

OPERATIONAL NOTE

PORTABLE BATTERY POWER AND SMALL-RESERVOIR MODIFICATIONS FOR PESTICIDE MISTING SYSTEMS

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ABSTRACT. United States military personnel deployed in austere hot-arid, temperate, and tropical conditions in remote locations worldwide rely on the Department of Defense (DoD) Pest Management System measures such as application of pesticide residual and ultra-low-volume or thermal fog treatments for protection from routine exposure to nuisance and disease-vector insects. Timed pesticide misting systems originally developed for residential outdoor use show promise as potential enhancements to standard DoD Pest Management System measures, in particular to protect perimeters surrounding US military field encampments. To investigate the capabilities of misting systems in remote locations in diverse environments, this technical engineering report describes the development of 2 key modifications to a commercial residential misting system to enable us to operate the system away from a standard power grid, and to safely operate the system with small volumes of a variety of pesticide misting formulations. The components needed to modify the commercial misting system include the following: 5,000-W inverter, 12-V 100 Ah battery, 24-gal tote, solar panel with charge controller, 18 in. (45.7 cm) 0-gauge wire with ½-in. (1.27-cm) eyebolt connectors, 5-gal container (wide mouthed), ½-in.-to-½-in. connector, ½-in. tubing, ⅜-in.-to-⅜-in. connector, ⅜-in. tubing, ¼-in.-to-¼-in. connector, ¼-in. flexible tubing, securable patio box (80 gal), 5-gal (18.9-liter) bucket (modified), and a canning funnel.

KEY WORDS Pesticide misting application, vector control, botanical, space spray, automatic chemical applicator

United States military personnel deployed in austere hot-arid, temperate, and tropical conditions in remote locations worldwide rely on the Department of Defense (DoD) Pest Management System for protection from routine exposure to nuisance and disease-vector insects. The DoD Pest Management System consists of personal protective measures such as permethrin treatment of uniforms and application of US Environmental Protection Agency–approved repellents such as deet to exposed skin, along with standard integrated vector control methods such as source reduction, deployment of larval control formulations, and application of pesticide residuals and ultra-low-volume (ULV) and thermal fog space sprays (AFPMB 2015). One technology that could be leveraged to enhance the DoD Pest Management System is timed pesticide misting systems. Unfortunately, little research has been conducted with pesticide misting systems to evaluate their control efficacy (Cilek et al. 2008; Revay et al. 2012, 2013).

A pesticide misting system typically consists of a large pesticide reservoir connected to a high-pressure pump controlled by a digital timer that sends pesticide through flexible tubing to a series of ULV nozzles that may be positioned at intervals around a protected area. The misting timer is set to deliver a focused ULV plume for one to several minutes simultaneously around the entire perimeter and can be synchronized with known peak biting-insect activity—for example, targeting day-biting mosqui-

toes. Pesticide misting systems were initially developed for backyard and patio residential use, but quickly expanded to include agricultural applications to protect livestock pens (McPhee and Hirst 1988, Meyer et al. 1990).

We investigated whether pesticide misting systems could be augmented to enhance the DoD Pest Management System in the field; for instance, protecting small US military outpost or operating base perimeters in deployed settings in a variety of environments. However, to conduct these investigations we required the misting system to function 1) in remote areas away from a standard power grid and 2) with a ≤5-gal (18.9-liter) pesticide reservoir more suitable for experimental trials. Therefore, this report describes 2 modifications to a commercial residential pesticide misting system: a portable solar rechargeable battery/inverter system to supply AC power, and a small reservoir to safely support misting trials with a variety of pesticides.

We used a MistAway Gen 1.3 (MistAway Systems, Inc., Houston, TX) for a base system to develop the portable power and small-reservoir modifications. The Gen 1.3 consists of a combined pump/digital controller unit (the “head”) that sits atop a 55-gal (208-liter) misting formulation reservoir and is connected to a user-configured circuit of steel ULV nozzles connected by ¼-in. (0.64-cm)-diam black Tygon™ tubing. Three Tygon tubes extend from the head downward into the reservoir: a

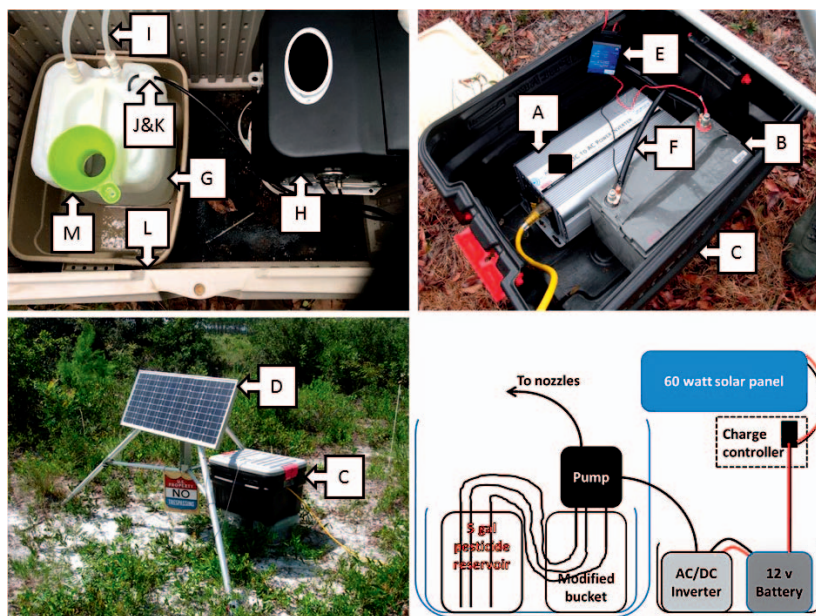


Fig. 1. MistAway Gen 1.3 residential misting system with modifications to power source for use in remote locations away from a power grid and modifications to the pesticide reservoir for portability and rapid changing of formulations for experimental trials. Letter labels are keyed to Table 1 and descriptions in the main text.

½-in. (1.27-cm)-diam main suction line, a ¼-in.-diam automatic drain line that allows liquid to drain back into the reservoir from the circuit, and a ⅜-in. (0.95-cm)-diam agitator line that enables recirculation of the misting formulation between the pump and the reservoir for 15 sec prior to a misting spray to mitigate settling or separation in the tank. The Gen 1.3 can be connected to a maximum of 75 ULV nozzles in a circuit linked by a total maximum of 900 ft (274 m) of ¼-in.-diam Tygon tubing. Misting can be programmed up to 24 times in a day, with each mist spray lasting 45–120 sec. Using a Sympatec laser system (Sympatec Inc., Clausthal, Germany), we found that the Gen 1.3 generated droplets with a droplet median diameter between $39.3 \pm 2.8 \mu\text{m}$ and $42.7 \pm 2.3 \mu\text{m}$ for 1 and 11 nozzles, respectively. Pesticide coverage over a spray area depends on the number of nozzles in the circuit, the number of sprays, and the length of time per spray. From observations of the visible plume from a 2-min spray in no-wind conditions we estimated that each nozzle produces a plume approximately 6 ft (1.83 m) wide, 6 ft high, and 8 ft (2.44 m) deep, or approximately 288 ft^3 (8.2 m^3). The portable pesticide misting system with both the power and reservoir modifications in place is shown in Fig. 1.

The MistAway Gen 1.3 from the manufacturer runs on standard 110-V household current through a 3-prong plug. The portable power modification simply provides 110-V power to this plug from a power inverter connected to a 12-V battery that is recharged by a solar panel. We used a minimum 5,000-W 12-V/110-V power inverter (Fig. 1A)

(AIMS power, Reno, NV) and 0-gauge battery cables (NAPA auto parts, Gainesville, FL) (Fig. 1F) because the load exerted on the battery from the pump is nearly 9 A. We attempted combinations of lower-wattage inverters and smaller-gauge cables and found that the initial draw as the pump activated would instantly trip the circuit, or would be insufficient to activate the pump at all. We found that only a heavy-duty deep-cycle 12-V battery such as an Ultracell UCG 100-12 (Ultracell LTD; Liverpool, UK) (Fig. 1B) with at least 100 Ah capacity would be able to power the pump through the inverter. This battery–inverter configuration could provide the system with enough energy to conduct up to 12 2-min misting sprays before needing to be recharged.

To recharge the deep-cycle 12-V battery in the field we selected a minimum 60-W output solar panel (Solarland, Ontario, CA) (Fig. 1D) fitted with a charge controller (diode) (Fig. 1E) to ensure that power did not leak from the battery back into the solar panel and to prevent the solar panel from overcharging the battery. The solar panel was fastened to a tripod in an area free from shadows most of the day, oriented north/south for maximum intensity and duration of sun exposure. We stored the inverter and battery in a 24-gal (90.8-liter) Action Packer (No. 1172; Rubbermaid, Atlanta, GA) container (Fig. 1C) with a small notch in the upper lip of the container under the lid for pass-through of the Gen 1.3 power cord and the solar panel charging wires. With an extension cord up to 50 ft (approximately 15 m) long, we could place the solar panel and portable power assembly in a sunny area yet

position the Gen 1.3 misting unit in experimental plots not necessarily exposed to the sun. The wiring schematic for the 12-V battery, 5-kW inverter, and 60-W solar panel are shown in the lower right panel of Fig. 1.

We developed a small-reservoir system for the Gen 1.3 for several reasons: the 55-gal reservoir was too large for small experimental trials where we typically only needed 5 gal of pesticide misting formulation; the head-reservoir configuration was optimized for infrequent reservoir fills by homeowners whereas we needed a configuration optimized for safe, quick changes so that we could conduct trials with a variety of formulations over a short period; we needed capability to leave the misting system overnight unattended and thus secured to prevent unauthorized access and potential pesticide exposure; and we needed enhanced secondary containment to prevent introduction of pesticides into the soil in remote locations.

The main component of the reservoir modification was to use a 5-gal polyethylene carboy (Qorpak Inc., Bridgeville, PA) (Fig. 1G) in place of the 55-gal drum supplied with the Gen 1.3, and to position the pump/controller head adjacent to the reservoir instead of on top of it. Conveniently, this 5-gal carboy fit inside a 30-gal (28.4-liter) plastic storage box (Rubbermaid Corp.) for secondary containment, which in turn fit inside a 80-gal (302-liter) lockable patio box (Lifetime Products, Clearfield, UT) (Fig. 1L) with enough space to also fit the Gen 1.3 head (Fig. 1H) next to it. We drilled 3 holes in the top of the carboy— $\frac{1}{2}$ in., $\frac{1}{4}$ in., and $\frac{3}{8}$ in.—to direct and support the 3 tubes from the head. We designed a custom tubing arrangement to connect the head to the adjacent reservoir, using approximately 3 ft (1 m) each of flexible stock $\frac{1}{2}$ -in., $\frac{1}{4}$ -in., and $\frac{3}{8}$ -in.-diam Tygon tubing (Fig. 1I) instead of the 3 fixed-length tubes supplied by the manufacturer.

To support the pump we placed it on an inverted 5-gal heavy-duty screw-top chemical containment bucket (Bway Corp., Atlanta, GA) with the bottom 3 in. (7.6 cm) removed so that the 3 tubes could hang freely below the head. These tubes were then fed through 3 adjacent 1-in. (2.5-cm) holes drilled into the side wall of the bucket approximately 6 in. (15.2 cm) from the top so that they could be routed to the adjacent 5-gal carboy (Fig. 1, lower right panel). The inverted screw-top bucket with the gasketed lid screwed on tightly conveniently served as a secondary containment for the head itself, to capture any leaks from the connection points of the 3 tubes. For an additional measure of spill protection inside the 80-gal patio box, we placed an inverted ~ 40 -in. \times 24-in. (102-cm \times 61-cm) plastic lid from a 50-gal (189-liter) storage box beneath all other components. We cut small notches in the upper edge of the patio box under the lid to permit pass-through of the misting tube and the Gen 1.3 power cord.

The 5-gal carboy includes a 2-in. (5.1-cm)-diam screw-cap opening in which a wide plastic canning

funnel (Ball Corp., Broomfield, CO) (Fig. 1M) fits tightly for rapid filling with formulation and water diluent. We cut the tip of the main suction tube from the pump with a shallow ~ 1 -mm bevel and pushed it down until it touched the bottom of the reservoir so that the majority of formulation would be used in spray trials, typically leaving < 50 ml to be disposed in accordance with formulation labels. The modified Gen 1.3 system was used effectively in misting trials with a variety of synthetic and botanical-based misting formulations in hot-arid desert, hot-humid tropical, and warm temperate/subtropical environments against a range of mosquito, sand fly, and filth-breeding fly insect targets, to be described in separate reports. The formulations we successfully used with the modified system include: (botanicals) EcoEX-EMPT MC (EcoSMART Technologies, Inc., Franklin, TN), Essentria IC³ (Envincio, LLC, Cary, NC); (pyrethroid) Sector Misting Concentrate (McLaughlin Gormley King [MGK] Co., Inc; Minneapolis, MN); and (pyrethrins) Vampyre Misting Concentrate (MGK Co.).

We have encountered a variety of impacts to the modified Gen 1.3 system from the environment. For example, ants have infiltrated the misting pump and misting computer, effectively shorting contacts and compromising the integrity of the system. Sealing the misting pump unit and the misting pump computer with silicone caulk could prevent further infiltration. We have experienced difficulty maintaining the viability of the nozzles over time due to buildup of grit in the nozzles. However, the manufacturer can provide inexpensive rebuild components for the nozzles, which may easily be repaired in the field without tools. Additionally, an in-line filter for the pesticide solution rather than filtering at the nozzle head could reduce blockages and may extend the life of the nozzles. Finally, there is the issue of organisms (rodents, amphibians, cockroaches, ants, snakes, and lizards) infiltrating into the secured containment boxes (Fig. 1L; Table 1) that house the spray pump and the pesticide. Little can be done to control for these organisms and prevent them from infiltrating the storage unit. Steps should be taken, however, to clean any debris and to sterilize infiltrated storage units before handling the misting unit given that intrusive organisms carry their own set of dangers.

In environments such as hot-humid tropical or other areas with heavy canopy, the solar panel is obviously not a reliable method to keep batteries charged. For field trials where > 12 sprays were needed to conduct consecutive daytime and nighttime trials, we rotated 12-V batteries. This shortfall presents challenges, but likely no barriers for future development for off-grid field use in military settings; these are challenges that could potentially be overcome by use of low-power/high-pressure pumps, or larger or higher-power solar panels.

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Table 1. Component parts for power system and pesticide reservoir modifications to the MistAway Gen 1.3 residential misting system, referenced to Fig. 1 and descriptions in the main text.

Fig. 1 reference	Product name	Purpose	Quantity
A	5,000-W inverter	Converts 12-V DC to 110-V AC power	1
B	12-V 100-aH battery	Provide power to mister	1
C	24-gal tote	Secondary containment	1
D&E	Solar panel with charge controller	Generate power to charge 12-V battery	1
F	18 in. 0-gauge wire with ½-in. eyebolt connectors	Connect battery to inverter	2
G	5-gal wide-mouthed container	Misting formulation solution reservoir	1
H	Spray pump	Delivers pesticide to nozzles	1
—	½-in.-to-½-in. connector	Connects ½-in. tubes	2
—	½-in. tubing	Tubing	3 ft
—	¾-in.-to-¾-in. connector	Connects ¾-in. tubes	2
I	¾-in. tubing	Tubing	3 ft
J	¼-in.-to-¼-in. connector	Connects ¼-in. tubes	2
K	¼-in. flexible tubing	tubing	3 ft
L	Securable patio box (80 gal)	Contains system with lock	1
—	Padlock or combination lock	Security	1
—	5-gal bucket (modified)	Pump head support and secondary containment	1
M	Canning funnel	Funnel for loading formulation into reservoir	1

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