Review of Scientific Instruments, Vol. 11, p.299, 1940

A Low Frequency Alternator

In seeking a source of a.c. power with a frequency less than ten cycles per second an extremely simple device was attained. Not only does it supply ample low frequency power but its frequency can be made continuously variable from zero up. Moreover the amplitude of the wave is entirely independent of the frequency.

A d.c. generator of suitable power rating is selected and rebuilt so that its brushes can be made to rotate continuously. The voltage delivered by the brushes is then an alternating voltage whose frequency is equal to the speed of rotation of the brushes and whose amplitude is the rated d.c. voltage of the generator used.

An automobile generator of the 30-ampere size served our purpose very well. It was provided with the rotating bushing and disk system shown at A in Fig. 1. This system carries the brushes C, C' and since it acts as the bearing for the shaft S it is made of bronze. Also mounted on the disk of A is an insulated slip ring R. The brush C' is connected to this ring while C connects directly to the disk and hence to the frame which becomes one terminal of the machine. A third brush mounted on, but insulated from, the housing makes contact with the slip ring as A rotates.

It was found necessary to modify the housing only by the welding in of the steel bushing D to provide a little more bearing surface for A. Although not shown in the figure, oil holes were drilled to provide lubrication for both bearing surfaces of A.

If a constant frequency is desired an extension can be put on the armature shaft and a system of gears arranged so that the brushes may be rotated with power from the shaft. On the other hand if A is turned by a variable speed rotator any frequency can be attained from zero up to the maximum speed of the rotator.

The converted automobile generator gives a very good wave form with only a barely noticeable commutator ripple. The frequency of this ripple varies with the direction of rotation of the brushes. The only trouble which has been experienced with this machine occurs when the brushes are rotating at the same speed and in the same direction as the armature. Under these particular conditions the brushes sometimes do not make good contact with the commutator segments.

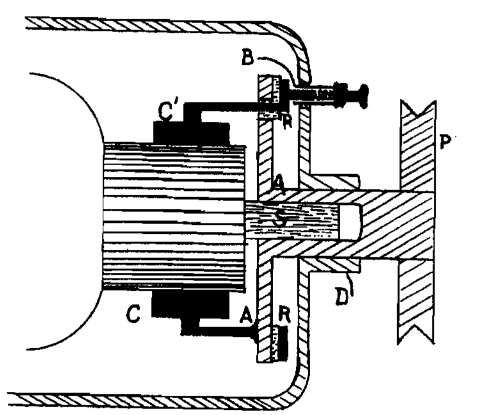

FIG. 1.

Although the device is now being used as a separately excited machine it would not be hard to mount two stationary brushes for the field excitation and thus make it self-excited.

WESLEY M. ROBERDS

Department of Physics,
University of Arkansas,
Fayetteville, Arkansas,
July 29, 1940.

Calcium Metaphosphate as a Target for Bombardment of Phosphorus by High Voltage Ion Beams

It has not been a simple matter to find a target material for phosphorus which is satisfactory in all respects. Red phosphorus and phosphorus pentoxide, which have been commonly used, have an inconveniently high vapor pressure at the temperatures produced by the ion beam. Metallic phosphides are difficult to prepare and are, in general, decomposed by the action of ordinary moist air. Phosphates are more stable but most of them have a low percentage of phosphorus.

Calcium metaphosphate, $Ca(PO_3)_2$, is a compound which possesses none of these disadvantages. Its phosphorus content is such that one expects yields of approximately 30 percent of those possible from a pure phosphorus target under the same nuclear bombardment. It is easily prepared from monocalcium phosphate, $Ca(H_2PO_4)_2 \cdot H_2O$, by dehydrating the latter compound over a Meker burner. The orthophosphate undergoes a marked swelling and efflorescence during the dehydration, and leaves a hard, brittle residue of metaphosphate which may be ground to a powder. To mount it on a platinum foil, a suitable quantity of the powder placed on the foil is fused by directing the full heat of a gas-air torch upon the foil from below. The salt melts to a clear, glassy liquid which, upon cooling, hardens without crystallizing and adheres firmly to the platinum surface. (If an oxygen flame is used, care should be taken not to heat the material more than enough to melt it, since P_2O_5 can be lost at higher temperatures.)

The fused calcium metaphosphate is very insoluble in all ordinary reagents, but fusion with sodium carbonate renders it easily soluble in nitric acid. If it is desired to remove the calcium and prepare pure phosphoric acid or another compound of radioactive phosphorus, the following procedure, based on a method by Swift,[1] may be used. Dissolve the carbonate fusion in 0.5 N HNO_3. Add $Bi(NO_3)_3$ in excess to the boiling solution. Filter and wash the $BiPO_4$, then dissolve it in HCl. Saturate this solution with H_2S and filter out the Bi_2S_3. The filtrate from this last precipitation contains only H_2S, HCl, and H_3PO_4, and the latter may be recovered in the pure state by simply evaporating the solution to dryness.

D. E. HULL
J. H. WILLIAMS

School of Chemistry (D. E. H.) and
Department of Physics (J. H. W.),
University of Minnesota,
Minneapolis, Minnesota,
July 12, 1940.

[1] Swift, *A System of Chemical Analysis* (Prentice-Hall, 1939), p. 305.

American Journal of Physics, Volume 5, Issue 4, pp. 182-184, 1937

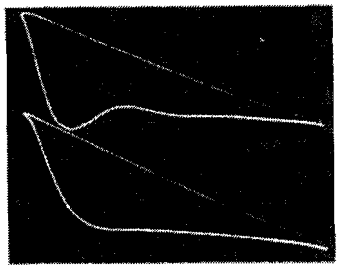

FIG. 2. *Top*, underdamping. *Bottom*, critical damping.

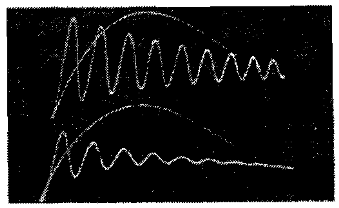

FIG. 3, Patterns with two different values of R.

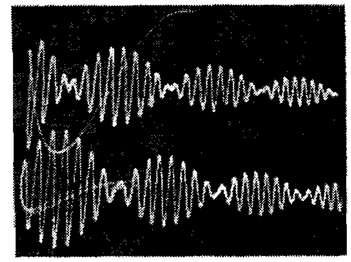

FIG. 4. *Top*, voltage across C of Fig. 5 *Bottom*, voltage across C' of Fig. 5.

patterns thus obtained are as stationary as any locked-in pattern. The frequency of the transient oscillations in the photographs was 12,000 cycles/sec. Each photograph consists of two exposures, the position of the pattern on the screen being shifted between exposures by

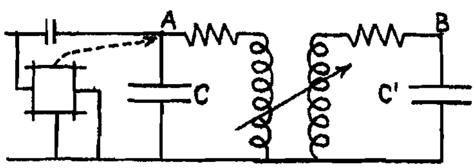

FIG. 5. Arrangement for study of coupled resonating circuits.

means of a bias on the vertically deflecting plates. Fig. 4 was made with the dotted connection to point A in Fig. 5 for the upper exposure, and to point B for the lower exposure.

Such patterns can be made the basis for a highly instructive laboratory exercise. Frequency may be determined by producing first the locked-in pattern of some known frequency, and then, without disturbing the sweep-frequency adjustments, producing the stationary transient pattern. The frequencies are in the inverse ratio of the respective wave-lengths on the screen. The coefficient of coupling is the reciprocal of the number of waves in one "group" of Fig. 4. The damping factor may also be measured directly. All these quantities may then be compared with those obtained from the known values of L, C, R and M. If C_1 is much smaller than C_2 and C, then both C_1 and C_2 may be omitted from these calculations.

The author wishes to express his thanks to Professor Bernhard Kurrelmeyer of this department for his helpful interest.

Some Simple Experiments on Optical Resolution*

WESLEY M. ROBERDS
Department of Physics, University of Arkansas, Fayetteville, Arkansas

SINCE, in common experience, resolution varies directly with magnification, it is difficult for the average student to conceive of these as being separate and distinct quantities. It is, therefore, quite important that the student should see an experiment where resolving power and magnification may be varied independently. While most texts in optics explain the theory of resolving power and how it depends upon diffraction, simple experimental demonstrations of these ideas are seldom described. It therefore may be useful to call attention to a few simple experiments which have been used with marked success by the author.

The simplest type of demonstration can be made by viewing ordinary window screen through holes of various size (0.5 to 4 mm in diameter) in cardboard or metal. The window screen should be well illuminated and 5 to 8 ft. away. The cardboard should be held close to the eye. As the screen is viewed through holes of increasing size, the resolution becomes better, but of course the magnification remains the same.

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American Journal of Physics, Volume 5, Issue 5, pp. 228-229, 1937

Some Experiments in Mechanics for the Elementary Laboratory *

IN designing experiments for the elementary laboratory the instructor often strives for elegance and accuracy at the expense of simplicity and directness. It is the author's belief that several important physical principles are being neglected in the laboratory because the student, in performing an experiment by some highly accurate method, finds in the end that the apparatus is so complicated or the procedure so involved that he really does not understand what he has done. Thus, the instructor discards such experiments as being unsuitable or else drives the student through them because they are recognized as "elegant." More might be gained if the student were allowed to use simple apparatus whose working principle could easily be grasped and then were encouraged to develop his own procedure as much as possible. Training in precision methods of measurement may not be the whole function of the elementary laboratory.

The physical pendulum. An excellent example of a principle that is not being emphasized in the laboratory is that of the physical pendulum. The theory dates from the time of Huygens and may be found in most of the older texts on mechanics. But few, if any, modern laboratory texts mention the physical pendulum, other than the Kater pendulum which, after all, is a very special type.

A successful experiment for teaching this principle has been used by us for some time. The pendulum is simply a large board of irregular shape and uniform thickness, suspended by thrusting into it from opposite sides two needle-point bearings (Fig. 1). If the needles are loosened slightly and the pendulum displaced through a small angle, it will oscillate fifty or a hundred times before coming to rest.

Before suspending the board it is covered on one side with a sheet of paper held by thumb tacks. The center of gravity C is located with the help of a plumb line in the familiar manner. Then with C as the center a large circle of some radius R_1 is drawn. Only a few points on the circumference of this circle need fall on the board. The board is then suspended in succession at several points on this circumference and each time its period is measured with a stop watch. Of course, the period should be the same for all these points.

Now starting near the center C, we determine the period for various other axes until one is located for which the period is the same as for axes through points on the circle. It is possible, of course, that no such axes will be found within the circle, in which case points outside should be examined. Points off the board may be investigated by suspending the board by a string (Fig. 2). When a point is located, its distance R_2 from the center of gravity is measured, and, if possible, a circle is drawn about C with R_2 as radius. The period determined for various points on this circle should be equal to that for points on the first circle.[1]

A simple pendulum of length R_1+R_2 is now made and its period determined. The period should be equal to that of the physical pendulum when suspended at any point on either of the two circles.

Thus it is shown that if any object is suspended so as to oscillate as a pendulum about an axis distant R_1 from its center of gravity, then: (1) its period will be the same for any parallel axis distant R_1 from the center of gravity; (2) in general, there exists another circle of radius R_2 which is the locus of parallel axes for which the period will be the same as for parallel axes through points on the circle of radius R_1; (3) this period will be equal to that of a simple pendulum of length R_1+R_2. With these general laws established it is easy to proceed to applications such as the Kater pendulum.

Falling body apparatus. We have used the apparatus shown in Fig. 3 with marked success. The Cenco impulse counter C is connected through a suitable resistance to a low voltage transformer Tr in series with a spring switch L. Normally this switch is kept closed by the tension in the spring. Another spring switch S serves as a release and normally is shunted across the impulse counter. So long as

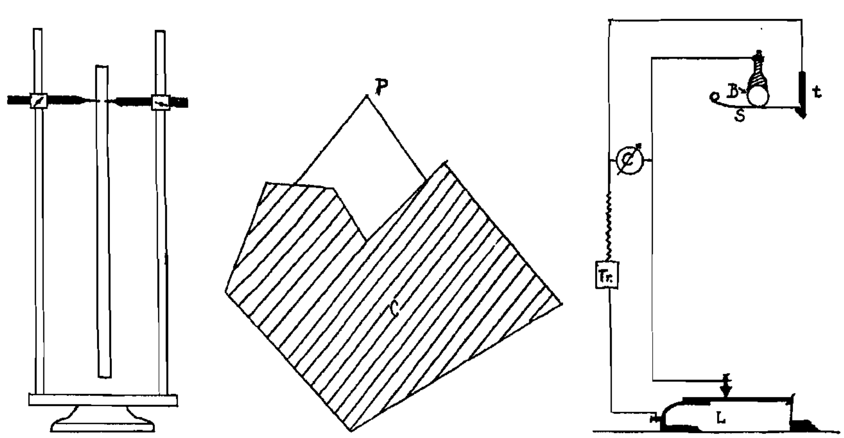

FIG. 1. (Left) Physical pendulum. FIG. 2. (Center) Case where the axis is off the board.
FIG. 3. (Right) Falling body apparatus.

High Frequency Conductance of Pyrex Glass in the Presence of Vapors

W. M. ROBERDS,* *University of Kansas*

(Received October 22, 1934)

The electrical conductance of "Pyrex" brand glass 774 was measured at frequencies between 40 kc and 1000 kc in the presence of ethyl alcohol vapor and water vapor. Data were taken at 50°, 65°, 79° and 107°C. The relations between conductance, degree of saturation, and frequency were found to be of the same form at all temperatures. There is a distinct discontinuity in the curves of conductance *vs.* frequency at about 500 kc. Vapor pressures of alcohol up to 85 percent of saturation cause no change in the conductance of the test piece. However, above this degree of saturation the conductance increases rapidly with pressure, becoming very high if condensation occurs. Conductance decreased with increasing current unless the test element was aged in the vapor several hours. Surface conductivities for both alcohol and water vapor are computed. Those for water vapor agree, well within the limits of error, with the results found by Yager and Morgan. An unexplained resonance effect occurred when high currents were used to measure the conductance while the test element was in the presence of small amounts of either alcohol or water vapor. The effect shows the double resonance peak and many of the other characteristics of close coupling between oscillating circuits. However, the effect is in some way due to the energy absorbed in the test element in the presence of a minute amount of water or alcohol since either an increase or decrease of pressure will cause the disappearance of the phenomenon. It was impossible to produce the effect by the substitution of any combination of capacity and artificial leak.

INTRODUCTION

YAGER and Morgan[1] have investigated the surface conductance of Pyrex glass in the presence of water vapor at frequencies up to 100 kc. They found that both the volume conductance and the surface conductance increased rapidly with frequency. In the presence of water vapor at high humidities the surface conductance increased enormously.

Knowles[2] in work on the dielectric constant of ethyl alcohol vapor found deviations from the theory at high degrees of saturation which he showed were closely associated with leakage across the insulators of his test condenser. However, when he measured the d.c. resistance of his insulators, he found values of leakage which were far too small to explain the discrepancies.

Poulter and Wilson[3] have shown that at high pressures ethyl alcohol behaves much the same as water in its tendency to penetrate the surface layer of glass. Therefore, it seemed reasonable that the high frequency resistance of the Pyrex insulators in the presence of alcohol vapor might have been low enough to have caused Knowles' anomalous results. And since Knowles' work is only one of the many instances where Pyrex glass is being used as insulators in high frequency apparatus, it was deemed worthwhile to investigate the manner of variation of the conductance of the glass both dry and in the presence of alcohol and water vapors at frequencies up to 1000 kc. Also, such data would extend the work of Yager and Morgan and might shed more light on the process of adsorption. Since the possibility of covering a wide range of frequencies was more to be desired than very high accuracy a substitution method of resistance measurement, a modification of that described in the *Proceedings of A. S. T. M.*,[4] was used rather than a bridge method.

EXPERIMENTAL METHOD

The wiring diagram of the test circuit is shown in Fig. 1. The procedure consisted in tuning the circuit with the switch S closed and observing the current in G, then opening S, retuning, and bringing the current back to its previous value by increasing r_{1-2}. The leakage resistance across the test element was then equivalent to the change in series resistance r_{1-2}.

Letting z be the impedance of the circuit between points A and B, X the capacitative reactance, and R_l the leakage resistance between

[redacted]

[1] W. A. Yager and S. O. Morgan, J. Phys. Chem. **35**, 2026 (1931).

[2] H. L. Knowles, J. Phys. Chem. **36**, 2554 (1932).

[3] T. C. Poulter and R. O. Wilson, Phys. Rev. **40**, 877 (1932).

[4] Proc. A. S. T. M. **27**, 1003 (1927).

Science Education, v 18, Issue 1, p 28-33, 1934

INDIVIDUALIZED INSTRUCTION FOR SUPERIOR STUDENTS IN INTRODUCTORY COLLEGE PHYSICS

J. R. Gerberich and W. M. Roberds
University of Arkansas

It is only within the past few decades that the development of the superior student has been recognized as an important educational problem. Early emphasis was placed upon the problems of the inferior or deficient student. More recently educators have come to realize that superior students have greater potential usefulness to society and that, therefore, educational institutions should be more concerned with the development of their marked capacities than has been true in the past. The study here reported is an attempt to determine the efficiency of rather highly individualized instruction for superior students in an introductory course in college physics.

Two methods have currently been used in attempts to make the educational process more effective. The first, individualization of instruction, has been at least partially accomplished through "honors" courses, varying rates of progress, differential assignments, and the like. The second, ability grouping or homogeneous grouping, has been rather widely applied in sectioning of classes. Neither method has proved unqualifiedly successful. High or prohibitive instructional costs have characterized many attempts at individualized instruction. The value of homogeneous grouping may still be considered a controversial matter, due in considerable degree to difficulties encountered in obtaining true homogeneous groups and in the problems of measuring some of the more complex and intangible outcomes of instruction.

Curtis[1] points out three stages of investigation in the teaching of science, his classification being based upon "the general aim or purpose served by the separate investigations." These are the stage of application to general problems of teaching method, the stage of application to more specific problems of teaching method, and the stage of individualized instruction or the determination of procedures and methods to insure "each individual pupil the maximum attainment of a specific objective." He comments upon this third stage as the ultimate goal in the teaching of science and suggests the need for research in this field.

Individualization of instruction may be classified into two types, with particular reference to science instruction: (1) an individual method, used primarily in the laboratory, in which the students individually and at varying rates of progress perform a set group of experiments, and (2) a more highly individualized method, more nearly comparable to "honors" work, in which each student, under the guidance of the instructor, conducts experiments of a more specialized nature in the field or fields of his greatest interest. Under the latter plan, it is, of course, necessary for the instructor to restrict the pursuit of special student interests so that adequate mastery of the subject-matter of the course is not impaired. It is with this second type of individualization that the experiment here reported deals.

Among those who have compared the first type of individualized instruction with other methods of science teaching are Hunter,[2] Cooprider,[3] Kiebler and Woody,[4] and Hurd.[5] Although such investigations have shown only slight superiority at the best for the individualized method, Hurd suggests that the results may, at least in part, be due to the failure of most criteria of final achievement to measure the types of outcomes resulting from the individualized method.

Among the comparatively few published

Review of Scientific Instruments, Vol. 2, p.519-521, 1931

A VACUUM TUBE RELAY AND RACE TIMER

By W. M. Roberds

[Physical Laboratory, University of Arkansas, Fayetteville, Arkansas.
Received May 29, 1931]

It is often desirable to close or open a circuit, and have it remain closed or open by a single impulse or excitation. Mechanical relays have been developed which will operate on a few milliamperes and which respond in a few hundredths of a second. However the author would like to call attention to a simple arrangement of vacuum tubes which will accomplish the desired result with as little as 1 microampere exciting current and which will operate in a few thousandths of a second at most.

A circuit diagram of the device is shown in Fig. 1. Normally the plate current of T_1 maintains the grid of T_2 so far negative that no plate

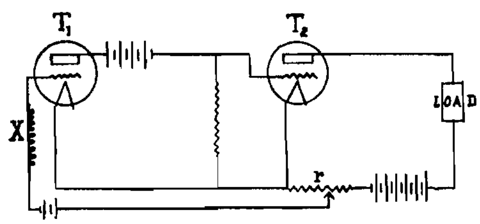

Fig. 1.

current flows. Now if some impulse is impressed on the grid of T_1 through X so as to make the grid slightly negative the plate current in this tube is decreased, thereby raising the potential of the grid of T_2. If the impulse is sufficiently strong, the plate current will flow in T_2 and, returning through r, will make the grid of T_1 further negative thus setting up a regenerative process. Under these conditions, the plate current of T_2 quickly builds up to a maximum. If the time constants of the various parts of the circuit are kept low then this maximum current may be reached in less than a thousandth of a second after the reception of the original excitation. Of course this current continues to flow until some external cause serves to make the grid of T_2 negative enough to stop it.

If X were a high resistance grid leak then of course less than a microampere through it might be enough to start the regeneration. The load is placed in the plate circuit of T and the tube used should be such as would supply the required power.

Review of Scientific Instruments, Vol. 1, p.473-478, 1930

AN EXPERIMENTAL X-RAY TUBE

BY W. M. ROBERDS

During the past few years there have been published a great many designs of special purpose x-ray tubes. Some designers have incorporated quite ingenious ideas in their plans. In the design herewith presented the author does not pretend to offer a completely new concept. Rather, there is presented the design of a cheap yet powerful x-ray tube which possesses the most desirable features of several other designs, and at the same time has the great educational advantage of being completely and easily dissectible. The student may take it apart and reassemble it in any of the many forms of gas or electron tubes. This feature also permits the study of various types of electrodes; of the influence exerted on the discharge, in gas tubes, by the size and shape of the tube, or by the positions of the electrodes. With a water cooled target, the tube may be run at high currents for hours, such as might be required for crystal analysis.

Essentially, the design consists in a brass central part or body, Fig. 1, to which may be bolted any type of electrode and tube that may be desired. All parts to be attached are permanently waxed or soldered to

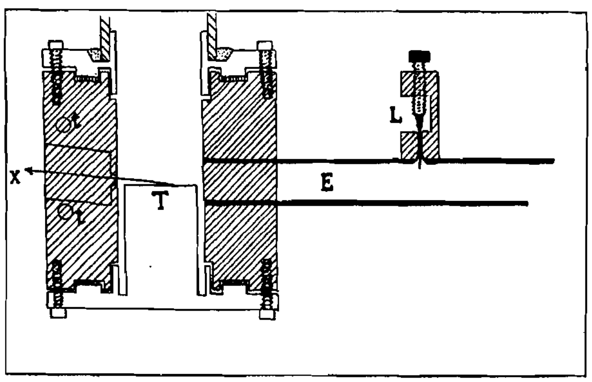

FIG. 1. *E: exhaustion tube; T: target; t, t: watercooling tubes; L: leak; X: x-rays.*

brass flanges and then these flanges are bolted to the body. A seal is secured with live rubber gaskets. The body is permanently connected to the exhaustion system and the tube is pumped continually while in operation. This fact limits the mobility of the tube and hence its practicability for medical purposes. But of course the tube is intended primarily for teaching and research.

Review of Scientific Instruments, Vol. 1, p.400-403, 1930

AN APPARATUS FOR STUDYING THE NATURE OF MAGNETISM*

By W. M. Roberds

Ewing in his "Magnetic Induction in Iron and Other Metals" has shown that all effects associated with ferro-magnetism may be produced with a group of little elementary magnets each of which is allowed to swing freely. Susceptibility and retentivity are shown to be due to the mutual attraction between magnetic molecules rather than to frictional resistance.

When more than two magnets are considered we have a three body problem and therefore cannot predict their actions mathematically. However we can study the actions of small groups of magnets under various conditions and thus be able to predict what will happen to large numbers of magnetic molecules under similar conditions.

The fact that such groups of elementary magnets follow so closely the behavior of magnetic substances makes this approach to problems in magnetism a most interesting one. It has been found that starting with an entirely "demagnetized" group, their hysteresis loop follows exactly that which is found in iron; even to the fact that on the first cycle the loop does not completely close. The Barkhausen Effect in such groups is a most pronounced phenomenon. The effects on hysteresis of regular spacing as in magnetic crystals, or of the state of individual magnetization of the individual magnets, make very interesting problems.

However, little has been done with such studies; one reason being the very laborious methods necessary in obtaining directly the degree of magnetization existing at any time. The magnetization of such a group in a given direction is taken as $\sum \cos \theta$, where θ is the angle between the direction in which the north pole is pointing and the given direction.

An apparatus is here described which will greatly simplify the taking of such observations. And not only does it aid in this approach to problems of magnetism but is a very useful instrument in teaching the true nature of magnetism.

The essential features of the instrument are a large magnetizing coil, several small magnets pivoted so they are able to swing freely in a horizontal plane, and an observing apparatus which facilitates the reading of the angular position of each. The little magnets are merely

* Research Paper No. 190, Journal Series, University of Arkansas.

THE RESISTANCE OF COPPER WIRES AT VERY HIGH FREQUENCIES

By W. M. Roberds

Abstract

At frequencies of the order of 10^7 cycles the distributed capacity of single loops of wire may cause sufficiently unequal current distribution in the loop to account for large apparent discrepancies between observed and calculated resistances. For a given frequency, more uniform current distribution is gained by decreasing the size of the loop and simultaneously increasing the capacity of the tuning condenser. Curves are plotted with ratio of observed to calculated resistance as ordinate and condenser setting as abscissa. For No. 20 copper wire at 0.86×10^7 cycles the ratio decreases to at least 1.05 as the current distribution along the wire is made more and more nearly uniform. For No. 16 oxide coated copper wire the ratio reduces to at least 1.35. The discrepancy in both cases is accounted for by the same value of condenser resistance. Observed resistance of a given loop is shown to vary greatly as condenser resistance is changed. Curves are run at 1.5×10^7 cycles on No. 20 bright copper wire, No. 20 oxide coated copper wire, and No. 20 silver wire. For all curves the ratio fell well below 1.45 and was still decreasing as far as data were taken. Since curves run on bright copper wire coincide with curves run on exactly the same wire after it had gained a heavy coating of oxide, it can be definitely stated that the presence of oxide has no appreciable effect on the resistance.

PREVIOUS experiments have shown a considerable discrepancy between observed and calculated values of the resistance of copper wires at frequencies of the order of 10^7 cycles. The results of one series of investigations[1] indicate that at a wave-length of 20 meters (1.5×10^7 cycles) the observed resistance of No. 18 copper wire is some four or five times the resistance as calculated from theoretical formulas. The object of the following experiments was to investigate whether such a discrepancy really exists.

The method of procedure was to construct a single rectangular loop of the wire whose resistance was to be measured and to couple this loop inductively to an oscillator radiating the desired frequency. It was found that if the loop was as near as 30 cm to the oscillator the current in the oscillator was reduced by about one percent as the loop was tuned. In order to avoid any effect due to coupling of loop and oscillator, the coupling was kept very loose. In no case was the loop nearer than one meter to the oscillator; in many cases it was over one and one-half meters away. The wave-length was measured by means of a wave-meter calibrated for short wave-lengths. The loop was tuned to the given

[1] Austin Bailey, Phys. Rev. 20, 154 (1922).