FIRE RETARDANT GROUND DISTRIBUTION PATTERNS FROM THE CL-215 AIR TANKER

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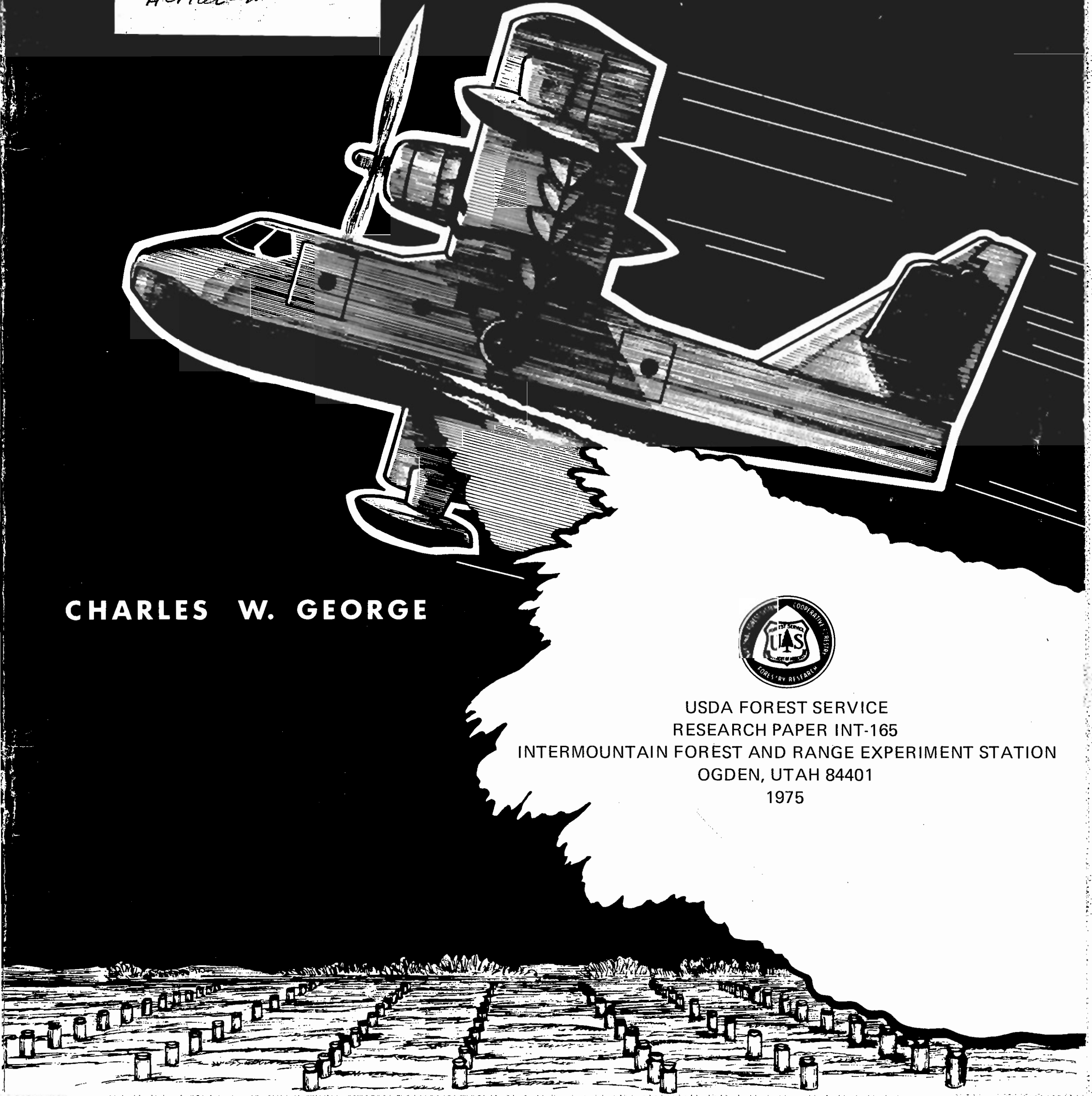

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CONTENTS

ABSTRACT

Several fire retardants in current use were dropped from the Canadair CL-215 to determine drop height effects and for evaluation of the tank and gating system. This was accomplished through the quantification and analysis of the characteristics of the ground distribution patterns--such as retardant recovery and pattern contour lengths. The effects of retardant type, load size, drop height and speed, aircraft attitude, and drop conditions on the ground distribution patterns were also determined.

Drop height and load size were found to be the most significant variables, affecting almost all measured parameters for the retardants dropped. Covariance analysis of linear drop height models for total recovery indicated the greatest difference existed between the gum-thickened retardants (Phos-Chek XA and Gelgard) and the unthickened or clay-thickened retardants (Fire-Trol 100 and water). The Phos-Chek XA had the greatest recovery, followed by Gelgard, and then Fire-Trol 100 and water. Similar results for contour areas and line lengths occurred in the nonlinear models developed for predicting effects of drop height.

The data analysis indicated the optimum drop height for the gum-thickened Phos-Chek XA and Gelgard to be as much as two to five times higher than that for Fire-Trol 100 and water. Thus, effective drop heights and safety may be greatly increased by the use of gum-thickened retardant.

The conclusions made were supported by an analysis of drop times and evaporation losses which indicated that the gum-thickened retardants had smaller drop times, greater cohesion, longer stripping times, and a larger mean droplet size after erosion.

Evaluation of the tank and gating system of the CL-215 and comparison of its performance with that of other presently used aircraft indicate its line-building efficiency to be equally effective. The performance and flexibility of the CL-215 tank and gating system could be improved, however, if a four-tank or gate system incorporating an intervalometer were adopted rather than the manually sequenced two-gate system.

INTRODUCTION

In the past 20 years, it has become increasingly common practice to slow or contain forest fires by cascading water or fire-retarding chemicals on or ahead of the flames, while firefighters construct firelines. This attack system was first used operationally in 1956 when fire control agencies in southern California, using converted military surplus airplanes and modified crop dusters, dropped about one-quarter million gallons of water and retardant solutions on fires. By 1960, the "air tanker" had become an accepted fire suppression tool.

Over 20 million gallons of retardant were applied aerially to fires in the United States in 1973, mostly from World War II-type aircraft, such as the B-26, B-17, and PB4Y2, flying at very near treetop level. In an effort to improve and update the aircraft fleet, newer military surplus-type aircraft, such as the C-119, P2V, and S2F, are being considered as replacement aircraft. In addition, the Canadair CL-215 has now become available. Unlike other aircraft presently being used or considered, the CL-215 is a special-purpose amphibious aircraft specifically designed to scoop water while planing on the water surface. This technique permits rapid delivery of water on a fire because no landing and shut-down type is required. The aircraft can also be used, however, to deliver retardant from fixed land bases.

The drop pattern required by the fire conditions, and the characteristics of the delivery platform or aircraft, dictate the effective and minimum safe drop heights. The performance above this minimum safe drop height is related to the efficiency of the tank and gating system. Whether or not a particular system can deliver an effective drop pattern depends on the volume of retardant solution, the properties of the retardant, and its flow rate upon release from the aircraft. Flow rates are related to the tank geometry and venting system, the size and shape of the gates, gate opening speed and degree of obstruction, and the aircraft speed and flight envelope effect.

Therefore, to improve the drop efficiency and safety, while updating the present air tanker fleet, emphasis must be placed on tank and gating system design, the properties of the fire retardant, and the relation between these two. The probable performance of proposed tank and gating systems must be known in order to assure selection of the best aerial attack systems and to optimize their performance. Therefore, the study reported here assessed the performance of the tank and gating system of the CL-215. (It does not necessarily reflect on the performance of the CL-215 as an aerial platform, however.) Similarly, the properties of various retardants and their performance must be known. Thus, the study evaluated several retardants that are currently used.

A series of test drops was carried out with the following specific objectives:

1. To provide data on characteristics of retardants when dropped, and on ground distribution patterns, for the purpose of evaluating the tank and gating system of the CL-215.

2. To determine the relative differences in drop characteristics between currently used long-term retardants, onboard-mixed short-term retardants, and water.

3. To provide basic data primarily for related studies of retardant delivery mechanization dealing with the effect of aircraft drop height and drop size on ground patterns.

PROCEDURES

The influences on ground distribution patterns and thus on the effectiveness of any cascade retardant drop are:

1. The physical and chemical properties of each general type of retardant, and the specific characteristics of the retardant when dropped.

2. The aircraft tank and gating size and configuration, the speed of door-opening, venting, airflow characteristics around the gates, and other parameters affecting the behavior of the retardant when released.

3. The speed, drop height, and attitude of the aircraft as the drop is released.

4. The environmental conditions such as temperature, humidity, windspeed, and wind direction at the time of the drop.

Retardants

The retardants used in the evaluation were Phos-Chek XA, Fire-Trol 100, Gelgard, and water. Phos-Chek XA is a product of Monsanto Co., St. Louis, Missouri; Fire-Trol 100, Chemonics Industries, Inc., Phoenix, Arizona (formerly Arizona Agrochemical Company); and Gelgard, Dow Chemical Co., Midland, Michigan. Phos-Chek XA and Fire-Trol 100 are long-term retardants; that is, besides building a blanket of water on fuels by means of a slurry, they chemically alter the pyrolysis and combustion reactions of the fuel so that smaller amounts of combustible products are formed. Thus, these two retardants retain considerable effectiveness after the water has completely evaporated from the slurry. They account for the majority of retardant currently dropped within the United States. Gelgard is a short-term retardant. It does not contain an active chemical but serves only to hold water in a viscous mixture, which theoretically shows better drop behavior than water. It also has better retention and forms an ablative layer on fuel surfaces. Gelgard was selected for the evaluation because it could be used for onboard thickening of salt-free water scooped by the CL-215.

Water was included in the tests because one of the prime attributes claimed for the CL-215 is its water-scooping and water-dropping capability. Water also serves as a baseline for comparing results of other studies.

The standard mixing proportions for these retardants were used in the test drops. These ratios and related physical-chemical characteristics of each fire retardant are given in table 1; for the composition of the formulations, see table 9 of Appendix I.

Standard mixing procedures and equipment were used to prepare the retardant solutions. Viscosity and salt content of the solutions were monitored frequently to assure quality control. Gelgard was mixed using an Aardvark disperser and was stored in a portable 1,000-gallon tank. Fire-Trol 100 was mixed in a high shear Lely mixer and was transferred to a 2,000-gallon holding tank. Phos-Chek XA was mixed using a portable air slide bin and a Monsanto-Hamp eductor. The mixed Phos-Chek XA was held in a 500-gallon saddle tank and a 3,000-gallon portable tank (fig. 1).

TABLE 1.--PHYSICAL-CHEMICAL CHARACTERISTICS OF SELECTED FIRE RETARDANTS[1]

Retardant	Recommended use level	Viscosity[2]	Density of slurry	Diammonium phosphate (DAP) $(NH_4)_2HPO_4$	Ammonium sulfate $(NH_4)_2SO_4$
	Lb/gal	*Centipoise*	*Lb/gal*	*Percent*	*Percent*
		LONG-TERM			
Phos-Chek XA	1.14	1,500-2,000	8.9	10.6	
Fire-Trol 100	2.78	1,500-2,500	9.4		15.6
		SHORT-TERM			
Gelgard	[3]0.024	800-1,200	8.33		
Water		1	8.33		

[1] Data from National Fire Protection Association (1967) and George (1971b).

[2] Measured by Brookfield Viscometer Model LVF at 60 r/min.

[3] The required use-level of Gelgard to provide a viscosity of 800-1,200 centipoise (Brookfield spindle No. 4) can be from 0.015 to 0.035 lb/gal of water, depending on the type and amount of water hardness.

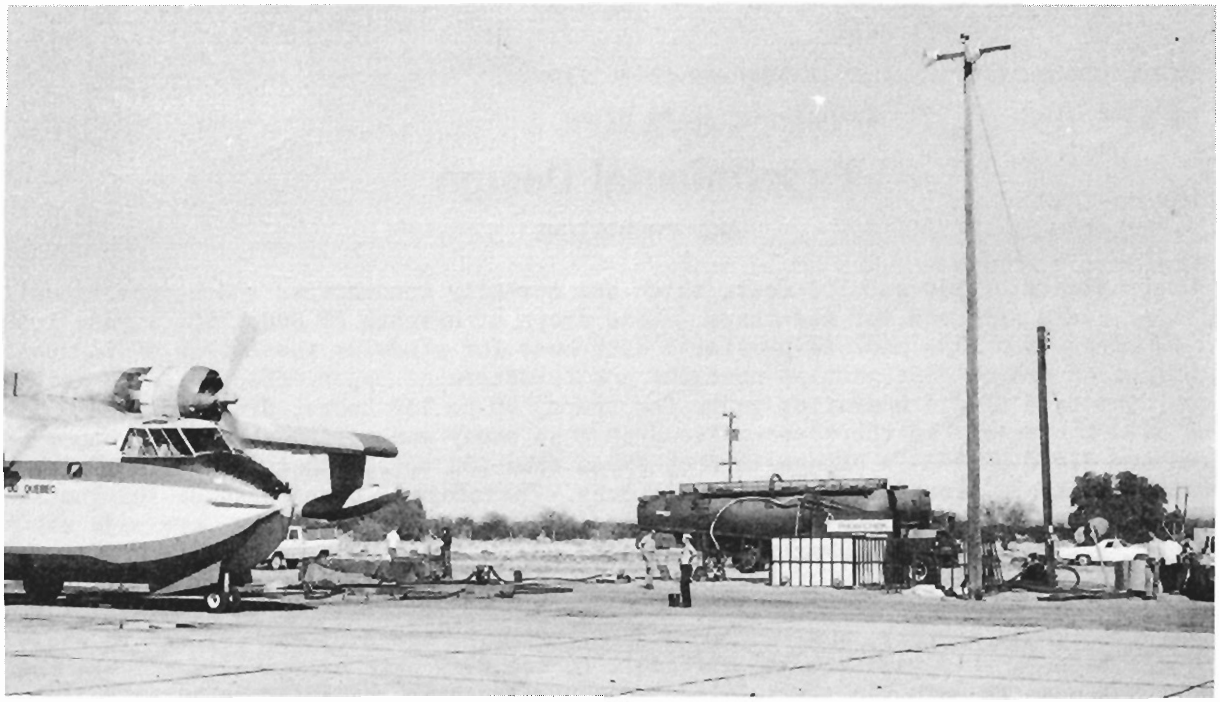


Figure 1.--Retardant mixing equipment and storage facilities used during the tests.

Simultaneous storage of the three retardant solutions and separate circulation and transfer pumps were desirable so that products could be randomly selected during the tests. The fill lines and CL-215 tanks were flushed with water before a new retardant was loaded. Problems caused by the sensitivity of Gelgard to contamination, water hardness, and storage in direct sunlight prevented completely randomized selection of retardants during the tests.

Tank and Gating System

The CL-215 tank system consists of two separate internal tanks with a capacity of 705.5 gallons each (600 Imperial gal), totaling 1,411 gallons. The capacity was determined with the tanks filled to the overflow or vent openings. For the test drops water was allowed to overflow, but retardants were not; although all loads were metered, control in the transfer system was such that the actual loads varied slightly (approximately ±10 gallons per tank). For computation and analysis purposes, loads of 700 gallons for a single tank drop and 1,400 gallons for a salvo drop were assumed. Either 700- or 1,400-gallon salvo drops or a 1,400-gallon sequential or "in-train" drop could be made. In the sequential drops the time interval between 700-gallon increments was at the discretion of the pilot.

One of the main objectives of the drop tests was to evaluate the CL-215 tank and gating system (fig. 2) through a detailed characterization of its drop performance. The dimensions of the tank and gating system and the time for door opening are the primary performance factors:

Gate opening: 31 by 61 inches (corners rounded) or 12.4 ft^2 per 700-gallon tank. Drop volume per unit area of gate opening: 56.5 gal/ft^2

Vent opening: 12-3/4 by 21 inches or 1.9 ft^2 per 700-gallon tank. Drop volume per unit area of vent: 376 gal/ft^2

Door-opening angle: 57° to 58.5° from fuselage (82° to 83.5° from horizontal)

Door-opening time: 0.5 s (single or salvo drop)

Release time: 0.75 s (single or salvo drop)

Experimental Design

DROP CONDITIONS

Drop heights of 150 and 300 feet, which are normally encountered under operational conditions, were selected for the tests. Some drops at heights of 500, 750, 1,000, 1,500, and 2,000 feet were also made to provide a data base for studying the effect of increasing drop height on ground distribution patterns and to determine upper effective drop height limits. The safe CL-215 operating range for drops, 90 to 135 knots, dictated drop speeds used in tests. In the Porterville drop test study made using the TBM "Avenger" (George and Blakely 1973) a change in drop speed from 100 to 125 knots had only insignificant effects on ground distribution patterns. Therefore, a drop speed of 105 knots was selected for a standard test condition and a minimal number of drops were made at 125 knots, slightly below the maximum safe speed.

Aircraft attitude was also thought to affect ground distribution patterns in that drop trajectory and history, and therefore drop patterns, are directly related to the attitude. Because this variable was difficult to quantify with existing equipment, the decision was made to hold the attitude constant by attaining desired drop heights far in advance of the release point. A few drops with changes in attitude were made by dropping in a bank, dive, and loft mode to determine the magnitude of the effect of

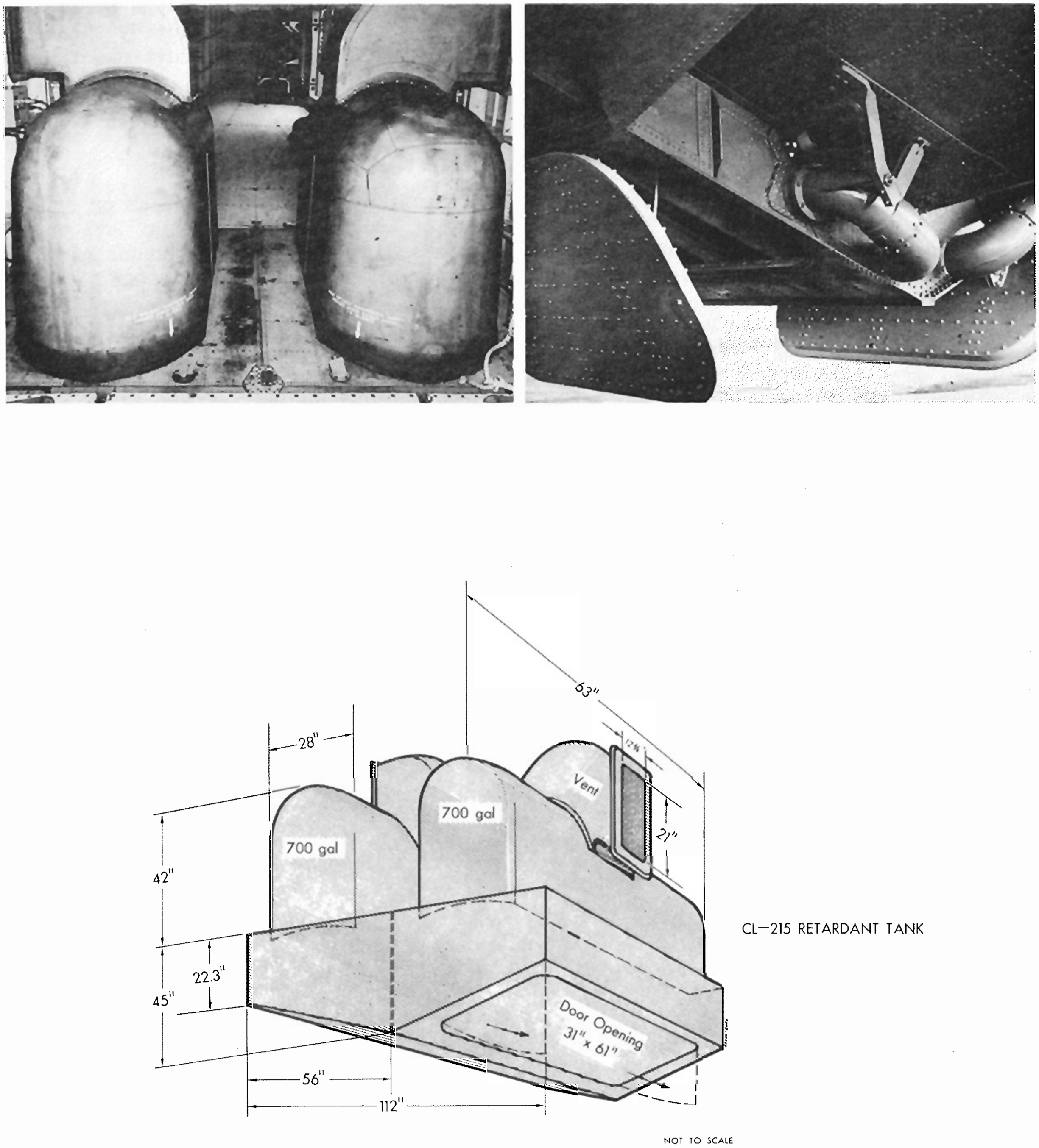


Figure 2.--CL-215 tank and gating system. Above left, *inside view of above-floor fiberglass tanks;* above right, *view of gates and water scooping snorkel;* below, *configuration and dimensions of the system.*

extreme differences in attitude on drop patterns. The effect of windspeed and wind direction, temperature, and relative humidity on drop patterns has been documented in previous studies (George and Blakely 1973) and thus no attempt to quantify these variables was made. It was hoped that drops could be made under wind conditions that would provide the least effect (<6 mi/h). A minimum temperature of 50°F and a maximum relative humidity of 50 percent were selected as condition goals for the study.

Test Matrix

After consideration of the objectives of the study and the influences on drop effectiveness, a test matrix (fig. 3) was selected that would provide maximum data on the performance of the CL-215 tank and gating system and quantify the influence of the variables while minimizing the number of drops performed.

The test matrix and a complete factorial design call for 320 drops. To reduce this requirement, it was decided that a minimum number of drops at 125 knots and in other than level flight would be performed. Also, it was recognized that as drop height increased, resulting average drop pattern concentrations would decrease to less than desirable levels (<1 gal/100 ft^2), and the drops at greater heights would not be necessary. With these limitations, approximately 75 drops would be required in a matrix that would lend itself to a multiple regression analysis and allow quantification of main effects and interactions. Significance of variables that were not factorialized in the matrix (aircraft speed, attitude) would be determined by comparison of means ("t" test).

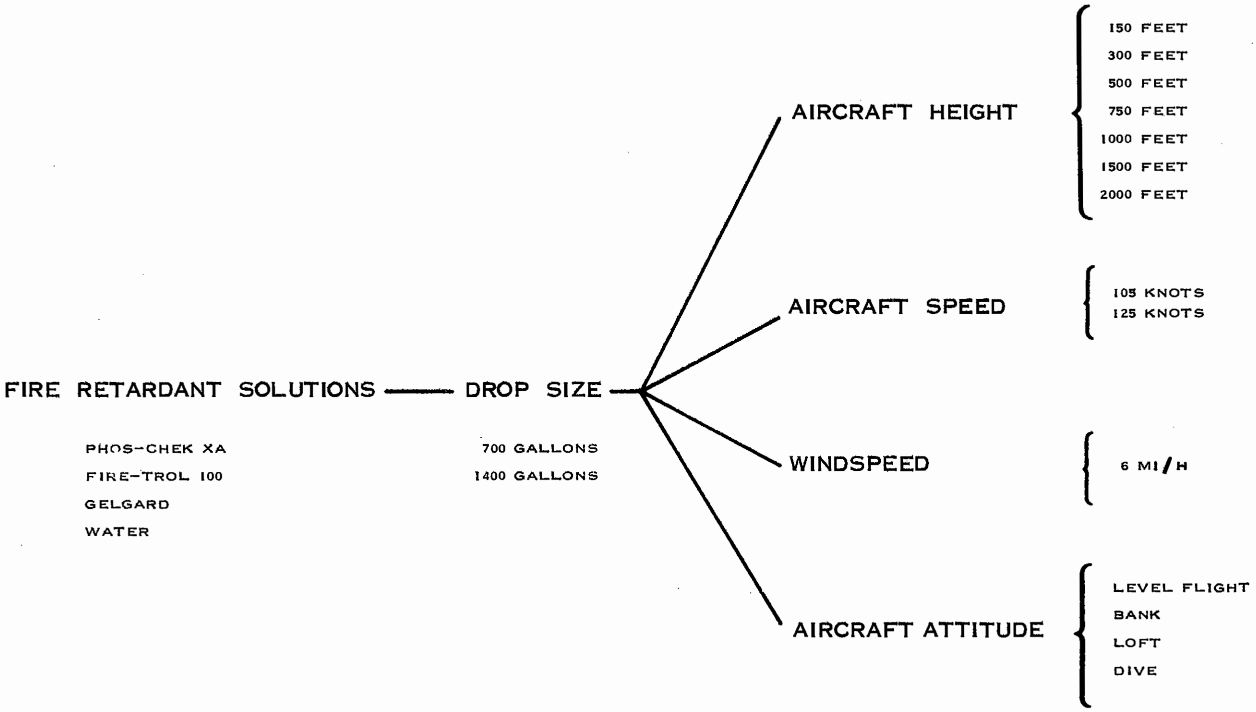


Figure 3.--Test matrix for the CL-215 tank and gating system evaluation.

MEASUREMENTS

The procedure used to sample and determine retardant characteristics, monitor environmental conditions during the drops, measure aircraft height and speed and retardant drop history, and determine ground distribution patterns was similar to procedures used in the Porterville retardant drop study (George and Blakely 1973). Minor changes made in some details are identified in the following discussion.

Retardant Properties

During the tests, samples were taken from the storage tanks and their quality was determined to assure uniformity in a standard mix at the recommended levels. The retardant was analyzed for salt content using the field method (George 1971b) and the viscosity was measured with the Brookfield Viscometer Model LVF at 60 r/min (National Fire Protection Association 1967; George and Hardy 1966). If deviations in the stored material occurred, proper adjustments could usually be made and the solution could be returned to a standard mix.

Before each drop, samples were taken from the aircraft and were similarly analyzed. In addition, a sample of this material was bottled and returned to the laboratory where the density was measured using a pycnometer and the salt content was chemically determined using the Kjeldahl method for nitrogen analysis (USDA Forest Service 1969). Only the viscosity and density of Gelgard were measured, as Gelgard forms a short-term salt-free solution.

After the drop had been made, a sample was taken by randomly consolidating the retardant received by several of the cups from the grid used for sampling ground distribution (described later in this paper). The composite sample was taken from more than 20 cups, after weighing. Its viscosity was recorded, and the sample was returned to the lab where its density and salt content were determined. The amount of water lost by evaporation during the drop was calculated from the difference in salt content before and after the drop. The weight of control samples handled under similar conditions was monitored; this indicated that evaporation before and after capping was insignificant. For the properties of each retardant used for each drop, the percent increase in salt content by evaporation, the corresponding water loss in gallons, and the percent of the original retardant drop that was lost due to evaporation, see Appendix I, tables 10-12.

Environmental Conditions

The environmental conditions monitored during the drop were windspeed, wind direction, temperature, and relative humidity. Wind measurements were made using a Teledyne Geotech Model 1657 wind system. The wind transmitter units were placed atop a 20-foot tower within 200 feet of the ground distribution grid. The transmitters were oriented in relation to the drop area and expected flight path so that the tailwind would be from 0°, a headwind from 180°, and a crosswind at right angles to the flight path from 90° and 270°. For the analysis, the wind direction was reduced to 0° to 180° left or right, because the effect of a crosswind was the same from either side at the same angle. Both windspeed and wind direction were recorded on strip chart recorders having a chart speed of 0.2 lineal inch per second. An event marker was used to denote the point at which the aircraft gates were opened and the point at which the first retardant hit the grid. Average windspeed and direction during the drop period were calculated from the recording.

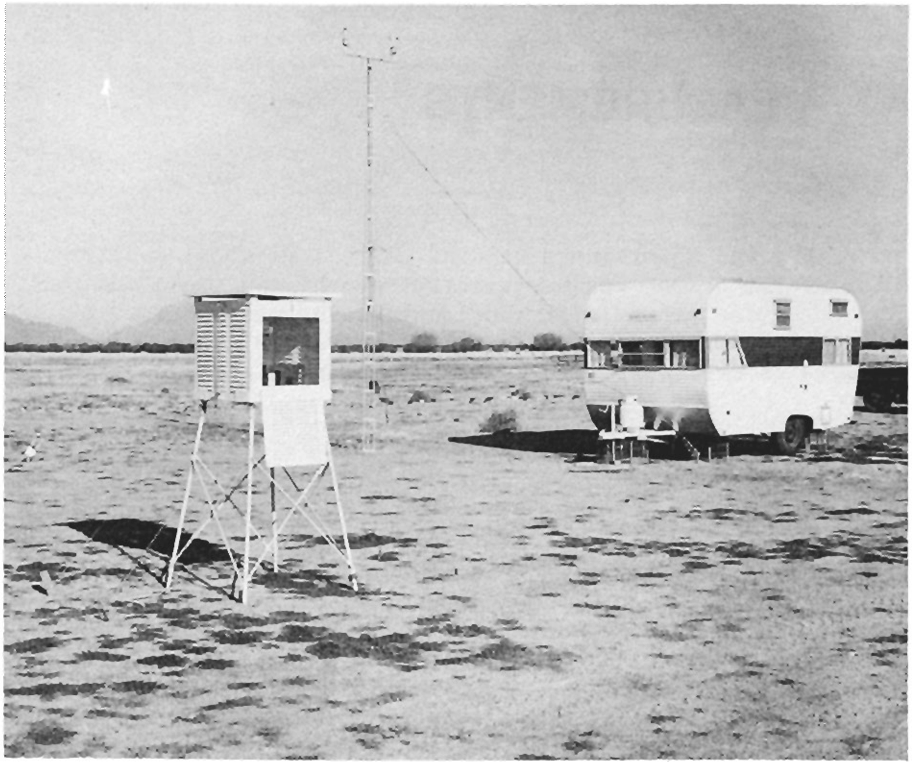


Figure 4.--Wind station and weather shelter situated adjacent to the grid.

The temperature and relative humidity were read from a hygrothermograph and a thermometer positioned in a weather shelter adjacent to the wind station at the time of the drop (fig. 4).

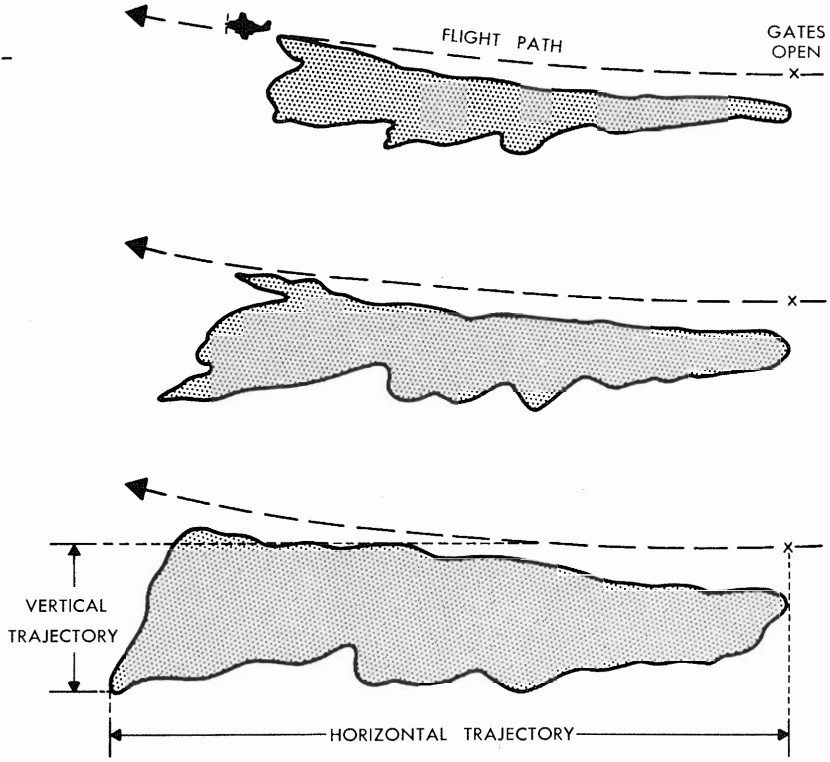
For average windspeed and direction, temperature, and relative humidity for each of the retardant drops, by product, see Appendix I, table 13.

Aircraft Height, Speed, and Retardant Drop History

Using the pressure altimeter and airspeed indicator, the pilot attempted to attain the desired drop height and speed with the maximum accuracy possible. Because variations in both drop height and speed are inevitable, precise height measurements were made from movie film taken from a right angle with a 70-mm Hulcher camera and from the 16-mm film taken from a front view. The aircraft's flight path and its distance from the ground distribution grid center line were determined from the 16-mm film. The 70-mm film was inspected with a microscope and the release point identified. Using the aircraft length as a base scale, the vertical distance to the ground level was calculated. Tick marks, placed electronically on the 70-mm film at 1/100-s intervals were used to calculate the groundspeed at the point of release.

The time required for the retardant to flow from the tank for the drops was determined using the 70- or 16-mm film. The 16-mm film was used when the 70-mm film was inadequate, but only after a comparison of times calculated from the two different films revealed that variations were insignificant. From the 70-mm film, the retardant drop trajectory was followed and the horizontal and vertical distance traveled from the release point calculated (fig. 5). Calculations were not possible for those drops where the release was slightly premature or late, causing the release or empty point to be out of view of the stationary camera. The elapsed time from the release point to initial retardant touchdown and the time required for the retardant to settle to the ground were determined using 16-mm film and the framespeed. The CL-215 making a water drop over the grid is shown in figure 6.

Figure 5.--Diagram showing the method for determining the horizontal and vertical trajectories.



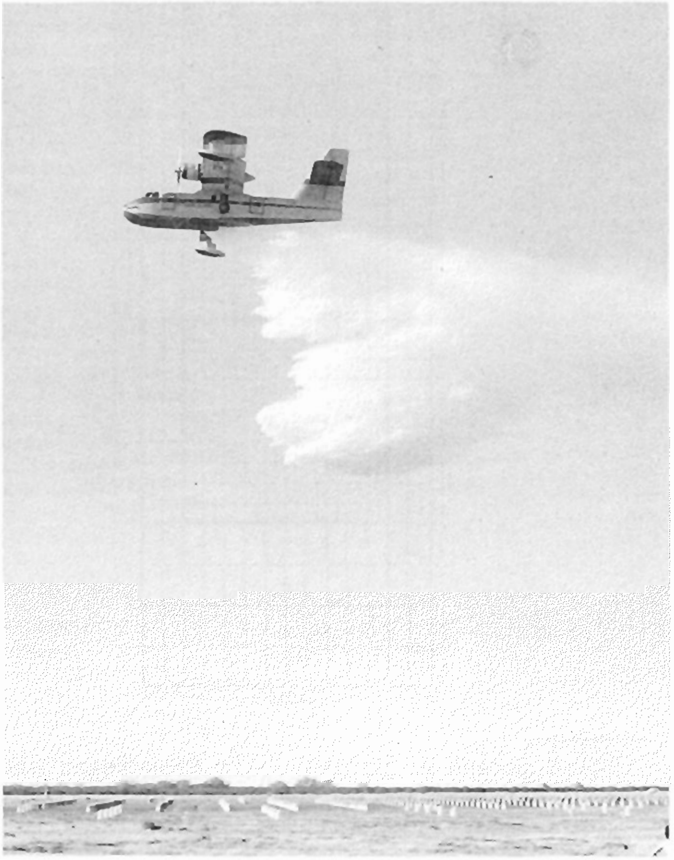


Figure 6.--The CL-215 making a water drop over the grid.

For drop height, aircraft groundspeed, retardant exit time, time to the ground, time to settle, and drop trajectories, see Appendix I, tables 14-17.

Ground Distribution Patterns

The method used for measuring the ground distribution patterns for all drops consisted of a grid system of cups, each cup representing a definite area. The cups were collected and weighed to provide a measure of the concentration at each grid point. Based on the results of previous drop studies (George and Blakely 1973; MacPherson 1967[1]), a grid which would best suit our expected drop dispersion patterns was laid out (fig. 7). The grid was divided into three portions: the inner grid containing 800

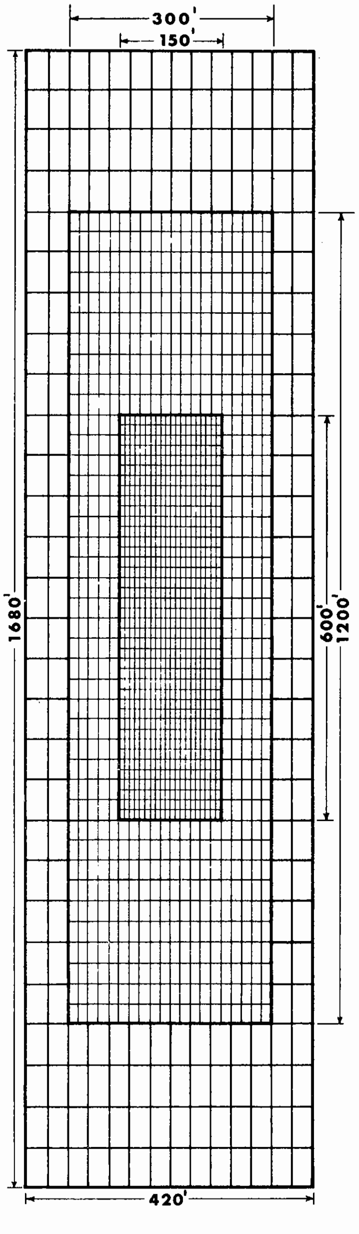


Figure 7.--Test grid. Cups are located at the center of each block. Inner grid, 800 blocks, each 7.5 by 15 feet; middle grid, 600 blocks, 15 by 30 feet; outer grid, 192 blocks, 30 by 60 feet.

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[1] Also Joseph E. Grigel. Air drop tests with the Snow Commander Airtanker and Gelgard F Fire Retardant. Master's Thesis on file at the School of Forestry, Univ. Mont., Missoula. 80 p., illus. 1970.

points in an area 150 by 600 feet; the middle grid containing 600 points and extending the grid to 300 by 1,200 feet; and the outer grid containing 192 points and extending the overall grid to 420 by 1,680 feet. The inner grid was sampled most intensively because it was expected to collect the majority of the pattern area. Each point in the inner grid represented an area 7.5 by 15 feet or 112.5 ft^2. Points in the middle grid represented an area 15 by 30 feet or 450 ft^2 while the points in the outer grid represented an area 30 by 60 feet or 1,800 ft^2.

At each point within the inner grid and in the five adjacent rows of the middle grid, was a polyethylene cup, permanently fastened to the lid of a foot-actuated garbage can. An identical cup was placed inside the first cup as the retardant receptacle. A rubber band, slipped around and over the two cups, held the inner cup from being blown out by drops made from lower heights, or by wind or drop turbulence. The garbage can was fastened to the ground with two hairpin-type stakes. The distance from the ground to the top of the cup was approximately 19.5 inches, a height which would prevent dirt or debris from being splattered into the cup when lower drops were made. At the remaining points in the middle and outer grid, a cup was permanently fastened to a plate welded to the top of a steel rod. Each rod had an identification plate and a metal stop which kept the rod at the proper aboveground cup height when in place. Both types of cupholders and the general grid layout are shown in figure 8. The garbage-can-type cupholders provided a base for the cup and space for the cups to be stored following capping after a drop. This allowed as many as five drops to be made before a collection of the inner grid was needed. Cups held by the stake-type holder were collected after each drop.

The cups used in the grid were 25.52 in^2 in area (5.7 inches in diameter) and were identical to those used in the Porterville study (George and Blakely 1973). The polyethylene cups and lids were weighed, and then separated into 0.5-gram categories and color coded. Cups were chosen for use so that the color code indicated a particular drop during the day as well as the tare weight. This size cup requires that approximately 14 grams of retardant be received to equal a concentration of 2 gal/100 ft^2. The Porterville study included tests indicating that the cup depth was adequate to prevent splashout of the cups at the lower drop heights. In addition, tests indicated that the grid sampling was sufficient and provided a measure of the expected variation (that is, the standard deviation as a function of concentration for the inner grid: for coverages of 3 gal/100 ft^2 and less, a standard deviation of less than 0.2 gal/100 ft^2 can be expected).

After no more than five drops, the cups were collected in compartmented boxes designed to hold two or more grid rows (fig. 9). The boxes were then moved to the weighing area where several top-loading Mettler balances were set up. The weight of the cup and retardant (in grams) was recorded for each of the drops (fig. 10).

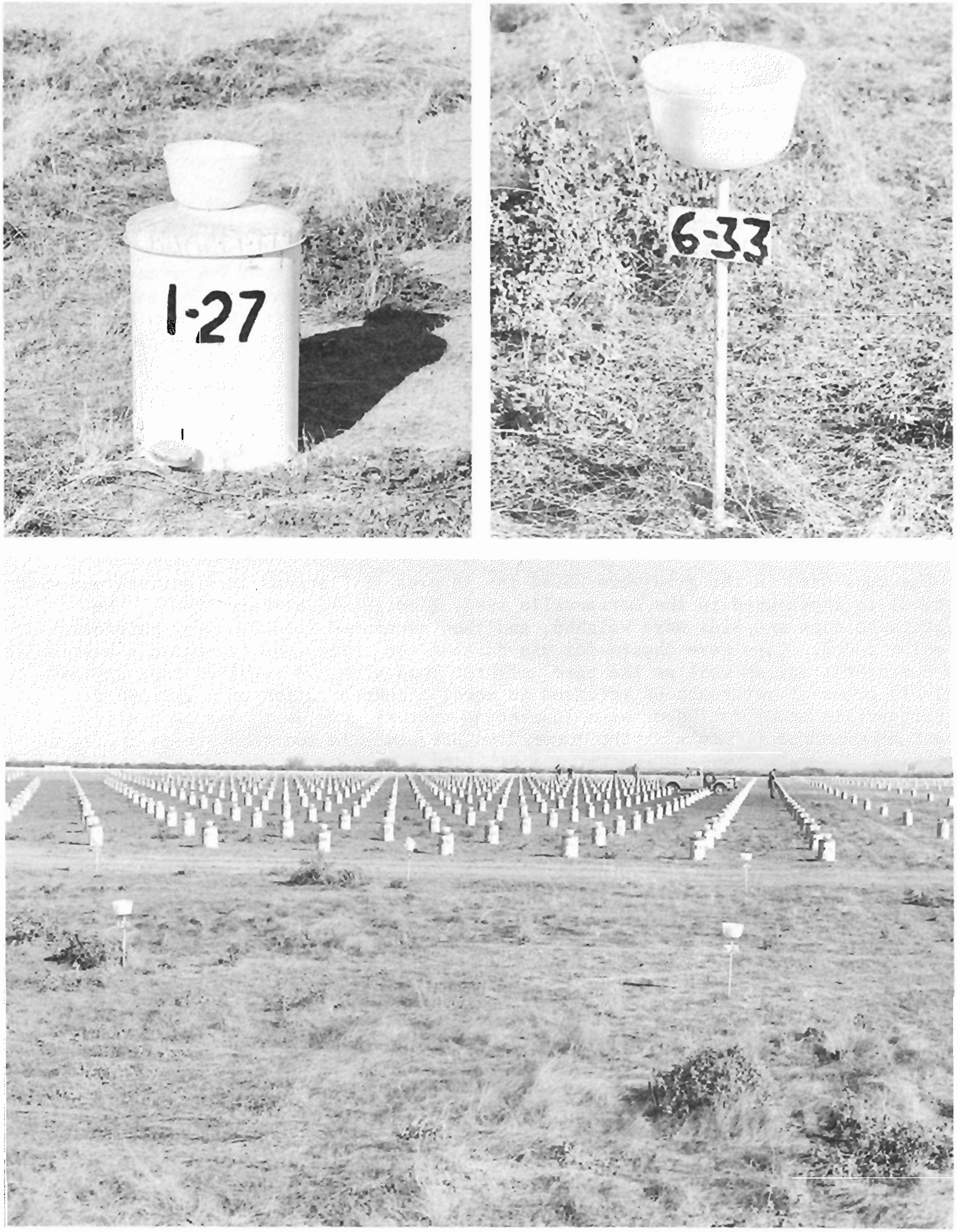

Figure 8.--The sampling method for ground distribution of retardant. Above, *types of cup holders used in the grid;* below, *general grid layout.*

Figure 9.--Collecting the cups following several retardant drops.

Figure 10.--Weighing and recording weights of collected cups.

ANALYSIS AND RESULTS

Compilation of Grid Data

The basic grid data, the cup and lid tare weights, environmental data, retardant characteristics, and drop conditions were put on computer cards. The weight of the retardant collected was converted to volume per unit area--the most commonly used unit is gal/100 ft^2. The conversion was made using the formula

$$R = K \left[\frac{W-T}{d/A}\right]$$

where

R = retardant coverage (gal/100 ft^2)
K = conversion factor for units
W = weight of cup, lid, and retardant (g)
T = tare for cup and lid (g)
d = density of retardant (g/cc)
A = area of cup (25.52 in^2)

or

$$R = 0.1491 \left[\frac{W-T}{d}\right] \text{gal/100 ft}^2.$$

Because the area represented by the inner, middle, and outer grid points varied, R was weighted in calculation of total volume as follows:

Inner grid points, volume = 1.125R gallons
Middle grid points, volume = 4.5R gallons
Outer grid points, volume = 18.0R gallons.

The total retardant reaching the grid was thus calculated as

Total retardant = Σ 1.125R inner grid points + Σ 4.5R middle grid points + Σ 18.0R outer grid points.

A computer program which summarized the grid data was set up. Volume of retardant recovered, in gallons per 100 ft^2, was calculated as a total for each of a series of concentration classes ranging from <0.02 to >5 gal/100 ft^2. The total area within each concentration class (area of coverage) was also calculated. A summary of these classes gives the total area covered and the total gallons recovered in the grid. A breakdown of areas and gallons by concentration class is provided in Appendix I, tables 18-25.

A computer program that would plot the concentration calculated for each grid point was developed. The plot was made to scale, with the decimal point for each concentration on the printout representing the location of the grid point. Using a method of linear proportioning, contour lines were hand drawn for concentrations of 0.2, 0.5, 1, 2, 3, and 4 gal/100 ft^2. From the distribution patterns, maximum lengths of the areas enclosed by the contour lines (to be called here "contour areas") for each concentration were determined. The 2 gal/100 ft^2 contour area is of special interest because studies of retardant effectiveness have shown that this is the minimum concentration that will produce a maximum reduction in the rate of spread, intensity, and radiation in a light fuel (0.5 lb/ft^2 or 11 tons/acre) when the retardant has lost all its moisture (George and Blakely 1972; USDA Forest Service 1969). The length of the 2 gal/100 ft^2 contour area with minimum widths of 5 and 10 feet, as well as the maximum contour area width, was measured. These 2 gal/100 ft^2 dimensions, as well as the lengths of each contour area, are given in Appendix I, tables 26-29.

Ground Pattern Responses

The criterion of drop effectiveness depends on the mode of retardant attack (direct or indirect) under actual conditions, and the strategy used (hotspotting, linebuilding, etc.). Either the length of adequate line built or the area of coverage and concentration for a drop may be the most important criterion. The value of a drop is always related, however, to the volume of retardant reaching the fuel. Thus, several ground pattern responses should be quantified and treated as dependent variables:

1. The total volume of retardant reaching the ground (recovery) and the distribution of this retardant per unit area;
2. The area of coverage at each concentration level; and
3. The dimension or length of each isoconcentration contour area.

The independent variables in the test matrix (fig. 3) were type of retardant, load size, drop height, aircraft speed, and aircraft attitude. The effect of wind, previously quantified in the Porterville study (George and Blakely 1973), was minimized and assumed constant because drops were made under low wind conditions. (The average windspeed for all drops was 5.8 mi/h; standard deviation $S_D = \pm 2.3$, standard error of the mean $S_m = \pm 0.26$.) Visual inspection of the data indicated that load size and drop height had the greatest effect on ground pattern responses (retardant recovery, area of coverage, and contour length). The ground responses were first plotted three dimensionally as a function of drop height and concentration for each retardant and load size. The aircraft speed, windspeed, and aircraft attitude for each point were then identified. Visual inspection of the data indicated that only aircraft speed had an effect of sufficient magnitude to cause the responses to fall outside the group data. On the basis of these plots, all responses except those for the few drops at higher aircraft speed (125 knots) were grouped, leaving type of retardant, load size, drop height, and aircraft speed as primary independent variables.

Retardant Recovery

Covariance analysis of the total retardant recovered as a linear function of drop height was undertaken for each type of retardant and load size. Results of the analysis suggest real differences existed between all retardants except Fire-Trol 100 and water. Phos-Chek XA gave the greatest recovery, followed by Gelgard and then Fire-Trol 100 and water. The effect of load size on percent recovery was not significant except for water and for water and Fire-Trol 100 pooled. Lack of significance between load size for the other retardants probably reflected a variation within the data that was as great or greater than the influence of real differences in load size. In figure 11, the effect

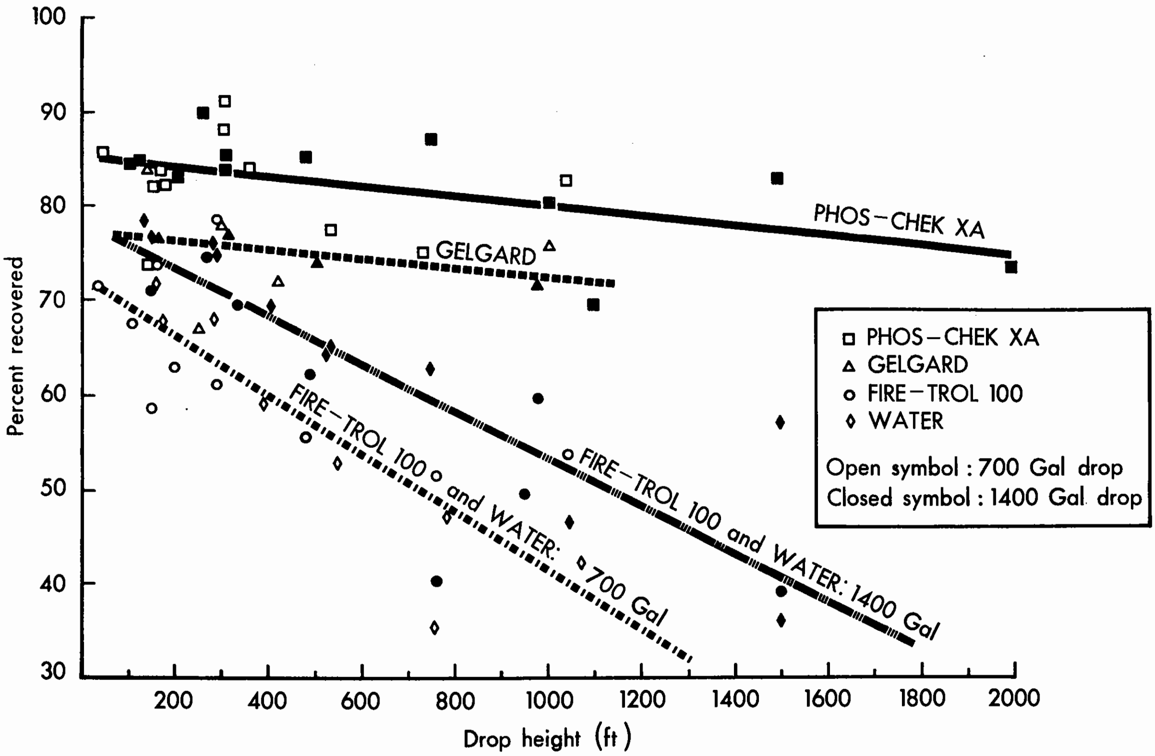

Figure 11.--Effect of drop height on percent of total retardant reaching the ground.

of drop height on total recovery, and the magnitude of differences between retardants are indicated by a plot of the actual drop data. The linear equations and the R^2 values (coefficients of multiple determination) indicating their goodness of fit, the data limits, and the results of tests for significance of differences between retardants are given in table 2. Predictions for the equations were calculated (table 3). In these predictions of total recovery (percent) for Phos-Chek XA and Gelgard, the two load sizes were pooled in the equations because load size did not cause a significant difference in recovery. For water and Fire-Trol 100, predictions were made from equations pooling drops of load size for Fire-Trol 100 and water for each load size, because 700-gallon drops of Fire-Trol 100 and water pooled were significantly different from 1,400-gallon drops of both retardants pooled.

Although the volume of retardant recovered is strongly indicative of effectiveness, the manner of distribution of this retardant is also important. The amount of retardant within concentration classes at increments of 0.5 gal/100 ft^2 was plotted against drop height. Visual inspection revealed that relationships were nonlinear and thus smooth curves in accord with expectation were fitted through these points. Because real differences in total retardant recovered for each type of retardant and load size appeared to exist in the simple linear models of the relationship, an algebraic portrayal of the drop height-retardant concentration (distribution) interaction was undertaken for each retardant and load size.[2] The algebraic models for the distribution are given in Appendix II in the form of FORTRAN IV statements for simplicity.

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[2] This method is similar to the one used by George and Blakely (1973) in the Porterville study in an analysis of retardant drop patterns and drop characteristics. For each retardant and load size, expected algebraic forms as a function of drop height for concentration classes ≥0.2, ≥1.0, ≥1.5, ≥2.0, etc., to ≥4.0 gal/100 ft^2 were fitted to the data by approximate least deviations. These resulting curves were described and formulated as surfaces using algebraic forms identified from Matchacurves I and II (Jensen and Homeyer 1970, 1971). An algebraic portrayal of the retardant recovered within a concentration contour area greater than or equal to each concentration level as a function of drop height was thus developed.

TABLE 2.--EQUATIONS FOR PREDICTION OF TOTAL RETARDANT RECOVERY FOR FOUR RETARDANTS AND TWO LOAD SIZES

Retardant	Load size	Data limits for drop height	Number of drops	Fit of equation to data: R^2	Equation[1]	Significance[2] Level
	Gallons	*Feet*			*Gallons*	*Percent*
Phos-Chek XA		51-2,000	23	0.25	REC=85.18-0.005354DH	99
Gelgard	Two sizes pooled	147-1,000	9	.10	REC=77.13-0.004639DH	99
Fire-Trol 100		39-1,500	18	.63	REC=72.23-0.02217DH	NS
Water		137-1,500	20	.62	REC=75.18-0.02487DH	
Water and Fire-Trol 100	700	39-1,073	19	.66	REC=72.30-0.02882DH	99
Water and Fire-Trol 100	1,400	137-1,500	19	.74	REC=78.45-0.02530DH	
Water and Fire-Trol 100	Two sizes pooled	39-1,500	38	.62	REC=75.67-0.02350DH	

[1] REC = Predicted Total Recovery (percent); DH = Drop Height (feet)

[2] NS = No significant difference between retardants existed for that particular response. Therefore, the pooled model should be used for predictions. Phos-Chek XA and Gelgard are significantly different at the 99 percent level and the individual regression equation should be used for predictions.

TABLE 3.--PREDICTIONS OF TOTAL RETARDANT RECOVERED AS A FUNCTION OF DROP HEIGHT FOR FOUR RETARDANTS

Drop height	Retardant			
			Fire-Trol 100 or water	
	Phos-Check XA	Gelgard	700-gallon drop	1,400-gallon drop
	Percent			
150	84	76	68	75
300	84	76	64	71
500	82	75	58	66
750	81	74	51	59
1,000	80	72	43	53
1,500	77	70	29	41
2,000	74	68	15	28

$$\text{Percent recovered} = b*YP*\left\{\frac{e^{-\left|\frac{\frac{6000\,-\,DH}{XP}\,-\,1}{1\,-\,I}\right|^{N}} - e^{-\left(\frac{1}{1\,-\,I}\right)^{N}}}{1 - e^{-\left(\frac{1}{1\,-\,I}\right)^{N}}}\right\}$$

where:

$b = 0.9898$
$XP = 6000$
DH = Drop height (ft)
C = concentration (gal/100 ft^2)

$$n = 1.45 + 0.55 * \left[\frac{e^{-\left|\frac{\frac{4\,-\,C}{3}\,-\,1}{.43}\right|} - 0.00479}{0.9955}\right] - 2.728 \times 10^{-13} * (4 - C)^{20}$$

$$I = 0.915 - 0.0401 * (4 - C)^{1.64} - 0.4868\left[e^{-\left|\frac{\frac{4\,-\,C}{3.8}\,-\,1}{0.193}\right|^{1.8}}\right]$$

$$YP = 64.9 + 5.525 * (4 - C)^{0.82} + 4.892\left[e^{-\left|\frac{\frac{4\,-\,C}{4}\,-\,1}{0.135}\right|^{1.5}}\right]$$

Figure 12.--The equation developed for the interaction between drop height and retardant distribution for 1,400-gallon drops of Phos-Chek XA.

The equation corresponding to the FORTRAN IV statement for 1,400-gallon Phos-Chek XA drops (fig. 12) illustrates the algebraic form of the interaction. Graphic forms for these models are shown in figures 13 and 14. Predicted values for the surfaces have been calculated and are presented in Appendix I, tables 30-33. Note that predictions of total recovery from the linear total recovery equations are somewhat larger than predictions from the algebraic distribution models at the ≥ 0.2 gal/100 ft^2 concentration level. The difference in predicted values is the amount of retardant falling in a trace category (0 to <0.2 gal/100 ft^2 concentration). Appendix I, table 34, gives the R^2 value at various concentration levels and the standard error of the estimate ($s_{y \cdot x_i}$) for each of the algebraic models for retardant and load size. (Note that an unknown number of degrees of freedom have been sacrificed in the development of the model surfaces, so that fairly strong data trends could be made evident. As a result, the estimates of the $s_{y \cdot x_i}$ may be conservative here.)

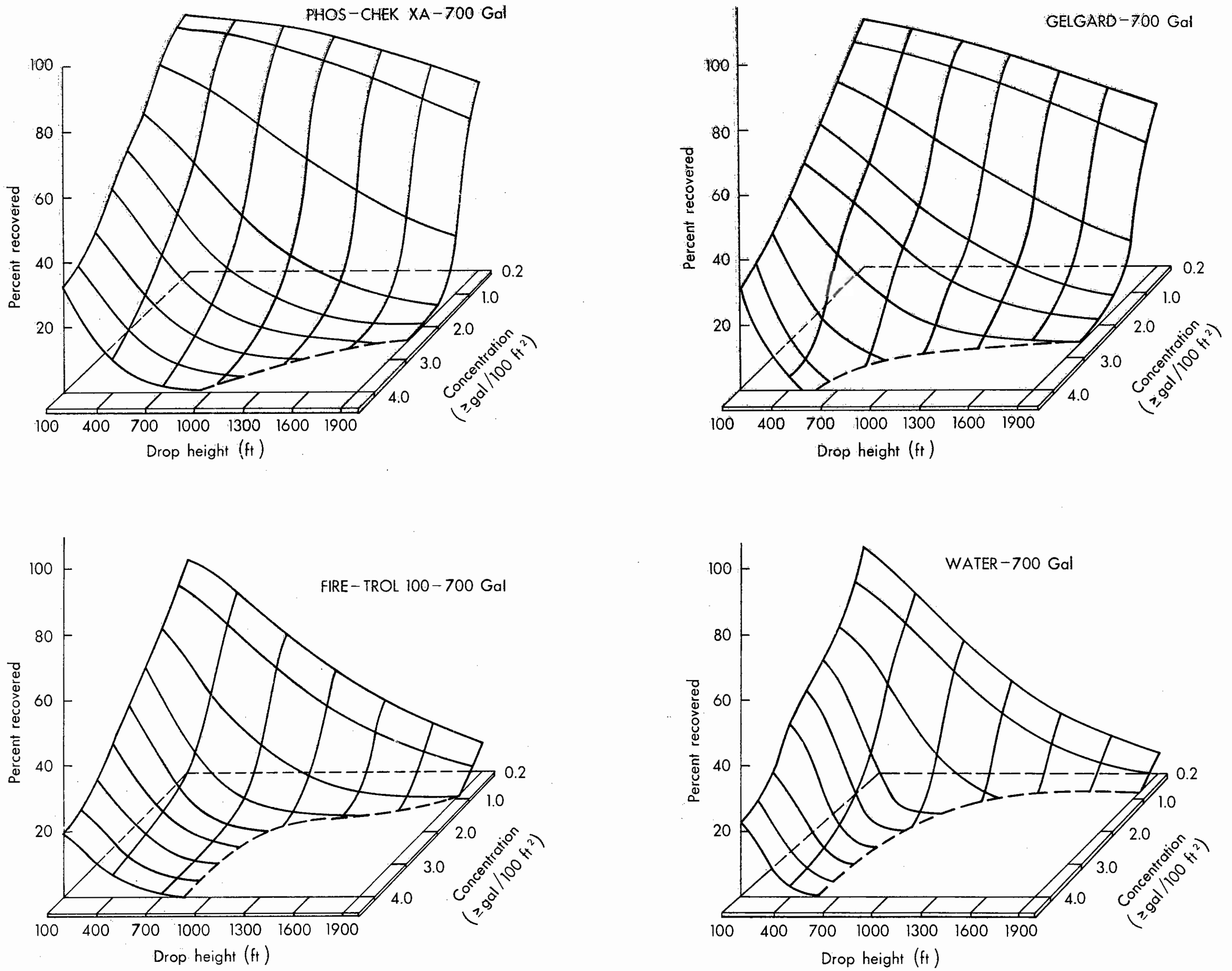

Figure 13.--Three-dimensional models for the distribution of 700-gallon drops of the four retardants, as a function of drop height and level of concentration.

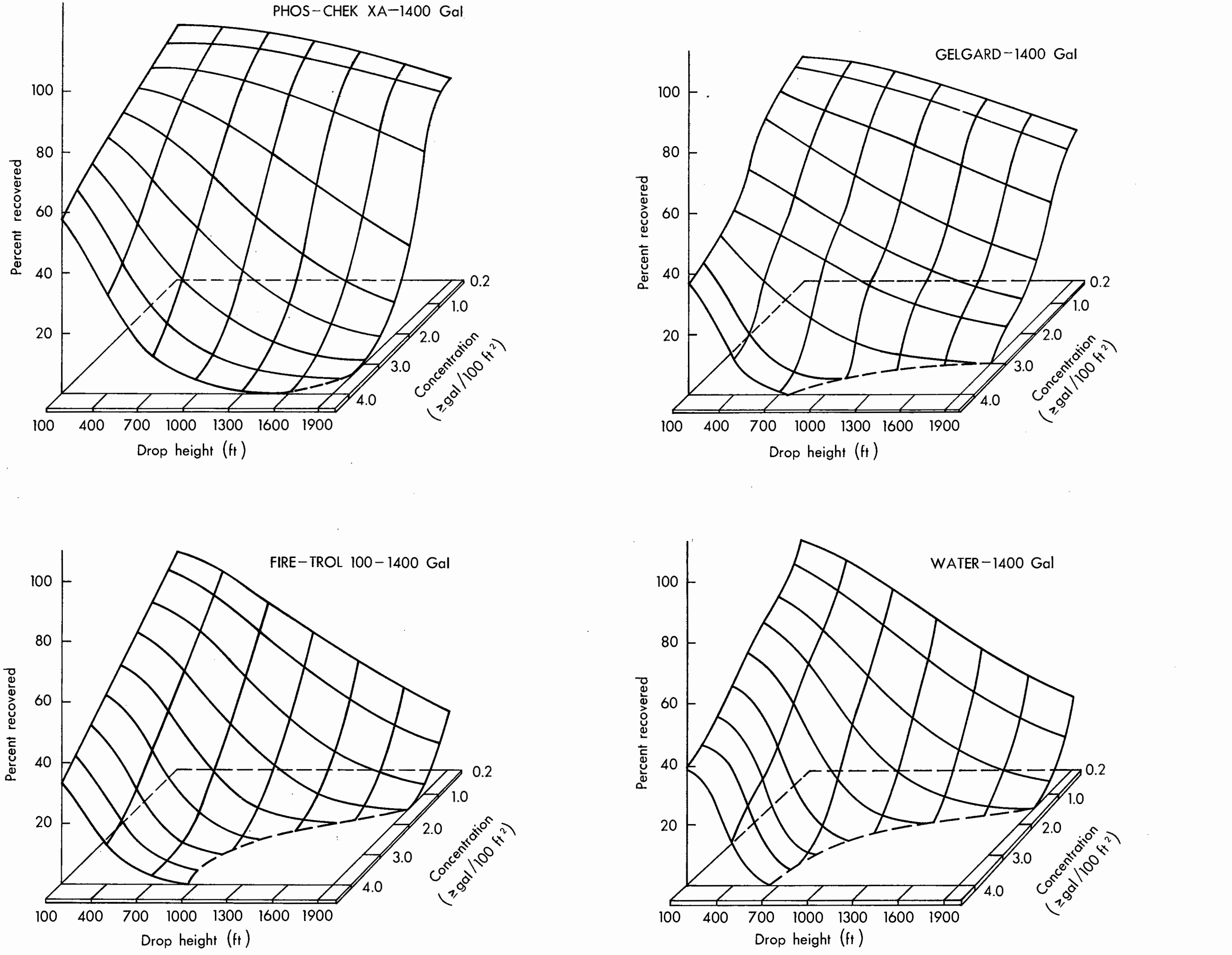

Figure 14.--Three-dimensional models for the distribution of 1,400-gallon drops of the four retardants, as a function of drop height and level of concentration.

Area of Coverage

The method used for analyzing the distribution of retardant reaching the ground was also used for analyzing the areas of coverage. Visual inspection of the data revealed large differences in the areas covered at different concentrations, as a function of load size. In areas of coverage, the differences between the retardants as a function of drop height appeared greater than the previously determined differences in retardant recovery by concentration level, as a function of drop height.

Load size obviously had a strong influence on area covered at selected concentration levels; the effect was much more pronounced than that of load size on percent recovery and distribution. Thus, models to predict area of coverage would require drop height and concentration level as independent variables for each type of retardant and load size. To predict areas of coverage at various concentration levels as a function of drop height, algebraic equations (models) were developed for each retardant and load size.

From the algebraic models, which are given as FORTRAN IV statements in Appendix II, for each retardant and load size, predictions of area of coverage were made (tables 35-38); graphic forms of these models were drawn and are shown in figures 15 and 16. Table 39 gives the R^2 values at various concentration levels and the standard error of the estimate ($s_{y.x_i}$) for each of the retardant and load size models. The three-dimensional models for area of coverage at each concentration level, as a function of drop height, show the magnitude of differences between both drop size and type of retardant. From the predictions, the drop height providing the maximum area of coverage at 0.2, 1, 2, 3, and 4 gal/100 ft^2 was determined. These drop-height values clearly illustrate the difference in drop characteristics of the retardants and the effect of load size (table 4).

The 2 gal/100 ft^2 concentration level previously discussed as a minimum effective concentration falls approximately in the center of the range of concentrations for all model surfaces (fig. 13-16); whereas, the 4 gal/100 ft^2 level is the upper concentration limit on these surfaces. Drop patterns from presently used aircraft[3] that are known to perform effectively under operational conditions, as well as the patterns from the CL-215, show that only small areas of concentration greater than 4 gal/100 ft^2 occur. It can, therefore, be rationalized that the 2 and 4 gal/100 ft^2 concentration levels are appropriate limits at which the performance of different retardants and tank and gating systems can be compared.

Assuming 2 and 4 gal/100 ft^2 to be effective concentrations in specific situations, depending on the fire, fuel, topography, weather, etc., some conclusions on effective drop heights can be made. Effective 700-gallon drops of Phos-Chek XA, for example, can be made from 100 to 600 feet if coverage of 8,400 to 8,900 ft^2 at 2 gal/100 ft^2 is adequate (with winds averaging 5.8 mi/h). If 4 gal/100 ft^2 are required, drop heights of 100 or 150 feet will provide 2,700 to 3,000 ft^2 of coverage. Drop heights can be greatly increased with larger drop sizes. Areas of coverage of between 16,000 and 23,000 ft^2 at the 2-gallon concentration level can be attained with 1,400-gallon Phos-Chek XA drops at any drop height between 100 and 1,400 feet; the maximum occurs at 806 feet (23,413 ft^2 of ≥ 2 gal/100 ft^2 coverage). If 4 gal/100 ft^2 concentrations are needed, 6,500 to 7,500 ft^2 of coverage can be achieved at drop heights between 100 and 500 feet (the maximum occurs at 200-foot drop heights). Water or Fire-Trol 100 can only approach the lower portion of this range of areas of coverage at drop heights near or below 200 feet.

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[3] Drop pattern data from 1972 Marana drop test. Data on file at the Northern Forest Fire Laboratory, USDA Forest Service, Missoula, Montana.

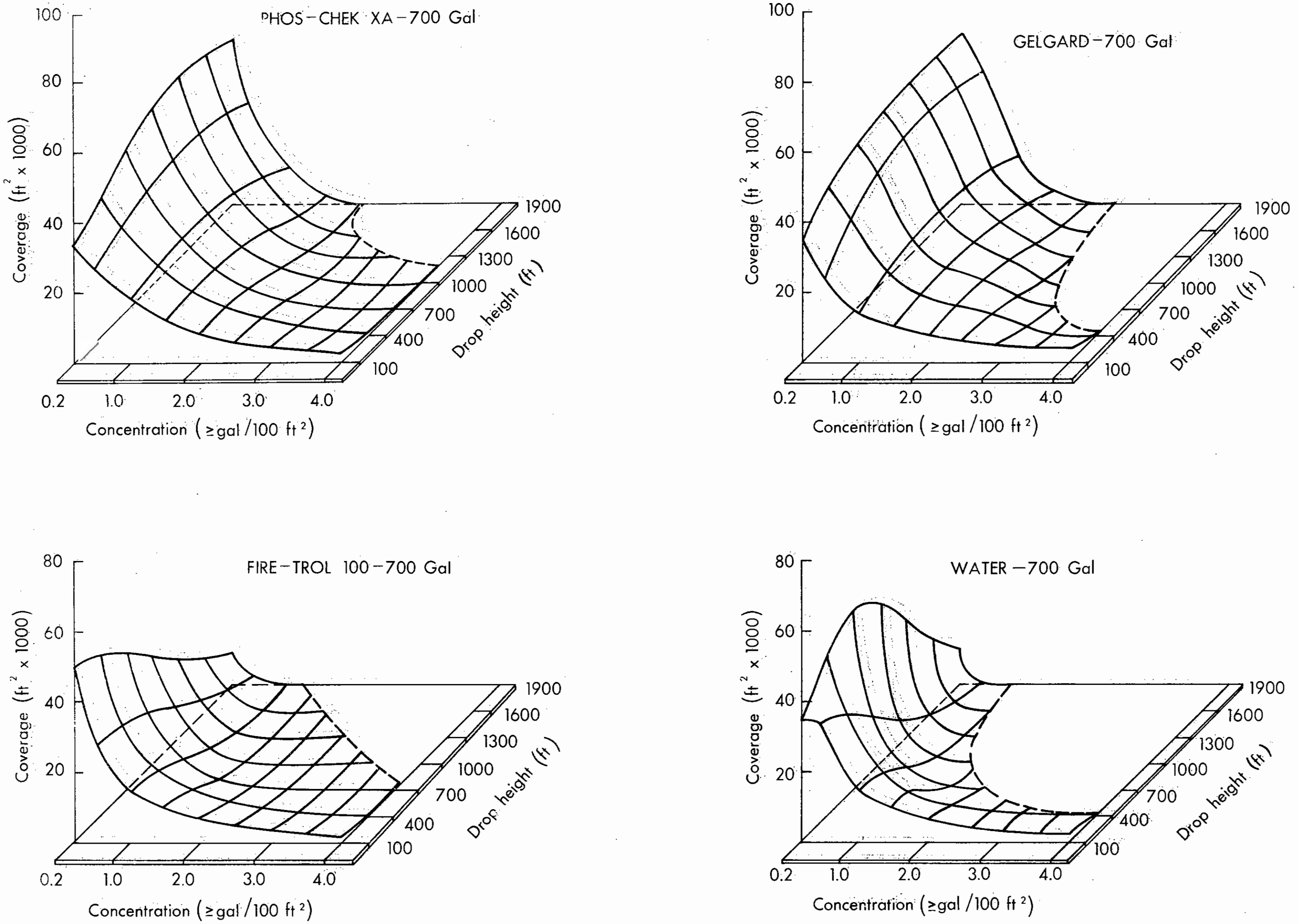


Figure 15.--Three-dimensional models for the area of coverage by 700-gallon drops of the four retardants, as a function of drop height and level of concentration.

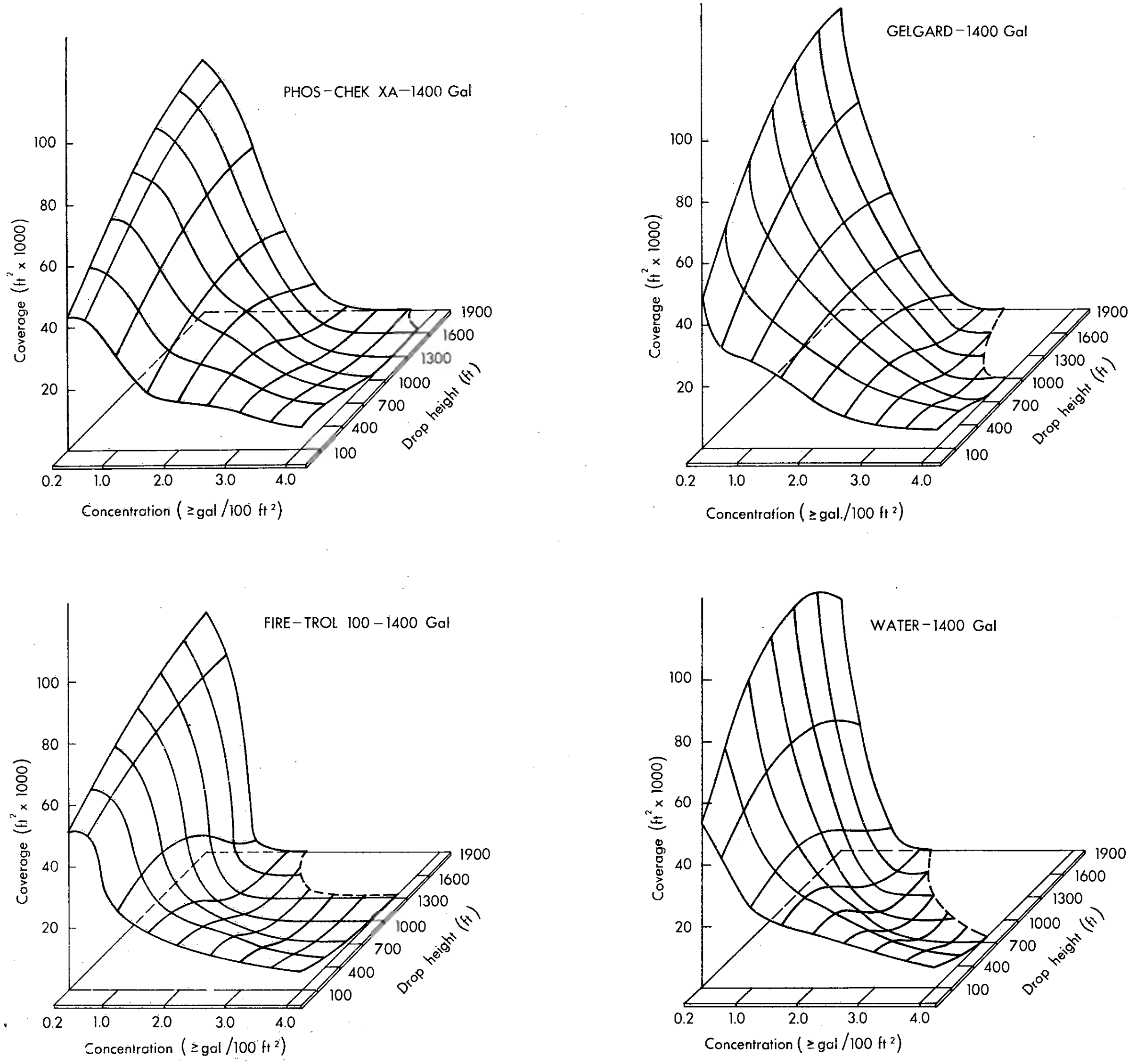


Figure 16.--Three-dimensional models for the area of coverage by 1,400-gallon drops of the four retardants, as a function of drop height and level of concentration.

TABLE 4.--DROP HEIGHTS PRODUCING THE MAXIMUM COVERAGE FOR EACH OF FOUR RETARDANTS AND TWO LOAD SIZES, BY CONCENTRATION LEVEL[1/]

Concentration level (gal/100 ft^2)	Phos-Chek XA		Gelgard		Fire-Trol 100		Water	
	Drop height	Max. area covered	Drop height	Max. area covered	Drop height	Max. area covered	Drop height	Max. area covered
	Ft	*Ft*^{2}	*Ft*	*Ft*^{2}	*Ft*	*Ft*^{2}	*Ft*	*Ft*^{2}
				700-GALLON LOAD				
0.2	1,314	51,983	1,400	49,810	150	49,517	697	50,748
1	733	20,598	1,007	20,677	150	14,482	150	14,522
2	268	8,994	404	8,711	150	7,020	150	6,936
3	150	4,715	150	5,143	150	3,083	150	3,234
4	150	2,688	150	3,367	150	1,500	150	2,124
				1,400-GALLON LOAD				
0.2	2,000	82,160	1,750	98,851	2,000	77,286	1,273	94,710
1	1,598	54,507	1,250	42,898	586	29,977	595	30,863
2	806	23,413	701	19,615	150	14,860	163	17,817
3	288	12,739	352	8,705	150	9,480	150	11,718
4	200	7,634	150	5,895	150	5,627	150	7,166

[1/] A minimum drop height of 150 feet is given because this height was generally near the lower drop test limits for each retardant. In comparing areas of coverage between retardants at a particular concentration level (horizontally), note the difference in corresponding drop heights.

Contour Area Lengths

The maximum length of contour areas was analyzed as a function of drop height at the ≥0.2, ≥1, ≥2, ≥3, and ≥4 gal/100 ft^2 concentration levels. Since real differences existed in the total recovery covariance analysis for the different retardants and load sizes, it was assumed that real differences would also be found for these variables in the contour length analysis.

The contour area lengths for each concentration class were plotted over drop height, and smooth curves in accord with expectation were fitted through these points. Inspection of these relationships revealed them to differ by type of retardant and load size. Thus again, an accurate algebraic portrayal of the drop height-contour length interaction was undertaken for each retardant and load size.

The algebraic models (Appendix II) are shown graphically in figures 17 and 18 and predictions from these models are given in Appendix I, tables 40-43. The R^2 values at various concentration levels and the standard error of the estimate ($s_{y \cdot x_i}$) for each retardant and load size model are given in table 44. The results of the analysis and a comparison of predictions suggest that in most situations the gum-thickened Phos-Chek XA produces longer pattern lengths (especially at concentrations of 1 to 4 gal/100 ft^2, which are usually necessary to provide effective coverage--table 5). Phos-Chek XA also produces tighter patterns (larger percentage of the higher concentration levels relative to the total pattern areas) as compared to the other retardants used in the drop tests.

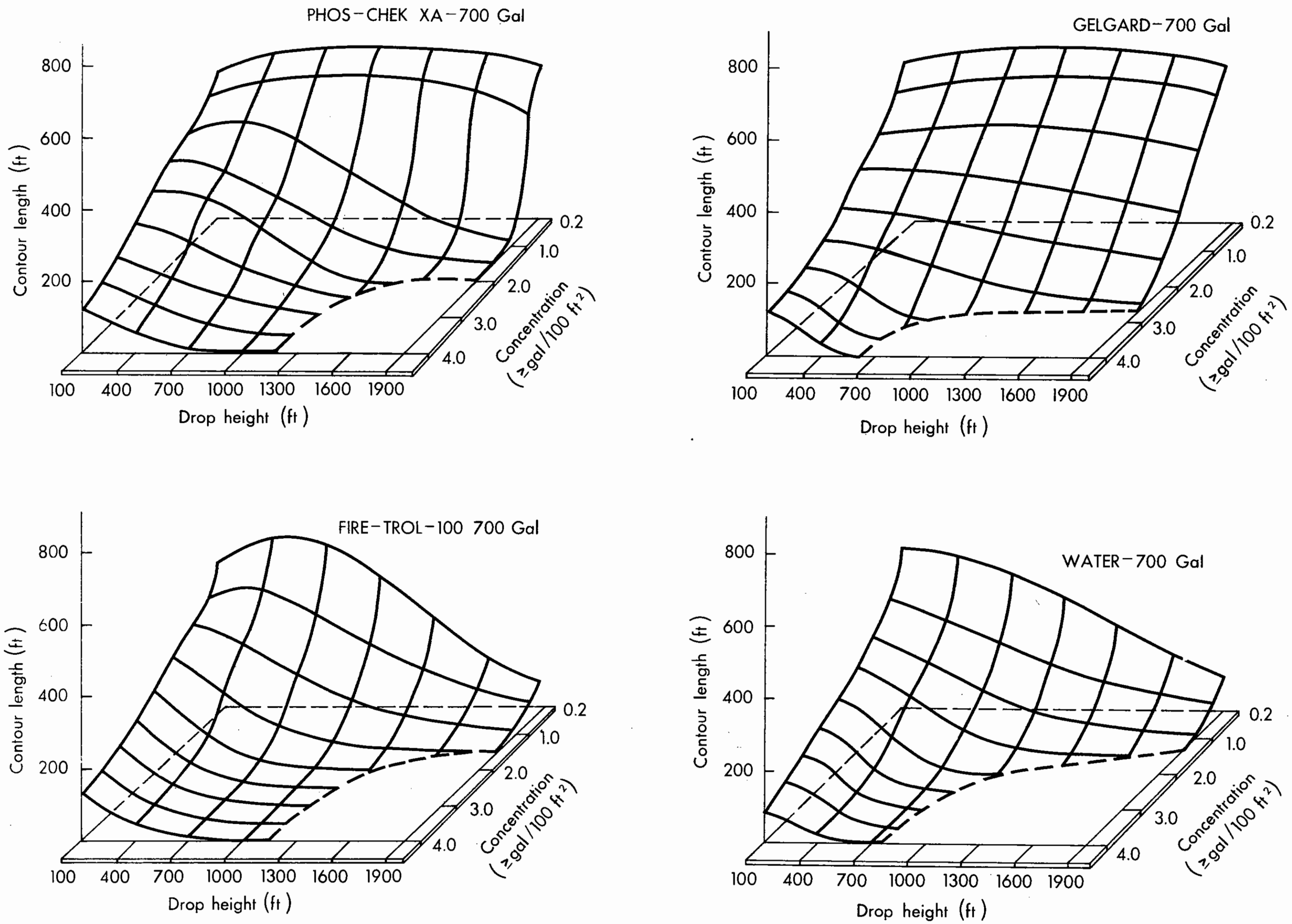
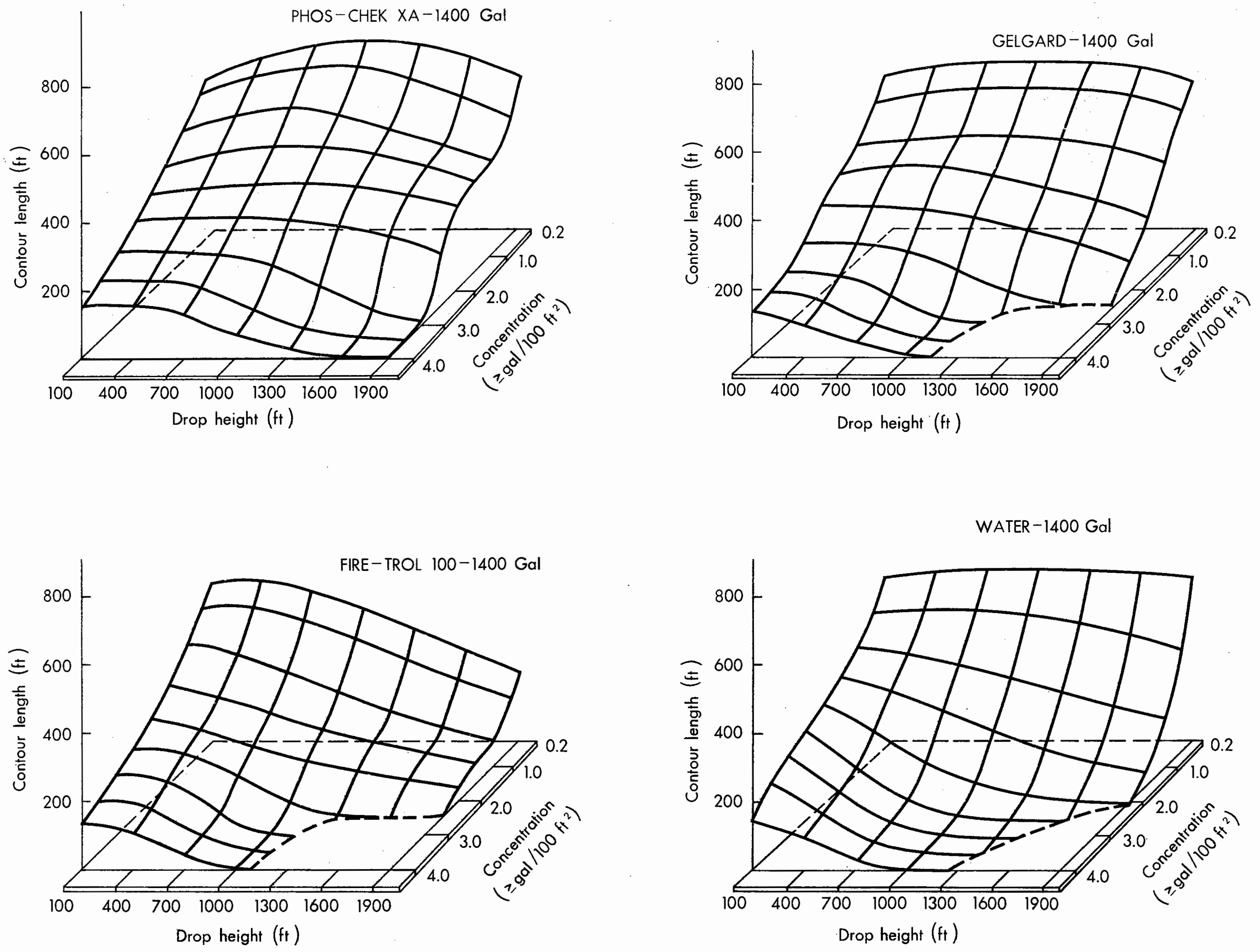


Figure 17.--Three-dimensional models for contour area lengths of 700-gallon drops of the four retardants, as a function of drop height and level of concentration.


PHOS-CHEK XA-1400 Gal

GELGARD-1400 Gal

FIRE-TROL 100-1400 Gal

WATER-1400 Gal

Figure 18.--Three-dimensional models for contour area lengths of 1,400-gallon drops of the four retardants, as a function of drop height and level of concentration.

TABLE 5.--DROP HEIGHTS PRODUCING MAXIMUM LENGTH OF FIRELINE FOR EACH OF FOUR RETARDANTS AND TWO LOAD SIZES, BY CONCENTRATION LEVEL[1]

Concentration level (gal/100 ft^2)	Phos-Chek XA		Gelgard		Fire-Trol 100		Water	
	Drop height	Line length	Drop height	Line length	Drop height	Line length	Drop height	Line length
	Feet							
	700-GALLON LOAD							
0.2	1,050	470	1,000	481	500	466	150	439
1	347	345	808	341	150	298	150	262
2	150	257	150	211	150	198	150	194
3	150	175	150	141	150	144	150	137
4	150	120	150	110	150	114	150	77
	1,400-GALLON LOAD							
0.2	1,000	548	1,000	483	300	461	150	479
1	700	435	807	341	150	352	150	358
2	898	313	197	240	150	235	150	277
3	399	215	150	149	150	172	150	222
4	300	159	150	128	150	126	150	141

[1] A minimum drop height of 150 feet is given because this height was generally near the lower drop test limits for each retardant. In comparing areas of coverage between retardants at a particular concentration level (horizontally), note the difference in corresponding drop heights.

Visual inspection indicated that contour area lengths at the lower concentrations (0.2 and 0.5 gal/100 ft^2) increased with the relatively small increase in aircraft drop speed (105 to 125 knots); whereas, the contour area lengths at higher concentrations (>2 gal/100 ft^2) tended to decrease. Variation in the data for the limited number of high-speed drops of each retardant precluded development of a model or adequate statistical testing.

One method commonly used for increasing the length of continuous effective ≥ 2 gal/100 ft^2 contour areas is to sequence drop increments at a selected time interval. Several of these sequential drops were made during the tests and are designated as trail drops in Appendix I, tables 14-17. The ≥ 2 gal/100 ft^2 contour areas were used for drop pattern comparison and are given in table 6. Assuming symmetry of contour areas and general pattern geometry, a maximum theoretical contour area length can be calculated. For a given drop height and retardant, the ≥ 1 gal/100 ft^2 and ≥ 2 gal/100 ft^2 contour area length (c.a. length) can be predicted from the mathematical contour area length model developed. If two 700-gallon drop patterns were overlapped properly, the 1-gallon portions of each pattern would provide additional ≥ 2 gal/100 ft^2 c.a. length. For example:

$$\geq 2 \text{ gal/100 ft}^2 \text{ c.a. length (sequential drop)} = 2 \, (\text{c.a. length} \geq 2 \text{ gal/100 ft}^2)$$
$$+ \tfrac{1}{2}[(\text{c.a. length} \geq 1 \text{ gal/100 ft}^2) - (\text{c.a. length} \geq 2 \text{ gal/100 ft}^2)]$$

For a 700-gallon Phos-Chek XA drop from 100 feet:

≥ 1 gal/100 ft^2 c.a. length = 319 feet

≥ 2 gal/100 ft^2 c.a. length = 257 feet.

The maximum predicted contour area length (≥ 2 gal/100 ft^2) would be:

$$2(257) + \tfrac{1}{2}(319 - 257) = 545 \text{ feet.}$$

TABLE 6.--PREDICTED AND ACTUAL CONTOUR AREA LENGTHS FOR SEQUENTIAL AND SALVO DROPS OF THREE FIRE RETARDANTS

Retardant and drop number[1]	Drop height	Gate interval[2]	Predicted contour area length ≥2 gal/100 ft^2 for load sizes of[3]			Actual contour area length ≥2 gal/100 ft^2 for 1400 gal sequential loads[4]
			700 gal	1400 gal	700 gal×2	
	Feet	*Seconds*	*Feet*	*Feet*	*Feet*	*Feet*
Phos-Chek XA	100		257	274	545	
	200		255	284	550	
	300		249	292	545	
3	110	1.75				499 (2)
35	208	.92				408 (2)
52	316	.24				329 (1)
64	313	.17				291 (1)
Fire-Trol 100	100		219	239	479	
	200		175	229	408	
	300		131	217	331	
34	183	.67				305 (1)
62	165	1.33				375 (3)
63	340	.57				275 (2)
Water	100		203	311	440	
	200		181	289	397	
	300		144	260	336	
33	286	.38				218 (1)
39	137	1.04				465 (1)

[1] Gelgard data have not been included since no sequential drops of Gelgard were made.

[2] The gate interval in seconds is the time elapsed between initiation of the first and second load increment of sequential drops.

[3] Predictions of contour area length are taken from the mathematical models (Appendix I, tables 40, 42, and 43); for sequential drops, length is calculated using 700-gallon drop predictions and the formula: ≥2 gal/100 ft^2 c.a. length (sequential drop) = 2(c.a. length ≥2 gal/100 ft^2) + 1/2[(c.a. length ≥1 gal/100 ft^2) -(c.a. length ≥2 gal/100 ft^2)].

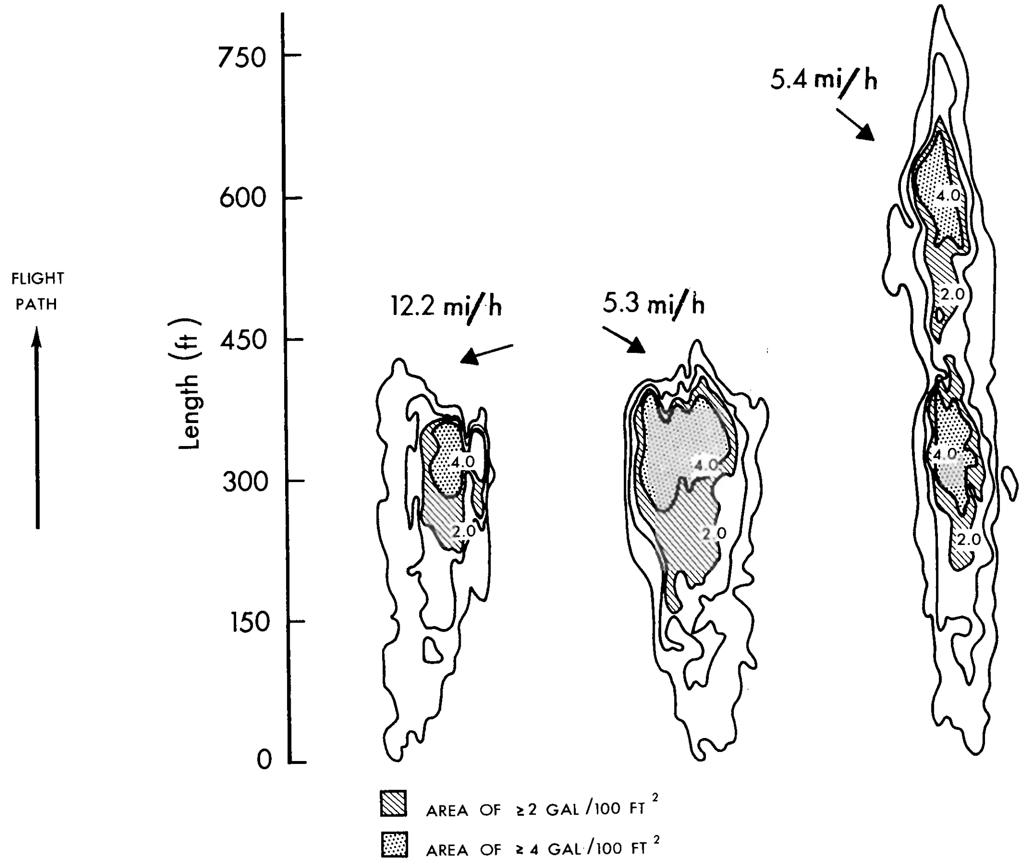
[4] The number in parentheses adjacent to the actual ≥2 gal/100 ft^2 contour area length indicates the number of units providing this length; (1) indicates a continuous contour.

Note that the above equation predicts contour area lengths that are slightly longer than actual lengths at the lower drop heights, but makes fairly accurate predictions for higher drops. The contour lines for lower drop heights are closer together at the forward portion of the drop, because of a change in drop pattern geometry as a function of drop height. At low drop heights the patterns are elliptical--being much longer than they are wide. As drop height is increased, the patterns become shorter and wider--eventually becoming round. Predicted maximum contour area lengths are given in table 6. Figure 19 shows actual 700-gallon, 1,400-gallon, and sequential drop patterns.

Inspection of the data on contour area lengths for the sequential or trail drops performed revealed, first, that pilot control of sequential timing is inconsistent and cannot be relied upon. Times between gate openings varied between 0.17 and 1.75 seconds, indicating that an adjustable intervalometer is necessary to achieve consistency and pattern uniformity. Second, the use of sequential drops can greatly increase line lengths as compared to a single 700- or 1,400-gallon drop (fig. 19). The limited accuracy with which a pilot can hit a target, and his inability to identify the effective portion of the pattern, limit the maximum length of line that can be obtained by sequential drops. According to the data in table 6, the longest continuous patterns were attained when the interval time was approximately 1.0 second. A properly set intervalometer incorporated into the gating system improves accuracy by eliminating the need for a second separate drop.

Drop number	5	16	3
Drop size (gal)	700	1400	1400
Mode	Salvo	Salvo	Sequential
Height (ft)	148	128	110
Groundspeed (knots)	109	103	105

Drop patterns (0.2, 1.0, 2.0, AND 4.0 GAL/100 FT^2 CONTOURS)



≥ 2 gal/100 ft^2 contour			
Number of segments	1	1	2
Length (ft)	207	254	499

Figure 19.--Effect of load size and drop mode on ground distribution patterns.

Other Drop Responses

In addition to the ground distribution patterns, several related drop responses are important in evaluating an aircraft tank and gating system and the drop characteristics of the different retardants. The ground distribution patterns are affected by the time required for the retardant to leave the aircraft (exit time or retardant flow rate), the trajectory of the retardant (aircraft attitude), and the time required for the retardant to reach the ground (evaporation losses). Each of these variables is affected by the retardant rheological properties,[4] which partially determine the rate of stripping of the retardant mass, the size and distribution of the droplets formed during the erosion process, and thus the total surface area of the droplets.

The importance of these parameters can be assessed by an analysis of exit times, drop trajectories, drop times, and evaporation losses for drops of each retardant.

Retardant Exit Time

The exit time for each retardant (Appendix I, tables 14-17) was studied as a function of load size; previous studies had indicated that drop speed, windspeed, and wind direction did not significantly affect exit times (George and Blakely 1973). It was anticipated that increasing load size would not cause an increase in exit time from the CL-215, because a 1,400-gallon drop is simply two 700-gallon drops released simultaneously. The mean exit times for both load sizes and all retardants were calculated, and a "t" test was used to determine the significance of differences in mean exit times for the two load sizes. The results (table 7) indicate that 700- and 1,400-gallon load sizes differed at the 95 percent significance level for only water and Gelgard. It is doubtful, though, that these differences are meaningful because the magnitude of the differences is small: 0.17 and 0.10 second for Gelgard and water, respectively.

Differences between mean exit times for each retardant and at each load size were also tested using a "t" test. Although the differences between retardants were small, they were significant. The difference between the uncolored retardants (Gelgard and water) and the colored retardants (Phos-Chek XA and Fire-Trol 100) was significant at a level greater than 98 percent. Because the exit times were determined from 70-mm or 16-mm movie film, the beginning and ending times are dependent upon visibility and thus color intensity. Therefore, it is reasonable to assume some of the differences between the colored and uncolored products could be due to judgment by those examining the film. This may explain why for some drops, exit times for the larger load sizes and highly viscous retardants (Phos-Chek XA and Fire-Trol 100) are not longer than those for the low viscosity retardants (Gelgard and water) as might be expected. In any event, the difference in exit times caused by load size and type of retardant is small (approximately 0 to 0.20 s) and probably not meaningful when related to the effect of other parameters.

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[4] Rheology is the science of the deformation and flow of material. It is primarily concerned with deformation of *cohesive* bodies and their stress-strain-time relationship. Here, cohesion relates to the sticking together of particles or drops to maintain a homogeneous mass. Rheologic properties should be differentiated from viscous properties. The viscosity of a retardant solution, as normally measured at a single rate of shear, is only one rheological parameter and does not necessarily define the cohesiveness of the material.

TABLE 7.--SIGNIFICANCE BY "T" TEST OF DIFFERENCES IN EXIT TIMES FOR 700- AND 1,400-GALLON DROPS OF FOUR RETARDANTS

Retardant	Load size	Number of drops	Mean exit time	Value of t	Degrees of freedom	Significance level[1]
	Gallons		*Seconds*			*Percent*
Phos-Chek XA	700	6	1.87	1.48	14	NS
	1,400	10	1.98			
Gelgard	700	4	1.65	3.05	7	98
	1,400	5	1.82			
Fire-Trol 100	700	4	1.96	.73	8	NS
	1,400	6	2.00			
Water	700	7	1.92	2.47	10	95
	1,400	5	1.82			
All retardants pooled	700	21	1.86	1.47	45	NS
	1,400	26	1.92			
All retardants pooled	All sizes pooled	47	1.89			

[1] NS = no significant difference (level of significance <0.90).

Drop Time and Trajectory

Under similar drop conditions (aircraft speed, drop height, windspeed and direction, aircraft attitude, etc.) the time required for a retardant to reach the ground is a function of the stripping and erosion process primarily determined by the retardant's rheological properties. Theoretically, an analysis of drop times for each of the retardants (Appendix I, tables 14-17) should support the earlier results showing that gum-thickened retardants produce larger droplet sizes with less erosion and drift (under similar conditions) and thus more concentrated patterns. Thus, drop times for the gum-thickened retardants should be shorter than for those retardants producing smaller droplet sizes.

Covariance analysis indicated that load size and type of aircraft, in addition to drop height, were the primary variables governing the drop time. The other variables may also affect drop time but because some of these variables were held constant as far as possible, and because of substantial variation within the data, they had insignificant effects. Testing the pooled versus unpooled models for load size for each retardant revealed significant differences at the ≥95 percent level for each retardant. These differences in drop times with load size were generally small (<1 s) and as in the analysis of exit times, are probably not meaningful. Larger differences with load size in the stripping and erosion of a retardant might be expected if a 1,400-gallon drop acted as a single entity rather than as two 700-gallon increments. (A larger single mass would require a greater distance and longer time for complete erosion or stripping to occur.)

An analysis of drop time similar to that for load size was undertaken for type of retardant. In all combinations, except when Phos-Chek XA and Gelgard were pooled, significant differences in drop times at the 99 percent level did occur. Drop times for

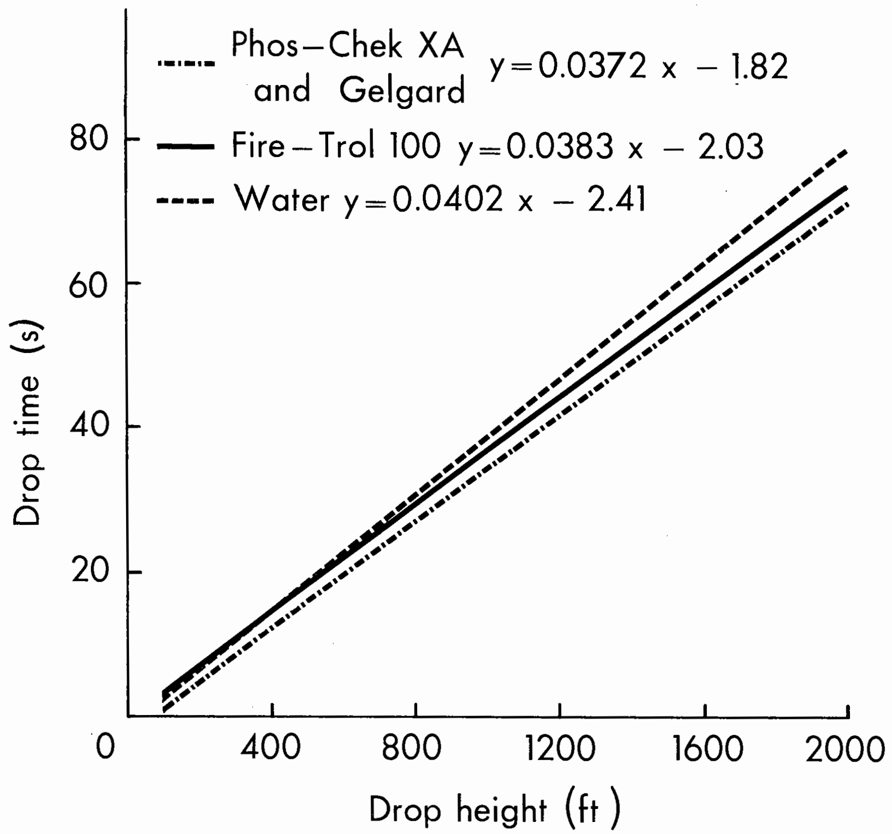

Figure 20.--Time required for the retardants to reach the ground as a function of drop height.

Phos-Chek XA and Gelgard were not significantly different although they had the shortest drop time for the retardants tested. Fire-Trol 100 required approximately one additional second and water required 2 to 3 additional seconds to reach the ground (depending on the drop height used for comparison). The regression equations are given and the difference between retardants is shown graphically for the retardants (load sizes pooled) in figure 20.

A "t" test was used to evaluate the difference in horizontal and vertical trajectories for the different load sizes and retardants. Inspection of the summary of these results indicated no general trend and results were inconsistent as to trajectories and load sizes. It is likely that the large amount of within-data variation caused by the many affecting variables limits the usefulness of other than average trajectory values for comparison. These values may, however, provide clues to a better understanding of the stripping and erosion processes taking place during a drop.

Quantification of the effect of increased airspeed on drop trajectory was considered impossible because of variation within the data, the limited number of drops of each retardant in the high-speed mode, and our indefinite results in analyses of drop trajectories in the normal-speed mode.

Evaporation Losses

The evaporation occurring during a drop under given environmental conditions is primarily a function of the degree of erosion and history of the drop mass; that is, droplet size and distribution and the fall history of the droplets, and thus the

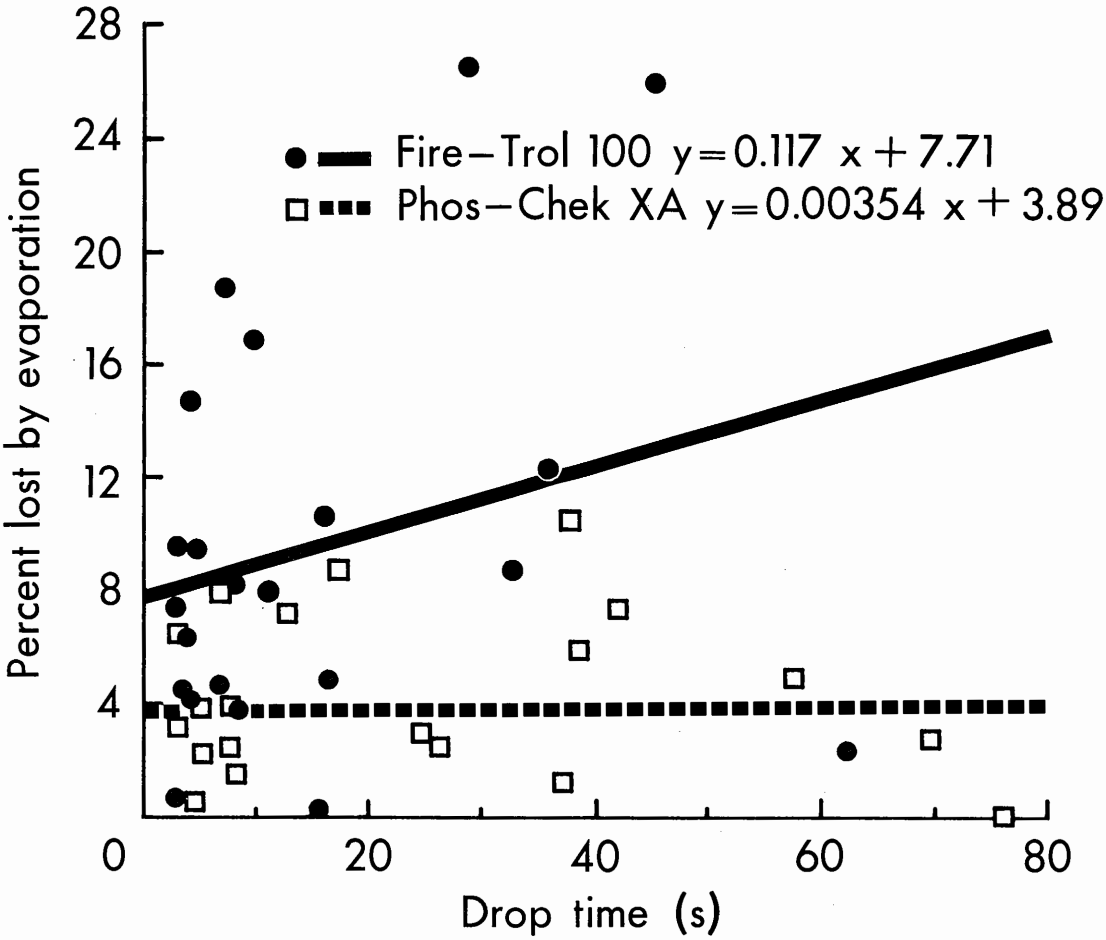

Figure 21.--Evaporation losses as a function of drop time.

relation between droplet surface area and atmosphere exposure. When evaporation losses have been determined, retardant loss from drift can be calculated as the remainder not accounted for in the ground distribution pattern.

The percent of the load lost to evaporation[5] for the two retardants containing salt (Phos-Chek XA and Fire-Trol 100) was plotted as a function of the drop time, which had previously been correlated to drop height. Covariance analysis suggested that no real differences between the 700- and 1,400-gallon load size existed for either retardant. As expected on the basis of differences in drop times, real differences were indicated between Phos-Chek XA and Fire-Trol 100, with less evaporation loss occurring during Phos-Chek XA drops in all cases (fig. 21). Regression equations for evaporation show losses for Fire-Trol 100 of between 6 and 15 percent; whereas, losses for Phos-Chek XA fall between 3 and 5 percent, depending on the drop time. For both retardants, increasing evaporative losses occurred as drop time increased.

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[5] The evaporation of water during a drop was calculated from the difference in retardant salt content before and after the drop (see earlier discussion of measurement of retardant properties).

DISCUSSION

The objectives of the study were to determine the effects of drop height and load size on ground distribution patterns of several retardants and provide performance data on the tank and gating system of the CL-215. These objectives were achieved by quantification and analysis of the amount of retardant reaching the ground and the distribution of this retardant, including the length of contour areas (fireline) at the various concentrations as affected by retardant type, load size, drop height and speed, aircraft attitude, and drop conditions.

Drop height and load size were found to be the most significant variables, affecting almost all measured parameters for the retardants dropped. Covariance analysis of the linear drop height models for total recovery indicated significant differences existed between all retardants except Fire-Trol 100 and water; i.e., Phos-Chek XA had the greatest recovery, followed by Gelgard, and then Fire-Trol 100 and water.

Because, in most instances, real differences between retardants appeared to exist in the simple linear models for total retardant recovered, three-dimensional models of the drop height-retardant concentration (distribution) interactions were developed; and because the total retardant values do not describe the actual distribution, similar three-dimensional models for area of coverage and contour area length were developed. In combination, these models describe the ground distribution patterns. In general, the models show that recoveries, areas of high concentrations (≥ 2 gal/100 ft^2), and contour area lengths were largest for Phos-Chek XA, with Gelgard, Fire-Trol 100, and water following in that order. Predictions were made from these models for each parameter, retardant, and load size (Appendix I, tables 14-17).

The models and predictions for the gum-thickened retardants (Phos-Chek XA and Gelgard) indicate that as load size is increased, the optimum drop height for any required concentration is also increased. For example, the drop height producing the maximum coverage at a concentration of ≥ 2 gal/100 ft^2 for a 700-gallon Phos-Chek XA drop is about 268 feet. The height for maximum coverage at this concentration level for a 1,400-gallon drop is about 806 feet. Thus, if the load size is doubled, the optimum drop height is tripled, and the actual area covered at the optimum height is more than doubled (8,944 ft^2 for a 700-gallon drop compared to 23,413 ft^2 for a 1,400-gallon drop). For comparison, the drop height producing the optimum coverage for Fire-Trol 100 and water drops at this concentration level is near 150 feet.

The data analysis indicates that the optimum drop height for Fire-Trol 100 and water for attaining maximum recovery, areas of coverage, and line lengths at a concentration level of ≥ 2 gal/100 ft^2 is near 150 feet. The optimum height for Phos-Chek XA and Gelgard can be as much as two to five times higher. Thus, effective drop heights and safety may be greatly increased by the use of gum-thickened retardants such as Phos-Chek XA and Gelgard. Also, comparison of the drop characteristics of Fire-Trol 100 and water indicates that little value is obtained by adding the clay thickeners to retardant solutions. Although increasing load size improves drop characteristics, the effect is not fully gained with the CL-215 because a 1,400-gallon drop is actually achieved by simultaneously opening two 700-gallon tanks separated by several feet. Thus, if progress is to be made in attaining higher effective drop heights, so as to develop the capability of a safe night retardant cascade delivery method for larger aircraft, the use of gum-thickened retardants offers the most promise.

The effects of increased aircraft drop speed on ground distribution patterns were studied. The effect of a 20-knot increase in speed (105 to 125 knots) was small or fell within experimental variation in the data. Visual inspection of the data indicated that greatest effect of airspeed was on contour area lengths at concentration levels of 0.2 and 0.5 gal/100 ft^2. These lengths tended to increase with the higher drop speeds. At concentrations of ≥2 gal/100 ft^2, contour area lengths decreased with the increased drop speed. The effect of aircraft attitude was also investigated by making drops from a level, bank, loft, and dive mode. In all drops, the ground pattern responses for the bank, loft, and dive mode fell within the responses attained for the level mode.

The average time required for the retardant to leave the CL-215 was 1.89 seconds, which is within the range of exit times for other presently used air tankers. The effect of load size on retardant exit times was found to be statistically significant for water and Gelgard, but not for Phos-Chek XA and Fire-Trol 100. It is doubtful that any of the differences are meaningful, as they are small (<0.20 s) and the variation within the data is comparatively large.

The drop times and evaporation losses were analyzed and support the conclusions made from ground distribution patterns. The drop times were shortest for Phos-Chek XA and Gelgard, followed by Fire-Trol 100 and water, in that order. Smaller drop times for a given retardant indicate greater cohesion in the drop, a longer stripping time, and a larger mean droplet size after erosion. Evaporation losses depend primarily on the amount of surface area exposed, and thus should be greater for droplets of smaller mean diameter. Significantly less evaporation occurred with Phos-Chek XA (3 to 5 percent lost) than with Fire-Trol 100 (6 to 15 percent lost). Evaporation losses for Gelgard and water could not be measured since they do not contain the salt which provided the basis for analysis.

Variation within the vertical and horizontal trajectory data, partially caused by the measuring techniques used, made it impossible to determine and quantify differences for the retardants. It was observed, however, that the mean horizontal and vertical trajectories for 600-gallon drops made from the TBM aircraft, as quantified in the Porterville study (George and Blakely 1973) were 487 and 84 feet, respectively; whereas, trajectories for the CL-215 (700- and 1,400-gallon loads performed similarly) were 544 and 160 feet. The increase in vertical trajectory for the CL-215 is most likely due to tank geometry and load size (the CL-215 has 56.5 gal/ft^2 of gate opening while the TBM has 35.0 gal/ft^2 of gate opening). The conclusion is that minimum drop heights should be raised for safety of aircraft having larger tank capacities or of tank and gating systems producing fast exit times and high volume flow rates.

Evaluation of the tank and gating system of the CL-215 and comparison of its performance with that of other presently used aircraft are complicated by the large number of variables affecting both the delivery system performance and the actual ground distribution requirements. A simple comparison of the lengths of contour areas at the ≥2 gal/100 ft^2 concentration level for the CL-215 tank and gating system and several presently used aircraft reveals no unusually large differences in performance (table 8 and fig. 22). A comparison of line building efficiencies (feet of adequate concentration or ≥2 gal/100 ft^2 line per gallon carried) shows the CL-215 to be as effective as other presently used air tankers; it provides 0.38 foot of fireline per gallon at 150-foot drop heights and 0.32 foot of fireline per gallon at 300-foot drop heights. The CL-215 does have the disadvantage of a low load capacity (1,400 gallons) as evident from the relatively large number of trips required per mile of line built (table 8). The performance and flexibility of the CL-215 tank and gating system could be improved if a four-tank or gate system incorporating an intervalometer were adopted rather than a manually sequenced two-gate system.

TABLE 8.--LINE BUILDING CAPABILITIES OF THE CL-215 AND SEVERAL OTHER AIR TANKERS WITH PHOS-CHEK XA[1]

Aircraft	Capacity	Maximum number of drop increments possible[2]	Drop height of 150 feet: Maximum length of adequate fireline[3]	Drop height of 150 feet: Foot of line per gallon carried	Drop height of 150 feet: Trips per mile of line[4]	Drop height of 300 feet: Maximum length of adequate fireline	Drop height of 300 feet: Foot of line per gallon carried	Drop height of 300 feet: Trips per mile of line
	Gallons							
CL-215	1,400	2	534	0.38	9.9	444	0.32	11.9
TBM (TBM, Inc.-60)	600	2	235	.39	22.5	186	.31	28.4
B-17-AU (Aero Union-17)	2,000	2	688	.34	7.7	456	.23	11.6
B-17-INT. (Intermountain-71)	2,000	4	908	.45	5.8	632	.32	8.4
PB4Y2 (Stell C-50)	2,400	8	904	.38	5.8	816	.34	6.5
C-119 (Aero Union-12)	2,400	4	904	.38	5.8	560	.23	9.4
P2V (USFS)	3,000	6	948	.32	5.7	876	.29	6.0
DC-6B (Gilbertson)	3,000	8	960	.32	5.5	784	.26	6.7
C-130 (MAFFS) (Air Force-FMC)	3,000	[5]1	1,800	.60	2.9	1,200	.40	4.4

[1] Data from George and Blakely (1973), USDA Forest Service (1973), and Marana Drop Test data on file at Northern Forest Fire Laboratory, Missoula, Montana.

[2] Does not consider special gating systems such as the gravity flow trail gates provided on the Aero Union B-17 and C-119. The number of increments is usually equal to the number of gates.

[3] Adequate retardant concentration was defined for this comparison as ≥ 2 gal/100 ft^2.

[4] Trips required to build 1 mile of fireline were chosen for comparison; this length of line would surround a 40-acre fire.

[5] Pattern flexibility is achieved through variable pressures producing flow rates up to 30,000 gal/min.

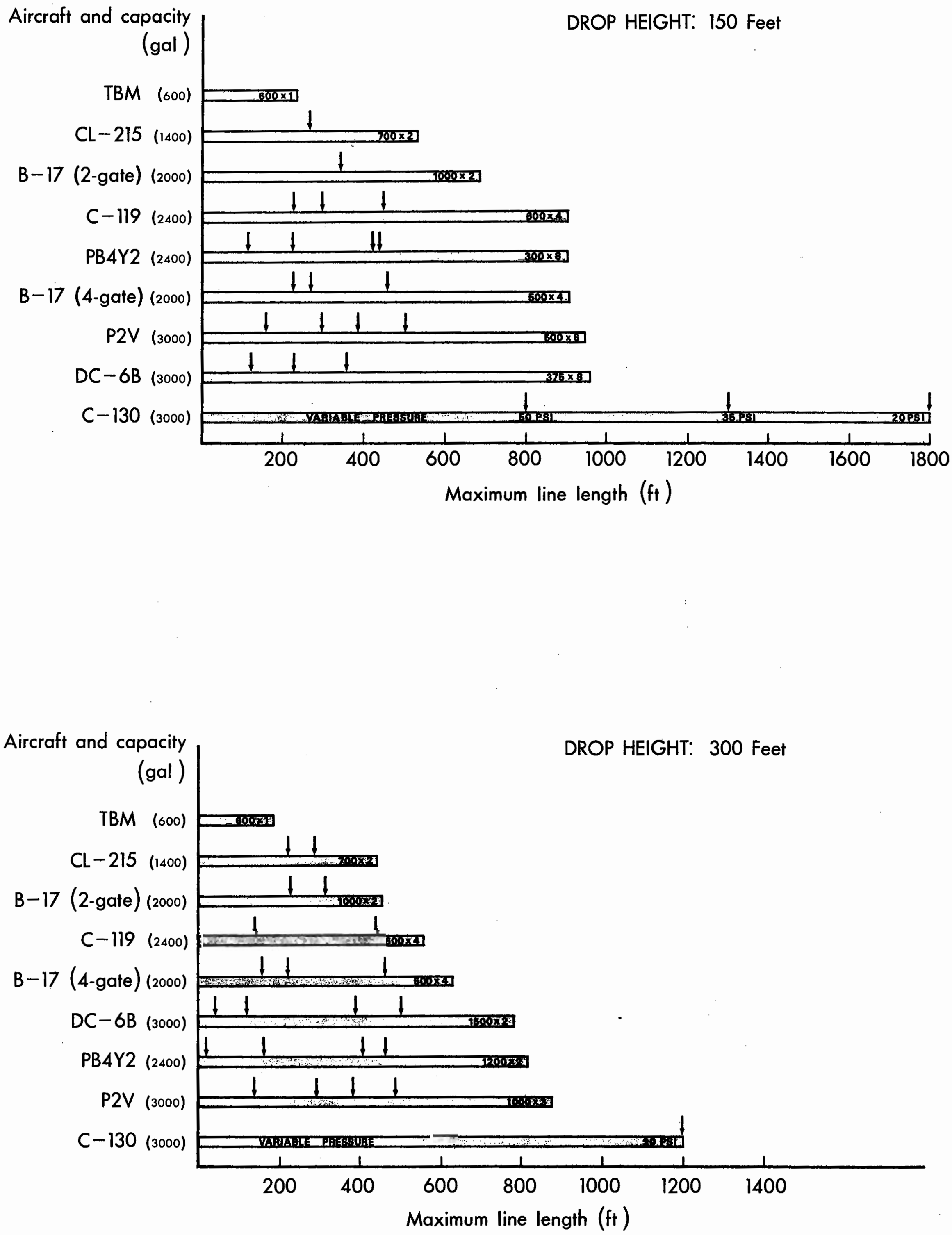

Figure 22.--The length of fireline capable of being built by several comparable airplanes at a drop height of 150 and 300 feet. The flexibility of various tank and gating systems (not including trail gate systems) is shown by the small arrows as possible fireline lengths using different gate combinations.

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APPENDIX I

Tables 9-44

TABLE 9.--COMPOSITION OF THE FIRE RETARDANTS EVALUATED[1]

	Composition	Approximate percent in dry product or concentrate
	LONG-TERM RETARDANTS	
Phos-Check XA	Diammonium phosphate $(NH_4)_2HPO_4$ (21-53-0)	89
	Guar gum (thickening agent)	8
	Iron oxide (coloring agent)	1
	Corrosion and spoilage inhibitors	2
Fire-Trol 100	Ammonium sulfate $(NH_4)_2SO_4$ (21-0-0)	62
	Attapulgite clay (thickening agent)	36
	Iron oxide (coloring agent)	1
	Corrosion inhibitor	1
	SHORT-TERM RETARDANT	
Gelgard[2]	Synthetic organic polymer	99
	Carmine 2B dye	<1

[1] From George 1971a.

[2] The standard Gelgard polymer (Gelgard M) is colorless. Gelgard containing a pigment (Gelgard F) can be obtained or dye can be added.

TABLE 10.--RETARDANT CHARACTERISTICS BEFORE AND AFTER EACH TEST DROP OF PHOS-CHEK XA

Drop No.	Characteristics before drop			Characteristics after drop		Increase in salt content	Water loss during drop[1/]	
	Viscosity	Density	Salt content	Density	Salt content			
	Centipoise	*G/cc*	*Percent* $(NH_4)_2HPO_4$	*G/cc*	*Percent* $(NH_4)_2HPO_4$	*Percent*	*Gallons*	*Percent*
3	1,600	1.088	13.21	1.089	13.26	0.4	6.6	0.5
4	2,400	1.094	13.81	1.096	14.04	1.7	12.7	1.8
5	1,550	1.074	10.98	1.081	11.73	6.8	49.0	7.0
16	1,590	1.067	10.11	1.068	10.19	.8	12.3	.9
17	1,650	1.069	10.35	1.072	10.77	4.1	29.1	4.2
21	1,390	1.064	9.85	1.071	10.69	8.5	118.4	8.5
35	1,690	1.068	10.40	1.074	10.97	5.5	80.2	5.7
36	1,960	1.077	11.53	1.082	12.05	4.5	33.3	4.8
37	2,175	1.077	11.36	1.077	11.46	1.0	6.1	1.0
38	1,700	1.071	10.44	1.078	11.62	11.3	150.3	10.7
45	1,800	1.070	10.50	1.071	10.63	1.2	8.6	1.2
46	2,050	1.069	10.56	1.080	11.79	11.6	158.8	11.3
50	1,560	1.064	9.49	1.071	10.24	7.9	110.0	7.9
51	1,200	1.065	9.81	1.067	9.85	.4	4.1	.6
52	1,775	1.071	10.42	1.074	10.86	4.2	60.5	4.3
53	2,950	1.093	13.80	1.096	14.17	2.7	20.1	2.9
54	1,850	1.076	11.28	1.081	11.99	6.3	89.0	6.4
57	1,600	1.070	10.46	1.088	13.19	26.1	308.1	22.0
64	1,600	1.072	10.73	1.071	10.99	2.4	31.8	2.3
65	1,960	1.078	11.75	1.080	12.10	3.0	43.0	3.1
66	1,500	1.067	10.13	1.070	10.67	5.3	74.6	5.3
73	1,550	1.067	10.34	1.073	10.57	2.2	19.1	2.7
79	1,940	1.073	10.99	1.075	11.05	.5	5.1	.7
80	1,760	1.068	10.22	1.071	10.56	3.3	24.4	3.5
81	1,410	1.068	10.28	1.074	10.58	2.9	47.3	3.4
Mean	1,767	1.073	10.91	1.077	11.44	5.1	53.7	5.0

[1/] The water loss during the drop is calculated from the increase in the salt content of the retardant reaching the ground. Percent values shown represent percent loss based on the drop size.

TABLE 11.--RETARDANT CHARACTERISTICS BEFORE AND AFTER EACH TEST DROP OF GELGARD

Drop No.	Characteristics before drop		Characteristics after drop
	Viscosity	Density	Viscosity
	Centipoise	*G/cc*	*Centipoise*
7	<500	--	--
8	1,100	--	--
9	--	--	1,410
11	850L/800R	0.999	875
12	850	.994	925
13	900	.999	875
14	650	1.003	925
15	875L/800R	1.000	1,050
74	900	--	--
75	600	--	--
76	600	--	--

TABLE 12.--RETARDANT CHARACTERISTICS BEFORE AND AFTER EACH TEST DROP OF FIRE-TROL 100

Drop No.	Characteristics before drop			Characteristics after drop		Increase in salt content	Water loss during drop[1/]	
	Viscosity	Density	Salt content	Density	Salt content			
	Centipoise	*G/cc*	*Percent* $(NH_4)_2SO_4$	*G/cc*	*Percent* $(NH_4)_2SO_4$	*Percent*	*Gallons*	*Percent*
18	1,950	1.141	14.71	1.141	15.31	4.1	27.4	3.9
19	2,300	1.146	15.26	1.159	16.86	10.5	73.5	10.5
25	2,380	1.142	15.35	1.148	16.11	5.0	73.0	5.2
26	1,700	1.136	15.20	1.152	15.98	5.1	86.8	6.2
27	2,280	1.129	14.99	1.171	18.34	22.3	296.7	21.2
28	1,930	1.115	15.40	1.133	15.44	.03	12.9	1.8
34	2,140	1.122	13.69	1.134	14.29	4.4	73.0	5.2
40	2,275	1.128	14.17	1.158	17.45	23.1	146.3	20.9
41	2,160	1.139	15.36	1.150	16.41	6.8	102.1	7.3
42	2,240	1.132	14.87	1.149	16.81	13.0	180.0	12.8
43	2,350	1.143	15.26	1.163	16.71	9.5	143.5	10.2
47	1,750	1.135	15.16	1.161	16.96	11.9	88.3	12.6
48	2,600	1.144	15.24	1.173	17.34	13.8	100.0	14.3
59	2,200	1.134	15.21	1.168	18.31	20.4	270.9	19.3
60	1,910	1.145	16.12	1.183	19.83	23.0	149.2	21.3
61	2,375	1.147	16.20	1.179	19.00	17.3	119.4	17.1
62	2,390	1.140	16.11	1.152	16.70	3.7	63.5	4.5
63	2,250	1.135	14.73	1.148	16.01	8.7	126.5	9.0
68	2,250	1.140		No sample				
69	2,250	1.141	14.82	1.161	16.08	8.5	131.9	9.4
70	2,075	1.136	15.08	1.154	16.68	10.6	77.0	11.0
71	2,260	1.130	14.54	1.134	14.65	.8	7.7	1.0
72	2,650	1.141	15.45	1.154	16.69	8.0	59.3	8.5
77	2,800	1.145	15.37	1.200	20.74	34.9	410.0	29.3
78	2,350	1.144	15.25	1.205	20.74	36.0	211.3	30.2
Mean	2,232	1.137	15.15	1.152	17.06	12.6	126.3	12.2

[1/] The water loss during the drop is calculated from the increase in the salt content of the retardant reaching the ground. Percent values shown represent percent loss based on the drop size.

TABLE 13.--ENVIRONMENTAL CONDITIONS DURING EACH TEST DROP OF WATER AND CHEMICAL RETARDANTS

Drop No.	Air temperature	Relative humidity	Windspeed	Wind direction[1]
	°F	*Percent*	*Mi/h*	*Degrees*
		PHOS-CHEK XA		
3	61	36	4.5	135 L
4	68	28	7.4	60 R
5	68	28	12.2	107 R
16	54	45	5.3	118 L
17	59	42	7.3	152 L
21	50	54	9.8	125 L
35	68	30	5.4	30 R
36	68	30	4.8	90 R
37	53	53	6.0	132 L
38	58	46	6.7	129 L
45	70	27	2.2	160 L
46	70	26	1.7	72 R
50	68	28	6.1	56 R
51	69	27	6.7	105 R
52	58	40	8.4	129 L
53	57	58	9.3	123 L
54	63	33	6.4	170 L
57	78	20	2.8	95 R
64	69	35	5.4	170 R
65	50	66	5.4	90 L
66	53	55	4.8	22 L
73	64	28	3.7	55 R
79	52	43	4.8	104 L
80	62	32	2.5	100 R
81	64	29	2.8	31 R
		FIRE-TROL 100		
18	69	30	1.7	129 R
19	70	28	1.7	11 R
25	65	35	7.4	113 L
26	69	32	3.2	112 L
27	72	24	5.7	90 R
28	69	26	8.2	93 R
34	69	32	1.8	90 L
40	69	28	2.1	52 L
41	68	28	7.3	51 R
42	55	48	3.0	138 L
43	62	36	5.3	80 L
47	54	48	6.7	116 R
48	62	36	--	75 R
59	75	22	10.1	85 R
60	75	22	9.8	76 R
61	74	21	8.3	60 R
62	69	36	9.6	170 R
63	69	35	7.5	170 R
68	59	43	4.8	82 R
69	62	42	9.2	98 R
70	62	38	4.2	45 R
71	62	34	8.1	74 R
72	63	30	4.3	75 R
77	67	28	7.2	65 R
78	67	26	5.5	92 R

Drop No.	Air temperature	Relative humidity	Windspeed	Wind direction[1]
	°F	*Percent*	*Mi/h*	*Degrees*
		GELGARD		
7	65	30	3.2	28 R
8	74	22	4.7	12 L
9	77	19	4.0	68 L
11	58	41	8.7	96 L
12	64	35	8.9	122 L
13	73	26	5.4	127 R
14	72	25	5.4	130 R
15	71	25	6.7	54 R
74	56	41	1.8	110 R
75	64	32	5.8	10 R
76	65	30	3.8	90 R
		[2]WATER		
1	69	22	5.3	63 R
2	68	22	5.6	67 R
6	63	34	2.0	61 R
10	75	18	4.2	110 L
20	71	25	5.0	57 R
23	58	44	8.3	143 L
24	63	40	8.0	132 L
29	69	26	6.2	62 R
30	68	27	7.1	68 R
31	66	28	5.3	32 R
32	52	55	6.8	110 L
33	56	50	7.2	138 L
39	68	29	2.3	179 R
44	65	35	4.7	82 L
49	68	28	6.2	32 R
55	66	30	7.2	102 L
56	71	28	5.8	112 L
58	81	20	6.5	158 R
67	57	44	8.7	88 R
82	65	23	6.4	90 R
83	66	20	8.3	92 R

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[1] Degrees left or right of grid center (0° = tailwind, 180° = headwind).

[2] At a viscosity of 1.0 centipoise and a density of 1.0 g/cc.

TABLE 14.--AIRCRAFT HEIGHT AND SPEED, AND DROP HISTORY AND TRAJECTORY FOR PHOS-CHEK XA

Drop No.	Load size and drop mode 1/	Drop speed	Drop height	Drop history 2/			Drop trajectory	
				Time to exit tank	Time to reach ground	Time to settle	Horizontal	Vertical
	Gallons	*Knots*	*Feet*	*Seconds*			*Feet*	
3	1,400(T)	105	110	3.67	2.81	10.58	--	--
4	700	107	315	1.94	8.21	--	534	205
5	700	109	148	2.10	3.19	8.92	--	--
16	1,400	103	128	1.90	2.88	10.33	--	--
17	700	97	311	1.79	8.17	--	526	205
21	1,400	92	296	1.94	6.94	13.04	--	--
35	1,400(T)	104	208	2.67	5.15	13.48	--	--
36	700	103	539	1.98	17.17	--	574	213
37	700(HS)	112	366	1.94	10.67	--	616	214
38	1,400	102	486	1.98	12.71	22.98	576	304
45	700	107	1,046	1.69	--	--	550	221
46	1,400	104	1,007	--	--	--	--	--
50	1,400	105	--	1.98	--	--	524	267
51	700(HS)	120	173	1.63	4.50	12.83	--	--
52	1,400	99	316	2.13	7.67	15.88	512	238
53	700	97	738	1.73	--	--	--	--
54	1,400	89	1,101	2.17	--	--	--	--
57	1,400	--	--	1.77	--	--	533	204
64	1,400	91	313	2.06	8.77	16.44	--	--
65	1,400	94	--	1.92	--	--	--	--
66	1,400	107	--	--	--	--	--	--
73	700(D)	116	183	1.54	5.33	12.71	--	--
79	700(B)	99	163	1.83	4.56	11.60	492	188
80	700(L)	123	51	1.40	3.06	9.79	--	--
81	1,400	93	--	1.90	--	--	--	--
Mean							544	226

1/ The aircraft drop mode is given by the letter in parentheses: T = 700 gallons × two trail drops, B = bank attitude. D = dive attitude, L = loft attitude, HS = high speed drop (approximately 125 knots). All others were salvo drops made with the aircraft in a horizontal attitude at a normal drop speed (approximately 105 knots).

2/ Available data depended on movie film coverage. Where data are lacking, the drop release or empty point was out of the camera's view.

TABLE 15.--AIRCRAFT HEIGHT AND SPEED, AND DROP HISTORY AND TRAJECTORY FOR GELGARD

Drop No.	Load size and drop mode 1/	Drop speed	Drop height	Drop history 2/			Drop trajectory	
				Time to exit tank	Time to reach ground	Time to settle	Horizontal	Vertical
	Gallons	*Knots*	*Feet*	*Seconds*			*Feet*	
7	700	120	147	1.60	3.94	11.00	--	--
8	700	106	974	--	29.71	--	--	--
9	700	109	463	1.69	15.15	28.46	--	--
11	1,400	99	164	1.75	3.88	11.91	--	--
12	700	96	301	1.56	8.90	19.06	496	183
13	1,400	96	982	1.79	--	--	--	--
14	1,400	102	495	1.92	14.46	--	530	267
15	1,400	104	310	1.77	7.97	--	--	--
74	700	--	--	1.75	--	--	--	--
75	700(HS)	130	250	1.73	7.73	20.17	--	--
76	1,400	91	508	1.88	14.83	31.06	524	243
Mean							517	231

1/ The aircraft drop mode is given by the letter in parentheses: HS = high speed drop (approximately 125 knots). All others were salvo drops made with the aircraft in a horizontal attitude at a normal drop speed (approximately 105 knots).

2/ Available data depended on movie film coverage. Where data are lacking, the drop release or empty point was out of the camera's view.

TABLE 16.--AIRCRAFT HEIGHT AND SPEED, AND DROP HISTORY AND TRAJECTORY FOR FIRE-TROL 100

Drop No.	Load size and drop mode[1]	Drop speed	Drop height	Drop history[2]			Drop trajectory	
				Time to exit tank	Time to reach ground	Time to settle	Horizontal	Vertical
	Gallons	*Knots*	*Feet*	- - - - - - - *Seconds*	- - - - -	- - - - -	- - - - *Feet*	- - - -
18	700	105	296	1.85	8.13	18.15	554	210
19	700	106	164	1.94	4.58	14.81	566	163
25	1,400	105	272	1.85	6.69	20.83	--	--
26	1,400	107	494	2.00	16.40	--	549	242
27	1,400	103	952	--	--	--	--	--
28	700	102	482	1.98	15.67	29.97	529	242
34	1,400(T)	103	183	--	4.04	19.48	--	--
40	700	100	1,043	--	--	--	--	--
41	1,400	94	157	2.13	3.92	13.40	--	--
42	1,400(HS)	118	294	2.13	8.19	21.25	589	258
43	1,400	109	981	2.10	--	--	--	--
47	700(HS)	125	294	1.92	10.60	27.08	584	181
59	1,400(HS)	123	299	2.04	9.58	23.44	679	188
60	700(HS)	121	214	2.06	7.19	18.90	620	156
61	700(B)	129	153	2.00	4.13	13.67	--	--
62	1,400(T)	97	165	2.80	4.46	17.25	--	--
63	1,400(T)	96	340	2.46	11.10	24.00	--	--
68	1,400	98	--	1.94	--	--	609	228
69	1,400	103	761	--	--	--	--	--
70	700(D)	107	200	1.46	3.00	12.50	--	--
71	700(B)	101	112	1.71	2.69	8.90	--	--
72	700(L)	126	39	1.54	2.90	13.02	--	--
77	1,400	101	--	2.00	--	--	633	272
78	700	98	763	2.06	--	--	692	275
Mean							600	220

[1] The aircraft drop mode is given by the letter in parentheses: T = 700 gallons × two trail drops, B = bank attitude, D = dive attitude, L = loft attitude, HS = high speed drop (approximately 125 knots). All others were salvo drops made with the aircraft in a horizontal attitude at a normal drop speed (approximately 105 knots).

[2] Available data depended on movie film coverage. Where data are lacking, the drop release or empty point was out of the camera's view.

TABLE 17.--AIRCRAFT HEIGHT AND SPEED, AND DROP HISTORY AND TRAJECTORY FOR WATER

Drop No.	Load size and drop mode[1]	Drop speed	Drop height	Drop history[2]			Drop trajectory	
				Time to exit tank	Time to reach ground	Time to settle	Horizontal	Vertical
	Gallons	*Knots*	*Feet*	- - - - - - - *Seconds*	- - - - -	- - - - -	- - - - *Feet*	- - - -
1	700(HS)	127	178	1.88	5.02	18.88	525	168
2	1,400(HS)	128	409	1.84	14.94	--	577	175
6	1,400	120	294	1.81	9.92	17.65	--	--
10	700	103	166	1.85	3.75	14.83	--	--
20	700	92	285	1.98	8.04	20.10	519	223
23	1,400	105	157	1.85	3.83	14.65	--	--
24	700	102	178	1.88	4.88	17.29	473	166
29	1,400	103	528	1.83	17.85	33.65	553	196
30	700	111	550	1.92	19.44	--	568	277
32	700(HS)	128	393	2.02	14.94	--	499	143
33	1,400(T)	95	286	2.44	9.00	--	--	--
39	1,400(T)	102	137	2.60	3.79	15.56	--	--
44	700	110	1,091	1.99	--	--	--	--
49	1,400	94	--	--	--	--	--	--
55	1,400	98	538	1.71	15.85	28.69	530	230
56	700	95	785	2.00	--	12.96	--	--
58	1,400	100	1,046	1.90	--	17.71	449	105
67	1,400	106	--	--	--	--	--	--
82	1,400	92	--	--	--	--	--	--
83	700	101	--	1.83	--	--	441	248
Mean							513	190

[1] The aircraft drop mode is given by the letter in parentheses: T = 700 gallons × two trail drops, B = bank attitude, D = dive attitude, L = loft attitude, HS = high speed drop (approximately 125 knots). All others were salvo drops made with the aircraft in a horizontal attitude at a normal drop speed (approximately 105 knots).

[2] Available data depended on movie film coverage. Where data are lacking, the drop release or empty point was out of the camera's view.

TABLE 18.--PHOS-CHEK XA RECOVERY BY CONCENTRATION CLASS AND TOTAL RECOVERY

Drop No.	Retardant dropped	Concentration class							Total retardant recovered	Drop recovered
		<0.2	0.2-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	≥5.0		
	Gallons	- - - - - - - - - - - - - - - *Gallons*- - - - - - - - - - - - - - -							*Gallons*	*Percent*
3	1,400	44.4	125.4	206.1	120.7	89.9	81.2	516.7	1,184	84.6
4	700	113.7	99.2	138.8	89.0	84.1	24.9	87.6	637	91.0
5	700	28.6	74.2	58.0	75.4	56.5	17.6	205.2	516	73.7
16	1,400	37.2	77.9	122.1	135.9	131.6	70.8	711.5	1,187	84.8
17	700	49.5	107.1	180.3	120.8	75.8	33.8	48.8	616	88.0
21	1,400	33.8	109.4	221.2	178.0	156.4	125.2	432.3	1,256	89.7
35	1,400	27.7	97.3	137.9	180.7	166.4	164.8	386.8	1,162	83.0
36	700	49.9	96.5	222.4	98.9	31.8	18.2	22.9	541	77.3
37	700	46.9	126.3	164.1	123.3	101.1	20.5	6.9	589	84.1
38	1,400	29.5	129.3	192.2	212.7	256.4	139.9	231.3	1,191	85.1
45	700	20.9	105.9	292.8	140.4	17.3	0	0	577	82.4
46	1,400	20.1	115.9	376.8	476.0	127.7	5.4	0	1,122	80.1
50	1,400	--	--	--	122.7	81.9	0	0	--	--
51	700	34.6	102.4	122.8	91.6	33.7	61.3	139.7	586	83.7
52	1,400	34.7	101.0	132.9	196.2	115.9	152.6	461.9	1,195	85.4
53	700	31.8	222.6	250.2	20.4	0	0	0	525	75.0
54	1,400	44.7	194.1	479.4	201.9	45.5	4.8	0	970	69.3
57	1,400	--	--	532.5	19.0	0	0	0	--	--
64	1,400	25.3	108.7	150.9	224.7	155.6	90.6	419.6	1,175	83.9
65	1,400	25.0	97.5	220.4	259.2	367.4	146.1	99.7	1,215	86.8
66	1,400	24.0	113.3	503.1	452.9	63.0	0	0	1,156	82.6
73	700	24.8	80.2	120.3	122.9	57.2	72.6	97.6	576	82.3
79	700	30.3	71.9	122.0	131.9	86.2	46.2	135.1	624	89.1
80	700	22.4	74.1	129.3	82.8	57.5	62.3	171.0	599	85.6
81	1,400	64.8	231.6	668.7	48.9	10.8	0	0	1,025	73.2

TABLE 19.--PHOS-CHEK XA COVERAGE BY CONCENTRATION CLASS AND TOTAL COVERAGE

Drop No.	Concentration class							Total area
	<0.2	0.2-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	≥5.0	
	- - - - - - - - - - - - - - - - *Square feet*- - - - - - - - - - - - - -							*Square feet*
3	60,188	24,863	14,288	4,827	2,700	1,800	5,064	113,730
4	141,751	19,575	9,675	3,600	2,475	563	1,351	178,990
5	77,513	18,113	4,951	3,488	1,913	450	2,589	109,017
16	47,588	14,625	8,888	5,400	3,825	1,575	5,852	87,753
17	63,111	21,150	12,376	4,726	2,250	788	789	105,190
21	41,514	21,826	14,851	7,088	4,275	2,813	5,064	97,431
35	35,888	17,438	9,788	7,313	4,838	3,826	5,177	84,268
36	64,801	20,475	14,400	4,388	1,012	450	450	105,977
37	57,826	27,225	11,362	5,175	2,925	450	113	105,076
38	33,300	23,288	13,725	8,549	7,425	3,150	3,375	92,812
45	24,525	18,112	19,238	6,075	563	0	0	68,513
46	24,525	22,163	24,075	19,913	3,826	112	0	94,614
50	--	--	--	5,400	2,250	0	0	--
51	41,963	21,600	8,551	3,713	1,012	1,350	1,801	79,990
52	41,626	19,801	9,112	7,875	3,375	3,713	5,176	90,678
53	37,463	42,525	18,225	900	0	0	0	99,113
54	50,737	34,537	33,975	8,550	1,351	113	0	129,263
57	--	--	37,800	900	0	0	0	--
64	31,725	21,264	10,576	9,113	4,500	2,025	5,177	84,380
65	38,250	19,125	14,625	10,463	10,575	3,375	1,688	98,101
66	24,863	20,813	32,400	19,125	1,913	0	0	99,114
73	29,475	15,638	8,438	5,063	1,688	1,575	1,239	63,116
79	36,358	15,076	8,775	5,401	2,475	1,013	1,689	70,787
80	24,750	15,300	8,663	3,375	1,688	1,350	2,365	57,491
81	85,062	41,963	48,589	2,025	338	0	0	177,977

TABLE 20.--GELGARD RECOVERY BY CONCENTRATION CLASS AND TOTAL RECOVERY

Drop No.	Retardant dropped	Concentration class							Total retardant recovered	Drop recovered
		<0.2	0.2-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	≥5.0		
	Gallons	*Gallons*							*Gallons*	*Percent*
7	700	40.2	92.1	84.6	121.4	54.5	55.5	138.0	586	83.7
8	700	--	--	--	112.0	126.1	--	--	--	--
9	700	30.4	94.3	163.6	145.2	50.8	5.0	13.5	503	71.9
11	1,400	22.6	112.5	152.1	168.2	81.9	72.8	462.0	1,072	76.6
12	700	35.6	144.7	139.5	103.8	71.8	29.3	19.9	545	77.9
13	1,400	30.9	140.2	345.0	437.5	46.3	--	--	1,000	71.4
14	1,400	--	--	338.2	299.2	135.2	90.7	102.9	--	--
15	1,400	24.2	246.5	223.0	259.7	90.3	58.9	177.2	1,080	77.1
74	700	21.4	164.3	163.6	180.0	0	0	0	529	75.6
75	700	27.9	108.2	116.7	144.6	57.2	14.4	0	469	67.0
76	1,400	34.0	155.5	215.8	262.5	212.2	123.4	29.8	1,033	73.8

TABLE 21.--GELGARD COVERAGE AND CONCENTRATION AND TOTAL COVERAGE

Drop No.	Concentration class							Total area
	<0.2	0.2-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	≥5.0	
	Square feet							*Square feet*
7	47,138	18,563	5,963	4,950	1,575	1,238	1,914	81,341
8	--	--	--	3,600	3,600	--	--	--
9	31,050	16,538	11,813	6,075	1,350	113	226	67,165
11	28,687	21,375	10,913	6,863	2,363	1,688	5,177	77,066
12	38,813	28,575	10,238	4,275	2,026	675	338	84,940
13	33,638	31,613	22,163	17,550	1,350	--	--	106,314
14	--	--	22,388	11,925	4,050	2,025	1,801	--
15	25,875	50,513	15,638	10,463	2,700	1,350	3,150	109,689
74	21,150	34,650	10,800	7,650	0	0	0	74,250
75	28,913	23,288	7,876	5,851	1,801	338	0	68,067
76	37,238	31,613	14,288	10,462	6,188	2,813	563	103,165

TABLE 22.--FIRE-TROL 100 RECOVERY BY CONCENTRATION CLASS AND TOTAL RECOVERY

Drop No.	Retardant dropped	Concentration class							Total retardant recovered	Drop recovered
		<0.2	0.2-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	≥5.0		
	Gallons	*Gallons*							*Gallons*	*Percent*
18	700	28.7	95.6	141.3	94.6	74.7	34.2	79.6	549	78.4
19	700	30.0	86.5	113.0	80.1	47.2	40.6	118.9	516	73.7
25	1,400	22.9	124.2	235.2	205.6	121.8	144.4	186.6	1,041	74.4
26	1,400	30.7	224.6	191.9	167.3	106.8	61.4	93.7	876	62.6
27	1,400	60.3	202.0	370.9	58.0	0	0	0	691	49.4
28	700	28.7	162.1	169.3	29.2	0	0	0	389	55.6
34	1,400	13.4	73.4	60.5	51.3	43.8	50.4	151.4	444	31.7
40	700	53.7	191.3	96.6	28.0	0	4.9	0	375	53.6
41	1,400	23.1	150.6	151.5	114.2	146.7	25.5	385.7	997	71.2
42	1,400	23.1	177.1	276.7	174.1	98.2	95.3	162.7	1,007	71.9
43	1,400	14.5	279.8	473.6	65.0	0	0	0	833	59.5
47	700	36.8	171.9	127.1	68.8	23.4	0	0	428	61.1
59	1,400	64.4	233.2	201.3	101.9	56.1	20.4	0	677	48.4
60	700	52.9	127.0	136.8	26.0	7.2	0	0	350	50.0
61	700	35.0	119.1	106.2	89.2	61.1	0	0	411	58.7
62	1,400	34.2	168.3	228.4	168.1	133.5	53.6	162.0	948	67.7
63	1,400	46.0	158.7	273.4	165.2	122.1	59.0	146.9	971	69.4
68	1,400	--	--	--	141.1	0	0	0	--	--
69	1,400	9.9	92.3	280.9	166.9	10.6	0	0	561	40.1
70	700	22.3	92.9	105.3	77.7	59.7	45.0	37.9	441	63.0
71	700	30.8	108.3	107.3	51.9	50.5	50.6	74.1	473	67.6
72	700	20.0	85.7	95.2	110.5	70.8	54.7	63.6	501	71.6
77	1,400	59.7	352.1	132.9	0	0	0	0	545	38.9
78	700	118.0	190.8	50.7	0	0	0	0	360	51.4

TABLE 23.--FIRE-TROL 100 COVERAGE BY CONCENTRATION CLASS AND TOTAL COVERAGE

Drop	Concentration class							
No.	<0.2	0.2-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	≥5.0	Total area
	Square Feet							*Square feet*
18	36,451	18,000	9,388	3,938	2,138	788	1,127	71,830
19	39,375	17,550	7,875	3,375	1,350	900	1,576	72,001
25	22,545	24,414	16,312	8,438	3,713	3,149	2,701	81,272
26	31,725	46,126	13,390	7,088	3,150	1,350	1,688	104,517
27	59,176	42,188	24,525	2,700	0	0	0	128,588
28	31,051	33,752	11,700	1,238	0	0	0	77,741
34	23,739	23,514	8,551	4,838	2,813	2,588	5,851	71,894
40	53,325	42,413	7,538	1,125	0	113	0	104,514
41	25,425	30,825	10,463	4,725	4,163	563	4,615	80,779
42	24,526	35,438	20,025	6,975	2,813	2,138	2,588	94,503
43	18,563	51,976	33,300	3,038	0	0	0	106,877
47	39,375	34,086	9,001	2,813	675	0	0	85,950
59	72,786	46,802	14,064	4,275	1,688	450	0	140,065
60	63,563	27,451	9,676	1,125	225	0	0	102,040
61	40,163	24,751	7,650	3,600	1,800	0	0	77,964
62	37,238	33,975	15,527	7,425	3,825	1,238	2,700	101,928
63	52,538	33,188	18,000	6,750	3,600	1,350	2,251	117,677
68	--	--	--	5,850	0	0	0	--
69	11,812	15,300	19,800	7,088	338	0	0	54,338
70	26,437	20,250	6,976	3,263	1,688	1,013	564	60,191
71	32,175	20,138	8,213	2,138	1,463	1,125	1,015	66,267
72	23,082	18,788	6,638	4,501	2,025	1,238	901	57,173
77	71,663	74,139	11,025	0	0	0	0	156,827
78	139,502	41,402	4,387	0	0	0	0	185,291

TABLE 24.--WATER RECOVERY BY CONCENTRATION CLASS AND TOTAL RECOVERY

Drop	Retardant	Concentration class							Total	
No.	dropped	<0.2	0.2-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	≥5.0	retardant recovered	Drop recovered
	Gallons	*Gallons*							*Gallons*	*Percent*
1	700	30.5	112.4	95.4	88.1	33.6	35.5	78.0	474	67.7
2	1,400	60.7	318.5	256.3	239.9	74.7	20.3	0	970	69.3
6	1,400	46.3	162.0	158.4	134.9	189.7	163.8	194.7	1,050	75.0
10	700	27.9	103.2	82.8	93.6	28.6	20.6	144.0	501	71.6
20	700	21.4	127.7	89.8	94.1	30.2	29.6	83.3	476	68.0
23	1,400	25.0	137.2	158.2	163.3	127.4	44.9	416.3	1,072	76.6
24	700	25.2	129.9	133.7	87.0	51.5	14.3	31.4	473	67.6
29	1,400	36.2	254.9	186.9	323.5	102.2	0	0	904	64.6
30	700	43.7	182.0	143.0	0	0	0	0	369	52.7
32	700	42.4	234.0	132.2	5.0	0	0	0	414	59.1
33	1,400	42.4	163.3	164.7	162.1	175.6	142.0	213.1	1,063	75.9
39	1,400	24.2	134.1	147.2	145.9	150.2	89.5	405.0	1,096	78.3
44	700	62.3	173.9	59.1	0	0	0	0	295	42.1
49	1,400	80.9	388.3	32.0	0	0	0	0	501	35.8
55	1,400	39.8	253.7	233.7	249.3	84.6	48.8	0	910	65.0
56	700	59.8	224.4	45.3	0	0	0	0	330	47.1
58	1,400	54.6	350.5	238.7	4.9	0	0	0	649	46.4
67	1,400	62.1	369.1	364.0	0	0	0	0	795	56.8
82	1,400	44.9	256.2	415.8	156.6	3.9	0	0	877	62.6
83	700	37.2	209.6	1.1	0	0	0	0	248	35.4

TABLE 25.--WATER COVERAGE BY CONCENTRATION CLASS AND TOTAL COVERAGE

Drop No.	Concentration class <0.2	0.2-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	≥5.0	Total area
	- - - - - - - - - - - - - - -	-	-	*Square feet*	-	-	- - - - - - - - - - - - - - -	*Square feet*
1	33,974	24,077	6,413	3,600	900	788	1,126	70,878
2	66,825	69,864	17,750	9,900	2,250	450	0	167,039
6	53,999	30,261	11,026	5,514	5,513	3,713	3,152	113,178
10	28,913	22,950	5,738	3,825	788	450	1,802	64,466
20	20,816	25,989	6,074	3,713	900	787	1,239	59,518
23	27,000	27,228	10,689	6,751	3,602	1,013	5,740	82,023
24	28,237	25,875	9,113	3,601	1,575	338	451	69,190
29	38,363	48,488	12,825	12,826	3,038	0	0	115,540
30	33,414	40,389	10,350	0	0	0	0	84,153
32	47,250	56,025	9,900	225	0	0	0	113,400
33	44,325	34,762	11,363	6,525	5,063	3,151	2,926	108,115
39	27,225	26,213	10,239	5,963	4,500	2,025	5,627	81,792
44	69,638	37,688	4,726	0	0	0	0	112,052
49	89,889	85,951	2,813	0	0	0	0	178,653
55	40,724	46,238	16,651	9,788	2,576	1,125	0	117,002
56	66,828	47,588	3,712	0	0	0	0	118,128
58	50,163	72,887	18,788	225	0	0	0	142,063
67	61,538	77,175	26,663	0	0	0	0	165,376
82	50,513	52,876	28,463	6,863	113	0	0	138,828
83	38,363	48,263	113	0	0	0	0	86,739

TABLE 26--DIMENSIONS OF PATTERN CONTOUR AREAS FOR PHOS-CHEK XA DROPS

Drop: No.	Maximum contour area lengths at concentrations (≥gal/100 ft^2) of... 0.2	0.5	1.0	2.0	3.0	4.0	Dimensions of contour areas, 2 gal/100 ft^2 coverage: Length at widths ≥(ft) of..: 5.0	10.0	Maximum width
	- - - - - -	-	*Feet-*	- - - - - - - - -	-	-	- - - - - -	*Feet*	- - - - - -
3	799	723	673	499	370	264	454	423	57
4	469	408	333	241	118	108	237	230	49
5	420	340	247	207	128	81	198	192	68
16	445	386	344	254	157	128	247	241	104
17	506	423	379	266	140	57	264	263	59
21	509	468	389	318	274	202	300	283	110
35	576	529	485	408	335	245	368	358	86
36	460	371	353	174	111	41	171	168	75
37	560	373	328	203	85	35	192	182	70
38	674	531	473	331	285	142	322	314	125
45	489	413	341	198	6	0	185	159	78
46	548	486	442	370	173	17	363	358	115
50	--	--	--	253	45	0	221	207	46
51	486	356	328	208	116	104	204	200	54
52	482	446	388	329	253	188	305	300	102
53	489	411	244	21	0	0	11	0	9
54	515	454	364	206	64	6	192	188	72
57	--	498	304	44	0	0	23	0	9
64	535	463	398	291	122	106	283	280	123
65	468	423	373	263	232	154	257	252	130
66	547	411	363	240	59	0	231	226	133
73	436	388	354	244	153	94	238	235	64
79	463	384	334	286	191	150	280	274	80
80	446	375	364	331	231	133	301	257	69
81	508	454	338	114	10	0	96	83	45

TABLE 27.--DIMENSIONS OF PATTERN CONTOUR AREAS FOR GELGARD DROPS

Drop No.	Maximum contour area lengths at concentrations (≥gal/100 ft^2) of...						Dimensions of contour areas, 2 gal/100 ft^2 coverage		
							Length at widths ≥(ft) of..:		
	0.2	0.5	1.0	2.0	3.0	4.0	5.0	10.0	Maximum width
	Feet						Feet		
7	486	398	319	251	144	123	246	241	58
8	--	--	--	136	27	0	126	115	75
9	406	360	295	200	90	36	190	179	55
11	454	377	309	264	139	122	261	258	137
12	456	373	341	141	79	47	140	137	79
13	497	376	316	249	31	0	243	239	124
14	--	429	359	280	135	87	271	263	137
15	456	430	347	255	129	88	250	245	112
74	596	572	528	156	0	0	149	135	35
75	416	319	286	238	114	28	238	222	63
76	466	416	329	230	164	88	227	224	132

TABLE 28.--DIMENSIONS OF PATTERN CONTOUR AREAS FOR FIRE-TROL 100 DROPS

Drop No.	Maximum contour area lengths at concentrations (≥gal/100 ft^2) of...						Dimensions of contour areas, 2 gal/100 ft^2 coverage		
							Length at widths ≥(ft) of..:		
	0.2	0.5	1.0	2.0	3.0	4.0	5.0	10.0	Maximum width
	Feet						Feet		
18	486	419	314	196	119	78	176	165	62
19	456	395	337	231	134	114	215	167	66
25	534	424	372	267	166	138	261	257	117
26	433	366	204	168	135	106	164	120	166
27	455	266	215	66	0	0	60	55	39
28	483	331	202	41	0	0	34	27	30
34	535	459	363	305	216	202	298	289	82
40	390	256	141	30	0	0	23	6	11
41	500	433	387	286	154	134	255	237	109
42	552	454	391	166	141	104	150	145	133
43	440	386	303	131	0	0	88	82	64
47	480	398	231	89	38	0	84	80	64
59	434	374	222	161	95	9	156	148	79
60	350	288	175	39	8	0	27	21	39
61	418	345	288	150	107	0	142	131	48
62	706	554	520	375	304	169	345	305	88
63	598	443	358	275	260	136	255	221	116
68	--	--	--	114	0	0	110	104	76
69	281	263	243	144	6	0	139	137	86
70	335	273	230	213	131	80	207	201	61
71	366	325	256	151	120	107	149	145	53
72	442	376	342	280	189	140	255	249	60
77	484	423	241	0	0	0	0	0	0
78	376	226	100	0	0	0	0	0	0

TABLE 29.--DIMENSIONS OF PATTERN CONTOUR AREAS FOR WATER DROPS

Drop No.	Maximum contour area lengths at concentrations (≥gal/100 ft^2) of... 0.2	0.5	1.0	2.0	3.0	4.0	Dimensions of contour areas, 2 gal/100 ft^2 coverage: Length at widths ≥(ft) of..: 5.0	10.0	Maximum width
	- - - - - - - Feet	- - - - - - - -					- - - - - Feet	- - - - - -	
1	419	370	231	156	77	73	151	147	65
2	506	405	254	163	72	14	159	154	132
6	481	441	338	199	165	136	184	176	148
10	431	314	261	216	109	84	203	171	63
20	442	365	194	143	100	82	141	138	73
23	519	401	358	318	258	134	306	284	149
24	441	379	284	184	86	28	174	156	73
29	440	386	249	182	89	0	169	164	142
30	374	253	174	0	0	0	0	0	0
32	429	254	179	12	0	0	9	6	15
33	506	404	334	218	179	153	213	197	122
39	682	591	526	465	375	309	456	452	71
44	350	181	94	0	0	0	0	0	0
49	533	418	72	0	0	0	0	0	0
55	452	409	279	160	94	41	145	141	148
56	415	328	101	0	0	0	0	0	0
58	540	394	299	19	0	0	13	6	12
67	459	376	339	0	0	0	0	0	0
82	446	368	312	149	0	0	106	101	61
83	308	195	0	0	0	0	0	0	0

TABLE 30.--PREDICTED VALUES FOR PERCENT OF PHOS-CHEK XA RECOVERED BY CONCENTRATION CLASS (RETARDANT DISTRIBUTION)

Drop height	Concentration ($\geq$gal/100 ft^2)								
	0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	- - - - - - - - - - - - *Percent* - - - - - - - - - - - -								
	700-GALLON DROP								
100	78	77	71	61	55	48	40	34	32
150	78	77	70	59	52	45	37	31	28
200	77	76	68	56	49	42	33	27	23
250	77	76	67	53	45	38	30	23	19
300	77	76	66	51	42	35	26	20	16
400	76	75	63	45	35	28	20	14	10
500	76	74	59	39	29	22	15	10	6
600	75	73	56	34	23	17	11	6	3
800	73	70	49	24	15	9	5	2	1
1,000	71	67	42	17	9	5	2	1	0
1,200	68	63	35	11	5	2	1	0	0
1,400	65	59	30	8	3	1	0	0	0
1,600	62	55	24	5	1	1	0	0	0
1,800	58	51	20	3	1	0	0	0	0
2,000	55	47	16	2	0	0	0	0	0
	1,400-GALLON DROP								
100	84	81	78	76	73	70	66	62	58
150	84	81	78	75	72	68	64	59	54
200	84	81	78	75	71	66	61	55	50
250	84	81	77	74	70	64	57	51	45
300	84	81	77	73	68	62	54	46	40
400	83	81	77	72	65	56	47	38	32
500	82	80	76	69	61	51	40	31	24
600	82	80	75	67	57	45	34	24	18
800	80	78	72	61	48	35	23	14	9
1,000	78	76	69	54	39	26	15	8	5
1,200	76	74	65	47	30	18	9	4	2
1,400	73	72	61	40	23	12	5	2	1
1,600	71	69	57	33	17	8	3	1	0
1,800	68	67	52	27	12	5	2	0	0
2,000	65	63	48	21	8	3	1	0	0

TABLE 31.--PREDICTED VALUES FOR PERCENT OF GELGARD RECOVERED BY CONCENTRATION CLASS (RETARDANT DISTRIBUTION)

Drop height	Concentration ($\geq$gal/100 ft^2)								
	0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	- - - - - - - - - - - - *Percent* - - - - - - - - - - - -								
	700-GALLON DROP								
100	76	72	65	57	50	44	38	34	31
150	75	72	64	55	49	42	34	28	26
200	75	71	63	54	47	39	29	22	20
250	74	71	61	52	45	36	24	16	14
300	74	70	60	50	42	33	19	11	10
400	73	69	57	45	38	27	12	4	4
500	72	68	54	41	33	22	6	1	1
600	71	66	51	37	28	17	3	0	0
800	68	63	45	28	20	10	1	0	0
1,000	65	59	38	21	14	5	0	0	0
1,200	62	55	32	15	9	2	0	0	0
1,400	59	51	27	11	6	1	0	0	0
1,600	55	47	22	8	4	0	0	0	0
1,800	52	43	18	5	2	0	0	0	0
2,000	48	39	14	3	1	0	0	0	0
	1,400-GALLON DROP								
100	74	73	70	66	54	46	43	39	37
150	74	73	69	65	53	45	40	36	34
200	73	72	68	63	52	44	38	31	30
250	73	72	67	62	50	42	36	27	25
300	72	71	66	60	49	41	33	23	21
400	72	70	64	57	45	38	28	15	12
500	70	69	62	54	42	35	23	9	6
600	69	68	60	51	39	32	19	5	3
800	67	65	56	45	33	26	12	1	0
1,000	64	62	52	39	28	21	7	0	0
1,200	61	58	47	34	23	17	4	0	0
1,400	57	55	43	29	19	13	2	0	0
1,600	54	51	39	24	16	11	1	0	0
1,800	51	48	35	21	13	8	1	0	0
2,000	47	44	31	17	10	6	0	0	0

TABLE 32.--PREDICTED VALUES FOR PERCENT OF FIRE-TROL 100 RECOVERED BY CONCENTRATION CLASS (RETARDANT DISTRIBUTION)

Drop height	Concentration ($\geq$gal/100 ft^2) 0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	Percent								
	700-GALLON DROP								
100	65	60	52	45	38	32	26	22	19
150	64	59	49	41	34	28	24	20	17
200	62	57	46	36	30	25	20	17	15
250	61	55	42	32	25	21	17	14	13
300	59	52	39	27	21	17	14	12	10
400	55	48	32	19	13	11	9	7	7
500	51	43	26	13	8	6	5	4	4
600	47	39	21	8	4	3	3	2	2
800	38	30	12	3	1	1	1	1	0
1,000	31	23	7	1	0	0	0	0	0
1,200	25	17	3	0	0	0	0	0	0
1,400	19	12	2	0	0	0	0	0	0
1,600	15	9	1	0	0	0	0	0	0
1,800	11	6	0	0	0	0	0	0	0
2,000	8	4	0	0	0	0	0	0	0
	1,400-GALLON DROP								
100	72	69	63	58	52	47	42	37	33
150	71	68	62	57	51	45	39	34	30
200	70	67	61	55	49	43	37	31	27
250	69	65	59	53	47	40	33	27	23
300	68	64	58	51	44	37	29	23	20
400	65	60	54	46	38	29	21	16	13
500	62	57	49	41	31	22	14	10	8
600	58	53	44	35	24	15	8	5	5
800	51	45	34	23	13	5	2	1	1
1,000	45	37	25	14	5	1	0	0	0
1,200	38	30	18	7	2	0	0	0	0
1,400	32	24	12	3	0	0	0	0	0
1,600	27	18	7	1	0	0	0	0	0
1,800	22	14	4	1	0	0	0	0	0
2,000	18	10	2	0	0	0	0	0	0

TABLE 33.--PREDICTED VALUES FOR PERCENT OF WATER RECOVERED BY CONCENTRATION CLASS (RETARDANT DISTRIBUTION)

Drop height	Concentration ($\geq$gal/100 ft^2) 0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	Percent								
	700-GALLON DROP								
100	68	61	52	47	43	38	28	24	23
150	66	59	51	45	41	35	25	21	20
200	64	57	49	41	36	31	21	17	16
250	62	55	46	36	31	25	17	13	12
300	60	53	43	30	24	18	12	9	8
400	55	48	35	18	11	7	5	4	3
500	50	44	27	8	3	2	1	1	1
600	45	39	19	2	1	0	0	0	0
800	36	29	8	0	0	0	0	0	0
1,000	28	21	2	0	0	0	0	0	0
1,200	21	14	0	0	0	0	0	0	0
1,400	15	10	0	0	0	0	0	0	0
1,600	11	6	0	0	0	0	0	0	0
1,800	7	4	0	0	0	0	0	0	0
2,000	5	2	0	0	0	0	0	0	0
	1,400-GALLON DROP								
100	76	71	65	62	57	51	46	41	38
150	75	70	64	65	56	50	45	40	36
200	74	69	63	59	54	48	43	39	34
250	73	76	61	57	51	45	41	36	30
300	72	66	59	54	48	41	36	33	25
400	69	62	54	48	40	31	25	22	14
500	66	59	49	42	32	20	12	10	6
600	63	55	44	35	23	10	4	3	1
800	56	47	34	23	10	1	0	0	0
1,000	50	39	25	13	3	0	0	0	0
1,200	43	32	18	7	1	0	0	0	0
1,400	37	26	12	3	0	0	0	0	0
1,600	31	20	8	1	0	0	0	0	0
1,800	26	16	5	0	0	0	0	0	0
2,000	22	12	3	0	0	0	0	0	0

TABLE 34.--DATA LIMITS, FIT OF EQUATION TO DATA (R^2), AND STANDARD ERROR ($sy.x_i$) FOR RECOVERY MODELS FOR EACH RETARDANT AND LOAD SIZE[1]

Retardant	Drop height limits	Level of coverage[2]	R^2	$sy.x_i$
	Feet	*Gal/100 ft²*		
	700-GALLON DROP			
Phos-Chek XA	51-1,046	0.2	0.99	6.4
		1.0	.95	11.3
		2.0	.97	8.3
		3.0	.99	3.6
		4.0	.99	2.3
Gelgard	147-1,000	0.2	.99	6.7
		1.0	.98	9.7
		2.0	.94	11.6
		3.0	.99	2.1
		4.0	.99	2.2
Fire-Trol 100	39-1,043	0.2	.95	13.5
		1.0	.94	11.0
		2.0	.90	9.7
		3.0	.80	9.1
		4.0	.64	8.1
Water	166-1,073	0.2	.99	5.8
		1.0	.99	4.4
		2.0	.94	6.5
		3.0	.89	5.4
		4.0	.76	6.3
	1,400-GALLON DROP			
Phos-Chek XA	128-2,000	0.2	.99	9.6
		1.0	.99	7.5
		2.0	.97	9.6
		3.0	.97	7.1
		4.0	.99	3.5
Gelgard	164-982	0.2	.99	4.4
		1.0	.99	8.1
		2.0	.98	7.3
		3.0	.93	9.8
		4.0	.97	4.8
Fire-Trol 100	157-1,500	0.2	.98	8.2
		1.0	.98	6.5
		2.0	.97	4.9
		3.0	.99	2.2
		4.0	.99	1.6
Water	137-1,500	0.2	.99	7.1
		1.0	.98	7.2
		2.0	.99	1.2
		3.0	.99	1.5
		4.0	.99	1.8

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[1] R^2 is the coefficient of multiple determination and is a measure of how well the regression fits the data. $sy.x_i$ is the standard error of the estimate.

[2] The limits on recovery by concentration class for all models are from 0.2 to 4.0 gal/100 ft².

TABLE 35.--PREDICTIONS OF AREA OF COVERAGE AS A FUNCTION OF DROP HEIGHT AND CONCENTRATION FOR 700- AND 1,400-GALLON PHOS-CHEK XA DROPS

Drop height	Concentration (≥gal/100 ft²)								
	0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	- - - - - - - - - - *Area of coverage (ft.²)* - - - - - - - - - -								
	700-GALLON DROP								
100	33,783	26,670	18,170	12,514	8,900	6,461	4,754	3,611	2,987
150	35,011	27,588	18,625	12,702	8,960	6,465	4,715	3,437	2,688
200	36,225	28,473	19,030	12,844	8,987	6,457	4,607	3,159	2,338
250	37,423	29,319	19,385	12,947	8,994	6,421	4,412	2,792	1,968
300	38,600	30,123	19,690	13,014	8,994	6,337	4,122	2,365	1,606
400	40,873	31,592	20,155	13,069	8,946	5,975	3,287	1,477	978
500	43,010	32,857	20,446	13,071	8,761	5,310	2,269	754	531
600	44,978	33,903	20,592	13,029	8,372	4,372	1,320	310	258
800	48,292	35,317	20,628	12,579	6,879	2,212	244	26	
1,000	50,612	35,885	20,367	11,390	4,672	687	17	1	
1,200	51,810	35,860	19,492	9,408	2,482	117			
1,400	51,885	35,212	17,839	6,913	978	10			
1,600	50,843	33,704	15,438	4,413	272				
1,800	48,671	31,303	12,505	2,393	51				
2,000	45,482	28,109	9,395	1,079	6				
	1,400-GALLON DROP								
100	43,276	42,484	31,146	18,878	15,905	14,670	12,052	9,128	7,571
150	44,732	43,833	32,286	19,822	16,799	15,342	12,383	9,255	7,624
200	46,192	45,183	33,429	20,765	17,666	15,937	12,609	9,300	7,634
250	47,654	46,532	34,572	21,703	18,500	16,445	12,731	9,284	7,624
300	49,115	47,878	35,712	22,630	19,290	16,859	12,754	9,916	7,571
400	52,028	50,553	37,970	24,435	20,711	17,386	12,518	8,748	7,245
500	54,915	53,190	40,181	26,142	21,870	17,509	11,866	7,934	6,550
600	57,758	55,771	42,320	27,713	22,721	17,253	10,836	6,824	5,498
800	63,236	60,691	46,282	30,303	23,412	15,541	8,033	4,242	2,919
1,000	68,307	65,160	49,657	31,962	22,798	12,581	5,058	2,050	973
1,200	72,814	69,025	52,258	32,548	20,859	9,112	2,690	756	185
1,400	76,601	72,135	53,922	32,051	17,862	5,886	1,203	210	18
1,600	79,519	74,349	54,507	30,475	14,285	3,383	451	43	1
1,800	81,424	75,530	53,897	27,953	10,654	1,727	141	6	
2,000	82,160	75,470	52,212	24,721	7,400	782	37	1	

TABLE 36.--PREDICTIONS OF AREA OF COVERAGE AS A FUNCTION OF DROP HEIGHT AND CONCENTRATION FOR 700- AND 1,400-GALLON GELGARD DROPS

Drop height	Concentration (≥gal/100 ft²)								
	0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	- - - - - - - - - - - *Area of coverage (ft²)* - - - - - - - - - - -								
	700-GALLON DROP								
100	34,991	24,026	13,688	10,245	8,385	6,633	5,212	4,196	3,852
150	36,411	25,691	14,587	10,566	8,499	6,648	5,143	3,787	3,367
200	37,768	27,315	15,436	10,841	8,577	6,649	4,948	3,080	2,591
250	39,056	28,885	16,228	11,071	8,624	6,642	4,577	2,176	1,682
300	40,271	30,386	16,954	11,258	8,650	6,609	4,015	1,288	883
400	42,473	33,141	18,197	11,518	8,661	6,393	2,495	229	108
500	44,356	35,512	19,147	11,652	8,652	5,878	1,064	13	3
600	45,919	37,459	19,815	11,701	8,587	5,018	279		
800	47,171	38,978	20,235	11,707	8,408	3,884	40		
1,000	49,307	41,281	20,558	11,502	6,795	791			
1,200	49,747	41,570	20,478	10,299	4,858	109			
1,400	49,810	41,550	19,891	9,395	2,790	6			
1,600	49,747	41,107	18,356	7,347	1,218				
1,800	49,307	39,620	15,676	5,010	383				
2,000	48,138	36,607	12,071	2,891	82				
	1,400-GALLON DROP								
100	48,881	32,818	28,264	22,380	15,603	10,306	7,606	6,473	5,991
150	51,569	34,630	29,435	23,226	16,336	11,030	8,106	6,520	5,895
200	54,220	36,445	30,581	24,024	16,999	11,633	8,432	6,528	5,942
250	56,829	38,260	31,699	24,770	17,585	12,111	8,610	6,524	5,823
300	59,391	40,067	32,783	25,460	18,091	12,465	8,680	6,490	5,597
400	64,355	43,636	34,829	26,660	18,362	12,851	8,683	6,193	4,743
500	69,074	47,103	36,683	27,607	19,329	12,938	8,454	5,426	3,421
600	73,514	50,421	38,317	28,298	19,542	12,908	7,659	4,171	1,986
800	81,440	56,432	40,837	28,980	19,545	12,004	4,231	1,388	278
1,000	87,936	61,351	42,309	29,017	18,876	9,255	1,033	158	8
1,200	92,891	64,958	42,821	28,472	17,028	5,353	79	4	
1,400	96,380	67,162	42,671	27,000	13,992	2,120	1		
1,600	98,188	68,042	41,701	24,522	10,253	528			
1,800	98,835	67,936	39,704	21,182	6,575	76			
2,000	98,650	66,748	36,600	17,298	3,627	6			

TABLE 37.--PREDICTIONS OF AREA OF COVERAGE AS A FUNCTION OF DROP HEIGHT AND CONCENTRATION FOR 700- AND 1,400-GALLON FIRE-TROL 100 DROPS

Drop	Concentration ($\geq$gal/100 ft^2)								
height	0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	Area of coverage (*ft*^{2})								
	700-GALLON DROP								
100	49,865	27,511	14,579	10,813	7,507	5,171	3,467	2,375	1,890
150	49,517	27,419	14,482	10,583	7,020	4,727	3,083	2,025	1,500
200	49,046	27,273	14,325	10,228	6,430	4,204	2,645	1,644	1,110
250	48,460	27,067	14,098	9,744	5,777	3,644	2,194	1,275	768
300	47,763	26,797	13,798	9,139	5,095	3,082	1,763	947	499
400	46,067	26,055	12,970	7,636	3,759	2,055	1,033	461	176
500	44,016	25,038	11,852	5,918	2,592	1,253	544	191	49
600	41,668	23,753	10,493	4,225	1,677	702	255	68	11
800	36,339	20,493	7,393	1,643	584	173	41	6	
1,000	30,582	16,622	4,439	430	161	31	4		
1,200	24,852	12,602	2,229	73	36	4			
1,400	19,510	8,886	920	8	6				
1,600	14,804	5,801	308	1	1				
1,800	10,860	3,491	82						
2,000	7,706	1,930	17						
	1,400-GALLON DROP								
100	51,275	50,314	25,592	18,363	14,910	12,183	9,700	7,653	6,043
150	52,464	51,122	26,607	18,356	14,860	12,071	9,480	7,214	5,627
200	53,636	51,912	27,482	18,328	14,757	11,864	9,115	6,805	5,214
250	54,792	52,682	28,215	18,261	14,582	11,538	8,597	6,236	4,707
300	55,929	53,434	28,806	18,140	14,318	11,076	7,931	5,573	4,175
400	58,146	54,874	29,589	17,673	13,462	9,736	6,255	4,111	3,120
500	60,277	56,227	29,925	16,818	12,119	7,912	4,389	2,709	2,186
600	62,316	57,487	29,977	15,509	10,320	5,842	2,695	1,585	1,439
800	66,081	59,712	29,419	11,623	6,018	2,232	640	371	350
1,000	69,380	61,516	27,006	6,967	2,407	476	75	51	
1,200	72,160	62,871	22,418	3,124	593	50	4	4	
1,400	74,373	63,762	16,379	980	81	2			
1,600	75,982	64,181	10,287	201	5				
1,800	76,959	64,142	5,436	25					
2,000	77,286	63,642	2,370	2					

TABLE 38.--PREDICTIONS OF AREA OF COVERAGE AS A FUNCTION OF DROP HEIGHT AND CONCENTRATION FOR 700- AND 1,400-GALLON WATER DROPS

Drop	Concentration ($\geq$gal/100 ft^2)								
height	0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	Area of coverage (*ft*^{2})								
	700-GALLON DROP								
100	33,285	33,948	14,631	10,189	7,015	4,753	3,317	2,585	2,334
150	35,559	33,492	14,522	10,138	6,936	4,663	3,234	2,487	2,124
200	37,780	32,870	14,325	10,004	6,714	4,420	3,022	2,254	1,782
250	39,919	32,091	14,022	9,727	6,248	3,939	2,622	1,852	1,346
300	41,945	31,169	13,599	9,245	5,455	3,180	2,028	1,315	896
400	45,541	28,953	12,367	7,487	3,010	1,272	698	339	249
500	48,336	26,350	10,655	4,809	809	175	75	22	
600	50,128	23,497	8,605	2,158	68	4	1		
800	50,065	17,586	4,439	77					
1,000	45,377	12,144	1,571						
1,200	37,560	7,742	354						
1,400	28,460	4,558	47						
1,600	19,770	2,479	4						
1,800	12,605	1,246							
2,000	7,382	579							
	1,400-GALLON DROP								
100	52,854	42,234	26,160	20,720	17,796	14,681	11,824	9,238	7,256
150	55,812	43,841	27,098	21,274	17,817	14,654	11,718	9,083	7,166
200	58.763	45,385	27,940	21,661	17,813	14,555	11,469	8,750	6,930
250	61,690	46,857	28,679	21,894	17,765	14,328	11,016	8,176	6,457
300	64,575	48,250	29,310	21,993	17,623	13,922	10,312	7,332	5,678
400	70,159	50,769	30,239	21,940	16,884	12,403	8,114	4,969	3,321
500	75,386	52,892	30,736	21,422	15,436	9,894	5,240	2,460	1,072
600	80,138	54,584	30,863	20,256	12,974	6,771	2,592	795	137
800	87,818	56,636	30,202	16,038	6,918	1,667	211	14	
1,000	92,655	57,105	27,858	10,470	2,208	136	2		
1,200	94,603	56,341	23,913	5,472	366	2			
1,400	94,339	53,907	18,944	2,234	27				
1,600	91,640	49,727	13,764	698	1				
1,800	86,005	44,055	9,123	164					
2,000	77,632	37,371	5,492	28					

TABLE 39.--DATA LIMITS, FIT OF EQUATION TO DATA (R^2), AND STANDARD ERROR ($sy.x_i$) FOR AREA OF COVERAGE MODELS FOR EACH RETARDANT AND LOAD SIZE[1]

Retardant	Drop height limits	Level of coverage[2]	R^2	$sy.x_i$
	Feet	*Gal/100 ft^2*		
	700-GALLON DROP			
Phos-Chek XA	128-2,000	0.2	0.98	7,116
		1.0	.98	3,607
		2.0	.89	3,211
		3.0	.99	497
		4.0	.96	470
Gelgard	147-1,000	0.2	.98	7,429
		1.0	.99	1,811
		2.0	.98	1,546
		3.0	.96	747
		4.0	.98	309
Fire-Trol 100	39-1,043	0.2	.87	15,278
		1.0	.96	2,647
		2.0	.93	1,623
		3.0	.86	1,101
		4.0	.70	940
Water	166-1,073	0.2	.99	2,553
		1.0	.92	3,079
		2.0	.99	568
		3.0	.96	434
		4.0	.75	689
	1,400-GALLON DROP			
Phos-Chek XA	128-2,000	0.2	.99	6,219
		1.0	.99	4,970
		2.0	.92	5,538
		3.0	.93	2,655
		4.0	.98	752
Gelgard	164-982	0.2	.94	20,201
		1.0	.99	3,941
		2.0	.99	624
		3.0	.98	1,272
		4.0	.99	811
Fire-Trol 100	157-1,500	0.2	.86	27,249
		1.0	.97	5,002
		2.0	.95	2,638
		3.0	.98	806
		4.0	.96	680
Water	137-1,500	0.2	.99	4,564
		1.0	.95	6,549
		2.0	.99	944
		3.0	.98	1,036
		4.0	.99	538

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[1] R^2 is the coefficient of multiple determination and is a measure of how well the regression fits the data. $sy.x_i$ is the standard error of the estimate.

[2] The limits on recovery by concentration class for all models are from 0.2 to 4.0 gal/100 ft^2.

TABLE 40.--PREDICTED VALUES FOR CONTOUR AREA LENGTHS BY CONCENTRATION CLASS FOR PHOS-CHEK XA

Drop height	Length of contour areas at concentrations (≥gal/100 ft^2) of ... 0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	- - - - - - - - - - - - - *Feet* - - - - - - - - - - - - - - -								
	700-GALLON DROP								
100	406	368	319	295	257	217	175	147	120
150	417	377	328	293	256	211	165	140	113
200	426	385	335	290	255	204	155	131	105
250	435	392	341	285	253	196	145	120	95
300	442	399	344	279	249	186	134	109	84
400	453	408	344	263	238	164	113	87	62
500	461	415	334	241	219	140	93	66	43
600	466	419	317	216	192	116	75	47	27
800	470	422	266	161	121	72	47	22	9
1,000	470	422	203	108	54	40	28	8	2
1,200	470	419	141	65	15	8	0	0	0
1,400	469	408	89	35	2	0	0	0	0
1,600	461	385	52	15	0	0	0	0	0
1,800	442	346	28	7	0	0	0	0	0
2,000	406	293	13	3	0	0	0	0	0
	1,400-GALLON DROP								
100	448	424	368	319	274	247	209	175	152
150	458	433	375	325	279	250	212	177	155
200	467	441	382	331	284	252	214	179	158
250	477	449	390	336	288	254	215	180	159
300	485	456	396	341	292	256	215	180	159
400	501	470	409	351	298	259	215	179	158
500	515	482	421	358	304	260	215	176	152
600	527	492	430	365	308	260	213	168	142
800	543	504	430	371	312	260	201	137	112
1,000	548	497	409	367	312	255	172	93	75
1,200	542	478	382	354	308	245	129	50	43
1,400	525	450	352	335	298	227	82	21	20
1,600	449	417	321	312	283	203	42	9	6
1,800	464	380	289	285	263	174	17	3	1
2,000	423	341	257	256	239	141	5	1	0

TABLE 41.--PREDICTED VALUES FOR CONTOUR AREA LENGTHS BY CONCENTRATION CLASS FOR GELGARD

Drop height	Length of contour areas at concentrations (≥gal/100 ft^2) of... 0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	- - - - - - - - - - - - - *Feet* - - - - - - - - - - - - -								
	700-GALLON DROP								
100	439	381	313	270	213	172	144	126	118
150	445	386	317	271	211	170	141	120	110
200	449	391	320	271	208	167	137	111	98
250	454	395	324	271	205	163	130	96	83
300	458	399	327	271	202	159	120	78	65
400	465	407	332	269	195	148	90	39	33
500	470	412	335	266	187	134	55	12	12
600	475	417	338	262	179	120	26	2	0
800	480	423	341	251	161	89	2	0	0
1,000	481	424	339	238	144	60	0	0	0
1,200	480	422	332	223	126	37	0	0	0
1,400	475	417	322	206	109	21	0	0	0
1,600	465	406	307	188	94	11	0	0	0
1,800	449	390	289	120	79	5	0	0	0
2,000	428	369	267	151	66	2	0	0	0
	1,400-GALLON DROP								
100	441	389	316	283	240	181	149	138	133
150	447	394	320	288	240	181	149	137	128
200	451	399	323	292	240	181	149	135	122
250	456	403	326	296	240	180	148	131	115
300	460	407	329	300	240	180	146	126	107
400	467	414	333	306	239	179	139	110	90
500	473	420	337	309	237	176	126	90	73
600	477	424	340	305	234	170	106	67	57
800	482	429	341	290	223	148	53	26	26
1,000	483	430	340	271	207	109	13	6	5
1,200	482	429	334	250	186	61	1	1	0
1,400	477	423	324	227	161	23	0	0	0
1,600	467	412	310	204	134	5	0	0	0
1,800	451	396	292	181	107	1	0	0	0
2,000	430	374	271	159	81	0	0	0	0

TABLE 42.--PREDICTED VALUES FOR CONTOUR AREA LENGTHS BY CONCENTRATION CLASS FOR FIRE-TROL 100

Drop height	Length of contour areas at concentrations ($\geq$gal/100 ft^2) of... 0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	Feet								
	700-GALLON DROP								
100	392	325	302	260	219	188	165	146	131
150	408	335	298	246	198	166	144	127	114
200	422	343	291	229	175	143	123	109	97
250	435	349	281	211	153	120	103	91	82
300	446	353	270	193	131	100	85	75	67
400	461	346	244	156	92	65	55	48	44
500	466	329	216	122	62	40	33	29	27
600	461	307	187	93	39	23	19	17	16
800	422	255	134	49	14	7	5	5	5
1,000	357	200	91	24	4	2	1	1	1
1,200	278	150	58	11	1	0	0	0	0
1,400	201	108	36	4	0	0	0	0	0
1,600	134	75	21	2	0	0	0	0	0
1,800	83	50	12	1	0	0	0	0	0
2,000	47	32	6	0	0	0	0	0	0
	1,400-GALLON DROP								
100	450	407	349	289	239	205	173	147	127
150	455	412	352	284	235	204	172	147	126
200	458	416	350	279	229	202	171	145	124
250	460	419	345	273	224	200	169	143	121
300	461	420	339	267	217	197	165	139	117
400	458	415	325	253	204	186	152	125	104
500	450	405	308	238	189	170	128	104	86
600	440	392	290	222	175	149	96	77	64
800	411	359	251	191	146	96	31	26	25
1,000	377	322	213	160	118	47	3	3	3
1,200	338	283	176	132	94	16	0	0	0
1,400	297	243	143	106	73	4	0	0	0
1,600	256	206	114	85	56	1	0	0	0
1,800	217	171	89	66	42	0	0	0	0
2,000	181	139	68	51	31	0	0	0	0

TABLE 43.--PREDICTED VALUES FOR CONTOUR AREA LENGTHS BY CONCENTRATION CLASS FOR WATER

Drop height	Length of contour areas at concentrations ($\geq$gal/100 ft^2) of... 0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	Feet								
	700-GALLON DROP								
100	440	326	271	237	203	172	143	115	86
150	439	319	262	228	194	163	137	111	77
200	437	310	252	217	181	148	126	104	66
250	434	301	242	204	164	129	109	92	54
300	431	292	230	190	144	106	89	76	41
400	421	272	206	158	102	60	46	39	20
500	409	251	181	125	64	25	15	12	8
600	394	231	157	95	34	8	3	2	2
800	355	191	113	47	7	0	0	0	0
1,000	309	156	78	20	1	0	0	0	0
1,200	258	124	51	7	0	0	0	0	0
1,400	206	97	33	2	0	0	0	0	0
1,600	158	75	20	1	0	0	0	0	0
1,800	116	57	12	0	0	0	0	0	0
2,000	81	43	7	0	0	0	0	0	0
	1,400-GALLON DROP								
100	476	407	351	315	286	259	235	208	144
150	479	409	350	311	277	246	222	198	141
200	482	412	348	305	266	229	207	187	136
250	484	413	345	299	254	211	189	172	130
300	486	415	342	292	240	192	170	156	122
400	489	417	334	277	210	153	132	122	101
500	491	418	325	259	179	117	97	88	77
600	492	417	315	240	150	85	67	59	53
800	493	411	291	201	97	40	28	22	19
1,000	493	400	265	162	58	16	9	6	4
1,200	493	384	237	126	32	6	3	1	1
1,400	492	364	209	96	16	2	1	0	0
1,600	489	339	181	70	8	0	0	0	0
1,800	482	311	155	50	3	0	0	0	0
2,000	470	281	130	35	1	0	0	0	0

TABLE 44.--DATA LIMITS, FIT OF EQUATION TO DATA (R^2), AND STANDARD ERROR ($sy.x_i$) FOR CONTOUR AREA LENGTH MODELS FOR EACH RETARDANT AND LOAD SIZE[1]

Retardant	Drop height limits	Level of coverage[2]	R^2	$sy.x_i$
	Feet	*Gal/100 ft²*		
	700-GALLON DROP			
Phos-Chek XA	51-1,046	0.2	0.99	47
		1.0	.97	60
		2.0	.88	87
		3.0	.96	31
		4.0	.94	27
Gelgard	147-1,000	0.2	.99	53
		1.0	.98	54
		2.0	.95	53
		3.0	.91	46
		4.0	.95	28
Fire-Trol 100	39-1,043	0.2	.98	55
		1.0	.97	49
		2.0	.93	50
		3.0	.93	37
		4.0	.98	18
Water	166-1,073	0.2	.99	48
		1.0	.91	61
		2.0	.95	28
		3.0	.90	26
		4.0	.75	29
	1,400-GALLON DROP			
Phos-Chek XA	128-2,000	0.2	.98	73
		1.0	.99	46
		2.0	.87	100
		3.0	.94	47
		4.0	.90	37
Gelgard	164-982	0.2	.99	12
		1.0	.99	23
		2.0	.98	38
		3.0	.97	27
		4.0	.97	19
Fire-Trol 100	157-1,500	0.2	.96	97
		1.0	.96	66
		2.0	.95	50
		3.0	.90	62
		4.0	.97	25
Water	137-1,500	0.2	.97	101
		1.0	.91	110
		2.0	.91	72
		3.0	.92	52
		4.0	.83	56

---

[1] R^2 is the coefficient of multiple determination and is a measure of how well the regression fits the data. $sy.x_i$ is the standard error of the estimate.

[2] The limits on recovery by concentration class for all models are from 0.2 to 4.0 gal/100 ft².

APPENDIX II

Algebraic Models

ALGEBRAIC MODELS FOR RETARDANT RECOVERED AS A FUNCTION OF CONCENTRATION (DISTRIBUTION) AND DROP HEIGHT FOR 700-GALLON DROPS OF EACH RETARDANT

```
       AB = EXP(-(ABS((((XLEN - DH)/XP)-1.0)/(1.0-XI))**XN))
       AC = EXP(-(ABS(1.0/(1.0-XI))**XN ))
       A(N,M) = B * YP * (AB-AC)/(1.0-AC)
       XCONC = 4.0 - CONC
       Z = CONC/4.0 - 1.0
       ZZ = XCONC/4.0 - 1.0
       ZY = XCONC/3.8 - 1.0


PHOS-CHEK XA 700  DIST
       B = .9886083452
       XLEN = 5000.0
       XP   = 5000.0
       YP = 59.1 + 19.7 * EXP(-(ABS(ZY/.32)**2.3)) - 20.9 * EXP(-(ABS(Z/.
      135)**3.0))
       XI = .935 - .03 * XCONC - .785 * EXP(-(ABS(ZZ/.19)**1.85))
       XN = 1.50 - .04 * XCONC + .45 * EXP(-(ABS(ZY/.182)**2.0))


GELGARD 700      DIST
       B  = .988113
       XLEN = 5000.0
       XP = 5000.0
       YP = 37.7 + 39.1 * (EXP(-(ABS(ZY/.605)**1.3))-.1463369)/.8536631
       XI = .83 - .75 * EXP(-(ABS(ZY/.137)**1.3)) + .119 * EXP(-(ABS(Z/.3
      195)**4.0))
       XN = 1.50 + .40 * EXP(-(ABS(Z/.29)**3.0))


FIRE-TROL 100  700  DIST
       B  = .965055
       XLEN = 4000.0
       XP = 4000.0
       YP = 22.5 + 8.10848 * XCONC**1.44 - 8.34 * (EXP(-(ABS(ZY/.268)**1.
      15))-.00074085)/.99925915
       XI = .910 -.210 * EXP(-(ABS(ZY/.183)**1.6))
       XN = 1.70 - .25 * EXP(-(ABS(ZY/.32)**5.0))


WATER 700        DIST
       B  = .9790687059
       XLEN = 3500.0
       XP = 3500.0
       YP = 44.0 + .1017158571 * XCONC**4.2 - 17.4 * EXP(-(ABS(Z/.35)**4.
      15))
       XI = .92 - .01 * XCONC - .182 * EXP(-(ABS(ZY/.20)**2.0))
       XN = 2.80 - 1.32 * EXP(-(ABS(ZY/.224)**2.2)) - .60 * EXP(-(ABS(Z/.
      128)**3.0))
```

ALGEBRAIC MODELS FOR RETARDANT RECOVERED AS A FUNCTION OF CONCENTRATION (DISTRIBUTION) AND DROP HEIGHT FOR 1,400-GALLON DROPS OF EACH RETARDANT

```
      AB = EXP(-(ABS((((XLEN - DH)/XP)-1.0)/(1.0-XI))**XN))
      AC = EXP(-(ABS(1.0/(1.0-XI))**XN ))
      A(N,M) = B * YP * (AB-AC)/(1.0-AC)
      XCONC = 4.0 - CONC
      Z = CONC/4.0 - 1.0
      ZZ = XCONC/4.0 - 1.0
      ZY = XCONC/3.8 - 1.0


PHOS-CHEK XA 1400 DIST
      B  = .9898195490
      XLEN = 6000.0
      XP = 6000.0
      YP = 64.9 + 5.524582204 * XCONC**.82 + 4.89176 * EXP(-(ABS(ZZ/.135
     1)**1.5))
      XI = .915 - .04010705929 * XCONC**1.64 - .486849 * EXP(-(ABS(ZY/.1
     193)**1.8))
      XN = 1.45 + .55 * (EXP(-(ABS(((XCONC/3)-1.0)/.43)**2.0))-.004791)/
     1.995521 - 2.7284811E-13 * XCONC**20


GELGARD 1400     DIST
      B  = .967540
      XLEN = 5000.0
      XP = 5000.0
      YP = 47.0 + 5.6 * XCONC   +  .94 * (EXP(-(ABS((CONC(N)-1.0)/.999)**
     112.5))-.363278)/.636721
      XI = .740 - .66 * EXP(-(ABS(ZY/.22)**2.0)) + .187 * EXP(-(ABS(Z/.3
     12)**4.0))
      XN = 1.28 + .72 * EXP(-(ABS(Z/.20)**2.0)) + .22 * EXP(-(ABS(ZY/.15
     15)**2.0))


FIRE-TROL 100  1400 DIST
      B  = .9802734525
      XLEN = 4000.0
      XP = 4000.0
      YP = 36.2 + 7.8184774 * XCONC**1.195
      XI = .42 + .3204384752 * CONC(N)**.38 - .00057848 * CONC(N)**3.4
      XN = 1.44 + .72 * (EXP(-(ABS(((CONC(N)/2.45)-1.0)/.9)**2.1))-.2871
     1805585)/.7128194414


WATER 1400       DIST
      B  = .9897637968
      XLEN = 4000.0
      XP = 4000.0
      YP = 38.6 + 7.915588013 * XCONC**1.33 - 7.52955 * EXP(-(ABS(ZY/.3)
     1**3.0))
      XI = .9457317537 * CONC(N)**.144 - .2 - .0547 * EXP(-(ABS(Z/.265)*
     1*2.4))
      XN = 1.45 + 2.15 * (EXP(-(ABS(((CONC(N)/3.3)-1.0)/.45)**1.4))-.046
     196006512)/.9530399348
```

ALGEBRAIC MODELS FOR AREA OF COVERAGE BY DROP HEIGHT AND CONCENTRATION CLASS FOR 700-GALLON DROPS OF EACH RETARDANT

```
      AB = EXP(-(ABS((((XLEN - DH)/XP)-1.0)/(1.0-XI))**XN))
      AC = EXP(-(ABS(1.0/(1.0-XI))**XN ))
      A(N,M) = B * YP * (AB-AC)/(1.0-AC)
      XCONC = 4.0 - CONC
      Z = CONC/4.0 - 1.0
      ZZ = XCONC/4.0 - 1.0
      ZY = XCONC/3.8 - 1.0
```

```
PHOS-CHEK XA 700  AREA
      B  = .9008551070
      XLEN = 6000.0
      XP = 6000.0 - 1425.0 * (EXP(-(ABS(ZZ/.35)**1.3))-.019942)/.9800558
     1157
      YP = 3650.0 + 1628.0 * XCONC**1.87 + 2.99705 * XCONC**7.0
      XI = .940 - .0214 * XCONC**2.05
      XN = 2.80 - .1715 * ABS(CONC(N)-2.0)**2.5
```

```
GELGARD 700      AREA
      B  = .9942035
      XLEN = 4000.0
      XN = 3.0
      XP = 2600.0 + 1400.0 * (EXP(-(ABS((((CONC(N)-.2)/3.8)-1.0)/.8)**3.
     10)) - .14183)/.85817
      YP = 4100.0 + 1150.0 * XCONC**2.0 + 29394.0 * EXP(-(ABS(ZY/.169)**
     12.0))
      XI = .59 + .345 * (EXP(-(ABS((((CONC(N)-.2)/3.8)-1.0)/.55)**3.2))-
     1.00114)/.99886 - .32 * EXP(-(ABS(ZY/.08)**1.2))
```

```
FIRE-TROL 100  700  AREA
      B = .9782396595
      XLEN = 6000.0
      YP = 2400.0 + 1557* XCONC**1.89 + 36808.0 * EXP(-(ABS(ZZ/.106)**2.
     10))
      XP = 6000.0
      XI = .886 + .018 * CONC(N) - .13 * (EXP(-(ABS((((2.0 -CONC(N))/1.8
     1)-1.0)/.51)**2.0)) - .021393 ) / .978607
      XN = 1.79 + .71 * EXP(-(ABS(((XCONC/3.0)-1.0) / .24)**5.0))
```

```
WATER  700       AREA
      B  = 1.010916634
      XLEN = 5000.0
      XP = 5000.0 - 1100.0 * EXP(-(ABS(ZZ/.057)**6.0))
      YP = 891.823385 * XCONC**2.35 + 2410.0 + 27242.0 * EXP(-(ABS(ZY/.1
     1)**2.0))
      XI = .775 + .149 * (EXP(-(ABS(((CONC(N)/3.0)-1.0)/.76)**3.6))-.068
     11677)/.9318322 + .0240196 * (EXP(-(ABS(Z/.15)**6))-.0012726)/.9987
     2273
      XN = 2.8 + 1.1772549 * XCONC**.25 - 2.493676 * EXP(-(ABS(ZY/.268)*
     1*3.07))
```

ALGEBRAIC MODELS FOR AREA OF COVERAGE BY DROP HEIGHT AND CONCENTRATION CLASS FOR 1,400-GALLON DROPS OF EACH RETARDANT

```
      AB = EXP(-(ABS((((XLEN - DH)/XP)-1.0)/(1.0-XI))**XN))
      AC = EXP(-(ABS(1.0/(1.0-XI))**XN ))
      A(N,M) = B * YP * (AB-AC)/(1.0-AC)
      XCONC = 4.0 - CONC
      Z = CONC/4.0 - 1.0
      ZZ = XCONC/4.0 - 1.0
      ZY = XCONC/3.8 - 1.0


PHOS-CHEK XA 1400 AREA
      B  = .954253667
      XLEN = 6000.0
      XI = .895 - .355  *    (EXP(-(ABS(((XCONC/3.0)-1.0)/.3)**1.1))-.02
     1328801931)/.9767119806 - .406476 * EXP(-(ABS(ZY/.12)**3.0))
      YP = 8000.0 + 5368.035 * XCONC**1.62 + 31427.0 * EXP(-(ABS(ZY/.25)
     1**3.0))
      XP = 3940.0 + 1860.0 * (EXP(-(ABS(Z/.697)**3.0))-.05216936253)/.94
     178306374
      XN = 2.08 - .18 * EXP(-(ABS(ZY/.31)**3.0)) + .57 * EXP(-(ABS(Z/.10
     16)**1.4))


GELGARD 1400    AREA
      B  = .998498
      XLEN = 4500.0
      XP = 4400.0 - 252.27 * XCONC**1.25 - 412.0 * EXP(-(ABS(ZY/.212)**2
     1.2))
      XI = 1.084 - .15139 * XCONC**1.26 - .194 * EXP(-(ABS(Z/.22)**2.0))
     1 - 8.325E-16 * XCONC**25
      XN = 2.2 + .84 *(EXP(-(ABS(Z/.57)**2.5))-.01696)/.98304 + 2.7907E-
     113 * XCONC**20
      YP = 6000.0 + 2704.8 * XCONC**2.33 + .0038114 * XCONC**11.95


FIRE-TROL 100  1400 AREA
      B  = .9402160937
      XLEN = 6000.0
      XP = 6000.0 - 2000.0 * EXP(-(ABS(ZY/.19)**2.0))
      YP = 6820.0 + 3624.84 * XCONC**1.32 + 54265.0 * EXP(-(ABS(ZY/.16)*
     1*2.0))
      XI = .83 + .09 * (EXP(-(ABS(Z/.5)**3.0))-.00033546)/.9996453 - .75
     1406432 * EXP(-(ABS(ZY/.15)**4.0))
      XN = 1.8 + .7985346 * XCONC**.81 -  2.1546 * EXP(-(ABS(ZY/.265)**2
     1.0))


WATER 1400      AREA
      B  = .9875917747
      XLEN = 5000.0
      XP = 5000.0 - 17.76230351 * XCONC**3.2
      YP = .1841706523 * XCONC**9.58 + 7370.0 + 4631.352384 * XCONC**1.1
     185
      XI = .915 - .01793504977 * XCONC**1.45 - .1907235607 * EXP(-(ABS(Z
     1Y/.219)**2.5))
      XN = 2.2475 + .0125 * CONC(N) + 1.015 * EXP(-(ABS(((CONC(N)/3.0)-1
     1.0)/.408)**3.6)) + 1.076 * EXP(-(ABS(Z/.069)**1.5))
```

ALGEBRAIC MODELS FOR CONTOUR LENGTHS BY DROP HEIGHT AND CONCENTRATION CLASS FOR 700-GALLON DROPS OF EACH RETARDANT

```
      AB = EXP(-(ABS((((XLEN - DH)/XP)-1.0)/(1.0-XI))**XN))
      AC = EXP(-(ABS(1.0/(1.0-XI))**XN ))
      A(N,M) = B * YP * (AB-AC)/(1.0-AC)
      XCONC = 4.0 - CONC
      Z = CONC/4.0 - 1.0
      ZZ = XCONC/4.0 - 1.0
      ZY = XCONC/3.8 - 1.0


PHOS-CHEK XA  700  LENGTH
      B  =.9503484734
      XLEN = 4000.0
      XI = .88 - .127 * (EXP(-(ABS(((XCONC/3.0)-1.0)/.7)**2))-.129922608
     13 / .8700773916 - .3227176356 * EXP(-(ABS(ZY/.12))**3.5))
      XN = 1.9 - .5 * XCONC**2 + 4.7263 * EXP(-(ABS(ZY/.57)**6)) - 6.762
     16E-4 * XCONC**5 + 4.721521872 * EXP(-(ABS(ZY/.1)**3)) - 1.1 * EXP(
     2-(ABS(((XCONC/2.5)-1.0)/.1)**20))
      XP = 4000.0 - 1050.0 * EXP(-(ABS(ZY/.2)**2))
      YP = 133.0 + 63.91275992 * XCONC**1.1 + 84.4446977 * EXP(-(ABS(ZY/
     1.15)**1.5))


GELGARD 700   LENGTH
      B  = .9813159087
      XLEN = 4000
      XI = .91 - .90 * (EXP(-(ABS(ZY/.5)**3.0))-.00033546)/.99968454
      XN = .881807 * XCONC**.75 + 2.55 * EXP(-(ABS(Z/.37)**6))
      XP = 4000.0 - 1000.0 * EXP(-(ABS(ZY/.31)**4.0))
      YP = 125.0 + 22.11807424 * XCONC**2.1


FIRE-TROL 100 700  LENGTH
      B = 1.017243819
      XLEN = 4000.0
      XI = .715 + .200 * EXP(-(ABS(Z/.76)**6.0))
      YP = 152.0 + 38.53159496 * XCONC**1.2 + 2.911623174E-10 * XCONC**
     120
      XN = 1.45 + .040 * XCONC + .43 * EXP(-(ABS(ZZ/.086)**3.0))
      XP = 4000.0 - 590.0 * EXP(-(ABS(ZZ/.169)**1.48 ))


WATER 700 LENGTH
      B = .9818835078
      XP = 4000.0
      XLEN = 4000.0
     1-.00028493)/ .999715
      XI = .32 + .46785 * CONC(N)**.31 - .122 * (EXP(-(ABS(Z/.35)**2.0))
      XN = .725 * CONC(N) + .81333 - 1.37634E-12 * CONC(N)**20 +
     18.623725436E-13 * XCONC**21
      YP = 94.0 + 53.994 *  XCONC**1.15 + 2.647005328E-10 * XCONC**20
```

ALGEBRAIC MODELS FOR CONTOUR LENGTHS BY DROP HEIGHT AND CONCENTRATION CLASS FOR 1,400-GALLON DROPS OF EACH RETARDANT

```
       AB = EXP(-(ABS((((XLEN - DH)/XP)-1.0)/(1.0-XI))**XN))
       AC = EXP(-(ABS(1.0/(1.0-XI))**XN ))
       A(N,M) = B * YP * (AB-AC)/(1.0-AC)
       XCONC = 4.0 - CONC
       Z = CONC/4.0 - 1.0
       ZZ = XCONC/4.0 - 1.0
       ZY = XCONC/3.8 - 1.0


 PHOS-CHEX XA  1400 LENGTH
       B = .97150
       XLEN = 5000.0
       XI = .5 + .33 * EXP(-(ABS( Z/.376)**4.4))
       XN = .9 + 2.0  * (EXP(-(ABS((CONC(N)/3.0-1.0)/.82)**1.36))-.269867
      1)/.730133 + 1.008 * EXP(-(ABS(ZY/.1)**2.3))
       YP = 164.0 + 57.7263 * XCONC**1.45
       XP = 4000.0 + 700.0 * EXP(-(ABS(Z/.42)**3.7)) + 300.0 * (EXP(-(ABS
      1((CONC(N)-1.0)/.58)**3.9))-2.3214E-4)/.999768


 GELGARD 1400 LENGTH
       B  = .9860537701
       XLEN = 4000.0
       XI = .84 - .83 * (EXP(-(ABS(ZY/.47)**2.5))-.001356)/.998644
       XN = 1.8 + 2.1 * XCONC - 6.00 * EXP(-(ABS(((XCONC/3.0)-1.0)/.41)**
      13.0)) - 2.8232 * EXP(-(ABS(ZY/.085)**3.0))
       XP = 4000.0 - 1000.0 * EXP(-(ABS(ZY/.39)**2.5))
       YP = 140.0 + 11.93626796 * XCONC**3.4 - 767.2047881 * EXP(-(ABS(ZY
      1/.216)**1.6))  + 80.0 * EXP(-(ABS(((CONC(N)/.5)-1.0)/.3)**8))


 FIRE-TROL 100 1400 LENGTH
       B  = .8803827977
       XLEN = 4000.0
       XI = .83 - .18 * EXP(-(ABS(((XCONC/3)-1.0)/.47)**4.0)) - .16271933
      162 * EXP(-(ABS(ZY/.1)**3.0))
       XN = 3.0 + .80 * XCONC - 3.9 * EXP(-(ABS(((XCONC/3.0)-1.0)/.48)**4
      1.0)) - .794 * EXP(-(ABS(ZY/.085)**3.0)) +.344 * EXP(-(ABS(((CONC(N
      2)/1.5)-1.0)/.2)**9.0))
       XP = 4000.0 - 300.0 * EXP(-(ABS(ZY/.24)**3.0))
       YP = 145.0 + 379.0  * (EXP(-(ABS(ZY/.6)**1.1))-.173077415)/.826922
      15849


 WATER  1400  LENGTH
       B  = 1.0
       XLEN = 4000.0
       YP = 145.0 + 102.4530192 * XCONC**.55 + .0023685571 * XCONC**8.2
       XI = .87 *(EXP(-(ABS(((CONC(N)/3.0)-1.0)/.9)**3.0))-.253664662)
      1/ .7463353379 + 3.515183925E-11  * CONC(N)**15
       XN = 1.7 + 3.7004798E-5 * CONC(N)**7.2 + 4.059271039E-12*XCONC**20
       XP = 4000.0 - 1000.0 * (EXP(-(ABS(ZY/.1))**1.5))
```

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GEORGE, CHARLES W.
1975. Fire retardant ground distribution patterns from the CL-215 air tanker. USDA For. Serv. Res. Pap. INT-165, 67 p., illus. (Intermountain Forest & Range Experiment Station, Ogden, Utah 84401.)

Several fire retardants in current use were dropped from the Canadair CL-215 aircraft to determine drop height effects and for evaluation of the tank and gating system. Mathematical models for each retardant and load size were developed for predicting the effects of drop height on ground distribution as shown by the retardant recovery, area of coverage, and contour (fireline) length as functions of concentration level.

OXFORD: 432.3: 843.1. KEYWORDS: aerial fire suppression, fire-retardant chemicals, models, predictions, ground distribution patterns, drop heights, air tankers.

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Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field Research Work Units are maintained in:

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