
# FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE





No. 99

October 20, 1955


## AIR DELIVERY OF WATER HELPS CONTROL BRUSH AND GRASS FIRES


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Dropping water or fire-retardant chemicals from low-flying aircraft can help ground forces control brush and grass fires. That such water drops are practicable has been demonstrated by a recent series of field trials and calibration tests conducted by the Mendocino National Forest and the California Forest and Range Experiment Station in cooperation with the Willows Flying Service, the California Division of Forestry, and the Arcadia Equipment Development Center. As much as 120 gallons of water at a time was carried to fires in an airplane normally used for crop dusting and other agricultural purposes. Water dropped through a single outlet designed by the Willows Flying Service proved effective in quieting hot spots on large fires and in retarding spread of small fires in brush and grass.

Previous studies [1/] have established several guidelines for dropping water from aircraft:

1. The danger to men, equipment, and buildings prohibit the use of missiles or droppable containers--in fact, any projectile--in populated areas or as close support to fire fighters on the ground.

2. Aircraft must be maneuverable and have a considerable reserve of power.

1/ See Bibliography, page 12.


The California Forest and Range Experiment Station is maintained at Berkeley in cooperation with the University of California.

3. Pilots should be capable of flying close to rough topography and of achieving pinpoint accuracy with safety.

4. Water dropped free-fall reaches the ground and has a significant effect on some fires.

In consideration of these guidelines, it was decided to test the adaptability of an agricultural aircraft as an aerial tanker, and to attempt drops of uncontained water on fires.

## THE AERIAL TANKER

At the suggestion of the fire-control staff of the Mendocino National Forest, the Willows Flying Service adapted a plane used in agricultural work for trial as an aerial tanker. This plane, a 450-horsepower biplane (fig. 1), has a 160-gallon tank in the fuselage and is equipped with conventional valves and nozzles for agricultural spraying and seeding operations. The spray equipment was removed and a single outlet was installed at the base of the tank (fig. 2). Removing the conventional equipment and installing the special tank outlet requires about 4 hours.

The outlet measures 7 by 18 inches and is constructed of heavy sheet metal. The outlet gate is hinged at the front and has a rubber gasket to insure watertight seal. At first, the gate was equipped with a simple latch released from the cockpit. With this arrangement, the sudden release of water caused the plane to jump about 100 feet and the pilot to black out temporarily. This difficulty was corrected by equipping the outlet gate with a controlling lever which permitted the pilot to open the gate more slowly, and in all subsequent tests when full loads were dropped the gate was opened slowly at first.

## PRELIMINARY TRIALS

Preliminary trials were conducted in early August 1955 over flat ground at an airport. These trials showed that water could be dropped successfully from this aircraft. In the first trial, a load of 120 gallons of water was dropped from an elevation of 30 feet at an airspeed of 80 miles per hour. The water from this drop covered an area approximately 30 feet wide and 285 feet long. A test fire in grass, 20 feet wide and 600 feet long, required three 120-gallon loads of water and 10 minutes of follow-up work by hand for control.

Figure 1. --The agricultural biplane used for the water-drop tests.

Figure 2. --Close-up of special tank outlet.

## FIELD TRIALS

The next step was to try water drops on actual wildfires. During August the plane was used 4 times on 3 fires (table 1). In three trials the air tanker proved to be of considerable help to ground forces although in one of these it was apparent that too much was expected of a single plane. One fire was under control when the plane arrived so that the water drop was unnecessary though helpful in mop-up.

On initial attack the loaded plane was dispatched from its Willows base immediately after ground forces were started to the fire. At the same time, aviation gasoline and a water tanker were sent to the airport nearest the fire. Prominent, well known peaks were used as landmarks. A reconnaissance plane, in communication with ground forces and the "refill" airport, correlated the ground and air activity. In the future the company plans to fly a maintenance mechanic to the airport to refuel and load the air tanker, do maintenance work as necessary, and prevent damage to the plane by well intentioned but inexperienced personnel during the loading operations.

## CALIBRATION TESTS

It was apparent that air delivery of water made this aircraft a practical fire fighting tool, but quantitative information was needed to improve tactical methods for water delivery. Accordingly, a limited series of tests was conducted at the Willows airport and Elk Creek Butte Lookout on August 31 and September 1, 1955 to obtain the following information:

1. The effect of plane height, plane speed, and wind velocity and direction on the amount and distribution of water received on the ground.

2. The amount of water loss to be expected during summer fire weather.

3. The effect on amount and distribution of dropping part of the total load in each of several runs (multiple passes) with the pilot aiming for the same spot each time.

4. The practicability of dropping a sodium-calcium borate fire-retardant from this aircraft.

Table 1.--Conditions and results of air tanker use on wildfires - Mendocino National Forest, 1955

| Name of fire and date | Conditions | Plane use | Results |
|---|---|---|---|
| Mendenhall August 12 | Fire about 400 acres; in grass, brush and timber. Crowning uphill. Weather hot, dry and windy. | Plane supported initial action forces on flank in grass and mixed oak with 240 gallons of water in 2 loads. | Effective support where used, but too much line for one plane to handle. |
| Mendenhall August 13 | Weather similar to August 12. Fire 700 acres and temporarily controlled at head and one flank. Lower end of fire, burning downhill in chamise, too hot to handle by direct attack and threatening to outflank existing control lines. | Plane, re-filling repeatedly at nearby airport, delivered 600 gallons in 5 loads to 15 chains of lower end of fire. | Fire cooled down enough that attack forces were able to build control line along fire edge. Fire spread no further. Firefighters stated they could not employ direct attack until flames suppressed by plane. In this trial, 120 gallons applied in 6 passes[1/] was not nearly as effective as when applied in 3 passes. |
| Mud Flat August 15 | Fire about one-fourth acre and already controlled. | Plane load dropped anyway. | Water of some help to mop up. Need for better communications shown. |
| John David place August 15 | Fire in bottom of narrow box canyon with adjacent slopes rising 2,000 feet on one side and 5,000 feet on the other. Burning in medium density mixed brush with grass. Head of fire controlled but hot-burning corner about to outflank control line. Corner too hot for direct attack and moving too fast for indirect attack. | Refilling at nearby airport, plane delivered 480 gallons in 4 loads to hot corner by flying up and down the canyon. | Hot corner cooled down enough to allow men to complete their control line close to fire edge. District Ranger and others reported air tanker instrumental in control. |

1/ Plane made 6 runs, dropping part of load each time until 120 gallons dropped.

5. The amount of penetration of water and retardant into brush cover.

## Procedure

For measuring the amount and distribution of water, 121 cans, 3 inches in diameter and 7/8 inches tall, were placed in a 50 by 300-foot rectangular grid. Within this grid the cans were spaced 5 feet apart across the width and 30 feet apart along the length. The cans were covered immediately after each test and the water received by each was weighed before making the next test. To measure penetration into brush, 10 pairs of cans were distributed in brush of different densities in the target area. Each pair consisted of one can at the top of brush crown, and one on the ground.

Wind direction and velocity were recorded automatically during each test. Temperature and relative humidity were measured immediately after each test. The line of flight of the plane with reference to the grid was also recorded.

Although this aircraft can carry a maximum of 160 gallons of water, nominal full-load tests were made with 125 gallons of water or 100 gallons of retardant. At elevations normally experienced on the Mendocino National Forest this is the maximum safe load.

## Results

During the tests wind velocity varied from calm to 8 miles per hour, air temperature from 80 to 110°F, and relative humidity from 6 to 19 percent. In one test the plane's tail was low and the propeller wash blew over some of the grid measuring cans.

The patterns of distribution from these tests were roughly oval, from 4 to 7 times longer that wide (fig. 3). When the full load was released in one pass the greatest concentration of water was obtained when the airplane was flying at low speed and low elevation into the wind (tables 2 and 3). Both higher speed and greater elevation increased the total length of pattern but gave lower concentration.

About 75 percent of the water reached the ground in measurable quantities in the low-altitude, low-speed, headwind tests; about 65 percent in the higher altitude, crosswind tests. At top speed and low elevation, about 70 percent of the water released reached the ground. Only

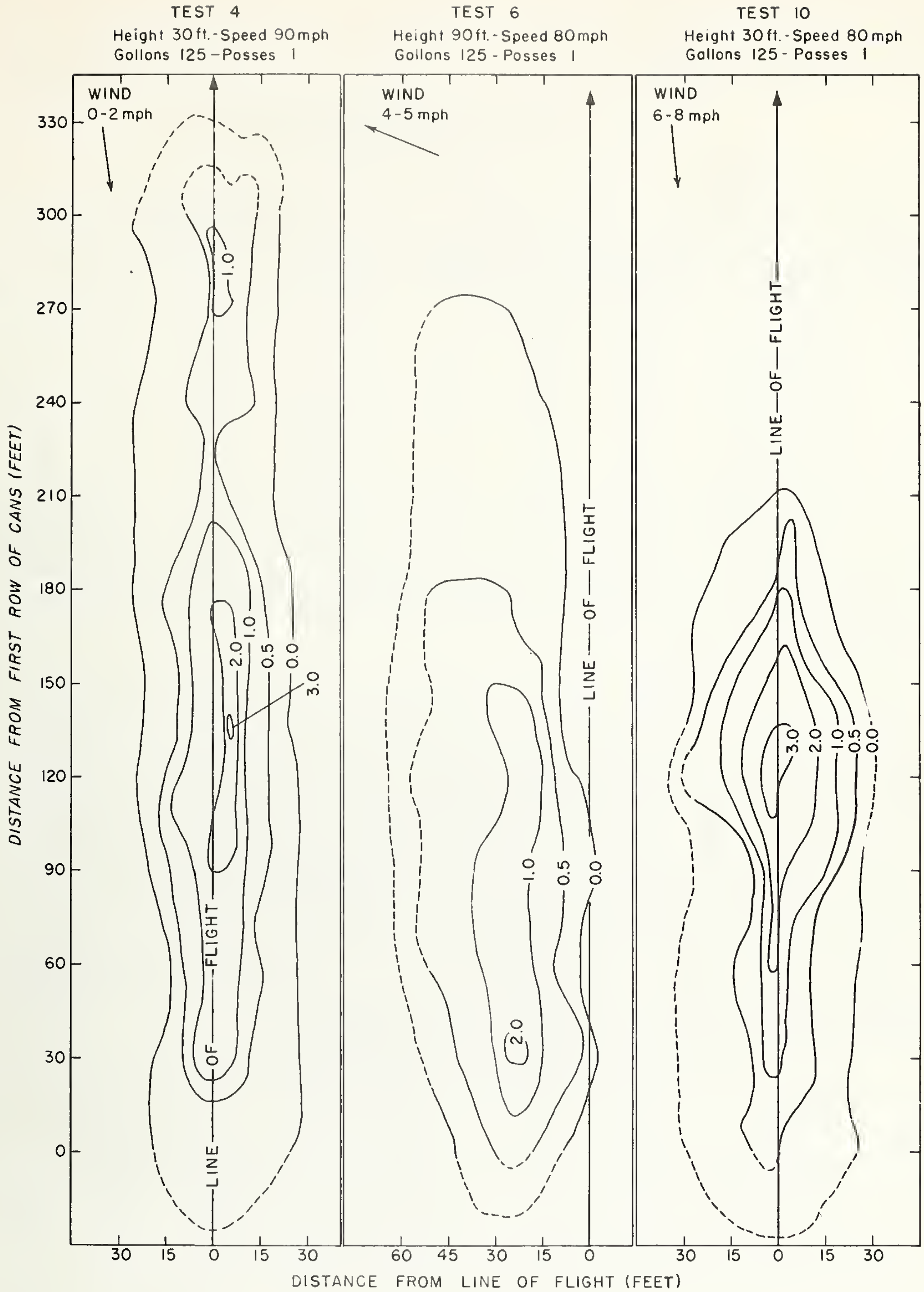


Figure 3. --Sample distribution patterns from water-drop tests; contour lines indicate concentration of water in gallons per 100 square feet.

Table 2. --Length of water pattern along line of flight, by concentration of water[1/]

| Test No. | Aircraft | | Wind | | Amount of Water dropped | No. of Passes | Total Length | Length when concentration (in gal. per 100 sq. ft.) was-- | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Height | Speed | Direction | Velocity | | | | 0.5 | 1.0 | 2.0 | 3.0 | 4.0 |
| | Feet | M.p.h. | | M.p.h. | Gallons | | Feet | Feet | Feet | Feet | Feet | Feet |
| 2 | 30 | 80 | Head | 3-5 | 125 | 1 | 230 | 210 | (2/) | (2/) | (2/) | (2/) |
| 10 | 30 | 80 | Head | 6-8 | 125 | 1 | 240 | 212 | 160 | 100 | 30 | 15 |
| 4 | 30 | 90 | Head | 0-2 | 125 | 1 | 360 | 305 | 210 | 85 | 10 | 0 |
| 3 | 30 | 90 | Cross | 0-1 | 125 | 1 | 330 | 280 | 160 | 50 | 0 | 0 |
| 5 | 90 | 80 | Cross | 3-4 | 125 | 1 | 290 | 230 | 100 | 20 | 0 | 0 |
| 6 | 90 | 80 | Cross | 4-5 | 125 | 1 | 290 | 175 | 135 | 10 | 0 | 0 |
| 7 | 30 | 80 | Cross | 1-4 | 125 | 3 | 285 | 210 | 185 | 0 | 0 | 0 |
| 8 | 30 | 80 | Cross | 2-4 | 125 | 5 | 345 | 219 | 165 | 20 | 0 | 0 |
| 9 | 30 | 80 | Head | 0-1/2 | 40 | 1 | 210 | 175 | 113 | 30 | 0 | 0 |
| 11 | 30 | 80 | Head | 6-8 | 3/ 40 | 1 | 165 | (2/) | (2/) | (2/) | (2/) | (2/) |

1/ Concentration measured along 5-foot strip parallel to fight line through area of greatest concentration.
2/ Collecting devices failed.
3/ Fire retardant chemical dropped.

Table 3. --Water distribution by area for different concentrations

| Test No. | Aircraft | | Wind | | Amount of Water dropped | No. of Passes | Total Area | Area covered by concentration (in gal. per 100 sq. ft.) of-- | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Height | Speed | Direction | Velocity | | | | 0.5 | 1.0 | 2.0 | 3.0 | 4.0 |
| | Feet | M.p.h. | | M.p.h. | Gallons | | Sq. Ft. | Sq. Ft. | Sq. Ft. | Sq. Ft. | Sq. Ft. | Sq. Ft. |
| 2 | 30 | 80 | Head | 3-5 | 125 | 1 | 9,613 | (2/) | (2/) | (2/) | (2/) | (2/) |
| 10 | 30 | 80 | Head | 6-8 | 125 | 1 | 11,332 | 5,644 | 4,000 | 1,656 | 269 | 26 |
| 4 | 30 | 90 | Head | 0-2 | 125 | 1 | 16,560 | 6,375 | 4,284 | 356 | 19 | 0 |
| 3 | 30 | 90 | Cross | 0-1 | 125 | 1 | 14,361 | 6,624 | 3,286 | 277 | 0 | 0 |
| 5 | 90 | 80 | Cross | 3-4 | 125 | 1 | 15,974 | 6,943 | 3,531 | 75 | 0 | 0 |
| 6 | 90 | 80 | Cross | 4-5 | 125 | 1 | 15,449 | 6,118 | 2,668 | 112 | 0 | 0 |
| 7 | 30 | 80 | Cross | 1-4 | 125 | 3 | 12,818 | 6,634 | 2,902 | 0 | 0 | 0 |
| 8 | 30 | 80 | Cross | 2-4 | 125 | 5 | 13,350 | 4,544 | 2,607 | 94 | 0 | 0 |
| 9 | 30 | 80 | Head | 0-1/2 | 40 | 1 | 7,275 | 3,038 | 1,569 | 150 | 0 | 0 |

1/ Test 11 not included because measuring device failed.
2/ Measuring device failed.

20 to 30 percent of the water reaching the ground was in concentrations of 1 gallon or more per 100 square feet. Apparently, wind direction and velocity is the most important factor affecting percent of water reaching the ground in a useful pattern.

Relatively high concentration was obtained when a 40-gallon load was dropped in 1 pass as compared with a 125-gallon load dropped in multiple passes. In making more than one pass with a capacity load, the manually operated outlet gate was only partially opened for each pass because it could not be closed against a full-stream discharge. As a result, only about half of the water reached the ground in measurable quantity. More rapid release of water should result in greater concentrations for all sizes of loads.

In medium and light brush there was no significant difference between the amounts of water received at the crown and on the ground. In heavy brush, however, there was considerable variation -- from 20 to 90 percent as much water reaching the ground as was received at crown level.

Results from the retardant tests were similar to those obtained with plain water. However, the heavy sodium-calcium borate suspension, weighing 10 pounds per gallon, did not disperse as readily as water (fig. 4) and had a smaller distribution pattern (table 2) with particularly heavy concentration in the center. All of the measuring cans in the center of the pattern were tipped over by the retardant. Penetration into heavy brush was more uniform than with water; 45 to 60 percent of the amount received at the crown level reached the ground. The standing brush was well coated with retardant.

## CONCLUSIONS AND RECOMMENDATIONS

These limited tests have shown that water or chemical dropped free-fall from small airplanes can have significant effect on small grass and brush fires, or on some parts of large ones. To obtain the greatest concentration of liquid on the ground, the airplane should fly as low and as slowly as conditions permit and as nearly into the wind as possible. The more rapidly water is released, the greater the concentration will be. Increasing the altitude or airspeed or dropping in a crosswind will give greater area coverage but will reduce concentration.

As with all specialized tools, the aircraft used for aerial tankers must be in top mechanical condition. Also, pilots must be

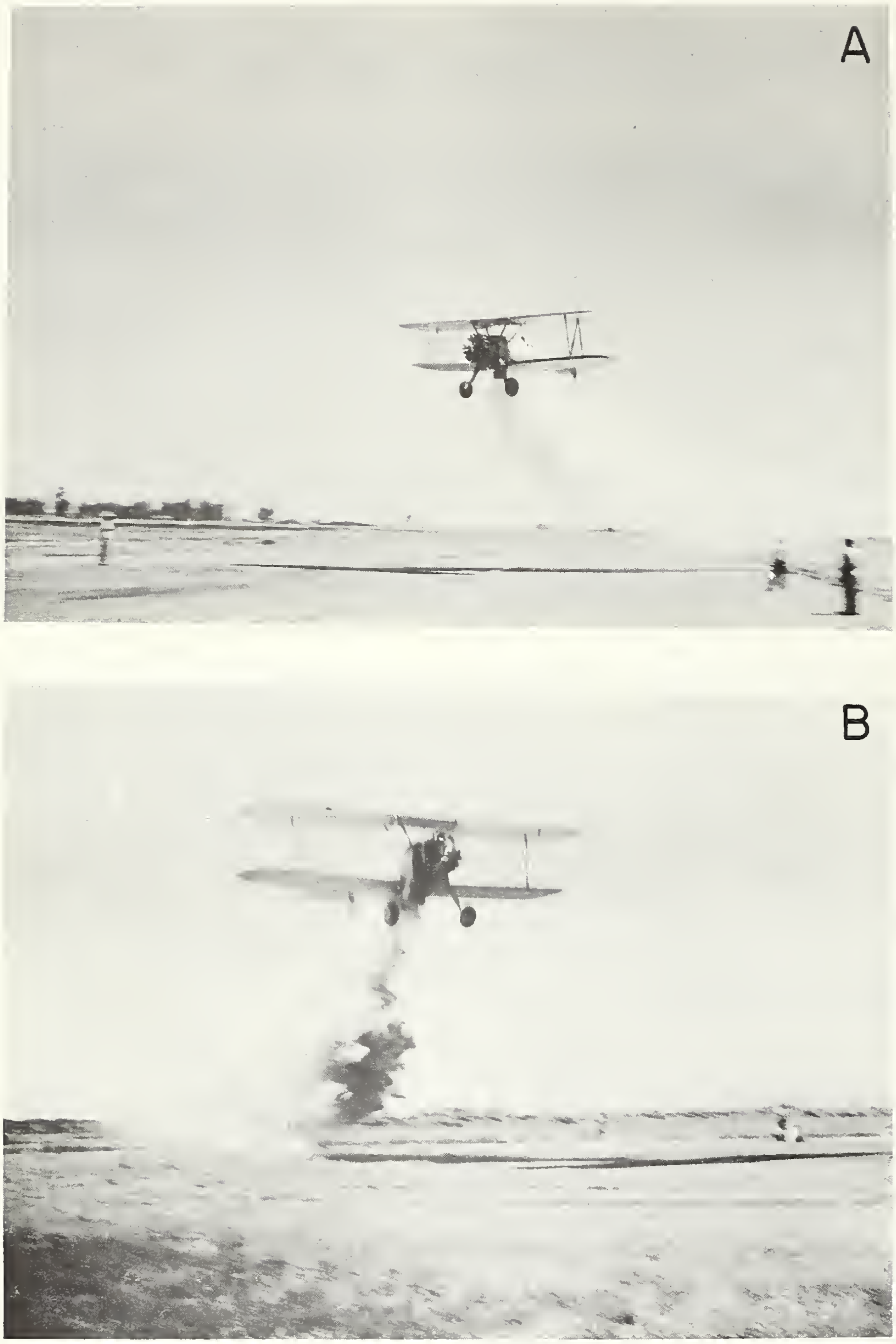


Figure 4. --Dropping water and retardant; note difference in break-up of the liquid A, water; B, retardant.

experienced both in flying under mountain conditions and in low level air drops. Pilots are cautioned to watch for sudden jumps when releasing large amounts of water. They should avoid a taildown plane attitude when dropping from low heights to minimize effects of slipstream on the water.

One aerial tanker has been of significant assistance to ground crews on fires. Indications are that several planes used in quick succession will not only be more efficient but may be able to hold temporarily short pieces of hot fire line. It is not necessary to evacuate the target area as uncontained water drops from this aircraft are not dangerous to personnel.

Considerable work still needs to be done before the aerial tanker can become a common fire fighting tool. The optimum speed, altitude, direction of flight, and method of releasing the water or chemical for each tactical situation need to be determined. Information is needed on the amount of water or chemical required to affect fires under different fuel and burning conditions. More test drops should be made under a greater variety of weather and fuel conditions, particularly at wind velocities greater than those encountered in these tests. A means of closing the outlet gate against a full stream of water is needed to permit higher concentrations of water than are now possible in multiple-pass drops. Ground-to-air communication should be improved for better tactical use.

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