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Energy Loss in Commercial Condensers

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NAME AND ADDRESS	DATE

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BY

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1910.

ENERGY LOSS IN COMMERCIAL CONDENSERS.

The investigation of the energy loss in condensers is one which electricians and experimenters have long carried on. Their efforts have been restricted chiefly to alternating currents. Many methods have been proposed and used with varying success.

The losses in condensers are due to dielectric hysteresis and leakage. That the dielectric of a condenser becomes heated when an alternating current is applied to terminals has long been known.

A condenser which has been charged does not lose its entire charge when it is discharged, part of it remaining as a residual charge.

Kleiner[1] used the thermo-couple imbedded in the dielectric to determine the heating effect. His observation showed considerable heating effect in ebonite, gutta-percha, glass and mica, but none in rosin and paraffin.

Paraffin paper condensers made by Boucherot[2] for

1. Wied. Ann., 50, p. 138.

2. L'Eclairage Electrique, Feb. 12, 1898.

8301

The investigation of the energy loss in condensers is one which electricians and engineers have [illegible] carried on. Their [illegible] particularly to alternating currents. [illegible] been attempted and used with varying success.

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Kleiner, used the [illegible] in the dielectric to determine the [illegible]. His observations showed [illegible] heating effect in [illegible], gutta-percha, glass or mica, but [illegible] and paraffin.

Paraffin paper condensers [illegible]

1. Elec. [illegible]

2. [illegible]

commercial circuits in Paris became so hot that it was necessary to reject them. A voltage of 3200 was applied across the condensers.

Bedell, Ballantyne and Williamson [3] investigated the heat loss in paraffin paper condensers. A condenser of 1.5 microfarad capacity was used, the efficiency of which was 95.6% showing 4.4% lost in heat.

The loss was determined by the three voltmeter method. The condenser was placed in a 500 volt circuit at a frequency of 160 cycles per second.

The most common method of measuring the energy loss in condensers is the wattmeter method. The frequency of the charge and discharge must be definite, and the electromotive force must be a simply harmonic one; that is, the upper harmonics must be eliminated. This is accomplished by inserting in series with the condenser a coil of wire with a large self-induction, but without an iron core. The variable permeability of the iron will give rise to the upper harmonics and assist in their maintenance instead of their elimination. This is especially noticable when the indication of the iron core attains large values. A coil without an iron core is thus necessary.

3. Physical Review, Oct., 1893,Vol,1, p. 81.

commercial circuits in Paris [illegible] as [illegible] it was necessary to reject them. [illegible] volts [illegible] applied across the condensers.

Bedell, Ballantyne and Williamson[1] measured the heat loss in paraffin paper condensers. A condenser of 1.5 microfarad capacity was used, [illegible] which was 96.35 showing 3.65 per cent in heat.

The loss was determined by the three voltmeter method. The condenser was placed in [illegible] circuit at a frequency of [illegible] cycles per second.

The most common method of measuring the energy loss in condensers is the wattmeter method. The frequency of the charge and discharge must be definite, and the electromotive force must be a [illegible] wave one; that is, the upper harmonics must be eliminated. This is accomplished by inserting in series with the condenser a coil of wire like a [illegible] coil, but without an iron core. The variable permeability of the iron will give rise to the upper harmonics and assist in their [illegible] [illegible] distortion. This is especially noticeable when the saturation of the iron core attains large values. A coil without an iron core is thus necessary.

1. Physical Review, [illegible]

Again if the self-induction of the coil is not large enough it will reinforce the upper harmonics instead of eliminating them. The best value for the self-induction of the coil is determined by the value of L in the equation $t = 2\pi\sqrt{LC}$ where t is the period of the fundamental component of the impressed electromotive force and C the capacity of the condenser.

The advantages of this arrangement are first; the resulting resonance raises the electromotive force at the terminals of the condenser saving the necessity of a transformer: second, a wattmeter can now be inserted across the low voltage supply mains to measure the power expended upon coil and condenser. Then subtracting the I^2r loss of the coil the remainder will give the power expended upon the condenser.

The Resonance Method by Wattmeter.

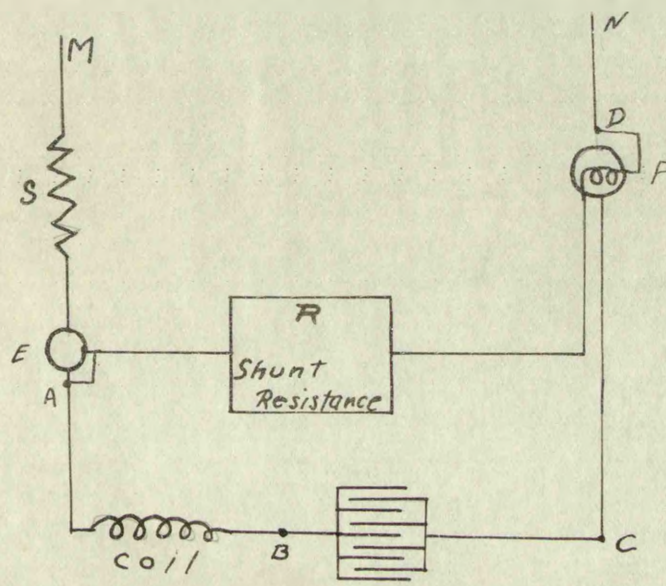

Fig 1.

Again if the self-inductance of the coil is not large enough it will reinforce the impulse giving in- stead of within that [illegible] [illegible] the self- induction of the coil is dependent upon the value of L in the equation $t=2\pi\sqrt{LC}$ where t is the period of the fundamental component of the impressed electromotive force and C the capacity of the condenser.

The advantages of this arrangement are first; the resulting resonance raises the electromotive force at the terminals of the condenser making the necessity of a transformer; second, a wattmeter can not be inserted across the low voltage supply mains to measure the power expended upon coil and condenser. Then subtracting the I^2r loss of the coil a correction will give the power expended upon the condenser.

The Resonance Method of Measurement.

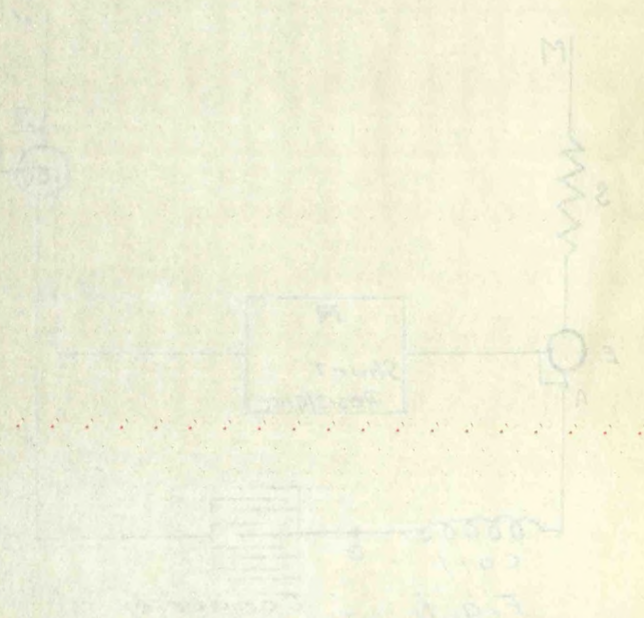

Fig. 1. shows the connections for this method. The coil is in series with the condenser. M N are supply mains of an alternating circuit. S is an adjustable resistance. E is a dynamometer, F a wattmeter, R a non-inductive resistance in shunt with the coil and condenser loining at points AD. This includes the I^2r loss in the fixed coil of the wattmeter.

The energy expended in the resonance coil and in the coil of the wattmeter, subtracted from the total power measured, gives the condenser loss. Experiment also shows this loss to be proportional to the square of the current. Then the loss in the condenser could be thus stated I^2r. I being the current in the circuit and r the condenser resistance which one authority has termed "equivalent resistance."

This method does not indicate by what process the energy is lost in the condenser, but that for a given condenser made of a given dielectric,at a given temperature and given frequency, the heating effect is the same as though there were certain resistance r_s in series with a perfect condenser of the same capacity. For the same capacity r_s (resistance of the condenser) changes with changes in temperature, frequency or with different dielectrics.

Although this method has its advantages there is, however, one serious difficulty which must be taken in-

Fig. 5. [illegible] coil is in series with the condenser. [illegible] of [illegible] circuit [illegible] resistance. [illegible] inductive [illegible] in the fixed coil of the variometer [illegible].

The energy stored [illegible] and is [illegible] of the condenser, [illegible] from the [illegible] power [illegible] of the current. [illegible] and q the [illegible].

[illegible] energy [illegible] different [illegible].

[illegible]

to consideration and eliminated as nearly as possible. The advantages which this method presents are these: (1) a resonance coil in series with the condenser quenches to a large extent the upper harmonics, (2) it raises the voltage upon the condenser, avoiding the necessity of a transformer, (3) enables measurements to be made more safely and conveniently upon a low voltage, and (4) the wattmeter problem is transfered from the most unfavorable condition (where the angle of phase difference is nearly 90^o) to the most favorable condition, where the electromotive force and current are nerely or quite in phase.

The difficulty to overcome is this; if the resonance coil is made of many turns of fine wire, it has great resistance and of the total power expended only a small part is used up in the condenser. Thus the condenser loss is the difference between two relatively large quantities and may not be as accurate as could be desired. Again if large wire is used in the coil, and the resistance is samll, there will be eddy currents set up in the copper and the power expended on the coil will be greater than the I^2r loss. This excess would be added to the condenser loss and introduce a considerable error.

This difficulty disappears if the wire is of large cross-section but stranded; then the resistance is small,

le specification [illegible] as great as possible.
The advantages which this [illegible] arrangement [illegible]:
(1) the resistance cell is always [illegible] condenser
[illegible] meter, (3) it
relieves the [illegible] upon the condenser, [illegible] the
necessity of a transformer; (4) enables measurements
to be made more rapidly and conveniently with [illegible]
age, and (4) the arithmetic [illegible]
the most unfavorable condition ([illegible]) [illegible]
difference is nearly 50 % to the most [illegible] con-
dition, where the [illegible]
purely or nearly in phase.

The difficulty [illegible] the resist-
ance cell is made of [illegible]
great resistance and of the [illegible]
A small part is [illegible]. [illegible]
condenser loss [illegible] are relative-
ly large quantities and [illegible] would
be desired. [illegible] cell,
and the resistance is small, there will [illegible]
set up [illegible] circuit
will be greater than [illegible] would
be added to the [illegible] consid-
erable error.

This difficulty [illegible]

cross-section [illegible]

the eddy currents negligible, and the coil will have large inductance.

The energy loss in a condenser for one voltage and frequency does not remain the same for a different frequency.

Increasing the frequency of the applied electromotive force across the terminals of a condenser decreases the capacity[4].

4. J. G. Coffin Physical Review, Aug. 1907, Vol. XXV, page 123.

the eddy currents negligible, and the coil will have
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The energy loss in a condenser is [illegible]
and frequency does not [illegible] with the [illegible]
frequency.

Increasing the [illegible] electro-
motive force between the terminals of a condenser [illegible]
es the capacity.

4. J. C. Dorfman [illegible]
V. 1, [illegible], page 142.

Description of Method Used.

The method used was a resonance one. A standard condenser, self-induction coil, a variable rheostat, a small resistance coil, and a variable self-induction coil were placed in series. The condenser whose energy loss was to be measured was placed in the circuit in parallel with the standard condenser. The maximum alternating current was measured by comparing it to a direct current which had an equal heating effect. The direct current was measured by means of a milammeter.

Resonance was first obtained in the circuit. This condition was obtained by adjusting the variable inductance.

When resonance was reached current and electromotive force were in phase and maximum current flowed. Maximum current caused maximum heating effect, and maximum heating effect was determined by the following method.

The small resistance placed in series with the circuit was a small coil of No. 36 double cotton insulated German Silver wire, wound in parallel on the same coil with this wire was another coil of No. 36 insulated copper wire. The whole was placed in a partial vacuum. The copper wire formed one arm of a Wheatstone bridge. On closing the switch and sending a cur-

rent through the condenser circuit the small resistance in the vacuum became greater as the current increased. When the maximum current was flowing the coil in the vacuum reached its maximum temperature and maximum resistance. This showed maximum deflection of the galvanometer.

The Wheatstone bridge was then balanced. The alternating current was now cut out and a direct current applied; first, however, the two condensers were taken out of the circuit and the milammeter put in their place. Then by means of the adjustable rheostat just enough current was let through the circuit to bring the Wheatstone bridge to a balance. This condition showed that the direct current then had the same heating effect as the alternating current.

When the alternating current was replaced by the direct, and the Wheatstone bridge balanced for equal heating effect, the voltmeter readings were less than when the electromotive force was applied.

The energy loss in the condenser was equal to EI, where E was the value of the electromotive force expended in the condenser. It was equal to the difference between the alternating electromotive force and the direct electromotive force. I was the current flowing through the circuit.

All the condensers used in the test were run in this rent through the condenser circuit [illegible] resistance in the vacuum became greater as the current increased [illegible] the maximum current was rising, the [illegible] vacuum reached its maximum long before [illegible] resistance. This agreed [illegible] of this galvanometer.

The Wheatstone bridge was then balanced. The alternating current was then put on and a direct current applied; first, however, the the condenser was taken out of the circuit and the milliammeter put in their place. Then by means of a Wheatstone rheostat the direct current was let through the circuit to make the Wheatstone bridge balanced. This condition proved that the direct current then had the same heating effect as the alternating current.

As the alternating current was equivalent to the direct, and the [illegible] bridge [illegible] heating effect, the voltmeter [illegible] when the electrodes [illegible].

The energy used in the [illegible] was equal to EI, where E was the value of the [illegible] pended in the [illegible]. [illegible] between the [illegible] direct [illegible] through the circuit.

All the [illegible]

manner, and finally two tests were made in which the standard condenser was replaced by one of the commercial condensers. From the data thus obtained it was possible to determine the energy loss in the standard condenser in all but three cases. Knowing this value the energy loss in each of the commercial condensers was obtained by subtracting that lost in the standard from that lost when both the standard and one of the commercial condensers were in the circuit, nearly the same current being used in all cases.

Where it was found possible the standard condenser was used at full capacity. Where full capacity was not used, the energy loss could not be determined in the usual way because of factors entering which could not be eliminated. This condition occurred in three tests, and only the approximate energy loss is recorded in the data.

In three other tests the capacity of the standard was only .92 M.F. but here it was possible to determine the energy loss by comparison.

The results of these tests show that the energy loss in the better class of commercial condensers was very little, if any, greater than that of the standard. In three of the commercial condensers, however, the loss was found to be twice as great. In these condenmanner, and finally two tests were made in which the standard condenser was replaced by one of the commercial condensers. From the [illegible] it [illegible] possible to determine the [illegible] in [illegible] condenser in all but three cases. [illegible] the energy loss in one of the commercial condensers was obtained by subtracting [illegible] loss [illegible] from that [illegible] the commercial [illegible] commercial condensers were in the circuit, nearly the same current being used in all cases.

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In three other tests the capacity of the primary was only .02 M.F. but here it was possible to determine the energy loss by comparison.

The results of these tests show that the energy loss in the dielectric of commercial condensers is very little, if any, greater than that of the air condenser. In three of [illegible] loss was [illegible] sers there was a large leakage per cent.

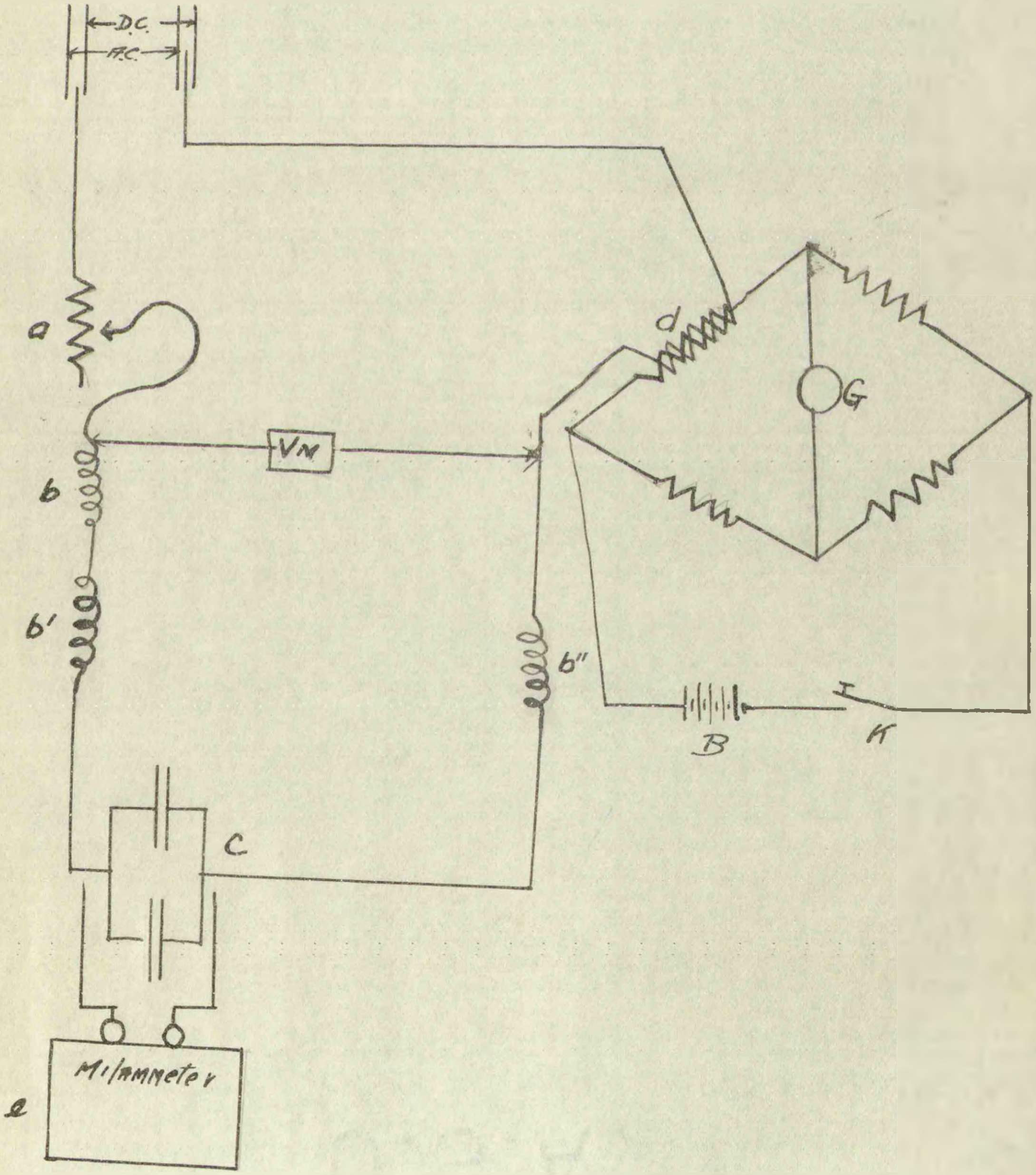
The advantage of this method is its simplicity. Once having the apparatus in working order any number of tests can be made, without any further adjustments, other than those which ordinarily occur.

zero there was a [illegible] leakage per [illegible].

The advantage of this method is its simplicity. Once having the apparatus [illegible] set up, any number of tests can be made, with [illegible] further adjustments other than those which are self-evident.

The Apparatus.

The apparatus for this experiment consisted of four self-induction coils, a variable resistance, a milammeter, a static voltmeter, a post office box, galvanometer and a standard condenser.



a=variable resistance.

b,b'=self-induction coils.

b"=variable self-induction coil.

c=condensers.

d=resistance heat coil.

e=milammeter.

G=galvanometer.

The variable resistance the self-induction coils, the two condensers in parallel, the variable self-induction coil, and the resistance heat coil were all connected in series. When the direct current was thrown in the circuit the only change made was that the milammeter was substituted for the condensers.

All the coils used in the experiment were wound in the shop; several were made having various inductances, so as to be able to produce resonance in the circuit, either by cutting out or placing in series in the circuit as the case may have been. One of the coils was made so as to have a variable inductance; this consisted of two coils of No. 18 wire having the same number of turns upon each, connected in series, one fitting inside the other so constructed,that the induction could be made as large as the self-induction of the two coils, and decreased from that amount to zero, by as small steps as was desired. This was accomplisha=variable resistance.

b,b'=self-induction coils.

b=variable self-induction coil.

c=condensers.

d=resistance heat coil.

e=milliammeter.

G=galvanometer.

The variable resistance [illegible] the self-induction coils, the two condensers in parallel, the variable self-induction coil, and the resistance heat coil were all connected in series. [illegible] the direct current [illegible] in the circuit the only change [illegible] that the milliammeter was substituted for [illegible].

All the coils used in the [illegible] in the shop; several were made having [illegible] inductances, so as to be able to [illegible] circuit, either by cutting out [illegible] the circuit at the same time. [illegible] was made so as to give a variable self-inductance; this consisted of two coils [illegible] number of turns [illegible] fitting inside the other [illegible] continuously [illegible] of the two coils [illegible] [illegible] ed by slipping the inner coil in or out and exchanging end for end as the condition may have required.

The other coils were not variable, the largest consisted of 27,500 turns of No. 30 wire. The others were made of No. 18 wire and had 3,000 and 1,500 turns each.

The resistance heat coil consisted of two wires of about five feet in length wound together and placed in a partial vacuum. The wire after being wound was placed in a cell prepared for the purpose and the air pumped out. Small platinum wires were led into the cell and silver-soldered to the ends of the coils. Some difficulty came when the current was thrown into the circuit, as the heating effect of the current was sufficient to expand the glass enough to break the cell in the first two cases. In the third case the wire was well annealed and worked very nicely.

The rheostat was used when the direct current was thrown into the circuit. By its adjustment the heating effect of the direct was made the same as that of the alternating current.

The direct current was measured with a Weston milammeter model 1, calibrated from 1 to 500 on one scale and from 1 to 16 on another. The milammeter was correct at 70^{o} and guaranteed to be correct to 1/4 of [illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible].

The money [illegible] was [illegible] [illegible]

consisted of 27,500 [illegible] [illegible]. [illegible]

were made of No. 10 [illegible] [illegible] [illegible]

tons each.

The resistance that [illegible] [illegible]

of about five feet in length [illegible] [illegible]

in a partial vacuum. The [illegible] [illegible]

placed in a cell [illegible] [illegible]

pounds [illegible]. Small [illegible] [illegible]

cell and [illegible] [illegible] of the [illegible].

Some difficulty [illegible] when the current was [illegible] into

the circuit, [illegible] [illegible]

sufficient to [illegible] [illegible]

in the [illegible] [illegible]

was [illegible] [illegible].

The [illegible] [illegible] [illegible]

[illegible] into the [illegible] [illegible] [illegible]

[illegible] of the [illegible] [illegible]

the [illegible] [illegible].

The [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible]

[illegible] [illegible] [illegible]

1 per cent between 20° and 70° on both scales.

The alternating and direct voltages were measured with a Kelvin electro-static voltmeter reading correct on D.C. and .2 of a volt high on A.C.

Either the direct or alternating current could be thrown in by means of a double pole double throw switch.

The alternating current was taken from the electric light circuit of the City, and the direct current was furnished by a General Electric Co's. direct current generator.

The galvanometer was balanced after the resistance was placed in the X arm of a post office box. Five Columbia dry cells in series furnished current for this circuit. The galvanometer was one of Leeds Northrup Co's. Type H D'Arsonval galvanometers used with a convex mirror and a spot of light. It was necessary to have a number of cells in the circuit to give sufficient sensibility.

1 per cent between 40° and 90° as [illegible].

The [illegible] log and [illegible] [illegible] with a Kelvin [illegible]-[illegible] [illegible] [illegible] on D.C. and [illegible] [illegible].

Although [illegible] [illegible] [illegible] [illegible] [illegible] current [illegible] be [illegible] [illegible] means of a [illegible] [illegible] switch.

The [illegible] [illegible] was [illegible] [illegible] light circuit of the [illegible] and [illegible] [illegible] furnished by [illegible] [illegible] [illegible] generator.

The [illegible] was [illegible] [illegible] [illegible] was placed in [illegible] [illegible] [illegible] [illegible] Dolezalek [illegible] [illegible] [illegible] [illegible] [illegible] circuit. [illegible] [illegible] [illegible] [illegible] Co's. Type [illegible] [illegible] [illegible] [illegible] [illegible] mirror and [illegible] [illegible] [illegible] a number of [illegible] [illegible] [illegible] [illegible] sensibility.

Data.

In taking the data it was found best to run as many tests as possible after the apparatus had once been heated rather than to run them one at a time. However it was impossible to run all at once, because it often took as long as two hours to run a single test. It was necessary to have as constant a voltage as possible. The alternating voltage was taken from the city mains, and the constant throwing in and out of lights in the city made the voltage fluctuate considerably in the morning and evening.

[illegible]

In taking the [illegible] it was found best to make as many tests as possible after the [illegible] had been heated rather than [illegible]. However it was impossible to do [illegible], because it often took so long to [illegible] a single test. It was necessary to have as [illegible] voltage as possible. The [illegible] voltage was taken from the city mains, and the [illegible] out of lights in the city made the voltage [illegible] considerably in the [illegible].

Interstate Manufacturing Co's. and Standard.

A.C. voltage =...................... 113.5

D.C. voltage 101.0

Milamperes......................... 127.0

Capacity of standard condenser....... 1 M.F.

Watts lost in both condensers .... 1.5875.

Watts lost in Interstate condenser... .4115.

Sterling and Standard Condensers.

A.C. voltage 113.2

D.C. voltage 94.7

Milamperes..........................124.5

Capacity of standard condenser........ .92 mf.

Watts lost in both condensers......... 2.30325

Watts lost in Sterling condenser...... 1.0826

Stromberg Carlson and Standard Condensers.

A.C. voltage 114.0

D.C. voltage 94.8

Milamperes.........................122.5

Capacity of standard condenser....... 1mf.

Watts lost in both condensers 2.352

Watts lost in Stromberg Carlson...... 1.176

Julius Andrae & Sons and Standard.

A.C. voltage........................... 111.9

D.C. voltage........................... 92.3

Milamperes............................. 123.0

Capacity of standard condenser........ .92 mf.

Watts lost in both condensers......... 2.4108

Watts lost in Julius Andrae & Sons.... 1.1902

Dean Electric Co. and Standard.

A.C. voltage........................... 113.1

D.C. voltage 94.2

Milamperes............................. 125.0

Capacity of standard condenser........ 1 mf.

Watts lost in both condensers......... 2.3625

Watts lost in Dean condenser.......... 1.1865

Leeds Northrup & Co. and Standard.

A.C. voltage........................... 114.3

D.C. voltage........................... 76.9

Milamperes............................. 102.0

Capacity of standard condenser........ 1 mf.

Watts lost in both condensers......... 3.8148

Watts lost in Leeds Northrup condenser 2.6388

Warner Electric Co.and Standard.

A.C. voltage	117.1
D.C. voltage	67.7
Milamperes..................	90.0
Capacity of standard condenser.........	1 mf.
Watts lost in both condensers..........	3.546
Watts lost in Warner condenser.........	2.37

Williams Condenser Co. and Standard.

A.C. voltage	112.5
D.C. voltage	80.6
Milamperes............................	108.0
Capacity of standard condenser.........	1 mf.
Watts lost in both condensers..........	3.445
Watts lost in Williams condenser.......	2.269

Century Telephone Construction Co.
and Standard.

A.C. voltage	116.0
D.C. voltage	95.2
Milamperes............................	124.5
Capacity of standard condenser.........	1 mf.
Watts lost in both condensers..........	2.6141
Watts lost in Century condenser........	1.4381

[illegible] Electric Co. [illegible] Condenser.

A.C. voltage.............................. [illegible]

D.C. voltage.............................. [illegible]

Milliamperes.............................. [illegible]

Capacity of standard condensers........... [illegible]

Watts lost in each condenser.............. [illegible]

Watts lost in Warner condenser............ [illegible]

Williams Condenser Co. [illegible] Condenser.

A.C. voltage.............................. [illegible]

D.C. voltage.............................. [illegible]

Milliamperes.............................. [illegible]

Capacity of standard condensers........... [illegible]

Watts lost in each condenser.............. [illegible]

Watts lost in Williams condenser.......... [illegible]

[illegible] Condenser.

[illegible]

A.C. voltage.............................. [illegible]

D.C. voltage.............................. [illegible]

Milliamperes.............................. [illegible]

Capacity of standard condensers........... [illegible]

Watts lost in [illegible] condenser....... [illegible]

[illegible] in [illegible]............... [illegible]

Automatic Electric Co. and Standard.

A.C. voltage.......................... 115.7

D.C. voltage.......................... 95.0

Milamperes............................ 125.5

Capacity of standard condenser.......

Watts lost in both condensers......... 2.59785

Watts cost in Automatic condenser.....

Sumpter Electric Co. and Standard.

A.C. voltage 113.1

D.C. voltage 93.3

Milamperes............................ 122.5

Capacity of standard condenser.......

Watts lost in both condensers......... 2.4255

Watts lost in Sumpter condenser.......

Electric Specialty Co. and Standard.

A.C. voltage 114.0

D.C. voltage 100.0

Milamperes............................ 121.0

Capacity of standard condenser ....

Watts lost in both condensers 1.694

Watts lost in Electric Specialty

condenser.............................

Dean Electric Co. and Stromberg Carlson.

A.C. voltage 112.9

D.C. voltage 93.7

Milamperes 122.5

Watts lost in both condensers.......... 2.352

Dean Electric Co. and Julius Andrae & Sons.

A.C. voltage 113.1

D.C. voltage 93.9

Milamperes........................... 121.5

Watts lost in both condensers.......... 2.3328

From the above data the loss of the standard condenser was determined to be :

Capacity 1 mf. (first determination)......1.176

Capacity 1 mf. (second determination).....1.18125

Capacity.92 mf. 1.22065

The first determination of energy loss in the standard condenser was used in the calculations.

Capacity of Condensers.

Standard Mica Condenser.

Charged 1 second .... 1 mf.

Charged 3 seconds........................... 1 mf.

Charged 10 seconds .... 1 mf.

Charged 30 seconds .... 1 mf.

Sumpter Condenser.

Charged 1 second ....1.1139 mf.

Charged 3 seconds ....1.1632 mf.

Charged 10 seconds ....1.2466 mf.

Charged 30 seconds ....1.299 mf.

Warner Condenser.

Charged 1 second .... .26618 mf.

Charged 3 seconds .... .3182 mf.

Charged 10 seconds .... .4459 mf.

Charged 30 seconds .... .4687 mf.

Automatic Condenser.

Charged 1 second .... .9879 mf.

Charged 3 seconds ....1.0679 mf.

Charged 10 seconds ....1.3236 mf.

Charged 30 seconds ....1.3958 mf.

Capacity of Condensers.

Standard Flat Condenser.

Charged 1 second .... [illegible]

Charged 5 seconds .... [illegible]

Charged 10 seconds .... [illegible]

Charged 20 seconds .... [illegible]

[illegible] Condenser.

Charged 1 second .... [illegible]

Charged 5 seconds .... [illegible]

Charged 10 seconds .... [illegible]

Charged 20 seconds .... [illegible]

[illegible] Condenser.

Charged 1 second .... [illegible]

Charged 5 seconds .... [illegible]

Charged 10 seconds .... [illegible]

Charged 20 seconds .... [illegible]

[illegible] Condenser.

Charged 1 second .... [illegible]

Charged 5 seconds .... [illegible]

Charged 10 seconds .... [illegible]

Charged 20 seconds .... [illegible]

Sterling Condenser.

Charged 1 second .... 1.1679 mf.

Charged 3 seconds .... 1.2158 mf.

Charged 10 seconds .... 1.2477 mf.

Charged 30 seconds .... 1.3826 mf.

Interstate Condenser.

Charged 1 second .... .7313 mf.

Charged 3 seconds .... .7753 mf.

Charged 10 seconds .... .81305 mf.

Charged 30 seconds .... .8244 mf.

Dean Condenser.

Charged 1 second .... .93099 mf.

Charged 3 seconds .... .9621 mf.

Charged 10 seconds ....1.0138 mf.

Charged 30 seconds ....1.0127 mf.

Stromberg Carlson Condenser.

Charged 1 second .... .9993 mf.

Charged 3 seconds .... 1.0269 mf.

Charged 10 seconds .... 1.0749 mf.

Charged 30 seconds .... 1.1016 mf.

Electric Specialty Co.

Charged 1 second .... 1.2615 mf.

Charged 3 seconds .... 1.4563 mf.

Charged 10 seconds .... 1.5 + mf.

Charged 30 seconds .... 1.5 + mf.

Julius Andrae & Sons.

Charged 1 second .... 1.0897 mf.

Charged 3 seconds .... 1.1266 mf.

Charged 10 seconds .... 1.1594 mf.

Charged 30 seconds .... 1.1604 mf.

Leeds Northrup Co.

Charged 1 second .... .43204 mf.

Charged 3 seconds .... .4842 mf.

Charged 10 seconds .... .52985 mf.

Charged 30 seconds .... .5524 mf.

Century Telephone Construction Co.

Charged 1 second .... .9666 mf.

Charged 3 seconds .... 1.101 mf.

Charged 10 seconds .... 1.2041 mf.

Charged 30 seconds .... 1.2356 mf.

Williams Co.

Charged 1 second	.6932 mf.
Charged 3 seconds	.7407 mf.
Charged 10 seconds	.8669 mf.
Charged 30 seconds	.95049 mf.

Standard Mica Condenser. (Second determination)

Charged 1 second	1 mf.
Charged 3 seconds	1 mf.
Charged 10 seconds	1 mf.
Charged 30 seconds	1 mf.

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