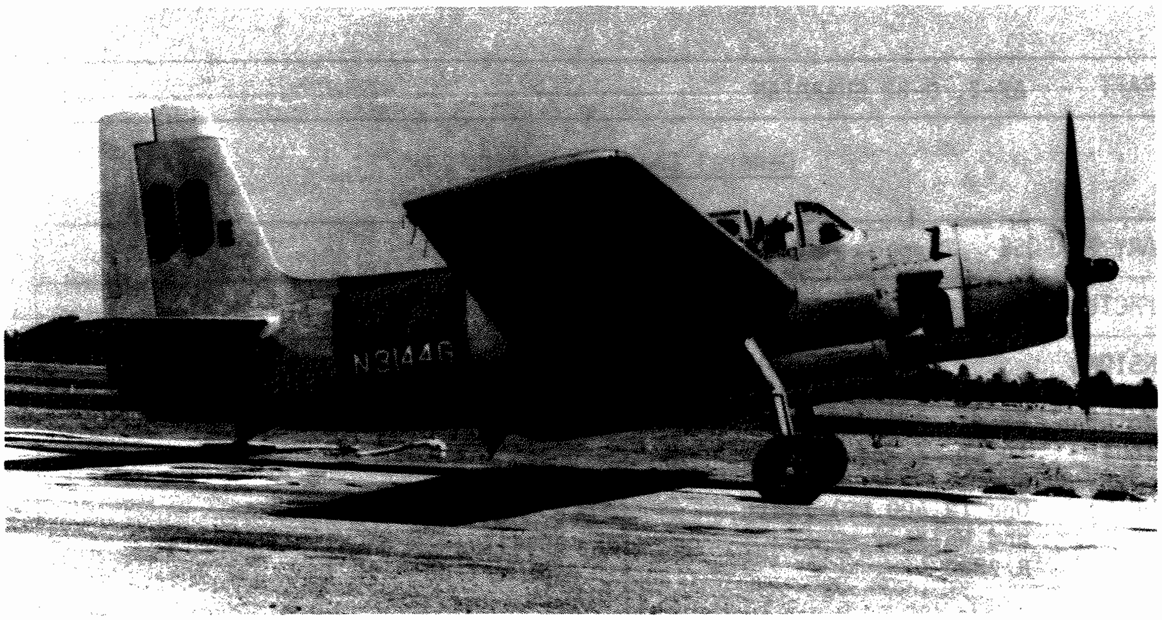

Figure 19. AF-1 Guardian (Photo: California Division of Forestry).

Figure 20. Photo not available.

AIRCRAFT	AF-2, G-82 GUARDIAN

General Characteristics

PRIMARY PURPOSE	Torpedo Bomber
MANUFACTURER	Grumman

DIMENSIONS		WEIGHTS	
length	43 ft. 4 ins.	empty	14,600 lbs.
wing span	60 ft. 8 ins. (16 ft. 5 in. folded)	maximum load	6,460 lbs.
height	16 ft. 2 ins.	gross take off	25,000 lbs.

ENGINE(S)	FUEL	
One (2,400 HP) Pratt and Whitney R 2800-48W.	capacity	350 imp. gal.
	consumption	92 imp. gal./hr.

Performance Data

SPEEDS		LOADINGS	
maximum	315 mph.	normal power	13.9 lbs/hp.
cruising	245 mph.(est)	wing	44.5 lbs/sq. ft.
stall	83 mph.	design load factor+	2.5 G.
rate of climb	650 ft/min.		

ENDURANCE		MINIMUM TAKE OFF ROLL
hours	3.1 hrs.	2000 ft.
ferry range	750 miles	
fully loaded range	600 miles	

Airtanker Characteristics

RETARDANT TANK CAPACITY		RETARDANT LOADING	
total	800 imp. gal.	time required	3.7 min.
with full fuel load	760 imp. gal.	lake length required	N/A

RETARDANT DISTRIBUTION PATTERNS *

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	225 X 40	155 X 30	80 X 15
2 Tank Salvo	275 X 85	205 X 65	140 X 50
2 Tank Trail	350 X 60	280 X 50	200 X 35

* Patterns for the AF-2 are not available. The above patterns are an average of the values for the PBY5A and 80% of the values given for the A-26 which carries 1000 imp. gallons. See remarks.

Costs

COST OF ACQUISITION (including conversion to an airtanker) $45,000 (used)	
FIXED COSTS pilot base salary $8,600 personnel 8,500 hangar space 3,500 yearly maintenance 4,000 cost of remote operation 4,500 depreciation 2,400 insurance 2,200 interest on fixed assets 1,500	HOURLY COSTS fuel & oil $ 33.00 engine overhaul labour 140.00 materials pilot per hour 22.00 landing fees 20.00
Total Fixed Cost $35,200	Total Hourly Cost $215.00
Cost per Hour $391. Cost per Hour per Gallon Capacity 0.49	

Remarks

The main advantage of the AF-2 is an above average flying speed. The AF-2 is used fairly extensively in the State of California where it is generally acknowledged to be a good airtanker. It appears to be well suited to missions where the flying distance is short to moderate and on fires of moderate size and intensity. The actual drop patterns have been reported as marginal due to a low ratio of door area to tank capacity.

AIRCRAFT	AG-2

General Characteristics

PRIMARY PURPOSE Agricultural Spraying	
MANUFACTURER Transland Aircraft	
DIMENSIONS length 28 ft. 5 ins. wing span 42 ft. height 9 ft. 8 ins.	WEIGHTS empty 3,608 lbs. maximum load 3,535 lbs. gross take off 7,700 lbs.
ENGINE(S) One 600 hp. Pratt & Whitney R-1340 53H1 or AN1 wasp.	FUEL capacity 50 imp. gal. consumption 24 imp. gal./hr.

Performance Data

SPEEDS maximum 142 mph. cruising 130 mph. stall 56 mph. rate of climb 900 ft./min.	LOADINGS normal power 17.1 lbs./hp. wing 23.9 lbs./sq. ft. design load factor + 4.0 (est)
ENDURANCE hours 1.4 hrs. ferry range 455 miles (with ferry Tank) fully loaded range 400 miles (with ferry Tank)	MINIMUM TAKE OFF ROLL 907 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY total 315 imp. gal. with full fuel load 315 imp. gal.	RETARDANT LOADING time required 1.8 min. lake length required N/A

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	175 X 50	115 X 45	85 X 30

There are no patterns available for the AG-2. The above are extrapolated from patterns for the S2-D.

Costs

COST OF ACQUISITION (including conversion to an airtanker) $20,000 (used, est)	
FIXED COSTS pilot base salary $8,600 personnel 8,000 hangar space 1,500 yearly maintenance 2,000 cost of remote operation 1,500 depreciation 1,100 insurance 1,000 interest on fixed assets 600	HOURLY COSTS fuel & oil $10.00 engine overhaul labour 20.00 materials pilot per hour 22.00 landing fees 20.00
Total Fixed Cost $23,200	Total Hourly Cost $72.00
Cost per Hour $188. Cost per Hour per Gallon Capacity $0.60	

Remarks

As an agricultural aircraft, the AG-2 has good maneuverability and a low flying speed. It has a slightly larger capacity than other agricultural aircraft, but its short endurance could be a problem. This aircraft has been used primarily in California. It would be suited to small fires close to a retardant source. It is well suited to regions with large numbers of readily accessible small airstrips.

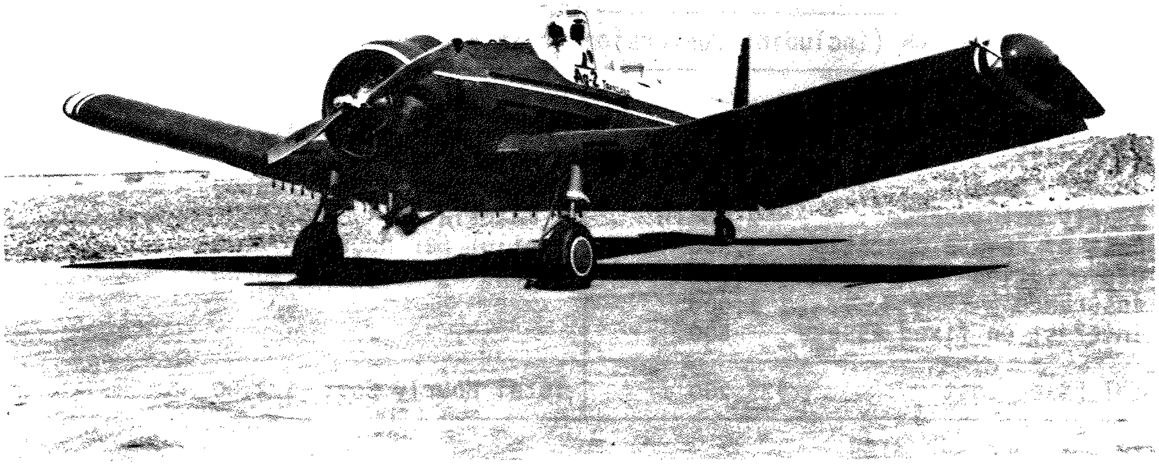

Figure 21. AG-2 (Photo: California Division of Forestry).

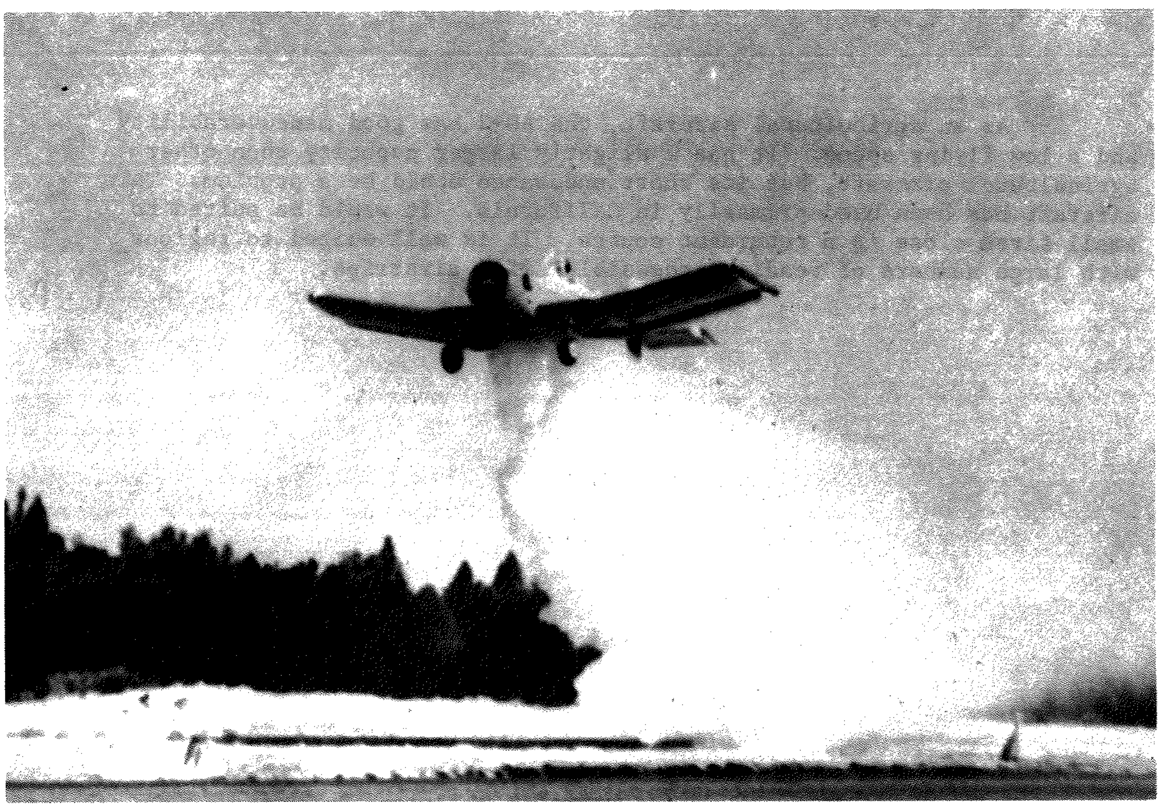

Figure 22. AG-2 (Photo: California Division of Forestry).

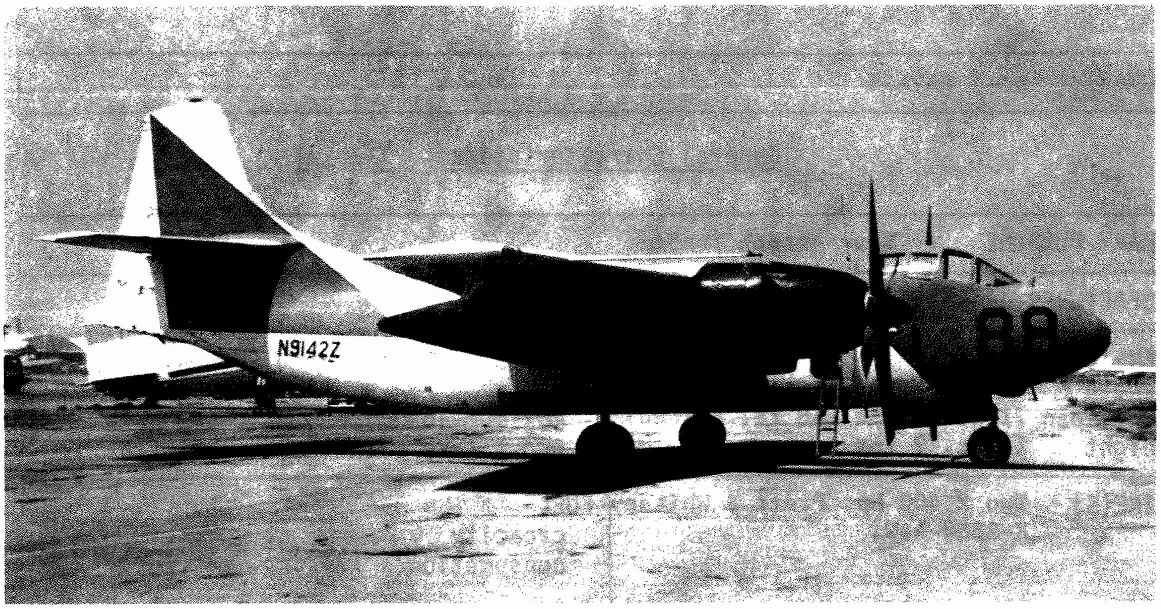

Figure 23. AJ-1 Savage (Photo: California Division of Forestry).

Figure 24. Photo not available.

AIRCRAFT	AJ-1 SAVAGE

General Characteristics

PRIMARY PURPOSE	Navy Attack Bomber
MANUFACTURER	North American

DIMENSIONS length 63 ft. 1 ins. wing span 71 ft. 5 ins.(48 ft. folded) height 15 ft. 2 ins.	WEIGHTS empty 25,000 (est) maximum load gross take off 50,000 lbs. (est)
ENGINE(S) Two 2,400 hp. Pratt & Whitney R-2800-44W.	FUEL capacity consumption 170 imp. gal./hr.

Performance Data

SPEEDS maximum 350 mph (est) cruising 260 mph (est) stall rate of climb	LOADINGS normal power 13.9 lbs./hp. wing design load factor + 3.5 (est)
ENDURANCE hours ferry range fully loaded range	MINIMUM TAKE OFF ROLL

Airtanker Characteristics

RETARDANT TANK CAPACITY total 1,600 imp. gal. with full fuel load	RETARDANT LOADING time required 6.9 min. lake length required N/A

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	200 X 40	140 X 30	80 X 15
2 Tank Salvo	275 X 85	200 X 60	140 X 50
2 Tank Trail	350 X 65	280 X 50	200 X 35
4 Tank Salvo	500 X 75	350 X 60	250 X 40
4 Tank Trail	650 X 65	500 X 50	350 X 35

The above patterns are the same as for the B-17.

Costs

COST OF ACQUISITION (including conversion to an airtanker)			$150,000 (used, est.)
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$10,000	fuel & oil	$ 60.00
personnel	9,500	engine overhaul	
hangar space	4,000	labour	200.00 (est)
yearly maintenance	5,500	materials	
cost of remote operation	6,500	pilot per hour	25.00
depreciation	8,000	landing fees	20.00
insurance	7,200		
interest on fixed assets	5,000		
Total Fixed Cost	$55,700	Total Hourly Cost	$305.00
Cost per Hour $583.00			
Cost per Hour per Gallon Capacity $0.36			

Remarks

Use of the AJ-1 has been limited primarily to California. Although there are very few data available its large load coupled with a relatively fast cruising speed for its capacity indicates that the AJ-1 should be well suited to an airtanker role. The original Navy versions had an additional jet engine in the fusilage for extra speed (up to a maximum of 425 mph) for take-off and fighter activities.

AIRCRAFT	B-17 FLYING FORTRESS

General Characteristics

PRIMARY PURPOSE World War II Bomber	
MANUFACTURER Boeing	
DIMENSIONS length 74 ft. 9 ins. wing span 103 ft. 9 ins. height 15 ft.	WEIGHTS empty 32,720 lbs. maximum load 17,000 lbs. gross take off 47,500 - 65,000 lbs.
ENGINE(S) Four 1200 hp Wright R 1820-97	FUEL capacity 1,510 - 2,068 imp. gal. consumption 272 imp. gal./hr.

Performance Data

SPEEDS maximum 295 mph. cruising 170 mph. stall 96 mph. rate of climb 2,260 ft./min.	LOADINGS normal power 13.9 - 18.0 lbs./hp. wing 33.5 - 45.2 lbs./sq. ft. design load factor + 2.5 G
ENDURANCE hours 5 hrs. ferry range 1,500 miles fully loaded range 1,100 miles	MINIMUM TAKE OFF ROLL 4,000 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY total 1600 imp. gal. with full fuel load 1600 imp. gal.	RETARDANT LOADING time required 6.9 min. lake length required N/A

RETARDANT DISTRIBUTION PATTERNS*

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	200 X 40	140 X 30	80 X 15
2 Tank Salvo	275 X 85	200 X 60	140 X 50
2 Tank Trail	350 X 65	280 X 50	200 X 35
4 Tank Salvo	500 X 75	350 X 60	250 X 40
4 Tank Trail	650 X 65	500 X 50	350 X 35

* Patterns for the B-17 are not available. The above values are an average of the PBY and 80% of the A-26 up to two tanks. For four tanks they are an average of the JRM-3, (single tank) and an extrapolation of the above values. See remarks.

Costs

COST OF ACQUISITION (including conversion to an airtanker)			$140,000 (used)
FIXED COSTS		HOURLY COSTS	
pilot base salary	$20,500	fuel & oil	$ 95.00
personnel	14,500	engine overhaul	
hangar space	6,000	labour	160.00 (est)
yearly maintenance	6,500	materials	
cost of remote operation	8,000	pilot per hour	50.00
depreciation	7,500	landing fees	20.00
insurance	6,700		
interest on fixed assets	4,600		
Total Fixed Cost	$74,300	Total Hourly Cost	$325.00
Cost per Hour $696.00 Cost per Hour per Gallon Capacity $0.44			

Remarks

The main advantage of the B-17 is its large load. The main disadvantages are the long paved runway required for take-off and a flying speed which is below average for military attack aircraft. Originally, more than 5,000 B-17's were built. To date it's use has been limited primarily to the U.S. where it is generally considered to perform satisfactorily. The B-17's main usefulness appears to be in it's ability to successfully contain larger fires than aircraft with smaller loads. It's low flying speed more than offsets the large load at long flying distance, however. This aircraft appears to be well suited to continuous operations. It would be suited to limited operations only where the fire size at the time of attack is relatively large. It has been reported that the basic tank design results in an excessive concentration of retardant in the center of the pattern. Several door modifications have been made in an attempt to achieve a greater aerial distribution. Current practice is to drop from greater than normal heights to achieve this goal.

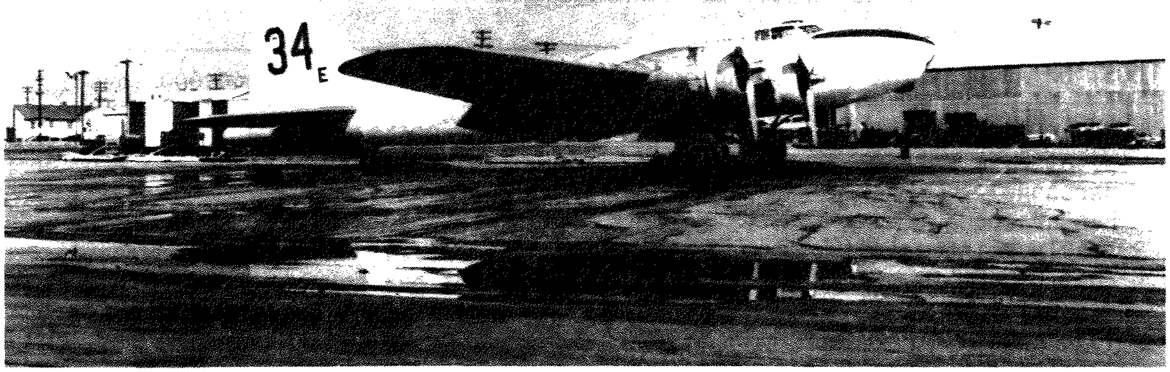

Figure 25. B-17 Flying Fortress (Photo: California Division of Forestry).

Figure 26. B-17 Flying Fortress (Photo: U.S. Forest Service).

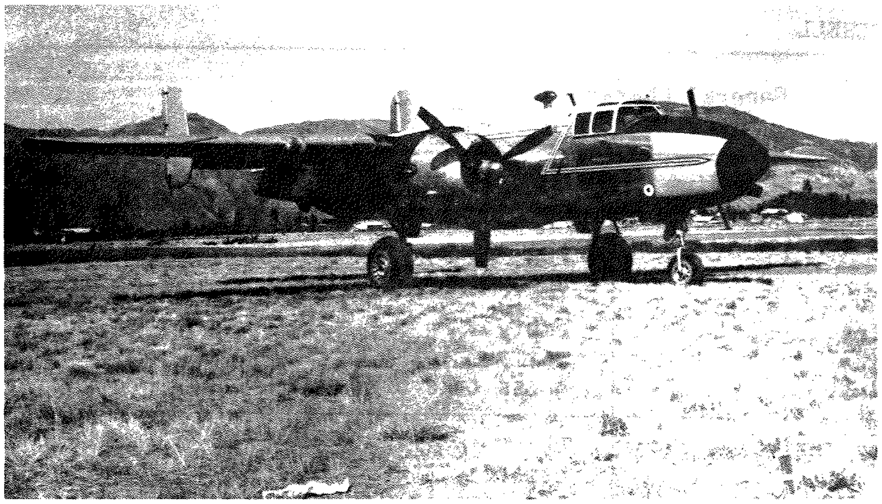

Figure 27. B-25 Mitchell (Photo: Author).

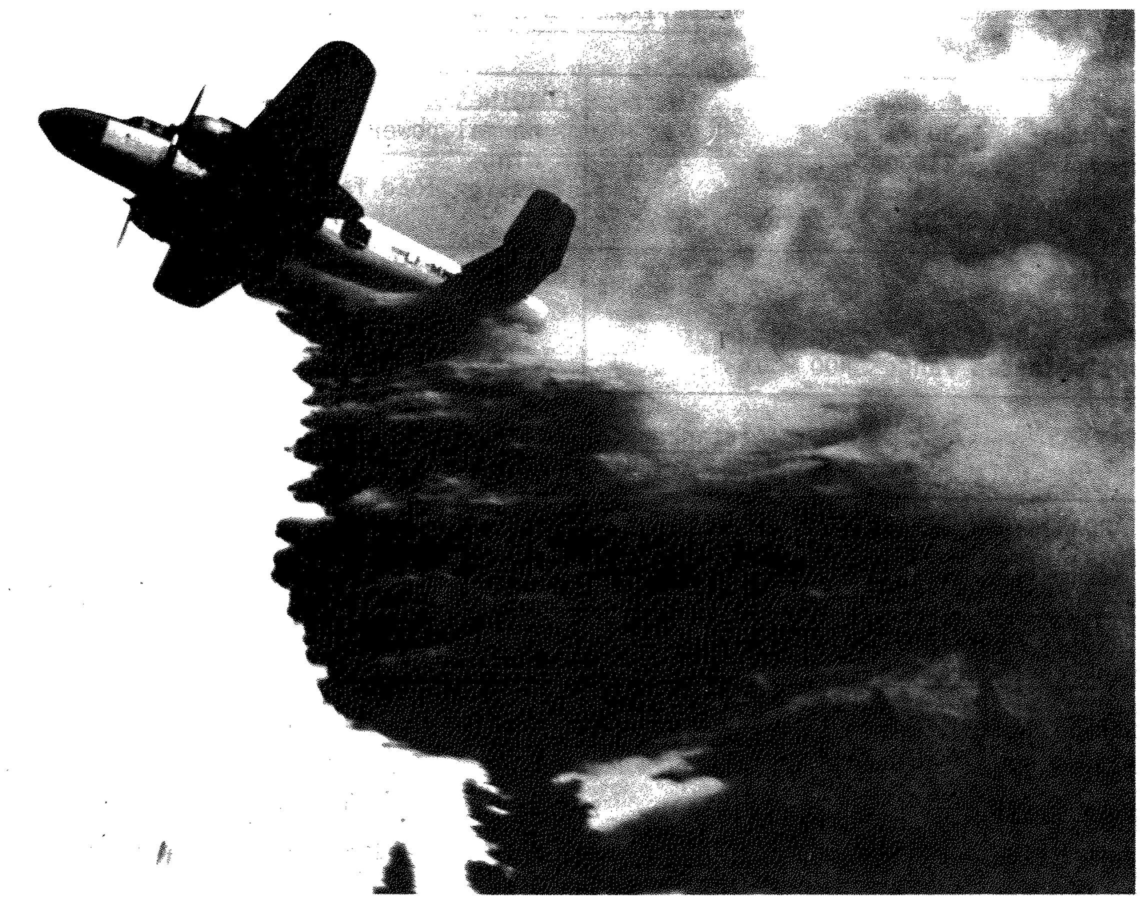

Figure 28. B-25 Mitchell (Photo: Alberta Forestry Service).

AIRCRAFT	B-25 MITCHELL

General Characteristics

PRIMARY PURPOSE World War II Medium Bomber	
MANUFACTURER North American	
DIMENSIONS length 53 ft. 5 ins. wing span 67 ft. 7 ins. height 15 ft. 9 ins.	WEIGHTS empty 21,100 lbs. maximum load 9,000 lbs. gross take off 33,500 lbs.
ENGINE(S) Two 1700 hp. Wright Cyclone R 2600-13	FUEL capacity 516 imp. gal. consumption 140 imp. gal./hr.

Performance Data

SPEEDS maximum 300 mph. cruising 210 mph. stall 85 mph. rate of climb 1330 ft./min.	LOADINGS normal power 13.1 lbs./hp. wing 55.8 lbs./ sq. ft. design load factor + 2.6 G
ENDURANCE hours 5 hours ferry range 890 miles fully loaded range 800 miles	MINIMUM TAKE OFF ROLL 4,000 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY total 950 imp. gal. with full fuel load 950 imp. gal.	RETARDANT LOADING time required 4.3 min. lake length required N/A

RETARDANT DISTRIBUTION PATTERNS*

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	120 X 25	85 X 20	45 X 15
2 Tank Salvo	240 X 40	170 X 30	115 X 20
2 Tank Trail	295 X 25	240 X 20	165 X 15
4 Tank Salvo	345 X 70	225 X 55	200 X 45
4 Tank Trail	430 X 55	330 X 45	260 X 40

* Patterns are not available for the B-25. The above values are 5% less than the A-26 which carries 1000 imp. gallons.

Costs

COST OF ACQUISITION (including conversion to an airtanker)			$30,000 (used)
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$10,000	fuel & oil	$ 95.00
personnel	9,000	engine overhaul	
hangar space	5,000	labour	110.00
yearly maintenance	5,000	materials	
cost of remote operation	6,000	pilot per hour	25.00
depreciation	1,600	landing fees	20.00
insurance	1,400		
interest on fixed assets	1,000		
Total Fixed Cost	$39,000	Total Hourly Cost	$250.00
Cost per Hour $445.00			
Cost per Hour per Gallon Capacity $0.47			

Remarks

The main advantages of the B-25 are an above average load size and a below average cost per foot of line held. The main disadvantages are the long runway required for take-off and a relatively low maneuver load factor. As a result of the latter problem the B-25 conversion has not been as widely accepted as some of the other military attack aircraft. Conflicting reports about the development of excessive negative gravity stresses during the load release and the aircraft's ability to withstand these stresses has resulted in reluctance by many operators to use the aircraft. Except for this problem, the aircraft has approximately the same characteristics as the A-26, with the exception of lower speed.

AIRCRAFT	C-82, C-119 Packet

General Characteristics

PRIMARY PURPOSE	Military Transport			
MANUFACTURER	Fairchild Engine and Airplane Corporation			
DIMENSIONS	C-82	C-119		
length	77 ft. 1 in.	86 ft. 6 ins.		
wing span	106 ft. 5 ins.	109 ft. 3 ins.		
height	26 ft. 4 ins.	26 ft. 3 ins.		

WEIGHTS	C-82	C-119
empty	32,500 lbs.	39,809 lbs.
maximum load	3,000 lbs.	17,150 lbs.
gross take off	50,000 lbs.	73,150 lbs.

ENGINE(S)

C-82 Two 2,100 hp. Pratt & Whitney R 2800-85

C-119C Two 3,500 hp. Pratt & Whitney R-4360-20W

FUEL	C-82	C-119
capacity	1,950 imp.gal.	2,185 imp.gal.
consumption	155 gal./hr.	265 gal./hr.

Performance Data

SPEEDS	C-82	C-119
maximum	248 mph.	275 mph.(est)
cruising	218 mph.	205 mph.
stall	85 mph.	108 mph.
rate of climb	950 ft./min.	820 ft./min.

LOADINGS	C-82	C-119
normal power	15.9 lbs./hp.	13.9 lbs./hp.
wing	35.7 lbs./ft.^{2}	50.5 lbs./ft.^{2}
design load factor	+ 2.8 (est)	

ENDURANCE	C-82	C-119
hours	17 hrs.	10.5 hrs.
ferry range	3,875 miles	2,300 miles
fully loaded range		

MINIMUM TAKE OFF ROLL

3,000 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY	C-82	C-119
total *	900 gal.	2,000 gal.
with full fuel load	300 gal.	1,715 gal.

RETARDANT LOADING	C-82	C-119
time required	4.9 min.	9.3 min.
lake length required	N/A	

RETARDANT DISTRIBUTION PATTERNS **

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	270 X 40	180 X 30	105 X 15
2 Tank Salvo	325 X 90	240 X 60	175 X 40
2 Tank Trail	410 X 65	335 X 50	235 X 35
4 Tank Salvo	600 X 95	425 X 65	300 X 45
4 Tank Trail	750 X 65	600 X 50	440 X 35

* With 6 hours of fuel plus reserves

** Patterns for the C-119 are not available. The above values are an average of the PBY5A and the B-17 plus 20% up to 2 Tanks, and an extrapolation of these values for 4 tanks.

Costs

COST OF ACQUISITION (including conversion to an airtanker)		$80,000 (used C-119)	
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	10,000	fuel & oil	90.00
personnel	10,000	engine overhaul labour materials	265.00
hangar space	6,000	pilot per hour	25.00
yearly maintenance	6,500	landing fees	20.00
cost of remote operation	8,000		
depreciation	4,500		
insurance	3,700		
interest on fixed assets	2,500		
Total Fixed Cost	51,200	Total Hourly Cost	400.00
Cost per Hour $656.			
Cost per Hour per Gallon Capacity $0.32			

Remarks

The C-119 is a newer version of the C-82. The main difference between the two is a larger power plant coupled with stronger wings for the C-119. The C-119's characteristics are similar to those of the P2V Neptune with the exception of a 20% smaller load for the C-119. Although this was one of the first airtanker conversions, there has been very limited experience with this aircraft.

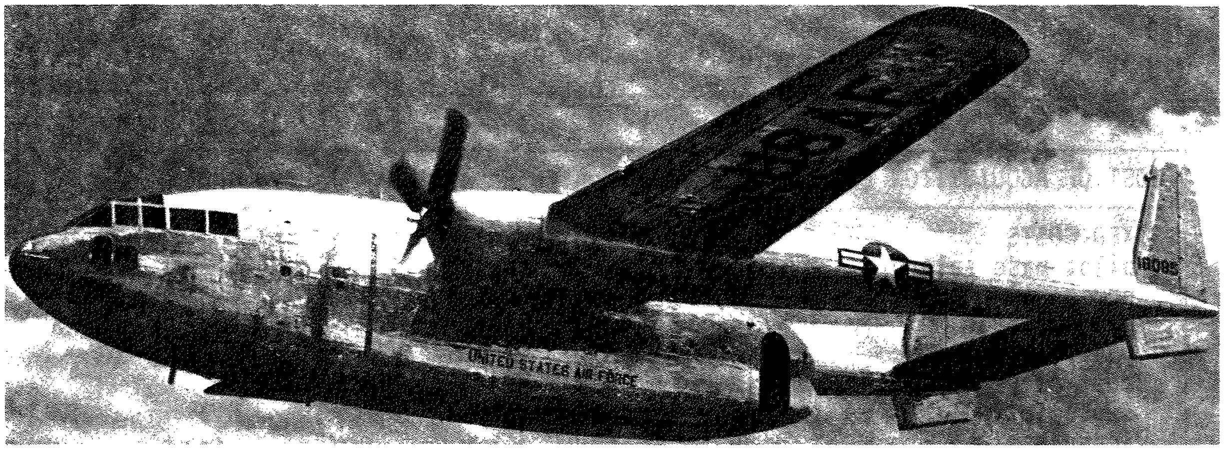

Figure 29. C-119 Packet (Photo: Janes "All The World's Aircraft" 1955-56).

Figure 30. C-119 Packet (Photo: U.S. Forest Service).

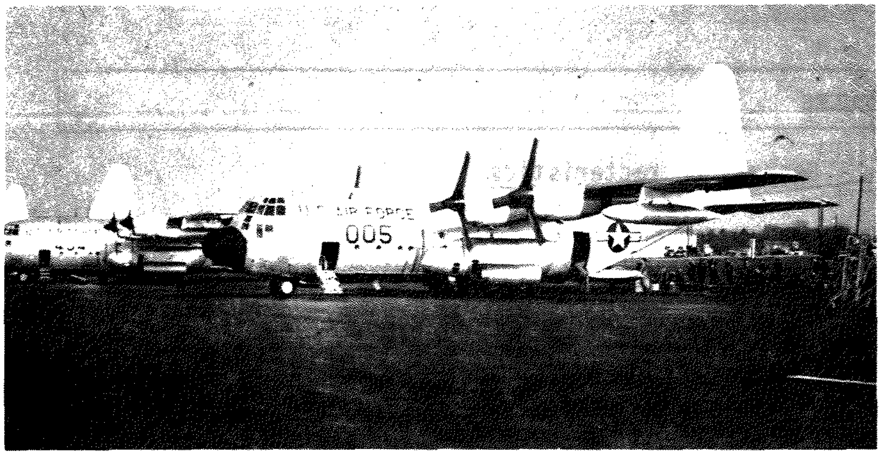

Figure 31. C-130 Hercules (Photo: Author).

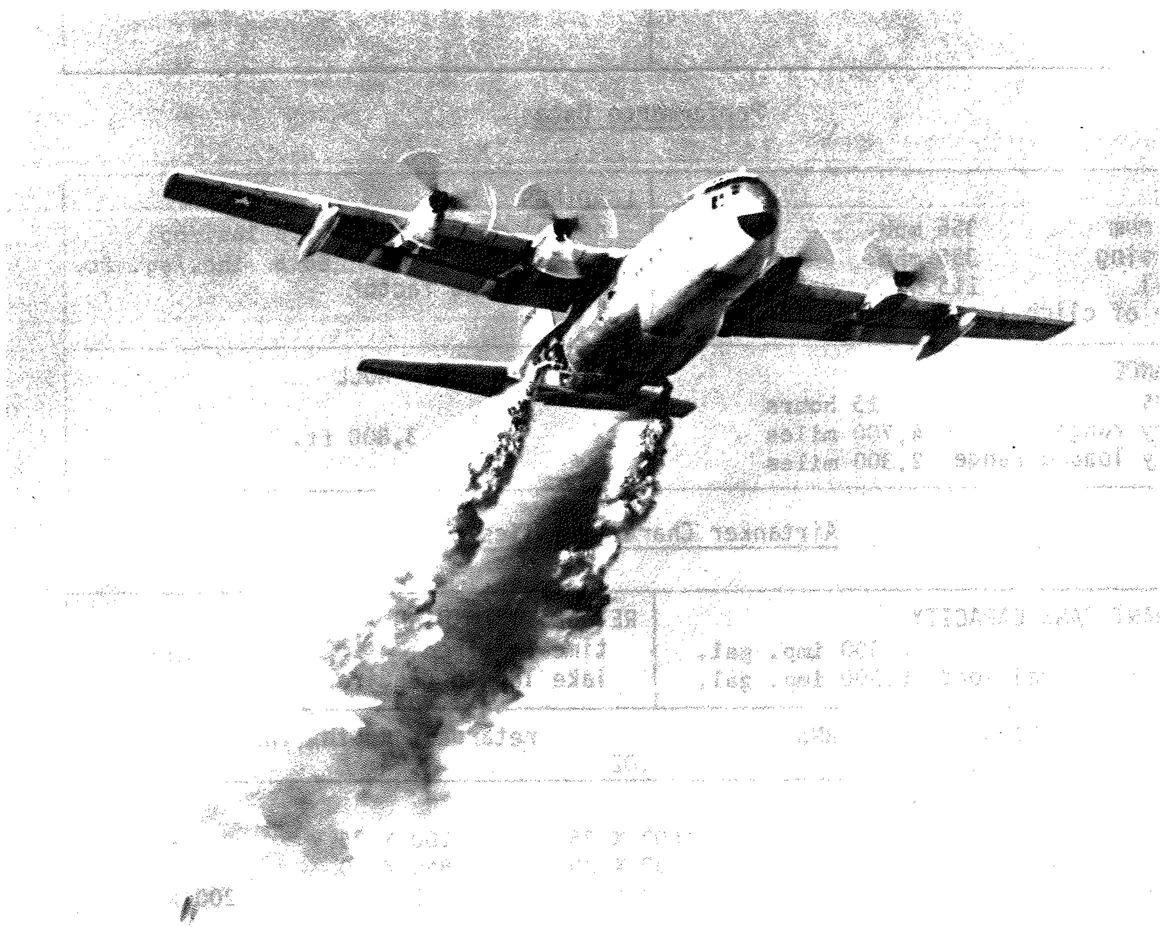

Figure 32. C-130 Hercules (Photo: U.S. Forest Service).

AIRCRAFT	C-130 HERCULES

General Characteristics

PRIMARY PURPOSE	Military Transport
MANUFACTURER	Lockheed

DIMENSIONS		WEIGHTS	
length	97 ft. 9 ins.	empty	72,900 lbs.
wing span	132 ft. 7 ins.	maximum load	40,000 lbs.
height	38 ft. 3 ins.	gross take off	155,000 lbs.

ENGINE(S)		FUEL	
	Four 4,050 hp. Allison T56-A-7 turbo-props	capacity	5570 Imp. gal. (Two 1090 imp. gal. external tanks)
		consumption	620 imp. gal. per hour.

Performance Data

SPEEDS		LOADINGS	
maximum	366 mph.	normal power	12.8 lbs./hp.
cruising	335 mph.	wing	88.8 lbs./sq. ft.
stall	115 mph.	design load factor	
rate of climb	1,600 ft/min.		

ENDURANCE		MINIMUM TAKE OFF ROLL
hours	15 hours	
ferry range	4,700 miles	3,800 ft.
fully loaded range	2,300 miles	

Airtanker Characteristics

RETARDANT TANK CAPACITY		RETARDANT LOADING	
total	2,500 imp. gal.	time required	10.5 min.
with full fuel load	2,500 imp. gal.	lake length required	N/A

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
Two Tank Trail 20 psi.	1400 X 75	200 X 25	-
Two Tank Trail 35 psi.	1230 X 80	860 X 50	-
Two Tank Trail 50 psi.	950 X 90	675 X 65	200 X 15

The above patterns are for thickened retardants at a drop height of 150 ft.

Costs

COST OF ACQUISITION (including conversion to an airtanker) $7.0 million (new)			
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$ 20,500	fuel & oil	$200.00
personnel	18,000	engine overhaul	
hangar space	7,500	labour	550.00
yearly maintenance	7,500	materials	
cost of remote operation	9,000	pilot per hour	50.00
depreciation	374,000	landing fees	20.00
insurance	336,000		
interest on fixed assets	231,000		
Total Fixed Cost	$1.0035 million	Total Hourly Cost	$840.00
Cost per Hour	$5,840.		
Cost per Hour per Gallon Capacity	$2.34		

Remarks

The C-130 has the second largest capacity of any aircraft which has been seriously considered for use as an airtanker. It is also relatively new and has a high flying speed. It also has some versatility in that it can also transport men and equipment from base to base. On the other hand the C-130 has the highest acquisition and operating cost of any aircraft considered. It also has low maneuverability and requires a long paved strip for take-off. Over 1,000 C-130 aircraft have been built and they can be found in many countries around the world. This aircraft has not been used operationally as an airtanker, but it is currently undergoing tests to determine it's feasibility as a massive initial attack aircraft. The current version releases its load through two 16-inch diameter openings at the ends of the retardant tanks. Release of the load is facilitated by compressor pumps at the front of the tanks. Tests conducted to date indicate that either larger openings or greater pressure will be needed to produce heavier concentrations in the drop patterns. The fixed costs preclude the acquisition of such an aircraft for fire control purposes exclusively. Further, the very limited range of optimum usefulness (large, hot fires) suggests that this aircraft would be flown for considerably fewer than the average number of hours experienced by other aircraft. The main hope of utilizing this aircraft lies with "MAFFS" (Modular Airborne Fire Fighting System) which can be relatively quickly and easily loaded into the aircraft. Units could be stored at military bases close to forested areas with the understanding that military C-130's could be used during difficult fire control situations.

AIRCRAFT	CL-215

General Characteristics

PRIMARY PURPOSE Amphibious Airtanker	
MANUFACTURER Canadair	
DIMENSIONS length 63 ft. 6 ins. wing span 93 ft. 10 ins. height 27 ft. 2 ins.	WEIGHTS empty 23,982 lbs. maximum load 11,400 lbs. gross take off 42,500 lbs.
ENGINE(S) Two 2,100 hp. Pratt & Whitney R2800-83 AN2	FUEL capacity 954 imp. gal. consumption 140 imp. gal./hr.

Performance Data

SPEEDS maximum 230 mph. cruising 184 mph. stall 73 mph. rate of climb 950 ft./min.	LOADINGS normal power 13.6 lbs./hp. wing 25.4 lbs./sq. ft. design load factor + 3.25 G, - 1.0 G.
ENDURANCE hours 6.8 hours ferry range 1330 miles fully loaded range 287 miles	MINIMUM TAKE OFF ROLL 2540 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY total 1,200 imp. gal. with full fuel load 1,140 imp. gal.	RETARDANT LOADING time required 5.3 min. lake length required 1 mile

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	210 X 90	160 X 65	125 X 50
2 Tank Salvo	295 X 115	210 X 95	170 X 85
2 Tank Trail	400 X 90	325 X 65	230 X 50

Costs

COST OF ACQUISITION (including conversion to an airtanker) $1.4 million (new)			
FIXED COSTS		HOURLY COSTS	
pilot base salary	$ 10,000	fuel & oil	$ 45.00
personnel	9,000	engine overhaul	
hangar space	5,500	labour	$140.00
yearly maintenance	5,500	materials	
cost of remote operation	7,000	pilot per hour	$ 25.00
depreciation	74,000	landing fees	-
insurance	126,000		
interest on fixed assets	46,200		
Total Fixed Cost	$283,900	Total Hourly Cost	$210.00
Cost per Hour $1,630 (Water)		$1,650 (land)	
Cost per Hour per Gallon Capacity		$1.36 (Water) $1.38 (land)	

Remarks

The CL-215 is a new aircraft which has been specifically designed as an airtanker. Being amphibious it is also versatile. It carries an above average load and has above average maneuverability. The major disadvantage is the high acquisition and operating cost. The CL-215 is the only aircraft which has been designed specifically as an airtanker. The design, begun in 1963, attempted to incorporate into a single aircraft all of the qualities of an ideal waterbomber, as determined by a consensus of opinion of Canadian firefighting experts. By and large, the designers appear to have succeeded, with the possible exception of the tank system which does not appear to incorporate some of the more recent developments. Being amphibious, the same aircraft can be used in both land and water-based operations as well as for transporting men and equipment, thus increasing its versatility. The use of the CL-215 in land-based operations does not appear to be particularly economical however. Unfortunately the acquisition and operating costs are so high that few if any firefighting organizations can afford to own and operate the aircraft. Optimum use of the CL-215 would appear to be in continuous water-based operations where its relatively high rate of production can be used to maximum advantage.

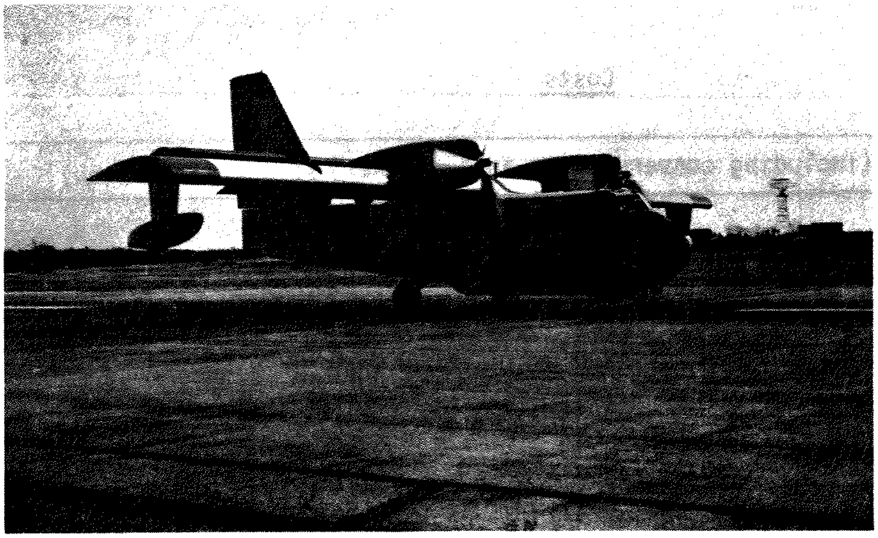

Figure 33. CL-215 (Photo: Author).

Figure 34. CL-215 (Photo: Author).

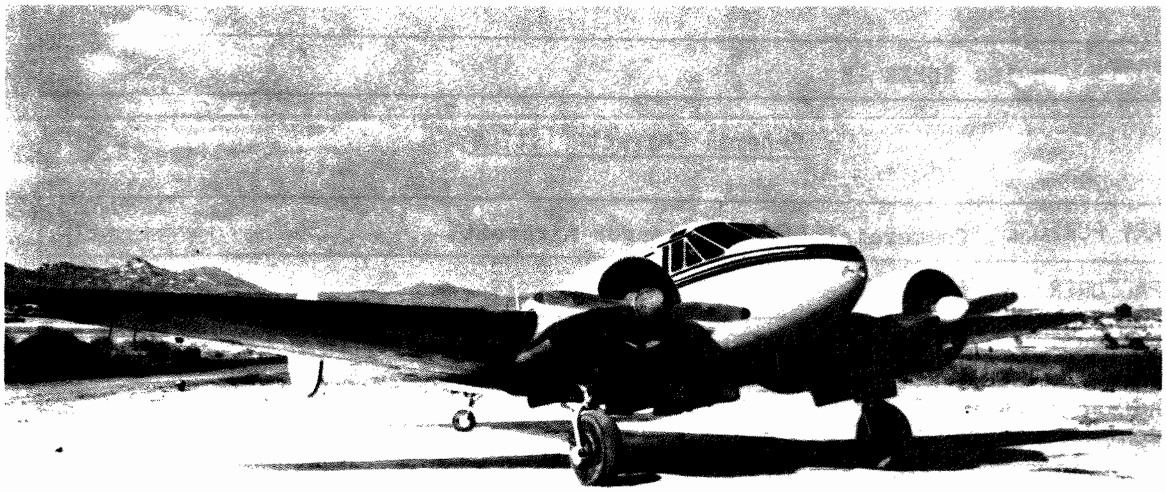

Figure 35. D18-S (Photo: California Division of Forestry).

Figure 36. D18-S (Photo: California Division of Forestry).

AIRCRAFT	D-18S SUPER 18

General Characteristics

PRIMARY PURPOSE	Commercial Light Passenger Aircraft
MANUFACTURER	Beechcraft

DIMENSIONS length 35 ft. 3 ins. wing span 49 ft. 8 ins. height 12 ft. 3 ins.	WEIGHTS empty 5,970 lbs. maximum load 1,950 lbs. gross take off 9,300 lbs.
ENGINE(S) Two 450 hp. Pratt & Whitney R-985-14 ANB	FUEL capacity 165 imp. gal. consumption 36 imp. gal./hr.

Performance Data

SPEEDS maximum 234 mph. cruising 205 mph. stall 77 mph. rate of climb 1,350 ft./min.	LOADINGS normal power 13.8 lbs./hp wing 25.8 lbs./sq. ft. design load factor + 3.0 (est)
ENDURANCE hours 3.8 ferry range 1,495 miles (with ferry Tanks) fully loaded range 400 miles	MINIMUM TAKE OFF ROLL 1,400 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY total 240 imp. gal. with full fuel load 195 imp. gal.	RETARDANT LOADING time required 1.5 min. lake length required N/A

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	145 X 45	95 X 40	70 X 25

There are no patterns for the D18-S. The above are the same as for the S2D.

Costs

COST OF ACQUISITION (including conversion to an airtanker) $35,000 (used)			
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$8,600	fuel & oil	$16.00
personnel	9,000	engine overhaul	
hangar space	2,500	labour	45.00
yearly maintenance	3,500	materials	
cost of remote operation	2,500	pilot per hour	22.00
depreciation	1,900	landing fees	20.00
insurance	1,700		
interest on fixed assets	1,100		
Total Fixed Cost	$30,800	Total Hourly Cost	$103.00
Cost per Hour $257.00			
Cost per Hour per Gallon Capacity $1.07			

Remarks

The D-18S is the smallest capacity twin engined aircraft included in this report. It has a significantly higher speed than agricultural and other comparable capacity aircraft, which would extend it's range of usefulness. It's runway length required for take-off is almost twice that of comparable aircraft however.

AIRCRAFT DC-6, C-118

General Characteristics

PRIMARY PURPOSE Commercial Passenger & Transport

MANUFACTURER Douglas

DIMENSIONS		WEIGHTS	
length	100 ft. 7 ins.	empty	51,495 lbs.
wing span	117 ft. 6 ins.	maximum load	24,750 lbs.
height	28 ft. 5 ins.	gross take off	97,200 lbs.

ENGINE(S)

DC-6 Four 2,100 hp. Pratt & Whitney Double Wasp R-2800-CA15

DC6-4 Four 2,500 hp. R-2800-CB17

FUEL

capacity 2,765 to 3,915 imp. gal.

consumption 340 imp. gal./hr.

Performance Data

SPEEDS		LOADINGS	
maximum	356 mph.	normal power	13.0 lbs./hp.
cruising	313 mph.	wing	66.4 lbs./sq. ft.
stall		design load factor +	2.5 (est)
rate of climb	1,070 ft./min.		

ENDURANCE

hours	14 hours
ferry range	4,610 miles
fully loaded range	3,820 miles

MINIMUM TAKE OFF ROLL

3,300 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY		RETARDANT LOADING	
total	3,000 imp. gal.	time required	12.5 min.
with full fuel load	2,475 imp. gal.	lake length required	N/A

RETARDANT DISTRIBUTION PATTERNS *

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	350 X 50	235 X 40	120 X 25
2 Tank Salvo	450 X 90	330 X 65	240 X 35
2 Tank Trail	600 X 70	450 X 55	325 X 30
4 Tank Salvo	800 X 100	600 X 70	425 X 40
4 Tank Trail	1000 X 70	800 X 55	600 X 30

* There are no patterns available for the DC-6. The above values are an average of the P 2V plus 10% and 50% of the JRM-3.

Costs

COST OF ACQUISITION (including conversion to an airtanker) $275,000 (used) (est)			
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	20,500	fuel & oil	120.00
personnel	16,000	engine overhaul	375.00
hangar space	7,000	labour	
yearly maintenance	7,500	materials	
cost of remote operation	8,500	pilot per hour	50.00
depreciation	14,600	landing fees	20.00
insurance	13,200		
interest on fixed assets	9,100		
Total Fixed Cost	96,400	Total Hourly Cost	565.00
Cost per Hour $1,047.			
Cost per Hour per Gallon Capacity $0.38			

Remarks

The DC-6 was successfully converted in the U.S. in 1971. It will be under evaluation in Canada in 1972. The DC-6A is a freight version of the DC-6. The DC-6 will be the second largest operational airtanker in current use. It's capacity is comparable to the current versions of the MAFFS system currently deployed in the C-130. Since the costs of the DC-6 are considerably less than for the C-130 the DC-6 would appear to have a considerable advantage as a very large airtanker.

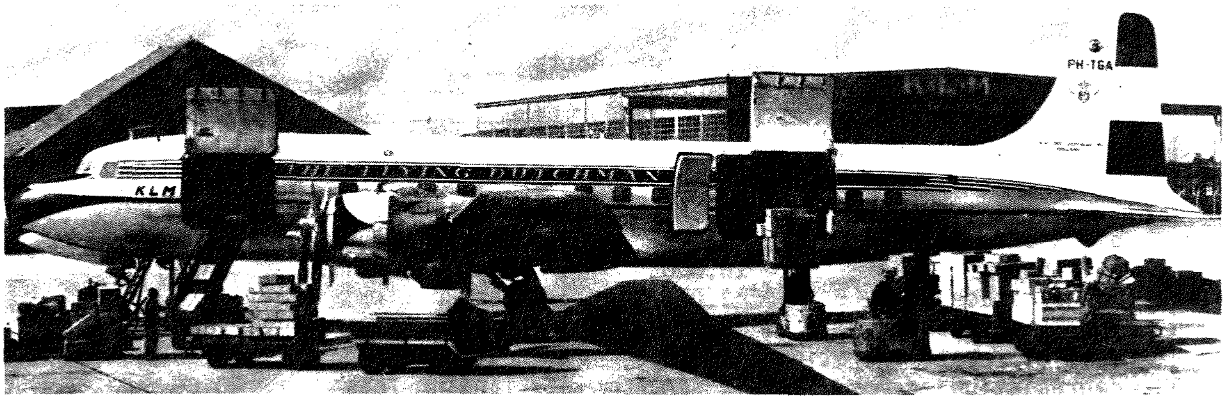

Figure 37. DC-6A (freight version) (Photo: Janes "All the World's Aircraft" 1955-56).

Figure 38. DC-6 (Photo: Janes "All The World's Aircraft" 1955-56).

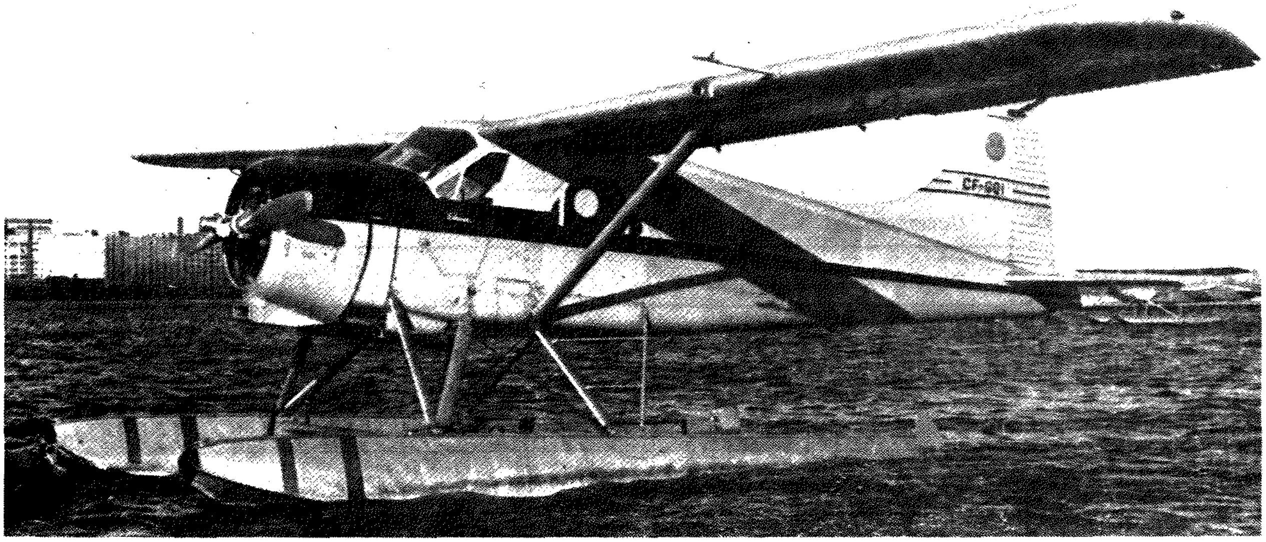

Figure 39. DHC-2 Beaver (Photo: Janes "All The World's Aircraft" 1955-56).

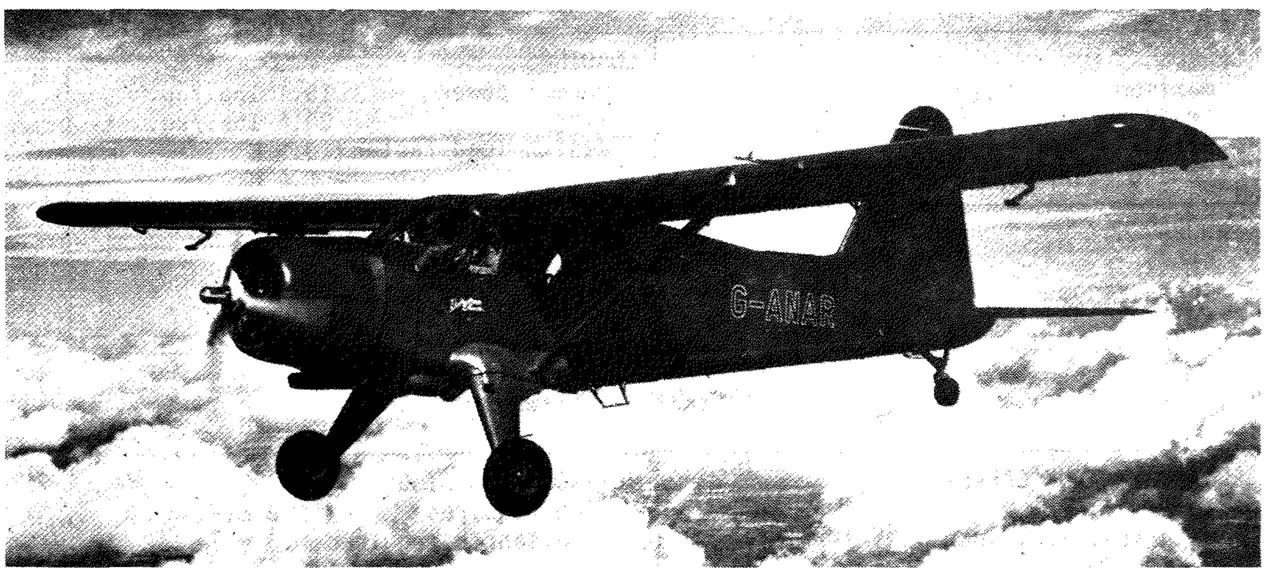

Figure 40. DHC-2 Beaver (Photo: Janes "All The World's Aircraft" 1955-56).

AIRCRAFT	DHC-2 Beaver

General Characteristics

PRIMARY PURPOSE	Commercial Light Utility Aircraft
MANUFACTURER	De Havilland

DIMENSIONS	FLOATS	LAND
length	32 ft. 9 ins.	30 ft. 4 ins.
wing span	48 ft.	48 ft.
height	10 ft. 5 ins.	9 ft.

WEIGHTS	FLOAT	LAND
empty	3,100 lbs.	3,000 lbs.
maximum load	1,240 lbs.	1,350 lbs.
gross take off	5,000 lbs.	5,100 lbs.

ENGINE(S): One 450 hp. Pratt & Whitney R 985 Wasp.

FUEL	
capacity	79 imp. gal.
consumption	18 imp. gal./hr.

Performance Data

SPEEDS	
maximum	160 mph.
cruising	130 mph.
stall	60 mph.
rate of climb	1,020 ft./min.

LOADINGS	
normal power	15.1 lbs./hp.
wing	20.4 lbs./sq. ft.
design load factor	+ 3.5 G - 1.4 G

ENDURANCE	
hours	6.4 hours
ferry range	778 miles
fully loaded range	483 miles

MINIMUM TAKE OFF ROLL	
FLOAT	LAND
885 ft.	560 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY	
total	90 imp. gal.
with full fuel load	90 imp. gal.

RETARDANT LOADING	
time required	0.8 min.
lake length required	0.5 mile

RETARDANT DISTRIBUTION PATTERNS *

tank configuration	retardant depth (ins.) .02	.04	.07
2 Tank Salvo	80 X 40	40 X 20	-

* The above data are extrapolated from data for the .01 contour.

Costs

COST OF ACQUISITION (including conversion to an airtanker)	$55,000 (used)

FIXED COSTS		HOURLY COSTS	
pilot base salary	$8,600	fuel & oil	$ 8.00
personnel	8,000	engine overhaul	
hangar space	2,000	labour	23.00
yearly maintenance	2,000	materials	
cost of remote operation	1,500	pilot per hour	22.00
depreciation	2,930	landing fees	-
insurance	2,640		
interest on fixed assets	1,830		
Total Fixed Cost	$29,500	Total Hourly Cost	$53.00

Cost per Hour $200.00 (water) $220. (land)
Cost per Hour per Gallon Capacity $2.22 (water) $2.44 (land)

Remarks

The main advantages of the DHC-2 are its high degree of maneuverability, its very short take-off distance and above average versatility. The main disadvantages are a very small load, a relatively high delivery cost per foot of line held and slow speed. As outlined in a previous section, the Beaver was one of the first aircraft converted to a water bomber in Canada as development moved from experimental to practical application. With the advent of larger and faster aircraft however, it receives very little use as an airtanker today. The effectiveness of the Beaver's load is not generally considered sufficient to warrant it's use, considering other aircraft which are currently available. Only six of the 31 Beavers used in Canada in 1970 were listed as having been used as airtankers. The Beaver has the lowest rate of production of all aircraft considered in this analysis. Both float and land-based versions are available, thus increasing the aircraft's versatility, although a single aircraft cannot function in both roles. It's most advantageous use would be on spot fires close to a landable lake. This aircraft is not well suited to continuous operations.

AIRCRAFT	DHC-2 MK II TURBO-BEAVER

General Characteristics

PRIMARY PURPOSE	Commercial Light Utility Aircraft
MANUFACTURER	De Havilland

DIMENSIONS		WEIGHTS	FLOAT	LAND
length	35 ft. 3 ins.	empty	3,430 lbs.	2,760 lbs.
wing span	48 ft.	maximum load		1,245 lbs.
height	11 ft.	gross take off		5,370 lbs.

ENGINE(S)	FUEL	
One 579 hp.	capacity	159 imp. gal.
Pratt & Whitney	consumption	34 imp. gal./hr.
PT6A-6		

Performance Data

SPEEDS		LOADINGS	
maximum	180 mph.	normal power	12.3 lbs./hp.
cruising	163 mph.	wing	21.5 lbs./sq. ft.
stall	60 mph.	design load factor	+ 3.5 G
rate of climb	1,185 ft./min.		- 1.4 G

ENDURANCE		MINIMUM TAKE OFF ROLL
hours	4.6 hours	
ferry range	675 miles	land: 500 ft.
fully loaded range	175 miles	

Airtanker Characteristics

RETARDANT TANK CAPACITY		RETARDANT LOADING	
total	160 imp. gal.	time required	1.1 min.
with full fuel load	120 imp. gal.	lake length required	0.5 mile

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
2 Tank Salvo	140 X 55	65 X 35	25 X 45

Costs

COST OF ACQUISITION (including conversion to an airtanker) $150,000 (new)			
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$8,600	fuel & oil	$ 9.00
personnel	8,000	engine overhaul	
hangar space	2,000	labour	24.00
yearly maintenance	2,000	materials	
cost of remote operation	1,500	pilot per hour	22.00
depreciation	8,000	landing fees	-
insurance	7,200		
interest on fixed assets	5,000		
Total Fixed Cost	$42,300	Total Hourly Cost	$55.00
Cost per Hour $267.00 (water) $287. (land)			
Cost per Hour per Gallon Capacity $1.67 (water) $1.79 (land)			

Remarks

The Turbo Beaver is a new STOL aircraft, meaning that it has a very short take-off and landing distance. It also has a high degree of maneuverability and above average versatility. The main disadvantage is a relatively small load. While the Turbo Beaver has twice the retardant capacity of it's predecessor, it's load is still considered relatively small. The fact that 28 of these aircraft were used as airtankers in 1970 indicates that the load is considered effective despite it's size. The aircraft's usefulness is greatly enhanced by its versatility. Both float and land-based versions are available, although a single aircraft cannot operate in both roles. The most advantageous use of the Turbo Beaver would appear to be on small fires close to a usuable body of water. This aircraft does not appear to be particularly well suited to continuous operations.

Figure 41. Photo not available.

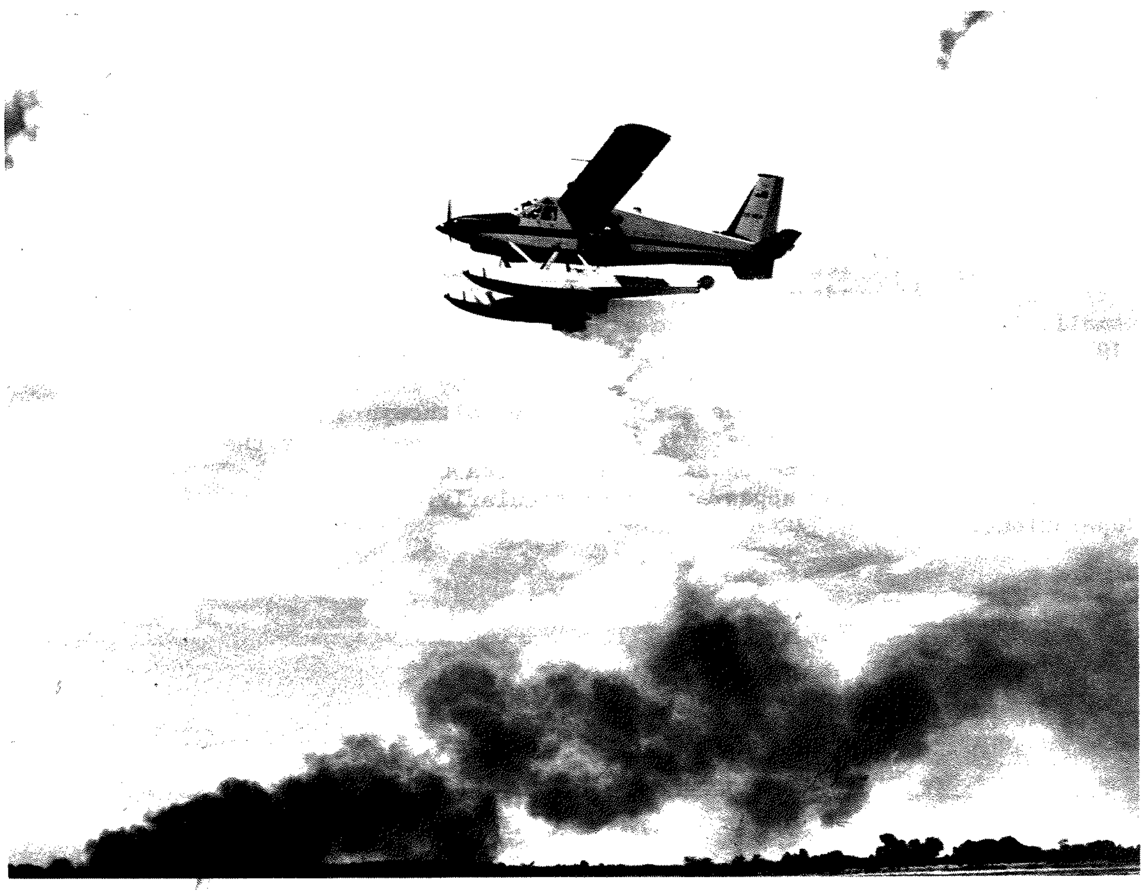

Figure 42. DHC-2 MK II Turbo Beaver (Photo: Author).

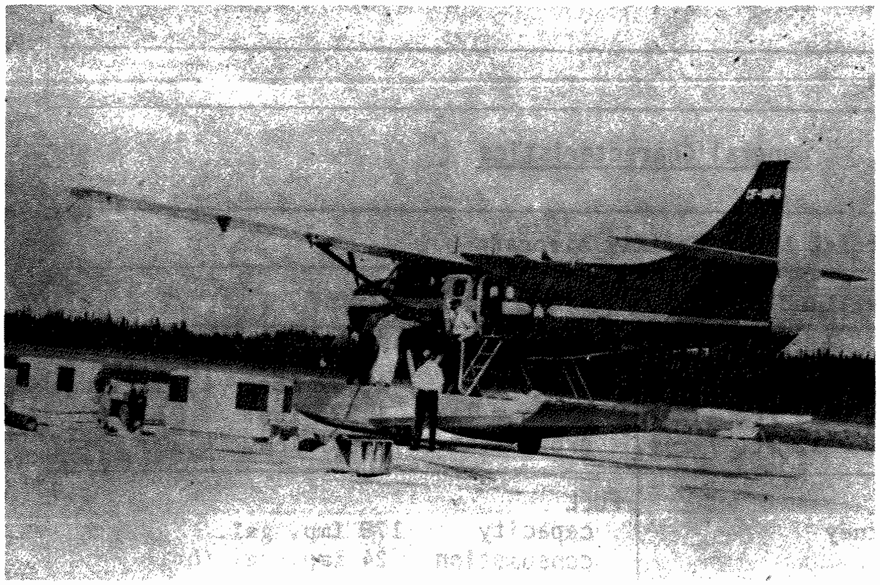

Figure 43. DHC-3 Otter (Photo: Canadian Forestry Service).

Figure 44. DHC-3 Otter (Photo: DeHavilland Aircraft Limited).

AIRCRAFT	DHC-3 OTTER

General Characteristics

PRIMARY PURPOSE	Commercial Light Utility Aircraft
MANUFACTURER	De Havilland

DIMENSIONS	FLOAT	LAND	WEIGHTS	FLOAT	LAND
length	41 ft. 10 ins.	41 ft. 10 ins.	empty	4,892 lbs.	4,431 lbs.
wing span	58 ft.	58 ft.	maximum load	1,575 lbs.	2,070 lbs.
height	15 ft.	12 ft. 7 ins.	gross take off	7,967 lbs.	8,000 lbs.

ENGINE(S)		FUEL	
One 600 hp. Pratt & Whitney R 1340		capacity	178 imp. gal.
		consumption	24 imp. gal./hr.

Performance Data

SPEEDS	FLOAT	LAND
maximum	153 mph.	160 mph.
cruising	120 mph.	125 mph.
stall		58 mph.
rate of climb	650 ft./min.	850 ft./min.

LOADINGS	
normal power	17.8 lbs./hp.
wing	21.4 lbs./sq.ft.
design load factor	+ 3.5 G
	- 1.4 G

ENDURANCE	FLOAT	LAND
hours	7.9 hrs.	8.6 hrs.
ferry range	855 mi.	945 mi.
fully loaded range	800 mi.	875 mi.

MINIMUM TAKE OFF ROLL	FLOAT	LAND
	1,050 ft.	630 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY	FLOAT	LAND
total	150 imp. gal.	180 imp.gal.
with full fuel load	150 "	180 "

RETARDANT LOADING	
time required	1.2 min.
lake length required	0.5 mile

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
Two Tank Salvo	170 X 45	115 X 30	80 X 20

Costs

COST OF ACQUISITION (including conversion to an airtanker)			$90,000 (used)
FIXED COSTS		HOURLY COSTS	
pilot base salary	$8,600	fuel & oil	$15.00
personnel	8,500	engine overhaul	
hangar space	3,000	labour	36.00
yearly maintenance	3,000	materials	
cost of remote operation	2,000	pilot per hour	22.00
depreciation	4,800	landing fees	-
insurance	4,300		
interest on fixed assets	3,000		
Total Fixed Cost	$34,200	Total Hourly Cost	$73.00
Cost per Hour	$244.00 (water)	$264. (land)	
Cost per Hour per Gallon Capacity	$1.63 (water)	$1.47 (land)	

Remarks

The main advantage of the Otter is it's good maneuverability and above average versatility, in that it can transport men and equipment as well as retardants. The main disadvantages are it's relatively small load and slow speed. The Otter like the Beaver was one of the first aircraft to be converted to an airtanker in Canada. It's main usefulness, as is the case for all small aircraft, would be on relatively small fires close to a body of water. Twenty of thirty Otters used in 1970 were listed as having had service as airtankers, which makes it the second most popular airtanker in Canada today. It is suspected however, that the advent of newer, larger and faster aircraft will gradually diminish the Otter's role as an airtanker.

AIRCRAFT	DHC-6 TWIN OTTER

General Characteristics

PRIMARY PURPOSE	Commercial Medium Utility Aircraft
MANUFACTURER	De Havilland

DIMENSIONS		WEIGHTS	FLOAT	LAND
length	51 ft. 9 ins.	empty	6,930 lbs.	6,030 lbs
wing span	65 ft.	maximum load	2,900 lbs.	3,750 lbs
height	18 ft. 7 ins.	gross take off	12,500 lbs.	12,500 lbs

ENGINE(S)		FUEL	
	Two 579 hp. Pratt & Whitney PT6A-20	capacity	340 imp. gal.
		consumption	68 imp. gal./hr.

Performance Data

SPEEDS	FLOAT	LAND	LOADINGS	
maximum	200 mph.	215 mph.	normal power	14.4 lb./hp.
cruising	175 mph.	185 mph.	wing	29.8 lb./sq. ft.
stall	77 mph.	77 mph.	design load factor	+ 3.5 G
rate of climb	1,300 ft./mi.	1,600 ft./min.		- 1.5 G

ENDURANCE		MINIMUM TAKE OFF ROLL	
hours	4.2 hours	FLOAT	LAND
ferry range	945 miles	1,050 ft.	700 ft.
fully loaded range	640 miles		

Airtanker Characteristics

RETARDANT TANK CAPACITY	FLOAT	LAND	RETARDANT LOADING	
total	400 imp. gal.	400 i.g.	time required	2.1 min.
with full fuel load	290 "	375 "	lake length required	0.5 mile

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank Float	150 ft. X 50 ft.	115 X 40	80 X 25
2 Tank Salvo Float	200 X 60	125 X 45	75 X 35
2 Tank Trail Float (est)	225 X 50	175 X 40	120 X 25
* Membrane Tank (observed)	420 X 20 ft.	60 ft. X 15 ft.	-
Membrane Tank (estimated)	600 X 20 ft.	-	-
Membrane Tank (estimated)	350 X 25	300 X 20	-
Membrane Tank (estimated)	250 X 25	200 X 20	175 X 20

* An earlier trial - The three estimates are based on visual observations of an improved version of the tank.

Costs

COST OF ACQUISITION (including conversion to an airtanker)	$675,000 (new)

FIXED COSTS		HOURLY COSTS	
pilot base salary	$10,000	fuel & oil	$23.00
personnel	9,000	engine overhaul	
hangar space	5,000	labour	64.00
yearly maintenance	5,000	materials	
cost of remote operation	6,000	pilot per hour	25.00
depreciation	36,000	landing fees	-
insurance	32,000		
interest on fixed assets	22,300		
Total Fixed Cost	125,700	Total Hourly Cost	$112.00

Cost per Hour $790. (water) $810.(land)
Cost per Hour per Gallon Capacity $1.97 (water) $2.02 (land)

Remarks

Like the Turbo-Beaver the Twin Otter is a new STOL Aircraft and it has above average versatility. By using the latest concepts in tank design both the float and land-based versions yield relatively high useful pattern lengths for the capacity of the aircraft. The aircraft is suited to a wide variety of roles, although a single machine cannot be used for both land and water-based operations. Unfortunately the acquisition and operating costs are relatively high, a problem common to all new aircraft. The optimum use of this aircraft would appear to be on an average mission i.e., where both flying distance and fire size and/or intensity are moderate.

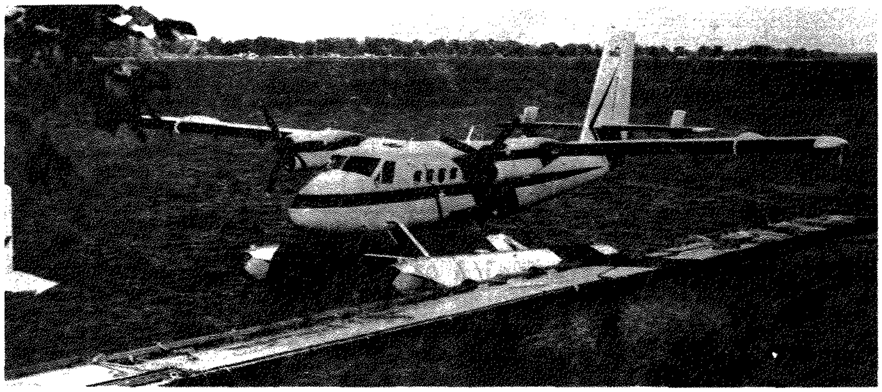

Figure 45. DHC-6 Twin Otter (Photo: Canadian Forestry Service).

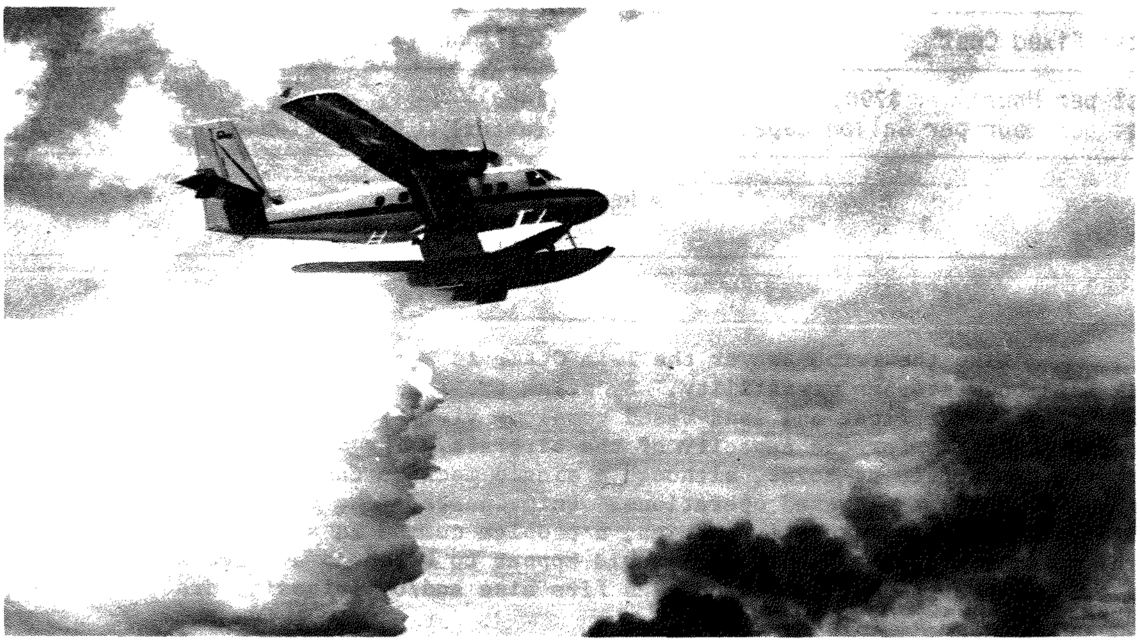

Figure 46. DHC-6 Twin Otter (Photo: Author).

Figure 47. DHC-6 Twin Otter with membrane tank (Photo: Author).

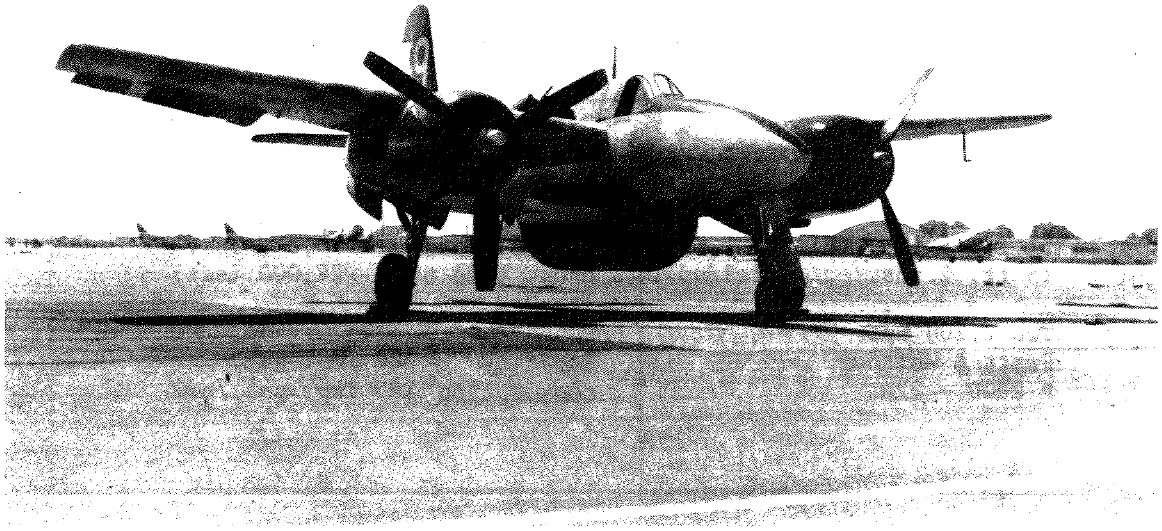

Figure 48. F7F (Photo: California Division of Forestry).

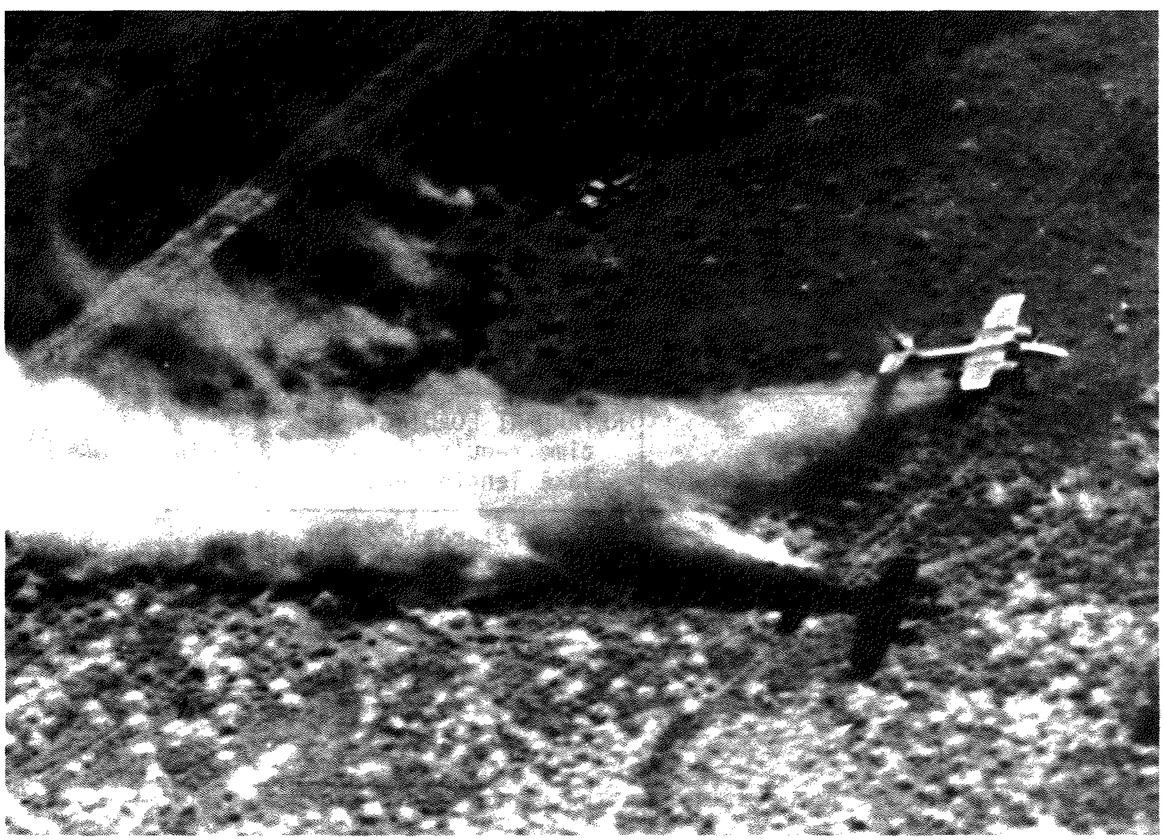

Figure 49. F7F (Photo: California Division of Forestry).

AIRCRAFT	F7F

General Characteristics

PRIMARY PURPOSE World War II Carrier Fighter	
MANUFACTURER	
DIMENSIONS length 45 ft. 4 ins. wing span 51 ft. 6 ins. (31 ft. 2 ins. height 15 ft. 2 ins. folded)	WEIGHTS empty 16,200 lbs. maximum load 6,500 lbs. gross take off 27,000 (est)
ENGINE(S) Two 2,100 hp. Pratt & Whitney R 2800 - 22W.	FUEL capacity 380 imp. gal. consumption 125 imp. gal./hr.

Performance Data

SPEEDS maximum 427 mph. cruising 330 mph. (est) stall 90 mph. rate of climb 4,260 ft./min.	LOADINGS normal power 6.9 lbs./hp. wing 47.5 lbs./sq. ft. design load factor +4.2 G
ENDURANCE hours 2.0 hrs. ferry range fully loaded range 660 miles	MINIMUM TAKE OFF ROLL 2,500 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY total 800 imp. gal. with full fuel load 650 imp. gal.	RETARDANT LOADING time required 3.7 min. lake length required N/A

RETARDANT DISTRIBUTION PATTERNS*

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	225 X 40 ft.	155 X 30	80 X 15
2 Tank Salvo	275 X 85 ft.	205 X 65	140 X 50
2 Tank Trail	350 X 60 ft.	280 X 50	200 X 35

* Patterns for the F7F are not available. The above values are based on the AF-2.

Costs

COST OF ACQUISITION (including conversion to an airtanker) $80,000 (used)	
FIXED COSTS	**HOURLY COSTS**
pilot base salary $10,000	fuel & oil $ 45.00
personnel 9,000	engine overhaul
hangar space 3,500	labour 150.00
yearly maintenance 5,000	materials
cost of remote operation 6,000	pilot per hour 25.00
depreciation 4,300	landing fees 20.00
insurance 3,800	
interest on fixed assets 2,600	
Total Fixed Cost $44,200	Total Hourly Cost $240.00
Cost per Hour $461.	
Cost per Hour per Gallon Capacity $0.58	

Remarks

The F-7F is the fastest aircraft in general use as an airtanker today. In addition, delivery costs are well below average. It has no significant disadvantages. The F-7F has been used entirely in the United States where it is rated as a highly successful airtanker. It's greatest usefulness appears to be on missions with long flying distances where the F-7F's rate of production equals that of the slower B-17 which has twice the capacity. In general the F-7F appears to be well suited to a wide variety of missions. It has been mentioned however, that the drop speed must be close to the stall speed (95-110 mph) in order to obtain an effective pattern. Also the effectiveness is, to a considerable extent, dependent on pilot skill.

AIRCRAFT	G-164A SUPER AG-CAT

General Characteristics

PRIMARY PURPOSE	Agricultural Spraying
MANUFACTURER	Grumman Aircraft Engineering Corp.

DIMENSIONS length 23 ft. 10 ins. to 24 ft. 5 ins. wing span 35 ft. 11 ins. height 11 ft.	WEIGHTS empty 2,400 to 3,159 lbs. maximum load 835 to 2,450 lbs. gross take off 3,750 to 4,500 lbs. (can be flown at 6,075 lbs.)
ENGINE(S) 1. One 275 or 300 hp. Jacobs R 755 2. One 450 hp. Pratt & Whitney R 985 3. One 600 hp. Pratt & Whitney R 1340 Earlier versions come equipped with 220 to 245 hp. engines.	FUEL capacity 37 to 64 imp. gal. consumption 20 to 24 imp. gal./hr.

Performance Data

SPEEDS maximum 131 to 147 mph. cruising 75 to 105 mph. stall 55 to 67 mph. rate of climb 660 to 1,600 ft./min.	LOADINGS normal power 29.5 to 13.5 lbs./hp. wing 18.5 lbs./sq. ft. design load factor + 3.5 to + 4.7G - 1.0G
ENDURANCE hours 1.1 to 2.5 hours (with ferry Tank) ferry range up to 200 miles fully loaded range up to 170 miles	MINIMUM TAKE OFF ROLL 400 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY total 195 or 240 imp. gal. with full fuel load 80 to 240 imp. gal.	RETARDANT LOADING time required 1.5 min. lake length required N/A

RETARDANT DISTRIBUTION PATTERNS*

tank configuration	retardant depth (ins.) .02	.04	.07
Salvo	115 X 40	85 X 35	60 X 20

* Estimated from patterns derived from the Snow Commander.

Costs

COST OF ACQUISITION (including conversion to an airtanker)	$40,000 (new)		
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$8,600	fuel & oil	$10.00
personnel	8,000	engine overhaul	
hangar space	1,200	labour	20.00
yearly maintenance	2,000	materials	
cost of remote operation	1,500	pilot per hour	22.00
depreciation	2,100	landing fees	20.00
insurance	1,900		
interest on fixed assets	1,300		
Total Fixed Cost	$26,000	Total Hourly Cost	$72.00
Cost per Hour $205. Cost per Hour per Gallon Capacity $1.17			

Remarks

The Super AG Cat is a new agricultural aircraft which in turn means that it has a very high degree of maneuverability and a very short take-off distance. It's major disadvantage is it's relatively slow speed. The Super AG Cat is the latest in a line of agricultural spraying aircraft, the first versions of which had 200 hp engines. Currently engine options up to 600 hp are available. The small load of the G-164A is somewhat of a hinderance, particularly as flying distance increases. The optimum role for the G-164A appears to be on small fires close to an airport where it's maneuverability and quick turn-around can be used to maximum advantage. It is well suited to regions with large numbers of small airstrips.

Figure 50. G-164A Super AG-cat (Photo: New Brunswick Forest Service).

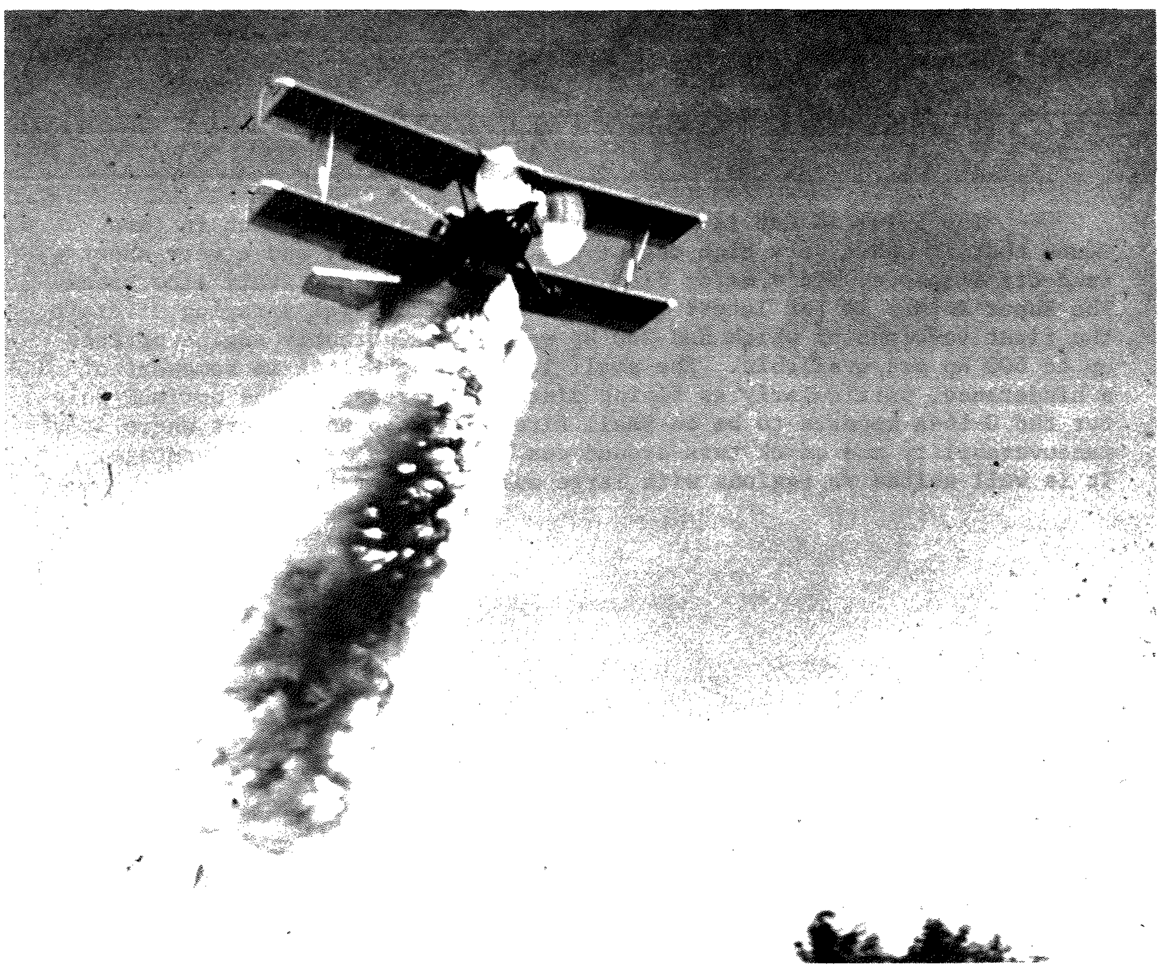

Figure 51. G-164A Super AG-cat (Photo: New Brunswick Forest Service).

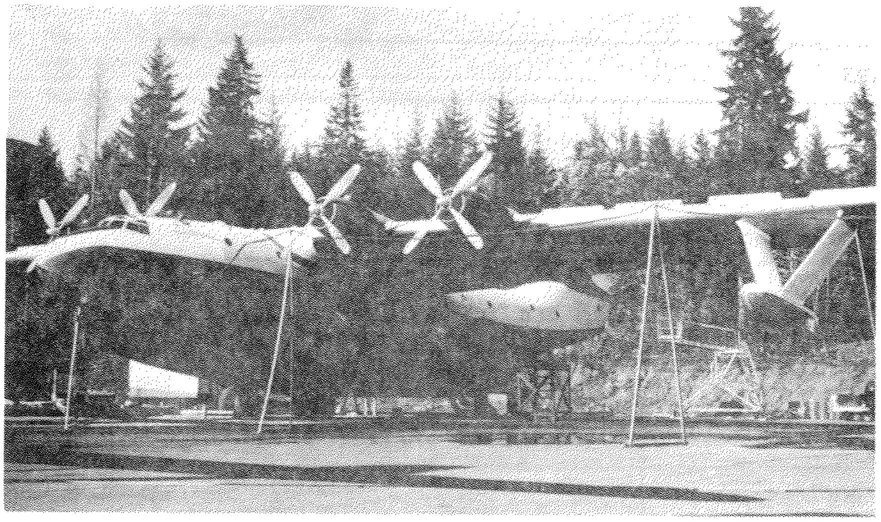

Figure 52. JRM-3 Mars (Photo: Canadian Forestry Service).

Figure 53. JRM-3 Mars (Photo: British Columbia Forest Service).

AIRCRAFT	JRM-3 MARS

General Characteristics

PRIMARY PURPOSE	Second World War II Amphibious Transport
MANUFACTURER	Martin

DIMENSIONS length 117 ft. 3 ins. wing span 200 ft. height 44 ft. 7 ins.	WEIGHTS empty 76,800 lbs. maximum load 9,000 lbs. gross take off 145,000 lbs. 162,000 lbs. when skiming.
ENGINE(S) Four 2,200 hp. Wright R 3350-18	FUEL capacity 10,500 imp. gal. consumption 530 imp. gal./hr.

Performance Data

SPEEDS maximum 220 mph cruising 153 mph. stall 77 mph. rate of climb 400 ft./min.	LOADINGS normal power 25.0 lbs./hp. wing 42.5 lbs./sq. ft. design load factor+ 2.8 G
ENDURANCE hours 20 hours ferry range 3,050 miles fully loaded range 465 miles	MINIMUM TAKE OFF ROLL 3000 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY total 6,000 imp. gal. with full fuel load 900 imp. gal.	RETARDANT LOADING time required 24.5 min. lake length required 3 to 5 miles

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
Single tank	675 X 75	500 X 50	225 X 30
2 Tank Salvo (est)	700 X 90	525 X 60	250 X 50
2 Tank Trail	850 X 100	550 X 75	250 X 50
3 Tank Salvo	700 X 175	550 X 150	400 X 125
3 Tank Trail (est)	1,000 X 100	750 X 70	600 X 60
4 Tank Salvo	750 X 200	600 X 160 ft.	450 X 125
4 Tank Trail (est)	1,150 X 110	900 X 75	700 X 65

Costs

COST OF ACQUISITION (including conversion to an airtanker)	$300,000 (used)		
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$20,500	fuel & oil	$180.00
personnel	20,000	engine overhaul	
hangar space	9,000	labour	750.00
yearly maintenance	7,500	materials	
cost of remote operation	15,000	pilot per hour	50.00
depreciation	16,000	landing fees	–
insurance	27,000		
interest on fixed assets	9,000		
Total Fixed Cost	$124,000	Total Hourly Cost	$980.00

Cost per Hour $1,600 (water) $1620. (land)
Cost per Hour per Gallon Capacity $0.27 (water) $0.27 (land)

Remarks

The Mars has the largest load of any airtanker in existence today. In addition, as an amphibious aircraft it has some versatility. On the other hand, operating costs seriously reduce this aircraft's usefulness in other roles. In addition, it has very limited maneuverability. Originally, only six Mars aircraft were built. Currently, the only two remaining aircraft are both owned by Forest Industries Flying Tankers Limited located in British Columbia. The greatest usefulness of the Mars would probably be on large fires which cannot be contained by other aircraft. The considerable capacity of the Mars offsets slow flying speed. The Mars appears to be particularly well suited to continuous water-based operations on large fires.

AIRCRAFT N2S STEARMAN (N3N BIBLANE)

General Characteristics

PRIMARY PURPOSE Navy Trainer	
MANUFACTURER Boeing	
DIMENSIONS length 25 ft. wing span 32 ft. 2 ins. height 9 ft. 2 ins.	WEIGHTS empty 1,936 lbs. maximum load 1,210 lbs. gross take off 3,600 lbs.
ENGINE(S) 1. one 220 hp. Lycoming R 680 2. one 220 hp. Continental R 670 3. one 220 hp. Jacobs R 755	FUEL capacity 36 imp. gal. consumption 9 imp. gal./hr.

Performance Data

SPEEDS maximum 124 mph. cruising 100 mph. stall 58 mph. rate of climb 840 ft./min.	LOADINGS normal power 12.0 lbs./hp. wing 10.9 lbs./sq. ft. design load factor + 7.0 G
ENDURANCE hours 3.2 hours ferry range 320 miles fully loaded range 250 miles	MINIMUM TAKE OFF ROLL 1,500 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY total 120 imp. gal. with full fuel load 120 imp. gal.	RETARDANT LOADING time required 1.0 min. lake length required 0.5 mile

RETARDANT DISTRIBUTION PATTERNS *

tank configuration	retardant depth (ins.) .02	.04	.07
Salvo	125 X 40	75 X 25	40 X 15

* There are no drop patterns available for the Stearman. The above values lie half way between the Beaver and Otter as the Stearman's capacity is halfway between these two aircraft.

Costs

COST OF ACQUISITION (including conversion to an airtanker) $10,000 (used)			
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$8,600	fuel & oil	4.00
personnel	8,000	engine overhaul	
hangar space	2,000	labour	31.00
yearly maintenance	2,000	materials	
cost of remote operation	1,500	pilot per hour	22.00
depreciation	530	landing fees	-
insurance	480		
interest on fixed assets	330		
Total Fixed Cost	$23,440	Total Hourly Cost	$57.00
Cost per Hour $174. (water) $194. (land) Cost per Hour per Gallon Capacity $1.45 (water) $1.62 (land)			

Remarks

The main advantage of the N2S is it's very high degree of maneuverability. The main disadvantages are it's small retardant tank and slow speed. Although originally designed as a navy trainer, the N2S's characteristics are virtually identical to agricultural spraying aircraft. As with the Beaver however, it's load is so small that it can be considered effective on only the smallest fires. The very quick turn-around of the Stearman appears to give it a slight edge over other small capacity aircraft at very short flying distances. It's optimum use would appear to be on spot fires close to the retardant source. The N2S Stearman is similar in appearance to the N3N Bi-Plane, the major difference is the slightly larger tank (160 Imp. gallons) of the N3N.

Figure 54. N2S Stearman (Photo: Canadian Forestry Service).

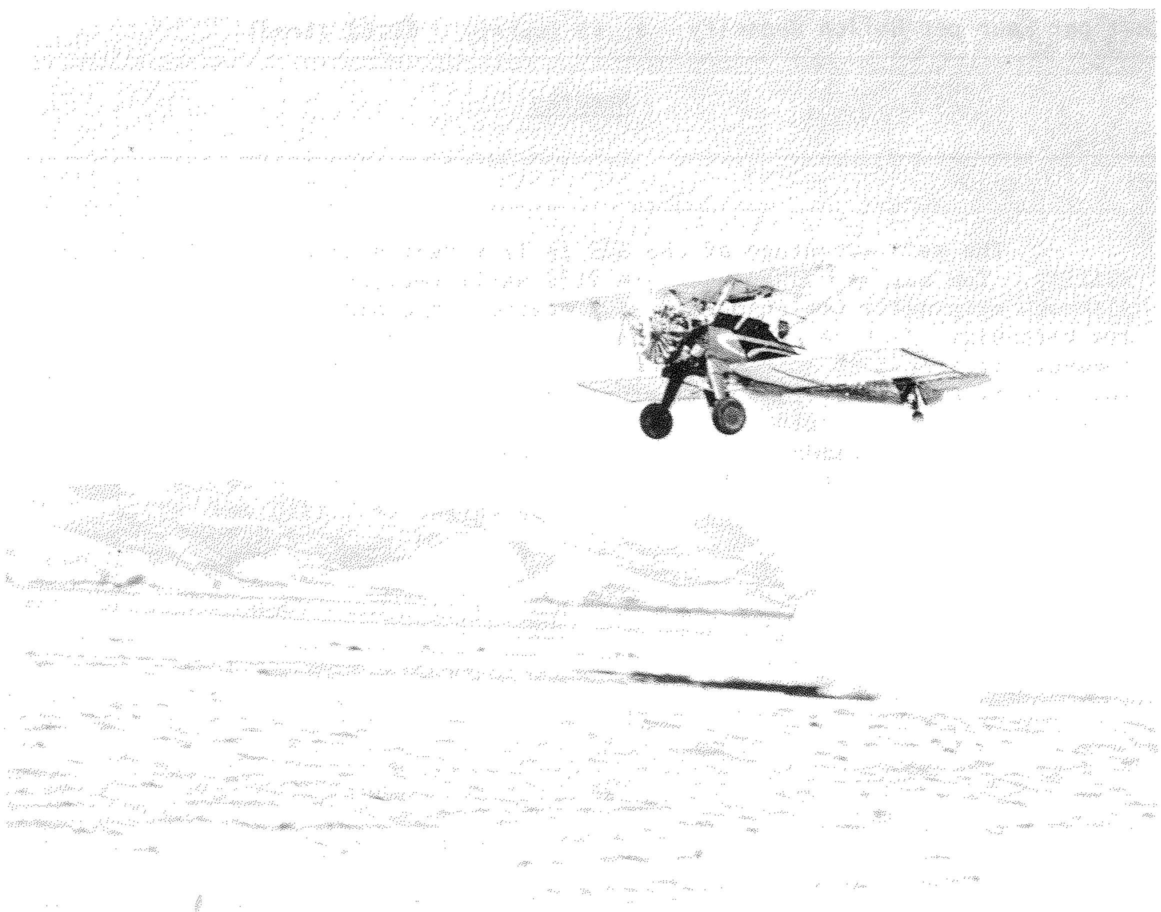

Figure 55. N2S Stearman (Photo: California Division of Forestry).

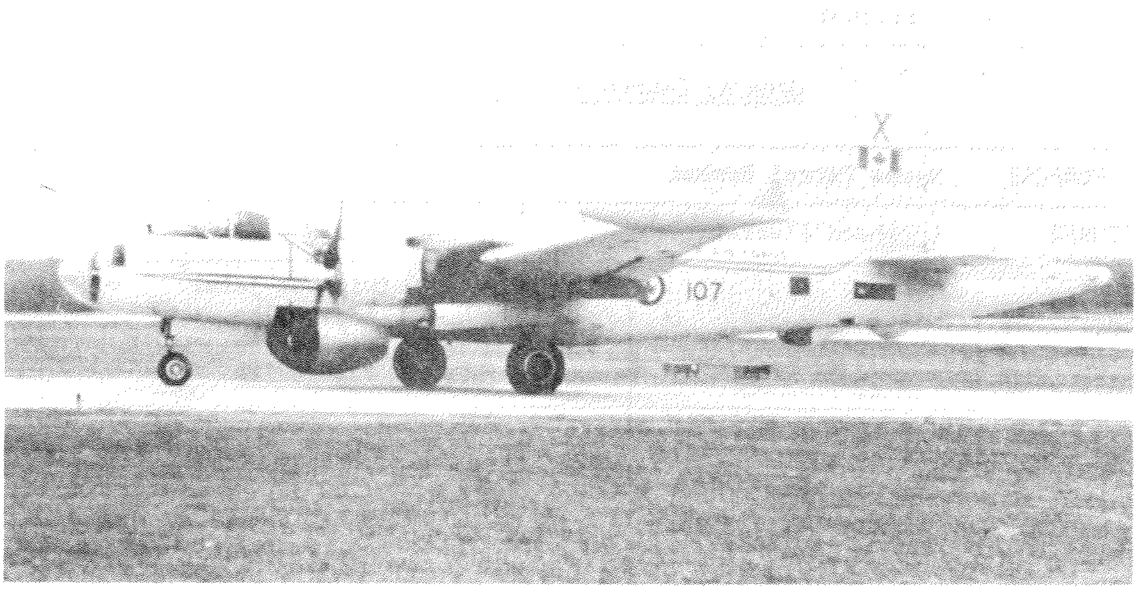

Figure 56. P2V Neptune (Photo: Canadian Forestry Service).

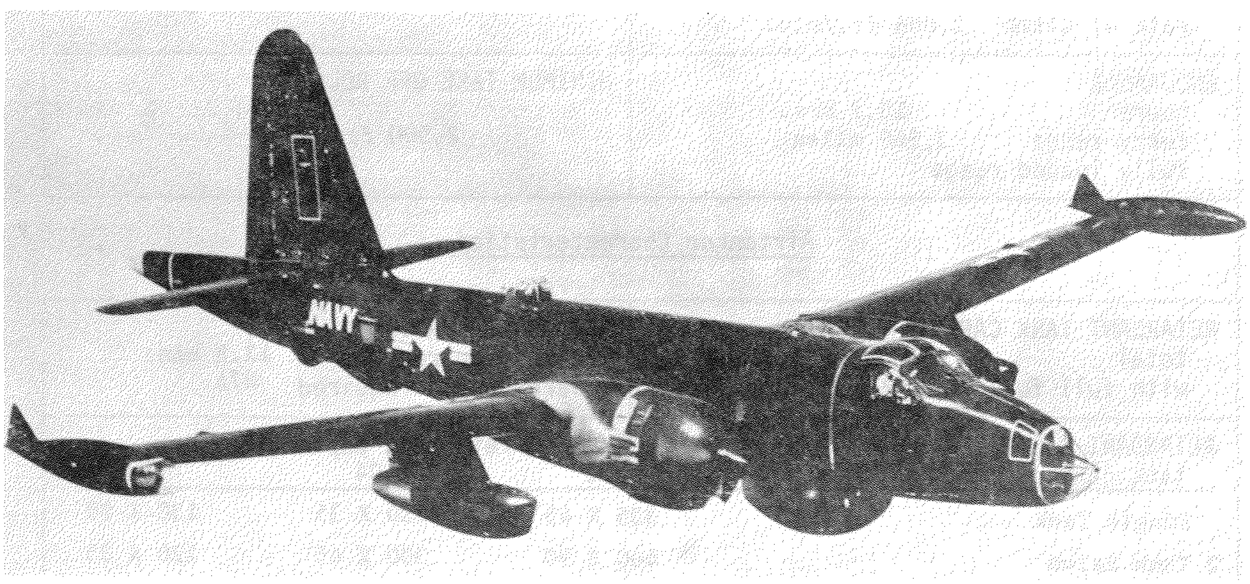

Figure 57. P2V-7 Neptune with auxiliary Westinghouse J-34 Turbojet engines (Photo: Janes "All The World's Aircraft" 1955-56).

AIRCRAFT	P2V-7 NEPTUNE

General Characteristics

PRIMARY PURPOSE	Naval Patrol Bomber
MANUFACTURER	Lockheed Aircraft Corp.

DIMENSIONS		WEIGHTS (without jets)	
length	76 ft. 10 ins.	empty	43,950 lbs.
wing span	100 ft.	maximum load	14,375 lbs.
height	28 ft. 1 in.	gross take off	72,000 lbs.

ENGINE(S)	FUEL
Two 3,500 hp. Wright R-3350-32 W Turbo Compound (optional) Two Westinghouse Wing mounted J34 Turbojet engines (3,400 lbs. thrust each)	capacity 1,830 imp. gal. consumption 260 imp. gal./hr. plus 580 imp. gal. ferry Tank.

Performance Data

SPEEDS	(P 2V-3)	LOADINGS	
maximum	288 mph.	normal power	13.7 lbs./sq.ft.
cruising	215 mph.(est)	wing	72.0 lbs./sq.ft.
stall	77 mph.	design load factor +	2.8 (est)
rate of climb	2,086 ft./min.		

ENDURANCE		MINIMUM TAKE OFF ROLL
hours	15.7 hrs.	2,500 ft.
ferry range	3,560 miles	
fully loaded range		

Airtanker Characteristics

RETARDANT TANK CAPACITY		RETARDANT LOADING	
total	2,600 imp. gal.	time required	12.8 min.
with full fuel load	1,435 imp. gal.	lake length required	N/A

RETARDANT DISTRIBUTION PATTERNS*

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	335 X 45	220 X 35	130 X 20
2 Tank Salvo	400 X 90	300 X 65	220 X 35
2 Tank Trail	500 X 70	410 X 55	300 X 30
4 Tank Salvo	750 X 100	550 X 70	400 X 45
4 Tank Trail	925 X 70	750 X 55	550 X 40

* Patterns for the P 2V are not available. The above values are for the C-119 plus 25%.

Costs

COST OF ACQUISITION (including conversion to an airtanker) $150,000 (used)(est)			
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	10,000	fuel & oil	90.00
personnel	10,000	engine overhaul labour materials	265.00 (est)
hangar space	6,000	pilot per hour	25.00
yearly maintenance	6,500	landing fees	20.00
cost of remote operation	8,000		
depreciation	8,000		
insurance	7,200		
interest on fixed assets	5,000		
Total Fixed Cost	60,700	Total Hourly Cost	400.00
Cost per Hour $704. Cost per Hour per Gallon Capacity $0.37			

Remarks

Three P2V-7 Neptunes will be used as airtankers in Canada in 1972. As of this date there is relatively little information available about the merits of this aircraft as an airtanker. The P2V appears to be comparable to the successful PB4Y2, with the advantages of a 25% greater capacity, only two engines and perhaps somewhat greater maneuverability. It would appear therefore that the P2V will probably be a successful large airtanker.

AIRCRAFT	PB4Y-2 PRIVATEER (SUPER)

General Characteristics

PRIMARY PURPOSE Long Range Bomber	
MANUFACTURER Consolidated Vultee	
DIMENSIONS length 74 ft. wing span 110 ft. height 26 ft.	WEIGHTS empty 32,500 lbs. maximum load 22,600 lbs. gross take off 70,000 lbs.
ENGINE(S) Four 1,250 hp. Pratt & Whitney R 2600-35	FUEL capacity 2,000 imp. gal. consumption 200 imp. gal./hr.

Performance Data

SPEEDS maximum 255 mph. cruising 180 mph. stall 75 mph. rate of climb 500 ft./min.	LOADINGS normal power 18.7 lbs./hp. wing 63.7 lbs./sq. ft. design load factor + 2.8 G (est)
ENDURANCE hours 9.25 hrs. ferry range 4,000 miles fully loaded range 600 miles	MINIMUM TAKE OFF ROLL

Airtanker Characteristics

RETARDANT TANK CAPACITY	REGULAR	SUPER
total	1,600	2,080
with full fuel load	950	2,080

RETARDANT LOADING	
time required	8.8 min.
lake length required	N/A

RETARDANT DISTRIBUTION PATTERNS*

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	200 X 40	140 X 30	80 X 15
2 Tank Salvo	275 X 85	200 X 60	140 X 50
2 Tank Trail	350 X 65	280 X 50	200 X 35
4 Tank Salvo	500 X 75	350 X 60	250 X 40
4 Tank Trail	650 X 65	500 X 50	350 X 35

* Patterns for the regular PB4Y-2 are not available. These values are the same as the B-17. Patterns for the Super PB4Y-2 should be approximately 20% longer.

Costs

COST OF ACQUISITION (including conversion to an airtanker) $150,000 (used)			
FIXED COSTS		HOURLY COSTS	
pilot base salary	$20,500	fuel & oil	$75.00
personnel	14,500	engine overhaul	
hangar space	6,000	labour	190.00
yearly maintenance	6,500	materials	
cost of remote operation	8,000	pilot per hour	50.00
depreciation	8,000	landing fees	20.00
insurance	7,200		
interest on fixed assets	5,000		
Total Fixed Cost	$75,700	Total Hourly Cost	$335.00
Cost per Hour $714.			
Cost per Hour per Gallon Capacity $0.45			

Remarks

As an airtanker the characteristics of the regular PB4Y-2 are virtually identical to those of the B-17. Therefore, all comments made with reference to the B-17 are also applicable to the PB4Y-2 with the one exception. The Super PB4Y-2 has a 20 percent greater tank capacity.

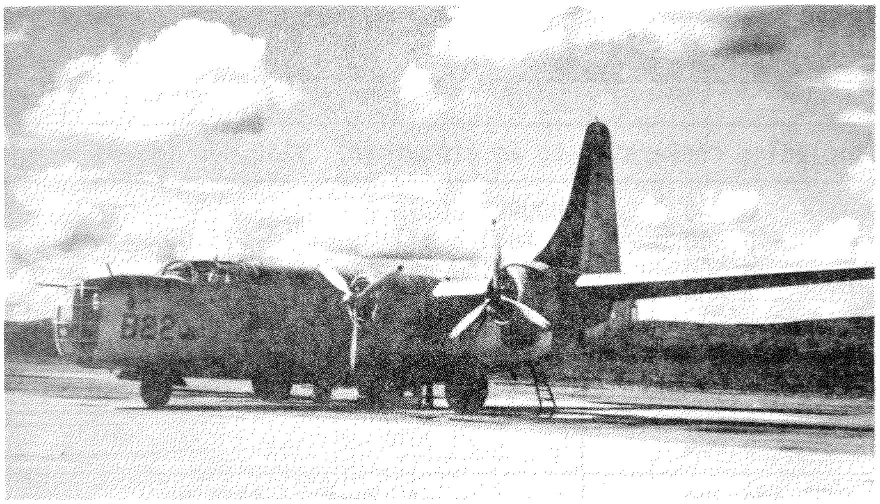

Figure 58. PB4Y-2 Privateer (Photo: Canadian Forestry Service).

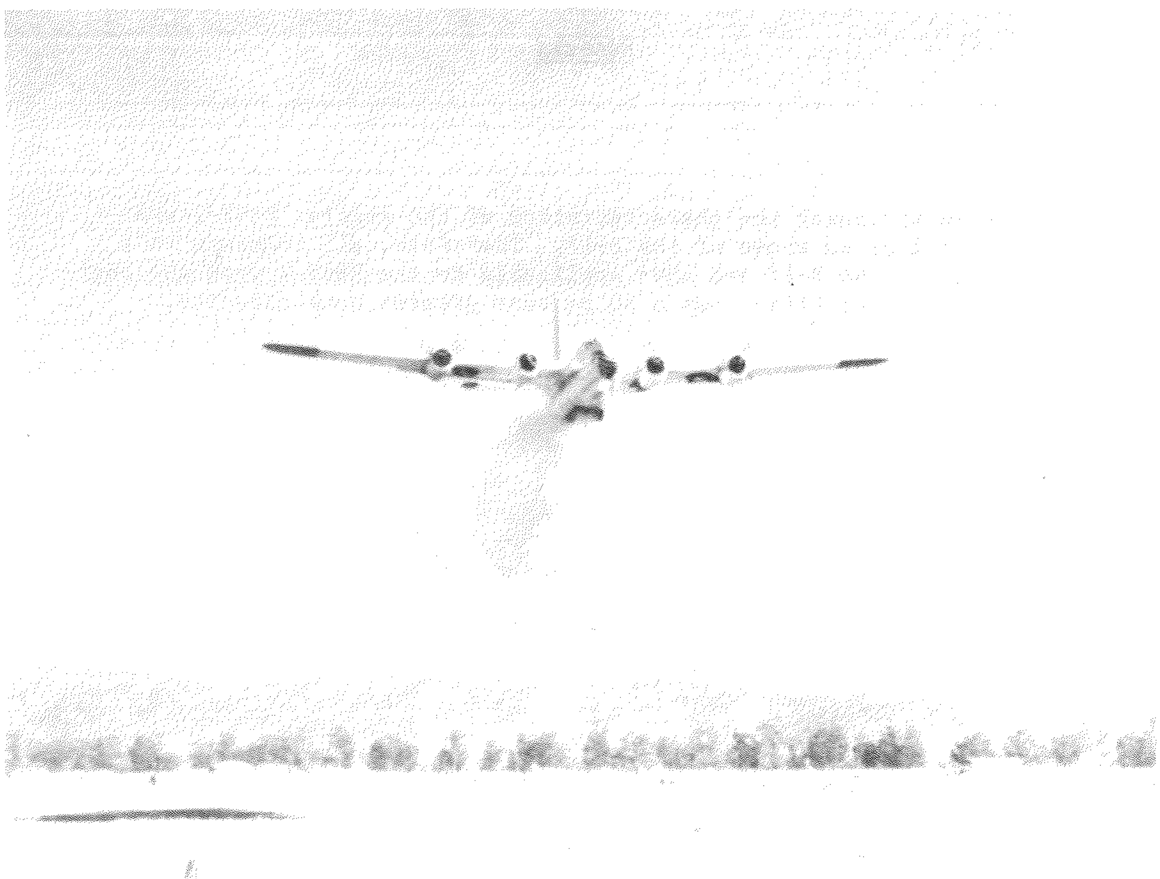

Figure 59. PB4Y-2 Privateer (Photo: California Division of Forestry).

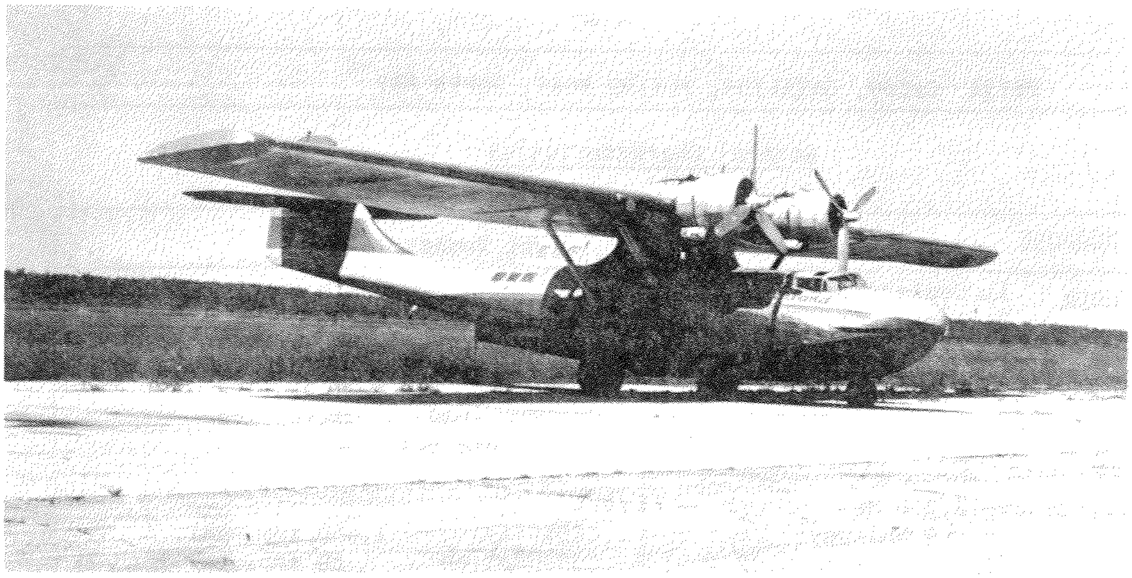

Figure 60. PBY5A Canso (Photo: Canadian Forestry Service).

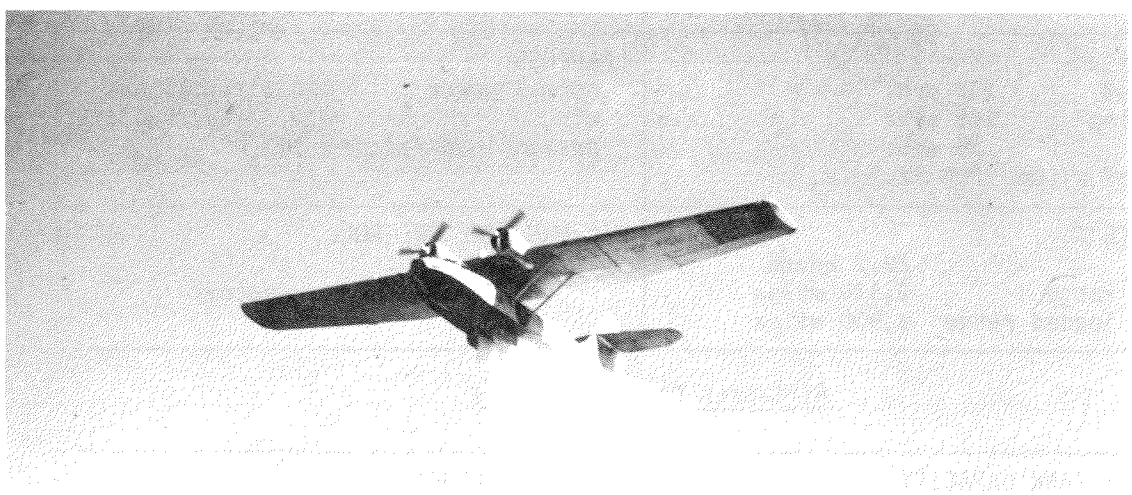

Figure 61. PBY5A Canso (Photo: Author).

AIRCRAFT	PBY5A CANSO, CATALINA, FLYING BOAT, SUPER PBY

General Characteristics

PRIMARY PURPOSE	Submarine Patrol Aircraft, Light Bomber
MANUFACTURER	1. Consolidated Vultee 2. Boeing of Canada Ltd. 3. Canadian Vickers Ltd.

DIMENSIONS		WEIGHTS	
length	63 ft. 10 ins.	empty	17,564 lbs.
wing span	104 ft.	maximum load	5,186 lbs.
height	18 ft. 10 ins.	gross take off	34,000 lbs.

ENGINE(S)		FUEL	
	Two 1,250 hp.	capacity	1,460 imp. gal.
	Pratt & Whitney	consumption	80 imp. gal./hr.
	Twin Wasps R 1830-92		

Performance Data

SPEEDS		LOADINGS	
maximum	196 mph.	normal power	18.1 lbs./hp.
cruising	145 mph.	wing	24.3 lbs./sq. ft.
stall	76 mph.	design load factor	+ 2.7 G
rate of climb	1000 ft./min.		

ENDURANCE		MINIMUM TAKE OFF ROLL
hours	17.2 hours	
ferry range	2,520 miles	4,500 ft. (water)
fully loaded range	1,900 miles	

Airtanker Characteristics

RETARDANT TANK CAPACITY		RETARDANT LOADING	
total	800 imp. gal.	time required	3.7 min.
with full fuel load	510 imp. gal.	lake length required	1.5 miles

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	250 X 40	165 X 30	95 X 15
2 Tank Salvo	265 X 100	200 X 75	145 X 50
2 Tank Trail (est)	340 X 60	275 X 50	190 X 25

Costs

COST OF ACQUISITION (including conversion to an airtanker)			$175,000 (used)
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$10,000	fuel & oil	$30.00
personnel	9,000	engine overhaul	
hangar space	5,500	labour	97.00
yearly maintenance	5,000	materials	67.00
cost of remote operation	6,000	pilot per hour	28.00
depreciation	9,300	landing fees	-
insurance	15,700		
interest on fixed assets	5,700		
Total Fixed Cost	$66,200	Total Hourly Cost	$222.00
Cost per Hour $553.00 (water)	$573.00 (land)		
Cost per Hour per Gallon Capacity	$ 0.64 (water)	$0.72 (land)	

Remarks

The main advantage of the PBY5A is the fact that it is amphibious. The same aircraft can be used both in water and land-based operations as well as for transporting men and equipment to and from fires. The PBY5A has no significant disadvantages. The Canso is another highly successful and widely used airtanker conversion. In 1970 there were more Canso air-tankers flying in Canada than any other type of aircraft - an obvious indication of it's populatity, particularly in typical Canadian conditions where usable lakes are quite often close to a fire. As a "medium" aircraft the Canso would be reasonably well suited to a wide variety of both limited and continuous operations, although it is more efficiently used in a water-based role. While there are other aircraft available which are superior to the Canso in most characteristics it's low acquisition and operating costs ensures that this aircraft will be around for several years.

A significant modification is the Super PBY which involves replacing the original engines with two 1900 hp Wright R-2600-20 (or similar) engines, yielding a 20-25 percent improvement in the performance characteristics and tank capacity with a corresponding decrease in the range. Another similarly successful approach involves adding two 240 hp Avco-Lycoming GSO 480 engines, thereby creating a four engined aircraft. The latter approach appears to have some advantages over the two engined modification.

AIRCRAFT	S2D SNOW COMMANDER, THRUSH COMMANDER

General Characteristics

PRIMARY PURPOSE Agricultural Spraying

MANUFACTURER Snow - Snow Aeronautical Corp.
Thrush - Aero Commander Div. North American Rockwell

DIMENSIONS	SNOW	THRUSH
length	24 ft. 6 ins.	28 ft. 4 ins.
wing span	41 ft. 4 ins.	44 ft. 7 ins.
height	8 ft. 7 ins.	9 ft. 2 ins.

WEIGHTS	SNOW	THRUSH
empty	3400 lbs.	3700 lbs.
maximum load	2720 lbs.	2500 lbs.
gross take off	6000 lbs.	6000 to 6900 lbs.

ENGINE(S) One 600 hp.
Pratt & Whitney
R 1340 AN1

FUEL	SNOW	THRUSH
capacity	66 imp. gal.	83 imp. gal.
consumption	25 imp. gal./hr.	

Performance Data

SPEEDS	
maximum	120 - 140 mph.
cruising	105 - 124 mph.
stall	55 - 75 mph.
rate of climb	650 ft./min./900 ft./min.

LOADINGS	SNOW	THRUSH
normal power	13.3	15.3 lbs./hp.
wing	18.4	21.1 lbs./sq.ft.
design load factor	+ 10.0 G	

ENDURANCE	SNOW	THRUSH
hours	2.7 hr.	2.6 hr.
ferry range	225 mi.	325 mi.
fully loaded range	200 mi.	200 mi.

MINIMUM TAKE OFF ROLL	
SNOW	THRUSH
850 ft.	775 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY	SNOW	THRUSH
total	250 imp. gal.	250 i.g.
with full fuel load	240 i.g.	210 i.g.

RETARDANT LOADING	
time required	1.5 min.
lake length required	N/A

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	145 X 45	95 X 40	70 X 25

Costs

COST OF ACQUISITION (including conversion to an airtanker) $49,000 (new)			
FIXED COSTS		HOURLY COSTS	
pilot base salary	$8,600	fuel & oil	$15.00
personnel	8,000	engine overhaul	
hangar space	1,500	labour	20.00
yearly maintenance	2,000	materials	
cost of remote operation	1,500	pilot per hour	22.00
depreciation	2,980	landing fees	20.00
insurance	2,270		
interest on fixed assets	1,500		
Total Fixed Cost	$28,350	Total Hourly Cost	$77.00
Cost per Hour $219.			
Cost per Hour per Gallon Capacity $0.88			

Remarks

The S2D has a very high degree of maneuverability, coupled with slow flying speed, a trait common to all agricultural aircraft. It would appear to be well suited to small fires close to a retardant source. It is well suited to regions with large numbers of readily accessible small air strips.

Figure 62. S2D Snow Commander (Photo: Alberta Forest Service).

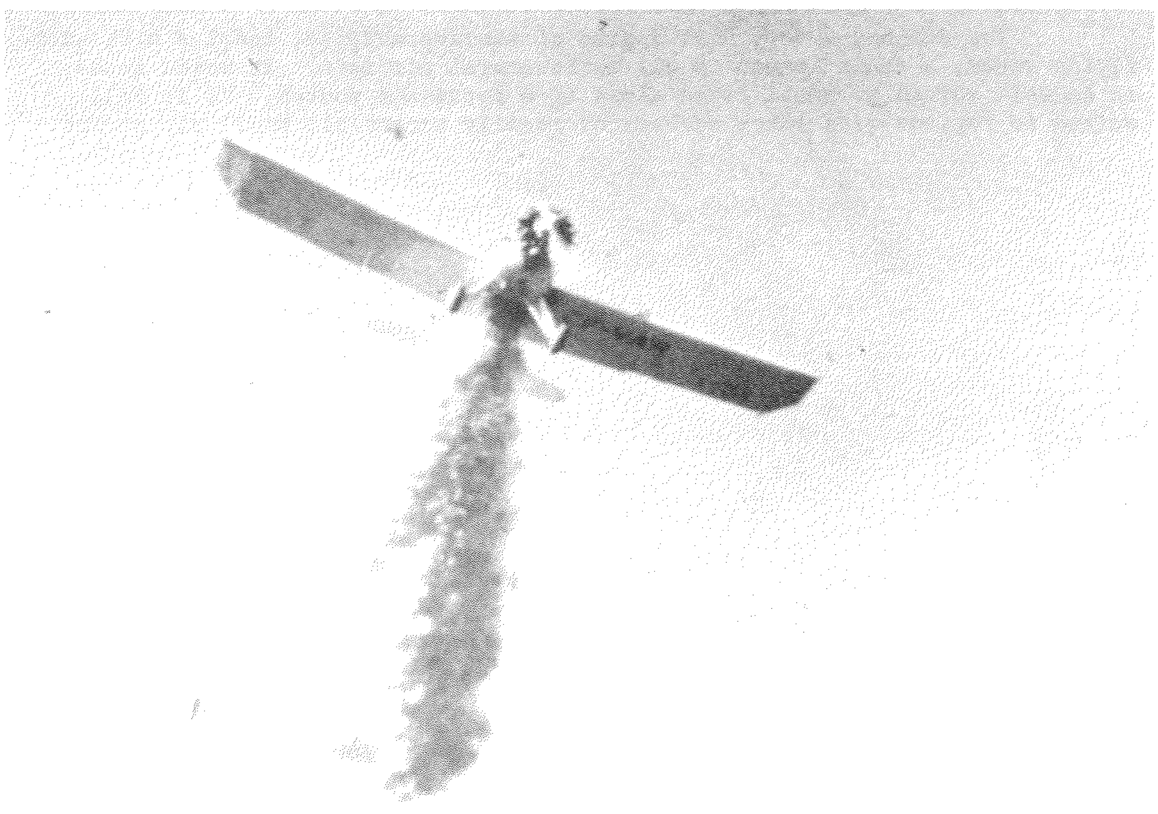

Figure 63. S2D Snow Commander (Photo: Alberta Forest Service).

Figure 64. S2F-1 Tracker (Photo: DeHavilland Aircraft Limited).

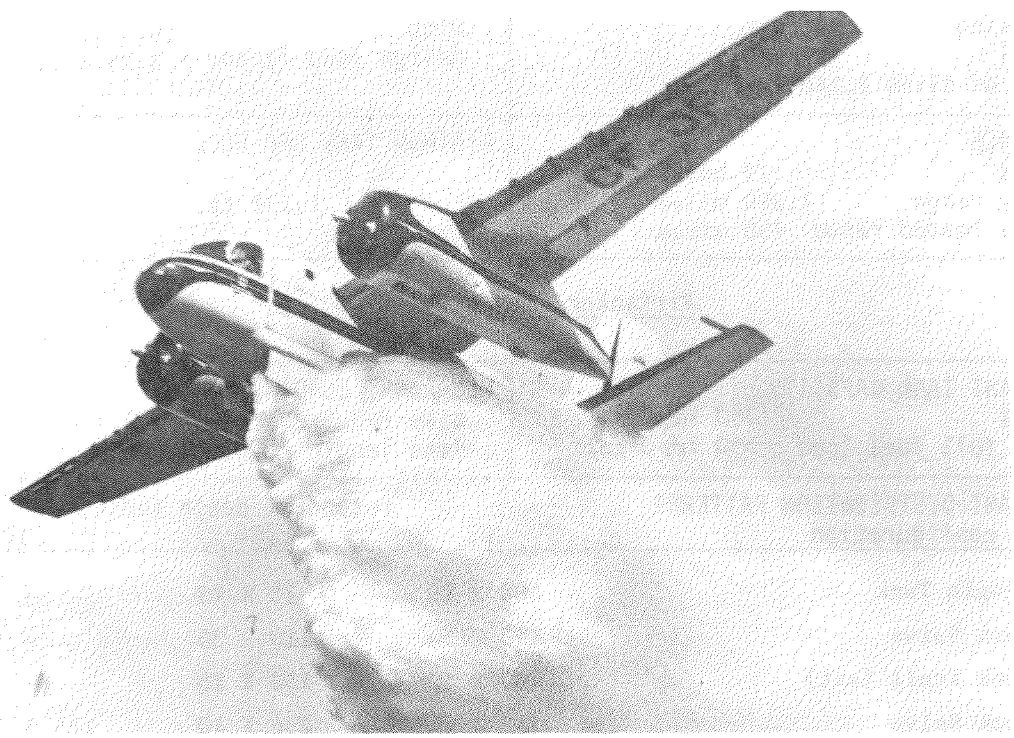

Figure 65. S2F-1 Tracker (Photo: DeHavilland Aircraft Limited).

AIRCRAFT	S2F, G-89 TRACKER

General Characteristics

PRIMARY PURPOSE	Light Bomber and Patrol Aircraft
MANUFACTURER	Grumman

DIMENSIONS		WEIGHTS	
length	42 ft. 6 ins.	empty	16,000 lbs.
wing span	72 ft. 7 ins. (27 ft. 4 ins. folded)	maximum load	5,500 lbs.
height	16 ft. 4 ins.	gross take off	25,775 lbs.

ENGINE(S)		FUEL	
Two 1,525 hp.	Wright R 1820	capacity	433 imp. gal.
		consumption	50 imp. gal./hr.

Performance Data

SPEEDS		LOADINGS	
maximum	265 mph.	normal power	11.3 lbs./hp.
cruising	200 mph.	wing	18.8 lbs./sq. ft.
stall	87 mph.	design load factor	+ 3.25 - 1.0 G
rate of climb	1,160 ft./min.		

ENDURANCE		MINIMUM TAKE OFF ROLL
hours	79 hours	1,135 ft.
ferry range	1,200 miles	
fully loaded range	750 miles	

Airtanker Characteristics

RETARDANT TANK CAPACITY		RETARDANT LOADING	
total	750 imp. gal.	time required	3.7 min.
with full fuel load	550 imp. gal.	lake length required	N/A

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank	100 X 20	15 X 10	-
2 Tank Salvo	190 X 50	110 X 30	-
2 Tank Trail (est)	230 X 50	150 X 25	-
4 Tank Salvo	350 X 45	230 X 40	175 X 35
4 Tank Trail	360 X 45	260 X 30	120 X 15

Costs

COST OF ACQUISITION (including conversion to an airtanker) $125,000 (used)			
FIXED COSTS		HOURLY COSTS	
pilot base salary	$10,000	fuel & oil	$49.00
personnel	9,000	engine overhaul	45.00
hangar space	1,500	labour	50.00
yearly maintenance	5,000	materials	52.00
cost of remote operation	6,000	pilot per hour	25.00
depreciation	6,650	landing fees	20.00
insurance	6,000		
interest on fixed assets	4,100		
Total Fixed Cost	$48,250	Total Hourly Cost	$241.00
Cost per Hour $482.			
Cost per Hour per Gallon Capacity $0.64			

Remarks

The main advantage of the S2F is it's above average maneuverability, particularly relative to other military attack aircraft. Otherwise, it is comparable to "medium" aircraft of this category both in terms of cost and production. With the decommissioning of the carrier Bonaventure, several Trackers became surplus to Defence Department requirements. In 1971, one of these aircraft was converted to an airtanker by the Province of Ontario. With testing completed several additional aircraft are scheduled for conversion in 1972. With well over 1,000 Trackers in use throughout the world there appears to be a good possibility that many will become available for conversion to airtankers in the future.

AIRCRAFT	TBM, TBF AVENGER

General Characteristics

PRIMARY PURPOSE	World War II Torpedo Bomber
MANUFACTURER	TBM-Eastern Aircraft Div., General Motors TBF - Grumman

DIMENSIONS		WEIGHTS	
length	40 ft.	empty	11,400 lbs.
wing span	54 ft. 2 ins. (19 ft. when folded)	maximum load	3,700 lbs.
height	16 ft. 5 ins.	gross take off	17,730 lbs.

ENGINE(S)		FUEL	
One 1,700 hp. Wright R 2600-8		capacity	330 imp. gal.
		consumption	51 imp. gal./hr.

Performance Data

SPEEDS		LOADINGS	
maximum	278 mph.	normal power	33.8 lbs./hp.
cruising	215 mph.	wing	36.2 lbs./sq. ft.
stall	76 mph.	design load factor	
rate of climb	1,075 ft./min.		

ENDURANCE		MINIMUM TAKE OFF ROLL
hours	5.8 hours	3,500 ft.
ferry range	1,400 miles	
fully loaded range	905 miles	

Airtanker Characteristics

RETARDANT TANK CAPACITY		RETARDANT LOADING	
total	500 imp. gal.	time required	2.5 min.
with full fuel load	370 imp. gal.	lake length required	N/A

RETARDANT DISTRIBUTION PATTERNS

tank configuration	retardant depth (ins.) .02	.04	.07
Single Tank (est)	150 X 35	100 X 30	60 X 20
2 Tank Salvo	230 X 85	165 X 65	95 X 20
2 Tank Trail (est)	250 X 75	180 X 50	110 X 20

Costs

COST OF ACQUISITION (including conversion to an airtanker)	$55,000 (used)		
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$8,600	fuel & oil	$ 18.00
personnel	8,500	engine overhaul	
hangar space	1,000	labour	100.00
yearly maintenance	4,000	materials	
cost of remote operation	4,500	pilot per hour	22.00
depreciation	2,900	landing fees	20.00
insurance	2,600		
interest on fixed assets	1,800		
Total Fixed Cost	$28,700	Total Hourly Cost	$160.00
Cost per Hour	$330.00		
Cost per Hour per Gallon Capacity	$0.66		

Remarks

The TBM is the smallest of the military attack aircraft to be converted. As such, it's production rates tend to be lower than other aircraft of this category although delivery costs per foot of line held are comparable. The Avenger was one of the first aircraft to be converted to an airtanker on a large scale. It has proved to be highly effective in this role. In 1970 the Avenger was the third most popular aircraft in terms of number of airtankers flying in Canada. It was the most predominant land-based aircraft. Despite age and the rigors of constant use in an airtanker role, the problem of keeping these aircraft airworthy does not seem to be too severe. One Canadian operator polled by a private investment evaluation concern estimated that he had sufficient parts to keep him in business for an additional 20 years. Being a medium aircraft both with respect to capacity and speed the TBM would appear to be well suited to a "medium" mission both with respect to flying distance and fire size.

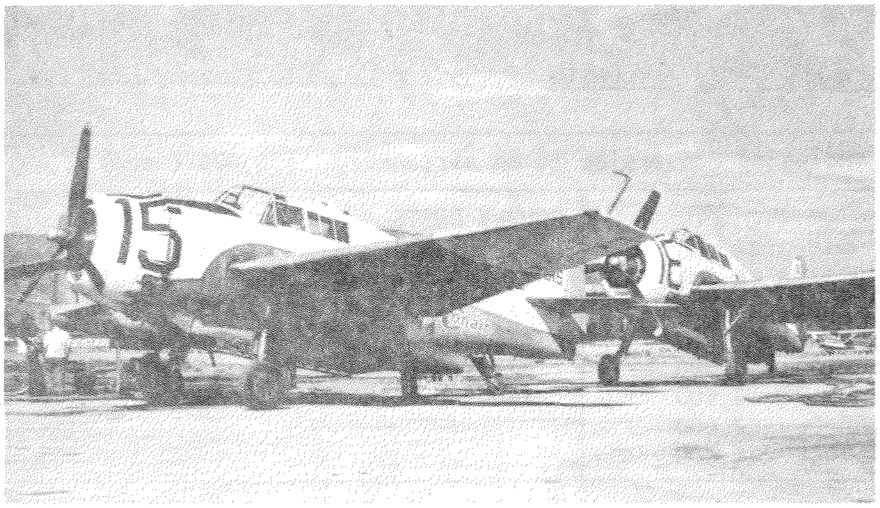

Figure 66. TBM Avenger (Photo: Author).

Figure 67. TBM Avenger (Photo: British Columbia Forest Service).

(b) Helicopters

USEFUL LOAD 1,060 lbs.	PASSENGERS 2

General Characteristics

PRIMARY PURPOSE light utility	
MANUFACTURER AND MODEL Bell 47G-3B-2	
DIMENSIONS length 43 ft. 7 in. width 8 ft.7 in.(skids) 11 ft. (floats) height 9ft.6in.(skids) 10ft.5in.(floats) rotor diameter 38 ft. 1 in. (2 blades)	WEIGHTS empty 1,915 lbs. maximum load 483 lbs. gross take off 2,950 lbs.
ENGINE(S) One 280 hp Avco Lycoming Vo Tvo-435-G1A	FUEL capacity 45 imp. gal. consumption 14.1 imp. gal./hr.

Performance Data

SPEEDS maximum 105 mph. cruising 81 mph. rate of climb 990 ft./min.	LOADINGS normal power 14.0 lbs./hp. disc 2.7 lbs./sq. ft.
ENDURANCE hours 3.0 hrs. ferry range 235 miles fully loaded range 200 miles (est)	HOVERING CEILING I.G.E. 16,600 ft. O.G.E. 12,300 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY

total	80 imp. gal. (one S-100 bucket)
with full fuel load	40 imp. gal.

RETARDANT DISTRIBUTION PATTERNS (estimated) retardant depth (ins.)

tank configuration	.02	.04	.07
	50 X 25	30 X 15	-

Costs

COST OF ACQUISITION $66,000. (new)			
FIXED COSTS		HOURLY COSTS	
pilot base salary	$8,600	fuel & oil	$ 7.00
personnel	8,000	engine overhaul	4.50
hangar space	500	labour	17.50
yearly maintenance	1,000	materials	5.00
cost of remote operation	1,500	pilot per hour	22.00
depreciation	3,400	landing fees	–
insurance	4,600		
interest on fixed assets	2,100		
Total Fixed Cost	$29,700	Total Hourly Cost	$56.00
Cost per Hour $205.			
Cost per Hour per Gallon Capacity $5.12			

Remarks

Although helicopters in 1,000 lb useful load range have very limited lifting capabilities, their fast turn-around and relatively efficient use of the limited material carried makes them economically competitive with small fixed wing aircraft. It should be noted that at least 2 parallel loads have to be dropped to create a 20-foot swath - the minimum width considered to be effective by many fire control officers. Their relatively slow speeds and small loads preclude their use in an initial attack role in land-based operations, as the base to fire distances normally exceed their optimum use range. In a water-based operation they could be used in initial attack although they would take somewhat longer to get to a fire scene than fixed wing airtankers - a factor not considered in the above costs. This useful load range has the largest cost per hour per gallon capacity of all helicopters considered. The optimum use for helicopters in this capacity range is probably scouting and intelligence work, where only one or two passengers are carried. It is also well suited to supplying small isolated crews.

USEFUL LOAD 1,550 lbs.	PASSENGERS 5

General Characteristics

PRIMARY PURPOSE Corporate and Business Utility	
MANUFACTURER AND MODEL Bell 206A	
DIMENSIONS length 39 ft. 1 in. width 6ft.3in.(skids) 10ft.11in.(floats) height 9ft.6in.(skids) 11ft.0in.(floats) rotor diameter 33 ft. 4 in. (2 blades)	WEIGHTS empty 1,480 lbs. maximum load 856 lbs. gross take off 3,000 lbs. (3,500 with external load.)
ENGINE(S) One 317 hp. Allison 250 - C18	FUEL capacity 60 imp. gal. consumption 15.8 imp. gal./hr.

Performance Data

SPEEDS maximum 156 mph. cruising 131 mph. rate of climb 1,450 ft./min.	LOADINGS normal power 14.1 lbs./hp. disc 3.8 lbs./sq. ft.
ENDURANCE hours 3.8 hrs. ferry range 440 miles (est) fully loaded range 325 miles	HOVERING CEILING I.G.E. 9,100 ft. O.G.E. 3,500 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY
total 80 imp. gal. (one S-100 bucket)
with full fuel load 80 imp. gal.

RETARDANT DISTRIBUTION PATTERNS (estimated)

tank configuration	retardant depth (ins.) .02	.04	.07
	100 X 25	75 X 15	40 X 5

Costs

COST OF ACQUISITION $125,000 (new)			
FIXED COSTS		HOURLY COSTS	
pilot base salary	$8,600	fuel & oil	$ 8.00
personnel	8,000	engine overhaul	10.00
hangar space	500	labour	15.00
yearly maintenance	1,000	materials	11.00
cost of remote operation	1,500	pilot per hour	22.00
depreciation	6,700	landing fees	-
insurance	9,000		
interest on fixed assets	4,100		
Total Fixed Cost	$39,400	Total Hourly Cost	$66.00
Cost per Hour $263. Cost per Hour per Gallon Capacity $2.39			

Remarks

Helicopters in this range use the same bucket as the 47G series, but can fill it to capacity, thereby doubling the amount of retardant carried. Since costs for this particular model are only 30 percent greater than for the previous model, a substantial saving in delivery cost per foot of line held can be achieved. Note however that two passes are still necessary to produce a 20-foot wide swath. The increased passenger and/or cargo capacity renders helicopters in this load range more versatile than the two place models. It would not be as desirable for intelligence gathering as the previous model however, because the additional capacity is not needed for such a role.

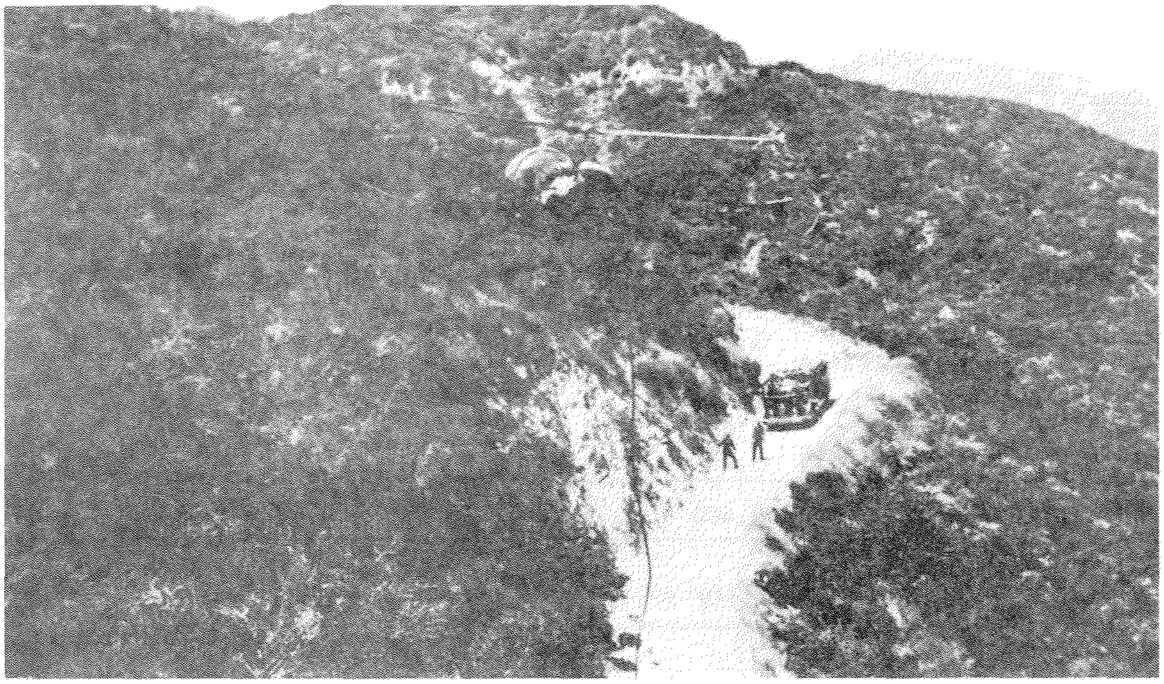

Figure 68. Bell 47-G laying hose (Photo: Bell Helicopter).

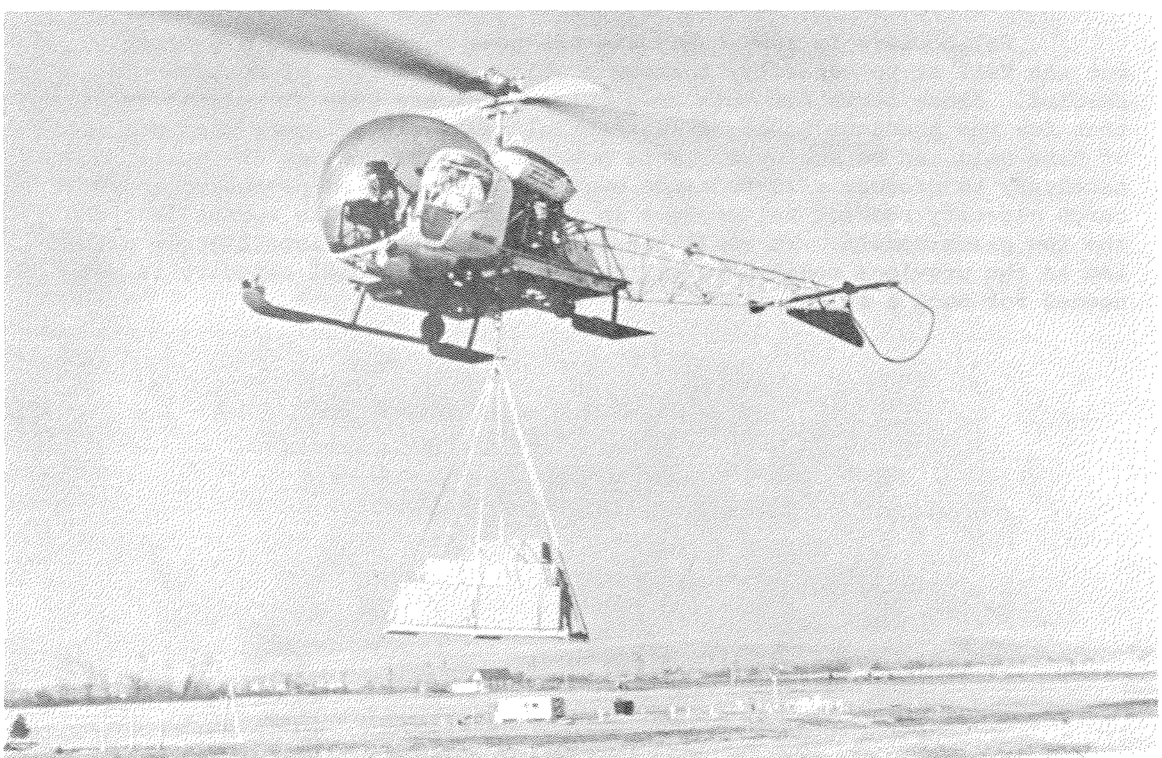

Figure 69. Bell 47-G3B with cargo sling (Photo: U.S. Forest Service).

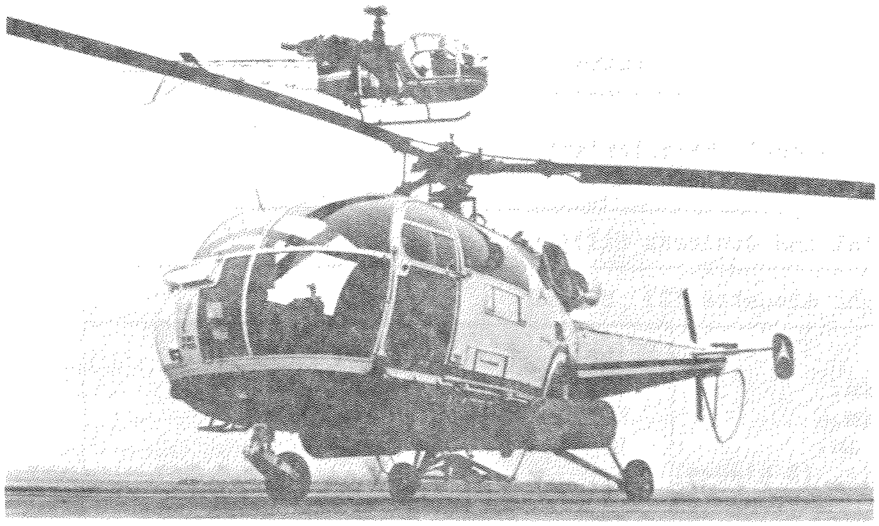

Figure 70. Vought Alouette II (flying) and III (static)(Photo: Vought Aircraft).

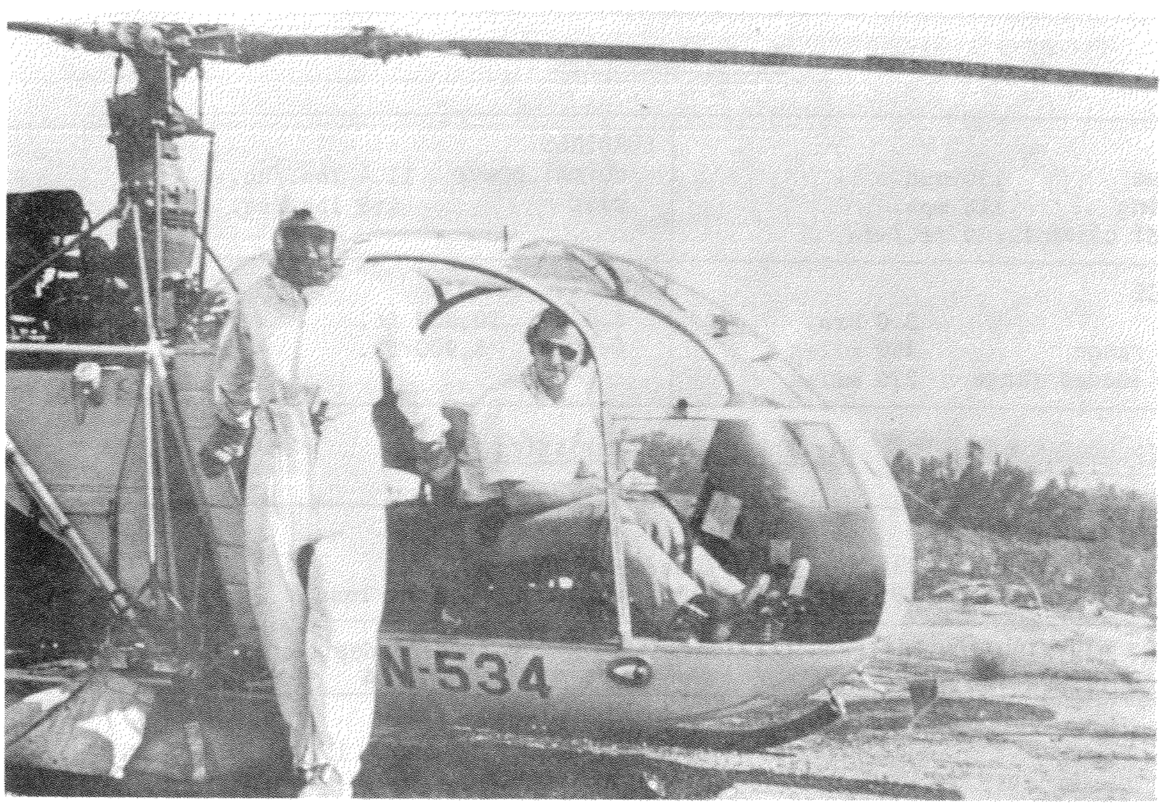

Figure 71. Vought Alouette II with helijumper (Photo: U.S. Forest Service).

USEFUL LOAD 2,160	PASSENGERS 7

General Characteristics

PRIMARY PURPOSE Commercial and Business Utility	
MANUFACTURER AND MODEL Vought Alouette III SE3160	
DIMENSIONS length 42 ft. 1 in. width 8 ft. 6 in. height 9 ft. 10 in. rotor diameter 36 ft. 2 in. (3 blades)	WEIGHTS empty 2,467 lbs. maximum load 960 lbs. gross take off 4,630 lbs.
ENGINE(S) One 542 hp. Artouste III B Turbine	FUEL capacity 130 imp. gal. consumption 40 imp. gal./hr.

Performance Data

SPEEDS maximum 130 mph. cruising 118 mph. rate of climb 1,400 ft./min.	LOADINGS normal power 11.4 lbs./hp. disc 4.5 lbs./sq. ft.
ENDURANCE hours 3.0 hrs. ferry range 350 miles fully loaded range 270 miles	HOVERING CEILING I.G.E. 10,000 ft. O.G.E. 8,900 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY
total 110 imp. gal. (One S-140 bucket)
with full fuel load 95 imp. gal. (110 gal. with 85% fuel load)*

RETARDANT DISTRIBUTION PATTERNS (estimated)

tank configuration	retardant depth (ins.) .02	.04	.07
	130 X 25	100 X 15	55 X 5

*110 imp. gal. enough for 2.5 hours of flying.

Costs

COST OF ACQUISITION	$209,000 (new)		
FIXED COSTS		HOURLY COSTS	
pilot base salary	$10,000	fuel & oil	$13.00
personnel	9,000	engine overhaul	8.00
hangar space	1,500	labour	21.00
yearly maintenance	2,500	materials	35.00
cost of remote operation	1,700	pilot per hour	25.00
depreciation	11,100	landing fees	-
insurance	15,000		
interest on fixed assets	6,900		
Total Fixed Cost	$59,700	Total Hourly Cost	$102.00
Cost per Hour	$400.		
Cost per Hour per Gallon Capacity	$3.64		

Remarks

This is perhaps 30 percent more helicopter than the previous model, in that it can carry two additional passengers and 30 percent more retardant. It has considerably improved performance characteristics particularly at high altitudes - a factor of some importance for forestry operations. With a cost increase of 35 percent over the previous model, these two helicopters can be considered as fairly close in desirability, with this model having a higher cost per gallon capacity.

USEFUL LOAD 2,950 lbs.	PASSENGERS 13

General Characteristics

PRIMARY PURPOSE Transport	
MANUFACTURER AND MODEL Sikorski S-62A	
DIMENSIONS length 45 ft. 5 in. width 15 ft. 9 in. (blades folded) height 16 ft. rotor diameter 53 ft. (5 blades)	WEIGHTS empty 4,938 lbs. maximum load 952 lbs. gross take off 7,900 lbs.
ENGINE(S) One 1,250 hp. Gen. Electric C758-110-1	FUEL capacity 250 imp. gal. consumption 48 imp. gal./hr.

Performance Data

SPEEDS maximum 101 mph. cruising 92 mph. rate of climb 1,140 ft./min.	LOADINGS normal power 8.8 lbs./hp. disc 3.6 lbs./sq. ft.
ENDURANCE hours 5.3 hrs. ferry range 462 miles fully loaded range 400 miles (est)	HOVERING CEILING I.G.E. 14,100 ft. O.G.E. 4,600 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY
total 360 imp. gal. (one S-450 bucket)
with full fuel load 70 imp. gal. (160 gal. with half fuel load)*

RETARDANT DISTRIBUTION PATTERNS (estimated)

tank configuration	retardant depth (ins.) .02	.04	.07
	150 X 35	110 X 25	75 X 10

* 125 imp. gal., enough for 2.6 hrs. of flying.

Costs

COST OF ACQUISITION $325,000 (new)			
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$10,000	fuel & oil	$ 9.00
personnel	9,000	engine overhaul	19.00
hangar space	1,500	labour	18.00
yearly maintenance	2,500	materials	16.00
cost of remote operation	1,700	pilot per hour	25.00
depreciation	17,400	landing fees	-
insurance	23,300		
interest on fixed assets	10,700		
Total Fixed Cost	$76,100	Total Hourly Cost	$87.00
Cost per Hour $468.			
Cost per Hour per Gallon Capacity $2.92			

Remarks

Helicopters in this capacity range can use the S-450 bucket at it's minimum loading. This yields a wider swath. As a result, only one pass is needed to obtain an adequate pattern. This results in an increase in efficiency and total production which offsets the increase in costs. The passenger carrying capacity is almost double the previous model. This allows a fairly substantial initial attack crew to be transported to the fire in one trip - a point in favour of helicopters in this useful load range. This particular model is hampered by its slower flying speed however. A faster model in this lifting capacity range would probably be similar to the previous two models with respect to costs per foot of line held.

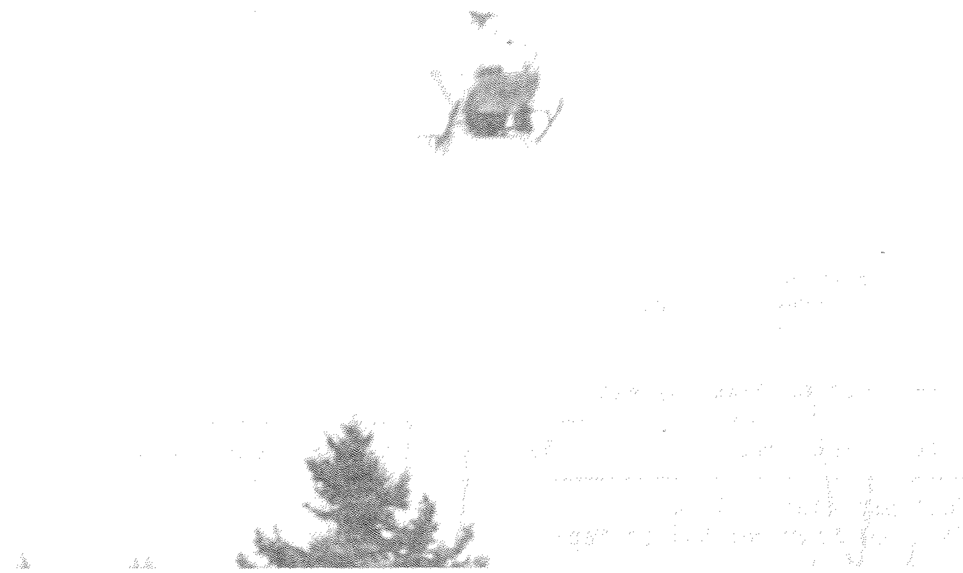

Figure 72. Vought Alouette II with side mounted conical tanks (Photo: U.S. Forest Service).

Figure 73. Bell 206A (Photo: Bell Helicopter).

Figure 74. Sikorsky S-62 (Photo: Sikorski Aircraft).

Figure 75. Kaman HH-43A twin rotor with bucket (Photo: U.S. Forest Service).

USEFUL LOAD 3,900 lbs.	PASSENGERS 10

General Characteristics

PRIMARY PURPOSE Corporate and Business Utility	
MANUFACTURER AND MODEL Bell 204B	
DIMENSIONS length 41 ft. 7 in. width 7 ft. 10 in. height 14 ft. 7 in. rotor diameter 48 ft. 0 in. (2 blades)	WEIGHTS empty 4,600 lbs. maximum load 2,500 lbs. gross take off 8,500 lbs.
ENGINE(S) One 1,100 hp. Lycoming T 5309 A Turbine	FUEL capacity 130 imp. gal. consumption 61 imp. gal./hr.

Performance Data

SPEEDS maximum 138 mph. cruising 120 mph. rate of climb 1,600 ft./min.	LOADINGS normal power 10.3 lbs./hp. disc 4.7 lbs./sq. ft.
ENDURANCE hours 1.9 hrs. ferry range 230 miles fully loaded range 200 miles	HOVERING CEILING I.G.E. 8,200 ft. O.G.E. 2,400 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY
total 360 imp. gal. (One S-450 bucket)
with full fuel load 250 imp. gal.

RETARDANT DISTRIBUTION PATTERNS (estimated) — retardant depth (ins.)

tank configuration	.02	.04	.07
	225 X 35	170 X 25	115 X 10

Costs

COST OF ACQUISITION	$400,000 (new)		
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$10,000	fuel & oil	
personnel	9,000	engine overhaul	
hangar space	1,000	labour	$75.00
yearly maintenance	3,000	materials	
cost of remote operation	2,000	pilot per hour	25.00
depreciation	21,400	landing fees	–
insurance	28,800		
interest on fixed assets	13,000		
Total Fixed Cost	$88,200	Total Hourly Cost	$100.00
Cost per Hour $551.			
Cost per Hour per Gallon Capacity $2.20			

Remarks

The Bell 204B has the lowest cost per gallon capacity of all the models considered so far, although it is only slightly lower than the Bell 206A. It also has a slightly lower passenger capacity than the previous model, although differences between 10 and 15 passengers are probably not particularly significant in a majority of situations. Although the costs per gallon are not greatly lower than previous models, the increased production is a factor in favour of the larger machines.

USEFUL LOAD 5,400 lbs.	PASSENGERS 15

General Characteristics

PRIMARY PURPOSE Transport	
MANUFACTURER AND MODEL Bell 205A-1	
DIMENSIONS length 57 ft. 1 in. width 9 ft. (skids) 13 ft. (floats) height 14ft.5in.(skids) 14ft.9in.(floats) rotor diameter 48 ft. (2 blades)	WEIGHTS (External load) empty 5,057 lbs. maximum load 2,706 lbs.; 3,706 gross take off 9,500 lbs.; 10,500
ENGINE(S) One 1,400 hp. Lycoming T531 3A/B	FUEL capacity 172 imp. gal. consumption 45 imp. gal./hr.

Performance Data

SPEEDS maximum 127 mph. cruising 115 mph. rate of climb 1,680 ft./min.	LOADINGS normal power 10.0 lbs./hp. disc 5.8 lbs./sq. ft.
ENDURANCE hours 4.0 hrs. ferry range 460 miles (est) fully loaded range 310 miles	HOVERING CEILING I.G.E. 10,400 ft. O.G.E. 6,000 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY

total 360 imp. gal. (One S-450 bucket)

with full fuel load 340 imp. gal. (360 gal. with 85% fuel load)

RETARDANT DISTRIBUTION PATTERNS (estimated)

tank configuration	retardant depth (ins.) .02	.04	.07
	320 X 35	240 X 25	160 X 10

The above patterns are based on actual field measurements.

Costs

COST OF ACQUISITION $450,000 (new)			
FIXED COSTS		HOURLY COSTS	
pilot base salary	$10,000	fuel & oil	$25.00
personnel	9,000	engine overhaul	22.00
hangar space	1,000	labour	22.00
yearly maintenance	3,000	materials	22.00
cost of remote operation	2,000	pilot per hour	25.00
depreciation	24,000	landing fees	-
insurance	32,400		
interest on fixed assets	14,900		
Total Fixed Cost	$96,300	Total Hourly Cost	$116.00
Cost per Hour $597.			
Cost per Hour per Gallon Capacity $1.66			

Remarks

For a slight increase in cost, this model carries 25 percent more retardant and five additional passengers than the previous model. This naturally results in an increase in production and a decrease in delivery cost per foot of line held. The Bell 205A1 has the lowest cost per gallon capacity of all the models in this report. It's passenger capacity is also fairly substantial. It can just fill a single S-450 bucket, resulting in maximum efficiency with a simple dropping system. This model would appear to be very useful and efficient for a wide range of operations, although perhaps somewhat expensive for smaller missions.

Figure 76. Bell 205A with permanently mounted tank (Photo: Bell Helicopter Corporation).

Figure 77. Bell 205A loading a bucket (Photo: Bell Helicopter Corporation).

Figure 78. Sikorsky S-58 with a bucket (Photo: U.S. Forest Service).

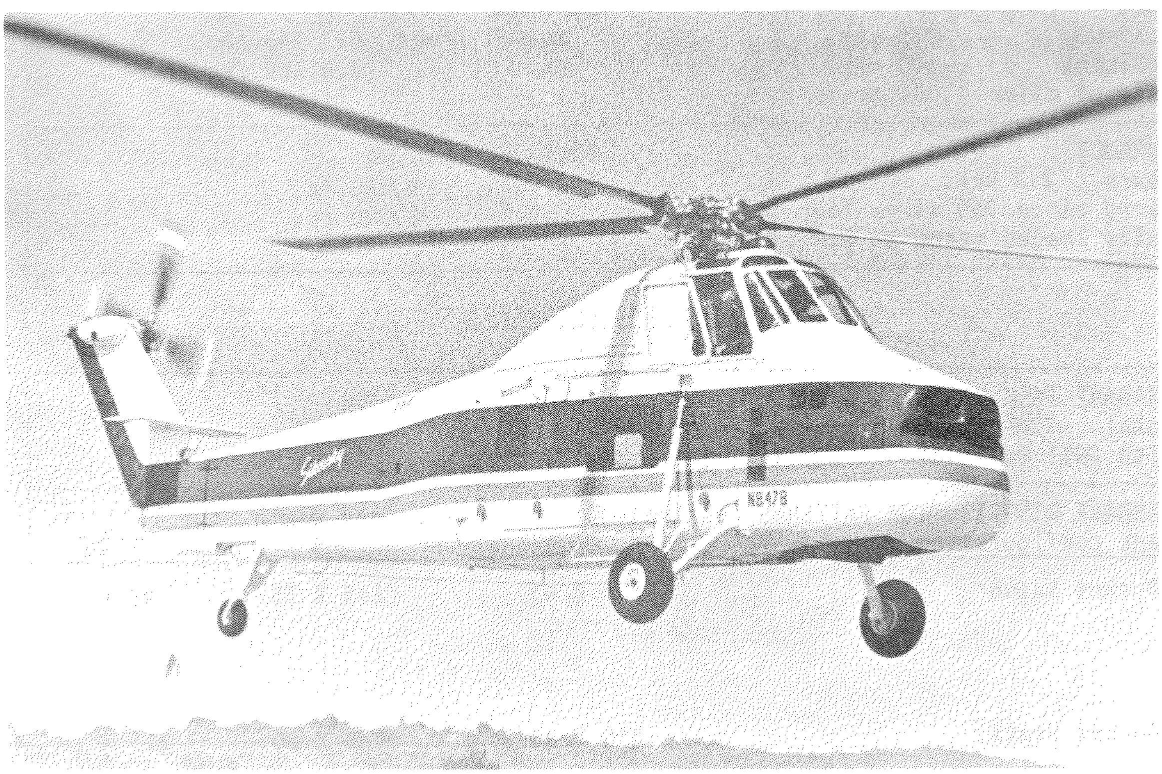

Figure 79. Sikorsky S-58T (Photo: Sikorsky Aircraft).

USEFUL LOAD 6,390 lbs.	PASSENGERS 18

General Characteristics

PRIMARY PURPOSE Commercial and Transport	
MANUFACTURER AND MODEL Vought Helicopter, Puma SA330	
DIMENSIONS length 59 ft. 6 in. width 9 ft. 10 in. (rotor folded) height 14 ft. 4 in. rotor diameter 49 ft. 2 in. (4 blades)	WEIGHTS empty 7,720 lbs. maximum load 4,860 lbs. gross take off 14,110 lbs.
ENGINE(S) Two 1,415 hp. Turbomeca Turmo IV Turbines	FUEL capacity 328 imp. gal. consumption 120 imp. gal./hr.

Performance Data

SPEEDS maximum 175 mph. cruising 140 mph. rate of climb 1,500 ft./min.	LOADINGS normal power 6.5 lbs./hp. disc 7.0 lbs./sq.ft.
ENDURANCE hours 2.2 hrs. ferry range 360 miles (can be extended fully loaded range to 910 miles with 4 100 imp. gal. ferry tanks)	HOVERING CEILING I.G.E. 9,280 ft. O.G.E. 6,570 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY
total 720 imp. gal. (two S-450 buckets)
with full fuel load 435 imp. gal.

RETARDANT DISTRIBUTION PATTERNS (estimated)

tank configuration	retardant depth (ins.) .02	.04	.07
2 Bucket Salvo	195 X 45	145 X 35	95 X 20
2 Bucket Trail	350 X 30	260 X 20	115 X 10

Costs

COST OF ACQUISITION	$950,000 (new)		
FIXED COSTS		**HOURLY COSTS**	
pilot base salary	$18,600	fuel & oil	$16.00
personnel	14,000	engine overhaul	30.00
hangar space	1,500	labour	40.00
yearly maintenance	5,000	materials	99.00
cost of remote operation	4,000	pilot per hour	47.00
depreciation	50,600	landing fees	–
insurance	68,400		
interest on fixed assets	37,600		
Total Fixed Cost	$199,700	Total Hourly Cost	$232.00
Cost per Hour	$1,230		
Cost per Hour per Gallon Capacity	$2.74		

Remarks

The Puma is the first of the large capacity machines to be considered. It can lift two partially filled S-450 buckets, but requires a slightly more complex system to enable it to do so. It's cost per gallon capacity is greater than most models in the medium range. Both retardant and passenger capacities are greater than previous models, however, thus enabling greater rates of production to be achieved. Models in this range would be well suited to larger operations and poorly suited to small jobs. The relatively high capital outlay necessary for purchasing such a machine may also be a disadvantage.

USEFUL LOAD 10,700 lbs.	PASSENGERS 26

General Characteristics

PRIMARY PURPOSE Military Transport, Commercial Passenger Service	
MANUFACTURER AND MODEL Sikorski S-61A	
DIMENSIONS length 57 ft. width 16 ft. 4 in. (blades folded) height 16 ft. 10 in. rotor diameter 62 ft. (5 blades)	WEIGHTS (External load) empty 9,763 lbs. maximum load 4,897 lbs.; 5,897 gross take off 20,500 lbs.; 21,500
ENGINE(S) Two 1,500 hp. General Electric T58-GE-5	FUEL capacity 765 imp. gal. consumption 161 imp. gal./hr.

Performance Data

SPEEDS maximum 189 mph. cruising 167 mph. rate of climb 1,800 ft./min.	LOADINGS normal power 8.6 lbs./hp. disc 7.1 lbs./sq. ft.
ENDURANCE hours 4.7 hrs. ferry range 625 miles fully loaded range 555 miles	HOVERING CEILING I.G.E. 7,200 ft. O.G.E. 5,000 ft.

Airtanker Characteristics

RETARDANT TANK CAPACITY
- total 720 imp. gal. (two S-450 buckets)
- with full fuel load 490 imp. gal. (720 gal. with 2/3 fuel load)*

RETARDANT DISTRIBUTION PATTERNS (estimated)

tank configuration	retardant depth (ins.) .02	.04	.07
2 bucket Salvo	350 X 50	265 X 40	175 X 20
2 bucket Trail	610 X 35	465 X 25	305 X 10

* 510 imp. gal. of fuel - enough for 3.1 hours of flying.

Costs

COST OF ACQUISITION	$1,350,000 (new)		
FIXED COSTS		HOURLY COSTS	
pilot base salary	$18,600	fuel & oil	$20.00
personnel	14,000	engine overhaul	35.00
hangar space	1,500	labour	44.00
yearly maintenance	5,000	materials	54.00
cost of remote operation	4,000	pilot per hour	47.00
depreciation	72,000	landing fees	-
insurance	97,200		
interest on fixed assets	44,600		
Total Fixed Cost	$256,900	Total Hourly Cost	$200.00
Cost per Hour $1,485.			
Cost per Hour per Gallon Capacity $2.06			

Remarks

This is the largest helicopter which will be considered in this report. With a total load of 720 Imp. gallons in two buckets it carries as much as a medium capacity fixed wing aircraft, but because of it's lower drop speed and greatly increased maneuverability and greater drop flexibility it uses the material much more efficiently. It's cost per gallon capacity is comparable with medium capacity helicopters but the hourly operating costs are more than double, thus precluding the use of machines in this range on any but the largest operations. As a result, the number of hours of operation per year may be considerably reduced, thus increasing the hourly cost even further. The very hign initial capital outlay is a further barrier to the use of such machines for forest fire control, except on a casual basis. In such a case they would be used only when the mission warranted a large machine, in which case the high cost could be easily justified.

Figure 80. Sikorsky S-61 (Photo: Sikorsky Aircraft).

Figure 81. Boeing Vertol 107-II (11,960 lb. useful load) (Photo: U.S. Forest Service).