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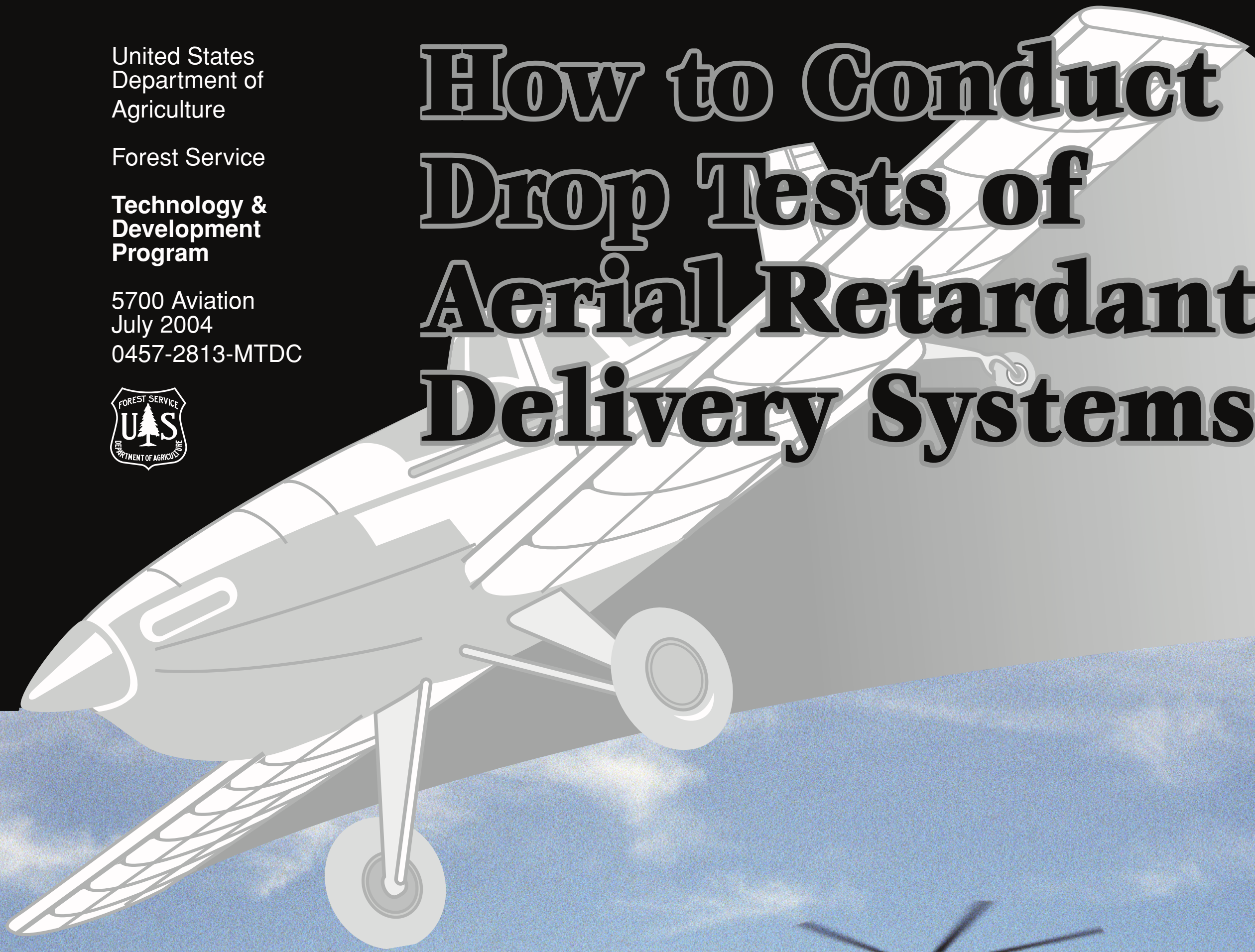
How to Conduct Drop Tests of Aerial Retardant Delivery Systems



How to Conduct Drop Tests of Aerial Retardant Delivery Systems

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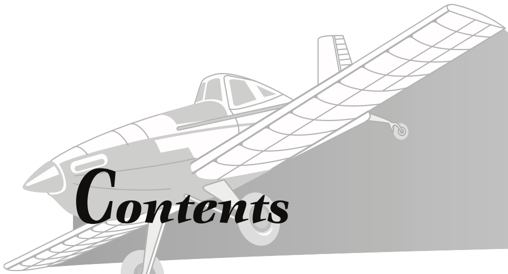

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Drop Test Procedures

Drop test procedures have been developed by the U.S. Department of Agriculture, Forest Service's aerial delivery project to quantify retardant drop patterns produced by rotary and fixed-wing airtanker retardant delivery systems (figure 1). More information on the history of drop testing can be found in the publication *Drop Testing Airtankers: A Discussion of the Cup-and-Grid Method* (0057–2868–MTDC). Drop testing serves as the most accurate means of measuring retardant ground patterns. Tests are performed under controlled conditions, over flat terrain during low winds with steady and closely monitored flight speed, altitude, and attitude. Data from drop testing are used to quantify performance of retardant delivery systems, to define performance requirements set by the Interagency Tanker Board (IAB), to establish a relationship between drop parameters (particularly flow rate) and drop pattern (coverage levels), and to compare the performance of different retardant delivery systems. Actual performance in the field may vary.

Before the drop test, metal stakes are arranged in a grid pattern and pounded into a level section of ground. A plastic cup is attached to the top of each stake. This cup holds a second cup that is cradled inside and held in place by a rubberband. Each cup holder is numbered according to its column and row location within the grid.

As the aircraft passes over, it releases the load of retardant. A lid is placed on each cup that is hit and the cup's location number is written on the lid. These cups are removed from the grid and taken to a weighing area. The weight of retardant contained in each cup and the cup's location are recorded. These data are used to report drop pattern characteristics.

Figure 1—Airtanker dropping water over a grid of cups during a drop test.

Preparing for a Drop Test

Preparation for a drop test should begin several months before the test. You will need to contact aircraft operators, airport managers, county engineers, retardant companies, coworkers, national forests, and the National Oceanic and Atmospheric Administration National Weather Service. Major activities include:

- Identifying aircraft to be tested
- Preparing a test matrix
- Selecting a test location
- Assembling test equipment
- Identifying personnel to prepare and execute the test
- Transporting equipment and personnel to the test site
- Setting up test equipment

Identifying Aircraft to be Tested

Technical information such as flow rates and drop volumes must be gathered for the system being tested. A static test will have to be arranged with the aircraft operator before drop testing. Logistical information such as operational drop heights and speeds must be gathered from the operators, pilots, and fire managers.

Preparing a Test Matrix

A test matrix is an outline listing all planned drops for a given system. Developing a test matrix requires full understanding of the system's design and operation, the needs and goals of the operator or agency, and any time and cost constraints. The test matrix will give an indication of how big the grid needs to be, the number of days needed for the test, how much retardant will be needed, and the number of people needed. As with many other aspects of drop testing, the test matrix will vary depending on the system being tested. For instance, many helicopter buckets drop the entire load using only one flow rate, while constant-flow airtankers can drop fractions of their load using several selectable flow rates. The operator or agency may just want to qualify the system to Interagency Airtanker Board performance standards at specified drop heights and speeds. Or they may wish to quantify the pattern response for a wider range of variables used operationally. Priorities may have to be established for the goals of the drop test, with the matrix including just the highest priority tests based on the availability of aircraft, personnel, or funding. Once the matrix has been prepared, it should be circulated for comments and possible revision before the start of the test. During the test, the matrix is used to plan each day's drop schedule and to monitor progress. Appendix A includes several examples of test matrices.

Selecting a Test Location

Select a test location at least 3 months before the test. Gather information on all possible locations before deciding which location to use. Required facilities and other considerations include:

- A runway that can support the aircraft being tested
- A runway in a lightly populated area with relatively light air traffic
- A community with lodging and restaurants that can accommodate up to 50 people
- A grid drop zone 150 to 250 feet wide and 600 to 2,500 feet long that is free of aerial hazards, allows a smooth, controlled descent to drop height, and does not force aircraft to fly over residential areas at low altitudes
- A sheltered area reasonably close to the grid drop zone where equipment can be stored and cups can be weighed
- A conference room for meetings and briefings
- A water supply and retardant mixing area close to aircraft taxiways or helicopter staging areas
- A dry climate with relatively light winds

These requirements will vary depending on the system being tested. For example, a longer runway with higher load rating will be needed when testing a Type I aircraft. If the test just includes helicopters, a runway isn't needed. Drop tests are typically performed on airport property. Arrangements will need to be made with airport managers or county engineers. They will need to know how much land will be needed for the grid, how much retardant will be dropped, and how long the test is expected to last. Retardant mixing and delivery to the aircraft will need to be arranged with retardant companies. The local national forest will want to be aware that a drop test is taking place in their area. Radio frequencies will need to be cleared though them.

Test Equipment Preparation

(Start preparing equipment at least 3 months before the test.) Test equipment should be listed during preparation for each drop test. The list helps test personnel reduce the number of overlooked items, keep track of government property, and prepare equipment for future drop tests. Appendix B is an example of a drop test equipment list. Much of the equipment may be needed for most drop tests, but the list will need to be amended depending on the system being tested. For example, under *Grid Points*, the required quantity of cup holders and stakes will vary depending on the grid's size. Items listed under *Washdown* would not be needed if retardant cups are thrown away rather than washed after use. Some leadtime is needed to identify, select, purchase, and bench test new equipment. A staging area should be established to store equipment before it is transported to the test site. Large durable items should be packed and labeled for shipment. Above all, assure that enough leadtime is available to have the required quantity of cups, holder cups, and stakes. New cups and lids may need to be weighed empty before the test to derive a statistical average tare weight (the weight of the empty cup and lid).

Personnel

(Start selecting personnel 2 to 3 months before the test.) It takes at least one person to coordinate equipment preparation and at least two others to help with purchasing and administrative tasks. Someone needs to make sure enough Forest Service employees are available during the test. Usually, the Forest Service employees include a core of six to eight individuals with previous drop test experience. Additional personnel can be hired through local temporary employment services, prison crews, youth employment organizations (such as the California Conservation Corps), smokejumpers, hotshot crews, local Forest Service employees, and volunteers associated with the system being tested. The number of additional people needed will depend on the size of the grid.

Getting There

(Begin making arrangements 2 to 3 weeks before the test.) Travel, lodging, and car rental arrangements need to be made at least 2 weeks before the start of the test. Allow flexibility for departure as the date may change at a moment's notice. Most test equipment should be shipped to the test site at this time. Forest Service personnel typically carry sensitive items such as laptops, radios, and video cameras with them when they travel to the test site.

Setup

Depending on the number of people available and the required tasks, setup usually takes 2 to 4 days (figure 2). A list of setup tasks for the 1999 test at Kingman, AZ, is in appendix C. This list could serve as a starting point to identify setup tasks for other drop tests. Test personnel can set the grid up once they arrive or it can be set up in advance by contract labor. In either case, instructions for setting up the grid need to be supplied. Appendix D includes instructions sent to the setup team for the Kingman test.

Figure 2—Setup tasks can vary. This grid was overrun by cattle. It took several days to straighten the stakes and replace the cup holders.

Drop Testing

Grid Preparation

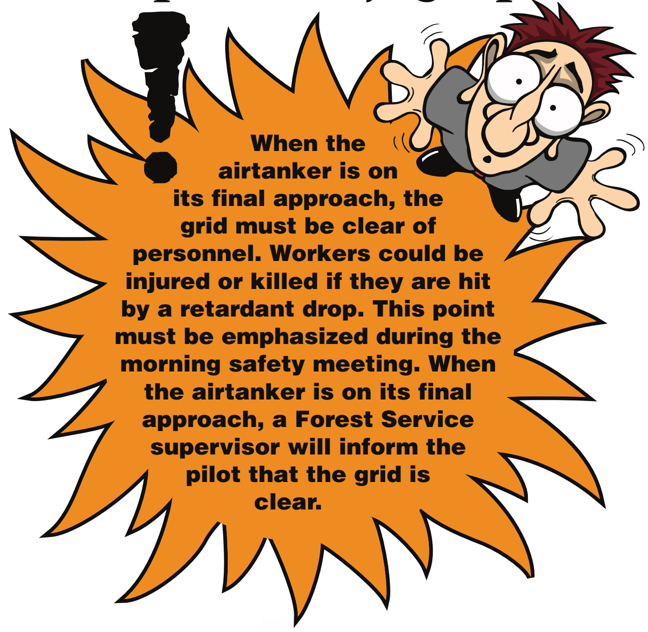
Place a supply of clean cups and lids every 200 to 500 feet along the grid so workers can resupply quickly between drops. These should be stacked on pallets rather than directly on the ground to prevent them from being damaged by rain and to keep the cups and lids dry. Boxes for picking up cups need to be distributed along the length of the grid. A safety meeting and briefing is performed as soon as workers arrive (figure 3). Each grid worker carries a canvas bag with a shoulder strap. The bag contains two sections, one for lids and the other for empty cups. Workers should fill their bags with cups and lids before the first drop. Each grid worker also needs a grease pencil and a supply of rubberbands. If sample cups were left in holder cups overnight, they must be checked for moisture from rain or dew. Otherwise, sample cups must be placed in the holder cups throughout the grid with a rubberband holding the sample cup in place.

Figure 3—The morning safety meeting and briefing before a day of drop tests.

Sample Collection

The grid worker is the real workhorse of the drop test. After the drop, grid workers: 1—cap cups, 2—mark cups, 3—pick up cups, 4—replace cups. Each task should be completed before proceeding to the next task. For example, once the drop has settled, all cups that have been hit must be capped as soon as possible to minimize evaporation. Forest Service supervisors are dispersed evenly among the grid workers. Using hand-held radios, the supervisors ensure that each step is progressing at about the same pace throughout the entire drop area. Personnel can be diverted from areas where tasks are being completed more quickly to areas where they are being completed more slowly.

Important Safety Tip!



Capping Cups

Once the drop has settled to the ground, the cups are capped. Grid workers use the lids in the canvas bags (figure 4) to cap the cups. Workers walk up and down the rows, completing each row before proceeding to the next. Caps should be placed on all cups that have at least a drop of material in them. Empty cups should not be capped. No worker should have to cap cups in more than four rows. A grid with 40 rows requires at least 10 grid workers. A grid with 100 rows

Figure 4—Placing caps on cups after a drop has settled.

requires at least 25 workers. Depending on the width of a drop, a row can be capped in about 1 minute. Ideally, the entire grid should be capped in 5 minutes or less. The entire grid must be capped before proceeding to the next step.

Marking Cups

Marking (figure 5) begins after all cups have been capped. Each cup has a row and column number designation written on the cup holder. The grid worker uses a grease marking pencil to write this number on the cap. The procedure is similar to capping. Complete each row before proceeding to the next row.

Figure 5—The number on the side of the cup holder is written on the cap that seals the cup.

Picking Up Cups

After all cups have been marked, the cups are picked up and placed in pickup boxes. Each box has six compartments. Each compartment can hold eight cups. All cups in a given row are picked up before any cups are picked up in the next row. Each compartment in the pickup box is filled before cups are placed in the next compartment. This procedure facilitates sorting when the cups are weighed (see page 7). Depending on how wide the drop is, each box can hold six to eight rows. Grid workers should work in pairs during the pickup process. One person places capped cups in boxes, while the other person replaces those that are picked up. This person replaces any missing rubberbands that hold the sample cup in place.

When it appears that all the cups have been picked up, supervisors need to walk the grid to verify that all cups in rows hit by the drop have been capped, labeled, picked up, and replaced with clean cups. This check must be carried out before the aircraft is on its final approach for the next drop.

Labeling Boxes with the Drop Number

Each box must be identified with the correct drop. Workers use the grease marking pencil to write the drop number on the lid of one of the top cups in the box (not on the box itself). Boxes from different drops must be separated from each other (figure 6). It is not unusual to have boxes with cups from several drops along the side of the grid at the same time. Keeping these drops separated from each other will avoid confusion when the cups are weighed.

Figure 6—Make sure all boxes are labeled according to drop number and that different drops are separated from each other.

Workers usually have a 5- to 10-minute break before the next drop. During this time, workers need to refill their canvas bags with cups and lids, pick up additional rubberbands (if needed), and sharpen their grease pencils.

Additional Tasks

During the drop test, someone needs to:

- Start the weather station data logger to begin 1-second scans during the drop (between drops, the scan rate is 1 minute).
- Make sure all boxes are properly labeled and kept separate from each other.
- Instruct the pilot when to drop over the grid, explain the drop configuration, and confirm that the grid is clear.
- Ensure that the data collection process is running smoothly and that all cups hit by the drop have been capped, marked, picked up, and replaced. The person performing this task has been affectionately referred to as the Grid Mother.
- Make sure that video cameras are set up each day before the drop tests and taken down each day. The person also ensures that the batteries for the video equipment are charged and that the videotapes are organized.
- Start the weather station in the morning and download data after the tests.
- Operate four video cameras.
- Drive full pickup boxes from the grid to the weighing area and bring empty pickup boxes and other supplies back to the grid.

Most of these tasks do not take long, but all are vital. Specific individuals should be assigned to each task. It should take 15 to 20 minutes from the time the drop settles until the grid is ready for the next drop. After the second or third drop has been collected, four people need to start weighing. Otherwise, it is possible to run out of empty pickup boxes. Since all drops should be weighed the same day they are collected, an early start helps ensure that the day's weighing will be finished as soon as possible. Normally, between 5 and 10 drops will be collected and weighed in 1 day.

Video Documentation

During the drop test, video is recorded from three positions: at the side, end, and corner oblique of the grid. Two cameras, one for an overall shot (side wide) and another following the aircraft (side pan), are operated side-by-side from the side view position. They are positioned in line with the middle row and perpendicular to the edge of the grid. White plywood panels at each end of the grid serve as markers.

The sidewide camera does not move during recording. It provides a wide-angle view of the grid. This camera should be far enough from the grid so that its view includes the plywood panels (see appendix C for plywood panel setup instructions). It should be aimed so that the ground is in view but takes up no more than the bottom fourth of the image.

The side-pan camera follows the aircraft as it passes over the grid. This camera should be zoomed to contain the largest possible image of the entire aircraft while including a view of the ground. The photographer should maintain this view while the aircraft is passing over both plywood panels. Once the aircraft has passed the second panel, the camera should be panned back to the retardant cloud. Document the locations of these cameras and plywood panels based on their distance from the edge of the grid.

The end camera is mounted on a tripod at the end of the grid to capture the grid and the aircraft as it approaches. This camera is aligned with the downrange centerline (middle column) of the grid. The centerline is often marked to help the aircraft pilot adjust the approach. The camera should be zoomed to view the largest possible image of the entire aircraft during the release, while including a view of the ground. The ground should take up no more than the bottom fourth of the image.

The video footage from the side and end cameras is used primarily to determine the aircraft's speed and height.

The oblique camera (on the corner of the grid) provides closer views of the release, the formation of the retardant cloud, and the drop's settling characteristics. For the best images, the operator should stand near one of the corners of the grid with the zoom adjusted so that the view contains the grid and the aircraft as it approaches. Once the drop takes place, the operator should keep the camera trained on the retardant cloud as it forms and settles to the ground. Between drops, the operator can carry the camera to take general interest footage of the grid operations. The photographer should return to the same vantage point at the corner of the grid to record the next drop.

After recording the drop, the camera operators should make their way back to the grid to help the grid workers complete their tasks. Camera operators need to return to their camera positions before the aircraft is on its final approach for the next drop.

Daily Shutdown

Once the last drop of the day has been collected, the side- and end-view cameras need to be retrieved. Depending on security, tripods may be left in place. Weather data should be downloaded and supplies of cups, lids, and pickup boxes should be covered with tarps. If rain or dew is expected before the start of the next day's drop tests, all cups (except holder cups) must be removed from the grid.

A short demonstration video has been prepared to help clarify some of the processes described above. A copy in VHS format can be obtained from Greg Lovellette at the Missoula Technology and Development Center. Grid workers will also be briefed on grid procedures and safety at the grid before the drop test. A revised version is expected by spring 2005.

Grid workers should drink plenty of water, use sunscreen, wear light, comfortable clothing, and wear shoes with ample ankle support.

Weighing Cups

The weighing process includes:

- Removing cups from the pickup boxes
- Sorting cups
- Placing sorted cups onto a carousel
- Transferring cups from the carousel to the balance
- Transferring cups from the balance to a holding bin.

The flow of cups has typically been from right to left, probably to allow cups to be transferred from the carousel to the balance with the right hand.

A disgorging apparatus is used to remove cups from pickup boxes. The apparatus, which is about 3 feet long, 2 feet wide, and 4 feet tall, removes cups from boxes easily.

Immediately to the left of the disgorging apparatus will be a 3- by 6-foot table. This space is used to organize cups that have been removed from the boxes.

Immediately to the left of the first table is another 3- by 6-foot table. The carousel, a 4-foot-diameter, round wooden platter with dowel rods placed along its perimeter, sits on the right end of this table. Stacks of sorted cups are placed along the carousel's perimeter. The dowel rods stabilize the stacked cups. The platter can be rotated as cups are removed and weighed.

A computer, monitor, and keyboard are at the left end of this table. A wooden stand in front of the computer straddles the keyboard and supports a balance. The stand is designed to allow the keyboard to be used easily while the balance is in position.

Immediately to the left of the second table is a holding bin where cups are placed after they have been weighed. Because a computer or operator error may require this pile of cups to be resorted and weighed again, the pile of cups is kept in the holding bin until all of the cups for a given drop have been weighed and the data file has been saved.

Two people, the weigher and the stacker, typically operate a weighing station.

The stacker's first task is to organize the pickup boxes for a given drop in ascending order by grid row number. A final check ensures that all boxes are properly labeled according to the drop number and that all the boxes are from the same drop. The disgorging apparatus is used to remove cups from the boxes, one box at a time, and the stacks of cups are placed on the table (figure 7).

Figure 7—Pickup boxes (foreground), disgorging apparatus (right rear), presorted cups (center table), and sorted cups on carousel (left rear).

A full box contains six columns of cups that yield six stacks. Each cup is labeled using a two-number system. The first number indicates the grid row and the second indicates the cup within that row. For instance, "1,12" refers to the cup in the first row and the twelfth column. The stacker organizes stacks so that cups of each row are in ascending order by column number, with the smallest number on the top of each stack. Stacking is easier if the cups are placed in the box properly when they are picked up. The grid worker should pick up all cups from a given row before proceeding to the next row and fill each column in the box before placing cups in the next column (see picking up cups, page 5).

The stacker places stacks of sorted cups onto the carousel where they will be ready for the weigher. When the weigher removes cups from the carousel and places them onto the balance, the stacker puts more stacks of unweighed cups onto the carousel. The stacker's goal is to keep the carousel full enough so that the weigher does not have to wait for cups.

The stacker's job is busier than that of the weigher. The stacker is constantly alternating between disgorging boxes, sorting cups, and placing stacks of cups on the carousel. The weigher's job is sedentary, but requires more attention to detail (figure 8).

The computerized weighing program asks the weigher questions, such as the aircraft operator's name, the retardant system's name and size, and the characteristics of the grid. After the first session, most of these will be correctly entered by default, but they should be verified at the beginning of each weighing session. Once the weigher has entered the grid characteristics and drop number, the program goes into the weigh mode, where the screen displays row number, column number, weight, and buttons to change the row and column number.

Figure 8—The weigher removes sorted cups from the carousel and places them on a balance. A computer records the weight of each cup.

After the weigher places the first cup on the balance, the *enter* key, the left mouse button, or a foot switch wired to the mouse is depressed to send the weight to the computer's serial port.

After the program has received and recorded the weight of the first cup, it retains the row number, advancing the column number by one. The weigher removes the first cup and places the next cup on the balance. Assuming the stacker has done the job properly, the number on the next cup should match the number on the monitor. When the weight of that cup has been sent to the computer, the program advances the column number by one, and so forth.

Assuming that each row has 20 cups, after the 20th cup is weighed, the program automatically advances the row number and resets the column number to 1. However, in most cases fewer than 20 cups are collected from a row, and the weigher must prompt the program to enter the next row/column designation.

An important feature of the computerized weighing program is that the program saves data every time a cup is weighed. If the power fails, someone trips over a power cord, or the computer crashes, all of the weights recorded to that point will have been saved. Another important feature is that the program does not overwrite data. For example, if data from a row of cups from one drop gets mixed with data from a row of cups from another drop, the data file will retain entries from both rows.

Errors in cup weight files can be discovered and corrected during data reduction. Weighers should make notes of errors if they become aware of them while weighing. A small notepad is kept beside the computer for this purpose.

Because the weighing area is typically dirty, a keyboard cover is a good idea. Have a few spare computer mice on hand and a spare computer as well.

The weighing program has been designed to be as user friendly as possible. The instructions don't include steps to solve *all* possible program errors. It's best to have someone nearby who can.

If possible, complete weighing cups the day of the drop. Even though the caps form a tight seal, some material will evaporate over time. Errors in marking or sorting the cups are easiest to resolve on the day of the drop. Boxes of cups from drops on different days cannot be mistakenly mixed if all cups are weighed on the day of the drop. This also ensures that the previous day's reusable supplies will be available at the grid at the beginning of the next day.

Data Reduction

Data collected during the weighing process are reduced to produce ground pattern contour plots and to calculate the coverage area and length downrange (line length) of different deposition concentrations (coverage levels). More information on data reduction is in *Estimating Methods, Variability, and Sampling for Drop-Test Data* (0257–2826–MTDC).

Delays

Drop testing can be performed only during light winds (typically 10 miles per hour or less) and dry conditions. Weather or aircraft mechanical problems often delay the drop test. Delays may be needed to catch up on chores such as removing lids from cups that have already been weighed, drying wet cups for reuse, removing grease pencil marks from lids, placing dried cups and cleaned lids into empty boxes, or general cleanup of the weighing area (figure 9). During long tests, the entire test team may need a day off.

Figure 9—Cups from water or foam drops can be stacked pyramid style to dry before being used again.

Breakdown

Once all drop test objectives have been met or when time has run out, breakdown can begin. The weighing stations are disassembled and packed for shipping. All equipment remaining at the grid is brought to the weighing area. This includes:

- Cases of unused cups and lids
- Empty boxes, pickup boxes
- The weather station
- Video cameras and tripods
- Plywood marker panels
- Tarps

Remove all cups and cup holders from the grid stakes. Remove stakes from the ground and pile them neatly on a wooden pallet in the back of a truck. A forklift can remove the pallet of stakes from the truck so they can be banded for shipment. Consolidate partially filled cases of cups and lids. Neatly stack and shrink-wrap boxes of cups, lids, and pickup boxes on wooden pallets. Using a wooden pallet as the bottom, construct a large holding bin to ship miscellaneous unbreakable items. Label the contents on all shipping boxes and containers. Use the equipment list (appendix B) to assure nothing is left behind and to document where items are shipped. Pack video cameras, radios, and laptops for team members to carry with them.

Appendix A—Examples of Test Matrices

The matrix (right) was developed during planning for a helicopter bucket drop test. The objectives of the test were to quantify drop patterns at three different dump-valve openings and at three different speeds, using water and retardant. Because helicopter availability was limited, all drops were made at 50 feet above the ground. To reduce costs, only two retardant drops were made, both at commonly used speeds and valve openings.

Valve opening (percent)	Drop speed (knots per hour)	Fluid
100	40	Water
100	60	Water
100	60	Retardant
100	80	Water
60	40	Water
60	60	Water
60	60	Retardant
60	80	Water
30	40	Water
30	60	Water
30	80	Water

The test matrix (below) was developed during planning for a constant-flow airtanker drop test. The objectives of the test were to:

- Quantify drop patterns at different volumes and flow rates while dropping at the same speed and altitude
- Compare drop patterns of water and retardant when all other variables are equal
- Compare drop patterns among replicate drops when all variables are equal

A drop speed and altitude were selected that best represented "typical" operational levels. Replicates were completed with low, medium, and high flow rates. During the test, additional drops were made at different drop heights and speeds to compare drop patterns of a gel product. These drops were made with the same low, medium, and high flow rates.

Load	Volume (gallons)	Coverage level	Flow rate (gallons per second)	Fluid	Evacuation (seconds)	Estimated pattern length (feet)	Repetitions
Full	1,200	1	190	Water	6.3	1,390	
Full	1,200	1	190	Retardant	6.3	1,390	
Full	1,200	2	315	Water	3.8	840	
Full	1,200	2	315	Retardant	3.8	840	
Full	1,200	3	440	Water	2.7	590	
Full	1,200	3	440	Retardant	2.7	590	3
Full	1,200	4	560	Water	2.1	460	
Full	1,200	4	560	Retardant	2.1	460	
Full	1,200	6	640	Water	1.9	420	3
Full	1,200	6	640	Retardant	1.9	420	3
$\frac{1}{2}$	600	1	170	Water	3.6	790	3
$\frac{1}{2}$	600	1	170	Retardant	3.6	790	3
$\frac{1}{2}$	600	4	560	Water	1.1	240	
$\frac{1}{2}$	600	4	560	Retardant	1.1	240	
$\frac{1}{3}$	400	0.5	60	Water	6.6	1,450	
$\frac{1}{3}$	400	0.5	60	Retardant	6.6	1,450	
$\frac{1}{3}$	400	1	175	Water	2.3	500	
$\frac{1}{3}$	400	1	175	Retardant	2.3	500	
$\frac{1}{3}$	400	2	270	Water	1.5	330	
$\frac{1}{3}$	400	2	270	Retardant	1.5	330	

Appendix B—Drop Test Equipment

Equipment List for Kingman, AZ, Drop Test, January 1999

Grid Points

Cup holders (600)
Nylon nuts, bolts, body washers
Stakes (600)
Cups (15,000)
Lids (15,000)
Rubberbands
Grid-marking panels for video analysis (three 4- by 8-foot sheets of plywood, painted white)

Grid Setup

100-foot tapes (2)
Steel cable with grid-width spacing
Stake-pounding hammers (4)
Screwdrivers
$^{7}/_{16}$-inch nut drivers
Map of grid layout
Grid setup instructions

Grid Pickup

Fiber tape
Carrier bags (30)
Carrying boxes (55)
Cutter knives
Grease pencils

Weighing and Recording (for two weighing stations)

Sartorious balances with serial (RS-232) ports (2)
Calibration weights
Cup carousels (2)
Wooden dowels (50)
Box disgorgers (2)
Balance support stand
Cordata 386 computer (2)
Monitors (2)
Serial cables connecting the computer to the balance cable (2)

Washdown

Large Fold-Da-Tanks with plywood sides (2)
Wash mitts
Goop hand cleaner and rubbing alcohol
Metal milk crates
Electric water pump
Suction hose, return line, and fittings
Spray nozzle
Spool of rope
Cargo nets
Bungee cords
Roll of wire
Towels

Weather Station

Tower
Relative humidity, temperature, windspeed, and wind direction instruments
Box with data logger
Associated computer cables
Logger software program
12-volt dc car battery
Battery charger

Communications

King hand-held radios (at least one for each Forest Service supervisor)
Batteries for radios
Power inverter
Base station
Large antenna and coax cable
Mobile radios
Five-bank battery charger

Photo and Video

S-VHS camcorder
Digital camcorders (3)
Associated cables
Batteries, power supplies, chargers
S-VHS tapes
Digital tapes
Tripods for video cameras (3)
Covers for video cameras
Video monitor
Video cables
Still cameras (4)
Color film

Salt Analysis

Sample bottles (50)
Paper towels
Retardant field test kit:
  pH meter
  Viscometer
  Refractometer
  Data sheets

Data Acquisition

Radar altimeter
Floats: 36 inches, 48 inches (2), and 60 inches
Associated cables and power supplies
12-volt dc batteries and charger
Door sensor assemblies
Cable position transducer
Pressure transducer and cables
Tubing
37-pin ribbon cable
Logger cables
Laptop computer
Labview hardware
Voltmeter
Wire ties
Wire crimps
Soldering iron and solder
Tornado tape
Flow meter and fittings
Silicone sealer
5-inch foam pad to protect laptop during flight
Equipment tiedown straps

Tools

Briefcase toolbox:
  Soldering iron and solder
  Tape measure
  Tri square
  Drill bits
  Wire crimp tool
Rechargeable drill and battery packs
Extension cords
Power converter

Data Analysis

Surge protectors (4)
Printer with spare cartridge
Paper (4 reams)
Small color printer
Color paper
Printer cables
3½-inch floppy disks (20), other removable media
PC or laptop computers
Appropriate software

Office Supplies

Clipboards (4)
Notepads
Black notebooks
Pens
Stapler and staples
Cellophane tape
Pencils
Paper clips
Grease pencils
Calculator

Miscellaneous

Toilet facilities: 1 toilet for every 10 workers
Garbage bags
Markers
Latex gloves
Work gloves
Folding chairs (4)
Water coolers (2)
Goggles
Earplugs
Tarps (all we have)
6-foot tables (2)
Stand for flip charts
Flip chart paper
High chair for weighing
Miscellaneous box straps and bungees
Large and small first aid kits

Appendix C—Final Setup Tasks

Meet with all personnel to give them an overview of operations, both from an overall perspective and from a job-specific perspective.

- Check out the grid setup.
- Mark grid points.
- Transport supplies (cups, lids, bags, pickup boxes) to the grid.
- Set up camera locations.
- Set up the weather station.
- Set up the weighing station.
- Establish an inside work area for data reduction and sample analysis.
- Establish a washdown area, set up Fold-Da-Tanks, and plumb the electric pump.
- Install instruments in the airtanker.
- Check out the mixing plant. This could possibly be done by local personnel.
- Set up grid markers.
  –Whitewash two 4 by 8 sheets of plywood.
  –Secure panels in an upright position at each end of the grid.
  –Document panel locations.

Appendix D—Example of Grid Setup Instructions

The data collection grid has 800 points (see grid map), arranged in 20 columns and 40 rows. Columns refer to the downrange component of the grid (its length) and rows refer to the crossrange component of the grid (its width). The grid should be oriented downrange, parallel to the prevailing winds.

Start by setting up the two outside columns (columns 1 and 20) as accurately as possible using a sighting device (transit or theodolite) and the marked cable (rolled up on a wooden spool, included with the stakes). The marked cable is 250 feet long (the width of the grid). Copper clasps, crimped along the cable, mark positions where stakes should be placed. Use the cable to determine the distance between the two outside columns of the grid. Use the sighting device to make sure the first row of the grid is perpendicular to the outside columns.

Once the outside columns have been staked, use the 100-foot tapes to place stakes at 15-foot intervals along the columns. Stakes should be driven carefully into the ground to the depth of the square washer. These stakes will mark the location of the 40 rows. Use the cable stretched between the two outside stakes of each row to position the stakes within each row.

I've divided this part of grid setup into three steps:

Step 1—Establish Four Corners of the Grid

Referring to the grid map below, mark the position of column 1, row 1 on the ground.

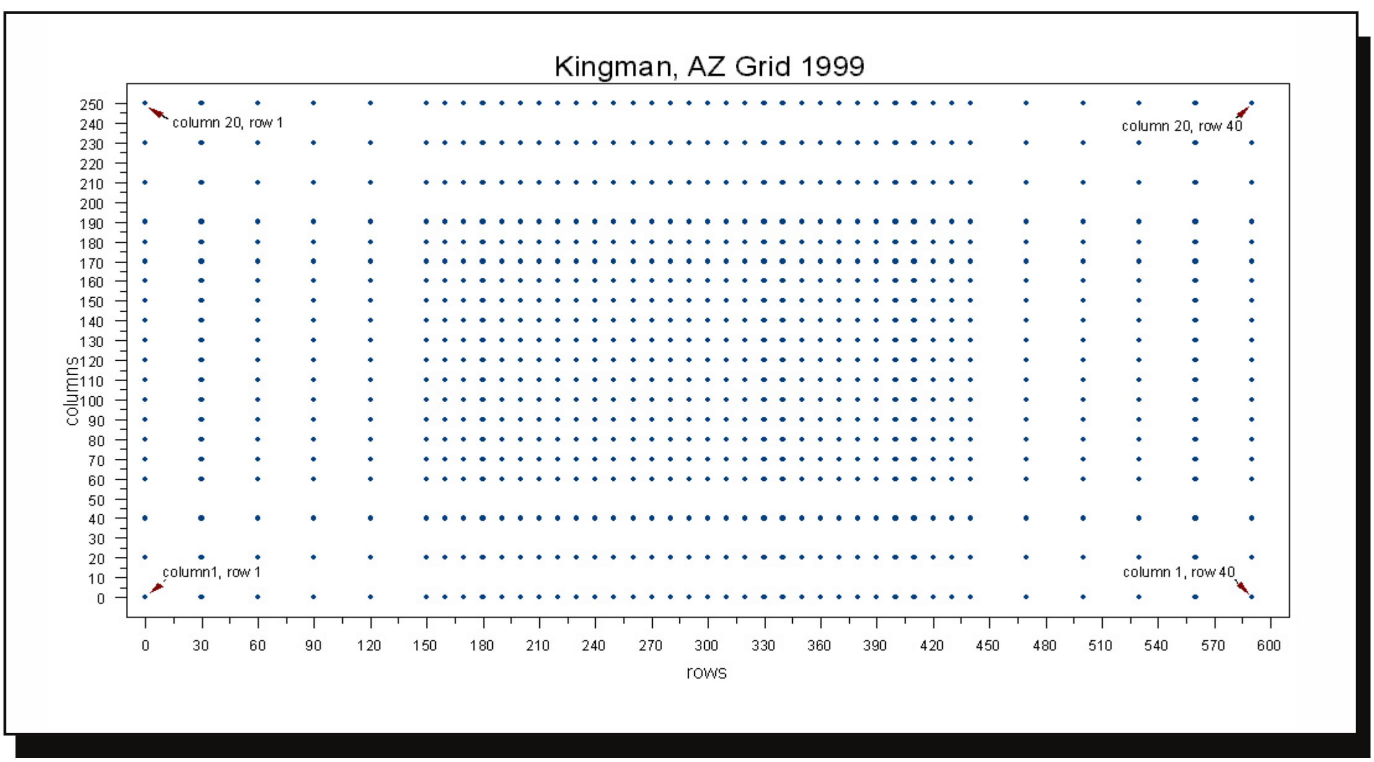
Place a theodolite at the point you just marked (column 1, row 1) and aim it in the directions where column 1, row 40 will be. Using the 100-foot tapes, place a marker every 100 feet out to 600 feet. The sighting device helps keep the markers in a straight line. The last marker, at 600 feet downrange, represents column 1, row 40.

Rotate the theodolite 90 degrees counterclockwise and stretch the 250-foot cable along this line. Mark the last point on the cable on the ground. This point represents column 20, row 1.

Relocate the theodolite to column 1, row 40 and aim it at column 1, row 1.

Rotate the theodolite 90 degrees clockwise and stretch the 250-foot cable along this line. Mark the last point on the cable on the ground. This point represents column 20, row 40.

There are other ways to establish the four corners of the grid, but I believe this process will provide the most accurate layout.



Grid map of the Kingman, AZ, drop test showing placement of stakes. To set up: 1—Place stakes at the four corners; 2—Place stakes along the two outer columns (columns 1 and 20); 3—Place stakes along each row between the two outer columns.

Step 2—Install Stakes Along Columns 1 and 20

Locate the theodolite over one of the grid corners. If you are following these directions exactly, the theodolite is still over column 1, row 40. Aim the theodolite at column 1, row 1. Using the 100-foot tape, insert stakes at intervals as indicated on the map. Use the theodolite to keep the stakes in a straight line.

Locate the theodolite over column 20, row 40 and aim it at column 20, row 1. Insert stakes as described above.

Step 3—Install the Rest of the Stakes

Load the rest of the stakes in the back of a truck. Drop 18 stakes next to each of the stakes in column 1.

Starting with row 1, have two people stretch and hold the 250-foot cable while two or more people insert the 18 remaining stakes for that row. Use the marks on the cable to guide stake placement. Continue with the next rows.

After the stakes are installed, install sample cup holders on the top of each stake. The sample cup holders are sample cups that have been drilled with two $\frac{1}{4}$-inch holes, one in the center to attach the cup to the stake and one near the edge for a drain hole. The shortest of the shrink-wrapped pallets contains three boxes of cup holders. Nylon nuts and bolts attach the cup holders to the stakes. Each cup holder requires a washer on both sides of the cup. The curve of the washer is oriented to support the bottom of the cup, which is slightly raised. A stake with an attached cup holder is included for an example. It is important that the washers are placed as described as in the example.

A system that has worked for us is to have several people inserting bolts and washers into the cups, several others placing one of these assemblies on the ground next to each stake, and several others armed with $\frac{7}{16}$-inch nut drivers (supplied) and a pocket full of nuts attaching the cups to the stakes.

Notes

About the Author

Greg Lovellette is a physical scientist at MTDC. He received a bachelor's degree in chemistry at the University of Montana in 1980. Before joining the USDA Forest Service in 1989, he worked as an oil well analyst throughout Montana, Wyoming, and North Dakota.

Library Card

Lovellette, Greg. 2004. How to conduct drop tests of aerial retardant delivery systems. Tech. Rep. 0457-2813-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 18 p.

Describes in detail the procedures for conducting drop tests to determine the ground pattern coverage of fire retardants, gels, or water dropped from airtankers or helicopters. Basically, a grid of cups is laid out and the airtanker drops the retardant over the grid. Cups with retardant are capped and weighed. Video cameras record the test. An earlier report, *Drop Testing Airtankers: A Discussion of the Cup-and-Grid Method* (0057-2868-MTDC), discusses the statistical basis of drop tests.

Keywords: airtankers, coverage levels, ground patterns, helicopters, protocols, study designs, wildand fire chemicals

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