I. Abstract

A primary goal in aerial firefighting applications is to deliver fire retardant at a uniform coverage level on the ground.

Recently, the application of low and moderate coverage levels has shown to be extremely effective early in the fire season for suppression of light to moderate grass and brush fires.

This paper deals with the clear advantages of constant flow delivery systems as compared to constant gate angle (timer based) systems.

II. Overview

The actual coverage level produced by systems utilizing a constant gate angle during delivery are compared with the coverage level produced by systems that vary the gate angle to maintain a constant flow rate during the delivery process.

The coverage levels shown in the document are derived from the tank flow rate seen (i.e. Coverage level is assumed to be proportional to retardant flow rate). The actual coverage pattern seen on the ground will vary depending a variety of aerodynamic effects.

III. Definitions

- **Constant Gate Angle Delivery (CGA)** – The gate is opened to a specific angle during the delivery operation. The gate opening is typically controlled by a timer or other means. This method does not yield consistent coverage patterns on the ground.
- **Constant Flow Rate Delivery (CFR)** – The gate is opened and closed as required during the delivery to accurately control the flow rate yielding a consistent ground pattern.
- **Ground Line** – The linear distance of the retardant pattern present on the ground after the delivery has been completed.

- **Continuous Flow Systems** – A system that uses a single set of doors to control the amount of gallons delivered from a single tank or hopper during retardant delivery operations (as opposed to systems having multiple hoppers). Both constant gate angle (CGA) and constant flow rate (CFR) systems are continuous flow systems.
- **Coverage** – The number of retardant gallons contained in a 100 square foot area inside the delivered ground pattern.

IV. Discussion and Comparison

Constant Gate Angle Delivery Systems

Constant gate angle systems are simple to design and construct since the only requirement is to open the door to a fixed angle for a given amount of time. This method is inexpensive to engineer and produce but does not have the ability to accurately control the flow rate produced by the system as the level of liquid retardant and acceleration forces on the aircraft vary during the delivery process.

Typically one timer is used to control how wide the doors open (a crude coverage control), and another timer is used to control how long the doors remain open (controls the amount of retardant delivered).

Constant gate angle systems will produce a ground pattern that is too heavy at the onset of retardant delivery and is too light at the end of the delivery.

These systems do not use retardant nearly as effectively as constant flow rate delivery systems.

Constant Flow Rate Delivery Systems

Constant flow rate delivery systems are more expensive to design and construct since the system must monitor various parameters during the retardant delivery and control the gatebox doors in a way to maintain constant flow rate.

These systems control the position of the gatebox doors to effectively maintain constant flow rate during retardant delivery operations.

Constant flow rate delivery systems will produce a superior ground pattern that is consistent throughout the delivery. These systems optimize the use of retardant during delivery operations and assure that the correct coverage level is maintained until just before the retardant tanks are empty.

Performance Comparison

The coverage levels produced by a constant gate angle (CGA) system is compared with the coverage level produced by a constant flow rate (CFR) system in Figure 1 and Figure 2 below.

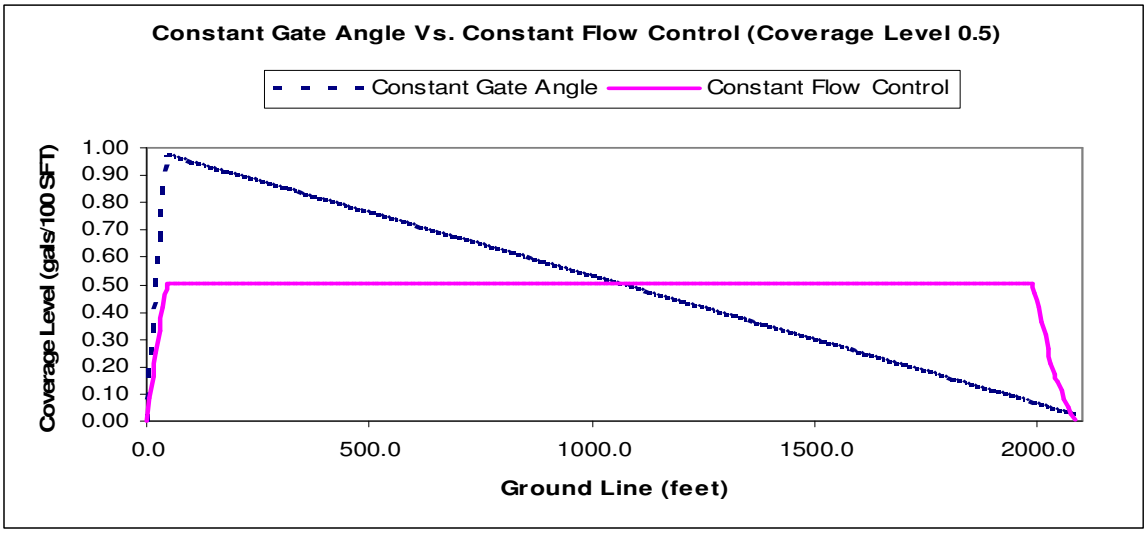

Figure 1 ~ Constant Flow Rate (CFR) versus Constant Gate Angle (CGA) compared at coverage level 0.5.

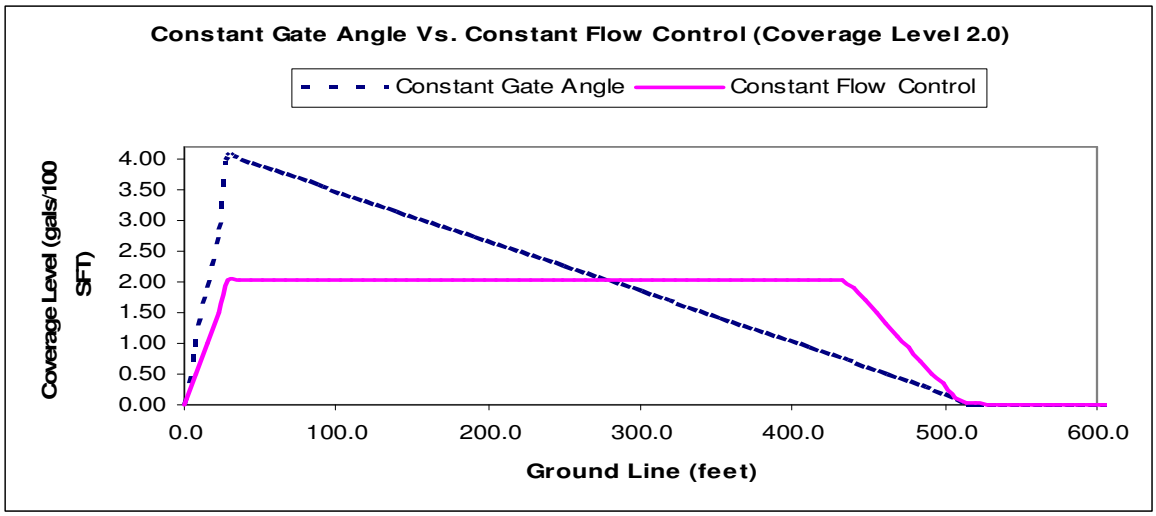

Figure 2 ~ Constant Flow Rate (CFR) versus Constant Gate Angle (CGA) compared at coverage level 2.0.

For both cases shown, the coverage level (proportional to flow rate) delivered by the constant gate angle system is much too high during the onset of the delivery and is much too low towards the end of the delivery.

In contrast, the constant flow rate system delivers consistent flow until the end of the retardant delivery.

The constant gate angle (CGA) delivery system provides a coverage pattern this is very undesirable as compared to the pattern provided by the constant flow rate (CFR) system. The two patterns are contrasted below for an aircraft having a retardant hopper capacity of 800 gallons and a desired coverage level of 0.5 gallons / 100 square feet:

Constant Gate Angle (CGA) Delivery

- **Coverage 2.0 / 800 Gallons** – Total ground line of 510 ft
  - Coverage is too high for 286 ft – Retardant is wasted.
  - Coverage is insufficient for 224 ft – Not enough retardant to suppress fire.

Constant Flow Rate (CFR) Delivery

- **Coverage 2.0 / 800 Gallons** – Total ground line of 510 ft
  - Coverage is optimal for 440 ft – Retardant usage is minimized.
  - Coverage is insufficient for 70 ft – Length of insufficient coverage is minimal.

Using the numbers above, the utilization of retardant can be calculated as follows for an 800 gallon delivery:

% Utilization = (Ground Line with Sufficient Coverage / Total Ground Line)*100

% Utilization CGA @ Cov 2.0 = 286 ft / 510 ft = 0.561

- Constant Door Angle System Effectively Covers 56.1% of the ground line.

% Utilization CFR @ Cov 2.0 = 440 ft / 510 ft = 0.863

- Constant Flow Rate System Effectively Covers 86.3% of the ground line.

The coverage provided for the two types of systems for a coverage level of 0.5 and an 800 gallon delivery can be directly compared as follows:

$$\text{Efficiency Ratio} = \frac{\text{Constant Gate Angle Sufficient Ground Line}}{\text{Constant Flow Rate Sufficient Ground Line}}$$

$$\text{CGA/CFR Efficiency Ratio}_{\text{Cov 0.5}} = \frac{286 \text{ feet (CGA)}}{440 \text{ feet (CFR)}} = 0.65$$

This shows that the constant gate angle system's (CGA) retardant utilization efficiency is only 65% as efficient as the more sophisticated constant flow rate delivery system for a coverage level of 2.0.

For a coverage level of 0.5 and an 800 gallon delivery, a similar analysis shows that the constant gate angle system's (CGA) retardant utilization efficiency is only 53.6% as efficient as the constant flow rate delivery system.

Note that the effects of acceleration on retardant flow were not considered in the above analysis. The effects of acceleration will render the constant gate angle system even less efficient than shown in the above calculations. As a point of reference, a two G aerobatic maneuver will increase the flow rate at a given fixed gate angle by approximately 40% or more.

V. Conclusions

While constant gate angle systems are simpler to design and produce, the utilization of retardant is far inferior to coverage level that is produced by constant flow rate systems.

The constant gate angle system was able to sufficiently apply retardant to only 53.6% of the ground line covered by the constant flow rate system at a coverage level of 0.5.

Since effective utilization of the limited retardant carried aboard aircraft is of paramount importance, constant flow rate delivery systems should be utilized when at all possible.

Utilization of constant flow rate delivery systems drastically improves the ability of a given aircraft and pilot to suppress fires due to the constant coverage delivered and longer ground lines that can be produced with a given amount of available retardant.

VI. Recommendations

Air Tractor has been producing sophisticated constant flow rate (CFR) retardant delivery systems since the early 1990's.

Air Tractor has invested over $800,000 in a new second generation design. This new design has the following very desirable features:

- Offers both constant flow rate (CFR) and constant gate angle (CGA) modes of operation.
- Constant Flow Rate Mode automatically compensates for aircraft acceleration and the gallonage remaining in the retardant hopper.

- Constant Gate Angle Mode opens the door to a fixed angle throughout the delivery. This mode uses almost no sensors for the utmost in simplicity and reliability.
- A fully redundant electromechanical backup system is provided to ensure mission readiness.
- Two independent backup systems are provided to ensure that the doors open when requested.
- Utilizes waterproof connectors, hardened electronics, and a dual head hydraulic pump that has been rigorously tested to over 7,000 flight hours.
- Utilizes hydraulic components that have been impulse tested for over 68 years of operation. This yields an expected service life of over 22 years using a scatter factor of 3.
- On board diagnostics for broken wire, damaged valve, pump, and hardware detection an reporting.
- A proven team of engineers and field support professionals to insure that your aircraft is ready to deploy.

If you are considering a dispersal system for your Air Tractor aircraft, contact Air Tractor regarding the new state of the art GENII FRDS system.

Installation of an Air Tractor GENII FRDS system insures that your aircraft will not become obsolete and is capable of meeting all standards likely to evolve regarding constant flow control capability requirements for retardant dispersal systems.