Protecting Our Forests — Protecting Our Future

Foray®
DiPel®

Forestry Technical Manual

VALENT BIOSCIENCES™ CORPORATION

1.0 INTRODUCTION

1.1 Message from The VBC Forestry Team

Commercial formulations of *Bacillus thuringiensis* subspecies *kurstaki* (Btk) have been used as a tool for the control of forest caterpillar pests since the mid-70's and over the past two decades both the product and the application technologies have evolved. Technical Bulletins and Manuals have been provided by Valent BioSciences to address these new developments. In our continued effort to support the appropriate and efficient use of Btk, and more specifically Foray and DiPel, we have produced this manual, which is in its ninth edition.

As in previous editions, we want to provide a comprehensive publication which addresses all aspects of Btk use. Therefore, as well as covering the purely operational aspects of its use, we have tried to address a number of peripheral issues pertaining to the use of Btk in the environment.

This edition sees a number of changes regarding units; because our products are used internationally, we have included metric units where relevant, avoiding the need for conversion from US units. As in the previous edition, the Technical Manual is published in a loose leaf, three-ring binder format. It is our intention to replace outdated information sheets and provide the latest technology available to our Btk customers on a timely basis. Please feel free to copy and distribute any information contained herein in support of your programs.

As always, we are receptive to feedback from our customers.

1.2 What's New?

Since their introduction over 25 years ago, Valent BioSciences has called its Btk formulations 'DiPel'. With the acquisition of the Plant Protection Division of Novo Nordisk, and their Foray formulations, we have decided to standardize upon 'Foray' as the main product identifier of our aqueous-based forest protection products. DiPel remains the brand name for our oil based formulation.

1.2.1 The Forestry Toxin Unit

Inside the manual, you will also find that we are starting to make Btk formulations more specific for particular forest pests.

With continuous development of our products, we have been able to make our Btk formulations easier to handle. You will find that even the high activity 76B formulations have low viscosities and flow easily.

Consequently, we are introducing the Forestry Toxin Unit (FTU) as a replacement of the Billion International Units (BIU) commonly used as a measure of Btk activity.

Forestry Products Available

Product	Formulation	Activity
Foray 48F	AF[1]	48 FTU/gal (12.7 FTU/L)
Foray 48B	AF	48 BIU/gal (12.7 BIU/L)
Foray 76B	AF	76 BIU/gal (20 BIU/L)
DiPel 8L	Oil[2]	64 BIU/gal (16.9 BIU/L)

[1] AF is an Aqueous Flowable formulation.

[2] Oil is a paraffinic oil-based formulation

1.2.2 Accurate Deposit Assessment Methodology (ADAM) of Btk Delta-Endotoxin

Adequate spray deposition and coverage is a prerequisite for treatment success. One method to measure spray deposition is to incorporate dyes into the Btk formulation (see Section 5.7.1). However, the use of dyes is limited in that they can be used only in experimental trials and for relatively small application areas. Furthermore, spray cards used for measuring the deposit require significant effort in placement prior to application and in analysis following the application. More importantly, cards have been shown to be an unreliable measure of the spray deposit actually found on the foliage. Dye incorporation is therefore not a practical or reliable way for determining deposit.

An ELISA (Enzyme Linked Immuno Sorbent Assay), therefore, has been developed to measure Foray/DiPel Bt deposits on foliage. This technology, available in kit form for field and research use to VBC customers, very accurately measures the deposition of Foray/DiPel Btk delta-endotoxin on foliage. Consult your Valent BioSciences field representative for further information on the "ADAM" kit.

1.3 What are Foray and DiPel?

Foray and DiPel are biorational insecticides containing the spores and crystalline proteins produced by the gram-positive bacterium *Bacillus thuringiensis* subspecies *kurstaki,* commonly known as B.t. or Btk. The vegetative cells of B.t. form spores which enable it to reproduce and survive in an adverse environment. During spore formation, the bacterium also produces unique crystalline proteins called delta-endotoxins. Together, the endotoxins and spores are toxic to many lepidopteran larvae.

Btk is considered "friendly" to human beings as well as to other species of animals. Btk has specific activity only against susceptible caterpillars. Foray's and DiPel's inert ingredients, which include various carriers, suspension agents, and stabilizers are classified by the Environmental Protection Agency (EPA) as inert ingredients of minimal toxicological concern to non-target organisms and the environment (EPA's List 4).

As Btk exhibits a unique insecticidal activity specific to caterpillars and because the inert ingredients are innocuous, Foray and DiPel do not exhibit any of the hazards often associated with chemical insecticides.

Several Foray and DiPel products are available for control of forest defoliators. They are Foray 48F, 48B, 76B and DiPel 8L. These products offer unique formulations to address the diversified requirements of individual pest control programs and aerial applications.

Foray and DiPel are very effective and are considered environmentally friendly and compatible.

1.4 How do Foray and DiPel work?

Btk is active only on the larval stages of Lepidoptera and must be eaten to be effective. Activation of the toxic proteins takes place in the insect's mid-gut where the alkaline pH and enzymes found there are essential to the process. Proteolytic enzymes (which are similar to trypsin), from both the insect gut and possibly the crystal, break the crystal down into smaller active toxins.

These activated toxins bind to the cell membrane lining the gut, generating pores that disturb osmotic balance and lead to cellular swelling and lysis. The effect of this process on the insect host is cessation of feeding, usually within an hour, lysis of gut lining cells through the action of active toxins, perforation of the intestinal wall, septicemia and death of the organism.

Different subspecies of Btk have differently shaped crystals composed of specific toxin combinations. For example, Foray Btk contains at least four toxin subtypes - CryIA(a), CryIA(b), CryIA(c), and CryIIA. Each toxin needs a specific receptor site on the gut for binding (and subsequent gut wall disruption) to occur. An insect must have the receptor sites for the specific Bt toxins in order to be susceptible to the insecticide.

2.0 FORAY AQUEOUS FORMULATIONS: TECHNICAL INFORMATION

2.1 General Description

Foray 48F, 48B, 76B are water based (aqueous) suspensions of Btk insecticide designed specifically for forestry applications. These formulations can be sprayed undiluted or diluted with water. Foray disperses readily into water to form a free-flowing spray suitable for conventional or low volume aerial applications. Foray formulations do not contain formaldehyde, benzene, xylene or other solvents of toxicological concern. Government regulatory agencies worldwide have expressed no concerns of a toxicological nature about Foray. These products are not classified as hazardous materials and are not regulated under DOT (US Department of Transportation) hazardous materials regulations (49 CFR 100-199).

When applied undiluted or when tank-mixed with water, Foray suspensions are slightly acidic, but they are not seriously corrosive to fittings normally encountered on mixing and application equipment. Foray is mildly acidic to ensure product storage stability and to optimize its efficacy.

The different formulations of Foray exhibit the following characteristics:

2.1.1 Physical Properties of Foray 48F

Appearance	Tan colored liquid
Potency	11,800 FTU/mg or 48 billion FTU[1] /gal
Specific Gravity	1.14 +/- 0.05
Weight	9.51 +/- 0.42 lbs/gal (1.14 +/- 0.05 kg/L)
pH	4.7 +/- 0.3
Dispersibility	Disperses readily into water
Viscosity @ 25°C	300-900 cP[3]
Viscosity @ 5°C	300-900 cP[3]

2.1.2 Physical Properties of Foray 48B

Appearance	Tan to light colored liquid
Potency	10,600 IU/mg or 48 BIU[2]/gal
Specific Gravity	1.14 +/- 0.05
Weight	9.51 +/- 0.42 lbs/gal (1.14 +/- 0.05 kg/L)
pH	4.7 +/- 0.3
Dispersibility	Disperses readily into water
Viscosity @ 25°C	150 - 800 cP[3]
Viscosity @ 5°C	150- 1000 cP

2.1.3 Physical Properties of Foray 76B

Appearance	Tan to brown colored liquid
Potency	16,700 IU/mg or 76 BIU[2]/gal
Specific Gravity	1.14 +/- 0.05
Weight	9.51 +/- 0.42 lbs/gal (1.14 +/- 0.05 kg/L)
pH	4.7 +/- 0.3
Dispersibility	Disperses readily into water
Viscosity @ 25°C	600-1800 cP[3]
Viscosity @ 5°C	600-2200 cP

[1] FTU = Forestry Toxin Unit
[2] BIU = Billion International Units
[3] cP = *centipoise*

2.2 Foray 48F and the FTU

In 1996, Valent BioSciences introduced the Forest Toxin Unit (FTU) as the standard measure of the activity of a forestry Btk product. The intention of the change was to use a reference standard which more accurately reflects the material's activity against the defoliator being controlled, rather than the cabbage looper, *Trichoplusia ni*, which is the standard insect used to assay Btk. The FTU should be used as the equivalent of the universally accepted International Unit (IU).

2.2.1 Foray 48F and Optimization of Btk Activity

In development of this product, Valent BioSciences focused upon the optimization of Btk activity for control of the gypsy moth. The production (fermentation) process has been optimized by using a new analytical technique and an insect-specific bioassay to measure and validate these improvements.

High performance liquid chromatography (HPLC) is being used in a new patented technology (U.S. Patent 5,356,788). This technology is capable of analyzing Bt products to provide separation and quantification of the individual toxins that are biologically active. It is the first analytical tool whose use has demonstrated a high degree of correlation between the ratios of different endotoxins and the target insect bioassay.

2.3 Compatibility Statements

Foray is a fully formulated product which contains ample surfactants to insure wetting and adhesion to most foliage surfaces. If a sticker is used when applying a diluted Foray mixture, read and follow the manufacturer's label for correct use and rates. Always add the sticker to the water prior to addition of Foray. NEVER ADD SPRAY STICKER TO UNDILUTED FORAY.

Never mix undiluted Foray with molasses, or any thickening agents and/or evaporation retardants. An excessively viscous spray mix may result.

Do not tank mix Foray with other insecticides, miticides, fungicides, spray oils, foliar nutrients, or herbicides unless the physical compatibility and safety of the tank mixture to plants has been thoroughly evaluated by standard methods.

2.4 Handling Undiluted and Diluted Aqueous Foray

2.4.1 Undiluted Applications

Foray is formulated to be applied as undiluted ULV sprays, but it can be mixed with water for higher volume applications. Undiluted applications increase payload efficiency and lower application cost.

The only precaution recommended for handling undiluted Foray is to thoroughly flush all tanks, pumps, pump lines and aircraft systems with clean water, followed by complete draining, before the addition of undiluted Foray. Clean in-line strainers and inspect for holes or gaps. Use strainers between 16 and 50 size mesh. A 30 mesh strainer is a good general recommendation. For nozzle strainers, follow the equipment manufacturer's recommendations. See section 5 for a detailed description of spray system screens and nozzles.

Foray is formulated with the correct amount of suspending agents to provide minimal settling of solid portions during storage and transport. However, it is recommended that product be recirculated at least once prior to use. During a spray operation and ferrying, it is not necessary or even recommended to maintain continuous agitation of Foray with bypass flow.

2.4.2 Diluted Applications

Foray is completely miscible with water and can be mixed in any ratio with water to obtain desired spray volumes. The preferred mixing sequence is to add Foray to water; however, the reverse procedure can also be used. All mixing and transfer equipment should be clean prior to the mixing of Foray. Clean in-line strainers and inspect for holes or gaps. Drums should be stirred, agitated, or rolled prior to dispensing. Water to be used in mixing should be clean and filtered to remove any coarse suspended matter. Water hardness levels should not exceed 340 ppm, and the pH of final mixture should be below 7.

Clean in-line strainers and inspect for holes or gaps. Use strainers between 16 and 60 size mesh. A 30 mesh strainer is a good general recommendation. For nozzle strainers, follow the manufacturer's recommendations.

2.4.3 Mixing Procedure

- Fill the mix tank or aircraft hopper with the necessary volume of water. Start hydraulic or mechanical agitation.
- If a sticker is being used, add to the water at this time.
- Add Foray gradually to agitating water.
- Rinse empty drums and bulk tanks previously holding Foray and use rinse water for any subsequent mixing.

It is recommended that Foray tank mixes be used immediately. However, in the event of application delays, Foray tank mixtures are stable for 72 hours, depending upon storage temperatures and water quality. Recirculate tank mixes prior to loading aircraft.

2.4.4 Aircraft Loading

In cold weather, especially with the first load of each spray day, all product in the pumps and hoses, (including the loading hoses) should be recirculated back through the storage tank. This will assure that all pumps, meters, valves and filters are operating properly. In addition, the product in the first load will be of a temperature and viscosity consistent with normal operations.

2.5 Cleaning Transfer, Mixing and Spray Equipment

Periodically, during the spray operation, it is recommended to rinse off any Foray residues which may be on the atomizers or the aircraft.

At the conclusion of the spray program, equipment should be cleaned according to the following recommendations:

- Remove in-line screens, nozzle screens and nozzles, and clean these in a detergent/water solution. If so equipped, Micronair variable restrictor units (VRU) should be set at #13 or pulled out to the "full open" position.
- Filling the mix tank or plane hopper with clear water, followed by agitation and spraying out is usually sufficient to clean Foray residues from the system. Optionally, a detergent solution can be used, followed by a clear water rinse.

2.6 Pump Seals

Most centrifugal pumps used in aerial application programs are fitted with inexpensive carbon-ceramic mechanical seals. Aircraft and transfer pumps equipped with these seals may have a tendency to leak when using Foray. As Foray is composed of suspended particles in a liquid medium, as with any such material, some mechanical abrasion may occur. Inexpensive carbon seals should be replaced. This does not occur with all centrifugal pumps, but the problem is alleviated with the substitution of tungsten carbide-silicon seals.

There are several manufacturers and numerous distributors for original equipment and/or replacement seals. Two manufacturers of such seals are:

1. FLOWSERVE
   (Formerly PAC-SEAL Inc.)
   211 Frontage Road
   Burr Ridge, Illinois 60521
   (847) 325-7119

2. John Crane Inc.
   6400 W. Oakton Street
   Morton Grove, Illinois 60053
   (847) 967-2400

If you intend to use a Foray aqueous formulation, discuss the matter of pump seals with your VBC Field Representative to assist with ordering seals. Ordering new or replacement seals should be done well in advance of the operational program because tungsten seals are not generally an inventory item.

Use positive displacement pumps where feasible. An example for wind driven systems is the Sorensen Sprayers Model 4000 gear pump. Smaller electric pumps are available for helicopters.

REFER TO MANUFACTURER'S DIRECTIONS FOR MECHANICAL SHAFT SEAL REPLACEMENT.

DO NOT RUN PUMP DRY.

ALWAYS PRIME PUMP BEFORE STARTING.

IN THE CASE OF SELF-PRIMING MODELS, THE PUMP CASING MUST BE FILLED.

2.7 Storage and Disposal

Do not store Foray in the direct sun where product temperature will exceed 90°F (30°C) for prolonged periods of time. Within normal storage temperature ranges of 32° to 90°F (0°- 30°C), there will be no adverse effects on the formulation.

Re-close all unused containers. Foray is an EPA Category III pesticide; refer to CAUTION statement on Foray label for handling and storage.

3.0 DIPEL OIL-BASED FORMULATION: TECHNICAL INFORMATION

3.1 General Description

DiPel 8L is an emulsifiable oil-based suspension of Btk designed especially for forestry applications. It can be sprayed undiluted for ultra low volume applications and it disperses readily into water or oil-based carriers to form a low viscosity spray suitable for conventional or low volume aerial applications.

The oil formulation uses a paraffinic mineral oil which is highly refined and hydro-treated to further purify and remove any potentially toxic substances which may be found in some mineral oils.

DiPel 8L does not contain formaldehyde, benzene, xylene, or other solvents of toxicological concern. Government regulatory agencies, worldwide, have expressed no concerns of a toxicological nature about DiPel. This product is not classified as a hazardous material and is not regulated under DOT (US Department of Transportation) hazardous materials regulations (49 CFR 100-199).

When applied undiluted or when tank-mixed with water, DiPel suspensions are slightly acidic, but they are not seriously corrosive to fittings normally encountered on mixing and application. DiPel 8L is mildly acidic to ensure product storage stability and to optimize its efficacy.

For calibration purposes DiPel 8L formulations exhibit the following physical characteristics:

3.1.1 Physical Properties of DiPel 8L

Appearance	Brown colored liquid
Potency	17,600 IU/mg or 64 BIU[1]/gal
Specific Gravity	0.94 +/- 0.20
Weight	7.84 +/- 0.17 lbs/gal (0.94 +/- 0.20 kg/L)
Dispersibility	Miscible with water, diesel fuel, kerosene, agricultural spray oils
Viscosity @ 25°C	300-700 cP[2]
Viscosity @ 5°C	2500 cP max.

[1] BIU = Billion International Units
[2] cP = *centipoise*

3.2 Compatibility Statements

DiPel 8L is a fully formulated product which contains ample emulsifiers to insure wettability of most foliage surfaces whether applied undiluted or diluted with water. If a sticker is used (dilute applications only), read and follow the manufacturer's label for correct use and rates. Always add the sticker to the water prior to addition of DiPel 8L .

NEVER ADD SPRAY STICKER TO UNDILUTED DIPEL 8L.

Currently available spray stickers are not compatible with undiluted DiPel 8L.

Never mix undiluted DiPel 8L with molasses or other thickening agents and/or evaporation retardants. An excessively viscous spray mix will result. Do not mix DiPel 8L with a combination of fuel oil and water or excessive viscosity will occur.

Do not tank mix DiPel 8L with other insecticides, miticides, fungicides, foliar nutrients, or herbicides unless the physical compatibility and safety of the tank mixture to plants has been thoroughly evaluated by standard methods.

3.3 Handling Undiluted and Diluted DiPel 8L

3.3.1 Undiluted Applications

Combinations of undiluted DiPel 8L with water, even as little as 0.5% of the total product volume can cause thickening, especially if water is allowed to remain in pump lines, strainers, booms and atomizers. To avoid problems associated with incorrect water/product mixes, follow these recommendations:

Recommendations for Bulk Storage and Transfer Equipment:

- Tanks, transfer lines and pumps for bulk storage should be clean and free of water prior to addition of undiluted DiPel 8L.
- Flush lines, pumps, metering devices, and tanks with an oil-miscible organic solvent (diesel, kerosene, crop oil) to evacuate any remaining water. After flushing, drain solvent completely and retain for further use if not excessively contaminated with water.
- DiPel 8L can be pumped into bulk tanks following flushing and draining.
- On standing, undiluted DiPel 8L will undergo slight separation of oil and solid phase components. Periodic recirculation of the entire tank volume of product by pumping from bottom to top of bulk storage tanks every 3 days during spray operations will maintain uniform product consistency.

- Bulk storage tanks should be fitted with a vented, rain-proof hatch.
- In-line screens or filters should be at least 16 size mesh, but not finer than 50 mesh. A general recommendation is a 30 mesh strainer.

Recommendations For Aircraft Spray Systems:

- Flush the spray system with clear water and drain completely. Make certain inside surfaces of booms and lines are clean and free of scale and sediment.
- Purge the spray system of any liquid using the most appropriate method for your aircraft.
- If you still need to eliminate all traces of moisture, perform the following: Fill the aircraft hopper with enough oil solvent (diesel, kerosene, crop oil) to insure that the pump can circulate material through the spray system. Clear the booms and atomizers by spraying solvent. Used solvent can be reused if not excessively contaminated with water.

  In most cases trace amounts of water will not affect the flow of DiPel 8L through the spray system. The detergent action of the formulation will purge the last traces of water from the system.
- Between spray sessions cover hopper lids securely with a tarpaulin or equivalent to prevent water from rain or moisture condensation from entering the hopper because of inadequate seals.
- Avoid excessive agitation of the undiluted formulation. Constant mixing or "whipping" can alter emulsion properties resulting in high viscosity.
- Solids may accumulate on the atomizer screens after continued use. These can be removed by rinsing the screens with an oil solvent or water. The rinsate can be reused for several cleanings. Rinsing off the DiPel deposit at the end of each day is a good practice.

3.3.2 Diluted Applications

Oil-based, emulsifiable suspensions of DiPel 8L are formulated with enough emulsifier to permit mixing with water at ratios greater than 50:50 water to undiluted product. Mixing of product with less than 50% water will result in an invert emulsion - a thick, viscous material that is difficult to pump and spray. A general recommendation is to use a 40:60 DiPel: water dilution as a minimum dilution ratio.

All mixing and transfer equipment should be clean prior to the mixing of DiPel. Clean the in-line strainers and inspect for holes or gaps. Drums should be stirred, agitated, or rolled prior to dispensing. Water to be used in mixing should be clean and filtered to remove any coarse suspended matter. Water hardness levels should not exceed 340 ppm, and the pH of the final mixture should be below 7.

Use strainers between 16 and 60 size mesh. A 30 mesh strainer is a good general recommendation. For nozzle strainers, follow the manufacturer's recommendations.

3.3.3 Mixing Procedure

- Fill the mix tank or plane hopper with the necessary volume of water. NEVER ADD UNDILUTED DIPEL TO TANK OR HOPPER BEFORE A SUFFICIENT VOLUME OF WATER IS ADDED.
- Start the mechanical and/or hydraulic agitation of water.
- If using a sticker, add sticker to agitating water prior to addition of DiPel.
- Steadily add DiPel to agitating water.
- Rinse empty drums and bulk tanks previously holding DiPel and use rinse water for any further mixing.

DiPel 8L, after it is diluted, will stay suspended during the normal course of application. Mild agitation via the by-pass flow in aircraft spray systems is adequate to maintain uniform suspension.

CAUTION: Avoid excessive agitation of the diluted formulation. Constant mixing or "whipping" can alter emulsion properties resulting in high viscosity.

It is recommended that DiPel tank mixes be used immediately. However, in the event of application delays, DiPel tank mixes are stable for 72 hours, depending on storage temperatures and water quality. Recirculate tank mixes prior to loading aircraft.

MIXING RATIOS: Do not mix DiPel 8L to a greater concentration than 1:1 (50:50) in water. Mixing a greater proportion of DiPel to water will result in an unworkable viscosity. If an error is made in mixing, resulting in a high viscosity mixture, add the appropriate amount of water to restore the correct mixture.

As a general recommendation, use mixtures having 40% or less DiPel 8L.

Typical Viscosities of DiPel 8L Tank Mixes

Ratio Product: Water	Approx. Viscosity (Centipoise)
25:75	<20
40:60	<40
45:55	1,500
50:50	2,000
60:40	4,000

3.3.4 Aircraft Loading

In cold weather, especially with the first load of each spray day, all product in the pumps and hoses, (including the loading hoses) should be recirculated back through the tank. This will assure that all pumps, meters, valves and filters are operating properly. In addition, the product in the first load will be of a temperature and viscosity consistent with normal operations.

3.4 Cleaning Transfer, Mixing, and Spray Equipment

At the conclusion of the spray program, ground and aircraft equipment should be cleaned according to these recommendations:

Remove in-line screens, nozzle screens and nozzles, and clean these in either oil solvent (undiluted applications) or detergent water solution (diluted applications). Micronair variable restrictor units should be set at #13 or pulled out to the “full open” position.

For diluted applications, filling the mix tank or plane hopper with clear water, followed by agitation and spraying out, is usually sufficient to clean DiPel residues from the system. Optionally, a detergent solution can be used, followed by a clear water rinse.

For undiluted applications, (1) add a small quantity of an oil solvent (diesel, kerosene, crop oil) in a sufficient volume to dilute and remove undiluted DiPel residues from internal walls of the pump and transfer system. (2) Agitate and flush system. (3) Rinse equipment with clear water and drain. (4) Replace screens and nozzles if they were removed.

Use the above procedures for cleaning transfer pumps, lines, and meters.

3.5 Storage and Disposal

Oil-based formulations are more stable than aqueous formulations when stored for long periods of time. DiPel 8L properly stored, will remain stable for a minimum period of two years, as indicated by product stability testing at 77°F (25°C). DiPel is stable at low temperatures. Storage of DiPel below freezing temperatures has not resulted in any undesirable effects on the formulation or on product potency.

Do not store DiPel in the direct sun where product temperature will exceed 100° F (38°C) for prolonged periods of time. Within normal storage temperature ranges of 32° to 90°F (0°- 32°C), there will be no adverse effects on the mixing properties or potency of DiPel.

Re-close all unused containers. DiPel is an EPA Category III pesticide; refer to CAUTION statement on DiPel label for handling and storage.

4.0 HANDLING, MIXING AND LOADING

4.1 Basic Principles

All aqueous and oil-based Btk formulations are suspensions, not solutions. They consist of water (or oil in the case of DiPel 8L), plus Btk spores and crystals, fermentation solids, adjuvants, stabilizers and other minor inert ingredients. Therefore, some basic principles can be stated about how these liquids should be handled in order to avoid problems.

4.1.1 Variable Viscosity

Temperature affects the viscosity of the material. Typical temperature changes during the day will not be noticeable in spray system flow rates. However, wide temperature ranges such as could be experienced between the start and finish of a project may require the use of different calibration constants in flow meters.

4.1.2 Suspensions

The suspended solids are small particles; filters finer than 30 (i.e. 50 to 100) mesh may collect these particles and eventually become plugged.

4.1.3 Detergent Action

Foray and DiPel formulations act as mild detergents and may loosen up dried-on accumulations of foreign matter from previous spray operations on the walls of hoppers, lines, pumps, booms and nozzles.

4.1.4 Stickers

Aqueous formulations of Foray contain additives to enhance sticking. Therefore, regular rinsing, especially of system parts exposed to the air where drying can occur, should be performed before complete drying occurs.

The oil-based DiPel 8L formulation is less volatile than water; consequently, equipment can be left longer (up to half a day) without drying occurring under most conditions.

4.1.5 Aeration

Any heavy, viscous liquid can entrap air and hold it for some period of time. When recirculating or transferring these products, it is important to avoid the entrapment of air. Submerging both the inlet and the outlet of the hoses/tubes when recirculating these products will help prevent excessive aeration.

4.2 Equipment

4.2.1 Pumps

Pumps with a 3” (7.5 cm) suction inlet are recommended. They should be powerful enough to transfer a minimum of 100 gpm (400 L/min). If 2” (5 cm) suction pumps are used with bulk tankers, it is better to use a 3” suction hose from the tanker to the pump and then reduce from 3” to 2” at the pump. Always have back-up pumps available in case of pump failure.

4.2.2 Hoses

Maximum hose diameters should be used wherever possible to improve the rate of flow of product from tank to tank or aircraft. Suction hoses of less than 2” in diameter and loading hoses of less then 1” diameter should never be used. Hoses should be in good condition and suction hoses must be airtight and free of holes and leaks. All fittings on the suction side must be airtight. Use the shortest possible suction hoses. With centrifugal pumps it is much more efficient to extend the hose length required on the pressure (outlet) side of the pump than on the suction (inlet) side of the pump.

4.2.3 Screens/Filters in Transfer/Loading Systems

Screens and filters in transfer and loading systems are designed to prevent damage to pumps and meters and to prevent larger particles from entering the aircraft spray system. Screens of 20-30 mesh size will accomplish this objective. A 20 mesh screen will allow improved flow rates, and will not plug as easily. If no in-line screens are being used in the aircraft system, then 30 mesh screens should be used in the loading system. See Section 5 for a detailed discussion on spray system screens.

4.2.4 Flow-Meters

Meters are used to measure the liquid volume of product being handled. Meter accuracies will vary with the slippage of the liquid past the meter vanes, and by the amount of entrapped air in the product. Meters should be calibrated for (1) the product being pumped and (2) the system being used. If meters are calibrated with water, aqueous formulations produce meter readings which are typically 3-4% higher than the actual amount of non-aerated product delivered. For example, a meter calibrated with water reading 100 gallons (or liters) will have actually only delivered 96 or 97 gallons (or liters) of Foray. No standard conversion factor can be provided because of variables such as viscosity of product as it passes through the meter and the extent of aeration.

At the start of the season, the calibration of transfer pumps should be checked by pumping material into a previously calibrated container, such as an aircraft hopper, and comparing the pump flow meter readings to the actual volume transferred.

4.3 Spill Management and Disposal

4.3.1 Spill Management of Aqueous Flowable Formulations (Foray F/B)

Always assure adherence to federal, state/provincial and local regulations subsequent to disposal. Foray formulations are Category III pesticides and are not classified as hazardous materials and are not regulated under DOT (US Department of Transportation) hazardous material regulations (49 CFR 100-199). Foray degrades naturally in the environment and does not accumulate in the soil. Therefore, spills on soil surfaces may be handled as follows:

Hose the area down with ample water to disperse into the soil and/or grass. The dilution effect will facilitate the biodegradation of Btk. Cover the spill with a layer of soil to enhance degradation. (This would be the most likely option in remote forested areas).

If a spill occurs on an impervious surface such as concrete or asphalt, rinse the area with clean water if the runoff is directed to a soil/grass surface.

OR

Use an absorbent material such as cat litter or commercially available absorbents (e.g. SorbAll) to soak up the spills. The material may be spread over soil surface or taken to an approved landfill.

While Btk has shown no adverse effects to aquatic organisms, do not rinse spills directly into streams, lakes or rivers.

Foray is listed with the Chemtrec Spill Notification Network (800) 424-9300.

4.3.2 Spill Management of Oil formulations (DiPel 8L)

DiPel 8L is a Category III pesticide, is not classified as a hazardous material and is not regulated under DOT hazardous material regulations (49 CFR 100-199). DiPel degrades naturally in the environment and does not accumulate in the soil.

However, the oil carrier is a purified paraffinic oil with low volatility. Every effort should be made to clean up any spill, whether or not it occurs on a soil surface, using absorbent material such as cat litter or commercially available absorbents. The used material should be taken to an approved landfill. Assure adherence to federal, state/provincial and local regulations subsequent to disposal.

While Btk has shown no adverse effects to aquatic organisms, do not rinse spills directly into streams, lakes or rivers.

DiPel 8L is listed with the Chemtrec Spill Notification Network (800) 424-9300.

4.4 Disposal of Rinsate

Foray and DiPel must be disposed of in accordance with federal, state/provincial and local regulations. For product and container disposal procedures, see label directions.

Rinsates are best disposed of by adding them to the spray mixture during the operation and applying the material on the target area. Rinsate may be added to undiluted materials so long as it constitutes no more than 5% of the total volume at any time. Aqueous rinsate should NEVER be added to undiluted oil-based DiPel 8L formulations.

4.5 Product Container Size Availability & Handling Procedures

Foray and DiPel formulations are available in the U.S. in 55 gallon drums, 275 gallon mini bulk containers and in bulk quantities from 4,000 to 5,900 gallons shipped in tanker trucks. In the rest of the world (RoW) Foray and DiPel are available in 209L drums, 1,000L mini bulk containers, and in bulk quantities up to 25,000 liters in tanker trucks. Each form of packaging requires somewhat different handling procedures.

4.5.1 Drum Handling

(SEE APPENDIX III for drum photo and dimensions.)

Delivery: Drums are normally delivered by truck on pallets (4 drums/pallet). If no fork-lift is available, drums may be rolled off the truck tailgate onto 2 or 3 old tires (without rims) stacked where the drum impacts the ground behind the tailgate.

Storage: Store drums upright in a dry location. Storage temperatures should be between 32° and 90°F (0° and 32°C). Keep out of direct sunlight at higher temperatures. During shipping and storage, some normal settling of the formulation will occur. To re-suspend, roll or shake drums prior to dispensing.

Loading: The drums may be configured with two 2" NPT threaded openings (North America) or a combination of a 2" NPT and a 5 cm metric threaded opening. Product can be dispensed either by pouring or use of a transfer pump having a minimum flow capacity of 100 gal/min (400 L/min), e.g. 5 HP gasoline engine - centrifugal pump with a standpipe (at least 42" [110 cm] in length, not more than 2" [5cm] in diameter) and non-collapsible hose. All pump and transfer lines should be flushed with plenty of clear water prior to pumping Foray and DiPel.

Diluted or undiluted Foray and DiPel left in the lines and pumps will not cause damage or plugging.

PILOT TIP: If a meter is unavailable and a partial drum quantity is required, a measuring stick may be used to determine the volume.

The liquid height in a standard drum containing 55 gals is approximately 33”. Therefore, 1” is equivalent to 1.67 US gals; in metric terms, 1.0 cm on the dipstick is approximately equivalent to 2.5L.

4.5.2 Mini Bulk Handling

(SEE APPENDIX III for photo and dimensions)

Storage: Store in a dry, preferably enclosed, location. The contents should be recirculated prior to use.

Handling: Mini-bulk containers (when full) weigh around 1 ton (1000 kg), and require a forklift to handle. The mini-bulk containers are mounted on a 4-way pallet. Do not stack more than 2 high. When empty, the containers can be handled manually (empty weight = 175 lbs or 80 kg).

Loading: There is a 5 cm male metric threaded outlet at the base of the container which is fitted with a valve. Each container is provided with a 5 cm male metric to 2” female NPT adapter. The top of the container has a large 8” (20 cm) opening, fitted with a screw-on lid, through which a 42” (110cm) standpipe may be inserted.

The transfer pump should be equipped with a 2” non-collapsible suction line and a 5 hp (minimum) motor capable of pumping 100 gpm (400 L/min).

Prior to use, the contents should be recirculated once by pumping the product from the outlet valve back through the top opening. The hose end should be submerged below the surface of the product. The lid to this opening must always be open or removed when unloading product to facilitate flow and prevent the collapse of the container. Replace the lid once the unloading operation is complete to prevent airborne contamination by dust, debris, rainfall or other moisture.

4.5.3 Bulk (Tanker) Handling

(SEE APPENDIX III for photo and dimensions)

Delivery: Bulk shipments are made in standard U.S./Canadian tank trucks. They may be off-loaded into the customer’s bulk facility or “spotted” / “dropped” for direct use by the customer. If the entire contents are off-loaded, no recirculation of the contents is required. Standard tank trucks are equipped with 3” male camlock outlet fittings.

Most bulk tankers are equipped with 2 valves to avoid accidental discharge. Both valves (internal and external) must be open to allow discharge of contents. External valve controls should be secured during non-use periods to prohibit unauthorized operation.

The product should be recirculated at least once prior to use if it has been sitting for 2 days or more. During recirculation the return hose should be submerged under the product surface to avoid entrapment of air and foaming of the product.

Loading: Off-loading and/or recirculating equipment recommended for bulk tankers include a 3” (7.5 cm) non-collapsible suction, 3” hose, transfer pump capable of pumping 250 gpm (1,000 L/min) and one or two 2” (5 cm) loading hoses of sufficient length to reach the top manhole and/or one or more aircraft for direct loading. If 2” suction pumps are used with bulk tankers, it is better to use a 3” suction hose from the tanker to the pump and then reduce from 3” to 2” at the pump. A 2” loading hose will provide a significantly slower flow rate than a 3”. (In the latter case a 3” to 2” camlock reducer will be required to connect the 3” suction to the 2” pump.) Always have back-up pumps available in case of pump failure.

The contents of the tanker should be completely recirculated once before partial unloading or usage. This can be done by pumping the product from the outlet valve through the open manhole. The hose end at the manhole should be submerged below the surface of the product. Precautions should be taken to prevent the hose end from coming out of the manhole and causing a spill or injury; usually the hose is tied into place at the manhole.

The lid of the tanker manhole must always be open when pumping to prevent the collapse of the tanker walls. The lid should be vented prior to opening the tanker to release any pressure that has built up. If the tanker has not been completely emptied, be sure to close the lid in order to prevent rain from contaminating undiluted product.

If the tanker is being dropped, it must be placed on solid ground with the front support dollies on solid planks or timbers (4-6” thick). The ground should be solid and level (or slightly inclined towards outlet) and the trailer wheels should be locked and chocked.

If the tanker unloads from the tail, the rear of the tanker should be lower than the front. If it unloads from the center, it should be level. If loading into a compartmentalized tanker that has been spotted on its dolly legs, load into the middle compartment first, the wheel end, and then the dolly end. Reverse the procedure when unloading from a compartmentalized tanker. No specific unloading procedure is necessary for compartmentalized tankers that are connected to a tractor. Whether unloading a tanker into another tanker or holding tank, the storage tanker or tank must be flushed and cleaned with clear water and completely drained prior to transferring undiluted product.

Aqueous formulations: When the container is almost empty (less than 200 gallons), rinse down the sides of the container with small amounts of water. This will assure that all delivered product is removed as the water will reduce the viscosity of the remaining contents which will then flow readily from the tanker. Small amounts (up to 5% by volume) of water in the undiluted product will not adversely affect the handling or efficacy of the product.

Oil based formulations: When the tanker is almost empty (less than 200 gal - 800L), rinse the sides with a small quantity of oil diluent (diesel, kerosene, crop oil) to ensure that most of the Btk is removed from the tanker. The small amount of diluent will not adversely affect any calibration rates. If preferred, this rinsate can be saved and dropped off with the rest of the rinsate from the aircraft and loading equipment.

4.6 Recirculation Protocol for Foray and DiPel Formulations

Undiluted oil and aqueous formulations of DiPel and Foray are stable suspensions. There is no need to recirculate the contents except prior to their use.

5.0 AIRCRAFT OPERATIONS WITH FORAY & DIPEL PRODUCTS

5.1 Aircraft Calibration

Proper calibration and spray atomization are paramount to achieving optimal efficacy. Several methods exist for calibrating flow rates, based on the kind of equipment that is fitted to the aircraft. In all cases, some basic calculations first have to be performed to establish the flow rate required by the spray system, and the flow rate through each atomizer or nozzle.

1) Determine the spray system flow rate

The formula for determining the *system flow rates* for US units and metric units are:

US Units

$$\text{Flow rate (gal/min)} = \frac{\text{Airspeed (MPH)} \times \text{Swath (ft)} \times \text{Application Rate (gal/acre)}}{495}$$

Metric Units

$$\text{Flow rate (l/min)} = \frac{\text{Airspeed (km/h)} \times \text{Swath (m)} \times \text{Application Rate (L/Ha)}}{600}$$

2) Choose the atomizer type and number

The droplet spectrum you require will determine the type of atomizer or hydraulic nozzle that you will use. Using nozzle or atomizer flow charts supplied by the manufacturer, determine the most accurate combination of number, pressure and flow setting (or nozzle orifice size) to deliver the desired flow per minute through each atomizer/nozzle.

Hydraulic nozzles have a narrow pressure (and flow rate) range for any particular droplet size. Rotary atomizers can be adjusted for different droplet sizes independent of their flow rates.

To obtain the *flow rate per atomizer* for either US or metric units, just divide the flow rate by the number of atomizers that will be fitted to the aircraft.

$$\text{Flow/Atomizer/Minute} = \frac{\text{System Flow Rate}}{\text{No. of atomizers}}$$

Example: (US units) If airspeed is 110 mph, and the expected swath width is 200 feet, what is the calibrated flow rate through each rotary atomizer if 6 Micronair AU5000 units will be used and the applied volume is 64 fluid oz/acre? (Don't forget to convert ounces to gallons!)

$$\text{Flow rate (gal/min)} = \frac{\text{Airspeed (110)} \times \text{Swath (200)} \times \text{Application Rate (0.5)}}{495}$$

$$= 22.2 \text{ gal/min}$$

$$\text{Gal/Min/Atomizer} = \frac{22.2}{6} = 3.7$$

The next step in the calibration process will depend upon the type of equipment fitted in the aircraft. If the spray system is powered by an engine driven pump (hydraulic or electric), and rotary atomizers are fitted, the aircraft can be statically calibrated on the ground, by catching and measuring the output of the atomizers. If there are many nozzles, or if the system pump is wind-driven, then ground calibration becomes impractical, and an airborne method is required.

Most aircraft are equipped with flow meters which are used to accurately calibrate the system and monitor flow rate during operations. At the start of a project, it may be a good idea to monitor the flow meter carefully to insure that the "displayed" totals match the actual "spray total" volumes. Although it is not necessary to calibrate such-equipped aircraft on the ground, if there are any doubts about the accuracy of the meters, such a calibration can be performed as a cross-check.

It is always essential to monitor the calibration during operational spraying, by comparing volume of product applied with the spray area treated.

5.1.1 Ground Calibration for Aircraft With Hydraulic or Electrical Pumps

1) Load sufficient product into the aircraft hopper to prime the entire spray system, and allow enough product for the required number of tests.

2) Place collectors under each atomizer/nozzle and operate spray system for one or more minutes, so that a measurable volume is produced. Measure volume output per minute from each atomizer/nozzle and compare to calculated rate. Check total output.

3) Adjust system pressure and/or atomizer setting, or change nozzle orifice size, to raise or lower output as needed. Re-test system as per step 2.

5.1.2 Airborne Calibration for Aircraft With Wind Driven Pumps

Note: It is often possible to get sufficient wind pump pressure by applying power while stationary. Consult the pilot for the standard operating procedure. In such case follow the calibration procedure in 5.1

1) Load product into the hopper as described in step 1 above, with the exception that the system must be primed in flight.

2) After the system is primed, position aircraft on a level surface and mark the spot. Add a measured volume of product to the spray tank and note the level either through the sight window or by measuring the distance from the top or bottom of the tank to the fluid surface of the product with a measuring stick.

3) Fly the aircraft as in a normal application and operate the spray system for a set amount of time, e.g., 1 minute, using a stopwatch.

4) Return aircraft to the exact spot on the ground as marked in step 3 above, and measure the volume of product needed to refill to the original level. This volume can then be used to calculate output per minute.

5) Make adjustments to the spray system, if necessary, to change output.

6) Alternatively, a known quantity of spray mix can be pumped into the aircraft which has had its spray system primed. Ground equipment, fitted with a previously calibrated and correct flowmeter, may be used for loading. Alternatively, the hopper site gauge may be used if the aircraft is parked on level ground.

The time taken to pump the measured volume is recorded with a stop watch, and the spray system settings adjusted accordingly and re-tested as necessary.

5.1.3 Aircraft with Electronic Flow Meters

Electronic flow monitors such as those manufactured by Onboard Systems (Crophawk) and Micronair greatly facilitate aircraft calibration and enable in-flight adjustments if conditions demand it. However, flow monitors and application computers should be calibrated with the product or spray mixture prior to operational use. Refer to equipment manufacturers' directions for volumetrically calibrating flow meters with fluids other than water.

Also, flow monitors that have interchangeable cartridges of different flow range sensitivities should have the correct cartridge or flow turbine installed. For example, for general ULV use, the Onboard Systems "Crophawk Series 4100" uses cartridge #2, which has a listed range of accuracy between 1.5 and 30 gal/min (5 - 100 L/min). Consult the appropriate manufacturers' directions for other flow monitors.

Additionally, some DGPS suppliers now offer a flow monitoring system interlinked with the DGPS system. Please consult with the technical representatives of DGPS manufacturers for more details. (See Appendix II: Sources & Resources.)

General Calibration Procedure

All Foray and DiPel formulations have been optimized so that their viscosity is as low as possible. Please note that the viscosity of current formulations is considerably lower than earlier Btk formulations.

1) Assume that the Foray and DiPel formulation of choice will behave like water, and use the appropriate calibration factor in the flow meter.

2) Add a known quantity of the spray material to the aircraft hopper. Ground equipment, fitted with a previously calibrated and correct flowmeter, may be used for loading. Alternatively, the hopper site gauge may be used if the aircraft is parked on level ground.

You may want to spray this first load as part of the operation, if you are confident that the application rate will be within +/-10 percent of the target rate.

3) Make an adjustment to your flow meter calibration constant if the total volume sprayed (as indicated by your flow meter) is different from the amount that was pumped into the hopper. Typically this adjustment is:

$$\text{New Calib. Constant} = \text{Old Calib. Constant} \times \frac{\text{Volume Applied}}{\text{Volume Indicated}}$$

Pilot Tip: Use the aircraft flow meter as your primary instrument for monitoring flow rate.

With the new calibration constant, adjust the pressure of the spray system until the desired flow rate appears. This step may have to be repeated once or twice to determine the correct flow rate constant.

5.2 Spray System Filters/Screens

Filters in aircraft spray systems are designed and installed to prohibit foreign particles which could block vital components from entering the system. Except for in-line screens, the smallest orifices are found in the nozzles fitted to the aircraft. Mesh size is defined by the number of openings there are per inch (e.g. a 30 mesh screen has 30 openings per linear inch of screen). But because of the thickness of the wire, the size of the orifice is not the inverse of the mesh size in inches.

The most common screen size found in aircraft in-line screens is 50 mesh (holes in 50 mesh screens are 0.011" across). Although undiluted Foray/DiPel will pass through a 50 mesh screen, the product solids will eventually build up the screen. When foreign matter is additionally collected on the screens, the buildup will occur more rapidly and will cause plugging of the screen. The same principle applies to 50 mesh nozzle screens. The pore sizes of various screen meshes, slotted strainer slots and nozzle openings are shown below in Figures 5.2 (a) and (b), in order of size increments.

It is clear from an evaluation of the sizes of various screen and nozzle openings shown above that the most commonly used nozzle openings (D-3, 8003 and VRU # 3

Figure 5.2(a): Filter and screen mesh sizes, in order of size (US

In-Line Screens	Nozzle Screens	Nozzle* Slotted Strainers	Hollow Cone	Nozzles Flat Fan 80 Series	Micronair VRU
50 mesh = 0.011”	50= 0.011”	50 = 0.010”			
30 mesh = 0.021”		25 = 0.020”			
	24 = 0.030”	16 = 0.032”		02 = 0.036”	1 = 0.030”
16 mesh = 0.045”			D2 = 0.041”	03 = 0.043”	3 = 0.046”
			D3 = 0.047”		
				04 = 0.052”	
				05 = 0.057”	
			D4 = .0631”	06 = 0.063”	5 = 0.063”
			D5 = .078”		
					7 = 0.094”

LARGER SIZES ↓

Slotted strainers are recommended (required) for suspended solids where nozzle straining is required.

Figure 5.2(b): Filter and screen mesh sizes, in order of size (metric

In-Line Screens	Nozzle Screens	Nozzle* Slotted Strainers	Hollow Cone	Nozzles Flat Fan 80 Series	Micronair VRU
50 mesh = 0.28mm	50 = 0.28mm	50 = 0.25mm			
30 mesh = 0.53mm		25 = 0.51mm			
	24 = 0.76mm	16 = 0.81mm		02 = 0.91mm	1 = 0.76mm
16 mesh = 1.14mm			D2 = 1.04mm	03 = 1.09mm	3 = 1.17mm
			D3 = 1.19mm		
				04 = 1.32mm	
				05 = 1.45mm	
			D4 = 1.60mm	06 = 1.60mm	5 = 1.60mm
			D5 = 1.98mm		
					7 = 2.39mm

LARGER SIZES ↓

Slotted strainers are recommended (required) for suspended solids where nozzle straining is required.

or 5) are significantly larger than a 30 mesh in-line screen pore size.

Therefore the use of a 30 mesh in-line screen or a 25 mesh slotted strainer installed in the nozzle body will enable the free flow of material to the atomizer orifices.

The minimum pore size recommended is 0.02” or 0.50 mm in cross section. No strainer or screen is necessary at the nozzle when using rotary atomizers.

5.3 Droplet Spectrum Size, Atomizer Selection & Spray Atomization

The manner in which the Btk insecticide is atomized can markedly influence the effectiveness with which it controls the target insect. The impingement of droplets in a forest canopy, their distribution on foliage, and the likelihood of the target insect obtaining a lethal dose are all strongly determined by the droplet size.

Not surprisingly, because of differing foliage shapes and densities, broad-leaf forests have slightly different droplet size parameters than coniferous forests. Additionally, target species can affect droplet size selection. Thus a free-roaming insect like the gypsy moth may require a different droplet spectrum than sequestered insects like the spruce budworm.

The choice of atomizer will be largely determined by the required droplet spectrum. At air speeds below 120 mph (190 km/h), rotary atomizers such as the Micronair can deliver smaller droplets than conventional hydraulic nozzles. Their great advantage is the ability to alter droplet size independently of aircraft boom pressure or airspeed, and to do this as spray conditions change.

At higher airspeeds, small drop diameter ranges are possible with standard hydraulic nozzles through the action of high pressure and wind shear. Such airspeeds are typically obtained with single engine turbine agricultural airplanes and multi-engine converted passenger/transport airplanes. Use of hydraulic nozzles (e.g. Teejet flat fan or hollow cone) is not recommended for application of undiluted Foray and DiPel at air speeds of less than 100 mph (160 km/h).

One factor which should be considered when selecting an atomizer is the range of meteorological conditions you will be encountering during the spray project. For example, as conditions become hotter and drier during the day, rotary atomizers can be adjusted to produce bigger droplets, which evaporate less quickly than smaller droplets, and are more likely to reach their desired target.

5.4 Droplet Size Considerations

Any particular droplet can produce eight droplets of half its diameter. For example, a 200 µm droplet will produce eight 100 µm droplets, which in turn produce eight 50 µm droplets. Thus the original 200 µm droplet can produce sixty-four 50 µm droplets. It can be seen that given the same volume of spray material, when effectively distributed throughout the forest canopy, numerous small droplets would increase the likelihood of encounter by a larva than a single large droplet.

However, there are physical and biological limits to the useful size of the droplets. Does the droplet contain a lethal dose? Will it survive the evaporation stresses during descent? Will it drift off-target?

The next two sub-sections deal in general with droplet sizes in needle and broad leaf forests. The recommendations provided are based on the two most researched insects in the respective forest types, the Eastern Spruce Budworm (*Choristoneura fumiferana*) and the Gypsy Moth (*Lymantria dispar*). However, many defoliators show similar susceptibility ranges, and foliage deposition considerations remain the same for the forest types. Consequently, many of the broad recommendations are directly applicable to other species of defoliators such as the Pine Processionary moth (*Thaumetopoea pityocumpa)* or the Nun moth (*Lymantria monacha)* in Europe.

5.4.1 Optimum Droplet Sizes in Needle Coniferous Forests

Some Eastern Spruce Budworm control programs are technically advised to maximize the number of small droplets produced by the atomizers to ensure effective distribution throughout the targeted forest canopy. In contrast, other program managers prefer to set up aircraft atomizers to produce fewer, larger droplets which maximize the toxic dose when ingested by larvae. The concern is that the dose contained in a very small droplet (<75 µm diameter) will be sub-lethal, and will inhibit feeding of the larvae for a time, thus preventing them from acquiring a lethal dose.

Field studies with the Eastern Spruce Budworm to date (spring 1997) have not conclusively demonstrated a clear advantage of larger droplets but they indicate that some degree of latitude exists regarding droplet size. Droplet sizes in the range of DV0.5 of 110-160 µm, DN0.5 40-80 µm, obtained with Micronair AU4000 atomizers set to turn at 4,500 rpm gave comparable biological results when compared with AU4000s spinning at 9,900 rpm producing a spectrum with a DV0.5 of 60-80 µm, DN0.5 of 25-30 µm.*

DV0.5 and DN0.5 (Volume median diameter and number median diameter also abbreviated as VMD and NMD) represent median droplet sizes which divide the volume of the spray droplet spectrum and the number of spray droplets into two parts containing the same volume of droplets and the same number of droplets respectively. DV0.5 is the most common term used when people describe a spray with one droplet size.

We recommend that the extremely low size regime be avoided, and that AU5000 atomizer speeds of 6,000 rpm and AU4000 speeds of 5,000 rpm, producing droplets with DV0.5 of around 80-120 µm, should be the goal for coniferous forest defoliators.

**K. van Frankenhuyzen and others. "Effect of droplet size spectrum and application rate on field efficacy of* Bacillus thuringiensis*" 1996 Spray Efficacy Research Group publication.*

5.4.2 Optimum Droplet Sizes in Broad Leaf Forests

As in coniferous forests, there are advantages and disadvantages to finely atomizing an application of Btk. Although small droplets give a good distribution in the forest canopy, this has to be balanced by the possibility of larvae obtaining sub-lethal doses from small droplets. Such doses may protect the larvae by inhibiting feeding and preventing them from ingesting further Btk deposits for a few days until recovery. Studies show that the size of the droplet required for effective mortality of gypsy moth larvae increases with larval instar, so that although droplets in the 100 µm DV 0.5 range are optimally effective against second instars, their size should be increased to 200 µm DV 0.5 range if the population is in the third and fourth instar stage. Droplets larger than 200 µm should not be applied because the resulting low droplet densities reduce the chance of effective dose acquisition by larvae.

Field studies on gypsy moth performed by the NEFAAT (Northeast Forest Aerial Application Technology) Group in the early 1990's with undiluted Foray 48B sprayed with different atomizers showed that a range of droplet sizes will provide a similar level of control on second and third instar larval populations. Small orifice hydraulic nozzles (Flat Fan 8004 and 8004 Twin-jets), as well as Micronair rotary atomizers, all produced droplets in size classes shown to be effective.

We recommend that for the control of gypsy moth and other broad leaf defoliators, the atomizers which deliver droplets in the 120-170 µm DV 0.5 range should be selected and adjusted. Micronair AU5000 atomizers should therefore be set to rotate at approximately 5,000 rpm. Use the smallest orifice flat fan nozzles which can deliver a sufficient volume with medium-speed agricultural aircraft (100-120 mph). We recommend the use of rotary atomizers, especially in slower aircraft, as the shear atomization which aids the production of small droplets by hydraulic nozzles is not adequate at low airspeeds.

If you are operating at the flow capacity limits of your nozzles/atomizers, it would be wise to modify the numbers and/or types of atomizers fitted to your aircraft. For example, if you are having to increase the VRU setting of the Micronairs to their highest setting, consider adding more atomizers. If you are working considerably below 40 psi (275 kPa) for hydraulic nozzles and cannot reduce their number, consider changing the orifice size, so that the adequate atomization, which is obtained at higher boom pressure, is assured.

The following measures will serve to decrease droplet size:

Hydraulic nozzles: Smaller orifice size, increase boom pressure, orientation to 45° forward.

Wind-driven rotary atomizers: Increase unit rpm - decrease blade angle; in slow helicopters use a longer blade.

Electrically or hydraulically powered rotary atomizers: increase rpm or change sleeve size.

5.5 Undiluted and Diluted Applications

Foray and DiPel may be applied as undiluted or diluted sprays to control gypsy moth larvae. In field and operational trials against gypsy moth, applications of undiluted product have been proven to give results equal to higher volume diluted sprays, ,provided the product is properly applied.

Traditionally, Btk formulations were diluted with water to provide a spray volume in the range of 96-128 oz/ac (3.5-4.7 l/ha). Currently, significant improvements in the non-evaporative properties of Btk formulations and application technology have meant that diluted Btk applications provide no significant advantages over undiluted ones.

The effectiveness of undiluted ULV applications of Foray and DiPel on other lepidopteran pests such as elm spanworm, cankerworms, and other native species has also been successfully demonstrated.

Program managers should consider maximizing the use of undiluted Foray and DiPel applications as comparable results can be achieved with diluted applications. Undiluted applications also provide significant improvements in aircraft payload efficiency and help to reduce application costs.

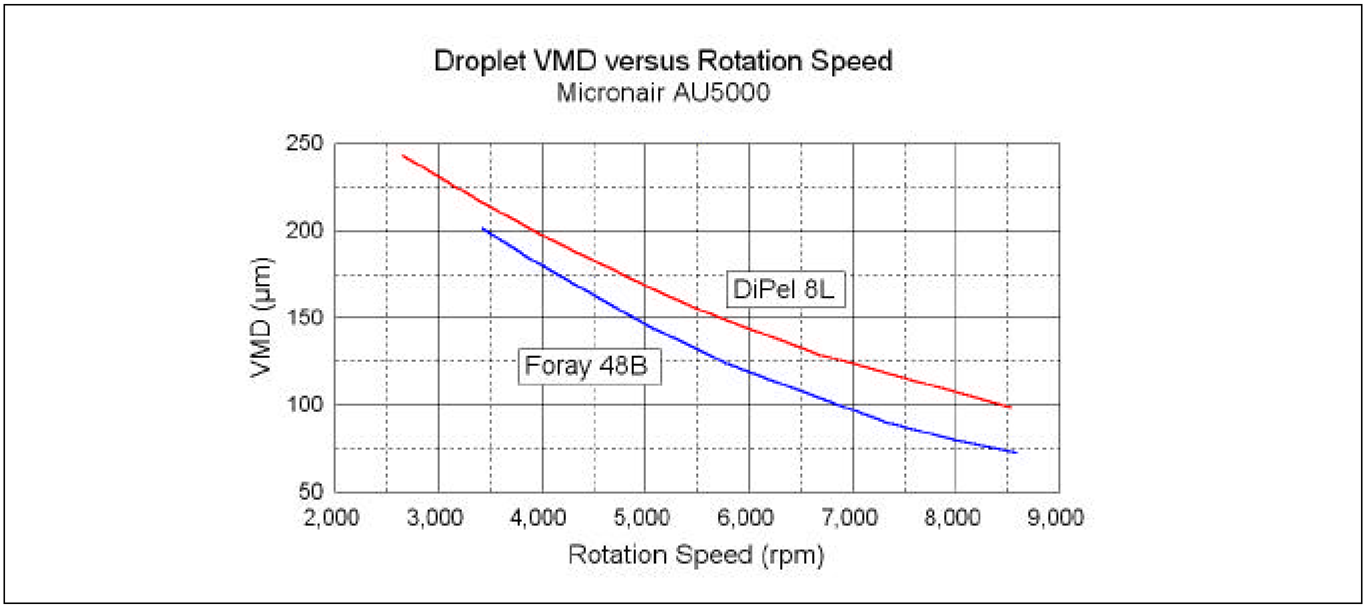
5.5.1 Micronair AU5000 Droplet Size Parameter Selection

Figure 5.5 shows wind tunnel data for droplet sizes (DV 0.5) for undiluted Foray 48B and DiPel 8L formulations applied using a Micronair AU5000 atomizer. The charts and figures provided in the Micronair AU5000 operator's handbook are based upon the atomization of water, and they encompass all possible applications in agriculture, vector and forestry spraying.

5.6 Lane Separations

Lane separation (or the effective swath width) is the offset distance between parallel tracks flown by a spray aircraft. It represents the span under the aircraft and parallel to the flight path which receives an effective deposit of the pesticide. When accurately flown under most weather conditions, there will be no significant over or under-application if this lane separation spacing is maintained. Note though that the effective swath is not the total swath; rather it is

Figure 5.5.1 Droplet Sizes (DV 0.5) obtained at different Micronair AU5000 rotation speeds



that cross section portion of the spray deposited that is considered as adequate to provide a lethal dose to the larvae and to ensure uniform and homogenous coverage of the forest canopy.

Btk has to be ingested by the larvae to be efficacious so an accurate application is essential to ensure that an adequate dose is deposited across the forest canopy to ensure larval mortality.

The lane separation of aircraft varies depending upon the aircraft/spray system parameters (release height, atomizer setting, aircraft speed), the pesticide formulation, as well as factors such as meteorology and forest canopy architecture.

Pattern testing of aircraft over flat ground as well as in forests has shown that droplet size is one of the major factors which can affect the lane separation distance. Smaller droplets are affected more by the aircraft wake and can travel greater distances. Wind direction has little effect on increasing the effective swath width. Although fine droplets may drift long distances, they do not form part of the effective swath as there is very little biological activity in this portion of the droplet spectrum. For convenience, lane separation determinations are normally performed by flying the aircraft into wind, so that the lateral drift of deposit is a function of the aircraft's wake, rather than wind-borne distribution.

The technique most used to measure the swath width is to assess deposit of dyed droplets on collectors, usually flat cards. White coated card stock (commercially known as Kromekote) has been the most popular collector. Historically, a droplet density of between 5 and 20 spots per square centimeter (range dependent on product potency) has been commonly held as an effective deposit for Btk products for field use. This standard is rarely used now as the number of fine droplets which are caught by flat cards is greatly influenced by the wind speed, and can give skewed readings under still conditions. With the increased use of image analysis pattern testing, it is more common to measure swath patterns in application rate units of gal/ac or L/ha.

Although measuring spray deposit on the target foliage would provide a more meaningful representation of swath width, this requires more sophisticated measurement techniques and is generally not practical for most operational programs.

Figure 5.6 presents various swath width ranges for a variety of aircraft and atomizers that have been used effectively in forestry programs with Btk formulations. USDA APHIS produced some guidelines in the 1980s, but most states have found these figures somewhat too conservative and have established their own lane separation guidelines, usually based on pattern testing of the aircraft. Increasingly, many states in the US require the use of rotary atomizers for forestry work, but some allow hydraulic nozzles, although typically a shorter lane separation is then assigned. The USDA Forest Service and several states and provinces which have performed extensive swath pattern testing using Swath Kit spray pattern analysis equipment provided the single-engine aircraft data. Multi-engine aircraft data were provided by

Figure 5.6: Suggested ranges of lane separations for Btk applications.

Aircraft	Lane Separation Range ft	m
Single Engine Fixed Wing Aircraft		
Piper Pawnee	65 - 100	20 - 30
Piper Brave	75	23
Cessna Ag Truck, Ag Wagon, Ag Husky	75 - 100	23 - 30
Ag Cat Model B	100 - 130	30 - 40
Antonov An-2	130 - 165	40- 50
Ayres Thrush SR2 - Turbine	150	45
Ayres Thrush SR2 - Piston	150	45
PZL M-18 Dromader	150 - 175	45 - 53
Air Tractor 400 Piston	150	45
Air Tractor 502 Turbine	175	53
Air Tractor 802 Turbine	200	60

Aircraft	Lane Separation Range ft	m
Multi Engine Fixed Wing Aircraft		
DC-3	225	75
DC-4, DC-6, DC-7	400	120
C-130	400	120
Beech 18	150	45
Helicopters		
Bell 47G	75	23
Hiller 12E	75	23
Hughes/MD 500	75 - 90	23 - 27
Kamov Ka-26	80 - 90	24 - 27
Bell 47G Soloy	100	30
Hiller 12E Soloy	100	30
Bell 206 Jetranger, Long Ranger	100 - 120	30 - 36
Mil Mi-2	98 - 131	30 - 40
Bell 204/205/212/412/UH-1	150	45

the Forest Service and the US Air Force, also based on studies with the Swath Kit™.

Where a range of lane separations is shown in the table, the greater figure was obtained with aircraft equipped with Micronair rotary atomizers.

5.7 Aircraft Guidance

Over the last decade, traditional aircraft navigation techniques (balloons, spotter aircraft etc.) have given way to the advent of satellite-based technology. Commonly referred to as GPS (Global Positioning System), the location of any feature, natural or man-made, can be confirmed through the use of intersecting signals from a series of orbiting satellites. Not only can locations be identified on the earth's surface, (by latitude and longitude), but aircraft may use the satellite transmissions to plan and follow a specific flight path above the earth's surface. Although accurate for waypoint navigation, the GPS system doesn't offer the accuracies required for proper spray aircraft guidance. An extra signal, called differential correction is required to achieve such precision. When the satellite signals are differentially corrected (DGPS), an aerial application aircraft can follow a swath width (lane interval) to accuracies within two meters.

DGPS systems calculate the aircraft's position (latitude, longitude and elevation) several times per second and use these calculations to provide the aerial applicator with a very accurate and sophisticated guidance system.

DGPS navigation has proven itself in the forest protection industry. Ground-based survey and assessment crews now use inexpensive portable "hand-held" GPS systems to establish treatment boundaries or to locate assessment plots in the forest; 'No Spray' zones are also easily marked.

Aerial applicators, using the same basic technology as the portable hand-held units, rely upon sophisticated instrumentation and cockpit displays to guide their aircraft across the sprayblock. Guidance lights, and small computer style screens provide continuous navigational assistance to the pilots by marking every swath and displaying the position of the aircraft in or near the treatment area. The most recent development in this technology is the interlinking of the aircraft's spray system (flow control) to the DGPS, ensuring that an accurate application rate is maintained across the spray block regardless of the aircraft's groundspeed.

The proven accuracy of DGPS technology has resulted in the rapid adoption of DGPS navigation by program managers and applicators alike. For example, in the USA, all forest protection contracts funded by the US government require the use of DGPS equipment that has USDA Forest Service approval. For the latest specifications, Ccontact the Missoula Technology Development Center of the USDA Forest Service. As the DGPS software is continously upgraded, the USFS maintains a set of technical specifications describing the features required for forestry spraying.

A list of DGPS manufacturers is included in Appendix II: Sources & Resources

5.7.1 Spray Pattern Modeling

In the 1980s and 90s the USDA Forest Service invested a considerable amount of resources in creating a computer program which could accurately predict aircraft spray patterns and deposition within a forest canopy when given inputs on the aircraft, atomizers, spray mixture properties, weather details and spray canopy structure.

The program which emerged from those efforts exists either as AGDISP, which models the 'near wake' deposit (the spray pattern close to the aircraft) but does not model drift or canopy deposition, or FSCBG, which adds a Gaussian plume model to AGDISP to simulate the latter effects.

A third derivative of AGDISP is Ag-Drift, which was created by the Spray Drift Task Force to model drift away from the site of application.

At time of writing (Summer 1997) the Forest Service announced intentions to make the models available on the Internet. Please contact Dr. Harold Thistle (406-329-3981) at the Forest Service's Missoula Technology Development Center for more information. The Spray Drift Task Force also announced that their Ag-Drift program will be made available to the public.

All three programs require some instruction before they can be used to model aerial spraying situations. Although they can be made to run with minimum effort, the maxim that a little knowledge is a dangerous thing should be taken to heart when running these powerful programs for the first time.

5.8 Swath Pattern Analysis

In many forestry projects, it is common practice to examine the spray pattern of contracted spray aircraft before spraying, to ensure that the aircraft has been optimally configured to apply the spray.

Figure 5.8.3: Dye tracers for use with Kromekote Cards

Formulation/Dilution	Dye	Concentration (% w/w)	Manufacturer[1]
Dye Tracers for coated (Kromekote) cards			
L formulations (undiluted)	Base Oil Red	0.4%	Becker-Underwood
L formulations (diluted) & AF formulations (diluted & undiluted)	Black Shade[2] FD&C Blue 1, Rhodamine WT Erio Acid Red	0.1 - 0.5% 0.1 - 0.5% 0.5% 0.3 - 0.5%	Warner-Jenkinson Warner-Jenkinson Various Various
Dye Tracers for Foliage and UV light studies			
L formulations (diluted) & AF formulations (diluted & undiluted)	CSF	0.5%	Carolina Color & Chemical Co.

1 See Appendix II
2 Recommended: Black Shade is a mixture of FD&C Blue, Red and Yellow

Although established methods using microscopes to analyze cards exist, the 1990s have seen the development of rapid and powerful methods of measuring the deposition obtained on a line of cards laid out on the ground perpendicular to aircraft flight.

The Swath Kit™ was developed for the USDA Forest Service and is in wide use by state and provincial forestry bureaus conducting forestry projects in the northeastern US and Canada. Information on the Swath Kit can be obtained from Droplet Technologies, Inc. (see Appendix II: Sources & Resources).

Another method uses a suspended string to capture droplets for deposit analysis, but is mainly used in agricultural projects by state aerial applicator associations in the US.

Figure 5.9.1 Weather-affected spray plume movement characteristics under a range of meterological conditions found throughout a typical spray day.

Stable Atmosphere (early morning)	
Low Wind	Low wake translation. Maximum vortex lifetime to carry material into canopy. High canopy top deposition. Warning: Highest chance of long range drift impact due to high concentrations of material downwind.
Transition Period - Growing Boundary Layer (mid-morning) & cloudy days. Neutral Stability	
Low Wind	Low wake translation, good penetration into the canopy. Little drift.
High Wind	High wake translation. Good penetration and coverage of canopy. High potential for wide spread drift, but downwind concentrations of material are low.
Boundary Layer Fully Developed (sunny: late morning and afternoon). Instability	
Moderate Winds	Some wake translation. Moderate drift will occur with much drifting material dispersing upwards in the air out of the surface layer.
Low winds	Low wake translation. High drift potential due to free convection. Alternating penetration/drift. Highly variable coverage of target forest.

It is recommended that you contact your local USDA Forest Service, state forestry bureau or state agricultural aviation association representatives for further information.

5.8.1 Droplet Spread Factors

Image analysis of spray deposits uses a spread factor to convert droplet stain sizes obtained on target cards to diameters of droplets which created the stains. The spread factor is a ratio of droplet diameter to stain diameter. Thus a 100 µm droplet giving a stain diameter of 200 µm is said to have a spread factor of 0.5. Multiply the stain by the spread factor to come up with droplet size. Some references use the inverse of 0.5 (2.0) to refer to the spread factor. If the spread factor is greater than 1.0, the inverse notation is used. In making quick and simple assessments in the field, a spread factor of 0.5 (2.0) may be used for diluted and undiluted Btk sprays.

5.8.2 Oil and Aqueous Flowable Formulations

The spread factor on Kromekote cards varies greatly according to the formulation. It is also affected by droplet size, and to a lesser extent by temperature and relative humidity. Oil formulations will spread rapidly into the card, leaving a central dyed deposit and an oily ring which increases in diameter up to several hours after spray. Although the cards can be read at different times after spraying the oil formulation, it is important that all runs be read at the same time after spray so that they can be directly comparable. Diluted oil formulations do not show the 'oily ring' effect.

Deposits of undiluted aqueous formulations and water dilutions for both aqueous and oil-based formulations dry shortly after impact on the cards and remain stable.

5.8.3 Tracer Dyes

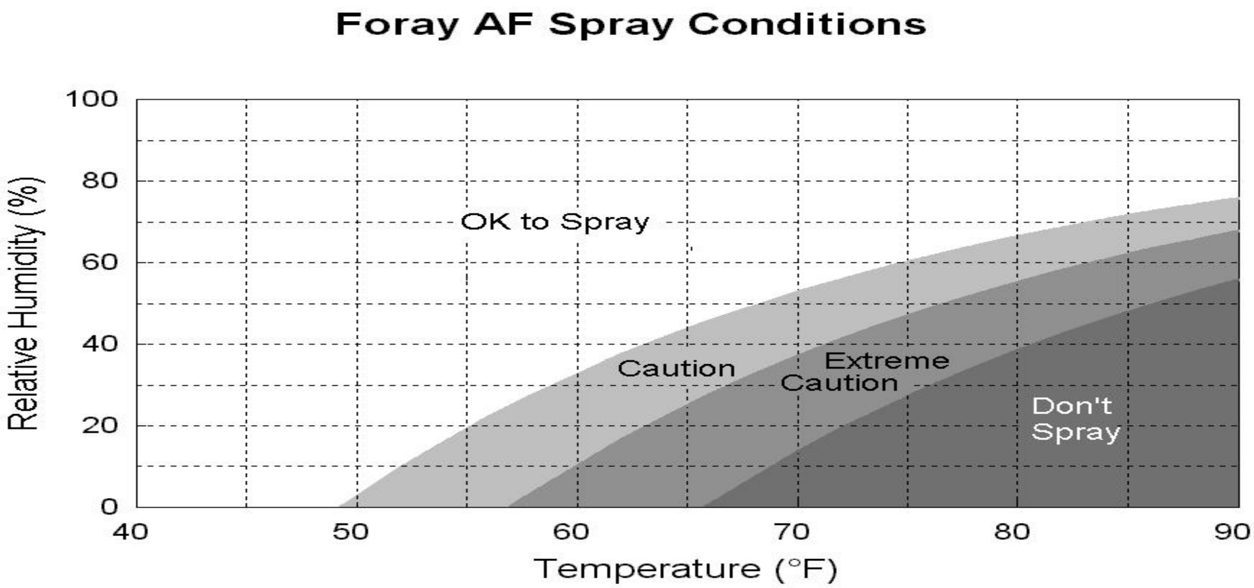
In order for droplet deposit analysis to be performed with white cards, a dye has to be added to the formulation in order to be visible on the target cards. Aqueous formulations can use a range of soluble food dyes, whereas undiluted oil formulations require dyes which can dissolve in oil solvents. Figure 5.8.3 is a limited list of dyes which have been shown to work effectively for their respective formulations.

5.8.4 Water and Oil-Sensitive Cards

A major alternative to using white target cards with added tracer is the use of water-sensitive or oil-sensitive cards. These cards have been specially developed to react to aqueous and oil-based formulations. Water sensitive cards work well with undiluted aqueous formulations, and all diluted formulations.

Droplets of the undiluted oil-based DiPel 8L formulation do not leave clear marks on oil sensitive cards, and small droplets leave no marks at all. It is, therefore, recommended to use oil sensitive cards.

Figure 5.9.2 Temperature/Relative Humidity relationship showing safe and unsafe meteorological conditions for spraying undiluted aqueous formulations and diluted formulations



Water and oil-sensitive cards are available from Spraying Systems Company. (see Appendix II: Sources & Resources).

5.9 Weather Conditions For Spraying

The weather has a tremendous impact on the aerial application process. Wind, temperature and humidity affect how the spray is deposited on the forest canopy; temperature affects the feeding activity of the caterpillars, and sun and rain both serve to reduce the active ingredient of Btk.

5.9.1 Wind

Two considerations are essential when spraying forests — maximizing spray deposit in the forest canopy while minimizing spray drift outside the target area. Wind plays an important role in both of these situations.

Figure 5.9.1 summarizes the effects of different wind speeds at different times of the day[1]. The best spraying conditions are during light to moderate wind with neutral stability, such as occurs during cloudy days. Stable atmospheric conditions result in good foliage coverage in partly expanded broad leaf canopies, but carry the risk of drift of fine droplets, with little dispersal as the spray cloud drifts downwind.

The atmosphere shows a stable condition when air movements are dampened by the temperature gradient in the air. A temperature inversion, where a layer of cold air lies below a layer of warmer air after a cold clear night is a typical case of stable air. An unstable atmospheric condition occurs when any air movement is strengthened by the temperature gradient. A wind gust may start an upward movement which will then continue as a thermal. Neutral conditions imply that any air movement will not be dampened or magnified by the state of the atmosphere.

[1]Further reference: An Atmospheric Primer for Aerial Spraying of Forests D. R. Miller et al. USDA Forest Service Publication FHM-NC-07-95 December 1995.

5.9.2 Temperature & Humidity

Undiluted DiPel 8L oil formulation is not affected by high temperatures and/or low humidities, and can be sprayed under quite dry conditions. Undiluted Foray aqueous formulations are formulated to be highly resistant to evaporation under dry conditions, but should not be sprayed under extreme conditions. Such extreme conditions are determined by a combination of temperature and humidity.

Relative humidity by itself is not a valid parameter for determining whether you can spray or not. Cool air can be very dry, but because of its low temperature, it is not able to hold much moisture and does not substantially affect the evaporation of the water content of droplets. Figure 5.9.2 shows the risks of spraying undiluted aqueous Foray under different temperature/relative humidity. **The figure is advisory in**

nature, and assumes that the correct droplet size is selected for the spray operation.

CAUTION: If you are in the 'safe' part of the graph on a morning when it is cool and the air is dry, monitor the temperature and humidity constantly, and be ready to shut down operations at short notice. As the dry air warms up, its ability to hold moisture (known as the *vapor pressure deficit*) will increase dramatically, and spraying of aqueous formulations will be compromised.

Because all Foray/DiPel formulations are manufactured to be resistant to evaporation, the most common reason for shutting down spray operations during the day is vertical movement of air in thermal convection cells, which form after the air close to the ground has been heated by the sun. Applications made under such conditions result in a highly variable coverage in the forest canopy, and significant (but highly dispersed) drift.

5.9.3 Rain & Dew

Formulation components of Foray/DiPel provide good weatherability of spray deposits, particularly with undiluted applications. However, rainfall (1/10" or more) within several hours after spray application can reduce the biological activity of the spray deposit. It is recommended that a 6 hour period free of precipitation be allowed for the spray deposit to dry and adhere to the foliage. Foray/DiPel should not be applied when rain is forecast within six hours. However, once Foray/DiPel deposits are dry, it is difficult to dislodge the droplets from the foliage surface.

If early morning dew (or previous night's rainfall) is sufficient to wet the foliage to the point of run-off, it is advisable to wait for a mild breeze or for warmer temperatures to dry the surface of the foliage before starting to spray. A small amount of foliage wetness (which does not produce run-off) will not affect the quality of the spray. However, if rainfall is forecast, ensure that the spray deposit has adequate time to dry before any precipitation. In general, 6 hours drying/feeding time is considered as adequate.

5.9.4 Cold Weather Operations

Aerial applications over forests are usually conducted when ambient temperatures are such that larvae are feeding in a forest canopy in which the new foliage has at least partially expanded. At higher latitudes, such conditions may still provide considerable diurnal temperature variations, with the possibility of near freezing temperatures at night.

A few common sense procedures minimize possible flow problems when applying Btk in cool weather conditions:

- Do not leave product in the aircraft hopper overnight.
- If possible, store product in bulk, as it is less likely to experience temperature changes.
- Before loading aircraft, recirculate any product that may be in loading hoses back into the bulk storage containers.

6.0 MANUFACTURER'S SUGGESTION

Careful consideration of these application recommendations will improve control of target insects. However, these recommendations are based on limited evaluations of Foray and DiPel and they are not intended to limit the application of Foray and DiPel through all known types of application equipment. The mention and description of a particular application and related equipment is not to be considered as a corporate endorsement of this equipment, rather it is a reflection of current industry standards and practices.

7.0 COMMONLY ASKED QUESTIONS CONCERNING FORAY & DIPEL, THE ENVIRONMENT AND THE SAFETY OF BTK

7.1 What are Foray and DiPel?

Foray and DiPel are microbial or biorational insecticides produced by Valent BioSciences. They contain the spores and unique crystalline proteins produced by a naturally occurring bacterium, *Bacillus thuringiensis* subspecies *kurstaki* (Btk). These biological components are combined with approved ingredients and water to make the final product.

7.2 What is *Bacillus thuringiensis* or Bt?

Bacillus thuringiensis or Bt is a naturally occurring rod-shaped, spore-forming, aerobic, gram-positive micro-organism (bacterium) that is found throughout most areas of the world. It can be found in soils and on leaves/needles and in other common environmental situations. When the bacteria produces spores, it also produces unique crystalline proteins. When eaten, these natural proteins are toxic to certain insects, but not to human beings, birds, or other animals.

7.3 How many other Bt's are There?

There are many varieties or subspecies of B.t., and they do not all share the same properties. *Bacillus thuringiensis* subspecies *kurstaki* (Btk) is the B.t. most widely used commercially to protect agricultural crops, fruit trees and rural and urban forests from defoliating lepidopteran larvae. This particular type of B.t. has been used for over 30 years. Other subspecies of B.t. developed commercially by Valent BioSciences are subspecies *aizawai,* active against lepidopteran pests; *israelensis*, active against mosquito and blackfly larvae; *sphaericus*, active against mosquito larvae, and *tenebrionis*, which is active against some beetle larvae.

7.4 How Does Btk Work?

Btk must be eaten by the target pest larvae in order to cause mortality. The ingested bacterium is not what kills the larvae, but rather a protein crystal produced by the bacterium. The crystal carries a toxin that is lethal to some lepidopteran larvae. To release the toxin, the crystals require the alkaline environment found in the gut of lepidopteran larvae. When Btk is eaten by a susceptible larva, the toxin is released, the midgut wall is destroyed, the gut becomes paralyzed, and the larva stops feeding within a few minutes. Destruction of the midgut wall allows the bacteria to enter the blood of the target insect, causing full-scale infection and death of the insect. This process may take 3-5 days so, unlike the situation with some chemical insecticides, there is not an immediate knockdown of insects following treatment.

7.5 Does Btk Occur Naturally?

Soil is the natural environment for Btk. Varieties of Bt were isolated from urban, forest, and agricultural soils long before the material was used in insect control programs. Bt has been detected in soils and other substrates around the world including Canada, the United States, Japan, Germany, France, and Israel. Bt can also be found on the leaves of deciduous and coniferous trees. Varieties of Bt have also been found in grain elevators and grain dust.

7.6 How are Foray and DiPel Made?

Foray and DiPel are produced from Btk grown in large quantities in enclosed fermentation tanks, in ways very similar to those used for the production of antibiotics and alcoholic beverages. The fermentation broth containing spores and the crystalline proteins is formulated with approved ingredients and water to make the final formulation.

7.7 How are Foray and DiPel Different From Chemical Insecticides?

Btk is not a chemical. Chemical pesticides kill a wider range of insects, including many beneficial ones. The active ingredient of Foray and DiPel is a natural bacterium, *Bacillus thuringiensis.* It has been shown to kill certain caterpillars such as the destructive gypsy moth. Additionally, Foray and DiPel are quickly biodegraded in nature, unlike a number of chemical pesticides that form by-products and residues of environmental concern.

7.8 Why is Btk used for Forest Spraying?

Btk was developed in response to the growing concern among the scientific community and the public in the 1960's and 1970's over the use of chemical pesticides in the forest environment. At that time, forest managers realized that an alternative to broad spectrum chemical insecticides would be needed if forest protection was to remain a component of future forest management efforts. The new insecticide would have to be: effective when applied in small amounts, more host-specific than chemicals, more quickly broken down in the environment than chemicals, and harmless to non-target organisms such as bees, birds, fish and mammals. As well, the cost of the new insecticide would have to be comparable to the cost of chemicals.

Btk was not an immediate success in terms of effectiveness and cost, but intensive research and development produced a product that now meets all of these criteria. Btk is now the material of choice in the majority of forest protection programs in North America. This product has gained a level of public acceptance that was unheard of even 10 years ago and, as a result, Btk is widely used to protect trees from insect infestations in both rural and urban settings. The major reasons that Btk is used today is because it is considered ecologically friendly and effective.

7.9 How Effective is Btk?

Btk effectiveness is comparable to chemical applications in controlling many pest insects when pest population densities are low to moderate. Btk is less likely to be as effective as chemicals when pest populations are extremely high unless multiple applications are conducted. However, a control strategy does not have to kill all the target insects in order to be successful. In fact, studies indicate that there are benefits to maintaining some pest insects in an area to support the population of natural enemies.

Because it can take several days for Btk to kill larvae, there is not an immediate reduction in the pest population as is the case when some chemical insecticides are used. This has created the erroneous perception that Btk does not work. Btk does work but it takes a little longer to see the results.

Appropriate conditions are essential for Btk to be effective. Btk is sensitive to sunlight and heat and will only persist on foliage for 3-7 days. Since Btk has to be eaten to kill target insects, sprays are most successful when medium-sized caterpillars are actively feeding.

Depending on the life cycle of the pest and climatic conditions, more than one application of Btk may be necessary to achieve the desired level of control. When eradication is the goal of a control program, a single application of Btk may be somewhat less effective than some chemical insecticides in reducing the population to zero. However, because of its low impact on non-target organisms, Btk is the product of choice for most forest pest control programs (including eradications) conducted in North America and around the world.

7.10 Are Foray and DiPel Harmful to Humans and Animals?

As required by the United States Environmental Protection Agency and Health and Welfare Canada, extensive, oral and intravenous animal studies have been conducted with Foray and DiPel. No evidence of any poisonous, infectious or disease-causing effects were found. In inhalation tests with Btk, there were no mortalities and the Btk was shown to have a low pathogenic potential.

Feeding, skin, breathing, and eye irritation animal studies were also carried out with Foray and DiPel. No toxic effects were seen when significant quantities of Foray and DiPel were fed or inhaled. Very mild, temporary skin irritation and moderate, temporary eye irritation was observed in the tests when Foray and DiPel were applied directly to the skin and into the eyes. These effects were totally reversible.

In addition, the Environmental Protection Agency and Agriculture Canada have determined that Foray and DiPel are exempt from the requirement of tolerance on all labeled crops. Due to this exemption, there is no required interval before re-entering a sprayed area. This exemption is based on extensive testing of Btk to determine both short-term and long-term effects on humans and warm-blooded animals.

Finally, Btk has been used extensively in commercial urban and rural forest pest management for over 30 years. A solid record of safety and health has been amassed over this time.

7.11 What Effect Will Bt Have On People, Especially Those with Immunodeficiency, Asthma or Allergies?

Bt is a common bacterium found in soils throughout the world. People are exposed to Bt and many other microbes everyday. Many of the microbes we encounter, including Btk, do not produce any toxins which affect humans.

Btk and other common microbes are frequently found in blood, urine and other samples from healthy people. It has been shown that the presence of Btk in patient specimen samples is not indicative of pathological or toxic effects. As with many other microbes naturally present in the environment, it can be detected as an insignificant contaminating organism among infection-causing organisms isolated from patient samples.

Individuals with an immuno-deficient condition are somewhat more likely to be affected by microbes that are normally controlled by a healthy immune system. Such microbes are referred to as opportunistic pathogens. Bt is not considered an opportunistic pathogen.

Exposure to a Btk spray program is not likely to result in the development of new allergies, asthma or other hypersensitive reactions.

Individuals with pre-existing allergies, asthma or hypersensitive individuals, especially those sensitive to normal exposure to soil or smoke and pollutants, could feel some temporary effect.

The exposure level to Btk from an aerial spray program is very low in comparison to the levels applied in safety and health related testing. Even at higher levels used in tests, Btk has been shown to be safe. That safety has been confirmed in over 30 years of use in urban and rural applications.

Individuals with any of the particular medical conditions described above should consider seeking the advice of their physician.

7.12 Will Foray or DiPel injure plants?

Foray and DiPel have been sprayed on millions of acres of trees and other plants. There have been no reports of any plant damage. Foray and DiPel and other Bt products produced by VBC are commonly used on market gardens and in greenhouses.

7.13 Are Foray and DiPel harmful to non-target animals, birds and beneficial insects?

The Btk in Foray and DiPel has been tested against mammals, birds and other insects. In all cases, when Foray and DiPel were tested at doses far in excess of the levels to which these organisms would be exposed during a routine forestry or urban tree spray program, no harmful effects were observed.

7.14 Are Foray and DiPel Harmful to Aquatic Organisms?

Foray and DiPel have shown no adverse effects in aquatic environments. Btk has been tested against freshwater fish and aquatic invertebrate. After extended exposure tests, there were no adverse effects observed.

7.15 Can Btk Grow and Replicate in the Environment?

Btk is a naturally occurring bacterium but it requires alkaline conditions to complete its life cycle. The vegetative form of Btk is generally not well adapted to soil, and it requires the specialized habitat of vulnerable insects to persist. However, Btk endospores can survive in some soils for at least four months. Foliage, water, and acidic soils are not suitable environments for Btk growth and replication. In these environments, Btk will degrade quite rapidly.

7.16 Won’t Target Insects Build Up a Resistance to Btk?

It is very unlikely that forest pests will build up a resistance to Btk. It appears that in order for an insect species to develop resistance to a pesticide, it must have several generations per year, and it must be exposed to multiple applications of the pesticide over a relatively short period of time. In forestry, only a very small area of the total forest is sprayed, and that area will likely not receive more than 2 or 3 treatments over the entire lifespan of the trees. The pest population exposure to Btk is, therefore, extremely low. The chances of a pest developing resistance to Btk in the forest is almost zero.

More intensive spray programs are used against agricultural pests. After repetitive applications of Btk to control the diamondback moth in watercress fields in Hawaii, the insect developed a resistance to Btk. Over 5 years, the watercress fields had been treated an average of 10-20 times/year. This is a very high level of exposure. New techniques of implanting Btk genes into cotton and food crops may lead to the development of resistance in the species that feed on the plants. However, these insects never cause infestations on tree species.

Resistance to Btk has been documented for the Indian meal moth and the almond moth, both stored-product insect pests. Storage-product insects are found in confined environments where a Btk treatment would not be subjected to the conditions that would inactivate it in the forest, such as rain or sunlight. In this closed environment, the probability of developing resistance to Btk is significantly greater than in the field.

7.17 What else is in Foray and DiPel besides Btk? Will These Other Ingredients Harm the Environment?

Foray and DiPel are biological insecticides which contain spores and crystal-shaped proteins produced by the naturally occurring bacterium *Bacillus thuringiensis* variety *kurstaki*, or Btk. Foray and DiPel are very selective insecticides and are not designed to control a wide variety of insect species.

All Bt products, including Foray and DiPel, are produced in a similar fashion. The Btk is grown in large enclosed fermentation tanks. Foray and DiPel are produced using ingredients and a technology which are similar to those used to make beer or spirits. During fermentation, the bacteria (Btk) reproduce in a pre-sterilized growth medium containing basic food sources, such as corn, potatoes, grains, etc. After the fermentation is complete and the bacteria are grown, the fermentation material, including the Btk, is collected. This material becomes the basic ingredient of Foray and DiPel.

This basic ingredient is composed of the Btk, which is the active ingredient, and the residual fermentation growth material and water. The water and residual fermentation growth material are referred to as "inerts" or inactive, because they are not "active" against insects. Several other inerts are added to this fermentation material, Btk and water, to make up the final formulations of Foray and DiPel. These other ingredients comprise a small proportion of the total formulation. In fact, nearly 90% of Foray 48B for example is composed of water, the residual fermentation growth material, and the Btk, (and one other inert which is a food-approved carbohydrate).

The other inactive or inert ingredients are added to maintain the quality of the Btk formulation, to make it easier to handle, and to protect the activity of the Btk. Some of these ingredients help ensure the microbial quality of Foray and DiPel by acting to control the level of possible contaminating natural microorganisms. These ingredients, added in very minor amounts to control contaminating bacteria and molds, are also used in many foods in Canada and the U.S. for the same purpose.

All inert ingredients in Foray and DiPel formulations are included in 40 CFR 180.1001. This list has been designated by the EPA as "exempt from the requirements of a residue tolerance on raw agricultural commodities". VBC verifies that none of its Btk formulations contain toxic inert ingredients, such as benzene, xylene, or formaldehyde. The Foray and DiPel toxicology profiles are outlined in Appendix VI.

Additionally, and of considerable importance, not just the Btk powder itself, but our final end-use formulations are tested toxicologically. In this process the safety of both the active ingredient and inerts are assessed and quantified.

7.18 How Can We Prove That Btk is Not a Harmful Product?

We can never prove that a product is absolutely safe. We can only demonstrate that when Btk is applied following the label instructions, that the risk to non-target organisms, whether they are birds or humans, is acceptably low. There are many drugs on the market today that, when properly taken, will effectively relieve pain or even save lives. Those same drugs come with the warning that if used improperly, they can be harmful or even cause death. As a society we must set standards and we do not permit the sale of commercial products until they have met those standards. Btk does meet the safety standards set in the USA, Canada and in all other countries. It is also acknowledged that Canada has some of the toughest regulatory standards in the world.

In the United States and Canada, commercially available products are reviewed and certified for use by federal agencies including the Environmental Protection Agency in the United States, and in Canada, several agencies including the Pesticide Management Regulatory Agency (Health Canada), Agriculture Canada, Natural Resource Canada, and Environment Canada. All pesticide applications must comply with local, state/provincial, and federal regulations. In addition, researchers continue to monitor programs for potential impacts.

7.19 Will Foray or DiPel Cause Damage To Car Finishes?

There is nothing in Foray or DiPel that will cause damage to automobile finishes. These products are formulated to stick to the surface of leaves when they dry. Therefore, it is easiest to remove from any surface while it is still wet. To remove dried Foray and DiPel from any surface, simply soak the dried droplets with water and then sponge or wipe with a soft cloth. A cleaning product normally labeled for car washing may be needed if the dried spray has been on the surface for awhile. The sooner the surface is cleaned, the easier it will be to remove the spray droplets.

If the automobile's paint is old, oxidized, and/or severely weathered, Foray and DiPel will adhere to this porous surface; it will be more difficult to remove. A large bath towel may be soaked and placed upon the painted surfaces for several minutes to allow the Foray and DiPel deposits to become rehydrated. This will make the spray deposit easier to remove. In extreme cases, several soakings with a wet towel may be required.

DiPel 8L will form oily rings on the car finish - these are especially apparent on weathered paint. Regular car cleaning detergents will completely remove these temporary blemishes.

APPENDIX I: FORAY AND DIPEL FIELD SUMMARIES

Foray 48F United States Field Trial Data Summaries

Location/year Researcher	Rate/Treatments BIU/ha	Dilution/ application rate	Aircraft and Spray Equipment	Result Summary
Gypsy Moth ***(Lymantria dispar)***				
Pennsylvania, 1995 Ticehurst	60	4.7 L/ha undiluted	Bell 206 AU5000 Micronair	less 5% defoliation 68% egg mass reduction
Michigan, 1995 Davis, Smitley	40 & 60	3.2 & 4.7 L/ha undiluted	Bell 47 AU5000 Micronair	98-99% EM Reduction 7-15% defoliation
Pennsylvania, 1996 Ticehurst	60	4.7 L/ha undiluted	Bell 206 AU5000 Micronair	99% EM Reduction 3% defoliation

Foray 48F (ABG-6387) Canadian Field Trial Data Summaries

Location/year Researcher	Rate/Treatments BIU/ha	Dilution/ application rate	Aircraft and Spray Equipment	Result Summary
Eastern Hemlock Looper ***(Lambdina fiscellaria fiscellaria)***				
Newfoundland, 1995 West	2 x 20 BIU/ha	1.6 L/ha undiluted	Cessna 188 AU4000 Micronairs	73-99% larval mortality 90-100% pupal mortality
Western Spruce budworm ***(Choristoneura occidentalis)***				
British Columbia, 1995 Otvos	45 BIU/ha	3.9 L/ha undiluted	Hiller 12E/T Beecomist	73% larval population reduction

Foray 48B Canadian Field Trial Data Summaries

Location/year Researcher	Rate/Treatments BIU/ha	Dilution/ application rate	Aircraft and Spray Equipment	Result Summary
Eastern Spruce Budworm ***(Choristoneura fumiferana)***				
Manitoba, 1996 Cadogan	30	2.4 L/ha undiluted	Cessna 188 AU4000 Micronairs	69-80% population reduction 13-14% defoliation
Quebec, 1996 Dugal (SOPFIM)	2 x 30 BIU	2.4 L/ha undiluted	Piper Pawnee AU5000 Micronairs	91% population reduction 19-26% defoliation
Western Spruce Budworm ***(Choristoneura occidentalis)***				
British Columbia, 1994 Otvos	60	4.8 L/ha	Hiller 12E/T	73% population reduction
	30	2.4 L/ha undiluted		32% population reduction
British Columbia, 1995 Otvos	60	4.8 L/ha undiluted	Hiller 12E/T Beecomist	94.4% population reduction

Foray 76B Canadian Field Trial Data Summaries

Location/year Researcher	Rate/Treatments BIU/ha	Dilution/ application rate	Aircraft and Spray Equipment	Result Summary
Eastern Hemlock Looper ***(Lambdina fiscellaria fiscellaria)***				
Newfoundland, 1996 West	2 x 40	2.0 L/ha undiluted	Cessna 188	70-90% mortality 0-14% defoliation
Eastern Spruce Budworm ***(Choristoneura fumiferana)***				
Alberta, 1995 Tomm	2 x 25	1.25 L/ha undiluted	AT401 AU4000 Micronairs	64-92% larval mortality 89% defoliation
New Brunswick, 1996 Kettela	30	1.5 L/ha undiluted	Cessna 188 AU4000 Micronairs	99% population reduction 1-2% defoliation
Quebec, 1996 Dugal (SOPFIM)	1 x 50 2 x 50	2.4 L/ha undiluted	Piper Pawnee AU5000 Micronairs	73-91% popluation reduction 28-35% defoliation

DiPel 8L European & Russian Field Trial Data Summary

Location/year Researcher	Rate/Treatments BIU/ha	Dilution/ application rate	Aircraft and Spray Equipment	Result Summary
Pine Processionary Moth ***(Thaumetopoea pityocampa)***				
Savoie, France Demolin	40 & 50	2.3 & 3.0 L/ha undiluted	Bell 47G 6 Airbi rotary atomizers	80-97% mortality
Nun Moth ***(Lymantria monacha)***				
Eberswalde, Germany, 1994	50 & 67 against L1 & L2 larvae	3.0 & 4.0 L/ha diluted, 35 L/ha		84% control after 14 days for both dose rates
Eberswald, Germany, 1995	40 & 50 against L1 & L2 larvae	2.5 & 3.0 L/ha diluted, 35 L/ha		97% control after 14 days for both dose rates
Poland, 1994 Glowacka	47 & 57 against L1 & L2 larvae	2.8 & 3.4 L/ha undiluted	An-2 10 Micronair AU5000	79% and 88% control after 16 days for 2.8L and 3.4L rates
Czech Republic, 1995 Strnady	40 & 50 against L1 & L2 larvae	2.5 & 3.0 L/ha undiluted	Zlin 37T Micronair AU4000	80 and 90% control
Chechersk, Belarus, 1995 Krushev	50	3.0 L/ha undiluted	Kamov KA-26	34%, 74%, and 82% control after 5, 10, and 15 days
Pine Moth ***(Bupalis piniarius)***				
Russia, 1995 Pushkino	25 & 30 against L1 & L2 larvae	1.5 & 3.0 L/ha diluted, 35 L/ha	An-2 Hydraulic nozzles	98% mortality for both dose rates
Gypsy Moth ***(Lymantria dispar)***				
Germany, 1994 Bogenshutz	33 & 50 1 & 2 applications	2 and 3 L/ha diluted 12 L/ha	12L: Bell 47/Alouette 2 6 Airbi rotary atomizers	3L x 1 70% control after 9 days 2L x 2 87% control after 9 days
B. Stiavnica, Slovakia, 1995 Novotny	3 L/ha	undiluted	Zlin 37T Miconair AU4000	6% control
Siberian Silk Moth ***(Dendrolimus Sibericus)***				
Krasnoyarsk, Russia, 1996 Soldatov	50 BIU 1st yr. and 2nd yr. generations	3 L/ha undiluted	An-2 Micronair AU5000	

Foray 48B European & Russian Field Trial Data Summary

Location/year Researcher	Rate/Treatments BIU/ha	Dilution/ application rate	Aircraft and Spray Equipment	Result Summary
Pine Moth (or Pine Lapet Moth) ***(Dendrolimus pini)***				
Eberswalde, Germany, 1994 (Autumn treatment)	50 BIU against L3 & L4 larvae	4.0 L/ha diluted wt. water to 35L/ha		99% control after 14 days
Miedzychod, Poland, 1993 (Spring, overwintering pops)	50	4.0 L/ha undiluted	An-2 10 Micronair AU5000	68-93% control
Gomel, Belarus, 1995 Fall, Some L5-6 from previous year	25 & 30	2.0 & 2.5 L/ha undiluted	An-2 8 Micronair AU5000	97% control after 10 days for both rates
Germany, 1996 Spring, L4-L6 larvae	38	3.0 L/ha undiluted	Helicopter 'ULV atomizers'	83% control after 30 days
Lithuania, 1995 Spring, L3 (30%) & L4 (60%)	38	3.0 L/ha undiluted	An-2 Micronair AU5000	92-97% control after 1 month
Lithuania, 1996 Spring, mostly L4	50 & 58	4.0 & 4.5 L/ha undiluted	Kamov Ka-26 8 Micronair AU5000	92% control after 1 month
Belarus, 1996 Fall, L1-2	50	4.0 L/ha undiluted	An-2/Ka-26 Micronair AU5000	9-99% control 10-15% defoliation
Pine Processionary Moth *(Thaumetopoea pityocampa)*				
Taragona, Spain, 1993 L3 (20%) L4 (75%) L5 (5%)	21 BIU/ha	3.0 liters diluted (water)	Bell 206 Jetranger 6 Airbi	66% control after 16 days 80% control after 27 days
Cordoba, Spain, 1994 L3 (10%) L4 (55%) L5 (37%)	38	3 L/ha undiluted	Piper Brave Micronair AU5000	57% control after 22 days 90% control after 47 days
Nun Moth ***(Lymantria monacha)***				
Poland, 1994 150,000 ha	38 & 50	3.0 & 4.0 L/ha undiluted	An-2 10 Micronair AU5000	72-99% control after 2 weeks 93-100% control after 4 weeks
Belarus, 1995 27,000 ha, L1-L3 larvae	38 & 50	3.0 & 4.0 L/ha undiluted	An-2/Ka-26 both with Micronair AU5000	90-100% control
Belarus, 1996 L1- L3 larvae	38 & 50	3.0 & 5.0 L/ha undiluted	An-2/Mi-2 both with Micronair AU5000	90-98% control 10-30% defolation
Green Oak Tortix ***(Tortix viridana)***				
Romania, Spring, 1993 L2-L3 larvae	19	3.0 L/ha diluted (water)	An-2 Micronair AU5000	93-99% control

APPENDIX II: SOURCES & RESOURCES

This section lists manufacturers of equipment and products and sources of information which can facilitate your operations. We have tried to make this manual as comprehensive as possible, but invariably will have left out some key contacts. Please contact us with any omissions; in future versions we will try to correct this situation. References used in the production of this manual are listed in Appendix IV.

As always, if a name of a supplier appears in our list, is should not be considered as an endorsement by Valent BioSciences; rather it is an industry-recognized supplier of the product or service.

Businesses move, mail and electronic addresses change, new area codes appear and the World Wide Web Internet sites may change. At time of writing, every effort has been made to have up-to-date information. If you find that some of the information is outdated, please contact Valent BioSciences so we can update the information for the next release of the manual.

ATOMIZERS

Hydraulic:
Spraying Systems Company
P.O. Box 7900, Wheaton, IL 60189 USA
Tel: 630-665-5000
Web site: www.spray.com (Does not have any agricultural content at time of writing)

CP Nozzles
C&E Enterprises
604 West McKellips Drive
Mesa, AZ 85201 USA
Tel: 602-834-5593
Fax: 602-969-6671

Rotary:
Micronair (Head Office)
Bembridge Fort
Sandown, Isle of Wight, PO36 8QS
England
Tel: (UK) 1983 406111
Fax: (UK) 1983 404461

(US Office)
Micronair Sales & Service
7792 N.W. 54th Street
Miami, FL 33166 USA
Tel: 800-368-6125
305-592-9250
Fax: 305-592-5432
Web site: www.charline.be/micronai/uk/welcmic1.htm

Beecomist Systems Inc.
31 Meetinghhouse Road
Telford, PA 18969 USA
Tel: 215-721-9424
Fax: 215-721-0751

FLOW METERS

CROPHAWK flow monitors and data recording systems
ONBOARD SYSTEMS
1212 NW St. Helen's Road, Portland, OR 97231 USA
Tel: 503-286-4956
Fax: 503-286-0370

MICRONAIR flow monitoring turbines and recording systems: See Micronair under Rotary Atomizers in this section.

DIFFERENTIAL GPS EQUIPMENT MANUFACTURERS

AG-NAV
Picodas Group, Inc.
100 West Beaver Creek Road, Unit #6
Richmond Hill, Ontario, Canada L4B 1H4
Tel: 905-764-3744
Fax: 905-764-3792

Trimble Navigation Limited
1440 Lake Front Circle, Suite 110
The Woodlands, TX 77380 USA
Tel: 713-363-4700
Fax: 713-292-8876

Del Norte Technology, Inc.
1100 Pamela Drive
Euless, TX 76039 USA
Tel: 817-267-3541
Fax: 817-354-5762

SATLOC
15990 N. Greenbay Hayden Loop, Suite 800
Scottsdale, AZ 85260 USA
Tel: 602-348-9919
800-4SATLOC
Fax: 602-348-6368

WAG Corporation
386 Highway 6 West
Tupelo, MS 38801 USA
Tel: 601-844-8478
Fax: 601-844-7247
Website: www.wagcorp.com

SWATH KIT

The Swath Kit is a laptop computer-based aircraft spray pattern analysis system. It uses an image analyzer to read cards sprayed by the aircraft and includes a weather station which helps in the interpretation of the spray pattern. The swath pattern analysis program runs in the Windows operating system.

For further information contact:

Droplet Technologies, Inc.
937-1 West Whitehall Road
State College, PA 16801 USA
Tel: 814-238-6857
Fax: 814-238-1366
Web site: www.mindspring.com/~droptech

COLOR TRACERS & DYES

The following dyes are suggestions only. It is the users' responsibility to carefully read all safety information about a candidate dye to ensure standards of human and environmental safety are maintained.

FD&C means that the dye is approved for use in food, cosmetics and drugs, and it can be assumed to be acceptable to spray on your site. However, in these litigious times it is best to check with the appropriate ruling body that they have no objections.

Tracer Dye	**Supplier**
FD & C Blue #1 FD & C Blue #1	Chemcentral 13395 Huron River Dr Romulus, MI 48174 USA Tel: (313) 941-4800
Black Shade R FD & C Blue #1 FD & C Blue #1	Warner-Jenkinson 2520 Baldwin Street St. Louis, MO 63106 USA Tel: (800) 325-8110
Rhodamine WT	Keystone Aniline Corp. 2501 West Fulton Street Chicago, IL 60612 USA Tel: (312) 666-2015 Web site: www.dyes.com
Bas Oil Red	Becker-Underwood 801 Dayton Avenue Ames, IA 50010 USA Tel: (515) 232-5907 Web site: www.bucolor.com
CSF	Carolina Color & Chemical Company 3400 Silas Ave Charlotte, NC 28206 USA Tel: (704) 333-5101 Fax: (704) 342-3023

SPRAY CARDS

Kromekote Cards

Kromekote® paper has been used for many years by printers. Ask for Mead Mark 1, 10 point cover stock or equivalent. It is advisable to use papers that are glossy on both sides to prevent card warping in moist environments. Since spread factors will vary depending on quality of Kromekote paper, it is necessary to use only one supplier for spray cards.

Many print shops will carry such card stock, and will be able to cut it to size. For typical Btk deposit analysis, 2" x 3" Kromekote cards are an ideal size.

An example in the northeastern US is:

Glove Printing
1437 Buffalo Run Road
Bellefonte, PA 16823 USA
Tel: (814) 355-2197
Fax: (814) 355-0188

Water & Oil Sensitive Cards

Supplied by 'Spraying Systems Company' see reference under “Hydraulic” in this section.

PUMP SEALS

The following companies are two major manufacturers of pump seals. These suppliers can direct you to their distributors for local service.

FLOWSERVE (Formerly PAC-SEAL, INC.)
211 Frontage Road
Burr Ridge, Illinois 60521 USA
Tel: (847) 325-7119
Web site: www.pacseal.com

John Crane Inc.
6400 W. Oakton Street
Morton Grove, Illinois 60053 USA
(847) 967-2400

SPILL NOTIFICATION

Chemtrec Spill Notification Network (800) 424-9300

Chemtrec (Chemical Transportation Emergency Center) is a public service of the Manufacturing Chemist Association to deal with chemical transportation emergencies.

In the event of chemical transportation emergency, Chemtrec provides immediate advice for those at the scene of emergencies, then promptly contacts the shipper of the chemicals for more detailed assistance and appropriate follow-up.

APPENDIX IV: PARTIAL LIST OF INSECTS CONTROLLED WITH FORAY AND DIPEL

Table 1 and Table 2 show a list of forest Lepidoptera against which Foray/DiPel has been successfully used.

Table 1: Major target pest species controlled with Foray/DiPel

Common name	Scientific name	Suggested dose BIU/ha	Suggested dose L/ha
Coniferous Forests			
Pine Processionary	*T. pityocampa*	12-40	1-3
Nun moth	*L. monacha*	50	4
Pine moth	*Dendrolimus pini*	25-50	2-4
Pine beauty moth	*Panolis flammea*	25-50	2-4
Pine Looper moth	*Bupalis pinarius*	25-50	2-4
Fir & Larch tortricids	*Zeiraphera spp*	25	2
Deciduous Forests			
Gypsy moth	*L. dispar*	25-60	2-5
Green Oak tortrix	*T. viridana*	25	2
Oak Processionary	*T. processionaria*	25-50	2-4
Fall Webworm	*H. cunea*	12	1
Brown tailmoth	*E. chrysorrhoea*	12-25	1-2
Tent caterpillars	*Malacasoma spp*	12-25	1-2
Ermine moths	*Yponomeuta spp*	12-25	1-2
Vapourer moth	*O. antiqua*	12-25	1-2
Winter moth	*O. bumata*	12-25	1-2

Table 2: Minor target pests species controlled with Foray/DiPel

Leucoma salicis on poplars
Dasychira pudibunda on beech
Drymonia ruficornis on Oak stands
Diocrytria spp in pine seed orchards
Epinolia spp in Christmas tree plantations, etc.
Orthesia cruda

The following two sections deal with species on which extensive research exists on the effect of Foray 48B.

Pine Moth
(Dendrolimus pini)

Dose

Both trial data from Germany and operational experience in Poland during the 1994 season, have shown exceptionally good results have been obtained against late instar larvae (L3-L4) of *Dendrolimus pini* at dose rates of 4L/ha.

The experimental and operational results indicate that the optimum dose rates for the various larval stages are:

L1-L2: 2 - 2.5 L/ha
L3-L4: 3 - 4 L/ha

Timing

The optimum period for treatments is when the larvae are actively feeding. This means that there are two periods during which *Dendrolimus pini* larvae may be treated:

In autumn to catch the L1 and L2 larvae, and
In spring for the over-wintering L3 and L4 larvae.

The "operational window" for *Dendrolimus pini,* depends more upon climatic conditions than the development of the larvae. Experience in Poland indicates that the larvae can be treated over an extended period in both the autumn and spring seasons, giving great operational flexibility.

The long susceptible phase of the larvae means that adverse weather need not be a limiting factor to successful control, and operations can be stopped until better conditions occur in order to get the optimal results.

Application

Rotary atomizers

Foray and DiPel should be applied undiluted whenever possible through rotary atomizers (e.g. Micronair or Beecomist) set to produce droplets in the range 75-125 µm.

Hydraulic nozzle systems

If rotary atomizers are not available, then standard hydraulic boom and nozzle systems can be used successfully. Application volumes are higher (ca 10-15 L/ha), so Foray and DiPel require dilution with water.

Pine Processionary Moth
(Thaumetopoea pityocampa)

Foray and DiPel are very effective products for the control of Pine Processionary Moth across the whole geographical range of the insect. They give excellent control of all the larval stages -1st & 2nd, 3rd, 4th and even 5th instar larvae, under a wide range of operational conditions. They also stop feeding soon after application, and limits the damage that the larvae can do.

Dose Rate

The rates vary according to a number of factors; such as the influence of:

-geography
-development of the larval population
-weather conditions

Timing

The "operational window" for Foray and DiPel is very long. Depending upon the geographical area it is usually 2-3 months. This means that periods of adverse weather should not affect the overall timing of treatments.

The optimum period for treatments is during the early season. Low dose rates can be used, which give corresponding reductions in application costs and increased aircraft utilization.

Mid to late season applications with Foray and DiPel, using the appropriately higher dose rates, are equally successful.

Winter applications against L4 & L5 larvae have been made as late as early February, and under cold conditions using 3 and 4L/ha, with equal success.

Aerial Application

Foray and DiPel should be applied whenever possible, undiluted, through rotary atomizers (e.g. Micronair, or Beecomist) set to produce droplets below 100 microns, preferably in the 60-80 micron range.

If rotary atomizers are not available, then the standard hydraulic systems may be used successfully.

Green Oak Tortrix *(Tortrix viridana)*

& Winter Moth *(Operopthera brumata)*

Foray and DiPel have been shown to be effective against the larvae of *T. viridana* when applied early in the spring, at bud burst on deciduous oaks (*Q. robur, Q. cerris* etc), and in early summer on both the evergreen oaks, *Q. ilex and Q. subor.*

Deciduous Oaks

Dose

Operational experience shows that a dose rate of 2-3 L/ha will give excellent results.

Timing

Both experimental and operational experience shows that early treatments, when the oak leaves are still in bud, are more effective in terms of larval mortality, and therefore foliar protection, than later ones.

Mixed infestations of:

- *virdana* and *O. brumata* should be treated simultaneously, while

- *viridana* and *L. dispar* should be treated separately, (if both populations need to be controlled) although it has been observed that late applications for *T. viridana* made when there are significant numbers of *L. dispar* present on the tree are equally effective against both species.

Application

Operational experience backed up by some experimental work in the USA indicates that equipment should set to produce Foray/DiPel droplets in the range 125-150 microns to get the best results.

Rotary atomizers and conventional hydraulic systems are capable of producing droplets within this range.

Nun Moth
(Lymantria monacha)

Nun moth is a relatively rare pest. When it occurs, it infests firs and pine trees, particularly those growing on the poorest soil. Its effects can be catastrophic. Foray 48B has been shown to be effective against the larvae of the nun moth *(L. monacha)*, under both experimental and operational conditions at dose rates between 3.5 and 4L/ha.

Dose

Pines

Operational experience in Poland during the 1994 season, has shown that exceptionally good results have been obtained against early stage larvae (L1-L3) of L monacha at dose rates of 3-4 L/ha.

The experimental and operational results indicate that the optimum dose rates for the various larval stages are:

L1-L2:	2 - 2.5 L/ha
L3-L4:	3 - 4 L/ha

Timing

Pines

The optimum period for treatments is when the larvae are actively feeding.

Applications were made in Poland to late 1st instar larvae in mid May through to early 3rd instar larvae in mid June, with equally good effect.

While there are no efficacy reports available at the time of writing of applications against late 3rd and 4th instar larvae, the higher dose rates should be used until further clarification is made.

Weather

The "operational window" for *L. Monacha*, depends more upon climatic conditions and the development of the new growth rather than the susceptibility of the larvae to Foray.

Experience in Poland indicates that the larvae can be treated over an extended period from L1 to L4, which in 1994 was 4-5 weeks. This would indicate that adverse weather need not be a critical factor, and operations can stop until better conditions occur in order to get the best results.

Application

Pines

Experience gained in 1994 show that the best results are obtained with equipment set to produce undiluted Foray and DiPel droplets in the range of 40-80 microns.

This means that Micronair AU5000 (and AU4000) atomizers should be run at between 8,500 and 9,500 rpm, and flow rates per atomizer should be maintained at less than 3L/minute, even if it means fitting an extra pair of atomizers per aircraft.

Spruce

Experience gained in 1994 and 1995 shows that it is important to obtain the finest droplets (40-60 µm) that the equipment is capable of producing in order to get the coverage required for good performance.

This means that Micronair AU4000 atomizers should be run at 10-12,000 rpm, and that AU5000 atomizers should be set to run at the maximum rotation possible, by setting the fan blade angles at 35° (or finer). Flow rates per atomizer should be maintained at less than 3 l/minute, even it means fitting an extra pair of atomizer per aircraft.

APPENDIX V: REFERENCES

A frequent comment of individuals concerned over Btk spray programs is that information provided by industry is suspect. Often the very opposite is true and the general public tends to be misinformed by other sources. The Btk field is very well researched, and a great many peer-reviewed publications are available for reference. The use of Btk in forestry has been extensively reviewed in 1994 by the USDA Forest Service (Reardon et al, 1994) and in 1993 by Forestry Canada (Otvos et al, 1993). In addition, Btk received wide coverage from the USDA Forest Service in 1995 with the publication of the new Environmental Impact Statement for gypsy moth.

The Canadian publication is the most comprehensive review of Btk use available, looking at every aspect of the use of this product by society. It has a very complete list of publications on the subject. We strongly recommend any interested persons to order the publication from the Canadian Forest Service, Natural Resources Canada (previously Forestry Canada) for further study.

In order not to overwhelm readers with a library stack of references, we present a limited list of key publications, with a few recent ones that did not make it into the above key references, as well as the sources used for the preparation of this technical manual.

Comprehensive Reviews of B.t. use

Otvos, I.S. and S. Vanderveen. 1993. Environmental report and current status of *Bacillus thuringiensis* var. *kurstaki* use for control of forest and agricultural insect pests. Forestry Canada and Province of British Columbia, Ministry of Forests; Victoria, B.C. 81 pp.

Reardon, R., N. Dubois, and W. McLane. 1994 *Bacillus thuringiensis* for managing gypsy moth: A review. USDA Forest Service, National Center of Forest Health Management, Morgantown, W.V. 32 pp.

Gypsy Moth Management in the United States: a cooperative approach. Environmental Impact Statement, Vols I-V, USDA, Forest Service and APHIS.

Recent publications not listed in Otvos and Vanderveen

Kreutzweiser, D.P., S.S. Capell, and D.R. Thomas. 1994. Canadian Journal of Forest Research 24: 2041-2049 Aquatic insect responses to *Bacillus thuringiensis* var. *kurstaki* in a forest stream.

Phero Tech Inc. and Deloitte & Touche. 1994. A risk assessment of European gypsy moth in British Columbia. Report prepared for the B.C. Ministry of Forests, Agriculture Canada, and the B.C. Ministry of Agriculture, Fish and Food. 73 pp.

Reardon, R. and A.E. Hajek. 1995. Gypsy Moth News 39: 3-4 Entomophaga maimaiga in North America: A review.

Richardson, J.S. and C.J. Perrin. 1994. Canadian Journal of Fisheries and Aquatic Science 51: 1037-1045 Effects of the bacterial insecticide *Bacillus thuringiensis* var. *kurstaki* (Btk) on a stream benthic community.

Health Risk Assessment of the Proposed 1997-1998 Control Programme for the White-Spotted Tussock Moth in the Eastern Suburbs of Auckland, NZ. A report to the Ministry of Forestry. Public Health Protection Service, Auckland Healthcare Services Limited. September, 1997, 79pp.

Reardon, Richard C. 1996. Appalachian Integrated Pest Management Gypsy Moth Project: Summary and Bibliography. USDA Forest Service. Forest Health Technology Enterprise Team. NA-TP-05-96. 47pp.

References used in preparation of the Foray & DiPel Technical Manual

D.R. Miller, R.C. Reardon and M.L. McManus (1995) An Atmospheric Primer for Aerial Spraying of Forests USDA Forest Service-Pub FHM-NC-07-95.

Van Frankenhuizen, K., N. Payne, L. Cadogan, B. Mickle and A. Robinson (1996) Effect of droplet size spectrum and application rate on field efficacy of *Bacillus thuringiensis*. Report submitted to the Spray Efficacy Research Group.

N.R. Dubois, K. Mierzejewski, R. C. Reardon, W. McLane, and J.J. Witcosky (1994) J. Environ. Sci. Health, B29(4), 679-695 *Bacillus thuringiensis* Field Applications: Effect of Nozzle Type, Drop Size, and Application Timing on Efficacy Against Gypsy Moth.

Dubois, Normand R., Richard C. Reardon and Karl Mierzejewksi (1993) Field Efficacy and Deposit Analysis of *Bacillus thuringiensis,* Foray 48B, against Gypsy Moth. Journal Econ. Entomol. 86 (1) 27-33.

Maczuga, Steven A. and Karl J. Mierzejewski (1195) Journal Econ. Entomol. 88 (5) 1376-1379 Droplet Size and Density Effects of *Bacillus thuringiensis kurstaki* on Gypsy Moth.

A good general, although now somewhat dated guide to aerial spraying in forests is available from the Forest Service: Aerial spraying for gypsy moth control: a handbook of technology. Author: Richard Reardon, NA-TP-20 (Updated Version) January 1991.

Internal research reports performed by and for Valent BioSciences

Manufacturers' literature

VALENT BIOSCIENCES

Foray®

FOR USE IN FORESTS

Toxicology Profile

Foray is a selective, microbial insecticide that effectively protects forests throughout the world from defoliating lepidoptera larvae, including gypsy moths, spruce budworms, and other leaf-eating caterpillars.

The active ingredient in Foray, *Bacillus thuringiensis kurstak*i, or Btk, is a naturally occurring bacterium commonly found on foliage and in soil. Unlike chemicals, Foray works by quickly paralyzing the digestive system of the pest after the active ingredient, Btk, is eaten, causing the insects to stop feeding immediately and die within a few days. Foray formulations are used to economically and effectively control a wide variety of damaging forest pests.

Toxicity Studies

Oral Toxicity Studies

No oral toxicity has been demonstrated in rats given Foray at 5000 milligrams per kilogram of animal body weight. In a separate study, a dose of 10^8 Btk Colony Forming Units (CFU: a measure of viable spore concentration) did not cause any toxic or pathogenic effects.

Inhalation Toxicity Studies

No toxic effects were observed in rats exposed to approximately 7 milligrams of Foray per liter of air for 4 hours.

The low pathogenic potential of Btk was demonstrated when rats were exposed to a concentration of approximately 10^8 CFU of Btk per liter of air for 4 hours. No overt symptoms of toxicity have been reported by individuals during the use of this or other Btk containing products.

Dermal Toxicity Studies

No toxic effects were observed when Foray at 2.5 gram per kilogram of body weight was applied as a single dose exposure to the skin of rats.

Dermal Irritation Studies

Very mild, temporary dermal irritation was seen when Foray was applied to the skin of rabbits for 4 hours. All signs of irritation cleared in all animals within 2 days after application.

Eye Irritation Studies

Foray was moderately irritating in a rabbit eye irritation test. No apparent redness or other ocular finding remained 7 days after the application of 10^9 CFU of Btk to the eye.

I.V. Injection Studies

A single I.V. dose of 10^8 CFU of Btk was not toxic to rats. Btk was not able to multiply in the tissue as examined periodically during the 167 days of the study.

Freshwater Fish Toxicity Studies

No toxicity or pathogenicity was shown in rainbow trout exposed to Btk for 31 days at a dose of 10^{10} CFU per liter of water and in the diet at 10^{10} CFU per gram of feed.

Freshwater Aquatic Invertebrate Toxicity Studies

Btk had no observed effect on *Daphnia magna* exposed to over 10^8 CFU of Btk per liter of water for 21 days.

Bird Toxicity Studies

No toxicity or pathogenicity was seen in bobwhite quail after they were orally dosed with Btk at 10^{11} CFU per kilogram body weight each day for 5 consecutive days.

No toxicity or pathogenicity was seen in mallard ducks orally dosed with Btk at 10^{11} CFU per kilogram body weight each day for 5 consecutive days.

Honey Bee Toxicity Studies

The LC50 for Btk on honey bees was determined to be 10^8 CFU per gram of feed and the no-observed-effect-concentration was determined to be 10^6 CFU per gram of feed.

Non-Target Insect Toxicity Studies

The LC50 of Btk on green lacewing larvae was greater than 10^8 CFU per gram of feed and the no-observed-effect-concentration was 10^8 CFU per gram of feed.

The LC50 of Btk on ladybird beetles was greater than 10^8 CFU per gram of feed and the no-observed-effect-concentration level for pathogenicity was 10^6 CFU per gram of feed.

The LC50 of Btk on a species of parasitic wasps was greater than 10^8 CFU per gram of feed and the no-observed-effect-concentration was 10^8 CFU per gram of feed.

Residues

As Foray has been shown to be non-toxic to non-target organisms, residues and spray drift are not considered hazardous.

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APPENDIX VII: LIST OF VBC SALES AND RESEARCH CONTACT PERSONS

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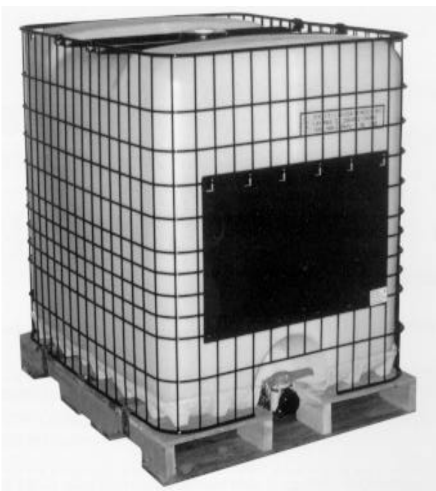
APPENDIX III - PRODUCT CONTAINERS & DIMENSIONS

DRUM

Capacity:	55 gallons 200 litres
Outside Diameter:	23 1/4”
Outside Height:	34 3/4”
Color:	Blue
Body:	High molecular weight polyethylene with ultraviolet light protection.
Closure:	(2) 2” bungs



MINI BULK

Capacity:	275 gallons 1000 litres
Length:	47 1/4”
Width:	40”
Height:	*45 3/4”*
Color:	White
Body:	Blow molded high density polyethylene
Cage:	1/4” solid rod steel
Filling port:	6”
Discharge Valve:	2” ball style valve. NPT threading
Stacking:	2 high

BULK TANKER

Capacity:	Up to 7,000 gallons
Tank Length:	43’
Tank Height:	12’
Unloading:	Center or rear