ARTICLES

A NEW WIND-TUNNEL SYSTEM FOR TESTING INSECTICIDAL AEROSOLS AGAINST MOSQUITOES AND FLIES [1]

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ABSTRACT. A new wind tunnel apparatus was designed in 1973 for testing insecticidal aerosols against mosquitoes and flies. The construction, calibration, and operation are discussed so the system can be utilized by other investigators. Also described are experimental methods and statistical analyses of results.

Our laboratory has been using a wind tunnel system for more than 20 years to evaluate insecticidal aerosols against mosquitoes and flies (primarily *Musca domestica* L.). The wind tunnel used until recently (Davis and Gahan 1961) was a modification of a system designed by Roan and Kearns (1948). In 1973 we designed and constructed a new wind tunnel system. Its design, construction, calibration, and operation are described here for the use of other researchers. We also describe our experimental methods and give statistical analyses of typical results.

DESIGN AND CONSTRUCTION. The new wind tunnel system is based on the same operating principle as the two earlier models: atomization occurs in the upwind portion of the tunnel, and the aerosol is transferred by horizontal wind movement to caged insects exposed in the downwind portion of the tunnel. The major change in design concerned this horizontal movement: air is blown through the new system rather than being drawn with a suction fan. The use of a blower eliminates the possibility of igniting flammable solvents and diluents by electrical and mechanical sparking that is present with a suction fan. Also, the need for periodic cleaning of deposits of insecticides on the suction fan is eliminated.

[1] This paper reflects the results of research only. Mention of a pesticide or a commercial or proprietary product in this paper does not constitute a recommendation or an endorsement of this product by the USDA.

The design of the wind tunnel aerosol exposure system can be seen in Figures 1–3. The components used for construction are as follows:

(A) Variable autotransformer (Steco-type 2PF 1010, 120 V, 10 amp, Steco Inc., Dayton, Ohio)

(B) Shaded Pole Blower (Dayton Model 2C 841, 120 V, 2.9 amp, Dayton Electric Co., Chicago 18, Illinois)

(C) Blower box or plenum chamber 20 in.^{3} (51 cm^3); constructed of 0.0375 in. (0.95 cm) plywood

(D) Front wind tunnel tube screen cover (16-mesh galvanized screen wire)

(E) Wind tunnel tube: cylindrical tube 6 in. (15.2 cm) in diameter x 36 in. (91 cm) long, constructed of 0.0625 in. (0.16 cm) rolled galvanized sheet metal

(F) Atomizing nozzle (see Fig. 3) constructed of 1 in. (2.54 cm) diameter brass stock x 2 in. (5.08 cm) long; centered in tunnel tube 4 in. (10.2 cm) from upwind end and soldered onto 0.5 in. (1.27 cm) ID copper tubing

(G) Front tube cover, 8.625 in. (21.9 cm) wide x 11.125 in. (28.3 cm) long, constructed of 0.0625 in. (0.16 cm) rolled galvanized sheet metal; hinged to tube in rear and latched in front

(H) Rear tube cover, 8.625 in. (21.9 cm) wide x 14.625 in. (37.2 cm) long; same construction as (G)

(I) Exposure cage holder, 3.375 in. (8.6 cm) diameter x 0.875 in. (2.22 cm) wide, constructed of 0.0625 in. (0.16 cm) rolled galvanized sheet metal and mounted 6 in. (15.2 cm) from downwind end of tunnel; the space

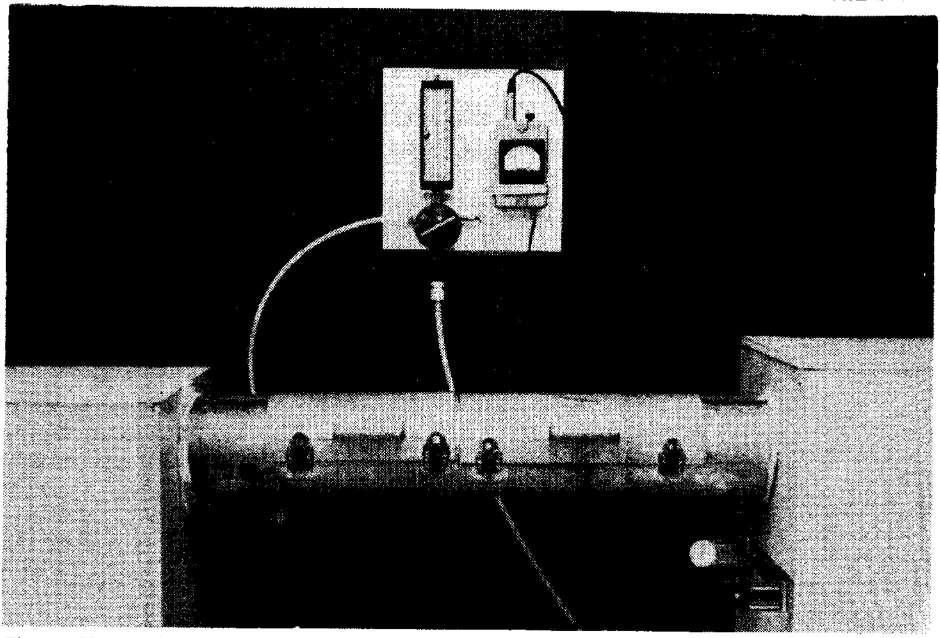

Fig. 1. USDA wind tunnel exposure system for testing insecticidal aerosols against mosquitoes and flies.

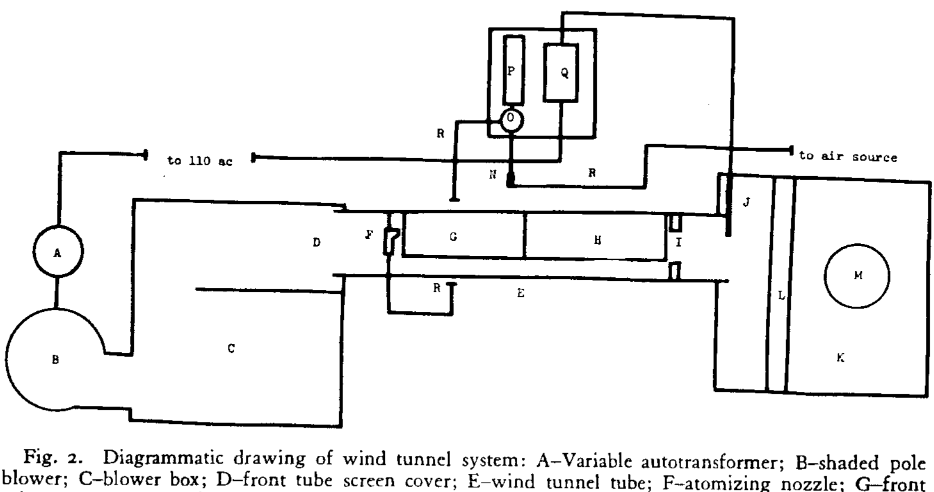

Fig. 2. Diagrammatic drawing of wind tunnel system: A–Variable autotransformer; B–shaded pole blower; C–blower box; D–front tube screen cover; E–wind tunnel tube; F–atomizing nozzle; G–front tube cover; H–rear tube cover; I–exposure cage holder; J–anenometer probe; K–exhaust box; L–fiberglass filter; M–exhaust port; N–air pressure valve; O–air pressure regulator; P–mercury manometer; Q–air velocity meter; R–air transfer lines.

between the cylindrical cage holder and the wind tunnel tube is covered with two layers of 16-mesh galvanized screen wire separated by 0.875 in.

(J) Anemometer probe

(K) Exhaust box 16 x 20 x 20 in. high (41 x 51 x 51 cm), constructed of 0.375 in. (0.95 cm) plywood

(L) Fiberglas filter-disposable; 16 x 20 x 2 in. (45 x 51 x 5.08 cm)

(M) Exhaust port, 6 in. (15.2 cm) opening to outside air

(N) Air pressure valve (brass gate valve)

(O) Air pressure regulator (Stewart Warner Model 7604, equipped with a needle valve for fine adjustment)

(P) Manometer, 3 in. (7.6 cm) mercury manometer (The Meriam Instrument Co., Cleveland, Ohio)

(Q) Air velocity meter—optional (Hot wire type, Model G-11, Hastings-Raydist Inc., Hampton, Virginia)

(R) Air transfer lines, 0.25 in. (0.64 cm) ID polyethylene tubing

The total cost of constructing our wind tunnel system (excluding our labor) in 1973 was ca. $500.00. Approximately one-half of this cost was the custom construction of the wind tunnel tube and atomizing nozzle. Another major cost was the optional hot-wire air velocity meter ($127.50).

CALIBRATION AND OPERATION. The new wind tunnel system was calibrated by trial and error until we learned the combination of settings that produced assays comparable to those produced by the old system. (This was done so that data produced by the new system could be compared directly with data obtained previously.) Obviously, the wind tunnel could be used successfully with various combinations of nozzle pressures, air velocities, and volumes of aerosol delivery. However, the aiming of the atomizing nozzle in the tube is a critical calibration that must oc-

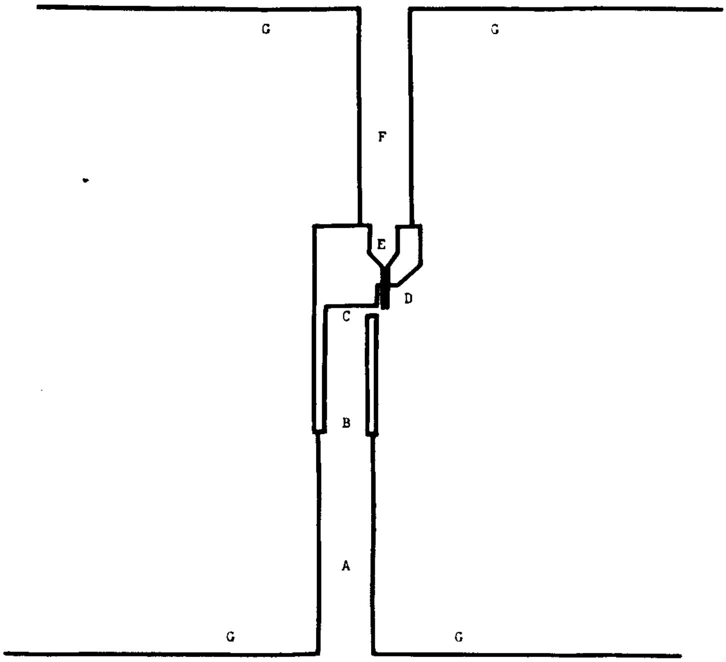

Fig. 3. Cross section of atomizing nozzle mounted in tunnel tube: A–0.5 in. (1.27 cm) copper tubing; B–0.125 in. (0.32 cm) pipe fitting; C–0.0625 in. (0.16 cm) air discharge tube; D–0.035 in. (0.089 cm) liquid discharge tube; E–0.25 in. (0.64 cm) liquid reservoir; F–0.5 in. (1.27 cm) copper tubing; G–wind tunnel tube.

cur in the final stage of construction. The nozzle must provide a uniform deposit of aerosol in the downwind portion of the tube. The aim can be calibrated with the aid of two 1 x 8.6-cm strips of oil-red dye card positioned crosswise in an exposure cage. The deposit pattern of mineral oil droplets is readily apparent on these oil-sensitive cords.

The tunnel is calibrated for an air velocity of 4 mph (6.4 km/hr) at the downwind end of the tube with an exposure cage positioned in the cage holder and the nozzle pressurized. Air velocity can either be measured periodically with most hand-held anemometers or monitored continuously with the optional hot-wire air velocity meter.

The nozzle air pressure is adjusted to 1.5 psi (106 g/cm^2). Coarse adjustment is made with the air pressure regulator diaphragm, and fine adjustment is made with the needle valve bleed. The air pressure is monitored with the mercury manometer. Air for our tunnel is supplied by a central system, but the nozzle could be supplied by a small air pump with a free air capacity of 1.3 ft^3 (0.037 m^3) /min and a maximum pressure of 15 psi (1.1 kg/cm^2).

Insecticides to be evaluated are diluted in acetone and pipetted (we use an automatic pipette for convenience and efficiency) as 0.25-ml aliquots into the nozzle (designed for total delivery of discrete pipettings). After an exposure cage is inserted and the rear tube cover is closed, we allow 5 sec for the air column to reach the end of the tube before pipetting the formulation. Also, we allow an additional 5 sec after pipetting before removing the cage to insure complete exposure of the insects to the insecticidal aerosol.

Pipettings of a serial dilution are made from low to high concentrations without cleaning the wind tunnel. However, the tunnel is cleaned at the beginning and end of each test series and before each new insecticide is tested as follows: The atomizing nozzle is rinsed with acetone with the tube closed. Next, the front and rear tube covers are opened, and the entire tube and covers are rinsed with acetone and dried with paper toweling.

Disposable 2 x 3.375-in. diameter cardboard cartons (5.08 x 8.6 cm) (Standard Packaging Corp., Union, NJ 07083) with 16-mesh galvanized screen wire tops and bottoms are used for exposure cages. Also, we use these same cartons (but with nylon screen tops) for holding cages prior to use as exposure cages. Thus these cartons receive double use before they are discarded. The rear tube cover of the wind tunnel is used to exchange exposure cages.

After exposure, the insects are anesthe-

Table 1. Probit analyses of routine aerosol exposures in the wind tunnel; 4 discriminating concentrations (%–w/v) per test with 150 specimens per concentration.

Test date	Regression tests		LC-50[c]	LC-90[c]
	χ^2[a]	F[b]		
		Musca domestica vs. ronnel		
10-29-73	1.7	145	0.06 (0.04 -0.08)	0.17 (0.13 -0.29)
1- 9-74	2.2	152	0.08 (0.06 -0.1)	0.2 (0.15 -0.31)
9-16-74	1.6	214	0.08 (0.06 -0.1)	0.2 (0.15 -0.31)
		Aedes taeniorhynchus vs. malathion		
11-13-73	1.5	200	0.015(0.01 -0.019)	0.046(0.034-0.07)
1- 2-74	1.4	165	0.01 (0.006-0.015)	0.039(0.029-0.07)
1- 7-75	4.3	56	0.012(0.007-0.016)	0.045(0.032-0.082)

[a] All not significant at the 5% level (P=0.75–0.05).
[b] All significant at the 99% level except "56" which was significant at the 95% level.
[c] 95% Fiducial limits in parentheses.

Table 2. Probit analyses of wind tunnel aerosol exposures and topical applications of 5 discriminating concentrations or doses of malathion to adult female *Aedes taeniorhynchus*.

Mosquitoes per dose or conc.	Regression tests χ^2 [a]	F [b]	LC- or LD-50 [c]	LC- or LD-90 [c]
		Topical application (ng/mosquito)		
20	3.2	25	5.4(4.5–6.8)	7.4(6.1–14)
60	1.1	220	5.7(5.1–6.5)	8.8(7.4–12)
		Wind tunnel-aerosol (ppm-w/v)		
50	6.7	37	117(89–151)	275(202–471)
150	26	163	112(95–131)	286(234–377)

[a] All not significant at the 5% level except "26".
[b] All significant at the 99% level except "25" which was significant at the 95% level.
[c] 95% Fiducial limits in parentheses.

tized with CO_2 and transferred to clean holding cages for 1 hr knockdown and 24 hr mortality observations. Cotton pads, soaked in 10% sugar-water solution are placed on top of the holding cages to provide food and water for the insects during the holding period.

EXPERIMENTAL DESIGN AND ANALYSES OF RESULTS. Our experimental design consists of exposing 50 insects in duplicate cages (25/cage). In tests against mosquitoes and house flies, new insecticides are first tested at concentrations of 0.25 percent and 2.5 percent (w/v), respectively. Then the concentration is successively reduced by one-half until the 24-hr mortality falls below 50 percent. This basic test is not intended to yield results that can be compared closely; however, it does eliminate those insecticides that are not toxic enough to warrant further testing, and it identifies the range of discriminating concentrations for those insecticides that are highly effective. This information is useful in the design of additional test programs.

The analyses of typical results in Table 1 show that three replications of the basic test design (150 insects/concentration) with a minimum of four discriminating concentrations (20–99 percent mortality range) provide sufficient data for probit analyses and subsequent critical comparisons of LC–50 and LC–90 values.

Another important consideration is the uniformity of exposure to test insects since this affects the number of specimens needed per concentration to insure statistically reliable results. Table 2 indicates the uniformity of exposure achieved with the wind tunnel by comparing the LC–50 and LC–90 for malathion against mosquitoes exposed in the wind tunnel and by topical application. (The topical applications were made with a calibrated repeatable dispenser (Microliter Syringe, Hamilton Co., Whittier, CA) that delivered an 0.5 μl volume of an acetone solution of malathion.) The wind tunnel data are comparable to the data for topical application when only 2.5x more test specimens are used.

Literature Cited

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Roan, C. C. and C. W. Kearns. 1948. Testing insecticide sprays. Soap San. Chem. 24:133–137, 149–151.