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SURVEY OF FEATURES OF GERMAN POWDERED IRON COMPONENTS

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ABSTRACT

The two most noticeable features of the German powdered iron components, as a class, are their complexity and lack of humidity protection. The Germans not only used a wide range of sizes of toroids, pots, spools, slugs and special shapes, but they resorted to very fine threaded parts, expensive ceramic coil forms and elaborate mountings which would have introduced production problems in this country. The Germans rarely accepted the sacrifice in Q attendant to molding a threaded brass adjusting screw into the core, but threaded the core itself or cemented it to a bakelite screw thread. The obvious engineering effort that went into the design of cores and mechanical accessories is worthy of notice. It is apparent that the Germans either gave higher consideration to, or had more industrial experience in, the application of powdered iron cores than our domestic users. It is unquestionable that, with the possible exception of the low-frequency materials, the German powdered iron materials in their components are superior to those that were generally available in this country at the start of the war. However, no materials tested for this report have shown marked superiority to currently available American materials. In fact, none of the German high-frequency cores have been found to approach the characteristics of those of several American manufacturers.

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INTRODUCTION

General

1. This investigation was undertaken by the Measurements and Components Section of the Naval Research Laboratory to study the various electrical and mechanical features of available German powdered iron components. Most of these components had been removed from equipment, or were contained in unidentified portions of equipment, so it generally has not been possible to analyze their circuit application.

2. The selection of components has been subdivided into the classifications of pots, spools, cylinders, toroids, and miscellaneous components. A brief description of each component has been compiled, listing interesting mechanical features or electrical characteristics, graphs of electrical performance, photographs, and, in some cases, scale drawings, core material and core material binder identification. A detailed study of the core material, while desirable, was not posaible because of the time element involved in perfecting core loss coefficient measuring equipment and in conducting metallurgical analysis.

Measurement Techniques

3. The Q-vs-frequency characteristic is probably the most significant single parameter of powdered iron-cored coils, and such characteristic curves have been obtained for most of the components studied in this report. The following explanation of the Q meter techniques employed will assist in evaluating the characteristics obtained. Most measurements were made on a Boonton Q Meter, Model 160A, though the Boonton Q Meter, Model 170 (ultra-high-frequency) was used for measurements above 30 Mc. An audio-frequency Q Meter built by the United Transformer Corp. was used for some measurements at frequencies below 10 kc, although the best results at frequencies below 50 kc were obtained from the Boonton 160A Q Meter. For these frequencies an external General Radio precision air capacitor and Leeds and Northrup decade mica capacitor were used, with the Q meter being driven from a Boonton Radio Corp. beat frequency oscillator through a shielded matching transformer.

4. Many of the powdered iron components, especially the toroidal and pot-cored coils, have quite high distributed capacitances which influence Q meter readings at high frequencies. Consequently, correction has been made for distributed capacitance whenever such corrections were significant. Distributed capacitance was measured from the intercept of the curve of $1/f^2$ plotted against tuning capacitance, usually with 5 points being taken at capacitance less than 100 mmfd. This method of measurements is considered preferable to the more common method involving the tuning capacitance for frequencies of a 2 to 1 ratio. The latter method can yield precise results only when the frequencies are known with great precision; but misleading results, including negative distributed capacitance, can be obtained when the Q meter frequency calibration is relied upon. The intercept method of measurement used in this report has the big advantage of giving no misleading impression of unjustified accuracy. It also averages out the errors from several measurements.

5. Considerable discrepancies were noticed between Q measurements made at the overlap frequencies of two ranges of the Q meter oscillator, particularly at 150 kc. These errors were traced to excessive harmonic content arising from the high LC ratio of the oscillator when tuned with minimum capacitance. These harmonics cause the thermocouple input meter (Q multiplier meter) to read high, whereas these harmonics do not affect the resonant voltage read by the vacuum tube voltmeter. It was determined that harmonic content was negligible after 1/3 of the oscillator tuning capacitance was used. Approximate corrections for this effect, amounting to as much as 10%, were made by distributing the observed overlap discrepancy in a tapering fashion over readings within the first third of the oscillator tuning condenser scale. (See Appendix 1.)

6. Trouble was experienced from the dissipation factor of mica capacitors used to pad the Q meter capacitor to lower frequencies. Approximate corrections were made in some cases, but, in general, the approach consisted of using the best available mica decade capacitor and ignoring the dissipation.

7. No corrections were made for the loading effect of the Q meter vacuum tube voltmeter, nor for the internal inductance of the Q meter terminals, as such corrections would be negligible for any but the highest-frequency coils. (See Appendix 1.)

8. Measurements of inductance, coupling coefficient, and dc resistance were made with a General Radio Model 650A 1000-cycle impedance bridge and are of limited accuracy.

History of RF Powdered Irons

9. The early work of Heaviside, the Marconi Co., John Stone Stone, Western Electric, and others, is of little significance for the purpose of this report. The first important names in the literature of modern RF core technology are W. J. Polydoroff in this country and Hans Voght in Germany. W. J. Polydoroff developed a finely powdered hydrogen-reduced iron and proposed its use in permeability tuners for broadcast receivers. This material became known to the trade as Polyiron and this term has, mistakenly, been applied to all iron dust materials. Hans Voght approached the problem of minimizing RF eddy current losses in a slightly different manner. Recognizing the desirability but impracticability of forming cores of sufficiently fine iron wire, Voght resorted to magnetic alignment of iron particles along the desired flux path. Iron powder was dusted on thin sheets of waxed paper, which were passed through a magnetic field to align the particles. These sheets were stacked and compressed under mild heat to the desired thickness. This material was marketed as Ferrocart. Even in the true laminated ferrocart, the magnetic alignment was of doubtful value since portions of the "E"- and "L"-shaped cores cut from this material were at right angles to the direction of magnetic alignment. The arguments for magnetic particle alignment of Ferrocart became absurd when it subsequently was produced in molded shapes, like Polyiron. (See Appendis 1.)

10. The next significant German development in RF core materials was the production of carbonyl iron by I. G. Farben Industries. Iron pentacarbonyl, a brownish liquid whose chemical formula is $Fe(CO)_5$, is formed by the reaction of carbon monoxide on iron at high temperature and pressure. This liquid decomposes from its vapor phase, above 200 degrees C, to produce spherical iron particles with diameters as small as one micron. Carbonyl iron now is produced in the United States by General Analine and Film Corporation, but prior to the war all carbonyl iron came from Germany and was too expensive for extensive use in American broadcast receivers. This situation was largely responsible for the more rapid development of powdered iron components in Germany, while the highly competitive nature of the American broadcast receiver industry favored the development of cheaper, but less efficient, magnetic iron oxide cores for inductance-adjustment IF transformers. (See Appendix 1.)

TOROIDS

T-1 to T-6 - Toroidal Choke Coils

11. These coils, shown in Plate 7 as received, appear to be typical toroidal coils as used in large numbers in the telephone industry. No information as to their manufacture or use is available. Numbers were assigned to the coils according to their inductance, starting with T-1 for the coil of the highest inductance.

12. Plate 8 shows a partially disassembled view of three of these coils. The cores differ in shape from those used by the Bell System in that they are not of a rectangular cross section, but are rounded on their top and bottom as shown in Plate 30. This rounded shape places less strain on the wire during winding and slightly reduces the amount of wire required for a given inductance, thus giving a slight improvement in Q. Each core is assembled from two halves and is enclosed in heavy formed paper covers which insulate the core from the winding. This method of insulating the core seems inferior to the present Bell System practice of coating cores with a heavy insulating enamel. The windings of all except T-2 were divided into series-connected quadrants. The cardboard separators either had internal fingers which were secured by the winding, or were held in position by treated silk tape. The exteriors of the coils were treated with cellulose cement or were wrapped with treated silk. T-5 was wound with unbraided litz of 35 strands, each 0.005" diameter. T-6 was wound with similar litz wire of 45 strands. This latter coil had suffered considerable rough handling and the silk covering of the litz wire was worn off and strands were broken in several places. The remaining coils were wound with appropriate sizes of silk insulated solid wire. (See Appendix 1.)

13. Q measurements are shown in Plates 31 and 32, while Plate 33 shows the decrease in Q resulting from increased hysteresis losses at higher signal levels. This pronounced hysteresis phenomena introduced complications in subsequent Q characteristic measurements, most of which had to be made with the modified Boonton Q meters. The UTC Q meter, used for data of Plate 33, operates with constant but adjustable voltage across the specimen coil,

whereas with the Boonton Q meter on its XI range (Q's less than 250) the voltage across the coil is the measure of Q, with 5 volts corresponding to a Q of 250. Other inaccuracies resulted from erratic dissipation of the capacitor decades of both Q meters so that the maximum values of Q may be in error by as much as 20% in some cases. (See Appendix 1.)

14. The table in Plate 30 gives a summary of the pertinent data on these six cores.

T-7 - Toroidal Transformer

15. As received, this unit was coated with a pitch which obscured details of its construction. Plate 7 shows the unit after most of the pitch has been removed.

16. The transformer consisted of two single-layer concentric windings separated and spaced from the core by molded shells. The coupling coefficient of the two windings was 0.852 and Q measurements were too low to be of interest. (See Appendix 1.)

17. The permeability of the core was found to be 555, which is higher than any known dust core; and as expected, the core proved to be a spiral strip. No further study has been made on this material.

CYLINDERS

C-1 - VHF Receiving Turret Assembly with Slug-Tuned Coils

18. Plate 12 shows one of two VHF tuning assemblies obtained from the Holabird Signal Depot, Baltimore, the second of these assemblies being for a slightly lower frequency range. It is believed that these assemblies were used in the FuHEV receiver covering 25 to 168 Mc. The unit consists of a transformer assembly, at the right in the photograph, the inductance of which is trimmed by coaxially driven copper slugs as shown in the foreground. All coils were padded with fixed and variable ceramic capacitors of orthodox design. The band switching terminal arrangement is especially interesting, consisting of a strong ceramic rod encompassed by the 16 contact rings. This contact arrangement was very rigid and apparently quite strong.

19. It was suspected that the powdered iron cores, which were coded blue, would represent an especially good grade of ultra-high-frequency iron. However, the Q curves shown in Plate 34 indicate little more than a very serious reduction in Q at 100 Mc. At this frequency the coil Q of 223 was reduced to 104 by addition of the powdered iron core screwed into the center of the coil. The distributed capacitance of the coil alone was 2.5 mmfd, but was increased 2 mmfd by addition of the core. The apparent permeability of the core was only 1.67. By extrapolation it appears that this core and coil would break even on Q at about 45 Mc, which compares very poorly with many American ultra-high-frequency core materials. With the American synthetic magnetite cores marketed by several manufacturers, coils can be made to break even on Q and appreciable tuning range can be obtained at frequencies in excess of 100 Mc.

20. One thousand diameter photomicrographs of this core, Plate 44, show it to be carbonyl iron of a grain size roughly equivalent to General Analine's grade D, but with a few large grain clusters. Spectographic examination of the core showed iron to be the only metallic substance present. X-ray analysis showed iron to be present only in metallic form. The specific gravity was approximately 4.0, indicating approximately 1/3 iron by weight of the sample. The binder was found to be soluble in toluene and was identified by the smell test as being polystyrene.

C-2 - IF Coil from E-230 Missile Receiver

21. One of the most interesting slug-tuned coils was found in the IF amplifier system of the E-230 receiver, used in the "Strassburg" radio control system for missiles such as the HS-293 rocket accelerated glide bomb and the PC-1400-FX high angle guided bomb. The E-230 receiver is a 12-tube super-heterodyne operating with a band-pass input circuit in the 47.5-50 Mc range, with an intermediate frequency of 2,9 Mc. The first IF coil in the RF mixer unit is link-coupled to the first coil of the IF unit, but all other IF coupling circuits are of the usual German construction; doubly tuned, capacitively coupled, with plate and grid leads tapped down on the coil.

22. Each of the two coils comprising a typical IF coupling circuit is housed in a separate rectangular aluminum shield, 3.5 x 2.2 cm and 4.9 cm long, open at both ends. The coil forms shown in Plate 13 are of a light brownish plastic, not previously seen, and identified by the Chemistry Division as Polyvinyl Carbazole, a thermoplastic recently marketed here by General Analine and Film Corporation under the trade name of Polecton. It has a power factor of 0.0003-0.001 and dielectric constant of 3. The coil form is composed of three pieces, cemented together, with the center section composed of four winding slots, 2 mm wide with 1 mm walls. The two end pieces are identical and carry the tinned terminal leads and the core adjustment assembly.

23. The core is solid slug, 1.25 cm long by 0.8 cm dia, apparently of carbonyl iron, and is cemented to the end of a short bakelite screw of 10 mm dia and 3 threads per mm, giving an adjustment of about 13 turns. The female portion of the thread is split and, though made of bakelite, it exerts sufficient spring friction to lock the core adjustment against vibration.

24. Q curves for one of these coils are shown in Plate 44A. These curves constitute a striking example of how an iron slug can raise the Q of a coil from a maximum 160 near 2.1 Mc to 240 near 1.4 Mc, and how a close fitting shield structure can more than nullify this gain. The distributed capacitance was quite low, 3.5 mmfd with or without the core and 4.0 mmfd in the shield. The inductance of the unshielded coil without its core was 49.5 microhenries and the core provided an inductance range of 93.5 to 129 microhenries, corresponding to an apparent permeability of 1.89 to 2.60. Addition of the shield lowered the maximum inductance to 105 microhenries.

25. The loss in Q produced by the shield assumes less importance when it is remembered that these coils were used at 2.9 Mc, at which frequency the Q's would be about 130 and 180 with and without the shield. The practice of using coils with very high L/C ratios, at frequencies much above the frequency of maximum Q, may be noticed in much of the German equipment. (See Appendix 1)

C-3 - Double Screw-Tuned Coupling Transformer

26. The double screw-tuned coupling transformer, shown in Plate 11, is very similar in construction to the singly-tuned coil (C-2) used in the IF amplifier of E-230 missile control receiver. The equipment in which these coils were used was not identified. The polyvinyl carbazole coil form appeared to have been fabricated from a combination of the same parts used in the C-2 coil form. However, the coils were six-turn solenoids of enameled wire of approximately 20 gauge. Each winding was doped with a transparent cement. The cores appeared to be ordinary carbonyl iron and were cemented to the ends of 2 bakelite screws, as in the case of C-2. The diameter of the cores was 9 millimeters, but their length was only 5 millimeters. With such short cores and with the end of the core reaching only to the middle of the winding space when the core was screwed in as far as possible, a minimum space of about 0.5 centimeters was left between the ends of the two opposite cores.

27. Initially, it was suspected that with this construction the adjustment of one core would produce appreciable effect upon the opposite coil. However, a test for this was made by measuring the Q of the bottom coil with its slug screwed in fully and varying the position of the core in the top coil. No change in the resonant frequency was detected over the normal tuning range of the core and the change in Q was negligible. It was impractical to detect any change in the coupling coefficient with variation of the core position by means of bridge measurements because the inductances and coupling coefficient were so small. Time did not permit testing the coil in an amplifier circuit to detect any possible change in coupling by variation in the shape of the selectivity curve. No compensating windings were used to correct for the effect of slug position on coupling, as has been done in some American transformers. But the fact that these slugs could not be screwed beyond the centers of the coils seems to be the most probable explanation for their slight mutual effect.

28. Plate 36 shows the Q curves for both windings of this transformer with slugs left in the positions in which they were found. Plate 35 shows Q curves for the upper coil with and without the tuning slug. Distributed capacitance measurements ranged from 1.3 to 3 mmfd, so an average of 2 mmfd was used for correcting the data for all four curves. The apparent permeability of 1.3 may be explained by the small sizes and limited travel of the cores.

C-4 - All-Wave Tuning Unit with Screw-Tuned Coils

29. The all-wave tuning unit shown in Plate 15 also was obtained as a loose sub-assembly from the Holabird Signal Depot and appears to have come from a German all-wave receiver constructed for non-military use. The long-wave coil at the extreme right, and its companion, represents the only examples of universal windings which have been observed among the German

components. Inductance trimming for the four coils is provided by means of powdered iron screws which are concealed within the bakelite coil tubes. The screws were similar to those used in the Lichtenstein receiver coils (C-7 and C-8) and in the Ferrocart pots (P-3) and appeared to have been molded of carbonyl iron. It did not appear worthwhile to run Q curves on these coils.

C-5 - 70 Microhenry Layer Wound Choke with Threaded Core

30. The choke shown in Plate 11 was of chief interest because of its very simple construction. The layer winding of about 18 gauge enameled wire was wax-dipped and tied with string to avoid the use of a coil form. The powdered iron core was used solely to increase inductance and to fasten it to the bakelite molded base. No inductance trimming action was intended. The coil was identified by the symbol 8(11)F printed in white between its terminals. The coil was obtained as a loose component from the Holabird Signal Depot and no information on its use is available. (See Appendix 1.)

31. Plate 38 shows its remarkably flat Q characteristic, reaching a maximum of about 50 near 1.8 Mc.

C-6 - 100 Microhenry Coil with Screw Core

32. This coil consists of a five-slot polystyrene former wound with very fine enamel wire, adjusted with a screw core and mounted between two bakelite plates. The unusual features of this core were the use of an open magnetic circuit with such a high inductance winding and the relatively crude method of mounting which almost seems to have been improvised.

33. As expected, the Q of this coil was quite low with or without its core. Also, Plate 37 shows that maximum Q's are obtained at low values of tuning capacitance, with or without the core, and the maximum Q was approximately 55. The screw core apparently was used only for inductance trimming in an application in which the highest Q was not required. The inductance measured 62.2 millihenries with the core removed and 106.8 millihenries with the core fully inserted, giving its core an apparent permeability of 1.61. The distributed capacitance was approximately 5.5 mmfd with or without the core. (See Appendix 1.)

34. The equipment in which this coil was used is unknown, but the coil obviously was used as a simple tuned circuit since, when received, four ceramic capacitors were connected across its terminals.

C-7 and C-8 - Screw-Tuned Solenoids from Lichtenstein Receiver

35. The receiver for the FuG 213 ASV radar, known as the Lichtenstein, employed seven screw-tuned solenoids as well as three miniature bakelite cased pots and a high-frequency coil trimmed by an aluminum screw. Four of the five screw-tuned solenoids are illustrated in Plate 16. Two of these coils were wound with 2-3/4 turns of bare copper wire and had been designated as C-7, whereas the remaining three coils, designated as C-8, were wound with 16 turns of silk enameled wire of about 28 gauge. These

latter three coils carried the circuit designations L-5, L-7 and L-8, whereas the 2-3/4 turn coils were designated L-23 and L-30. The screw cores of all five screws were color-coded with yellow paint.

36. The characteristics of C-7 were of considerable interest in view of the use of powdered iron cores at very high frequencies and it was hoped that a better grade of iron would be discovered than had been used in the C-1 VHF tuning assembly. However, Plate 39 shows an even less impressive set of Q curves with a maximum coil Q of 220 at 85 Mc being reduced by addition of the core to a maximum of about 98 at 27 Mc. The apparent permeability of 1.53 is slightly higher than obtained with the C-1 coil, as would be expected from the use of a longer and closer fitting core. High Q may have been of no importance in this application, but it would seem that better Q's might have been maintained more easily by the use of a copper or aluminum screw to lower the inductance rather than by the use of such poor powdered iron. (See Appendix 1.)

37. Plate 40 shows the effect of the tuning screw position upon the Q and resonant frequency of one of these coils when tuned with 60 mmfd. As explained by the very short length of the coil the effect of the screw is more abrupt at the mid position where its end passes through the center of the winding.

38. No sensible measurement of distributed capacitance could be obtained by the intercept method when using the 170A ultra-high-frequency Q meter. Only 0.6 mmfd was obtained with the screw in and, with the screw removed, the intercept passed squarely through 0. Consequently no correction was made for distributed capacitance, although it is more probable that its value was 1 or 2 mmfd.

39. As shown by the two curves in Plate 42, the 16-turn coils designated C-8 made better utilization of the powdered iron. In this case use of the core resulted in an improvement in Q below 11.5 Mc, although the maximum value of 140 obtained with the core fully screwed in was less than that obtained above 13.5 Mc with the core removed. Distributed capacitance was measured as 2 mmfd with or without the core. (See Appendix 1)

40. Plate 41 shows the effect of the powdered iron screw position on Q and on the resonant frequency when tuned with 11 mmfd. The frequency variation is gradual and uniform as would be expected from the considerable length of the winding. The unusual shape of the Q curve and its relative flatness may be explained by the fact that with 100 mmfd operation was nearly at cross points of the Q curves with and without the core.

C-9 - Screw-Tuned Transmitting Coil on Ceramic Form

41. Plate 17 shows a small transmitting coil wound on a ceramic form of interesting open-ribbed construction. Several such ceramic coil forms have been observed, but this is the only one which has been tuned with a threaded core. The core appears to be carbonyl iron and shows definite longitudinal fins from sideways molding. The cylindrical portion of the core has a diameter of 10 millimeters and a length of 20 millimeters, the screw portion being

15 millimeters long and 7 millimeters overall diameter with 12.5 threads per centimeter. The screw thread is remarkably sharp and clean for a side molding. This screw threads into a bakelite molding, numbered 1605 and carrying a manufacturer's trademark which could not be identified. The designation U-94 was printed in red on the ceramic form and probably represents the circuit symbol. The threaded portion of the bakelite piece contains a felt insert to provide friction to the screw, with the felt insert retained by a brown bakelite split washer. (See Appendix 1.)

42. Plate 46 shows that this core increases the Q of the coil slightly over the 2-to-7.5 Mc range of measurements. The distributed capacitance of 2 mmfd is increased to 3 mmfd by addition of the core. The low apparent permeability of 1.45 is not surprising from the large ratio of coil-to-core diameter.

43. Plate 45 shows that when the coil is tuned with 50 mmfd a tuning range of 5.82 to 6.29 Mc is obtained as the core is screwed in, and the Q is remarkably constant over this entire range.

44. No investigation has been made of the limitation on RF current imposed by use of the core, since this coil obviously was intended for very low power applications and core heating would be expected to be negligible.

SPOOL CORES

General Information

45. German engineers have pioneered the use of spool shaped powdered iron cores, sometimes referred to as "cotton reel" cores. These cores have a geometry intermediate between the simple cylindrical slug and the completely closed magnetic circuit of the pot core, and consist of a center cylindrical core with spool ends, but without the cylindrical cover of the pot core. Friedlaender (Wireless Engineer, September 1938) has advocated greater attention to such cores which he claims were used extensively in Germany prior to the war at frequencies in the broadcast range and which offer exceptionally high Q in the awkward range between the frequencies at which pot cores and cylindrical cores are most useful. (See Appendix 1.)

46. In view of this it was quite surprising to find that only 1 of the 8 spool cores available was used at frequencies above a megacycle, whereas 6 of these coils were used as line filter chokes in dynamotors, and the 8th one was used at frequencies near 10 kilocycles as a selective circuit for modulation frequencies in the E-230 guided missile receiver. All of the generator filter chokes were of very similar construction, with cylinders and end plates assembled to bakelite supports by means of a center screw and with slotted bakelite winding spools carrying the choke windings for both sides of the line. These windings had a series-opposing connection. In all of the dynamotor chokes the powdered iron had the characteristic shiny appearance of annealed iron, similar to American hydrogen irons, although it was most likely the annealed carbonyl iron. The following paragraphs give a more detailed description of the spool core coils. (See Appendix 1.)

S-1 - Large Dynamotor Choke of Unknown Origin

47. The choke illustrated in Plate 9 was obtained from the Holabird Signal Depot, Baltimore, without identification. Its similarity to chokes later removed from dynamotors indicates that it doubtless was used in some dynamotor which has not yet been seen. The choke is wound in a double bakelite spool having eight slots for each winding, with each slot being approximately the width of the 14 gauge enameled wire. The coil has not been disassembled, but there appears to be about six turns of wire in each slot.

48. Plate 77 shows Q curves for this choke as measured for a single winding and for both windings connected in series-aiding. The inductance of each winding was 108 microhenries with a Q of 9.5 at 1000 cycles, as measured on a General Radio 650A bridge. The series-aiding inductance was 321 microhenries and the coupling coefficient between windings was 0.49. The distributed capacitance of a single coil was 11.5 mmfd and with both coils in series-aiding was 11.0 mmfd.

S-2 - LN-27384 Dynamotor Input Choke

49. Plate 10 shows the input line filter choke from the LN-27384 dynamotor. Its construction is so obvious as to need no comment.

50. Plate 78 shows a greater difference between the single coil and series-aiding Q curves than was obtained with the preceding choke. The Q curve for a single coil is especially flat and is greater than 50 over almost a 10 to 1 frequency range. The inductances of the individual windings were 33.0 and 36.0 microhenries. The series-aiding inductance was 112 microhenries, with 27 microhenries when connected series-opposing, giving a coupling coefficient between windings of 0.614. The distributed capacitances were 10 mmfd for a single winding and 9 mmfd for both windings connected in series-aiding.

S-3 - LN-27384 Dynamotor Output Line Choke

51. This very small-sized choke is shown in Plate 10. Its construction requires no further comment.

52. Plate 79 shows surprising equality between the maximum Q's obtained from a single coil and from the series-aiding connection, both being nearly 100 at 250 kc and 175 kc respectively. High Q's at such low frequencies are expecially interesting in a component of this size. (See Appendix 1.)

53. Inductances of the individual windings were 1.48 and 1.49 millihenries, with a series-aiding inductance of 4.42 millihenries, as compared to 1.53 millihenries when connected series-opposing, representing a coupling coefficient of 0.486. The distributed capacitances were 8 mmfd for a single section and 7 mmfd for both sections connected series-aiding.

S-4 - Input Filter Choke, D_1D_2 of U10/S Dynamotor

54. This choke, shown in Plate 9 is the largest one of its type which has been seen. Each section is wound with 16 turns of #10 cotton-covered wire, with two turns per slot and 4 slots.

55. This winding was so difficult to work with and the inductance was so low that Q curves were taken only with the series-aiding connection as shown in Plate 80. The inductance of each winding was 11 microhenries with a thousand-cycle Q of 6. The series-aiding inductance was 33 microhenries. Maximum Q was obtained near 150 kc, and even at a megacycle the tuning capacitance required was so high that the correction for distributed capacitance was negligible.

S-5 - Slip Ring Choke of U10/S Dynamotor

56. The U10/S dynamotor incorporated a pair of slip rings to supply a low power ac output. Plate 9 shows the spool choke D_3D_4 used for RF filtering in this slip ring circuit. The only unusual feature of this coil, other than its stubbiness, was the fact that it was wound with unvarnished cotton-covered wire of about 20 gauge.

57. Plate 81 shows that maximum Q was obtained near 0.5 megacycles for a single winding and near 0.7 megacycles for the two windings in series-aiding. The inductance of a single coil was 47 microhenries with a Q of 3.2. The series-aiding and series-opposing inductances were 165 and 26 microhenries respectively, indicating a coupling coefficient of 0.75.

S-6 - U10/S Dynamotor Choke D_6D_7 from High Voltage DC Output Circuit

58. Plate 9 shows this coil to differ from the others chiefly in its bakelite molded supports and in the fact that the spool slots were random wound with enameled wire of about 28 gauge.

59. The Q curves shown in Plate 82 appear somewhat unusual in that no definite peak was observed above 50 kilocycles for the Q of a single coil, whereas in a series-aiding connection maximum Q appeared to occur near 70 kc. In all previous cases the frequency of maximum Q for a single coil occurred at a higher frequency than for the two coils in series-aiding. No explanation for this can be offered except that the curves peaked so close to the low limit of the Q meter that their peaks are not well defined and the results might be drastically modified by error in very few points. The maximum Q of 111 is especially high for such a small spool core wound with enameled wire.

S-7 - Draloperm Spool Diode Transformer

60. This unit shown in the center of Plate 11 is believed to have come from the Wuerzberg radar equipment. It consists of a seven-slot polystyrene former housing a two-piece spool-type core of draloperm powdered iron, a product of the Steatite Magnesium Company, Berlin. The core is not a true spool shape in that the ring forming one end-plate is embedded in a poly-

styrene form, and the remainder of the core threads into the polystyrene with an adjustable air gap between it and the fixed ring. Friction is provided for the adjustable element by three small cork blocks fitted in depressions in the core and rubbing against the recess in the polystyrene former. This core is very unusual in that it is threaded with approximately 40 threads per inch. The threads appear to have been machined rather than molded. American manufacturers have not been known to attempt making powdered iron parts with such fine threads.

61. Plate 76 is a 1,000 diameter photomicrograph of this core. The material appears to be carbonyl iron of very fine grain size, possibly equivalent to General Aniline's TH grade. Spectroscopic examination disclosed no materials other than iron.

62. As received these transformers had windings of solid silk-covered wire in slots 2, 4, and 6 only. The transformers were used as diode transformers with the outer two pies connected to the two diode plates and a center tap. The screw core was used to balance the inductance of the two outer windings, and tests of the transformer as received showed an extremely accurate adjustment.

63. Plate 83 shows Q-versus-frequency curves for this transformer. Curves 1 and 2 apply to the original winding connected with all three pies in series-aiding. For curve 2 the core was screwed into its maximum inductance position, while for curve 1 the movable section was removed, with the fixed ring remaining embedded in the polystyrene form. Presence of the core more than doubled the Q and gave an apparent permeability of 3.23. Curve 3 shows the Q of the center winding alone. It was recognized that these values of Q were not representative of the full capabilities of the core, although they are amply high for service as a diode transformer. Consequently, the unit was rewound with 225 turns of 7/44 litz, filling all seven pies. Curve 4 shows that a maximum Q of 275 was attained in this condition, but that the frequency of maximum Q dropped to about 400 kc from its original location at 3 Mc or higher. These curves illustrate the extreme versatility of design possible by changing the windings of powdered iron components. It is also interesting to note that with partially filled windings, the maximum Q occurred with capacitances lower than the 30 mmfd minimum of the Q meter, whereas with the full winding of litz wire maximum Q occurred with a capacitance of about 100 mmfd.

64. Plate 84 shows the effect of the movable screw upon the Q and upon the resonant frequency when tuned with 50 mmfd. The frequency range is unusually wide and is accompanied by a correspondingly severe change in Q.

S-8 - Draloperm Spool Coils from E-230 Guided Missile Receiver Selector Circuit

65. Plate 11A shows the type of draloperm spool cores used in the tuned circuits which select the 8 and 12 kc modulation frequencies in the E-230 guided missile receiver. These coils are of considerable historical interest in that they were first noticed in guided bombs used against allied shipping in the Mediterranian during 1943-44. The coils recovered from

missiles were so badly damaged that only fragments of the powdered iron were found, and it was assumed that these were powdered iron pot cores. One would naturally expect a closed magnetic circuit to be used in coils tuned to such low frequencies. Therefore, when undamaged receivers became available for examination, the discovery that simple spool cores had been used caused considerable surprise.

66. These coils were used as singly tuned transformers between the plate circuit of the audio output tube and the miniature Cu-O rectifiers which drove the sensitive relays. For the 8 kc coil the primary inductance was 49 millihenries (tuned plate winding) and the secondary inductance was 8.2 millihenries. The coupling coefficient, obtained from series-aiding and series-opposing inductance measurements, was 0.854, which is quite high for a spool-type core. For the 12 kc coil the primary inductance was 17.35 millihenries and the secondary inductance was 3.6 millihenries with a coupling coefficient of 0.869. The following data was copied from labels on the windings of these coils:

12 kc coil					
I	35 ohms	±5%	728	0.15	CuLr
II	44 ohms	±10%	310	0.1	CuLr
8 kc coil					
I	82 ohms	±5%	1090	0.12	CuLr
II	64 ohms	±10%	455	0.1	CuLr

67. Plate 85 shows Q curves for the primary windings of the two coils. The Q's of the secondary windings were low and are not of interest since it was the primary windings which were tuned. These coils had the highest distributed capacitance which has been observed, even including toroidal coils, being 60 mmfd for the 8 kc coil and 80 mmfd for the 12 kc coil. The Q curves superimposed at frequencies up to 40 kc, and the divergence at higher frequencies may result partially from differences in the distributed capacitance or from errors in its measurement. However, the 8 kc coils shows the lower Q, as would be expected.

Summary on Spool Cores

68. It is especially interesting to notice that the Germans would use coils showing maximum Q's of 115 and 120 above 60 kc and employing dralo-perm spool type cores which might be used at radio frequencies for an application at which high Q near 10 kc was indispensable. The Q's obtained at 8 and 12 kc were 23.5 and 34.5 respectively. It seems that such modest Q's might have been obtained from pot-cored coils of even smaller size, or that far higher Q's could have been obtained with pot cores of equivalent size. It is probable that the Germans did not want coils with extremely high Q for this application. The modulation frequencies were generated from simple self-excited oscillators, and it probably was necessary to allow for moderate drift. Also control of direction was obtained by keying the 8 and 12 kc tones alternately, the relative duration of the two tones being used to control the direction. The keying repetition rate was approximately 11 cycles per second, and individual tones might have durations shorter than

10 milliseconds. Therefore, a band width of several hundred cycles was necessary just to preserve the keying shape. It might be assumed that these particular cores were used because of their availability from other equipment and because sufficiently high Q's were obtainable with them. However, these cores have not been seen in other equipment, whereas the P-12, four-piece soft iron pot would seem to have been more suitable and was used very widely. (See Appendix 1.)

POT CORES

P-1 and P-2 - Miniature Two-Piece Pot Cores

69. The smallest pot-shaped core which has been found has been used with two types of mountings in the coils designated P-1 and P-2. Plate 68 shows a cross-sectional drawing of this core which has a height of 8.5 millimeters and overall diameter of 14 millimeters. One piece constitutes the center and one end-plate, while the other piece constitutes the outside shell and the remaining end-plate. Attention is invited to the fact that these end-plates are less than a millimeter thick, whereas with three-piece American pots of similar size the combined thickness of both end-plates practically equals the axial length of the winding space. This again illustrates the more difficult molding techniques employed by the Germans. (See Appendix 1)

70. While both were identical in dimensions, the cores in the ceramic cases (P-1) were designated FC.-spz, whereas the cores from the bakelite cases (P-2) were designated FC.-sp. The supposition that these markings indicate different grades of iron is supported by the Q measurements. The F may denote Ferrocart cores, made by the Ferrocart Corp., Berlin.

71. The bakelite cup mounting for P-2 shown in Plate 19 is very similar to that used for several larger pot coils such as P-7 and P-10. The mounting for P-1 was the most unique and interesting example of metallized ceramic technique which has been seen. The coil was housed in a ceramic cup as shown in Plate 18, with a metal shield sprayed around its circumference and around the mounting screw hole, which provides the ground connection. Terminals are provided by two ceramic segments on top of the case which are drilled radially for each terminal, with the ceramic metallized around each terminal hole. It is difficult to see how these holes could be molded, and they probably were drilled before the ceramic was fired. The core and coil were located inside of the case by a bakelite disc, a metal washer, and a spring locking ring which fitted in a groove around the lower inside of the ceramic case. No difficulty has been experienced in soldering to the metallized ceramic terminals. All together this is the simplest, most compact, and possibly the cheapest type of housing for pot coils which has been seen.

72. The coil forms used for both P-1 and P-2 also were beautiful examples of ceramic technique. These two-section spools had flanges of almost eggshell thickness. Yet, of six such spools examined no evidences of chipping or fracture were observed.

73. Plate 43 is a Q curve for the P-1 coil which showed maximum Q of 120 near 1 Mc and which had an inductance of 102 microhenries. (See Appendix 1)

This coil was wound with solid silk-insulated wire. The P-2 coil, removed from a FuG-213 (Lichtenstein radar) receiver was wound with enamel wire and consequently had a considerably lower Q as shown in Plate 46A. An interesting aspect was the surprising flatness of its Q curve above 0.5 Mc. One of these coils was rewound with 245 turns of 7/44 litz. As rewound the coil alone showed a maximum Q of 96 near 0.9 Mc, and placing it in the pot raised the maximum Q to 130 at 0.45 Mc. This is more than a two-fold increase in Q over that initially obtained with the winding of enamel wire, but still is not especially interesting inasmuch as Q's of 180 have been obtained in American pots of similar size and at similar frequencies. The distributed capacitances of these coils ranged between 6 and 12 mmfd.

P-3 - Ferrocart Csp Cores

74. The small ferrocart Csp core, as shown in Plate 24, was used very extensively in German equipment. Generally it was mounted in a hexagonal metal can as shown in Plate 21, but occasionally it was used in a similar unshielded mounting as shown in Plate 24. Plate 21 is an exploded view of the Bv 16714 transformer. In either case the core was clamped between bakelite molded members, the upper one of which carried four pairs of terminal positions. A heavy felt washer surrounded the powdered iron inductance adjusting screw and served to lock its position by means of friction. Three-slot ceramic coil forms generally were used, and these were of beautiful construction.

75. Plate 69 is a cross-sectional drawing of this core showing that only 1/2 of the cup was internally threaded for the adjusting screw which occupied a large portion of the internal diameter and restricted the area available for the winding.

76. Plate 20 shows 1,000-diameter photomicrographs of this ferrocart core material. The material obviously is carbonyl iron of reasonably fine average grain size, but it contains some very large iron inclusions of unexplainable origin. These may have resulted from contamination with iron filings as it is not probable that the Germans would have added such large iron particles intentionally.

77. Plate 47 shows Q-vs-frequency plot for the core when used as a diode transformer. Curve #1 shows effect of connecting three windings in series; curve #2 shows effect of one section only.

78. Plate 48 shows a Q curve for the unshielded core which is illustrated in Plate 24. This coil was incompletely wound with solid silk-covered wire and shows its maximum Q of 215 at approximately 1.5 Mc.

79. Plate 49 shows the results obtainable with the Ferrocart Csp pot when rewound with 7/38 litz wire. The first four curves apply to a coil of 138 turns wound in the three slots of the original ceramic coil form while the last curve shows the results obtained with a universal winding of 156 turns. In this case use of the powdered iron pot almost triples the Q obtainable from the coil alone. The inductance adjusting screw makes a very limited inductance adjustment and reduces the Q slightly as it is unscrewed. Pre-

sence of the shield can lowers the maximum Q in the screw-in position from 250 to 184. The universal winding shows a much higher distributed capacitance than the three-pie winding with 19 mmfd as compared to 8.5 mmfd, and the larger number of turns changes the point of maximum Q to a slightly lower frequency.

80. Plate 50 shows the effect of the inductance screw adjustment upon the Q and upon the resonant frequency when tuned with 450 mmfd, using the 156-turn universal winding.

P-4 - AEG Pot Core for Oscillator

81 The AEG pot core assembly SK 635 301 shown in Plate 22 is a good example of a three-piece pot using a movable end-plate for inductance adjustment. Traverse of this end-plate is accomplished by means of a fine thread bakelite screw cemented to the powdered iron plate. Once adjusted, the screw is secured by means of a wax or paint seal in the bushing.

82. Plate 70 shows a cross section of the iron path and dimensions. Proportions of the various parts appear to be similar to those used in this country.

83. Plate 51 gives plots of Q-vs-frequency for maximum and minimum inductance and frequency-vs-end-plate traverse. The peak Q value of about 190 occurs just below 2 Mc, and a frequency adjustment of 15% was possible with 100 mmfd of capacitance.

84. Attention is invited to the two-piece bakelite housing, Plate 22, which provides core clamping, mounting, and provisions for as many as nine terminals (attached by simply inserting a flat lug and twisting). The sectionalized coil form is also of interest for its extremely thin wall thickness.

P-5 - IF Coil from FuG-16 Aircraft Receiver

85. The pot type coils MV311, MV312 shown in Plate 23 are the three-piece movable end-plate type similar in construction to component P-4. The transformer SK 558 282, N 506 271/23 from a FuG-16 Aircraft Receiver is a 2.9 Mc IF unit of the capacitive coupled type, with inductances and capacitances adjustable from the top of the can.

86. Each pot is housed in a two-piece molded bakelite mounting which has metal inserts molded in for mounting, slotted-countersunk holes for a twist type terminal lug, and molded-in lugs for mounting the tubular condensers.

87. Curve plots on Plates 52, 53 give the Q-vs-frequency characteristic for the pots with the original solid wire and the characteristics with a rewind of 7/38 litz wire. Effective permeability, determined by the ratio of coil inductance-in-pot to inductance-in-air, was 3.9.

P-6 - SK 630291 Pot Coil

88. The pot-type component shown in Plate 24 is an audio coil apparently used as an oscillator. The core consists of five pieces; two end-plates, a shell, and a two-part center hollow-cylinder slug. Adjustment of inductance is accomplished by moving one piece of the center cylinder to introduce an air gap in the center of the coil. This mechanical movement is obtained by having the slug cemented to a knurled bakelite cap having a threaded concentric hole to fit a threaded screw which is in the axis of the component.

89. Plate 55 shows the Q-vs-frequency plot for the core with the original coil of random-wound solid enameled wire. The coil peaks at 6 kc giving a Q of 70, which is probably inferior to values obtainable with domestic permalloy dusts. Rewinding the core with 20/38 litz produces good Q values at frequencies of 40 to 80 kc as shown in Plate 54.

90. The rather elaborate two-piece molded bakelite end-plates provide mounting, core clamping, and terminals.

P-7 - HF-B1 Pot Coil

91 The pot-type coil HF-B1 shown in Plate 25 is a low-frequency adjustable inductance. The coil consisted of a random wound solid wire three-section assembly, wound in a porcelain form.

92. The core construction as shown in Plate 71 consists of two half- shells with threaded center hole, and a threaded adjustable slug. Threads in the shell piece appear to be machined while those on the slug are formed in the molding process. No provision is made for locking the slug in adjustment other than a tight thread fit.

93. Plate 56 is a plot of Q-vs-frequency for the two extremes of adjustment with the original coil. A maximum Q of 128 was attained at 33 kc for this coil. Rewinding the coil to fill the form with 10/38 litz wire resulted in a maximum Q of 232 at 550 kc, Plate 58. The effective permeability of the pot is 3.6.

94. The mounting consists of a two-piece molded bakelite clamp with provision for solder lug type terminals. Clamping of the two half-shell cores is assured by two tension springs.

P-8 - Ferrocart Cspz Core

95. The pot-type coil shown in Plate 26 is similar in mechanical detail to component P-7 except for a single-section coil form. No technical data were taken because the core's material, Ferrocart Cspz, was similar to others in this report. The pot was received unmounted.

P-9 - Pot Coil from WES-2 Radiosonde

96. A photograph and cross-sectional drawing of this coil are shown in Plates 27 and 72. The coil was wound with very fine enameled wire on a three-section polystyrene spool. Since the leads had been broken in removing

the coil, no measurements could be made. Presumably the coil had very high inductance and poor Q because of the fine enameled wire. The iron resembles that of many other pot cores and presumably is carbonyl. Doubtless the coil could be rewound with litz to yield Q's approaching 200 at lower inductances.

97. The chief point of interest appears to be the use of a completely threaded inner member to permit inductance trimming by a powdered iron screw, together with mounting to the chassis by means of a bakelite screw. This provides the simplest and lightest method of mounting a pot core in a radiosonde. Terminals were dispensed with for such an application. This use of a powdered iron screw in such a small pot core results in a relatively large diameter of the center leg and a consequent loss of winding space.

P-11 - SK 638 421 - Transformer in Shielded four-piece Pot Core

98. A photograph of this coil is shown in Plate 24 and a cross-sectional view of its core is shown in Plate 73. The coil is wound with fine enameled wire and consequently shows a Q too low to be of interest. Terminals A_1, A_2, and A_3 connect to a tapped winding having a total inductance of 600 millihenries and a dc resistance of 190 ohms. The tap, A_2, is asymmetrically located, with a resistance of 33 ohms to terminal A_1. The B_1B_2 winding has an inductance of 21 millihenries and dc resistance of 135 ohms. The coupling coefficient was calculated from series-aiding and series-opposing inductance measurements to be 0.885, which is reasonably high for this type of coil.

99. An unusual feature of this coil is its extremely close-fitting shield can, which lowers the inductance about 1.5%. The effect on the Q is probably much more pronounced, but the Q is too low to be of interest.

100. The core is of soft powdered iron having the characteristic glossy surface, and the core is assembled from four pieces by means of a central screw which also assembles it in the shield can.

P-12 - Four-piece Pot Core MV280

101. The inductance shown in Plate 28 is a four-piece pot similar in proportion to some of our larger domestic pots. Dimensions are given in Plate 74. Terminals are molded into the disc type bakelite end-plates used for clamping. The entire assembly is secured by means of a brass screw down the center of the core. This is one of the few instances where metal was introduced into the magnetic path. The coil was of enameled wire wound into a four-section plastic former.

102. Plate 57 gives a Q-vs-frequency plot for the original coil and for a rewind with 15/44 litz wire. An attempt to raise the Q by removing the bright surface of the core resulted only in a loss of Q, probably proportional to the reduction in iron area.

P-13 - Pot-type Transformer SK 637 481/1

103. The pot-type transformer shown in Plate 28 is on a four-piece core similar, except for size, to component P-12.

104. Plate 67 gives the Q-vs-frequency plot for one section of the coil and for all sections in series. Performance is comparable to that of domestic cores.

P-14 - 175 kc IF Transformer

105. Plate 29 shows an interesting design of an intermediate-frequency transformer obtained as a loose component from Holabird Signal Depot. The windings of this transformer are completely housed in separate powdered iron pots which are adjusted in position by sliding along the metal side pieces of the assembly. Sufficient magnetic flux leaks through these powdered iron pots to provide the requisite loose coupling. Both coils were tuned by variable air capacitors, padded with mica capacitors. These mica capacitors were not of the usual molded construction but appeared to have been dipped in some hard wax. The 0.25 mmfd Ducati tubular capacitor (71) was used as a plate by-pass capacitor. This capacitor is an Italian make of molded construction, though it resembles our cheap tubular paper capacitors. The large size of this transformer, together with its use of variable air trimmers and mica padders, suggests that it is of pre-war construction, and its low frequency (175 kc) suggests that it came from a low-frequency communication receiver.

106. Plate 75 shows a selectivity curve of this transformer as connected in an amplifier of conventional design. Its 3 db band-width was 2.7 kc, which is definitely too selective for voice frequency use.

Conclusion - Pot Cores

107. See Appendix 1, page 27.

MISCELLANEOUS CORES

M-1 - Transmitting Coil on Ceramic Form with Hollow Cylindrical Core

108. This coil shown in Plate 1 was obtained from the Holabird Signal Depot without identification except for the symbol P19F stamped on its base. The coil is wound with 15 turns of about 18 gauge bare copper wire, with a mean diameter of 4 centimeters and a winding length of 3 centimeters. The last turn of the winding is tapped at numerous points. The carbonyl iron core had an inside diameter of 1.8 centimeters, outside diameter of 3.2 centimeters and was 3.4 centimeters long, with a groove cut lengthwise to clear the coil leads where they were anchored through the ceramic form. The core was cemented into the ceramic form with a ceramic cement which was very difficult to chip loose without damaging the core. The binder used in this core material was identified as bakelite by means of its odor when scrapings were heated on a spatula.

109. Plate 59 shows Q curves of this coil with and without its core. The inductance, calculated from Q meter data, was 7.22 microhenries without the core and 14.5 microhenries with the core, giving an apparent permeability of only 2.0. The distributed capacitance was 4.5 mmfd without the core and increased to 7.5 mmfd when the core was inserted. The Q curves indicate that

the core lowered the Q of the coil very seriously at the higher frequencies and improved the Q only below 2.5 Mc. (See Appendix 1.)

110. Plate 64 shows the temperature rise of this coil as a function of RF current, taken at a frequency of 4 Mc. The heat became excessive at currents above 2.6 amperes and a faint odor was noticed from the ceramic cement. Similar tests with the core removed indicated that approximately twice as much current could be handled for equal temperature rise at the same frequency without the core. Altogether, it is quite difficult to understand why a powdered iron core was employed in this transmitting coil since no increase in Q was obtained and the added weight of this core appears to have represented too great a price to have paid for the slight saving in size which it produced. (See Appendix 1.)

M-2 - Siemans Halske Dynamotor Choke from VG-136 Nachtfee Equipment

111. This choke, shown in Plate 2, was one of the most unusual powdered iron components discovered. The core was composed of four "L"-shaped pieces which were assembled into a closed magnetic circuit through two series-connected coil bobbins wound with enameled wire. The coil was potted with wax in a metal can. The case carried the identification SDR 1734, 500 V, 4 amps, 225 microhenries, 60°C. (See Appendix 1.)

112. Plate 60 shows that the Q characteristic was reasonably flat with a maximum Q of 38 occurring at 600 kc. These results were obtained with the coil in its case, and somewhat higher values probably would have been obtained with the case removed. But high Q is not to be expected in a dynamotor choke.

M-3 - 56.8 Millihenry Choke with "E-I" Core

113. Plate 3 shows a photograph of this choke removed from its shield can. This choke is believed to have been removed from the DT5012 transmitter rectifier of the FuM026 ship radar. Similar coils have been seen in a variety of German electronic equipment. The core is of an "E-I" shape, and is composed of 2 "E-I's" stacked together. The edges are concealed by insulating strips, and many observers have mistaken it for a conventional laminated core. These cores are very fragile and all such cores thusfar examined have been fractured in one or more places so it is possible that slightly superior Q characteristics might be obtained with an unfractured core.

114. The winding consisted of enameled wire wound in layers in the four slots of a bakelite spool of nearly circular winding section, with each winding covered with strips of empire cloth. The wire size was estimated to be about #30.

115. The Q characteristic of this coil, shown in Plate 61, seems decidedly disappointing for a coil of its size, especially when compared with M-4, the type F-22 120 millihenry choke occupying about 1/10 the volume and having a greater maximum Q. It is believed that the size of the "E-I" choke was dictated more by voltage insulation requirements than by the need for maximum Q.

M-4 - Type F-22 Choke with Double L-Section Core

116. This choke, shown in Plate 3, was mounted in a bakelite molding and housed in a cylindrical can. Its rated inductance was 120 millihenries, ±10% with its resistance R_g = 190 ohms ±10%.

117. Plate 62 shows that the maximum Q of 108 was reduced to 70 when the coil was placed in its shield can. These Q's are relatively high for such a small coil layer wound with enameled wire. The manufacturer's trade mark also is shown on Plate 62, but has not been identified.

M-5 - Variometer from FuG-10 Antenna Coupling Unit

118. This variometer, shown in Plate 4, was a very interesting example of ceramic technique and employed a very large core within its rotor. Both the stator and the rotor were wound with flat copper ribbon, and the rotor winding was symmetrically connected to the split stator winding. The variometer also contained a compensating winding metallized on the inner surface of the stator and completed by means of broad copper straps. The core was so mounted inside of the rotor that it could not be removed except by breaking the ceramic. Therefore, it was impossible to check the effect of removing the core.

119. A toroidal ring machined from this core showed a permeability of 12.1. The material could be machined only with a carbaloy cutter, indicating that the material was unannealed carbonyl iron. The binder was identified as bakelite. Several of these cores showed very noticeable rust spots, indicating lack of corrosion protection.

120. Loss separation measurements were attempted without success because the copper resistance of the toroidal winding masked the hysteresis and eddy current loss resistances within the frequency range of the impedance bridge which was available. This result was not surprising in view of the low permeability of this material.

121. Plate 63 shows Q characteristic curves taken with the rotor in its maximum and minimum inductance positions. The tuning range was approximately 2.5 to 1, which is not much greater than would be expected from variometers without cores. The maximum Q was not as high as might be expected from a coil of this size, but there was no large variation in maximum Q with rotation of the variometer. (See Appendix 1.)

M-6 - Airborne Direction-Finding Loop Cores

122. Plate 5 shows the LN-28067 airborne direction-finding loop antenna which employs a powdered iron core consisting of four rounded rods positioned inside of a loop case. The loop itself is wound with 14 turns of very heavy litz wire placed in slots in the bakelite case. (See Appendix 1.)

123. No measurements were made on this antenna coil itself since it has received extensive prior study by the aircraft people. A test toroid and an RMA test core were cut from one of the powdered iron rods as shown in Plate 6. This toroid showed a permeability of 51, which is exceptionally high for

powdered iron materials. Q-vs-frequency plot for the ring is shown in Plate 65. The ease with which this material was machined without dulling ordinary cutters indicated that it was an anealed carbonyl iron similar to General Analine's HP grade. Altmann and Beller (Electronic Industries, November 1945) obtained permeabilities of 55, together with satisfactorily low loss coefficients from the American HP carbonyl iron. Loss separation measurements are being attempted on another toroid similar to the one in Plate 6.

124. Plate 66 shows a comparison between Q curves obtained with RMA test slugs of the Pyroferric Company's type PAT iron and the slug cut from the German loop core, together with Q curves for the three lowest frequency RMA test coils as measured without cores. It will be noticed that similar values of maximum Q were obtained with both cores, but the German material showed considerably higher permeability. No information is available at present concerning the material used in the Pyroferric type PAT cores, but presumably it is a hydrogen reduced iron. No RMA cores of General Analine HP carbonyl were available for comparison.

125. Attempts to determine the binder used in this core were unsuccessful. A very slight amount of binder was present, and its odor was somewhat similar to that of some waxes.

BINDER MATERIALS

126. Several specimens of iron were submitted to the Chemistry Division for determination of the binders used in molding various cores. The analysis technique consisted merely of crushing a sample of the core, heating it sufficiently to decompose the binder, and identifying the organic material by its odor. In this manner it was determined that the screw cores used in the C-1 ultra-high-frequency turret assembly and in the C-7 and C-8 Lichtenstein receiver coils used polystyrene as a binder. The core used in the FuG-10 antenna coupling variometer contained a bakelite binder as did the soft iron used in the Sk 630 291/1 pot cores (P-6). The core used in the M-1 transmitting coil also had bakelite binder. A positive identification could not be obtained for the binder used in the draloperm core for the S-4 diode transformer. The binder seemed to be an organic resin and was present in sufficient amounts to be smelled easily.

127. No positive identification could be obtained for the binders used in the M-2 dynamotor chokes, nor in the M-6 d-f loop antenna cores. Both of these cores seemed to contain very minute amounts of binder, and the best guess that could be hazarded was that it was some form of wax.

CONCLUSIONS

Toroid Cores

128. All of the toroid cores studied were for low-frequency application and appear to have conventional electrical characteristics. Physical differences such as two-halve molding, paper-cup core insulation, and paper sectional barriers for random winding, are of interest. The radius of curvature on the corners of the cores was considerably greater than domestic

products and probably f cilitated higher winding speeds without excessive strain on the wire strands. None of the samples had permeabilities as high as our domestic products, but this is no indication that such materials were not used. The advantage of litz wire for large wire size at low frequencies was recognized and used in two of the six components studied. The advantages of toroid coils and cores are so well known and their use so universal that nothing of undue interest was found or could be expected.

Cylinder Cores

129. The cylinders examined were of the carbonyl type of iron and were used principally for permeability trimming. Effective permeabilities of 1.5 to 2.6 were found, and the lower values were used at frequencies up to 100 Mc. However, the highest frequency component studied broke even on Q at about 45 Mc, a frequency somewhat lower than that of our best domestic core materials. The repeated use of finely molded threads on cylinders, and the cementing of the cylinders to threaded phenolic stubs were of interest, as was the use of narrow multi-pie plastic coil forms, a method of coil construction reputed to be superior at higher frequencies to universal-wound coils.

Spool Cores

130. The spool core, though seldom used in domestic applications, is a type of core known to be superior in the frequencies between pot and cylinder cores. It was somewhat disappointing to find that most of the components studied were for dynamotor line filtering with lower-frequency characteristics. All of the coils were of the multi-pie type wound in either phenolic or draloperm forms. The choice of the spool core for these dynamotor filters, rather than a closed core, may have been governed by mechanical considerations.

Pot Cores

131. The various pot cores studied were probably the most interesting of all the cores. They offered the greatest variety of shapes, intricate molding, threads, coil forms and mechanical mounting. All of the permeability inductance trimming was accomplished by means of threaded slugs instead of threaded rods molded into the slugs. All the core materials identified were of the carbonyl type. With the exception of the lowest-frequency components, which used materials inferior to some of our permalloys, characteristics were comparable to that of domestic materials.

Miscellaneous Cores

132. Two types of closed cores discussed, an "E-I" and a double "L" were of interest for their shapes, molded coil forms, and simple mounting. The Q value of the latter, 108 and 70 out of and in a case, was high for so small a component. The variometer was an interesting example of the combination of molded powdered core material and ceramic form with a compensating winding plated on the inside of the form. The one transmitter coil core was of very ordinary quality and contributed a size reduction only at some sacrifice in quality of the coil. The direction-finding loop was of interest chiefly for its high permeability anealed carbonyl core, which seemed to be similar to the doemstic General Analine HP grade.

133. The core materials studied were, in general, superior to those available in this country at the start of the war with the exception of the low-frequency permalloys. However, the materials were not superior to our present domestic products and were inferior to our highest-frequency materials. It would seem that it was principally the German attention to mechanical design and application that was most noteworthy in this survey.

ACKNOWLEDGEMENTS

134. An acknowledgement is made to Mr. Jack B. Greenberg who performed much of the testing and evaluation work, and to Mr. Harold M. McKee who aided in the final preparation of this report. In addition, valuable suggestions and comments were made by Mr. W. J. Polydoroff of Chicago, Ill. A portion of Mr. Polydoroff's comments are included as an Appendix to this report.

APPENDIX 1

Remarks by W. J. Polydoroff on the Tentative Draft of the NRL Report on German Powdered Iron Components

Abstract

We do not try to get excessively high performance of iron cored components in this country. Army and Navy specifications usually limit the performance of coils to medium "Q", which could be easily maintained in adverse atmospheric conditions. To my knowledge, which was confirmed by General Analine Works, Germans did not have materials like carbonyl SF or IRN 15-16-17-8 & 9, which are of different than pure iron composition and therefore applicable to very much higher frequencies.

Introduction

5. It is believed that the mistake due to high harmonic content can be corrected by using an external capacitor with the oscillator circuit with lower inductance coil of previous range, which of course would require recalibration of the oscillator.

7. In existing construction of Q meter the loading effect of the voltmeter tube is already noticeable in 170-A type meter; when working with extremely small inductance values of this meter the correction of internal inductance of the meter should be always applied.

9. Early "Polyiron" materials were fine hydrogen reduced powder (George S Mepham Type 14-B) which was insulated by organic varnishes and then molded with phenolresin (Bakelite). The "Ferrocart" in paper laminated core layers was abandoned by Voght in 1933, and all further cores of this company were molded with bakelite.

10. The magnetite cores (Fe_3O_4) were largely used and patronized by the radio industry because of its cheapness and for certain patent reasons. Its usefulness is limited to IF transformers at 456 kc or lower and for inductance adjustments up to 2 Mc. The further developments of carbonyl by GAW brought out two finer grades called TH - particle size 1 to 8 microns, and SF - 0.8 to 4 microns, which are obtained by air separation from the basic E.

11. Further developments in this country of purely American origin were alloyed powders obtained by simultaneous reduction in hydrogen of mixtures of oxides of iron and other materials, which alloyed particles possess much higher material resistivity.

Toroids

12. The toroidal loading cores produced by the Automatic Electric Co. of Chicago are usually molded in two halves, each having semi-circular cross sections so that two cores together form a cross-section of a circular pattern.

13 . From these data hysteresis loss coefficient can be approximately computed. Plate 30 shows, as should be expected, that the toroidal core having the lowest mu produced highest Q at high frequency.

16. In spite of very high mu of the material, the coupling coefficient is rather low as compared with domestic designs of pot trans formers in which K up to 0.92 is available.

Cylinders

25. Missile Transformer. Very high L/C gives higher gain and reduced stability of operation.

30. These screw cores of Choke C-5 can be adjusted and locked by the nut shown on the photograph, Plate 11.

33. This construction demonstrates how easy it is to obtain high Q at low frequencies.

36. Very poor performance according to American standards where at those frequencies Q over 150 could be expected.

39. Apparently the iron powder used is too coarse.

41. All American screws were at first side-pressed in molds. Recently the technique was developed to thread the cylindrical cores on circular grinders before they are cured.

Spool Cores

45. This is German preferred construction with two moldings and cemented plastic coil former which is threaded, from which one obtains easy adjustment, high Q, and the effects approaching a closed type core.

46. German Carbonyl C is an anealed powder used for radio frequency and telephone cores. The coils when extracted from molds are naturally shiny.

52. This is a usual English construction for low but constant frequency. The chokes discussed in paragraphs 49-59 indicate that at higher frequencies for better choking high grade coils with iron are preferable.

Summary on Spool Cores

68. This shape is neglected in this country although it proves itself quite well in Germany through different advantages for inexpensive applications of such construction in midget IF transformers where high Q, high mu, and semi-closed pot are available.

Pot Cores

69. Even small pots were molded by Ferrocart Corp. of America in the U.S. during the war.

73. Remarkably good performance for such small coil as P-1.

Conclusion - Pot Cores

107. Nothing new can be learned from German pot cores except their extensive use of threading cores for adjustment. American industry prefers molded threaded inserts in cylindrical cores.

Miscellaneous Cores

109. Transmitter core of Plate 1 is very interesting construction. It appears from the use of bakelite binder that this core should not be used in cases where heat dissipation is in excess of 100°C, after which temperature bakelite starts to decompose itself into carbon. It is not that the Q of the coil alone is noticeably higher than the Q of the core. It would be interesting to learn what would be the Q of the coil of same inductance wound on the same tube but without the core. If it proves to be higher, then the use of iron was unnecessary.

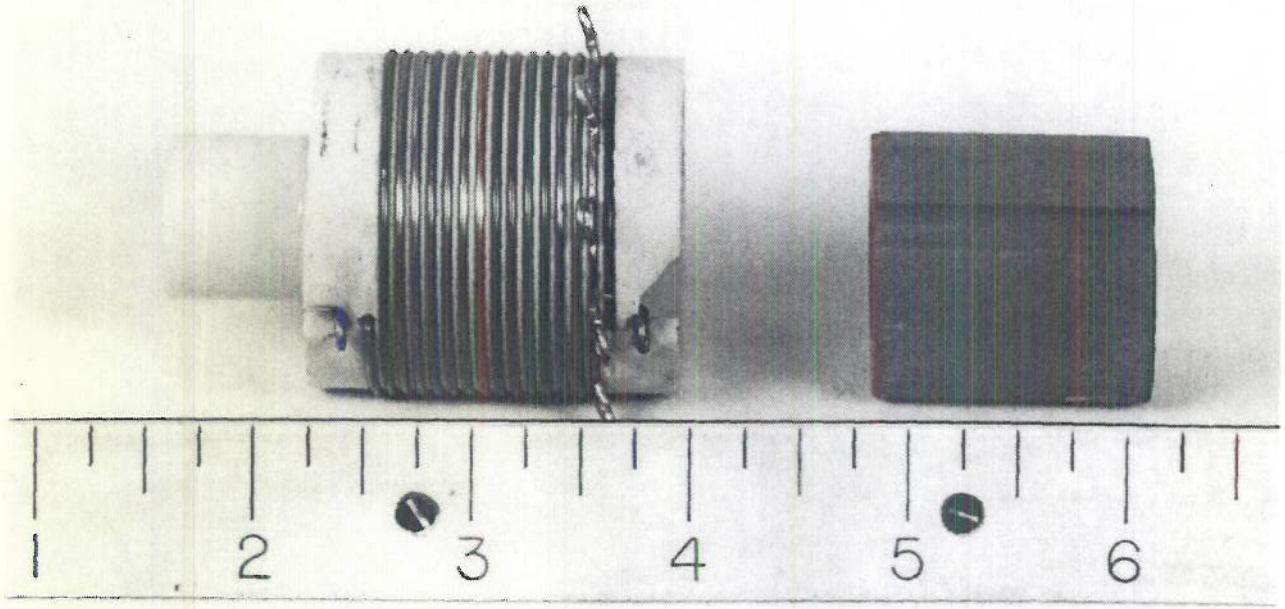
110. The only apparent justification of iron may be in the increased coupling coefficient if this coil is coupled to the antenna as may be indicated by the various tabs.

111. This was preferred construction of British Marconi Company before the war.

121. It is believed that large inductance variation could be expected from such variometer. Maximum and minimum inductance should be measured as well as Q at the corresponding maximum and minimum frequency with fixed capacitor across.

German Loop Core

122. This is a second, advanced design of German loop and was not as well created as the first loop employing oval cores. It would be of considerable interest to learn the apparent permeability of the core in that loop as it is in the direction of increased h effective due to the iron.



COMPONENT M1 - TRANSMITTING COIL

PLATE 1

COMPONENT M2 - SIEMANS HALSKE DYNAMOTOR CHOKE

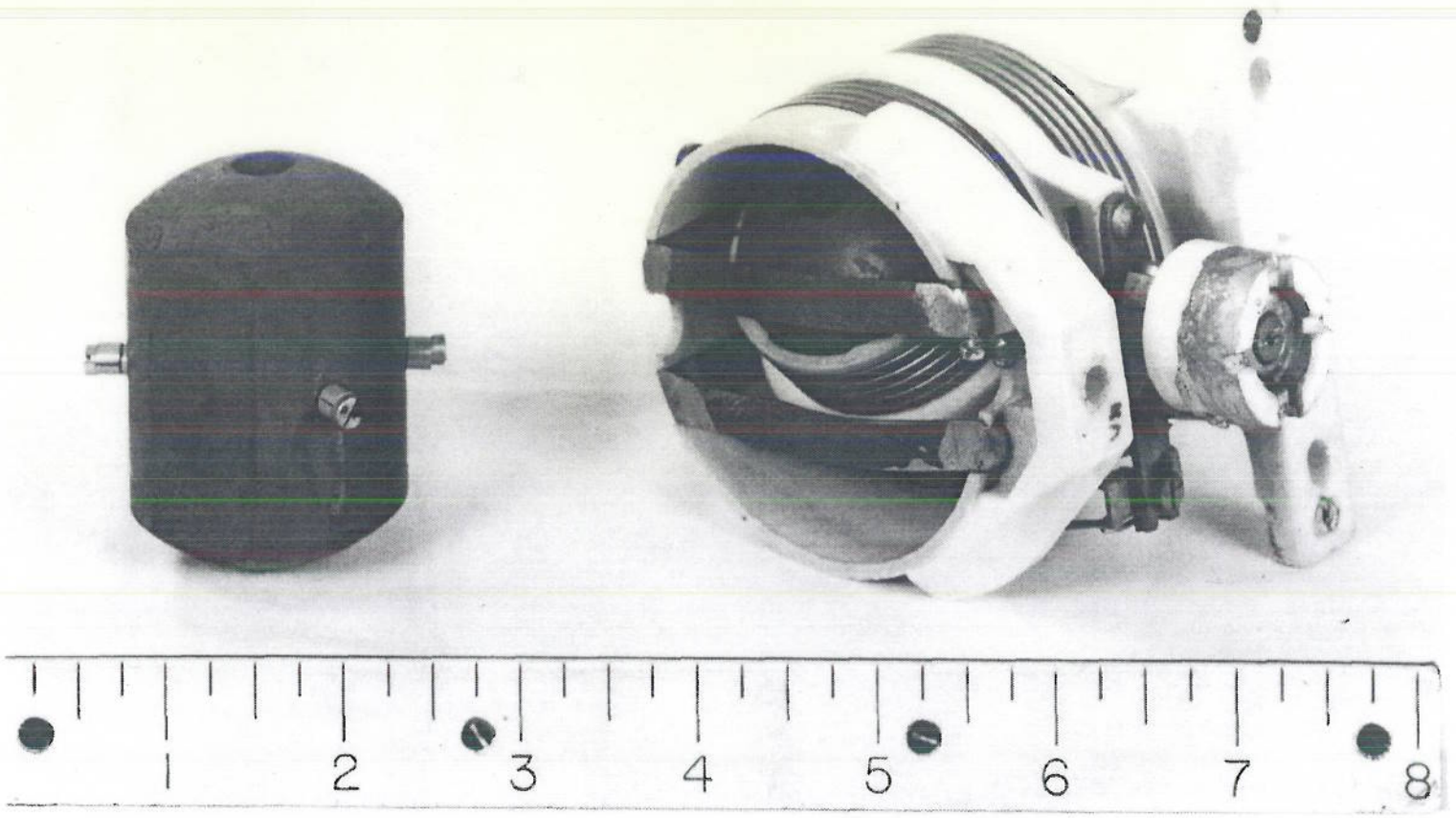
PLATE 2

COMPONENT M3
56.8 MH. CHOKE WITH
EI TYPE CORE

COMPONENT M4
F22 CHOKE WITH
L TYPE CORE

M-3, M-4

PLATE 3



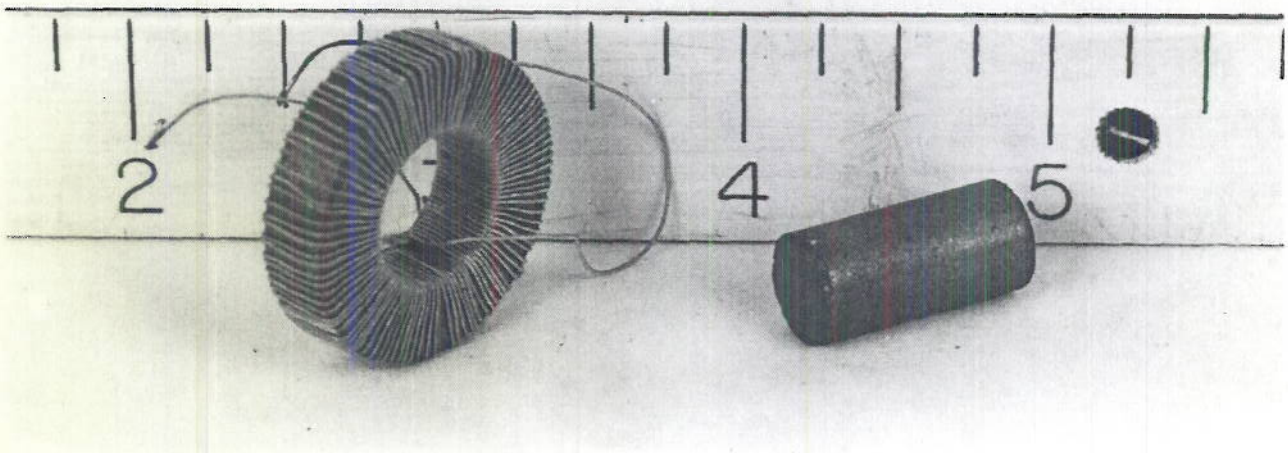
COMPONENT M5
VARIOMETER FROM FuG-10 ANTENNA COUPLING UNIT

M-5

PLATE 4

COMPONENT M6
AIRBORNE DIRECTION FINDING LOOP

PLATE 5



COMPONENT M6
TOROID RING AND SLUG CUT FROM D.F. LOOP CORE

PLATE 6

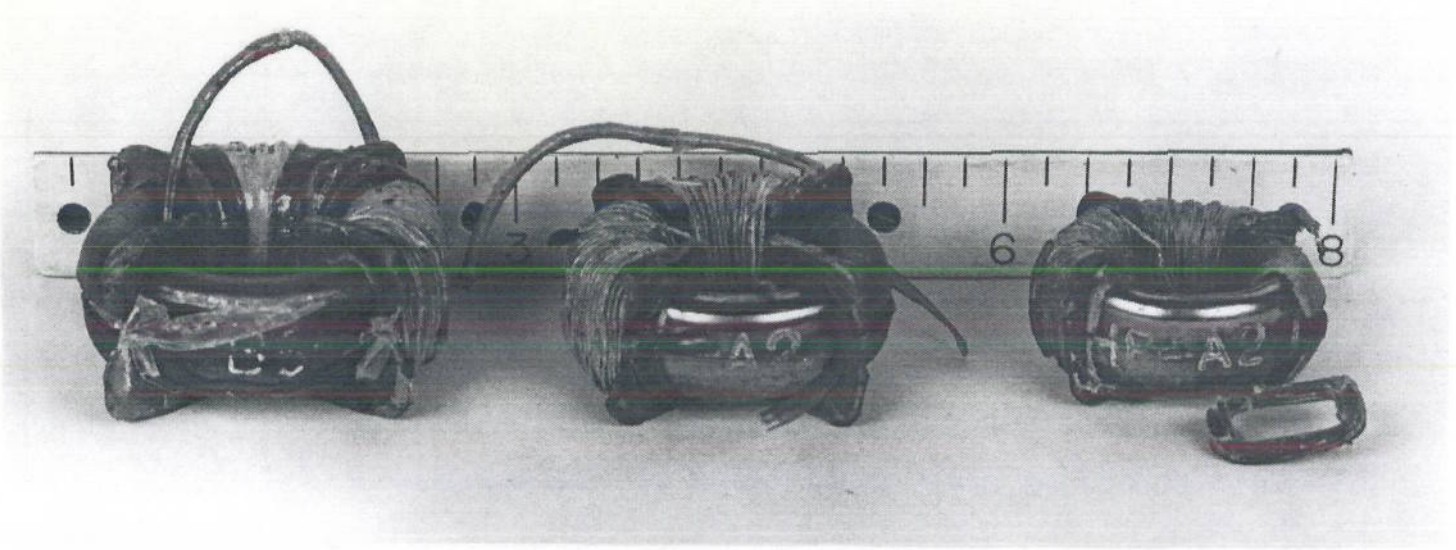
T-1 TO T-1

PLATE 7

COMPONENT
T-5

TOROID CORES
COMPONENT
T-6

COMPONENT
T-4



T-5

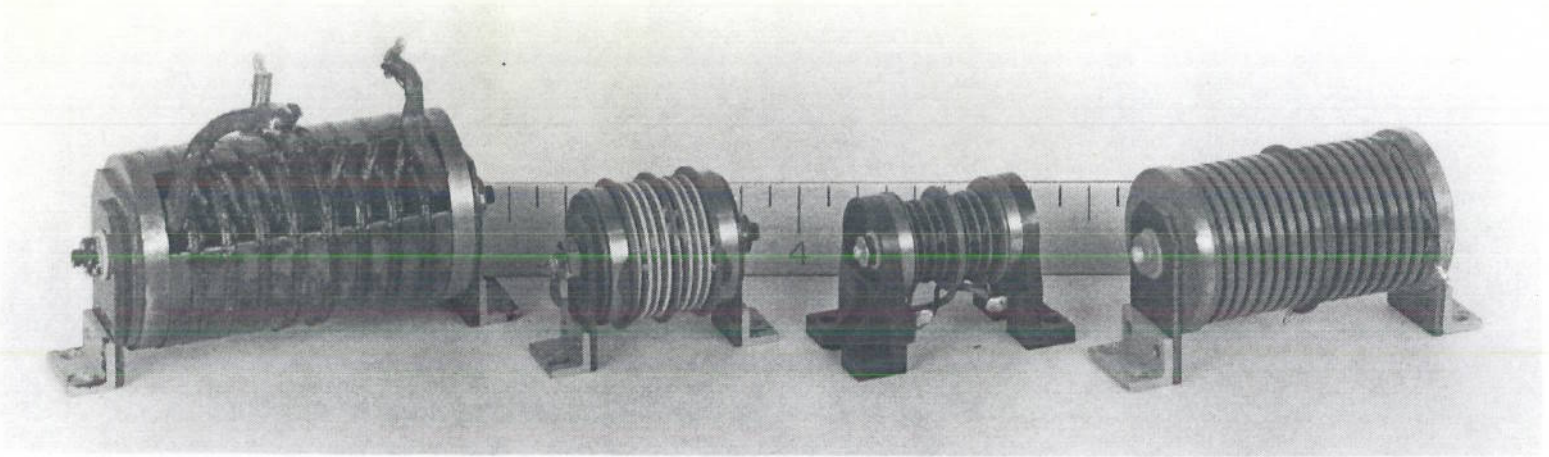
T-6

T-4

PLATE 8

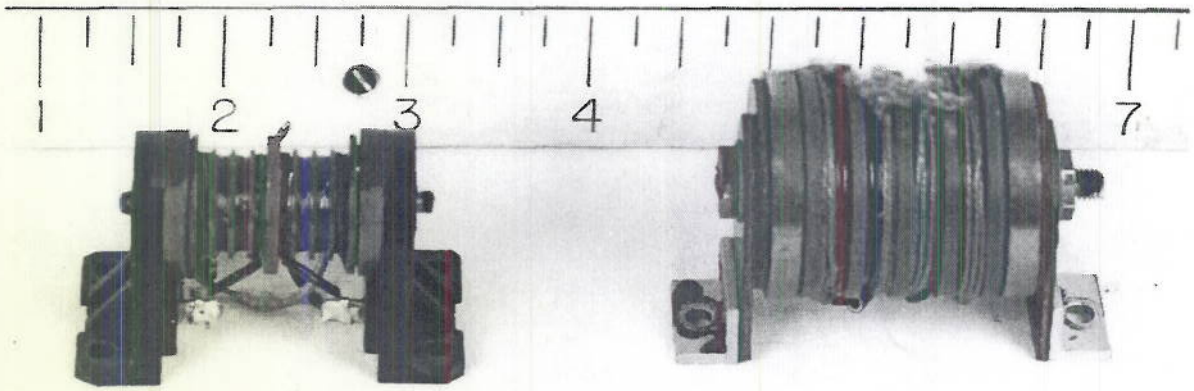
DYNAMOTOR CHOKES

COMPONENT S-4 COMPONENT S-5 COMPONENT S-6 COMPONENT S-1



S-4 S-5 S-6 S-1

PLATE 9



S-3

S-2

DYNAMOTOR CHOKES

COMPONENT S-3

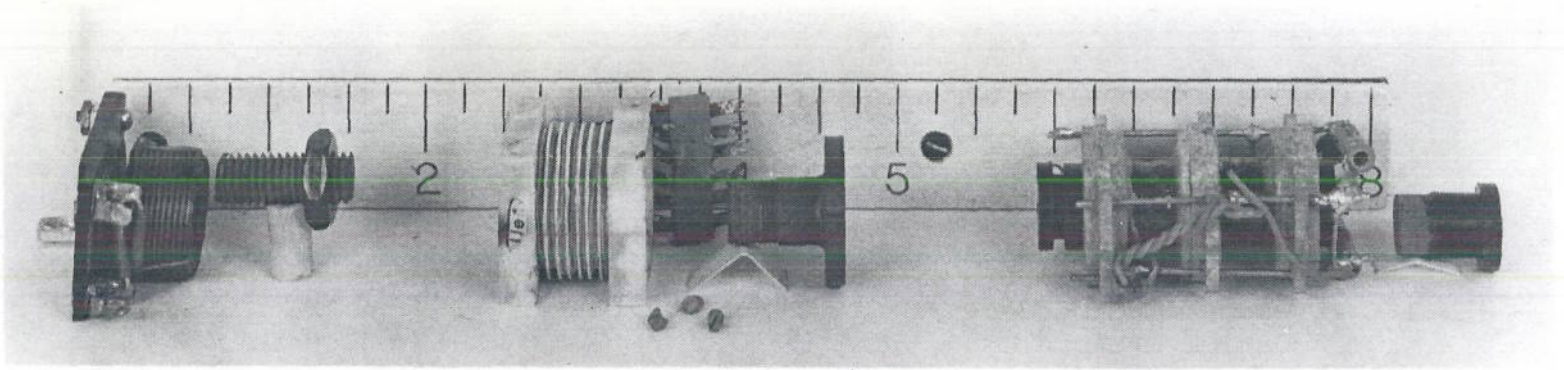
COMPONENT S-2

PLATE 10

COMPONENT C-5
CHOKE

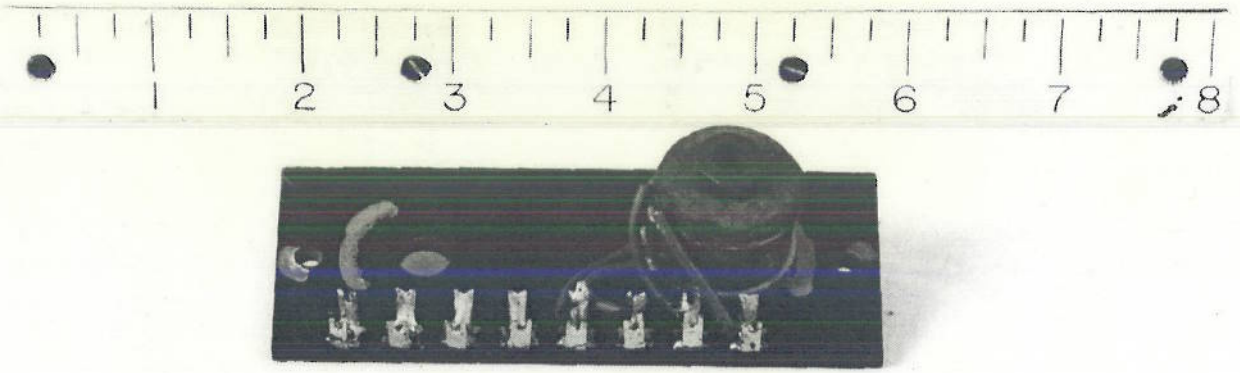
COMPONENT S-7
DRALOPERM DIODE TRANSFORMER

COMPONENT C-3
DOUBLE SCREW-TUNED
COUPLING TRANSFORMER

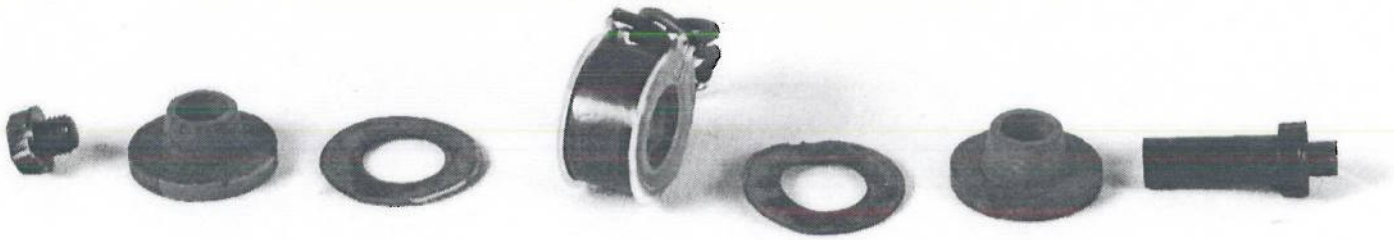


C-5 S-7 C-3

PLATE II



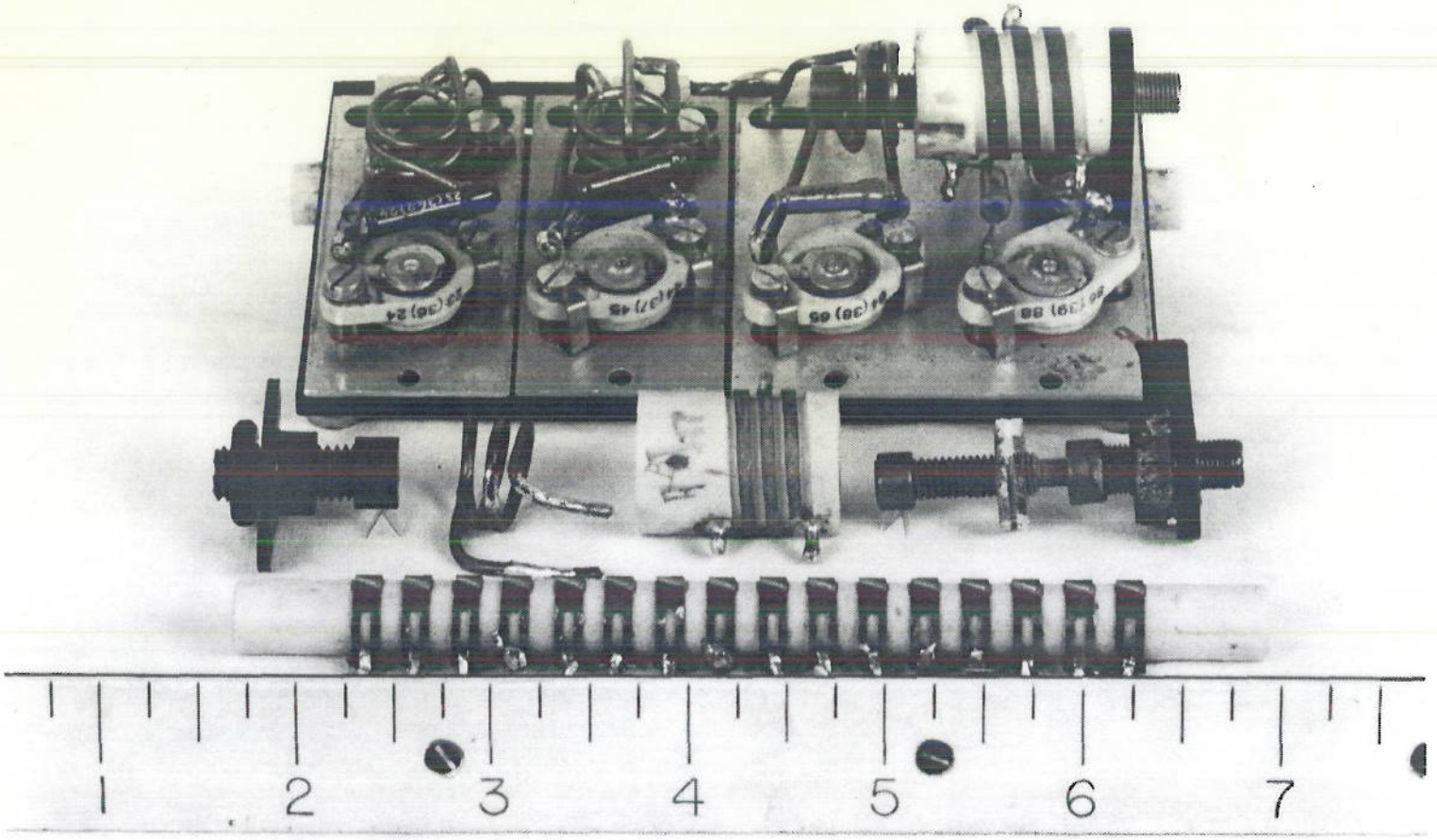
8KC COIL



12KC COIL DISASSEMBLED

PLATE 11A

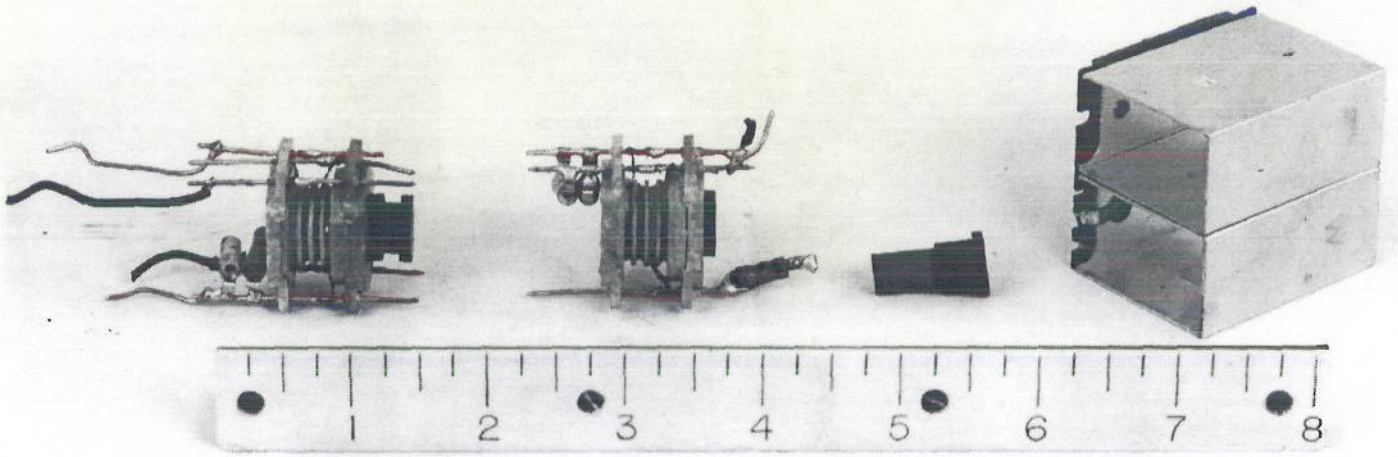
COMPONENT S-8
DRALOPERM COILS FOR
E-230 RECEIVER



C-1

PLATE 12

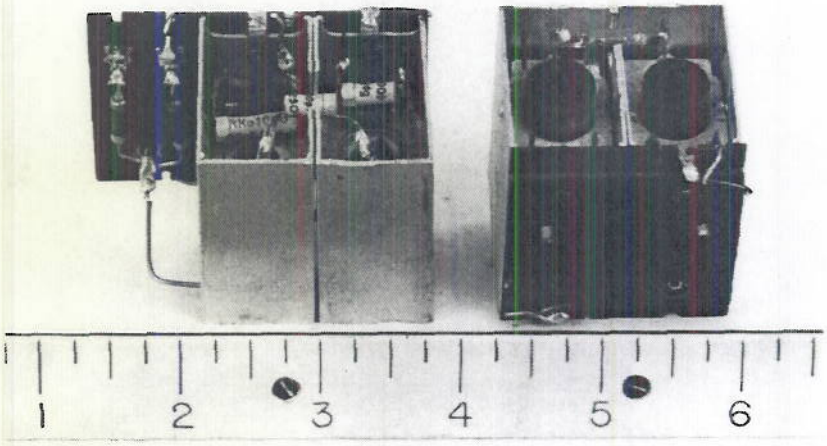
COMPONENT C-1
VHF RECEIVING TURRET ASSEMBLY



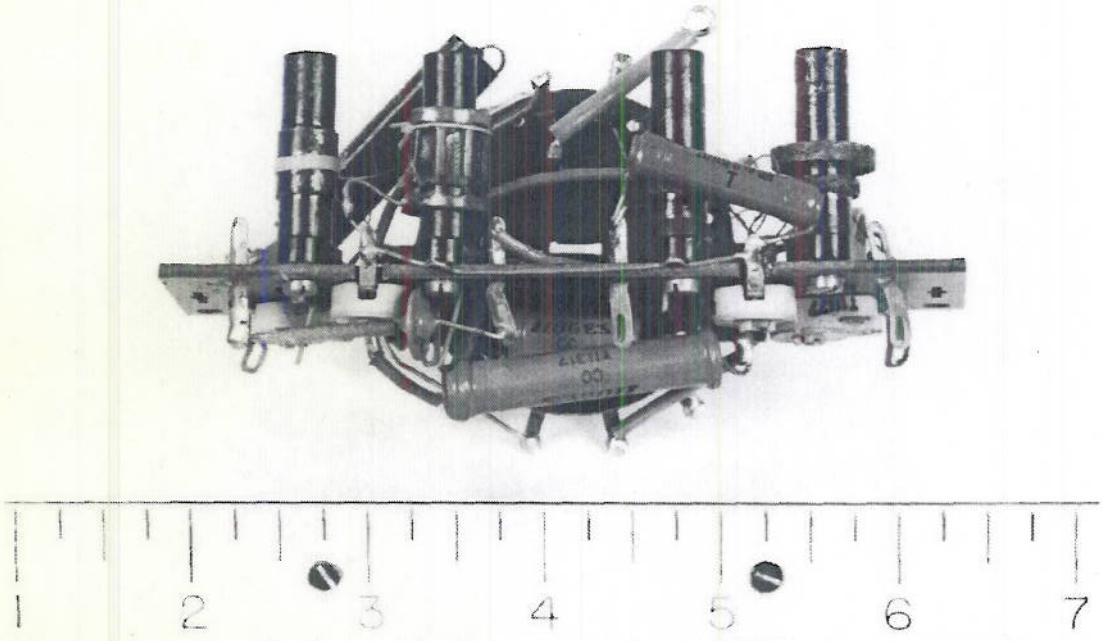
COMPONENT C-2
I.F. COILS AND SHIELD FOR E230 MISSILE RECEIVER

C-2

PLATE 13



COMPONENT C-2
I.F. TRANSFORMER ASSEMBLY FOR E230 MISSILE RECEIVER



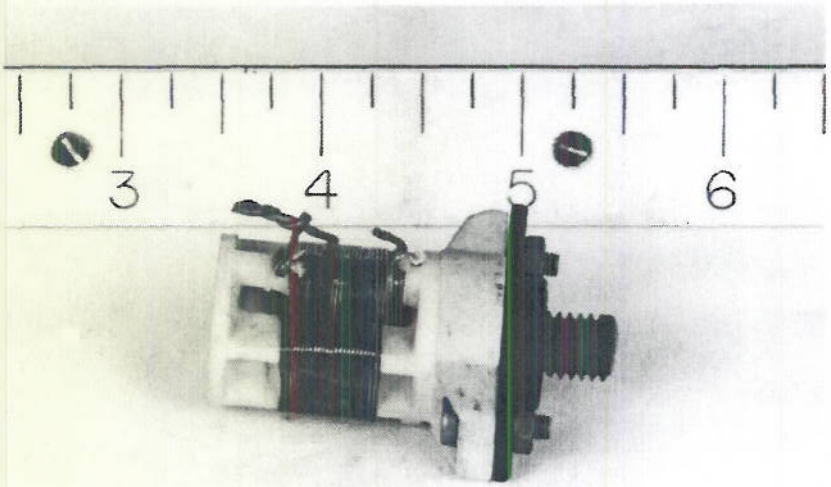
COMPONENT C-4
ALL WAVE TUNING UNIT

COMPONENT C-7
SCREW TUNED SOLENOIDS FROM LICHTENSTEIN RECEIVER

COMPONENT C-8

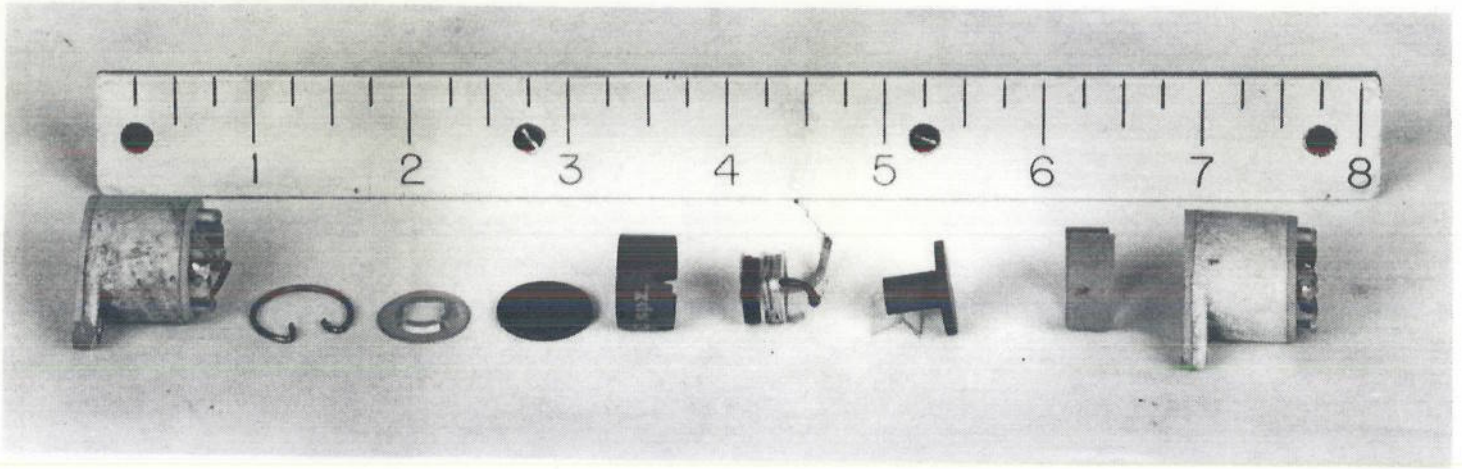
C-7, C-8

PLATE 16



COMPONENT C-9
SCREW TUNED TRANSMITTING COIL

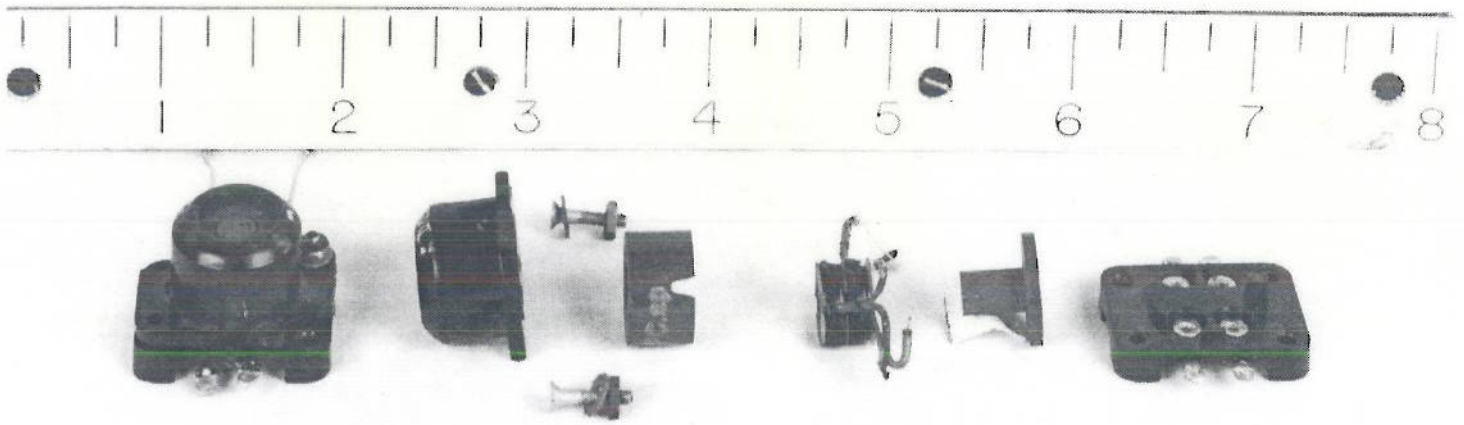
PLATE 17



P-1

COMPONENT P-1
MINIATURE POT COIL WITH CERAMIC HOUSING

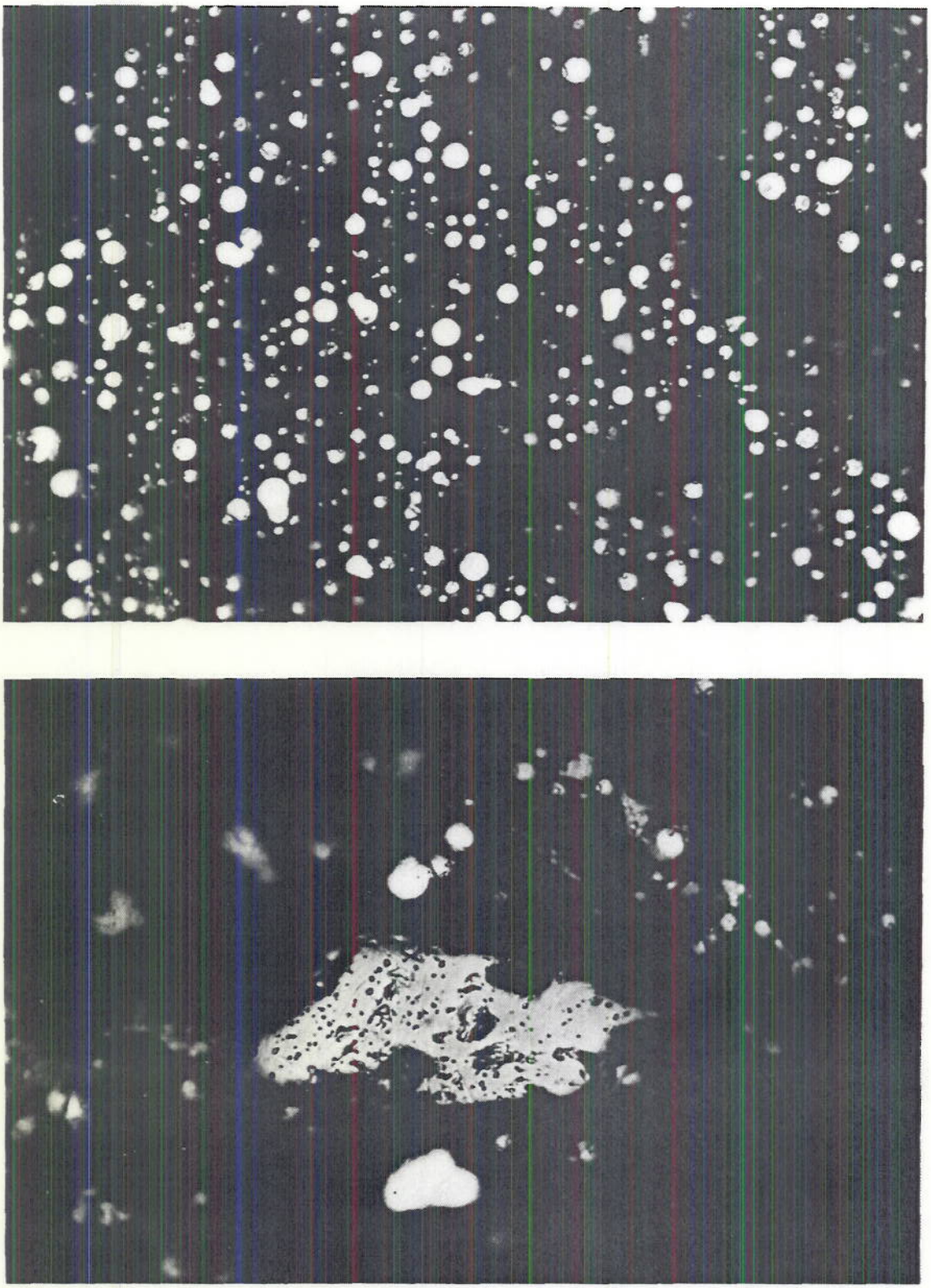
PLATE 18



P-2

COMPONENT P-2
MINIATURE POT COIL WITH BAKELITE HOUSING

PLATE 19

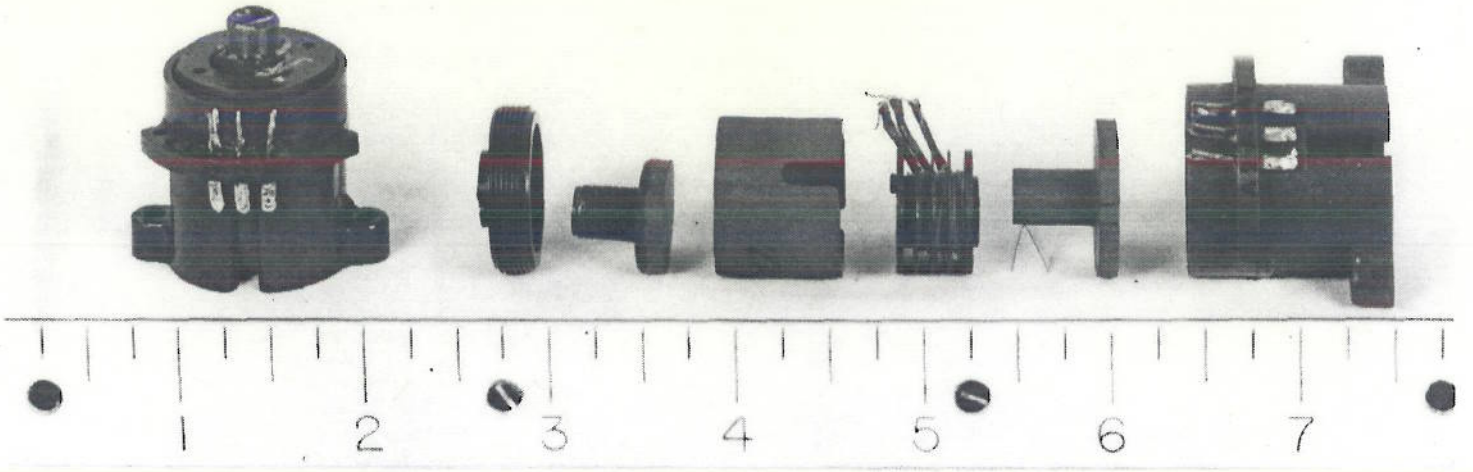


COMPONENT P.3
1000 DIAMETER PHOTOMICROGRAPHS OF FERROCART CSP CORE

PLATE 20

COMPONENT P-3
FERROCART CSP CORE IN BV 16714 TRANSFORMER

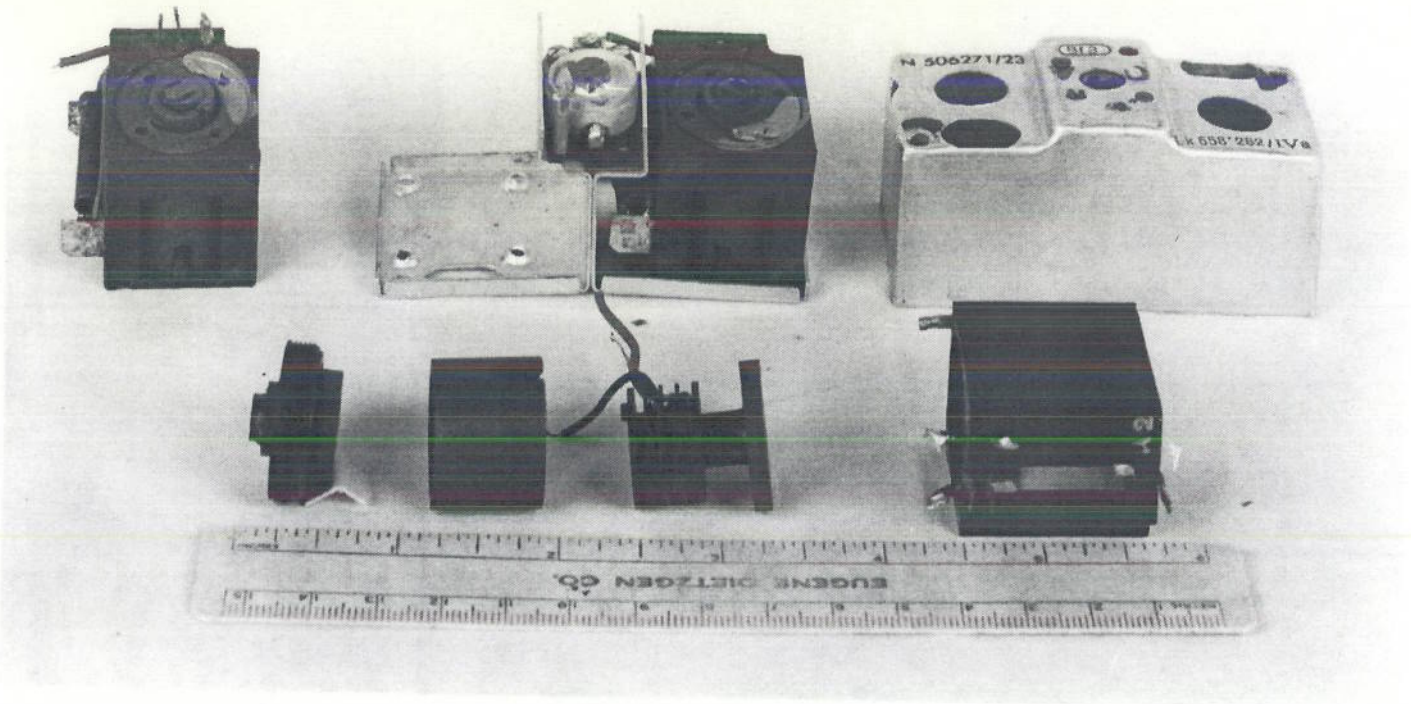
PLATE 21



P-4

COMPONENT P-4
AEG SK635301 POT CORE ASSEMBLY

PLATE 22



COMPONENT P-5
I.F. TRANSFORMER FROM FuG-16 AIRCRAFT RECEIVER

P-5

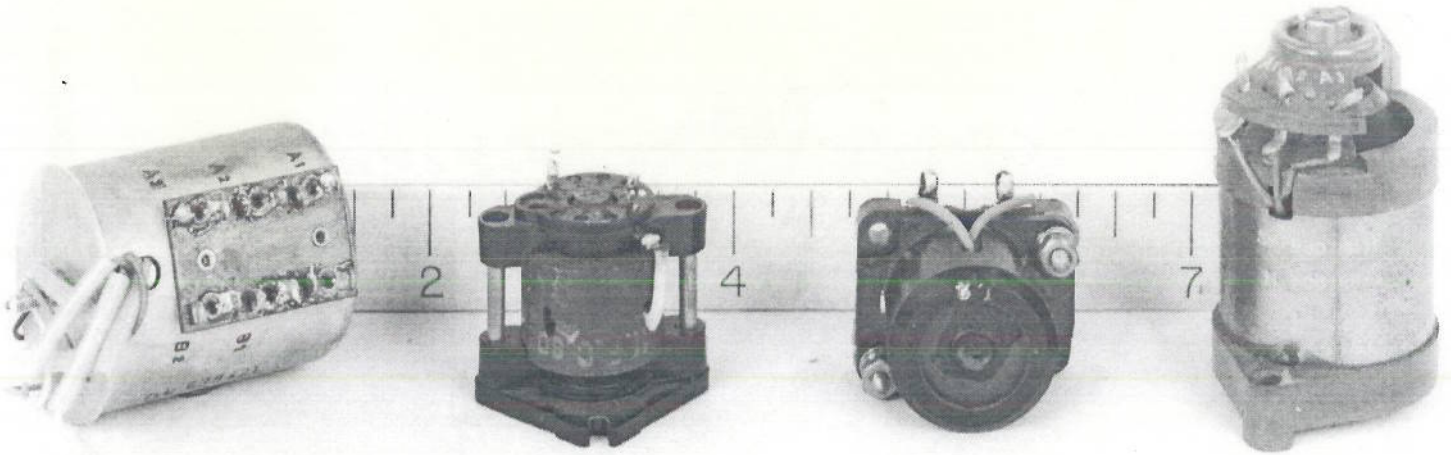
PLATE 23

COMPONENT
P-11
SK 638421 POT

COMPONENT
P-3
FERROCART CSP POT

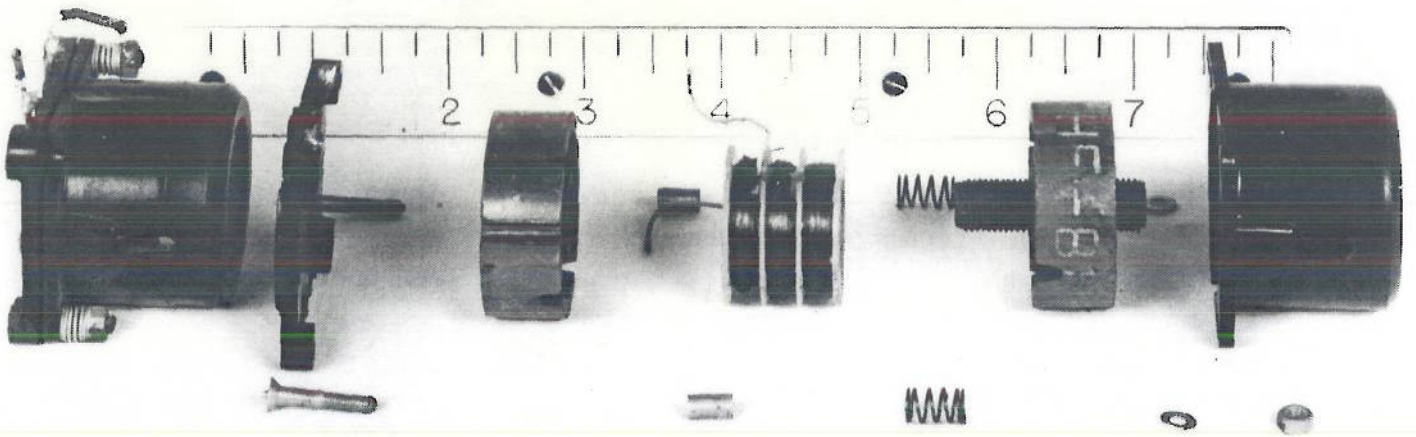
COMPONENT
P-7
HF-B1 POT

COMPONENT
P-6
SK 630291/1 POT



P-11 P-3 P-7 P-6

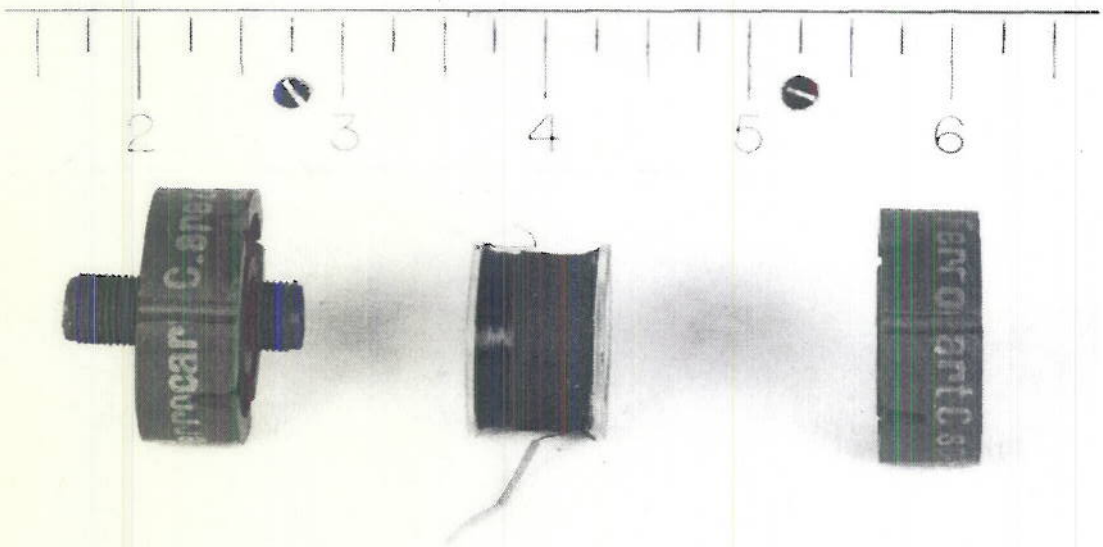
PLATE 24



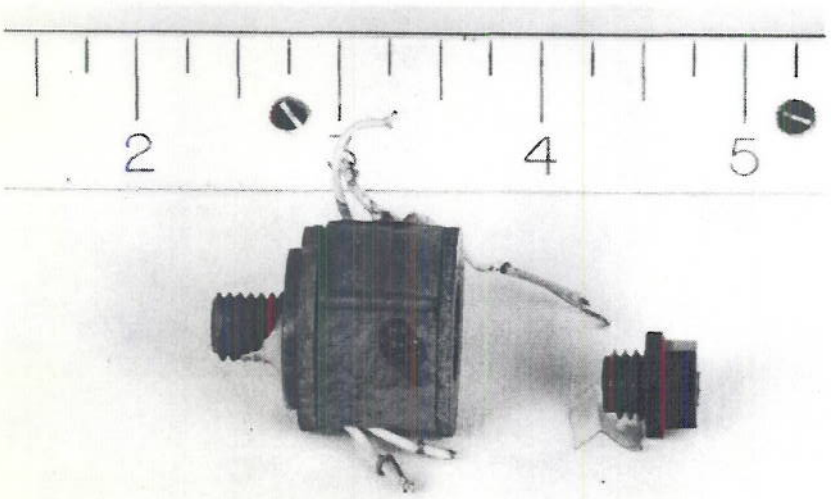
COMPONENT P-7
HF-81 LOW FREQUENCY POT COIL

P-7

PLATE 25

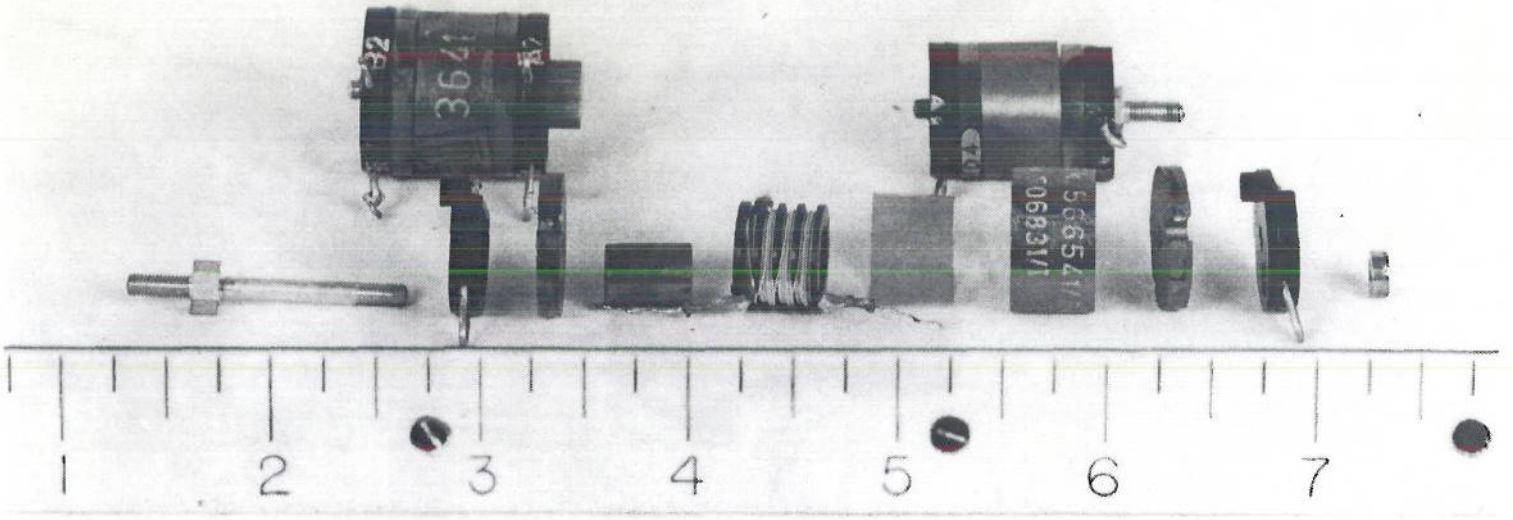


COMPONENT P-8
FERROCART CSP POT COIL



COMPONENT P-9
POT COIL FROM WES-2 RADIO SONDE

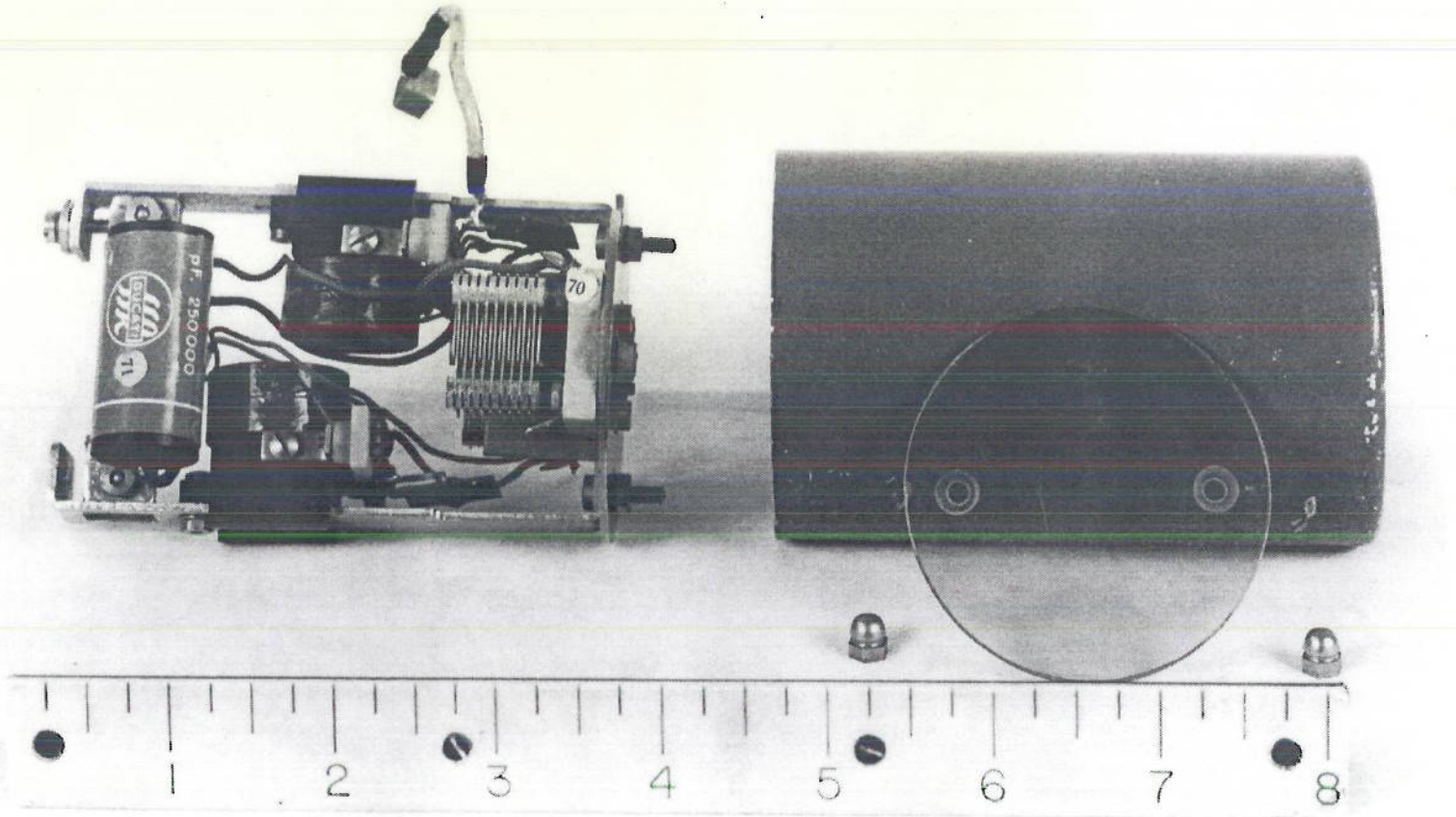
P-13, P-12



COMPONENT P-13 COMPONENT P-12

4 PIECE POT COIL ASSEMBLIES

PLATE 28



P-14

PLATE 29

COMPONENT P-14
175 KC. I.F. TRANSFORMER

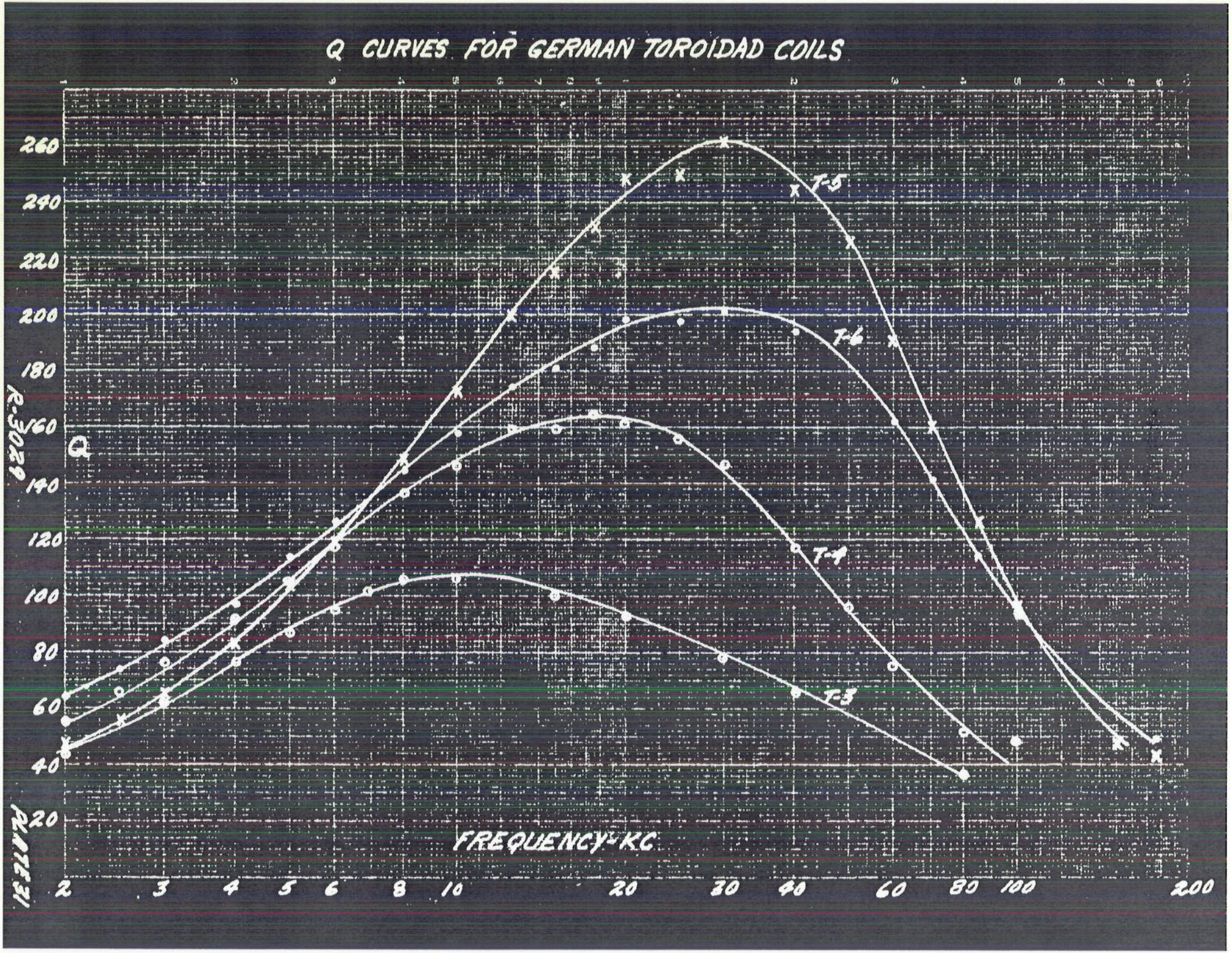
Dimensions in Inches

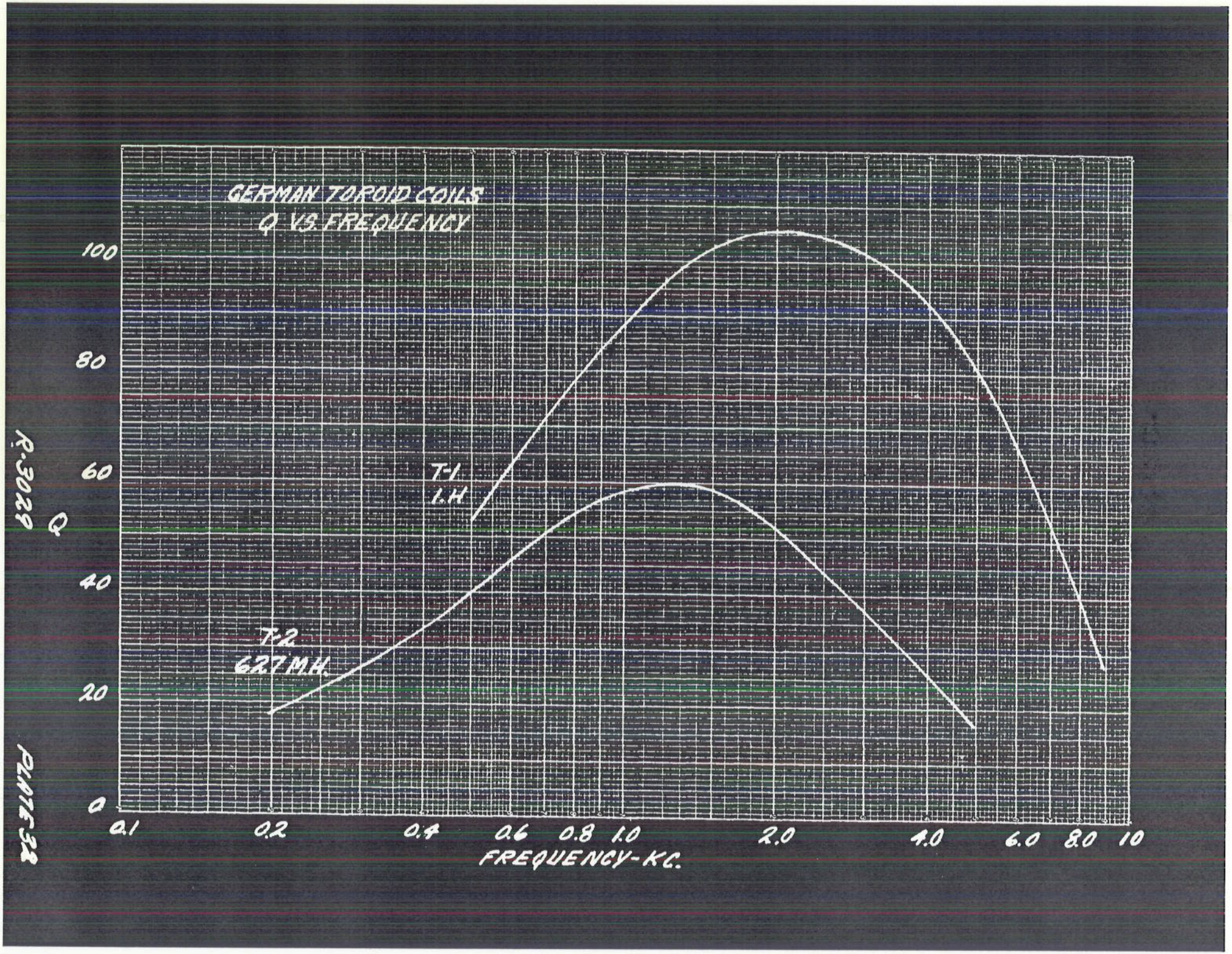
Component	OD	ID	H	R	μ
T-1	2.37	1.43	.94	.23	56
T-2	1.60	1.00	.64	.13	53
T-3	1.30	.95	.59	.09	53
T-4	1.45	.99	.59	.12	53
T-5	2.05	1.27	.70	.19	21
T-6	1.83	1.12	.64	.17	56
T-7	-	-	-	-	-

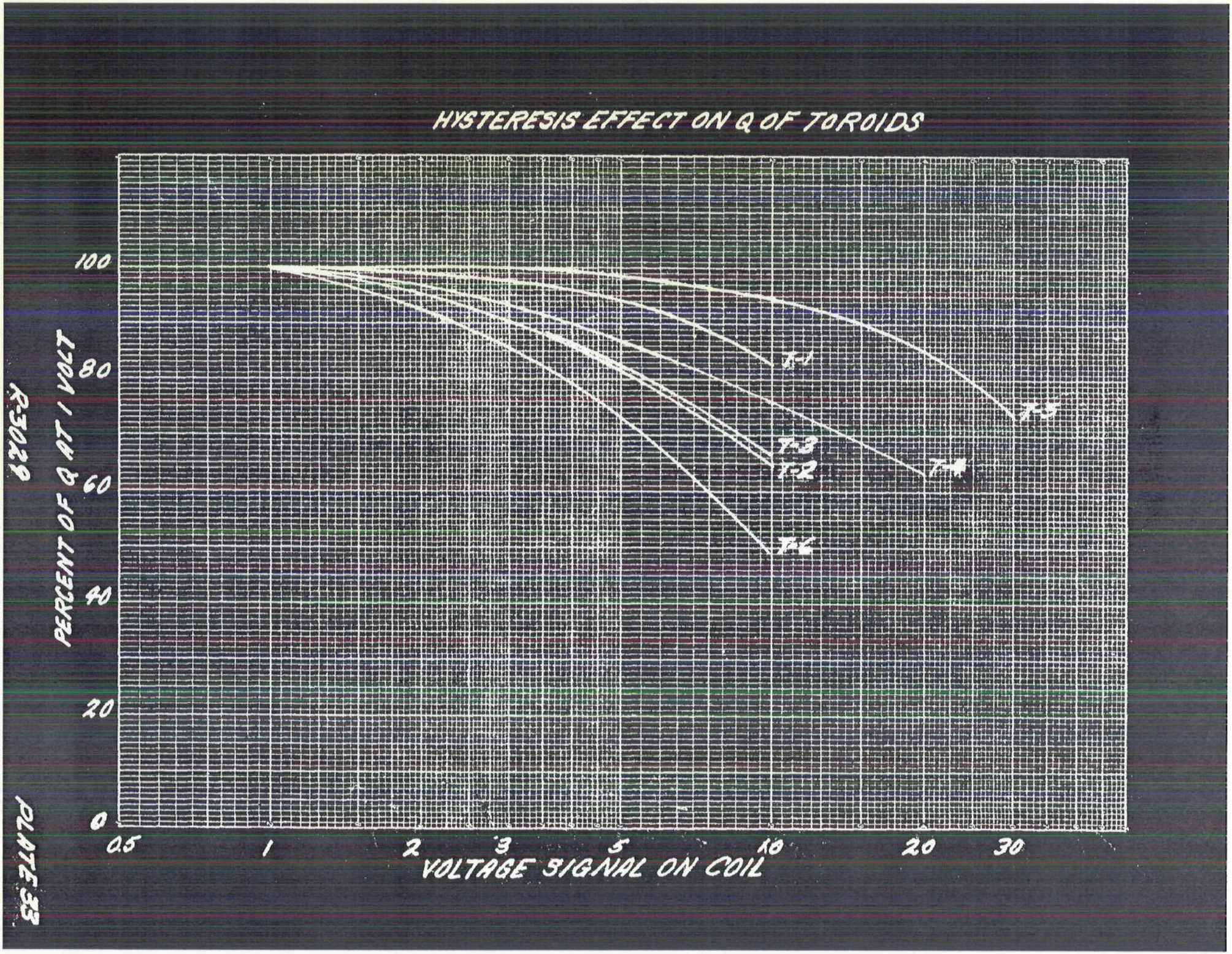
PHYSICAL DIMENSIONS OF TOROIDAL CORES

B-3029

PLATE 30.

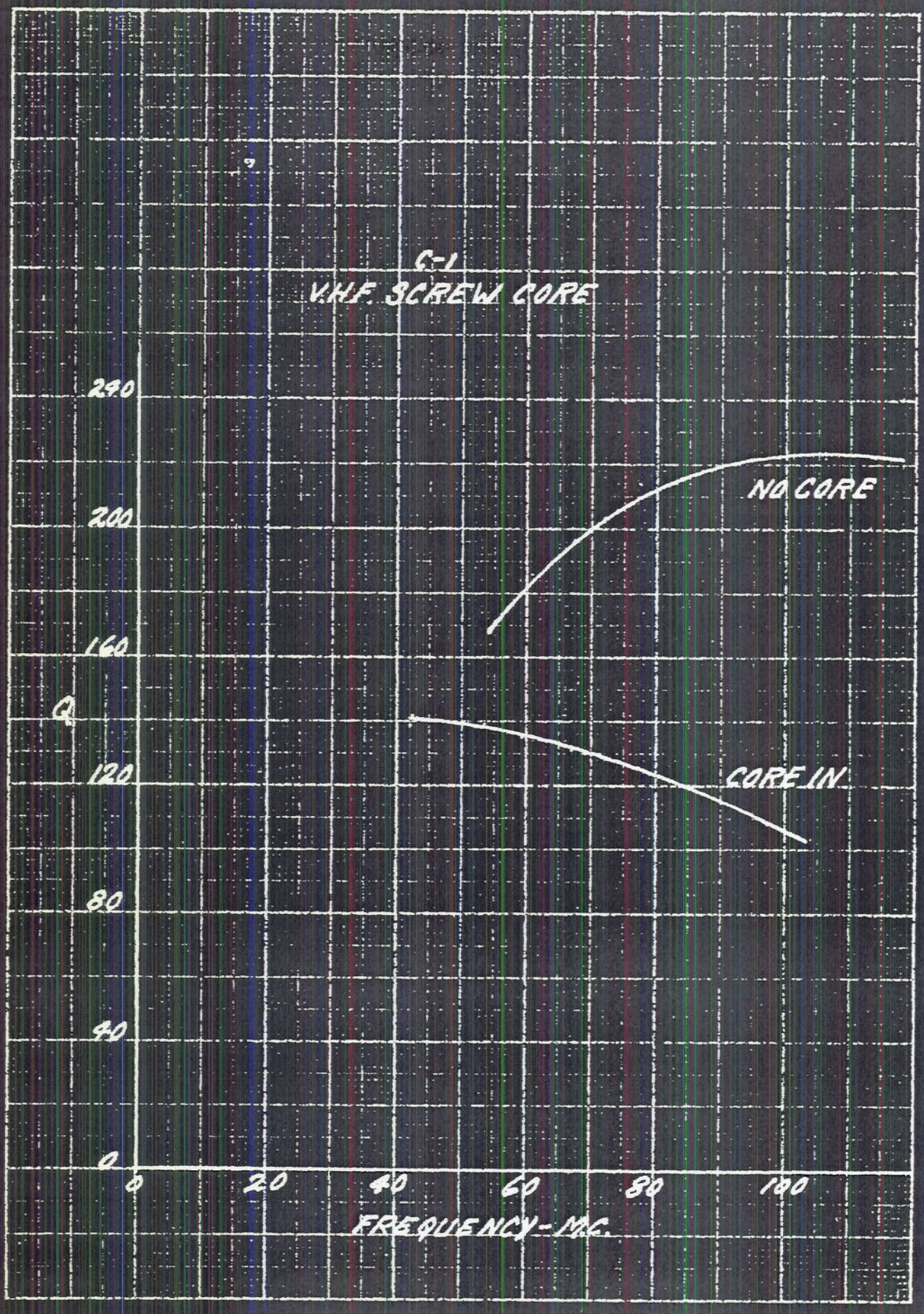

Q CURVES FOR GERMAN TOROIDAD COILS
260
240
220
200
180
160
140
120
100
80
60
40
20
Q
R-3024
T-5
T-6
T-1
T-3
FREQUENCY-KC
2
3
4
5
6
8
10
20
30
40
60
80
100
200
RANTEC 31


GERMAN TOROID COILS
Q VS. FREQUENCY
100
80
60
40
20
0
Q
T-1
1.H
T-2
627 M.H.
0.1
0.2
0.4
0.6
0.8
1.0
2.0
4.0
6.0
8.0
10
FREQUENCY-KC.
R-3029
PLATE 38



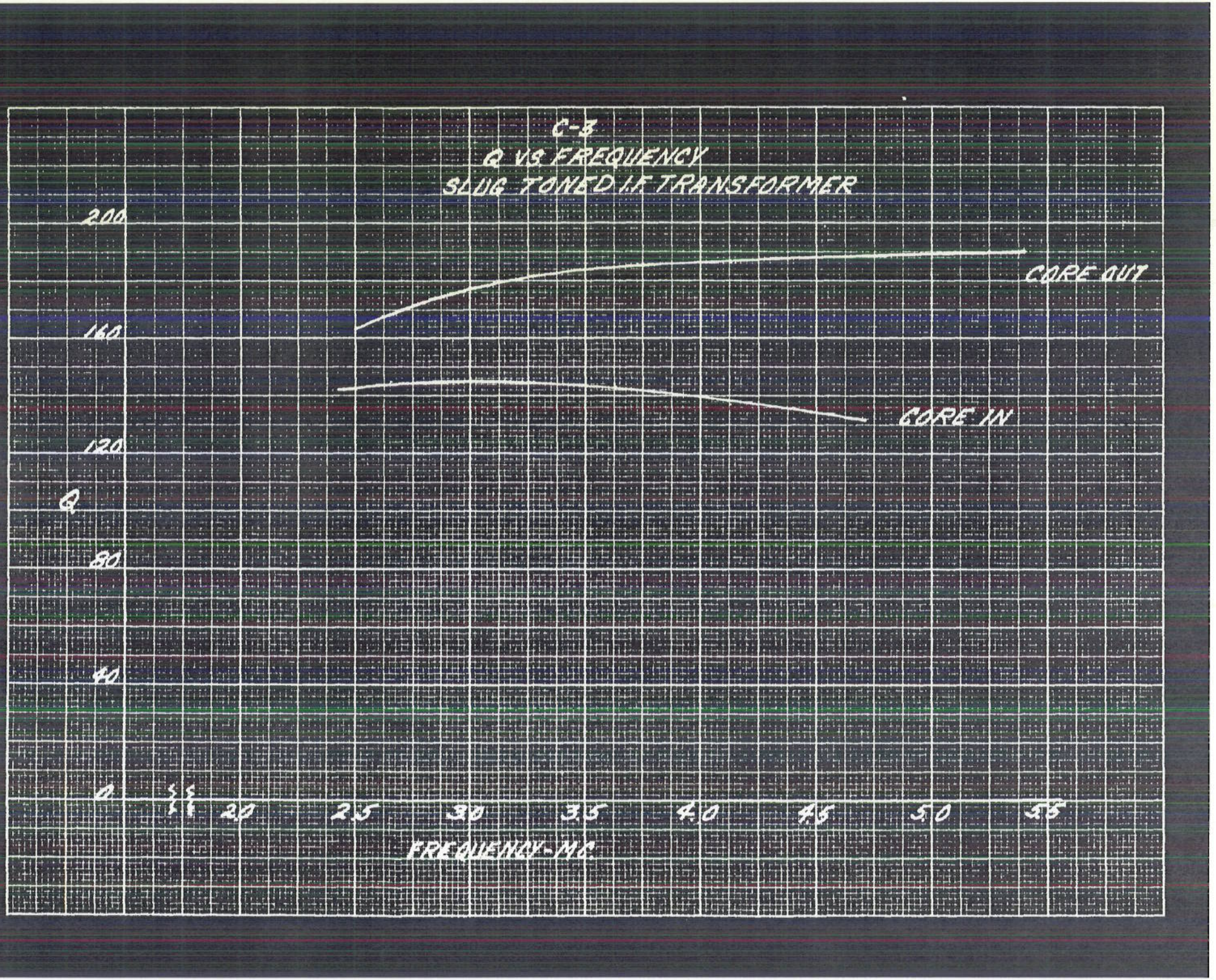
R-3020

PLATE 33



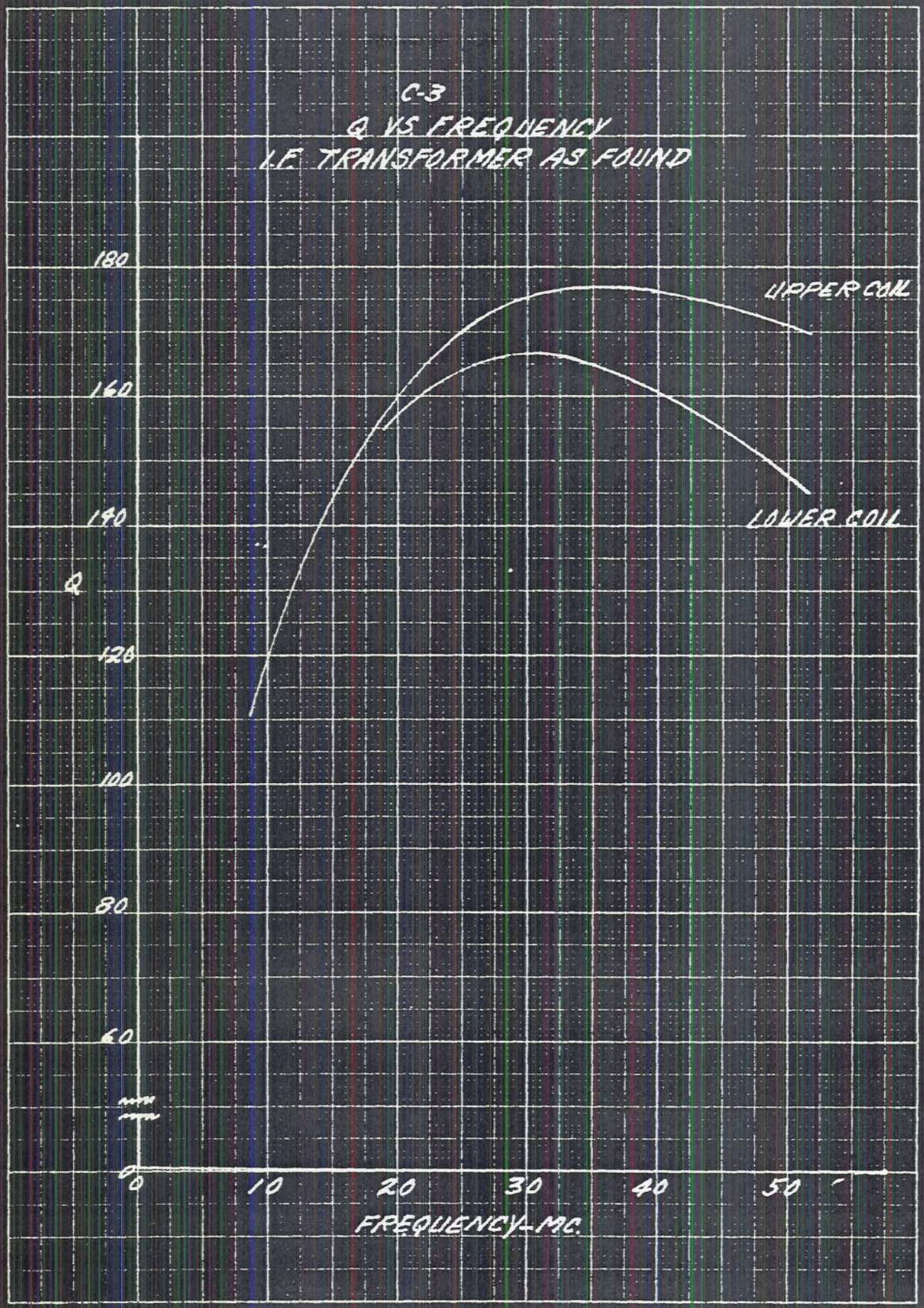
R-3029

PLATE 34



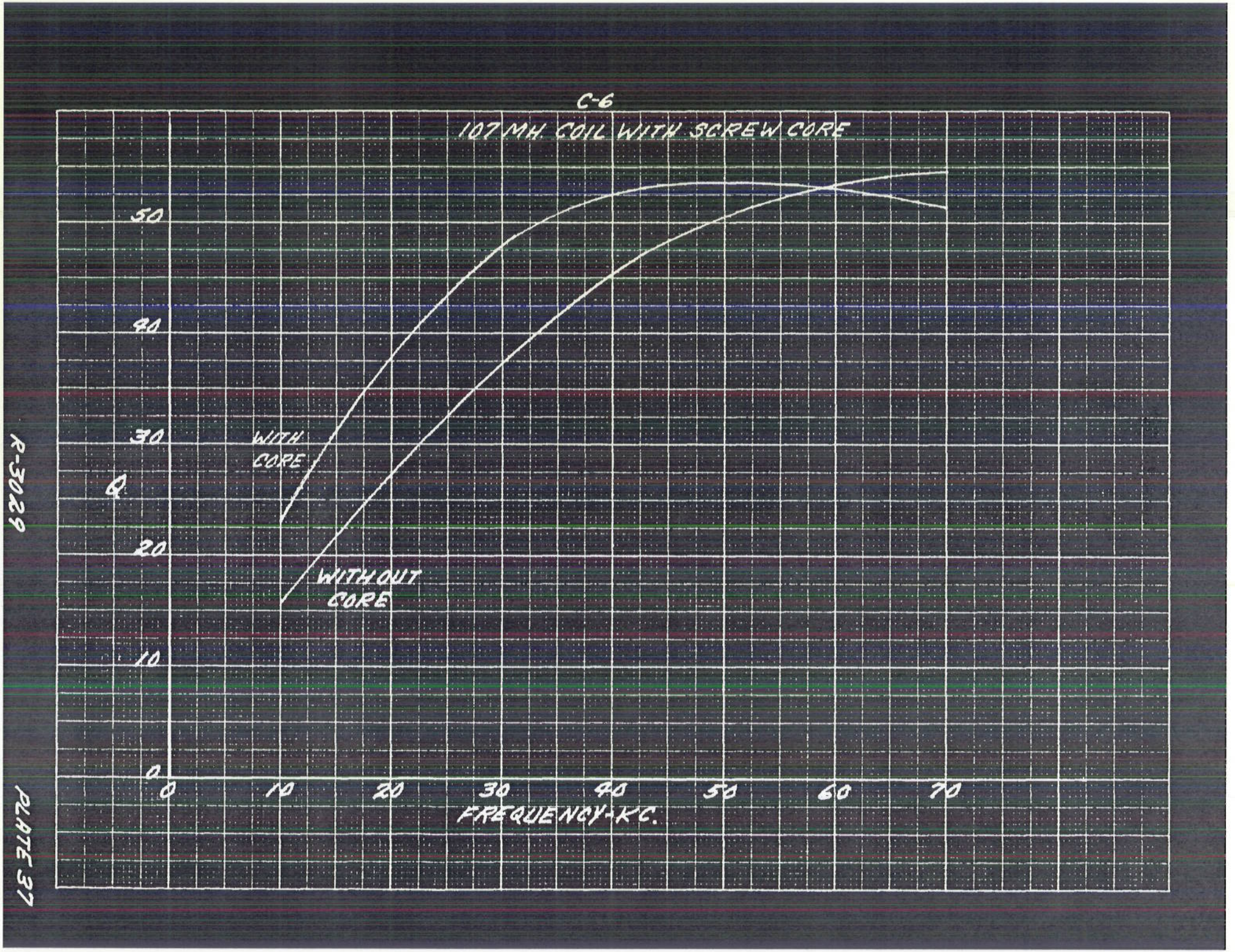
P-3029

PLATE 35



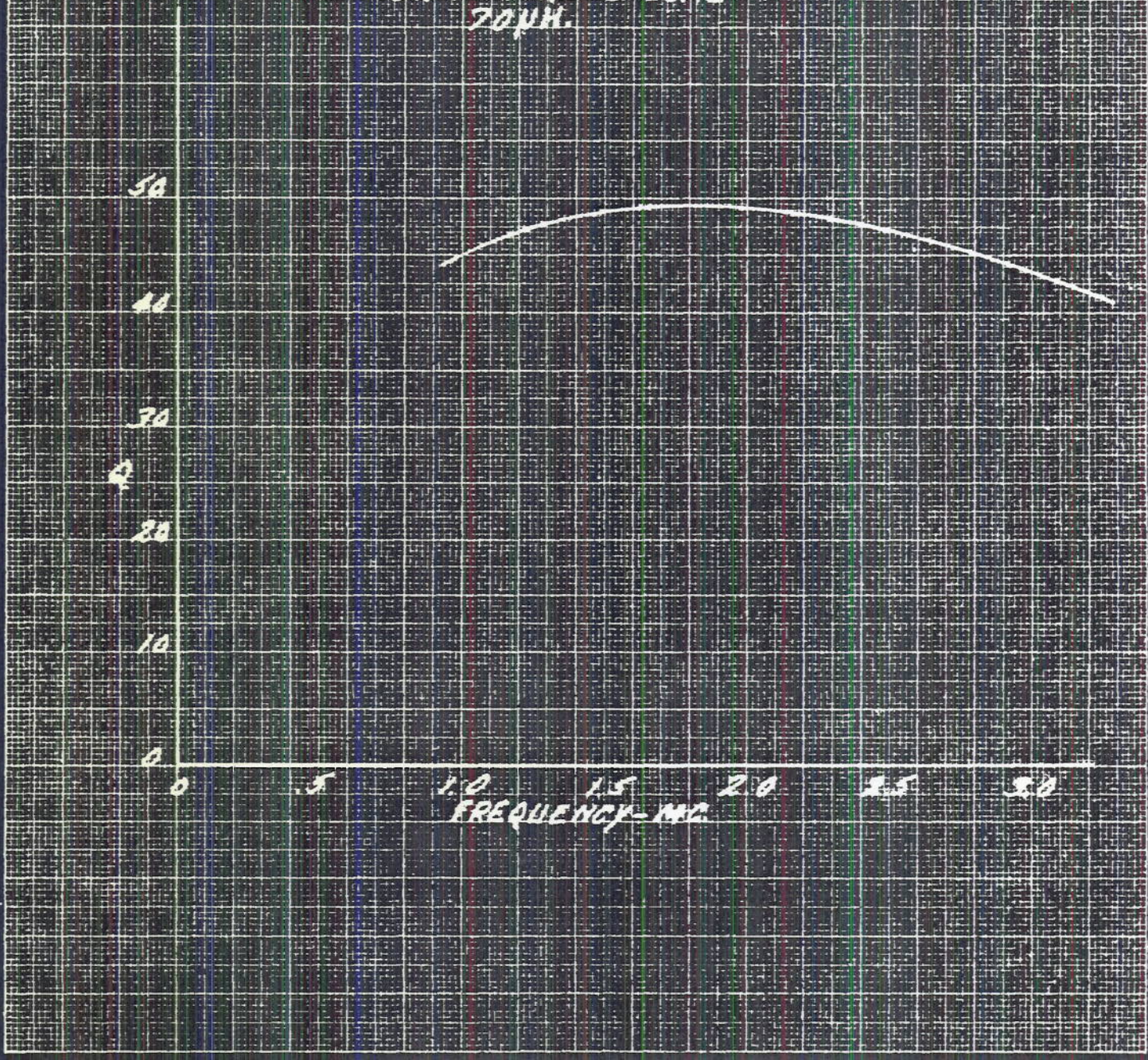
R-3029

PLATE 36


C-6
107 MH. COIL WITH SCREW CORE
50
40
30
Q
20
10
0
WITH CORE
WITHOUT CORE
0
10
20
30
40
50
60
70
FREQUENCY-K.C.
R-3029
PLATE 37

C-5

LAYER WOUND CHOKE
ON THREADED CORE
70 μH.



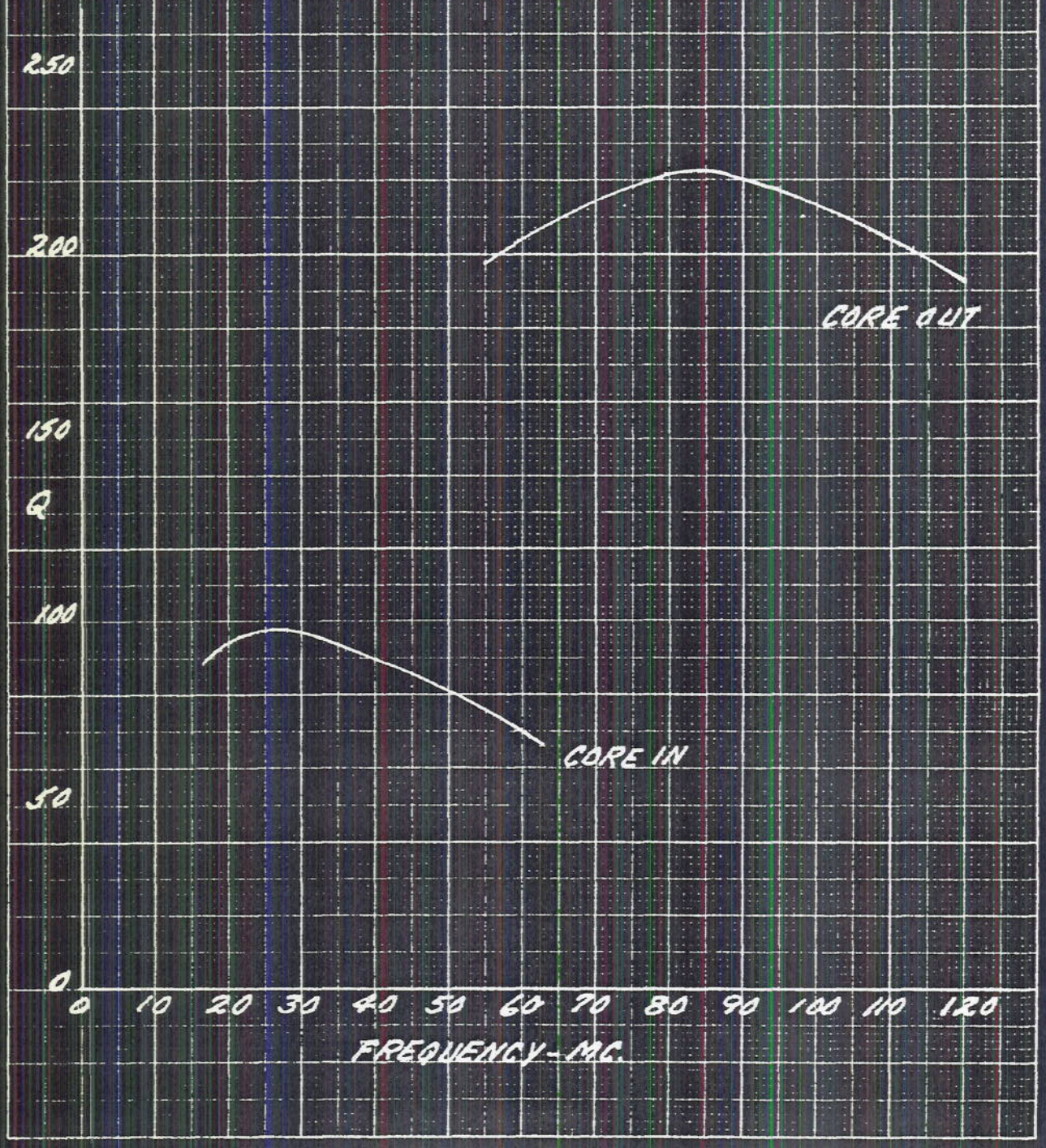
R-3029

PLATE 38

C-7

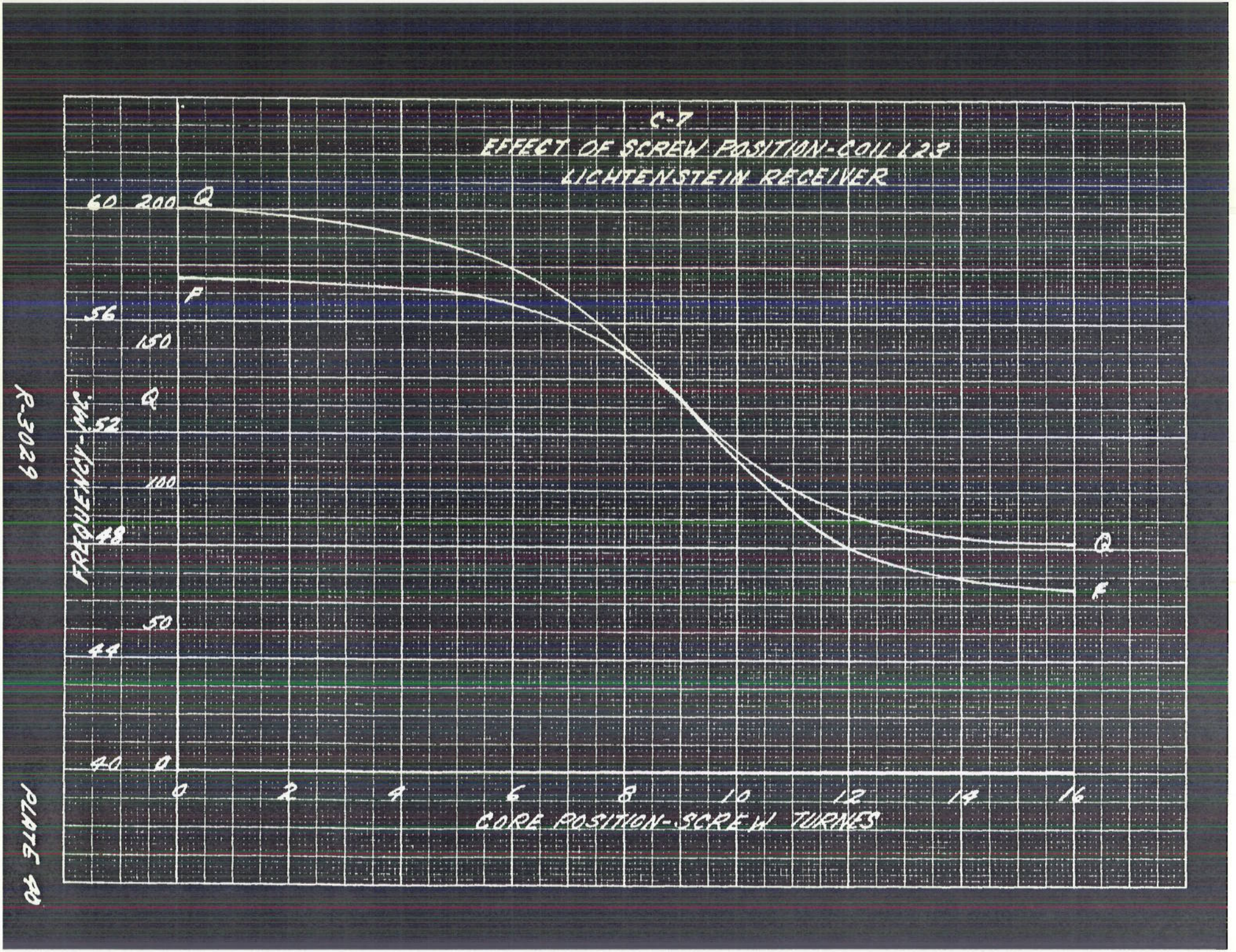
Q VS. FREQUENCY PLOT

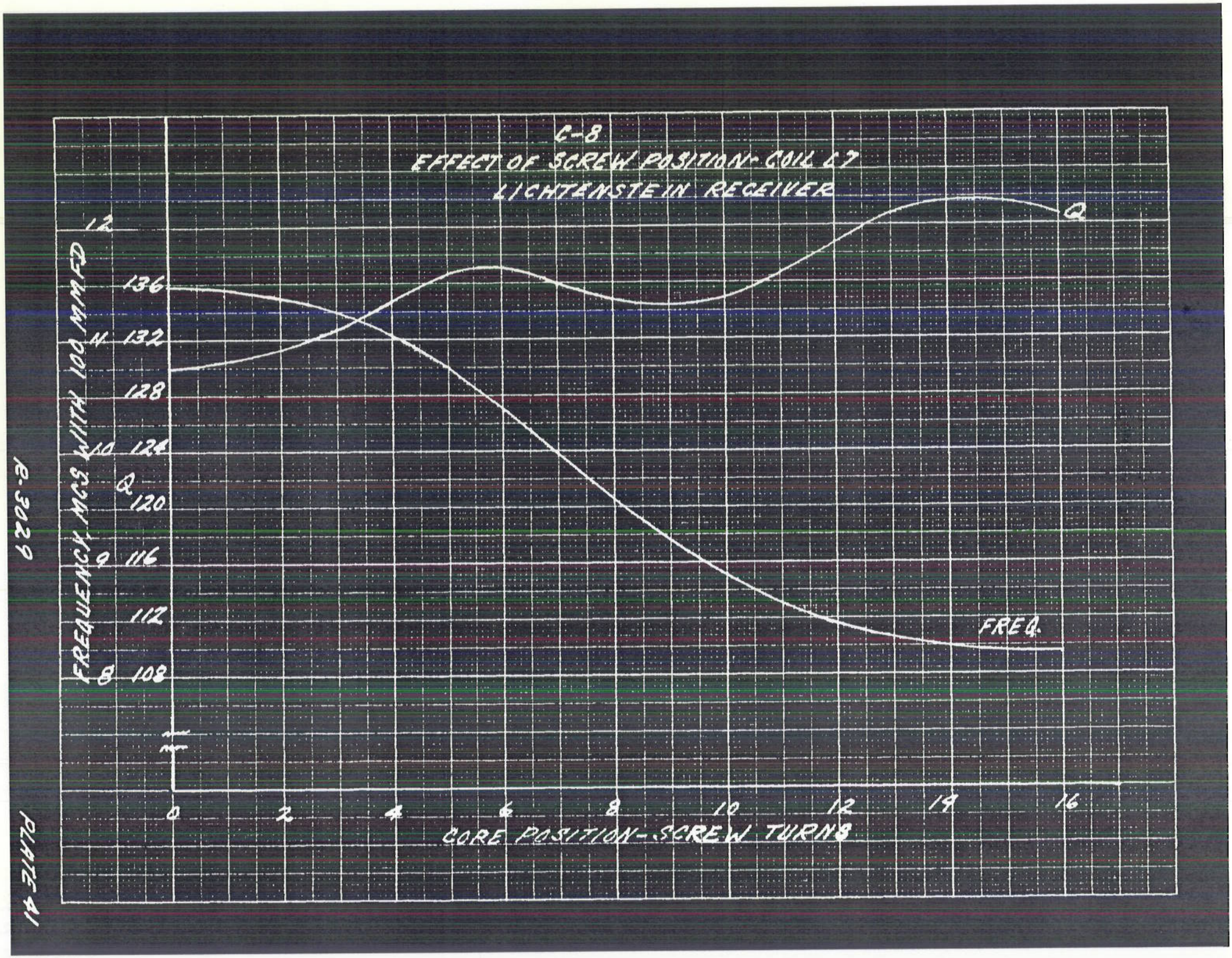
FOR L23 COIL OF FIG. 213

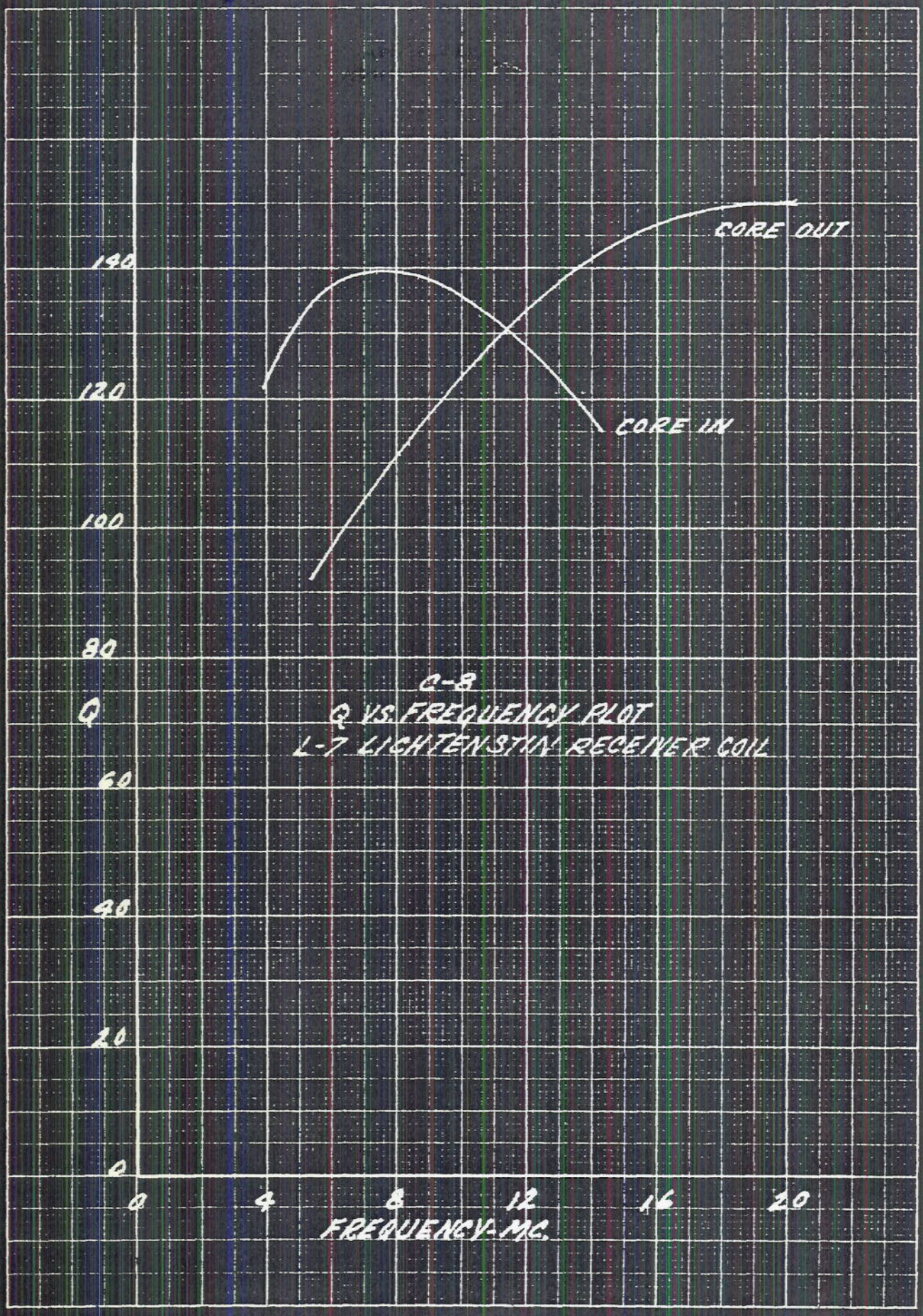


R-3029

PLATE 39


C-7
EFFECT OF SCREW POSITION-COIL L23
LICHTENSTEIN RECEIVER
60
200
Q
F
56
150
Q
52
100
48
50
44
40
0
FREQUENCY-MC.
0
2
4
6
8
10
12
14
16
CORE POSITION-SCREW TURNS
R-3029
PLATE 40


C-8
EFFECT OF SCREW POSITION - COIL C7
LICHTENSTEIN RECEIVER
Q
FREQ.
FREQUENCY MCS WITH 100 MMFD
12
136
132
128
124
120
116
112
108
Q
0
2
4
6
8
10
12
14
16
CORE POSITION - SCREW TURNS
E-3029
PLATE 41



C-8

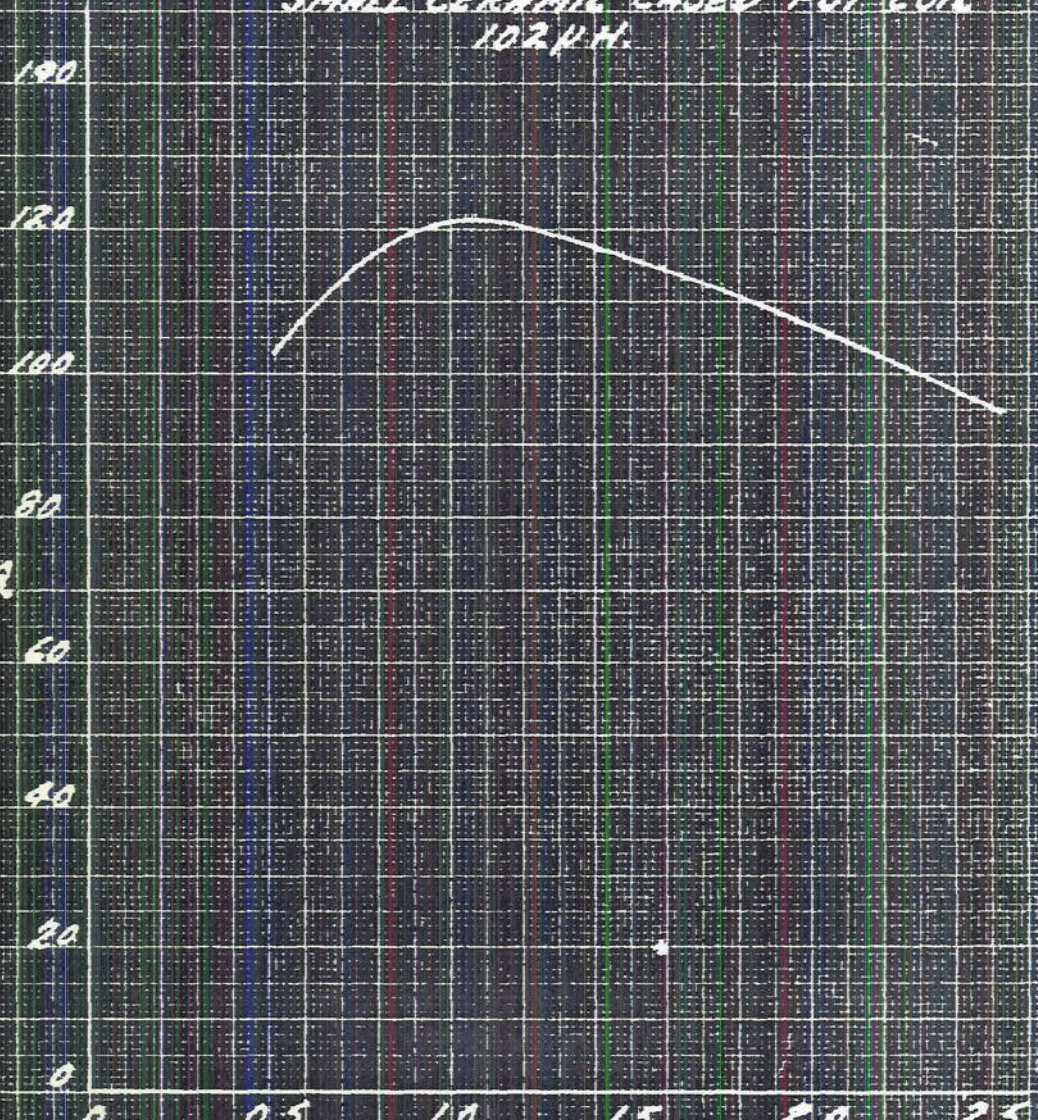
Q VS. FREQUENCY PLOT

L-7 LICHTENSTIN RECEIVER COIL

R-3029

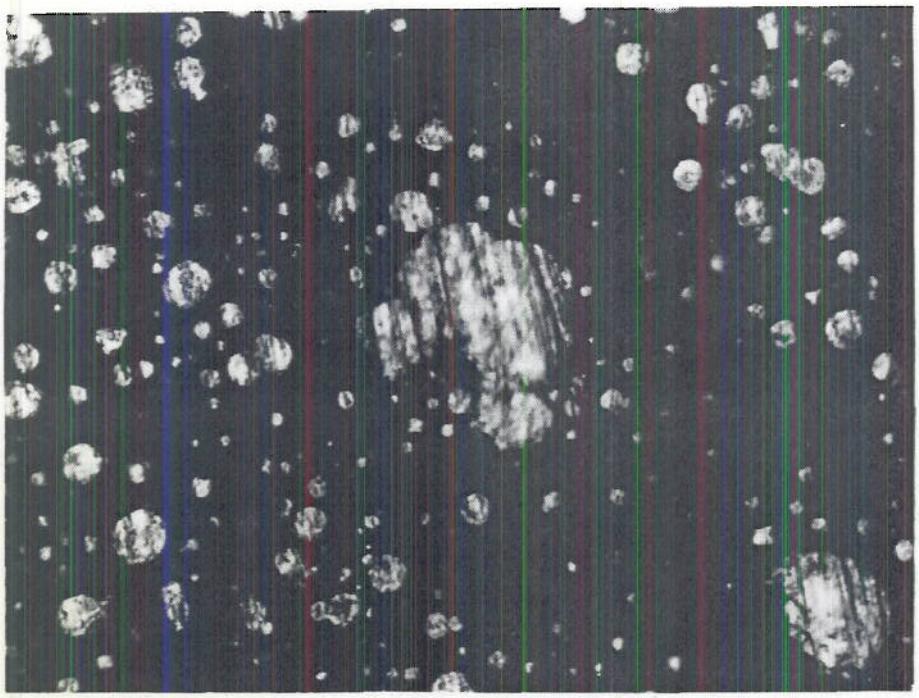
PLATE 42

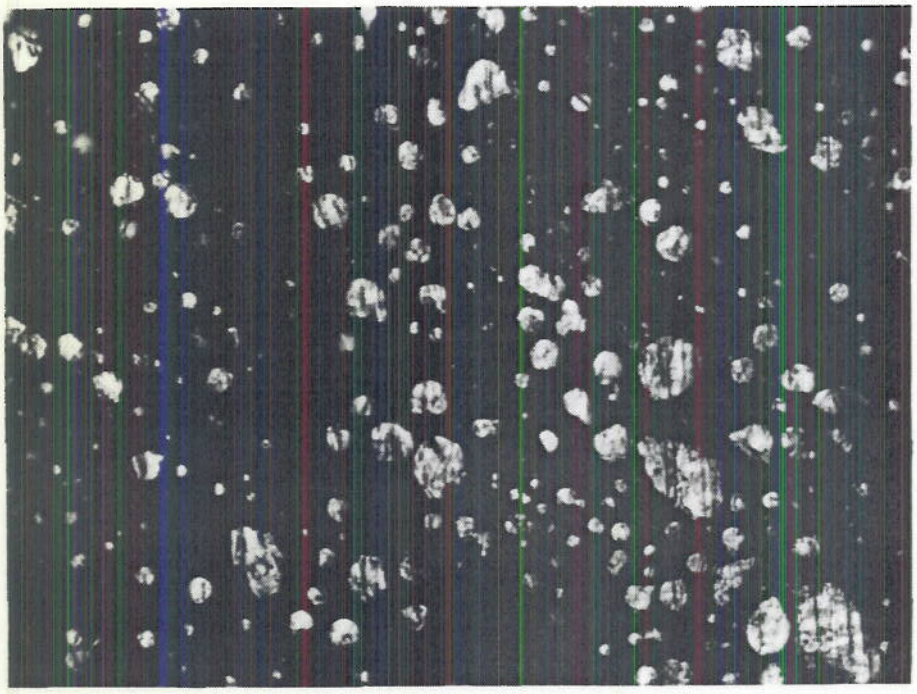
P-1
SMALL CERAMIC CASED POT COIL
102 μ.H.



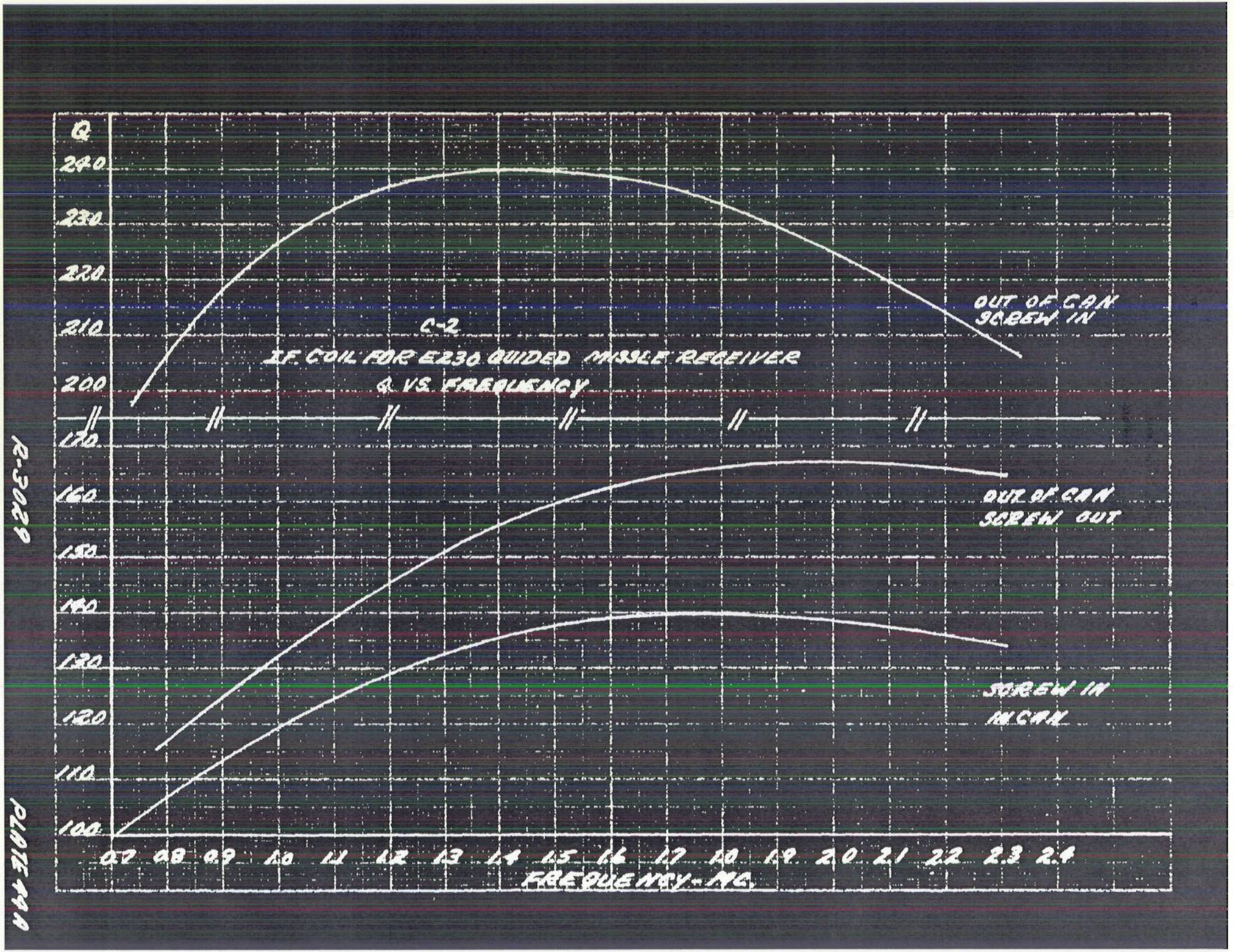
R-3029

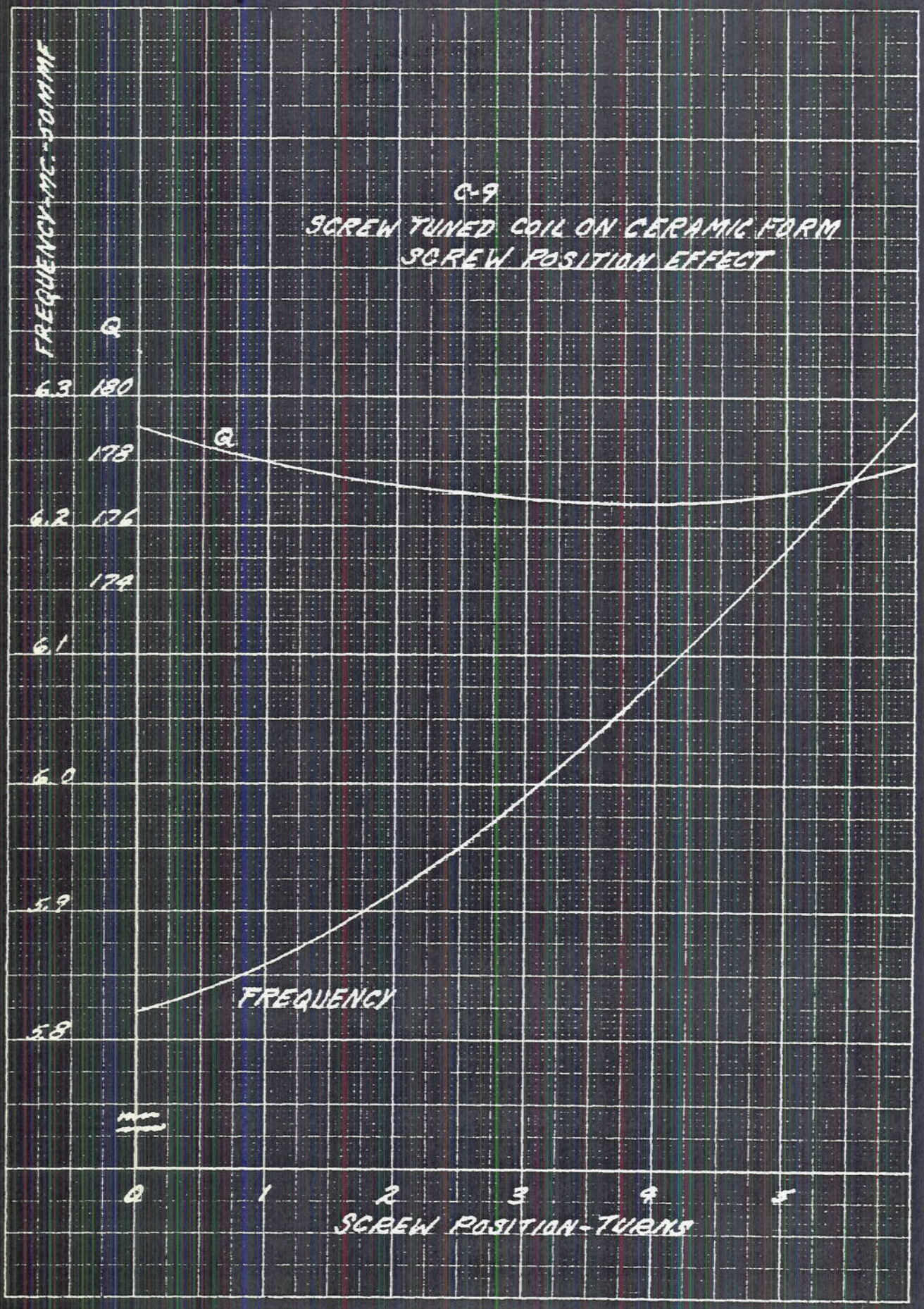
PLATE 43





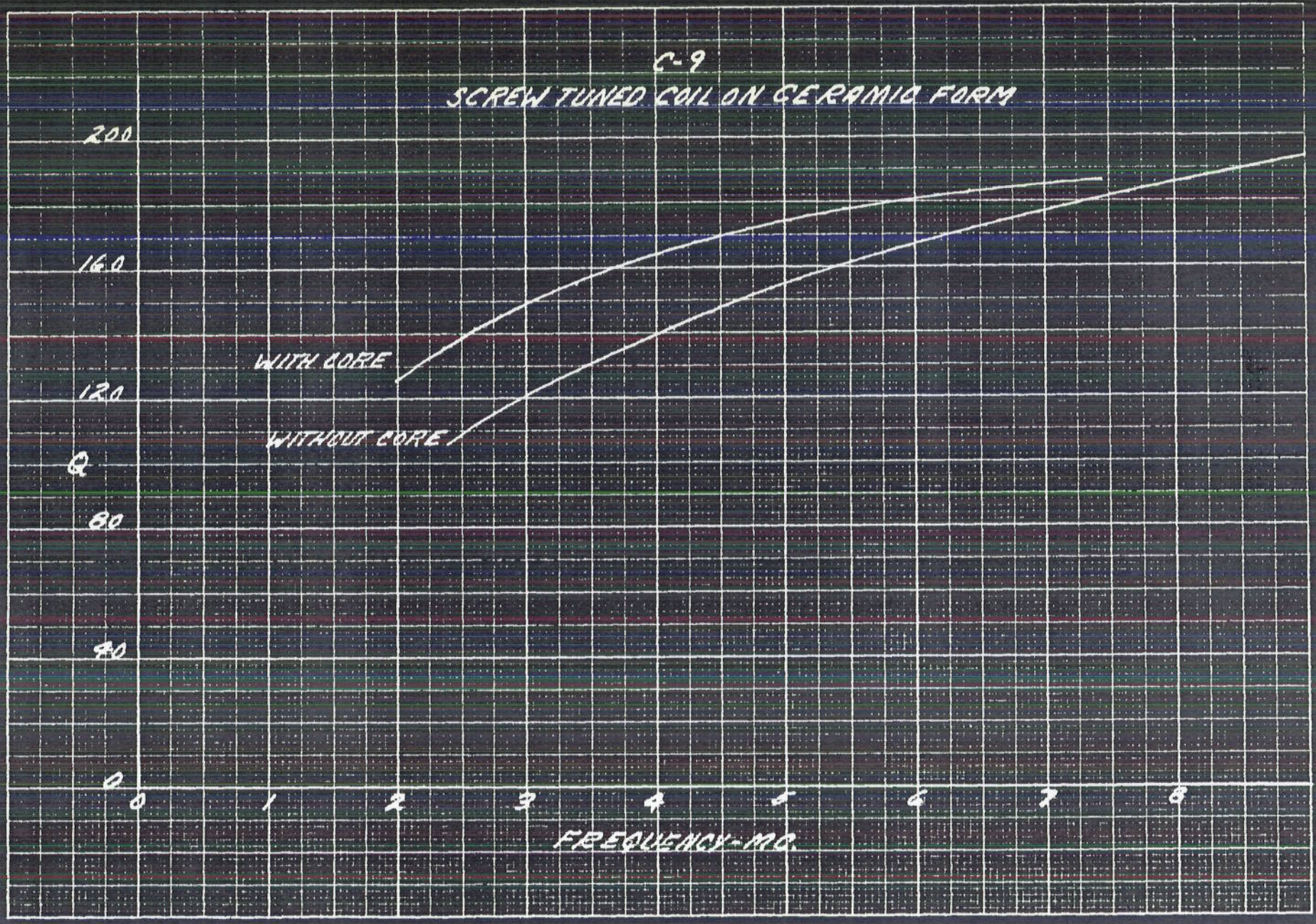
COMPONENT C-I
1000 DIAMETER PHOTOMICROGRAPHS OF RECEIVING TURRET SLUGS


Q
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
C-2
I.F. COIL FOR E230 GUIDED MISSLE RECEIVER
Q VS. FREQUENCY
OUT OF CAN SCREW IN
OUT OF CAN SCREW OUT
SCREW IN CAN
.07 .08 .09 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4
FREQUENCY - MC.
R-2028
PLATE 144



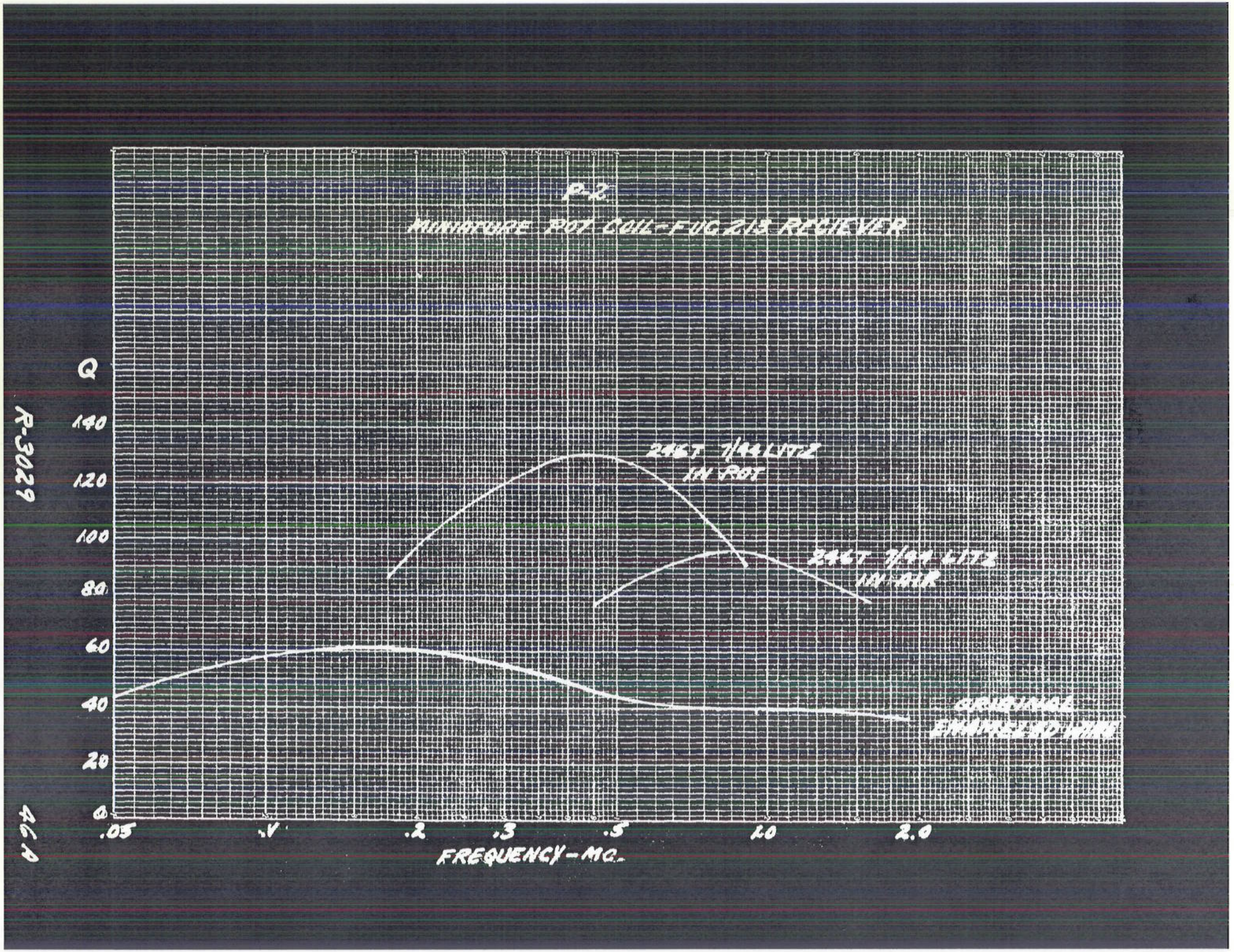
R-3029

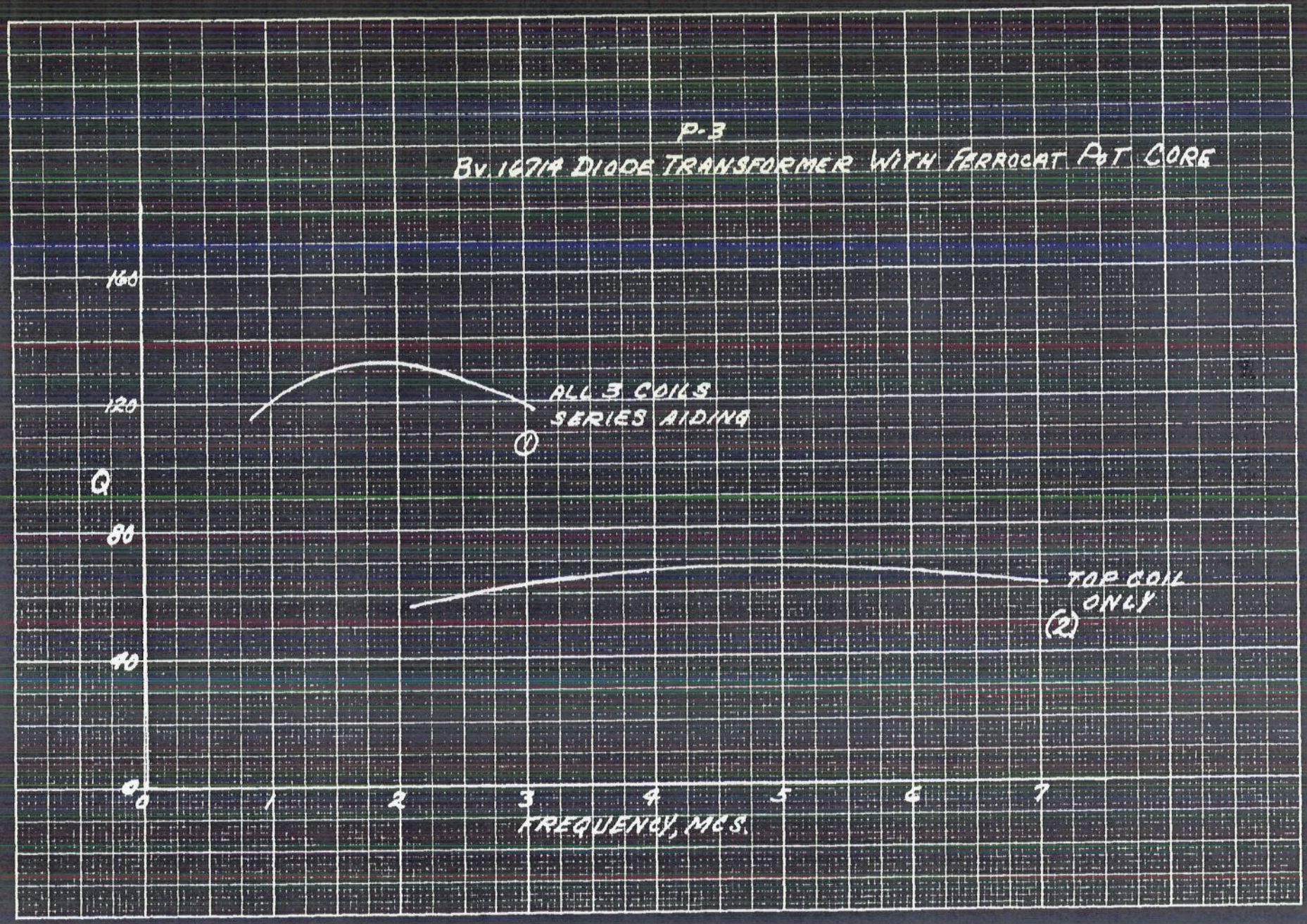
PLATE-95



R-3029

PLATE 46

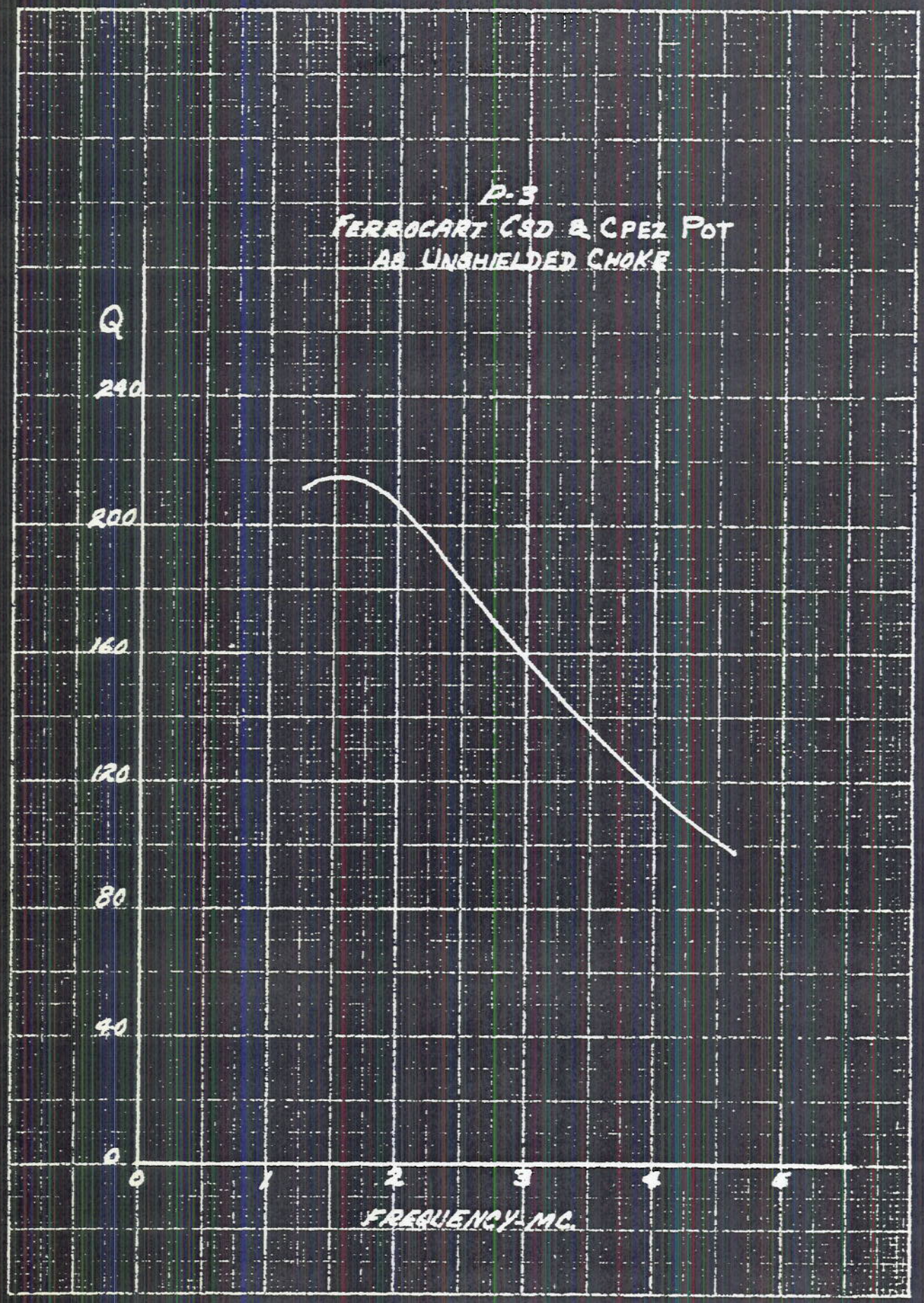

P-2
MINIATURE POT COIL - FIG. 21X RECEIVER
Q
140
120
100
80
60
40
20
0
.05
.1
.2
.3
.5
1.0
2.0
FREQUENCY - MC.
24GT 7/44 LITZ IN POT
24GT 7/44 LITZ IN AIR
P-3029
AC-4



R-3029

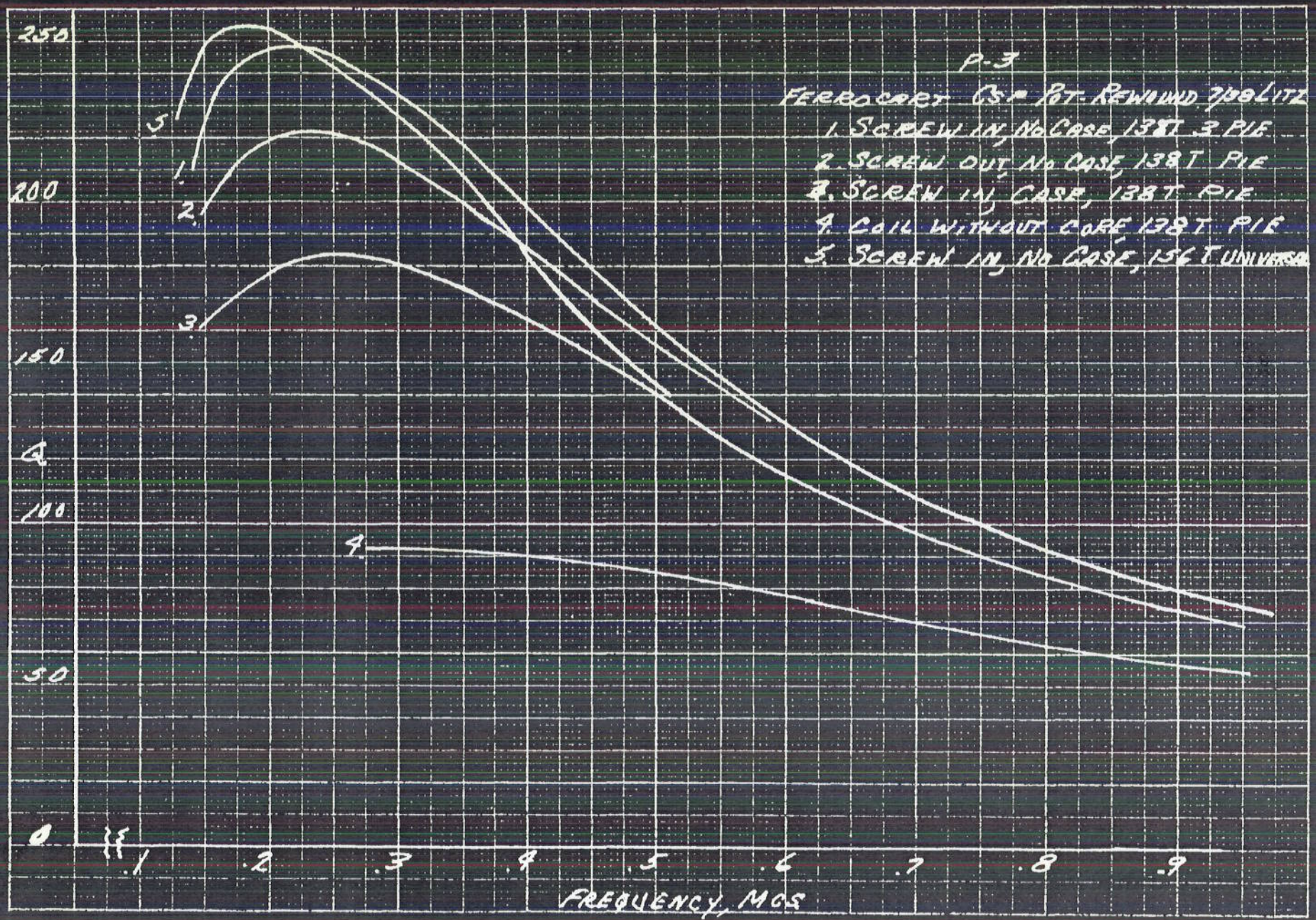
PLATE 47

P-3
FERROCART C9D & CPEZ POT
AS UNSHIELDED CHOKE



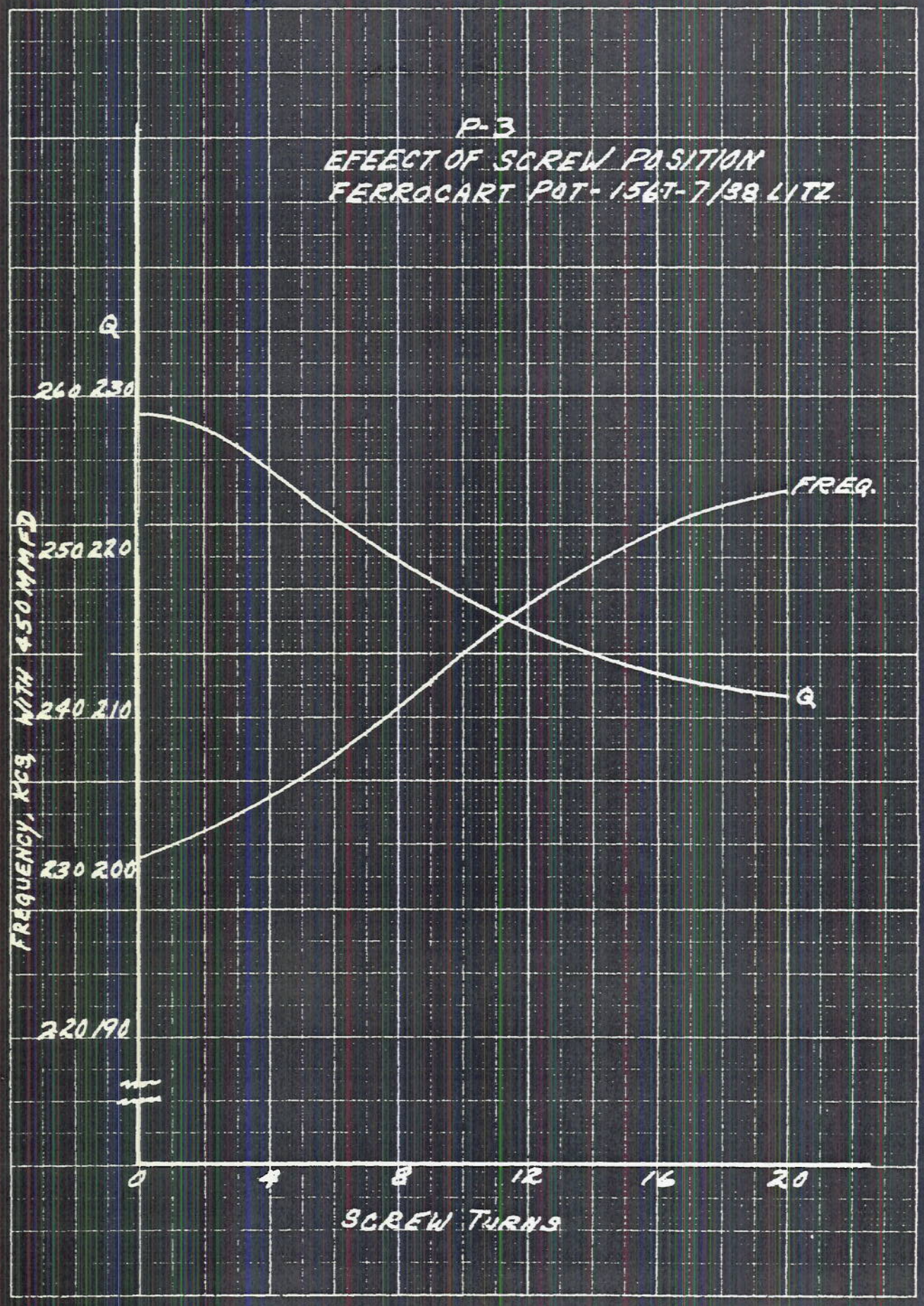
R-3029

PLATE 48



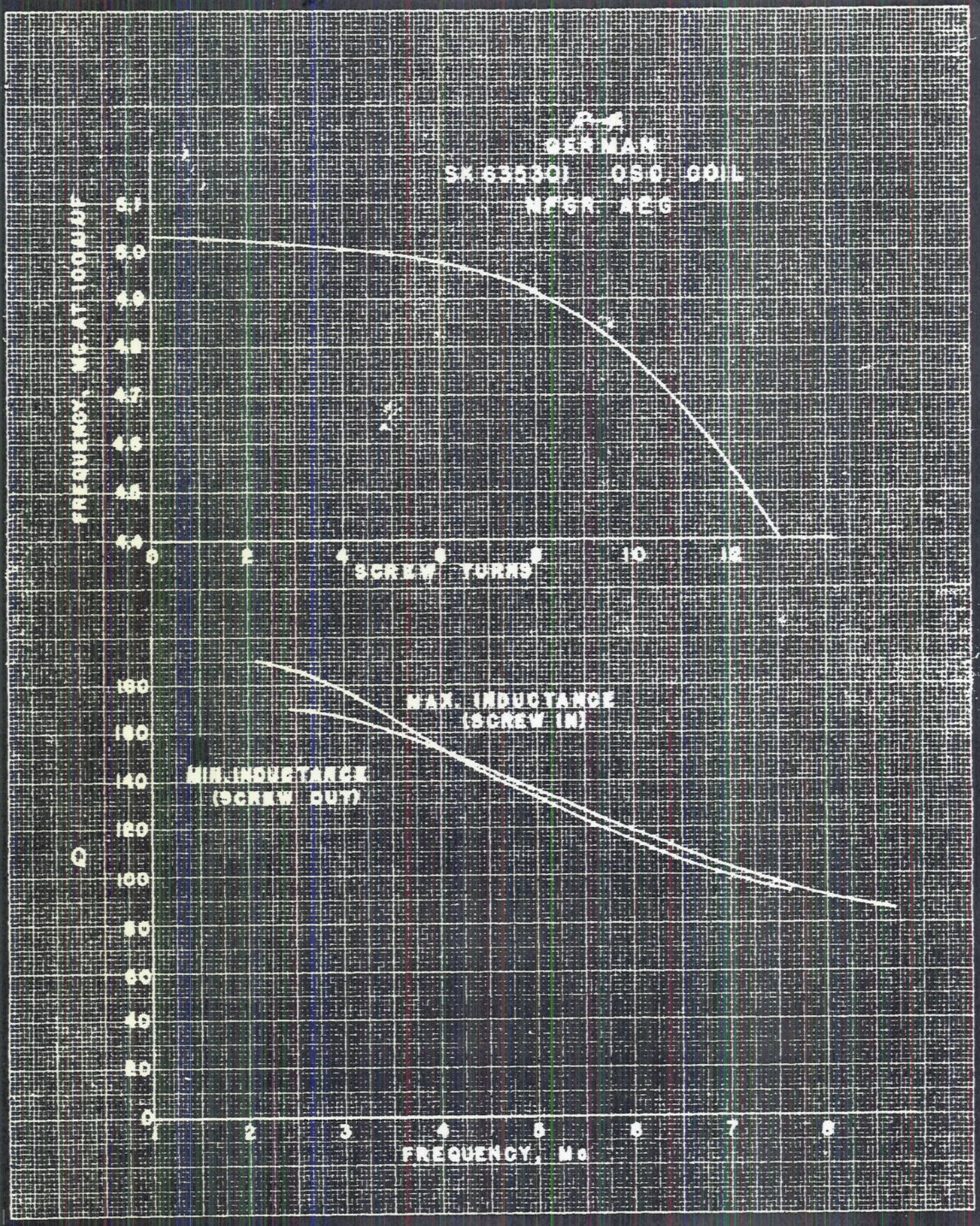
P-3029

PLATE 49



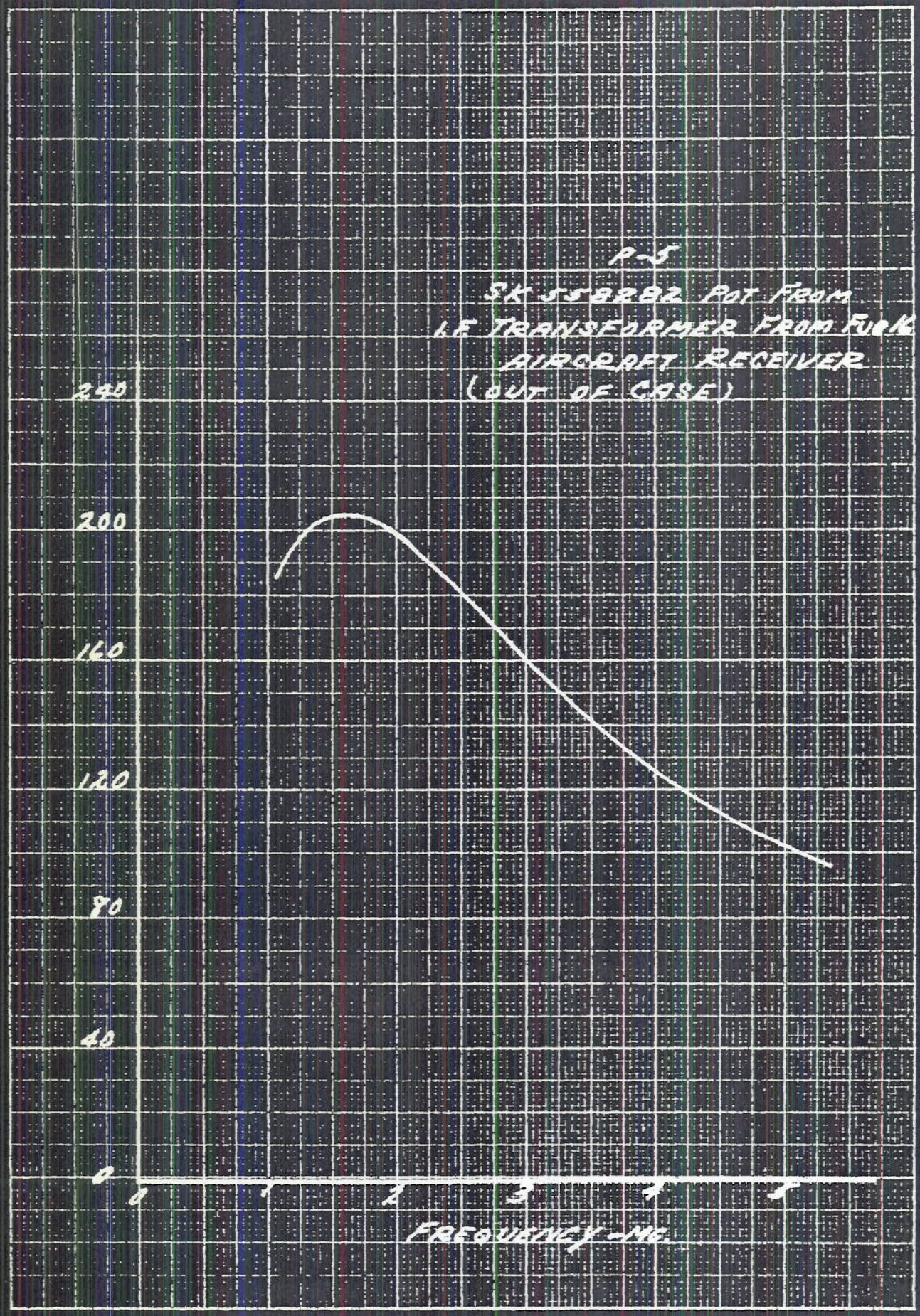
R-3029

PLATE 50



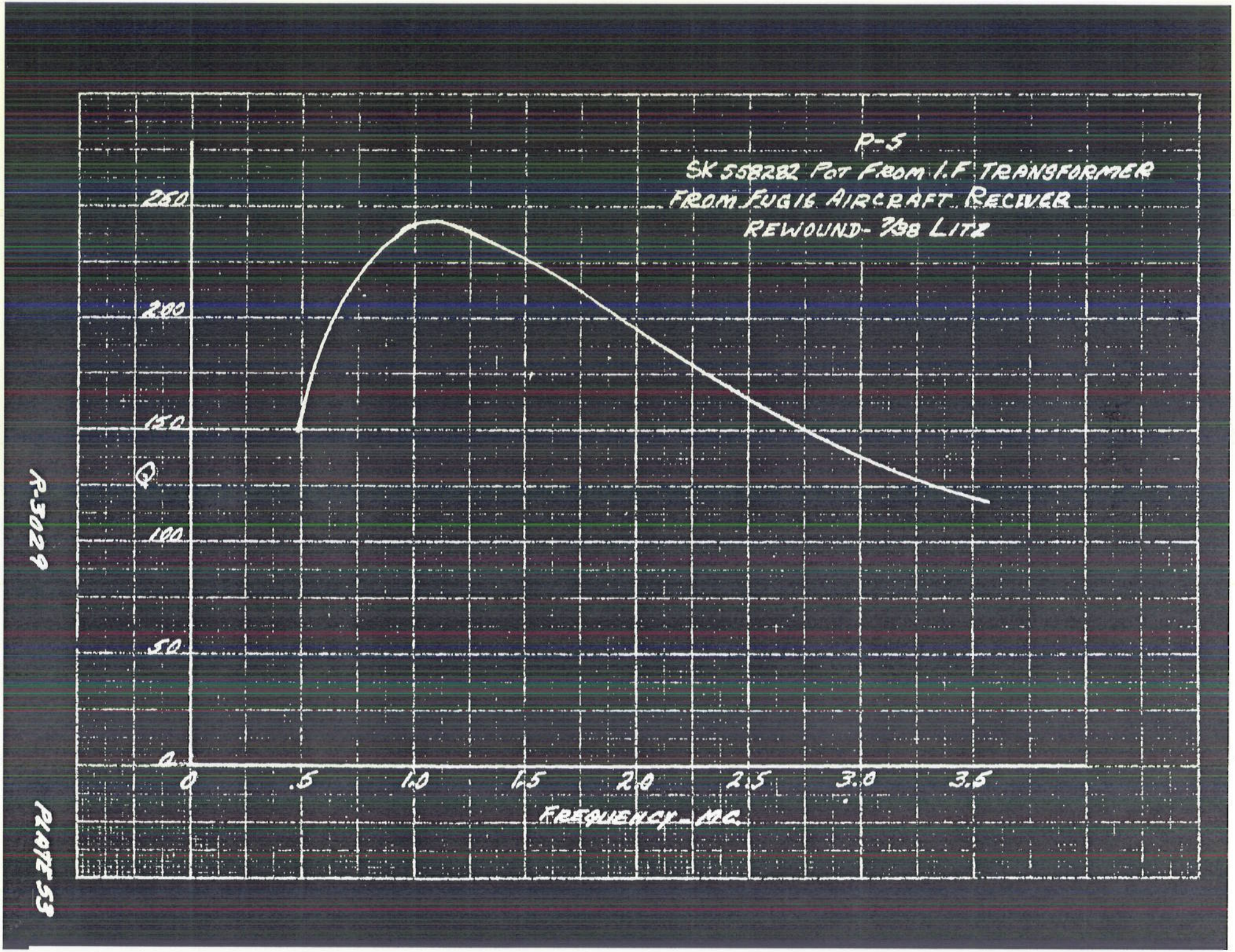
R-3029

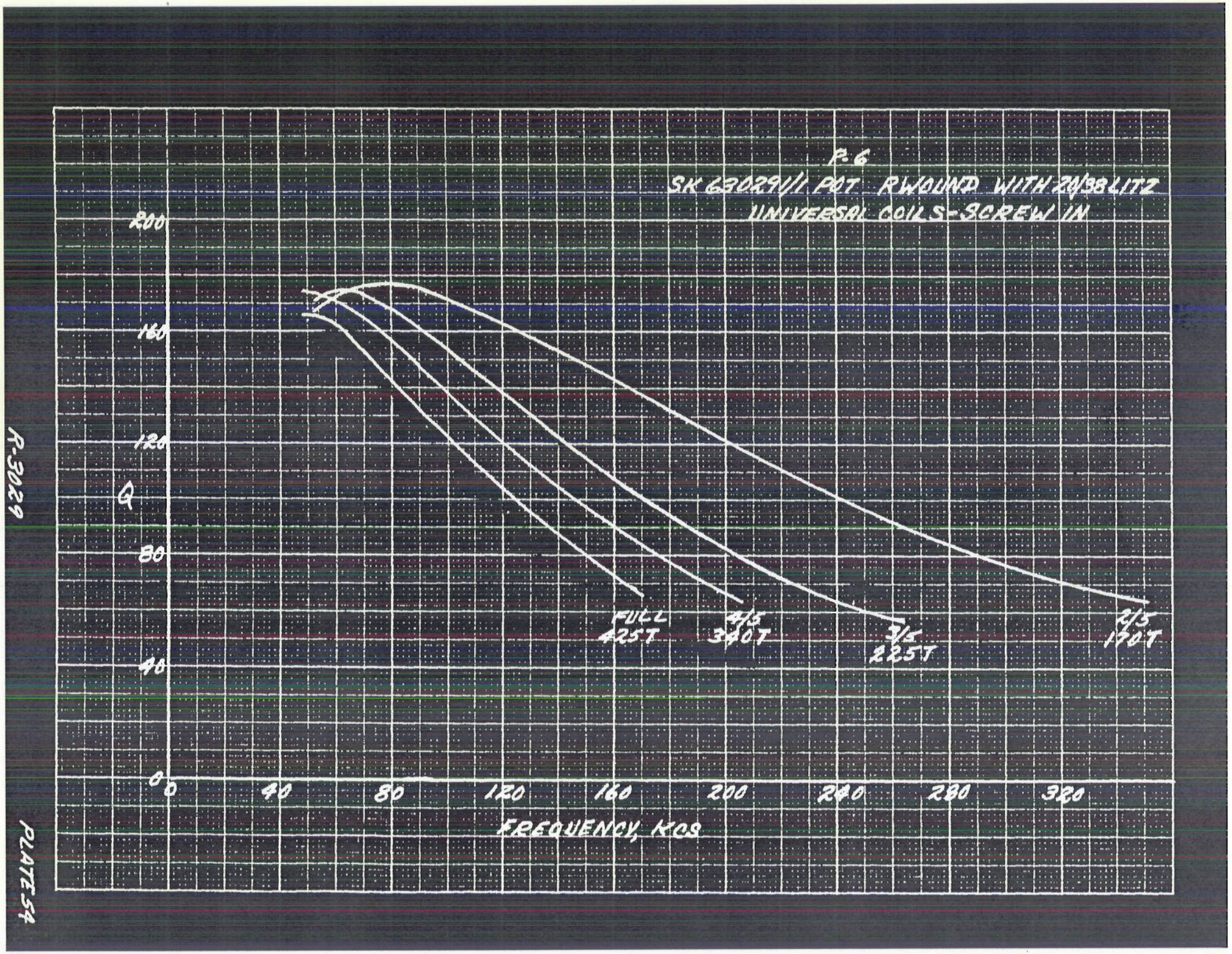
PLATE 51



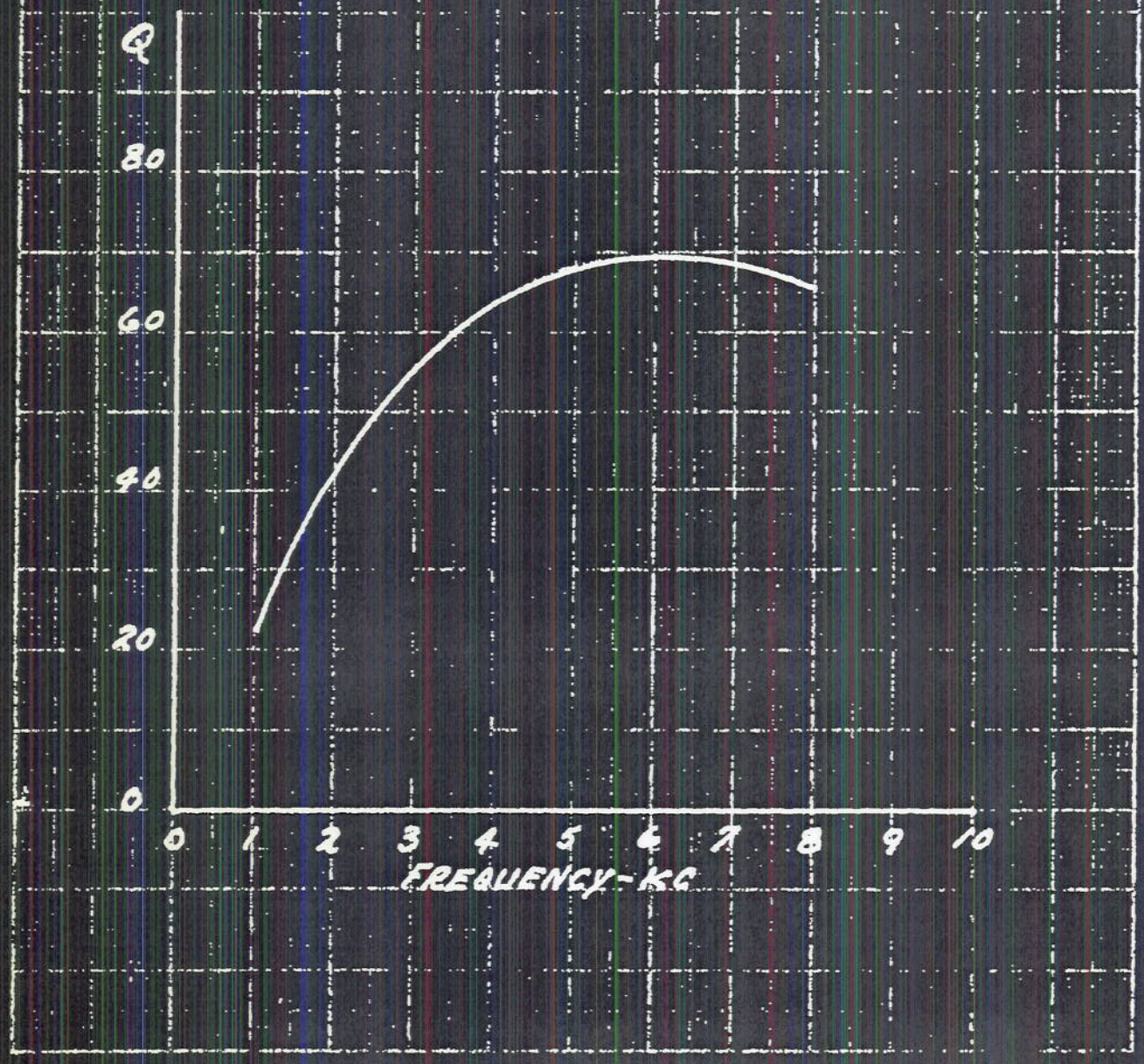
R-3029

PLATE 52


P-5
SK 558282 Pot From I.F. TRANSFORMER
FROM FUGIS AIRCRAFT RECIVER
REWOUND- 7/38 LITZ
250
200
150
Q
100
50
0
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
FREQUENCY - MC.
R-3029
PLATE 53

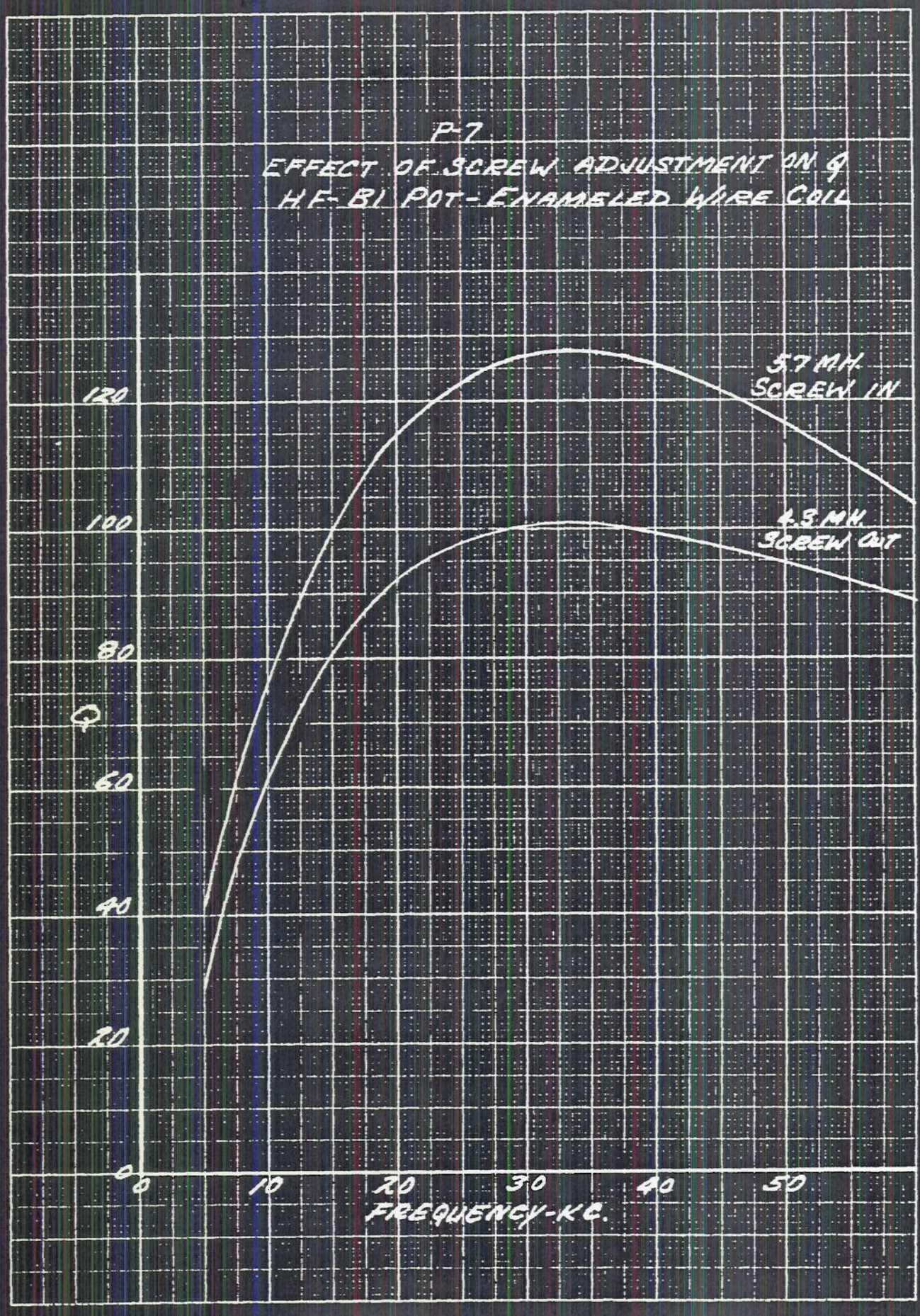

P.6
SK 63029/1 POT REWOUND WITH 24/38 LITZ
UNIVERSAL COILS - SCREW IN
200
160
120
Q
80
40
0
0
40
80
120
160
200
240
280
320
FREQUENCY, KCS
FULL
425T
4/5
340T
3/5
225T
2/5
170T
R-3029
PLATE 5A

P-6
SK 30291/1 POT COIL
ORIGINAL COIL



R-3029

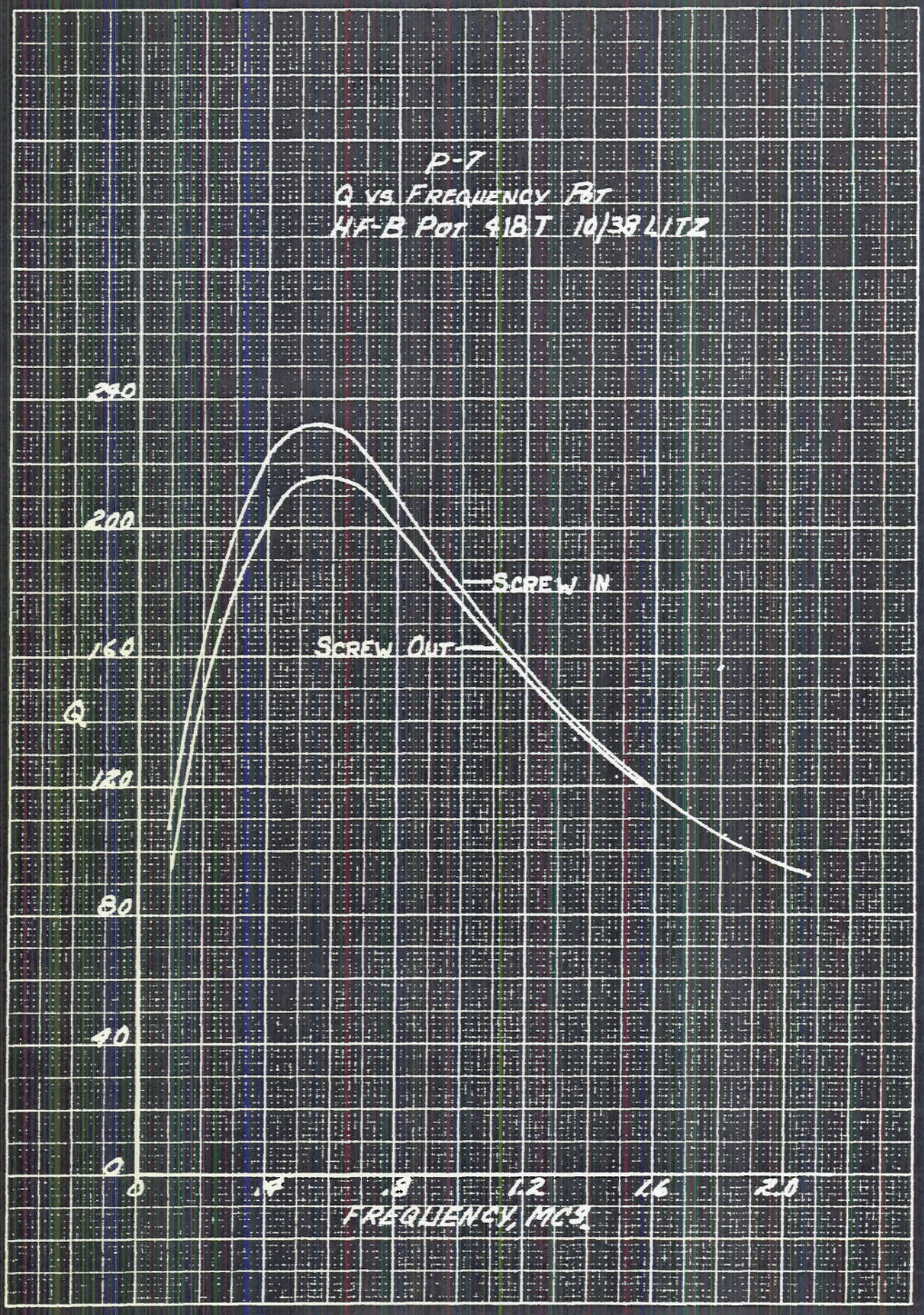
PLATE 55



R-3029

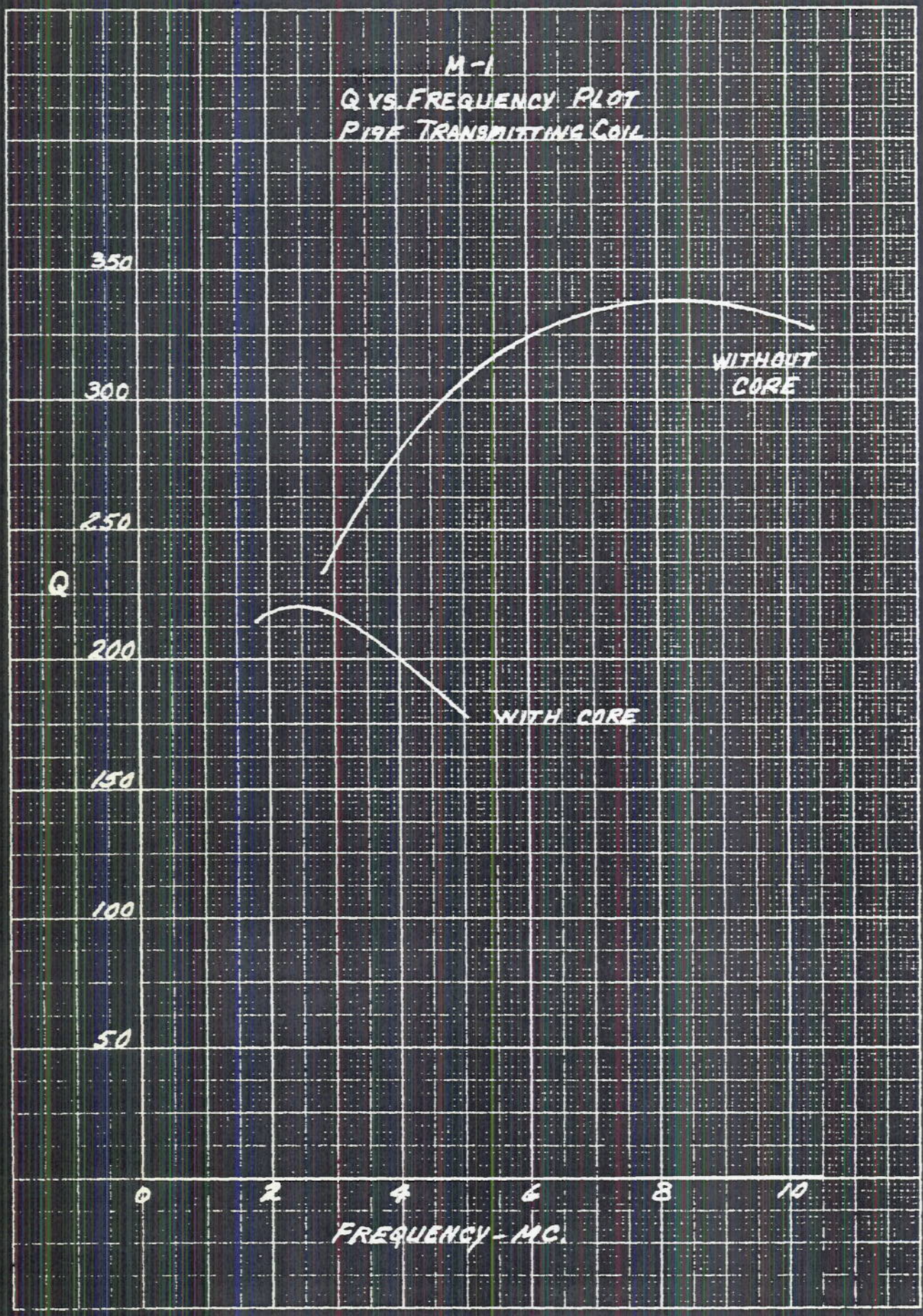
PLATE 56

GERMAN A. PLATE POT CORES
P.12
A= ASBESTOS AS PACKING
B= STEEL RIBBON WOUND
C= POT WITH SLOTS REMOVED
FREQUENCY IN KC.
10000
1000
100
150
Q 100
50
R-3029
PLATE 57



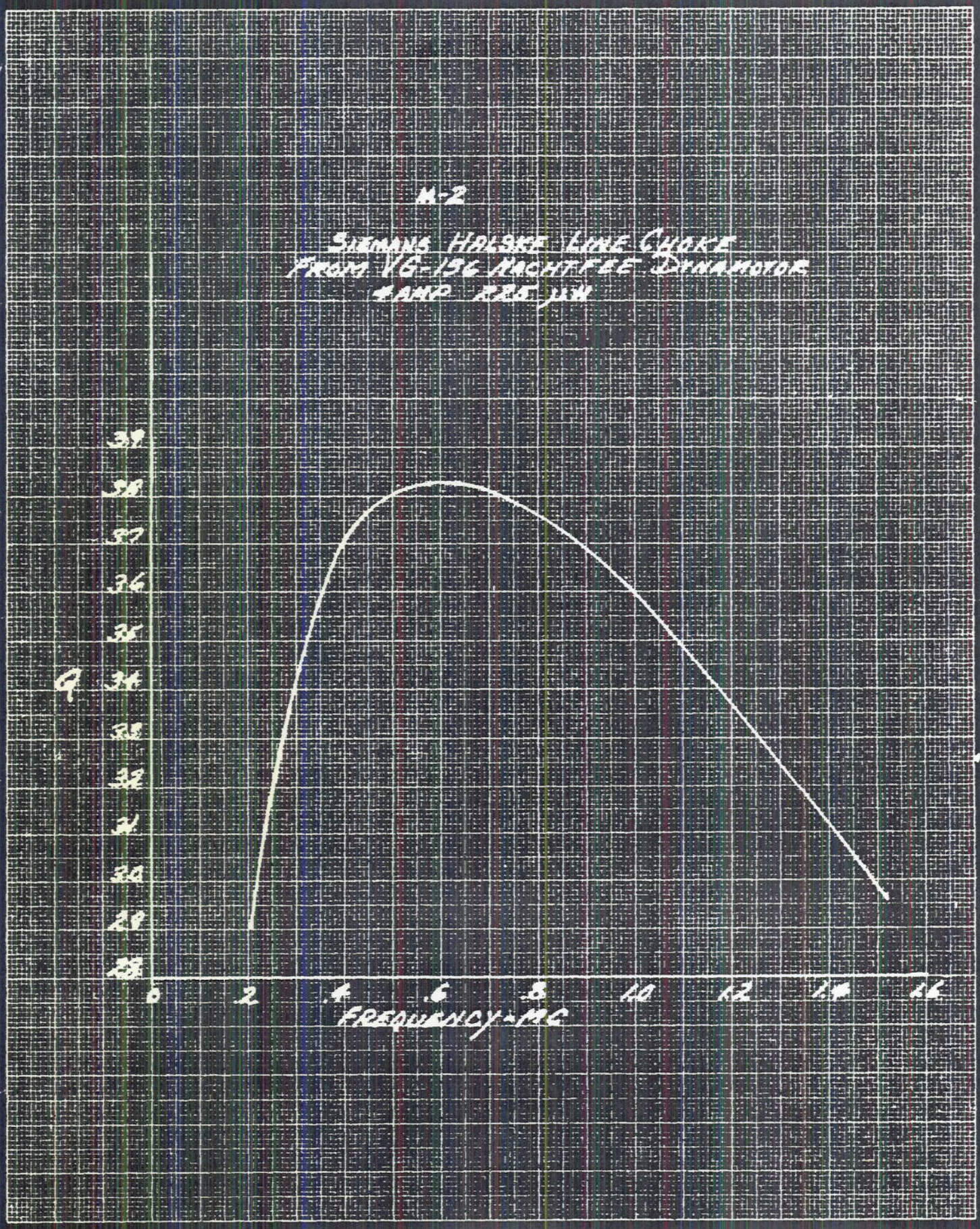
R-3029

PLATE 58



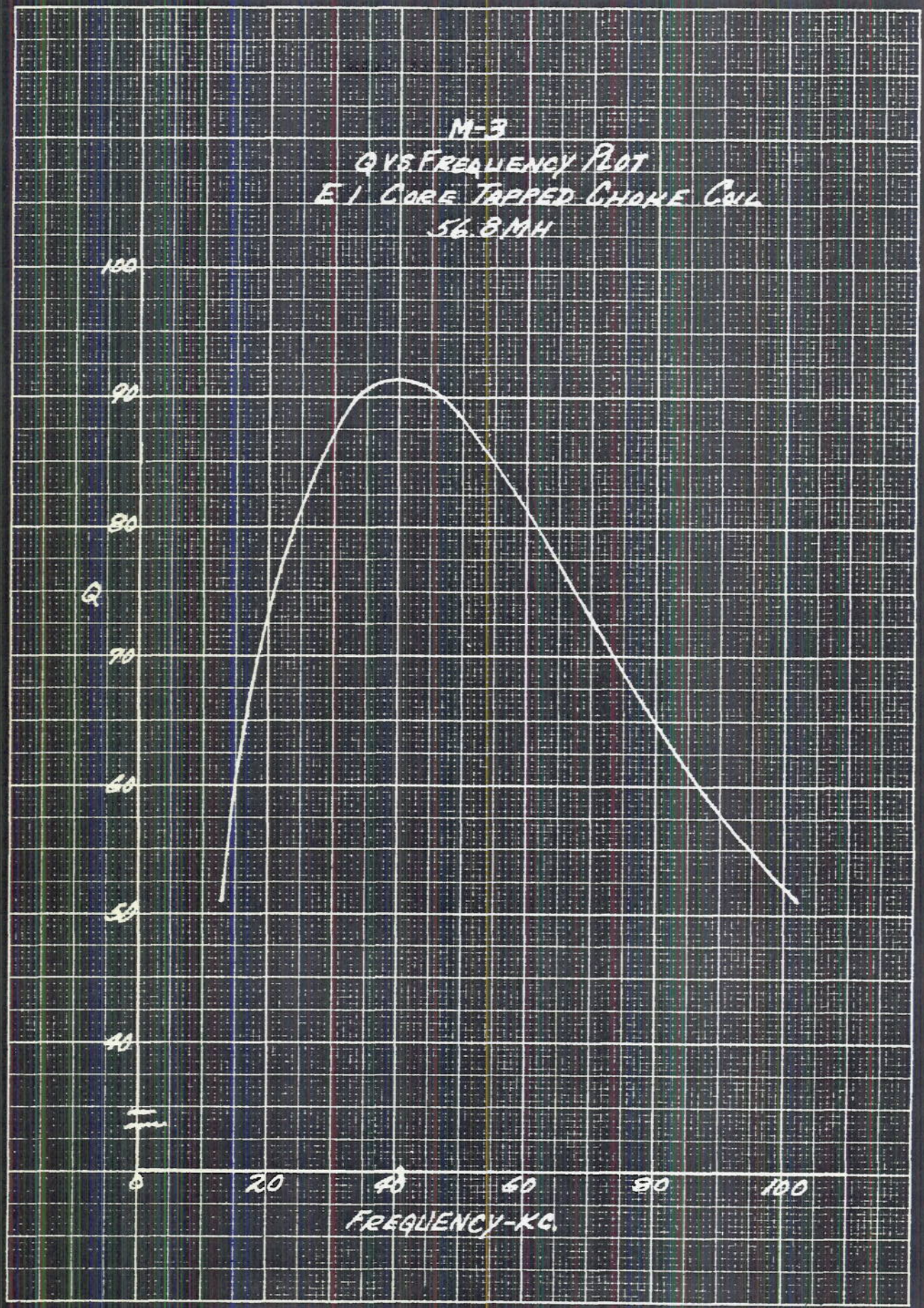
R-3029

PLATE 59



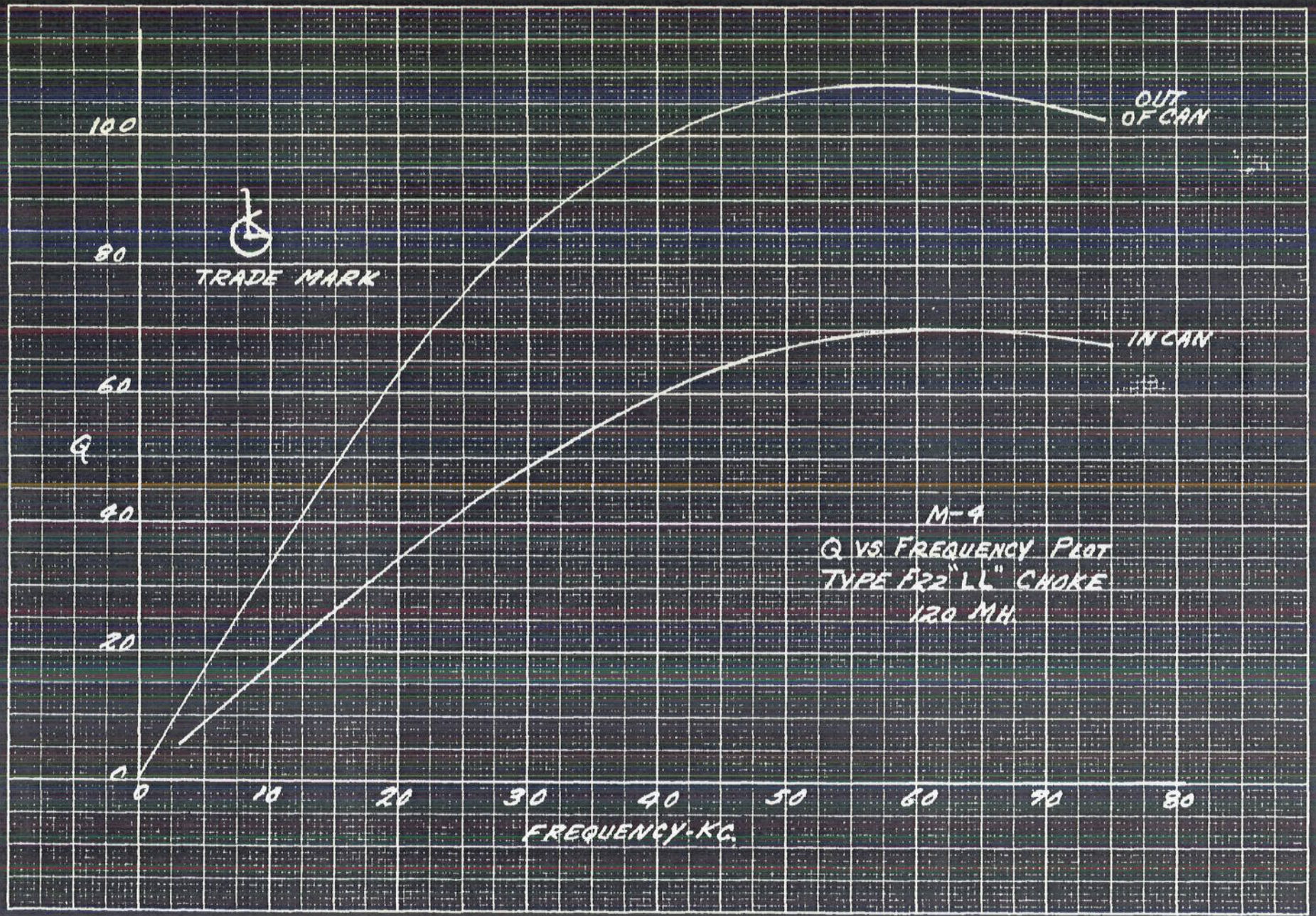
R-3029

PLATE 60



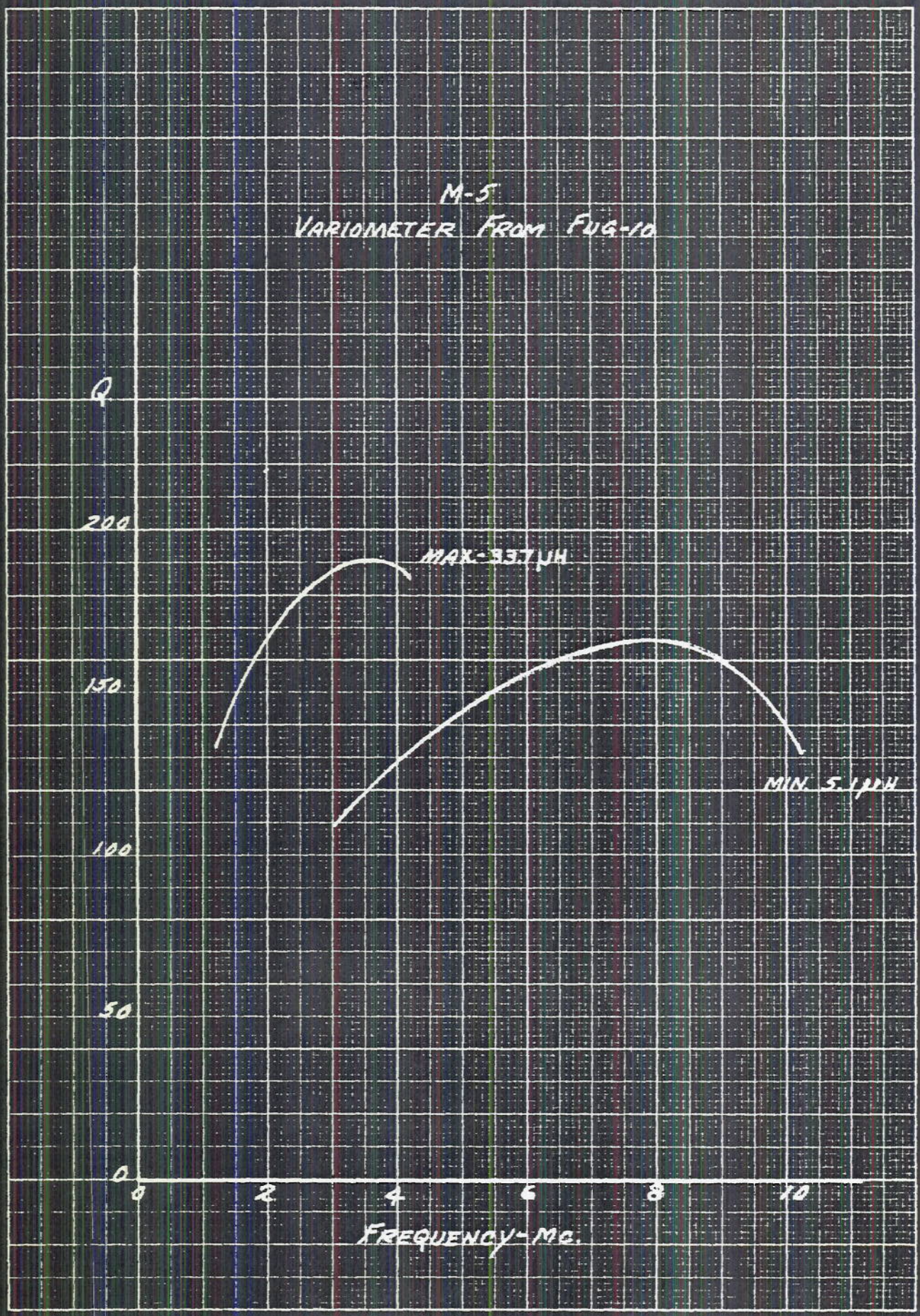
R-3029

PLATE 61



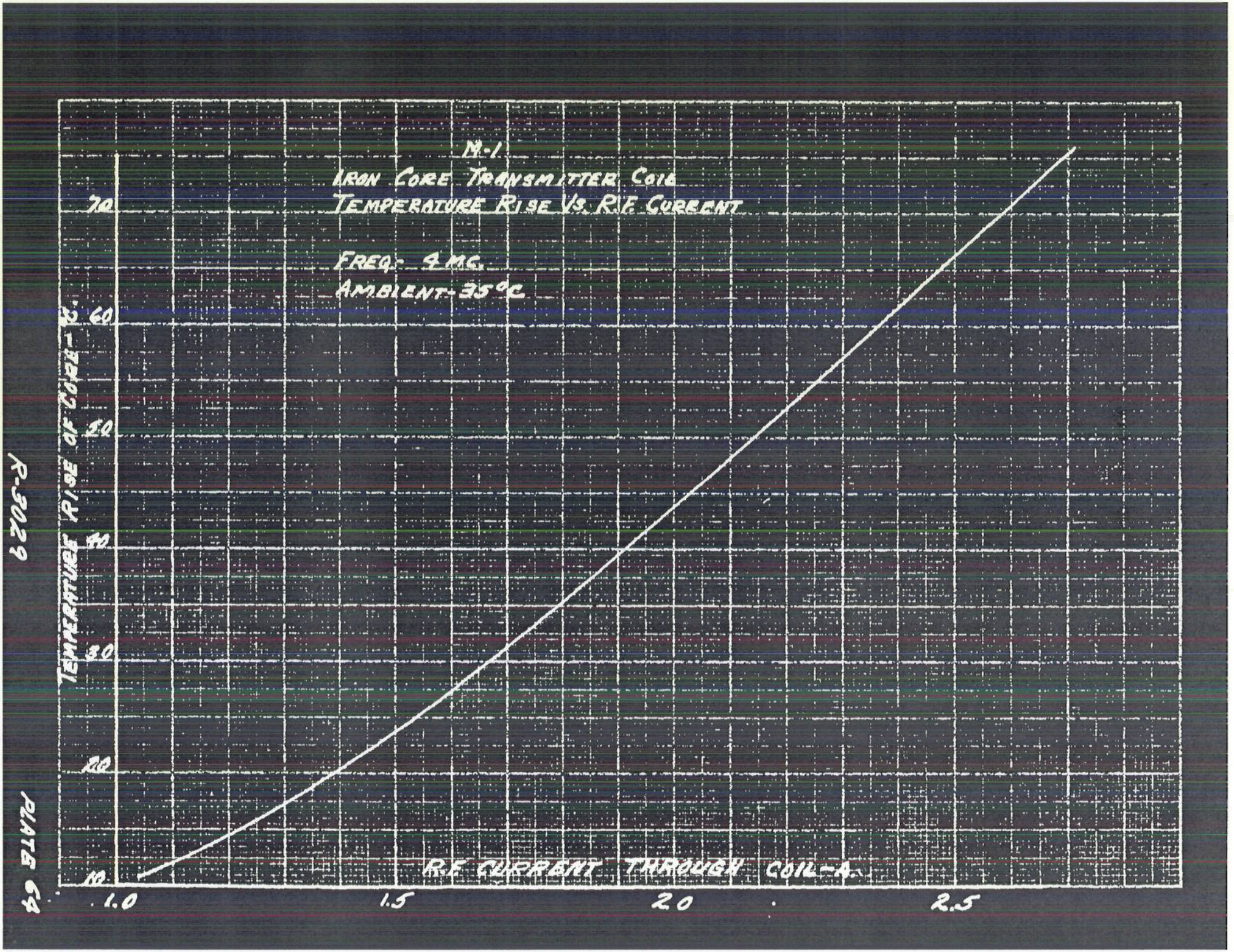
R-3029

PLATE 62



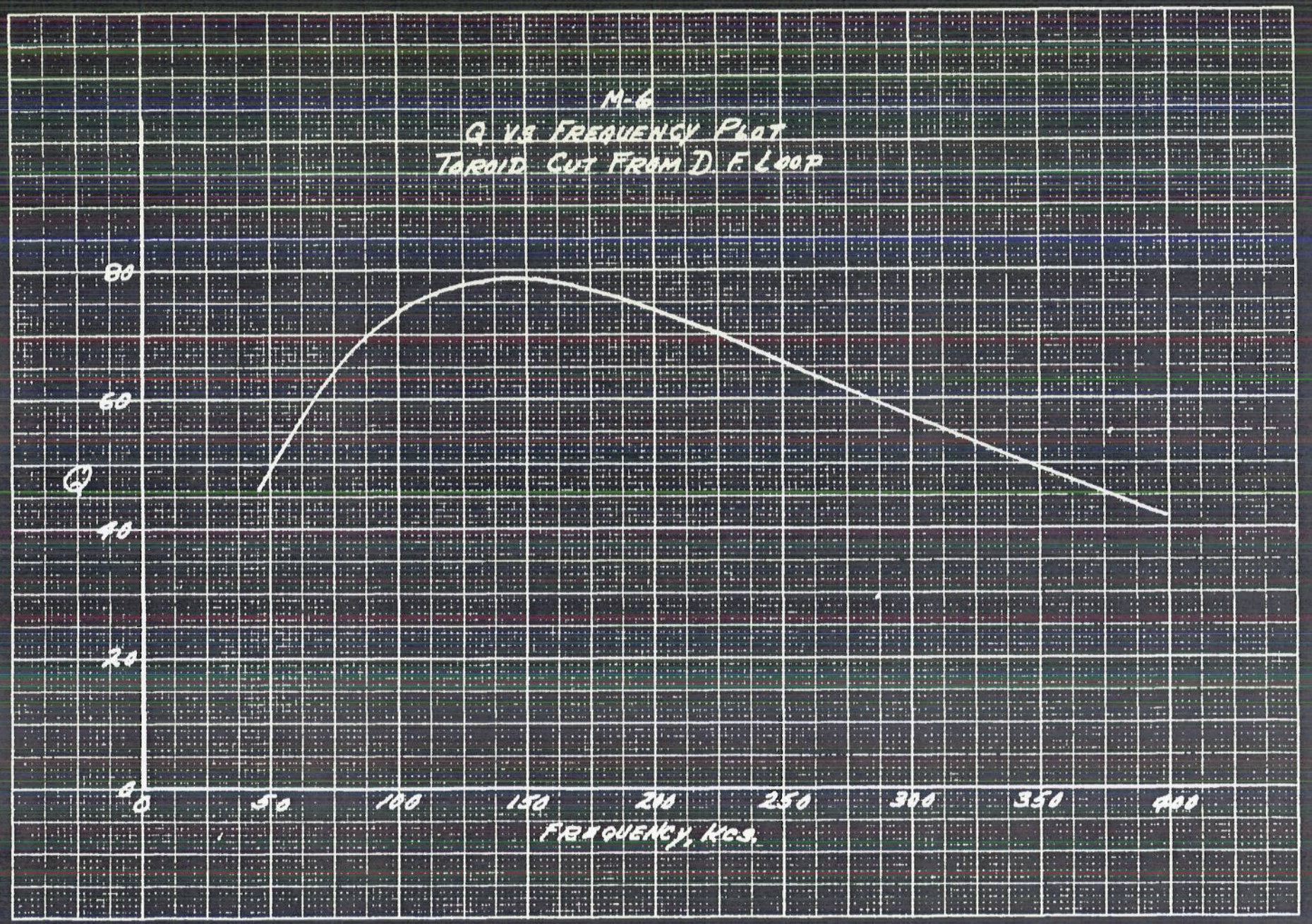
R-3029

PLATE 63



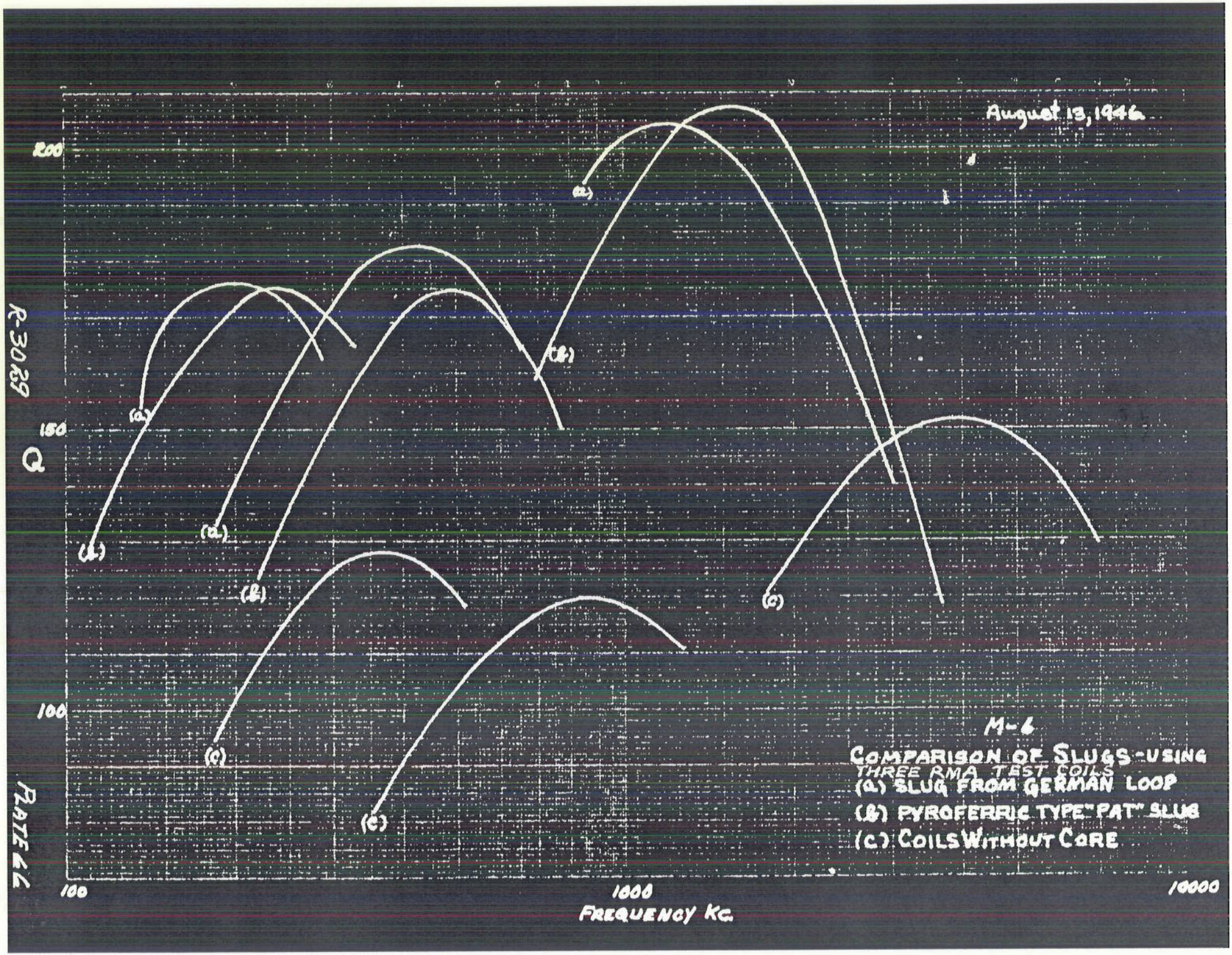
R-5029

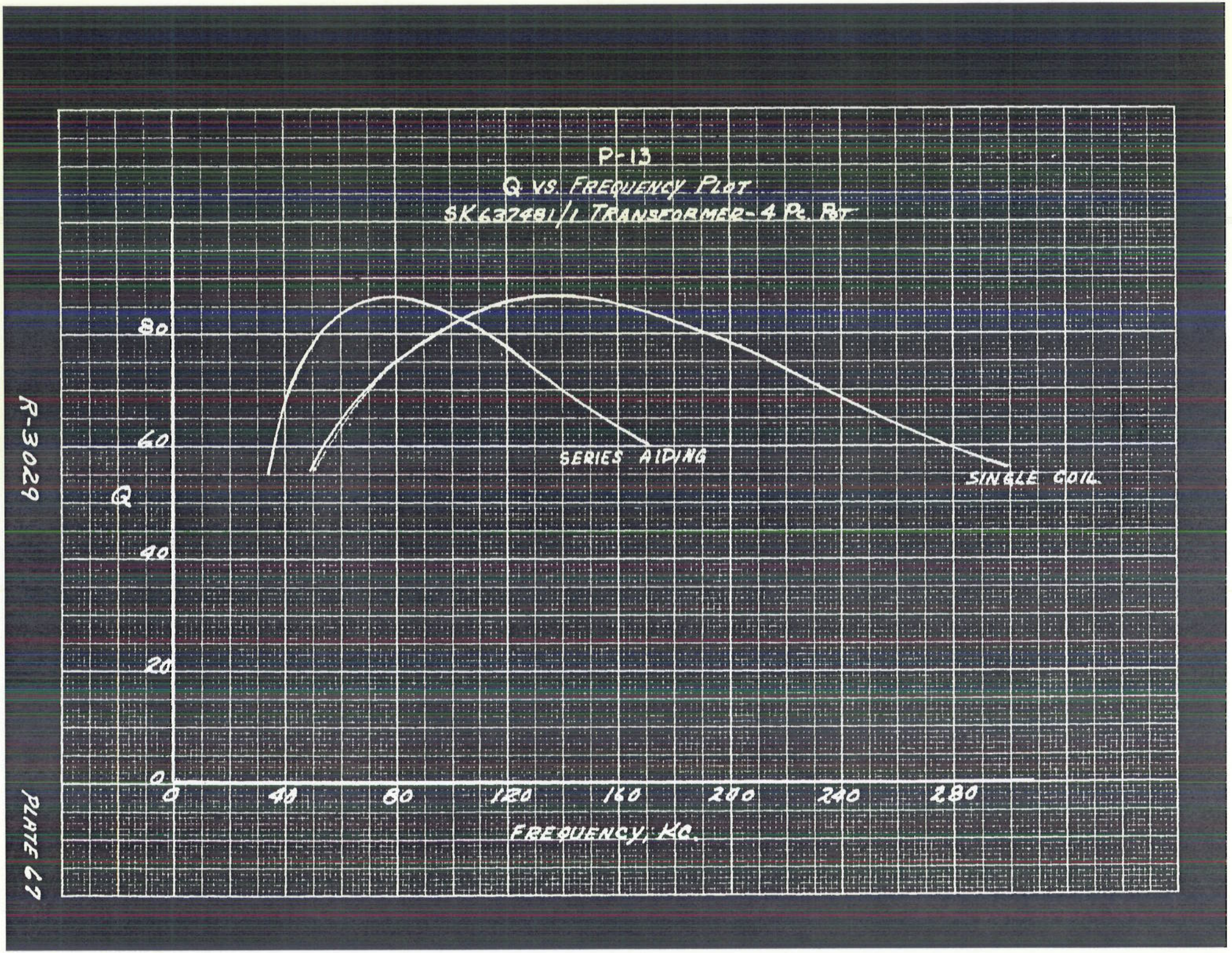
PLATE 69

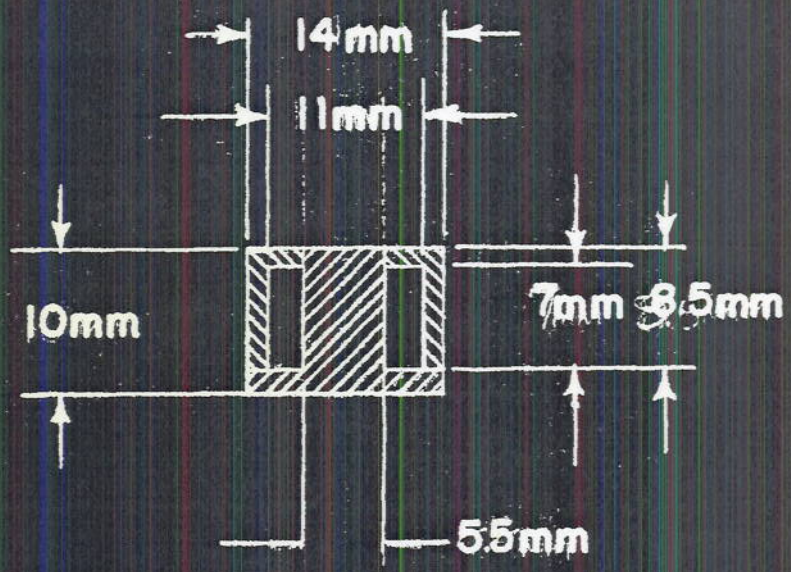


P-3029

PLATE 65


August 13, 1946
200
150
100
R-3039
Q
PATENT
100
1000
10000
FREQUENCY KC.
(a)
(b)
(c)
M-6
COMPARISON OF SLUGS - USING
THREE RMA TEST COILS
(a) SLUG FROM GERMAN LOOP
(b) PYROFERRIC TYPE "PAT" SLUG
(c) COILS WITHOUT CORE

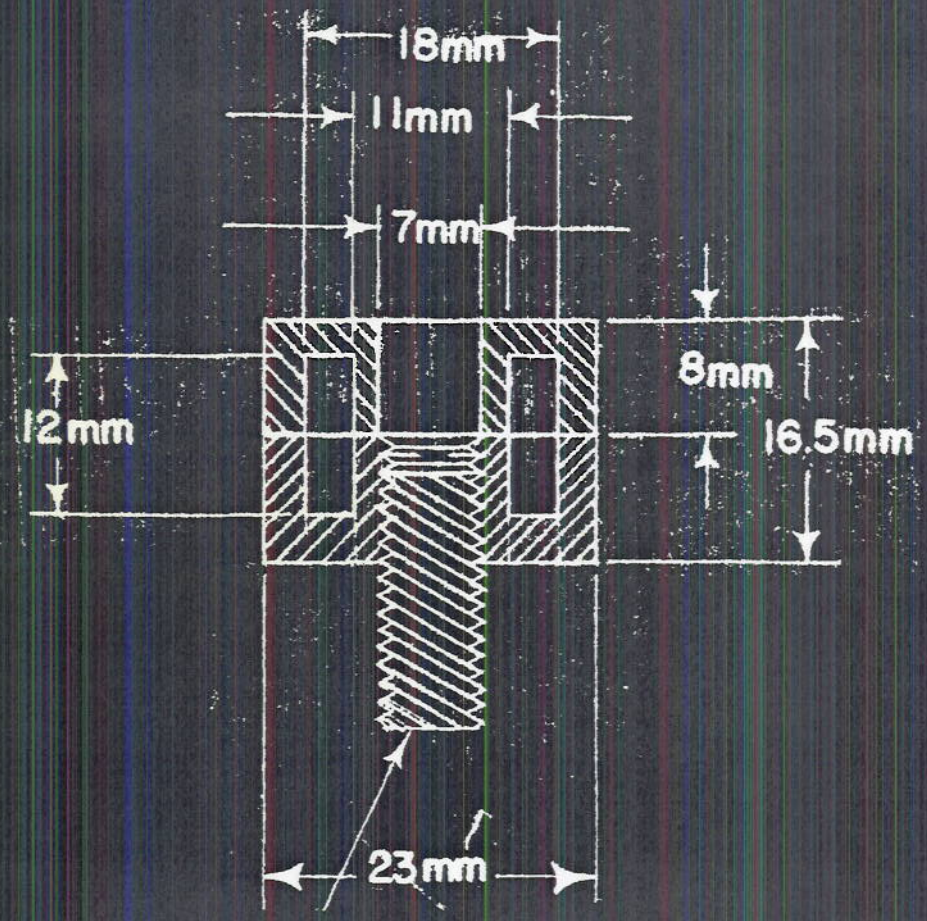

P-13
Q VS. FREQUENCY PLOT
SK 637481/1 TRANSFORMER-4 Pc. Pot
80
60
Q
40
20
0
0
40
80
120
160
200
240
280
FREQUENCY; KC.
SERIES AIDING
SINGLE COIL
R-3029
PLATE 67



P-1, P2

R-3029

PLATE 68

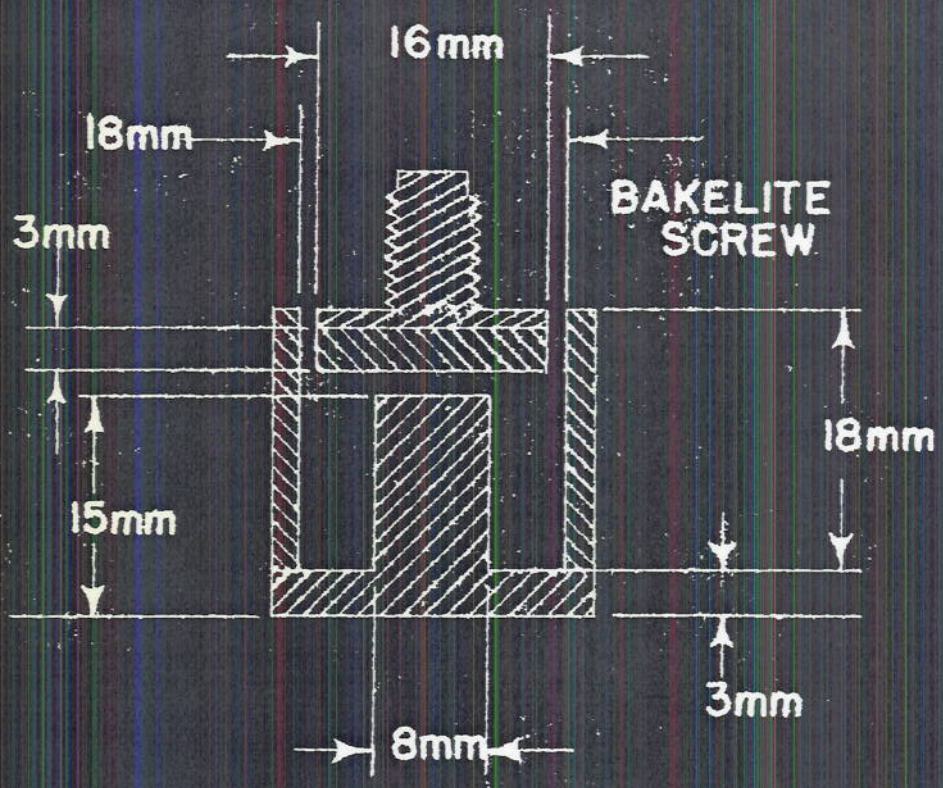


POWDERED IRON SCREW
21 mm LONG
7mm DIA.

P-3

R-3029

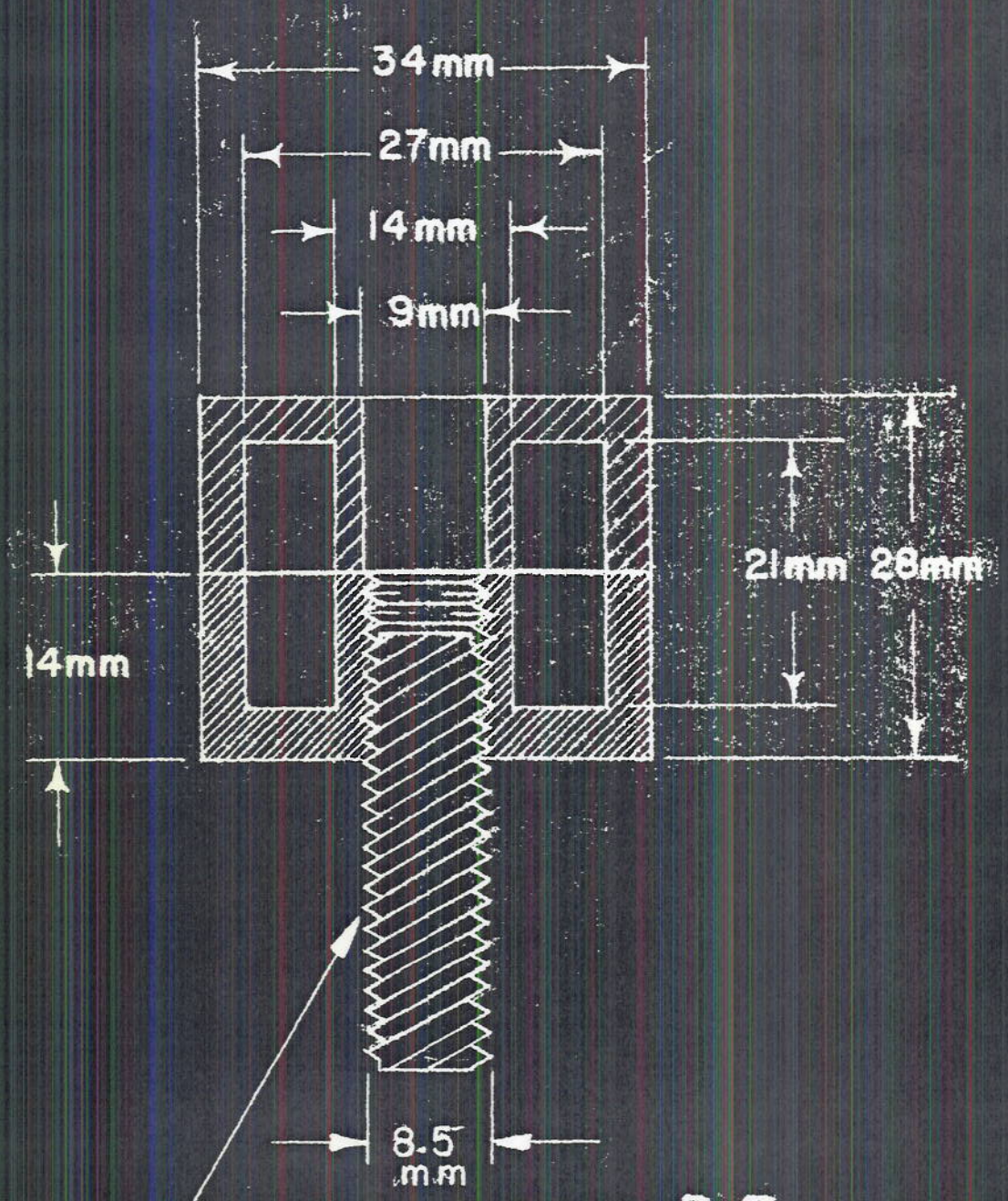
PLATE 61



P-4 & P5

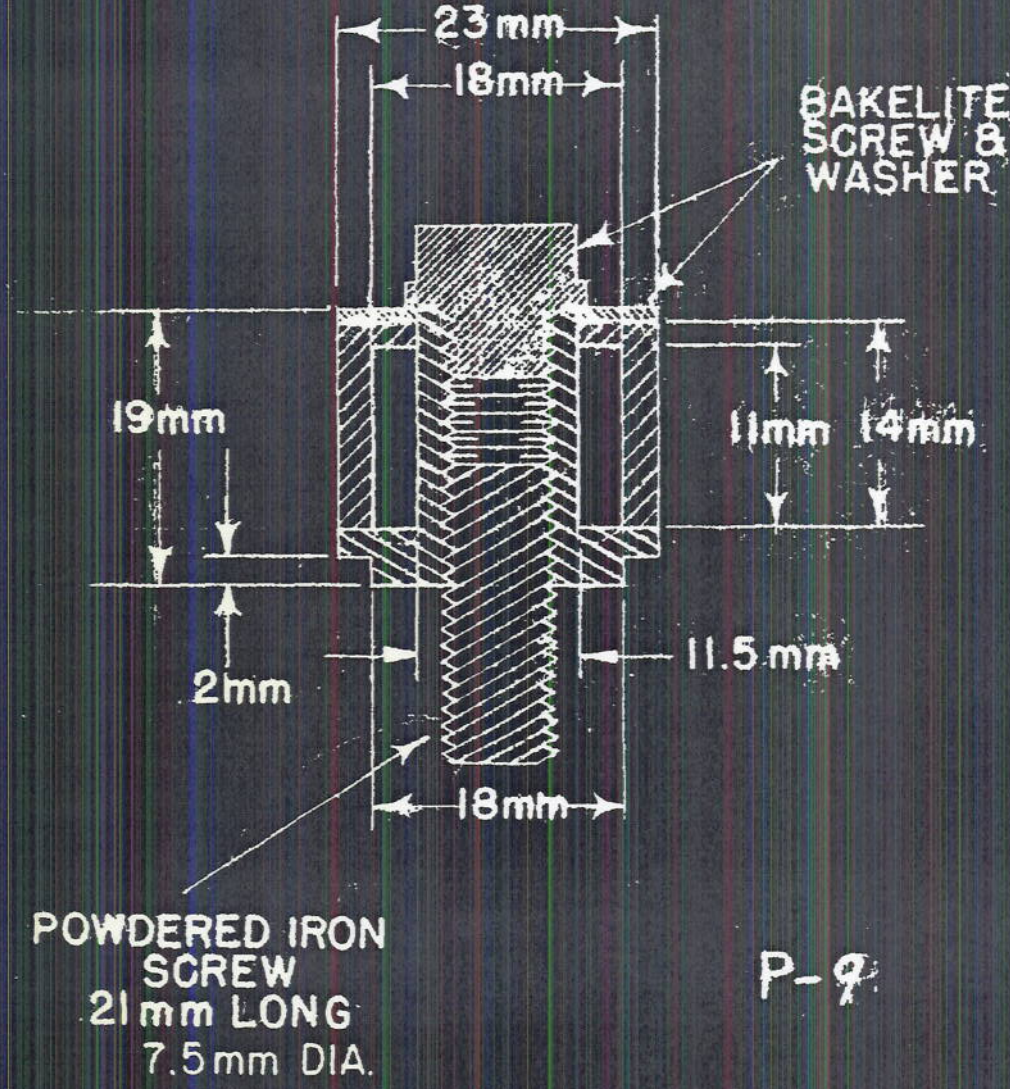
R-3029

PLATE 70



R-3029

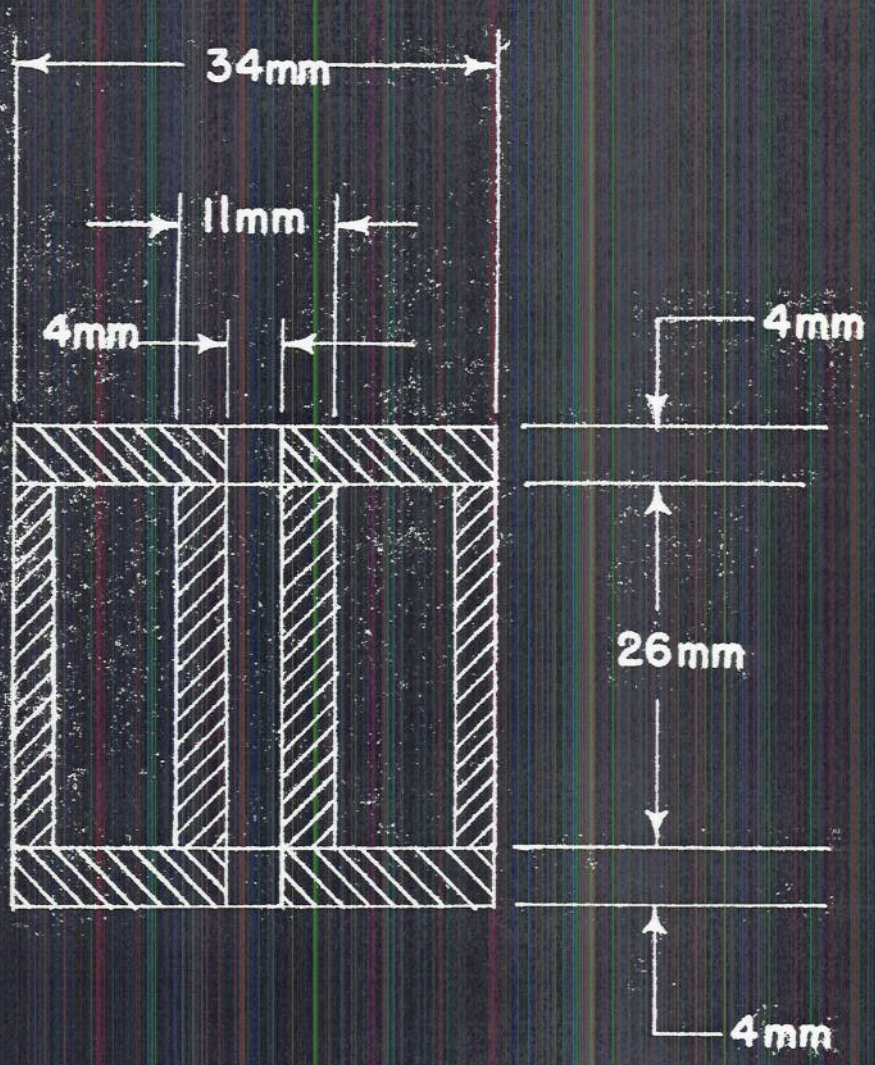
PLATE 71



P-9

R-3029

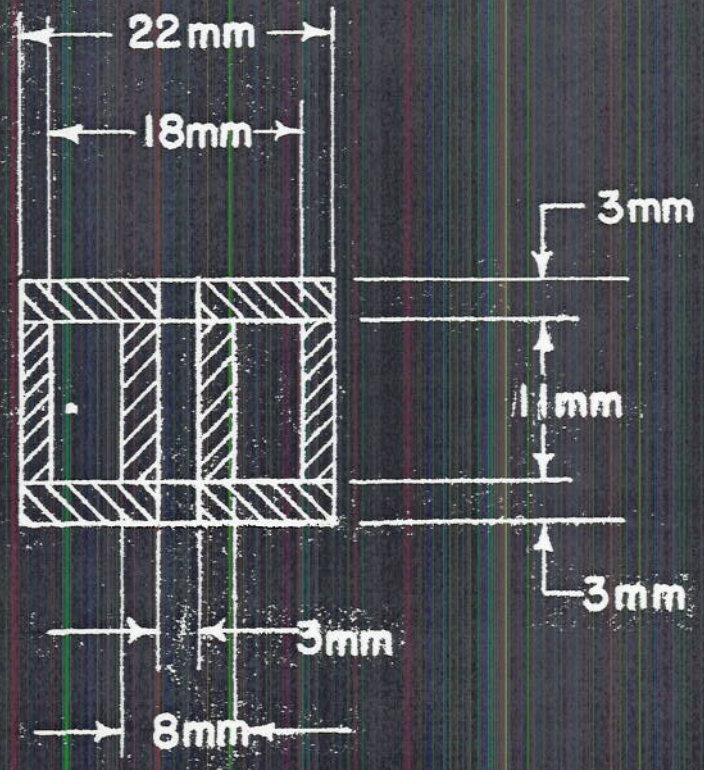
PLATE 28



P-11

R-3029

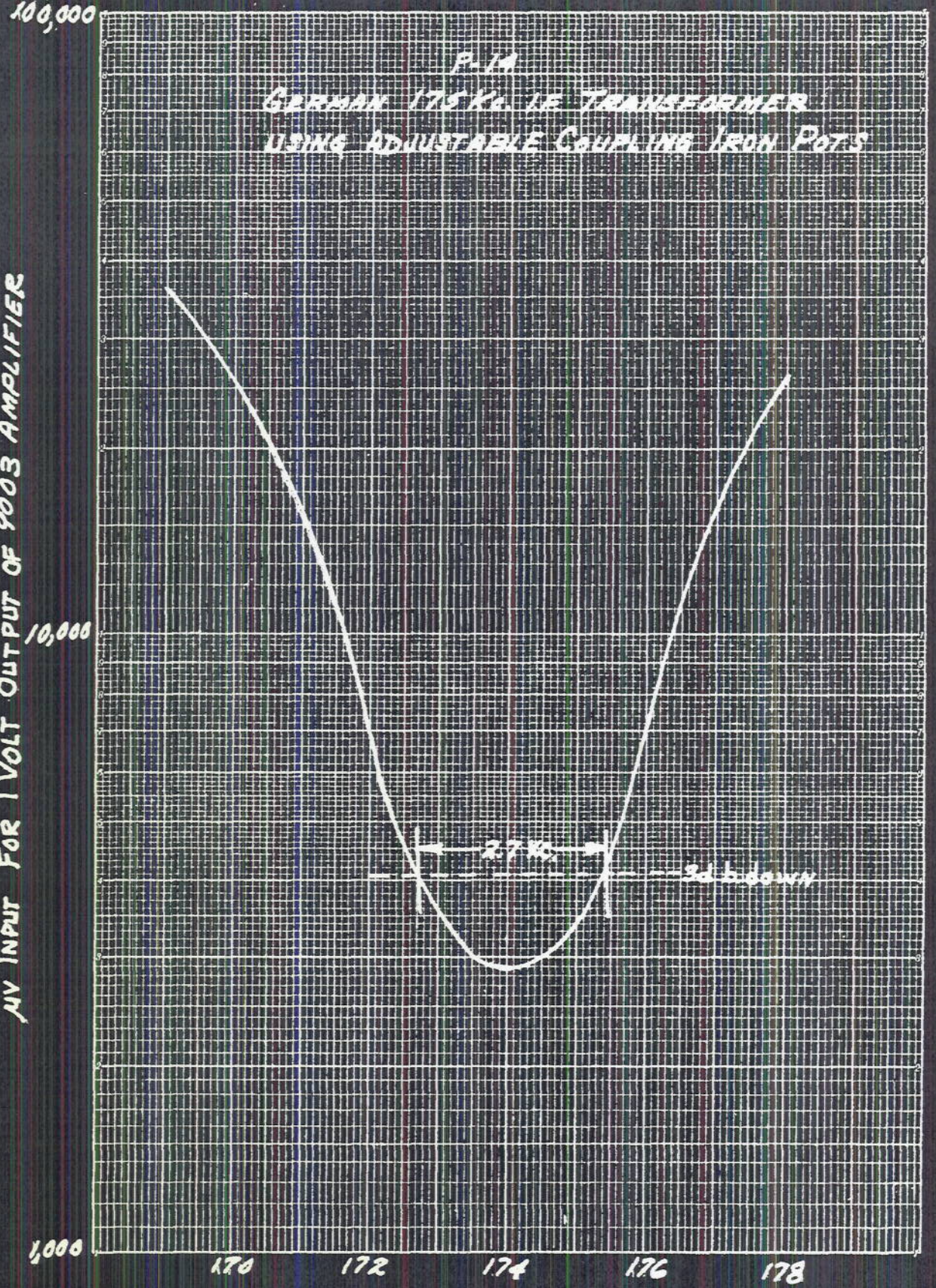
PLATE 73



P-12

R-3029

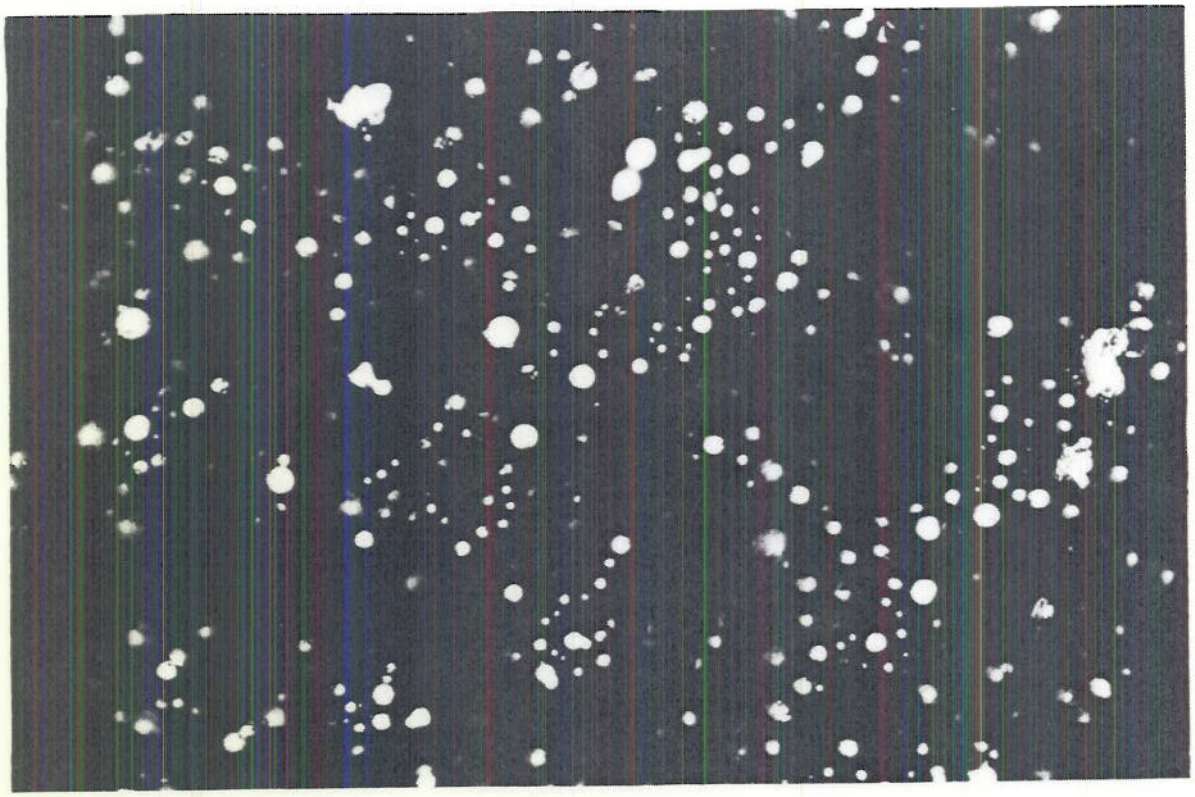
PLATE 74



MV INPUT FOR 1 VOLT OUTPUT OF 9003 AMPLIFIER

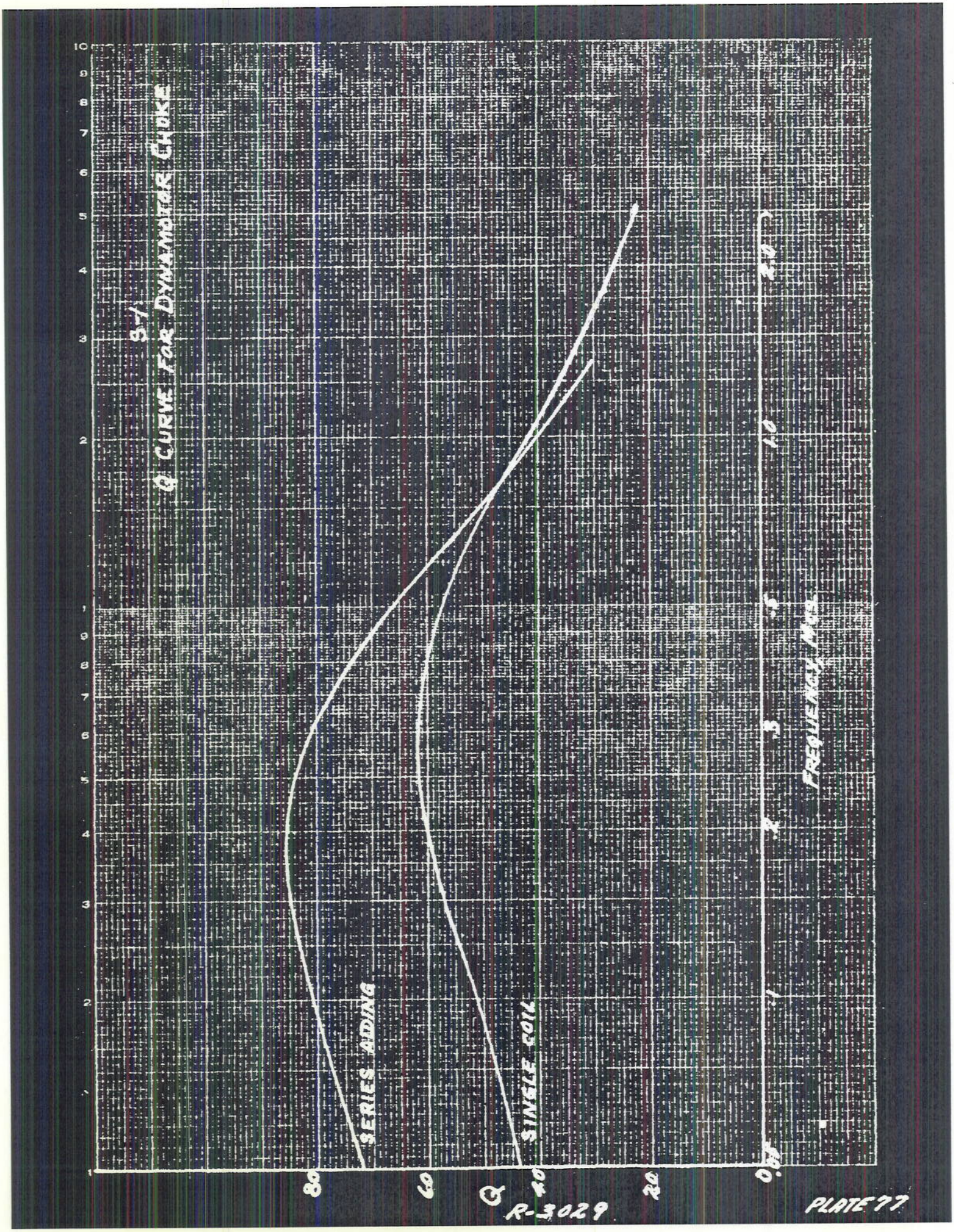
R-3029

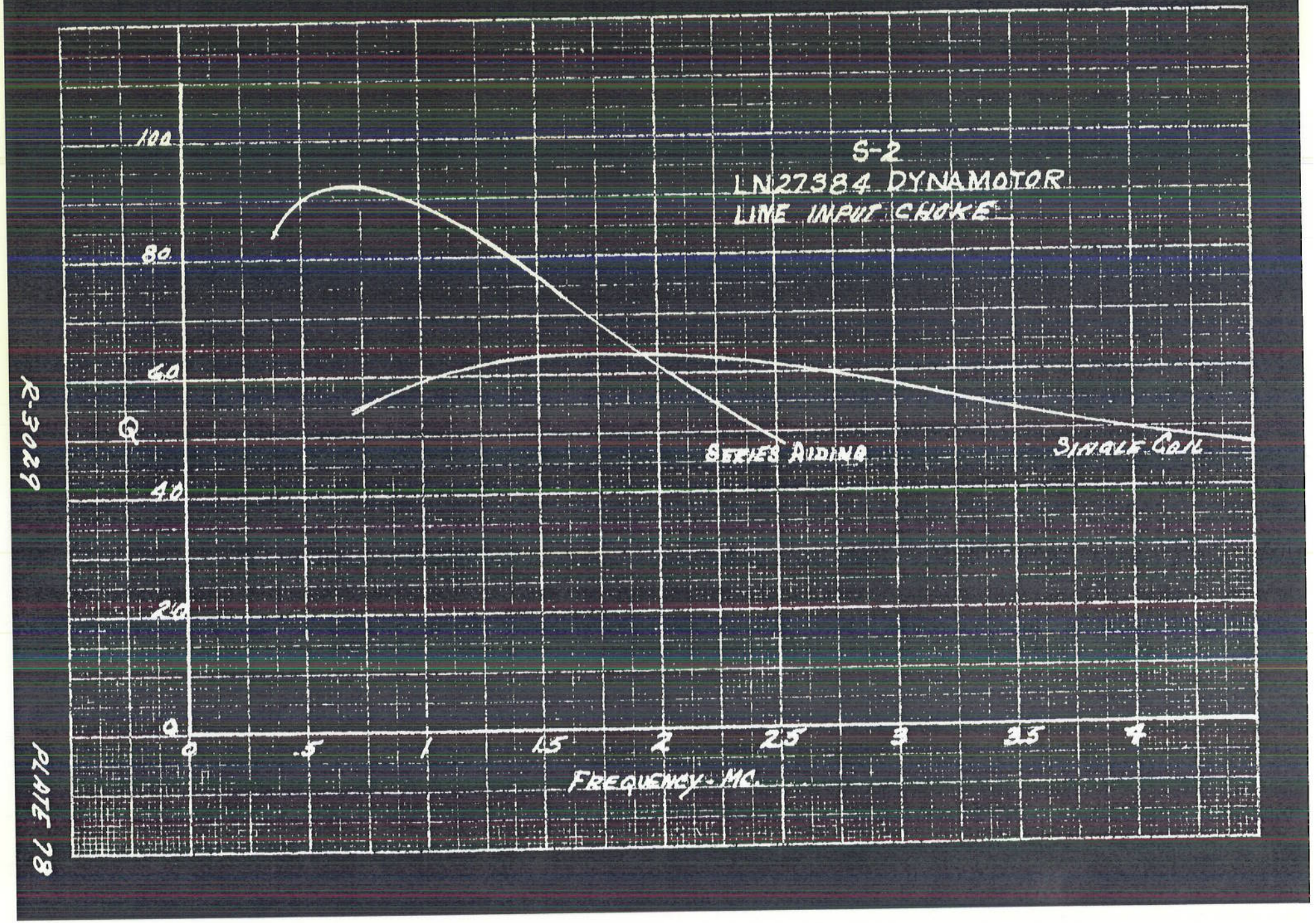
PLATE 75

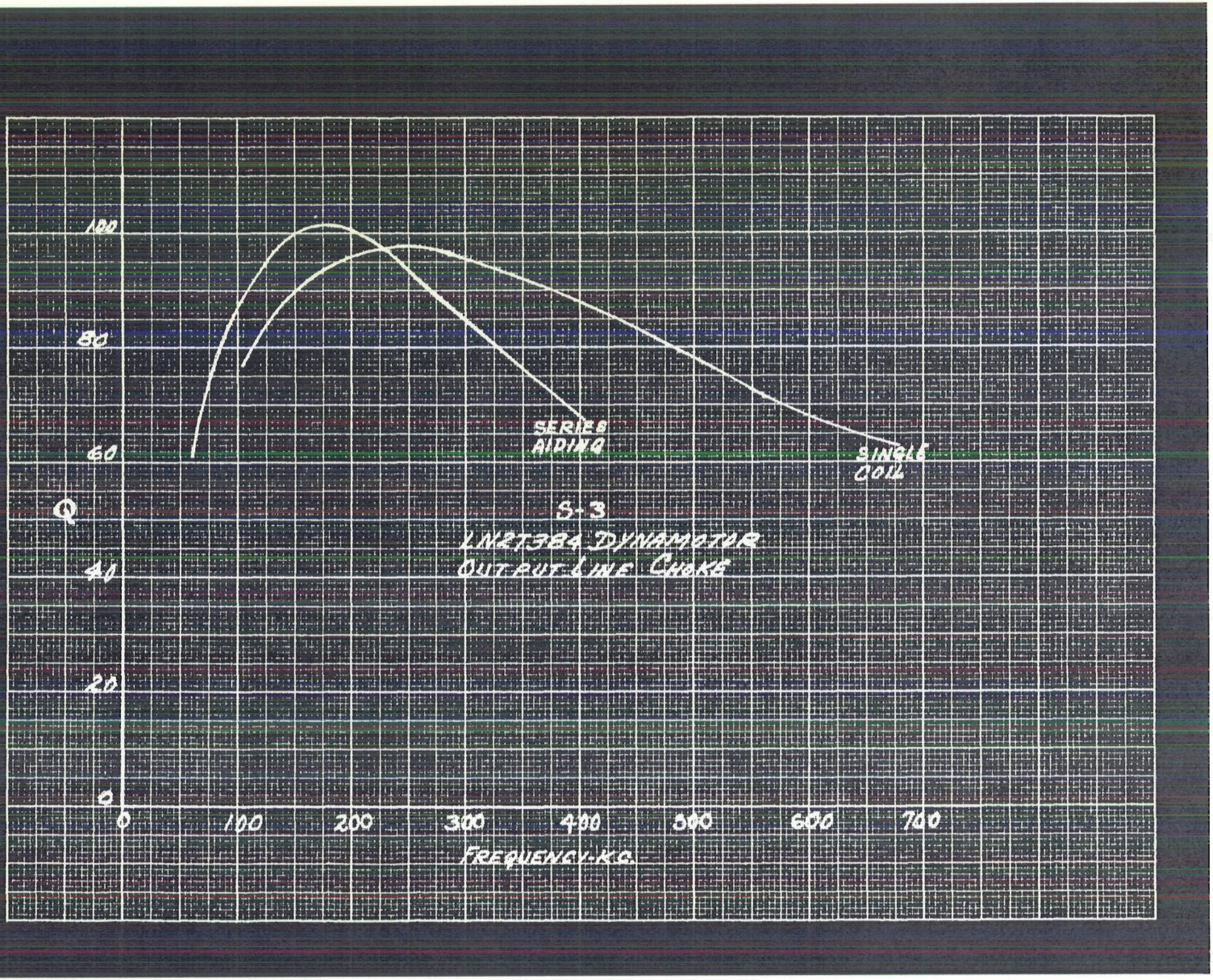


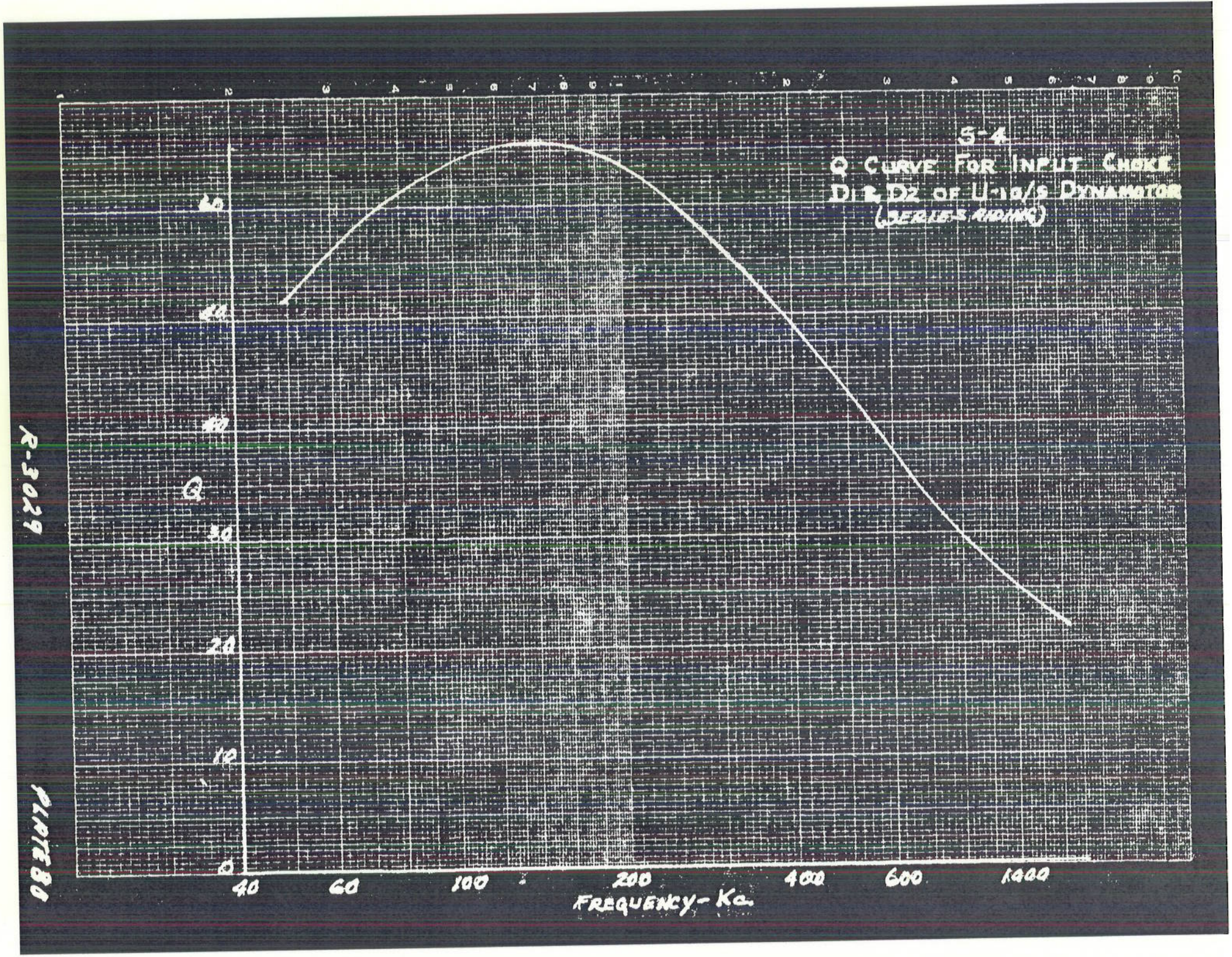
S-7
1000 DIAMETER MICROPHOTOGRAPH DRALOPERM CORE

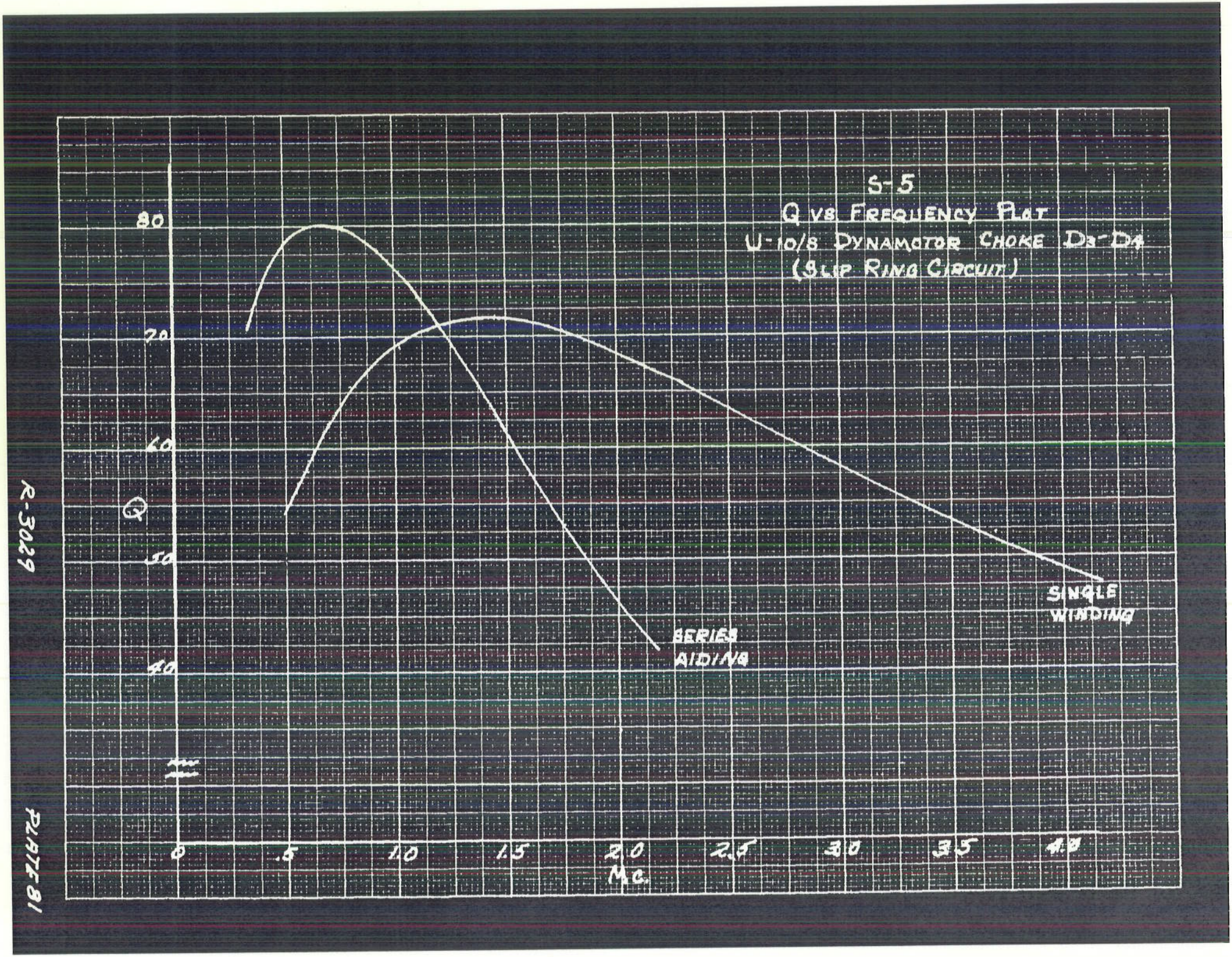
PLATE 76

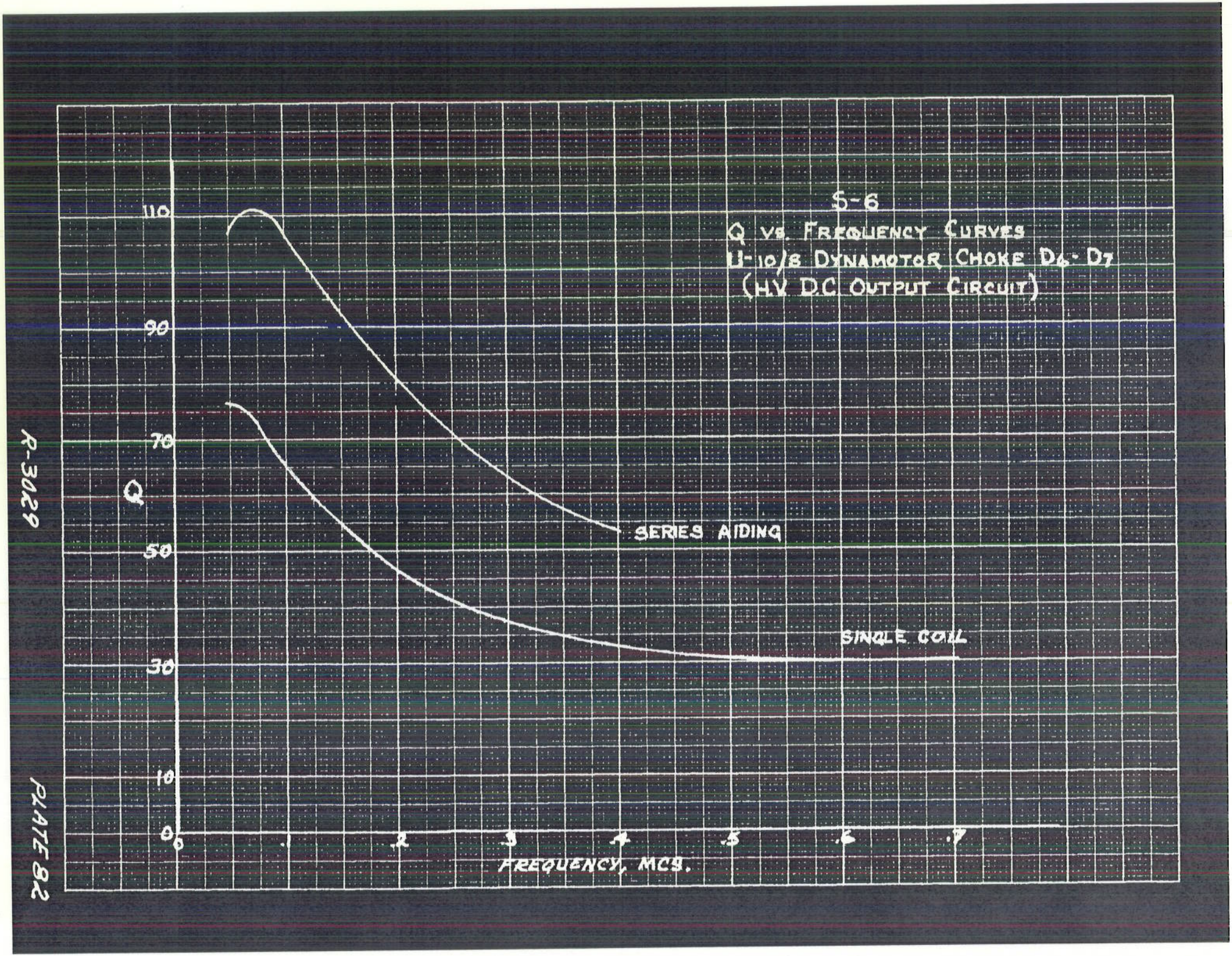

Q CURVE FOR DYNAMOTOR CHOKE
SERIES ADING
SINGLE COIL
FREQUENCY MC
Q
R-3029
PLATE 77

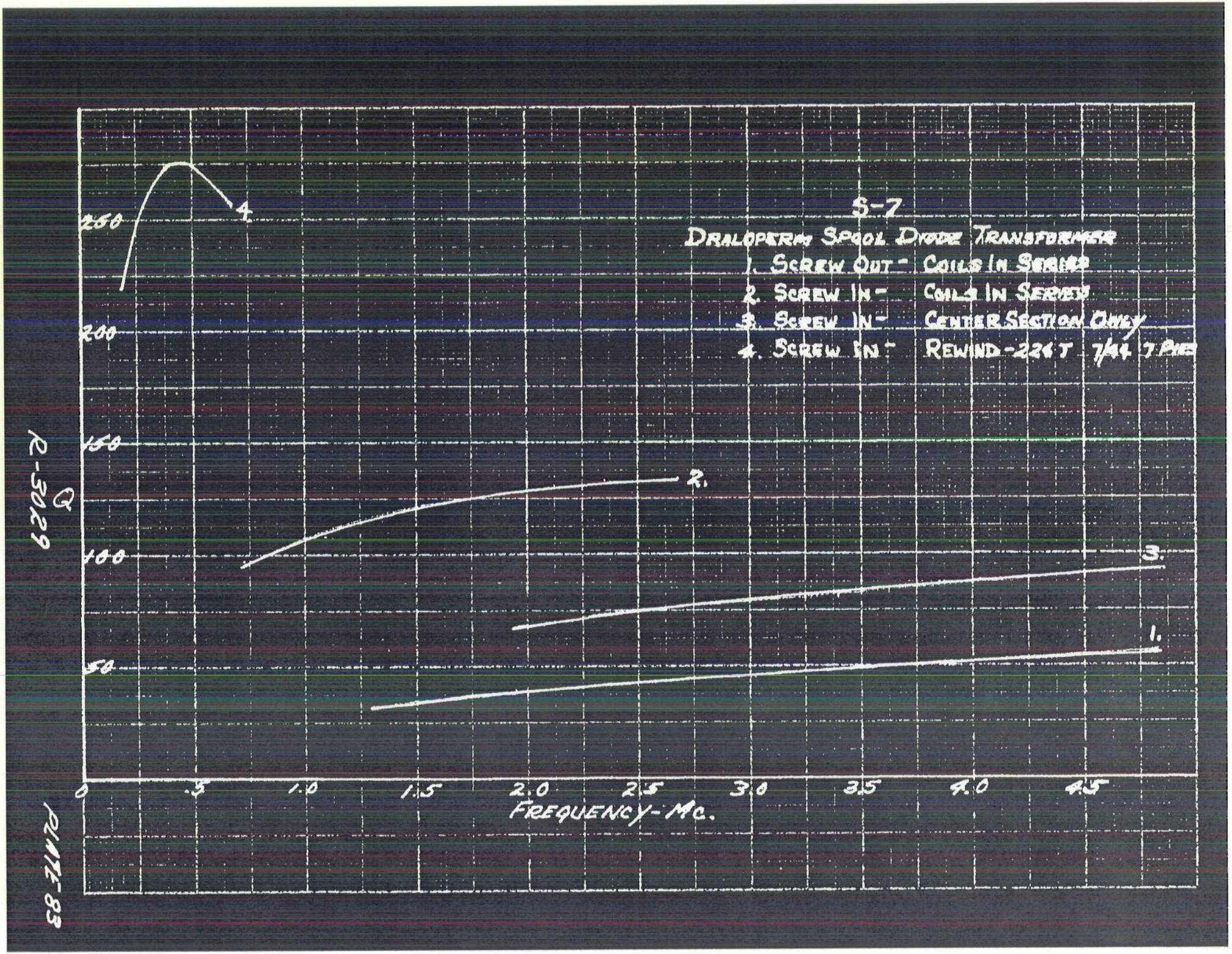

S-2
LN27384 DYNAMOTOR
LINE INPUT CHOKE
100
80
60
Q
40
20
0
0
.5
1
1.5
2
2.5
3
3.5
4
FREQUENCY - MC.
SERIES AIDING
SINGLE COIL
R-3029
PLATE 78

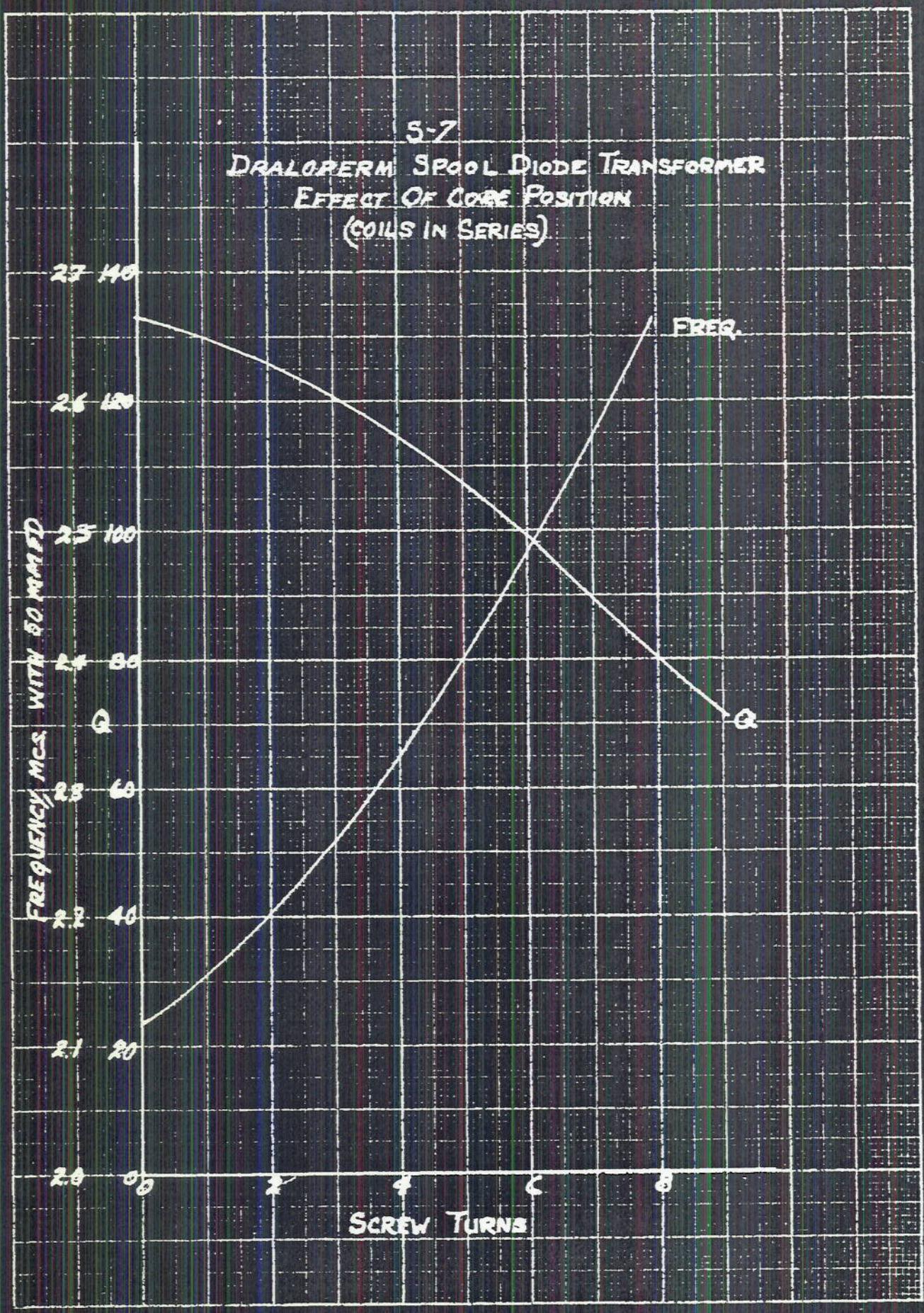

R-3029
PLATE 79
100
80
60
40
20
0
Q
0
100
200
300
400
500
600
700
FREQUENCY-K.C.
SERIES AIDING
SINGLE COIL
S-3
LW21384 DYNAMOTOR
OUTPUT LINE CHOKE


S-4
Q CURVE FOR INPUT CHOKE
D1 & D2 OF U-10/S DYNAMOTOR
(SERIES RADIAL)
Q
60
40
30
20
10
0
40
60
100
200
400
600
1000
FREQUENCY - Kc.
R-3029
PLATE 80


S-5
Q VS FREQUENCY PLOT
W-10/8 DYNAMOTOR CHOKE D3-D4
(SLIP RING CIRCUIT)
80
70
60
Q
50
40
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
MC.
SERIES AIDING
SINGLE WINDING
R-3029
PLATE 81

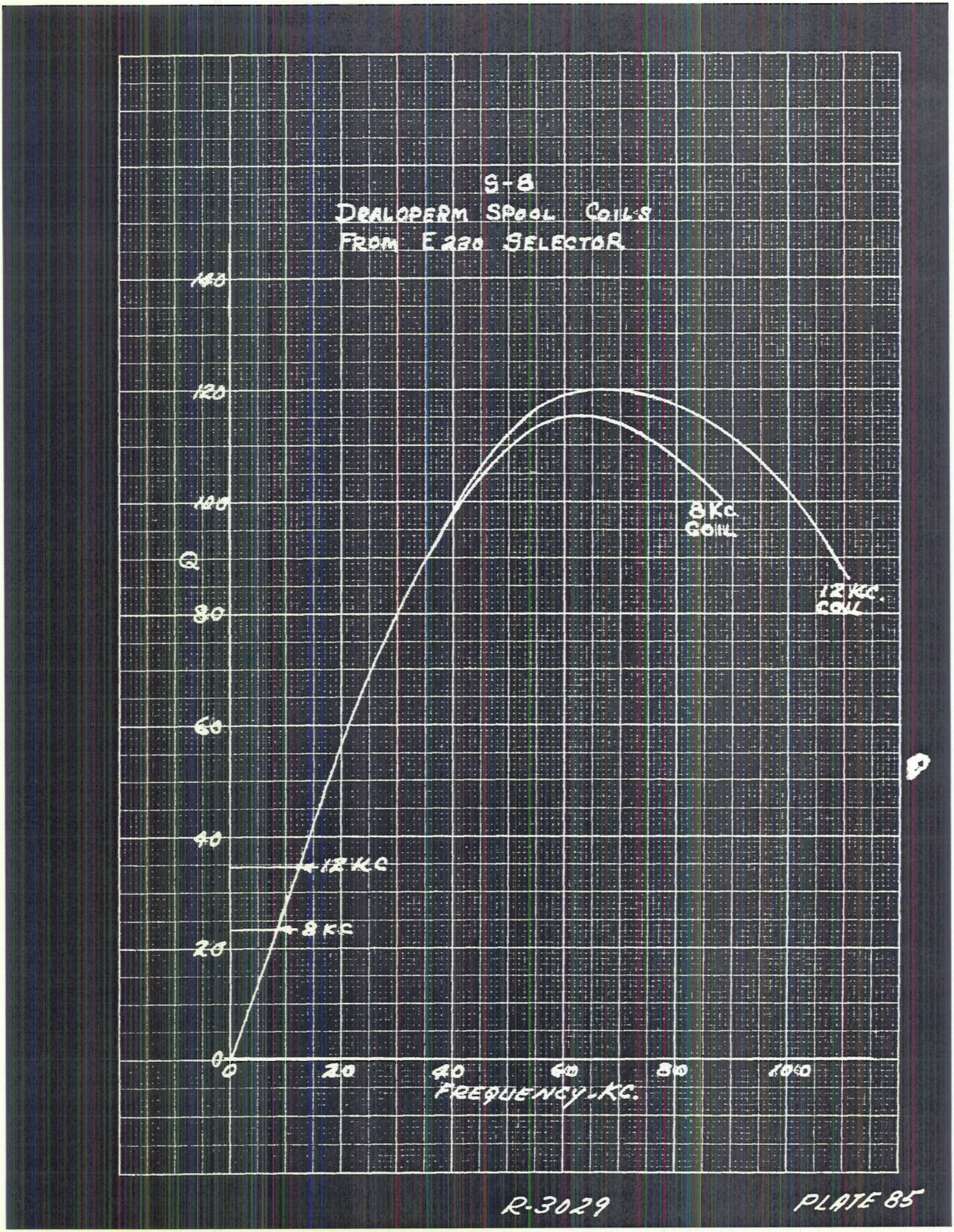

S-6
Q VS. FREQUENCY CURVES
U-10/S DYNAMOTOR CHOKE D6-D7
(H.V. D.C. OUTPUT CIRCUIT)
110
90
70
50
30
10
0
Q
SERIES AIDING
SINGLE COIL
0
.1
.2
.3
.4
.5
.6
.7
FREQUENCY, MCS.
R-3029
PLATE 82


S-7
DRALOPERM SPOOL DIODE TRANSFORMER
1. SCREW OUT - COILS IN SERIES
2. SCREW IN - COILS IN SERIES
3. SCREW IN - CENTER SECTION ONLY
4. SCREW IN - REWIND - 22 T 7/44 T PIE
Q
R-5029
250
200
150
100
50
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
FREQUENCY - MC.
1.
2.
3.
4.
PLATE-83



R-3029

PLATE 84



R-3029

PLATE 85