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High Frequency Conductivity and Dielectric Effect of Fresh Fertile and Infertile Hens' Eggs.

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In the previous studies of Romanoff and Cottrell[1] evidence was presented that at radio frequencies from 14 to 14.4 megacycles the conductivity is lower and the dielectric effect higher in fresh fertile hens' eggs than in infertile. In view of these results it was deemed desirable to extend the study of the intact egg to higher frequencies. Also to follow up this work an investigation of the physical properties of each component of the egg—yolk and various layers of albumen—was required in order to determine the exact seat of the differences between fertile and infertile eggs and the conditions under which they are maximum.

Methods and materials. To cover the range between 2 and 60 megacycles, 2 vacuum tube oscillators were used. The source for the lower frequency range, from 2 to 15 megacycles, was the oscillator described in the previous article.[1] For the generation of the higher frequencies, 15 to 60 megacycles, the special oscillator was assembled (Fig. 1-A). The power supplies for both oscillators were fed from a 60 watt voltage regulator and there was negligible frequency drift or detuning on loading.

The oscillators were coupled inductively to a resonant tank circuit which was connected in parallel with a pair of circular plates forming the dielectric cell. The 3 to 15 $\mu\mu$f variable tank condenser was provided with a very accurate micrometer worm drive and dial permitting settings of the condenser capacity to an accuracy of ± 0.002 $\mu\mu$f. In the center of the tank coil was mounted a small 2.3 v flashlight bulb above which was a photronic cell protected by a copper sulphate heat filter. A galvanometer shunted to critical damping registered the intensity of the light from the bulb.

The entire apparatus was placed in a shielded cage and operated by remote control. The power output from the oscillators showed a long period drift of less than 1 cm galvanometer scale reading per hour for the ultra-high frequency oscillator and somewhat more for the lower frequency oscillator.

[1] Romanoff, A. L., and Cottrell, C. L., PROC. SOC. EXP. BIOL. AND MED., 1939, **42**, 298.

When measurements on whole eggs were being made the egg was mounted inside the resonant tank coil by means of an egg-holder sliding on a track and consisting of 2 opposing glass cups pulled together by a spring. The long axis of the egg was thus automatically made to coincide with the principal axis of the coil. By this method the effect of position of the egg was reduced to a minimum and readings on an individual egg could be repeated very precisely. The coupling between the oscillator and the resonant tank was standardized by means of a glass egg filled with egg albumen.

In studying the separate components of the egg, 10 g samples were weighed out to 0.01 g in small Petri dishes, 50 mm in diameter, and introduced between the plates of the dielectric cell. The readings on yolk and middle dense albumen were made alternately on fertile and infertile individual eggs. Outer and middle fluid layers of albumen, owing to the small amounts available from each egg, were studied from composite samples only.

The fertile and infertile eggs in these investigations were obtained from 2 biologically identical flocks of White Leghorn hens *(Gallus domesticus)*. The eggs from the flock with males were tested for fertility either by incubation or by examination of the blastoderm in dissected eggs.

Experimental. Measurements of conductivity and dielectric effects on several lots of intact eggs at frequencies of 54.6 and 27.3

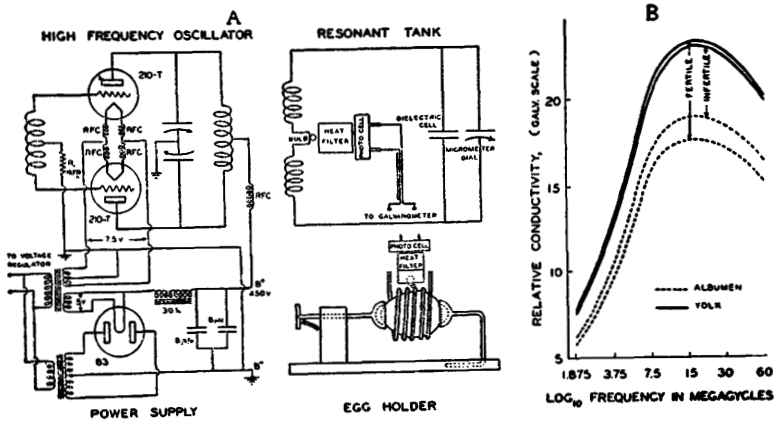

FIG. 1.

A. Circuits of power supply, high frequency oscillator and resonant tank. The 450 volt power supply feeds a tuned plate-tuned grid type oscillator using two 210-T's in push-pull mounted base to base, which in turn drives the resonant tank with egg coil or dielectric cell.

B. The relative conductivity measurements on yolk and dense albumen of fresh fertile and infertile eggs plotted against the logarithm of the frequency in megacycles. (Based on the observations of 20 dissected eggs in equal numbers of fertile and infertile).

megacycles showed tendencies in relative values of fertile and infertile eggs very similar to those previously observed at lower frequencies.[1] There was greater separation in conductivity in favor of infertile eggs. The dielectric effect was less consistent, although again showing higher values for fertile than for infertile eggs.

The measurements of the conductivity and dielectric effect of the egg components yolk and albumen were then made to locate the region where the principal differences between fertile and infertile eggs occur. The curves on relative conductivity (Fig. 1-B) show that the values for various parts of the egg were maximum at about 15 megacycles. The difference in power absorption of any sample between high and low frequencies was large, but the percentage difference between 2 different samples remained almost constant over the entire frequency range employed. The observations on the dielectric effect show that there was little increase in values and a gradual levelling off toward lower frequency.

The separation in values of relative conductivity of yolk and albumen of infertile eggs was only 18.6%, while of fertile eggs it increased to 28.4%. It should be noted that with fertilization the conductivity for the yolk was greater, while that for albumen was smaller, thus tending to mask the detection of fertility of the intact egg. For the dielectric effect the reverse is true. The separation of yolk and albumen was decreased from 13.2% in the infertile egg to 10.6% in the fertile egg.

Since several distinct layers of albumen are known[2] the relative values for conductivity and dielectric effect of the 3 outermost layers—outer liquid, middle dense, and middle liquid—were determined (Table I). The measurements of the outer fluid gave

TABLE I.
Effect of Fertility on Relative High Frequency Conductivity and Dielectric Effect of Various Egg Components.[1]
(at F = 15 megacycles)

Egg components	Conductivity galv. scale readings			Dielectric Effect dial scale readings		
	Infertile	Fertile	% diff.	Infertile	Fertile	% diff.
Layers of albumen:						
Outer liquid	16.15	14.10	—14.5	78.15	76.05	—2.1
Middle dense	17.03	15.90	—13.4	77.40	76.43	—1.3
Middle liquid	12.35	11.15	—10.8	74.10	71.70	—3.4
Yolk	20.20	20.42	+ 1.1	69.22	69.13	—0.13

[1] Based on the observations of 28 dissected eggs in equal numbers of fertile and infertile.

[2] Romanoff, A. L., and Sullivan, R. A., *Ind. and Eng. Chem.*, 1937, **29**, 117.

substantially the same values as the middle dense layer for conductivity and dielectric effect. On the other hand, the middle fluid showed a considerably lower value of conductivity than any of the other parts of the egg, while its dielectric effect lay about midway between those of the yolk and middle dense albumen.

These data indicate that the difference between the fertile and infertile egg in relation to conductivity and dielectric effect occurs principally in the albumen. The conductivity of fertile eggs was 7.4% lower than that of infertile eggs. The dielectric effect showed tendencies in favor of fertile eggs, but the differences were exceedingly small and of the same order of magnitude as the probable error. The values for the yolk showed no appreciable difference between fertile and infertile eggs.

Summary. The apparatus and methods for the precise measurements of small differences in the high frequency conductivity and dielectric effect of the intact egg and samples of the contents of the egg have been described.

The relative conductivity and dielectric effect of the intact egg at frequencies of 27.3 and 54.6 megacycles gave results indicating that fresh infertile eggs have a higher conductivity and a tendency towards lower dielectric constant than fertile eggs.

In dissected eggs the difference between the fertile and infertile egg in relation to conductivity and dielectric effect was observed to occur principally in the albumen. The conductivity of the albumen of fertile eggs was 7.4% lower than that of infertile eggs.

The conductivity values for various parts of the egg were maximum at about 15 megacycles. There was no frequency dependence for the percentage separation between yolk and albumen over the range from 2 to 60 megacycles.