

## AN UPDATE ON THE OPERATIONAL RETARDANT EFFECTIVENESS (ORE) PROGRAM

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### ABSTRACT

To determine how much chemical or retardant is needed to do a given fire suppression job and to relate those amounts to fuel and fire behavior characteristics, a major cooperative Operational Retardant Effectiveness (ORE) study was undertaken. A pilot study at Hemet in southern California in 1983 demonstrated the feasibility and value of the approach conducted under actual operational conditions. This study was expanded and operated for full fire seasons from Hemet in 1984 and 1985 and from Redding in northern California from 1986 to 1988. Temporary operations were also conducted in Redmond, Oregon, during 1985. The high fire activity during 1985 and 1987, with less than normal to normal activity occurring in the other years, provided excellent research opportunities. Some study results were implemented operationally in near real-time and other results were incorporated in training at various levels, in contract specifications, and in national or interagency criteria. Considerable data were used in ongoing retardant and delivery research and development programs. This paper presents the status of the Operational Retardant Effectiveness (ORE) study, discusses the expanding and changing objectives, and provides examples of study findings and spin-offs.

### WHAT IS THE ORE STUDY?

Numerous studies have quantified aspects of aerial fire suppression (George 1981, 1984). Some studies were theoretical, some were conducted in the laboratory, and others were conducted under controlled field conditions to simulate certain aspects of retardant application. Although most of these studies have provided insight into specific parts of the overall problem of aerial delivery and suppression of wildland fires, they have not simultaneously integrated the many influencing variables into one scenario. Although the need for this integration under actual field and use conditions can be argued, the credibility and acceptability of results to fire personnel involved in the application of wildland fire chemicals are obviously enhanced. As the name implies, the ORE study is an "operational" evaluation of the effectiveness of wildland fire chemicals applied from aircraft. Initially planned to concentrate on fixed-wing application, the study was later expanded to include helicopter use. In both instances, the operational nature of the study allowed for both the observation of the various application tactics and strategies and the effectiveness of various types of wildland fire chemicals, including water, foam, and long- and short-term retardants.

To determine how much chemical or retardant is needed to do a given fire suppression job the pilot study sought to do the following:

1. Identify methods, techniques, and criteria for the evaluation of on site retardant effectiveness in actual fuel and fire conditions.
2. Determine the retardant concentration requirements for specific fuel models in fire situations, and validate or refine, if necessary, retardant coverage levels prescribed in retardant coverage decision aids.
3. Evaluate the accuracy and usefulness of the existing decision aids in selecting the optimum drop conditions, for example, height, speed, tank configuration, and drop sequence.
4. Identify delivery system characteristics that provide the most efficient control of drop performance and patterns in actual fuel and fire situations.
5. Develop appropriate guidelines and training for the effective application and management of aerial retardant.

The approach to conducting the study under operational conditions consisted of aerial evaluation of the entire suppression operation, evaluation by a ground team who traveled to the site by helicopter when the opportunities and situation allowed, and documentation of the condition under which the aerial application occurred, using onboard aircraft instrumentation. The California Department of Forestry and Fire Protection (CDF) supplied a fixed-wing aircraft. The aerial observation team consisted of two people: an evaluator who was qualified as an air-attack supervisor and an equipment operator. Onboard equipment included FLIR (Forward Looking InfraRed) capability, a video camera, and video recorders. Video signals from the cameras as well as operational and intercom-evaluation comments provided a permanent record of the operation and evaluation. The ground evaluation team consisted of a fire behavior analyst, an experienced line fireman, and a retardant research specialist.

The helicopter specialist was experienced as a line fireman and normally participated in the evaluation. He also operated a video camera documenting the actions of the ground evaluation team, the fire behavior, suppression operation, and aerial suppression application. The ground evaluation team took fire behavior measurements and appropriate fuel and fuel moisture samples. Estimates of the retardant ground pattern distributions, including retardant coverage, were made. A postmortem, when possible, helped determine the effective retardant coverage level. Postmortems were made by selecting appropriate fuel samples to which retardant had been applied such that the retardant was effective in stopping or minimizing the fire spread. The fuel samples were returned to the laboratory for analysis, and the effective retardant coverage level was determined.

To provide definition of the retardant release characteristics and drop conditions, instruments were installed in the locally based air tankers and sometimes in additional air tankers (George 1982). The equipment consisted of a high-precision pulse radar altimeter system, which provided a continuous record of the drop height during a pass, and an airspeed transducer to record airspeed. The electrical circuit from the door-opening system was used so that signals to the door-opening solenoids were recorded, providing the exact time of door opening, time interval between releases, and thus the drop configuration for any release sequence. Self-contained velocity gravity height (VGH) recorders from the National Aeronautics and Space Administration were also installed on the air tankers selected for instrumentation. These recorders

provided additional information, including time-history records of aircraft speed, altitude, and acceleration during the mission. The VGH records also provided a history of the mission's flight duration, time to first drop, dash speed to first drop, rate of descent, maneuver acceleration fraction, drops per mission, maximum airspeed, and time from drop to touchdown. Video cameras were also installed on the sun screen of the air tankers when practical. The cameras provided a video coverage of the general approach to the target, the topography, the fuel, and fire behavior. Radio communications and intercom talk between the pilot and copilot were recorded on one of the audio channels of the video tape.

Miscellaneous other data were considered essential or especially valuable in documenting the mission effectiveness. These included information regarding the fire retardant qualities for each drop or mission. On completion of the retardant loading operation, a sample of retardant was taken from the fill line. This sample provided a record of the type of retardant being used and was later analyzed to provide the actual retardant salt content and viscosity, which could have a significant effect on the effectiveness of a drop. The sample was also used as a check in situations where a question about the retardant quality arose, such as lack of color or volume, excessive drift or low viscosity, or ineffectiveness in retarding combustion. Other data included the use of postfire information from interviews of operational air-attack personnel, air tanker pilots, lead-plane pilots, ground personnel, or others having firsthand knowledge about the incident. Dispatch records, fire reports, and other records were also used to supplement evaluation data.

## ORE STUDY OBJECTIVES

The ORE (operational retardant effectiveness) study sought answers in quantitative terms that could lend themselves to more in-depth analysis to fill knowledge gaps. Study areas concentrated on relating effective retardant coverage and fuel and fire characteristics; tailoring the chemical or retardant to the need; optimizing tank and gating system performance; and developing adequate use guidelines for air tanker selection, allocation, deployment, and real-time use.

In the course of the ORE study, other significant questions and needs arose, leading to modifications in the original study design. Some of the more important changes included the following:

- 1986 - Conceptual evaluation of the use of wildland fire foam from fixed-wing aircraft
- Operational evaluation of two new long-term fire retardant formulations (Fire-Trol LC-A and LC-S)
- 1987 - Pilot study aimed at determining the operational effectiveness of helicopters (using methods, procedures, and instrumentation from the ORE study):
- using wildland fire foam, water, or chemical retardants; and
  - providing input for continued development of a helicopter delivery simulation model
- 1988 - Emphasis on conceptual evaluation of wildland fire foam delivered from either helicopters or fixed-wing aircraft
- Operational evaluation of a new concept in variable flow delivery from fixed-wing aircraft (Aero-Union SP-2H)
  - Operational evaluation of a new long-term fire retardant formulation (Fire-Trol PS-F)

#### ORE DATA COLLECTION

Although all fire seasons since 1983 have been fairly productive, the majority of the data were collected during the 1985 through 1987 seasons, as illustrated in Table 1. Complete numbers of observations are not available for 1988 nor are certain types of information for earlier years, such as helicopter data (primarily video/FLIR) for the years prior to emphasis

on evaluating the aerial suppression capabilities and effectiveness of helicopters.

#### ORE STUDY FINDINGS

##### Research Methods, Procedures, and Instrumentation

One of the initial concerns in conducting the ORE study was whether meaningful data could be collected under actual operational conditions given the logistics of the problem, the number of previously unquantified variables, and the necessary subjectivity of the evaluation of the effectiveness of tactical applications that resulted from the interrelationship of method of attack (i.e., indirect as a strict retardant or direct as an extinguishing agent) and the resulting effectiveness. Early study results demonstrated that the instrumentation developed and perfected, the methods and techniques used, and the analysis procedures had many practical applications. The onboard air tanker instrumentation developed to document the performance of the air tanker and the conditions under which the drops or retardant applications were made proved crucial to the evaluation. The video and FLIR recordings provided invaluable documentation for training and operational applications, which will be discussed in a later section. Study results showed the ability to move a ground evaluation team to necessary locations in near real-time.

**Table 1. Summary of basic operational retardant effectiveness (ORE) study data, 1983-88**

Item	Year						6-y total
	1983	1984	1985	1986	1987	1988	
Months ORE active	1.8	2.2	2.7	3.0	4.3	3.8	17.8
Number of fires							
ORE data	9	25	42	69	112	73	330
Helicopter data	—	—	—	—	55	42	97
Number of observed drops							
Total	15	189	299	363	1168	729	2763
Fixed-wing	15	189	299	354	629	450	1936
Helicopter	—	—	—	9	539	279	827

## Air Tanker Performance Guides

The performance of air tankers as described in existing air tanker performance guides and retardant coverage computer/slide charts has been partially validated. Estimates of performance and effect of primary parameters, such as drop height, drop configuration, and retardant type (waterlike or gumlike) have been demonstrated to be adequate. The advantage of using increased drop heights in many instances to provide more uniform and efficient retardant distributions has been confirmed. The value of using gum-thickened retardant to minimize evaporation and drift during operational use (especially when winds normally associated with difficult fire behavior are encountered) has been substantiated under operational conditions. The importance of drop interval in sequential drops was shown to have a major and often limiting effect on the resulting pattern—especially continuity. Manual or inappropriate drop intervals frequently caused patterns to contain gaps and allow retardant line to be ineffective, which resulted in inefficient coverage levels and was extremely unreproducible. As a result of these early findings, intervalometer requirements were proposed to the Interagency Air Tanker Board (IATB). The proposed standards were accepted and have been incorporated into IATB mandatory requirements and agency contract specifications.

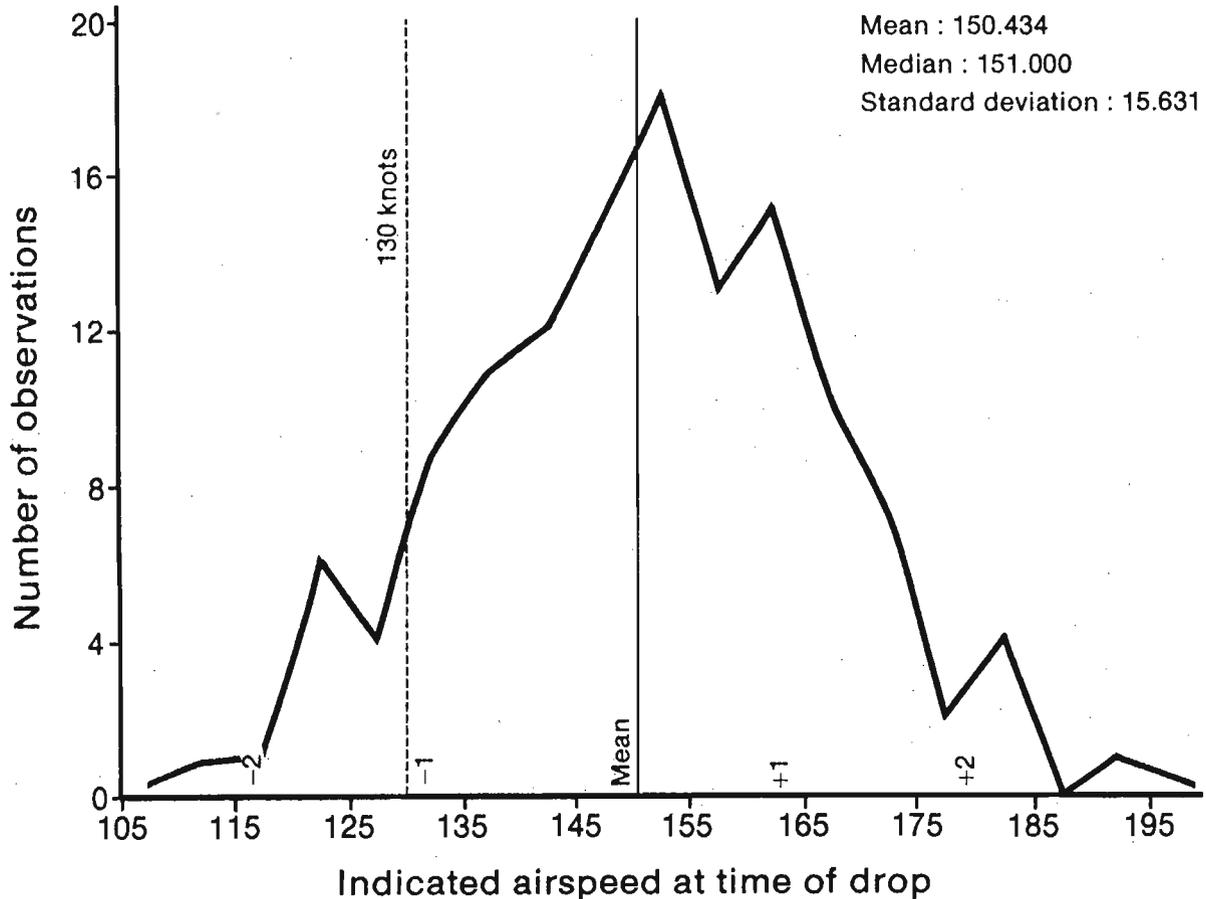
The value of variable flow rate, and hence coverage level, has been similarly demonstrated and proposed for inclusion in standards and requirements. One of the spin-offs of the ORE study associated with air tanker performance is quantification of the operational envelope under which air tankers are operated. Although the use of data collected onboard air tankers to study the operational use aspects was secondary, the opportunity to gain knowledge on this facet of use exists. An example of such a situation and data can be shown regarding the C-119 aircraft. As a result of recent accidents with the C-119 (the latest during the 1987 fire season in northern California) and questions concerning conditions under which these aircraft have been operated, a quick analysis of a portion of the drop condition data was made. VGH data from several seasons of use from a C-119 showed that maximum drop airspeeds set forth in the supplemental type certificate for the C-119 and  $g$ -loads of 2.5  $g$  (that are interrelated) are frequently being exceeded during fire control operations (Figs. 1-4). Specifically, maximum drop speeds were exceeded over 90% of the time, and 2.5  $g$  were exceeded on more than 25% of the drops. Although this problem cannot be addressed simply,

the data certainly have implications to air tanker operations. It is difficult to keep airspeed down in much of the steep terrain where downslope runs are required. The data, however, assist in defining operational flight conditions and suggest a number of additional questions that should be addressed:

1. If the C-119 cannot be operated within the prescribed envelope, should it have been used as an air tanker?
2. What efforts or steps did operators and agencies take to attempt to keep airspeeds within the appropriate flight envelope? Was this covered in training? If not, why?
3. Can this type of data be used by the IATB or individual agencies to evaluate the suitability of new or existing aircraft?
4. Do similar situations exist for other types of currently used aircraft?

## Helicopter Water and Foam Delivery

The pilot study initiated in 1987 was aimed at determining the operational effectiveness of helicopters and whether procedures developed during the preceding ORE study to accomplish a similar objective with fixed-wing aircraft was applicable. Results in 1987 and 1988 indicate that subjective results are obtainable. The same degree of quantification with helicopters is currently not possible for two reasons. First, the instruments required to document the operational flight envelope and the delivery performance of the water or retardant release system (usually a bucket) have not been developed. Secondly, the pattern of use and the situations in which helicopters are used are often unstructured and unpredictable. The general effectiveness of helicopters has been subjectively evaluated, and their effectiveness in support of helitack or other ground suppression activities has been clearly documented. The use of foam from helicopters is quite valuable depending on the tactical use, fuel, fire behavior, and application conditions. The greatest benefits were obtained when direct fire attack was being made in close support of ground suppression activities. Foam properties can have a significant effect on the foam's effectiveness, that is, dry foams do not penetrate overstories well and can detract from their ability to penetrate heavy ground fuels. There is also a need to differentiate between long-term retardants that can be used effectively for indirect



**Figure 1. Distribution of indicated airspeeds of the C-119 aircraft at the time of drop.**

attack in situations where their moisture probably will have evaporated and foam whose effectiveness is dependent on the moisture it holds (foam, water, and long-term retardants, dry at similar rates when applied and exposed to similar conditions).

The use and effectiveness of helicopters and fixed-wing aircraft are obviously different. The ORE study has many examples illustrating the effectiveness of both helicopters and fixed-wing aircraft under different conditions and tactical applications. These tools clearly are different, and their use needs to be evaluated differently. It is not appropriate to compare their costs or effectiveness in most situations unless careful and quantitative comparisons of their suppression productivity are included.

#### **Evaluation of New Wildland Fire Chemicals**

Another spin-off of the ORE study has been the evaluation of several new long-term retardant formulations. The participation of the ORE team in this has depended on such factors as location of the selected retardant base and how the new formulation differs from existing products. The capabilities of the ORE team have resulted in coordination of field evaluations with the ORE study and use of evaluation procedures, instrumentation, and personnel. Examples of coordinated efforts were the evaluation of new formulations, Fire-Trol LC-A, LC-S, and Fire-Trol PS-F and the conceptual evaluation of wildland fire foams. As a result, Fire-Trol LC-A and Fire-Trol PS-F have satisfied evaluation requirements and have been approved

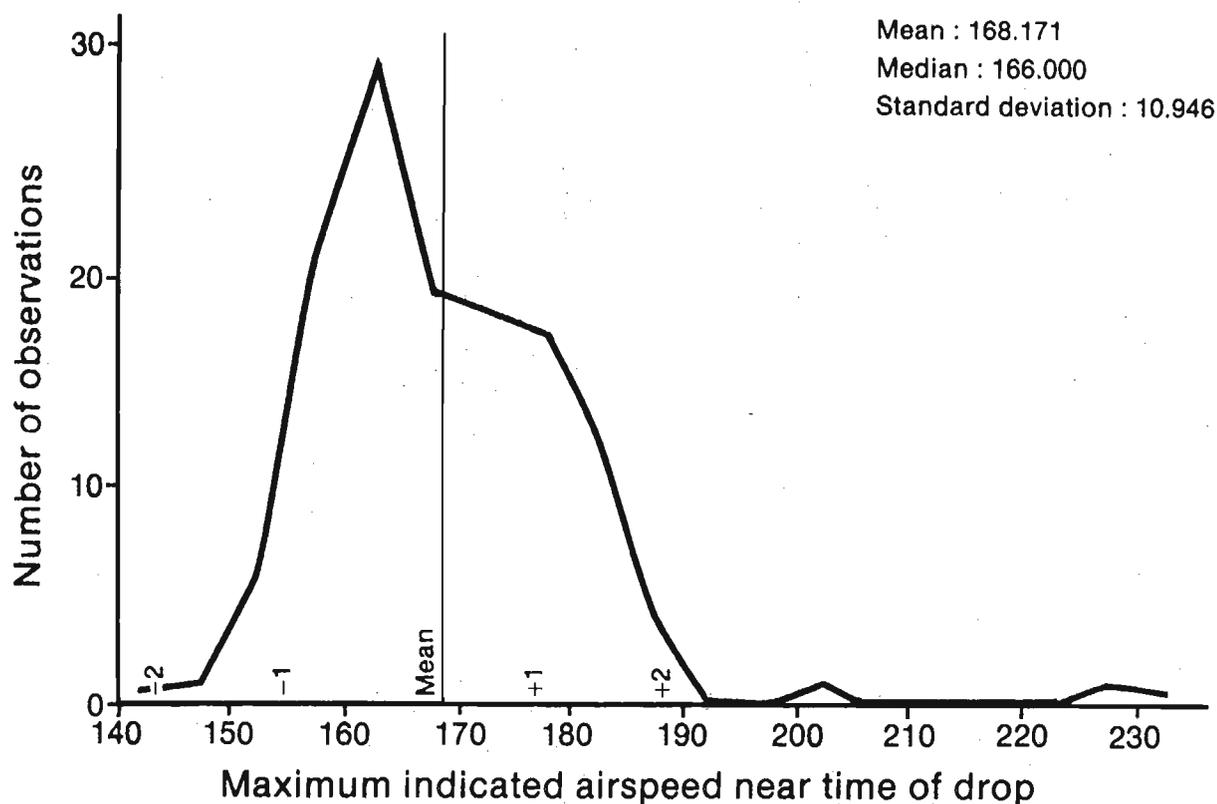


Figure 2. Distribution of maximum indicated airspeeds of the C-119 aircraft near the time of drop.

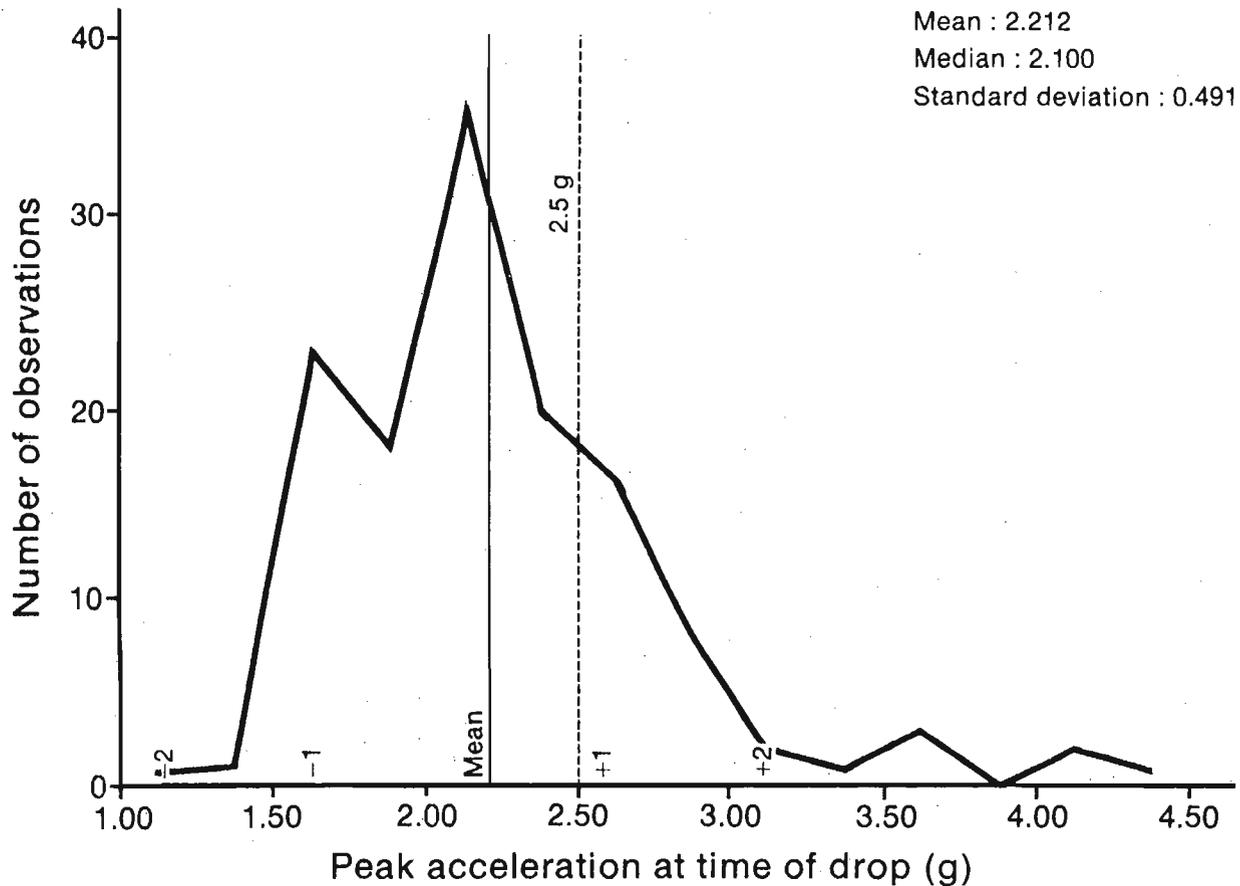
for operational use. Likewise, four wildland fire foams for use from helicopters using buckets and one from helicopters using fixed tanks have been approved.

A conceptual evaluation of the use of wildland fire foam from fixed-wing aircraft (in addition to the evaluation from helicopters, previously discussed) was initiated late in the 1986 season and continued through 1987 and 1988. Results have indicated that foams can be effective when applied from fixed-wing air tankers in direct attack situations on lower intensity fires, especially in the support of ground suppression personnel. Use in and around structures, vehicles, and improvements can have related advantages compared to alternatives involving chemicals and coloring agents that often require special post-suppression clean-up activities. Fixed-wing aircraft using foams have a narrow "use" window as compared to those using long- or short-term retardants. Increased drop speed and especially drop height, as well as wind, can have a very deleterious effect on foam delivery, and low drop

heights do not provide the time needed for foam to develop.

Results also indicate that distance and time required for the breakup and development of foam is not significantly different (as thought) from normal aerially delivered retardant nor substantially safer as far as ground personnel are concerned. Also, characteristics of specific fixed-wing delivery systems greatly influence the efficiency of foam development and distribution patterns. When considering the properties of the foam itself, the wet foams (and lower expansion) are more effective than dry foams. Dry foams are intercepted to a greater degree by aerial vegetation and are more easily dispersed by wind. The retention of dry foams by the aerial portion of the fuel, even in grass, has allowed fire to burn underneath the moisture that is being held above by the foam.

One of the needs identified in the foam evaluation is the need for performance standards for mixing



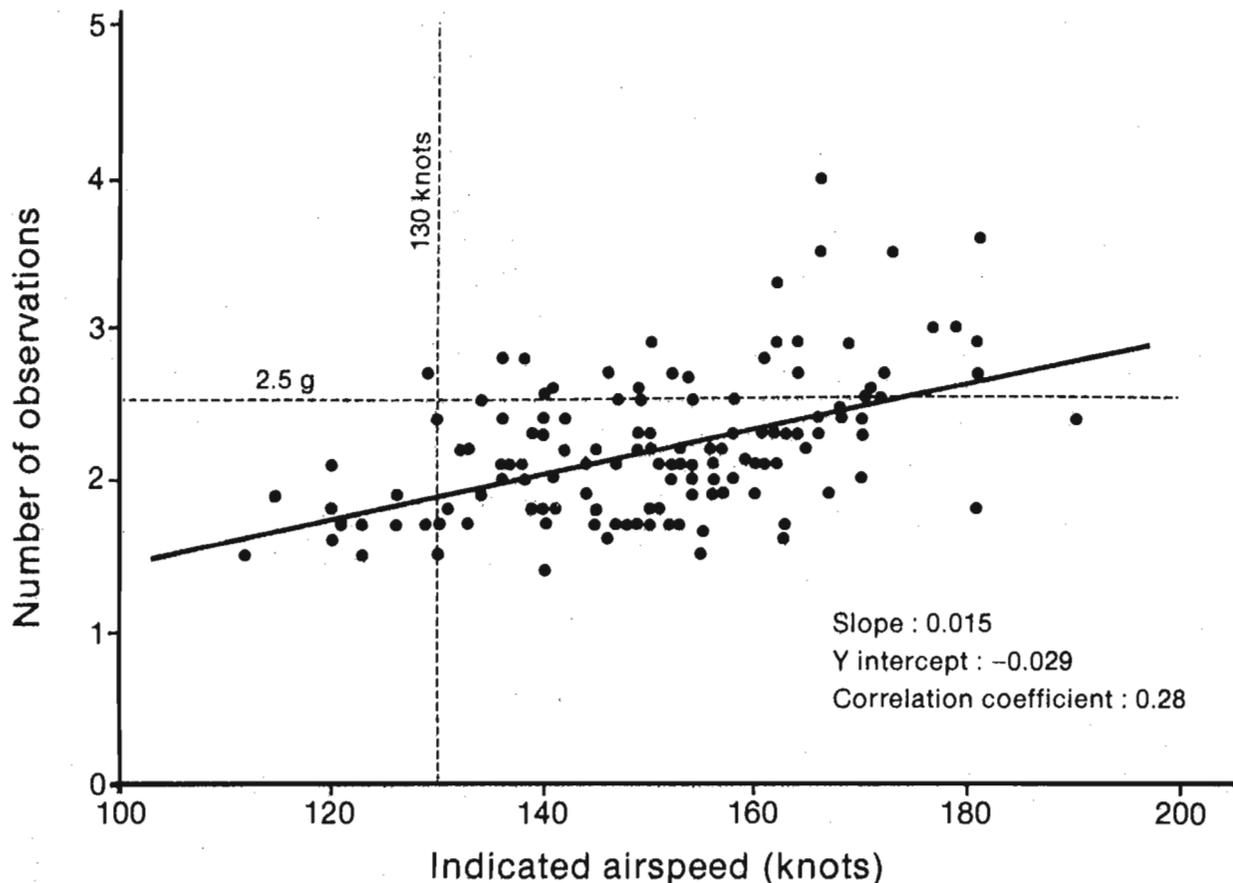
**Figure 3. Distribution of peak accelerations at the time of drop from the C-119 aircraft.**

and injection and storage and handling of the foam concentrate. Numerous problems in early developed hardware indicate a number of shortcomings; these included lack of precision in concentrate ejection; inadequate mixing; handling and mixing that allowed contamination; and inadvertent ejection and return-flow of the foam concentrate.

A key factor is the practicality of using foam in fixed-wing aircraft intermittently with long-term retardant. Efficient use of foam and any advantage offered depend on the tactic being used, the fire suppression situation, and logistical ability to make chemical selections in a real-time situation (i.e., to change between using foam and long-term retardant).

### **Retardant Effectiveness**

Less than anticipated progress was made toward quantitatively relating the effective retardant requirement with fuel properties and fire behavior. The majority of observations have been in light fuels, although some observations have been made in nearly all of the U.S. fuel models used for predicting fire behavior. Results to date, however, have verified the current recommended coverage levels by fuel model as reasonable estimates or rule-of-thumb for effective retardant coverage, although more accuracy is needed to improve efficiency and provide quantitative input to tailored retardant formulations, optimized delivery



**Figure 4. Distribution of drops in relation to the 130-knot maximum airspeed and 2.5-g peak acceleration criteria.**

system design and flexibility, and use guidelines to encompass various planning and real-time needs.

The effective retardant levels for given fuel models depend on fire-line intensity or flame length and can vary as much as 800% (e.g., 0.5 g/cm to 4.0 g/cm for Fuel Model A [grass]). The variability with the fuel models currently used contributes largely to variation in fire-line intensity and effective coverage relationships. Until more definitive fuel and fire behavior models are developed, improvements to recommended retardant coverage levels will likely be limited. Further analysis of the existing ORE data will undoubtedly provide additional and more quantitative results in this and other areas of study.

### Management

It might be beneficial to point out a couple of observations from the ORE study:

1. Aerial fire suppression (using fixed-wing aircraft and helicopters) can be extremely effective; however, poor management can quickly overshadow gains made in chemicals, delivery systems, and application guidelines.
2. Use of FLIR by air attack supervisors can be easily demonstrated to have major payoffs in terms of improved fire suppression capability and efficiency. Numerous examples can be shown

where information easily provided by use of FLIR on a single incident could be projected to pay for the cost of an FLIR unit and its implementation.

Further analysis of existing ORE data and incorporation of results into standards and guidelines will undoubtedly provide substantial benefits.

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### THE AUTHOR

**CHUCK GEORGE** worked seven seasons for the USDA Forest Service in various fire positions before receiving his B.Sc. degree in forest engineering in 1964 and M.Sc. degree in forestry in 1969. He joined the Intermountain Research Station's staff in 1965 where he has conducted studies related to prescribed fire, pyrolysis and combustion, fire retardants, and aerial delivery systems. Chuck is currently the Project Leader of the Fire Suppression Research work unit at the Intermountain Fire Sciences Laboratory, with a mission to conduct research to improve fire control capabilities, including wildland fire chemical suppression technology. His most-recent major effort has been in conducting an Operational Retardant Effectiveness (ORE) evaluation with emphasis on the use of air tankers and helicopters in the application of fire retardants, water, and foam.

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