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SUBJECT

Report of

Magicore Samples

Manufactured by Henry L. Crowley and Company

by

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Office of Naval Research
Navy Department
Washington 25, D. C.

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Report of

Magicore Samples

Manufactured by Henry L. Crowley and Company

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

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AUTHORIZATION

1. The tests herein reported were authorized by ref.(a). Other pertinent data are listed as refs.(b) to (q), inclusive.

Reference: (a) BuEng let. S67/30/L5(9-19-38) of 21 Sept.1935.
(b) "Some Measurements on Iron Cored Tuning Coils", by K. Kaschke (The Wireless Engineer, No.148, Vol. XIII, Jan.1936, pp.14-20).
(c) "Ferro Inductors and Permeability Tuning", W. J. Polydoroff (Proc.I.R.E., No.5, Vol.21, May 1933, pp.690-709.)
(d) "Tuning by Permeability Variation", Ralph H. Langley (Electronics No.1, Vol.III, July 1931, pp.9-10.)
(e) "Iron Core Intermediate Frequency Transformers" Alfred Crossley (Electronics, No.11, Vol.VI, Nov.1933, pp.298-299.)
(f) "Further Notes on Iron Cored Coils for Use at R.F. and I.F.", W.J.Polydoroff (Electronics, No.1, Vol.VII, Jan.1934, pp.13.)
(g) U. S. Patent No. 1,887,380.
(h) U. S. Patent No. 1,940,228.
(i) U. S. Patent No. 1,978,568.
(j) U. S. Patent No. 1,978,599.
(k) U. S. Patent No. 1,978,600.
(l) U. S. Patent No. 1,982,689.
(m) U. S. Patent No. 1,982,690.
(n) U. S. Patent No. 1,997,453.
(o) U. S. Patent No. 2,005,203.
(p) U. S. Patent No. 2,002,500.
(q) U. S. Patent No. 2,018,626.

OBJECT OF TEST

2. The object of the test was to determine the suitability of the subject magnetic material for use in Naval radio equipment, with a view to ascertaining its possibilities as a substitute for metal and air cores in radio frequency transformers or for any other particular applications which may suggest themselves.

ABSTRACT OF TESTS

3. The data reported herein are the results of the following measurements and calculations.

(a) Measurement of radio frequency resistances and tuning capacities for several unshielded air and Magicore cored coils when resonated at five radio frequencies.

(b) Measurement of the true inductances of the same unshielded air and Magicore cored coils used for the measurements of paragraph 3(a).

(c) From the data obtained from the measurements of paragraphs 3(a) and 3(b) above, the "Q's" of the several air and Magicore cored coils were calculated for the frequencies to which the coils were particularly suited.

(d) The natural periods of the coils whose "Q's" were calculated were measured for the purposes of determining their distributed capacities.

(e) Each coil was measured for d.c. resistance.

(f) The influence of shield cans of various diameters and position of the coils within the shield cans upon the initial "Q's" of the coils was determined.

(g) The uniformity of the apparent permeability was determined for two lots of Magicore cores obtained at different dates from Henry L. Crowley and Company.

(h) The coils in commercial air and molyiron cored I.F. transformers were measured for "Q" under shielded and unshielded conditions.

Conclusions

(a) The Magicore core samples are cylindrical in form and possess certain magnetic properties which make their application to tuned inductances for operation at radio frequencies particularly advantageous. These magnetic properties are remarkably uniform to the extent that any one core is, within practical limits, exactly the same as any other. Each possesses an apparent permeability that is nearly twice that of air and also constant within the frequency range explored, so that for a given inductance a coil much smaller than an equivalent air coil may be employed. Hence, a saving in space, weight, and cost of material and labor may be realized. Each core is formed by compressing together, under high pressure and with a suitable binder, individually insulated and extremely minute particles of iron. Measurements have shown that the resistance due to the core at any frequency, within the frequency spectrum considered, is low, and for a given inductance this r.f. resistance due to the core when added to the r.f. resistance of the coil itself produces a total r.f. resistance that is less than that of an equivalent air coil measured at the same frequency. In other words, the reduction in the radio frequency resistance of the coil used with a Magicore core at a given frequency, as compared with an equivalent air coil, more than compensates for the added radio frequency resistance due to the core itself.

(b) From the group of coils available for test, one Magicore cored coil and one air coil were selected as being the ultimate design for each of the test frequencies. While these selected coils were by no means the best in design, they were the best available for the purpose. It was found that coils wound with #36 d.s.c. copper wire (the smallest wire used for the test coils) and having shape factors of less than 1.7 had the best "Q" values whether or not the core was of Magicore material. Obviously, placing these coils in shield cans causes a reduction in their initial "Q" values, depending upon the extent to which their normal flux paths were interfered with by the shield cans. Measurements showed that if this reduction in "Q" due to the presence of the shield can were limited to 10%, a larger diameter shield can was required for a Magicore cored coil than for a corresponding air coil. This was due primarily to the fact that the Magicore cores produce a spreading out of the flux lines around their associated coils. Hence, although a very much higher "Q" is realized from a Magicore cored coil as compared with its corresponding air coil, a greater space is generally required for the coil and shield can assembly if the same advantage of the available "Q" is taken in either case. However, if for a given Magicore cored coil the same size of shield can be employed as for the corresponding air coil, the "Q" of the former coil will still be very appreciably greater than for the air coil and enough greater as to make the use of the Magicore core material worthwhile. Now, if a sacrifice be made in the initial "Q" of Magicore cored coil by the use of a shield can of such diameter as to reduce the initial "Q" of the coil to the extent that the final "Q" will equal that of the corresponding air coil, a very great saving in space requirement is realized. This feature is very important and should be of particular interest to designers of aircraft equipment.

(c) The basic facts of paragraph (b) above, may be briefly outlined as follows:

(1) For optimum conditions, the "Q" of the Magicore cored coil is greater than for the corresponding air coil and the shield can diameter is generally larger.

(2) For the same space requirements, the "Q's" of the Magicore cored coils are appreciably greater than for the corresponding air coils.

(3) For the same "Q", there is a great saving in the space requirements for the Magicore cored coils.

(d) While solid double silk insulated copper wire was employed in the construction of the test coils, higher "Q" values could be obtained from the use of Litz wire, all other factors remaining the same. Litz wire was used for the coils in the commercial I.F. transformers examined and available on the open market. These coils were superior to those used for the subject tests.

(e) Thus far, the cylindrical type of molyiron cores are the only kind manufactured on a production basis in this country. The cores tested are now considered to be obsolete because the more recent cores developed in Europe have shapes which may be used to better advantage in I.F. circuits. Recent developments in this field in Europe have proven that the so-called "pot shape" cores, when used in conjunction with coils having sectionalized windings wound with Litz wire of several strands, have "Q" values far superior to those obtained from the cylindrical cored universal coils commercially available in this country. "Q" values as high as 400 are claimed for this European design. The Laboratory has been informed by a consultant of a manufacturing concern interested in the development of molyiron cores that "pot shape" cores will be manufactured for use in this country as soon as sufficient interest has been aroused to warrant the expense of setting up for their production. The exploitation of molyiron cores for radio frequency inductances is only a comparatively recent venture in this country. The acceptance of the use of molyiron cores in I.F. transformers is not yet general among the manufacturers of receivers, particularly in the broadcast field and the underlying reasons for this are not obvious.

(f) Kaschke has shown in his peper, reference (b), that for a coil designed for operation in the broadcast frequency band, the most efficient design yet developed in Europe is one having a pot shaped molyiron core and sectionalized windings wound with Litz wire. His curves for this design show that the "Q" of such a coil varies from a value better than 400 to about 200 between 550 and 1500 kilocycles respectively. This characteristic would make the application of such a highly efficient coil of questionable value in ganged tuned radio frequency circuits where tuning is accomplished by capacity variation. In such circuits more uniform overall gain and selectivity would be acquired over the given frequency spectrum only by the use of less efficient inductances, but such a procedure would at once defeat the potential advantages of molyiron inductances. The original inventor of molyiron core material has suggested "Permeability Tuning" as a solution to this problem. It is claimed for this method that the full advantage of the high "Q" feature

of molyiron inductances may be retained in ganged tuned circuits without sacrificing uniformity in overall gain or selectivity over the frequency range for which these circuits were intended. This method provides for tuning the circuits by inductance variation instead of by the conventional capacity variation method. Tuning by inductance may be accomplished by the simple expedient of fitting a movable molyiron core to each coil in the ganged circuit. The inductance of a coil is at a minimum when the core is removed and at a maximum when the core is completely inserted. A fixed capacity is connected across each coil. It is claimed that by winding each coil on a tapered form it is possible to provide a ratio of inductance to resistance that remains substantially constant over the tuning range. Hence, uniform gain and selectivity may be expected.

Recommendations

It is recommended:

(a) That the cylindrical type of molyiron core be considered as being suitable for use in tuned inductances operating at intermediate radio frequencies in Naval radio equipment, and particularly in aircraft equipment where its properties may be used to best advantage, provided that the manufacturers of this material shall satisfactorily demonstrate that its properties are not altered when the material is subjected to wide changes of temperature and a.c. and d.c. magnetizing forces.

(b) That samples of the "pot shape" type of molyiron core be obtained immediately and be submitted to the Laboratory for test.

8. Measurement of R.F. Resistance and Tuning Capacity of Unshielded Coils - The radio frequency resistances of the coils under test were measured by the substitution method, using a General Radio Type 516C radio frequency bridge. These measurements were made at five frequencies; namely, 175, 260, 370, 456, and 525 kilocycles. The arrangement of the apparatus and the method employed for determining the radio frequency resistance of an inductance will be described in detail later. Suffice to say, at this time, that this method of measurement provides a means for directly determining the effective radio frequency resistance of an inductor under test and since, in order to accomplish this end, the inductor must be resonated to the test frequency, therefore a measure of the tuning capacity is obtained simultaneously. The coils selected from the seventy-two coils available for tests were those which, for any given test frequency, did not require a tuning capacity greater than 100 mmf. or less than 30 mmf., or whose r.f. resistance values did not exceed 220 ohms. This arbitrary limit placed on tuning capacity range was selected to confine the selection of the coils within the range of the capacities of commercially available air dielectric variable condensers suitable for trimming I.F. transformers and which could be mounted within the transformer shield can without requiring that its diameter be excessively large. The limit placed on radio frequency resistance was governed by the range of the radio frequency bridge at which such measurements could be accurately determined. Radio frequency resistance measurements were made on the coils with the coils unshielded and employing first an air core and then a Magicore core. Since the tuning capacity range was limited, the selection of a given coil for a given frequency was governed by its inductance, which in turn was direct function of the type of core employed at the particular instance.

9. Calculation of the "Q's" of the Unshielded Coils - The "Q's" of the coils selected for the several test frequencies were calculated from the data acquired from the above measurements and from the corresponding inductance data obtained as described below in paragraph 10. The "Q" of a given coil under a given set of conditions for measurement was calculated from the equation:

$$Q = \frac{\omega L}{R}$$

Where Q = a measure of the efficiency of the coil

$\omega = 2\pi f$, where f = frequency in kilocycles

L = true inductance of the coil in millihenries

R = radio frequency resistance in ohms

10. Measurement of Coil Inductance - The inductances of the coils selected, as described in paragraph 8, were measured on a General Radio impedance bridge, Type 650A, Serial No.103, used in conjunction with a General Radio audio amplifier, Type 514A, Serial No.1. The impedance bridge permits the direct measurement of true inductance in millihenries. All measurements were made at 1000 cycles. The inductances of the coils were measured with and without Magicore cores. These measurements assume that the permeability of the Magicore cores remains constant between the frequency range of 1 to 525 kilocycles. Subsequent measurements, as will be shown later, demonstrated that this assumption is sound.

11. Measurement of Self-Capacity of Unshielded Coils - The self-capacities of the coils selected, as described in paragraph 8 above, were determined by measuring the natural period of the coils with and without Magicore cores by coupling the coils one at a time to a grid dip driver and hence obtaining the measurement of the natural period of the coil under test. The equipment used for this test consisted of a Type SS 1325 R.F. driver and a high frequency grid dip driver, both of which were designed and manufactured at the laboratory. The application of one or the other of these two instruments was governed by the natural period of the coil under test. From these data, the self-capacities of the coils were calculated from the following equation:

$$C_1 = \frac{10^9}{4\pi^2 f^2 L}$$

where C_1 = self-capacity of coil in micromicrofarads

f = natural period of coil in kilocycles

L = self-inductance of coil (at 1000 cycles) in millihenries

(Note discussion under paragraph 27.)

12. L/C Ratio of Unshielded Coils - The L/C ratios of the selected unshielded air and Magicore cored coils were calculated by dividing the true inductance (paragraph 10) of a given coil under consideration by the sum of its self capacity (paragraph 11) and the capacity (paragraph 8) that was required in addition to its self capacity to cause the coil to resonate at a given frequency. This ratio is an expression of Inductance in Henries divided by Total Capacity in Farads.

13. Shape Factor of Test Coils - The dimensions of the selected coils were carefully measured. In this report the ratio between the depth of the winding to the width of the winding shall be considered as the "shape factor" for a given coil, all dimensions being in inches.

14. D.C. Resistance - The d.c. resistance of the coils used for the above tests was measured with a Weston selective analyzer CV-22193, Serial No. 3012.

15. Selection of best Unshielded Coils with and without Magicore Cores for the Test Frequencies. From the data recorded from the foregoing measurements and calculations, three coils with air cores and three coils with Magicore cores were selected for each test frequency as being the ones most suited, when unshielded, for use at these frequencies. The characteristics of the test coils which governed the order in which they were selected are as follows and this statement applies to both classes of test coils (i.e., air or Magicore cored test coils).

First Preference. A coil which had a high L/C ratio attended by a high "Q" without regard to "shape factor".

Second Preference. A coil which had a high "Q" attended by a reasonable L/C ratio and a good "shape factor" (less than 1.75).

Third Preference. A coil which had a reasonably good "Q" without regard to L/C ratio or "shape factor".

The physical and electrical characteristics of these selected test coils were tabulated for each of the corresponding test frequencies.

16. R.F. Bridge Method of Determining R.F. Resistance and Tuning Capacity - Fig.1 of Plate I shows diagrammatically the arrangement of the equipment employed for indirectly determining the "Q" of an inductor, under test, at a given frequency. It provides a means for directly determining the radio frequency resistance of an inductor and the capacity of the series tuning condenser required to resonate the inductor to the test frequency. From this data the "Q" of the inductor may be calculated, provided that the inductance of the inductor is known, from the relation, $Q = 2\pi fL/R$ as given in paragraph (9).

(A) Measuring Equipment. The radio frequency bridge employed was Type No. 576C, Serial No. 23, of General Radio manufacture. The radio frequency signals applied to the bridge were obtained from a General Radio Type LS-1, Serial No. 13, standard signal generator. A Model RAA low frequency receiver was employed as a null detector. The standard signal generator and Model RAA receiver were connected to the bridge by means of shielded conductors, the shields serving as the ground lead. One ground terminal of the bridge was connected to the screened booth - this grounded terminal being indicated on the diagram. The functions of the remaining auxiliary equipment shown on the diagram will be made apparent under the method of test procedure.

(B) Procedure - The test procedure about to be described is known as the "Substitution Method" of measurement and was selected by virtue of the fact that the errors in the calibration of the bridge controls or those due to external influences are constant and are therefore at once eliminated from all calculations for "Q".

(a) The standard signal generator was adjusted for a given test frequency (this frequency being checked against a crystal controlled calibrator) and the output adjusted to a reasonably high level.

(b) A shunt shown as a dotted line on the diagram was placed across the series resistance terminals in such a way that the leads to R_3 and C_0 become a part of the bridge circuit. By way of explanation, mention should be made here that R_1, R_3, C_0, the coil under test and the variable air condenser of the bridge labeled "Capacitance" (C_3) together with C_1, which was in parallel with it, formed one arm of the bridge; while R_2 and C_2 were in a second and opposite arm of the bridge. The other elements which completed these two arms as well as the remaining two arms need not be described here since they were internal and needed no further adjustments for the measurements reported herein.

(c) The values of the fixed condensers C_1 and C_2 were chosen so that C_1 would permit the adjustment of C_3 to some point within its calibrated range at the test frequency, and C_2 would aid in correcting for any unbalance in the resistance arm of the bridge which could not be balanced out with resistance alone (R_2).

(d) The bridge was now balanced with R_1 set at 110 ohms or $R_1 + R_3$ (if R_3 were required) to 220 ohms and by adjusting R_2, C_3 and the power factor controls. Adjustments were continued until the signal from the head telephone set became just audible and there was a distinct and sharp indication of null having been reached.

(e) The shunt was then removed, thus placing in series with R_1 the series connected precision variable condenser C_0 and the test coil. When this external circuit is tuned to resonance, this circuit becomes in effect, a pure resistance in series with R_1 or ($R_1 + R_2$) whichever the specific conditions demanded.

(f) C_0 was then adjusted for resonance while at the same time R_1 (or $R_1 + R_3$) was being reduced in value by an amount equal to the radio frequency resistance of the circuit being measured. When a new null, as sharp as the original, had been obtained, the radio frequency resistance of the circuit under test became

R_{ac} = Original resistance of R_1 (or R_1+R_2) minus final resistance of R_1 (or R_1+R_2)

In making these adjustments, R_2, C_3, and the power factor control were not disturbed from their original settings. The output of the signal generator was adjusted to such levels as were consistent with the degree to which null was approached.

(g) The data recorded were the readings of R_1 (or $R_1 + R_3$) for the initial adjustment of the bridge and the final adjustments of R_1 (or $R_1 + R_3$) after the test circuit had been tuned to resonance. The settings of C_0 were also recorded and from the calibration of this condenser the capacity required to tune the coil under test was immediately ascertained.

17. Test Coil Mounting - In order that consistent results might be obtained from this investigation a special coil mounting was made as shown in Figs. 1 and 2 of Plate 1. It consisted of a victron plate, 1/4" thick, 1" long, and 5/8" wide, tapped at either side and the center of its face for 6/32 screw threads. The core and coil assembly was secured to the victron plate by means of a fiber screw which passed through the bore of core and threaded into the center tapped hole in the victron plate. A wooden core having the same dimensions as the Magicore was used when the latter was not used. This was done in the interest of consistency in spacing coil from the victrol plate and to make the results obtained with a given coil with an air core comparable with those obtained with the same coil but with a Magicore core. It has been assumed that the results obtained with a wooden core would be essentially the same as would be obtained without the core, all other factors remaining the same. Therefore it should be borne in mind that "air core" results imply the use of a wooden core as a means for mounting the coil. Two threaded brass rods were screwed into the remaining tapped holes in the victron plate so as to project away from the coil. Bakelite spacers 15/16" wide, 1/4" thick and of varying widths, and each having two clearance holes for 6/32 screws running parallel to the width of the spacers and at opposite sides, were slid onto the threaded brass rods with their 1/4" edges parallel to the plane of the victron plate. These spacers were used in the tests for determining the influence of shields on the "Q" of a given coil under measurement. The varying widths of the spacers permitted placing the coil at definite distances from the closed end of the shields as illustrated in Fig. 2 of Plate 1. The threaded brass rods, in this case, passed through two holes in the top of the shield can and were secured in place by a bakelite clamp.

18. Influence of a Shield Can on the "Q" of a Coil. Each of the test coils chosen for the "preferred list" of unshielded coils as described in paragraph 15 above was measured for "Q" when shielded in unplated copper cans of various diameters to determine the influence of shield can diameter and location of the coil within the shield can on the "Q" of the coil. For a given coil under measurement at a given frequency, the type of core employed (air or Magicore) was the same as that used when that coil was selected as being suitable (when unshielded) for use at the given frequency.

(a) Measuring Equipment. The equipment used for these measurements consisted of a Q-Meter Type 100A, Serial Number 177, manufactured by the Boonton Radio Corporation, one each of several unplated cylindrical copper shield cans each 4" in length and having diameters of 1", 1-1/4", 1-3/8", 1-1/2", 1-5/8", 1-3/4", 2", and 2-1/4", and a coil mounting the same as described above in paragraph 17. The Q-Meter is a self contained instrument and requires simply a connection to a 115 volt 60 cycle supply to place it in operation. It affords a means of directly measuring the "Q" of an inductor (shielded or unshielded) at any given frequency within the range of the instrument as well as the capacity required to resonate the inductor under test at that frequency. Unless it is desired to know the r.f. resistance of the inductor under test, it is not necessary to have

any knowledge of the inductance of the inductor to determine its "Q" with the Q-Meter. The "Q's" of the unshielded coils selected as described in paragraph 15 were calculated from the inductances of the coils and their r.f. resistances measured on a radio frequency bridge at five different radio frequencies. This method for obtaining "Q" was used because the Q-Meter was not made available to the Laboratory until after these measurements had been completed. However, if complete information regarding a given coil is desired - principally inductance - r.f. resistance and "Q", the calculations involved are about the same for either method, for if "Q" is known (Q-Meter method) the corresponding r.f. resistance must be calculated and if the r.f. resistance is known (r.f. bridge method) the corresponding "Q" must be calculated. The original data, however, from which calculations may be made is more easily and more quickly compiled under the "Q" meter method as differentiated from the r.f. bridge method described in paragraph 16 above.

(b) Procedure. The Q-Meter and auxiliary equipment were set up as shown in Fig.2 of Plate I with the outside lead of the coil under test and the shield can, used at the moment, connected to a common ground post on the Q-Meter. As shown on the diagram, the axis of the coil was parallel to and coincident with the axis of the shield can. The frequency at which measurements were made for a given coil was that frequency for which the coil was selected in the "preferred list" of unshielded coils as described in paragraph 15. At that frequency, measurements of the "Q" of the coil under test and the tuning capacity required to resonate the coil to that frequency were made with the coil spaced at various distances from the closed end of the shield. These distances were measured from the inside surface of the closed end of the shield can to the center line of the coil at right angles to its axis. The minimum distance obtainable with the type of coil mounting and support employed was 5/8". This procedure was repeated for the several sizes of cans starting with the smallest that would fit over the coil to the largest and using only as many of the intermediate sizes as were necessary to adequately give the desired information. A measurement was also made on the coil without a shield can. In addition to the measurements, similar measurements were made for each of an air cored coil and a Magicore cored coil when placed in the shield can so that the axis of the core was at right angles to axis of the shield can - the coil and core assembly otherwise being centrally located within the circumferential area of the shield can.

19. Measurement of Constancy of Apparent Permeability of Magicore Cores. The apparent permeability of each of several Magicore cores of two separate lots of cores obtained from Henry L. Crowley Company on dates differing from one another by approximately five months was determined by measuring the inductance at 1000 cycles of a coil of known physical constants, first with an air core and then with each of the Magicore cores in succession. The ratio between the inductance of the coil obtained when using any one of these cores to that obtained without the core is a measure of the apparent permeability of that core. Hence, the variation in the apparent permeability among the several cores may be noted. Further remarks on this subject are given in paragraph 39.

20. Test on Commercial I.F. Transformers. The "Q's" of the coils in two Hammarlund air cored I.F. transformers and four molyiron I.F. transformers of "X" manufacture were measured with and without shields and at their respective rated frequencies to which they were tuned. These measurements were made with the Q-Meter with the coil leads and shields connected (when shields are used) as shown in Fig.2 of Plate 1.

DATA RECORDED DURING TEST

21. Data taken during the tests are embodied in Tables 1 and 3 and Plates 1 to 20 inclusive, appended to this report.

PROBABLE ERRORS IN RESULTS

22. An estimate of the accuracy to be expected of each class of measurement reported herein is given in the tabulation below.

Nature or Class of Measurement	Estimated Accuracy
R.F. resistance of coil by R.F. bridge method	± 5%
Tuning capacity for resonance by R.F. bridge method	± 3 uuf.
Inductance of coil at 1000 cycles	± 3%
Natural period of coil	± 5%
L.C. resistance of coil	± 5%
"Q" of coil (shielded or unshielded) Q-Meter method	± 7%

23. The accuracy of the radio frequency resistance obtained by the radio frequency bridge method of measurement is a direct function of the degree to which the standard signal generator may be adjusted to a given frequency and maintain that adjustment over a definite period of time, the precision of the decade resistor on the bridge itself, the percent error in the count of the number of turns on the coil winding under test, and finally the error introduced by an unsymmetrical flux distribution resulting from not placing the coil exactly midway between the two ends of the core. The error in the adjustment of the frequency of the signal from the standard signal generator was reduced to a minimum by checking the initial setting against a crystal controlled calibrator. This setting, when finally fixed, gave a radio frequency accurate to within ± 0.2% of that desired. The only additional error in the frequency of the signal from the standard signal generator would be that due to the natural drift of the standard signal generator throughout

the period of time during which the initial frequency adjustment was maintained. In some instances, this time element was as much as eight hours. Taking this condition as the worst extreme, the drift of the signal frequency from the standard signal generator could be expected to change by not more than ± 0.3% so that the total error in frequency would be ± 0.5% or ± 0.1% depending upon the direction of the drift and whether the initial frequency was higher or lower than that desired. The precision with which the decade resistor in the bridge may be adjusted was accurate to within ± 1% for any single setting of the decade. Now, inasmuch as two settings of the decade were necessary for each measurement of radio frequency resistance and since the value of this measurement was the difference between two settings of the decade, the error of measurement was ± 2% or 0% depending upon whether the individual errors of the two adjustments were both positive or both negative or of opposite signs. While the two sources of errors in the measurement of radio frequency resistance discussed above are of sufficient importance to merit consideration, those errors contributed by an inaccurate count of the number of turns on the test coil and an inaccurate placement of the coil on the core are of still greater importance. It has been demonstrated that the count of the number of turns on a coil is accurate to within ± 1%. Since some of the flux lines pass through the victron plate upon which the coil and core assembly was mounted for these tests, it is important that the spacing between the coil and victron plate be uniform for all coils. Since the most symmetrical distribution of flux around the coil and the condition which was attended by the least amount of stray flux lines passing through the victron plate was that in which the coil was centrally located on the core, this spacing between a given coil under test and the victron mounting plate was carefully measured. Moreover the fit between the coil and the core was sufficiently snug to prevent any change of the position of the coil with respect to its core due to slipping during handling. The error in the measurement of the radio frequency resistance due to some of the flux lines passing through the victron plate rather than through air may be considered as being as much as ± 1% so that the total error taking all contributing factors into account was probably ± 5%.

24. The error in determining the tuning capacity required to tune a given coil to resonance at a given frequency was due to several factors; namely, the accuracy of the calibration of the precision air dielectric variable condenser used for tuning the coil, "hand effect" while adjusting the condenser, and the distributed capacities between the leads of the coil and between the coil and coil leads to ground. The calibration of the precision condenser is accurate to ± 1 uuf. Hand effect was found to be negligible. The added stray capacities were reduced to a minimum by spacing the coil as far from any grounded metallic surfaces as was consistent with the use of short coil leads. These stray capacities were probably in some cases as much as ± 2 uuf making the total error in capacity measurements equivalent to ± 3 uuf.

25. In the measurement of the true inductance of a coil, here again, the importance of centralizing the coil on its core was a governing factor in determining the accuracy of measurement. With careful adjustment of the coil on its core and mounting this assembly on the same mounting as used for the radio frequency bridge measurements, the error of measurement may be kept within reasonable limits. Obviously, the error in the count of the number of turns was also an important item. As explained above, if the error due to a maladjustment of the coil on its core was

± 1% and the error due to the count of the number of turns was also ± 1% and since the calibration of the impedance bridge was accurate only to within ± 1%, the maximum total error in inductance to be expected was ± 3%.

26. The equation for the calculation of "Q" at a given frequency from its measured 1000 cycle inductance (L) and radio frequency resistance (R) at the given frequency is

$$Q = \frac{\omega L}{R} \qquad \text{where } \omega = 2\pi f$$

Taking logarithms

$$\text{Log } Q = \log \omega + \log L - \log R$$

and differentiating

$$\frac{\delta Q}{Q} = \frac{\delta \omega}{\omega} + \frac{\delta L}{L} - \frac{\delta R}{R} + C$$

(C = a constant allowing for slide rule errors)

Now since $\frac{\delta \omega}{\omega}$, $\frac{\delta L}{L}$, and $\frac{\delta R}{R}$ are constants of error expressed in the same terms (i.e., in this case as percentages), from paragraphs 23 to 25, the maximum percent error in the calculation of "Q", where $\frac{\delta Q}{Q}$ is an expression of that error, is

$$\frac{\delta Q}{Q} = 0.5 + 3.0 - 5.0 + 0.5 = -1\%$$

(The sign in this case has no particular significance.)

27. The measurement of the natural period of a given coil was dependent directly upon the accuracy of the calibration of the grid dip driver employed and upon the precision with which resonance may be obtained with the least amount of detuning of the driver due to too close coupling of the driver coil with the coil under test. An estimate of the error of this type of measurement is ± 5%. Now since the self capacity of the coil under test was calculated from the equation

$$C_1 = \frac{10^9}{4\pi^2 f^2 L}$$

where the constants are as stated in paragraph 11. The error in the calculation of C_1 is accomplished by the following steps. Taking logarithms

$$\text{Log } C_1 = \log 10^9 - (\log 4 + 2 \log \pi + 2 \log f + \log L)$$

Now since log 10^9, log 4 and 2 log π are constants that do not vary, they may be ignored. Hence,

$$\text{Log } C_1 = 2 \log f + \log L$$

Differentiating:

$$\frac{\delta C_1}{C_1} = 2 \frac{\delta f}{f} + \frac{\delta L}{L}$$

and from paragraph 25 the % error in the calculation of C_1 is therefore,

$$\frac{\delta C_1}{C_1} = +10 + 3 = 13\%$$

Adding 1% for errors in observations, calibration of grid dip driver, etc., the total error in the calculation of C_1 is $\pm$ 14% maximum.

28. The error in the measured d.c. resistance of any given coil was dependent upon the accuracy of the instrument employed and the amount of contact resistance present. This error was not more than $\pm$ 5%.

29. From the discussion given in paragraphs 25 and 27 the maximum error in the calculation of the L/C ratio of the given coil was

$$\log (\text{ratio}) = \log L - \log c$$

$$\frac{\delta (\text{ratio})}{\text{ratio}} = \frac{\delta L}{L} - \frac{\delta c}{c}$$

$$= +3 - 9 = 6\%$$

30. When employing a Q-Meter for the measurement of the "Q" of a given coil, with or without a Magicore core, and shielded or unshielded, the accuracy of this measurement depended upon the accuracy of the Q-Meter, the adjustment of the coil on its core with respect to the length of the core and the spacing between the coil and victron plate (paragraph 23) and the degree of centralization of the coil within the circumferential area of the shield can (when one is employed). Allowing $\pm$ 5% for the rated accuracy of the Q-Meter and $\pm$ 2% for the errors due to the other named contributing factors, the results obtained from the Q-Meter measurements for "Q" were accurate to within $\pm$ 7%. The indication of tuning capacity obtained with the Q-Meter is dependent upon the calibration of the tuning dial with the Q-Meter and upon the stray capacities of the coil leads and between the coil and leads to ground, and upon the capacities of the internal circuit of the Q-Meter. The error may be considered to be not greater than $\pm$ 5%.

RESULTS OF TEST

31. Table 1 gives a comparison of the electrical and physical properties of unshielded air and Magicore cored coils most suited for use at the test frequencies. Except for the "air" column for 175 kilo-

cycles there are listed the electrical and physical constants for each of three air cored and three Magicore cored coils for each frequency at which measurements were made. These coils are listed in the order of their preference for air or Magicore cores. Under the "air" column for 175 kilocycles only one coil was listed; namely, D-36-1, and this was listed as number three in the "preference" column by virtue of the fact that chosen on the same basis as the other selected coils, it was not exactly suited for use at that frequency because of the high capacity required to tune it. This capacity exceeded the arbitrary upper limit for tuning capacity by approximately 25%. The coil was listed merely to indicate the approximate "Q" to be expected at that frequency when employing an air core in the type of coil construction used for the coils wound for this investigation. Physically, coil D-36-1 was the largest of all of the test coils and possessed the highest inductance.

32. Special attention is invited to the fact that with the exception of the coils selected as preference number two under both the "air" and Magicore" columns for 260 kilocycles, the coils listed in the order of their preference under the "air" column for any other frequency differ from the coils listed in the same order of preference in the "Magicore" column for the same frequency. It is to be emphasized here that the coil listed under a given order of preference in the "air" column bears absolutely no relation to the coil listed in the same order of preference under the "Magicore" column for the same frequency.

33. Now, in spite of the statements made in paragraph 32, for any frequency, a coil having an air core and listed under a given "preference column may be compared on a relative basis only with a coil having a Magicore core and listed under the preference column of the same number. For example, at 260 kilocycles, coil C-36-1 listed as preference one under the "Magicore" column. This relative comparison may be made in view of the fact that the rules governing the selection of the group of air cored coils apply also to the selection of the group of Magicore cored coils. Hence, as given in the example, coils C-36-1 and D-36-2 may be thus compared because, taking their respective types of cores in consideration, each possesses a high L/C ratio attended with a relatively high "Q" irrespective of its "shape factor".

34. From an examination of Table 1 it is evident that for any frequency the group of Magicore cored coils have substantially higher "Q" values by a factor of 50%, or better, depending upon the frequency, than the corresponding group of air cored coils; both sets being selected on the same basis as described in preceding paragraphs, and having inductance values which are governed by the fixed arbitrary limits placed on tuning capacity as has been previously mentioned. This statement is not made to imply that this is the maximum improvement in "Q" to be expected by the use of Magicore cores, for, on the contrary, the improvement in the "Q" of a given coil effected by the use of a Magicore core instead of an air core is in some instances nearly 2 to 1, depending upon the shape of the coil, its inductance, and size of wire employed. Table 1 furnishes complete self-explanatory information relative to the constants of the coils listed, and therefore any further comments other than those already made are not essential for a complete understanding of the table.

35. Up until now no mention has been made relative to the measured or calculated characteristics of those coils not shown on Table 1, but nevertheless studied under the subject investigation. The data for these coils are not included in this report for the reason that they would serve no purpose other than to confuse the issue at hand. However, it would be well, in passing, to briefly state at this time the important fundamental relations found as the result of this investigation. These are as follows:

(a) In the interests of making the variation of the "Q" of any coil with frequency self evident, the relation $Q = 2\pi f L/R$ (par.9) may be expressed as $Q = 2\pi L \frac{f}{R}$

For any coil, L, or the true inductance of the coil is a constant. Hence, the value of its "Q" will vary in accordance with the ratio of f/R. Obviously, when f equals zero, "Q" will also be zero. The "Q" of a coil therefore will gradually increase with frequency until it reaches a maximum and then will decrease with frequency until the natural period of this coil has been reached. The rate at which the "Q" will increase or decrease with frequency will depend solely upon the construction of the coil. Maximum "Q" will occur at that frequency beyond which an incremental change in frequency is accompanied by a larger incremental change in effective coil resistance and below which the reverse relation is true.

(b) Of any three air cored coils, one wound with size #32 wire, one wound with size #34 wire and one wound with size #36 wire, but all wound for the same coil width and for the same inductance, the coil wound with size #36 wire had the highest "Q" at any of the test frequencies. This may be explained by the fact that for a given inductance and coil width, and the same kind of wire (i.e., solid, d.s.c. copper wire) as the wire diameter is increased, the diameter of the coil is increased, hence the effective radio frequency resistance is increased due to the increase in eddy current losses resulting from the increase in the length of copper wire and increase of dielectric losses due to the increase in dielectric material. These statements apply to Magicore cored coils when compared under similar conditions.

(c) The following shows the range of "Q's" for the three sizes of wire used for the coils measured and which complied with the limits applied to the subject measurements.

Air Core		Magicore Core	
Wire Size	Range of Q	Wire Size	Range of Q
#32	15 - 33.5	#32	24.6 - 78.2
#34	34.2 - 58.8	#34	62.2 - 113
#36	56.4 - 78.0	#36	96.3 - 120

36. The curves on Plate 12 show the variation of radio frequency resistance in ohms per millihenry with frequency for the Series D-36 and C-36 test coils with and without Magicore cores. The points plotted represent average values for these coils. It will be evident from these curves that the decrease in coil losses resulting from the use of a smaller coil made possible by the Magicore material, as compared with an equivalent air coil, more than offsets the added losses introduced by the core material itself, so that the total resistance per millihenry for a Magicore cored coil is materially less than that of an equivalent air coil at the same frequency.

37. The variation of "Q" and tuning capacity with frequency are shown by curves on Plate 13 for test coil C-36-4 unshielded, and having various cores. These curves are shown to illustrate the improvement in "Q" and saving in size of tuning condenser effected by the use of a molyiron core in a coil of a given design. It will be noted that for this particular coil design, maximum "Q" occurs at approximately 300 kilocycles for any particular kind of core. Also, at this frequency the increase in the "Q" of the coil with a Magicore coil was 1.86 times the "Q" of the coil with an air core. The improvement in "Q" effected by the molyiron core (product of "X" manufacturer) was less than by the Magicore coil. This may be partially explained by the fact that this molyiron core has a 0.199" diameter bore instead of a 0.120" diameter bore, as is the case of the Magicore core, but is otherwise similar to the Magicore core. Hence, the total volume of magnetic material is less. Measurements have shown that the molyiron core of the dimensions given has less resistance than the Magicore core and less apparent permeability. The net result was that, at the frequencies where the material was investigated, the ratio of ω L/R was less than for the Magicore core, both samples measured with the same coil. The improvement in "Q" effected by the use of the solid molyiron core (also a product of "X" manufacturer) was very nearly the same as for the Magicore core. The relative reduction in the required tuning capacity made possible by the use of molyiron cores may be appreciated by an examination of the curves. The curves on Plate 13 show the Magicore material to be superior to both types of molyiron core material of similar design.

38. Another product of "X" manufacture, a molyiron core, 1/2" diameter, 1/2" long and having a 0.199" diameter bore was also tested. It was found that the improvement in the "Q" of a given coil effected by the use of this material was, in general, less than for a corresponding coil designed for a 0.382" diameter molyiron core. The tests covered by this investigation do not indicate any advantage to be gained by the use of this particular shape of core.

39. Table 3 shows the results of measurements made on a C-36-4 coil when using each of several Magicore coils in succession. Two lots of cores were investigated and all measurements were made on the Q-Meter. It is evident from the data shown that a group of Magicore cored coils for use in ganged tuned circuits may be matched for inductance within very close limits by the proper selection of their cores, provided, of course, that their self-inductances are within close agreement with one another. The self-inductance of the C-36-4 coil at 1,000 cycles was 1.32 millihenries. Hence, the apparent permeability of the cores tested ranged from 1.89 to 2.03. It was found that within the range of 1 to

500 kilocycles the apparent permeability of any one of the cores tested was independent of frequency. This fact was proven by the calculation of the value of the inductance for the coil using one of the Magicore cores from the wavelength squared curve plotted against frequency, which value agreed with the measured inductance values obtained at 1 kilocycle and also from the fact that the distributed capacity of the coil as determined from this same curve was the same as that calculated in accordance with paragraph 11, where it was assumed that the true inductance of the coil was independent of frequency. The effective inductance of the coil was calculated from the measured effective "Q" and tuning capacity for each of the five frequencies shown in Table 3 from the equations

$$R_{eff} = \frac{10^9}{C\, Q_{eff}}$$

and

$$L_{eff} = \frac{Q_{eff}\, R_{eff}}{\omega}$$

where R_{eff} = effective radio frequency resistance in ohms

C = tuning capacity in micromicrofarads

Q_{eff} = effective efficiency of the coil and core

ω = $2\pi f$, where f = frequency in kilocycles

L_{eff} = effective inductance in millihenries

It was found that for each frequency the calculated effective inductance was equal to within 2% of the true inductance. The percentage of error is less than that associated with the measured constants. Therefore, it may be stated that the apparent permeability of the Magicore cores tested remains constant within the frequency range of 1 to 500 kilocycles and would probably remain constant up to at least 1500 kilocycles. The influence of a wide variation in temperature or a wide variation in magnetizing forces upon the apparent permeability of the Magicore cores was not determined. However, it is claimed by the inventor of this material that its apparent permeability is not affected by either a wide temperature variation or a variation of magnetic intensity of from 0.01 to 10 gauss.

40. Each of the coils listed under the "air" and "Magicore" columns of each test frequency shown in Table 1 was measured in accordance with paragraph 18 of this report to determine the influence of the diameter of a shield can and the position of the coil within the shield can upon the initial "Q" and initial tuning capacity of the unshielded coil. From this data, one shielded coil having an air core and one shielded coil having a Magicore core were selected for each frequency as being the ultimate design (within the scope of this investigation) for that frequency. It was found that for any given group of coils from Table 1, whether air or Magicore cored, that for the corresponding frequency, the shielded coil having the highest "Q" for the group considered was that one which had the lowest "shape factor".

41. Parametric curves on Plates 2 to 6 inclusive show for each of these coils the variation in the "Q" of the coil with variation in the distance from the coil to the closed end of the shield can, with the shield can diameter as the parameter. On each plate are shown two sets of these curves, one for the ultimate air cored coil and one for the ultimate Magicore cored coil, both sets being drawn for but one frequency. An examination of Plates 2 to 6 inclusive will reveal the fact that the coils selected for each frequency are those which are listed as preference number two under the "air" and "Magicore" columns for the corresponding frequency in Table 1. It is significant that for any group of coils, the coil selected from that group as being the ultimate in design was the one whose ratio of winding depth to winding width was the lowest in magnitude. This obviously adapted the coils to shield cans of smaller diameters than would otherwise have been necessary. For each of the curves shown on Plates 2 to 6 inclusive, the percentage reduction in "Q" is a measure of the change in the "Q" of the coil from its initial value (when measured without a shield can) caused by the dimensions of the shield can.

42. On Plates 7 to 11 inclusive are curves showing the percentage reduction in "Q" and percentage increase in tuning capacity, both of these variables being plotted with respect to variation of shield can diameter, for the ultimate air and Magicore cored coil designs, chosen as described above, for the several test frequencies. These "Q" curves were derived from the corresponding curves shown on Plates 2 to 6 inclusive, for $\frac{d}{D}$ = 1.0 inch, while the capacity curves were plotted from corresponding measured tuning capacity data.

43. From an examination of Plates 2 to 11 inclusive, certain fundamental relations at once become apparent and are the result of placing a coil in a copper shield can. These are as follows:

(a) The coil's distributed capacity was increased as the result of the capacity between the various parts of the coil and the shield can, and this increase was inversely proportional to the ratio between the shield can diameter and coil diameter.

(b) Since for a given set of measurements on a given coil the frequency was constant, the L/C product also remained constant and therefore, when the required tuning capacity was increased by the use of a shield can, the inductance of the coil must have decreased. It follows, then, that the percentage increase in the tuning capacity was essentially the same as the percentage decrease in inductance neglecting the added increase in the distributed capacity due to the shield can and which was small relative to the total capacity. The amount by which the effective inductance of the coil was decreased depended upon the extent to which the shield interfered with the normal flux paths, inasmuch as the restriction of the magnetic flux lines to a space within a copper shield can increases the reluctance of the

magnetic circuit. It will be noted from Plates 7 to 11 inclusive that the reduction in the effective inductance of the given coil for any frequency was greatest when the shield can was in close proximity to the coil and was least when the shield can diameter was large with respect to the coil diameter. The extent to which the inductance of a coil was reduced by a given size of shield can depended primarily upon the dimensions of the coil which, of course, determined the distribution of the flux paths around the coil.

(c) The effective coil r.f. resistance was increased by an amount that depended upon the extent to which the copper shield can interfered with the normal flux paths, because the energy consumed by these eddy currents was furnished by the coil. Moreover, the increase in the r.f. resistance for a given size of can was dependent upon the dimensions of the coil which, in turn, governed the distribution of the flux paths.

(d) By virtue of the changes in properties of any coil, regardless of the type of core employed, or the frequency, affected by the use of a shield can, as discussed under (a), (b), and (c) above, the "Q" of the coil was reduced when that coil was shielded. The amount of reduction was a function of the extent to which the shield interfered with the normal flux path of the given coil so that if the diameter of the shield can were large relative to the diameter of the coil, this reduction in "Q" was small. It will be be noted from Plates 2 to 11 inclusive that the reduction in the "Q" of a Magicore cored coil was greater than for an air cored coil for a given size of shield can, and this was independent of frequency. The reason for this is that in spite of the fact that the Magicore cored coil was in general physically smaller than its corresponding air cored coil, the Magicore coil causes a greater spreading out of the flux paths for the former than for the latter by virtue of the fact that this core extends beyond the sides of the coil. Consequently, more lines of flux would link with the shield can and would cause a greater increase in the effective r.f. resistance of the coil and a greater reduction in its effective inductance due to the eddy currents generated in the shield can. It will be noted from Plates 2 to 6 inclusive that for either type of core the closed end of the shield can had no effect upon the "Q" of the coil for values of $\frac{}{}$ greater than 1.0 inch.

44. It was found that when a coil, either air or Magicore cored, was placed with its axis at right angles to the axis of the shield can, the end of the shield can had no influence on the "Q" of the coil so long as the peripherial surface of the coil was at least 1/8" from the closed end of the shield can.

45. Table 2 is a composite table showing, in brief, the relative constants of the shielded and unshielded air and Magicore cored coils selected from Table 1 for test "Q" values for each corresponding test frequency when the coils were shielded. Note also, that these are the identical coils whose "Q" curves are shown on Plates 2 to 6 inclusive. The sub-tables of Table 2 except for sub-table C may be explained and discussed as follows:

Table A: This table was prepared to show primarily the diameter of shield can that should be employed for each coil at the corresponding frequency to attain not more than a 10% reduction in the "Q" of the coil from its initial value when unshielded. The percent increase in tuning capacity, indicative of the decrease in inductance, incurred by the use of a shield, is also given for each coil. Other useful constants are also tabulated for these coils. In this table is the minimum distance that may be allowed between the center line of a coil at right angles to its axis and the nearest metal surface parallel to the plane of the coil to avoid any influence of "end effect" from that metal plate on the "Q" of the coil.

Table B: This table is similar to Table A except that it was prepared for the corresponding Magicore cored coils. It will be noted from this table that any given coil the diameter of shield can required to assure not more than 10% reduction in the initial "Q" of the coil is larger than for the corresponding air cored coil in Table A for the same percentage reduction in "Q". Note also that the percent increase in tuning capacity (or decrease in effective coil inductance) is less for each coil than for the corresponding air cored coils. This is evidence of the fact that the reduction in "Q" caused by the shield was due more to eddy current losses than to reduction in inductance.

Table B-1: This table was designed to show the size of shield can that may be employed with each of the coils listed in Table B so as to maintain approximately the same "Q" value as for the corresponding air cored coil in Table A. While this incurs in each instance, a great sacrifice of the available "Q", a very appreciable saving in space will be obtained over that required for an equivalent shielded air cored coil. Attention is invited to the fact that the percentage changes in "Q" and tuning capacity were based on their initial values, as listed in Table B for the unshielded conditions.

Table B-2: This table was designed to illustrate the improvement in "Q" realized for a tuned circuit by the use of a Magicore coil instead of air cored coils for the same frequency and for the same shield can size. In spite of the relatively large reduction in the available "Q" of a given coil incurred by the use of the specified shield can size, the "Q" was still very appreciably higher than for the corresponding air cored coil in the same size of shield can and at the same frequency.

46. The data compiled for sub-tables A, B, B-1, and B-2 of Table 2 were derived from the curves shown on Plates 2 to 11 inclusive and the measured data recorded during this investigation.

47. In sub-table C of Table 2 are tabulated the constants of the molyiron alloy coils of four commercial I.F. transformers when shielded or unshielded, and the air cored coils of two Hammarlund I.F. transformers under similar conditions. These constants were measured in accordance with the procedure described under METHOD OF TEST of this report. For these measurements the coils were disconnected from their associated tuning condensers, but the measurements include the leads furnished with the transformers. All coils for both makes of I.F. transformers were wound with silk insulated Litz wire which appear to be of 7/41 stranding. Attention should be paid to the following features of these coils when compared with those of the corresponding test coils whose constants are tabulated under sub-tables A or B.

(a) The L/C ratios are generally lower.
(b) The shield cans employed for the Hammarlund coils are very much larger.
(c) The same size of shield can is employed for the "X" manufacturer's coils regardless of frequency and causes a reduction in "Q" of from 17.7 to 28.4% depending upon the frequency. This shield can is very much smaller in volume than the Hammarlund shield cans or those listed under sub-table B.
(d) With the sizes of shield cans furnished, the "Q's" of the "X" manufacturer's I.F. transformer coils are only from 20 to 40% better than for the Hammarlund I.F. transformer coils. The improvement in "Q" increases with frequency by virtue of the fact that the influence of the shield cans of the molyiron cored coils decreases with frequency. This is self-evident from a study of the data shown on sub-table C of Table 2.

48. The improvement in the selectivity and gain of an I.F. transformer by the use of molyiron alloy cores instead of air cores in coils of equal inductances and of similar construction and, as claimed by the supplier of these molyiron cored I.F. transformers used in these tests, is illustrated by the selectivity curves and gain data shown on Plate 14 appended hereto. Curve "A" applies to their 456 kilocycle I.F. transformer, which is the same as I.F. transformer number 3 or 4 of sub-table C of Table 2. Plate 14 is a reproduction of the published curves furnished by this supplier for this particular type of I.F. transformer.

49. U.S. Patent 1,978,568, reference (1) of this report, is of special interest because it applies particularly to the design of universal coils for use with the cylindrical type of molyiron cores studied under the subject investigation. It is believed, therefore, that consideration should be given to the factors claimed, by the authors of the patent, to be most influential in determining the successful design of the type of coil construction which they recommend for use with cylindrical molyiron alloy cores (i.e., the universal coil - as studied under this investigation).

50. A resume' of the factors as advanced by reference (i) governing first, the choice of the kind and size of wire to be employed, the construction of the winding and its inductance for a given frequency and second, the ideal proportions of the winding and core, is felt to be not out of order in this report because it is believed that this information has no little value and will justly serve to augment that found or verified by actual test and measurement as previously discussed in this report. In this regard a correlation between this information and that gathered by measurement will be made whenever such is applicable.

51. The following table briefly outlines the recommended wire sizes, type of winding and inductances for several frequencies.

Tabulation of Recommended Coil Winding Data

Freq. kcs.	Kind of Copper Wire, size and insulation	Inductance millihenries	Type of Winding	Cross-overs per turn
175	Solid #38 B&S silk and enamel insulated	8.0	Universal close wound	one
456	7 strands, #41 B&S silk insulated each strand and overall	1.5	Universal close wound	one
550 to 1500	10 strands, #41 B&S silk insulated each strand and overall	0.25	Universal wound with space between turns equal to overall diameter of conductor	six

52. In regard to the ideal proportions of the coil winding and of the core, the following is recommended.

(a) The universal winding should have a ratio of length to radial depth considerably less than unity. Referring to Fig.1 of Plate 15, depending upon the inductance value and the frequency at which the inductance is to be used, the ideal shape of the winding is given by the expression $0.375 < C < 0.66D$. This relation has been verified by a wide margin by the dimensions of the coils listed as preference number two under the Magicore column of Table 1.

(b) Referring again to Fig.1 of Plate 15, it will be observed that the molyiron core is centrally located in the hole in the coil and extends to either side. The ideal length of the core may be expressed as follows: $0.75\ A < B < 1.5A$. Each of the cores used in the subject tests had a dimension of "A" 0.382", and "B" 0.500 so that in this case, $0.295 < 0.500 < 0.572$ which confirms the specified

requirement for ideal core length. It is further stated in reference (i) that if the length is materially decreased below the lower limit given above, the apparent permeability of the core will diminish and greater number of turns, representing more wire and greater losses will be required to produce a given inductance value. Also, if the length of the core is increased materially beyond the maximum given above, there will be only a small possible reduction in the amount of wire for a given inductanve value, while the losses due to the core will be disproportionately increased.

(c) The ideal relation between the depth of the winding and the external diameter of the coil may be expressed as follows: $0.4A < D < 0.9A$. This relation was not fully verified by the coils listed as preference number two under the "Magicore" column of Table 1 and those selected as the "ultimate" for the frequencies considered. The coils chosen for 175 and 260 kilocycles comply with the relation, but for the coils for 370, 456, and 525 kilocycles, "D" is slightly greater than 0.4A but less than 0.9A by a wide margin. It is stated that between the limits given by the above relation, the complete inductance will have minimum capacity and minimum resistance for a given inductance value.

(d) The ideal relation between the wall thickness of the core and the external diameter of the core may be expressed as follows: $0.2A < E < 0.4A$. In the case of the Magicore cores, used upon the subject tests $A = 0.382$, $E = 0.131$; therefore $0.0764 < 0.131 < .1525$. Hence the wall thickness of the Magicore core is well within these limits. It is further stated that increasing the wall thickness of the core above the proportions above stated, gives only a very slight increase in apparent permeability, with a disporportionate increase in losses. Decreasing the wall thickness of the core beyond the proportions above given, materially decreases the apparent permeability of the core without giving a proportionate decrease in the losses.

53. The proportions given under paragraph 52 above determines the best design of a given coil for a given frequency regardless of the inductance chosen for that frequency. It remains only to select a wire size so that for the number of turns required to give the chosen inductance, the wire may be wound within the space allowed for it by those proportions.

54. The presence of the molyiron alloy core materially alters the distribution of the magnetic field around the coil. If these were not present or if it were only of the same length as the coil, the flux lines would lie much closer to the sides of the coil thus increasing

the eddy current losses in the turns of the coil itself, and decreasing the effective induction. The presence of a core of the proportion shown decreases the concentration of the flux adjacent the turns of the coil and thereby tends to keep the losses due to the eddy currents in the coil at a minimum. This spreading out of the flux lines by the molyiron alloy cores was clearly demonstrated by measurements made at the Laboratory. Evidence of this fact was unmistakably shown by the curves on Plate 4, where the percent reduction in the initial "Q" of a given coil, when placed in a shield can of a givendiameter, was greater when the core was of Magicore material than when it was of air.

55. Subsequent to the eventual completion of the measurements conducted under the subject investigation, there appeared, in the January 1936 issue of the Wireless Engineer, a paper by Mr. K. Kaschke entitled "Some Measurements on Iron Cored Tuning Coils". This paper treats on the application of molyiron alloy coils to transformers designed for use at radio frequencies, the advantage realized from their use at these frequencies as compared with air cored transformers and finally the merits of various types of cores developed in Europe. It is felt that this report would not be complete without due recognition of Mr. Kaschke's findings as he has described them in his paper. Perhaps what is still more important is the fact that his measurements relate to forms of cores not yet either made available or explcited in this country. However, the Laboratory has been informed that cores similar to those described in the reference paper will be produced in this country as soon as facilities are made available for their production. Now, inasmuch as these types of cores were not available for test and since the samples provided for test are already obsolete, an inclusion of an abstract of Mr. Kaschke's paper in the report would be most valuable for future reference. Accordingly, sketches of the forms of core and coil structures as well as curves shown in that paper are reproduced herein.

56. The ideal design of highly efficient iron cored coils differs from the rules generally applied to air cored coils for maximum efficiency. Highly efficient air cored coils are obtained by the use of a winding arranged on a low loss insulating cylinder of large diammeter, in a single layer using Litz wire with thick insulation to get sufficient distance between the turns (Fig.2, Plate 15). This generally accepted rule was applied to the early design of W. J. Polydoroff patented in 1929, and illustrated as Fig.3 on Plate 15. This design did not prove popular because its greater cost and lower efficiency as compared with an equivalent air core coil more than offset the advantage gained in reduction of size. At that time core material having small high frequency losses was not available.

57. The introduction of Ferrocart, a new low loss core material, in 1932, precipitated the development of the toroidal type of iron core construction illustrated in Fig.4. Here again, the same principles of spacious arrangement of coil were followed and here again also the increase in cost due to the use of special magnetic material and elaborate winding method far outweighed the advantage of small volume and stray field of such iron cored coils compared to equivalent air cored coils.

(a) Coil weight is one-tenth that of single layer coils.
(b) The small size of core permits direct molding in automatic machines.
(c) The winding may be spooled upon a small coil form by a winding machine.
(d) Relatively cheap Litz wire may be used and only a fraction of the length of wire needed with air cored coils or single layer iron cored coils is required.
(e) The whole coil form is compact, self contained, and the wire is mechanically protected from danger or displacement.
(f) The inductance of the coil may be adjusted by the use of suitable air gap without introducing additional losses.

The electrical characteristics of such miniature coils are more critical than with large spacious coils so that relatively small mistakes in construction will affect the coil considerably. Hence, low loss insulating materials must be employed not only in the construction of the coil itself but also in its associated circuit.

CONCLUSIONS

63. The Magicore core samples are cylindrical in form and possess certain magnetic properties which make their application to tuned inductances for operation at radio frequencies particularly advantageous. These magnetic properties are remarkably uniform to the extent that any one core is, within practical limits, exactly the same as any other. Each possesses an apparent permeability that is nearly twice that of air and also constant within the frequency range explored, so that for a given inductance a coil much smaller than an equivalent air coil may be employed. Hence, a saving in space, weight, and cost of material and labor may be realized. Each core is formed by compressing together, under high pressure and with a suitable binder, individually insulated and extremely minute particles of iron. Measurements have shown that the resistance due to the core at any frequency, within the frequency spectrum considered, is low, and for a given inductance this r.f. resistance due to the core when added to the r.f. resistance of the coil itself produces a total r.f. resistance that is less than that of an equivalent air coil measured at the same frequency. In other words, the reduction in the radio frequency resistance of the coil used with a Magicore core at a given frequency, as compared with an equivalent air coil, more than compensates for the added radio frequency resistance due to the core itself.

64. From the group of coils available for test, one Magicore cored coil and one air coil were selected as being the ultimate design for each of the test frequencies. While these selected coils were by no means the best in design, they were the best available for the purpose. It was found that coils wound with #36 d.s.c. copper wire (the smallest wire used for the test coils) and having shape factors of less than 1.7 had the best "Q" values whether or not the core was of Magicore material. Obviously, placing these coils in shield cans causes a reduction in their initial "Q" values, depending upon the extent to which their normal flux paths were interfered with by the shield cans. Measurements showed that if this

reduction in "Q" due to the presence of the shield can were limited to 10%, a larger diameter shield can was required for a Magicore cored coil than for a corresponding air coil. This was due primarily to the fact that the Magicore cores produce a spreading out of the flux lines around their associated coils. Hence, although a very much higher "Q" is realized from a Magicore cored coil as compared with its corresponding air coil, a greater space is generally required for the coil and shield can assembly if the same advantage of the available "Q" is taken in either case. However, if for a given Magicore cored coil the same size of shield can be employed as for the corresponding air coil, the "Q" of the former coil will still be very appreciably greater than for the air coil and enough greater as to make the use of the Magicore core material worthwhile. Now, if a sacrifice be made in the initial "Q" of Magicore cored coil by the use of a shield can of such diameter as to reduce the initial "Q" of the coil to the extent that the final "Q" will equal that of the corresponding air coil, a very great saving in space requirement is realized. This feature is very important and should be of particular interest to designers of aircraft equipment.

65. The basic facts of paragraph 64 above, may be briefly outlined as follows:

(a) For optimum conditions, the "Q" of the Magicore cored coil is greater than for the corresponding air coil and the shield can diameter is generally larger.

(b) For the same space requirements, the "Q's" of the Magicore cored coils are appreciably greater than for the corresponding air coils.

(c) For the same "Q", there is a great saving in the space requirements for the Magicore cored coils.

66. While solid double silk insulated copper wire was employed in the construction of the test coils, higher "Q" values could be obtained from the use of Litz wire, all other factors remaining the same. Litz wire was used for the coils in the commercial I.F. transformers examined and available on the open market. These coils were superior to those used for the subject tests.

67. Thus far, the cylindrical type of molyiron cores are the only kind manufactured on a production basis in this country. The cores tested are now considered to be obsolete because the more recent cores developed in Europe have shapes which may be used to better advantage in I.F. circuits. Recent developments in this field in Europe have proven that the so-called "pot shape" cores, when used in conjunction with coils having sectionalized windings wound with Litz wire of several strands, have "Q" values far superior to those obtained from the cylindrical cored universal coils commercially available in this country. "Q" values as high as 400 are claimed for this European design. The Laboratory has been informed by a consultant of a manufacturing concern interested in the development of molyiron cores that "pot shape" cores will be manufactured

for use in this country as soon as sufficient interest has been aroused to warrant the expense of setting up for their production. The exploitation of molyiron cores for radio frequency inductances is only a comparatively recent venture in this country. The acceptance of the use of molyiron cores in I.F. transformers is not yet general among the manufacturers of receivers, particularly in the broadcast field and the underlying reasons for this are not obvious.

68. Kaschke has shown in his paper, reference (b), that for a coil designed for operation in the broadcast frequency band, the most efficient design yet developed in Europe is one having a pot shaped molyiron core and sectionalized windings wound with Litz wire. His curves for this design show that the "Q" of such a coil varies from a value better than 400 to about 200 between 550 and 1500 kilocycles respectively. This characteristic would make the application of such a highly efficient coil of questionable value in ganged tuned radio frequency circuits where tuning is accomplished by capacity variation. In such circuits more uniform overall gain and selectivity would be acquired over the given frequency spectrum only by the use of less efficient inductances, but such a procedure would at once defeat the potential advantages of molyiron inductances. The original inventor of molyiron core material has suggested "Permeability Tuning" as a solution to this problem. It is claimed for this method that the full advantage of the high "Q" feature of molyiron inductances may be retained in ganged tuned circuits without sacrificing uniformity in overall gain or selectivity over the frequency range for which these circuits were intended. This method provides for tuning the circuits by inductance variation instead of by the conventional capacity variation method. Tuning by inductance may be accomplished by the simple expedient of fitting a movable molyiron core to each coil in the ganged circuit. The inductance of a coil is at a minimum when the core is removed and at a maximum when the core is completely inserted. A fixed capacity is connected across each coil. It is claimed that by winding each coil on a tapered form it is possible to provide a ratio of inductance to resistance that remains substantially constant over the tuning range. Hence, uniform gain and selectivity may be expected.

FREQUENCY	175 KILOCYCLES						260 KILOCYCLES						370 KILOCYCLES					
CORE	AIR			MAGICORE			AIR			MAGICORE			AIR			MAGICORE		
PREFERENCE	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
TEST COIL NO.			D-36-1	D-36-1	D-36-2	D-36-1	D-36-1	D-36-3	C-36-1	D-36-2	D-36-3	C-36-1	C-36-1	D-36-3	C-36-2	C-36-3	D-36-5	B-36-
B&S WIRE GAUGE D.S.C.			36	36	36	34	36	36	36	36	36	36	36	36	36	36	36	36
TURNS			690	690	630	600	690	540	520	630	540	520	520	540	465	410	415	349
D.C. RES. OHMS			57.0	57.0	50.0	35.5	57.0	40.0	44.0	50.0	40.0	44.0	44.0	40.0	36.0	31.0	27.3	28.8
"D" CORE DIAMETER INCH			0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.38
"C" COIL WIDTH INCH			0.224	0.224	0.224	0.225	0.224	0.224	0.156	0.224	0.224	0.156	0.156	0.224	0.156	0.156	0.224	0.09
"A" COIL DIAMETER INCH			1.016	1.016	0.958	1.032	1.016	0.877	1.016	0.950	0.877	1.016	1.016	0.877	0.950	0.888	0.758	1.01
RATIO $\frac{B}{C}$			1.42	1.42	1.29	1.44	1.42	1.11	2.03	1.29	1.11	2.03	2.03	1.11	1.85	1.63	0.838	3.2
INDUCTANCE MILLIHENRIES			6.60	11.6	9.90	9.82	6.60	3.80	4.23	9.90	7.25	7.12	4.23	3.80	3.14	4.76	4.41	3.4
DISTRIBUTED CAPACITY $\mu\mu f$			3.20	3.07	3.09	3.37	3.20	3.58	2.63	3.09	3.57	2.84	2.63	3.58	2.76	2.76	3.77	2.4
R.F. RESISTANCE			95.5	110.8	92.5	97.3	156.0	86.6	90.1	158.8	107.6	101.6	144.6	143.8	106.6	101.2	104.2	68.
TUNING CAPACITY $\mu\mu f$			123.0	68.0	80.5	81.5	54.5	97.5	86.0	32.2	45.4	50.0	39.2	43.4	53.6	34.6	36.6	48.
$L/C \times 10^6$			52.2	163.0	118.0	115.0	114.0	37.6	47.8	280.0	148.0	135.0	101.0	80.8	55.7	127.0	109.0	68.
Q			74.8	115.5	118.4	111.0	69.1	71.8	76.8	102.0	110.0	115.0	68.0	61.6	68.6	109.5	98.2	117.

GAUGE D.S.C.																	
TURNS			690	690	630	600	690	540	520	630	540	520	520	540	465	410	415	340
D. C. RES. OHMS			57.0	57.0	50.0	35.5	57.0	40.0	44.0	50.0	40.0	44.0	44.0	40.0	36.0	31.0	27.3	28.8
"D" CORE DIAMETER INCH			0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382
"C" COIL WIDTH INCH			0.224	0.224	0.224	0.225	0.224	0.224	0.156	0.224	0.224	0.156	0.156	0.224	0.156	0.156	0.224	0.099
"A" COIL DIAMETER INCH			1.016	1.016	0.958	1.032	1.016	0.877	1.016	0.950	0.877	1.016	1.016	0.877	0.950	0.888	0.758	1.016
RATIO $\frac{B}{C}$			1.42	1.42	1.29	1.44	1.42	1.11	2.03	1.29	1.11	2.03	2.03	1.11	1.85	1.63	0.838	3.20
INDUCTANCE MILLIHENRIES			6.60	11.6	9.90	9.82	6.60	3.80	4.23	9.90	7.25	7.12	4.23	3.80	3.14	4.76	4.41	3.48
DISTRIBUTED CAPACITY $\mu\mu f$			3.20	3.07	3.09	3.37	3.20	3.58	2.63	3.09	3.57	2.84	2.63	3.58	2.76	2.76	3.77	2.48
R.F. RESISTANCE			95.5	110.8	92.5	97.3	156.0	86.6	90.1	158.8	107.6	101.6	144.6	143.8	106.6	101.2	104.2	68.9
TUNING CAPACITY $\mu\mu f$			123.0	68.0	80.5	81.5	54.5	97.5	86.0	32.2	45.4	50.0	39.2	43.4	53.6	34.6	36.6	48.2
L/C X 10^6			52.2	163.0	118.0	115.0	114.0	37.6	47.8	280.0	148.0	135.0	101.0	80.8	55.7	127.0	109.0	68.6
Q			74.8	115.5	118.4	111.0	69.1	71.8	76.8	102.0	110.0	115.0	68.0	61.6	68.6	109.5	98.2	117.5

FREQUENCY	456 KILOCYCLES						525 KILOCYCLES					
CORE	AIR			MAGICORE			AIR			MAGICORE		
PREFERENCE	1	2	3	1	2	3	1	2	3	1	2	3
TEST COIL NO.	C-36-2	C-36-3	B-36-1	B-36-1	D-36-6	C-36-4	C-36-3	D-36-5	B-36-1	B-36-2	C-36-5	B-36-3
B. & S. WIRE GAUGE D.S.C.	36	36	36	36	36	36	36	36	36	36	36	36
TURNS	465	410	340	340	345	325	410	415	340	295	275	270

Comparison of electrical and physical properties of unshielded air and Magicore cored coils most at the test

Q			74.8	115.5	118.4	111.0	69.1	71.8	76.8	102.0	110.0	115.0	68.0	61.6	68.6	109.5	98.2	11

FREQUENCY	456 KILOCYCLES						525 KILOCYCLES					
CORE	AIR			MAGICORE			AIR			MAGICORE		
PREFERENCE	1	2	3	1	2	3	1	2	3	1	2	3
TEST COIL NO.	C-36-2	C-36-3	B-36-1	B-36-1	D-36-6	C-36-4	C-36-3	D-36-5	B-36-1	B-36-2	C-36-5	B-36-3
B. & S. WIRE GAUGE D.S.C.	36	36	36	36	36	36	36	36	36	36	36	36
TURNS	465	410	340	340	345	325	410	415	340	295	275	270
D.C. RES. OHMS	36.0	31.0	28.8	28.8	21.3	21.3	31.0	27.3	28.6	23.5	15.7	20.0
"D" CORE DIAMETER INCH	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382
"C" COIL WIDTH INCH	0.156	0.156	0.099	0.099	0.224	0.156	0.156	0.224	0.099	0.099	0.156	0.099
"A" COIL DIAMETER INCH	0.950	0.888	1.016	1.016	0.698	0.779	0.888	0.758	1.016	0.932	0.710	0.880
RATIO $\frac{B}{C}$	1.85	1.63	3.20	3.20	0.710	1.28	1.63	0.838	3.20	2.78	1.05	2.52
INDUCTANCE MILLIHENRIES	3.14	2.55	2.10	3.48	3.00	2.68	2.55	2.03	2.10	2.60	1.66	2.06
DISTRIBUTED CAPACITY $\mu\mu f$	2.76	2.66	2.18	2.48	3.75	3.01	2.66	3.77	2.18	7.28	3.24	2.61
R.F. RESISTANCE	144.9	121.0	84.3	88.2	93.0	72.3	156.6	130.4	103.3	77.5	53.8	60.1
TUNING CAPACITY $\mu\mu f$	34.7	42.8	57	31.6	35.0	40.9	31.4	39.1	39.6	31.7	54.0	40.3
L/C X 10^6	83.7	56.0	35.5	102.0	77.3	61.9	74.8	47.3	50.2	76.5	29.1	48.0
Q	62.1	60.4	71.0	113.0	92.5	106.5	56.4	51.2	67.0	111.0	102.0	113.0

TABLE I

Comparison of electrical and physical properties of unshielded air and Magicore cored coils most suited for use at the test frequencies.

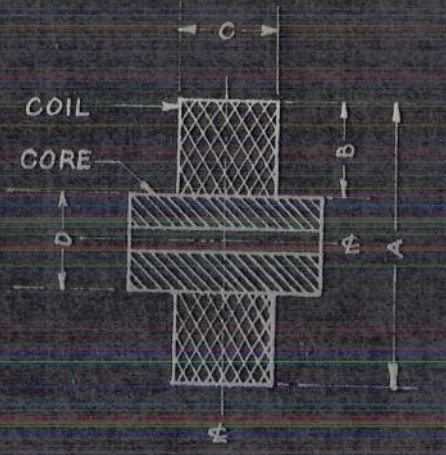


Table 1

FREQUENCY	175 KILOCYCLES						260 KILOCYCLES						370 KILOCYCLES					
CORE	AIR			MAGICORE			AIR			MAGICORE			AIR			MAGICORE		
PREFERENCE	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
TEST COIL NO.			D-36-1	D-36-1	D-36-2	D-36-1	D-36-1	D-36-3	C-36-1	D-36-2	D-36-3	C-36-1	C-36-1	D-36-3	C-36-2	C-36-3	D-36-5	B-36-1
B&S WIRE GAUGE D.S.C.			36	36	36	34	36	36	36	36	36	36	36	36	36	36	36	36
TURNS			690	690	630	600	690	540	520	630	540	520	520	540	465	410	415	340
D. C. RES. OHMS			57.0	57.0	50.0	35.5	57.0	40.0	44.0	50.0	40.0	44.0	44.0	40.0	36.0	31.0	27.3	28.8
"D" CORE DIAMETER INCH			0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382
"C" COIL WIDTH INCH			0.224	0.224	0.224	0.225	0.224	0.224	0.156	0.224	0.224	0.156	0.156	0.224	0.156	0.156	0.224	0.099
"A" COIL DIAMETER INCH			1.016	1.016	0.958	1.032	1.016	0.877	1.016	0.950	0.877	1.016	1.016	0.877	0.950	0.888	0.758	1.016
RATIO $\frac{B}{C}$			1.42	1.42	1.29	1.44	1.42	1.11	2.03	1.29	1.11	2.03	2.03	1.11	1.85	1.63	0.838	3.20
INDUCTANCE MILLIHENRIES			6.60	11.6	9.90	9.82	6.60	3.80	4.23	9.90	7.25	7.12	4.23	3.80	3.14	4.76	4.41	3.48
DISTRIBUTED CAPACITY $\mu\mu f$			3.20	3.07	3.09	3.37	3.20	3.58	2.63	3.09	3.57	2.84	2.63	3.58	2.76	2.76	3.77	2.48
R.F. RESISTANCE			95.5	110.8	92.5	97.3	156.0	86.6	90.1	158.8	107.6	101.6	144.6	143.8	106.6	101.2	104.2	68.9
TUNING CAPACITY $\mu\mu f$			123.0	68.0	80.5	81.5	54.5	97.5	86.0	32.2	45.4	50.0	39.2	43.4	53.6	34.6	36.6	48.2
L/C X 10^6			52.2	163.0	118.0	115.0	114.0	37.6	47.8	280.0	148.0	135.0	101.0	80.8	55.7	127.0	109.0	68.6

FREQUENCY	456 KILOCYCLES						525 KILOCYCLES					
CORE	AIR			MAGICORE			AIR			MAGICORE		
PREFERENCE	1	2	3	1	2	3	1	2	3	1	2	3
TEST COIL NO.	C-36-2	C-36-3	B-36-1	B-36-1	D-36-6	C-36-4	C-36-3	D-36-5	B-36-1	B-36-2	C-36-5	B-36-3
B. & S. WIRE GAUGE D.S.C.	36	36	36	36	36	36	36	36	36	36	36	36
TURNS	465	410	340	340	345	325	410	415	340	295	275	270
D.C. RES. OHMS	36.0	31.0	28.8	28.8	21.3	21.3	31.0	27.3	28.6	23.5	15.7	20.0
"D" CORE DIAMETER INCH	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382	0.382
"C" COIL WIDTH INCH	0.156	0.156	0.099	0.099	0.224	0.156	0.156	0.224	0.099	0.099	0.156	0.099
"A" COIL DIAMETER INCH	0.950	0.888	1.016	1.016	0.698	0.779	0.888	0.758	1.016	0.932	0.710	0.880
RATIO $\frac{B}{C}$	1.85	1.63	3.20	3.20	0.710	1.28	1.63	0.838	3.20	2.78	1.05	2.52
INDUCTANCE MILLIHENRIES	3.14	2.55	2.10	3.48	3.00	2.68	2.55	2.03	2.10	2.60	1.66	2.06
DISTRIBUTED CAPACITY $\mu\mu f$	2.76	2.66	2.18	2.48	3.75	3.01	2.66	3.77	2.18	7.28	3.24	2.61
R.F. RESISTANCE	144.9	121.0	84.3	88.2	93.0	72.3	156.6	130.4	103.3	77.5	53.8	60.1
TUNING CAPACITY $\mu\mu f$	34.7	42.8	57	31.6	35.0	40.9	31.4	39.1	39.6	31.7	54.0	40.3
$L/C \times 10^6$	83.7	56.0	35.5	102.0	77.3	61.9	74.8	47.3	50.2	76.5	29.1	48.0
Q	62.1	60.4	71.0	113.0	92.5	106.5	56.4	51.2	67.0	111.0	102.0	113.0

TABLE I

Comparison of electrical and physical properties of unshielded air and Magicore cored coils most suited for use at the test frequencies.

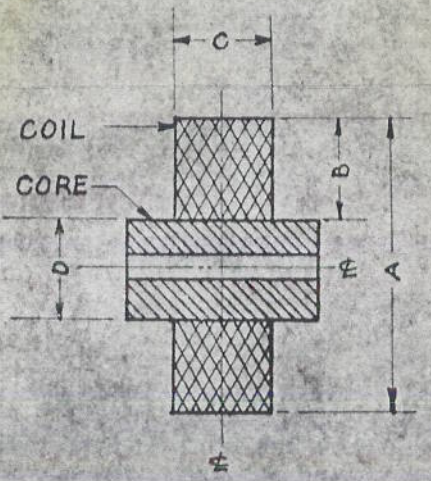


Table 1

AIR CORE

TABLE A:— SHIELD SIZE SELECTED TO MAINTAIN 90% OF Q OBTAINABLE WITHOUT SHIELD

COIL NO.	FIG. NO.	RATIO $\frac{e_p}{e_s}$	D.C. RES. OHMS	L INDUCTANCE MILLIHENRIES	C_o TUNING CAPACITY $\mu\mu f$		% INCREASE IN C_o DUE TO SHIELD	Q		% DECREASE IN Q DUE TO SHIELD	SHIELD DIAM. INCH	Δ_o INCH	FREQUENCY
					WITHOUT SHIELD	WITH SHIELD		WITHOUT SHIELD	WITH SHIELD				
D-36-1	1	1.42	57.0	6.60	121.6	129.9	6.8	73.0	65.7	10.0	1-13/16	7/8	17[illegible]
D-36-3	1	1.11	40.0	3.80	96.5	106.2	10.0	69.0	62.1	10.0	1-1/2	3/4	26[illegible]
D-36-3	1	1.11	40.0	3.80	45.2	49.6	9.7	61.0	54.9	10.0	1-1/2	5/8	37[illegible]
C-36-3	1	1.63	31.0	2.55	44.1	49.7	12.7	58.0	52.2	10.0	1-3/8	1/2	45[illegible]
D-36-5	1	0.84	27.3	2.03	41.0	47.2	15.0	50.5	45.4	10.0	1-3/16	1/2	52[illegible]

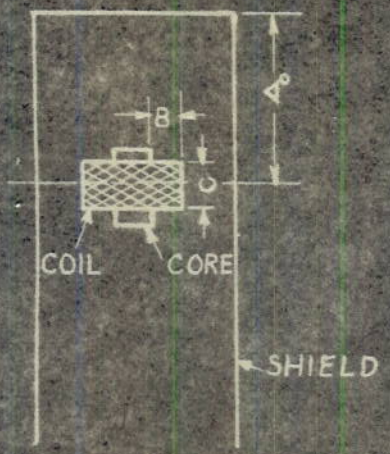


FIG. 1

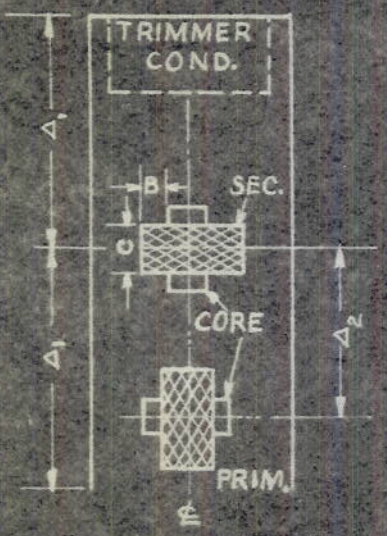


FIG. 2

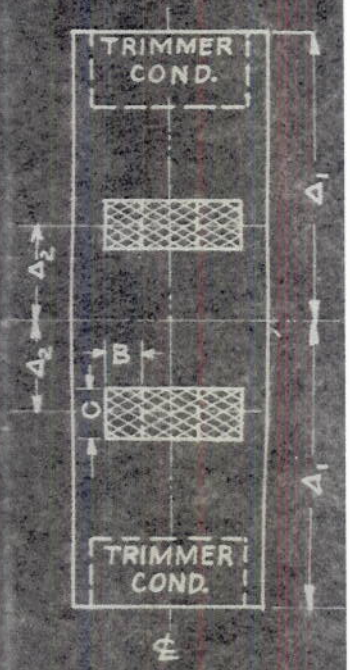


FIG. 3

CONSTANTS OF SHIELDED A

AIR CORE

TABLE A:- SHIELD SIZE SELECTED TO MAINTAIN 90% OF Q OBTAINABLE WITHOUT SHIELD

COIL NO.	FIG. NO.	RATIO $\frac{B}{C}$	D.C. RES. OHMS	L INDUCTANCE MILLIHENRIES	C_o TUNING CAPACITY $\mu\mu f$		% INCREASE IN C_o DUE TO SHIELD	Q		% DECREASE IN Q DUE TO SHIELD	SHI DIA IN
					WITHOUT SHIELD	WITH SHIELD		WITHOUT SHIELD	WITH SHIELD		
D-36-1	1	1.42	57.0	6.60	121.6	129.9	6.8	73.0	65.7	10.0	1-1
D-36-3	1	1.11	40.0	3.80	96.5	106.2	10.0	69.0	62.1	10.0	1-1
D-36-3	1	1.11	40.0	3.80	45.2	49.6	9.7	61.0	54.9	10.0	1-1
C-36-3	1	1.63	31.0	2.55	44.1	49.7	12.7	58.0	52.2	10.0	1-1
D-36-5	1	0.84	27.3	2.03	41.0	47.2	15.0	50.5	45.4	10.0	1-1

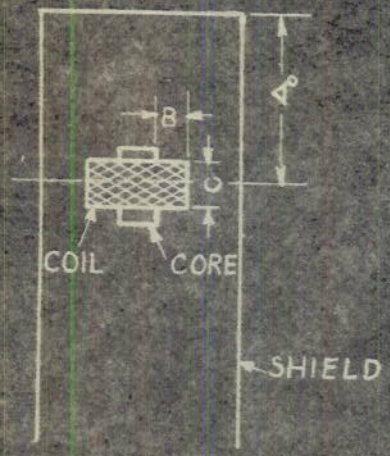


FIG. 1

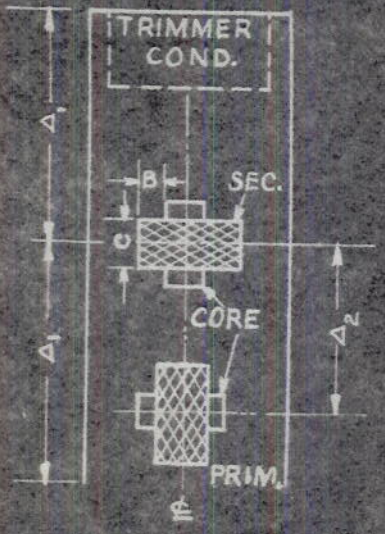


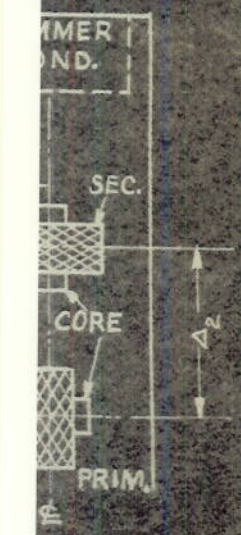
FIG. 2

TO MAINTAIN 90% OF Q
ITHOUT SHIELD

% INCREASE IN C_o DUE TO SHIELD	Q WITHOUT SHIELD	Q WITH SHIELD	% DECREASE IN Q DUE TO SHIELD	SHIELD DIAM. INCH	Δ_o INCH	FREQUENCY KILOCYCLES
6.8	73.0	65.7	10.0	1-13/16	7/8	175
0.0	69.0	62.1	10.0	1-1/2	3/4	260
9.7	61.0	54.9	10.0	1-1/2	5/8	370
2.7	58.0	52.2	10.0	1-3/8	1/2	456
5.0	50.5	45.4	10.0	1-3/16	1/2	525

TABLE B:- SHIELD SIZE SELECTED
OBTAINABLE W

COIL NO.	FIG. NO.	RATIO $\frac{B}{C}$	D.C. RES. OHMS	L INDUCTANCE MILLI HENRIES	C_o TUNING CAPACITY $\mu\mu f$ WITHOUT SHIELD	C_o TUNING CAPACITY $\mu\mu f$ WITH SHIELD
D-36-2	1	1.29	50.0	9.90	79.0	84.1
D-36-3	1	1.11	40.0	7.25	48.0	50.9
D-36-5	1	0.84	27.3	4.41	39.0	40.8
D-36-6	1	0.71	21.3	3.00	36.7	39.8
G-36-5	1	1.05	15.7	1.66	52.3	56.0



G. 2

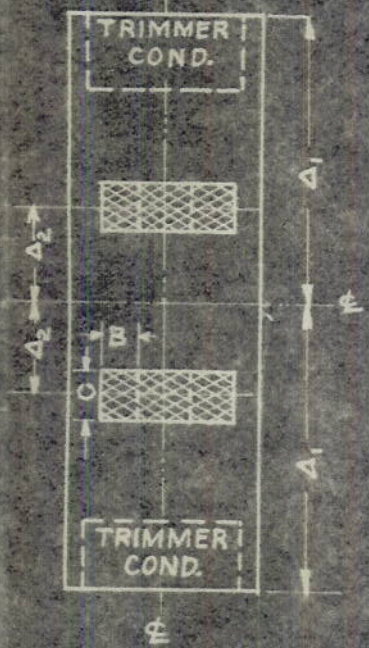


FIG. 3

TABLE C:-

I.F. TRANS. NO.	FIG. NO.
1	2
2	2
3	2
4	2
5	3
6	3

AIR AND MAGICORE — MAGICORE

TABLE B:— SHIELD SIZE SELECTED TO MAINTAIN 90% OF Q OBTAINABLE WITHOUT SHIELD

COIL NO.	FIG. NO.	RATIO $\frac{B}{C}$	D.C. RES. OHMS	L INDUCTANCE MILLIHENRIES	C_o TUNING CAPACITY $\mu\mu f$ WITHOUT SHIELD	C_o TUNING CAPACITY $\mu\mu f$ WITH SHIELD	% INCREASE IN C_o DUE TO SHIELD	Q WITHOUT SHIELD	Q WITH SHIELD	% DECREASE IN Q DUE TO SHIELD	SHIELD DIAM. INCH	Δ_o INCH	C_o TUNING CAPACITY WITH SHIELD	% INCREASE
2	1	1.29	50.0	9.90	79.0	84.1	6.5	112.5	101.3	10.0	2-1/8	1	104.6	32
3-6-D	1	1.11	40.0	7.25	48.0	50.9	6.0	106.0	95.4	10.0	1-15/16	15/16	65.3	36
5-9-D	1	0.84	27.3	4.41	39.0	40.8	4.6	96.5	86.9	10.0	1-7/8	7/8	55.0	41
8-36-D	1	0.71	21.3	3.00	36.7	39.8	8.3	87.5	78.8	10.0	1-9/16	3/4	53.4	45
9-93-D	1	1.05	15.7	1.66	52.3	56.0	7.1	100.0	90.0	10.0	1-5/8	5/8	79.5	52

TABLE B-1 MAINTA... CORRES...

TABLE C:— CONSTANTS OF SHIELDED AND UNSHIELDED AIR... IN COMMERCIAL I.F. T...

I.F. TRANS. NO.	FIG. NO.	MAKERS' NAME	COIL	FREQ. K.C.	CORE MATERIAL	D.C. RES. OHMS	RATIO $\frac{B}{C}$	L
1	2	"X" MANUFACTURER	Prim. Sec.	175	moly-iron	34.5 34.0	1.33	
2	2	"	Prim. Sec.	260	moly-iron	21.5 21.5	1.0	
3	2	"	Prim. Sec.	456	moly-iron	8.7 7.5	1.40	
4	2	"	Prim. Sec.	456	moly-iron	7.5 7.4	1.40	
5	3	Hammerlund	Prim. Sec.	175	air	35.0 35.0	1.10	
6	3	"	Prim. Sec	525	air	6.8 6.6	1.5	

TABLE B-1:- SHIELD SIZE SELECTED TO MAINTAIN APPROXIMATELY SAME Q AS CORRESPONDING SHIELDED COIL IN TABLE A						TABLE B-2:- Q OBTAINABLE WITH SHIELD SIZE THE SAME AS FOR THE CORRESPONDING COIL IN TABLE A					
C_o TUNING CAPACITY WITH SHIELD	% INCREASE IN C_o DUE TO SHIELD	Q WITH SHIELD	% DECREASE IN Q DUE TO SHIELD	SHIELD DIAM. INCH	Δ_o INCH	C_o TUNING CAPACITY WITH SHIELD	% INCREASE IN C_o DUE TO SHIELD	Q WITH SHIELD	% DECREASE IN Q DUE TO SHIELD	SHIELD DIAM INCH	Δ_o INCH
104.6	32.5	66.4	41.0	1-5/16	3/4	86.5	9.7	93.3	17.0	1-13/16	7/8
65.3	36.0	61.5	42.0	1-3/16	5/8	55.2	15.0	82.2	22.5	1-1/2	3/4
55.0	41.0	56.9	41.0	1-1/16	1/2	43.9	12.5	80.6	16.5	1-1/2	7/8
53.4	45.3	53.4	39.0	1	1/2	41.8	14.0	73.5	16.0	1-3/8	1/2
79.5	52.0	45.4	54.6	7/8	1/2	63.3	21.0	74.0	26.0	1-3/16	1/2

HIELDED AIR AND MOLYIRON ALLOY CORED COILS
CIAL I.F. TRANSFORMERS.

RATIO B/C	L INDUCTANCE MILLIHENRIES	C_o TUNING CAPACITY $\mu\mu f$		% INCREASE IN C_o DUE TO SHIELD	Q		% DECREASE IN Q DUE TO SHIELD	SHIELD DIAM INCH	Δ_1 INCH	Δ_2 INCH	$\Delta_1 - \Delta_2$ INCH
		WITHOUT SHIELD	WITH SHIELD		WITHOUT SHIELD	WITH SHIELD					
1.33	8.55 8.37	90.7 94.4	97.5 109.2	7.5 15.7	144.5 132.5	103.5 95.5	28.4 28.0	1-1/2	1-3/4	3/4	1
1.0	4.25 4.29	83.3 83.9	87.1 93.6	4.6 11.6	131.5 132.0	106.5 104.5	19.0 20.8	1-1/2	1-3/4	3/4	1
1.40	1.52 1.54	75.6 75.5	79.9 84.3	5.7 11.7	151.5 144.0	121.5 118.0	19.8 18.1	1-1/2	1-3/4	3/4	1
1.40	1.52 1.55	76.0 74.6	80.5 83.4	5.9 11.8	159.0 150.0	128.5 123.5	19.2 17.7	1-1/2	1-3/4	3/4	1
1.10	8.65 8.65	85.7 85.9	92.8 93.7	8.3 9.1	95.5 99.0	85.5 87.0	10.5 12.1	2	2-1/2	5/8	1-7/8
1.5	1.02 1.02	82.9 82.9	86.7 86.6	4.6 4.5	100 101	93.5 94.0	6.5 6.9	2	2-1/2	5/8	1-7/8

TABLE 2

Comparison of Values of True Induc
for Different Fre
when using each of Seve

Magnicore Core No.	True Inductance Millihenries	% Change from Average	175 kcs				260 kcs			
			Effect Q	% Difference from Average	Tuning Capacity $\mu\mu f$	% Difference from Average	Effect Q	% Difference from Average	Tuning Capacity $\mu\mu f$	% Difference
First Lot of										
1	2.68	4.28	105	3.24	307	4.27	121.	3.06	140.3	4.
2	2.68	4.28	105.5	3.74	307	4.27	121	3.06	140.4	4.
3	2.50	2.72	99	2.67	330.4	3.02	115	2.04	150.5	2.
4	2.53	1.55	101	0.69	326.2	1.72	116.5	0.77	147	0.
5	2.56	0.39	101	0.69	321	0.94	117	0.34	147	0.
6	2.55	0.78	101	0.69	322.6	0.59	117	0.34	148	0.
7	2.56	0.39	101	0.69	322.1	0.44	117	0.34	149	1.
8	2.55	0.78	101.5	0.20	321.4	0.22	117	0.34	147.5	0.
9	2.54	1.17	100.5	1.18	323	0.72	116	1.19	148.5	1.
10	2.53	1.56	101.5	0.20	326	1.65	116	1.19	149.0	1.
Av.	2.57		101.7		320.7		117.4		146.7	
Second Lot o										
1	2.69	1.12	106	0.95	305	0.46	122	0.83	139.2	1.
2	2.68	0.75	106	0.95	305.3	0.56	122	0.83	140.1	0.
3	2.68	0.75	106	0.95	305.7	0.69	121.5	0.41	140.1	0.
4	2.53	4.88	101	3.00	322	4.75	117.5	2.90	148.0	4.
5	2.68	0.75	106	0.95	304.9	0.43	122	0.83	139.8	0.
6	2.68	0.75	106	0.95	304.5	0.30	122	0.83	139.8	0.
Av.	2.66		105		303.6		121		141.0	

Comparison of Values of True Inductance and Tuning Ca
for Different Frequencies of C-36-A Co
when using each of Several Magicore Cores in

Magicore Core No.	True Inductance Millihenries	% Change from Average	175 kcs				260 kcs				370 kcs		
			Effect Q	% Difference from Average	Tuning Capacity $\mu\mu f$	% Difference from Average	Effect Q	% Difference from Average	Tuning Capacity $\mu\mu f$	% Difference from Average	Effect Q	% Difference from Average	Tuning Capacity
First Lot of Magicore Cores													
1	2.68	4.28	105	3.24	307	4.27	121.	3.06	140.3	4.36	119	2.32	67.
2	2.68	4.28	105.5	3.74	307	4.27	121	3.06	140.4	4.29	119	2.32	67.
3	2.50	2.72	99	2.67	330.4	3.02	115	2.04	150.5	2.59	114.5	1.54	73.
4	2.53	1.55	101	0.69	326.2	1.72	116.5	0.77	147	0.24	115.5	0.69	71
5	2.56	0.39	101	0.69	321	0.94	117	0.34	147	0.24	116	0.26	71
6	2.55	0.78	101	0.69	322.6	0.59	117	0.34	148	0.89	116	0.26	71
7	2.56	0.39	101	0.69	322.1	0.44	117	0.34	149	1.57	116	0.26	73
8	2.55	0.78	101.5	0.20	321.4	0.22	117	0.34	147.5	0.55	116	0.26	71
9	2.54	1.17	100.5	1.18	323	0.72	116	1.19	148.5	1.23	115.5	0.69	72
10	2.53	1.56	101.5	0.20	326	1.65	116	1.19	149.0	1.57	115.5	0.69	73
Av.	2.57		101.7		320.7		117.4		146.7		116.3		71
Second Lot of Magicore Cores													
1	2.69	1.12	106	0.95	305	0.46	122	0.83	139.2	1.28	120	0.50	67
2	2.68	0.75	106	0.95	305.3	0.56	122	0.83	140.1	0.64	120	0.50	67
3	2.68	0.75	106	0.95	305.7	0.69	121.5	0.41	140.1	0.64	120	0.50	67
4	2.53	4.88	101	3.00	322	4.75	117.5	2.90	148.0	4.96	117	2.01	72
5	2.68	0.75	106	0.95	304.9	0.43	122	0.83	139.8	0.85	120	0.50	67
6	2.68	0.75	106	0.95	304.5	0.30	122	0.83	139.8	0.85	120	0.50	67
Av.	2.66		105		303.6		121		141.0		119.4		68

encies of C-36-4 Coil
l Magicore Cores in Succession.

	370 kcs				456 kcs				500 kcs			
	Effect Q	% Difference from Average	Tuning Capacity mmf	% Difference from Average	Effect Q	% Difference from Average	Tuning Capacity mmf	% Difference from Average	Effect Q	% Difference from Average	Tuning Capacity mmf	% Difference from Average
agicore Cores												
	119	2.32	67.5	5.20	110	1.57	43.1	4.42	103	1.08	35.5	4.57
	119	2.32	67.5	5.20	110	1.57	43.1	4.42	103	1.08	35.5	4.57
	114.5	1.54	73.0	2.53	107	1.20	46.4	2.88	101	0.88	38.3	2.96
	115.5	0.69	71.0	0.28	108	0.28	45.5	0.89	101.5	0.39	37.4	0.54
	116	0.26	71.4	0.28	108.5	0.17	45.2	0.22	101.5	0.39	37.2	0
	116	0.26	71.7	0.70	108	0.28	45.5	0.89	101.5	0.39	37.4	0.54
	116	0.26	73	2.53	108	0.28	45.6	1.55	102.0	0.40	38.0	2.14
	116	0.26	71.4	0.28	108.5	0.17	45.2	0.22	101.5	0.39	37.4	0.54
	115.5	0.69	72.5	1.83	107.5	0.74	45.4	0.67	102.0	0.10	37.6	1.08
	115.5	0.69	73.0	2.53	107.5	0.74	45.8	1.55	102.0	0.10	37.9	1.88
	116.3		71.2		108.3		45.1		101.9		37.2	
Magicore Cores												
	120	0.50	67	1.76	111	0.91	42.8	1.15	105	0.77	35.1	1.68
	120	0.50	67.5	1.03	110	0	43.0	0.69	105	0.77	35.3	1.12
	120	0.50	67.6	0.88	110	0	43.1	0.46	105	0.77	35.6	0.28
	117	2.01	72.5	6.31	108	1.80	45.6	5.32	103	1.05	37.6	5.32
	120	0.50	67.5	1.03	110.5	0.45	43.0	0.69	104.5	0.29	35.4	0.84
	120	0.50	67.5	1.03	111	0.91	43.1	0.46	105	0.77	35.5	0.56
	119.4		68.2		110		43.3		104.2		35.7	

TABLE 3

CONSTANTS OF SHIELDED AND

AIR CORE

TABLE A:- SHIELD SIZE SELECTED TO MAINTAIN 90% OF Q OBTAINABLE WITHOUT SHIELD

COIL NO.	FIG. NO.	RATIO $\frac{B}{C}$	D.C. RES. OHMS	L INDUCTANCE MILLIHENRIES	C_o TUNING CAPACITY $\mu\mu f$		% INCREASE IN C_o DUE TO SHIELD	Q		% DECREASE IN Q DUE TO SHIELD	SHIELD DIAM. INCH
					WITHOUT SHIELD	WITH SHIELD		WITHOUT SHIELD	WITH SHIELD		
D-36-1	1	1.42	57.0	6.60	121.6	129.9	6.8	73.0	65.7	10.0	1-13/16
D-36-3	1	1.11	40.0	3.80	96.5	106.2	10.0	69.0	62.1	10.0	1-1/2
D-36-3	1	1.11	40.0	3.80	45.2	49.6	9.7	61.0	54.9	10.0	1-1/2
C-36-3	1	1.63	31.0	2.55	44.1	49.7	12.7	58.0	52.2	10.0	1-3/8
D-36-5	1	0.84	27.3	2.03	41.0	47.2	15.0	50.5	45.4	10.0	1-3/16

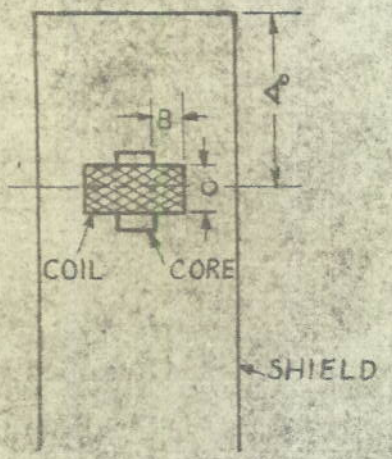


FIG. 1

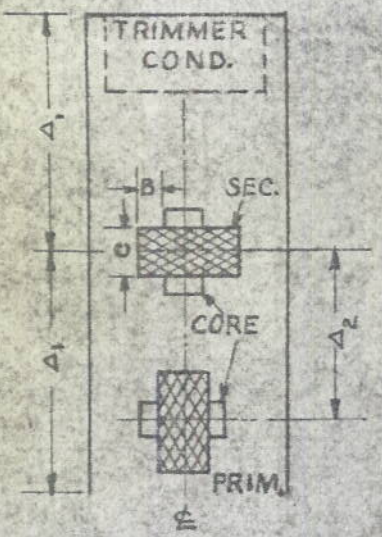
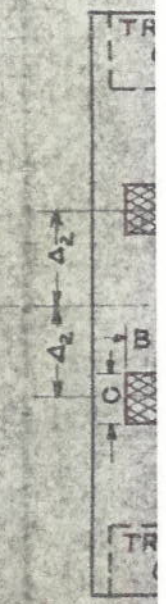


FIG. 2



F

/HEN THE COILS ARE SHIELDED

DUE TO SHIELD	Q WITH SHIELD	% DECREASE IN Q DUE TO SHIELD	SHIELD DIAM. INCH	Δ_o INCH	C_o TUNING CAPACITY WITH SHIELD	% INCREASE IN C_o DUE TO SHIELD	Q WITH SHIELD	% DECREASE IN Q DUE TO SHIELD	SHIELD DIAM. INCH	Δ_o INCH
	SHIELD SIZE SELECTED TO APPROXIMATELY SAME Q AS ONDING SHIELDED COIL IN TABLE A				TABLE B-2:- Q OBTAINABLE WITH SHIELD SIZE THE SAME AS FOR THE CORRESPONDING COIL IN TABLE A					
5	66.4	41.0	1-5/16	3/4	86.5	9.7	93.3	17.0	1-13/16	7/8
)	61.5	42.0	1-3/16	5/8	55.2	15.0	82.2	22.5	1-1/2	3/4
)	56.9	41.0	1-1/16	1/2	43.9	12.5	80.6	16.5	1-1/2	7/8
)	53.4	39.0	1	1/2	41.8	14.0	73.5	16.0	1-3/8	1/2
)	45.4	54.6	7/8	1/2	63.3	21.0	74.0	26.0	1-3/16	1/2

AND MOLYIRON ALLOY CORED COILS
ANSFORMERS.

MILLIHENRIES	C_o TUNING CAPACITY $\mu\mu f$ WITHOUT SHIELD	C_o TUNING CAPACITY $\mu\mu f$ WITH SHIELD	% INCREASE IN C_o DUE TO SHIELD	Q WITHOUT SHIELD	Q WITH SHIELD	% DECREASE IN Q DUE TO SHIELD	SHIELD DIAM. INCH	Δ_1 INCH	Δ_2 INCH	$\Delta_1 - \Delta_2$ INCH
5	90.7	97.5	7.5	144.5	103.5	28.4	1-1/2	1-3/4	3/4	1
7	94.4	109.2	15.7	132.5	95.5	28.0				
5	83.3	87.1	4.6	131.5	106.5	19.0	1-1/2	1-3/4	3/4	1
9	83.9	93.6	11.6	132.0	104.5	20.8				
2	75.6	79.9	5.7	151.5	121.5	19.8	1-1/2	1-3/4	3/4	1
4	75.5	84.3	11.7	144.0	118.0	18.1				
2	76.0	80.5	5.9	159.0	128.5	19.2	1-1/2	1-3/4	3/4	1
5	74.6	83.4	11.8	150.0	123.5	17.7				
5	85.7	92.8	8.3	95.5	85.5	10.5	2	2-1/2	5/8	1-7/8
5	85.9	93.7	9.1	99.0	87.0	12.1				
2	82.9	86.7	4.6	100	93.5	6.5	2	2-1/2	5/8	1-7/8
2	82.9	86.6	4.5	101	94.0	6.9				

TABLE 2

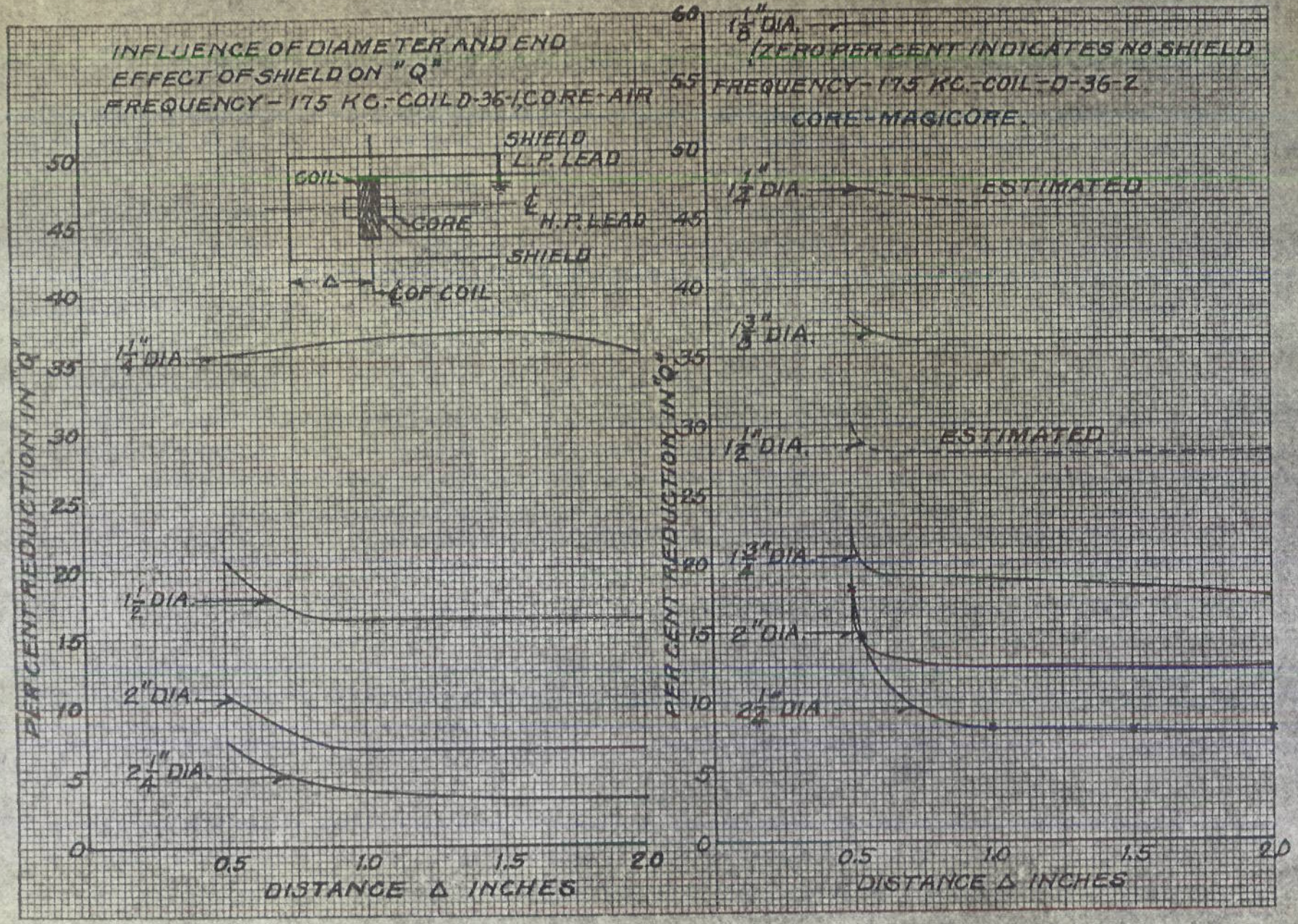
Comparison of Values of True I
for Different
when using each of

Magnetic Core No.	True Inductance Millihenries	% Change from Average	175 kcs				260 kcs			
			Effect Q	% Difference from Average	Tuning Capacity $\mu\mu f$	% Difference from Average	Effect Q	% Difference from Average	Tuning Capacity $\mu\mu f$	
First Lo										
1	2.68	4.28	105	3.24	307	4.27	121.	3.06	140.3	
2	2.68	4.28	105.5	3.74	307	4.27	121	3.06	140.4	
3	2.50	2.72	99	2.67	330.4	3.02	115	2.04	150.5	
4	2.53	1.55	101	0.69	326.2	1.72	116.5	0.77	147	
5	2.56	0.39	101	0.69	321	0.94	117	0.34	147	
6	2.55	0.78	101	0.69	322.6	0.59	117	0.34	148	
7	2.56	0.39	101	0.69	322.1	0.44	117	0.34	149	
8	2.55	0.78	101.5	0.20	321.4	0.22	117	0.34	147.5	
9	2.54	1.17	100.5	1.18	323	0.72	116	1.19	148.5	
10	2.53	1.56	101.5	0.20	326	1.65	116	1.19	149.0	
Av.	2.57		101.7		320.7		117.4		146.7	
Second L										
1	2.69	1.12	106	0.95	305	0.46	122	0.83	139.2	
2	2.68	0.75	106	0.95	305.3	0.56	122	0.83	140.1	
3	2.68	0.75	106	0.95	305.7	0.69	121.5	0.41	140.1	
4	2.53	4.88	101	3.00	322	4.75	117.5	2.90	148.0	
5	2.68	0.75	106	0.95	304.9	0.43	122	0.83	139.8	
6	2.68	0.75	106	0.95	304.5	0.30	122	0.83	139.8	
Av.	2.66		105		303.6		121		141.0	

ce and Tuning Capacity a Effective "Q"
ncies of C-86-4 Coil
Magicore Cores in Succession.

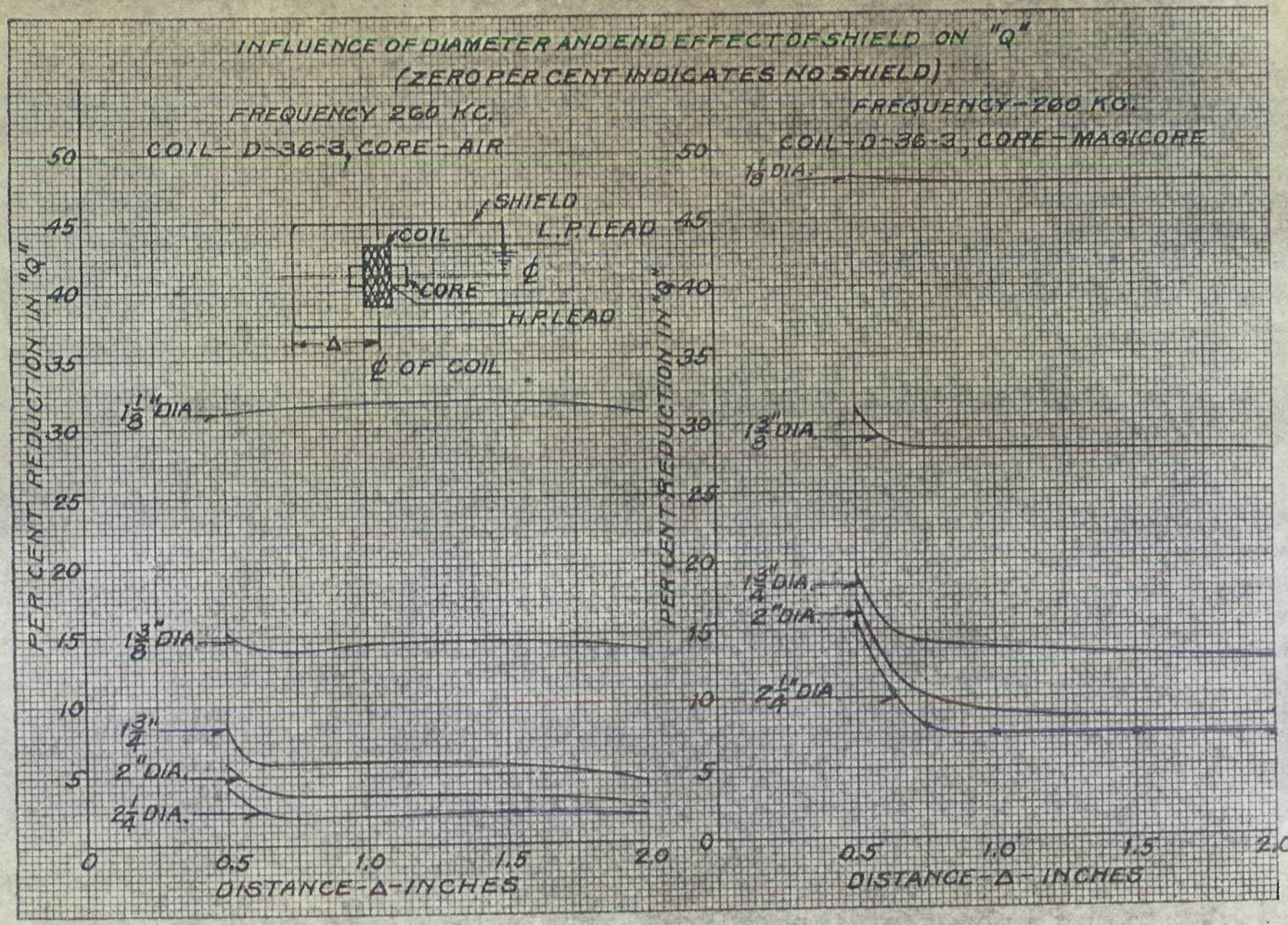
370 kcs				456 kcs				500 kcs			
Effect Q	% Difference from Average	Tuning Capacity mmf	% Difference from Average	Effect Q	% Difference from Average	Tuning Capacity mmf	% Difference from Average	Effect Q	% Difference from Average	Tuning Capacity mmf	% Difference from Average
gicore Cores											
119	2.32	67.5	5.20	110	1.57	43.1	4.42	103	1.08	35.5	4.57
119	2.32	67.5	5.20	110	1.57	43.1	4.42	103	1.08	35.5	4.57
114.5	1.54	73.0	2.53	107	1.20	46.4	2.88	101	0.88	38.3	2.96
115.5	0.69	71.0	0.28	108	0.28	45.5	0.89	101.5	0.39	37.4	0.54
116	0.26	71.4	0.28	108.5	0.17	45.2	0.22	101.5	0.39	37.2	0
116	0.26	71.7	0.70	108	0.28	45.5	0.89	101.5	0.39	37.4	0.54
114	0.26	73	2.53	108	0.28	45.8	1.55	102.0	0.40	38.0	2.14
116	0.26	71.4	0.28	108.5	0.17	45.2	0.22	101.5	0.39	37.4	0.54
115.5	0.69	72.5	1.83	107.5	0.74	45.4	0.67	102.0	0.10	37.6	1.08
115.5	0.69	73.0	2.53	107.5	0.74	45.8	1.55	102.0	0.10	37.9	1.88
116.3		71.2		108.3		45.1		101.9		37.2	
agicore Cores											
120	0.50	67	1.76	111	0.91	42.8	1.15	105	0.77	35.1	1.66
120	0.50	67.5	1.03	110	0	43.0	0.69	105	0.77	35.3	1.12
120	0.50	67.6	0.88	110	0	43.1	0.46	105	0.77	35.6	0.28
117	2.01	72.5	6.31	108	1.80	45.6	5.32	103	1.05	37.6	5.32
120	0.50	67.5	1.03	110.5	0.45	43.0	0.69	104.5	0.29	35.4	0.84
120	0.50	67.5	1.03	111	0.91	43.1	0.46	105	0.77	35.5	0.56
119.4		68.2		110		43.3		104.2		35.7	

N. R. L. 34A



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IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY

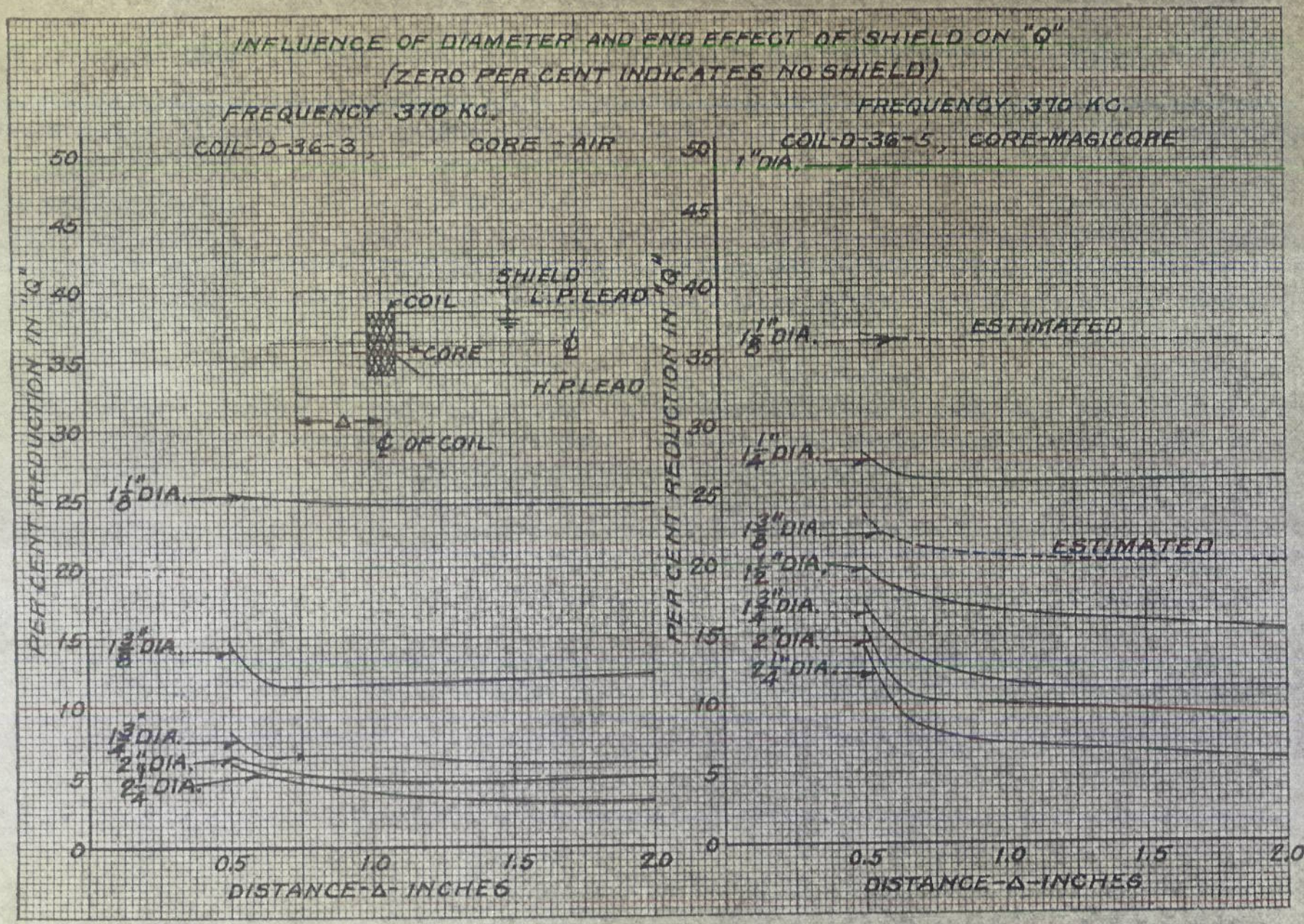


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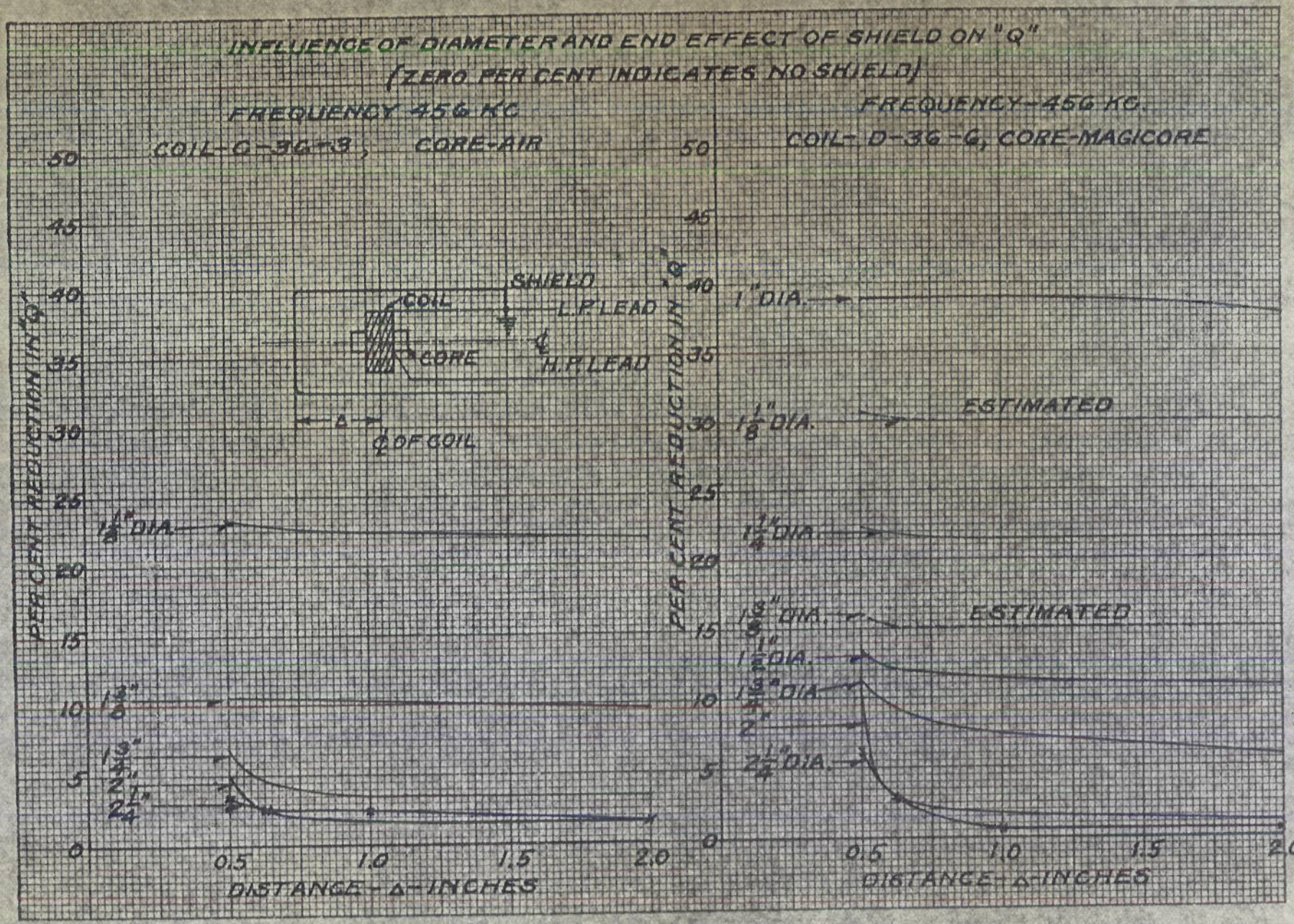
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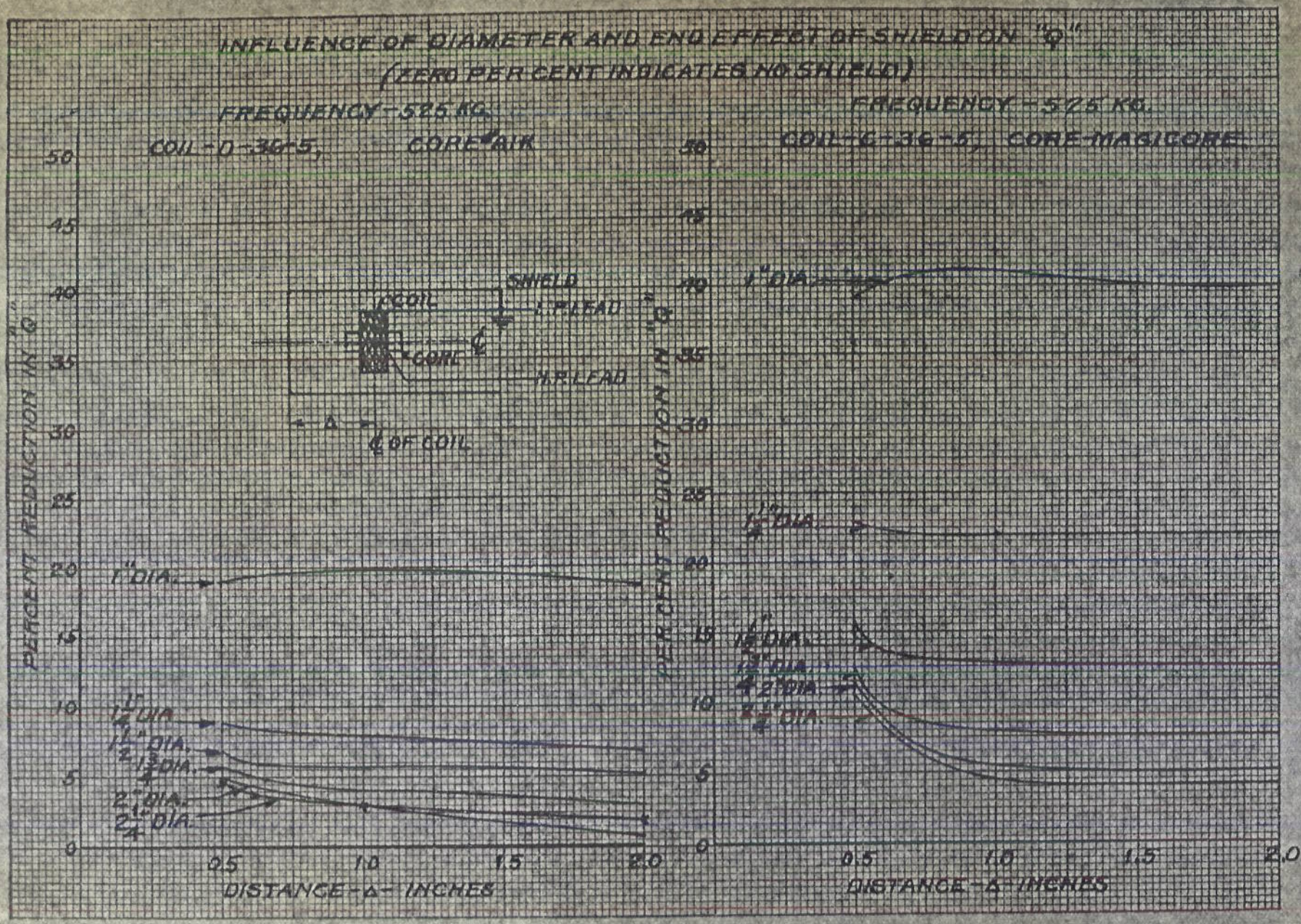
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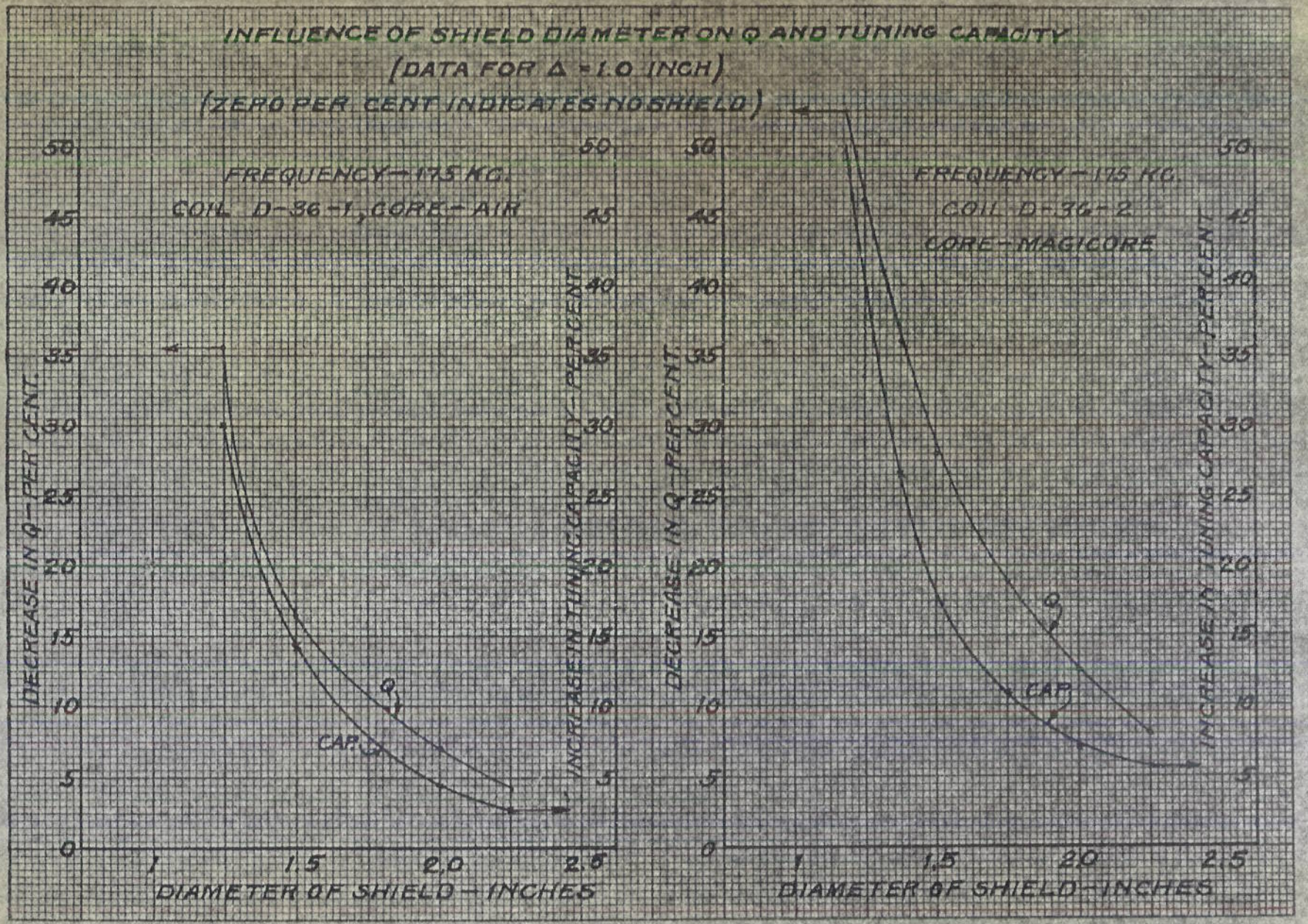
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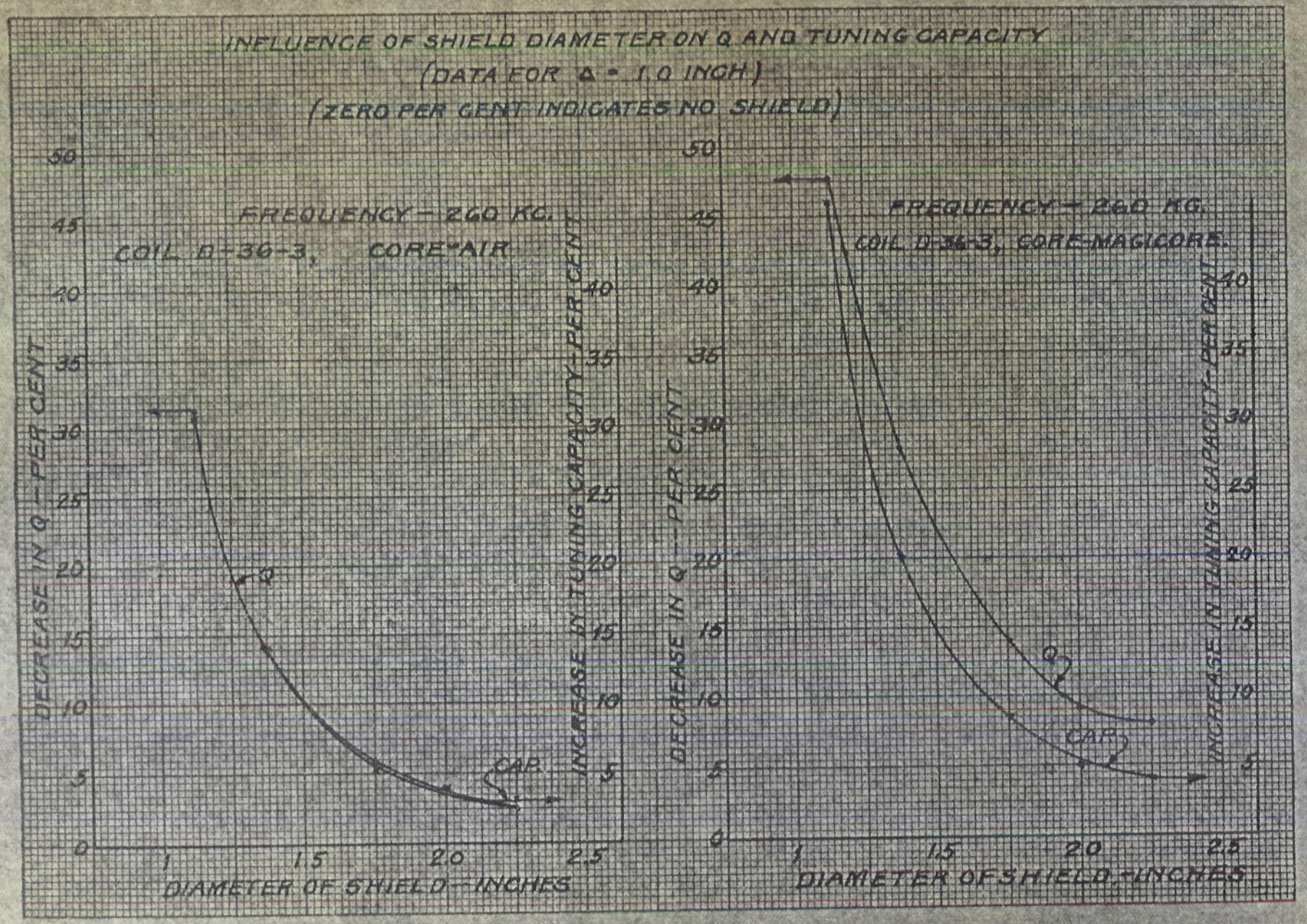
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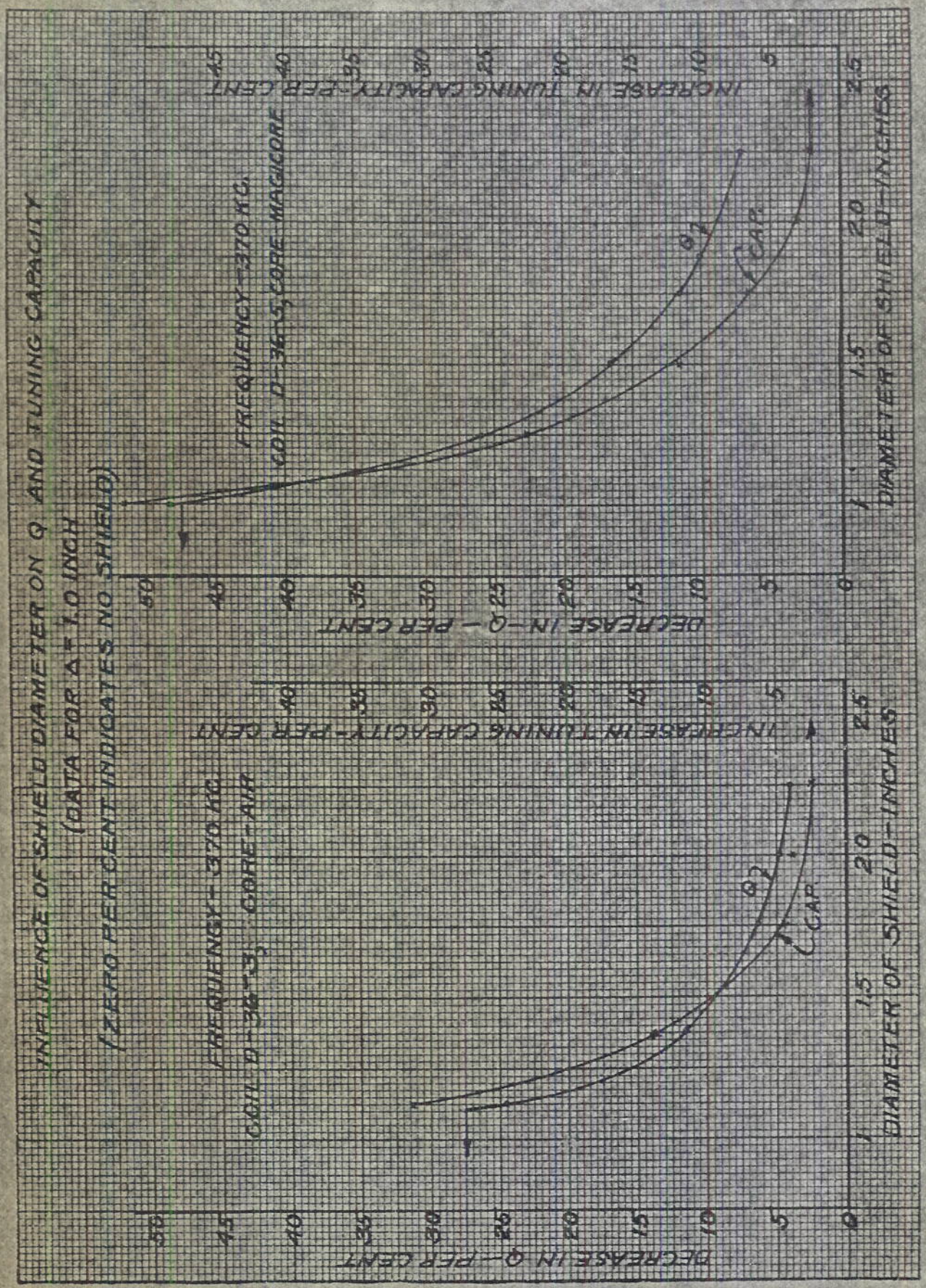


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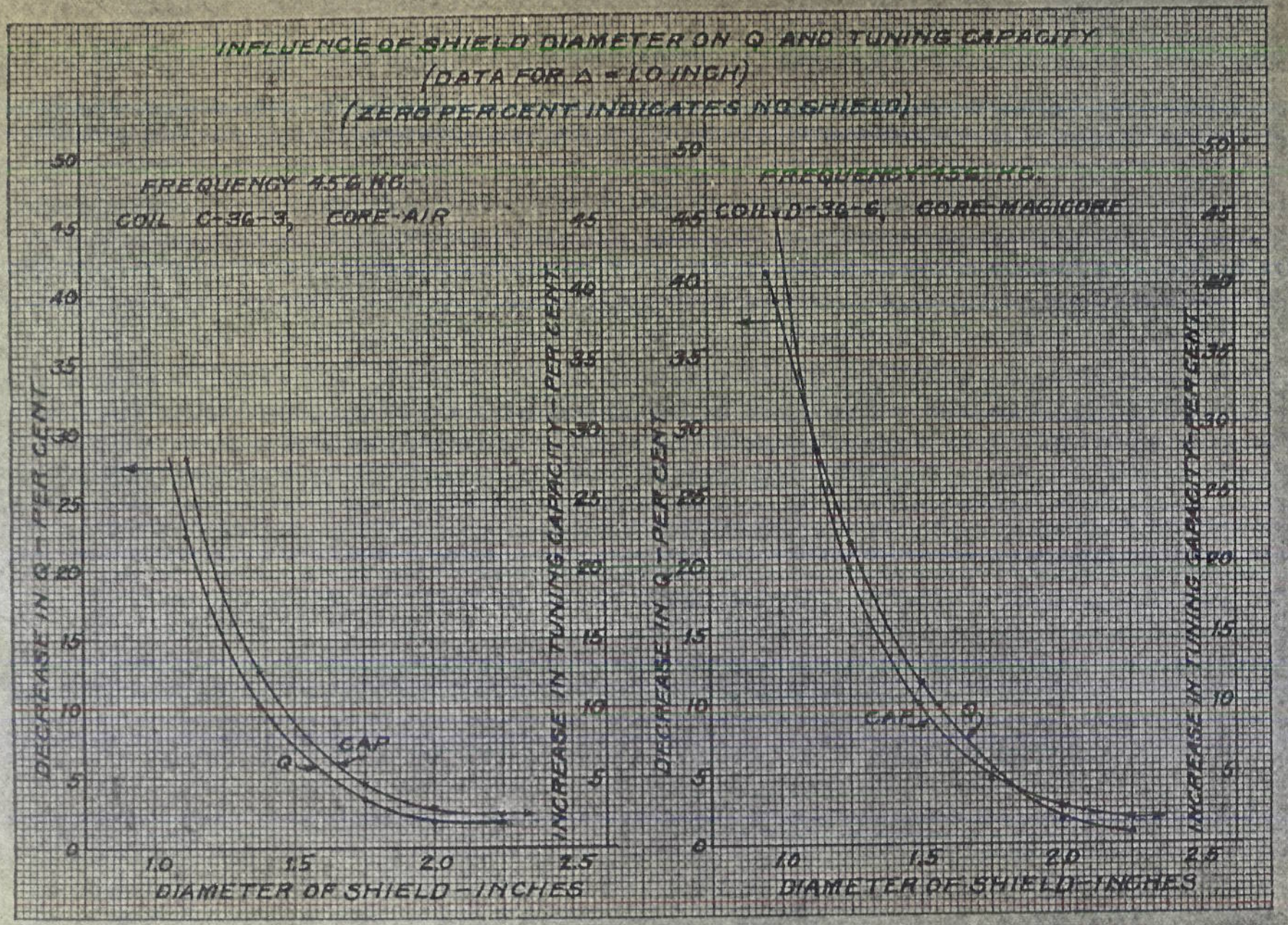


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INFLUENCE OF SHIELD DIAMETER ON Q AND TUNING CAPACITY
(DATA FOR Δ = 1.0 INCH
(ZERO PER CENT INDICATES NO SHIELD)
FREQUENCY = 370 KC.
COIL D-36-5, CORE MAGICORE
INCREASE IN TUNING CAPACITY-PER CENT
DECREASE IN -Q- PER CENT
DIAMETER OF SHIELD-INCHES
Q
CAP.
FREQUENCY = 370 KC.
COIL D-36-3, CORE-AIR
INCREASE IN TUNING CAPACITY-PER CENT
DECREASE IN Q - PER CENT
DIAMETER OF SHIELD-INCHES
Q
CAP.

N. R. L. 31A

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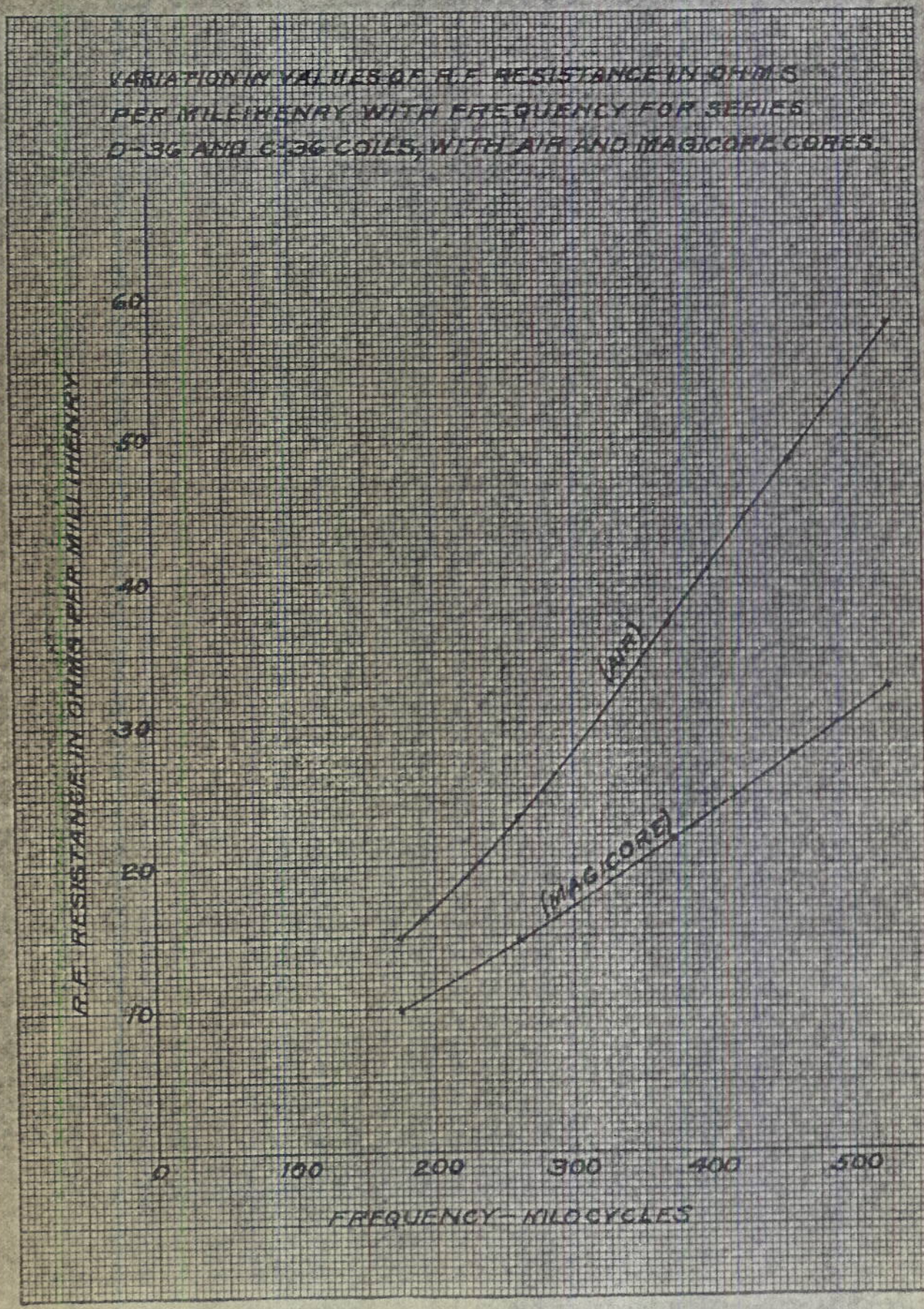
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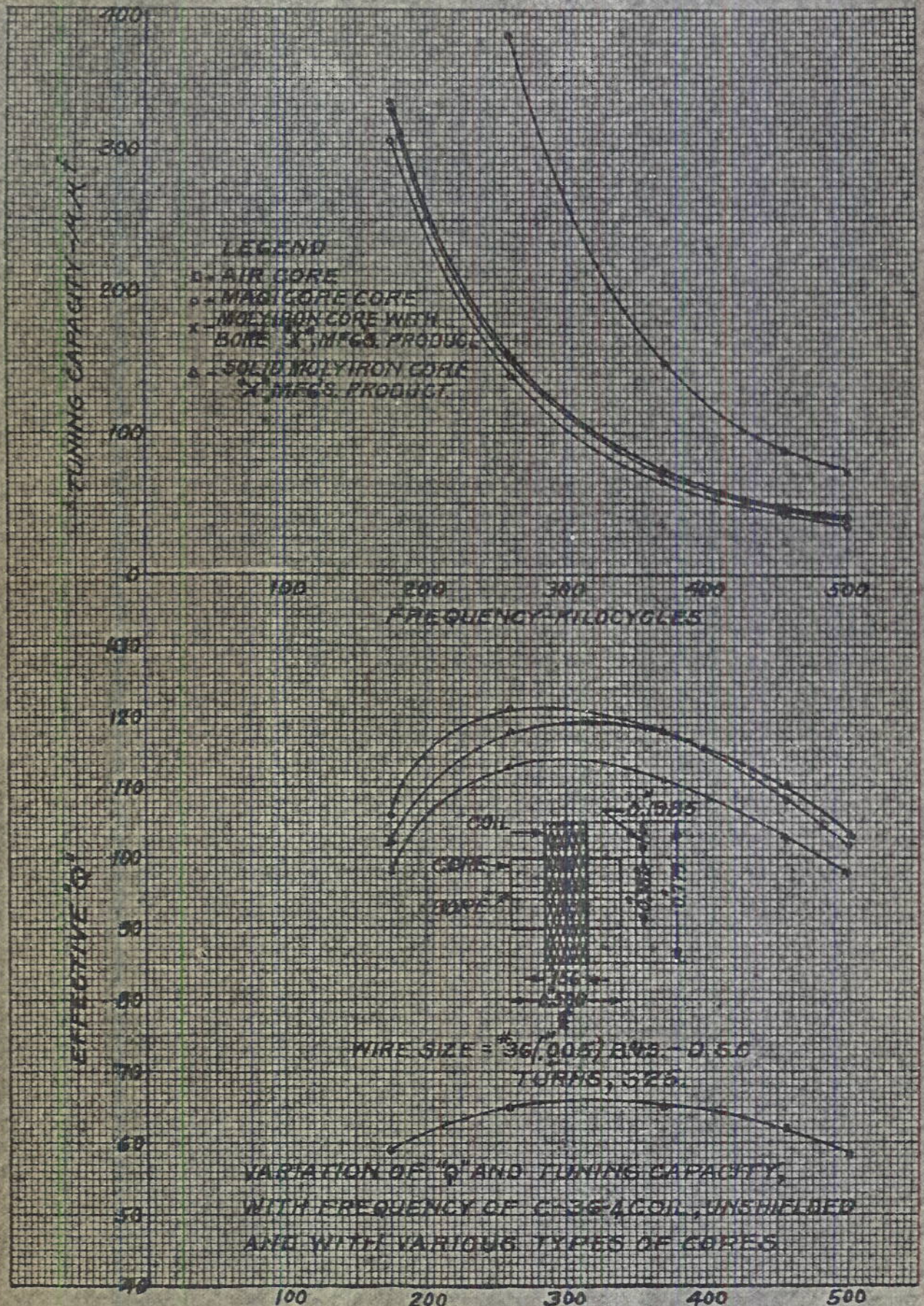
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N. R. L. 31A


VARIATION IN VALUES OF R.F. RESISTANCE IN OHMS PER MILLIHENRY WITH FREQUENCY FOR SERIES D-36 AND C-36 COILS, WITH AIR AND MAGICORE CORES.
R.F. RESISTANCE IN OHMS PER MILLIHENRY
60
50
40
30
20
10
0
100
200
300
400
500
FREQUENCY - KILOCYCLES
(AIR)
(MAGICORE)



VARIATION OF "Q" AND TUNING CAPACITY WITH FREQUENCY OF C-36-A COIL, UNSHIELDED AND WITH VARIOUS TYPES OF CORES.

N. R. L. 514

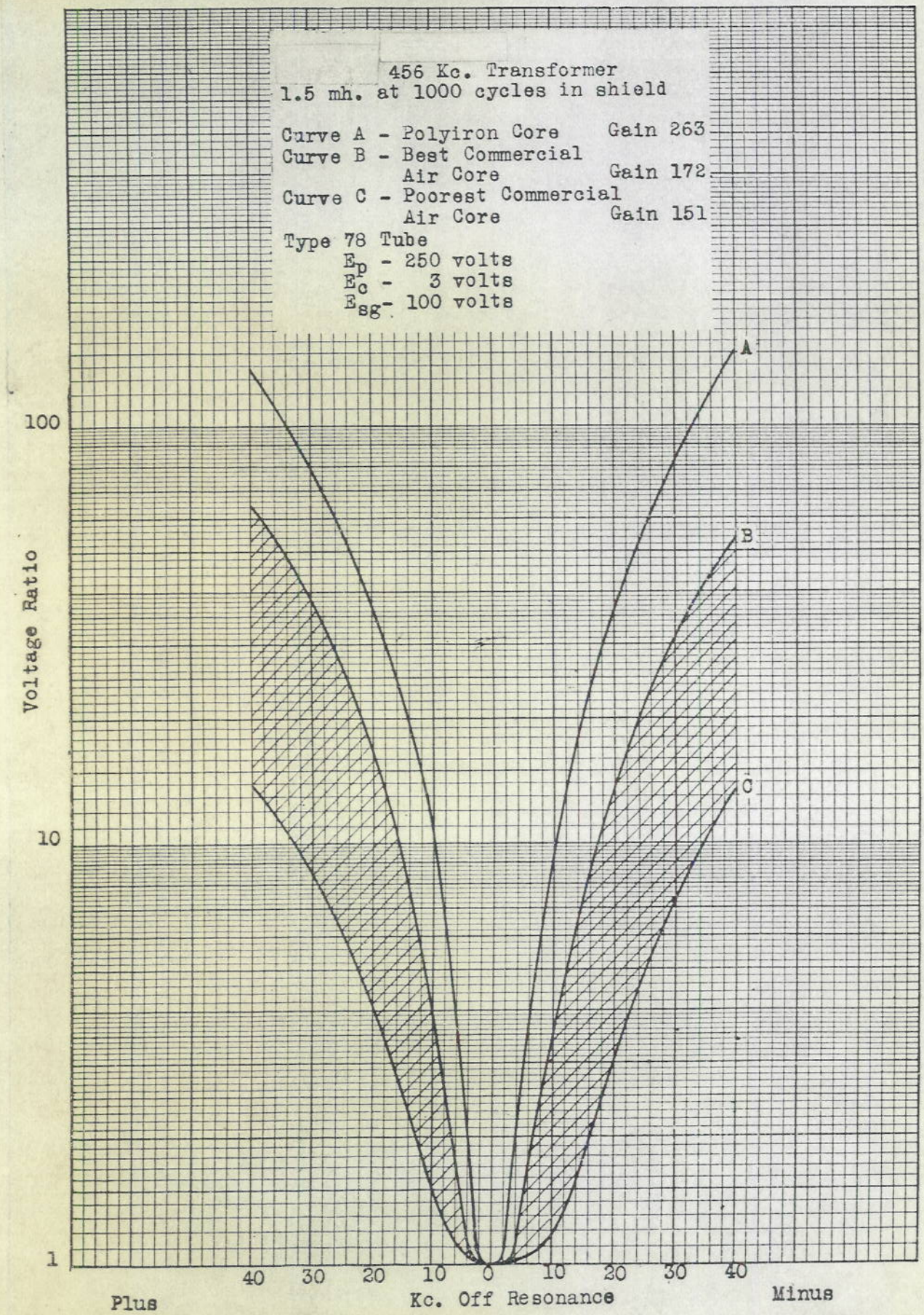

456 Kc. Transformer
1.5 mh. at 1000 cycles in shield
Curve A - Polyiron Core Gain 263
Curve B - Best Commercial Air Core Gain 172
Curve C - Poorest Commercial Air Core Gain 151
Type 78 Tube
E_p - 250 volts
E_c - 3 volts
E_{sg} - 100 volts
A
B
C
100
10
1
Voltage Ratio
40 30 20 10 0 10 20 30 40
Plus
Kc. Off Resonance
Minus

Plate 14

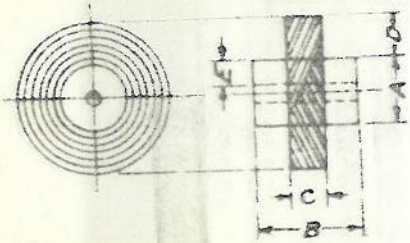


Fig. 1. General Dimensions for Universal Coil and Molyiron Core.

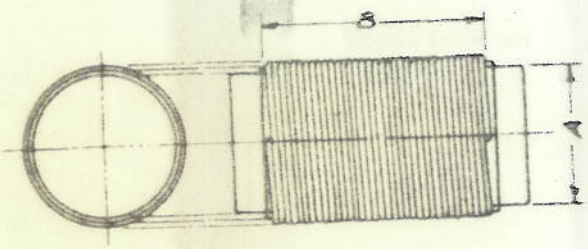


Fig. 2. Cylindrical Air Coil, Single Layer Lits Wire - 60 Strands of S.W.G. #45 (≒ #41 B.&S.G.) with Thick Insulation. L = 160 μh, A = 2", B = 3-1/8".

Fig. 2A. Same as Fig. 2 except Cylindrical Iron Cored Coil. Same Lits Wire Single Layer Wound. L = 160 μh, A = 1-3/16", B = 1-3/4".

Fig. 2B. Same as Fig. 2A except With Lits Wire 20 Strands of S.W.G. #47 (≒ #44 B.&S.G.)

Fig. 2C. Same as Fig. 2A except With Solid Wire S.W.G. #29 (Nearest Equiv. = 27 B.&S.G.)

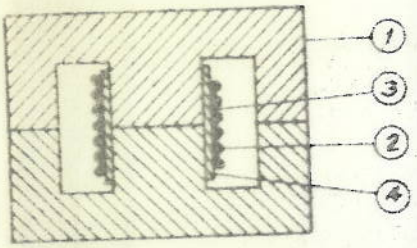


Fig. 3. Sectional View of Iron Cored Coil Form According to Fig. 6 of British Patent Specification No.366,475 of Polydoroff of 1929 - Suggesting Single Layer Space Wound Arrangement.

1 - Pot Shaped Magnetic Core
2 - Winding
3 - Intermediate Threads for Spacing the Turns of Wire
4 - Insulation Between Core and Winding

Winding - Single Layer, Space Wound, Lits Wire - 20 Strands of S.W.G. #45 (≒ #41 B.&S.G.). Winding Diam. 1", Winding Length 2", L = 160 μh.

Core - External Diam. 1-9/16", Height 2-7/16", Wt. 9-1/2 oz.

PLATE 15

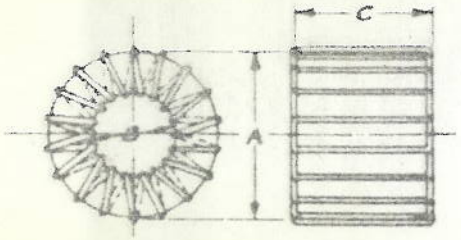


Fig. 4. Toroidal Coil Having a Core of Laminated Ferrocart Winding. Solid Wire of S.W.G. #29 (Nearest Equiv. #27 B.&S.G.) Single Layer Space Wound. L = 160 μh. Core: A = 1-5/8", B = 3/4", C = 1-7/16". Wt. = 5-1/4 oz.

Fig. 4A. Same as Fig. 4 Except Winding: Litz Wire, 30 Strands of S.W.G. #47 (≑ #44 B.&S.G.)

Fig. 4B. Same as Fig. 4 Except Core: C = 1/2". Wt. = 1-3/4 oz.

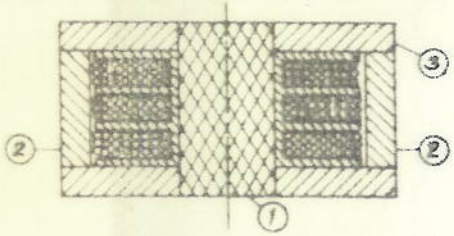


Fig. 5. Diagrammatic View of Up-to-date Tuning Coil with a Multi-layer Litz Winding Concentrated to Small Space. Low Capacity Winding with Approximately Square Shaped Winding Cross Section (Low Loss Sectionalized Coil Form of Trolitul)

1 = Rod core
1 + 3 = H Core (or if Parts 3 are Round Discs, Spool Type Core.)
1 + 2 + 3 = EI Core, or, If Circular, Pot Core.

Fig. 5A. Winding Litz Wire, 20 Strands of S.W.G. #47 (≑ #44 B.&S.G.) on Sectionalized Coil Form of Trolitul. Winding Diam. Int. = 3/8", Winding Length = 1/4", L = 160 μh. Core: Moulded Pot Shape Ext. Diam. = 13/16". Wt. = 1/2 oz.

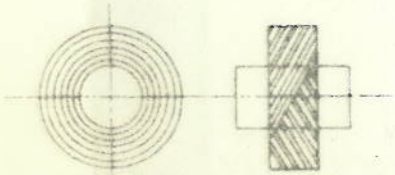


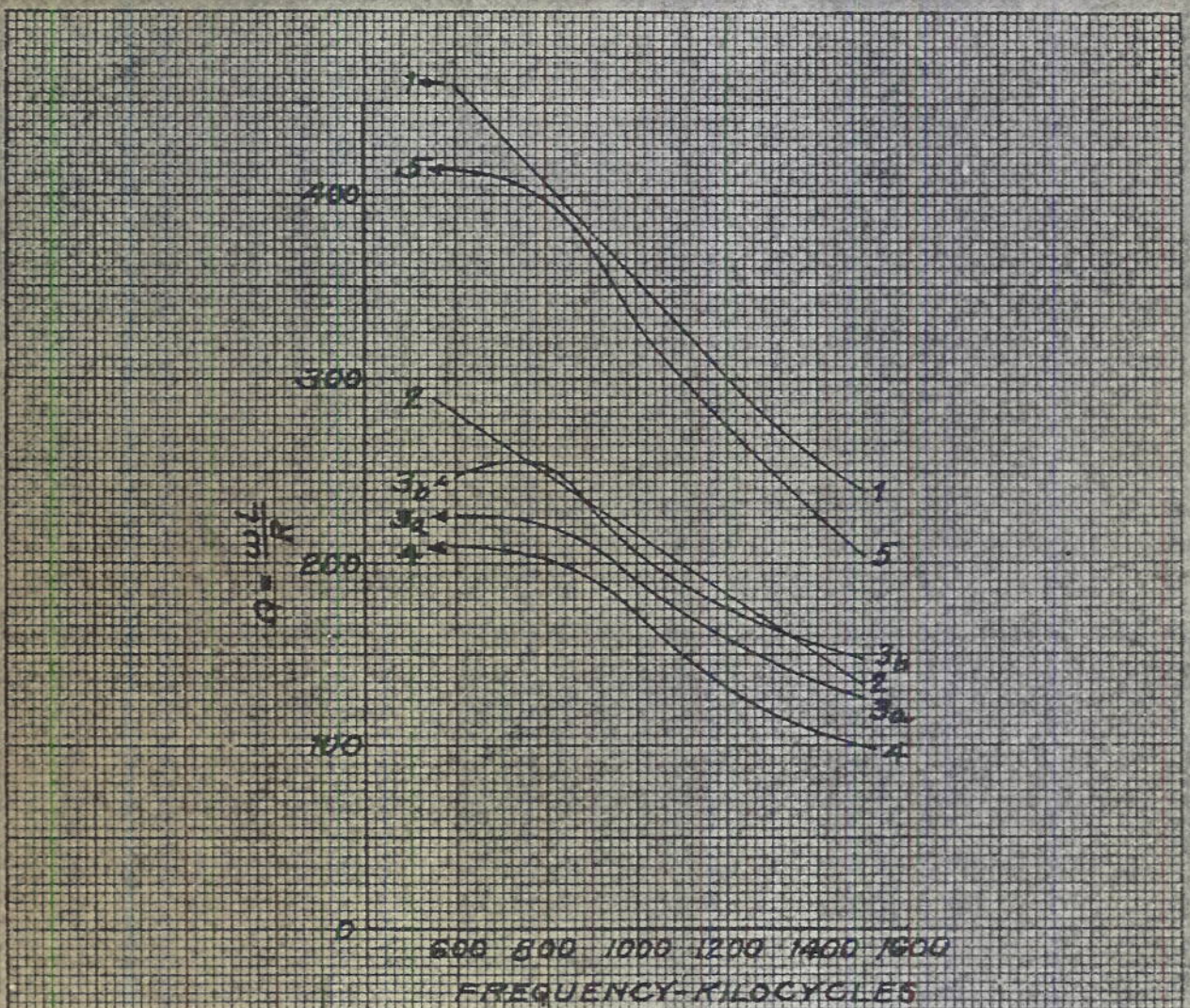
Fig. 6. Air Cored Coil with Universal Winding. Winding: Litz Wire, 60 Strands of S.W.G. #45 (≑ #41 B.&S.G.). Int.Diam. = 1", Winding Length = 5/16", L = 160 μh.

Fig. 6A. Same as Fig. 6 Except with Iron Core and Sectionalised Coil Winding Length = 5/16". Core Diam. = 9/16".

Fig. 6B. Same as Fig. 6A Except Coil Wound with Litz Wire, 20 Strands of S.W.G. #47 (≑ #44 B.&S.G.)

Fig. 6C. Same as Fig. 6A Except Coil Wound with Solid Wire S.W.G. #29 (Nearest Equiv. #27 B.&S.G.)

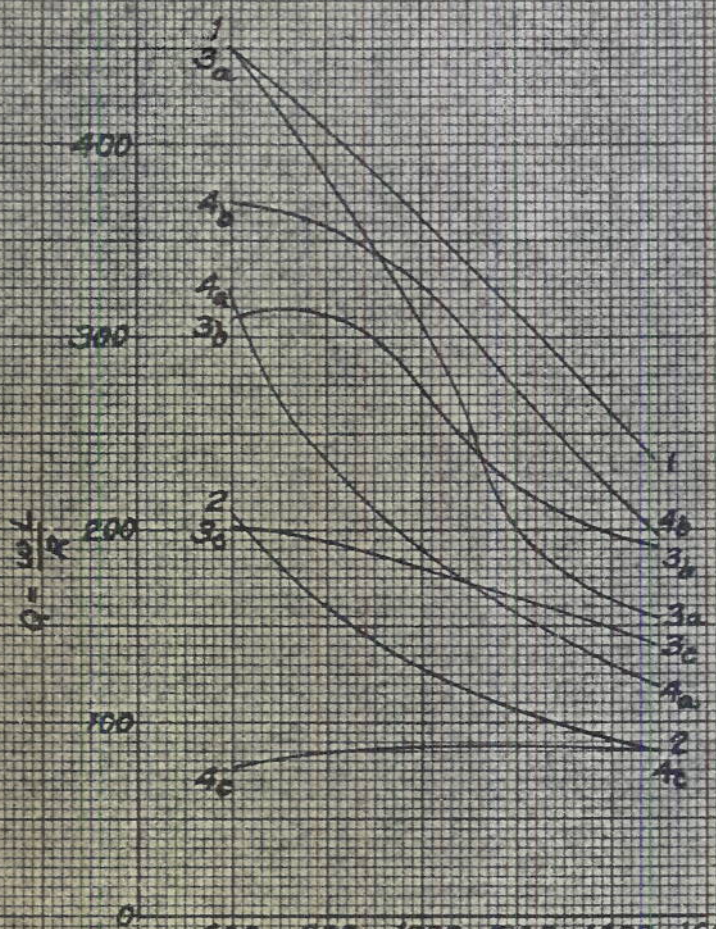
PLATE 16



COMPARISON OF THE VARIATION OF Q WITH FREQUENCY FOR VARIOUS CONSTRUCTIONAL FORMS OF COILS ILLUSTRATED ON PLATES 15 AND 16

CURVE 1 CYLINDRICAL AIR COIL -- FIG. 2, PLATE 15
" 2 IRON CORED COIL - - - FIG 3, " 15
" 3_a TOROIDAL COIL WITH LAMINATED FERROCART CORE - - - FIG 4_2 " 16
" 3_b TOROIDAL COIL WITH LAMINATED FERROCART CORE - - - FIG. 4A " 16
" 4 TOROIDAL COIL WITH LAMINATED FERROCART CORE - - - FIG. 4B " 16
" 5 UP TODATE SECTIONALIZED LITZ-COIL WITH MOULDED POT-SHAPED CORE - FIG. 5A - PLATE 16

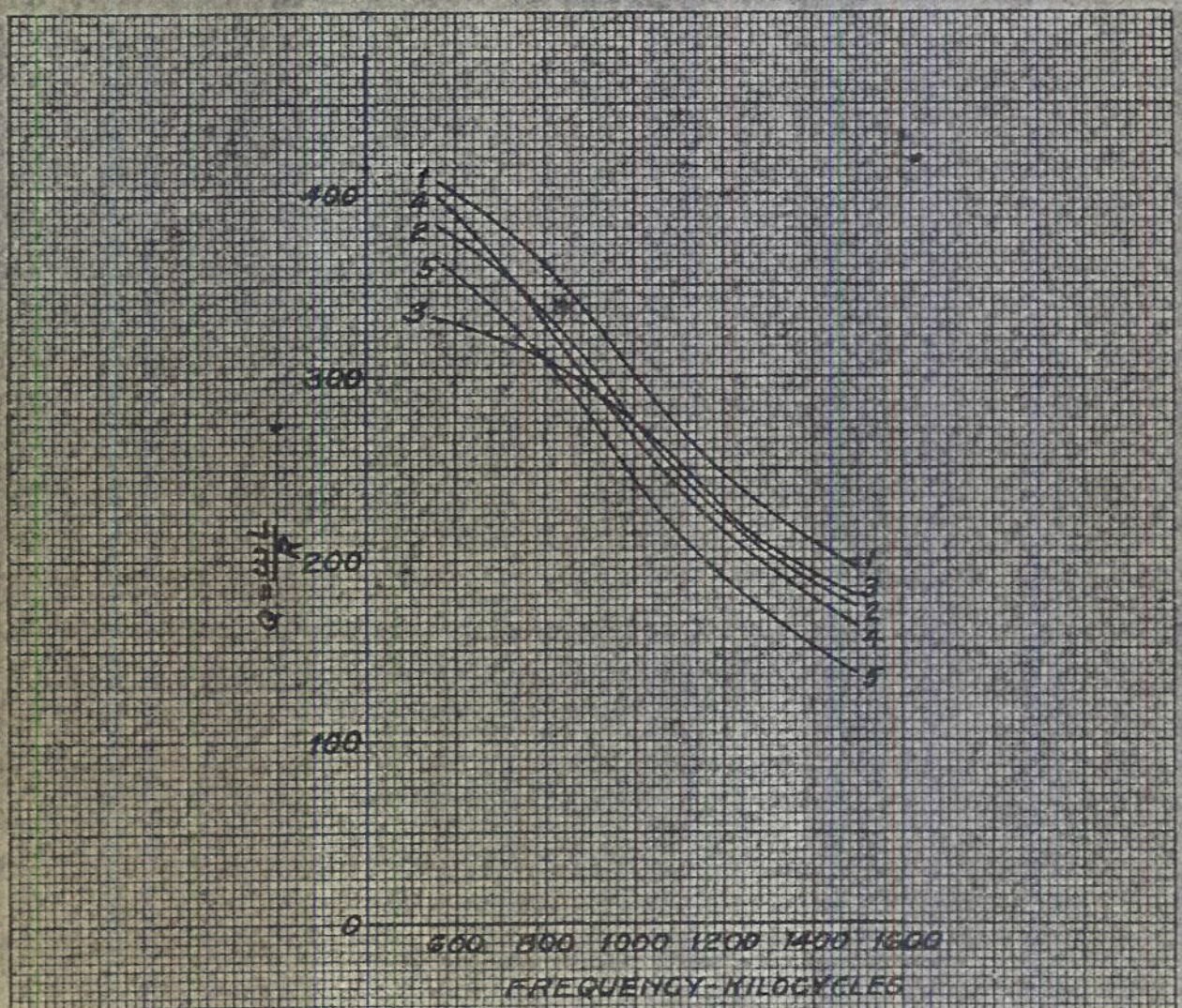
N. R. L. 31A



COMPARISON OF THE VARIATION OF Q WITH FREQUENCY FOR AIR AND IRON CORED COILS WITH SPACED AND CONCENTRATED WINDINGS, ILLUSTRATED ON PLATES 15 AND 16.

CURVE 1	CYLINDRICAL AIR CORED COIL	FIG.	2	PLATE 16
" 2	AIR CORE COIL WITH UNIVERSAL WINDING	"	6	" 16
" 3_a	CYLINDRICAL IRON CORED COIL	"	2A	" 15
" 3_b	" " " "	"	2B	" 15
" 3_c	" " " "	"	2C	" 15
" 4_a	IRON CORED COIL WITH SECTIONALIZED WINDING	"	6A	" 16
" 4_b	" " " "	"	6B	" 16
" 4_c	" " " "	"	6C	" 16

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THE INFLUENCE OF VARIOUS FACTORS ON THE EFFICIENCY OF IRON CORED COILS WITH CONCENTRATED WINDINGS, AS PER FIG. 5, PLATE 14.

CURVE 1- OPTIMUM CONDITIONS:- LITZ WIRE OF 30 STRANDS #44 B.& S. GAGE, LOW LOSS INSULATION, COIL FORM IN THREE SECTIONS OF TROLITUL.

THE FOLLOWING CURVES WERE OBTAINED BY CHANGING EACH ONE OF THESE FEATURES, MAINTAINING ALL OTHERS, THUS:-

CURVE 2- COIL FORM WITHOUT SECTIONS.

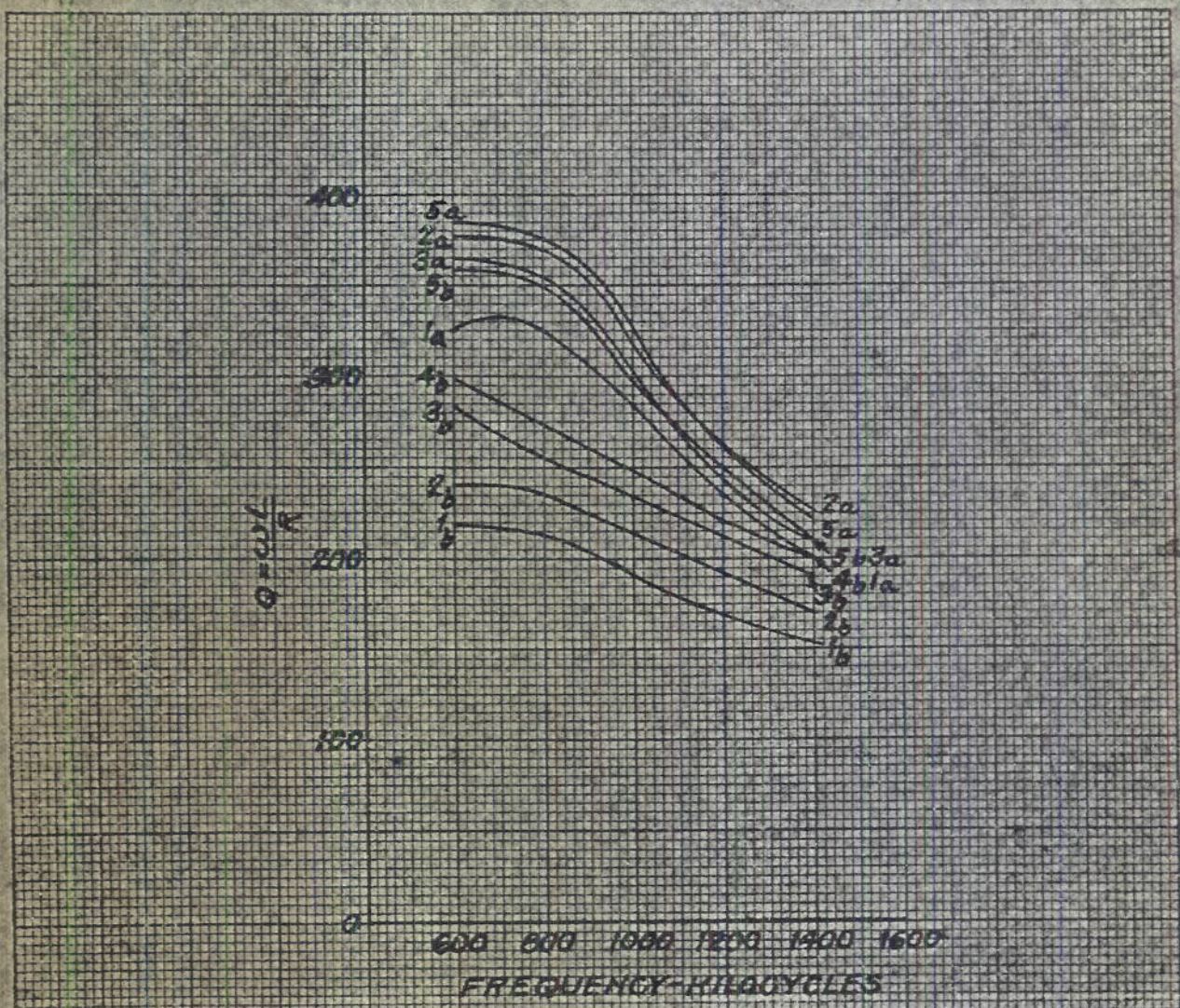
" 3- UNIVERSAL WOUND COIL INSTEAD OF SECTIONALIZED COIL.

" 4- COIL FORM OF HARD PAPER INSTEAD OF TROLITUL.

" 5- SAME LITZ WIRE BUT WITH INSULATION OF HIGHER LOSSES.

IF SHEET IS READ THIS WAY (HORIZONTALLY) THE BOOT SHOULD BE ON THE RIGHT SIDE

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THE INFLUENCE OF CORE SHAPE ON THE "Q" AND SCREENING LOSSES.

CURVE 1 - ROD CORE $\frac{21}{64}$" x $\frac{21}{64}$" x 1 $\frac{1}{16}$" LONG

" 2 - H CORE

" 3 - SPOOL TYPE CORE

" 4 - E-I CORE

" 5 - POT "

REFER TO FIGS. 5B-5A OF PLATE 16

NOTES:-

SUBSCRIPT "a" DENOTES UNSCREENED

" "b" " SCREENED WITH A COPPER SHIELD CAN, 1 $\frac{9}{16}$" DIA., 1 $\frac{27}{64}$" HIGH.

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PLATE 20