
An Operational Retardant Effectiveness Study

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In recent years, considerable attention has been given to the aerial retardant program as a result of rising costs, tight budgets, and general interest in the use of airtankers and fire retardants. "An Evaluation of Fire Retardant Use" prepared by the Forest Service's Policy Analysis Staff (3) identified a number of opportunities to improve the cost effectiveness of retardant use and prompted an "Aerial Retardant Program Improvement Plan" to be developed by Aviation and Fire Management (1).

The analysis of retardant use and action plan both dealt with our inability to answer a basic question, "How much chemical or retardant is needed to do a given fire suppression job?" Fire managers have tried to answer this question in general terms through trial and error. The answers have not, however, been in quantitative terms that lend themselves to further analysis. Detailed answers to more specific questions, such as those discussed in the following three sections, are needed.

(1) What is the optimum tank and gating system? What criteria will provide the best performance? What characteristics provide the most flexibility in terms of performance capability?

There is presently little standardization in the design of airtanker delivery systems and thus in performance. The flow rate of retard-

ant from the tank determines the drop pattern, and flexibility is generally provided only by the number of compartments selected for release. The range of effective retardant coverages an airtanker can provide may be relatively narrow—in other words, it may be quite efficient for some retardant coverage requirements but be incapable of providing others. Knowledge of individual airtanker performance can be utilized to a limited extent in allocation and deployment and in formulating guidelines for onsite use.

(2) What retardant properties (chemical and physical) provide the greatest efficiency? Can these properties be matched or tailored to the delivery system and operating requirements?

The price of retardants can be increased or reduced by simply changing the retardant salt content or other properties. Current levels have been selected through experience; however, a consensus as to the requirements does not exist. For example, do we need a long-term chemical? Can we get by with a short-term (thickened water) retardant? Is it essential to thicken water or retardants?

(3) Do adequate guidelines exist for optimizing the selection, allocation, deployment, and use of airtankers and retardants (including the limits of effectiveness)?

The effectiveness of aerially delivered retardant under varying

conditions and tactical situations is not known with the certainty and precision to allow a thorough assessment. The information necessary to properly make tradeoffs between different sizes and types of airtankers as well as tradeoffs between suppression alternatives (handcrews, bulldozer or plow units, or retardant aircraft, for example) is not available. Figure 1 illustrates retardant effectiveness interrelationships and complexities.

Recommended fire retardant coverage levels for different fuel types have been published in airtanker performance guides and retardant coverage computers (4). The coverage levels were derived from laboratory studies of maximum useful retardant concentration, film thickness, and fluid capture capacities of different fuels. The predictions of the required coverage levels were prepared by Honeywell (9) with guidance from the Intermountain Fire Sciences Laboratory.

These coverage levels are keyed to the fuel models of the National Fire-Danger Rating System (2). The brief general descriptions of the fuel models were provided by H.A. Anderson and the coverage-level values were first identified using the concept of maximum useful retardant concentration (MUC) calculated by Rothermel and Philpot (7). Rothermel added to the computation the retardant film-thickness concept, originated

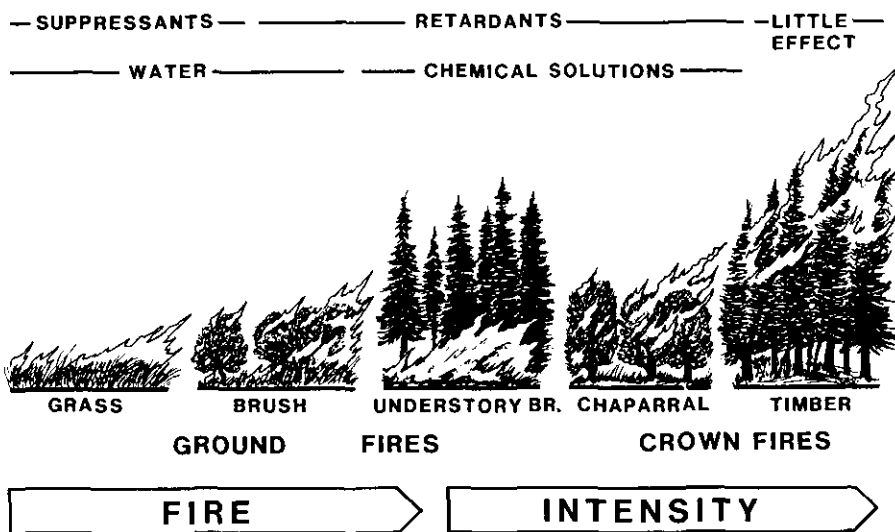


Figure 1—Retardant effectiveness interrelationships and complexities.

Recommended For:		
Coverage Level	Fuel Model ¹ (1978 NFDRS)	Description
1	A. L. S	Annual and Perennial Western grasses; tundra
2	C. H. P. U E. R.	Tall grasses; Conifer (with grasses/forbs/needles and/or woody shrubs understory) Hardwoods (winter and summer)
3	K. F ² . N. T	Light slash (conifer or hardwood); Intermediate brush (green); Sawgrass; Western woody shrubs
4	G	Shortneedle conifer (heavy dead litter)
6	D. Q. F ²	Southern Rough; Alaska Black Spruce. Intermediate brush (cured)
Greater than 6	B. I. J. O	California mixed chaparral; Medium and heavy slash; High Pocosin

For creeping or smoldering fires, reduction of one coverage level may be considered.
¹Fuel models considered to be in flammable condition.
²Coverage level requirements for intermediate brush depend on its stage of curing.

Figure 2—Recommended retardant coverage levels in gallons/100 ft² for the fuel models described in the 1978 National Fire-Danger Rating System.

by Grah and Wilson (6), which was later applied to retardant application by Swanson and Helvig (8). The recommended coverage levels in gallons per 100 square feet for the 20 fuel models described in the 1978 National Fire-Danger Rating System are shown in figure 2.

The ORE Study

In an attempt to determine how much chemical or retardant is needed to do a given fire suppression job and relate the answer to

fuel and fire behavior characteristics, an operational retardant effectiveness study (ORE) was undertaken. A pilot study was conducted in 1983 and expanded in 1984. The evaluation was conducted from Hemet, CA, in cooperation with the California Department of Forestry. Hemet was selected as the study location based on history of use (frequency and total amount), opportunity to work with a variety of fuel types and fire intensities, and relatively accessible areas of high fire fre-

quency. The study was designed to build on existing retardant research programs by taking advantage of recent studies dealing with aerial delivery system performance, retardant characteristics and effectiveness, measurements of drop conditions in the field, and other related topics.

The objectives for the ORE pilot study were:

- (1) Identify methods, techniques, and criteria for the evaluation of onsite retardant effectiveness in actual fuel/fire situations.
- (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 computers.
- (3) Evaluate the accuracy and usefulness of retardant coverage computers in selecting the optimum drop conditions (height, speed, tank configuration, and drop sequence, for example). Identify delivery system characteristics that provide the greatest and most efficient control of drop performance and patterns in actual fuel/fire situations.

(4) Develop appropriate guidelines and training materials for the effective application and management of aerial retardants.

The approach to conducting the study under operational conditions consisted of:

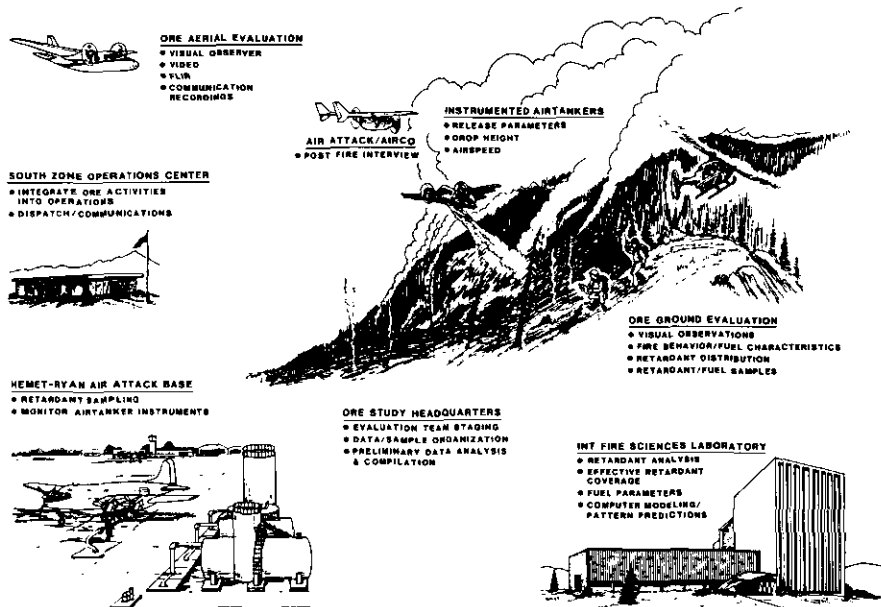


Figure 3—Elements of the ORE Study.

- Instrumenting local airtankers to quantify the retardant release characteristics and the conditions the drops were made under.

- Use of video and FLIR (forward looking infrared) to provide a permanent record of the operation.

- Use of audio recordings of air attack or AIRCO (Air Attack Coordinating Officer), lead plane, airtanker, ground-to-ground, and ground-to-air communications to provide documentation and insight as to air suppression activities and strategies.

- Aerial observation and evaluation of the operation, including effectiveness of retardant use, by a qualified air attack specialist dedicated to the study.

- Ground evaluation, where possible, by a dedicated evaluation team consisting of a fire behavior specialist, experienced line firefighter, and retardant research specialist.

Figure 3 illustrates the basic elements of the study.

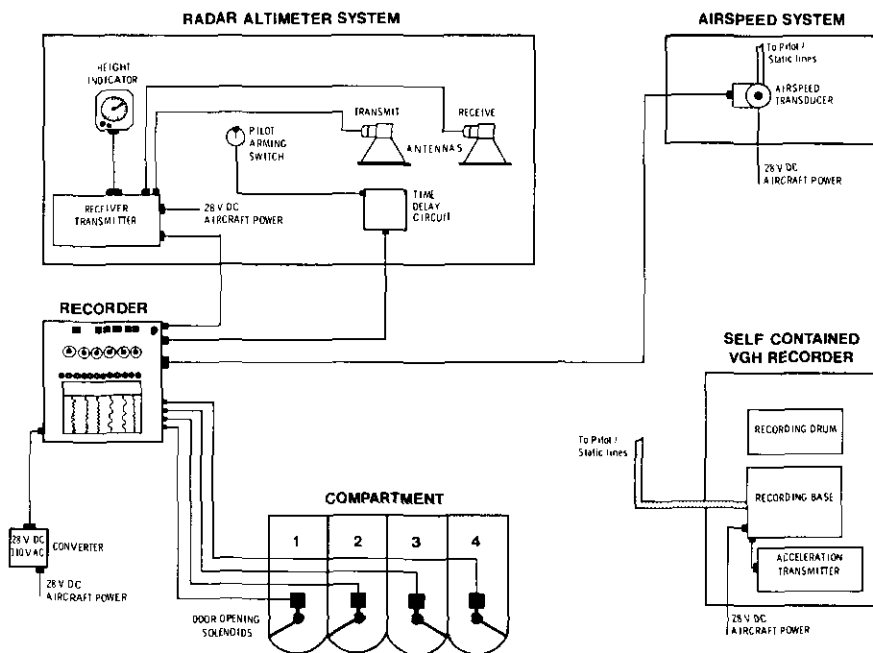


Figure 4—Schematic of onboard airtanker instrumentation.

Airtanker Instrumentation

Three of the four airtankers on contract to the Forest Service and California Department of Forestry were instrumented with equipment (previously used for measurements of airtanker drop conditions during firefighting operations) to provide definition of retardant release characteristics and drop conditions

(5). The equipment, diagramed in figure 4, consists of a high-precision pulse radar altimeter system to provide a continuous record of 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.

In combination, the recorded information provided height above vegetation during the drop (including minimum drop height and height at release), airspeed at time

of release, release configuration, and release interval. For each precalibrated airtanker delivery system the retardant distribution (pattern lengths and widths at selected coverage levels) can be predicted for a "best case" situation using the airtanker performance guides, retardant coverage computers, or computer simulation programs.

Self-contained NASA VGH recorders were also installed in each airtanker, to provide supplemental information, including *time-history records of aircraft* speed, altitude, and normal acceleration during the entire mission. These recorders are specially built and contain a remote acceleration transmitter for measuring acceleration, two pressure sensitive elements for measuring airspeed and altitude, and a timing mechanism. From the recorded history, information such as flight duration, time to first drop, dash speed to first drop, rate of descent, maneuver acceleration fraction, drops per flight, time between drops, maximum airspeed, and time from last drop to touchdown can be determined. This information is used to help define the overall mission events, as well as to interpret recorded data.

Video, FLIR, and Audio Recordings

Video and FLIR cameras (fig. 5) were mounted side by side on a fluid head pedestal that was fixed to the floor of fixed-wing air observer aircraft. An Aero Commander and a Cessna 337 were the aircraft used. Imagery from each camera was simultaneously recorded using separate recorders. In addition to recording the time, the audio channel recorded air-to-air communications. The air observer or video operator comments provided a tie between the fire suppression operation and the evaluation. The FLIR imagery enabled evaluation of the retardant drop, including placement and effectiveness in altering the fire behavior, and monitoring when smoke obscured the visual or video observation. The coolness of the retardant drop zone, relative to the surroundings and the fire, for some time after the drop was made (usually 5 to 10 minutes), allowed the drop to be definitely located and effectiveness to be observed.

Audio cassette recorders were used to record additional communications among air and ground fire suppression personnel. Although the communications between the airtanker pilot, lead plane pilot, and air attack supervisor or AIRCO were of primary interest, the ground-to-ground and ground-to-air communications

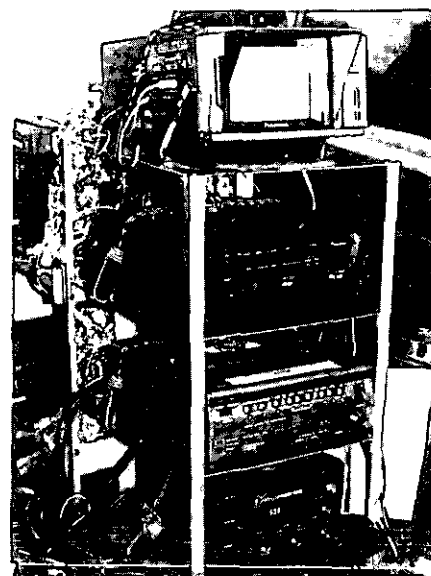


Figure 5—Video and FLIR camera and recording instrumentation mounted in Cessna 337 air observer/evaluator aircraft.

allowed an understanding of the suppression strategy or tactic to be followed. The simultaneous audio recordings also allowed recordings from the various sources (video, FLIR, and audio) to be time matched. Observations of the air evaluator and the video/FLIR camera operator also were put on cassette recorder. Following each mission or incident the evaluation notes were summarized, and contact with operational personnel and the ground evaluation team was made to complete documentation to the fullest extent possible.

Ground Evaluation

The ground evaluation team was composed of a fire behavior specialist, an experienced line firefighter, and a retardant research specialist. The helicopter foreman assisted the ground evaluation team on occasions when a dedicated helicopter was used for transportation to fires. Fire behavior measurements were taken when possible, as well as appropriate fuel and fuel moisture samples. Estimates of retardant ground pattern distributions, including retardant coverage, were made.

A postmortem was conducted, if possible, and constituted a primary element of the evaluation. Where the retardant drop was effective in holding or stopping the fire, a representative unburned retardant-treated sample was taken (all the fuel and retardant on a plot 6 inches by 6 inches). Several samples were usually taken for each drop or area of effective coverage. The samples were returned to the Intermountain Fire Sciences Laboratory where they were analyzed for retardant concentration (and hence coverage level) by means of previously developed procedures (10).

Results of this analysis provided the effective retardant coverage level for the specific fuel/fire situation encountered. In some instances, the effective level of retardant coverage was a small

area at the center of the drop (unburned island—usually high coverage and intensity), and in other cases the effective level was at the perimeter of the drop (low coverage and usually low intensity). The technique of fuel sampling/retardant analysis was also occasionally used to determine the peak coverage level of the drop—the concentration in the core or heaviest part. The peak coverage area/concentration is one of the characteristics most easily related to the retardant release and drop conditions.

The study was conducted during 1983 (August–September) and 1984 (mid-July through September). Only limited progress toward meeting the basic objectives was made because of the abnormally slow fire seasons in southern California and the few occurrences and opportunities for evaluation of retardant effectiveness in high fire intensity situations. Few observations could be made in other than light fuels. To the extent possible, quantitative relationships will be developed for the fuel models and fire behavior experienced.

Although limited success was achieved in meeting the primary objective of determining actual fire retardant requirements as a function of the fuel characteristics and fire behavior under operational field conditions, there were several spinoffs. The results of the project and recommendations by the ORE

Task Force/Steering Committee were summarized in a status report to the Chief of the Forest Service¹ and are repeated here.

Results of Project

1. Retardant coverage computers have been partially validated. There have been no indications of error.

2. The safe drop heights on the retardant coverage computer appear to be accurate. These safe drop heights differ from and frequently exceed the 150-foot minimum in the Forest Service Manual (FSM) and the contract.

3. Video and infrared imagery collected during the ORE Program have proved invaluable in assessing retardant use and effectiveness operationally. Some of the imagery lends itself to training and also demonstrates a potential for providing information to fire managers by use of real-time down link.

4. A weakness in the effectiveness of retardant has been identified and shown to be related to the continuity of the retardant line—in other words, the existence of gaps.

¹ Products of project and recommendations as summarized in a letter dated October 30, 1984, to Chief, USDA Forest Service, from Dick Cox, Steering Committee Chairman and Director of Aviation and Fire, Southern Region, USDA Forest Service.

This weakness is due to improper selection of the drop sequence, drop interval, or both. Retardant drop selector systems, including intervalometers, contained in contract aircraft are not universally adequate to provide an accurate pre-selectable release. Thus, our ability to apply information contained in retardant coverage computers is limited.

5. Airtanker pilot and air attack personnel interest in using the latest technology is increasing.

6. Many firefighters nationally have been trained in the use of the retardant coverage computer; however, the need for training is still great.

7. Cost concerns are creating more demand for efficient retardant products.

8. Some data have been collected on the effectiveness of short-term retardant.

9. Data gathering methods have been greatly improved.

Recommendations

1. Standardize a drop selector control including intervalometer.

2. Incorporate airtanker performance training into transitional training for NIIMS. Specific courses which should include this training were identified. Regions are encouraged to include this training in fire management offi-

cers' meetings, instruction of airtanker pilots, and meetings with cooperators.

3. Reconsider policies and contracts to change safe drop height from 150 feet to those shown on the retardant coverage computer. This change will actually raise the minimum safe drop height, which is related to the type of drop (flow rate). For example, a single tank drop from a high-flow-rate airtanker may require a minimum drop height of 160 feet for safety, whereas a split drop may require 200 feet and a salvo 250 feet.

4. Continue the ORE study in fiscal year 1985 as now structured while formalizing an expanded program with interagency support and commitment.

5. Transfer technology from the ORE study to fire managers.

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