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# THE USE OF ARTHROPODS AS PERSONNEL DETECTORS

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## FOREWORD

The work described in this paper was a cooperative effort by the U. S. Army Limited War Laboratory and the U. S. Department of Agriculture, Agricultural Research Service, Insects Affecting Man and Animals Research Laboratory, Gainesville, Florida. Supervision was continuously provided by USALWL technical personnel. Technical and technician personnel, laboratory space, insectary services, field test areas in Florida and considerable preliminary testing were provided at Gainesville, Florida, by the Gainesville Laboratory.

Field tests in which technical personnel from both LWL and the Gainesville Laboratory participated were conducted at Gainesville, Florida, Aberdeen Proving Ground, Maryland, and in the Panama Canal Zone.

## LIST OF ILLUSTRATIONS





## INTRODUCTION

The problem of detecting people in hiding from a distance is central to developing reliably effective methods of countering ambushes in military operations. Techniques that depend upon detection of airborne human effluents are among those that have at one time or another been considered and/or tried. There comes to mind immediately the well known sensitivity of the canine olfactory apparatus; though the absolute threshold for human odor of a given dog is difficult to determine, it is a matter of observation that a trained dog will "alert" on airborne human scent at a distance of several hundred yards downwind from its source. Perhaps even more phenomenal is the sensitivity of the males of at least some species of insects to sex attractants produced by the females. It has been demonstrated experimentally that the male American cockroach will respond to as few as about 30 molecules of the sex attractant; the male Gypsy moth can detect the presence of a female at a distance of a mile or more upwind. One must ask the question, might not insects that are normally attracted to people be ~~somehow~~ utilized as biosensors in a sensitive and reliable personnel detector?

In examining the problem of utilizing the sensory capabilities of insects for the detection of people, it is reasonable that insects that actively seek out and attack man should be given primary consideration. Candidate species that were tested experimentally in the present study were the giant conenose bug, Triatoma infestans, the common bedbug, Cimex lectularius, the Oriental rat flea Xenopsilla cheopis and the mosquitoes, Anopheles quadrimaculatus, Aedes aegypti and Culex quinquefasciatus. Additionally, the tick Amblyoma americanum was tried in an intrusion monitoring role.

## SELECTION OF SPECIES AND EXPERIMENTAL APPROACHES

### A. Preliminary Tests

The utilization of arthropods for people detection requires two essential components: a sensitive species capable of smelling the effluent of man, and a transducer which will enable the operator to know when the organism has smelled people.

### B. Selection of Arthropod Species

It seemed reasonable to work with those species of arthropods that normally parasitize man. Lice, biting flies, mosquitoes, bedbugs, fleas and ticks are obvious candidates for use as people detectors.

Lice. Lice were considered and ruled out early. In a preliminary test they simply crawled about at random and gave no clear change in behavior to indicate the presence or absence of man. If louse-infested clothing is hung on the bedpost and a man sleeps in the bed, the lice do not orient to or find the man, but will starve to death in the clothing. The necessity for daily blood meals to keep body lice alive considerably lessens their potential value as biosensors.

Fleas. The oriental rat flea was tried in a preliminary test and appeared to have some promise. Its behavior changes from rest to violent jumping when breathed on. Even though this reaction may be caused by the flea being sensitive to $CO_2$, or by the sudden change in relative humidity or temperature, it is possible that fleas have sufficient sensitivity to human odor to be useful in an ambush detector. Field trials were made with a "tin lid" transducer chamber. When the fleas were stimulated they jumped against the metal top of the chamber. The sounds resembled popcorn popping. It was easy to discern a change in activity level. The fleas were slow to quiet down, however, after being excited. This fact coupled with their need for frequent blood meals reduces the potential usefulness of fleas.

Ticks. Ticks live out of doors and survive for long periods of time between feedings. They sit and wait quietly and appear to increase activity instantly when a potential host comes near. They have the disadvantage of being so "soft footed" that only by visual observation was it possible to tell if they were active. Weights attached to their feet did not work out. Ticks were ruled out for extensive testing.

Mosquitoes. Mosquitoes are sensitive biosensors of warm blooded animals. They are "at home" in jungle environments and are reasonably hardy, living as long as 30 days under laboratory conditions. There are such wide variations in species habits, however, that behavior constituting a response can be expected to vary widely. *Anopheles quadrimaculatus* is normally at rest and will fly on the approach of a host. *Aedes aegypti* will normally be at rest or in flight and will land and display a feeding response (probing) when stimulated by the presence of a host.

Attempts were made to find a suitable transducer by which the probing action of *A. aegypti* could be detected. Two arrangements were tried. First, it was thought that the electrical resistance between a metal screen on which mosquitoes rested, and salt solution inside a feeding membrane would change during the probing process. Measurements using an Ohmmeter with a resistance of 100,000 ohms showed no detectable decrease in resistance. The second arrangement was to affix the stretched membrane to a thread fastened in turn to a phono pickup transducer. The mosquito chamber was arranged so that air carrying human odor was admitted through a screen in proximity to the membrane. Mosquitoes would land on the screen, penetrate the membrane with their probosces and immediately withdraw them to probe again. The sounds of the amplified transducer signal sounded like the plucking of a guitar string. Sound was produced only on withdrawal of the probosces.

Newly hatched bedbugs *Cimex lectularius*. When one walks into a room where a dish of newly hatched, unfed bedbugs is exposed, the bugs almost instantly respond to the human presence and become active. It appeared, therefore, that this stage of this species would be a good candidate for development as a biosensor. The problem is one of converting the bugs' activity into noise which can be picked up through a phono pickup. A coil spring of .006" piano wire, sanded so that the bugs could get a foothold, and stretched slightly to separate the coils, was sensitive to the crawling of a single newly hatched bedbug. When one end of the spring was extended and inserted into the rubber block portion of the phono pickup, loud and clear noise of activity was heard. When the bugs were confined to the spring in tiny nylon mesh envelopes, the sounds were deadened. It was not until a chamber matrix of loosely packed fine steel wool was used as a substrate for the tiny bugs, that a device could be tested. In this device the fine mesh wire cage was in turn connected with .006" piano wire to the phono pickup.

Adult bedbugs. Adult *Cimex lectularius* also appeared to have promise. They normally are at rest and are aroused only when a host is at hand. In preliminary tests, cell sensitivity was a problem and in addition, the insects did not quiet down readily after being stimulated.

Adult Triatoma. The giant conenose bug, *Triatoma infestans*, was selected for extensive testing mainly because of the relative ease of handling the loud signal it generates on moving and its apparent sensitivity to human odor. A portable hand-carried chamber was developed which was sensitive to a footstep of a bug and at the same time insensitive to the mechanics of carrying and joggling and to ambient noise.

## HAND-CARRIED CLOSED CELL INSECT AMBUSH DETECTOR

### A. Description of Equipment

The insect detector shown in fig. 1 consisted of a closed cell or "transducer" chamber mounted within a cylindrical bellows air pump, an acoustical amplifier, and a headset. The arrangement of the parts of the detector is shown diagrammatically in fig. 2. The transducer chamber containing the insects was fastened solidly and inside the bellows air pump. This arrangement eliminated noise from movement of rubber tubing used in earlier models. The cell or transducer chamber confined the insects on the outside of a 1" x 4" plastic cylinder covered with nylon mesh, enabling the insects to gain a foothold. The cylinder was loosely wrapped with .006" piano wire which had been kinked by winding tightly on a 6" triangular file. The wire was spaced in windings about 1/2" apart. The bugs had to find a comfortable resting position among the windings, usually in contact with the wire.

The wire ends were anchored into the phono pickup. Leg movements of the bugs were transmitted by the wire as noise. The phono pickup output was amplified and transmitted to ear phones. Minute movements of insects in the transducer chamber were readily detected. Gentle movement of the pump produced a flow of air over the insects. Flap valves insured a one-way flow of air through the system, although there probably was a small amount of back flow since the valve action was not instantaneous. The inlet to the pump system was a plastic tube about 24 in. long which could be kept clear of the operator's own aura. The outlet was a somewhat shorter tube, directed away from the inlet tube.

B. Test Results

Field trials were made with the ambush detector using 6 adult Triatoma, 3 male and 3 female, at Gainesville, Florida, and in the Panama Canal Zone. In the Gainesville tests the detection target was one man who stood at the end of a road toward whom the test device was carried along the road. The Panama tests were conducted on a jungle road near Ft. Sherman on the Atlantic side of the isthmus. An ambush party of 12 people was divided into 3 groups of 6, 4 and 2 men respectively, stationed on either side of the road and approximately 10 yards off the road in dense jungle growth over a distance along the road of about 75 yards. In all of the tests the detector was carried toward the target personnel while the operator listened for noise caused by heightened bug activity. The operator's location relative to target personnel when he heard noise peaks was noted and the distance to the target personnel was then paced off.

The results of these tests are summarized in Table I. In both series of tests the temperature ranged from 80°F to 85°F, relative humidity $>$ 80%. The tests at Gainesville were conducted in a wooded area in the late afternoon following a rainstorm. The Panama tests were conducted in the morning under a fairly heavy overcast.

In the course of field tests of the closed cell whole insect personnel detector it was found that adult T. infestans exhibited occasional activity in the detector cell at times when there seemed no immediate reason for such activity. It was thought that this erratic behavior occurred at least in part as a result of motion of the detector assembly. It was also observed that the activity of the insects in any one test gradually became continuous after 6 to 8 discrete activity peaks had occurred. It then became impossible to differentiate distinct peaks above the general background noise. An interval of at least 1 hr. of rest was required before the insects quieted sufficiently to be used again.

As a result of these observations it was realized that it would be necessary to make a close study of the occurrence of unwanted activity and its causes in adult T. infestans before an accurate evaluation of field test data could be made. The data in Table 1 should be considered preliminary because no attempt was made in the tests to differentiate "spontaneous" activity from true response activity.

TABLE I

RESULTS OF FIELD TESTS OF A PORTABLE AMBUSH DETECTOR USING ADULT *TRIATOMA INFESTANS*

| Place and date | Test | Response | Distance to target, ft.* |
|---|---|---|---|
| Gainesville, 24 June 65 | 1 | No | - |
| | 2 | Yes | 75 |
| | 3 | Yes | 25 |
| | 4 | No | - |
| | 5 | Yes | 75 |
| | 6 | Yes | 50 |
| | 7 | Yes | 25 |
| | 8 | No | - |
| | 9 | No | - |
| | 10 | Yes | 50 |
| | 11 | Yes | 25 |
| | 12 | Yes | 10 |
| Panama, C.Z., 21 Apr 66 | 1 | Yes | Began at about 175 yd. from nearest ambusher and continued at intervals to 65 yd. beyond last ambusher. |

Subsequent experiments established the existence of cyclic activity peaks in *T. infestans*. These peaks seem to be related to the daily light-dark cycle. There is also some indication that the insects are sensitive to infrared radiation from humans and from the sun, and it was confirmed that the insects can be activated by motion of the detector assembly.

Some general observations in addition to those relating to the occurrence of unwanted activity of *T. infestans* in the

*The detector was carried to within about 6 ft. of the target in all tests in which no response was obtained.

portable personnel detector, were made in the Gainesville and Panama tests pertaining to optimal operating conditions for this type of detector. These conditions include:

1. Optimum numbers of conenose bugs per cell are three (3) males, three (3) females for adults and eight to twelve (8-12) for nymphs.

2. Cell should be operated intermittently by sampling air for two or three seconds and then listening for about ten seconds.

3. Air must be sampled with slow pumping - about 50-80 ml air/sec.

4. A transducer chamber with coiled fine wire is the most sensitive.

5. Best results are probably obtained when relative humidity is above 80%.

6. Temperatures above 80°F probably give the best results.

7. Provision must be made for adequate training in technique so that the operator does not pump his own effluents into the detector.

STATIONARY CLOSED CELL INSECT PERSONNEL DETECTOR

A. Equipment and procedure

The least ambiguous results of tests of closed cell whole insect personnel detection devices were obtained when the insects were subjected to as little motion as possible. Thus, in a number of the field tests the device was hand-held by a person standing on one place or sitting in an automobile, or else it was anchored a few feet off the ground and operated from a remote position with lengths of plastic air hose and lead wire connecting cell to pump and amplifier. The target person circled the device upwind or traversed the upwind quadrant. The monitor was blindfolded and made his announcement of increased bug activity without knowing the location of the target. The target person then immediately marked his position relative to the detector.

Four series of such tests were conducted. In the first two, at Gainesville and Aberdeen Proving Ground, test devices were placed about 1 ft. off the ground in an open wooded area. The target person walked circles of various radii from 15 ft. to 75 ft. around the cell as air was sampled through the device by a pump operator located downwind. Detections were made when the target person was upwind to about 60 ft. away from the cell.

TABLE II

Summary of Tests in Which Cell Was Closed But Not Carried, Remaining More or Less Stationary. All Tests in PM; In All Tests One Person Was Upwind as Target

| Test Series No. | Date | Location | Insect | Temperature | Relative Humidity | Wind MPH | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | Jul 64 | Gainesville, Fla., open woods. | Triatoma 6 large nymphs | 80° + | High | 0-5 | 5 detections from 8 to 17 yards. |
| 2 | Sep 64 | Spesutie Island, APG | Triatoma 6 adults | 80° + | 50%+ | 3-5 | 7 detections from 2 to 20 yards. |
| 3 | Apr 66 | Panama, CZ | 6 Triatoma adults | 80-84° | High | | 23 detections from 10 to 32 yards. |
| 4 | Apr 66 | Panama, CZ | 6 Triatoma adults | 80-84° | High | | 17 detections from 4 to 32 yards. (4 probable false alarms because man was downwind) |

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In the 3rd and 4th series of tests, conducted near Ft. Sherman, Panama Canal Zone, the procedure was as follows:

The detector operator was seated in an automobile in the center of the test area with inlet and outlet tubes of the detector projecting out of the automobile window, which was kept nearly closed. One man then proceeded to walk around the automobile in circles of decreasing radius, or else, he traversed the upwind quadrant. The operator slowly and intermittently pumped air through the detector while holding the transducer chamber as still as possible. Observations of wind direction and relative velocity were made. The detector operator sounded the horn of the car each time he noted a significant increase in bug activity and the target person dropped a numbered card to mark his position the moment the horn sounded.

B. Test Results

The results of the above series of tests are summarized in Table II. In all of the tests, the target was a single person. It is of considerable interest that the maximum range at which significant increases in activity of Triatoma infestans were noted was on the order of 60 feet where the single target person was upwind of the detector. This is nearly equal to the maximum range obtained in tests with single stationary targets shown in Table I.

None of the field tests with closed cell whole insect detectors were subjected to rigorous control of all variable factors. The results may not, therefore, be definitive, though they are highly suggestive. An important consequence of these tests was the identification of a number of factors that might influence the level of insect activity in the test situations. Of the factors that were postulated to have an effect on the activity of adult Triatoma infestans, cell motion seemed the easiest to study in that the detector could be kept stationary. An obvious solution to this problem is to use whole insect activity monitoring devices in a static role for the purpose of intrusion detection.

STATIC EMPLACED ARTHROPOD PERSONNEL DETECTOR

A. Equipment and procedure

The use of arthropods in trail monitoring devices or intrusion detectors is an attractive possibility. Several species of arthropods were tested along a roadway in a wooded area near Gainesville, Florida. The cage designed for mosquitoes is shown in fig. 3. It consisted of a one-gallon battery jar containing 2 inches of water, mosquitoe larvae, larval food, and pupae. Emerging adults are confined by a fine mesh screen cylinder, taped to the battery jar at the bottom and closed at the top with fine nylon net held in place with a rubber band.

Test cages were placed by the roadside in a partially concealed situation. Groups of 1 to 7 people walked toward and past the devices, approaching to within 3 to 5 feet of them. Arthropod activity was monitored with a phono pickup or a microphone attached to each cage. A length of wire, 100 ft. to 200 ft. long was led from the devices to an amplifier and headset. With suitable amplification, increases in activity of test animals were clearly heard and correlated with the approach and passing of people on the road.

B. Test results

Table III shows summarized results of tests using Anopheles quadrimaculatus in open cages as an anti-intrusion device.

In general, mosquitoes hold the most promise of all the insects tested in this application. They are at home in out-of-door exposed situations, and in a number of tests (table III) gave unambiguous increases in activity when one or more persons came near. Even in situations where they were fairly active, they became still more active upon the approach of people. With the development of suitable instrumentation it is possible that clear alarms may be consistently obtained. This remains to be tested.

Longevity tests using A. quadrimaculatus in chambers of the kind shown in fig. 3 suitable for intrusion detection were conducted in a wooded area in Gainesville, Florida in September 1966. In these out-of-door tests an effective population of adult mosquitoes (100 per chamber) lived for approximately 10 days.

If the population were replenished by maturing pupae from within the chamber, the useful field life could probably be extended to 20 days or more.

DISCUSSION

Assessment of the potential military value of the devices developed and tested in this study can be accomplished only provisionally at this time. As a first approximation some preliminary estimates have been formulated based on the test data and general experience with the various devices.

The devices for which provisional estimates of potential military usefulness are an insect ambush detector, and an insect intrusion detector. The first is intended to function as a lightweight, man-carried portable instrument while the second is designed to function in a static mode.

The major problem that was encountered in tests of man-carried detectors using Triatoma infestans was the occurrence of activity peaks apparently unrelated to the presence of human targets.

TABLE III

Results of Tests of *Anopheles Quadrimaculatus* in Open Cages Used in Anti-Intrusion Testing in Open Wooded Area at Gainesville, Fla.

| Test No | Date | No. & sex of insects | Temp | Relative Humidity | Wind MPH | No. of People | Results |
|---|---|---|---|---|---|---|---|
| | 1965 | | | | | | |
| 1 | 7/14 | 20 ♀ | 82 | 80 | 0-7 | 5 | Stayed active |
| 2 | 7/27 | 20 ♀ | 84 | 80 | 0-1 | 5 | Stayed active |
| 3 | 7/27 | 20 ♀ | 84 | 80 | 0-1 | 5 | " " |
| 4 | 7/27 | 20 ♀ | 90 | 61 | 0-5 | 5 | Good, activity increased |
| 5 | 7/28 | 20 ♀ | 75 | 98 | 0-1 | 5 | " " |
| 6 | 7/29 | 20 ♀ | 77 | 90 | 0-1 | 5 | " " |
| 7 | 8/11 | 20 ♀ | 91 | 47 | | 1 | " " |
| 8 | 8/12 | 15 ♀ | 86 | 70 | | 1 | Doubtful response |
| 9 | 8/12 | 15 ♀ | 56 | 90 | | 1 | " " |
| 10 | 8/13 | 9 ♀ | 70 | 85 | | 1 | Good, activity increased |
| | 1966 | | | | | | |
| 11 | 5/4 | 100 ♀ | 68 | 80 | | 1 | Stayed active |
| 12 | 5/4 | 100 ♀ | 68 | 80 | | 1 | " " |
| 13 | 5/5 | 100 ♀ | 78 | 63 | | 1 | No response |
| 14 | 5/5 | 100 + | 78 | 66 | | 1 | " " |
| 15 | 5/10 | 100 + | 66 | 84 | | 1 | Good, activity increased |
| 16 | 5/10 | 100 + | 61 | 83 | | 1 | " " |
| 17 | 5/11 | 100 + | 81 | 64 | | 1 | " " |
| 18 | 5/11 | 100 + | 76 | 66 | | 1 | Stayed active |
| 19 | 5/11 | 100 + | 70 | 86 | | 1 | " " |
| 20 | 5/11 | 100 + | 76 | 66 | | 1 | Good, activity increased |
| 21 | 5/11 | 100 + | 70 | 86 | | 1 | No response |
| 22 | 5/17 | 100 + | 79 | 74 | | 5 | Stayed active |
| 23 | 5/17 | 100 ♀ | 79 | 74 | | 5 | " " |

It is difficult to rule out the possibility that the apparently random fluctuations in activity of T. infestans were not in fact responses to airborne human scent. The field tests in which the empirical data were obtained did not easily lend themselves to control of all variables. Experience with other detectors of airborne constituents has quite generally shown that local meteorological conditions, especially wind direction, cannot be predicted from moment to moment on the basis of the generalized prevailing conditions. This is particularly true in forested areas such as were utilized in the present studies. Results obtained in the laboratory experiments show that comparable activity fluctuations occur in sealed devices subjected to motion associated with hand-carried operation; they also show an apparent correlation between activity level and light-dark cycles. The available evidence, therefore, suggests strongly that the activity of Triatoma infestans under the conditions in which it was tested, fluctuates in response to stimuli other than airborne human odor. Motion and/or mechanical vibration appear to be stimuli to which these bugs are sensitive. It is an open question whether other species of conenose bugs would show the same responses as T. infestans.

Attempts to condition T. infestans to continuous motion were not successful. Neither were attempts to restrict their freedom of movement by mechanical means. The problem is a difficult one since movement is the mechanical link between the insect's neuromuscular stimulus response and the ancillary instrumentation. Any treatment that interferes with the insect's freedom of movement may be self-defeating.

An anti-intrusion device employing mosquitoes as the detecting element avoids all problems occasioned by the necessity for hand-carrying, and at the same time provides an elegantly simple mechanism as the basis for continuous monitoring. Even though the mosquito's response is not specific to humans, the circumstances under which devices of this kind are used would appear to favor a minimal false alarm rate; at least errors would be false positives rather than false negatives. Questions concerning sensitivity and reliability can be resolved by appropriate test procedures.

## CONCLUSIONS

1. It is technically feasible to use arthropods that normally seek warm-blooded animals as the sensing component of people-detecting devices.

2. The hand-carried, closed cell, whole insect device developed in this study, using Triatoma infestans, cannot be used for ambush detection because of uncontrolled increases in bug activity stimulated by motion and darkness. The effects of motion can be eliminated by using the device in a static role.

3. It is technically feasible to use the mosquito Anopheles quadrimaculatus in an appropriately instrumented open cage to detect the approach of people during darkness. This insect exhibits marked activity peaks associated with change from dark to light (sunrise) and from light to dark (sunset), but it is normally quiescent during darkness.

4. Provisional estimates of the potential military value of the various kinds of devices investigated show that a static, insect, anti-intrusion device appears technically more promising for development for practicable field use than the other modes considered.

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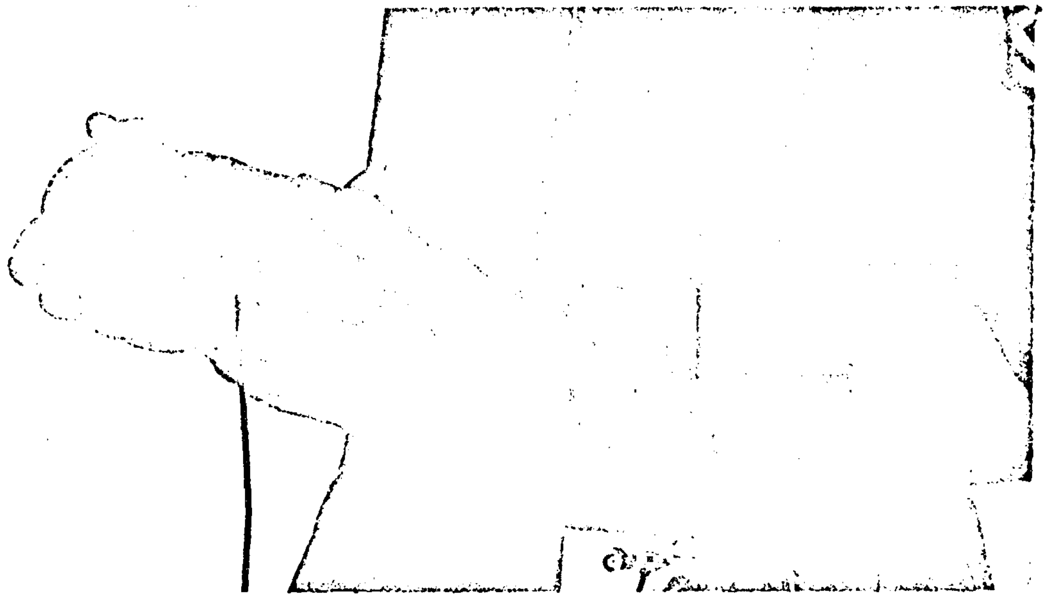

Figure 1. Insect Ambush Detector

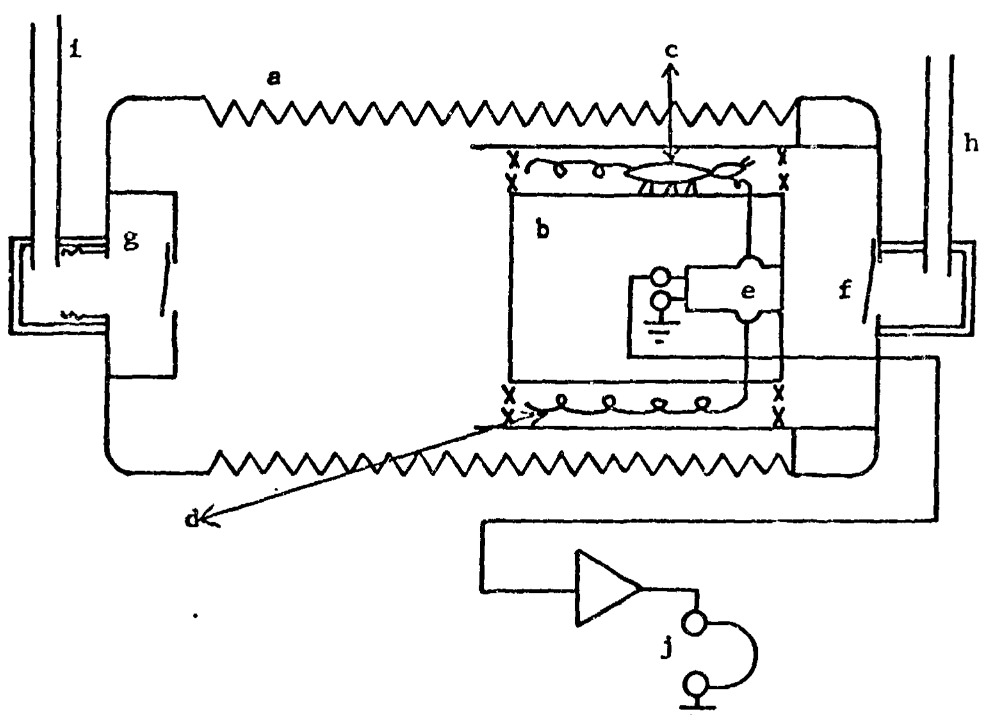


Figure 2. Diagram of insect ambush detector. a. Bellows pump. b. Cylindrical plastic tube. c. Bug. d. Piano wire entanglement. e. Phono pickup cartridge. f. Intake valve. g. Exhaust valve. h. Intake tube. i. Exhaust tube. j. Amplifier & headset.

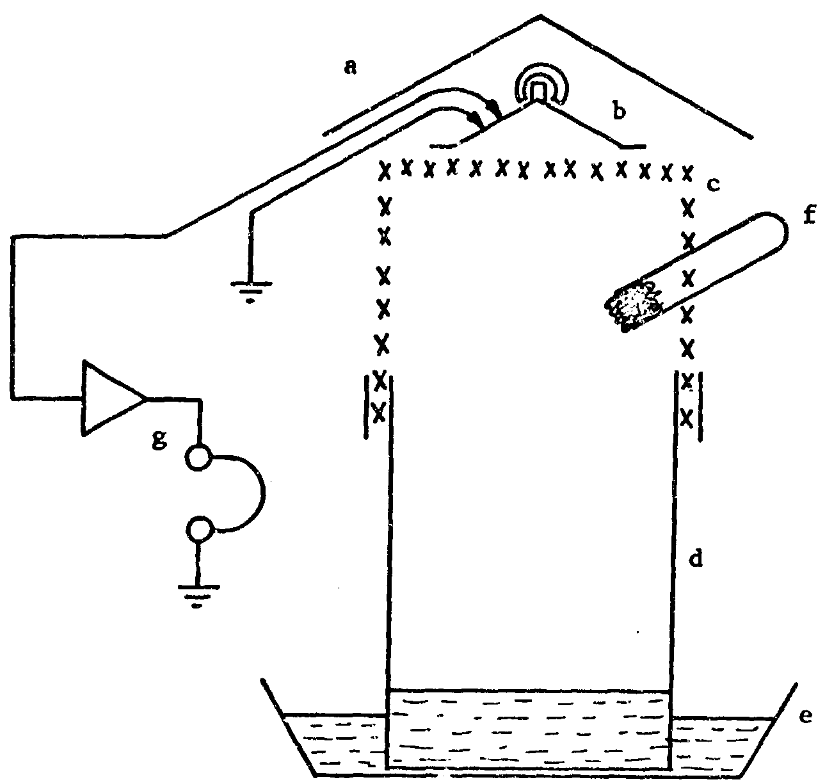


Figure 3. Diagram of mosquito cage intrusion detector.
a. Roof. b. Microphone. c. Wire screen cage, 16 mesh.
d. Battery jar. e. Ant guard (water-filled base pan).
f. Sugar water feeding tube.
g. Electronic monitor (amplifier and headset).