Initial Comparison of the Standard Organophospate Treatment, Malathion (Fyfanon®) and a Pyrethroid, β-Cyfluthrin (Baythroid® XL) Applied at the Label Rates for Control of Rangeland Grasshoppers in South Dakota, 2009.

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Abstract

The efficacy of an organophosphate, (Fyfanon® ULV) was compared to a pyrethroid, (Baythroid®) applied as 100% and reduced area-agent treatments (RAATs) on native rangeland near Edgemont, SD. At 2 days post-treatment, the 100% blanket treatment resulted in 91.7% and 94.5% mortality for Baythroid XL XL and Fyfanon respectively. At 7 days post-treatment the mortality was 86.4% and 96.3% mortality, respectively. At 2 days post-treatment, the RAATs, produced 75.2% and 78.4% mortality, for β-cyfluthrin and malathion respectively. At 7 days post-treatment the mortality was 72.5% and 76.2% mortality, respectively for the pyrethroid and organophosphate respectively. The Baythroid XL XL performed as well as the Fyfanon under the treatments and field conditions as tested.

Introduction

Malathion has been one of three insecticides used by USDA, APHIS, PPQ for aerial application to control rangeland grasshoppers for the last 30 years. The other two materials are carbaryl and diflubenzuron, all have an outstanding safety record. Malathion has a short residual and is highly effective against all grasshopper instars and new adults on rangeland. An attribute that make malathion especially attractive for control of large acreages includes its ULV label which means the aircraft can carry enough material to treat large acreages. A reduced area-agent treatments (RAAT) strategy also enhances its cost effectiveness (Foster et al. 2000). Recent review of Reregistration Eligibility Decision (RED) by the EPA for malathion (Federal Register, 2009), has resulted in continued ultra low volume (ULV) label use for USDA, APHIS, PPQ control

programs. However, malathion's long term status *vis a vis* regulatory and environmental concerns may eventually limit its registration for this use. In an effort to look at labeled alternatives, β-Cyfluthrin (Baythroid© XL) was selected as a representative of this class of materials and field tested for efficacy and other characteristics. Additionally, its current label includes grasshoppers on rangeland and contains no grazing restrictions. Other pyrethroids, registered for grasshopper control on rangeland have grazing restrictions. The work with alternative treatments has been ongoing since carabryl may be lost as the EPA continues examining its impact on the environment compared with newer reduced risk insecticides.

Hewitt and Onsager (1983) estimate that more than 20% of annual forage production in the western United States is lost to grasshoppers and while the use of insecticides has reduced the impact of rangeland grasshoppers; cost and timely application remains as a potential problem. The deployment of additional insecticides as alternatives to the current list of control materials is imperative to meet the expectations of both the EPA and current stakeholders. The current profile for an acceptable material includes known toxicological impacts, persistence and availability. Pyrethroids as a class are relatively non toxic to terrestrial vertebrates, highly effective against insect pests and some of them have relatively long half lives in the environment compared to the early materials labeled (EXTOXNET). Most have been employed in crop protection, residential uses and public health applications. The crop protection includes barrier treatments for grasshopper control around crops and for aerial applications to alfalfa and pastures.

Although two pyrethroids are labeled for rangeland grasshopper management, this class of chemicals that has not been fully investigated for adaptation to rangeland control programs for wide use by USDA, APHIS, PPQ, primarily because of cost. Baythroid XL XL has no restrictions on pre-harvest interval, or grazing and 12 hour reentry into the treated area. The other pyrethroid has a restrictrion on treating over livestock but otherwise similar. In 2009 a trial to test the efficacy of β-cyfluthrin (Baythroid XL © XL, BayerCropScience) compared with malathion (Fyfanon ULV, Cheminova).

A study that closely compares the recommended aerial application rate of β-cyfluthrin (Baythroid) rate on rangeland, 2.6 fluid ounces in two gallons of water, and a RAATs treatment, 2.08 fluid ounces at 125 ft spacing with the malathion applied at 8 fl oz/acre and 4 oz/acre RAATs treatment.

Objectives:

1. Determine the control efficacy of β-cyfluthrin compared with Malathion in solid and RAATs applications at 2 and 7 days post treatment when applied to rangeland.

2. Examine the cost of the treatments for both the solid and RAATs applications for malathion and β-cyfluthrin.

Materials and Methods

Study Site

The center of the study was located in northwestern Fall River County, South Dakota, approximately 9 miles north and 10.5 miles east of the town of Edgemont on the Mark Tubbs ranch (lat. 43.41, lon. 103.98). The site was selected because of grasshopper diversity, density, age, history of grasshopper problems, and abundance of contiguous grasshopper infested land. This area of South Dakota rangeland can be characterized as a warm-season grassland primarily used for livestock production with less than 10% devoted to dry land wheat and alfalfa.

Treatments and Experimental Design

The Fyfanon ULV formulation of malathion (Cheminova, Inc) was used as the standard treatment against which the the Baythroid XL XL formulation of β-cyfluthrin (Bayer CropScience, LP) was compared. The malathion is a standard treatment applied for grasshopper control by USDA, APHIS, PPQ when the population has aged beyond the stage where diflubenzuron, an insect growth regulator, is considered effective. Treatments were applied in replicated 40 acre plots arranged as a stratified block design based on grasshopper population density. Each block contained all treatments and untreated control for the experimental layout of the 20 plots (Figure 1).

The materials were applied at label rates in both 100% coverage and RAATs. The RAATs was achieved by calibrating the aircraft for 100 ft swath width and then making the application with 125 ft spacing. Standard malathion treatments, 100% coverage and RAATs, 80% coverage, were applied on June 28, and 30 June respectively. β-Cyfluthrin standard treatment was applied on 1 July and the RAATs on 2 and 4 July 2009. Materials were applied at the label recommended field rates. A Cessna Ag Truck owned by the USDA, Animal Plant Health Inspection Service (APHIS) and equipped with winglets (DBA- Ag Tips: Clack Oberholtzer, Alberta, Canada). Winglets reduce the production of fine droplets and improve handling characteristics of the plane which was piloted by, an USDA APHIS pilot. The aircraft was also equipped with differentially corrected guidance and recording system standard and a commercial spraying system. Ground personnel also provided guidance and ensured acceptable operating parameters during application.

Prior to application the aircraft was calibrated to operate under parameters which resulted in delivery of spray within 1% of the label rate per acre. Calibration was accomplished by collecting and measuring the amount of material sprayed

through each nozzle for a predetermined time and making adjustments to the pressure until the target output was achieved. The aircraft was calibrated for a 100 foot swath and flown at 120 mph for all treatments. Stainless steel flat fan 8002 and 8020 spray tips were used for malathion and β-cyfluthrin treatments respectively, Table 1. The malathion was applied as a ultra low volume (ULV) application at 8 oz per acre (0.61 lb ai/ac; 683.7 g ai/ha) and the β-cyfluthrin was applied at 2.6 fl oz per acre (0.0205 lb ai/ac; 22.95 g ai/ha) with water. The RAATs application for the malathion was as specified by the label, 4 fl oz applied at 80 percent coverage (0.30 lb ai/ac; 336.25 g ai/ha) and the β-cyfluthrin was applied at the label rate of 2.6 fl oz and brought up two gallons of water per acre at 80 percent coverage (0.016 lbs ai/ac; 18.38 g ai/ha). This was achieved by increasing the swath width spacing to 125 ft, leaving an indirectly treated strip.

The meteorological conditions recorded during applications are summarized in Table 2. Conditions were favorable during application of all treatments. Figure 2 shows the maximum and minimum temperatures and rainfall recorded from a temporary weather station established in the treated area for the duration of the study.

Sampling Methods

Grasshopper density and species composition sampling followed protocols established by Foster and Reuter, 1996. Grasshopper populations in treated and untreated plots were counted and sampled 1 to 3 days before treatment and at 2 and 7 days after treatment. Untreated control plots were also counted and sampled on any day a treated plot was monitored. Grasshopper densities were determined by counting grasshoppers in (40) 0.1 m^2 rings arranged in an approximate 100 yards diameter circle near the center of each 40 acre plot. Rings were separated from adjacent rings by ca. 5 yards. The abundance of each species was determined from uniform sweep samples taken at each site (Foster and Reuter, 1996). Each sample consisted of 25 high and fast sweeps and 25 low and slow sweeps. Low and slow sweeps performed at ground level insured capture of very young instars and less active grasshopper species while high and fast sweeps performed at the canopy of the vegetation insured capture of older instars and the more active species. Sweep samples were always collected immediately after grasshopper densities had been determined at each site on each visitation. Densities of individual species can be determined by multiplying the frequency of occurrence times the total density of grasshoppers at the same site. After collection, samples were cold stored until they could be sorted and identified in the lab.

Analysis

For the general population, data were expressed as percent survival based on pretreatment counts in the same plot and were adjusted for the natural population change by the method of Connin and Kuitert (1952) using the mean values of the untreated plots on the appropriate day. The adjusted percentage control of the treatment (which takes into account natural changes in the

untreated population) was calculated by the formula 100 (1 – (Ta x Cb)/(Tb x Ca)), where Tb equals the total population of grasshoppers counted before the plot was treated, Ta equals the total counted after treatment, Cb equals the total counted for the check sites before treatment, and Ca equals the total counted for the check sites after treatment. This converts data from percentage mortality to percentage control and accommodates the natural population change to insure against natural mortality and other environmental factors that affect grasshopper counts, which can confound real differences between treatments.

Percentage control data were converted to rank data (Conover and Iman, 1981). An analysis of variance was performed with the Tukey's HSD multiple comparison test used to separate means. All analyses were performed with JMP® 8 (2008) for Windows.

Results and Discussion

Pretreatment densities from individual sites ranged from 28.25 to 51 grasshoppers/m^2 and averaged 39.02 grasshoppers/m^2 in the treated plots and from 29.25 to 58 grasshoppers/m^2 and averaged 42.12 grasshoppers/m^2 in the untreated plots. At the time of treatment the population was composed of 1st instars (0.18%), 2nd instars (1.97%), 3rd instars (7.11%), 4th instars (27.29%), 5th instars (38.69%) and adults (24.77%). The age maturity index was 4.77 which is optimal for the control profile of malathion. The dominant species were *Ageneotettix deorum* (29.38%), *Aulocara elliotti* (23.03%) and *Cordillacris occipitalis* (23.02%), Philbostroma quadrimaculatum (6.05%), *Amphitornus coloradus* (5.94%), *Melanoplus sanguinipes* (5.58%) and *Trachyrhachys kiowa* (3.30%). These seven species represent 96% of the field population. They are primary grass feeders considered to be serious pests in the environment. All species collected are shown in Table 3.

The population density of the untreated plots was stable through the time course of the experiment and is presented in Figure 3. There is a distinct drop in the population on the 30 June 2009 sample date due to high winds, 30 plus mph, gusts to nearly 50 mph, during the sample collection.

Maximum temperatures during the experiment were near seasonal averages, 85 to 88°F, during the sample collections. Rainfall in Edgemont was recorded at 12.94 inches from the first of January through the end of June, which compares with the long term (1971 through 2000) at 9.13 in for the period resulting in very good range grass production. However, the rangeland condition deteriorated due to the heavy grasshopper population that was continuing to develop. When the average density of the four untreated plots is examined over the twelve days of the experiment, it can be seen that the population <u>continues</u> to increase indicating that conditions are favorable for ongoing grasshopper population development through the time course of the experiment.

The analysis of variance on the ranked data was significant at both the two and seven days after treatment (two days, F=8.44; df=3, 9; Prob=0.0055; seven days, F=6.98; df 3, 9; Prob=0.01). The block by treatment interaction term was not significant. Mean separation using the Tukey's HSD in presented in Table 4. The results indicate that the malathion and β-cyfluthrin 100% coverage treatments were not statistically different at two days after treatment 94.5% compared with 91.7%. Statistically there was no difference between the malathion and β-cyfluthrin mortality at seven days after treatment 96.3% versus 86.4% even though the β-cyfluthrin mortality had begun to fall off a bit compared to its two day response. The two and seven day RAATs β-cyfluthrin and malathion treatments resulted in 75.3% and 78.4% control at two days and 76.2 and 72.5 percent control at seven days. Overall the total coverage applications resulted in higher mortality. At the seven day interval analysis, the β-cyfluthrin population control was better than the two RAATs application but not statistically different. These results are similar to those seen elsewhere (Weiland, et al. 2002). They report that pyrethroids have a strong initial effect, but typically have short residuals compared to diflubenzuron.

Cost of Control

An attempt is made to compare the cost of control for the Malathion and β-cyfluthrin and the two application methods using estimates based on available information. The cost per gallon of the malathion is substantially less than the β-cyfluthrin Table 5. A gallon of malathion treats 16 to 40 acres depending on whether it is applied as a solid blanket or as RAATs application while a gallon of β-cyfluthrin treats from 49 to 62 acres depending on the coverage. However, with the β-cyfluthrin, the rangeland label requires two gallons of water be used as the diluent for each acre treated. This becomes problematic on smaller aircraft often used to treat grasshoppers. The load limit for the aircraft used in this experiment is 1800 lb. Two gallons of β-cyfluthrin and 196 gallons of water is enough to treat 98 acres and weighs 1584 lb. Under field conditions of 120 mph and 100 foot swath, the aircraft will cover 24 acres per minute and will be done in about 4 minutes of spray time. At this point the aircraft will have to land, reload before continuing to treat. The process is then repeated until the job is completed. Based on experience, the window for treatment will probably last no more than about 3 hours on any given day. Suppose, that the plane can land and load 3-4 time per hour depending on the ferry distance, one plane may cover 300 to 400 acres in a day. While the same aircraft, if loaded with 150 gallons of malathion (weight 1485 lb), could cover between 2400 and 3200 acres, depending on coverage, 100% or RAATs in a little over an hour and one-half. The analysis also assumes that if large areas are to be treated that the water and transfer equipment will be essentially without cost. This is hard to imagine, if 10,000 acres are to be treated, about 200 gallons of β-cyfluthrin and 20,000 gallons of water will have to be available on site. The pesticide alone will cost $49,000. It would take 625 gallons of malathion and cost $21,875. If RAATs treatment is used, then the cost of material drops to $38,707.00 and only 16,000

gallons of water is needed. For malathion RAATs, only 250 gallons is needed and costs $8,750.

It is easy to see that to become competitive with malathion ULV, the amount of water will have to reduced greatly. Fortunately, the β-cyfluthrin has been registered for a ULV application for other crops including cotton, corn, peanut, sorghum, soybean, sugarcane, sunflower and sweet corn (Anonymous, 2008). This means that the label maybe amended to include 1 quart of oil per acre on rangeland. However, this amount of oil may be a problem and lesser amounts of oil and water or mixes should be explored. If this can't be changed, it will severely limit the amount of rangeland that can be treated with this product.

Conclusions

Ultra low volume (ULV) applications of malathion are not likely to be replaced by β-cyfluthrin until a ULV formulation is included in the β-cyfluthrin label for rangeland grasshopper control. This would reduce the need for water and increase the acres treated by a single load. For example, to treat 640 ac would require 160 gallons of oil and 12.25 gallons of β-cyfluthrin and would require 26.4 minutes of spray time.

ULV formulations already exist for some crops and under the 'grass' portion of the label which includes pasture, rangeland, grass for seed, grass for hay, and grass in mixed-stands with alfalfa for instance that can be treated with no grazing restrictions. It is worth stating that the only pyrethroid registered for rangeland grasshopper control with no grazing or slaughter restrictions is β-cyfluthrin.

With a ULV registration for rangeland applications, one of the next objectives would be to refine the amount of β-cyfluthrin needed to control grasshoppers on rangeland under operational conditions.

Acknowledgements

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Tables and Figures

Table 1. Summary of treatments and calibration parameters.

Treatment	AI oz/ac	Material fl oz/ac	Total fl oz/ac	Nozzle no.	Tip Size	Screen size	Pressure psi	Aricraft speed	Swath width	Percent Coverage
Malathion	7.72 oz	8	8	8	8002	50	40	120	100	100%
"	3.86 oz	4	4	4	8002	50	40	120	125	80%
β-Cyfluthrin	0.328 oz	2.6	256	27	8020	50	40	120	100	100%
"	0.262 oz	2.08	205	27	8020	50	40	120	125	80%

Table 2. Meteorological conditions recorded during aerial applications of treatments in the grasshopper studies near Edgemont, South Dakota, 2009.

				Temperatures ºF.								
	Plot	No.		Time (AM)		Ground		Air		Pilot	Wind (mph)	
Treatment	No.	Passes	Date	Start	End	Start	End	Start	End		Start	End
Fyfanon ULV Std.	21	13	6/27	5:18	5:30	50	54	55	56	56	1-2 NW	3-4 W
	27, 34[1]	13	6/27	6:25	6:38	55	56	55	58	56	1-2	3-Feb
	40	13	6/27	6:40	6:52	58	60	60	62	59	1-2 W	2-4 W
Fyfanon ULV RAATs	23	10	6/29	5:10	5:17	51	50	55	54	63	1-2 SW	< 1 SW
	25, 28[1]	11	6/29	5:18	5:30	52	52	54	54	63	1-2	1
	30	10	6/29	5:30	5:40	46	45	54	52	62	< 1 SW	< 1 SW
Baythroid XL Std.	38	13	6/30	5:10	5:17	53	54	57	56	60	< 1 SW	< 1 SW
	39	13	6/30	5:44	5:57	54	54	57	57	60	< 1 SW	< 1 SW
	35	13	6/30	6:17	6:35	57	63	59	66	63	1-2 W	1-2 W
	31	13	6/30	6:58	7:12	65	67	66	67	64	2-3 W	2-3 SW
Baythroid XL RAATs	36, 37[1]	11	7/1	6:02	6:14	57	58	58	62	62	1-2 E	< 1 SE
	33	11	7/3	5:22	5:33	63	65	64	67	64	1-2 NW	1-2 NW
	26	11	7/3	5:40	5:51	62	63	64	63	64	1-2 NW	< 1 NW

[1]Adjacent plots treated at the same time.

Table 3. Grasshopper species composition and age structure before treatment near Edgemont, South Dakota, 2009.

	Instar							
Grasshopper species	1	2	3	4	5	Adult	Total	%
Subfamily Gomphocerinae								
Ageneotettix deorum		28	200	1137	721	6	2092	29.38
Amphitornus coloradus			3	83	311	26	423	5.94
Aulocara elliotti			3	148	1014	475	1640	23.03
Aulocara femoratum		1	4	10	3		18	0.25
Cordillacris crenulata				11	17		28	0.39
Cordillacris occipitalis				12	423	1204	1639	23.02
Eritettix simplex						1	1	0.01
Mermiria bivittata		1	1	4			6	0.08
Opeia obscura	1	22	22	17			62	0.87
Phlibostroma quadrimaculatum	9	42	86	224	70		431	6.05
Psoloessa delicatula						4	4	0.06
Subfamily Melanoplinae								
Melanoplus bowditchi			2	3	1		6	0.08
Melanoplus confusus						33	33	0.46
Melanoplus infantilis		2	14	10	5		31	0.44
Melanoplus occidentalis					3	3	6	0.08
Melanoplus packardii		1	2	4	1		8	0.11
Melanoplus sanguinipes		35	126	132	99	5	397	5.58
Phoetaliotes nebrascensis			1				1	0.01
Subfamily Oedipodinae								
Hadrotettix trifasciatus		1	2	8	3		14	0.20
Metator pardalinus				8	12		20	0.28
Pardalophora haldemani	2					7	9	0.13
Spharagemon collare		1	2	5	2		10	0.14
Spharagemon equale	1	2	3	1			7	0.10
Trachyrhachys kiowa		4	35	126	70		235	3.30
Totals	13	140	506	1943	2755	1764	7121	
%	0.18	1.97	7.11	27.29	38.69	24.77		

Table 4. Mean percentage mortality of grasshoppers (adjusted for natural mortality) treated with malathion and β-cyfluthrin near Edgemont, South Dakota, 2009.

	Mean % mortality @ indicated days after treatment[1]			
Treatment	2 DAT	Mean separation	7 DAT	Mean separation
Malathion	94.5	a	96.3	a
Baythroid	91.7	a	86.4	a,b
Malathion RAATs	78.4	b	76.2	b
Baythroid XL RAATs	75.2	b	72.5	b

Table 5. Cost to protect an acre using malathion and β-cyfluthrin in either the 100% or RAATs coverage.

Material	Cost per gal	Acres per gal	Diluent per acre	Total Insecticide + Diluent	Cost of Material per acre protected
Malathion	$35.00	16	none	1 gal	$2.19
Malathion RAATS	$35.00	40	none	1 gal	$0.88
Beta Cyfluthrin	$245.00	49	2 gal H_2O	98 gal	$5.00
Beta Cyfluthrin RAATS	$245.00	61	2 gal H_2O	122 gal	$4.02

β-Cyfluthrin Standard	β-Cyfluthrin RAATs	Untreated Check	β-Cyfluthrin Standard	Malathion RAATs	Untreated Check	X
β-Cyfluthrin Standard	β-Cyfluthrin RAATs	β-Cyfluthrin RAATs	Malathion RAATs	Malathion RAATs	Untreated Check	Malathion Standard
Malathion Standard	β-Cyfluthrin Standard	Malathion Standard	Malathion Standard	β-Cyfluthrin RAATs	Malathion RAATs	Untreated Check

N

Figure 1. Arrangement of treatments in the study area near Edgemont, South Dakota, 2009.

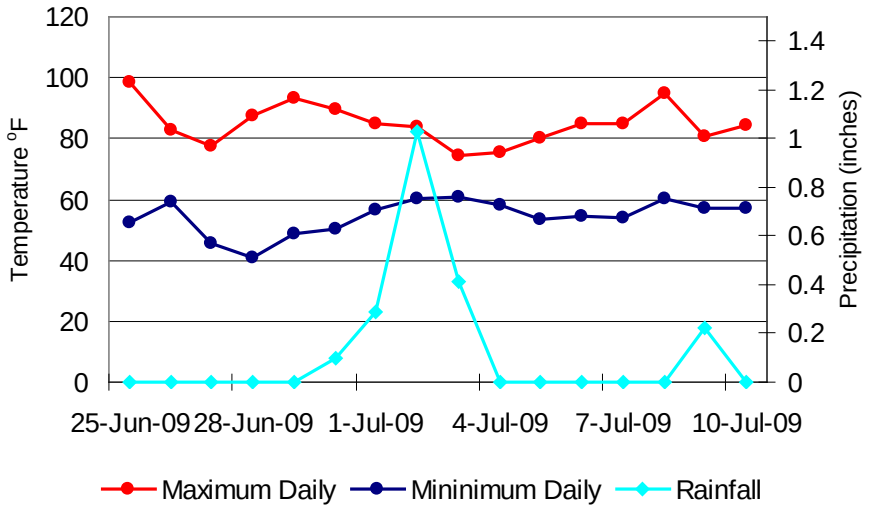

Figure 2. Maximum and minimum temperatures and precipitation recorded at the study site near Edgemont, South Dakota, 2009.

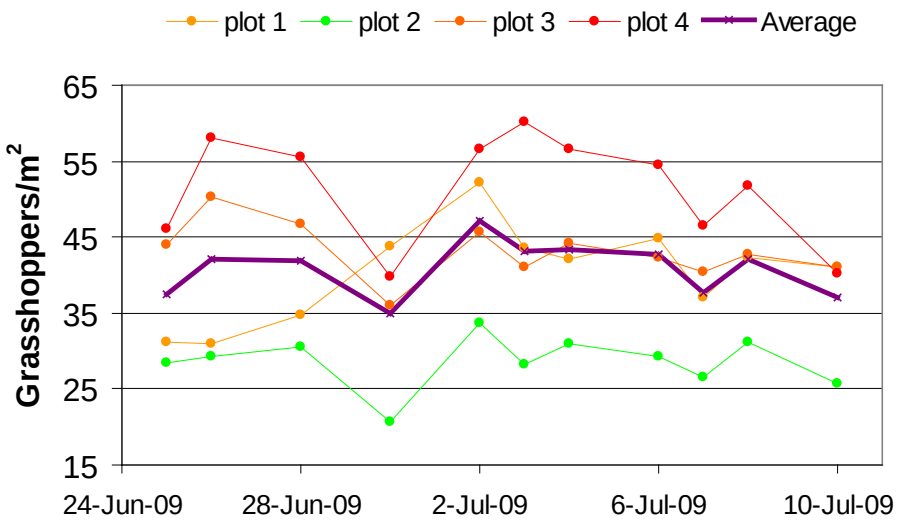

Figure 3. Grasshopper densities in four untreated plots included in the experimental design near Edgemont, South Dakota 2009.

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Further development / Advances in replacing traditional volumes of oil and water in ULV diflubenzuron sprays with alternative diluent mixes for rangeland grasshoppers

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Abstract

Aerially applied experimental treatments containing selected ratios of Dimilin, In-Place and water and the standard Dimilin, oil and water mix resulted in statistically equivalent control of grasshoppers on rangeland. All mortality values were significantly higher than occurred in untreated populations at 7, 14 and 21 days after treatment. Field efficacy was considered clearly acceptable. Treatments containing three-fourths to one fl oz/acre of Dimilin and 1/3 fl oz of In-Place applied in water at a total volume/acre of 12 fl oz/acre produced 92% to 94% mortality at 3 weeks after treatment compared to the standard Dimilin treatment applied in a total volume mix of 31 fl oz/acre which resulted in 91% mortality during the same period. Clean-up problems did not occur. However, a substantial amount of precipitation remained in the aircraft hopper after the draining and clean up phases. The reason for formation and the composition of the precipitation is currently unknown.

Introduction

Diflubenzuron, in the Dimilin 2L formulation, has been an ULV option for the USDA APHIS sponsored grasshopper management program since 2000 (Foster et al. 2000; USDA 2002). It was originally applied at 31 total fluid oz (one fl oz Dimilin 2L plus 10 fl oz oil and 20 fl oz water) per treated acre in traditional and RAATS applications (Foster et al. 2001). Since the original registration, mixes of this formulation have evolved to include vegetable oil, paraffinic oil or combinations of both in various ratios. While this flexibility has facilitated greater use, the accompanying inherent complications should be considered. Depending on the brand and/or oil type, different diluents or diluent mixes can exhibit different specific gravities, and flow characteristics that effect equipment calibration. The type of emulsifier used in the preparations can also affect specific gravity, flow characteristics and calibration.

The current label has been modified to allow for lower total volume per acre applications. In ULV applications the label now allows total volumes of at least 12 – 32 fl. oz per acre but requires at least 4 fl oz of emulsified vegetable or paraffinic crop oil per acre, with at least two parts of water for each part of oil. Obviously, the wide range in total per acre diluent use can impact the economics of the treatment. The higher total volume occupies more space in an aircraft hopper (less acres treated per load compared to lower volume treatments) and requires more mixing time. Additionally, more oil increases the diluent cost and mixes of oils can complicate calibration of equipment because various oils and emulsifying agents may require different application parameters.

Initial studies conducted with two selected mixes of Dimilin 2l, water and In-Place (a deposition and drift management agent envisioned to replace the oil requirement and purported to encapsulate the active ingredient to reduce evaporation and thus increases deposition.) and water resulted in excellent field efficacy (Foster et al. 2008). However, precipitation in the aircraft tank and some difficulty in post application clean up was of substantial magnitude to cause concerns.

In an attempt to prevent these problems and to simplify and standardize the pre-spray mixing and calibration of diflubenzuron spray treatments while improving the economics of diluting materials used in low volume applications for control of rangeland grasshoppers, the following study was conducted.

Objectives

1. Improve the economics of the diluting materials used in diflubenzuron spray mixes.
2. Simplify pre-spray mixing by reducing types and volumes of diluents used with a consistent standard.
3. Simplify calibration by replacing different types and brands of oil diluents (vegetable and paraffinic) and emulsifying agents with a consistent standard.
4. Solve previous precipitation and clean up problems experienced with experimental Dimilin, In-Place (a deposition and drift management agent purported to encapsulate

the active ingredient to reduce evaporation and thus increases deposition.) and water mixes.

5. Specifically, compare three selected ratios of Dimilin 2L, In-Place and water mixes for ease of use and efficacy.
6. Specifically compare experimental, In-Place and water diluent mixes with the traditional Dimilin 2L treatment mix for field efficacy.

Materials and Methods

Study Site

The study was conducted in Fall River County of southwestern South Dakota ca. 6 miles north and 7 miles west of the town of Edgemont on the Mark Tubbs ranch during the period of June 19 - July 15, 2009. The location was selected because of the diversity in grasshopper species and grasses, density of grasshoppers, history of grasshoppers in the area, better than average range condition, contiguous rangeland suitable for aerially applied replicated plot studies and proximity to another proposed study.

Treatments and Experimental Design

The Dimilin 2L formulation of diflubenzuron (Chemtura Corp) was used in all spray treatments studied. The specific treatments were: (1) 0.75 fl oz of Dimilin 2L plus 0.33 fl oz of In-Place, (deposition and drift management agent – Wilbur Ellis Company) plus 10.92 fl oz of water/acre equaling a total volume of 12 fl oz/ acre and **termed (¾ Dim 1/3 IP, 12 TV)** (2) one fl oz of Dimilin 2L plus 0.33 fl oz of In-Place plus 10.67 fluid oz water/acre equaling a total volume of 12 fl oz/ acre and **termed (1 Dim, 1/3 IP, 12 TV)** (3) one fl oz Dimilin plus one fl oz In-Place plus 29 fl oz water/acre equaling a total volume of 31 fl oz acre and **termed (1 Dim, 1 IP, 31 TV)** and (4) one fl oz of Dimilin 2L plus 10 fluid oz of oil (Ferti-Oil - Compton Ag Services LLC, Casa Grande, Arizona) plus 20 fl oz water/acre equaling a total volume of 31 fl oz/ acre and **termed (1 Dim, 31TV)** (the standard Dimilin treatment currently used in APHIS sponsored grasshopper programs).

All treatments were aerially applied at 100% coverage to square 40 acre grasshopper infested rangeland plots and were replicated four times. Four untreated plots were included in the experimental design for comparison. The replicated study consisted of 20 forty acre plots. To insure that any one treatment was not assigned exclusively to plots with high or low grasshopper densities and that all treatments were tested against similar population densities, pretreatment counts were arranged in descending order and divided into groups of four. Subsequently, each of the 5 treatments, including the untreated control, was randomly assigned to one of the four plots within each group **(Figure 1).**

The treatments applied at a total volume per acre of 12 fl oz (1 Dim, 1/3 IP, 12 TV) and 3/4 Dim, 1/3 IP, 12 and were applied on June 21 and 22 respectively. The high total volume per acre treatment containing In-Place (1 Dim, 1 IP, 31 TV) was applied on June 22. The standard treatment (I Dim, 31 TV) was applied over a two day period due to excessive winds to one plot on June 23 and 3 plots on June 24. All treatments were

applied with a Cessna Ag Truck owned by the USDA, Animal and Plant Health Inspection Service (APHIS) and equipped with winglets (DBA- Ag Tips: Clack Oberholtzer, Alberta, Canada). Winglets are added to spray aircraft to reduce the production of fine droplets and to improve handling characteristics. The aircraft was operated by a USDA – APHIS pilot **(Figure 2).** The aircraft was equipped with a standard commercial spraying system and differentially corrected guidance and recording system (Figure 1). Ground personnel also provided guidance and ensured acceptable operating parameters during application. All applications occurred from an altitude of 30 to 40 feet. Prior to application the aircraft spray system was calibrated to operate under parameters which resulted in delivery of spray within 1% of the desired rate per acre. Calibration was accomplished by collecting and measuring the amount of material sprayed through each nozzle for a predetermined amount of time, and making adjustments in pressure until the desired output was achieved. The aircraft was calibrated for a 75 feet wide swath and operated at 120 mph for all treatments.

The specific mix, total volume applied per acre, number of nozzles, nozzle screen size, nozzle tip size, boom pressure, aircraft speed, and swath width used for each of the 4 different treatments is summarized in **Table 1**. Winds during application ranged from <1 to 5 mph and averaged 2.2 mph. Ground temperatures did not exceed air temperatures (taken by ground personnel) at any time during applications. Other meteorological conditions recorded during application are summarized in **Table 2**. The precipitation and daily minimum and maximum temperatures recorded by a temporary weather station established in the treated area for the duration of the study are shown in **Figure 3.**

Sampling Methods

Generally, grasshopper density and species composition sampling followed protocols established by Foster and Reuter, 1996. Grasshopper populations in treated and untreated plots were counted and sampled 1 to 3 days before treatment and at 7, 14 and 21 days after treatment. Untreated control plots were also counted and sampled on any day a treated plot was monitored. Grasshopper densities were determined by counting grasshoppers in (40) 0.1 m^2 rings **(Figure 4)** arranged in an approximate 100 yard diameter circle near the center of each 40 acre plot. Rings were separated from adjacent rings by ca, 5 yards.

The abundance of each species was determined from uniform sweep samples taken at each site (Foster and Reuter, 1996). Each sample consisted of 25 high and fast sweeps and 25 low and slow sweeps. Low and slow sweeps performed at ground level insured capture of very young instars and less active grasshopper species while high and fast sweeps performed at the canopy of the vegetation insured capture of older instars and the more active species. Sweep samples were always collected immediately after grasshopper densities had been determined at each site on each visitation. Densities of individual species can be determined by multiplying the frequency of occurrence times the total density of grasshoppers at the same site. After collection, samples were cold stored until they could be sorted and identified in the lab.

Analysis

For the general population, data were expressed as percent mortality based on pretreatment counts in the same plot and were analyzed as such. Additionally, prior to analysis, data was adjusted for the natural population change by the method of Connin and Kuitert (1952) by using the mean values of the untreated plots on the appropriate day. This allowed for converting data from percentage mortality to percentage control and accommodated the natural population change to insure against natural mortality and other environmental factors that affect grasshopper counts, which can confound real differences between treatments.

The adjusted percentage control of the treatment (which takes into account natural changes in the untreated population) was calculated by the formula 100 (1 – Ta x Cb/Tb x Ca), where Tb equals the total population of grasshoppers counted before the plot was treated, Ta equals the total counted after treatment, Cb equals the total counted for the check sites before treatment, and Ca equals the total counted for the check sites after treatment.

An analysis of variance was performed with the Tukey's HSD multiple comparison test used to separate means. All analyses were performed with Systat 6.1 For Windows.

Results and Discussion

Pretreatment densities from individual sites ranged from 13.5 to 49.0 and averaged 33.69 grasshoppers/m^2 in the treated plots and from 26.0 to 62.5 and averaged 37.0 grasshoppers/m^2 in the untreated plots. At the time of treatment the population was composed of 1st instars (2.3 %), 2th instars (10.5 %), 3th instars (31.5 %), 4th instars (32.7 %), 5th instars (21.0 %), and adults (2.1 %). The total average instar age or population maturity index was 3.658, between third and fourth instar. The age mixture is considered to be very realistic of an ideally timed program treatment. The six most dominant species were *Ageneotettix deorum* (34.9 %), *Cordillacris occipitalis* (17.2 %), *Aulocara elliotti* (11.5 %), *Melanoplus sanguinipes* (8.8 %), *Amphitornus coloradus* (8.3 %), and *Trachyrhachys kiowa* (7.2 %). The relative abundance of all species in pretreatment samples is shown in **Table 3**.

Population densities of the four untreated plots are shown in **Figure 5.** Two dropped slightly and one remained relatively unchanged during the study. However, one dropped unexpectedly. It is noted that grass in this plot appeared to be grazed by both grasshoppers and cattle more than other plots and could explain some grasshopper movement due to decreasing vegetation and high grasshopper densities. Additionally, the movement of cattle, particularly high numbers, within a plot may also effect density estimates. It is also noted that this plot may have received some drift of pesticide from an adjacent treatment. When treatment began on an adjacent plot wind increased in speed after five passes and application was discontinued until the next day when wind speed was acceptable. For these reasons analysis was conducted on two sets of data. One including the unexpected control plot and another excluding that data.

All treatments produced reductions significantly greater than occurred in untreated populations in analysis with all four untreated plots **(Table 4)** or excluding one questionable untreated plot **(Table 5).** These reductions were statistically equivalent among all treatments, regardless of the post treatment interval. At 7 days after treatment (DAT), all treatments had reduced populations statistically similarly by 66% to 74%. At 14 DAT, reductions in treated plots increased to 87% to 92%. At 21 DAT reductions remained near those at 14 DAT but numerically increased slightly, 91% to 94%. Untreated populations (excluding the questionable plot) decreased 4%, 9% and 19% at 7, 14 and 21 DAT, respectively, an average of 0.9 % a day during the study. Additional analysis with data adjusted for mortality that occurred in untreated populations showed similar results regardless of using data from 3 or 4 untreated plots**. (Tables 6 and 7).** In summary, the treatments resulted in 89-92% (Dimilin standard 88%) adjusted mortality with an average instar age of 3.658 and 2.06 % adults. The levels of control attained in this study are similar but lower than those obtained in a 1999 study with Dimilin. (Foster et al. 2001). In that study the adjusted mortality was 99% with an average instar age (population maturity index) of 4.06 and 1.83 % adults in the population two days before treatment. Our results wre also slightly lower than those seen in the previous year (Foster et al. 2008). In that study, the adjusted mortality was 95% (Dimilin standard 91%) with an average instar age of 3.496 and 2.00% adults in the population 2 days before treatment. This difference can be seen in more detail when the adjusted mortality from two treatments common to the 2008 and 2009 studies are compared. The 1 DIM,1 IP, 31 TV produced 79, 97 and 95 % mortality at 7, 14 and 21 DAT respectively in 2008 and 67, 91 and 91 % mortality at the same time intervals in this study. The Dimilin standard, 1 DIM, 31 TV, produced 77, 95 and 91 % mortality at 7, 14 and 21 DAT, respectively in 2008 and 68, 87 and 88 % mortality at the same time intervals in this study.

While it appears that there is no difference in mortalities produced with either a total volume of 12 or 31 oz/acre or the addition of one or 1/3 oz of In- Place, major differences were seen during the aircraft hopper clean up phase of application between the standard Dimilin treatment and treatments containing In-Place. As recorded previously (Foster et al. 2008), substantial precipitation and settling of the mix occurred **(Figure 6).** After the aircraft hopper was drained, an ca. ¼ inch thick layer of precipitate remained at the bottom of the hopper which was scraped out and saved for analysis **(Figure 7).** This is troubling since it is unknown if this precipitate contains the active ingredient, other inert ingredients in the formulation, In-Place or minerals in the water. Any of these could have implications for the most effective and economical mix used with Dimilin. If the precipitate contained substantial active ingredient, this could explain the lower mortalities seen in this study and in 2008 (Foster et al. 2008) compared to those mortalities reported earlier (Foster et al 2001).This possibility is supported by the age structure in the three studies. The populations in the most recent studies were actually younger and should have been susceptible to yielding equal or better mortality than occurred in 2001. However, the opposite occurred. The older population in 2001 resulted in a higher resulting mortality after treatment with Dimilin.

Chemical analysis conducted by the Analytical Services Laboratory, South Dakota State University, Brookings South Dakota, revealed that the precipitate was composed of 67.4 percent diflubenzuron. An additional chemical analysis conducted by Middlebury Formulations Group – Chemtura Corp. Middlebury, CT, showed that the precipitate was composed of 75.3% diflubenzuron (wet sample) and 84.8% diflubenzuron (dried sample). This is extremely important and helps explain the lower than expected grasshopper mortality seem in the field.

Clean up of all treatments was not a problem in this study as a power washer was used for final equipment rinse. With a power washer even the precipitate easily washed off of the equipment. This was not the case in the previous study (Foster et al. 2008) when a power washer was not available and normal water pressure was not sufficient for clean up. Wilbur-Ellis representatives indicate that a further reduction in the amount of In-Place and or the minor addition of another adjuvant may solve the precipitation problem.

Only further testing including those conducted under operational conditions will confirm acceptable alternative mixes of Dimilin in terms of mixing and clean up efficiency, field efficacy and treatment economics. Because the composition and cause of the precipitation is unknown at this time, further physical testing of mixes in an aircraft hopper is required. Additionally, after a final mix composition has been determined a large scale efficacy study should be conducted under operational conditions. Completing both of these studies is extremely important because it appears that rangeland grasshoppers are reaching the largest outbreak numbers in much of the western Unites States since 1985 and 1986 when about 21 million acres of rangeland was treated for grasshoppers in USDA APHIS sponsored control programs (USDA, 2002). Further testing may be additionally warranted because In-Place encapsulates material to reduce evaporation and thus increases deposition, which may lead to further reductions in Dimilin AI requirements and substantial application and chemical costs reductions.

Conclusions

Grasshopper reductions resulting from the standard and experimental Dimilin treatments at 1 to 3 weeks after treatment were statistically similar and significantly greater in treated populations compared to untreated populations. Treatments with In –Place at the low rate, 1/3 oz/acre, performed as well as at the high rate, one oz/acre. Treatments containing 12 fl oz total volume/acre performed as well as the standard and experimental treatments containing 31 fl oz total volume/acre.

In terms of efficacy, both the one fl oz Dimilin plus one-third fl oz In-Place applied in water at a total mix volume of 12 fl oz/acre and the three-fourths fl oz Dimilin plus one-third fl oz In-Place applied in water at a total mix volume of 12 fl oz/acre treatments, appear acceptable. However, it is important to note that both 2008 and 2009 treatments produced sizably less mortality than that seen in the large scale operational scale study in 2000.

Compared to problems experienced in the past with some experimental mixes of Dimilin and In-Place, clean-up at these ratios appears to be without problem if a power washer is available. However, a substantial amount of precipitate remained in the aircraft hopper during the draining and clean up phases. The composition of the precipitate and reason for its formation is currently unknown. The somewhat lower than expected mortality could be explained if the precipitate contains substantial active ingredient thus reducing the amount applied to the field.

Further testing is needed to determine the composition of the precipitation and additional development work is required to prevent its formation. Future testing and development could lead to further reductions in Dimilin AI requirements and substantial application and chemical costs reductions.

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3/4 Dimilin 12	3/4 Dimilin 12	3/4 Dimilin 12	Dimilin 31	Dimilin IP 31
1 Dimilin 12	Untreated	1 Dimilin 12	Dimilin IP 31	Untreated
Dimilin 31	3/4 Dimilin 12	Dimilin IP 31	Dimilin 31	Dimilin 31
1 Dimilin 12	Untreated	Dimilin IP 31	1 Dimilin 12	Untreated

N

Figure 1. Arrangement of treatments in the study area near Edgemont, South Dakota, 2009.

Figure 2. Aerial application of selected experimental mixes of Dimilin and diluents for control of grasshoppers on rangeland near Edgemont, South Dakota, 2009.

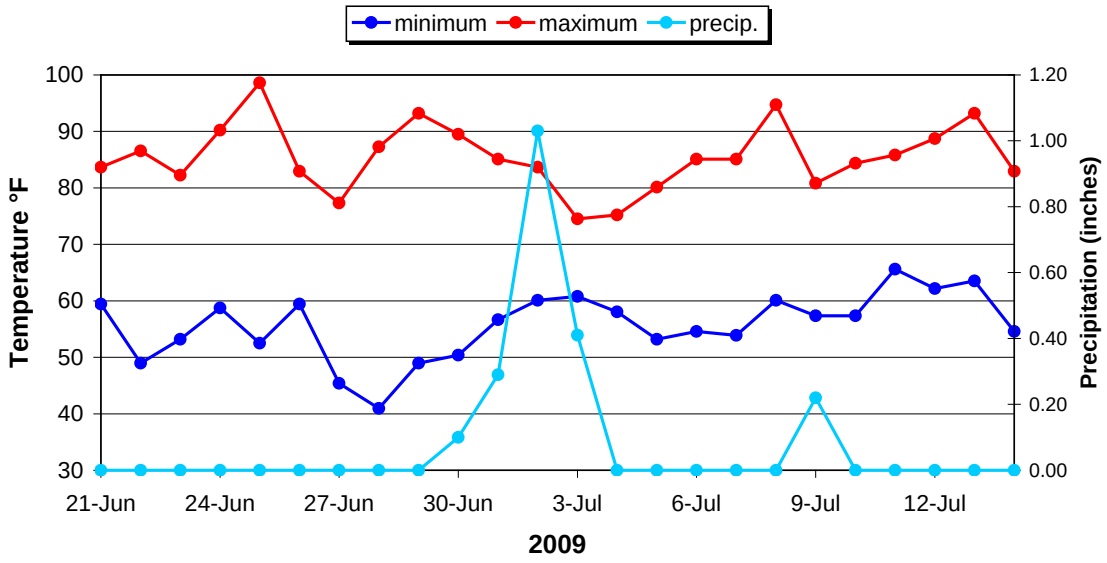

Figure 3. Minimum and maximum temperatures and precipitation recorded at the study site near Edgemont, South Dakota, 2009.

Figure 4. One of forty 0.1 m^2 rings located near the center of each 40 acre plot used to estimate grasshopper densities near Edgemont, South Dakota, 2009.

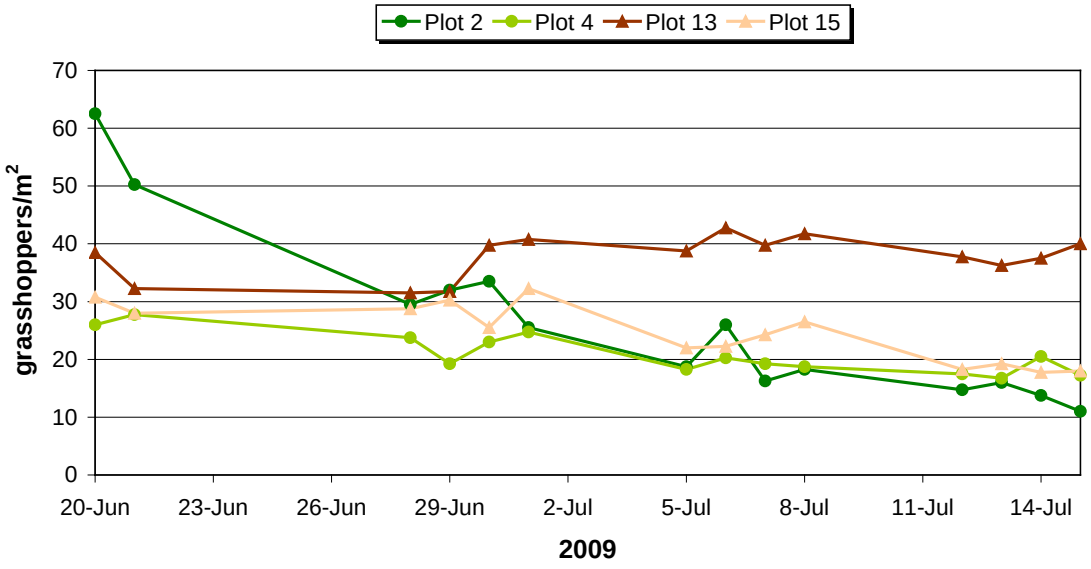

Figure 5. Grasshopper densities in four untreated plots included in the experimental design near Edgemont, South Dakota, 2009.

Figure 6. Unknown precipitate remaining in the aircraft hopper after application.

Figure 7. One-fourth inch thick layer of precipitate remaining at the bottom of the aircraft hopper after application.

Table 1. Summary of treatments and calibration parameters.

Treatment [1] AI/acre	Coverage %	Dimilin 2L fl oz/ac	Diluent [2] fl oz/ac	Diluent fl oz/ac	Total fl oz/ac	Nozzle no.	Tip size	screen size	pressure psi	Aircraft speed	Swath width
0.012 lbs 5.32 g	100	0.75	0.33 In-Place	10.92 water	12	6	8003	50	28	120	75
0.016 lbs 7.09 g	100	1.0	0.33 In-Place	10.67 water	12	6	8003	50	28	120	75
0.016 lbs 7.09 g	100	1.0	1.0 In-Place	29.0 water	31	15	8003	50	30	120	75
0.016 lbs 7.09 g	100	1.0	10.0 Ferti-Oil	20.0 water	31	15	8003	50	28	120	75

[1] Diflubenzuron AI
[2] In-Place is a deposition and drift management agent. Ferti-Oil is a vegetable oil and emulsifier adjuvant.

Table 2. Meteorological conditions recorded during aerial application of treatments in the grasshopper infested rangeland study plots near Edgemont, South Dakota, 2009.

						Temperatures ºF.						
	Plot	No.		Time (AM)		Ground		Air		Pilot	Wind (mph)	
Treatment	No.	Passes	Date	Start	End	Start	End	Start	End		Start	End
1 Dimilin 12	10	15	6/21	5:15	5:29	60	61	62	64	64	1-2 S	2-3 S
	18	16	6/21	5:32	5:47	58	58	64	63	64	2-3 S	< 1 S
	20	16	6/21	5:54	6:09	61	63	64	65	64	1-2 S	1-2 S
	5	15	6/21	6:20	6:35	59	63	63	67	64	1-2 SE	2-3 S
¾ Dimilin 12	14	17	6/22	5:26	5:40	47	48	54	53	57	1-2	1
	9,16,17	16	6/22	5:40	5:57	45	53	52	55	57	0-2 SE	< 1 SE
Dimilin IP 31	7	16	6/22	6:53	7:07	55	60	57	63	59	1-2 NW	2-3 NW
	11,12	18	6/22	7:08	7:28	62	62	63	62	62	2	3
	1	17	6/22	7:30	7:44	59	62	64	67	63	2-3 W	2-3 W
Dimilin 31	8	16	6/23	5:25	5:38	52	50	58	58	57	1-2 SE	3-4 NW
	3,6 [1]	5	6/23	5:42		53		57			1-2	
		12	6/24	5:14	5:25	55	58	60	61	64	2-3	4-5
	19	18	6/24	5:28	5:42	55	56	60	61	64	3-5 S	1-3 SE

[1] Wind speeds in the plots increased to unacceptable levels after 5 passes and spraying was suspended for the day. The plots were completed the next day when conditions were more acceptable.

Table 3. Grasshopper species composition and age structure prior to treatment near Edgemont, South Dakota, 2009.

	Instar							
Species (20-21 June 09)	1	2	3	4	5	Adult	**Total**	%
Gomphocerinae								
Ageneotettix deorum	14	158	1010	716	36		1934	34.93
Amphitornus coloradus			79	324	54		457	8.26
Aulocara elliotti	1	1	34	282	315	6	639	11.54
Aulocara femoratum		2	8	1			11	0.20
Cordillacris crenulata		2	5	37			44	0.79
Cordillacris occipitalis		1	10	164	739	37	951	17.18
Eritettix simplex						3	3	0.05
Mermiria bivittata	6	5	9				20	0.36
Opeia obscura	20	85					105	1.90
Phlibostroma quadrimaculatum	10	118	99	55			282	5.09
Psoloessa delicatula						24	24	0.43
Melanoplinae								
Melanoplus bowditchi		5	8	26	5		44	0.79
Melanoplus confusus						40	40	0.72
Melanoplus gladstoni	6	1					7	0.13
Melanoplus infantilis		8	15	10			33	0.60
Melanoplus packardii		1	3	3			7	0.13
Melanoplus sanguinipes	60	156	146	116	10		488	8.82
Oedipodinae								
Arphia conspersa						2	2	0.04
Arphia pseudonietana		2					2	0.04
Hadrotettix trifasciatus			3				3	0.05
Metator pardalinus			3	14	1		18	0.33
Pardalophora haldemani						2	2	0.04
Spharagemon collare		4	13				17	0.31
Spharagemon equale	2	2	1				5	0.09
Trachyrhachys kiowa	7	28	299	63	1		398	7.19
Totals	126	579	1745	1811	1161	114	**5536**	
%	2.28	10.46	31.52	32.71	20.97	2.06		

Table 4. Mean percentage mortality of grasshoppers treated with selected diluent mixes of diflubenzuron near Edgemont, South Dakota, 2009 (4 untreated plots included).

	Mean % mortality @ indicated days after treatment [1]		
Treatment	7d	14d	21d
1 Dim, 31 TV	66 a	87 a	91 a
1 Dim, 1 IP, 31 TV	71 a	92 a	93 a
1 Dim, 1/3 IP, 12 TV	74 a	91 a	92 a
¾ Dim, 1/3 IP, 12 TV	66 a	89 a	94 a
Untreated	15 b	24 b	31 b

[1] A one-way analysis of variance was conducted on the primary data. Means in a column followed by the same letter are not significantly different ($P \leq 0.05$) as determined by the Tukey HSD multiple comparison test.

Table 5. Mean percentage mortality of grasshoppers treated with selected diluent mixes of diflubenzuron near Edgemont, South Dakota, 2009 (3 untreated plots included).

	Mean % mortality @ indicated days after treatment [1]		
Treatment	7d	14d	21d
1 Dim, 31 TV	66 a	87 a	91 a
1 Dim, 1 IP, 31 TV	71 a	92 a	93 a
1 Dim, 1/3 IP, 12 TV	74 a	91 a	92 a
¾ Dim, 1/3 IP, 12 TV	66 a	89 a	94 a
Untreated	4 b	9 b	19 b

[1] A one-way analysis of variance was conducted on the primary data. Means in a column followed by the same letter are not significantly different ($P \leq 0.05$) as determined by the Tukey HSD multiple comparison test.

Table 6. Mean percentage mortality of grasshoppers (adjusted for natural mortality – 4 untreated plots) treated with selected diluent mixes of diflubenzuron near Edgemont, South Dakota, 2009.

	Mean % mortality @ indicated days after treatment [1]		
Treatment	7d	14d	21d
1 Dim, 31 TV	61 a	83 a	84 a
1 Dim, 1 IP, 31 TV	63 a	90 a	88 a
1 Dim, 1/3 IP, 12 TV	63 a	86 a	85 a
¾ Dim, 1/3 IP, 12 TV	53 a	84 a	90 a

[1] A one-way analysis of variance was conducted on the adjusted data. Means in a column followed by the same letter are not significantly different ($P \leq 0.05$) as determined by the Tukey HSD multiple comparison test.

Table 7. Mean percentage mortality of grasshoppers (adjusted for natural mortality – 3 untreated plots) treated with selected diluent mixes of diflubenzuron near Edgemont, South Dakota, 2009.

	Mean % mortality @ indicated days after treatment [1]		
Treatment	7d	14d	21d
1 Dim, 31 TV	68 a	87 a	88 a
1 Dim, 1 IP, 31 TV	67 a	91 a	91 a
1 Dim, 1/3 IP, 12 TV	70 a	90 a	89 a
¾ Dim, 1/3 IP, 12 TV	60 a	88 a	92 a

[1] A one-way analysis of variance was conducted on the adjusted data. Means in a column followed by the same letter are not significantly different ($P \leq 0.05$) as determined by the Tukey HSD multiple comparison test.

Comparison of the USDA, APHIS, PPQ Standard 80° with a 40° Flat Fan Nozzle Tip for Control of Rangeland Grasshopper

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Abstract

The aerial application industry has moved toward clusters of nozzle tips that allow quick changes from one nozzle tip type to another, however, the focus has shifted from the 80° flat fan tip to a 40° flat fan tip. Revisions of the USDA, APHIS, PPQ aerial application equipment statement of work to meet these current industry trends requires field tests. Trials comparing 80° flat fan nozzle to 40° flat fan nozzle were conducted using low dose low-volume (0.75 fl oz / ac 13 fl oz total volume) diflubenzuron (Dimilin®) applications. The 40° flat fan tip is touted as producing fewer 'fines', a small component of the droplets produced, but responsible for much of the 'offsite drift' of the insecticides thought to be a significant source of nontarget mortality. The mortality following application with the 80° and 40° tips was not significantly different 96 versus 89 percent corrected mortality respectively. The 40° flat fan tips as tested, had slight burrs that may have distorted the droplet pattern and produced excess fines.

Introduction

Aerial pesticide application began in 1921 when insecticidal dusts were applied to control an outbreak of cotton leaf worm (Giles 2008). Originally, aircraft were used for quick application of insecticidal dusts from crude hoppers modified to spread dust through sliding gates, initially with hand driven and later air driven feeders. From this beginning, their use continued to expand. Today as the application technology evolves, the use of aircraft for rangeland grasshopper control has kept pace and the current recommendations can be found in Aerial Application Manual (2006). Although USDA, APHIS, PPQ specifies that an eighty degree flat fan nozzle be used to make pesticide applications on rangeland grasshopper and Mormon cricket control programs many private applicators have expressed a desire to use other nozzles that are touted to perform better, easier to change and more popular than the specified in the statement of work (SOW).

Efforts to be more flexible will require field testing of the new designs under program conditions. When looking at the types of nozzles available, it is possible to get lost in a bewildering array of products that offer many choices. Nozzle selection has been reviewed and the specified 80° flat fan nozzle has been repeatedly tested and used in control programs with few problems. Familiarity with conditions during application, aircraft setup and calibration are well established and can be conducted with a minimum of time and a few simple items readily available. The use of nozzle other than the specified 80° flat fan will require some testing and development of additional guidelines that will outline calibration and govern their use on programs.

The 40° flat fan tip was chosen as one of the first nozzle to test because the droplet spectra is supposed to produce fewer small droplets whose diameter is measured in micrometers (µm), is less than ten percent of the total volume applied ($D_{v0.1=}$ diameter in µm). At the same time the tip produces fewer large droplets defined as those with a large diameter, defined as those droplets such that 90% of the droplet are smaller than X µm ($D_{v0.9=}$ diameter in µm). A third droplet category is used to describe the median size of droplet ($D_{v0.5=}$ diameter in µm) that provides the median droplet size based on the physical characteristics of the material applied. Using these three dimensions it is possible to describe how much of the material is likely to drift and how much is deposited. Large droplets fall rapidly while small droplets remain suspended in the air column. So, for instance, a high number of large droplets would limit the total number of treated spots available, while a high number of small droplets would allow substantial time for movement off target. Therefore, the best solution would be to a high number of droplets that are likely to remain on target and provide a large number of the droplets that contain an appropriate amount of active ingredient leading to increased mortality.

The following study was designed to compare a 40° flat fan nozzle tip to the standard 80° flat fan tip. Since the mix of insecticide, adjuvants and equipment can interact in many different ways; comparisons are essentially unique and limited to the mix of materials specified, speed of the aircraft, direction of the nozzle in the air stream, characteristics of the chosen nozzle and conditions during tests. Differences in deposition may vary and change if another mix or setup is used. Deposition of the insecticide was evaluated by using a low dose of Dimilin 2L® (diflubenzuron) at 0.75 fl oz with 0.4 fl oz of paraffinic oils and 3.4 fl oz vegetable oil brought up to a total of 13 fl. oz water per acre and were applied to a mixed population of grasshoppers near Edgemont, SD in late June 2010. The 80 and 40° flat fan nozzles tips are designed to produce the same flow rate and any difference will be due to the spray droplet spectra produced. The results were assessed by monitoring population mortality rather than directly quantifying the deposition of diflubenzuron.

Objectives:

To compare 40° flat fan nozzle tips with the standard 80° flat fan nozzle tips specified in the SOW by applying diflubenzuron at a low, but known to perform well, dose and follow mortality of target population of grasshoppers.

To learn how the 40° flat fan nozzle tips performs during calibration for an application.

Methods and Materials

Study Site

The study was conducted in Fall River County of southwestern South Dakota ca. 6 miles north and 7 miles west of the town of Edgemont on the Mark Tubbs ranch during the period of June 27 – July 19, 2010. The location was selected because of the diversity in grasshopper species and grasses, density of grasshoppers, history of grasshoppers in the area, better than average range condition, contiguous rangeland suitable for aerially applied plot studies and proximity to several other ongoing studies. The center point for the plots was latitude 43.404 longitude -104.036.

Treatments and Experimental Design

The insecticide used was diflubenzuron applied at 0.75 fl oz / acre, 0.6 fl oz paraffinic oil, 3.4 fl oz vegetable oil and brought up to a total volume of 13 fl oz. Six T-Jet® SS-8003 80° flat fan stainless steel tips, sold by Tee-Jet Technologies, (Wheaton Facility, P.O. Box 7900, Wheaton, IL 60187 USA) previously calibrated for another trial were used to make the first application. The aircraft was then reconfigured with the 4003 flat fan stainless tips manufactured by UniJet® (RELAB, Changan town Dongguan City Guangdong Province, P. R. China) and sold by Industrial Spray Systems. See Table 1 for calibration parameters.

The treatment was aerially applied using RAATs coverage on June 28, 2010 to replicated 40 ac plots of grasshopper infested rangeland with a Cessna Ag Truck owned by the USDA, Animal and Plant Health Inspection Service (APHIS) and equipped with winglets (DBA- Ag Tips: Clack Oberholtzer, Alberta, Canada). Winglets are added to the aircraft to reduce the production of fine droplets and to improve aircraft handling characteristics. The aircraft was operated by a USDA – APHIS pilot and was equipped with a standard commercial spraying system and differentially corrected guidance and recording system. Ground personnel also provided guidance and ensured acceptable operating parameters, wind and temperature regimes, during application. Oil sensitive dye cards (used to check deposition, developed by CIBA-GEIGY and sold through TeeJet by Spraying Systems, Wheaton, IL 60188) were placed in the field on the north edge of the ring sites. The numbered cards were set sensitive side up, at canopy level and position recorded with a GPS unit. The spacing was 15 ft (5 m) apart to assure that they were treated during the application. Analysis of the card was carried out using a business card reader **(**NeatReceipts® Neat Business Cards Mobile Full Color Card Reader/Scanner, The Neat Company). The cards were then analyzed using a program developed by Zhu (2009) for measuring the impact of droplets treated during applications of herbicides and comparing the field result with results obtained by Kirk (2007).

Prior to application the aircraft spray system was calibrated to operate under parameters which resulted in delivery of spray within 1% of the desired rate per acre. Calibration was accomplished by collecting and measuring the amount of material sprayed through each nozzle for a predetermined amount of time, and making adjustments in pressure until the desired output was achieved. The aircraft was equipped with 6, 8003 or 6, 4003 stainless steel flat fan spray tips operating at 32 psi. The aircraft was calibrated for a 75 feet wide swath and operated at 120 mph at an altitude of 30 feet during treatment. On application, the aircraft flew a 150 ft swath spacing for RAATs and was calibrated to deliver the same amounts of active ingredient and adjuvants.

Meteorological conditions at the time of application were recorded by field observers and the pilot and are presented in Table 2. Conditions were favorable throughout the applications. Figure 1 shows the maximum and minimum temperatures and rainfall recorded from a temporary weather station established in the treated area for the duration of the study.

Sampling Methods

The replicated 40 acre plots were sampled according to protocols established by Foster and Reuter, 1996. Grasshopper populations in treated and untreated plots were counted and sampled 1 to 3 days before treatment, there after every seven (7) for 21 days. Corresponding check samples were taken when treated plot was sampled. Grasshopper densities were determined by counting grasshoppers in (40) 0.1 m^2 rings arranged in an approximate 100 yards diameter circle near the center of each 40 acre plot. Rings were separated from adjacent rings by ca. 15 feet (5 m). The abundance of each species was determined from uniform sweep samples taken at each site. Each sample consisted of 50 high and fast sweeps and 50 low and slow sweeps. Low and slow sweeps performed at ground level insured capture of very young instars and less active grasshopper species while high and fast sweeps performed at the canopy of the vegetation insured capture of older instars and the more active species. Sweep samples were always collected immediately after grasshopper densities had been determined at each site on each visit. Densities of individual species can be determined by multiplying the frequency of occurrence times the total density of grasshoppers at the same site. After collection, samples were frozen and stored until they could be sorted and identified in the lab.

Analysis

For the general population, data were expressed as percent survival based on pretreatment counts in the same plot and were adjusted for the natural population change by the method of Connin and Kuitert (1952) using the mean values of the untreated plots on the appropriate day. The adjusted percentage control of the treatment (which takes into account natural changes in the untreated population) was calculated by the formula 100 X (1 – (Ta x Cb/Tb x Ca)), where Tb equals the total population of grasshoppers counted before the plot was treated, Ta equals the total counted after treatment, Cb equals the total counted for the check sites before treatment, and Ca equals the total counted for the check sites after treatment. This converts data from percentage mortality to percentage control and accommodates the natural population change to insure against natural mortality and other environmental factors that affect grasshopper counts, which can confound real differences between treatments. All analyses were performed with JMP® 8 (2008) for Windows.

Results and Discussion

Pretreatment densities from individual sites ranged from 7.5 to 20.5 grasshoppers / m^2 and averaged 14.15 grasshoppers / m^2 on all plots. The 80° flat fan tips plots ranged from 8.5 to 20.5 grasshoppers / m^2 and the 40° plots ranged from 7.5 to 15.75. The untreated plots ranged from 11.25 to 20.5 grasshoppers / m^2. At the time of treatment the population was composed of 1st instars (0.18%), 2nd instars (1.97%), 3rd instars (7.11%), 4th instars (27.29%), 5th instars (38.69%) and adults (24.77%) see Table 2. The age maturity index was 3.79 optimal for the control profile of diflubenzuron. The dominant species were *Ageneotettix deorum* (32.44%), *Cordillacris occipitalis* (24.42%), *Aulocara elliotti* (16.71%) and *Melanoplus sanguinipes* (14.40%), these four species represent 87.97% of the field precount population captured. The combination of species is common in the Northern Mixed Grass Prairies of Northern Plains and can cause extensive damage at high population densities (Pfadt, 2002).

The temperature regime and rainfall were collected with a field recording thermometer and rain gauge. The results are shown in Figure 1. The average high temperature is 81.4° F and the low is 55.8° F (NOAA, 2010), which is close to the observed mean high temperature 85.0° F and mean low of 53.6° F. There was some precipitation, enough to continue forage growth which maintains grasshopper population in good condition as indicated by the population on the check plots. Over the 22 days of trial, the population of grasshoppers in the check plots averaged 15.63 grashopper / m^2 and ranged from 14.5 to 16.9 grashopper / m^2 (Figure 2).

Analysis of the grashoppers / m^2 following treatment indicates a strong response to the treatments see Figure 3. The two treated populations are significantly different than the untreated plots (Model df=3, error df=44, F=12.4866 P<.0001*). This was not unexpected, the real question is was there a difference between the two nozzle tips. Using a repeated measures design on the mortality calculated using the following Connin and Kuitert's correction, it was found that there are no detectable differences between the nozzle tips (F Test = 2.2640, df = 1, 5, Prob>F 0.193) see Figure 4. The 40° tip mortality is about 6 percent lower than the other plots. Rep 1 appeared to be low and resulted in reduced overall mortality. The other reps show consistent results. When the data is analyzed using repeated measures on the percent mortality, there is no difference between the tips tested (F Test = 2.2640, df=1, 5 Prob>F 0.1927).

It was expected that the 40° flat fan nozzle tip would provide better control than recorded because the droplet spectrum was supposed to produce fewer small droplets in the <100 µm range and consequently less drift Table 4, and see Figure 5, for a pair of scanned images. Comparing the observed results from the scanned card with the expected parameters from Kirk, 2007, indicates the spectra measured were close. However, the differences were not as dramatic as expected. On closer examination of the nozzle tips, it was determined that the 40° tips had 'burrs' probably due to failure to do a final finish on the tips (Figure 6). It must also be mentioned that the author failed to inspect them closely before use. The burring of the tips was probably enough to disrupt the droplet spectra and obscure any result that may have resulted in greater deposition leading to higher grasshopper mortality. However, the burring on the 40° flat fan nozzle tip was not enough to result in enough fines to cause a failure of the application.

Conclusions

The 0.75 fl oz rate of diflubenzuron (0.75 fl oz / acre , 0.6 fl oz parafininic oil, 3.4 fl oz vegetable oil and applied in a total volume of 13 fl oz) resulted in 96% grasshopper population control with the 80° tip and 89% mortality with the 40° stainless steel flat fan nozzle tip. The standard recommended nozzle has not been improved upon to date. The burrs on the 40° stainless steel flat fan nozzle probably produced more fine droplets than expected. As new nozzle tips are developed experiments will have to be conducted to determine if there are any advances to the technology that improve control or reduce drift off target sites.

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Tables

Table 1. Calibration parameters for the two treatments.

Type	Mfg	Size	Strainer	Mesh	Pressure PSI	Aircraft speed	Calibrated Swath Width	Application Spacing
80 °	TeeJet	8003 SS	Yes	50	32 lbs	120	75 ft	100 ft
40 °	UniJet	4003 SS	Yes	50	32 lbs	120	75 ft	100 ft

Table 2. Meteorological condition at the time of application recorded by field personnel.

						Temperatures ºF.						
	Plot	No.		Time (AM)		Ground		Air		Pilot	Wind (mph)	
Treatment	No.	Passes	Date	Start	End	Start	End	Start	End		Start	End
Dimilin 40°	104	9	28-Jun	4:59	5:10	53	53	55	56	58	1-1.5 NW	< 1 NW
	53	9	28-Jun	5:22	5:30	56	56	58	58	56	< 1 NE	< 1 NE
	35	9	28-Jun	5:32	5:41	56	55	58	56	57	< 1 NE	< 1 NE
	18	9	28-Jun	5:49	6:04	54	57	56	58	58	< 1 W	1-1.5 W
Dimilin 80°	27	9	28-Jun	6:38	6:45	58	60	61	61	*	1-1.5 W	< 1 W
	14	10	28-Jun	6:54	7:02	60	63	61	64	*	1-1.5 W	1-1.5 W
	32	9	28-Jun	7:03	7:12	63	63	64	64	*	1-2 W	1-1.5 W
	12	10	28-Jun	7:17	7:26	63	65	64	67	*	1-2 W	1-1.5 W

* Problem with radio in aircraft, no temperatures were recorded

Table 3. Species and age composition of the plots prior to treatment.

	Instar								Average age
Grasshopper species	1	2	3	4	5	Adult	Total	%	
Subfamily Gomphocerinae									
Ageneotettix deorum		42	235	251	6		534	32.44	3.41
Amphitornus coloradus			13	51	10		74	4.50	3.96
Aulocara elliotti		1	43	159	72		275	16.71	4.10
Cordillacris crenulata			1	1			2	0.12	3.50
Cordillacris occipitalis			11	163	214	14	402	24.42	4.57
Opeia obscura		2					2	0.12	2.00
Phlibostroma quadrimaculatum	3	17	10	3			33	2.00	2.39
Subfamily Melanoplinae									
Melanoplus bowditchi			1				1	0.06	3.00
Melanoplus confusus						12	12	0.73	6.00
Melanoplus gladstoni	2	3					5	0.30	1.60
Melanoplus infantilis		4	7	3			14	0.85	2.93
Melanoplus occidentalis					1		1	0.06	5.00
Melanoplus packardii			3	3	2		8	0.49	3.88
Melanoplus sanguinipes		49	99	79	10		237	14.40	3.21
Phoetaliotes nebrascensis		2					2	0.12	2.00
Subfamily Oedipodinae									
Hadrotettix trifasciatus		10	14				24	1.46	2.58
Pardalophora haldemani						3	3	0.18	6.00
Spharagemon collare		1	2				3	0.18	2.67
Trachyrhachys kiowa			9	5			14	0.85	3.36
Totals	5	131	448	718	315	29	1646		3.79
Percent in each instar	0.3	7.96	27.22	43.62	19.14	1.76			

Table 4. Model results and observed droplet spectra for the 40 (4003 SS FF) tip and 80 (8003 SS FF) degree flat fan nozzle tips operated at 32 psi, 90° into the wind, flown at 120 mph.

Parameter	40° Model		40° Obs		80° Model		80° Obs		Explanation
DV0.1 =	50	µm	88.64	µm	39	µm	65.54	µm	= Droplet size such that 10% of the spray volume is in droplets smaller than $D_{V0.1}$.
DV0.5 =	216	µm	217.60	µm	198	µm	161.31	µm	= Volume median diameter
DV0.9 =	310	µm	268.87	µm	293	µm	208.44	µm	= Droplet size such that 90% of the spray volume is in droplets smaller than $D_{V0.9}$.
RS =	1.25		0.83		1.31		0.89		=Calculated RS
Total Area=			49.98				44.48		
Drops cm^2=			34.13				45.89		

Figures

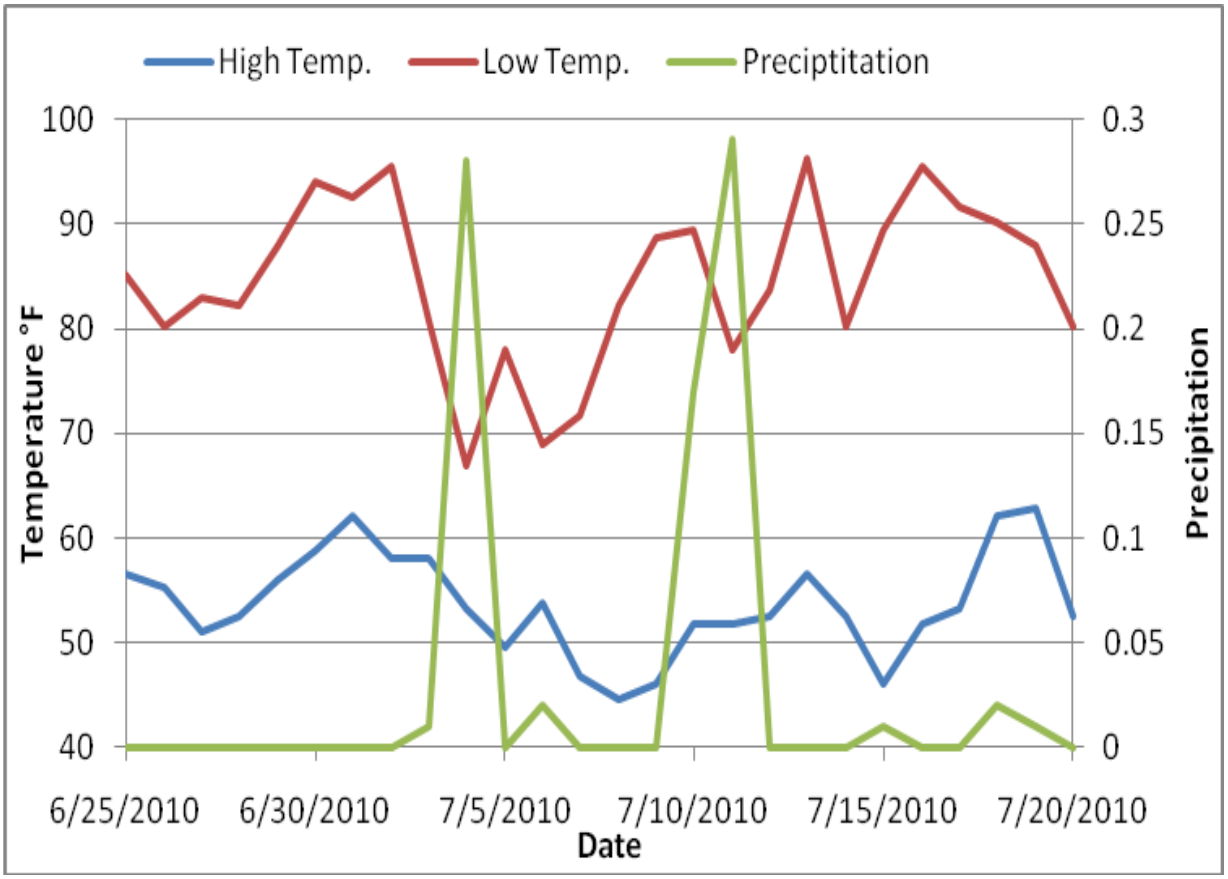

Figure 1. Meteorological conditions through the time course of the trial.

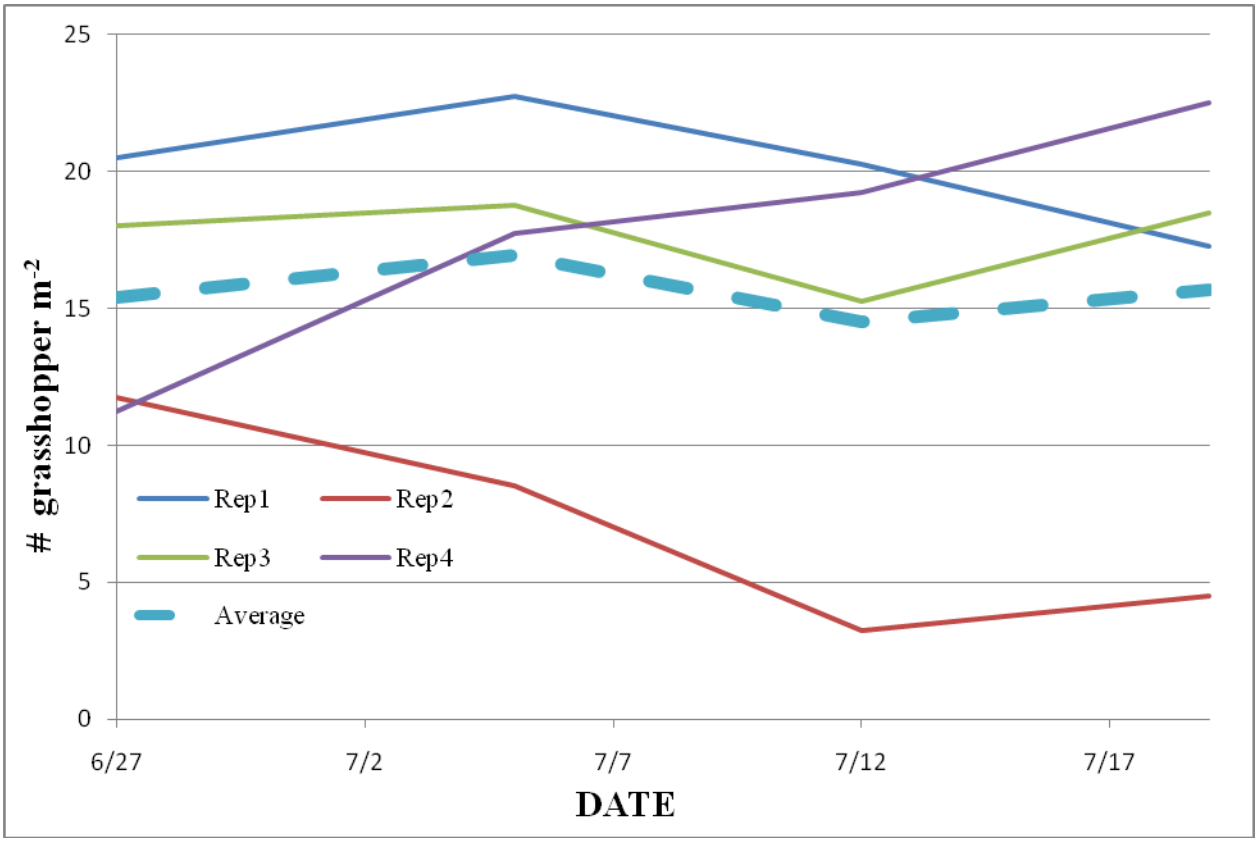

Figure 2. Check plot changes during the course of the trial.

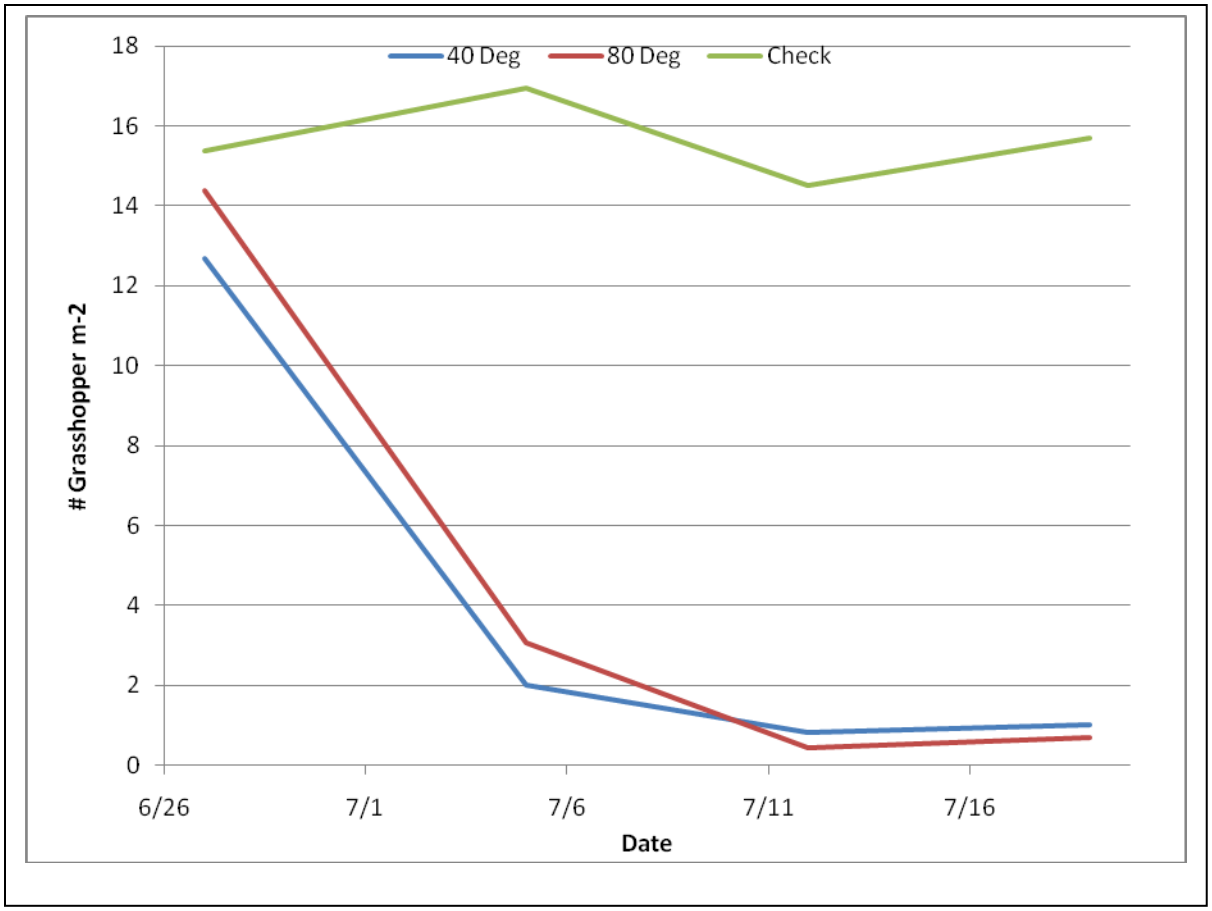

Figure 3. Changes in grasshopper density following treatment with 80° and 40° stainless steel flat fan nozzles 0.75 fl oz with 0.4 fl oz of paraffinic oils and 3.4 fl oz vegetable oil brought up to a total of 13 fl. oz water per acre. The check plot was significantly different than the treated plots.

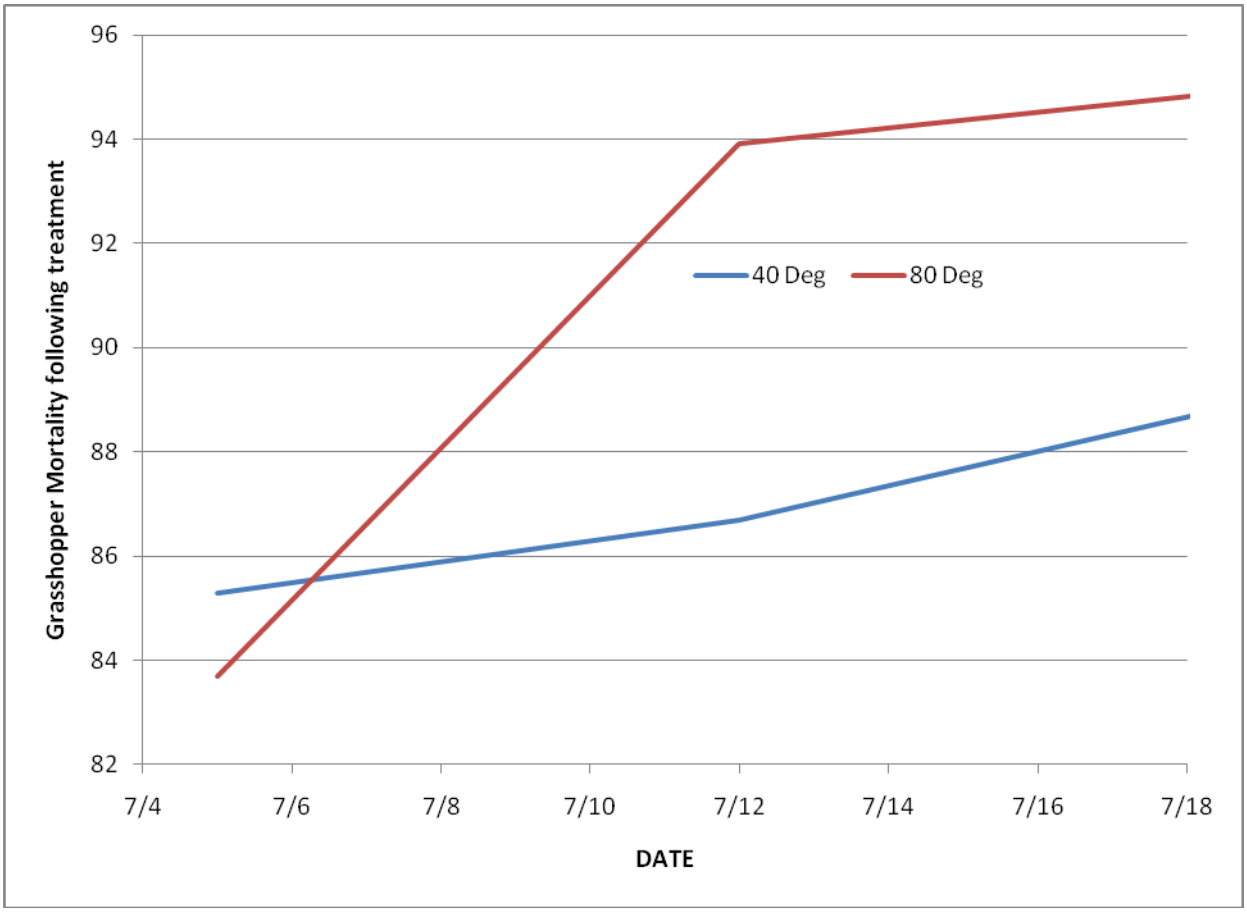

Figure 4. Percent mortality following treatment with statandard 80° stainless steel flat fan nozzles compared with 40° stainless steel flat fan nozzles applying dimilin at 0.75 fl oz in 13 fl oz total volume.

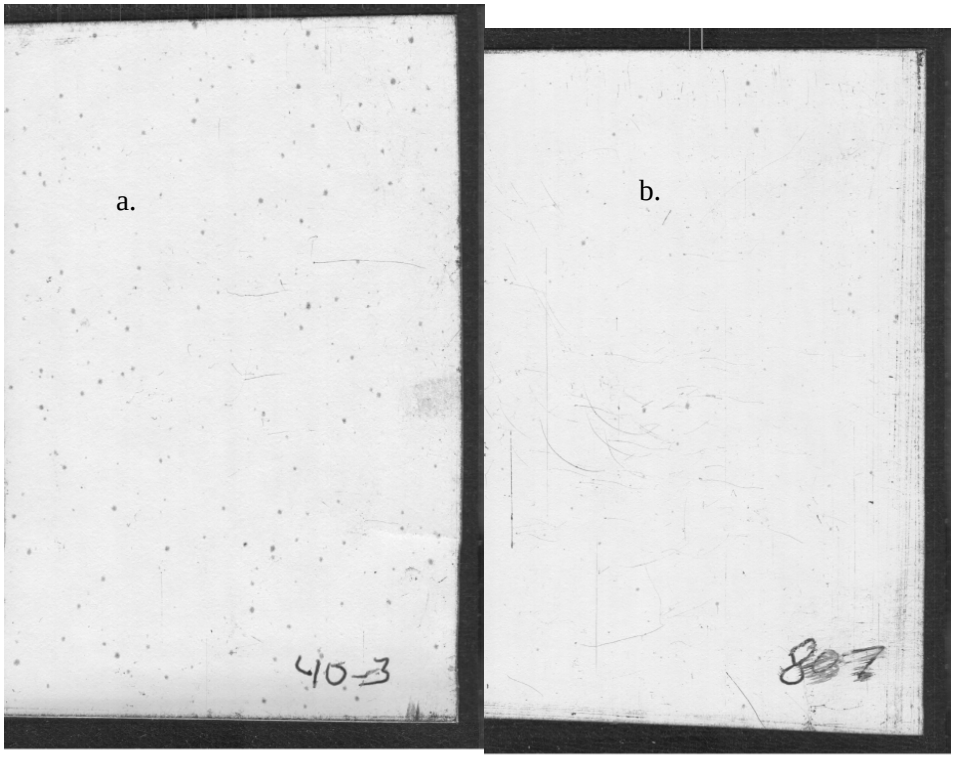

Figure 5. Card, exposed to diflubenzuron aerial treatment. The 40° card is labeled “a.” and the 80° card is labeled “b.” The “a” card appears to have more droplets than the “b” card even though analysis of areas selected to exclude scratches, showed no differences.

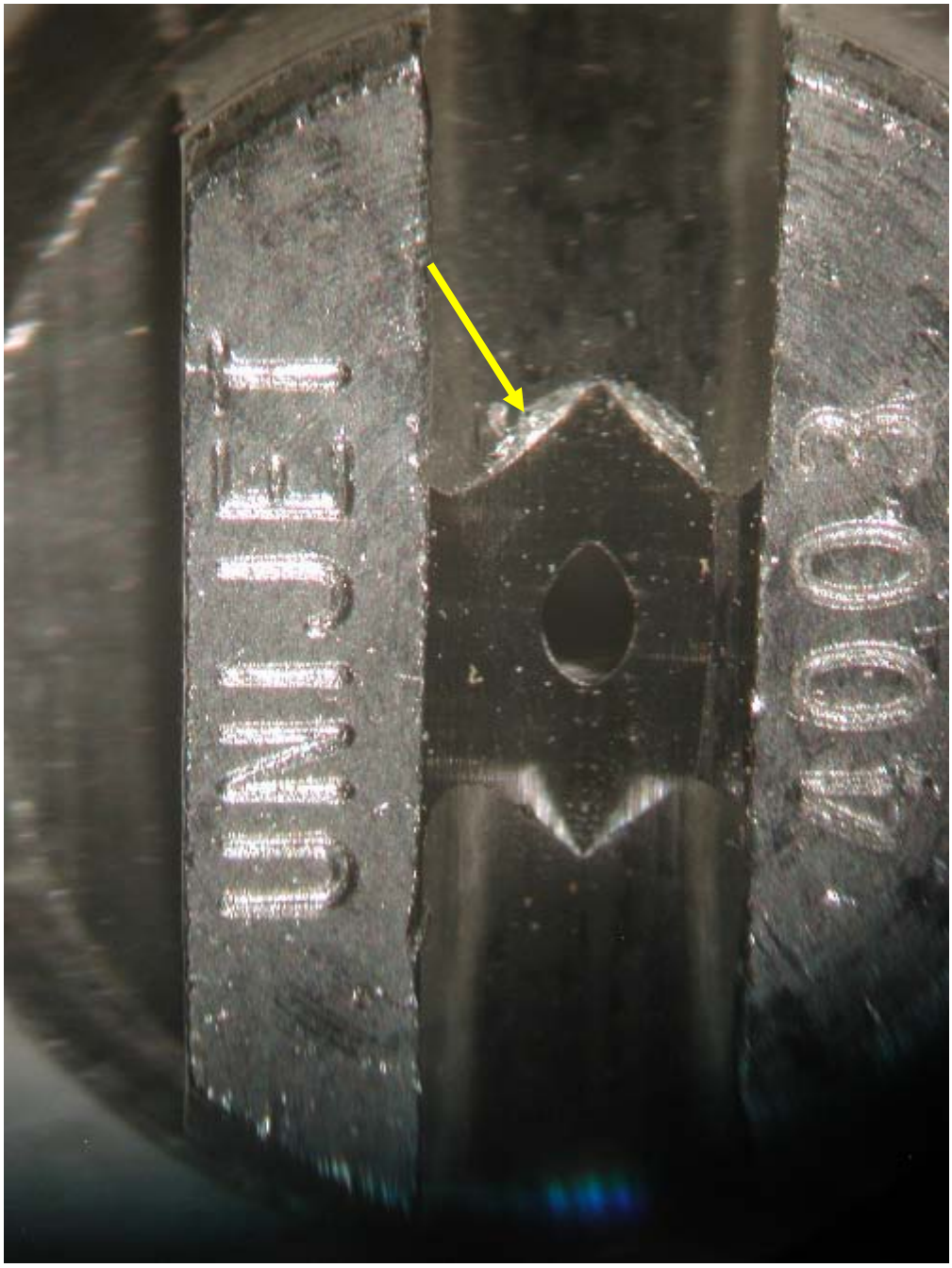

Figure 6. The arrow points to a burr that was common on the 4003 UniJet® nozzles that were used in the trial.

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Improving ground application technology for treating rangeland grasshoppers and Mormon crickets: Developing ultra low volume capability

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Abstract

New ultra low volume spray technology was developed for ground applications. Several commercial spray tips, used for ground applications, were evaluated for swath width on an ATV mounted commercial ground spraying system. The BoomJet nozzle, which produced the widest swath, was selected for further development. It was evaluated on the Jackrabbit Sprayer System which was modified with a 0.1 sec adjustable timer activated solenoid valve to quickly switch the spray on and off. Activation on and off at 0.1 sec intervals, reduced flow rates 41% to 49%. Other intervals tested resulted in flow rates being reduced by as much as 79%. The timer off intervals tested allowed only one to 7 feet to be traversed by the ATV when the spray was off. The distance traversed when the spray system was off was irrelevant, since edge of pattern overspray and natural drift mixed the spray between the distances covered in the on/off cycles of the system. The modification produced ULV ground application rates similar to those used aerially. This groundbreaking improvement saves ferrying, mixing and loading time as well as some diluting materials currently required of ground applications. The timer activated on/off solenoid valve modification can be easily adapted to any spray system, and will greatly impact ground spray applications, especially, ultra low volume sprays.

Introduction

Ultra low volume (ULV) sprays (defined as less than 0.5 gallon per acre) were developed shortly after World War II for the control of desert locusts in East Africa (Mass, 1971). These first ULV sprays were applied by ground equipment and relied on the very fine atomization and drift of the spray. While successful and accepted in many parts of the world, these characteristics are currently unacceptable in United States Department of Agriculture (USDA) sponsored control efforts against rangeland pests. Development of aerial ULV sprays in the United States, which rely on larger droplets than those produced in atomization sprays, was achieved by the Plant Pest Control Division of the USDA in cooperation with American Cyanamid in the early 1960's (Mass, 1971). These efforts led to the ULV aerial application of malathion at 8 fluid oz/acre against rangeland grasshoppers (Skoog and Cowen, 1968), a treatment still available today (USDA, 2002).

Ultra low volume application rates are affected by flow rate, swath width and speed of application. In aerial application, a faster speed allows for a large amount of acreage to be covered in a short period of time. This is greatly reduced in ground applications where speed is restricted. For example: In an aerial application, with a 100 ft wide swath applied at 120 mph, 24.24 acres/min would be covered. At a desired application rate of 8 fluid oz per acre, 1.5 gal/per min would be delivered. In a ground application, with a 40 foot wide swath applied at 10 mph, 0.81 acres/min would be covered. At the same desired application rate of 8 fluid oz/acre, 0.05 gal/min would be delivered. Applying this small amount per minute without atomizing the material is the challenge. Standard commercial equipment currently used by APHIS in ground applications deliver about 3 gallons/acre, many times what an aerial application would require. As a result, much higher amounts of dilluent are required in ground applications. Compared to aerial applications, these high volumes are expensive in terms of ferrying and loading times as well as the cost of some additional diluting materials. Being able to apply spray volumes by ground similar to those in aerial applications would provide distinct operational and economic advantages.

Substantial ULV ground application development work has been conducted since the initial ULV development. However, it still relies on atomization and drift. We report here on efforts to use acceptable droplet sizes and drift in newly developed ground application systems. The following study was conducted to evaluate modifications in ground spraying equipment to deliver ultra low volume sprays at volumes/acre similar to those used in aerial applications.

Objectives

1. Reduce total liquid volume/acre requirements in ground application equipment used against grasshoppers and Mormon cricket on rangeland.

2. Develop ground application equipment to apply less total volume of liquid/acre for use against grasshoppers and Mormon cricket on rangeland.

3. Evaluate efficacy of newly developed ULV ground application equipment against rangeland grasshoppers in the field and compare to efficacy resulting from currently used

Materials and Methods

Equipment development

A commercial ground application spray system, Jackrabbit Pro ATV Sprayer (Warne Chemical and Equipment Co., Rapid City, SD) mounted on a Suzuki Vinson QuadRunner ATV (Fig. 1) was modified with an adjustable timer activated solenoid valve (Fig. 2) to quickly switch the spray on and off. Using a rapid on/off spray procedure essentially reduces the overall flow rate. During application in the field, the natural edge of pattern overspray and drift will mix the spray droplets between the small distances traveled during the on and off spray phases. The timers used were Eaton, Durant ® timer #E42DP55 and Eaton timer #E5-248-C142 (Carlton-Bates Company, Little Rock AR) and accommodated 0.1 sec or 0.2 sec on/off time intervals respectively (Figs. 3 and 4). The solenoid was an ASCO Next Generation Solenoid Valve # 8262P212 ¼ in 12-24 DC (Industrial Automation, Cornelius, NC.).

The spray system was fitted with candidate standard commercial nozzles and tips (Fig. 5). The spray nozzles studied were Boominator 1250 and 1160, Boomjet 5880 (body composed of 5 spray tips retrofitted with check valves (Figs. 6 and 7), FieldJet 1/4KLCSS5, XP BoomJet ¼ 10-VP and CPP experimental. The check valves were installed to prevent fluid between the solenoid valve and the tip leaking during the off phase. The spray system was also fitted with a pressure regulator and a liquid filled pressure gauge to increase accuracy (Fig. 8). A bypass of the solenoid valve (Fig. 2) was also installed for ease in evaluating the standard spray system. The nozzle was mounted about 50 inches above ground (Fig. 9) and directly behind the spray tank for all tests except for the Boomjet which was mounted about two feet behind the spray tank (Fig. 10). All nozzles and tips were supplied by Spray Systems Technology, Wheaton Ill except Boominator nozzles (supplied with Jackrabbit Pro ATV sprayer) and CCP experimental (CP Products Company, Tempe Arizona).

Candidate nozzles were tested first in the unmodified standard system to determine the most productive in terms of swath width. The nozzle with the widest swath was then tested at numerous on/off intervals with two timers (a second timer was tested because the original timer is no longer available). Booms with nozzles positioned several feet apart were not studied because of the difficulty in using an extended lateral boom on rangeland terrain.

Swath widths were determined by spraying water through each configuration on dry pavement in a parking lot and measuring the overall and effective swath (Fig. 11). Flow rates for each nozzle were determined by collecting and measuring the amount of water

sprayed through each type of nozzle for a predetermined amount of time (Fig. 12). Flow rate measurements were replicated 8 times for each configuration. The specific nozzle, material composition, configuration, number of orifices, boom pressure, swath width and flow rate used for each of the selected spray nozzles are summarized in Table 1.

Field evaluation.
Two rangeland field plots each containing 4 grasshopper evaluation sites will be treated with Dimilin 2L. One will be treated using the commercial Boominator 1250 and the other will be treated using the modified spray system and Boomjet 5880. Pre and post grasshopper counts will be used to assess and compare the efficacy of each system. Oil and water sensitive spray cards will also be used in the field evaluation. (MORE DETAIL WILL BE ADDED AS THIS STUDY SECTION OCCURS).

Results and Discussion

Equipment development.
The widest swath (41-42 ft) was produced by the BoomJet 5880 nozzle containing 5 tips, all on one nozzle (Table 1.). This was followed by the Boominator 1250 (32ft) and 1160 (29 ft), XP BoomJet ¼ 10-VP (18 ft), FieldJet ¼ KLCSS5 (17 ft) and CPP experimental (12 ft). The width of the swath was directly related to the number of tips. The smallest swath widths resulted from those relying on a single tip, FieldJet 1/4KLCSS5 and CPP experimental. While single tip produced swaths could be increased by adding additional tips, this would require developing a much wider boom that would be subject to substantial flexing in the field during operation. The lowest gallon per acre delivered by a standard configuration was 1.58 and 1.59 gallons per acre at 12 mph with the FieldJet ¼ KLCSS5 and BoomJet 5880, respectively. Because of the wider swath produced by the BoomJet 5880, it was selected to test with the timer activated solenoid on/off valve.

Currently field applicators are applying about 2 to 3.5 gallons of spray mix per acre at 10 mph with the FieldJet 1/4KLCSS5 and Boominator 1250 respectively. Current label rates for Dimilin allow no less than one gallon per acre by ground, however, this label restriction can be changed in the future The change would require the registrant to petition EPA for the change and pay a fee or a special local need registration (SLN) be requested in each of the states involved (personal Communication - Dan Largent, Chemtura Crop Protection). Field personnel desire total volume application rates similar to those used in aerial applications. The current aerial application rates/acre are 4-8 fluid oz for malathion, 16 – 32 fluid oz for Sevin XLR Plus and 12-32 fluid oz for Dimilin 2L.

When a timer activated solenoid was added to the spray system a dramatic reduction in total application volume per acre resulted (Table 1). Volumes less than one gallon per acre resulted in 13 of 16 scenarios with timer DP55 and 10 of 12 scenarios with timer C142. The second timer was included in the study after discovering that the original DP55 was no longer being produced.

Flow rates with C142 timer on/off settings 0.2/0.2, 0.2/0.4, and 0.2/0.6 should have been similar to flow rates with DP55 timer on/off settings 0.1/0.1, 0.1/0.2, and 0.1/0.3 respectively. Flow rates with the C142 at 0.2/0.2 were similar but slightly less than those with DP55 0.1/0.1 (13.8 to 14.8 % less). Flow rates with C142 at 0.2/0.4 were very similar to those with DP55 0.1/0.2 (5.5 to 7.6 % more) Flow rates with C142 at 0.1/0.6 were similar (24.1 to 25.9 % higher) but higher than those with DP55 0.1/0.3. In this study timer DP55 and C142 produced flow rates as low as 0.23 and 0.36 gal/acre, respectively. These are near the high range of rates (0.24 gal/acre) used in APHIS sponsored aerial applications on rangeland and are certainly an improvement over currently used ground application rates. It is important to note that further reductions in volume application rates could easily be achieved with the modified system using on/off intervals 0.1/0.5 sec. or more. These reduced flow rates translate into greater acreages being treated per spray tank and thus save time in ferrying, mixing and loading as well as some diluting materials. In an aerial application example, Mass (1971) determined that 58% of the time required in conventional spraying could be saved by using the ULV technique.

The distances traversed during the off intervals are seen in Table 2. They range from 0.73 feet to 1.76 feet at 6 to 12 mph, respectively, for a timer interval of 0.1/0.1 sec. and range from 2.9 feet to 7.04 feet at 6 to 12 mph, respectively, for a timer interval of 0.1/0.4 sec.. As stated earlier, this distance where the spray system is off appears irrelevant, since edge of pattern overspray and natural drift mixes the spray between the distances covered during the on/off cycles of the system.

Field evaluation.
Proposed / ongoing.

Conclusions

Ultra low volume spray application technology was developed and demonstrated for ground applications. The advantages of modifying existing ground spraying systems with a timer activated solenoid valve to quickly shut the spray on and off is obvious as it greatly reduces flow rates. Volumes of liquids applied by ground can be applied at rates similar to those used in ULV aerial application sprays. This remarkable economical improvement saves ferrying, mixing and loading time as well as diluting materials currently required of ground applications. With further timer adjustments, there appears to be no reason that all currently used USDA APHIS aerially applied per acre rates cannot be achieved in ground applications also. Additionally, this modification should be easily adapted to any spray system, therefore greatly broadening the scope of impact on ground applications, especially, ultra low volume.

The modified BoomJet and unmodified Boominator (currently used by PPQ grasshopper program personnel) should be compared under operational field conditions for efficacy. The study is planned for the summer of 2009. However, the near term potential of this

work has prompted the generation of a report before the field efficacy data could be generated. This report should be considered preliminary but useful.

Acknowledgements

Thanks are extended to the following people who used timer activated solenoids in both ground and aerial experimental application development work to apply large single dollops of liquid pheromone spaced at substantial intervals in cotton fields to combat pink bollworm: N. Colletto, N. Foster, D. Hill, J. Jenkins, J. Ploski, T. Roland, R. Staten and M. Walters. That work contributed in part to the development work reported above.

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Foster, R.N. and K.C. Reuter. 1996. Evaluation of rangeland grasshopper controls: A general protocol for efficacy studies of insecticides applied from the air. In: Cunningham, G.L., and M.W. Sampson tech cords. Grasshopper integrated pest management user handbook. Tech Bull. 1809. Washington, DC: U.S. Dept. of Agriculture, Animal and Plant Health Inspection Service: II.2-1—II.2-7.

Fig. 1. Jackrabbit Pro ATV Sprayer on Suzuki Vinson Quadrunner ATV.

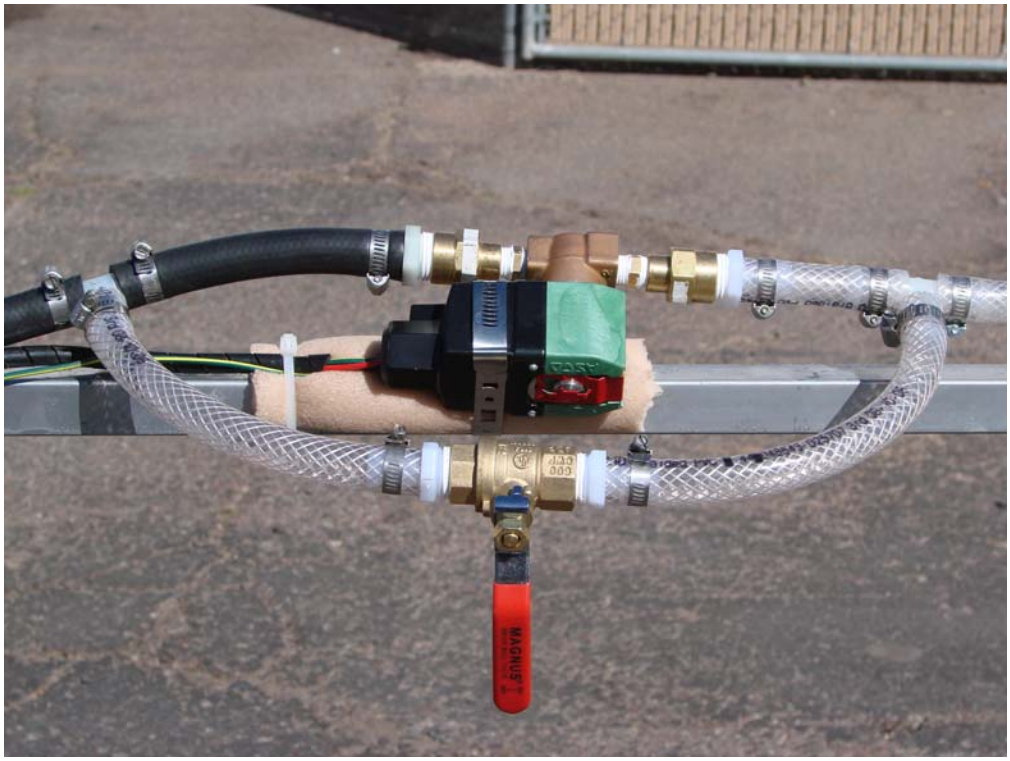


Fig. 2. Jackrabbit sprayer modified with a timer activated solenoid valve to continuously switch the spray system on and off and a bypass.

Fig. 3. Eaton timer # E5-248-C142 used to activate solenoid valve.

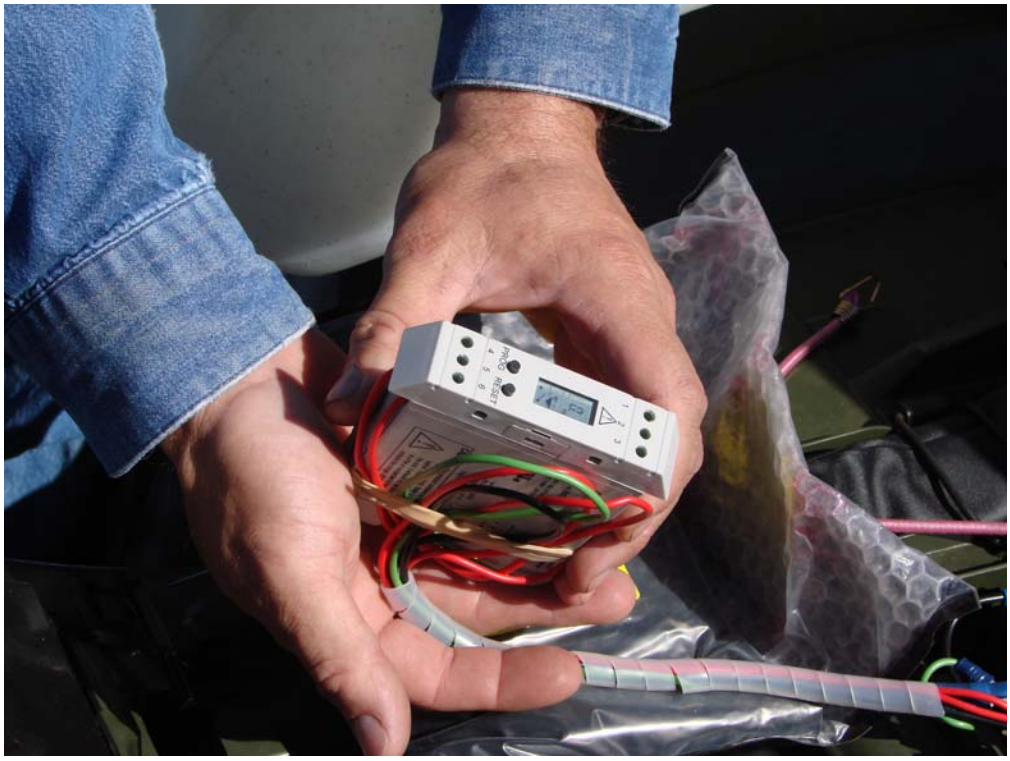


Fig. 4. Eaton Durant timer # E42DP55 used to activate solenoid valve.

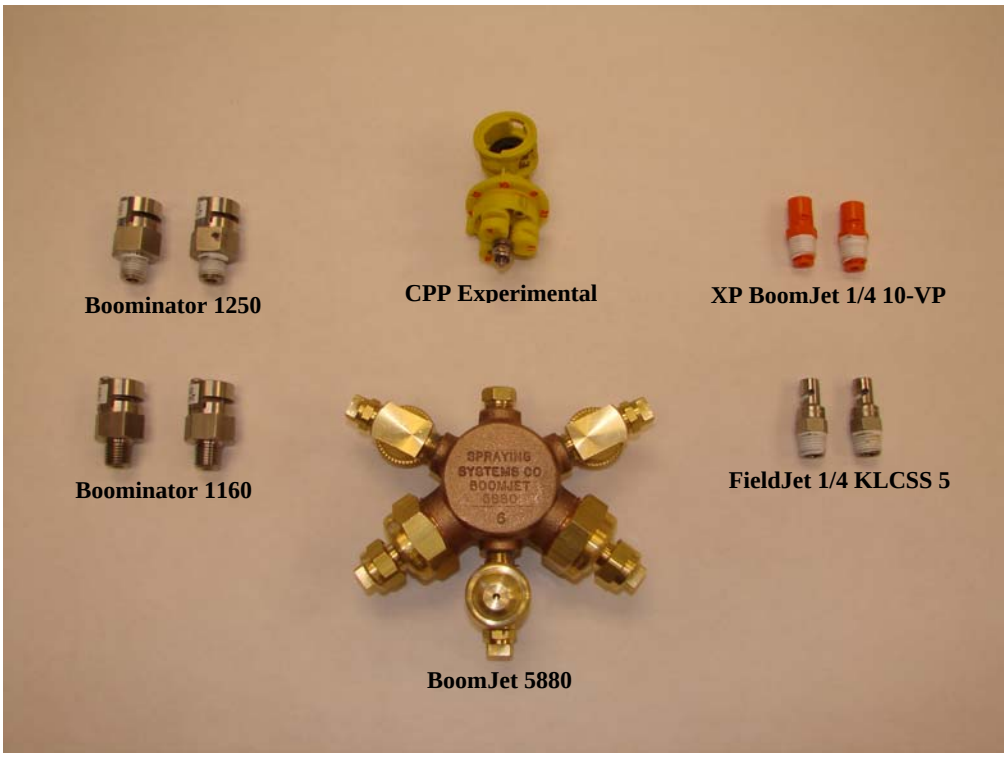


Fig. 5. Standard commercial nozzles and tips used in the study.

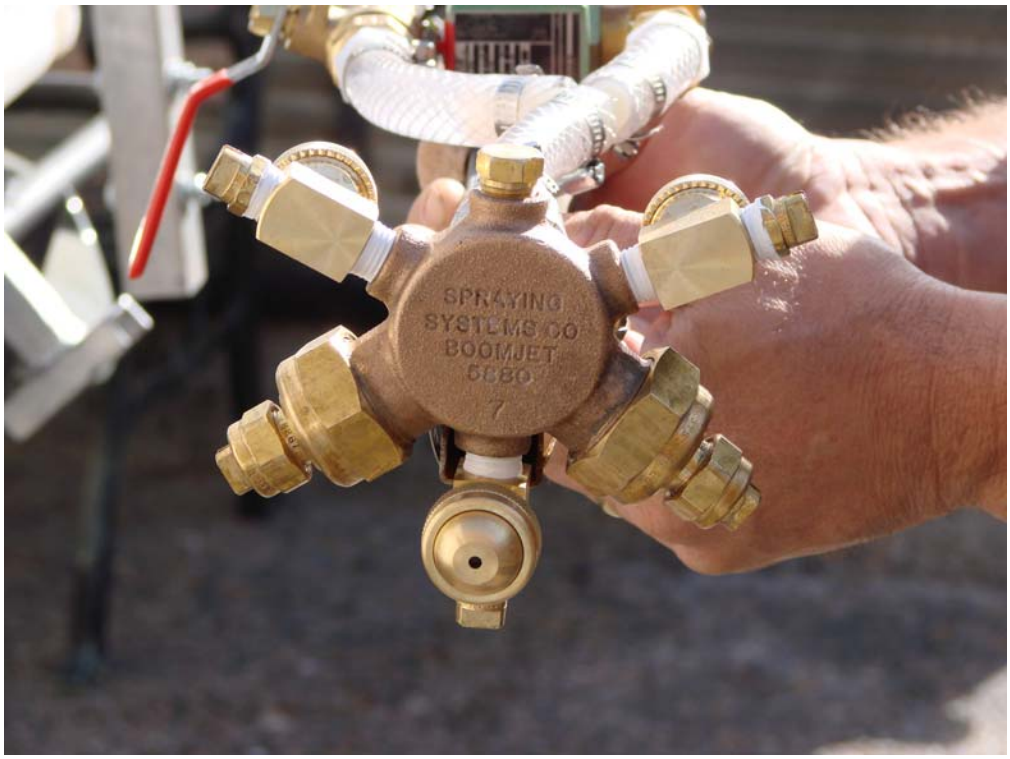


Fig. 6. BoomJet nozzle 5880 and 5 spray tips retrofitted with check valves.

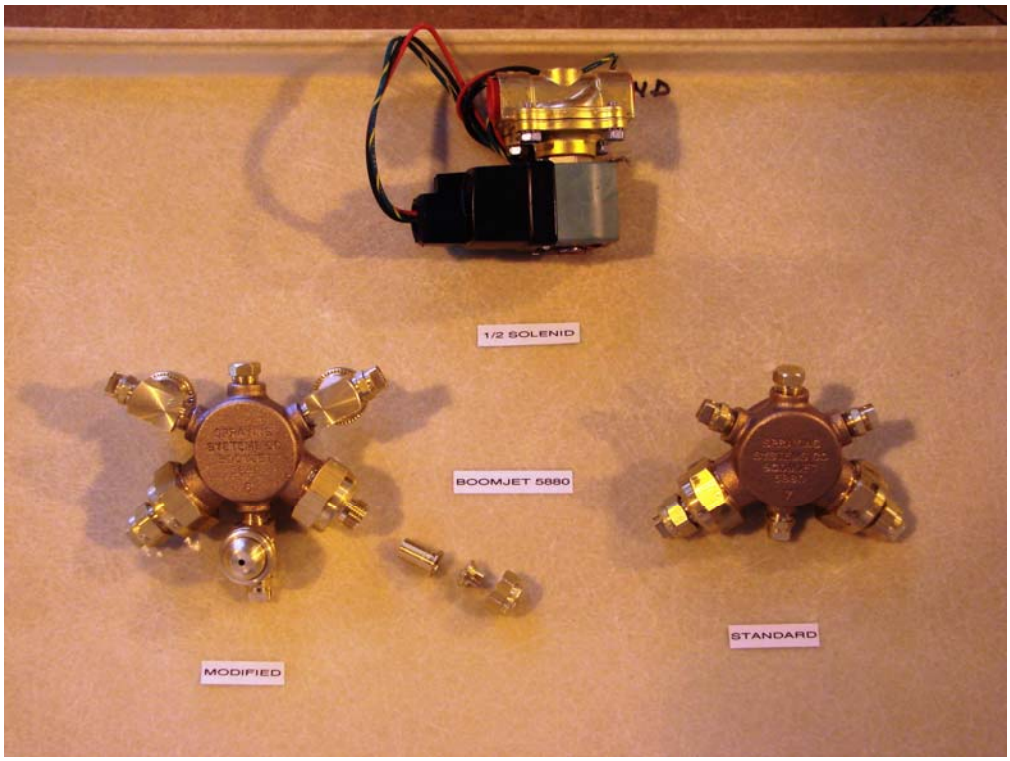


Fig. 7. Standard and modified BoomJet Nozzle 5880 and solenoid valve.

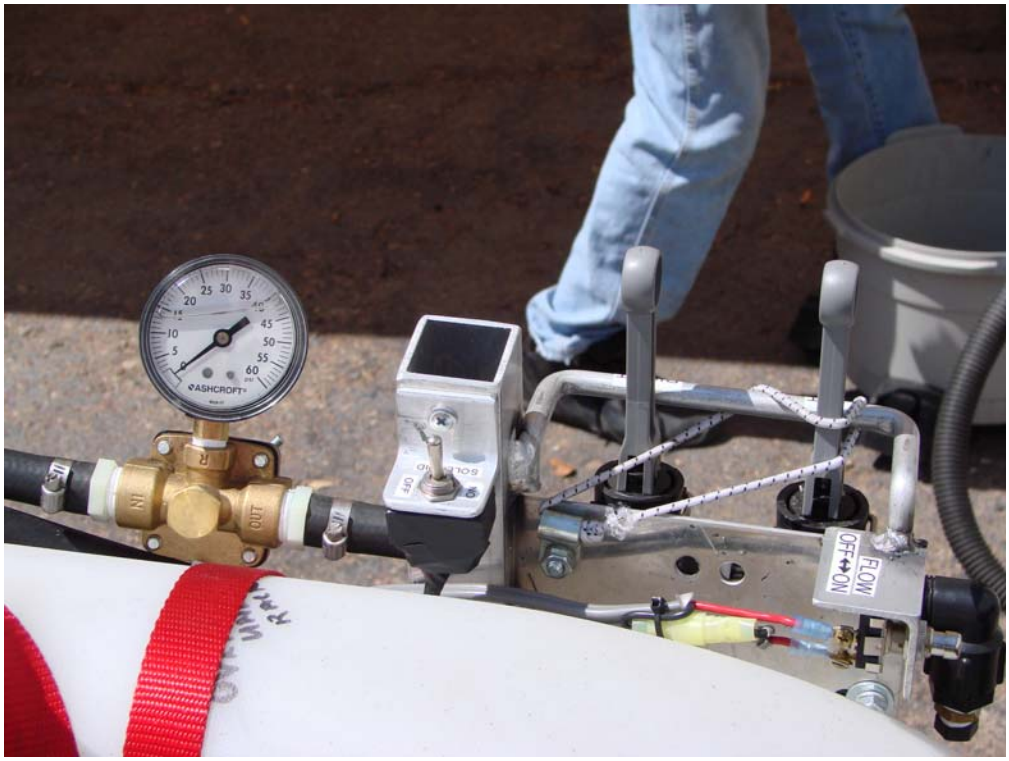


Fig. 8. Pressure regulator and liquid filled pressure gauge.

Fig. 9. A standard Boominator nozzle mounted about 50 inches above ground behind the spray tank (Photo by D. Hirsch).

Fig. 10. BoomJet Nozzle mounted about 2 feet behind the spray tank.

Fig. 11. Spraying water on dry pavement to determine swath width.

Fig. 12. Selected spray tips were calibrated by collecting and measuring water sprayed for a predetermined amount of time.

Table 1. Operating parameters of selected nozzles at different on/off spray intervals.

									gal/acre @ (acres/min)			
Nozzle	comp.	(no. of orifices) config.	timer type	timer interval (sec on/off)	Boom pressure psi	swath width ft	Mean total gal/min	std dev	6 mph	8 mph	10 mph	12 mph
BoomJet 5880	brass	(5) standard		all on	24	42	1.62	0.010	(0.51) 3.18	(0.68) 2.39	(0.85) 1.91	(1.02) 1.59
		(5) solenoid	DP55	0.1/0.1	24	42	0.96	0.007	(0.51) 1.89	(0.68) 1.41	(0.85) 1.13	(1.02) 0.94
		(5) solenoid	DP55	0.1/0.2	24	41	0.44	0.005	(0.50) 0.88	(0.66) 0.66	(0.83) 0.54	(0.99) 0.44
		(5) solenoid	DP55	0.1/0.3	24	41	0.29	0.005	(0.50) 0.58	(0.66) 0.44	(0.83) 0.35	(0.99) 0.29
		(5) solenoid	DP55	0.1/0.4	24	41	0.23	0.007	(0.50) 0.46	(0.66) 0.35	(0.83) 0.28	(0.99) 0.23
		(5) solenoid	C142	0.2/0.2	24	42	0.82	0.007	(0.51) 1.61	(0.68) 1.21	(0.85) 0.97	(1.02) 0.81
		(5) solenoid	C142	0.2/0.4	24	42	0.48	0.014	(0.51) 0.94	(0.68) 0.71	(0.85) 0.57	(1.02) 0.47
		(5) solenoid	C142	0.2/0.6	24	42	0.37	0.005	(0.51) 0.73	(0.68) 0.55	(0.85) 0.44	(1.02) 0.36
Boominator 1250	stainless steel	(2) standard			22	32	2.30	0.006	(0.39) 5.93	(0.52) 4.45	(0.65) 3.56	(0.78) 2.96
Boominator 1160	stainless steel	(2) standard			20	29	2.16	0.008	(0.35) 6.14	(0.47) 4.61	(0.59) 3.69	(0.70) 3.07
FieldJet 1/4 KLCSS 5	stainless steel	(1) standard			24	17	0.65	0.016	(0.21) 3.15	(0.27) 2.36	(0.34) 1.90	(0.41) 1.58
XP BoomJet 1/4 10-VP	plastic	(2) standard			24	18	0.76	0.006	(0.22) 3.49	(0.29) 2.61	(0.36) 2.09	(0.44) 1.74
CPP Experimental	plastic	(1) standard			25	12	0.55	0.000	(0.15) 3.79	(0.19) 2.84	(0.24) 2.27	(0.29) 1.89
		(orifice 10 tip 6)										

Table 2. Distance traveled at various speeds with selected intervals of spray off.

nozzle	swath width	pressure psi	gal/min	speed	acre/min	gal/acre	timer on:off	distance/off
BoomJet 5880 DP55	42	24	1.62 n = 8	5	0.4242	3.82	all on	none
				6	0.5091	3.18		none
				7	0.5939	2.73		none
				8	0.6788	2.39		none
				9	0.7636	2.12		none
				10	0.8485	1.91		none
				11	0.9333	1.74		none
				12	1.0182	1.59		none
BoomJet 5880 DP55	42	24	0.96 n = 8	5	0.4242	2.26	1:1	0.1 sec 0.73 ft
				6	0.5091	1.89		0.88 ft
				7	0.5939	1.62		1.03 ft
				8	0.6788	1.41		1.17 ft
				9	0.7636	1.26		1.32 ft
				10	0.8485	1.13		1.47 ft
				11	0.9333	1.03		1.61 ft
				12	1.0182	0.94		1.76 ft
BoomJet 5880 DP55	41	24	0.44 n = 8	5	0.4141	1.06	1:2	0.2 sec 1.47 ft
				6	0.4970	0.89		1.76 ft
				7	0.5798	0.76		2.05 ft
				8	0.6626	0.66		2.34 ft
				9	0.7455	0.59		2.64 ft
				10	0.8283	0.53		2.93 ft
				11	0.9111	0.48		3.23 ft
				12	0.9939	0.44		3.52 ft

BoomJet 5880 DP55	41	24	0.29 n = 8	5	0.4141	0.70	1:3	0.3sec 2.20 ft
				6	0.4970	0.58		2.64 ft
				7	0.5798	0.50		3.08 ft
				8	0.6626	0.44		3.52 ft
				9	0.7455	0.39		3.96 ft
				10	0.8283	0.35		4.40 ft
				11	0.9111	0.32		4.84 ft
				12	0.9939	0.29		5.28 ft
BoomJet 5880 DP55	41	24	0.23 n = 8	5	0.4141	0.56	1:4	0.4 sec 2.93 ft
				6	0.4970	0.46		3.52 ft
				7	0.5798	0.40		4.11 ft
				8	0.6626	0.35		4.69 ft
				9	0.7455	0.31		5.28 ft
				10	0.8283	0.28		5.87 ft
				11	0.9111	0.25		6.45 ft
				12	0.9939	0.23		7.04 ft
nozzle	swath width	pressure psi	gal/min	speed	acre/min	gal/acre	timer on:off	distance/off
BoomJet 5880 C142	42	24	0.82 n = 8	5	0.4242	1.93	0.2/0.2	1.47 ft
				6	0.5091	1.61		1.76 ft
				7	0.5939	1.38		2.05 ft
				8	0.6788	1.21		2.35 ft
				9	0.7636	1.07		2.64 ft
				10	0.8485	0.97		2.93 ft
				11	0.9333	0.88		3.23 ft
				12	1.0182	0.81		3.52 ft

BoomJet 5880 C142	42	24	0.48 n = 8	5	0.4242	1.13	0.2/0.4	2.93
				6	0.5091	0.94		3.52 ft
				7	0.5939	0.81		4.11 ft
				8	0.6788	0.71		4.69 ft
				9	0.7636	0.63		5.28 ft
				10	0.8485	0.57		5.87 ft
				11	0.9333	0.51		6.45 ft
				12	1.0182	0.47		7.04 ft
BoomJet 5880 C142	42	24	0.37 n = 8	5	0.4242	0.87	0.2/0.6	4.40
				6	0.5091	0.73		5.28 ft
				7	0.5939	0.62		6.16 ft
				8	0.6788	0.55		7.04 ft
				9	0.7636	0.48		7.92 ft
				10	0.8485	0.44		8.80 ft
				11	0.9333	0.40		9.68 ft
				12	1.0182	0.36		10.56 ft

On the following pages you will find a parts list for each unit to be modified and the source of material.

PARTS LIST AND SOURCES FOR ATV SPRAYER MODIFICATION

WARNE CHEMICAL AND EQUIPMENT CO. 1-800-658-5457

- 1-Jackrabbit Pro ATV Sprayer (complete) $1059.00

SPRAYING SYSTEMS CO. (TEEJECT TECHNOLOGIES) CATALOG #50A
ITEMS ORDERED FROM WHEATON ILL. (630)517-1310 (ask for research discount and save some money)

- 1- BoomJet nozzle #5880-3/4-2Toc06 $81.02
- 3- Diaphragm check valves #10742A $12.47 ea.
- 2- TeeJet check valves #11750 $2.32 (must be brass or stainless)

All of these items combine to make the finished nozzle minus the 50 mesh screen located in the center of the boom nozzle; this must be removed to install the check valve on the bottom

GRAINGER

- 1- Watts Water pressure regulator #2A645 SKU#0335015 $44.40
- 1-Ashcroft fluid filled pressure gauge #4ZG22 SKU#63W3005PHL02L XZG 60# $34.44

CARLTON BATES CO. 1-866-600-6040

- 1- Eaton (Durant) timer #E5-248-C1420 $109.00

INDUSTRIAL AUTOMATION 1-800-511-0100

- 1-ASCO Solenoid valve Part # 8210P94-12-24/DC Stock # 44313 $160.55

LOCAL HARDWARE STORE

- Assorted brass and poly plumbing fittings and hose clamps.
- ½ " ID clear poly reinforced hose
- 2- 1/2" ¼ turn stainless valves (return/circulation and solenoid bypass
- 2- 1/4" stopcock valves for tank drain valves. (see picture)
- 1 in Square tubing, 1" angle and 1 ¼" channel for boom arm and support. Approximately 2' each.

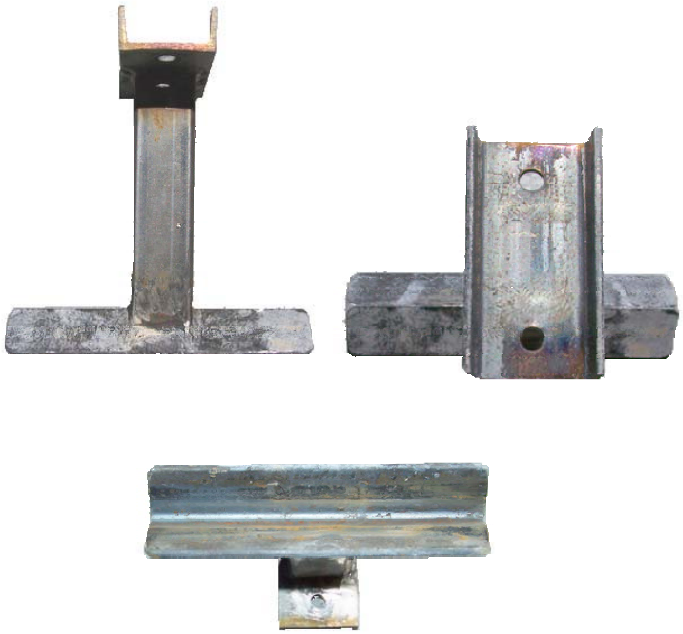
- Plywood ½” and rubber pad under tank for slightly elevating the tank and for abrasion resistance to the tank bottom.

NAPA (or other auto parts store)

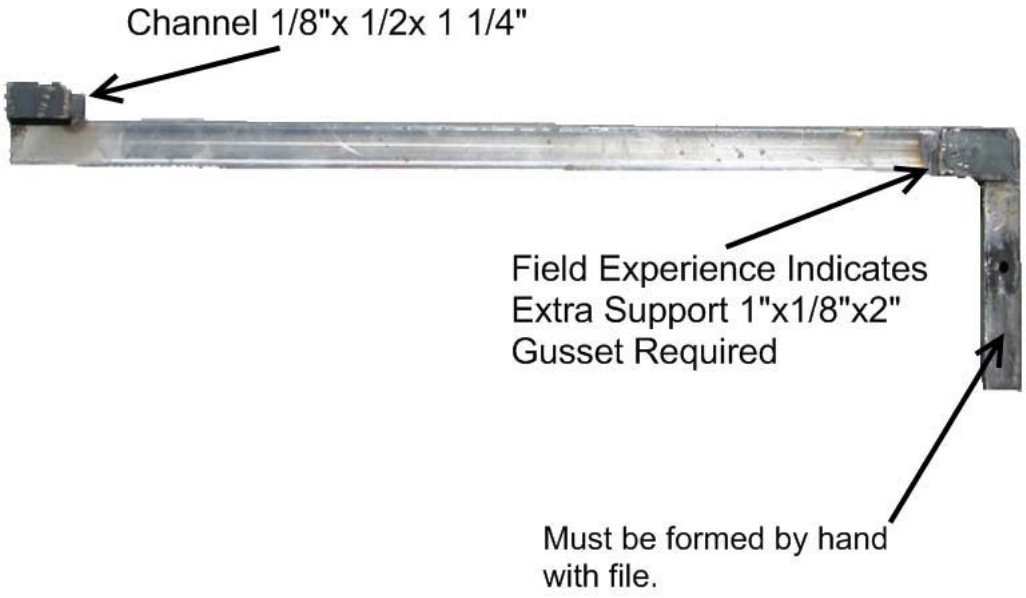
- You will need butt splice connectors, ring terminals, a fuse holder and fuse (5 amp) 14 gauge wire, and a single pole toggle switch rated for at least 10 amp DC.

NOTE: Some parts of this system are not off the shelf items and must be fabricated by welding on site. In addition some wood working tools are required.

Support Bracket

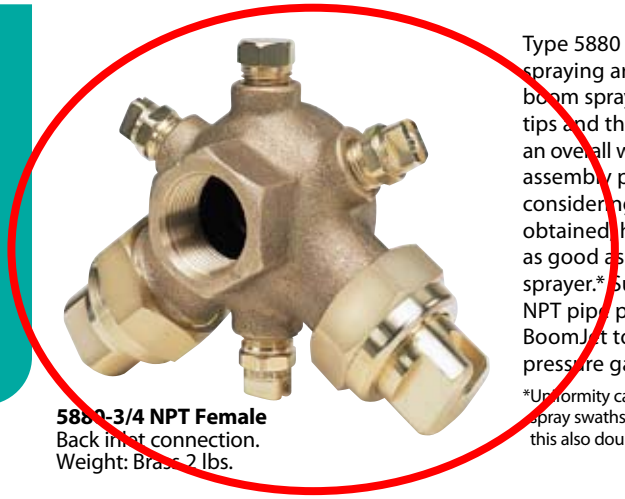


Boom Bracket



The following pages are catalog cuts for each item and more detailed information that you may need to build the system.

BoomJet® Boomless Nozzles with Extra-Wide Flat Spray Projection

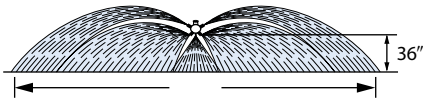


5880-3/4 NPT Female
Back inlet connection.
Weight: Brass 2 lbs.

Type 5880 BoomJet nozzle is used for spraying areas not easily accessed with a boom sprayer. It combines two off-center tips and three VeeJet® nozzles to produce an overall wide swath flat spray. The nozzle assembly provides good distribution considering the wide pattern coverage obtained however, the uniformity is not as good as with a properly operated boom sprayer.* Supplied with one additional ¼″ NPT pipe plug and one blank tip for setting BoomJet to one side only. Also has a ¼″ NPT pressure gauge port.

*Uniformity can be optimized by double overlapping spray swaths on successive sprayer passes. Remember, this also doubles the application volume.

How to order:
Specify BoomJet nozzle number.
Example: 5880-3/4-2TOC-06



W = Maximum effective coverage with nozzle mounted at 36″ height.

	(2)	(2)	(1)	PSI	GPM	"W" (FEET)	GPA 4 MPH	GPA 5 MPH	GPA 7.5 MPH	GPA 10 MPH	GPA 15 MPH	GALLONS PER 1000 SQ. FT. 2 MPH	3 MPH	4 MPH	5 MPH
5880-3/4-2TOC06	6733-OC06	H1/4VV-1506	H1/4VVL-9502 with 50 mesh strainer	20	1.84	33.5	6.8	5.4	3.6	2.7	1.8	0.31	0.21	0.16	0.12
				30	2.25	34	8.2	6.6	4.4	3.3	2.2	0.38	0.25	0.19	0.15
				40	2.60	34.5	9.3	7.5	5.0	3.7	2.5	0.43	0.28	0.21	0.17
5880-3/4-2TOC10	OC10	H1/4U-0508HE	H1/4VVL-11004 with 50 mesh strainer	20	2.83	39.5	8.9	7.1	4.7	3.5	2.4	0.41	0.27	0.20	0.16
				30	3.46	40	10.7	8.6	5.7	4.3	2.9	0.49	0.33	0.25	0.20
				40	4.00	40.5	12.2	9.8	6.5	4.9	3.3	0.56	0.37	0.28	0.22
5880-3/4-2TOC20	OC20	H1/4U-0520HE	H1/4VVL-9506 with 50 mesh strainer	20	6.08	47	16.0	12.8	8.5	6.4	4.3	0.73	0.49	0.37	0.29
				30	7.45	50	18.4	14.8	9.8	7.4	4.9	0.84	0.56	0.42	0.34
				40	8.60	52	20	16.4	10.9	8.2	5.5	0.94	0.62	0.47	0.37
5880-3/4-2TOC40	OC40	H1/4U-0540HE	H1/4U-9510	20	12.0	56	27	21	14.1	10.6	7.1	1.2	0.81	0.61	0.49
				30	14.7	60	30	24	16.2	12.1	8.1	1.4	0.93	0.69	0.56
				40	17.0	63	33	27	17.8	13.4	8.9	1.5	1.0	0.76	0.61

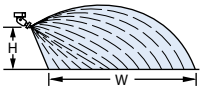
Note: Always double check your application rates. Tabulations are based on spraying water at 70°F (21°C).
See pages 173–187 for useful formulas and information.

TeeJet® Swivel Spray Nozzles with Off-Center Flat Spray Tips — Larger Capacities

Large capacity swivel nozzles, available in both single or double styles, are available with ¾″ NPT (F) inlet connections for use as boomless type nozzles. For double swivels the tabulated GPM (l/min) capacities are twice those shown for single swivels.

How to order:
Specify swivel number and material.
Example: 4629-3/4-TOC10 Brass

Extra Wide Flat Spray Coverage



W = Maximum effective coverage with nozzle mounted at 36″ height.

Type 4629-3/4-TOC Single Swivel
with ¾″ NPT (F) pipe connection. Brass.

Type 4418-3/4-2TOC Double Swivel
with ¾″ NPT (F) pipe connection. Brass.

	PSI	GPM	"W" (FEET)	HEIGHT = 36″ GPA 5 MPH	GPA 10 MPH	GPA 15 MPH
4629-3/4-TOC10	30	0.87	18	4.8	2.4	1.6
	40	1.00	18.5	5.4	2.7	1.8
	60	1.22	18.5	6.5	3.3	2.2
4629-3/4-TOC20	30	1.73	23.5	7.3	3.6	2.4
	40	2.00	24.5	8.1	4.0	2.7
	60	2.45	24.5	9.9	5.0	3.3
4629-3/4-TOC40	30	3.46	26	13.2	6.6	4.4
	40	4.00	27	14.7	7.3	4.9
	60	4.90	27	18.0	9.0	6.0
4629-3/4-TOC80	30	6.93	29	24	11.8	7.9
	40	8.00	30	26	13.2	8.8
	60	9.80	30	32	16.2	10.8
4629-3/4-TOC150	30	13.0	30.5	42	21	14.1
	40	15.0	31.5	47	24	15.7
	60	18.4	31.5	58	29	19.3
4629-3/4-TOC300	30	26.0	32	80	40	27
	40	30.0	33	90	45	30
	60	36.7	33.5	108	54	36

Note: Always double check your application rates. Tabulations are based on spraying water at 70°F (21°C).
See pages 173–187 for useful formulas and information.

TeeJet® Nozzle Parts

Standard Parts

TeeJet Spray Nozzle

=

Type T or TT nozzle body

+

5053 Strainer

+

Optional Tip Gasket CP5871-BU

+

Spray Tip

+

CP1325 TeeJet Cap

11750 TeeJet Check Valve

For larger capacity TeeJet nozzles where strainers are not required. Ball check opens at 5 PSI (0.34 bar), 10 PSI (0.7 bar) spring also available. Recommended for flow rates from .40 to 1.5 GPM (1.5–5.7 l/min). Made in choice of stainless steel, brass, aluminum or polypropylene with stainless steel ball and spring.

Brass or Stainless only

TeeJet Nozzle Bodies

Type-TT
Male Inlet NPT or BSPT Connection

TEEJET BODY NUMBER	FOR TEEJET NOZZLE TYPE	MALE SIZE	MATERIAL
CP(B)1336	1/8TT	⅛″	Brass
CP(B)1322	1/4TT	¼″	Brass
CP(B)8028-NYB	1/4TT-NYB	¼″	Nylon
CP(B)1322-I	1/4TT-I	¼″	Steel
CP(B)1322-SS	1/4TT-SS	¼″	Stainless Steel
CP(B)1324	3/8TT	⅜″	Brass
CP(B)1340	1/2TT	½″	Brass

(B) = BSPT

Type-T
Female Inlet NPT or BSPT Connection

TEEJET BODY NUMBER	FOR TEEJET NOZZLE TYPE	FEMALE SIZE	MATERIAL
CP(B)1335	1/8T	⅛″	Brass
CP(B)1321	1/4T	¼″	Brass
CP(B)12094-NYB	1/4T-NYB	¼″	Nylon
CP(B)1321-I	1/4T-I	¼″	Steel
CP(B)1321-SS	1/4T-SS	¼″	Stainless Steel
CP(B)1323	3/8T	⅜″	Brass
CP(B)1339	1/2T	½″	Brass

(B) = BSPT

CP1325

CP18032A-NYB

TeeJet Nozzle Caps

Secure interchangeable TeeJet tips to the various nozzle bodies. 18032A-NYB winged TeeJet cap allows quick change of spray tips with no tool required.

TEEJET BODY NUMBER	MATERIAL
CP1325	Brass
CP8027-NYB	Nylon
CP8027-1-NYB	Nylon (Extra-long size)
CP1325-AL	Aluminum
CP1325-I	Steel
CP1325-SS	Stainless Steel
CP18032A-NYB	Winged Cap, Nylon

45° Nozzle Body

Ideal for use with FullJet®, FloodJet® and Turbo FloodJet® nozzles. Can be used with QJ4676 Quick TeeJet® cap or standard 4676 outlet adapter. Made of polypropylene.

TEEJET BODY NUMBER	INLET	OUTLET
(B)22669-1/4-PPB	¼″ (M)	11⁄16″–16 (M)

(B) = BSPT

Clamp Assemblies

Consist of upper and lower clamps and bolt for use with hose shank nozzle bodies.

AA111

PART NUMBER	TO CLAMP ON
AA111-1/2	½″ Pipe (13⁄16″ & ⅞″ O.D. Tubings)
AA111-3/4	¾″ Pipe (1″ & 1 1⁄16″ O.D. Tubings)
AA111-1	1″ Pipe (1⅛″, 1¼″ & 1⅜″ O.D. Tubings)
AA111-1-1/4	1¼″ Pipe (1 9⁄16″ & 1 11⁄16″ O.D. Tubings)

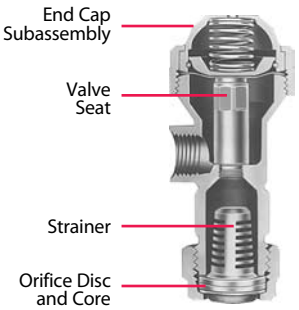
AA111SQ

PART NUMBER	TO CLAMP ON
AA111SQ-1	1″ Square Tubing
AA111SQ-1-1/4	1¼″ Square Tubing
AA111SQ-1-1/2	1½″ Square Tubing

ChemSaver® Diaphragm Check Valves

In this type of nozzle body, the diaphragm check valve is an integral part of the nozzle assembly. This design eliminates the pressure drop associated with ball-type check valves. The spring-backed diaphragm ensures dependable closure. Originally developed for use in aerial spraying, nozzle bodies of this design are now widely used wherever drip-free shutoff is required. For maximum operating pressures of 125 PSI (9 bar).

Typical Assembly



8355

Made of Nylon with Nylon/polypropylene end cap assembly. Check valve opens at 10 PSI (0.7 bar) pressure. Choice of ⅛″ or ¼″ NPT (F) inlet connections. Flow rate for ⅛″ is 3 GPM at 5 PSI pressure drop (11.4 l/min at 0.34 bar). Flow rate for ¼″ is 3.9 GPM at 5 PSI pressure drop (15 l/min at 0.34 bar). Overall length 2¾″ (70 mm). Weight: 1½ ounces (43 g).

Reference page 62 for Quick TeeJet QJ8355.

12328-NYB

Made of Nylon with Celcon® bonnet. Check valve opens at 7 PSI (0.5 bar) pressure. (M) inlet connection and (F) outlet connections. Choice of ½″ and ¾″ NPT sizes. Flow rate for ½″ is 12 GPM at 5 PSI pressure drop (45 l/min at 0.34 bar). Flow rate for ¾″ is 16 GPM at 5 PSI pressure drop (61 l/min at 0.34 bar). Overall length 3″ (76 mm). Weight: 9 ounces (0.26 kg).

8360

Made of Nylon with Nylon/polypropylene end cap assembly. Check valve opens at 10 PSI (0.7 bar) pressure. ¼″ NPT (M) inlet connection. Flow rate of 2.25 GPM at 5 PSI pressure drop (8.5 l/min at 0.34 bar). Overall length 2″ (51 mm). Weight: 1 ounce (28 g).

Reference page 62 for Quick TeeJet QJ8360.

ChemSaver® Diaphragm Check Valve Nozzle Bodies

Similar in design and performance to the TeeJet® Diaphragm Check Valve nozzle bodies, but with pipe thread outlet connections for spray nozzles instead of TeeJet caps and spray tips. For maximum operating pressures of 125 PSI (9 bar).

4664B

Made in choice of brass or aluminum with replaceable stainless steel valve seat. Check valve opens at 7 PSI (0.5 bar) pressure. ⅛″ NPT (F) inlet connection. Flow rate of 2.0 GPM at 5 PSI pressure drop (7.5 l/min at 0.34 bar). Overall length 2⁵⁄₁₆″ (59 mm). Weights: brass 3 ounces (85 g), aluminum 1 ounce (28 g).

4666B

Made in brass with replaceable stainless steel valve seat. ⅛″ NPT (F) inlet and outlet connections. Flow rate of 2.0 GPM at 5 PSI pressure drop (7.5 l/min at 0.34 bar). Overall length 1¹⁵⁄₁₆″ (49 mm). Check valve opens at 7 PSI (0.5 bar) pressure. Weight: 2½ ounces (71 g).

6140A

Made of brass. Check valve opens at 7 PSI (0.5 bar) pressure. Choice of ¼″ and ⅜″ NPT (F) inlet connections. Outlet connection has dual ½″ NPT external (M) thread and ⅜″ NPT internal (F) thread. Flow rate of 4.5 GPM at 5 PSI pressure drop (17 l/min at 0.34 bar). Overall length 2⅜″ (61 mm). Weight: 2½ ounces (71 g).

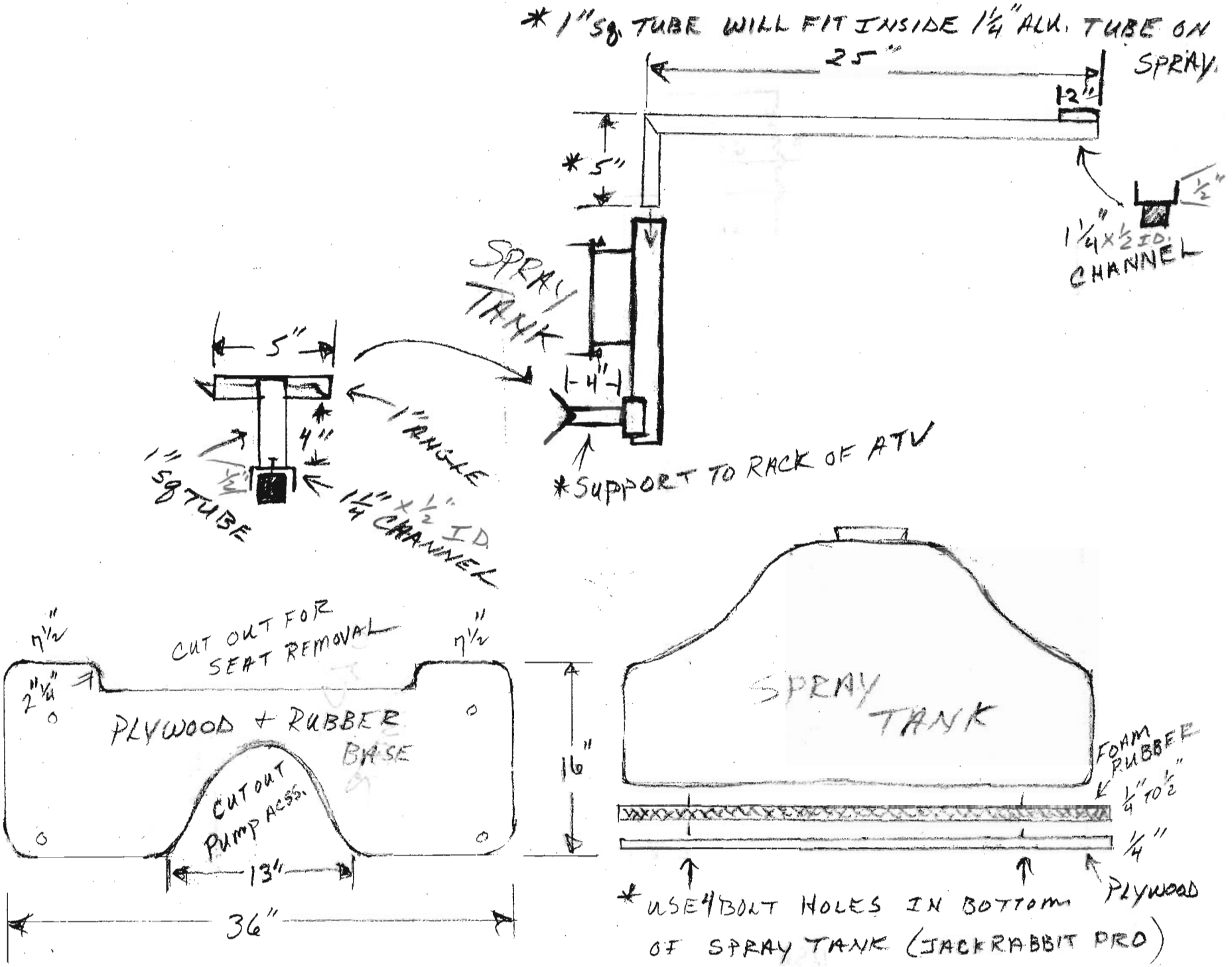
6135A

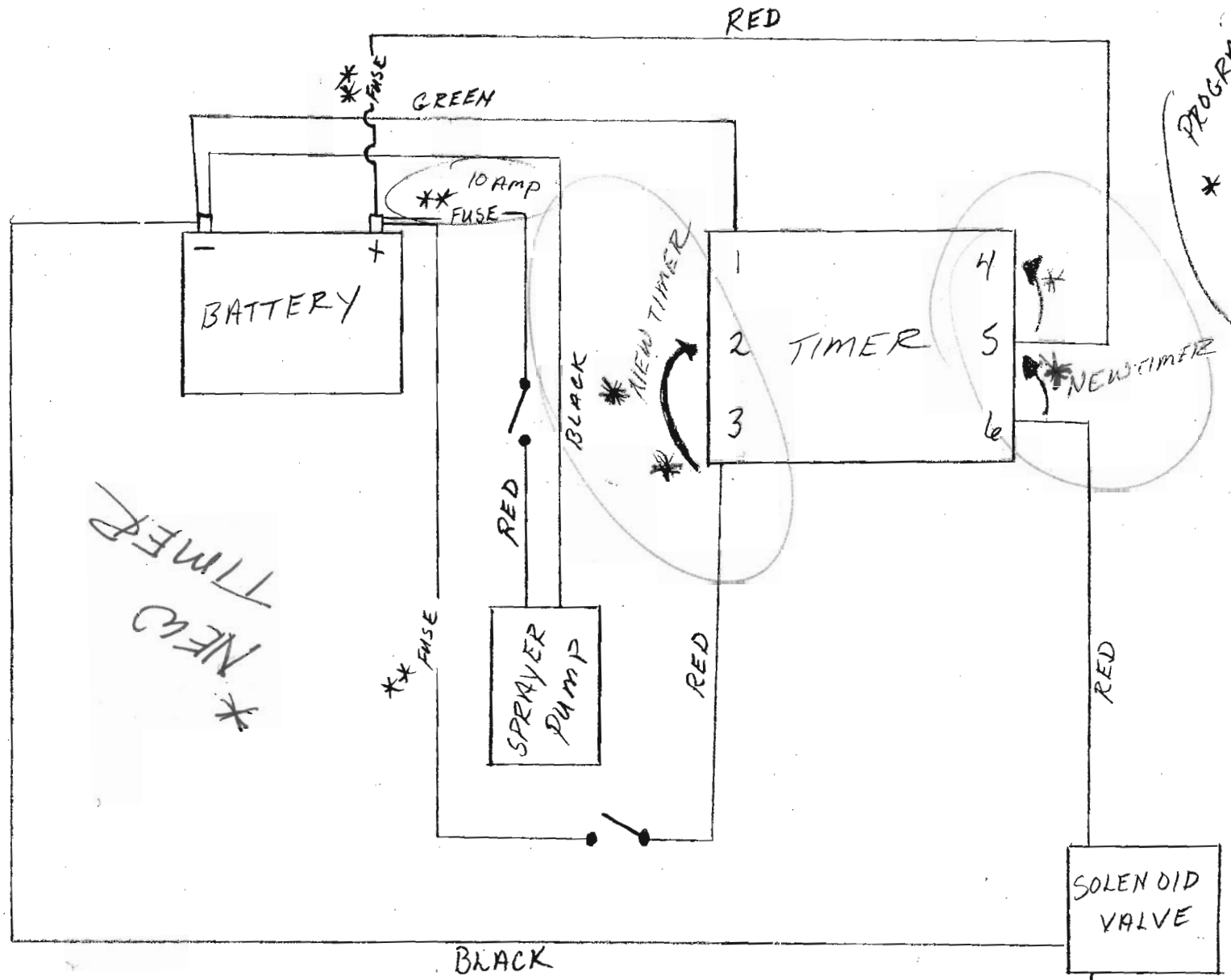
Made of brass. Check valve opens at 7 PSI (0.5 bar) pressure. Choice of ¼″ and ⅜″ NPT (F) inlet connections. Flow rate of 4.5 GPM at 5 PSI pressure drop (17 l/min at 0.34 bar). Overall length 2⅝″ (67 mm). Weight: 4½ ounces (128 g).

(B)10742A

Made in choice of brass or aluminum. Check valve opens at 7 PSI (0.5 bar) pressure. ¼″ NPT (M) inlet and (F) outlet connections. Overall length 1⁷⁄₁₆″ (37 mm). Flow rate of 2.25 GPM at 5 PSI pressure drop (8.5 l/min at 0.34 bar). Weights: brass 2½ ounces (71 g), aluminum 2 ounces (57 g).

(B)=BSPT


* 1" SQ. TUBE WILL FIT INSIDE 1¼" ALU. TUBE ON SPRAY.
25"
12"
* 5"
SPRAY TANK
1¼" x ½ I.D. CHANNEL
½"
5"
4"
1" ANGLE
1" SQ TUBE
½"
1¼" x ½ I.D. CHANNEL
4"
* SUPPORT TO RACK OF ATV
7½"
CUT OUT FOR SEAT REMOVAL
7½"
2¼"
PLYWOOD + RUBBER BASE
CUTOUT PUMP ACCS.
13"
36"
16"
SPRAY TANK
FOAM RUBBER ¼" TO ½"
¼"
PLYWOOD
* USE 4 BOLT HOLES IN BOTTOM OF SPRAY TANK (JACKRABBIT PRO)



PROGRAMING REMINDER
* 1st # is TIME ON
2nd # is TIMEOFF

WIREING DIAG.
ATV SPRAYER
3/27/09

** 2-5 Amp FUSES
1-10 Amp FUSES

(1) 2A645

1 2A645

Water Pressure Regulator

SKU# 0335015

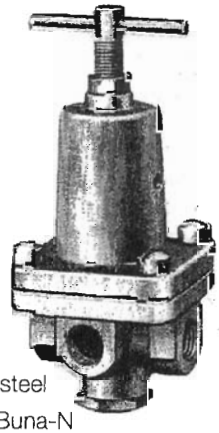
09/05/08

IS-2A645

Installation Instructions

2A645 3 WAY REGULATOR

Maximum Inlet: 300psi
Reduced Pressure Range: 3 to 50psi
Operating temperature range: - 0° to 140°F



Installation

Before installing, flush out pipe line to remove scale and other foreign matter. Install regulator in pipe line so that flow will be from in to out and as near as possible to equipment being supplied. "R" port is low pressure port for gauge installation if required.

Adjustment

Clockwise turning of the adjusting screw increases the reduced or regulated pressure. Regulator adjustment for lower reduced pressure will not be obtained until the reduced pressure system is "bled-off" or until flow starts.

Maintenance

If the supply is kept clean, the regulator should provide long periods of uninterrupted service. Erratic regulator operation or loss of regulation is most always due to dirt in the disc area, and cleaning is in order.

Cleaning

Remove bottom plug, spring and disc. Clean part, wipe off seat and blow out body with compressed air. Reassemble parts as a unit and screw into regulator-before tightening bottom plug, make sure disc is in center hole in body.

Materials

Body-brass
Spring cage-aluminum
Disc-Buna-N stainless steel
Diaphragm-reinforced Buna-N

CALIFORNIA PROPOSITION 65 WARNING

WARNING: This product contains chemicals known to the State of California to cause cancer and birth defects or other reproductive harm. (California law requires this warning to be given to customers in the State of California.)

For more information: www.wattsind.com/prop65

WATTS® REGULATOR

USA: 815 Chestnut St., No. Andover, MA 01845-6098; www.wattsreg.com
Canada: 5435 North Service Rd., Burlington, ONT. L7L 5H7; www.wattscanada.ca

ISO 9001 CERTIFIED

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Printed in U.S.A.

Pressure Gauge

WARNING:

Pressure gauges must be selected and installed so that the possibility of failure resulting in injury or damage caused by misuse or misapplication is minimized. Personnel responsible for selection and installation should read ASME B40.1 which is available from ASME, 345 East 47th Street, NY, NY 10017. The most important factors which must be considered in selecting the proper gauge are as follows.

PRESSURE: - THE RANGE OF THE GAUGE SHOULD BE APPROXIMATELY TWICE THE INTENDED OPERATION PRESSURE. AVOID APPLYING PRESSURE BEYOND TOP OF SCALE.

VIBRATION: - EXCESSIVE VIBRATION COULD CAUSE MOVEMENT WEAR RESULTING IN LOSS OF ACCURACY. THE GAUGE SHOULD BE ISOLATED FROM THE SOURCE OF VIBRATION, OR A LIQUID FILLED GAUGE SHOULD BE USED.

PULSATION: - EXCESSIVE PRESSURE PULSATION, USUALLY EVIDENCED BY CONTINUOUS RAPID POINTER OSCILLATION, COULD RESULT IN FATIGUE FAILURE OF THE PRESSURE ELEMENT, OR RAPID MOVEMENT WEAR. A PULSATION DAMPENING DEVICE AND A LIQUID FILLED GAUGE SHOULD BE CONSIDERED.

TEMPERATURE: - EXCESSIVE TEMPERATURE COULD RESULT IN LONG TERM CREEP OF SOLDERED JOINTS, AND POSSIBLY EVENTUAL FAILURE. MAXIMUM RECOMMENDED OPERATING (AMBIENT) TEMPERATURE IS 150°F

PROCESS: - MATERIALS OF PRESSURE CONTAINING PARTS AND JOINTS MUST BE RESISTANT TO THE PROCESS FLUID. A DIFFERENT PRESSURE ELEMENT MATERIAL, OR A DIAPHRAGM SEAL MAY BE REQUIRED.

GAUGES USED ON HIGH PRESSURE GAS, OR ON POTENTIALLY HAZARDOUS SERVICES SUCH AS OXYGEN, SHOULD BE CAREFULLY SELECTED IN ACCORDANCE WITH THE RECOMMENDATIONS OF ASME B40.1. USE ALUMINUM SOCKET GAUGES ON AIR OR OIL ONLY. FOR ADDITIONAL INFORMATION CONTACT THE MANUFACTURER.

ASHCROFT®
Instruments
STRATFORD, CONNECTICUT

(1) 4ZG22

63W3005PHL02L XZG 60#

HECHO EN BR.

FABRIQUE AUX BRAZIL

(1) 4ZG22

1 4ZG22

Operating Instructions
Timers
E5-248-C1420

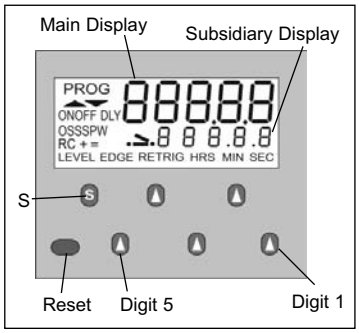
DESCRIPTION

This programmable timer has a two line black on silver LCD readout with the timing on the Main Display and the Set Time on the Subsidiary Display. A wide range of modes can be selected in programming.

FRONT PANEL

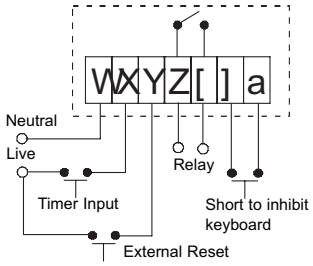
The key below each digit sets the Set Time on the Subsidiary Display. The red reset key resets the unit to zero when timing up or to the Set Time when timing down. Direction of timing is programmable. There are several annunciators as follows:

- PROG appears in programming mode
- ▲ and ▼ indicate direction of timing
- Various segments of the suite of mode annunciators indicate the current mode and status at a point in time
- Relay Symbol. Indicates whether relay contacts are open or closed
- LEVEL EDGE RETRIG indicates triggering mode.
- HRS MIN SEC together with the decimal point position indicates which timing range is selected.



CONNECTIONS

1	Common for terminals 2 + 3	
2	Timing input. Programmable to level or edge triggered	These inputs can be 12-240V AC or DC. For DC input the polarity is unimported
3	Reset input	
4/5	Voltage free relay contacts. Programmable to NO or NC	
6/7	Connect together to disable front panel keys	



Typical Installation Wiring

BATTERY REPLACEMENT

Slide the cover backwards off the top of the timer to gain access to the two ½AA lithium cells. Lift out each cell and observe the polarity sign on the PCB beneath it. Ensure that the replacement batteries are inserted the correct way. You will need to re-program the timer after replacing the batteries.

DO NOT THROW LITHIUM BATTERIES IN THE FIRE.

SPECIFICATIONS

Dimensions
48 mm x 48 mm x 93 mm
(1.89" x 1.89" x 3.66")
depth including rear connector

Panel Cut-out
Square 45 +0.6 -0 mm (1.77" +0.2" -0")

Display
2 rows of 5 digits, black on silver LCD. Upper row 6.5 mm (0.25") high indicates Time, Lower row 3.5 mm (0.14") high indicates Set Time. Also mode and relay

Batteries
Two 3V ½AA Lithium batteries. 10 year or >500,000 relay operations expected life

Set Time
Single user selectable value within the selected range

Accuracy
Timing
+50ms -20ms or ± 0.5% of Set Time whichever is greater
Repeat
±0.3% of Set Time

Timing and Reset Inputs
Opto-isolated 12-240V ±10% AC or DC. Minimum pulse width 20ms. Input impedance 180k

Installation Category (IEC 664)
Overvoltage category II
(Pollution degree 2)

Output Relay
Contacts
SPST voltage free contacts programmable as NO or NC.
Contact Rating
8A 250V AC cosø =1
5A 250V AC cosø =0.4
8A 30V DC cosø =1
Reaction time
<20ms.
Expected life
Electrical 8A resistive load 100,000 operations
Electrical 2A resistive load 1,000,000 operations

Operating temperature
-10 to +60°C (14 to 140°F)

Storage temperature
-20 to +70°C (-4 to 158°F)

Altitude
Up to 2000m

Relative Humidity
80% max up to 31°C (88°F), decreasing to 50% max at 40°C (104°F)

Environmental protection
IP65 when properly installed using the sealing gasket supplied

TIMING RANGE AND DISPLAY

There are nine timing ranges and against each is given (in brackets) the flowchart display which selects it.

- 1 to 99999 seconds (C3)
- 0.2 to 9999.9 seconds (B3)
- 0.20 to 999.99 seconds (A3)
- 1 to 99999 minutes (E4)
- 0.1 to 9999.9 minutes (E3)
- 0.01 to 999.99 minutes (D3)
- 1 to 99999 hours (B4)
- 0.1 to 9999.9 hours (C4)
- 0.01 to 999.99 hours (D4)

These can be displayed as elapsed time (time up) or time remaining (time down).

Elapsed time is annunciated with ▲ and reset is to zero.

Time remaining is annunciated with ▼ and reset is to Preset (t, t+ or t=).

PROGRAMMING

To enter programming mode press and hold the Digit 1 and Digit 2 keys together for 3 seconds until the word PROG is annunciated.

The PROG annunciator appears on the display all the time in programing but has been omitted from the flowchart for the sake of clarity. On the flowchart the annunciators are very much bigger in proportion to the numeric digits than the real display. This is to aid legibility.

Whenever you enter programming mode the options and values displayed are the ones in current use. Go through all the stages in the flowchart using S to step backwards and forwards though the options at each stage and Reset (R) to move on to the next stage.

Line 1

Select one of 8 timing modes which, on the flowchart (only) overflows on to line 2.

Line 3

Select one of 9 timing ranges, hours, minutes or seconds and resolution. The selection you make here determines the range in which the Time is displayed. This stage overflows (on the flowchart only) on to line 4.

Line 5

Here the programming sequence automatically takes one of three branches. The route it takes depends on the timing mode selected above.

For modes ON DLY, OFF DLY, SS, RC= and RC= DLY, the sequence goes to column A on the flowchart with the appropriate annunciator showing. For these modes you need only one Set Time. The next press of Reset goes to line 7.

Modes RC DLY and RC require 2 Set Times. Enter t+ at B5, press Reset and enter t- at B6.

For mode OS only you enter t, press Reset and then enter a Pulse Width. Pulse Width (C6) is always in seconds to 2 places of decimals.

Line 7

Use the S key to step though LEVEL TRIGgered, EDGE TRIGgered and EDGE RETRIGgerable and Reset to move on.

Line 8

Select increment time (up) in which reset is to zero or decrement (down) in which reset is to Preset (Set Time).

Line 9

Select normally open (NO) or normally closed (NC) for the relay contacts.

At the end of the sequence, accept the settings by going through all the stages again without making any changes.

NOTE:

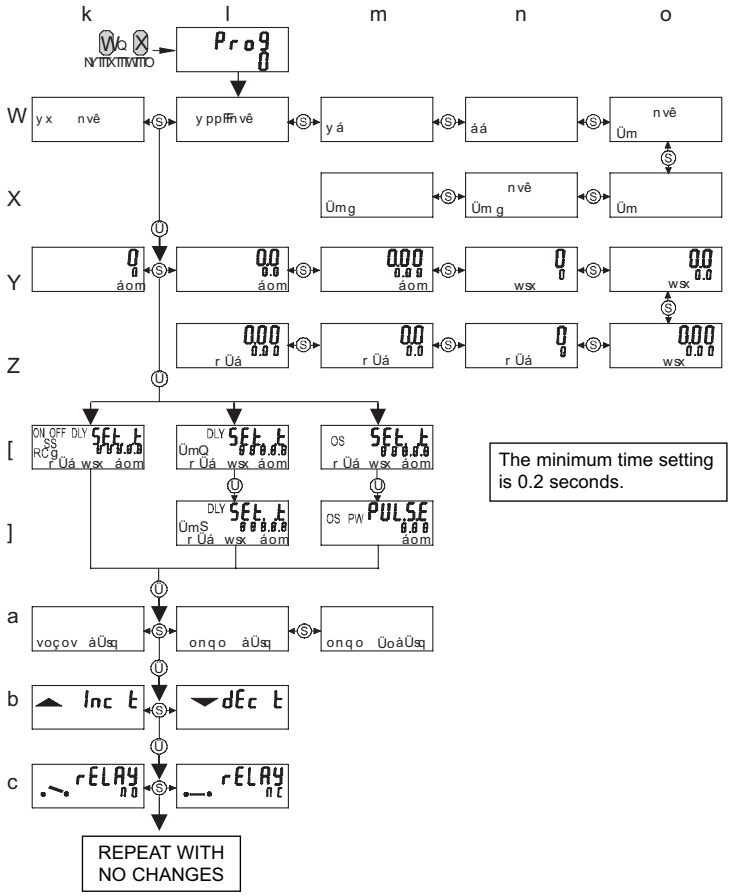
You can also set any of the Set Times (t, t+, t- or t=) “on the fly” during normal operation. To do this you use the digit keys and the Set Time appears on the subsidiary display. If the timer is running in a cyclical mode, the Set Time which changes when you press the keys is the one being annunciated at that instant.

Initial Programming

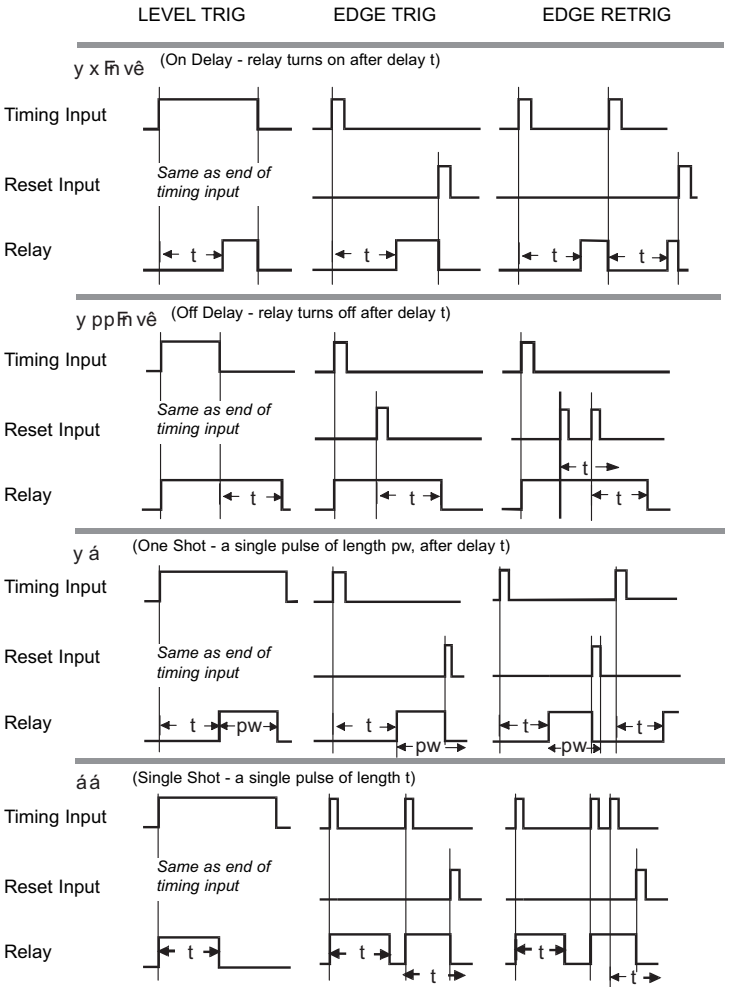
Mode RC=
Time 0.0 (tenths of second)
Time 1=.02
Time 2=.05
Level Triggered
DEC -t
Relay NO

These settings are just a starting point each treatment will require some adjustments after calibration.

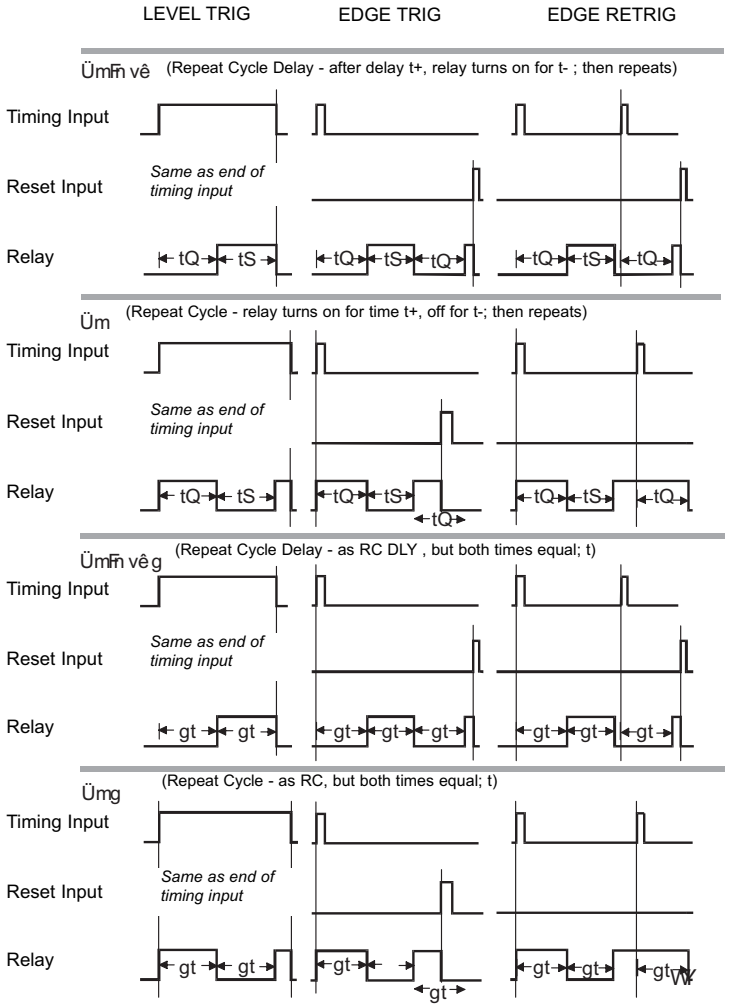
PROGRAMMING FLOWCHART



TIMING


LEVEL TRIG
EDGE TRIG
EDGE RETRIG
y x fn vê
(On Delay - relay turns on after delay t)
Timing Input
Reset Input
Same as end of timing input
Relay
t
y pp fn vê
(Off Delay - relay turns off after delay t)
Timing Input
Reset Input
Same as end of timing input
Relay
t
y á
(One Shot - a single pulse of length pw, after delay t)
Timing Input
Reset Input
Same as end of timing input
Relay
t
pw
á á
(Single Shot - a single pulse of length t)
Timing Input
Reset Input
Same as end of timing input
Relay
t

MODES


LEVEL TRIG
EDGE TRIG
EDGE RETRIG
(Repeat Cycle Delay - after delay t+, relay turns on for t- ; then repeats)
Timing Input
Reset Input
Same as end of timing input
Relay
tQ
tS
(Repeat Cycle - relay turns on for time t+, off for t-; then repeats)
Timing Input
Reset Input
Same as end of timing input
Relay
tQ
tS
(Repeat Cycle Delay - as RC DLY , but both times equal; t)
Timing Input
Reset Input
Same as end of timing input
Relay
gt
(Repeat Cycle - as RC, but both times equal; t)
Timing Input
Reset Input
Same as end of timing input
Relay
gt

WARNING
THIS UNIT CONTAINS A LITHIUM BATTERY AND MUST NOT BE DISPOSED OF IN A FIRE OR EXPOSED TO TEMPERATURES BELOW -20 C OR ABOVE +70 C.

WARNING
Installation and maintenance must be carried out by suitably qualified personnel only. Hazardous voltages may be present on the connection terminals.

Installation

This product is intended to be installed in accordance with the operating and installation requirements of Overvoltage Category II and Pollution Degree 2 (as defined by IEC 664).

It must be fitted in a suitable enclosure which is accessible to qualified personnel only.

The relay output circuits must be fitted with fuses suitable for the voltage and current being switched.

Maximum fuse ratings:

250V AC	@ 8A cosØ= 1	fuse rating 8A
250V AC	@ 5A cosØ= 0.4	fuse rating 5A
30V DC	@ 8A cosØ= 1	fuse rating 8A

All conductors carrying hazardous voltage should have external switching or disconnect mechanisms fitted which provide at least 3 mm of contact separation in all poles.

Failure to install or operate the unit in accordance with the above requirements may result in the electrical safety of the unit being impaired.

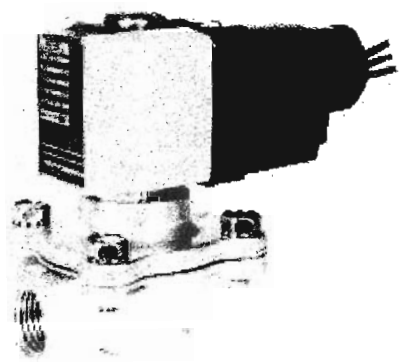
Maintenance

Ensure that all power sources to the unit are isolated prior to maintenance, inspection or cleaning.

There are no user serviceable parts inside this unit. Under no circumstances should the case be opened.

All external wiring connections should be inspected at regular intervals. Any damaged wiring should be replaced and any loose connections should be retightened.

Cleaning should be carried out using a dry cloth to wipe the casing of the unit.



ASCO

Next Generation Sol Valve 1/2", 12-24/DC

Stock #:	**44313**
Brand:	ASCO
Series:	8210P-Norm Closed
Mfr Part #:	8210P94-12-24/DC

Usually Ships: 7 Days

Price:
Buy 1 for $160.55 each
Buy 3 for $152.10 each

Qty: 1 Add to Cart

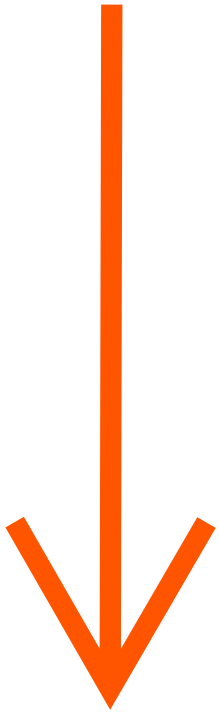
Email Page Print Page

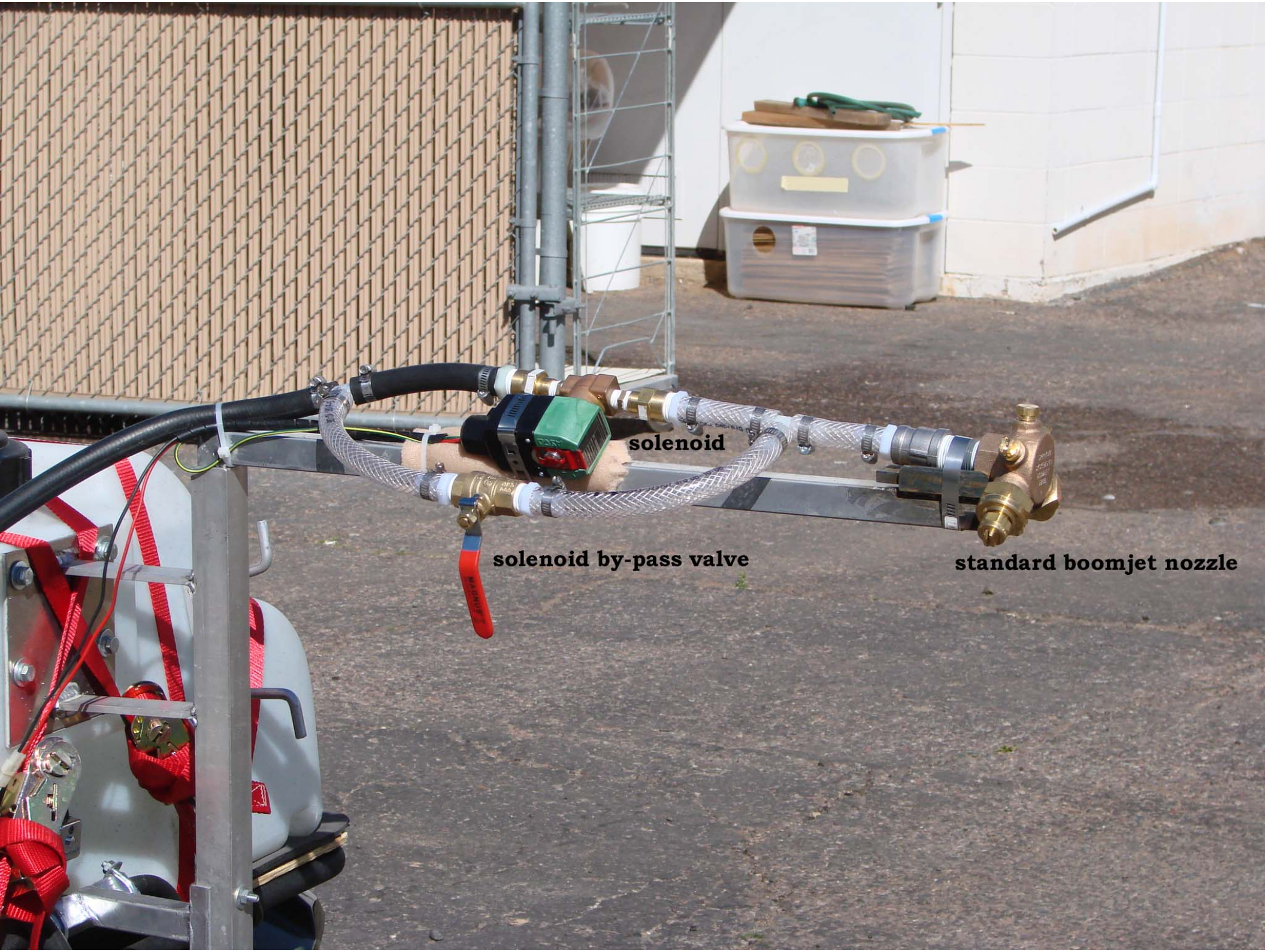
Specifications

ASCO Red Hat Next Generation solenoid valves offer up to 80% reduction in power consumption - ideal for control of air, water, and non-corrosive media. The nominal power rating for this valve is 2 watts, compare to conventional solenoids which may require 17 watts or more. The savings in power usage over the installed life of the valve will lower the total cost of ownership up to 14% or more. Extended coil life due to lower operating temperatures and built-in electrical surge suppression. This 2-way normally closed valve has one inlet and one outlet and does not pass fluid until the coil is energized. Suitable for vacuum service from 0-29 inches Hg. Solenoid approvals to UL, CSA and CE standards. Three year warranty on the coil.

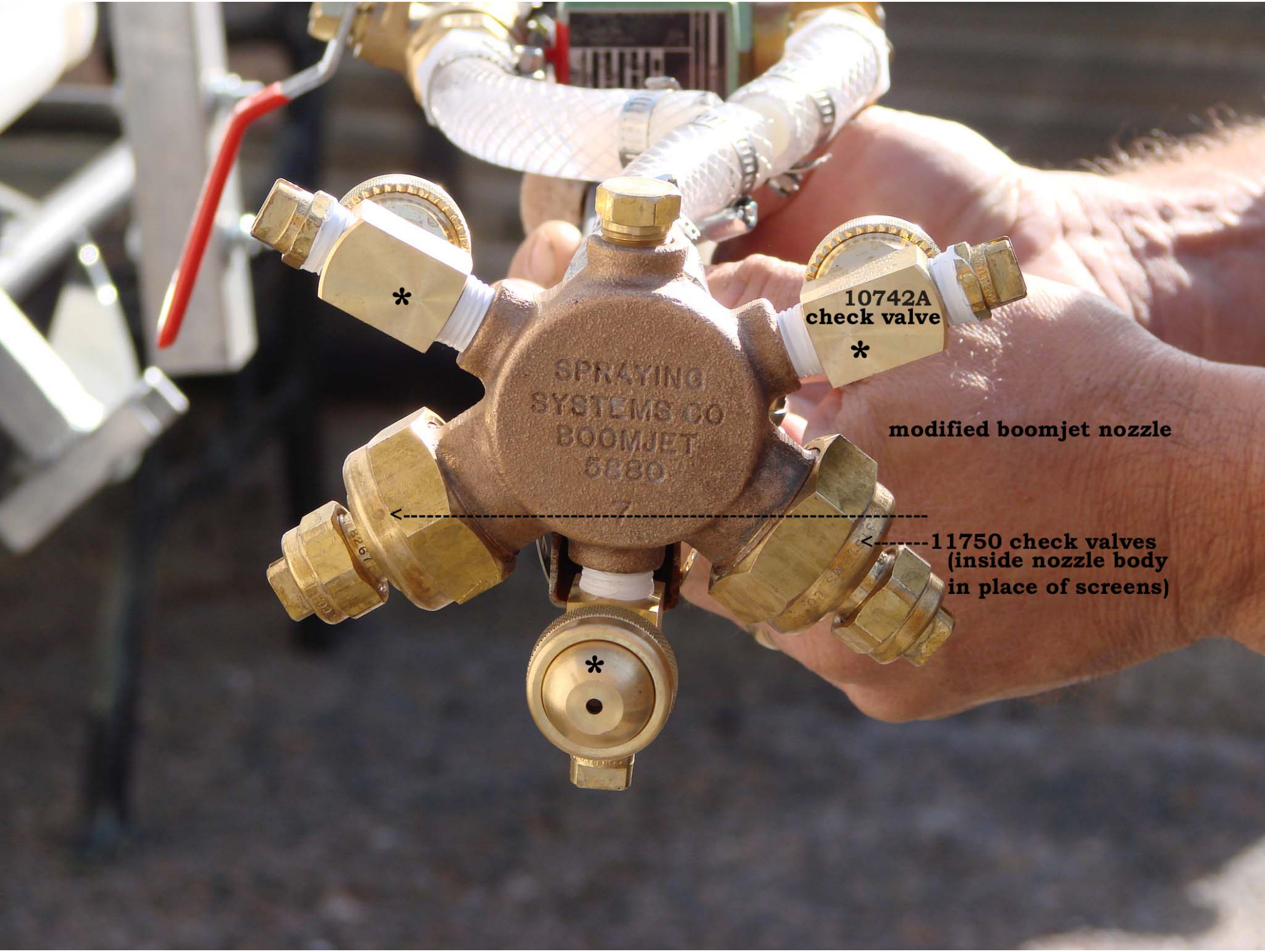
Type: 2-Way Normally Closed (energize to open)
Pipe Size: 1/2" NPT, 5/8" Orifice, Cv 4
Construction: Brass Body, NBR (buna-n) seals, other materials include stainless steel 305, 430F, 302, and a copper shading coil
Pressure (Min-Max): 0-150 PSI (air), 0-150 PSI (water)
Flow Rate (Min-Max): 0-49 GPM (water), 0-394 SCFM (air)
Coil Type: General purpose/watertight, dusttight, corrosion resistant
Enclosure Rating: Type 1, 2, 3, 3S, 4 & 4X
Coil Rating: 12 to 24 VDC, 2 watts nominal (peak inrush current 3.2 amps - maximum duration = 72ms) , class H continuous duty service
Coil Termination: 1/2" Conduit Hub with 24" lead wires
Agency Approvals: UL, CSA, and CE standards
Media Temperature: 180° F maximum
Ambient Temperature: 32-140° F nominal (minimum 0° F where freezing water is not a factor)
PDF Data Sheet: ASCO Next Generation 2-Way Valves

Picture Gallery




solenoid
solenoid by-pass valve
standard boomjet nozzle

control valves
boom by-pass
back to tank
JACKRABBIT
4x4
500


*
10742A
check valve
*
SPRAYING
SYSTEMS CO
BOOMJET
5880
modified boomjet nozzle
11750 check valves
(inside nozzle body
in place of screens)
*

lower boom support
(top view)

lower boom support
(side view)

added drain valve each side lowest
points of jackrabbit pro spray tank

control valves
&
switches
JACKRABBIT Pro
WARNE
CHEMICAL
& EQUIPMENT CO.
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www.warnechemical.com
RANGELAND
boom by-pass valve
pressure regulator & gauge
drain
valve

complete newly modified jackrabbit pro spray system mounted on 2007 suzuki vinson 500 with calc-an-acre distance tracking system

new timer
(E5-248-C1420)
EATON
place in a protective covering
and slip in tool area under seat

December 8, 2009

Advised Part Replacement for ATV Sprayer Modification Parts List

One of the parts previously listed for the ATV Sprayer modification is being replaced.

We suggest that:
the ½ inch solenoid valve
(1-ASCO Solenoid valve Part # 8210P94-12-24/DC Stock # 44313 $160.55) be replaced with a ¼ inch solenoid valve
(1-ASCO Solenoid valve Part # 8262P212-12-24/DC Stock #44308 $113.50)

The data developed in the report "Improving ground application technology for treating rangeland grasshoppers and Mormon crickets: Developing ultra low volume capability" was generated with the ¼ inch solenoid. The ½ inch solenoid was substituted for it in the original parts list for standardization. However, the charts developed for the ¼ inch solenoid are not accurate for the ½ inch solenoid. Additionally, after evaluating the ½ inch valve we discovered that while it works it may not provide the versatility that the ¼ inch valve seems to provide. If you have already purchased the ½ valve it will work but the original charts will not be accurate. We are currently generating charts for the ½ inch valve. For these reasons if you have not already purchased the parts listed earlier, we suggest you purchase the ¼ inch solenoid instead of the ½ inch solenoid.

If you have any questions please call Nelson Foster (602) 437-12956 ex 225 or Lonnie Black (602) 437 1295 ex 232.

Thank you.