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Kolz,A.L.; Johnson, Richard E.

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COULOMETRIC RECORDER FOR TIMING AND COUNTING EVENTS IN THE FIELD

By A. Lawrence Kolz and Richard E. Johnson

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COULOMETRIC RECORDER FOR TIMING AND COUNTING EVENTS IN THE FIELD[1]

A. LAWRENCE KOLZ, U.S. Fish and Wildlife Service, Wildlife Research Center, Denver, Colorado 80225

RICHARD E. JOHNSON, U.S. Fish and Wildlife Service, Wildlife Research Center, Denver, Colorado 80225

Abstract: An event recorder for timing and counting was developed specifically for field application. The new recorder uses inexpensive coulometers for data storage and requires only microwatts of power from long-lasting batteries. Stored data are retrieved from the recording cells with a simple laboratory readout instrument. Six of these recorders were used to record the number of visits and accumulated feeding time in a food preference experiment with ricefield rats (*Rattus rattus mindanensis*). The results indicated that such visit count and feeding time records can be used to estimate accurately food preference based on consumption and, with suitable regression equations, predict weight of food consumed. When accuracy was checked by simultaneous recordings at one of the feeders, readings from the coulometric recorders never deviated more than about ±6 percent from those obtained with conventional electromechanical counters and timers. These results show that valid measurements of activity can be made with the event recorders when used as rat feeding monitors. Other applications are suggested.

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Biological studies often require the counting and timing of events, and it is convenient if this can be done with automatic recording equipment. Unfortunately for the field biologist, most electromechanical counters and timers are expensive and complex devices that are designed for use in the laboratory.

We developed a simple event recorder by using coulometers as data storage cells. These recorders offer several advantages to the field biologist: they are silent, battery-operated, long-lived, operationally simple, and relatively inexpensive (less than $20 in electrical parts). A special readout instrument recovers stored data and clears the cells for reuse.

Our event recorders performed well when tested as feeding activity monitors in food preference tests with ricefield rats. The data recorded (number of feeding visits and accumulated feeding time) proved sufficiently accurate and sensitive to allow prediction of the food consumed.

DESCRIPTION OF THE EVENT RECORDER

The recorder system consists of two parts: a data recorder and a data readout instrument. The uniqueness of the recording system lies in its coulometric method of storing data for later retrieval.

The Data Recorder

Electrical Properties of the Storage Cell.—The storage cell of the data recorder is a coulometer, an electrolytic cell that measures the passage of an electrical charge by a proportional chemical reaction. The coulometer we used is a commercial component sold under the name E-Cell (Plessey Electro-Products, Los Angeles, Calif.; reference to trade names does not imply U.S. Government endorsement of commercial products).

The E-Cell consists of two electrodes, one silver and one gold, surrounded by an electrolyte to provide a conductive medium

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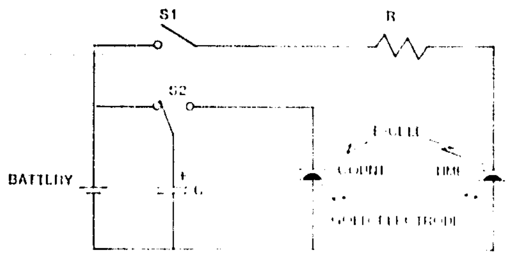

Fig. 1. Basic circuit for coulometric timer and counter

between them. When an electric current is passed in one direction through a cell (the recording current), silver ions are electroplated onto the gold electrode. Reversing this current (the read current) transfers the silver ions from the gold electrode back to the silver. When the silver is depleted from the gold electrode, no further ion conduction can occur and the E-Cell becomes an electrical open circuit.

Basic Design of a Data Recorder for Timing and Counting.—A pair of E-Cells can record the occurrence and duration of any event that can be sensed by an electrical switch. In its simplest form, the circuit requires only seven components (Fig. 1). For timing an event, switch *S1* is closed, which causes current to pass through the timing E-Cell. The amplitude of this current is limited by the resistor (*R*) and is constant for the duration of the closure. Thus, the quantity of electroplated silver is directly proportional to the duration of the switch closure. For counting an event, switch *S2* is closed, which causes the electrical charge stored in capacitor (*C*) to pass through the counting E-Cell. This charge is always the same, so the quantity of electroplated silver is directly proportional to the number of switch closures.

If several switches are wired in parallel, a single E-Cell may be used to accumulate data from several independent events. The only restriction is that the effective parallel resistance of all associated resistors must be at least 10 times the series resistance of the E-Cell, which is normally less than 200 ohms.

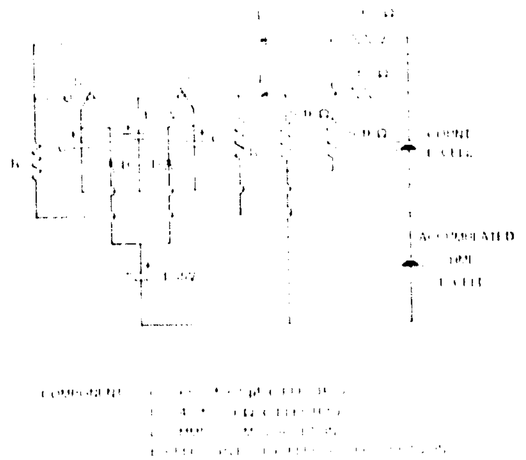

Fig. 2. Circuit for two treadle rat feeding activity monitor.

Two-treadle Feeding Activity Monitor.—We designed a special timing and counting recorder to predict food consumption by measuring the feeding activity of ricefield rats. It was our goal to develop a practical field device, and many of our ideas were directed toward simplifying the instrumentation for the field biologist.

The feeding activity monitors were designed with two treadle switches on either end of a food container. We used single switches and designed a circuit (Fig. 2) to limit the number of moving parts, improve the recorder's reliability, and simplify the problems associated with sealing against moisture. When rats visited the food container, the number of visits and the accumulated feeding time were recorded in the two E-Cells. The circuit requires a maximum of 275 μA at 1.4 V, and small mercuric oxide batteries are a good power source. However, we found it necessary to drain current from these batteries before inserting them into the data recorders to ensure operation within the linear portion

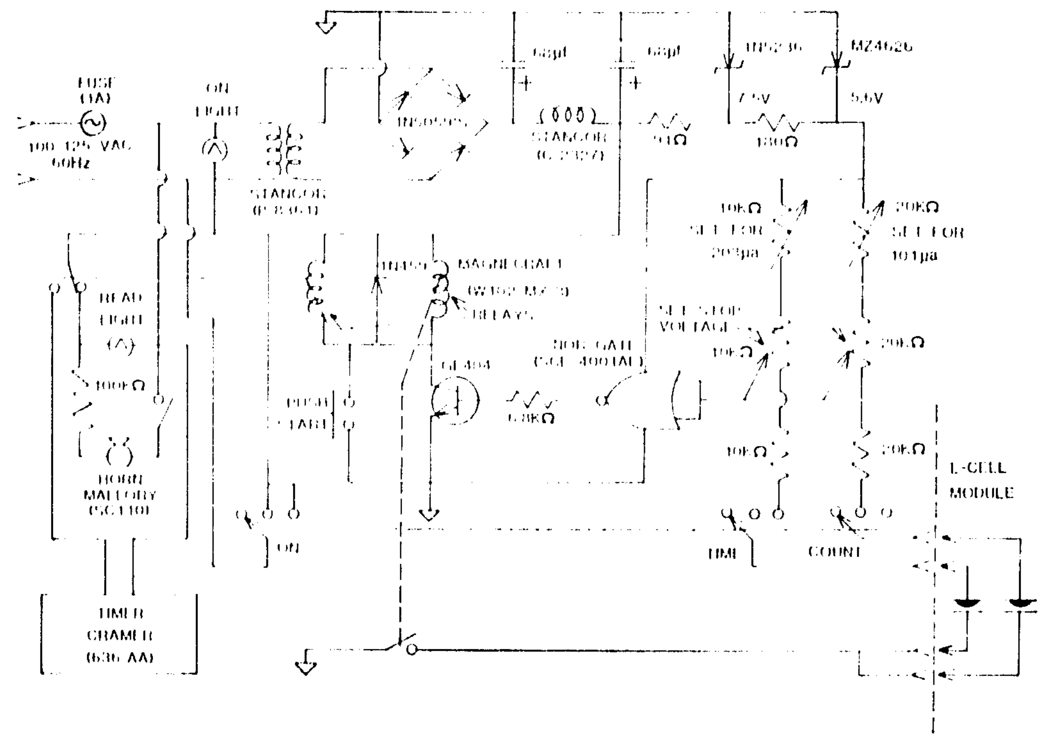

Fig. 3. Circuit for E-Cell readout instrument.

of their discharge curve (we drained about 10 percent of the total battery capacity).

Each activity monitor is supplied with two recording modules. The module is a pocket-sized polarized plug containing the two E-Cells. In operation, one module is plugged in at the activity monitor while the other is being read at the laboratory. Thus, data can be recorded continuously, and only one readout instrument is needed.

The Readout Instrument

Any instrument designed to recover data from an E-Cell must use a measure related to the quantity of silver electroplated onto the gold electrode. One way to measure this quantity is to drive a known current through a cell and record the time required to deplete the electroplated silver and reach the open circuit condition. The total electrical charge passing through the cell is directly related to the number of available silver ions. By multiplying the current (I, in amperes) by the depletion time (t, in seconds), we can calculate the charge (Q, in coulombs) by the formula: $Q = It$. Thus, with a constant current source, an accurate elapsed-time indicator is adequate to recover data from an E-Cell.

The readout instrument we designed is AC-powered and intended for use in the laboratory (Fig. 3). It contains a reset timer that runs or stops, depending on the voltage sensed across an E-Cell. If this is less than about 0.3 V, a constant current is driven through the cell and the timer accumulates. At the end of the readout cycle, as the last of the silver is depleted from the gold electrode, the voltage rises sharply. When the voltage exceeds 0.3 V, the timer stops and the current is removed from the cell to prevent possible damage.

The electrical components for the rat activity monitor and readout instrument (Figs. 2, 3) were selected so that the number of rat visits and tenths of minutes of feeding time could be read directly from any timer with a resolution of 0.01 minute. Thus, with a 5-digit timer and a charge storage capacity of 3.6 coulombs (for a Series 560 E-Cell), our readout instrument could count up to 58,500 rat visits and accumulate up to 3,000 minutes of feeding time.

The plug-in modules returned from the field are inserted into the readout instrument and the selector switch is set to read either time or count data. When an E-Cell is depleted and the timer stops, a light or horn alerts the operator to transfer the reading to a permanent record, after which another cell can be read.

We designed the readout instrument to play back at a rate 10 times faster than recorded; for example, an accumulated feeding time of 52 minutes would be read in 5.2 minutes.

FOOD PREFERENCE TESTS WITH RICEFIELD RATS

We tested the usefulness and reliability of these activity monitors in a study of feeding activity of ricefield rats. The resulting data were correlated with measured food consumption and preference ratings between two foods. As a check, the data recorded by one of the monitors were recorded simultaneously by conventional electromechanical devices.

The test was conducted in three 3.1- × 3.1-m enclosures each containing 3 rats. Two monitors in opposite corners supplied their food. Ground rice was placed in one monitor and ground Purina Laboratory Chow in the other; their positions were alternated each measurement period. Over 12 days (8 measurement periods), each monitor recorded the feeding time and number of rat visits. In addition, the food in each monitor container was weighed at the beginning and end of each period to determine consumption.

Four kinds of data were tabulated: consumption, accumulated feeding time, number of feeding visits, and the product of feeding time and number of visits (time-count product). All four measures showed the rats to have a definite preference for rice over chow. Preference ratings for feeding time and the time-count product were close to the ratings based on consumption (which was considered the standard, since it was based on weights of food actually eaten); the ratings for number of visits had a greater deviation. This pattern also was shown by linear regression analysis to determine how accurately the weight of consumed food could be predicted from the recorded time and count data. Correlation coefficients (r) were 0.87 for the time-count product, 0.84 for feeding time, and 0.81 for number of visits. For the average feeding time per visit (total time divided by total visits), r was only 0.35. As a final analysis, we calculated a multiple linear regression for predicting food consumption ($\hat{Y}$) from both number of visits (X_1) and feeding time (X_2). The coefficient of multiple correlation was $R = 0.92$, normally an adequate level of precision for a study of this kind.

To check the accuracy of the coulometric recorder, we modified one of the feeding activity monitors so that, in addition to storing data in an E-Cell, its treadle switches also activated a digital counter and a clock with a resolution of 0.1 second. The readings recovered from the E-Cells were compared against this conventional means of counting and timing.

During the 12-day food preference test, deviations of the E-Cell readings from the electromechanical readings ranged from −0.2 to +6.2 percent for timing data and from −5.6 to +5.8 percent for count data. The manufacturer of E-Cells claims a component accuracy of ±2 percent. This, plus additional errors due to variations among electrical components, battery voltages, and readout instrumentation, is a basic design limitation.

DISCUSSION AND CONCLUSIONS

Our food preference test showed that the coulometric recorders are useful for monitoring such events as rat feeding activity, but other uses are apparent. For example, the silent timing and counting capability of these recorders could easily record the usage of a trail, time the incubation period of a bird, detect an animal's preference between two scents, be adapted as a rodent censusing technique, or monitor physiological events such as sleeping cycles in mammals. The simplicity of these coulometric recorders should allow the field biologist many other novel applications at a nominal expense.

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AN ELEVATING MECHANISM FOR MOBILE RECEIVING ANTENNAS

When biologists are radiotracking wildlife, the low power levels of small transmitters make antenna height critical to good reception. Often a small increase in antenna height will more than double the effective tracking range. To gain antenna height and still have speed and mobility for tracking wild birds, we mounted a rotating antenna system on a commercial elevating platform that attaches to a vehicle roof. The result was a successful field unit that raises the antenna mount about 2.6 m above the vehicle roof for tracking, yet brings it down to only about 50 cm above the roof for traveling.

The elevating mechanism (Fig. 1), manufactured by Weaver Division, Dura Corporation, Springfield, Illinois (reference to trade names does not imply U.S. Government endorsement of commercial products), is housed in a metal box that clamps on the vehicle's rain gutter or roof rails as do most popular car-top carriers. We found this mounting satisfactory even though the system with antenna and rotor weighs 107 kg. Because the box measures only about 140 × 51 × 18 cm, it is compact enough to fit a pickup truck cab. We considered other types of elevating systems but judged the Dura Corporation system the best compromise from the standpoint of weight, elevation height, ease and speed of operation, minimum vehicle modifications, and power requirements.

We mounted the antenna above the lid of the metal box, which serves as the elevating platform and can be raised 2.1 m by a hydraulic scissor-jack mechanism inside. Hydraulic pressure is provided by a 12-V electric pump powered by the vehicle battery. Raising or lowering the unit requires a maximum of about 40 A and takes about 0.5 minute. We have used both Adcock and Yagi antennas and have experienced no reception interference from the metal lid.

We mounted the antenna rotor under the lid next to the built-in floodlight and attached all controls into a remote-control unit inside the vehicle by a 15-conductor cable, which required rewiring the elevating mechanism and floodlight. The radio signal from the antenna is carried to the receiver inside the vehicle by a separate coaxial cable. The rotor and the remote-control unit, which includes a dial to indicate antenna position, are our own design because we could find no commercial units that operate on 12 V DC. The rotor has a maximum sweep rate of 1 revolution (360°) in 6 seconds and operates in 2 modes: a manual sweep in which the operator controls the direction, start, and stop, and an automatic sweep that reverses every 1-¼ revolutions (450°). The 450° reversing sweep is used instead of a continuous 1-direction sweep to provide complete azimuth coverage without the expense and noise problems of rotating connectors for the coaxial cable.

A parts list, circuit diagram, and assembly diagram are available from the senior author.

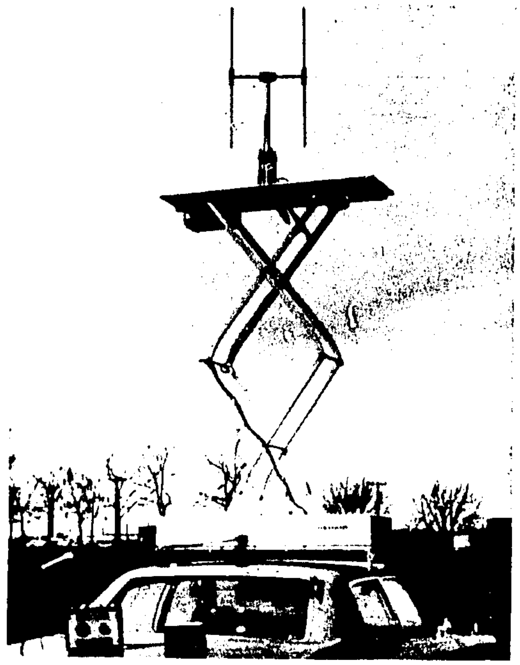

Fig. 1. Elevating platform with Adcock antenna.

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A. Lawrence Kolz and **Richard E. Johnson**, *U.S. Fish and Wildlife Service, Wildlife Research Center, Building 16, Federal Center, Denver, Colorado 80225.*

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