TELEMETRIC EGG FOR MONITORING NEST MICROCLIMATE OF ENDANGERED BIRDS

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ABSTRACT

A series of artificial eggs has been developed for the New York Zoological Society to measure conditions in the nest of the white-naped crane (*Grus Vipio*). Investigations undertaken at the Bronx Zoo have endeavored to improve artificial incubation of the eggs of endangered species of birds. Artificial eggs were constructed and camouflaged so that a pair of birds would accept and incubate them. Inside each counterfeit egg, a radio telemetry transmitter was hidden to report on the temperature and humidity in the nest and the orientation of the egg itself with respect to gravity.
KEYWORDS: Telemetry, egg, incubation, temperature, humidity.

INTRODUCTION

The most advanced system, Egg-2 (Figure 1), contains a nine-channel radio telemetry transmitter that measures the following: six temperatures around the circumference of the egg (straight arrows), the humidity and temperature in the vented "nose-cone" of the egg (curved arrows), and the orientation of the egg with respect to gravity.

The system was able to follow the complete 35-day incubation period of *Grus Vipio*, and report on the "micro-climate" conditions in the nest. Simultaneous temperature and humidity recordings were made from the surrounding environment using a commercial Rotronic weather probe. The birds' behavior was logged by real-time comments and video recordings.

Over the four-year course of the project, two eggs have been designed and constructed, called "EGG-1" and "EGG-2". This paper will discuss the technical aspects of both, emphasizing the improvements of EGG-2 over EGG-1.

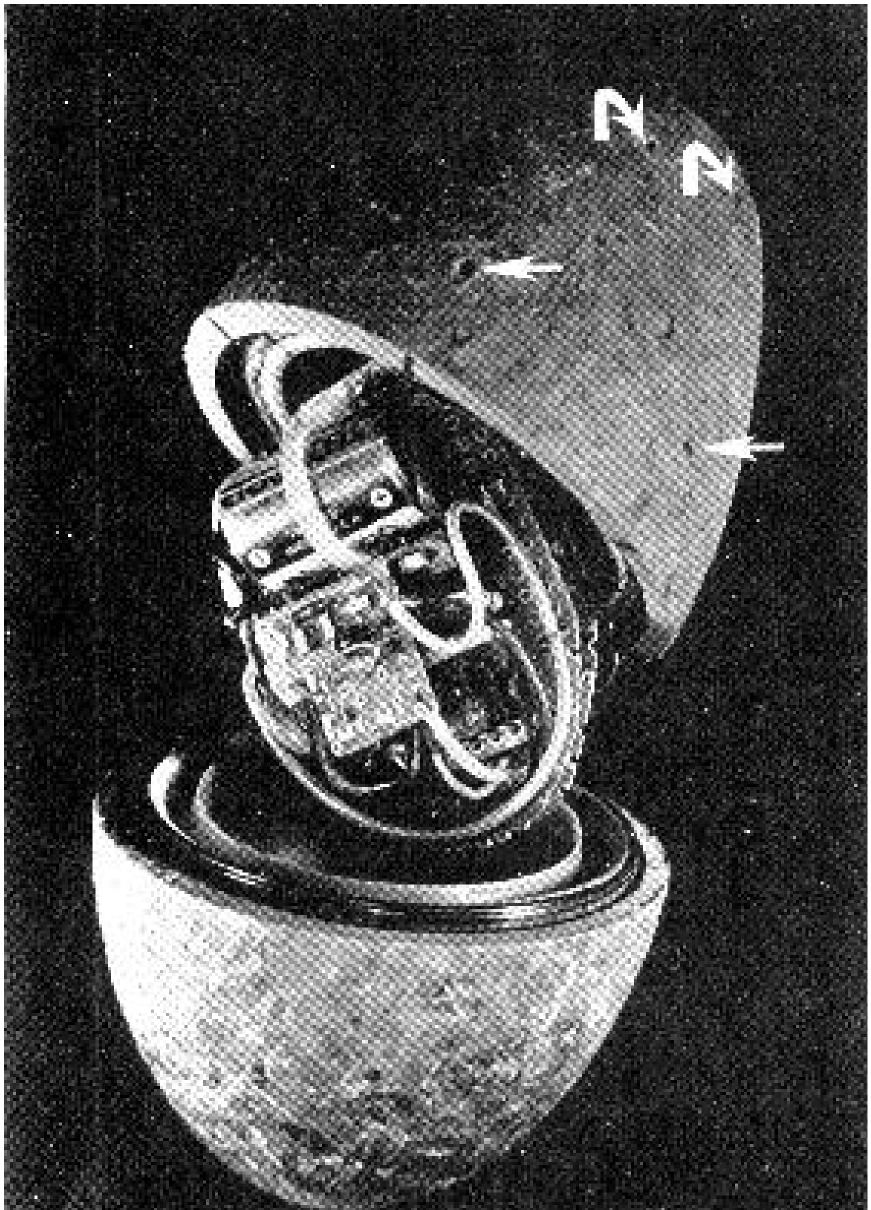

Figure 1 : EGG-2 Radio Transmitter

METHODS

Temperature is sensed in the eggs by tiny thermistors (Thermometrics “ruggedized thermobeads”). These come from the factory sealed in glass for long-term stability. Each egg also contains a humidity-sensitive resistor (Phys-Chemical Research Corporation, PCRC-55), and three miniature mercury switches to determine orientation.

Egg-1 is divided into two compartments: (1) the “nose cone”, which is vented to the outside, containing one humidity sensor and one thermistor, and (2) the sealed interior of Egg-1 which contains the transmitter circuitry and three mercury switches, one in each of three perpendicular directions (X, Y, and Z). Thus it can tell which end of the egg (narrow vs. fat) is higher, and which of four rotational orientations around the long axis of the egg is up.

For its transmitter, Egg-1 contains a National Semiconductor 1871 chip, used commercially in radio-controlled cars, planes, etc., delivering 35 milliwatts of power at 49.89 MHZ. The receiver for Egg-1 was designed around the matching 1872 chip. Egg-1 employs a pulse-width modulation scheme to encode the data, transmitting a sync pulse followed by a series of three pulses each of whose duration is proportional to a different piece of data: temperature, humidity, or orientation.

Egg-2 (Figure 2) has a vented nose-cone compartment similar to Egg-1, containing a humidity sensor and a thermistor. In addition, six surface thermistors are arranged around the circular equator at 60-degree intervals. Three mercury switches inside Egg-2 form an equilateral triangle in the equatorial plane of the egg, allowing the discrimination of six orientations, corresponding to the six surface thermistors as the egg is rotated around its long axis. Egg-2 does not measure whether the narrow or flat end of the egg is pointing up, since it was found that birds just don't turn their eggs up on their ends.

Egg-2 modulates a miniature transmitter delivering 15 milliwatts at 164.335 MHZ. An inexpensive commercial scanner is used to receive signals from Egg-2. To encode the data, Egg-2 uses an interval-duration scheme, which is much more power-conservative than Egg-1. Short (1 millisecond) pulses are separated by variable intervals of silence. Egg-2 transmits data once every two-to-three minutes.

The data from both eggs are demodulated with crystal-controlled timers, operated by an Hitachi 64180 microprocessor. The microprocessor coordinates data from Egg-1, Egg-2, and the Rotronic humidity/temperature probe, talking via RS-232 to an IBM PC. The PC time-stamps the data along with real-time comments from an observer, and stores everything on diskette.

At the start of each season, both eggs were calibrated in a custom-designed computer-controlled chamber, against a mercury thermometer (second-generation National Bureau of Standards) and a set of standard salt solutions for humidity.

A conservative estimate of the accuracy for the data from Egg-1 and Egg-2 is 5% RH and 1.0 deg C., although the precision of these systems is 10-100 times greater. To the limits of their precision, all systems are virtually noise-free in the short term, producing reproducible data in a constant environment. Drift and hysteresis seemed to be more of a problem with humidity than temperature, probably because of chemical contamination and moisture on the sensor surface.

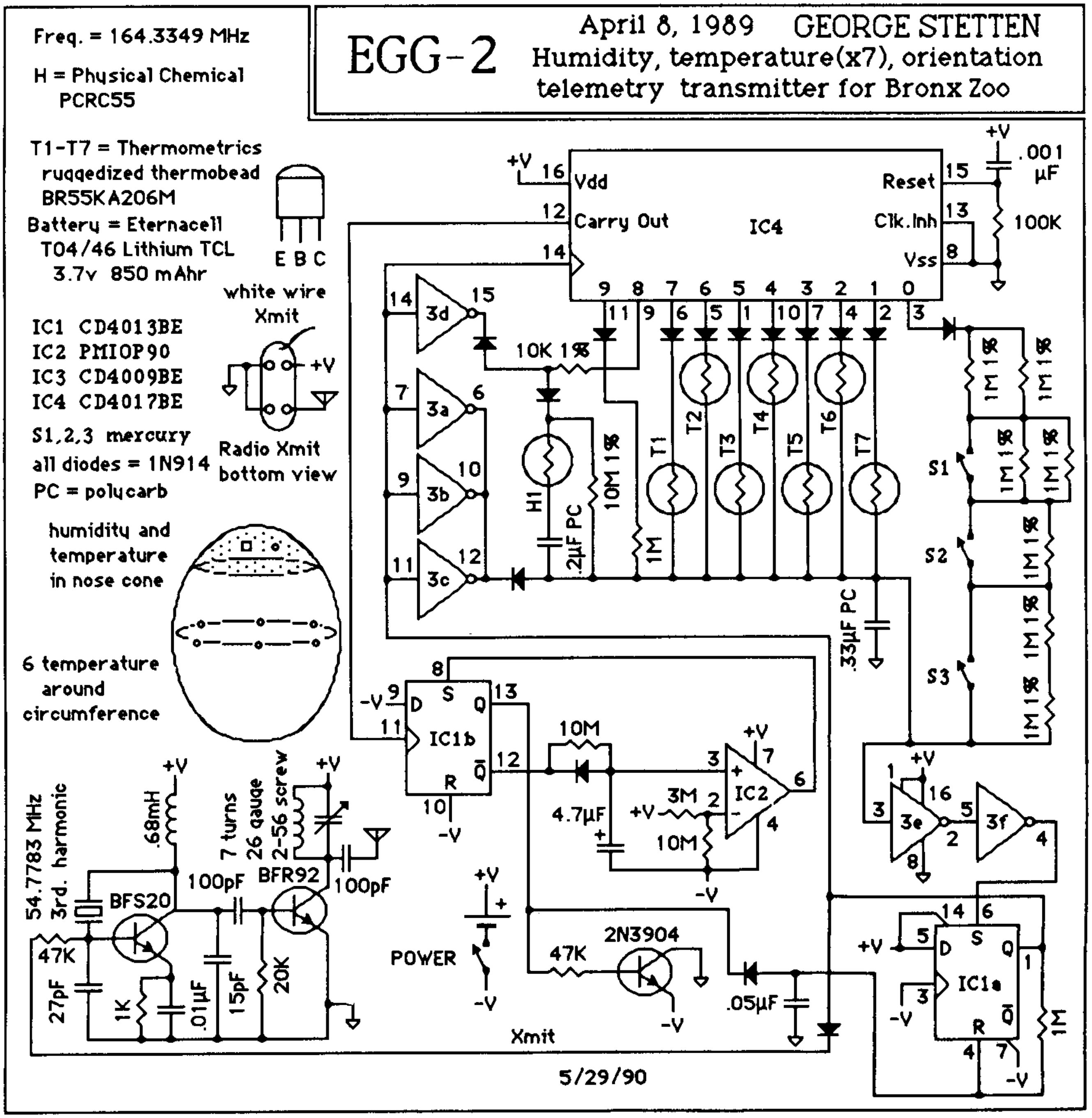

Figure 2 : Schematic of EGG-2 Telemetry Transmitter

Batteries in the eggs are lithium thionyl-chloride ½ AA cells, at 3.4 volt, 0.85 ampere-hour. Egg-l contains two such batteries and runs for six weeks without changing. Egg-2 transmits for more than 3 months, and contains just one battery.

The camouflaged epoxy housings for the eggs measure 110 mm in length, and 65 mm in diameter at the widest point. They are threaded for opening to turn on and off, change batteries, and implement modifications. Both eggs employ small curved whip antennas.

The behavior of the nesting birds was monitored at the Bronx Zoo with a SONY HVM-332 CCD video camera, equipped with an 18-LED infrared illuminator (Fuhrman Diversified Inc.) for night viewing. A time lapse video cassette recorder (Panasonic AG-6720) was used to record all day and night for the entire incubation period. The data were superimposed on the video via a Video Serial Interface made by American Video Equipment. (Figure 3) The six temperatures around EGG-2 are shown on the right, with the orientation (5) in the middle of the circle of temperatures. The top temperature is warmest, corresponding to that part of the egg nearest the bird. Ambient and nose-cone temperature and humidity are listed on the left, along with time and date.

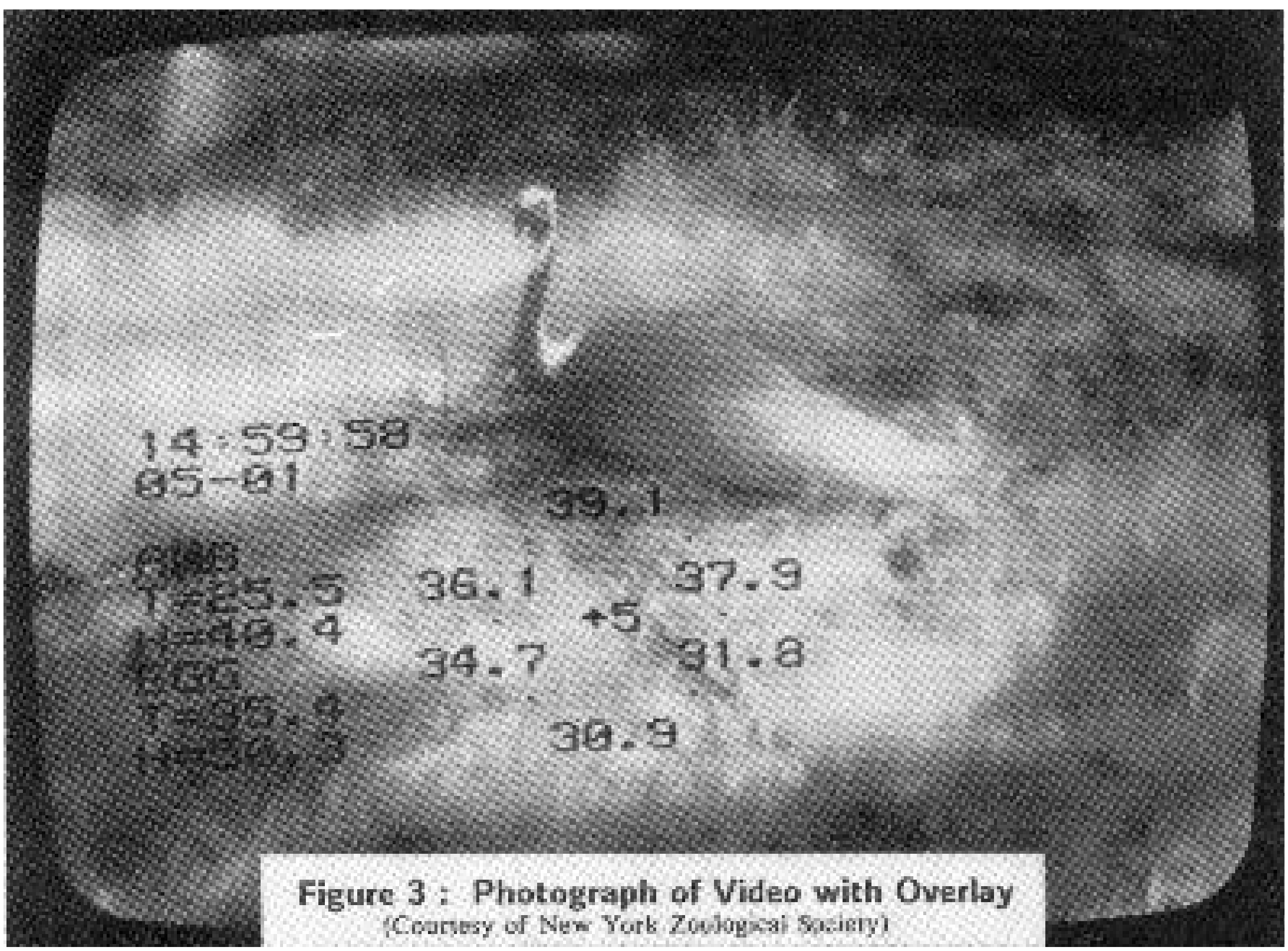

Figure 3 : Photograph of Video with Overlay
(Courtesy of New York Zoological Society)

DISCUSSION

Most of the design constraints, including size, weight, battery-life, range, precision, number of channels, and number of readings per hour, involve a tradeoff summarized by the following:

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                                              battery-life
    size and        must be traded            range
    weight          off against               precision
                                              # of channels
                                           # of readings/hour
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Even with lithium-TCL batteries, which have the highest power density commercially available, size and weight constraints are serious limitations to the available power. This, in turn, limits the range of transmission, and the number of weeks before the batteries go dead. Since both eggs have "sleep" circuits, the power drain is proportional to the number of transmissions per hour.

Precision also takes power. In measuring the duration of a pulse, or the interval between two pulses, the precision of the receiver is limited by the time it takes to determine the presence or absence of the signal. Even in the ideal case, a radio signal takes a certain number of cycles of the sine wave to be detected. Realistically, the response time of both receivers is much slower than this. Thus, the only way to increase precision is to use longer pulse-widths (Egg-1), or longer intervals between pulses (Egg-2). Both of these cost power. With Egg-1 it means greater transmitting time, and with Egg-2 it means more time in the "non-sleep" mode. The following table compares the results.

Parameter	Egg-1	Egg-2
modulation scheme	pulse-width	interval
frequency (MHZ)	49.8	165.3
# batteries (3v, 850 mAH)	2	1
range (feet)	10	20
number of channels	3	9
number of readings/hour	20	20-30
battery life (weeks)	6	12
precision	0.1 %	0.5 %

Because of the power saved by using an interval modulation scheme, Egg-2 is better than Egg-1 in all respects, except precision. This last was an intentional concession, since the true accuracy did not warrant the high precision of Egg-1.

The range of transmission is limited by the tiny space for the transmitting antenna in both eggs, as well as the close proximity to the ground and the bird. The higher frequency of Egg-2 made transmission more efficient.

The nest is an interesting environment for electronic equipment. Birds usually shield their eggs from direct rainfall, and treat them carefully, (after all, real eggs are fragile). Humidity remains a constant threat to high-impedance circuitry. Traditionally, wildlife transmitters are embedded permanently in epoxy to seal out water. We decided against this, and made the eggs screw open. The thread was coated with sealant, and a package of desiccant was inserted.

CONCLUSION

Useful and previously unreported data were obtained by EGG-2 (Figure 4). The fact that the top of Egg-2 was, at times, more than 10 degrees Celsius warmer than the bottom suggests that the air-warmed incubators used in zoos today generate too uniform a temperature in eggs, perhaps accounting for some of the observed high rate of failure with artificial incubation of non-domestic birds. Humidity (not shown in this paper) in the nest does not seem to be influenced by water contributed, or removed, by the bird. Rather, relative humidity in the nest tends to mirror that of the outside environment, corrected for the temperature in the nest.

Artificial incubation is an important tool in the propagation of rare species of birds. When eggs are taken from the nest early in the incubation period, the birds will usually lay more. This process can often be repeated as many as five times in a season, thereby greatly increasing the productivity of a given pair of birds, assuming most of the eggs survive. It is hoped that the data from such studies as ours will enable greater success in the artificial incubation of the eggs from endangered species, and thereby increase their chances for survival.

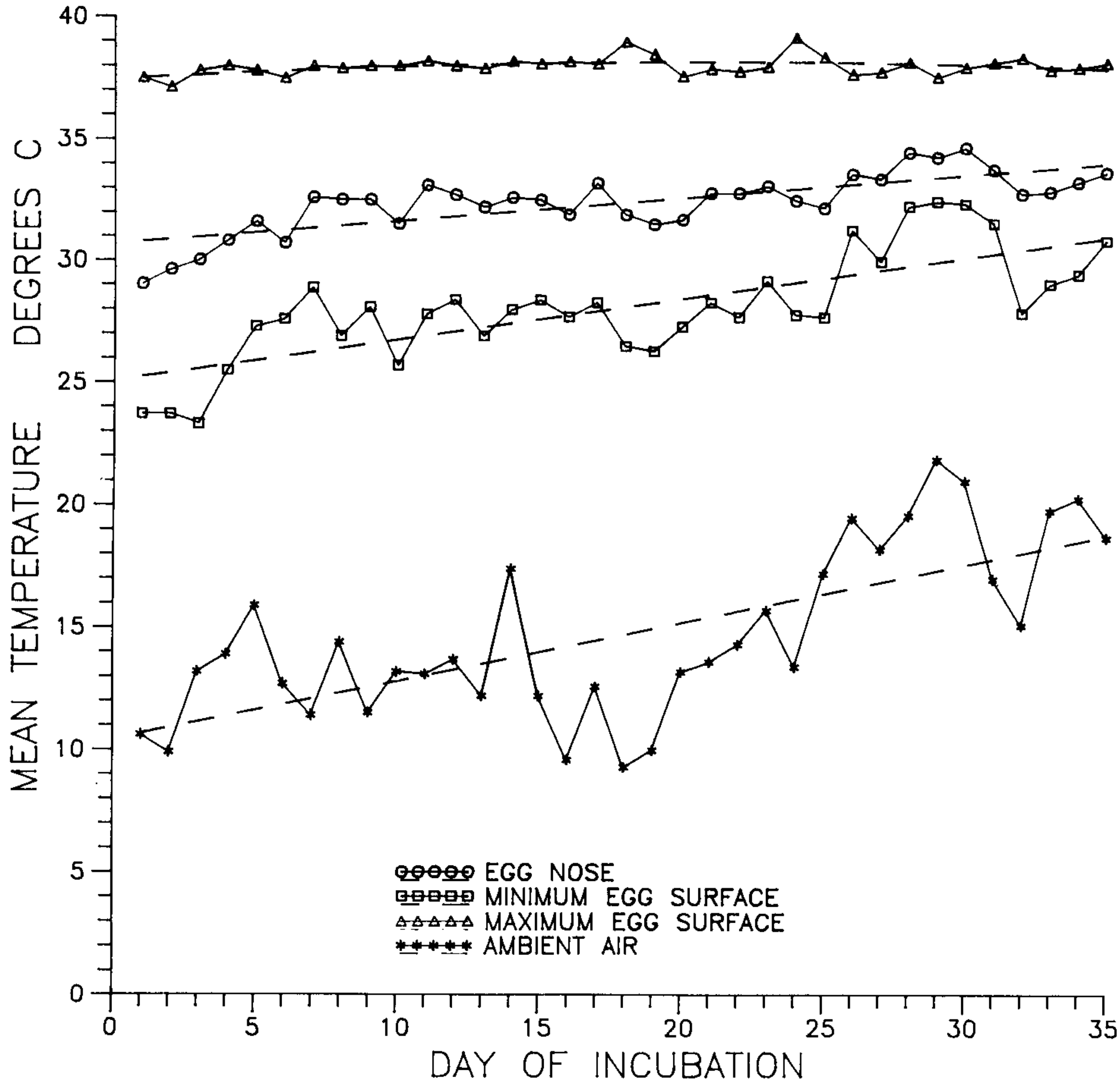

Figure 4 : Data from 1989 Season, EGG-2

ACKNOWLEDGEMENTS

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