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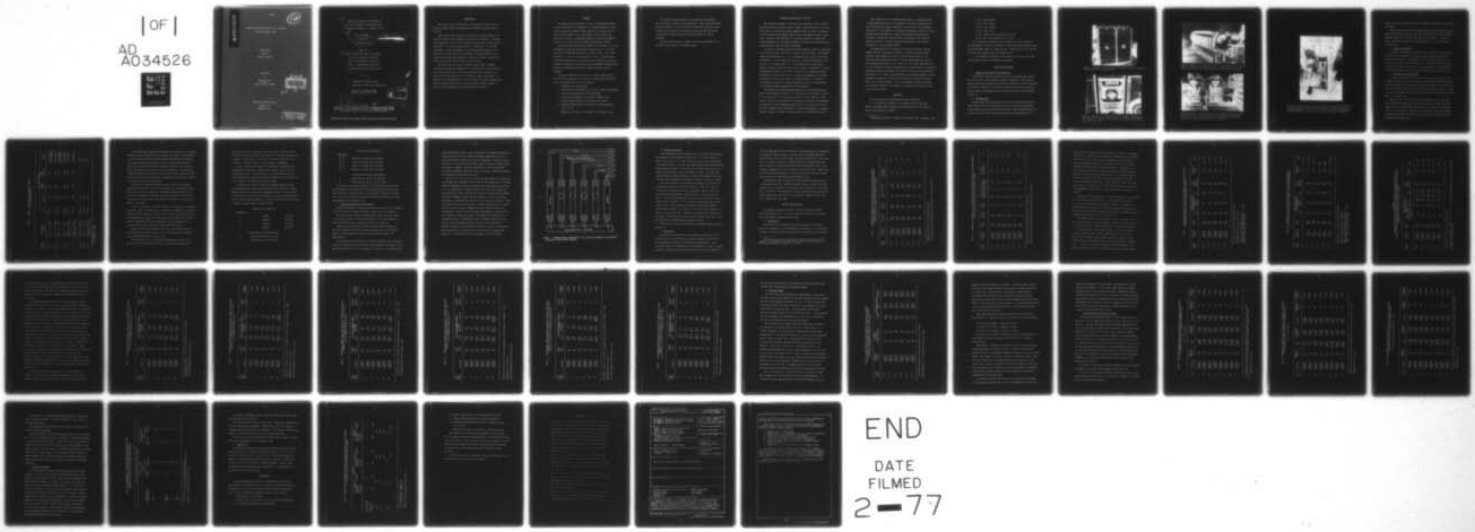

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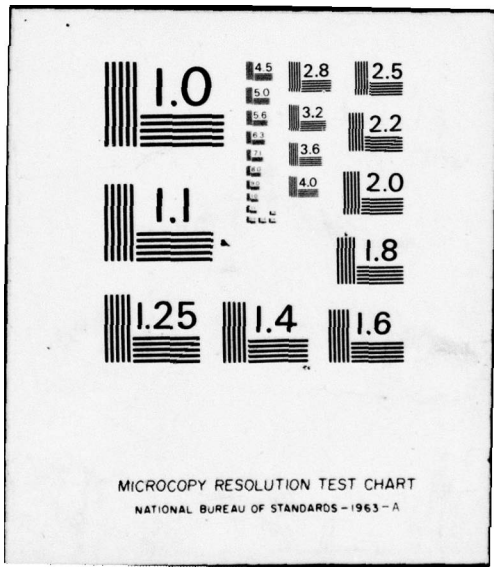
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Extremely Low Frequency Electric and Magnetic Fields in Domestic Birds

Final Report

Phase II

(Modulated Wave)

Departments

of

Animal Science
and
Electrical Engineering

University of Rhode Island

Kingston, RI

December, 1976

Influence of Extremely Low Frequency Electric and Magnetic Fields Upon Growth Development and Behavior in Domestic Birds

Final Report. 15 Sep 71 - 30 Apr 76)

Phase II.

(Modulated Wave).

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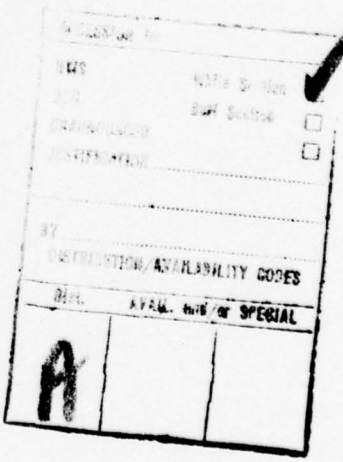

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INTRODUCTION

The research herein reported was a continuation of that covered by Technical Report, Phase I (Continuous Wave) which was compiled March 1, 1975 (1).

The continuous wave studies were conducted with chick embryos, cultured chick embryo cells, immature chicks and adult chickens. Continuous wave frequencies of 45, 60 and 74 hertz were used; magnetic field intensities were 1, 5, 8 and 30 gauss; electric fields were 1, 10 and 3600 volts/meter. While chick embryo cell growth (in vitro) appeared to be inhibited by all but one ELF field studied, "no other responses (intact birds) were of sufficient magnitude or consistent enough to support the belief that they were due to the Elf fields tested."

The research in this report utilized the same special equipment and facilities which were designed for the earlier (CW) studies and which were easily adaptable for use with the modulated field frequencies in which the Navy was interested at the time the research was planned. In addition to the equipment used for the CW studies, specially designed equipment was supplied by the Navy to provide modulated signals intended to simulate the transmission from an ELF communication system.

ABSTRACT

The domestic fowl was used in a series of experiments designed to allow evaluation of the influence of continuous exposure to modulated extremely low frequency (ELF) fields of low intensity upon 1) growth and development of the chick embryo; 2) early post-natal growth of the chick; 3) subsequent growth of the sexually immature bird; and 4) social interaction among sexually mature females.

The fields used were modulated between 72 and 80 hertz (76 ± 4 Hz). The magnetic fields were maintained at intensities of 1 or 8 gauss. The electric fields were maintained at either 10 V/m; 1 V/m; 10 V/m plus 60 Hz, 3.5 V/m; or 1 V/m plus 60 Hz, 3.5 V/m. Uniform fields at identical frequencies and amplitudes were provided for continuous exposure of embryos and chicks during the preincubation holding period, incubation and hatching periods and through the first 28 days of brooding.

Statistical analyses of the results of these studies revealed that neither the magnetic nor the electric fields tested had significant or consistent effects on the following:

1. Hatchability of fertile eggs.
2. Embryo survival during the most critical stages of development.
3. Early post-hatching growth and development.
4. Growth and development of the sexually immature bird.
5. Carbon dioxide production of the developing embryo.
6. Subsequent aggressiveness (as adults) of females exposed early in life.
7. Hematocrits of birds at 4-6 weeks or at 8 months of age.

The fields may have prolonged the incubation period slightly, but not enough to interfere with hatchability. More precise procedures would be necessary to better evaluate the effects of exposure to these fields upon the length of the incubation period and upon the growth of chicks which had been removed from field exposure soon after hatching.

The ELF fields used do not appear to have been detrimental to the survival or well-being of the exposed chicks.

TECHNICAL DESCRIPTION OF THE WORK

The research described in this report was conducted in the facilities described earlier in Technical Report, Phase I (Continuous Wave) (1) and (2). These reports described the special equipment which was used to provide the uniform extremely low frequency (ELF) electric and magnetic fields at identical frequencies and amplitudes for continuous exposure of embryos and chicks throughout the preincubation holding, incubation, and hatching periods and through the first four weeks of brooding.

The earlier continuous wave work involved magnetic fields at frequencies of 45, 60 and 75 hertz and electric fields at 60 and 75 hertz. The magnetic fields were maintained at 1, 5, 8 or 30 gauss and the electric fields were maintained at 1, 10 and 3600 volts per meter. These ELF fields had no significant or consistent effects on: 1) hatchability of fertile eggs; 2) embryonic survival during the most critical stages of development; 3) early post-embryonic growth (to four weeks of age); and 4) learning and memory consolidation in the neo-nate chick. Growth and development to ten weeks of age was not affected by earlier (four-week) exposure. A 60 hertz, 5 gauss magnetic field had no effect on metabolic activity of chick embryos as determined by embryo growth rate and CO_2 production.

Chick embryo cells grown in vitro appeared to be inhibited when incubated in 60 Hz magnetic fields at 1, 5 or 8 gauss; in 60 Hz electric fields of 1 or 10 V/m and in a 75 Hz electric field at 1 V/m. However, a 75 Hz electric field at 10 V/m appeared to accelerate cell growth. No explanation was offered for these seemingly opposite effects of the two 75 Hz fields. No other responses (intact birds) were of sufficient magnitude or consistent enough to support the belief that they were due to the ELF fields tested.

Upon completion of the continuous wave studies, it seemed desirable to gather additional data on the responses of the fowl to modulated ELF fields maintained at similar amplitudes to those used in the CW studies. Consequently, it was decided to use modulated frequencies close to 75 hertz. Existing special equipment for holding (preincubation) hatching eggs, incubation, hatching and rearing chicks to four weeks of age required modification only in electrical inputs and this added to the economic feasibility of these extended studies.

Four MSK generators were supplied by the Naval Electronic Systems Command from the IIT Research Institute to provide the desired signal modulation when properly connected to the ELF field simulators. The desired modulation parameters were " a pseudo random modulation pattern utilizing peak switching and a bit rate of 16. For these conditions and a center frequency of 76 Hz, the generator will switch between 72 and 80 Hz."[1] Subsequent references throughout this report will identify this modulated frequency as 76 ± 4 hertz. The amplitudes of the modulated magnetic fields proposed for study were 1 and 8 gauss and those for the electric fields were 1 and 10 volts per meter. It was also planned to study the effects of the electric fields in the presence of continuous wave 60 hertz fields at 3.5 volts per meter.

OBJECTIVES

The objectives of the ELF modulated field studies were:

A. To evaluate the influence of continuous exposure (from egg pickup, through holding, incubation, and chick rearing to four weeks of age) to the following six fields:

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[1] Communication from M. H. Benedick, Trip Report, URI, 7 February, 1975.

1) 76 ± 4 Hz, 8 gauss

2) 76 ± 4 Hz, 10 V/m

3) 76 ± 4 Hz, 1 gauss

4) 76 ± 4 Hz, 1 V/m

5) 76 ± 4 Hz, 10 V/m plus 60 Hz CW, 3.5 V/m

6) 76 ± 4Hz, 1 V/m plus 60 Hz Cw, 3.5 V/m

B. To evaluate the influence of ELF fields 1), 2) and 5) above on the development of adult social behavior of hens continuously exposed during early development (prior to 4 weeks of age). (Field 5 was not used because the birds were immature until late January, 1976).

C. To evaluate the influence of ELF fields 1), 2) and 5) above upon carbon dioxide output of developing chick embryos.

MATERIALS AND METHODS

1. Magnetic and Electric Field Simulators.

The ELF field simulators used in the earlier continuous wave studies were also used for these modulated frequency experiments. The incubator modifications and the hatcher-brooders used in both series (CW and modulated) can be seen in Figures 1-5. Detailed descriptions of the field simulators and the internal environments which prevailed in each have been presented earlier (1).

2. The Egg Supply.

Hatching eggs from flock mated pens of White Plymouth Rocks (WPR) and White Leghorn (WL) fowl, maintained at the R. I. Agricultural Experiment Station poultry farm were used in these studies. White Plymouth Rocks were used in the trials which involved chick growth and subsequent adult be-

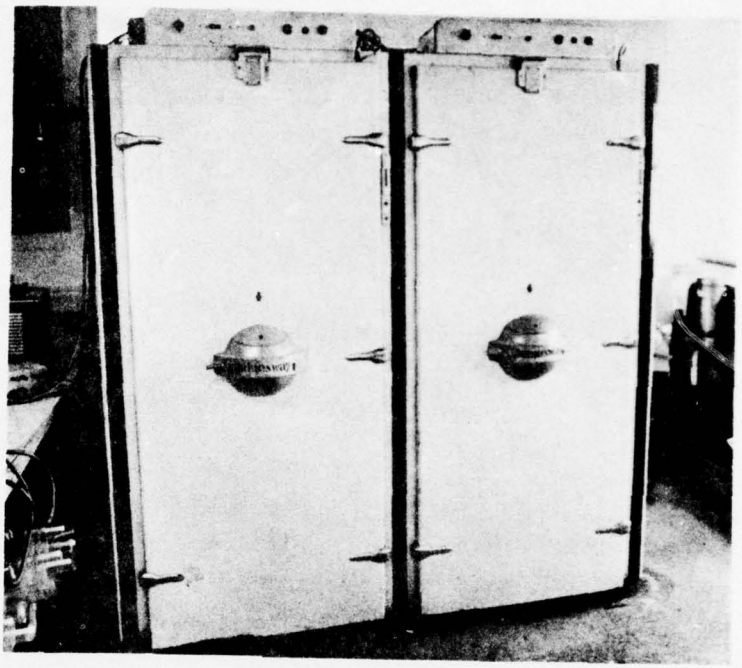

Figure 1. Exterior of Jamesway Model 252 incubators modified internally to accomodate ELF field simulators.

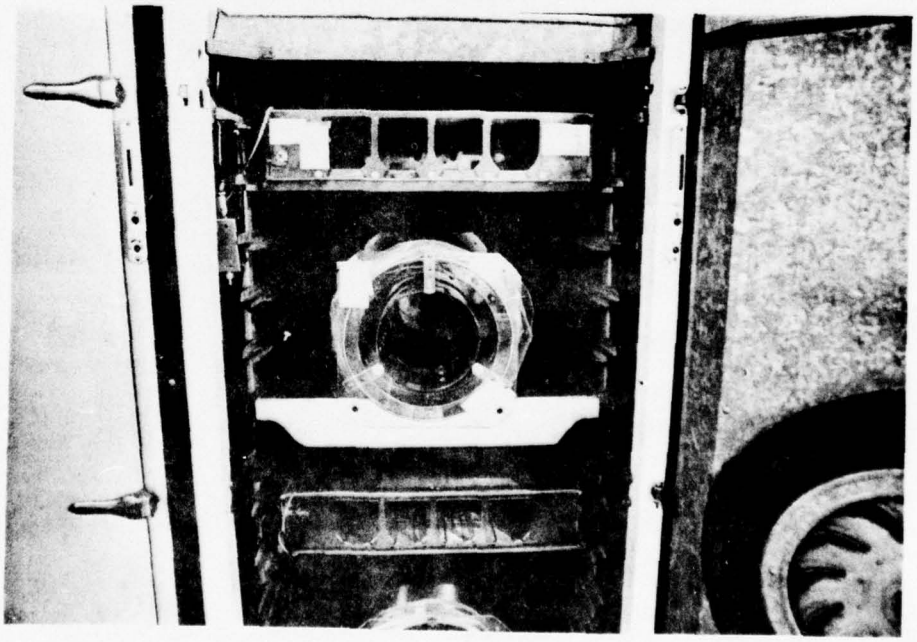

Figure 2. Interior view of Jamesway Model 252 incubator showing one electric field simulator in place at the top; a magnetic field simulator is at the center. Similar field simulators are in place in the lower part of the compartment.

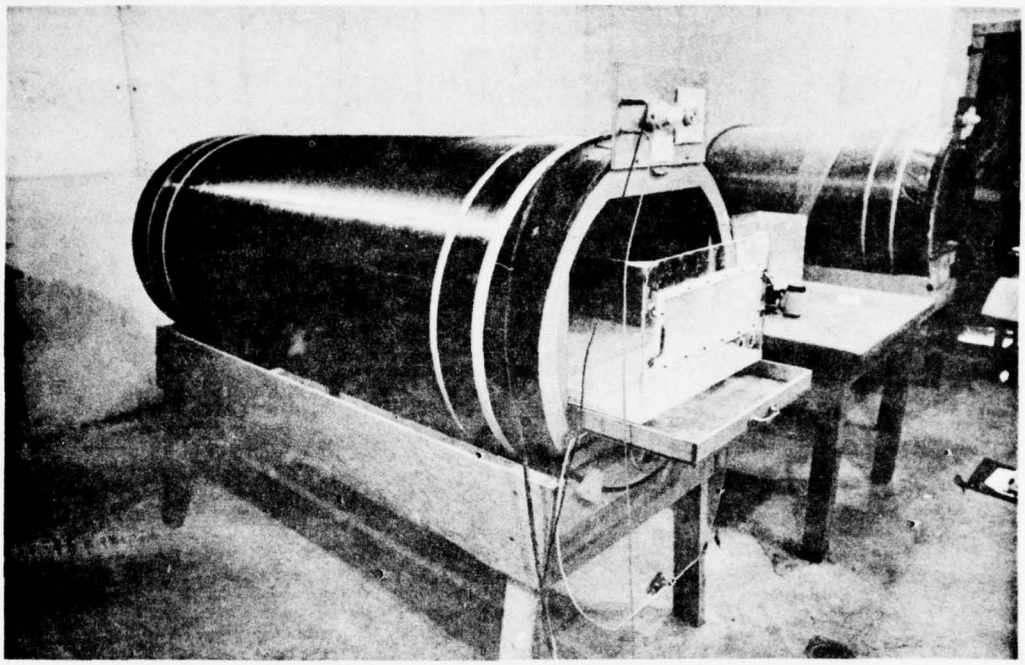

Figure 3. Magnetic field simulator (1 of 2) for hatching eggs and brooding chicks to four weeks. One chick compartment and dropping tray are shown partly removed; the other compartment is accessible from the other end.

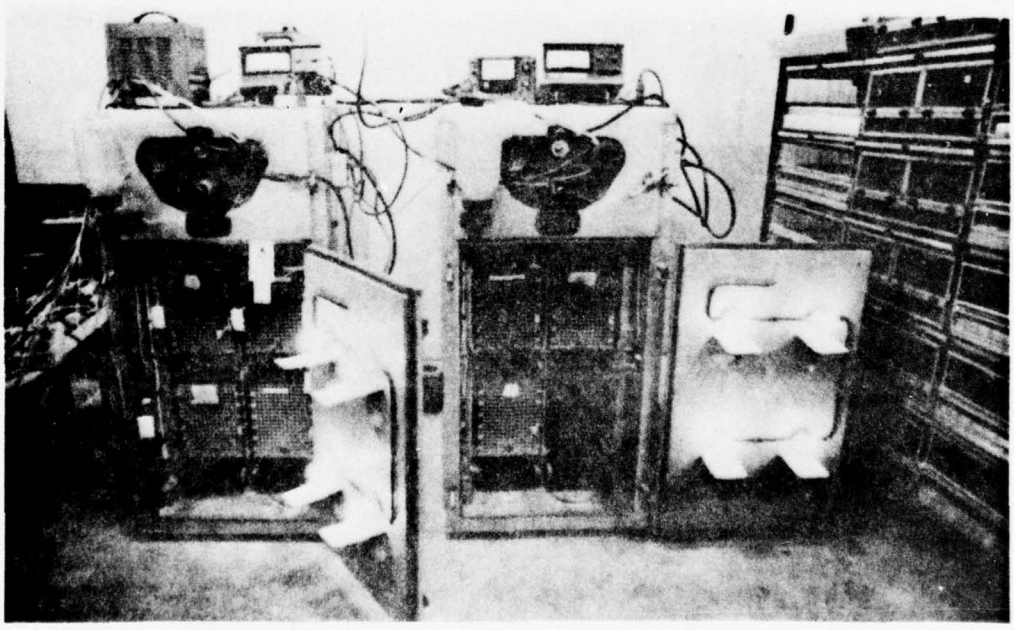

Figure 4. Electric field simulators used for hatching and brooding chicks through four weeks. Four plastic chick compartments are shown in place in one of the two heated E-field chambers. Each chamber is partitioned vertically to restrict field exposure to one side only.

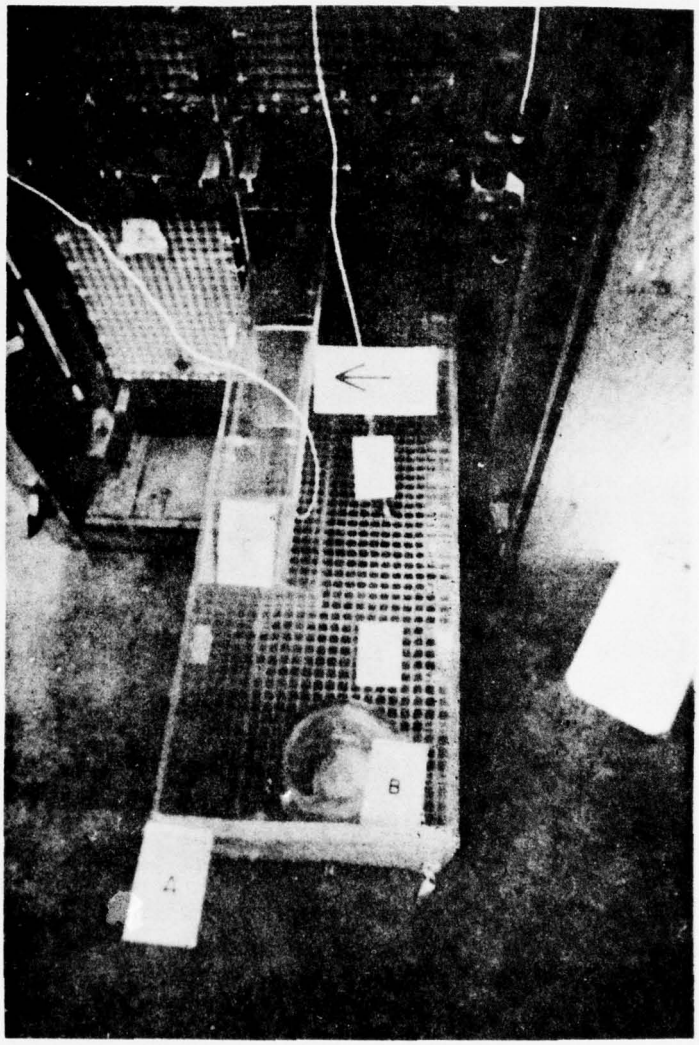

Figure 5. Top view of one electric field chick compartment with furnishings in place showing; A, plastic chick compartment, 35" long, 8.5" wide; B, waterer, 2-quart; C, feeder; D, electric field probe (attached to feeder); E, plastic grid base (droppings pass through to plywood tray beneath).

havior because of the rapid growth rate customarily associated with chicks of this breed.

Leghorn eggs were used in the carbon dioxide studies because the smaller eggs from these birds could be used with less difficulty in the respiration chambers available for use with the infra-red CO_2 analyzer. (Each cylindrical respiration chamber had an inside diameter of 1.75 inches and was 8 inches long).

3. Coding of Experiments.

The Phase II Modulated Field studies were considered a continuation of the earlier CW experiments so a similar coding system was used for bird and data identification. The magnetic field trials were labeled M 2- and the electric field trials were labeled E 2-. The ELF field exposures used in Phase II are shown in Table 1 with the appropriate trial identification code, trial period dates, and brief notes about the nature of each trial.

4. Egg Handling and Body Weight.

All eggs collected daily from the breeder pens were placed in an egg holding room where they were maintained at approximately 60-70^{o}F and 60-80% relative humidity until sufficient numbers were available for a complete setting. The holding period for each setting did not exceed ten days. The magnetic field experiments used 352 eggs and the electric field trials used 384 eggs for a complete set.

Within 24 hours after delivery to the holding room, each day's eggs were divided into equal numbers and stored in separate areas so that equal numbers of eggs of the same age would be set in the control or energized fields of the incubators. Eggs which were intended for ELF field exposure during incubation were continuously exposed to the same field during the preincubation holding period.

TABLE 1. SUMMARY OF MODULATED ELECTRIC AND MAGNETIC FIELD EXPOSURE STUDIES

Trial Code*	ELF Field Exposure	Trial Period Dates				
		Set	Hatched	Age 28 days	Age 10 weeks	Study
M 2-1	76 Hz ± 4, 8 gauss	1/31/75	2/21	3/21	5/2	Body Weight; Adult Behavior
M 2-2	76 Hz ± 4, 1 gauss	3/ 7/75	3/28	4/25	6/6	Body Weight
E 2-1	76 Hz ± 4, 10 V/m	2/17/75	3/10	4/7	5/19	Body Weight; Adult Behavior
E 2-2	76 Hz ± 4, 1 V/m	3/24/75	4/14	5/12	6/23	Body Weight
E 2-3	76 Hz ± 4, 10 V/m + 60 Hz CW, 3.5 V/m	7/ 3/75	7/24	8/21	10/2	Body Weight
E 2-4	76 Hz ± 4, 1 V/m + 60 Hz CW, 3.5 V/m	8/ 7/75	8/28	9/25	11/6	Body Weight
M 2-3	76 Hz ± 4, 8 gauss	5/11/75	6/1			CO_2
E 2-5	76 Hz ± 4, 10 V/m	6/ 3/75	6/24			CO_2
E 2-6	76 Hz ± 4, 10 V/m + 60 Hz CW, 3.5 V/m	6/12/75	6/27			CO_2

*M = magnetic field
E = electric field

When enough eggs (approximately 400) had been collected for a complete setting, they were identified as to treatment and candled to allow removal of cracked or porous shelled eggs which would be unsuitable for hatching. The remaining eggs were then sorted in such a way that equal numbers of eggs of each age (days held before incubation) occured in each simulator and in the same relative position within each simulator. This was accomplished by dividing each magnetic field cylinder into two 12-egg end zones and four 16-egg internal zones, and by subdividing each of the four electric field capacitors into six 16-egg zones.

Data used for comparisons between controls and ELF field-exposed embryos and chicks were collected from the eggs set in the internal zones. Chicks from the end zone eggs were subsequently reared under more "conventional" environmental conditions to provide an estimate of the effects of the special brooders (other than the ELF field effects) on early development of the chicks.

After 17 or 18 days of incubation (eggs set on Fridays were transferred on Mondays; eggs set on Mondays were transferred on Fridays), all eggs were removed from the incubators, candled to allow removal of infertile eggs and dead embryos, and all eggs with living embryos were transferred to hatcher-brooder compartments which were subdivided to allow continuation of the incubator setting zone designation through the hatching period.

Appropriate ELF field exposures, identical to those used during the preincubation and incubation periods, were continued during hatching and until the chicks reached four weeks of age.

Visual observations of the hatching compartments were made on the 21st day, starting at 496 hours (20 days, 16 hours) after setting, and

continuing at four-hour intervals until 512 hours (21 days, 8 hours). The chicks which had hatched at each observation time were identified by a series of toe-web marks and recorded to allow an estimation of the influence of the ELF fields on overall embryonic development.

On the 23rd day after setting, the chicks which had hatched were wing banded for individual identification, weighed, and the end zone chicks were moved to a starting battery. Unhatched eggs were placed under refrigeration, with those previously removed at transfer time, for later breakout to determine time of embryo death.

At seven days of age, all chicks were weighed individually and chick populations in the ELF field simulators were adjusted by removal, whenever possible, of chicks with odd-numbered bands. This plan should have resulted in the following distribution of chicks (a thermostat malfunction causing high mortality in E 2-1 and a miscount in M 2-2 resulted in smaller starting numbers in those trials):

Magnetic Field Simulators

Compartment		
A	Exposed	20 chicks
B	Control	20 chicks
C	Control	20 chicks
D	Exposed	20 chicks

"Conventional" Battery Compartment

E	Excess from A and D, 20 chicks
F	Excess from B and C, 20 chicks

Electric Field Simulators

Compartment	
A_1, A_2	Exposed, 10 chicks each; 20 chicks
B_1, B_2	Control, 10 chicks each; 20 chicks
C_1, C_2	Control, 10 chicks each; 20 chicks
D_1, D_2	Exposed, 10 chicks each; 20 chicks

"Conventional" Battery Compartments

G	Excess from A_1, A_2, D_1, D_2; 20 chicks
H	Excess from B_1, B_2, C_1, C_2; 20 chicks

At 28 days of age, after weighing, all remaining chicks were transferred from the field simulators or starting battery units to floor pens where all birds of each trial were reared together. The birds in trials M 2-1 and E 2-1 were reared to maturity for behavioral studies; all others were marketed after 10 weeks of age.

5. Carbon Dioxide Production of Embryos

Three experiments were conducted to evaluate the effects of one magnetic field and two electric fields (see Table 1) upon intact chick embryos.

The electronic gas analyzer (Beckman, Model IR 315) described earlier (1) was used to measure carbon dioxide output of intact chick embryos at 2-day intervals from day 6 through the 20th day of incubation.

Eggs from flock mated White Leghorns were used and for purposes of ELF field exposure were treated the same as those used for chick growth studies. Several handling differences were necessary, however, for these studies.

One incubator only was used for each study, and because the field simulators were located one above the other in each incubator (see Figure 2) the eggs were switched from one field simulator to another at two day intervals

after measuring CO_2 output. This was intended to eliminate differences in CO_2 output which may have resulted from slight temperature and other position differences within the incubator compartment. Electrical input connectors for each field allowed easy change of energized simulators when the eggs were changed. Continuous monitoring of each field, periodic recording of energized simulators, and color coding of exposed and control egg trays helped avoid switching errors.

At days, 6, 8, 10, 12, 14, 16, 18 and 20 equal numbers of exposed and control eggs were transferred hourly from the field simulators to a holding incubator (negligible ELF field) located in the room housing the gas analyzer. At approximately 15-minute intervals four eggs (two exposed and two control) were placed individually in the four heated analysis chambers. Two analysis chambers remained sealed throughout to provide continuous monitoring of instrument drift and warn of air leaks in the system. (Since CO_2 content of the room air was high, any leaks allowed room air to blend with that from the analysis chambers and caused dramatic increases in recorded CO_2). Figure 6 shows the general arrangement of the CO_2 collection chambers and associated tubing. The chambers were enclosed in a compartment heated to approximately $100^{o}F$ to minimize temperature fluctuations of the developing embryos which would have resulted from handling the eggs at room temperature ($68-74^{o}F$). Except for the one-hour period required for CO_2 analysis at 2-day intervals, all exposed eggs remained in the designated ELF field throughout each trial period.

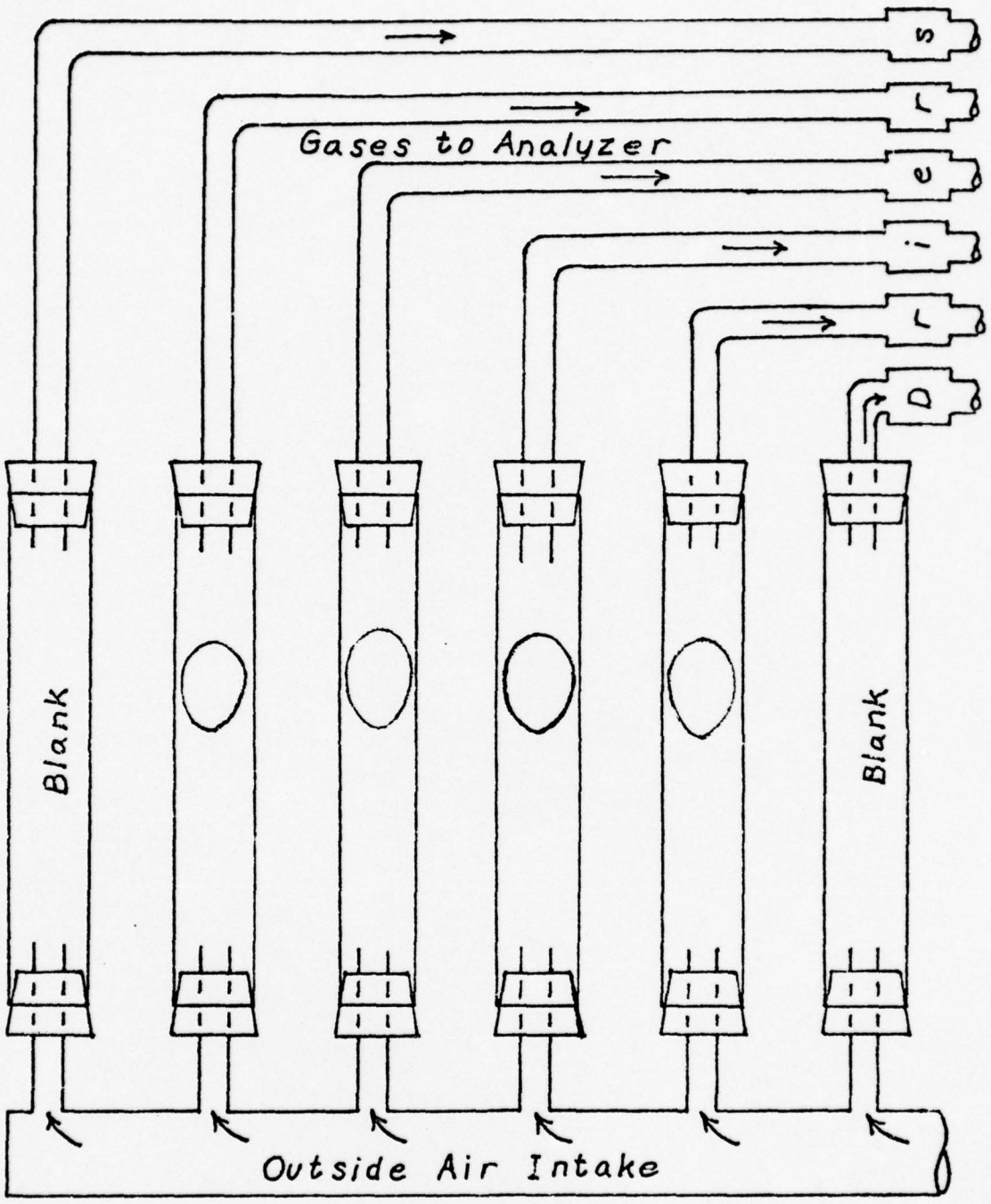

Figure 6. Diagram showing arrangement of CO_2 collection chambers and associated tubing used with the gas analyzer.

6. Behavioral Studies

Adult females which had previously (until four weeks post-hatching) been exposed to an ELF magnetic field (M 2-1, 76 ± 4 Hz, 8 gauss) or electric field (E 2-1, 76 ± 4Hz, 10 V/m) were used in peck order trials to determine whether or not the early field exposures had influenced their aggressiveness as adults. Four trials were conducted and each trial consisted of establishing a peck order among ten birds. Two trials were conducted among the females exposed as chicks to the magnetic field and two were conducted among those exposed as chicks to the electric field.

The pullets used were approximately 8-9 months of age and were in egg production when the trials were conducted. Each trial consisted of ten birds which had been placed in individual cages, to earse previous peck order hierarchies, three weeks prior to starting the test trials. Each trial was composed of ten birds; five were from control groups and were numbered 1-5, and five were from exposed groups and were numbered 6-10. After spending three weeks in cages without physical contact with one another, all birds in a trial were placed together in a 10-foot x 12-foot floor pen. Adequate food and water were available at all times. Daily observations of bird activities were made until a peck order had been established (usually within 3-4 days).

The data were analyzed by Chi-Square and Spearman's Rank Correlation methods (4).

7. Hematocrits

The hematocrit (packed cell volume expressed as percent of total blood) is low in young chickens and increases slightly in females and and framatically in males as they approach sexual maturity. Since circulating levels of testosterone increase hematocrits as well as aggressiveness in chickens, the hematocrit has been proposed as an indicator

of social aggressiveness in this species. Because hematocrit determinations are relatively simple to make, it was felt that this measure might have some potential value in these studies, particularly since some of the birds were to be reared to maturity. Therefore hematocrit determinations were made on samples of chicks which had been reared through four weeks of age in either a magnetic (M 2-1) or an electric (E 2-1) ELF field. Hematocrits were also determined on samples of the M 2-1 birds after they had reached sexual maturity (at approximately eight months of age).

The hematocrits were determined on small samples of blood drawn from a subcutaneous wing vein. (Several prominent veins are readily accessible as they cross or run parallel to the ulna, radius or humerus on the ventral side of the wing). The blood was collected in heparinized micro-hematocrit tubes, plugged with "Seal-Ease"[1] and centrifuged. Hematocrits were read with a "Spiro-Crit" tube reader.

RESULTS AND DISCUSSION

The reader should refer to Table 1 for associating the assigned trial code numbers (M 2-1, E 2-1, etc.) with the ELF magnetic or electric field description for which they were used.

1. Hatchability.

The effects of the various ELF fields upon embryonic chick development were examined from the standpoints of hatchability of fertile eggs set (Table 2) embryo mortality by incubation period (Table 3) and hatching

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[1]Micro-hematocrit tubes, "Seal-Ease", "Spiro-Crit" reader and micro-hematocrit centrifuge were products of Clay Adams, Division of Becton, Dickinson and Company, Parsippany, NJ 07054.

TABLE 2. COMPARISON OF HATCHABILITY OF FERTILE EGGS SET BETWEEN CONTROLS AND EGGS EXPOSED TO VARIOUS MODULATED ELECTRIC AND MAGNETIC FIELDS DURING THE HOLDING AND INCUBATION PERIODS

Trial Code	Treatment Group	No. Eggs Set	Fertile Eggs	Chicks Hatched[1] No.	%	chi-Square Value(DF=1)	P
M 2-1	Exposed	128	108	67	62.0	3.27	> .05
	Control	128	106	78	73.6		
M 2-2	Exposed	128	120	74	61.7	1.83	> .10
	Control	128	126	88	69.8		
E 2-1	Exposed	128	123	78	63.4	0.95	> .30
	Control	128	117	67	57.3		
E 2-2	Exposed	128	117	80	68.4	.29	> .50
	Control	128	123	88	71.5		
E 2-3	Exposed	128	105	71	67.6	----[2]	
	Control	128	---	77	---		
E 2-4	Exposed	128	110	77	70.0	1.63	> .20
	Control	128	99	61	61.6		

[1]Number and Percent of Fertile Eggs Hatched.

[2]Control eggs were discarded without checking for embryo mortality.

TABLE 3. COMPARISON OF MORTALITY BY INCUBATION PERIODS BETWEEN CONTROLS AND EMBRYOS EXPOSED TO VARIOUS MODULATED ELECTRIC AND MAGNETIC FIELDS

Trial Code	Treatment Group	Eggs Set	Chicks Hatched	Early Dead[1]	Mortality by Incubation Period (Days)			Chi-square Value (DF=3)	P
					1-7	7-14	14-21		
M 2-1	Exposed	128	67	20	19	1	21	1.56	> .50
	Control	128	78	22	13	1	14		
M 2-2	Exposed	128	74	7	35	2	9	7.28	> .05
	Control	128	88	2	23	0	15		
E 2-1	Exposed	128	78	5	21	1	23	5.90	> .10
	Control	128	67	11	33	2	15		
E 2-2	Exposed	128	80	11	20	1	16	3.25	> .30
	Control	128	88	5	16	0	19		
E 2-3	Exposed	128	71	23	16	3	15	[2]	
	Control	128	77		--	-	--	----	
E 2-4	Exposed	128	77	18	19	0	14	2.42	> .30
	Control	128	61	29	25	1	12		

[1] Includes infertile and mortality prior to incubation.

[2] Control eggs were discarded without checking for embryo mortality.

time in terms of hours after setting (Table 4, 5 and 6). In examining these data it should be kept in mind that the eggs used in four trials (M 2-1, M 2-2, E 2-1 and E 2-2) were gathered, held, and incubated during cold weather; those used in two trials (E 2-3 and E 2-4) were gathered, held and incubated in July and August. In addition, the rate of egg production of the breeders necessitated holding the eggs longer in most cases (up to two days) than is the customary commercial practice (usually 5-6 days) and these factors probably accounted for the low hatchability experienced in these studies. However, the identical practices followed with the control and exposed eggs (other than the experimental variables under study) made these data suitable for analysis.

Hatchability of fertile eggs set (Table 2) appeared to be unaffected by the ELF fields used and mortality by incubation period (days 1-7, 7-14, and 14-21) were similarly unaffected (Table 3). Hatchability differences between exposed and control eggs approached significance in only one trial (M 2-1) and differences in mortality by incubation period appraoched significance in only one trial (M 2-2).

Since embryo survival did not appear to follow a pattern in favor of either the exposed or control condition, however, it seems unlikely that these differences could be attributed to the ELF field exposures.

In conducting the earlier studies (Phase I, Continuous Wave) the observation had been made, without supporting data, that the eggs which had been incubated in one magnetic field coil seemed to hatch earlier than either the control eggs or those from the other energized coil. Therefore, an attempt was made to determine whether or not differences existed in hatching time between controls and eggs exposed

TABLE 4. COMPARISON OF HATCHING TIME BETWEEN CONTROLS AND EMBRYOS EXPOSED TO VARIOUS MODULATED ELECTRIC AND MAGNETIC FIELDS

Trial Code[1]	Treatment Group	Eggs Set	Chicks hatched by Hatching Time[2]			Total Chicks Hatched	Chi-Square Value	P DF=2
			Early	Inter-mediate	Late			
M 2-1	Exposed	128	20	15	32	67	9.34	.01 >.005
	Control	128	41	17	20	78		
M 2-2	Exposed	128	15	16	43	74	2.58	.30 >.25
	Control	128	23	25	40	88		
E 2-1	Exposed	128	21	22	35	78	0.65	.75 >.70
	Control	128	17	23	27	67		
E 2-2	Exposed	128	16	30	34	80	7.15	.05 >.025
	Control	128	28	39	21	88		
E 2-4	Exposed	128	54	22	1	77	4.14	.20 >.10
	Control	128	50	9	2	61		

[1]See Table 1 for Trial Code identification.

[2]Hatching Time (21 days = 504 hours)

Early: < 500 hours after setting.
Intermediate: 500-508 hours after setting.
Late: > 508 hours after setting.

TABLE 5. COMPARISON OF HATCHING TIME BETWEEN ALL EGGS INCUBATED IN TWO TOP SIMULATORS AND THOSE INCUBATED IN TWO BOTTOM SIMULATORS

Trial Code[1]	Incubator Position	Eggs Set	Chicks hatched by Hatching Time[2]			Total Chicks Hatched	Chi-Square Value	P DF=2
			Early	Inter-mediate	Late			
M 2-1	Top	128	30	16	16	62	4.77	.10 > .05
	Bottom	128	31	16	36	83		
M 2-2	Top	128	23	16	37	76	4.04	.20 > .10
	Bottom	128	15	25	46	86		
E 2-1	Top	128	26	30	18	74	21.00	.001 >
	Bottom	128	12	15	44	71		
E 2-2	Top	128	33	37	18	88	17.58	.001 >
	Bottom	128	11	32	37	80		
E 2-4	Top	128	62	10	0	72	10.51	.01 > .005
	Bottom	128	42	21	3	66		

[1] See Table 1 for Trial Code identification.

[2] Hatching time (21 days = 504 hours).

Early: < 500 hours after setting.
Intermediate: 500-508 hours after setting.
Late: > 508 hours after setting.

TABLE 6.
COMPARISON OF HATCHING TIME BETWEEN CONTROLS AND EMBRYOS EXPOSED TO VARIOUS MODULATED ELECTRIC AND MAGNETIC FIELDS WHEN HATCHING TIME IS BASED ON APPROXIMATE MEAN HATCHING TIME OF CONTROLS

Trial Code[1]	Treatment Group	Eggs Set	Control Mean Hatching Time (Hours)[2]	Chicks Hatched by Hatching Time: Early No.	Early %	Late No.	Late %	Number Chicks Hatched	Chi-Square Value	P DF=1
M 2-1	Exposed	128		20	29.9	47	70.1	67	7.63	.01 >.005
	Control	128	500	41	52.6	37	47.4	78		
M 2-2	Exposed	128		23	31.1	51	68.9	74	3.50	.10 > .05
	Control	128	504	40	45.5	48	54.5	88		
E 2-1	Exposed	128		29	37.2	49	62.8	78	.32	.70 > .50
	Control	128	504	28	41.8	39	58.2	67		
E 2-2	Exposed	128		30	37.5	50	62.5	80	3.69	.10 > .05
	Control	128	504	46	52.3	42	47.7	88		
E 2-4	Exposed	128		34	44.2	43	55.8	77	3.71	.10 > .05
	Control	128	496	37	60.7	24	39.3	61		

[1]See Table 1 for Trial Code identification.

[2]Hours after setting at which 42-61% of the control chicks had hatched; time used to distinguish early from late hatched chicks.

to the various fields. The chicks which hatched were recorded at four-hour intervals during hatching and the analyses of the data collected appear in Tables 4-6. The numbers of chicks which hatched early, intermediate and late are presented, together with the Chi-Square analysis of the data.

The differences between the control and exposed eggs were great enough in two trials (M 2-1 and E 2-2) to encourage further observations of the data. Therefore, the data were compared by position (top simulator vs. bottom) in the incubators with exposed and control data pooled. This analysis indicated a position effect (Table 5) and prompted the analysis shown in Table 6 which shows a comparison between exposed and control embryos when early and late hatch designations depend upon approximately 50 percent hatch of the controls. These data are not precise because of the difficulty of measuring time at 50 percent hatch with the procedure used (observations at 4-hour intervals), however they show a trend toward a prolongation of the hatch which may have been due to slight retardation of development during incubation. In order to evaluate more precisely the influence of the ELF fields on this response, greater care would be necessary to eliminate position and temperature differences during incubation. While these factors did not appear to affect eventual hatchability of the fertile eggs, it is well known that slight temperature differences during the full 21-day incubation period can have a dramatic effect (retardation or acceleration by several hours) on the time of hatch.

The observations at hatching time of E 2-3 were inadequate for analysis. The differences in hatching time between the control and exposed chicks in E 2-1 were not significant, but differences between

TABLE 7 . COMPARISONS BETWEEN BIRD BODY WEIGHTS OF CONTROLS AND CHICKS EXPOSED TO A MAGNETIC FIELD OF 76 ± 4 Hz, 8 gauss (M 2-1) THROUGH 28 DAYS OF AGE

Bird Age (Days)	Treatment	Number of Birds	Bird Body Weight (grams) Mean	Standard Deviation	Variance	Degrees of Freedom	Computed t Value[1]
2	Exposed	40	37.1	4.17	17	78	0.7259
	Control	40	37.7	3.18	10		
7	Exposed	39	48.3	10.25	105	77	0.5388
	Control	40	47.2	6.73	45		
14	Exposed	37	90.5	21.85	478	74	0.4904
	Control	39	88.4	15.81	250		
21	Exposed	39	150.3	38.78	1504	77	0.0314
	Control	40	150.5	30.09	906		
28	Exposed	40	237.5	41.48	1721	78	0.1386
	Control	40	238.8	46.14	2129		
70	Exposed[2]	39	1470.1	315.37	99461	76	0.7909
	Control	39	1413.8	318.75	101599		

[1]Critical t value at .05 level of significance and 75 degrees of freedom = 1.995.

[2]No field exposure after 28 days of age.

TABLE 8. COMPARISONS BETWEEN BIRD BODY WEIGHTS OF CONTROLS AND CHICKS EXPOSED TO A MAGNETIC FIELD OF 76 ± 4 Hz, 1 gauss (M 2-2) THROUGH 28 DAYS OF AGE

Bird Age (Days)	Treatment	Number of Birds	Bird Body Weight (grams) Mean	Standard Deviation	Variance	Degrees of Freedom	Computed t Value[1]
2	Exposed	40	40.0	3.52	12	77	1.8495
	Control	39	38.5	3.91	15		
7	Exposed	40	53.9	4.07	16	77	2.5895*
	Control	39	50.9	6.07	37		
14	Exposed	40	99.4	10.69	114	77	1.0056
	Control	39	96.8	12.68	161		
21	Exposed	40	146.8	17.59	310	77	0.9287
	Control	39	150.7	19.66	387		
28	Exposed	40	253.4	29.09	846	77	0.4458
	Control	39	256.4	31.30	980		
70	Exposed[2]	34	1326.2	585.77	343131	70	0.0387
	Control	38	1322.0	311.39	96965		

[1] Critical t value at .05 level of significance and 75 degrees of freedom = 1.995.

* Significant at the .02 level.

[2] No field exposure after 28 days of age.

TABLE 9. COMPARISONS BETWEEN BIRD BODY WEIGHTS OF CONTROLS AND CHICKS EXPOSED TO AN ELECTRIC FIELD OF 76 ± 4 Hz, 10 V/m (E 2-1) THROUGH 28 DAYS OF AGE

Bird Age (Days)	Treatment	Number of Birds	Bird Body Weight (grams)			Degrees of Freedom	Computed t Value[1]
			Mean	Standard Deviation	Variance		
2	Exposed	35	36.2	12.9	166	64	0.0488
	Control	31	36.4	13.7	188		
7	Exposed	31	58.8	31.1	970	70	0.6917
	Control	41	55.2	12.0	145		
14	Exposed	37	122.5	34.7	1200	76	0.6097
	Control	41	118.5	22.9	526		
21	Exposed	39	229.6	37.6	1416	76	0.8857
	Control	39	218.9	66.4	4411		
28	Exposed	39	387.2	58.6	3431	78	1.7351
	Control	41	361.9	71.9	5176		
84	Exposed	38	2418.2	474.8	225471	71	0.4166
	Control	35	2343.2	1009.4	1018971		

[1]Critical t value at .05 level of significance and 75 degrees of freedom = 1.995.

[2]No field exposure after 28 days of age.

TABLE 10. COMPARISONS BETWEEN BIRD BODY WEIGHTS OF CONTROLS AND CHICKS EXPOSED TO AN ELECTRIC FIELD OF 76 ± 4 Hz, 1 V/m (E 2-2) THROUGH 28 DAYS OF AGE

Bird Age (Days)	Treatment	Number of Birds	Bird Body Weight (grams) Mean	Standard Deviation	Variance	Degrees of Freedom	Computed t Value[1]
2	Exposed	40	36.3	3.3	11	78	2.0975*
	Control	40	37.8	3.4	12		
7	Exposed	40	50.5	7.6	57	78	0.8722
	Control	40	51.8	6.3	39		
14	Exposed	40	101.4	18.3	336	78	0.6191
	Control	40	103.6	14.9	222		
21	Exposed	40	198.8	33.5	1122	78	0.1168
	Control	40	197.9	32.0	1021		
28	Exposed	40	318.5	47.0	2206	78	0.9927
	Control	40	328.6	44.6	1986		
70	Exposed[2]	20	1386.3	1149.3	1320933	40	0.0807
	Control	22	1411.4	876.5	768175		

[1]Critical t value at .05 level of significance and 75 degrees of freedom = 1.995.

*Significant at .05 level.

[2]No field exposure after 28 days of age.

TABLE 11. COMPARISONS BETWEEN BIRD BODY WEIGHTS OF CONTROLS AND CHICKS EXPOSED TO AN ELECTRIC FIELD OF 76 ±4 Hz, 10 V/m plus 60 Hz CW, 3.5 V/m (E 2-3) THROUGH 28 DAYS OF AGE

Bird Age (Days)	Treatment	Number of Birds	Bird Body Weights (grams) Mean	Standard Deviation	Variance	Degrees of Freedom	Computed t Value[1]
2	Exposed	40	38.8	3.0	9	78	0.0703
	Control	40	38.7	3.4	11		
7	Exposed	40	63.6	8.0	64	78	0.8035
	Control	40	62.2	7.1	50		
14	Exposed	40	110.1	16.0	256	77	2.2679*
	Control	39	100.2	22.6	509		
21	Exposed	39	187.7	51.1	2616	74	1.2110
	Control	37	171,9	62.8	3948		
28	Exposed	39	313.1	85.2	7253	73	1.1491
	Control	36	287.3	110.6	12234		
70	Exposed[2]	31	1413.1	714.1	509915	54	0.0685
	Control	25	1399.0	840.3	706166		

[1]Critical t value at .05 level of significance and 75 degrees of freedom = 1.995.

*Significant at .05 level

[2]No field exposure after 28 days of age.

TABLE 12. COMPARISONS BETWEEN BIRD BODY WEIGHTS OF CONTROLS AND CHICKS EXPOSED TO AN ELECTRIC FIELD OF 76 ±4 Hz, 1 V/m plus 60 Hz CW, 3.5 V/m (E 2-4) THROUGH 28 DAYS OF AGE

Bird Age (Days)	Treatment	Number of Birds	Bird Body Weight (grams) Mean	Standard Deviation	Variance	Degrees of Freedom	Computed t Value[1]
2	Exposed	40	37.0	3.4	12	78	1.8476
	Control	40	35.9	3.1	10		
7	Exposed	40	67.8	6.8	46	78	0.0961
	Control	40	67.6	7.2	52		
14	Exposed	40	145.2	15.7	247	77	0.0791
	Control	39	144.8	28.7	821		
21	Exposed	40	249.3	31.8	1010	77	0.1313
	Control	39	248.1	48.5	2351		
28	Exposed	40	398.8	49.3	2430	77	0.1917
	Control	39	401.6	78.4	6148		
70	Exposed[2]	34	1304.4	487.1	237245	67	0.1957
	Control	35	1282.1	464.7	215957		

[1]Critical t value at .05 level of significance, 75 degrees of freedom.

[2]No field exposure after 28 days of age.

controls and exposed chicks in the remaining four tirals indicate that the ELF fields retarded embryo development slightly.

2. Bird Body Weight

After all viable chicks had hatched (approximately 23 days after setting), they were wing banded for individual identification and weighed. They were again weighed individually at 7, 14, 21, 28 and 70 days after hatching (exception: the birds in trial E 2-1 were weighed at 12 weeks rather than at ten weeks of age). The body weight data and their analyses are shown in Tables 7-12 for each growth trial. Since individual data were available, the analyses made use of this fact, avoiding the need to use the means derived from replicated groups.

The variation in bird numbers whose body weights were available for analysis at the various periods was due to several factors. In several instances, lost wing bands were replaced without body weight determinations at the appropriate time but in such bases body weight was taken at the next regular time. Chicks which died within the first two weeks were considered abnormal and their body weights were not analyzed. In the case of trial E 2-1. a malfunction of one of the hatcher-brooder temperature controls caused overheating of the unit and loss of most of the chicks at day 8. Since the surplus chicks had been removed only one day earlier, the lost chicks were replaced by returning surplus chicks to the experimental chambers from the battery brooder maintained in the same room. The exposed chicks in this trial were therefore outside the experimental ELF field for approximately 20 hours.

In a few instances, an occasional chick was overlooked on "weigh day", presumed dead, then discovered on the succeeding weigh day. In such cases only the available data as recorded were analyzed, but bird

TABLE 13. BODY WEIGHTS OF BIRDS EXPOSED TO VARIOUS ELF MAGNETIC OR ELECTRIC FIELDS THROUGH SEVEN DAYS OF AGE AND REARED IN BATTERY COMPARTMENTS THROUGH 28 DAYS OF AGE

Trial Code	Early Treatment Group[1]	Number Chicks @		Body Weight (grams)		
		2 days	70 days	2 days	28 days	70 days[2]
M 2-1	Exposed	17	15	36.8	256.2	1550.3
	Control	18	18	32.9	277.8	1478.3
M 2-2	Exposed	20	20	39.0	374.4	1507.5
	Control	20	19	37.8	335.2	1405.0
E 2-1	Exposed	17	16	38.0	367.5	2549.1
	Control	20	19	38.4	365.7	2444.2
E 2-2	Exposed	20	8	38.7	381.9	1500.0
	Control	20	16	37.7	353.3	1448.1
E 2-3	Exposed	20	18	38.7	318.8	1418.9
	Control	20	13	38.5	319.0	1315.5
E 2-4	Exposed	20	18	37.1	390.8	1326.7
	Control	20	13	36.5	403.6	1285.8

[1]No birds were exposed to ELF fields after 7 days of age.

[2]Body weights of E 2-1 birds were at 84 days of age.

numbers in the tables appear to fluctuate. In several cases, a sharp decrease in bird numbers between 28 and 70 days is obvious (especially E 2-2 and E 2-3). This was due to the mortality caused mostly by coccidiosis which is particularly troublesome in flocks started on grills which prevent ready access to their droppings during early development. Such birds develop little resistance to coccidia and when placed on litter often experience heavy mortality. Proper preventive medication of such birds is difficult.

Body weight differences between exposed and control chicks were great enough to be significant at the .05 level in only three instances:

in trial M 2-2, Exposed > Control at 7 days;

in trial E 2-2, Control > Exposed at 2 days;

in trial E 2-3, Exposed > Control at 14 days;

These data do not support a hypothesis that bird body weight prior to ten weeks of age was influenced by the ELF electric or magnetic fields studied.

Body weights of surplus chicks removed at seven days and reared in battery compartments are shown in Table 13. Birds from the exposed groups were reared in compartments separate from the ones from the control groups. Body weights at 48 hours, 28 days and 70 days are shown. When these body weight data are compared with the ones in Tables 7-12 they indicate that a population density of 20 chicks per magnetic field simulator compartment and 10 chicks per electric field simulator compartment allowed growth responses comparable to those observed in the battery compartments (20 chicks per unit).

At 70 days of age (84 days for E 2-1) the chicks which originated from the energized groups (until 7 days post-hatching) had greater body

weights than comparable control chicks. Since exposure to the ELF fields was terminated at 7 days of age, and because other exposed (through 28 days of age) chicks did not show consistently similar differences from their controls, it is difficult to explain the apparently greater growth of the previously exposed, battery reared chicks. Approximately equal numbers of previously exposed and control chicks were used in each battery compartment to eliminate position effects (chicks were identified by band number).

3. Carbon Dioxide Production of Embryos.

The mean carbon dioxide production of chick embryos from day 6 through day 20 were summarized in Tables 14-16 for trials M 2-3, E 2-5, and E 2-6. The data were gathered from individual embryos whose identity was maintained throughout the trial period. The tables include analyses of the differences in carbon dioxide production between control embryos and those continuously exposed to a modulated magnetic field of 8 gauss (M 2-3) a modulated electric field of 10 V/m (E 2-5) or a modulated electric field of 10 V/m plus 60 Hz CW, 3.5 V/m (E 2-6). The data show repeated measurements on the same embryos and therefore if the ELF fields had influenced metabolic rate of carbon dioxide production, it is reasonable to assume that the effects would have been cumulative or at least would have shown a trend. The data do not indicate any such trend.

In trial M 2-3, the exposed embryos exceeded the controls slightly throughout; the difference was significant only on day 18.

In trial E 2-5, the exposed embryos produced CO_2 at a more rapid rate than the controls on days 6, 8, 10 and 16; on days 12, 14, 18 and 20 the controls produced more CO_2.

TABLE 14. COMPARISON BETWEEN MEAN CO_2 PRODUCTION (ml CO_2/egg/hr) OF CONTROLS AND EMBRYOS EXPOSED TO A MODULATED MAGNETIC FIELD

76 ± 4 Hz, 8 gauss

Day	Treatment	Number of Embryos	Mean	Standard Deviation	Variance	Degrees of Freedom	Computed t value[1]
6	Exposed	19	0.892	0.124	0.0154	39	1.7001
	Control	22	0.826	0.127	0.0161		
8	Exposed	10	1.658	0.253	0.064	20	0.9884
	Control	12	1.545	0.291	0.085		
10	Exposed	19	2.258	0.394	0.155	38	1.7337
	Control	21	2.059	0.341	0.116		
12	Exposed	18	4.660	0.856	0.733	37	1.3409
	Control	21	4.335	0.673	0.453		
14	Exposed	19	9.863	2.330	5.428	39	0.539
	Control	22	9.539	1.516	2.298		
16	Exposed	19	15.335	1.579	2.493	39	0.7627
	Control	22	14.758	3.002	9.134		
18	Exposed	19	21.783	2.252	5.071	39	3.0936*
	Control	22	19.891	1.695	2.872		
20	Exposed	18	21.083	2.479	6.144	36	0.1804
	Control	20	20.911	3.380	11.421		

[1]Critical t value at 5% level of significance, 20 degrees of freedom = 2.086
Critical t value at 5% level of significance, 40 degrees of freedom = 2.021.

*Significant at .005 level.

TABLE 15. COMPARISON OF MEAN CO_2 PRODUCTION (ml CO_2/egg/hr) OF CONTROLS AND EMBRYOS EXPOSED TO MODULATED ELECTRIC FIELDS

76 ± 4 Hz, 10 V/m

Day	Treatment	Number of Embryos	Mean	Standard Deviation	Variance	Degrees of Freedom	Computed t value[1]
6	Exposed	43	0.747	0.218	0.0474	90	0.9216
	Control	49	0.712	0.144	0.0209		
8	Exposed	43	1.256	0.320	0.103	90	2.0811*
	Control	49	1.151	0.140	0.0196		
10	Exposed	44	2.172	0.396	0.157	90	1.183
	Control	48	2.081	0.344	0.119		
12	Exposed	43	4.187	0.638	0.408	90	0.3216
	Control	49	4.227	0.561	0.314		
14	Exposed	43	9.961	1.318	1.736	90	0.5464
	Control	49	10.104	1.205	1.453		
16	Exposed	43	17.599	1.593	2.537	90	1.0618
	Control	49	17.236	1.691	2.859		
18	Exposed	43	20.514	2.253	5.077	90	0.8569
	Control	49	20.872	1.766	3.118		
20	Exposed	42	21.837	3.173	10.065	87	1.7156
	Control	47	22.921	2.820	7.950		

[1]Critical t value at 5% level of significance, 60 degrees of freedom = 2.000.

*Significant at .05 level.

TABLE 16. COMPARISON OF MEAN CO_2 PRODUCTION (ml CO_2/egg/hr) OF CONTROLS AND EMBRYOS EXPOSED TO A MODULATED ELECTRIC FIELD

76 ± 4Hz, 10 V/m, plus 60 Hz CW, 3.5 V/m

Day	Treatment	Number of Embryos	Mean	Standard Deviation	Variance	Degrees of Freedom	Computed t value[1]
6	Exposed	45	1.059	0.321	0.103	80	1.1666
	Control	37	0.992	0.154	0.0236		
8	Exposed	44	1.379	0.259	0.067	80	0.5014
	Control	38	1.353	0.204	0.0418		
10	Exposed	42	2.709	0.313	0.098	78	0.5063
	Control	38	2.742	0.268	0.072		
12	Exposed	44	5.962	0.689	0.475	79	0.6588
	Control	37	5.856	0.769	0.591		
14	Exposed	44	12.139	1.113	1.239	79	2.0833*
	Control	37	12.662	1.156	1.337		
16	Exposed	44	18.077	2.179	4.746	79	0.2548
	Control	37	18.199	2.137	4.565		
18	Exposed	44	22.473	3.459	11.965	78	0.7662
	Control	36	23.040	3.118	9.742		
20	Exposed	44	24.323	4.635	21.481	79	0.8227
	Control	37	25.178	4.754	22.604		

[1]Critical t value for 5% level of significance, 60 degrees of freedom = 2.000.

*Significant at .05 level.

In trial E 2-6, the exposed embryos produced CO_2 at a higher rate than the controls on days 6, 8 and 12; on days 10, 14, 16, 18 and 20 they produced less CO_2.

The differences in CO_2 production were less than significant (.05 level) on most days measured.

These data indicate that the ELF fields used did not alter metabolic rate of the chick embryos enough to be measured as a significant change in carbon dioxide production rate. While these data do not support the evidence cited earlier that ELF fields may have slowed embryonic development slightly, it seems reasonable to assume that embryonic development could have been slowed enough to retard hatching time by a few hours without significantly reducing CO_2 production (considering individual embryo variation and the limits of precision imposed by the measuring procedures).

4. Behavioral Studies.

Adult female White Plymouth Rock pullets which had been reared together, then isolated by housing in individual cages, were identified by their wing bands according to their earlier (through 28 days post-hatching) ELF magnetic or electric field exposure and were provided with readily visible wing badges numbered 1-10. Within each trial, birds numbered 1-5 were from control groups and those numbered 6-10 were from previously exposed (M 2-1 or E 2-1) groups. Frequent observations of the birds after recombining in floor pens by assigned numbers (1-10) revealed the establishment of new peck orders within three to four days. Table 17 shows the peck orders established in the four trials conducted. The birds were ranked by aggressiveness; the most aggressive was placed at the top and the least aggressive (most submissive)was placed at the bottom.

TABLE 17. COMPARISONS OF AGGRESSIVENESS BETWEEN ADULT PULLETS EXPOSED AS CHICKS (THROUGH 28 DAYS OF AGE) TO A MAGNETIC OR ELECTRIC ELF FIELD AND THEIR CONTROLS

	Rank of Aggressiveness by Bird Number[1]			
	Electric Field E 2-1 76 ± 4 Hz, 10 V/m		Magnetic Field M 2-1 76 ± 4 Hz, 8 gauss	
Order of Aggressiveness	Trial I	Trial II	Trial III	Trial IV
Most	6	9	8	6
↑	1	1	9	10
	9	2	1	9
	2	6	4	8
	3	8	10	4
Aggressive	8	4	6	1
	4	5	3	3
	5	10	7	2
↓	7	7	2	7
Least	10	3*	5	5

[1] In each trial, 1-5 were from control groups;
6-10 were from previously exposed groups.

*Bird No. 3 died on day 2 of the trial.

Chi square and Spearman's Rank Correlation analyses were used to test the significance of the results.

With the exception of Trial IV, the orders constituted a random order; Trial IV approached non-randomness. Combining all tests and testing for agreement among tests revealed "no agreement". This indicated that previous exposure to the ELF field tested did not influence peck order.

No correlation was found between peck order and body weight or between peck order and hematocrit at 4 or 6 weeks of age.

5. Hematocrits.

The hematocrits determined on randomly selected birds from the groups previously exposed to either an Elf magnetic field (M 2-1, 76 ± 4 Hz, 8 gauss) or to an ELF electric field (E 2-1, 76 ± 4 Hz, 10 V/m) appear in Table 18. Determinations were made on the M 2-1 birds at 6 weeks and at 8 months of age; those on the E 2-1 birds were made at 4 weeks of age. No significant differences between the hematocrits of the previously exposed and control birds were found.

CONCLUSIONS

The data gathered from a series of experimental trials in which chick embryos and neo-nate chicks were continuously exposed to modulated ELF magnetic or electric fields indicate that the fields investigated did not cause consistent or significant changes in the following:

1. Hatchability of fertile eggs.
2. Embryo survival during the most critical stages of development.
3. Early post-hatching growth and development.

TABLE 18. HEMATOCRITS OF IMMATURE AND ADULT CHICKENS EXPOSED TO AN ELF MAGNETIC OR ELECTRIC FIELD FOR FOUR WEEKS AFTER HATCHING

	Immature[1]				Adult[2]	
	M 2-1		E 2-1		M 2-1	
	Exposed 76 ± 4 Hz 8 gauss	Control	Exposed 76 ± 4 Hz 10 V/m	Control	Exposed 76 ± 4 Hz 8 gauss	Control
Chick Number	10	10	9	9	11	11
Hematocrit						
Mean	33.3	33.3	32.3	31.7	36.6	34.8
s.d.	2.03		2.03		3.81	
s.e.	.91		.96		1.62	
t	0.0		.69		1.07	
D.F.	18		16		20	
P	>.9		.5-.6		.25-.30	

[1] M 2-1 chicks were 6 weeks old
E 2-1 chicks were 4 weeks old

[2] Birds were approximately 8 months old.

4. Growth and development of the sexually immature bird.
5. Carbon dioxide production of the developing embryo.
6. Subsequent aggressiveness (as adults) of females exposed early in life.
7. Hematocrits of birds at 4-6 weeks or at 8 months of age.

The fields may have prolonged the incubation period slightly, but not enough to interfere with hatchability. More precise procedures would be necessary to better evaluate the effects of exposure to these fields upon the length of the incubation period and upon the growth of chicks which had been removed from field exposure soon after hatching.

The ELF fields used do not appear to have been detrimental to the survival or well-being of the exposed chicks.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Chicks and embryos of the domestic fowl were continuously exposed to ELF magnetic or electric fields modulated between 72 and 80 hertz. The magnetic fields were maintained at an intensity of 1 or 8 gauss and the electric fields were maintained at either 10 V/m; 1 V/m; 10 V/m plus 60 Hz, 3.5 V/m; or 1 V/m plus 60 Hz, 3.5 V/m. Uniform fields at identical frequencies and amplitudes were provided for continuous exposure of embryos

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and chicks and during the preincubation holding period, incubation and hatching periods and through the first 28 days of brooding.

Statistical analyses of the results of these studies revealed that neither the magnetic nor the electric fields tested had significant or consistent effects on the following:

1. Hatchability of fertile eggs;
2. Embryo survival during the most critical stages of development;
3. Early post-hatching growth and development;
4. Growth and development of the sexually immature bird;
5. Carbon dioxide production of the developing embryo;
6. Subsequent aggressiveness (as adults) of females exposed early in life; or
7. Hematocrits of birds at 4-6 weeks or at 8 months of age.

The fields may have prolonged the incubation period slightly, but not enough to interfere with hatchability. More precise procedures would be necessary to better evaluate the effects of exposure to these fields upon the length of the incubation period and upon the growth of chicks which had been removed from field exposure soon after hatching.

The ELF fields used do not appear to have been detrimental to the survival or well-being of the exposed chicks.