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.

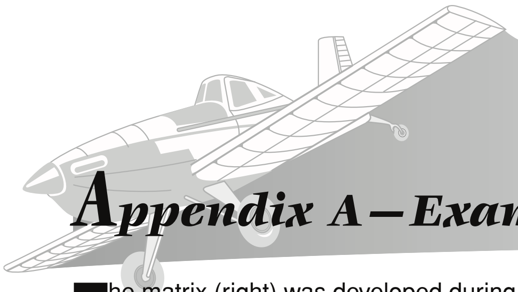
Figure 9—Cups from water or foam drops can be stacked pyramid style to dry before being used again.

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.

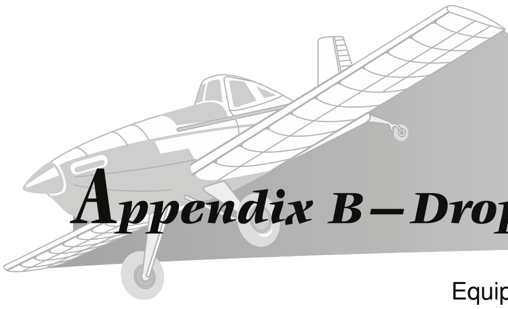
Valve opening (percent)	Drop speed (knots per hour)	Fluid
100	40	Water
100	60	Water
100	60	Retardant
100	80	Water
60	40	Water
60	60	Water
60	60	Retardant
60	80	Water
30	40	Water
30	60	Water
30	80	Water

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
1/2	600	1	170	Water	3.6	790	3
1/2	600	1	170	Retardant	3.6	790	3
1/2	600	4	560	Water	1.1	240	
1/2	600	4	560	Retardant	1.1	240	
1/3	400	0.5	60	Water	6.6	1,450	
1/3	400	0.5	60	Retardant	6.6	1,450	
1/3	400	1	175	Water	2.3	500	
1/3	400	1	175	Retardant	2.3	500	
1/3	400	2	270	Water	1.5	330	
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
$3\frac{1}{2}$-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.

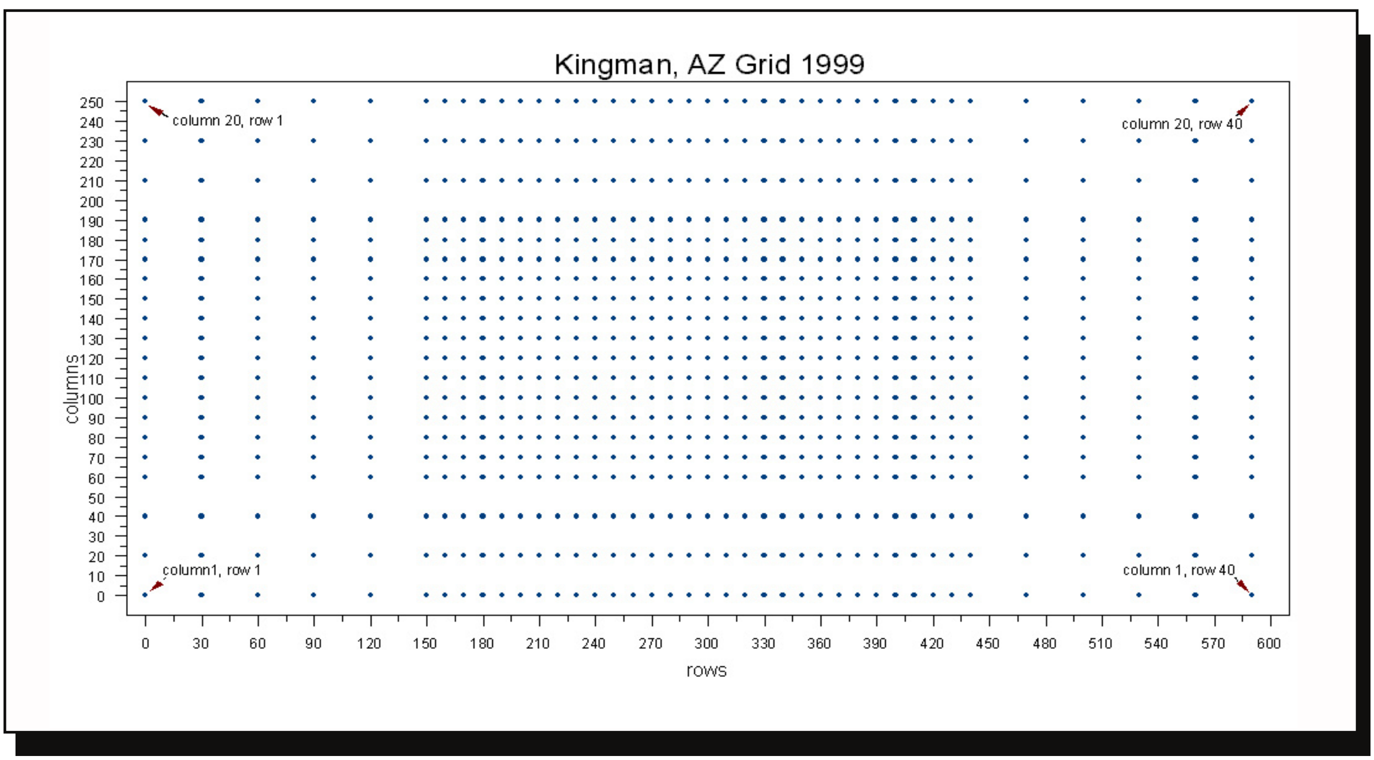
Place a theodolite at the point you just marked (column 1, row 1) and aim it in the directions where column 1, row 40 will be. Using the 100-foot tapes, place a marker every 100 feet out to 600 feet. The sighting device helps keep the markers in a straight line. The last marker, at 600 feet downrange,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