Productivity of Skimmer Air Tankers

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PRODUCTIVITY OF SKIMMER AIR TANKERS

Abstract

Data analyses were made of the drop patterns of the five fixed-wing skimmer air tankers currently in use in Canada, and the productivity of the tankers was determined for 11 application levels, ranging from 0.05 to 1.75 centimetres.

Test-fire data for four slash fuels were used to relate each air tanker's suppression capability to frontal fire intensity for fires burning in open areas as well as where canopy interception of 0.1 and 0.2 cm was anticipated.

Limits for air tanker turnaround times relative to the Fire Weather Index were derived from the data on delivery capability.

Résumé

On a analysé les données sur le processus de largage de l'eau par 5 avions-citernes à écopes, couramment utilisés au Canada, et on a calculé la productivité de ces avions pour 11 épaisseurs de la lame d'eau larguée, variant de 0,05 à 1,75 centimetres.

On s'est servi des résultats du brûlage expérimental de quatre types de rémanents pour corréler la capacité d'extinction de chaque avion avec l'intensité du front d'incendie, dans les zones à découvert ainsi que dans celles où l'on s'attendait à une interception de 0,1 à 0,2 cm d'eau par le couvert.

En se fondant sur la capacité d'arrosage des avions, on a calculé combien de fois ces derniers devaient faire la navette en tenant compte de l'Indice forêt-météo.

INTRODUCTION

The skimmer air tankers currently used by the forest fire suppression agencies in Canada are the Turbo Beaver, the Otter, the Twin Otter, the Canso, and the Canadair CL-215. These aircraft deliver approximately 75 percent of the total suppressant/retardant volume delivered by fixed-wing air tankers annually to control forest fires. This 75-percent portion represents slightly more than 130 million litres of water. The Canso is credited with the delivery of one-half of this amount.

Air tanker load capacities are, at best, only rough indicators of the relative capabilities of these aircraft in laying down a water suppression line of the specified minimum application level required to control the spread of forest fires. Major factors in maximizing tanker capability are the load-release rate and load erosion during descent. Distribution of the load and ground recovery patterns are reflected in the drop contours drawn from ground-level catch data. These contour patterns are regarded as 'footprints' for each type of air tanker. For a given air tanker, variations in drop-pattern configuration and distribution are due to differences in drop height, air speed, and wind direction and velocity in relation to the aircraft's flight path.

ANALYSIS OF DATA

The drop patterns for the five skimmer air tankers used in this productivity analysis are for water drops made from altitudes of 30 m or less when wind velocities were less than 10 km/h.

The line-building values of the tankers were based on the assumption that load overlapping was precise in each case. These values, which represent the maximum attainable pattern length, should not be construed as absolute but should be regarded only as a reasonable estimate of productivity. Based on the average length per drop, comparisons of productivity were made using metres of line laid per hour, number of loads per kilometre of line, length of line laid per 21 384 L of water dropped (equivalent of four CL-215 loads), and number of loads required to deliver a given amount.

The factor that ultimately determined the success of an aerial mission was the intensity of the fire that the air tanker was attempting to control.

Studies of test fires in slash fuels provided the data for the determination of the suppressive capabilities of water when fires were burning in open areas under no-wind conditions.

Air tanker load-carrying capacity

The quantity of water released from an air tanker and its rate of release determine the configuration of the drop pattern. The patterns in this analysis (Figs. 1 and 2) indicated that contour lengths (Table 1) bore little relationship to the amount released.

Within each drop pattern there were peaks of high application, but these islands were too small to be significant. The highest effective application level of a single drop was 0.25 cm for the Turbo Beaver pattern, 0.38 cm for the Otter and the Twin Otter, 0.50 cm for the Canso, and 1.75 cm for the CL-215. However, if successive, perfectly positioned (overlapped) drops are made, the highest effective level per drop increases to 0.38 for the Turbo Beaver, 0.50 cm for the Otter, and 0.75 cm for the Twin Otter and the Canso.

The mean lengths per drop (Table 1) represent the best pattern length that can be achieved for the given application levels, provided evaporation losses are negligible between successive drops. The effective length per drop increases fractionally as payload volumes increase, indicating that the distribution of water is governed to a great degree by its rate of release. The comparisons between the Canso and the CL-215 in the salvo mode (simultaneous release from both tanks) confirmed that in most cases the Canso excelled in length of effective line built relative to the load volume per drop (metres-per-litre basis). When application levels exceeding 0.5 cm are needed, this requirement can be met only by using the CL-215. The superiority of the CL-215 is most evident when the aircraft is used in the trail-drop mode. This mode has seldom been used, but the line-building potential data (Table 1) indicates that the fractional-second delay between tank door openings should be perfected if the pattern coverage of the CL-215 is to be optimized.

The marginal differences between pattern lengths of the one-tank and the two-tank deliveries of the CL-215 were due to lateral displacement of the respective tankloads rather than to superimposition of one on the other.

The curves in Figure 3 imply that the use of the air tankers of smaller capacity maximizes line-building output. This is true only when the objective is to deliver a fixed volume, in this case 21 384 L, without regard to time, cost, and application-level limitations. These factors are important if a given goal is to be reached with a minimum number of loads in the shortest possible time. A delivery of 21 384 L of water could be accomplished in 4 trips by the CL-215, 6 by the Canso, 12 by the Twin Otter, 22 by the Otter, and 34 by the Turbo Beaver.

The Canso and the CL-215 (in the salvo-drop mode) build comparable continuous fire line in the range 0 to 0.5 cm, but the Canso's effectiveness is limited by its inability to exceed the 0.75-cm application level (Fig. 4). The advantage of trail dropping over salvo dropping with the CL-215 was once again demonstrated by the reduction in number of trips required per kilometre of line.

In a turnaround time of 8 min (Fig. 5), the CL-215 (in trail-drop mode) could build fire lines faster than the other tankers could. The Canso's output compared favourably with the salvo of the CL-215 within the levels 0 to 0.50 cm. The CL-215 output per hour at the 0.50-cm level was 56 percent higher for the two-door trail drop than it was for the salvo drop (315:202) and 62 percent greater than the next best performer, the Canso (315:195). Assuming a fire-to-lake distance of 15–20 km, the turnaround times were estimated to be as follows: Turbo Beaver, 15 min; Otter, 18 min; Twin Otter, 13 min; Canso,

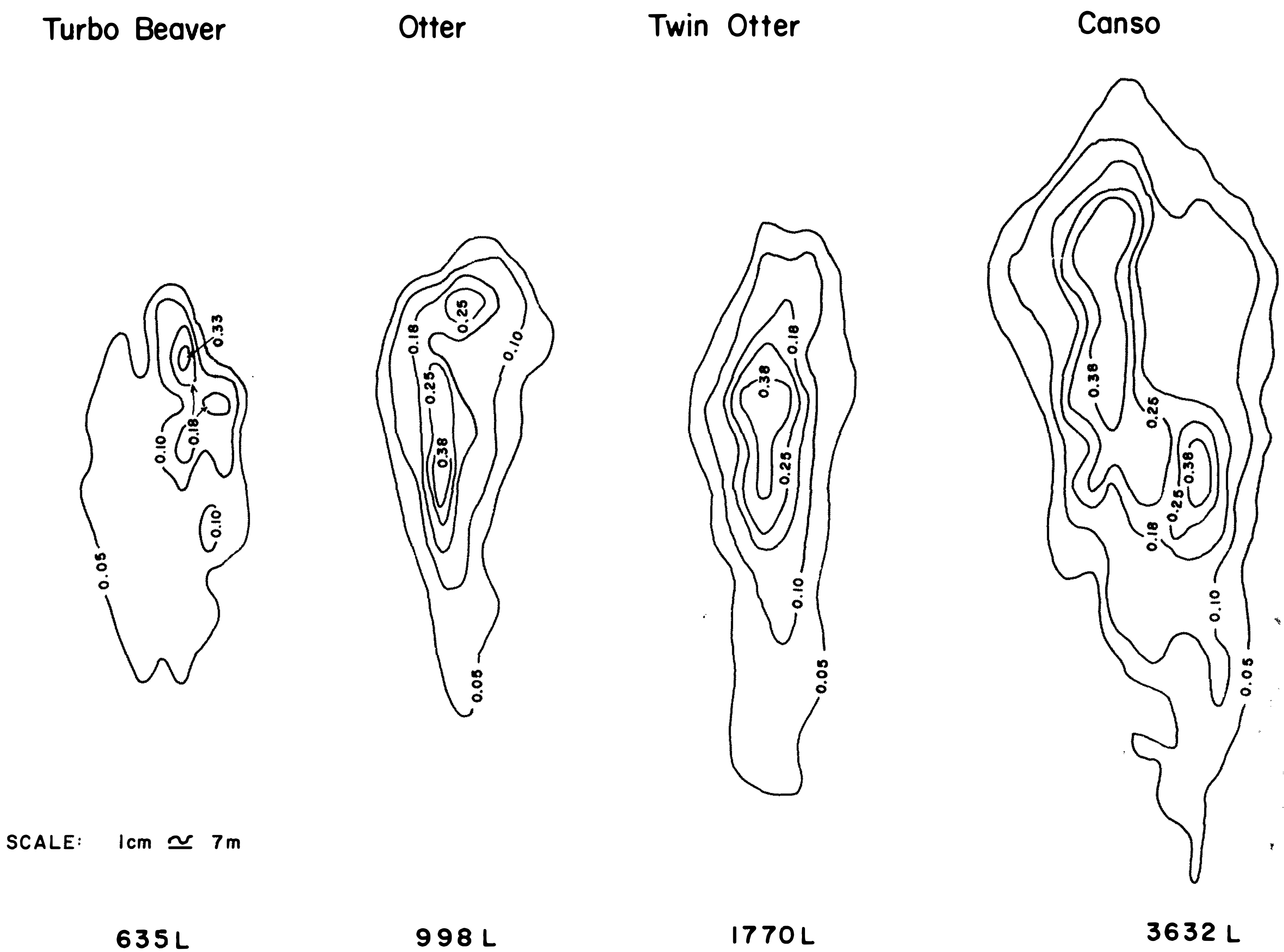

Figure 1. Ground distribution of water released from four skimmer air tankers (depth contours in centimetres).

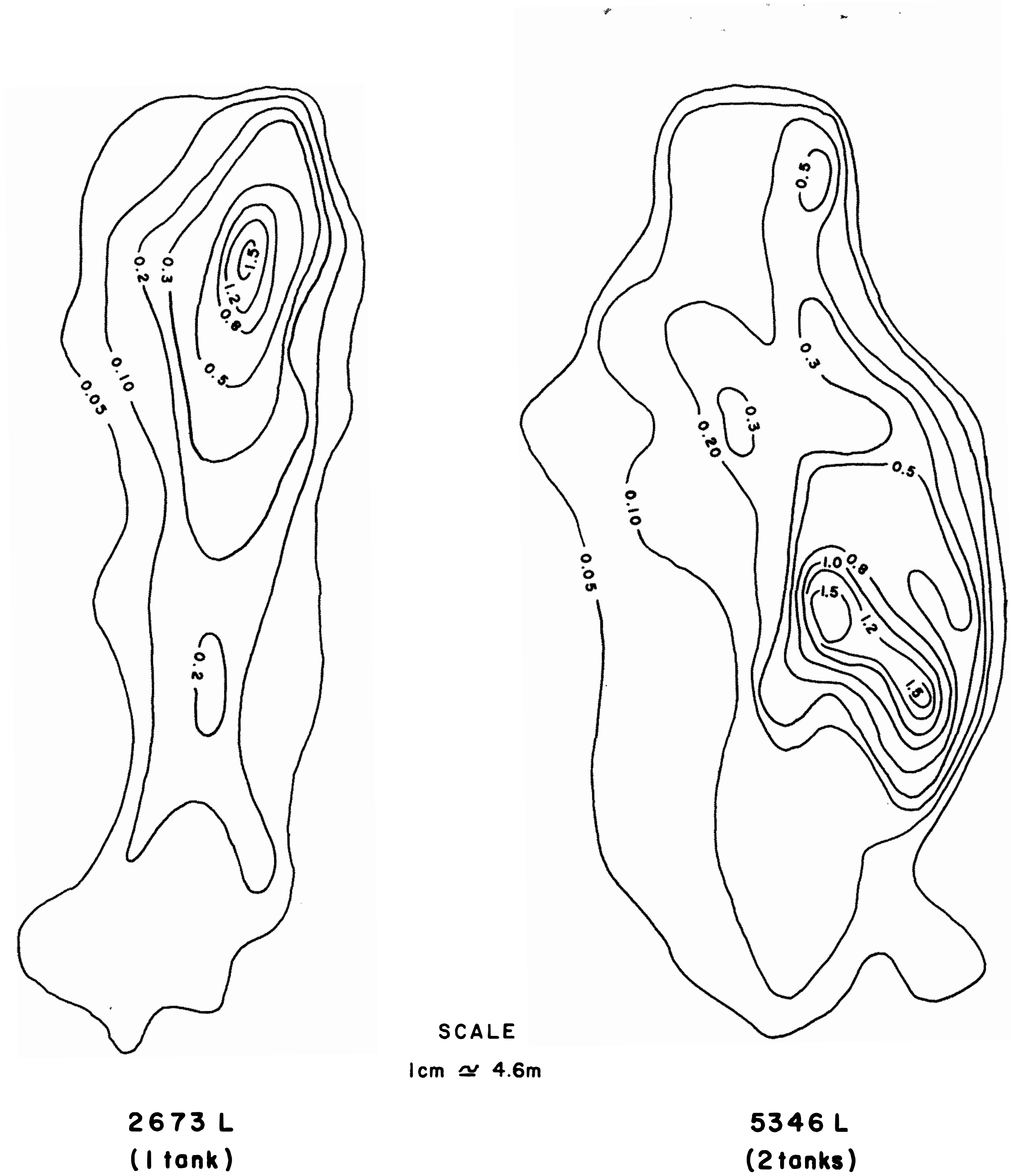

Figure 2. Ground distribution of water released from a Canadair CL-215; depth contours in centimetres.

Table 1. Line built per drop delivered by each skimmer air tanker

Application Depth	Turbo Beaver (635 L)	Otter (998 L)	Twin Otter (1770 L)	CL-215 (1/2 load) (2673 L)	Canso (3632 L)	CL-215 (salvo) (5346 L)	CL-215 (trail) (5346 L)
(cm)			(m)				
0.05	42 (41)	51 (50)	73 (60)	-- (64)	85 (85)	65 (65)	130 (--)
0.10	23 (20)	39 (35)	50 (41)	-- (55)	71 (58)	63 (62)	110 (--)
0.18	13 (7)	32 (29)	36 (27)	-- (43)	51 (42)	46 (48)	89 (--)
0.25	9 (3)	28 (17)	30 (20)	-- (20)	41 (37)	45 (46)	61 (--)
0.38	6 (0)	19 (6)	22 (12)	-- (18)	36 (25)	36 (23)	49 (--)
0.50	-	12 (0)	20 (0)	-- (14)	26 (8)	27 (22)	42 (--)
0.75	-	-	9 (0)	-- (11)	12 (0)	21 (15)	29 (--)
1.00	-	-	-	-- (8)	-	16 (13)	19 (--)
1.25	-	-	-	-- (5)	-	13 (10)	17 (--)
1.50	-	-	-	-- (3)	-	11 (4)	11 (--)
1.75	-	-	-	-- (0)	-	9 (2)	9 (--)

Note: Of the pairs of numbers listed under the names of tankers, those outside parentheses are the mean lengths per drop when successive drops were overlapped, and those inside parentheses are the lengths for single drops.

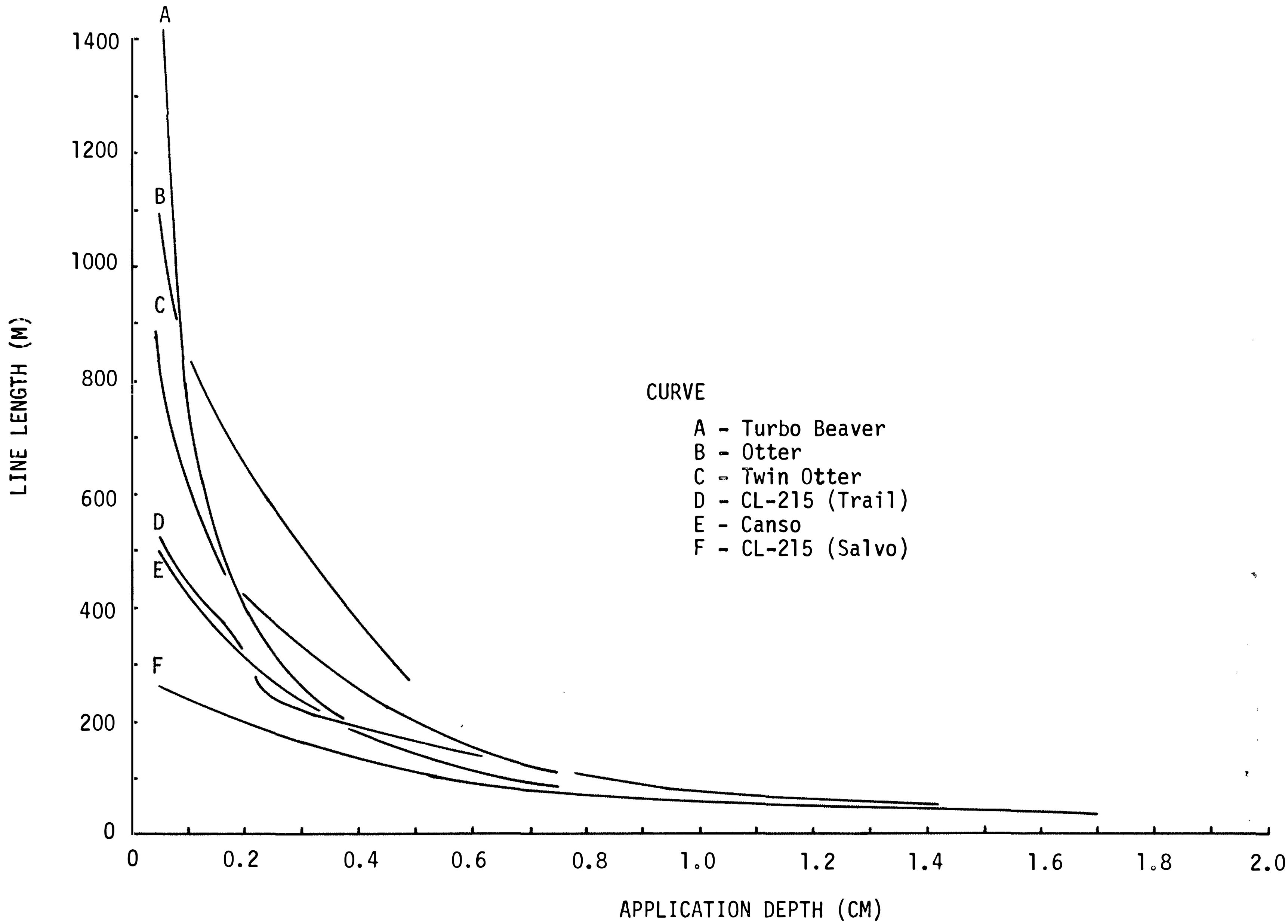

Figure 3. Metres of fire line built per 21 384 L of water.

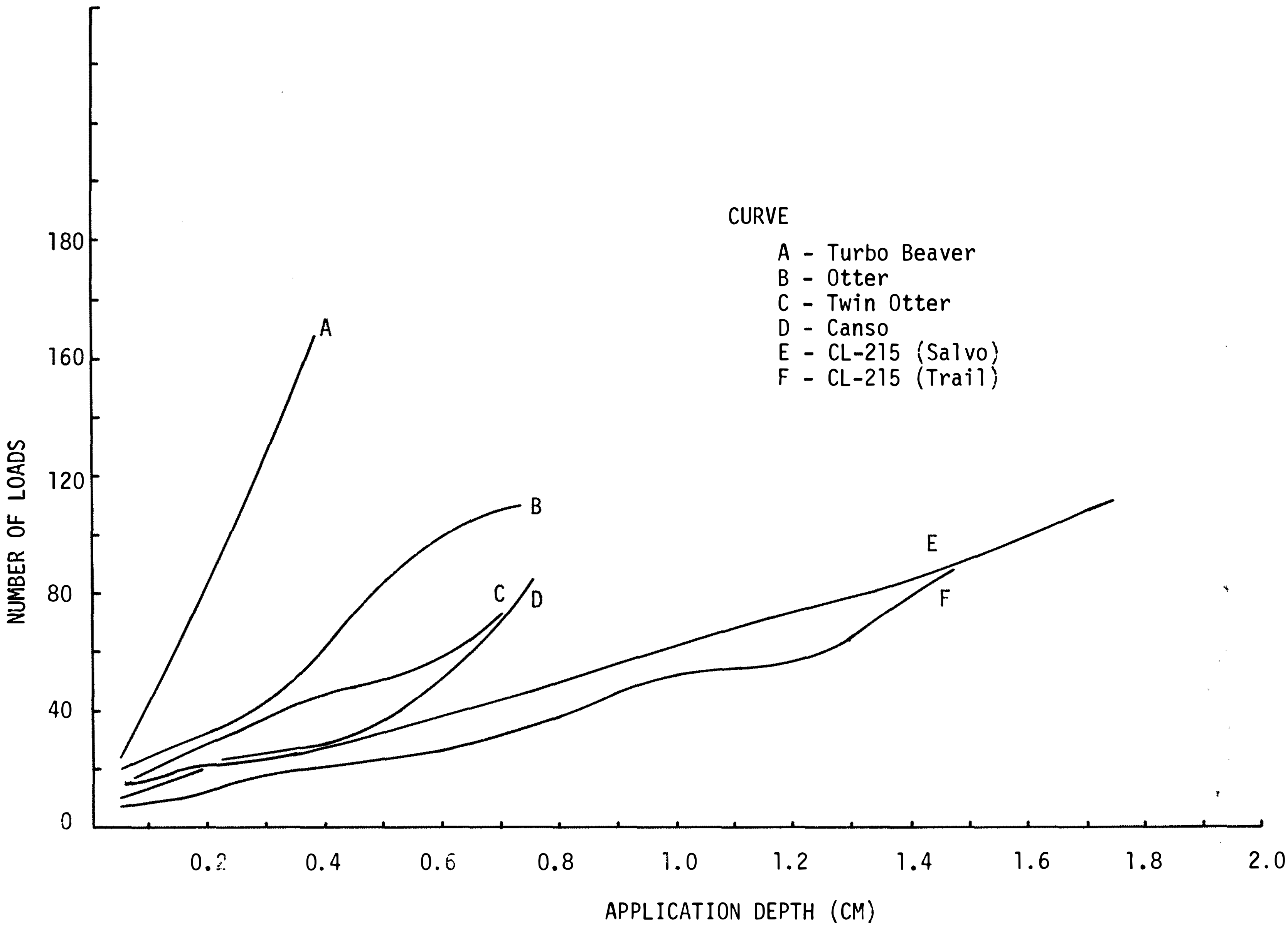

Figure 4. Number of loads required per kilometre of line.

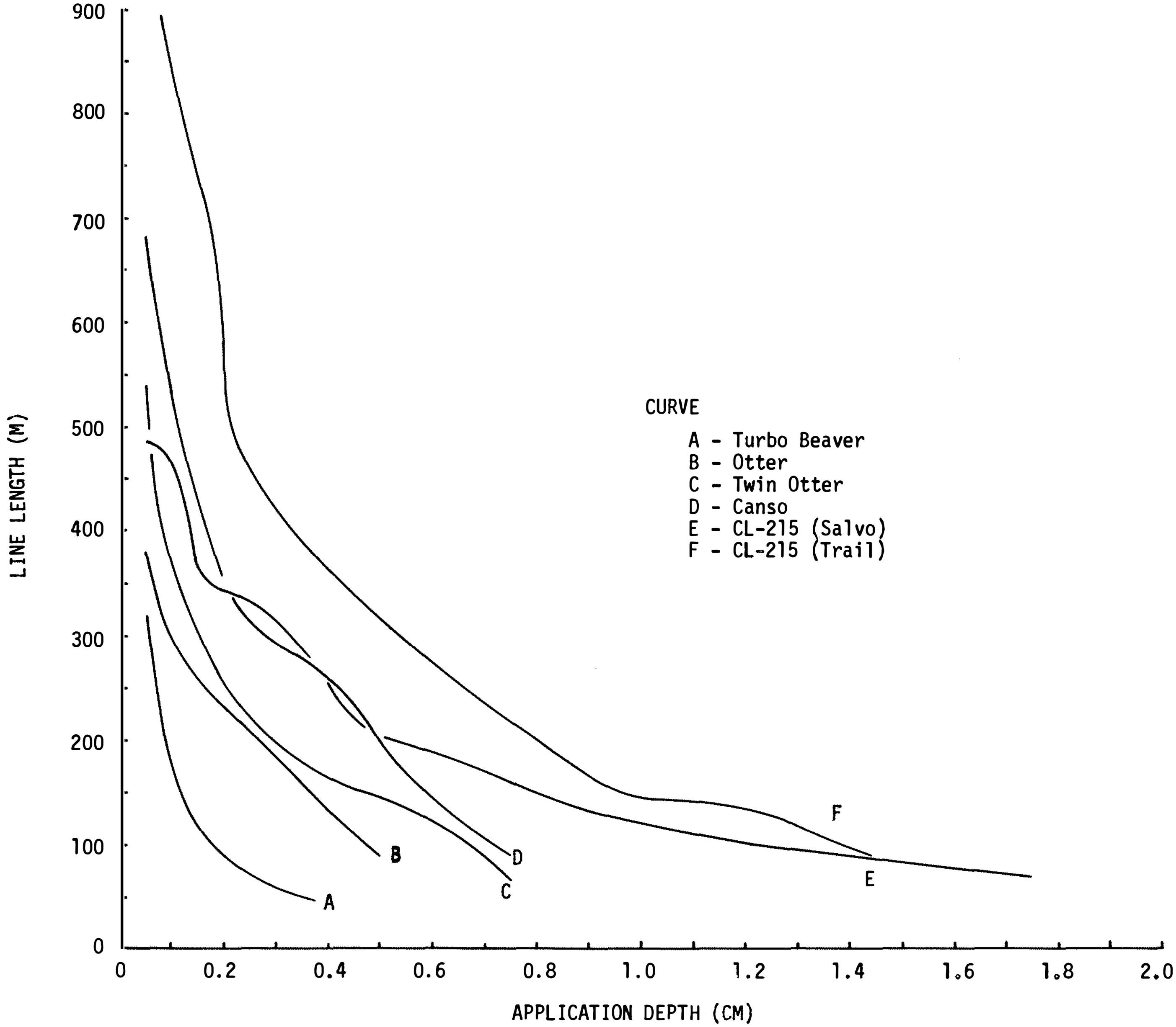

Figure 5. Metres of line built per hour at 8-min turnaround times.

14 min; and CL-215, 10 min. The curves in Figure 6 indicate that at the 0.50-cm application level, the CL-215's trail-drop-to-salvo ratio remained constant (252:162, 56 percent higher) but its output was 127 percent higher relative to the Canso (252:111). The Twin Otter's turnaround time was only 3 min longer than the CL-215's, but its reduced payload made it only one-third as productive in establishing a suppression line.

Application levels of 0.05, 0.10, and 0.18 cm were included in all tables, but in practice, applications below 0.25 cm are usually insufficient to control fire. Such applications might be successful on fires in fine, light fuels or where fuel loadings are very low. Most fires occur in forest areas where water applications of 0.25 cm or higher are necessary to achieve control. The Turbo Beaver, having a line-building capability of 9.5 m per drop, would satisfactorily contain spot fires spreading at a very low linear rate. The time lapse between deliveries would be critical in determining the success of the Turbo Beaver's attack. Only partial reduction in fire spread would be attained if insufficient amounts were applied, and repeated applications would be required.

Fire intensity

A simplistic classification using three ranges of fire intensity can be used to identify the limitations of suppression by air tankers:

Frontal Fire Intensity (kWm^{-1})	Control Rating
0–2000	easy to difficult
2000–3000	difficult to impossible
3000 +	impossible

Insufficient water application is not the only problem of control; others are rapid spread of fire, torching out, crowning, and spotting. In situations such as these, the effective width of the drop-pattern becomes as critical a factor as its effective length. Once a fire becomes active, the ability to continuously deliver the required amount of water to the fire front must be considered when relating an air tanker's output to fire intensity. An incremental aerial drop is momentarily effective, but the fire's spread rate and growth pattern overcome the tanker's action, and the perimeter of the fire continues to increase. The effective length of the drop pattern influences the rate of rejuvenation of the fire line.

The relationship between the amount of water applied and the intensity of the fire controlled in the four slash fuel types (Fig. 7) was derived from tests conducted under stable burning conditions. The range of intensities encountered during test-fire execution was predominantly at the low end of the scale, hence most of the values in Figure 7 were derived by extrapolation. The variations in the requirements for water application were due to differences in slash fuel characteristics. The limits of control by each of the air tankers in the four types of slash fuel fires (Table 2) indicated that the only water-carrying air tanker capable of effectively attacking fires in the 'difficult to control' category was the Canadair CL-215. The rate of spread of the fire in relation to the effective length of the

Table 2. Maximum intensity controlled by each tanker (slash fuel fires in open areas)

	Intensity			
	White Spruce	Jack Pine	Black Spruce	Balsam Fir
	(kWm^{-1})			
Turbo Beaver	555	835	1000	1390
Otter	845	1265	1520	2110
Twin Otter	845	1265	1520	2110
Canso	1110	1665	2000	2775
CL-215	3335	5000	6000	8335

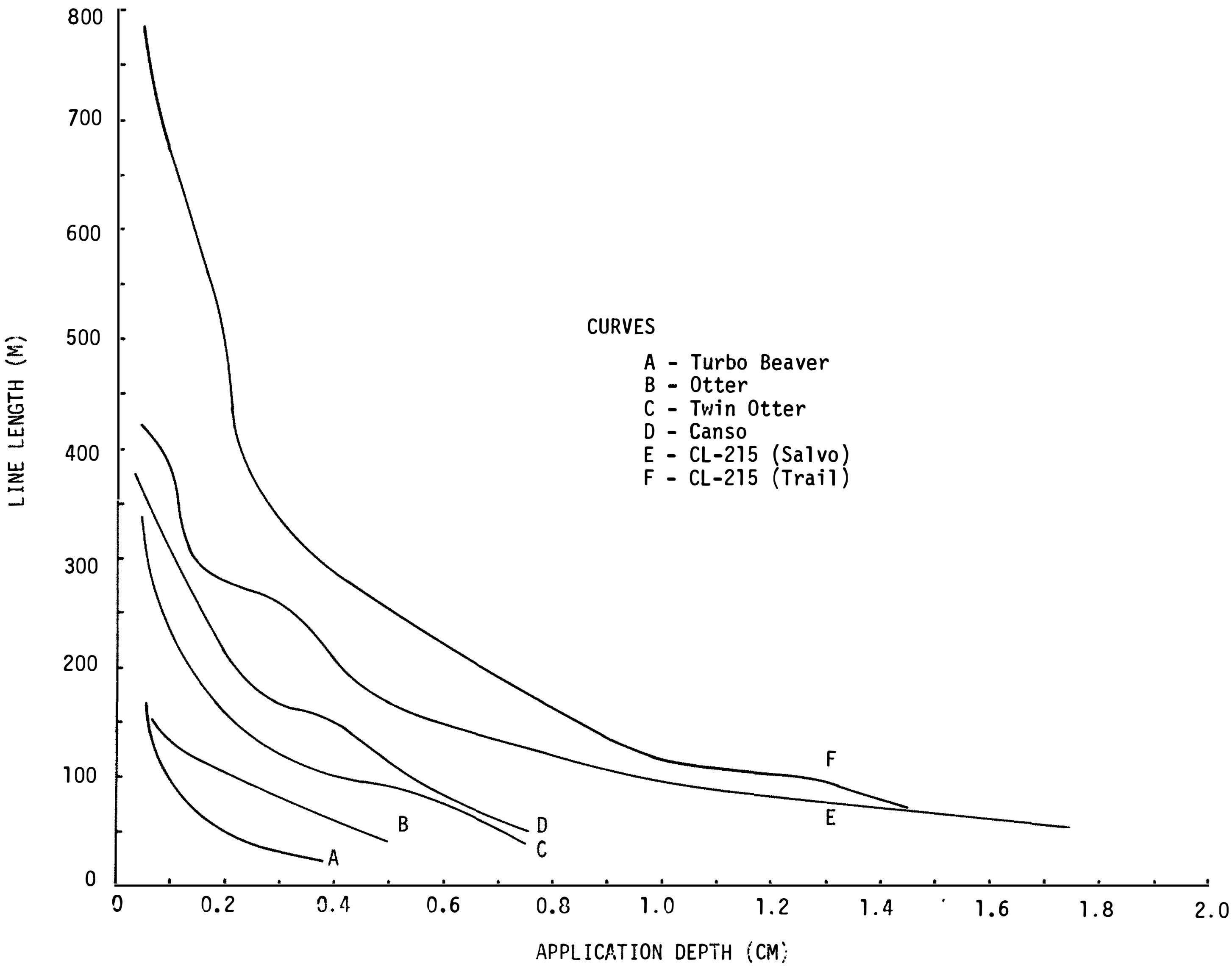

Figure 6. Metres of line built per hour when lake-to-fire distance is 15 to 20 kilometres.

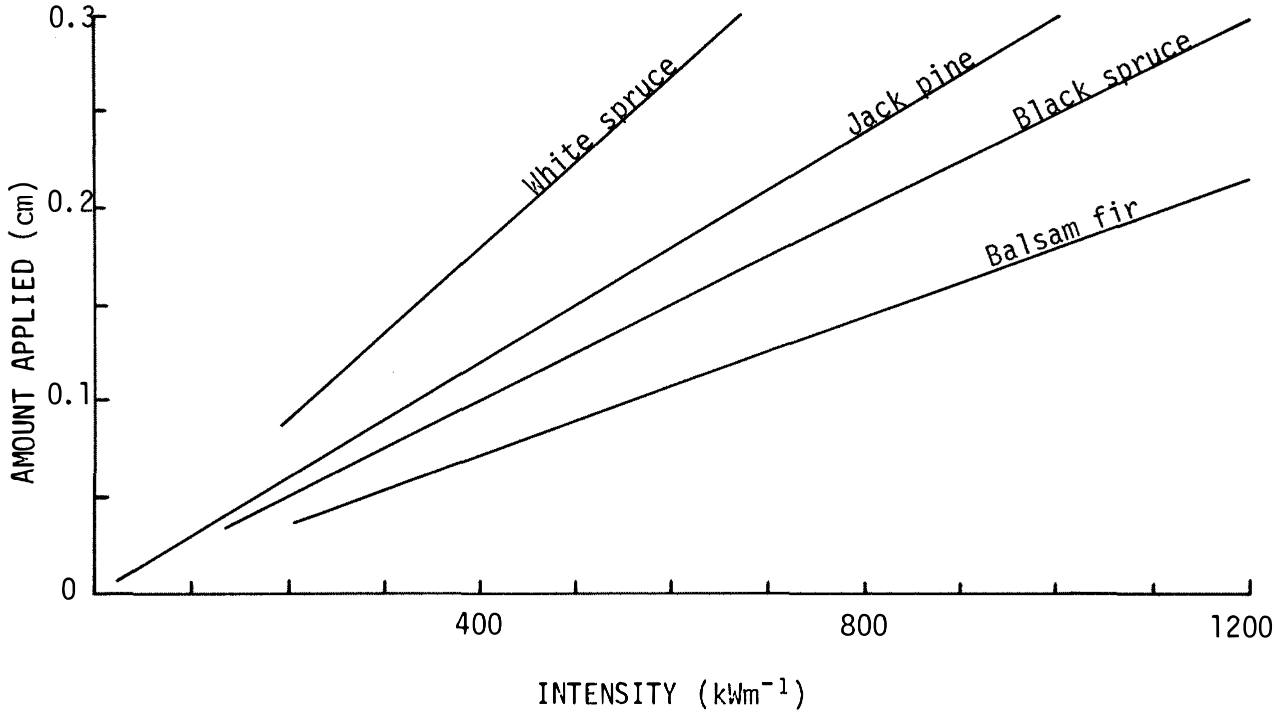

Figure 7. Minimum application of water required in relation to fire intensity to contain the four types of slash fuel fires.

drop pattern dictates whether or not an air tanker can control the spread of a fire. The intensity limits may well apply to suppression of spot fires but not to fires having a front that is several times longer than the effective drop length.

The intensities quoted as controllable in Table 2 are for fires burning in open areas, but in practice the airtanker drop must frequently pass through overhead fuels before reaching the fuels on or near ground level. Tree-canopy interceptions of 0.1 cm or greater are common. The figures shown in Table 3 indicate the frontal intensities that can be controlled after allowing for interception of 0.1 and 0.2 cm of water. It is evident that severe limitations are encountered when a Turbo Beaver is used, and significant restrictions are experienced when the Otter, Twin Otter, or Canso are used. In spite of the quantity of water that does not reach the ground fuels, the Canadair CL-215 still has a strike force unmatched by the smaller skimmer air tankers.

The decline in air tanker effectiveness when the water is intercepted is illustrated in Figure 8. When interception equals 0.0 cm, the Turbo Beaver's load can handle fire line intensities that do not exceed 835 kWm^{-1}; however, when a depth of 0.1 cm of the water is intercepted by aerial fuels during the load's descent, the maximum controllable intensity is reduced by 40 percent to 500 kWm^{-1}. The maximum that the Otter or the Twin Otter could control under these conditions decreases by 26 percent--from 1265 kWm^{-1} to 935 kWm^{-1}. The effect of interception declines as the level of application increases.

In the productivity relationships that have been developed in this report, no reference has been made to the Fire Weather Index (FWI) system. The FWI does not truly reflect the fire situation in any particular circumstances because it is the end product of several indices, each of which has a different impact on the final FWI value. The same FWI value can be derived by using different Initial Spread Index (ISI) and Buildup Index (BUI) combinations. The ISI is a measure of how fast a fire is expected to spread without regard to the amount of fuel that is consumed. The BUI, on the other hand, is a measure of the amount of fuel that is consumed. The curves in Figure 9 indicate how BUI and ISI can vary to yield a given FWI value. Fires occurring when the BUI is low and the ISI is high will burn superficially at high rates of spread and can be controlled by relatively light applications of water. Pattern length per drop and drop frequency are the important factors in this situation. Fires occurring at the same FWI but when the BUI is high and the ISI is low are deep-seated and require heavy applications of water. The quantity applied per unit area is the important factor in determining the productivity of a tanker. A given air tanker would not perform at the same level of effectiveness in both cases.

The theoretical turnaround time-limit curves in Figure 10 are a general guide to determining the suitability of each skimmer air tanker based on actual performance data and the FWI of the day. The curves are properly positioned in relation to each other, but collectively their position in relation to the FWI scale may require a lateral shift when additional data becomes available.

CONCLUSIONS

The Turbo Beaver can be employed in aerial suppression only when fires are expected to spread very slowly or occur where fuel loadings are very light and burning conditions are relatively stable. The Canso outperforms all other fixed-wing skimmer air tankers in load distribution, but when the time element or higher application levels are taken into consideration, the Canadair CL-215 (especially in the trail-drop mode) surpasses all other skimmer air tankers in controlling a wide variety of fires.

Table 3. **The effects of interception on the maximum fire intensity that can be controlled by various application levels**

Water Applied	Intensity							
	White Spruce		Black Spruce		Jack Pine		Balsam Fir	
(cm)	Interception							
	0.1 (cm)	0.2	0.1 (cm)	0.2	0.1 (cm)	0.2	0.1 (cm)	0.2
	(kWm^{-1})							
0.05	0	0	0	0	0	0	0	0
0.10	0	0	0	0	0	0	0	0
0.18	175	0	320	0	265	0	445	0
0.25	335	110	600	200	500	165	835	275
0.38	620	400	1120	720	935	600	1555	970
0.50	880	665	1600	1200	1335	1000	2220	1665
0.75	1445	1220	2600	2200	2165	1835	3610	3055
1.00	2000	1775	3600	3200	3000	2665	5000	4445
1.25	2555	2335	4600	4200	3835	3500	6390	5835
1.50	3110	2890	5600	5200	4665	4335	7775	7220

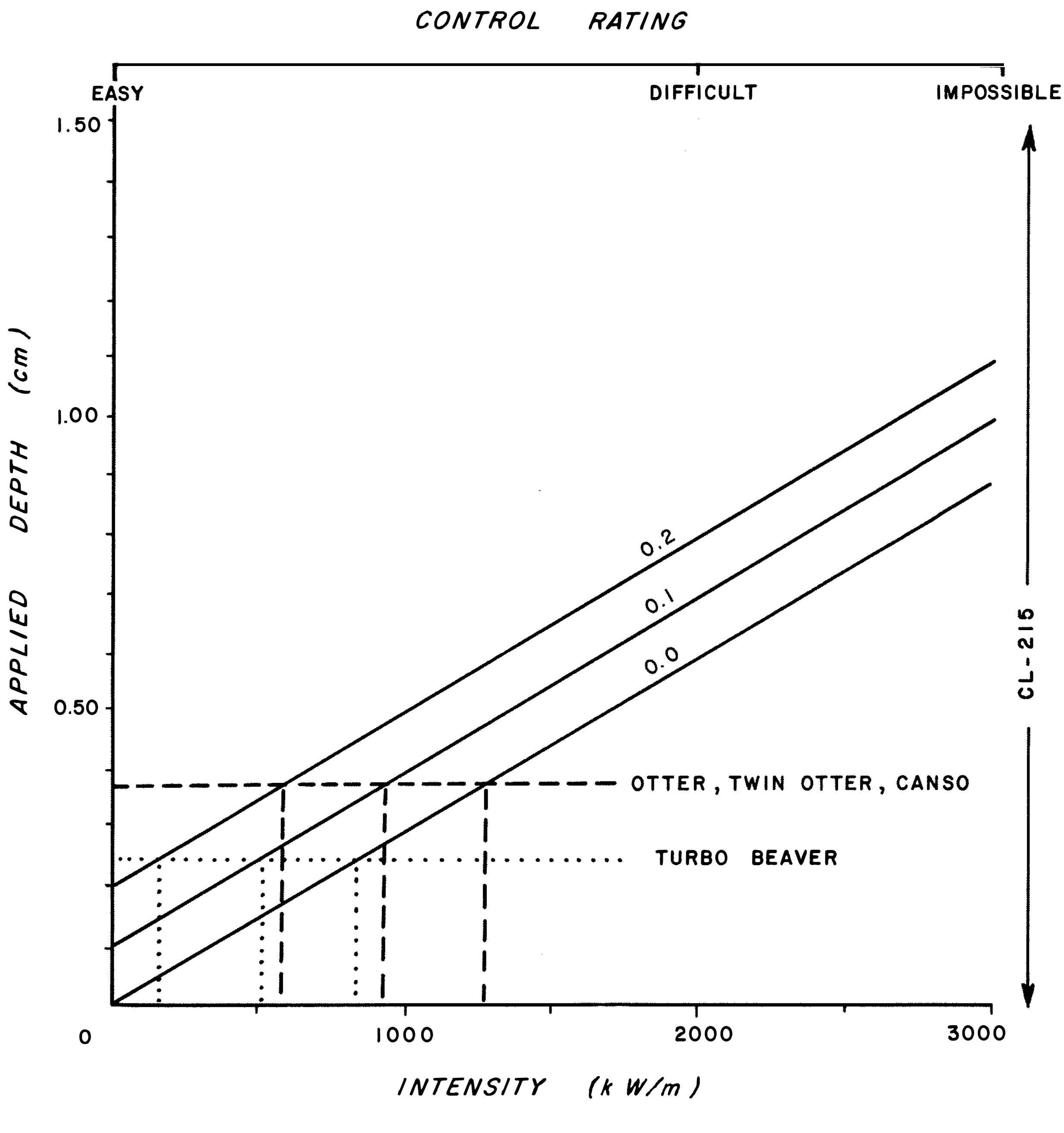

Figure 8. Water application required to control fire in Jack Pine slash when crown interception is 0, 0.1, and 0.2 centimetres.

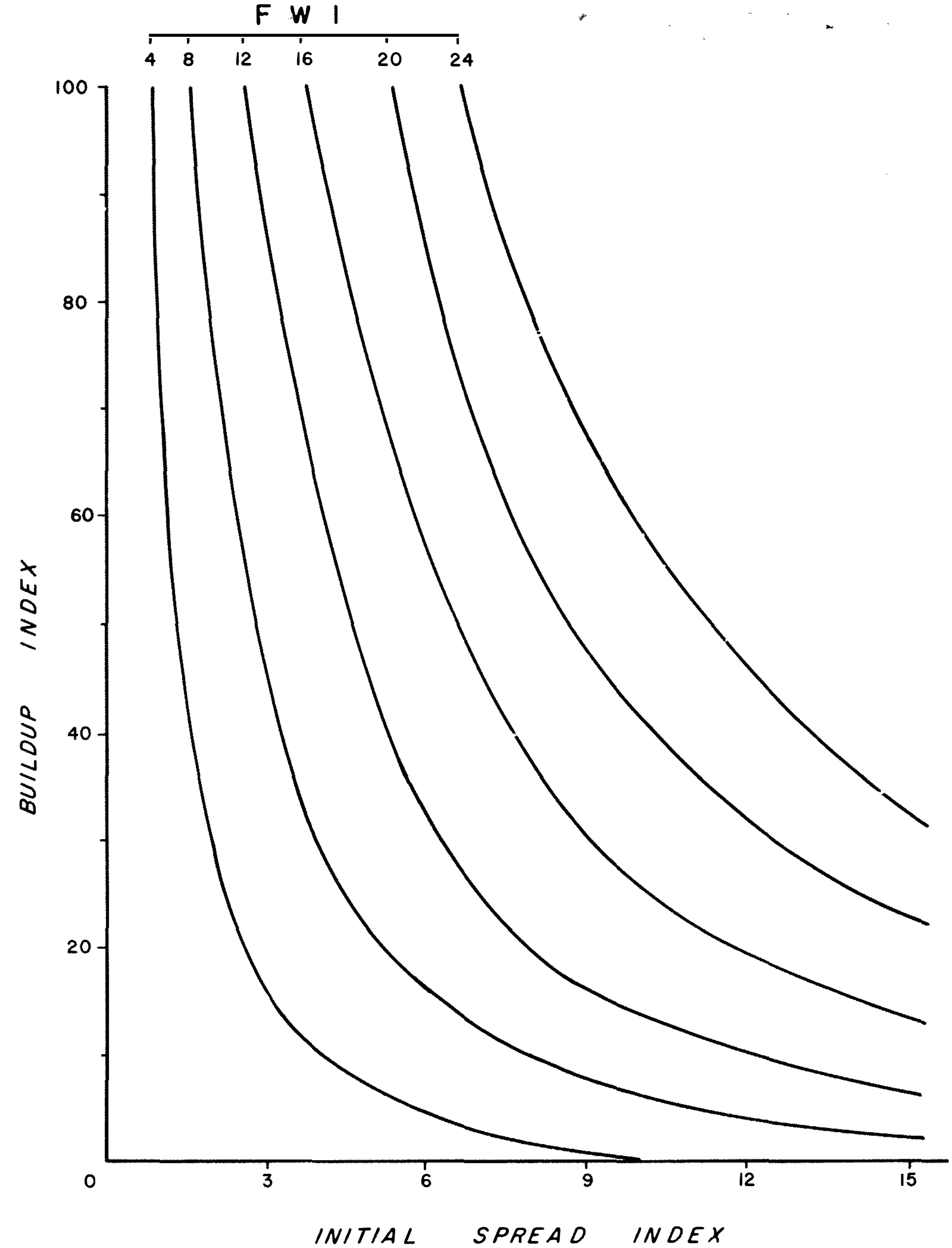

Figure 9. The effects of Initial Spread Index and Buildup Index values on the resultant FWI (Fire Weather Index) values.

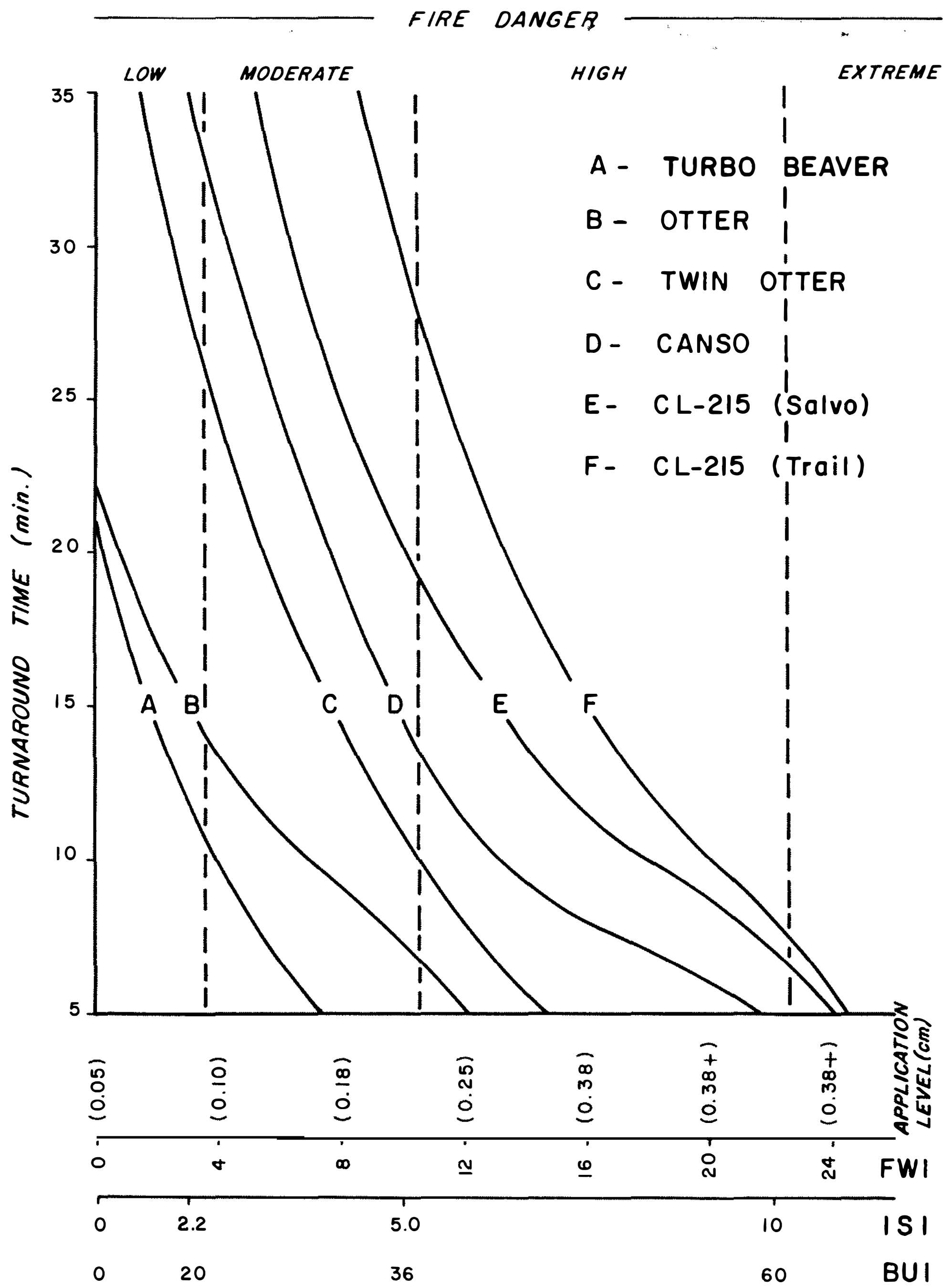

Figure 10. Theoretical limits for air tanker turnaround times based on delivery capability relative to FWI (Fire Weather Index). (ISI—Initial Spread Index; BUI—Buildup Index.)