LIV. On the law of the condenser in the induction-coil

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lead screens. This penetrating radiation may have its origin in the radioactive matter which is distributed throughout the earth and atmosphere. It was not found possible to obtain sufficient excited activity on a wire charged negatively in the open air to show the presence of a very penetrating radiation due to it. The effect observed is too large to be accounted for by the excited activity distributed on the walls of the laboratory.

(2) That all the substances examined give forth a radiation of a not very penetrating character; that this is probably the cause of all the residual ionization in the electroscope when surrounded by heavy metal screens; and that this activity varies with different substances, being very low in the case of brass.

(3) The reduction by the experimental arrangements of the number of ions produced per c.c. per second in air under atmospheric pressure from 14 to 5.

In conclusion, I wish to thank Prof. Rutherford, at whose suggestion and under whose very kind supervision this research was undertaken and carried out.

McGill University, June 23, 1903.

LIV. *On the Law of the Condenser in the Induction-Coil.*
By JAMES E. IVES, *Ph.D.*, *Instructor in Physics in the University of Cincinnati**.

[Plate XVII.]

THE optimum capacity, in an induction-coil, is defined as that capacity of condenser which, when placed around the break, will give the longest spark in the secondary. It has also been found by experiment to be the least capacity that causes the sparking at the break to disappear, or if not entirely to disappear to become very small.

In the July number of the *Physical Review* I proposed a formula for it, based upon theoretical considerations, viz.:—

$$K = \frac{I_0}{av_0}$$

where K is the optimum capacity; I_0 the steady current in the primary at the instant of breaking the circuit; v_0 the velocity with which the circuit is broken; and a some constant which depends upon the medium in which the break is made. Unfortunately for this theory, experiments made

* Communicated by the Author.

later, and recorded in the same paper, make it untenable at least for moderate speeds, since the speed of breaking, 70 cms. per second or less, was found to have very little effect upon the electromotive force induced in the secondary.

An attempt has therefore been made to find by experiment the relation between the optimum capacity and the other constants of the primary circuit, viz., the current, the resistance, and the inductance.

For this purpose a primary coil was used without a secondary, as it is well known that the action of the primary is unaffected by the presence of an open secondary. The break consisted of an amalgamated copper wire, one millimetre in diameter, dipping into a cup of mercury. The surface of the mercury was covered by two or three centimetres of distilled water. The breaking was done by hand. In making an experiment the capacity of the condenser, around the break, was gradually increased, and the value noted at which the sparking suddenly disappeared or became very small. The batteries used were large lead chloride cells.

A primary circuit may be regarded as made up of the three branches shown in the accompanying diagram.

The first branch, containing the primary coil and battery, and having a resistance R_p , an inductance L , and an electromotive force E ; the second containing the break, and having a resistance R_b , divided between the two sides; and the third containing the condenser, and having a capacity K , and a resistance R_c . By suitable manipulation any one of these quantities can be varied while the others are kept constant.

This was done, and although I have not yet been able to derive a general law connecting the optimum capacity with these different variables, certain well-marked and somewhat remarkable results have been obtained.

1. It was found that for the same current the optimum capacity is much greater when the breaking pole is negative than when it is positive. See Table I. and Pl. XVII. fig. 1. The change of sign was obtained by reversing the cell connexions.

TABLE I.
 R_b and R_c small.

Breaking-Pole Negative.			Breaking-Pole Positive.		
Current in Amperes.	Optimum Capacity in Microfarads.	$\frac{K}{I^2}$.	Current in Amperes.	Optimum Capacity in Microfarads.	$\frac{K}{I^2}$.
1.20	.057	.0396	1.15	.033	.0250
1.80	.126	.0390	1.70	.062	.0215
2.15	.182	.0394	2.10	.097	.0221
2.60	.261	.0386	2.60	.126	.0187
3.25	.377	.0357	3.60	.283	.0219
4.00	.566	.0354	4.65	.383	.0177
4.60	.680	.0321	5.40	.480	.0165

2. If R_p or E is varied so as to vary the current, the optimum capacity varies; in general, as a power of the current greater than the square and less than the cube. This is shown in Tables I. to IV., and in figs. 1 to 4 (Pl. XVII.). In fig. 1 the current is increased by decreasing the resistance R_p , and in figs. 2 to 4 by increasing the electromotive force of the battery E . It will be observed that the same curves are obtained in the two cases. In some of the tables is given the ratio of the optimum capacity to the square of the current. If the optimum capacity varied as the square of the current this should, of course, be a constant. It will be seen that when R_b and R_c are very small, that is, when the resistances of the break and condenser connexions are small, this is approximately true.

TABLE II.
 $R_c = 1.0$ ohm.

No. of Cells.	$R_b = .2$ ohm.			$R_b = .5$ ohm.			$R_b = 1.9$ ohm.		
	Current in Amperes.	Optimum Capacity in Microfarads.	$\frac{K}{I^2}$.	Current in Amperes.	Optimum Capacity in Microfarads.	$\frac{K}{I^2}$.	Current in Amperes.	Optimum Capacity in Microfarads.	$\frac{K}{I^2}$.
1 ...	.45	.008	.0395	.40	.010	.0625	.35	.030	.245
2 ...	.90	.033	.0408	.85	.035	.0485	.70	.139	.284
3 ...	1.30	.084	.0497	1.25	.095	.0608	1.00	.440	.440
4 ...	1.80	.171	.0528	1.65	.179	.0656	1.35	1.201	.660
5 ...	2.30	.318	.0600	2.15	.293	.0635			
6 ...	2.75	.536	.0710	2.55	.557	.0854			
7 ...	3.25	.870	.0824	3.00	.946	.1050			
8 ...	...	...	...	3.40	2.091	.1800			

TABLE III.

$R_c=0.$

No. of Cells.	$R_b=.5$ ohm.		$R_b=1.0$ ohm.		$R_b=1.9$ ohm.	
	Current in Amperes.	Optimum Capacity in Microfarads.	Current in Amperes.	Optimum Capacity in Microfarads.	Current in Amperes.	Optimum Capacity in Microfarads.
1 ...	.75	.048	.65	.090	.50	.049
2 ...	1.50	.231	1.30	.464	.95	.291
3 ...	2.20	.587	1.90	1.359	1.40	1.359
4 ...	2.90	1.156				
5 ...	3.60	1.750				

TABLE IV.

$R_b=.25$ ohm.

No. of Cells.	$R_c=0$ ohm.			$R_c=.5$ ohm.			$R_c=1.0$ ohm.		
	Current in Amperes.	Optimum Capacity in Microfarads.	$\frac{K}{I^2}$.	Current in Amperes.	Optimum Capacity in Microfarads.	$\frac{K}{I^2}$.	Current in Amperes.	Optimum Capacity in Microfarads.	$\frac{K}{I^2}$.
1 ...	.80	.033	.0516	.85	.038	.053	.90	.035	.043
2 ...	1.60	.139	.0543	1.60	.204	.080	1.70	.213	.074
3 ...	2.45	.335	.0559	2.40	.470	.082	2.40	.638	.111
4 ...	3.25	.725	.0686	3.10	1.166	.116	3.20	1.578	.154
5 ...	3.90	.980	.0644	3.90	1.750	.115			
6 ...	4.60	1.359	.0643						
7 ...	5.20	1.720	.0637						

3. The optimum capacity is a function of R_b and R_c . The results are given in Tables V. and VI. and in figs. 5 & 6. They are very remarkable, and show that the optimum capacity depends not only upon the primary current, but upon the resistances of the connexions leading to the break and to the condenser. The same primary current was, of course, used in each experiment. The form of these curves for small values of R_b and R_c was carefully examined by supplementary experiments, and found to be that shown in the figures. The curves therefore have a point of inflexion, and the optimum capacity is apparently a cubic function of these resistances.

TABLE V.

Four cells. Current = 2.1 amperes.

R_b in ohms.	Optimum capacity in Microfarads.			
	$R_c=0$.	$R_c=1$ ohm.	$R_c=2$ ohms.	$R_c=3$ ohms.
.00	.030	.184	.430	1.051
.35	.132	.350	.703	1.750
.71	.172	.470	1.086	
1.06	.237	.589	1.586	
1.41	.313	.859		
1.77	.388	1.163		
2.12	.636	1.578		
2.47	.926			
2.82	1.163			

TABLE VI.

Four cells. Current = 2.1 amperes.

R_c in ohms.	Optimum capacity in Microfarads.			
	$R_b=.5$ ohm.	$R_b=1$ ohm.	$R_b=1.5$ ohm.	$R_b=2$ ohms.
.00	.122	.213	.377	.646
.35	.236	.375	.616	1.163
.71	.340	.536	.850	1.750
1.06	.418	.726	1.163	
1.41	.480	1.049	1.700	
1.77	.589	1.450		
2.12	.859			
2.47	1.162			
2.82	1.720			

4. The two parts of R_b play exactly the same part in the primary circuit, and it is indifferent which of the two is changed. The same is true for the two parts of R_c . This was proved by a number of experiments, although it might have been presupposed.

5. The optimum capacity is a function of the *same form* both of R_b and R_c . This is shown by the results already given in figs. 5 & 6.

6. The optimum capacity is a function of the inductance of the primary. It varies less rapidly than a linear function, and soon becomes practically independent of it. This is shown by the results given in Table VII. and fig. 7 (Pl. XVII.). They were obtained by replacing the solenoid by a variable inductance, keeping the current constant by putting in or taking out

non-inductive resistance. The variable inductance was free from iron. The curves in fig. 7 suggest that the optimum capacity may be related to the inductance in the following manner:—

$$K = \frac{aR_b L}{\sqrt{b^2 L + c}} + d,$$

a , b , c , and d being constants. Curves of this form, but arising in an entirely different way, are discussed in my paper on the Induction-coil, already referred to*.

TABLE VII.

Current = 2·1 amperes. $R_c = 1$ ohm. $E = 4\cdot2$ volts.

Inductance in Millihenries.	Optimum capacity in Microfarads.			
	$R_b = 0$ ohm.	$R_b = \cdot 2$ ohm.	$R_b = \cdot 5$ ohm.	$R_b = \cdot 7$ ohm.
·00	·182	·226	·263	·280
·03	...	·226	·300	·303
·06	·182	·244	·313	·338
·16	·182	·236	·350	·397
·43	·182	·280	·423	·414
1·60	·192	·293	·420	·506
4·44	·213	·303	·470	
6·04	·189	·318		
7·64	·283			

In all the experiments recorded above, unless otherwise stated, the breaking-pole was negative. The solenoid used in the experiments had an air-core and an inductance of ·28 of a millihenry.

The optimum capacity was always taken as that capacity at which the break-spark was reduced from a large spark to a very small one. For small resistances and small currents this point is usually very well marked, but as the current or resistance increases it becomes more difficult to determine.

A phenomenon which appears well worthy of notice and which frequently attracted my attention in these experiments, especially in the case of a large primary inductance, is that as the capacity around the break is gradually increased the volume and "snappiness" of the spark increases up to a certain point, and then suddenly decreases, this value of the capacity being that taken as the optimum capacity. As the capacity is increased the potential appears to increase up

* Physical Review, vol. xiv. pp. 300-304 (1902).

to a certain point, and then to diminish. This behaviour of the spark suggests a resonance phenomenon.

From these experiments it will be evident that for this kind of a mercury-break any equation representing the optimum capacity as a function of E , R_p , R_b , R_c , and L will be quite complicated.

Summarizing these results we may make the following statements with regard to the optimum capacity for the particular kind of mercury-break used.

It depends upon the sign of the breaking-pole.

It is, in general, proportional to a power of the primary current, greater than the square and less than the cube.

• It depends very markedly upon the resistances of the connexions leading both to the break and to the condenser.

It is a function of the inductance of the primary, but for large inductances becomes practically independent of it.

In conclusion, I wish to express my indebtedness to Mr. Gordon Farnham, of the University of Cincinnati, for the great assistance which he has rendered me in this research.

University of Cincinnati,
June 1902.

LV. *On an Instrument for Measuring the Lateral Contraction of Tie-bars, and on the Determination of Poisson's Ratio.* By J. MORROW, M.Sc. (Vict.), Lecturer in Engineering, University College, Bristol*.

THE ratio of the lateral to the longitudinal strain in a bar under the action of a simple pull or push in the direction of its axis has been the subject of much controversy and a considerable amount of research. Some French mathematicians, including Poisson and Navier, held that this ratio was $\frac{1}{4}$ for all isotropic substances, their arguments were based on a theory of the constancy of the ratio of the elastic coefficients for all materials.

Wertheim endeavoured to show that this theory was false. He filled hollow prisms with liquid and subjected them to a tensile force. The interior of the prism communicated with a capillary tube, and the change of volume of the interior was measured by the distance the fluid advanced or receded in the tube. If Poisson's ratio be denoted by σ , change of unit volume = tensile strain $(1 - 2\sigma)$ very approximately. He maintained that the ratio σ should really be

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FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

FIG. 7.