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THIRD QUARTERLY REPORT

(Report No. IX)

DESIGN METHODS
for
HIGH FREQUENCY TRANSFORMERS

Period of
Jan. 1, 1954/Mar. 30, 1954

Object:

The object of this development is to conduct study and research related to the design, fabrication and test of high frequency transformers and to establish and record prescribed methods for their design.

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1. PURPOSE

The objective of this development is the establishment of prescribed methods of optimum electrical and mechanical design of radio frequency transformers for military applications.

This objective was considered by the Services to be best served by the presentation of the results of this development in the form of a design manual or handbook which would be complete in all aspects including materials of construction, analytical and physical design, test methods and all other necessary reference information.

The specific requirements covering the scope of the development together with those electrical and physical parameters of design which are of military interest are presented in detail in the Technical Requirements for this contract entitled "Design Method for High Frequency Transformers" dated 8 January 1953, a copy of which is included as Appendix A of this report.

2. ABSTRACT

A discussion of contemporary literature with particular emphasis of recognized shortcomings, opens this report.

Progress is reported in coupled circuit work at frequencies both higher and lower than the original 455 kc.

The final form of temperature coefficient testing equipment is described as are findings relative to the effect upon coil stability of wire insulations and coil form materials. This section of the report appears in two column format with all lines justified, having been prepared on a VariTyper as an example of the approximate form to be followed in the Design Manual.

Advances in the universal coil study dealing with multiple-pi windings and with the effect upon Q of varying twists per foot of Litz wire are discussed.

A report on progress in writing the various chapters of the manual and the presentation of test data completes this report.

3. LITERATURE, CONTACTS AND CONFERENCES

3.1 Books Reviewed

Coriano, William F.
"Designing Inductively Coupled Traps"
TELE-TECH, April 1954

George, Howard
THE THEORY OF UNIVERSAL WINDINGS,
Coil Winding Equipment Co., Oyster Bay, New York, 1954

Henney, Keith
RADIO ENGINEERING HANDBOOK, 3rd Edition
McGraw-Hill Book Co., New York, 1941

Katz, George
"Effective Temperature of Iron Powder Cores"
ELECTRICAL MANUFACTURING, February 1954

Lafferty, R. E.
"Effective Permeability of Cylindrical Iron Cores"
TELE-TECH, February 1954

Querfurth, William
COIL WINDINGS, 1st Edition, George Stevens Mfg. Co.,
Chicago

Sziklai, G.C. and Schroeder, A. C.
"Cathode Coupled Wide Band Amplifiers",
PROCEEDINGS OF IRE, October 1945

Sziklai, G. C. and Schroeder, A. C.
"Band Pass Bridged T Network for Television Intermediate
Frequency Amplifiers", PROCEEDINGS OF IRE, October 1945

Terman, F. E.
RADIO ENGINEER'S HANDBOOK, 1st Edition
McGraw-Hill Book Co., 1943

BRC NOTEBOOK, Boonton Radio Corp., Spring 1954

Dishal, M.
"Federal Band Pass Nomographs", Federal Telephone &
Radio Corporation, 1946

Sodaro, J. F.
No. 25 Reactance Nomograph, TELE-TECH, March 1954

Terman, F. E.
ELECTRONIC MEASUREMENTS, 2nd Edition
McGraw-Hill Book Co., New York, 1952

3.2 Conferences

14 January 1954

Place: Automatic Manufacturing Corporation
Newark, New Jersey

In Attendance:
Messrs. H. Salomon - Irvington Varnish and Insulation Company
A. M. Hadley - Automatic Manufacturing Corporation

Purpose: General discussion of progress on this project and of insulation problems in general. Particular emphasis paid to insulations made up of Mylar film both singly and in combination with paper, fiber, and Quinterra.

Conclusion: Irvington Varnish will continue to supply technical data and samples whenever requested.

* * * * *

22 January 1954

Place: Automatic Manufacturing Corporation
Newark, New Jersey

In Attendance:
Messrs. G. Tarrants - Air Force, Wright Field
D. Elders - Signal Corps, Squier Laboratory
J. P. Tucker - Automatic Manufacturing Corporation
A. M. Hadley - Automatic Manufacturing Corporation

Purpose: General discussion of the project and of the manual which is to constitute the final report. The proposed outline for the manual and the first quarterly report were discussed point by point and suggestions were offered by the Service Representatives as to exactly what portions would be of greatest value to them. Among the specific points discussed were:

a. Rearrangement of the material in Part I more in accord with its physical properties.

b. Inclusion of a separate section (or chapter) dealing with good design practices.

c. Inclusion of a separate section (or chapter) on finishes. (Stamping and marking to be included in this section).

d. Arrangement of the text of the manual in a manner permitting extraction as a complete and separate section of that portion of the manual dealing with design methods.

Conclusion: Automatic Manufacturing Corporation will attempt to follow all recommendations of the services.

* * * * *

5 February 1954

Place: McGraw-Hill Book Company, Inc.
New York, N. Y.

In Attendance:
Messrs. Keith Henney - McGraw-Hill Book Company, Inc.
Robert Craig - McGraw-Hill Book Company, Inc.
Leonard Adler- McGraw-hill Book Company, Inc.
J. P. Tucker - Automatic Manufacturing Corporation
A. M. Hadley - Automatic Manufacturing Corporation

Purpose: Discussion of the parts that McGraw-Hill might play in providing Automatic Manufacturing Corporation with editorial and other assistance in the preparation of the Design Manual.

Conclusions: Automatic Manufacturing Corporation will forward such of the manuscript as is in readiness. McGraw-Hill will read this manuscript and offer criticism and suggestions. A proposal covering the cost of McGraw-Hill's participation will then be forwarded to Automatic Manufacturing Corporation.

15 February 1954

Place: Squier Signal Laboratory
Fort Monmouth, New Jersey

In Attendance:
Messrs. D. Elders - Signal Corps, Squier Laboratory
A. Rand - Signal Corps, Squier Laboratory
A. Allocca - Signal Corps, Squier Laboratory
A. M. Hadley - Automatic Manufacturing Corporation

Purpose: General discussion of progress on this project. Specimen chapters of text material left with the service representatives for comments.

Conclusions: After reading the manuscript, service representatives will forward their comments to Automatic Manufacturing Corporation.

* * * * *

18 February 1954

Place: Squier Signal Laboratory
Fort Monmouth, New Jersey

In Attendance:
Messrs. D. Elders - Signal Corps, Squier Signal Laboratory
A. Rand - Signal Corps, Squier Signal Laboratory
S. Danko - Signal Corps, Squier Signal Laboratory
A. M. Hadley - Automatic Manufacturing Corporation

Purpose: General discussion of the project with particular emphasis on reports and consultants.

Conclusions: It was generally agreed that work should continue in accordance with the plans originally layed out for this project and that outside consultants should be brought into play at the earliest possible date.

* * * * *

2 March 1954

Place: Automatic Manufacturing Corporation
Newark, New Jersey

In Attendance:
Messrs. H. J. Bolles - Minnesota Mining & Mfg. Company
A. H. Hadley - Automatic Manufacturing Corporation

Purpose: General discussion of the progress on this project to date. Specific discussion of corrosion problems. Mr. Bolles supplied a copy of a recent corrosion report prepared by Minnesota Mining & Mfg. Company which definitely supports the theory that materials containing cellulose may, under certain conditions, induce electrolytic corrosion.

Conclusions: Mr. Bolles will follow the remaining stages of this project closely and provide all possible assistance.

* * * * *

12 March 1954

Place: McGraw-Hill Book Company, Inc.
New York, N. Y.

In Attendance:
Messrs. Keith Henney - McGraw-Hill Book Company, Inc.
Robert Craig - McGraw-Hill Book Company, Inc.
A. H. Hadley - Automatic Manufacturing Corporation

Purpose: General discussion of the manual and the steps to be taken to insure the best possible presentation of the material to be included in the book. Discussed the format to be followed, type and number of illustrations, make-up of chapters, and the type of printing to be used.

Conclusions: It was agreed that McGraw-Hill would forward quotations to Automatic Manufacturing Corporation covering not only editorial assistance, but the cost of a series of conferences for the purpose of determining the make-up and presentation of the manual.

25 March 1954

Place New York, N. Y.

In Attendance:
Messrs. C. L. Christiansen - Dow-Corning Corporation
A. M. Hadley - Automatic Manufacturing Corporation

Purpose: General discussion of the project and of advances in the field of high temperature insulations. Among the many items discussed were DC997 which, because of better curing characteristics, is slated to replace DC996 and the new "Bondeze-type" silicone insulated magnet wires capable of operation at 250 C which are now well along in the experimental stage.

Conclusions: Mr. Christiansen will keep in close touch with this work and will render all possible assistance.

4. FACTUAL DATA

4.1 Literature Review

The policy outlined in the First Quarterly Report--that of keeping literary review and research closely associated with the portions of the manual being written--has continued through the third quarter.

As a consequence, emphasis was this time placed on basic circuit theory, particularly as applied to series and parallel resonant circuits. The works of Terman, Henney, Pender and McIlwain, along with the Radiotron Designer's Handbook formed the core of this study which was supported by numerous contemporary magazine articles and by the books of other authors.

A second avenue of exploration was centered in the literature pertaining to coil winding. The book by William Querfuth recently published by George Stevens Manufacturing Company and the nomographs and accompanying article by Howard George of Coil Winding Equipment Company have been studied and evaluations of the recommended methods are now in process. Both of these articles appear to have made substantial progress along lines of simplification of machine setups and the selection of practical gear combinations and winding arrangements.

As this review of literature progresses, the role to be filled by the Design Manual becomes more apparent. Contemporary literature, while fairly abundant and generally of high quality, is open to criticism from at least the following angles:

1. Lack of uniform notation in mathematical interpretations.

The result of non-uniformity in notation introduces confusion when comparing the presentations of different authors. As a consequence, the reader must constantly refer to a list of symbols or to previous portions of the text in order to keep up with the meaning of the various elements of the equations. Not only is this true of the less often used symbols but on a term as common as resonant frequency, there is no uniformity with some writers using f_r while the majority prefer f_o.

2. Over-emphasis on theory.

Contemporary literature is filled with the theory of coils and transformers. Many--in fact, most---presentations are thorough, well written, and lacking only in one regard--practical applications. The importance of basic theory should not and cannot be underestimated. However, the translation of theory into its practical aspects where it can offer assistance in, for example, transformer design is lacking in nearly every reference book. Currently there is little in print to bridge that gap which exists between the wealth of theoretical and mathematical material from which comes the necessary background for design and those procedures which will convert this theory into practices having as their end product a transformer whose operation will be in accordance with the design theory.

3. Complicated presentations.

Contemporary literature is often unnecessarily complicated in its presentation. Admittedly, the basic theory of coils and transformers is founded on mathematics but this does not completely justify the time devoted by many authors to long and involved mathematical discussions of subjects which could have been treated far more simply.

4. Lack of illustrative examples.

The average contemporary book on the subject of coils and transformers is felt to be sadly lacking in examples with which to illustrate the points made in its text. It appears that these books are written for an above-average mentality, thus making it difficult for an average reader to get a sufficient grasp of the subject without the assistance of examples based on the principles under discussion.

In the preparation of the Design Manual it is proposed to take full advantage of the fact that it is always easier to follow than it is to lead. Every possible attempt will be made to present all pertinent data and information including mathematics, but to avoid all unnecessary explanations and to use simple, direct language, and an abundance of illustrations and examples.

4.2 Coupled Circuit Work

Following the 455-kc coupled circuit work reported in Section 4.2 of the Second Quarterly Report, this activity was extended into the frequency ranges of 262-kc, 175-kc, 1400-kc, and 4.3 Mc.

To facilitate comparisons, the shield can size was held at 2 inches square by 3-1/2 inches in height—the same as in the case of the 455-kc units. Complete information concerning the construction of those transformers is to be found in Appendix B, Pages 2, 9, 16, and 23 of this report.

The methods of test and measurement previously reported have been followed at the new frequencies. The outcome of this work is reported in graph form in Appendix B, Pages 3 through 29.

The high frequency portion (5-150 Mc) of this work is about to start as the design and fabrication of special test fixtures is nearing completion. It is planned to emphasize this phase of activity since it represents one in which more widely diversified problems may be expected to develop.

Note:

As in the case of the First Quarterly Report where a draft of one chapter was included to show the form in which material would later appear, so in this report, one section of Factual Data (4.5) will be presented in the format which will be used in the Design Manual.

Following a conference with Keith Henney of McGraw-Hill Book Company and members of his staff, it was decided to use two three inch columns per page. Tables, graphs, sketches, and other illustrated materials will be fitted into the text in either one or two column width as required by the nature of the material.

It is probable that the type may be changed from that used in this sample since it is the opinion of Mr. Henney that the use of a sans-serif type detracts slightly from the readability of the text. In the event that a change is made, the sans-serif type will be retained for headings. An Engineering Mathematics Varityper font has been ordered. Use of this font should improve the appearance of equations and formulas. All copy will be prepared on the Varityper and will be justified.

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4.3 Temperature Coefficient Work

In the Second Quarterly Report on this project, Section 4.3 devoted to temperature coefficient work ended with the statement "It therefore appears that set-up difficulties have been overcome and the way now seems clear to proceed with the scheduled tests." Subsequent events proved this statement to be founded on unwarranted optimism.

Quickly reviewing the history of this experiment, it will be recalled that the oscillator originally employed a Colpitts circuit. When the output of this particular oscillator was found to contain so many spurious responses as to render it worthless for the scheduled tests, it was replaced with a negative resistance type of circuit which, as was reported in the above referenced report, seemed at first to provide a satisfactory voltage source for the testing program.

Early in the current year, trouble was encountered with this new system in that at maximum test temperatures (85 C) the oscillator would frequently cease operation and would become operative again only after adjustments had been made. Indications were that the coil resistance was changing with heat to a point where it was impossible to maintain oscillation. Adjustment at maximum temperature being considered impractical, it was decided to once again change the basic circuit to one less dependent for its operation upon circuit resistance.

A decision to try the "negative transconductance" or Transistron type of oscillator was eventually reached. This decision was based partly upon previous experience with this circuit and partly upon the ease with which our apparatus could be changed over to this particular circuit.

As can be seen from the circuit diagram in Appendix B, Page 1, the 6SK7 tube was replaced by a 6A8 and as in previous designs, the output was again coupled out through a cathode follower.

First tests with this new circuit were encouraging, but again it seemed that the test frequencies were too low and erratic drift characteristics were still noted in many instances.

To pinpoint the source of the trouble, new coils were prepared which were much lower in inductance thus raising test frequencies to the range of 250 to 300-kc. Part of these coils were treated with a wax*, part with an air drying lacquer**, and part were left untreated. By far the best and most consistent results were obtained from the smaller windings--particularly those which had not been given any treatment.

Recalling the experiences of other contractors (See Second Quarterly Report--Page 23) it was decided to conduct the tests on wire insulations and coil form materials only in the hot portion of the cycle, which is to say from room temperature up to 85 C and back to room temperature. This decision made it possible to consider the elimination of all impregnation materials and to work only with coil forms and wire--since abandonment of the cold cycle removed the danger of condensation of moisture within the windings.

The reasoning which had prompted the original selection of coils of the type described on Page 19 of the Second Quarterly Report seemed to have been invalidated by the smaller coils which consistently gave results of a sort which experience indicated were as reliable as those obtained from the best of the large coils and which, in addition, were entirely lacking in the erratic and unexplainable characteristics associated with the larger, impregnated windings.

It was therefore decided to scrap the original windings which were large in

* T-1
** T-9

size, high in inductance, and thoroughly impregnated in T-1. This decision was reached with considerable reluctance since it meant the scrapping of many manhours of effort. However the uniformity of results obtained with the new windings, the fact that our results were in conformity with results obtained by other contractors added to the fact that our findings were intended to be of a comparative nature only seemed to offer no alternative.

The coils finally adopted for use in the temperature coefficient testing phase of our laboratory effort were wound to the following specifications:

Coil forms:

Size: 1/2 inch OD x 3/8 inch ID x 2 inches long

Material: For wire checks--CF-5
For coil form checks-Various

Wire:

Size: No. 39

Insulation: For coil form checks-W-2

For insulation checks-Various

Gears: For film insulated wires--103/68

For textile served wires--as required

Cam: 1/16 inch

Inductance: 1.275 mh ±3 per cent

Q Range - Film insulations 55 to 62

Textile Insulations - 57 to 70

Preconditioning: Prior to test, all coils subjected to 20 each alternate 15 minute cycles of exposure to -120 and +85 C.

Treatment: None

The study of wire insulations and their effect upon the thermal stability of universal coils disclosed some very interesting results*. Measured in parts per million per degree centigrade, the range of the various insulations tested extended from a low of 21 for W-10 (a high temperature insulation) to a high of 95 for W-6 (a solderable insulation).

It is interesting to note that comparable products from different manufacturers in certain cases exhibited widely differing temperature characteristics as for example, W-1 and W-2 while in other instances they were almost identical as in W-12 and W-20.

A point worthy of note is the very excellent stability exhibited by W-1, a single celanese enamel wire. The temperature coefficient of this type of served wire was only 22 as compared with the next best textile-served wire which was found to be 38 ppm/°C--an increase of over 75 per cent. It is not possible at this time to explain why wire of this type should be so stable, but these findings are in support of a fairly universal recognition of the stable qualities of this type of serving.

As might be expected in the case of the various coil form materials, the excursion was somewhat less than with the various wire insulations. All coil forms were of the same physical dimensions and were fitted with identical windings all made with the wire of one supplier thereby making variations encountered in the testing essentially a function of the coil form materials.

It will surprise no one to find ceramic coil forms heading the stability list with 28 ppm/°C while nylon at 94

* See Appendix B, Pages 30 through 32

ppm/°C occupied the other end of the scale. It may surprise some readers to learn that forms of untreated Kraft paper from two suppliers were worsened by approximately 50 per cent when subjected to wax impregnation—a procedure made necessary in practice by the hygroscopic properties of the paper.

A check of the coefficients of linear expansion of the various materials shows reasonably good correlation with the temperature coefficients of coils wound on these materials. This may possibly be interpreted as pointing to the advisability of having at hand complete information on the physical as well as the electrical properties of materials under consideration for use in transformers of maximum stability characteristics.

As has been said before, no attempt was made to take absolute measurements in the above mentioned testing program. Results are given in ppm/°C because of a desire to conform to accepted practice. Since the basic conditions under which the tests were conducted were held uniform and because the operating personnel made every effort to avoid deviations from established practice, it is felt that the indications obtained may be considered as representative of the materials and that they may safely be used as guides to good design practice.

To conclude this phase of the program it is proposed to evaluate in similar fashion both treatment materials and their methods of application. The final step will be to check the validity of the findings by combining the best wire, the best coil form, and the best treatment and then to compare coils thus constituted with others representative of the average and the poorest of the three basic materials.

4.4 Universal Coil Study

The universal coil study has been continued throughout the past quarter. Much additional information has been taken and the study extended to coil forms of varying sizes.

An attempt was made to evaluate the effect upon universal coils of a change in wire size while holding gears, coil forms, and inductance constant. Windings were made with No. 39 heavy Formvar using gears which provided a tight winding. Without any change in the machine, coils were wound with No. 40 heavy Formvar, No. 41 heavy Formvar, and No. 42 heavy Formvar.

Contrary to the outcome predicted by several engineers, these windings showed the Q progressively decreasing in value with the decrease in wire size. Since these results are not in conformance with established practice in certain sections of the electronics industry, it is proposed to further explore the effect of wire size on Q while holding gears and inductance constant.

An important part of the universal coil study during the preceding quarter was that devoted to the study of multi-pi universal windings. These studies were conducted on coils wound with 1/16 inch and 1/8 inch pi's which were spaced 1/16 inch, 1/8 inch and 1/4 inch apart. Windings studied consisted of 1, 2, 3, 4, and 5 pi's. The inductance in all cases was held at 5 Mh ±5 per cent and the 1/16 inch pi windings were wound with 90/44 gears and the 1/8 inch pi's with 100/66 gears. No. 39 SSE wire was used in all instances. Reference to Appendix B Pages 33 through 37 will show the results of this work. Of particular significance is the observation that, contrary to widely held opinions, breaking a winding down into two or more pi's does not necessarily increase the Q. If, however, a winding of a given inductance made with a 3/8 inch cam is split up into three windings each made with a 1/8 inch cam but having a total inductance equal to that of the original winding, it will be found that the Q of the multi-pi winding will be higher and the distributed capacity lower than that of the original winding. A definite advantage of multi-pi windings appears in the smaller OD's which lessen the losses caused by shielding.

4.5 Litz Wire Studies

It is well known that the use of multi-strand wire of the type commonly known as Litz offers substantial advantages, particularly in that portion of the frequency spectrum from around 300-kc upwards to about 1500-kc. One feature of this type of wire about which there is not complete uniformity of understanding is the effect of varying the twists per foot of the individual conductors. Genuine Litzendraht wire, which is not made commercially in the United States, is more than a twisted wire in that it has the individual conductors so arranged that each conductor appears on the outside of the stranding as often as it appears on the inside. This is to say that not only are the individual strands twisted but in addition they are displaced in a manner similar to braiding thus insuring accurate placement of the strands. By contrast to this rather complicated manufacturing process, American Litz wire is supplied in a number of forms ranging from no twists other than those resulting from the passing of the individual strands through the serving machine to a probable maximum of 18 twists per foot in the case of one supplier. Even higher numbers of twists per foot are frequently supplied on special order at the request of specific customers.

In an attempt to evaluate the effect of twists per foot, a supply of 5/44 SSE Litz wire was ordered with the number of twists per foot varying from 0 to 70 in increments of 5. Regular production Litz having 18 twists per foot was also procured from this same manufacturer.

This 5/44 SSE Litz was wound into coils consisting of 300 turns on a 1/2 inch OD form using a 3/32 inch cam and 67/44 gears. Coils were left unimpregnated and were checked for Q at 455-kc on a Model 260A Q meter using approximately 66.5 mmf of capacity in the circuit.

In the check of twists per foot, the lowest Q (average of 5 coils) was 107 at 15 twists per foot and again at 45 twists per foot. The highest Q obtained was 110 at 65 twists per foot.

Evaluation of the results was made somewhat more difficult by the fact that the regular production wire from this same supplier gave coils with a Q of 109 when measured under the same conditions whereby 5/44 SSE Litz from another supplier wound on the same machine by the same operator produced coils averaging 113 for Q readings.

Investigation of the two regular production Litz wires disclosed that the wire producing coils of the lowest Q was made up of 5 strands of No. 44 wire all of which were running on the minimum acceptable NEMA tolerance for OD whereas the conductors in the Litz from the second supplier were running at the maximum allowable dimension. Whether or not it is safe to conclude that variations in wire size within NEMA tolerances will always produce Q differentials of this magnitude is not certain at this time. It is considered of sufficient importance that an attempt will be made to evaluate this particular point.

Through the efforts of the Signal Corps, a sample of 5/44 European type Litz wire was procured for evaluation in this program. This wire was received marked as 5/44 single Rayon enamel, but a check revealed this marking to be in accordance with British wire gauge instead of American wire gauge making it more nearly comparable to our 5/40 Litz and it is upon this basis that comparisons were made. Test coils were wound using a 3/32 inch cam in a winding of 290 turns which at 455-kc produced an average Q of 112 on the British Litz compared to a 295 turn winding made with the same setup on 5/40 single silk enamel American Litz where the test coils had a Q averaging 116. It is unfortunate that the serving on the British Litz was of a synthetic yarn since it makes impossible a direct comparison with silk but in view of the recognized fact that rayon served wires give lower Q's than silk served wires it seems safe to assume that European Litz might show a slight Q advantage if provided with the same type of serving.

It is generally accepted that the number of twists per foot has a definite influence upon the Q of Litz coils. Because our findings did not support this premise, it was decided to try windings having a different form factor in order to establish whether the coils first selected had some peculiar characteristic which lessened the importance of the twists per foot of the conductors. New coils were wound, also on a 1/2 inch form, using 5/48 gears and a 1/16 inch cam. Four 5/44 Litz wires--parallel, 18 twists per foot, 40 twists per foot, and 65 twists per foot--were selected for the test. The Q of all windings was found to range between 94 and 95. The situation was further

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checked by the use of windings made with a 1/4 inch can and 54/106 gears. Here the range of Q was found to be between 84 and 87. It therefore appears that the effect of twists per foot upon Q is less pronounced than is commonly believed.

In Appendix B Page 38 will be found a graph showing the effect upon Q and OD of various wires—all single silk enamel—ranging from No. 37 solid (equal in cross section to 5/44) through various Litz wires from 2/41 up to 30/44. All readings were taken at 455-kc.

4.6 Shielding Study

In this phase of laboratory activity the primary purpose was to determine the effect of variations in shield can size, shape, and material upon windings having relatively low and relatively high Q's and of air core and iron core construction.

A fixture shown in the sketch in Appendix B Page 46 was built to fit the Model 260A Q meter and provide a firm base upon which the coils could be mounted and the shields placed for studying their effect upon the coils.

To keep conditions as constant as possible all shields were cut to a length of 1-3/4 inches. Round, square, and rectangular cross-sections were checked as were shields made of aluminum, copper, brass, steel, and zinc. An end spacing between coil and top of shield of approximately 0.426 inch was maintained in all tests. Measurements were made with shields grounded and ungrounded..

Page 47 of Appendix B shows the results of these measurements and points out the effect upon Q and L of shields of varying sizes and different materials. From these results it is apparent that grounding the shield has only a slight effect upon the readings when compared to the same shield ungrounded.

The material of which the shield is composed has a considerable effect upon the enclosed coil. It is well recognized that placing a metallic shield about a winding which is energized by an a-c current produces what is effectively a transformer, the untuned secondary of which consists of the shield can. It follows naturally that the better the conductivity of the shield material, the higher the degree of shielding afforded the coil and less the losses that will be reflected to the inductor.

Reference to Appendix B Page 44 will show this premise to be supported inasmuch as copper—the best conductor—had the least effect upon Q and L of all materials tested while steel—the poorest conductor—lowered both Q and L to the greatest degree. Since aluminum has only a slightly lower conductivity than copper, it shows only minor differences in its effect upon enclosed coils when all other factors are held constant.

The effect of shield shape and proximity is shown on Page 45 of Appendix B where the old adage that "a shield can should never be closer to a coil than a distance equal to the coil diameter" appears to be well supported.

It is worthy of note that the effect of a shield upon a coil of moderately high Q is substantially greater than it is upon coils of lower Q's. Whether or not the coil is of the air core type or has a powdered iron core does not seem to be of much importance so long as the Q is approximately equal in both cases.

It is planned to continue this study of shielding in the vicinity of 11 Mc and again around 50 Mc and to explore the effect

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of copper foil liners in steel shield cans. From the results of these studies it is planned to include in the Design Manual concrete recommendations for shield design based upon the effect of such shields upon the inductances which they enclose.

4.7 Writing

Substantial progress in this phase of the work has been accomplished during this quarter.

The portion of the manual devoted to materials of construction has been completely revised and rewritten. Accumulation of visual material has been started as has work leading to the arrangement of material within the chapters where, insofar as is possible, supporting visual material (including tables, graphs, photographs, nomographs, etc.) will be located in close proximity to the related text.

The second portion of the manual dealing with theory and design is well under way. Greatest progress has been in that portion devoted to the theory of coils and coupled circuits. Here such subjects as inductance, capacitance, resonance, phase, impedance, Q, amplification, and those other terms closely associated with high frequency transformers are discussed in sufficient detail and with sufficient supporting mathematics to enable a person with engineering training to quickly review basic principles—or a beginner to acquire a background.

It is felt that this manual will achieve maximum value only if it is so arranged that it may be used efficiently by two distinct methods and by two distinct classes of readers.

For that group who are interested only in producing a transformer whose performance will fulfill stated requirements, there will

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be a chapter complete within itself, in which a step-by-step procedure will outline the means whereby a coil may be designed and produced and which will also suggest courses to be followed if the end product falls short of expectations. There will be no mathematical derivations of theoretical explanations in this chapter but footnotes or other references will tie this portion to the main section of the manual.

In the main section will be the background material which will provide engineering-trained personnel with sufficiently detailed explanations of fundamentals to serve either as a review for a graduate engineer or as a text for an engineering trainee. It is proposed to make this portion complete while at the same time employing every means possible to keep the presentation simple, logical, direct, and well illustrated.

The task will not be an easy one. It is obvious that in a field so large and so complicated it will be difficult to avoid errors and omissions. The goal of the contractor continues to be to include as much pertinent information on coils and transformers as is necessary to provide that uncluttered background from which may be drawn design principles which are basically sound. Stated another way, it is hoped that this manual will be a definite step towards converting the art of coil design to the science of coil design.

5. CONCLUSIONS

While but little of the data accumulated in the course of this study has been completely evaluated, it is possible to once more extract certain findings and to arbitrarily assign to these findings the importance usually attached to conclusions.

From the work of the third quarter, the following findings are presented:

1. Multiple pi coils do not necessarily have higher Q's than single pi coils of the same inductance.
2. Multiple pi windings of a specific inductance require more turns per pi as the spacing between pi's is increased.
3. Coil forms of ceramic materials show greatest temperature stability.
4. The greater the coefficient of linear expansion, the less the temperature stability of a coil form material.
5. The addition of a textile serving adds materially to the cost of magnet wire.
6. Magnet wire film insulations showing the greatest temperature stability over the room to 85 C range are those insulations intended for high temperature operation.
7. In general, the most stable coils are wound with film insulated rather than textile-served magnet wires.
8. The effect upon Q of twists per foot of Litz wire does not appear to be as great as is generally believed.
9. Universal windings containing large amounts of magnet wire do not appear to be more sensitive to temperature changes

than windings containing substantially less wire.

10. The effect of a shield is proportionally greater upon coils of relatively high Q's than it is upon coils of low Q's.

11. The effect of shielding upon a coil does not seem to be influenced by the presence of an iron core so long as the Q in air of the coil is unchanged.

12. Overcoupled transformers show definite double peaks while critically coupled and undercoupled transformers show only one peak.

13. Increasing the coupling of a transformer broadens its response curve.

14. Transformers designed to operate into a diode require higher couplings than units designed for interstage operation.

6. PLANS FOR FOURTH QUARTER

The laboratory phases of this project may be expected to conclude well within the coming quarter. It is inevitable that as data is collected and evaluated the need may arise for further explorations along specific lines in order to fully clarify or explain certain observed characteristics, an explanation of which seems necessary for the manual. For this reason it is planned to review all test data early in this quarter. In this way the findings of the laboratory program may be fairly evaluated in advance of the time when results must be incorporated in the text and if work must be repeated or expanded, time will thus be available.

The activities of those who are serving as consultants to this project will be accelerated. Their contributions will be fitted into the text in a manner such that their particular specialties will assume optimum values in the overall project.

The major activity of the Project Supervisor and his assistant will necessarily be devoted to the assembly of the text of the manual along with the charts, graphs, sketches, photographs, nomographs, and other related visual materials which will support the text. In this phase of activity, the McGraw-Hill Book Company—particularly Mr. Keith Henney, Editorial Director—will work closely with the contractor to see that the resulting text is as complete and readable as possible.

Following the completion of the portion of the manual dealing with the theory of coils and transformers, a design method (or methods) will be extracted and prepared as a separate section.

7. ESTIMATE OF PROGRESS

Continuing the policy of estimating progress on each phase of activity associated with this project, the following is believed a fair statement of progress achieved as of 1 April 1954:

PART I - MATERIALS OF CONSTRUCTION

1.	Introduction	20%
2.	Shields	75%
3.	Conductors	[illegible]
4.	Plastics	30%
5.	Ceramics	75%
6.	Magnetic Cores	5%
7.	Electronic Hardware. . . .	70%
8.	Waxes, Varnishes, Lacquers and Cements.	75%
9.	Tapes & Film Insulations .	60%

PART II - DESIGN TECHNIQUES

10.	Introduction	25%
11.	Windings	60%
12.	Types of Construction. . .	40%
13.	Methods of Testing	15%
14.	Tricks of the Trade. . . .	10%
15.	Methods of Design	20%

APPENDIX

16.	Bibliography	40%
17.	Standards of the Industry.	40%
18.	Buyer's Guide	Work suspended at request of Service Representative

8. MANHOURS EXPENDED

Manhours expended during the third quarter

1 January 1954 to 31 March 1954

A. M. Hadley.	494.5 Hours
A. DeCarlo	474.0 "
C. Kruczek	286.5 "
W. O'Connell.	244.7 "
E. McCormick.	432.5 "
P. Dolan	177.5 "
C. Burgin	164.5 "
TOTAL	2274.2 Hours

9. IDENTIFICATION OF TECHNICIANS

Bert E. Smith is Vice President of the Corporation.

Joseph R. Mazzola, Director of Engineering, is a graduate of the New York University Engineering College with a degree of Bachelor of Science in Electrical Engineering. Mr. Mazzola has been in radio engineering since 1928, and has been with Automatic Manufacturing Corporation since 1936, having been successively Chief Production Engineer, Assistant Chief Engineer, Chief Engineer, and Director of Engineering. He is a member of the Consultants Group on RF and IF Transformers of the Research and Devlopment Board, and a Senior Member of the Institute of Radio Engineers.

In his capacity as Director of Engineering he is in close touch with this project and through consultation and supervision is making substantial contributions to the various phases of the development.

John P. Tucker holds an E.E. degree from the University of Cincinnati, and the rank of Lieutenant Colonel, United States Army Reserve. Mr. Tucker has been employed by General Motors Corporation, Crosley Radio Corporation, and from 1934 to 1941 was Chief Engineer of the Gen-Rel Manufacturing Company, later the General Coil Division of the Muter Company. From 1941 to 1942 he was employed by Henry L. Crowley and Company in development and application of high frequency powdered metal cores. From 1942 to 1945 he served as Staff Officer in the Production Division of Army Service Forces, Washington, D. C. Since 1945, he has been Assistant Chief Engineer of Automatic

Manufacturing Corporation.

He has been intimately connected with this project since its beginning. Together with the Project Leader, he formulated the general plan of attack and remains active in the dual roles of advisor and consultant.

Allan M. Hadley holds a Bachelor of Arts degree from Clark University. He has attended the Graduate Schools of Clark University and the University of Massachusetts. Following sixteen years of teaching Chemistry, Physics, and Photography in the public schools of New York and Massachusetts he became, in 1942, a Civilian Instructor in Mathematics and Basic Electricity at the Signal Corps Enlisted Reserve School at Springfield, Massachusetts.

In September 1943 he joined the Engineering Staff of the F. W. Sickles Company of Chicopee, Massachusetts as Senior Research Engineer. From then until July 1947 he was engaged in research and development, mostly in connection with RF and IF coils. He holds several patents on IF Transformers, permeability tuners, and iron cores. From July 1947 until October 1951 he served as Manufacturing Engineer with responsibility for Production Engineering, Methods, Test and Inspection, Treatments, and Quality Control. Incidental duties included Engineering Control of Incoming Inspection, Technical Advisor to Purchasing Department in matters pertaining to the quality of purchased materials, and Engineer-in-Charge of Magnet Wire.

Forced by ill health to resign his position, he was inactive until March 1952 at which time he joined the Engineering

Staff of Automatic Manufacturing Corporation as Engineer-in-Charge of Research and Special Projects.

He is an Associate Member of the Institute of Radio Engineers.

As Project Leader, he is presently devoting full time to this development and is directly responsible for all phases of the work.

Zenobius Szulczynski graduated in June 1951 from Seton Hall University with a degree of Bachelor of Science in Mathematics (Magna Cum Laude). His degree was accompanied by a departmental gold medal award in mathematics. From 1943 to 1946 he served in the U. S. Infantry where he participated in the Army Specialized Training Program, later becoming an instructor in Radio Theory and Practice. His first industrial employer was the Electronics Division of Curtiss-Wright in Carlstadt, New Jersey, where he was employed as a specifications Engineer between August 1951 and March 1952.

He joined the Engineering Staff of Automatic Manufacturing Corporation in March 1952 as a Coil Engineer. His duties involve all phases of coil development including winding, impregnation and treatment, testing, and general development on RF and IF transformers. In addition, he is continuing his Engineering education and is an Evening School Instructor at Seton Hall University in Trigonometry and Calculus.

His assignments in this project are of a research nature, particularly those where mathematic interpretation is necessary.

Ed. A. Zeliff entered Upsala College in 1938. During

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summer vacations he worked on Police Radio Communications Equipment at Link Radio in New York City. In 1941 he left college and accepted a position as Final Systems Tester on telephone carrier and teletype equipment with the Kearny Works of Western Electric Company. During 1943 he transferred to the Bell Telephone Laboratories at Murray Hill, New Jersey for development work on classified electronic equipment, later returning to Western Electric to assist in the production of this equipment. In 1945 he became a Cost Planning Engineer associated with the production of 400 cycle power and pulse transformers, IF transformers, and chokes for radar equipment. He later served as Equipment Engineer for telephone apparatus and as Equipment Engineering Analyst.

In September 1948 he left Western Electric Company to complete his final year at Upsala College, graduating in June 1949 with a Bachelor of Science degree in Physics. He then joined the Engineering Staff of Automatic Manufacturing Corporation where he is now Group Leader responsible for the design and application of high frequency RF and IF coils for FM, television, and associated fields.

In 1952 he completed a course in measurements and testing in radio and television at New York University. He has been a licensed amateur radio operator since 1938 (Class A since 1939) and has held two commercial licenses which have now expired. He is a member of the American Radio Relay League and an Associate Member of the Institute of Radio Engineers.

In this development he has been largely responsible for planning the high frequency portion of the work program and will assist in its supervision and in the interpretation of the resulting experimental data.

Chester R. Kruczek attended Newark College of Engineering, leaving for the Navy in 1945. While in service, he completed the Electronics Technicians Program and became an instructor in the Navy's Chicago Training School. Following his discharge he enrolled in the RCA Institute in New York City where he studied Advanced Technology, graduating in 1949. From 1949 to 1952 he served as television technician with a private service organization.

In 1952 he joined the Engineering Department of Automatic Manufacturing Corporation where he has been associated with television tuner developments and with related test equipment in both the UHF and VHF bands.

Since mid-September he has been assigned full time to this project. His responsibilities include coil and transformer measurements, design of special equipment, and supervision of temperature coefficient tests.

Anthony DeCarlo received his Bachelor of Science degree in Electrical Engineering at Rutgers University in 1951, having completed four years of electrical engineering and one year of industrial engineering. From 1943 to 1946 he served in the Army - first as radio operator in the Field Artillery and later as Traffic Analyst in Radio Intelligence in the European theater. In 1951 he joined the Engineering

Department of Automatic Manufacturing Corporation as Design Engineer on IF transformers, RF chokes, and special coils. He is an Associate Member of the Institute of Radio Engineers.

Assigned full time to this project in September, he is presently responsible for coil winding and transformer design.

Estelle McCormick is a graduate of Drake's Business College of Newark, New Jersey. She has been in the employ of Utility Electronics Corporation, Link Radio Corporation, Wright Aeronautical Division-Curtiss Wright Corporation, and Peter Pan Manufacturing Corporation.

Her business career has been largely spent in engineering work where she has collected, recorded, and interpreted engineering data. She assisted in the PRC-8, 9, 10 standardization and test programs and has done intensive work in the preparation of graphs based on engineering data.

She joined the Engineering Department of Automatic Manufacturing Corporation in September 1953 as Engineering Assistant assigned to this program. She will actively assist the Project Leader in all phases of the development - particularly in the preparation of the manual, the translation of experimental and engineering data into visual forms, and in the general coordination of the project.

Philip J. Dol[illegible] Jr. attended the public schools of Union City, New Jersey. Enlisting in the U. S. Navy in 1949, he graduated from the Class A Electronic Technicians School

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before serving as electronic technician with the Atlantic Fleet.

His industrial experience includes work for the Electronics Division of Curtiss-Wright Corporation and Vitro Corporation of America. He is presently enrolled in the Newark College of Engineering where he is studying electrical engineering.

He is assigned to this project as laboratory technician with responsibilities including coil measurements, temperature coefficient testing, coil impregnation, and other general laboratory duties.

Cecil B. Burgin attended the Illinois Institute of Technology. During World War II at Northwestern University and University of Chicago he took numerous E.S.M.W.T. courses in ultra-high frequency techniques, vacuum applications at ultra-high frequencies, higher mathematics for engineers and physicists, and other subjects.

His professional experience includes seven years in the Engineering Dept. of Stewart Warner Corporation where he designed and developed radio receivers. During World War II he did engineering and developing work on loop antennas for aircraft, altimeters, and direction finders. Since 1945 he has worked on weather observation equipment and has participated in research and development work on r-f and i-f coils and their applications to electronic equipments.

His responsibilities on this project are primarily in the field of coupled circuit measurements.

APPENDIX A

SQUIER SIGNAL LABORATORY

COMPONENTS AND MATERIALS BRANCH

COMPONENT PARTS SECTION

FORT MONMOUTH, NEW JERSEY

TECHNICAL REQUIREMENTS

For PR&C No. 53-ELS/D-3438

8 January 1953

* * * * *

DESIGN METHOD
for
HIGH FREQUENCY TRANSFORMERS

I. Objectives and Scope

These requirements cover research and development related to design, fabrication and test of high frequency transformers such as i-f and low power rf. Classes to be included are: untuned, single tuned, double tuned, triple tuned, and tapped versions of all these types. Research and development is to cover the following phases:

A. Study and research into the theoretical and material requirements for optimum electrical, magnetic, and mechanical design of high frequency transformers.

B. The establishment of prescribed methods of design of these transformers.

II. Requirements

A. Electrical and Mechanical

The method of design to be established should take into account the various operating parameters that could be specified because of the circuit applications, as well as those which are necessary for the proper design of r-f transformers. The following factors which are considered essential to such design will be considered in the course of this development:

1. Inductance

2. Q

3. Impedance (input and output)

4. Distributed capacity
5. DC resistance
6. Bandwidth
7. Gain
8. Resonant frequency
9. Temperature rise
10. Protection
11. Coefficient of coupling (k), mutual inductance, and coupling factor.

B. Environmental

The design method shall include design procedures for r-f transformers operating on ambient temperatures of the following ranges:

1. -55°C to +85°C
2. -55°C to +125°C
3. -55°C to +200°C

The r-f transformer should be capable of withstanding static storage for three days at -65°C with no physical damage or adverse effect on electrical performance within the operating temperature range.

C. Shielding

Present types of electromagnetic and electrostatic shielding shall be studied to determine their effectiveness. Possibility of recommending a standard series of transformer can should be investigated. Proper spacing of the shield from the coil for optimum performance should also be considered.

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D. Windings

Various types of conductors and windings shall be studied to find those most suitable for use based on temperature ranges of operation and electrical considerations. To be included are insulated wire, bare wire, Litz wire and tubing as well as wire size and factors of space winding, space factor and methods of obtaining optimum "Q". Types of windings shall include space winding, universal winding, duo-lateral winding, and Pi winding.

E. Dielectric Materials

The temperature and moisture resistant properties of the dielectric materials used for coil forms, base plates, supports, wire insulation, etc., shall be investigated. Types of wire insulation should include silk, cotton, nylon, enamel, and various types of resin coatings.

F. Mounting and Core Locking Devices

The types of mountings and core locking devices presently available shall be evaluated to determine which will meet service requirements, particularly in regard to vibration and shock.

G. Methods of Measurement

All methods of measurement used to evaluate design, construction, and performance shall be presented in detail.

3. Methods of Design

The design method shall be presented step-by-step in a clear, concise manner. The presentation shall be such as to be readily understandable by electrical engineers not intimately associated with the r-f transformer industry. The use of tables, charts, graphs, and nomographs may be used and is encouraged where such use permits simplification of design procedures. Reference to readily available technical literature where derivations of all formulas and discussions of the technical concepts used may be found should be included. Some articles of direct interest are "Band Pass Nomographs" published by Federal Tel. & Radio Corp., and "Practical Aspects of Design of R-F Transformers" by C. E. F. Ridgers (British). An outline of the design method shall be included as well as design examples for typical r-f transformers. All necessary formulas, charts, curves, tables and nomographs shall be included. The design method should include the following pertinent information:

1. Methods of selecting the core material including characteristic curves, losses, frequency limitations.
2. Design of coils, including insulation choices, type of winding (single layer, universal, bank), size and type of wire, number of turns, etc.
3. Methods of determining inductance, Q, coefficient

of coupling, bandwidth, etc., and other pertinent electrical parameters.

I. Electrical Ratings

High frequency transformers shall include units operating between 30 MC and 200 MC.

Low power r-f transformers shall include units having electrical ratings up to and including 5 watts.

J. Tests

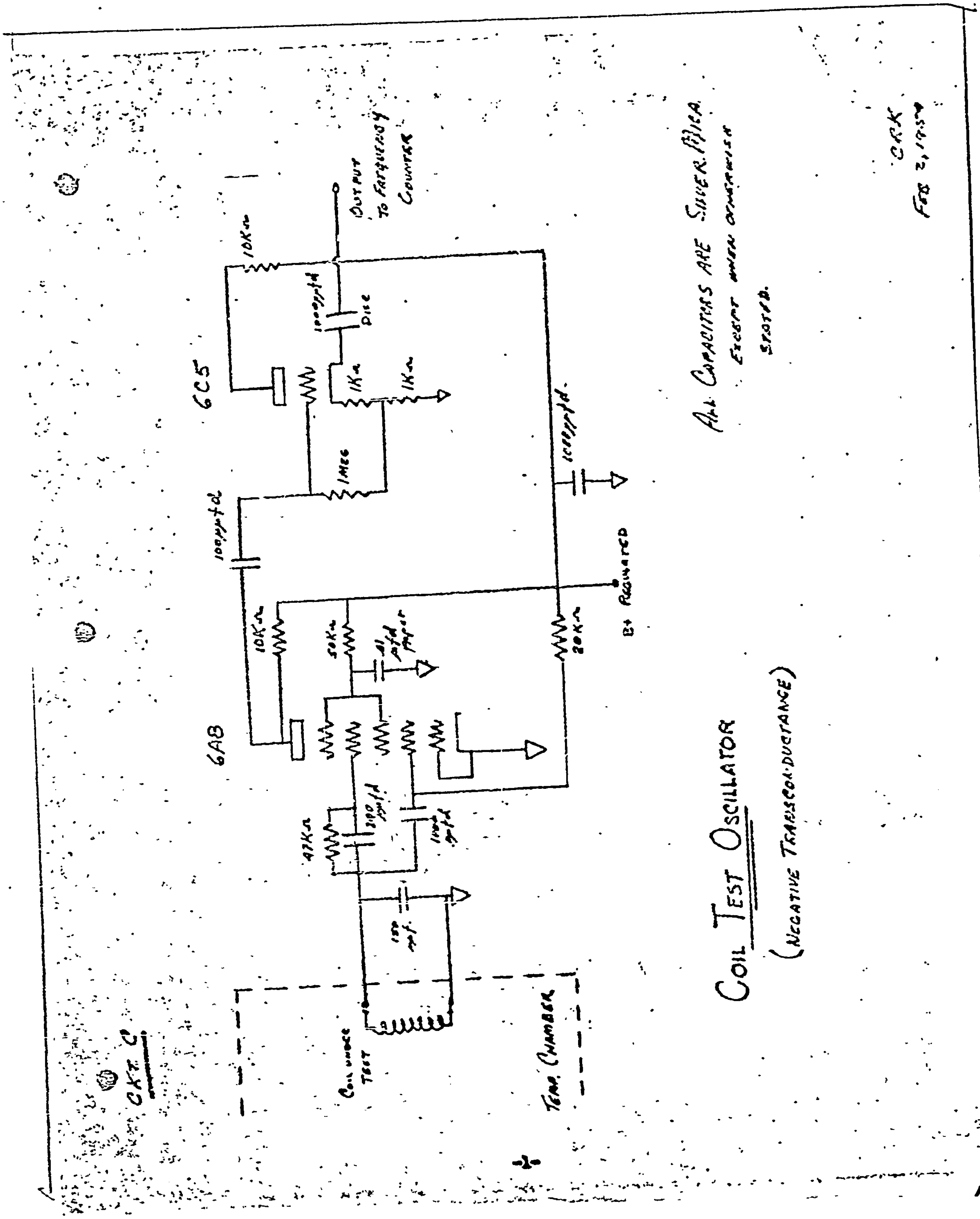
The "Proposed" Specification on "Coils R-F, Transformers I-F, and Transformers R-F", ASESA Project 146, in whole or in part (as applicable) shall be used as a guide in the design, choice of materials of construction, and test of R-F transformers.

K. Design Examples

The principles of design established shall be illustrated by examples. Construction and testing of models based on these design examples may be used, if necessary, to prove out the design principles. Items so constructed need not be submitted, but full documentation of construction and test data should be included in the reports. The choice of design examples shall be as mutually agreed upon between the Contractor and the Contracting Officer's Representative and will be predicated upon the extent of progress achieved (or anticipated) at the time of agreement.

APPENDIX B

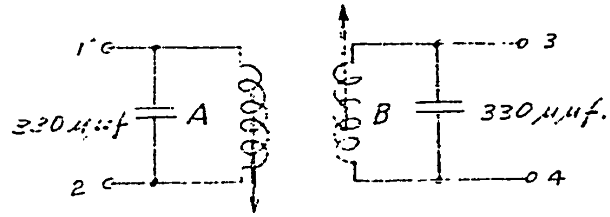
Circuit Diagrams
Test Data
Curves and Graphs



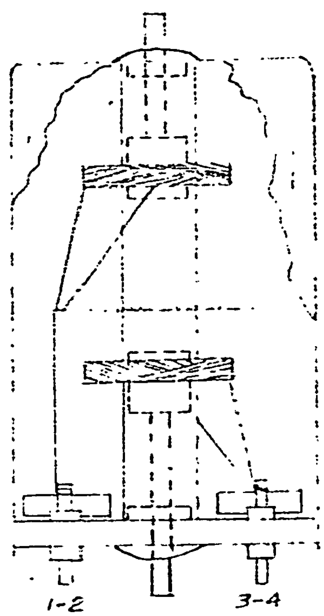
6C5
6AB
10KΩ
1000μμfd
Disc
1KΩ
1KΩ
1MEG
100μμfd
1000μμfd
Output to Frequency Counter
All Capacitors are Silver Mica Except when otherwise stated.
CRK
Feb 2, 1954
B+ Regulated
10KΩ
50KΩ
20KΩ
.01 μfd paper
47KΩ
390 μμfd
1000 μμfd
150 μμf.
Coil under Test
Temp. Chamber
Ckt. C
Coil Test Oscillator
(Negative Transconductance)

EXPERIMENTAL 135 KC IF TRANSFORMER

WIRE 3/41 SSE.
GEARS 42/88.
CAM 3/16.
TURNS A 480 - B 480.
FORM 1/2 OD. 3/8 ID. 3 1/4 L.
SHIELD CAN 3 1/2 x 2 x 2.
CORE 3/8 OD. x 1/2 L.
SK-133, G3.



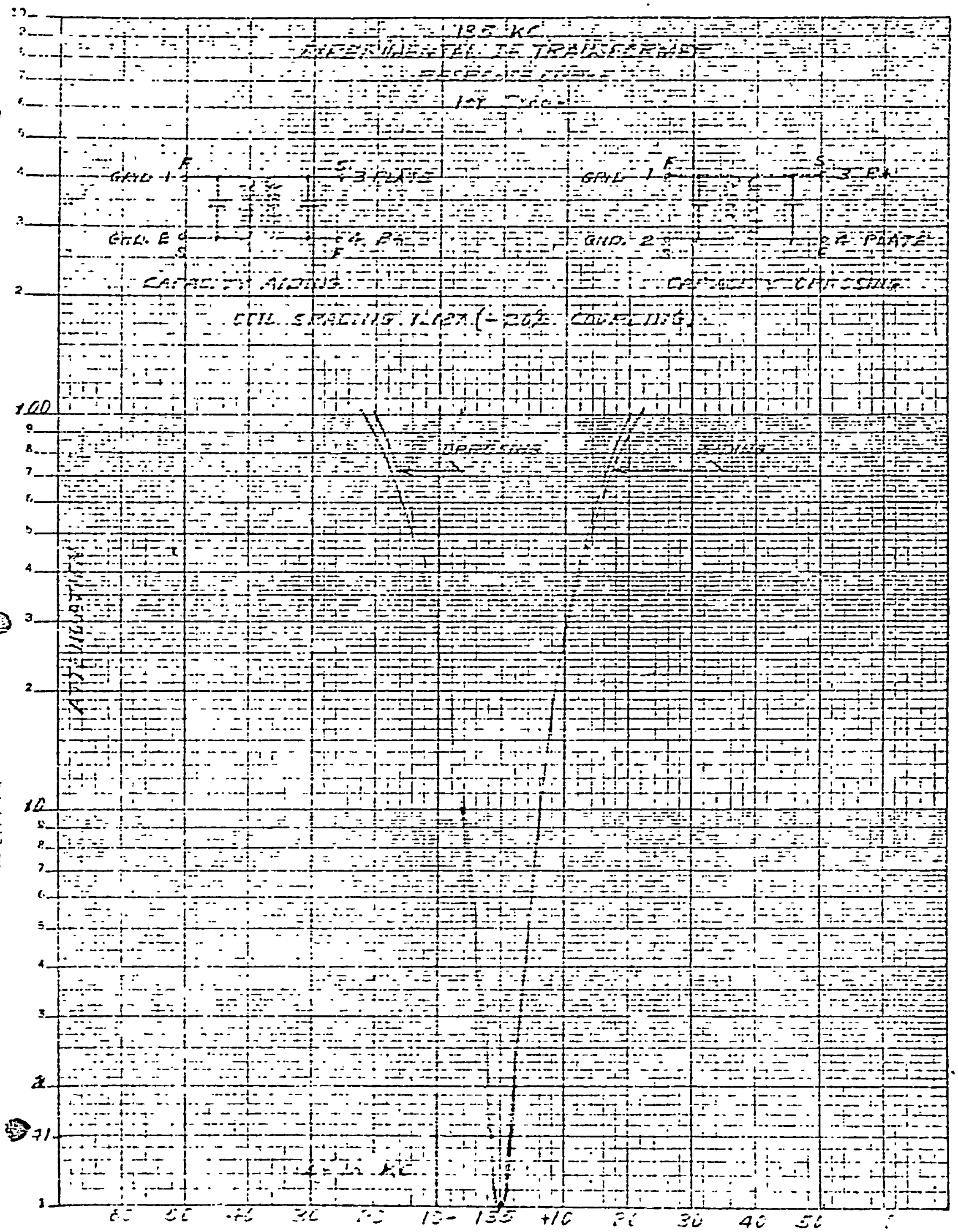
COIL AFTER IMP. WITH CORE IN CAN	COIL AFTER IMP. WITH CORE OUT OF CAN	COIL AFTER IMP. WITHOUT CORE IN CAN	COIL AFTER IMP. WITHOUT CORE OUT OF CAN
f = 135 KC	f = 135 KC	f = 135 KC	f = 135 KC
C = 338	C = 329	C = 376	C = 369
Q = 75	Q = 79	Q = 69	Q = 72



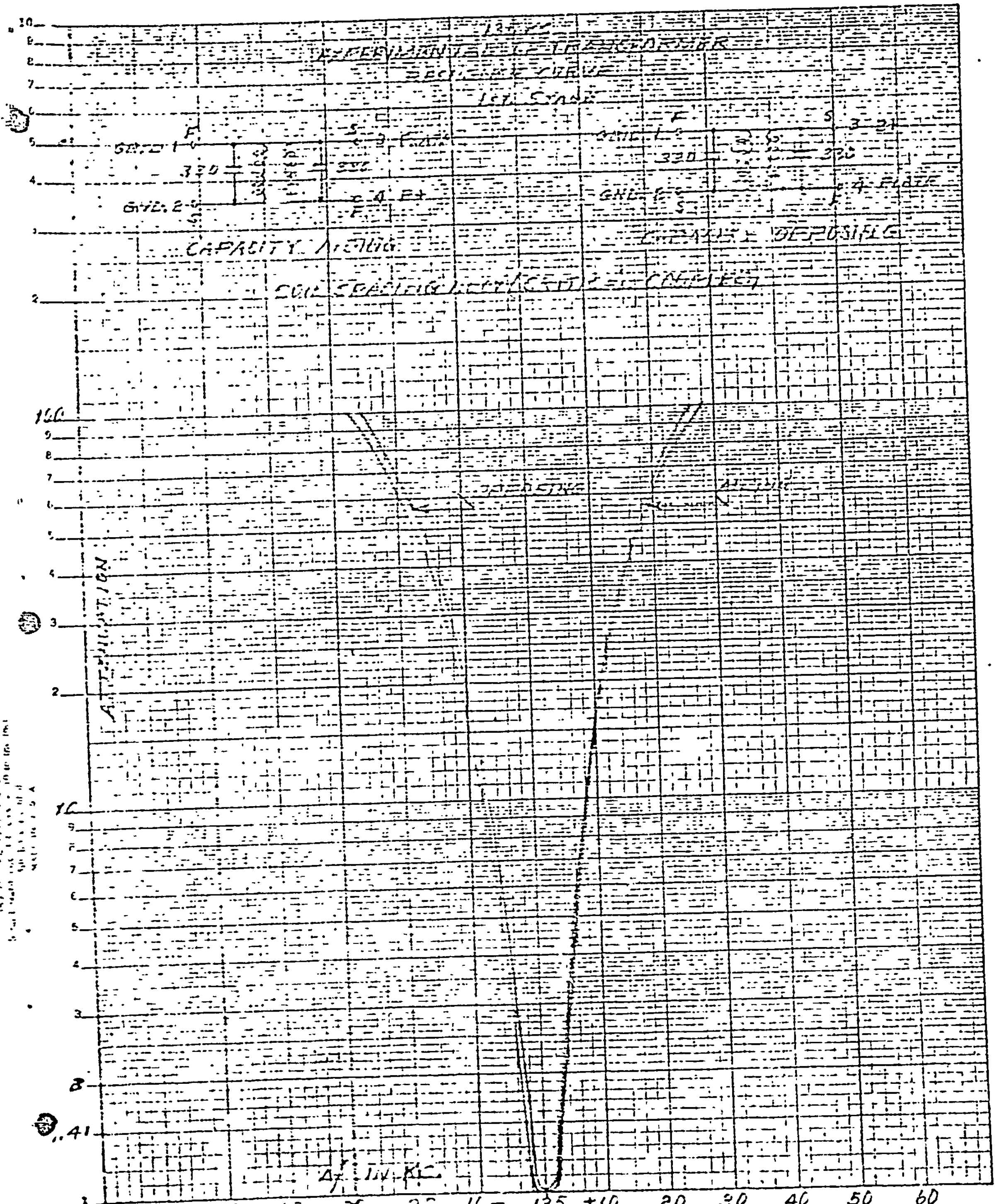
ASSEMBLED TRANSFORMER

NOTE:
TRANSFORMER TUNED ON Q-METER WITH C = 335 μμf.
i.e. 330 μμf BASE CAP + 5 μμf. STRAY CAPACITY.

BASE CAPS ARE ... MICA.



135 KC
GRID 1
3 PLATE
GRID 2
4 PLATE
CAPACITY AIDING
OPPOSING
AIDING
100
10
1
135
+10
30
40



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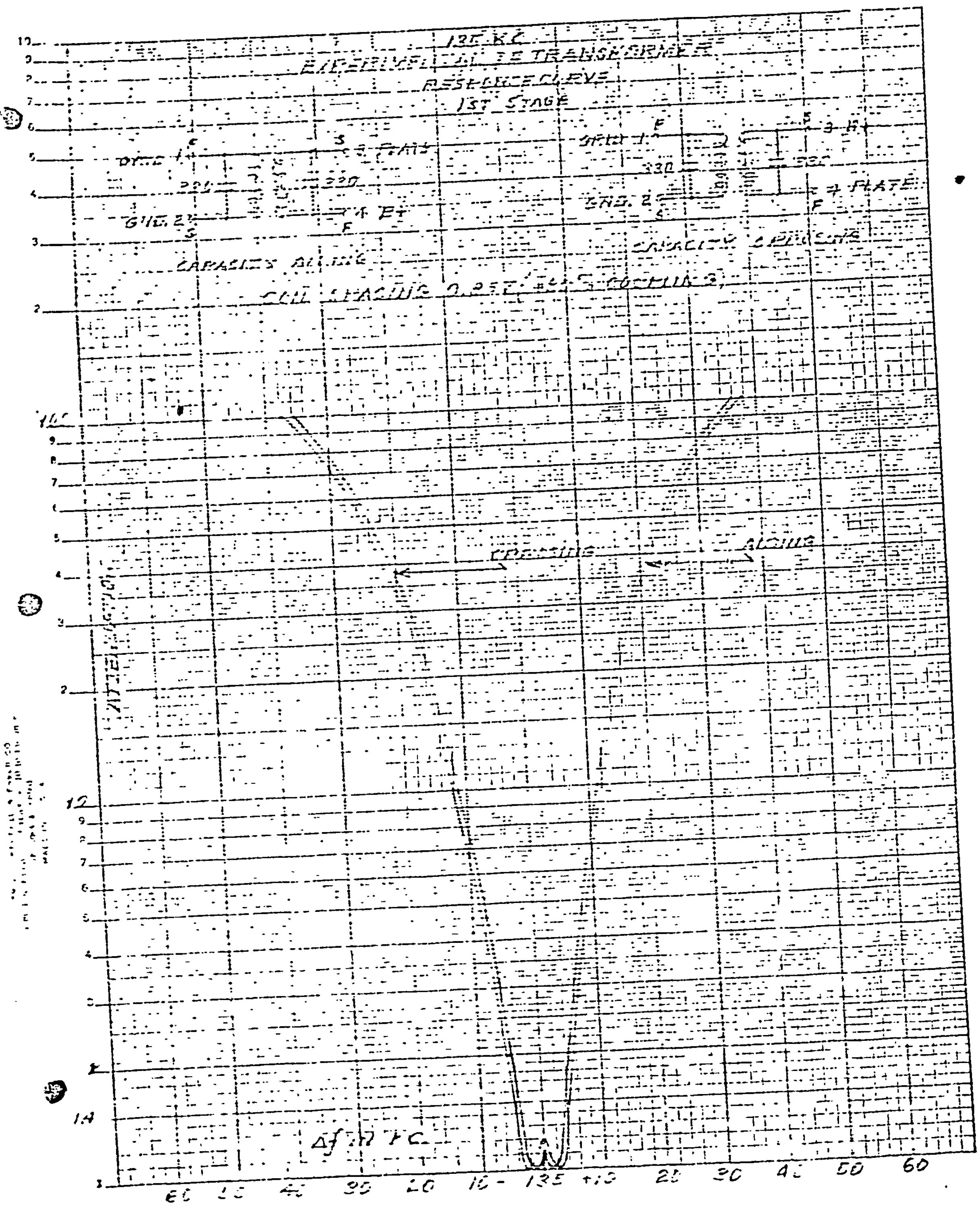
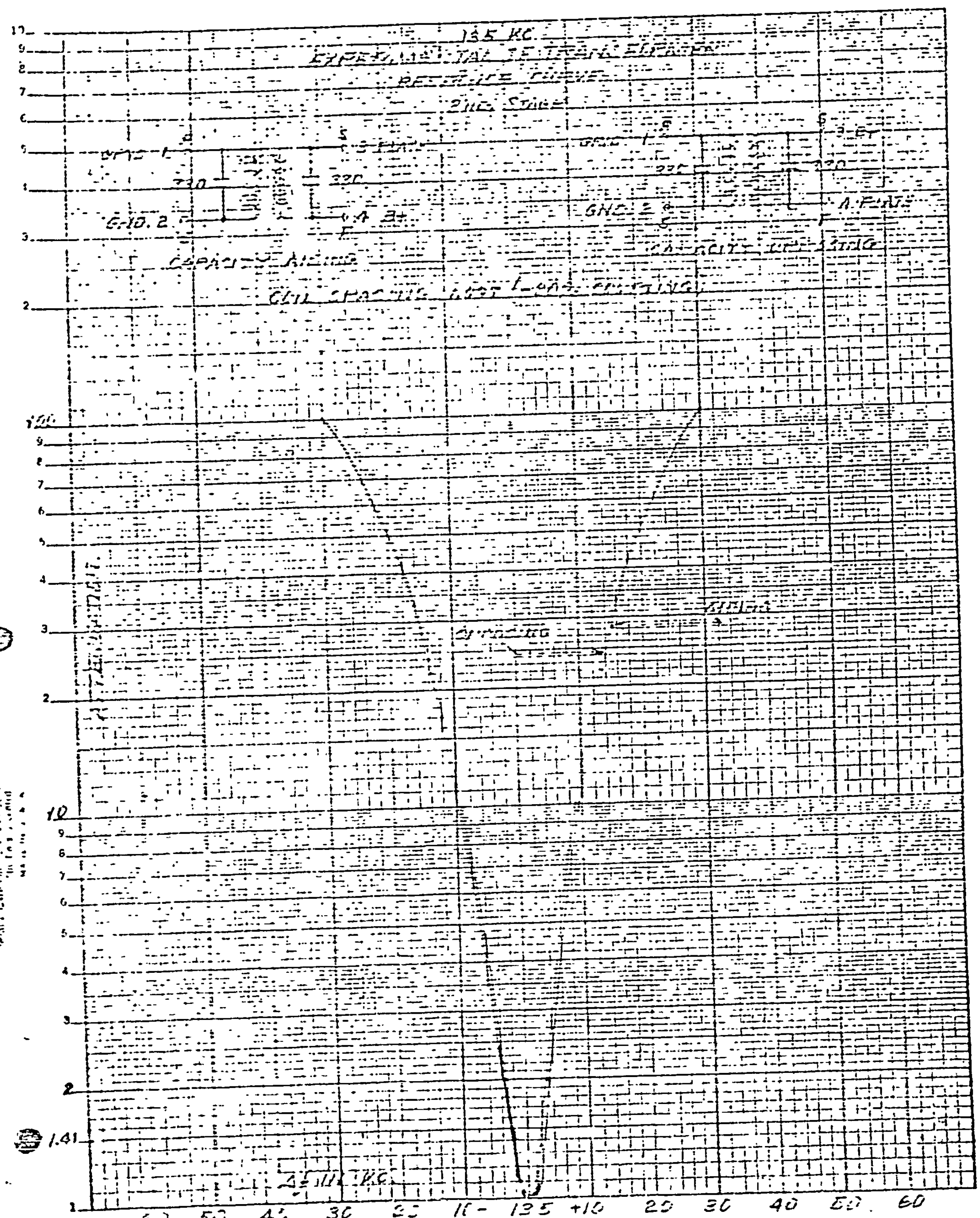
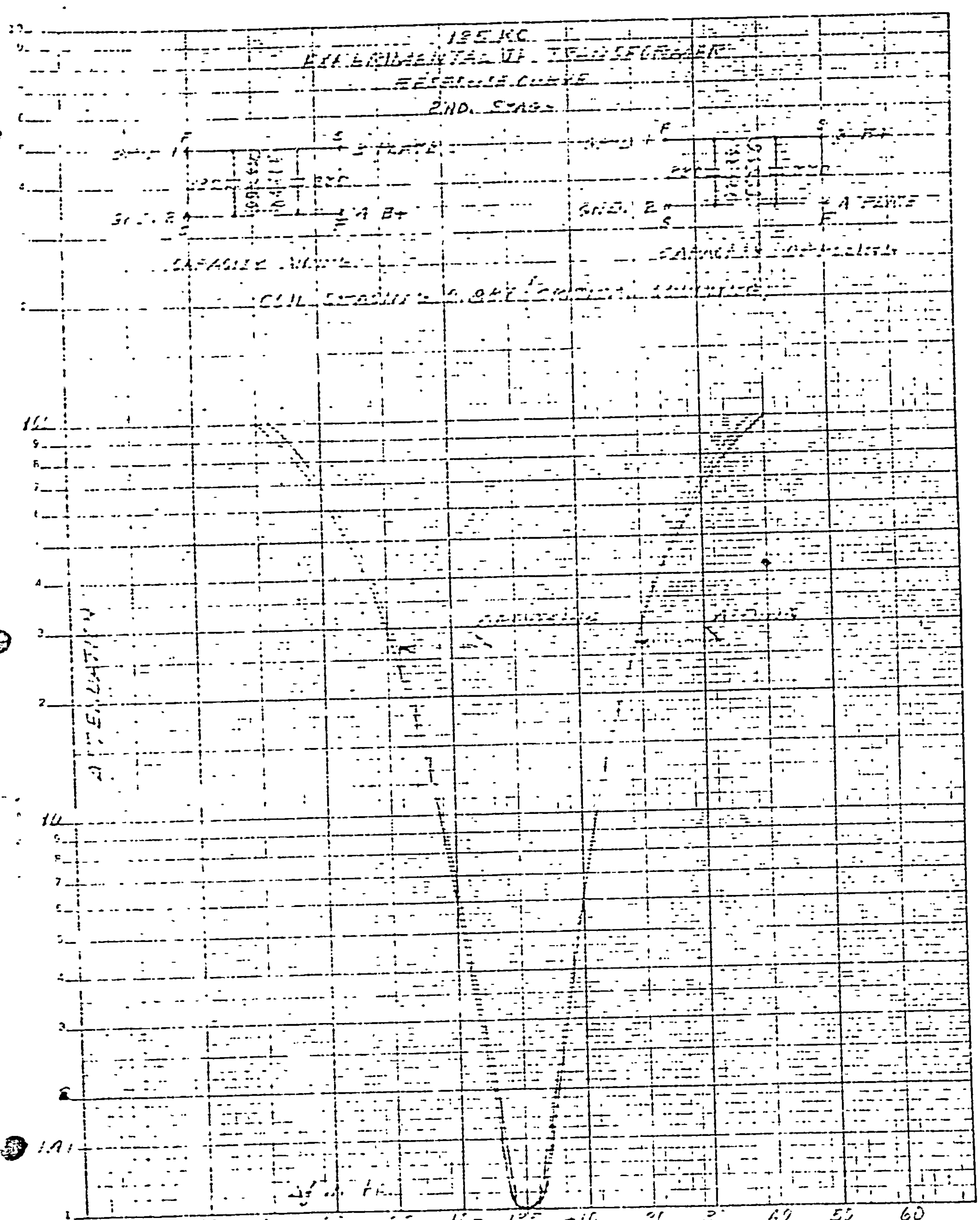
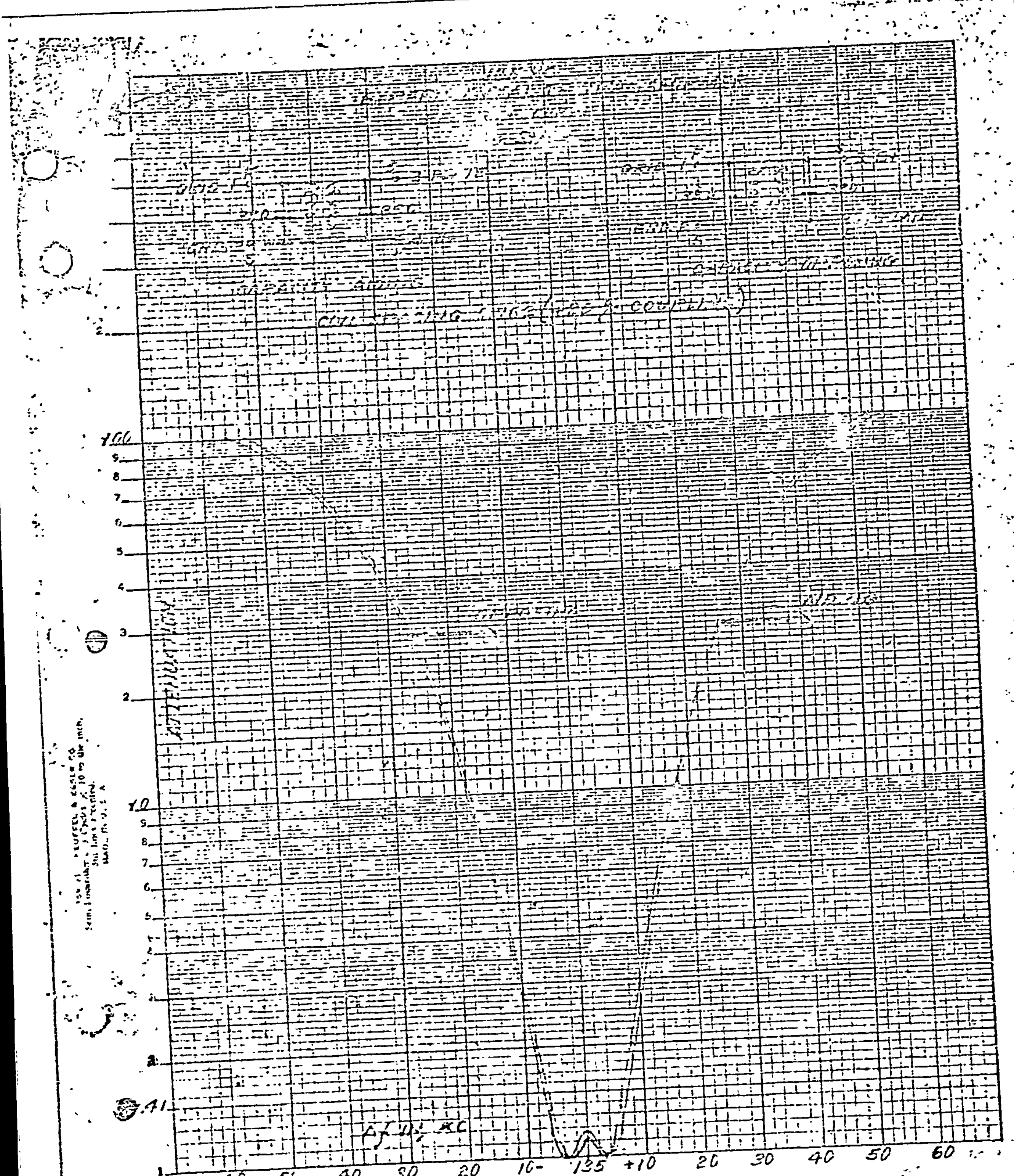

135 KC
RESONANCE CURVE
1ST STAGE
PLATE
330
GRID 2
4 PLATE
CAPACITY AIDING
CAPACITY OPPOSING
ATTENUATION
Δf IN KC
60
40
30
20
10 - 135 + 10
20
30
40
50
60

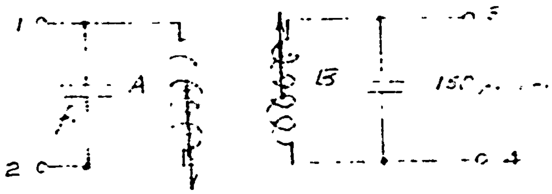

135 KC.
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
2ND STAGE
1.41
60 50 40 30 20 10 - 135 +10 20 30 40 50 60


125 KC
2ND. STAGE


100
10
60 50 40 30 20 10 135 +10 20 30 40 50 60

EXPER[illegible] 262 KC IF TRANSFORMER

[illegible] 3/4 [illegible]
[illegible] AL [illegible]
[illegible] 3/16.
[illegible] A35 [illegible]
[illegible] 1.5[illegible] 3/16 [illegible] 3/4 L.
SHIEL[illegible] CAN [illegible] 2 x [illegible]
CORE 3/[illegible] x 1/2 L.
SK-133, G3.

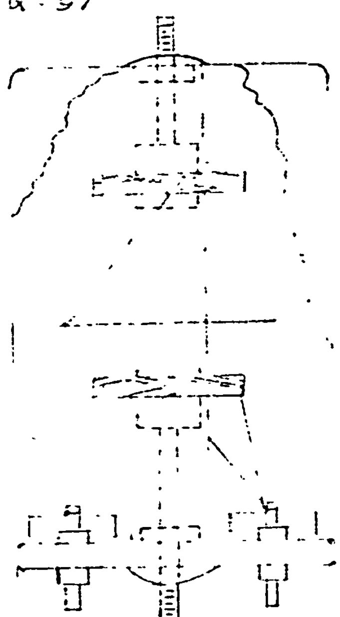


COIL AFTER IMP. WITH CORE

IN CAN	OUT OF CAN
f = 26[illegible] KC.	f = 26[illegible] KC.
C = 158	C = 154
Q = 93	Q = 97

C[illegible] AFTER IMP. WITH [illegible] CORE

IN CAN	OUT OF CAN
f = 262 KC.	f = 262 KC.
C = 195	C = 192
Q = 82	Q = 85

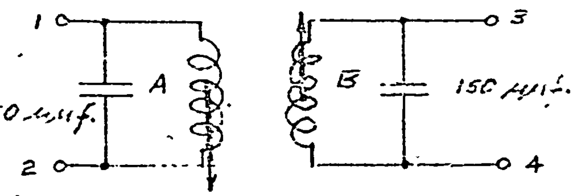


ASSEMBLED TRANSFORMER

NOTE:
TRANSFORMER TUNED ON
Q-[illegible] WITH C = 155 [illegible]
[illegible] 150 [illegible] BASE [illegible]
+ 8 [illegible] STRAY CAP.
BASE CAP. ARE SILVER MICA.

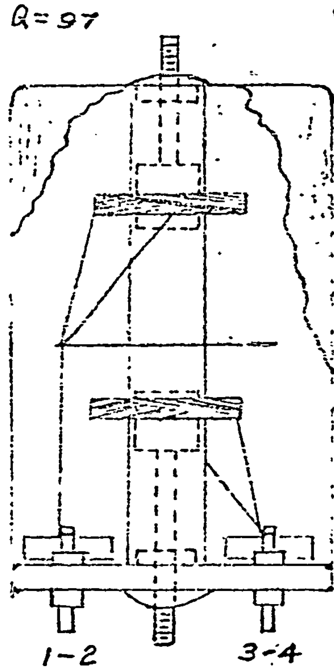
EXPERIMENTAL 262 KC IF TRANSFORMER

WIRE 3/41 SSE.
GEARS 42/82.
CAM 3/16.
TURNS A 350 - B 350.
FORM 1/2 OD. 3/8 ID. 3 1/4 L.
SHIELD CAN 3 1/2 x 2 x 2.
CORE 3/8 OD. x 1/2 L.
SK-133, G3.



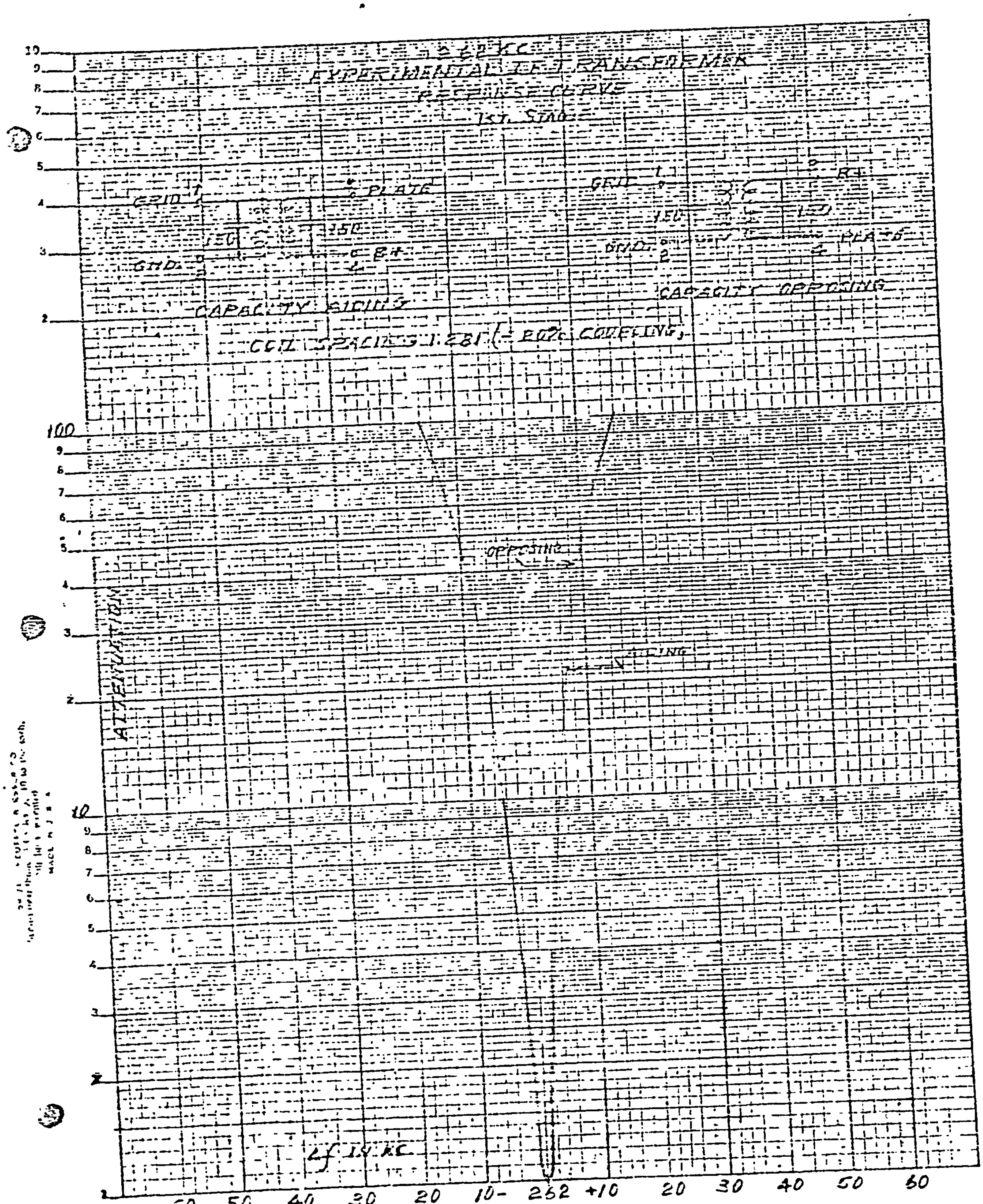
COIL AFTER IMP. WITH CORE	
IN CAN	OUT OF CAN
f = 262 KC.	f = 262 KC.
C = 158	C = 154
Q = 93	Q = 97

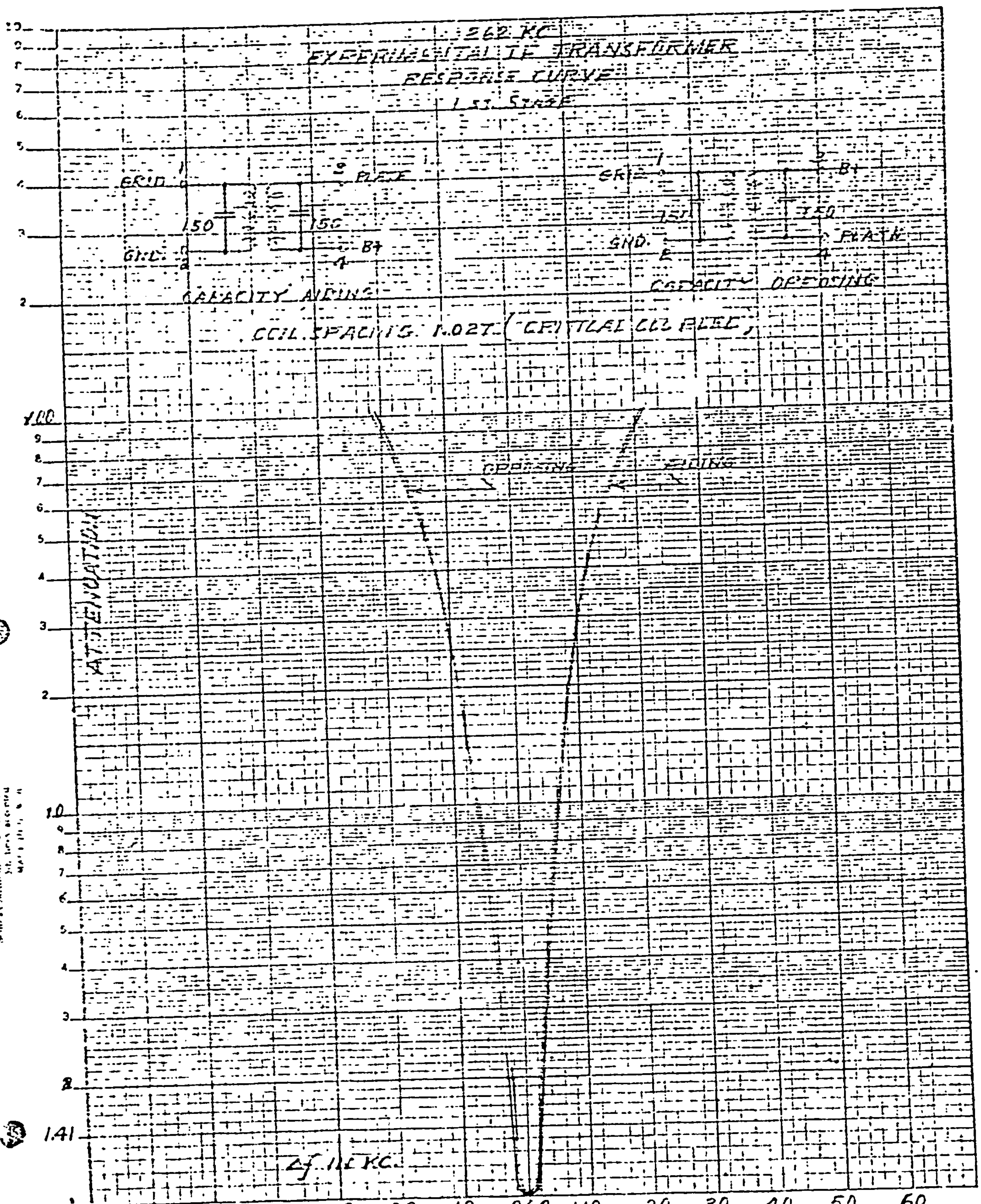
COIL AFTER IMP. WITHOUT CORE	
IN CAN	OUT OF CAN
f = 262 KC.	f = 262 KC.
C = 195	C = 192
Q = 82	Q = 85

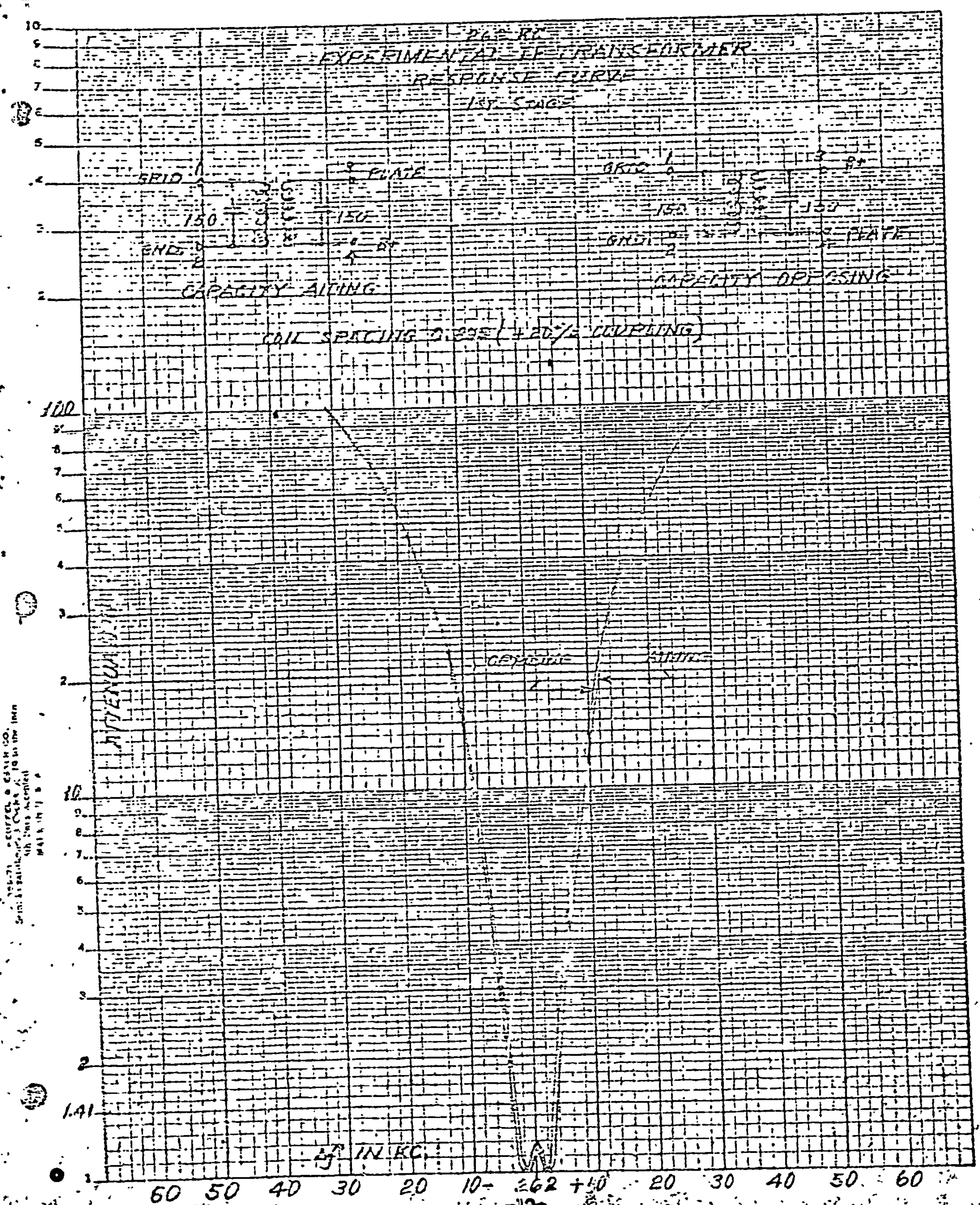


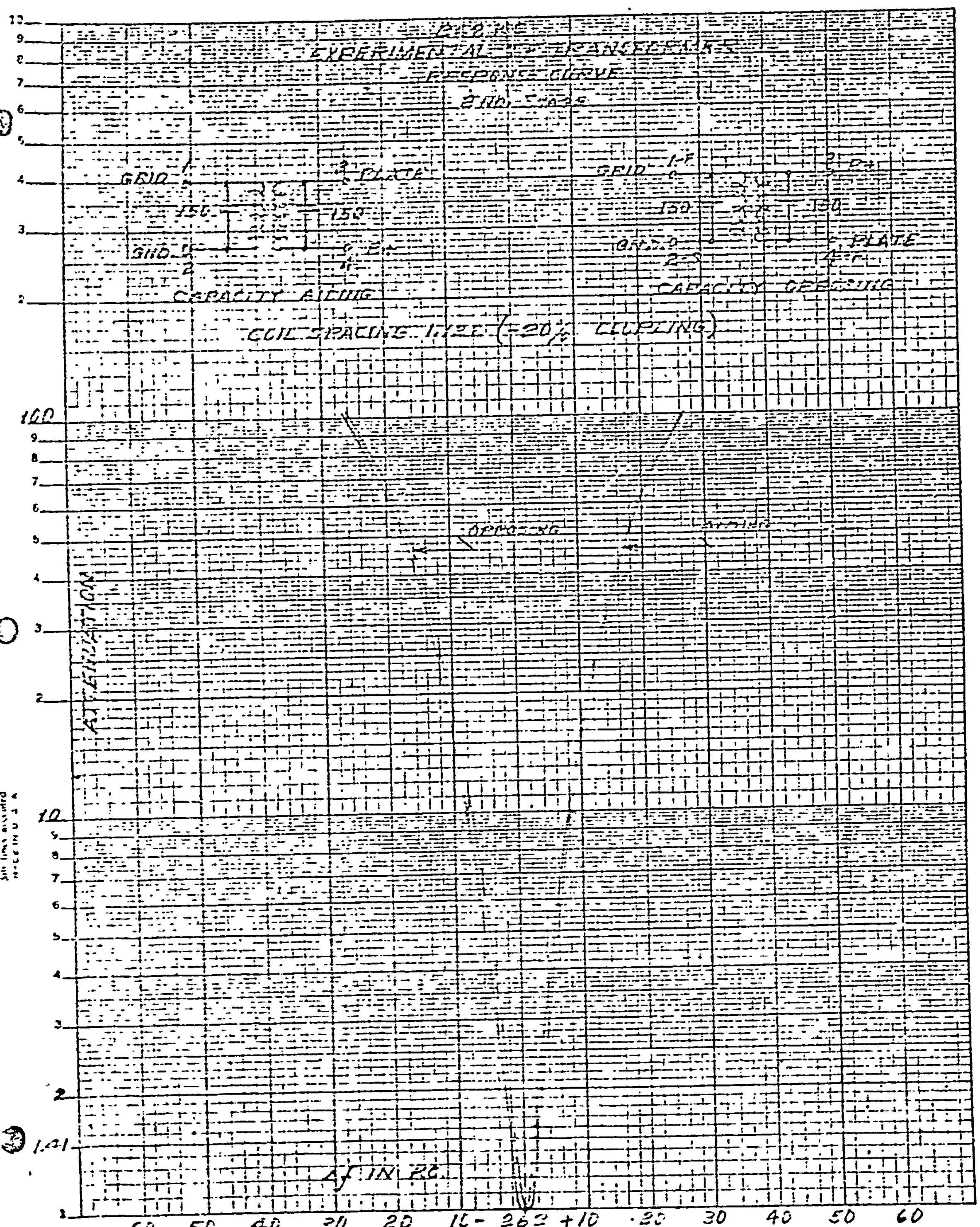
ASSEMBLED TRANSFORMER

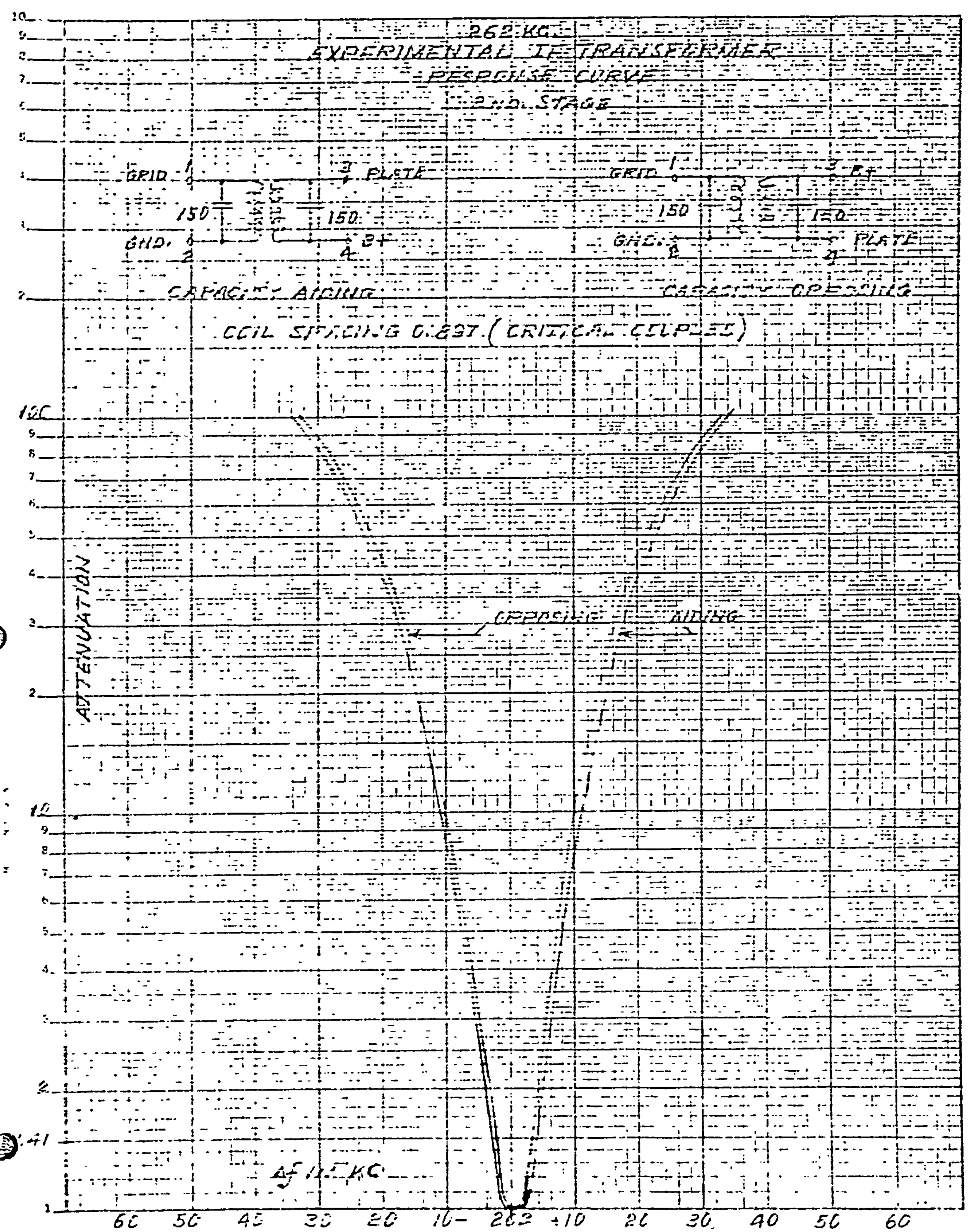
NOTE:
TRANSFORMER TUNED ON Q-METER WITH C = 158 μμf.
ie. 150 μμf BASE CAP.
+ 8 μμf STRAY CAP.
BASE CAP. ARE SILVER MICA.

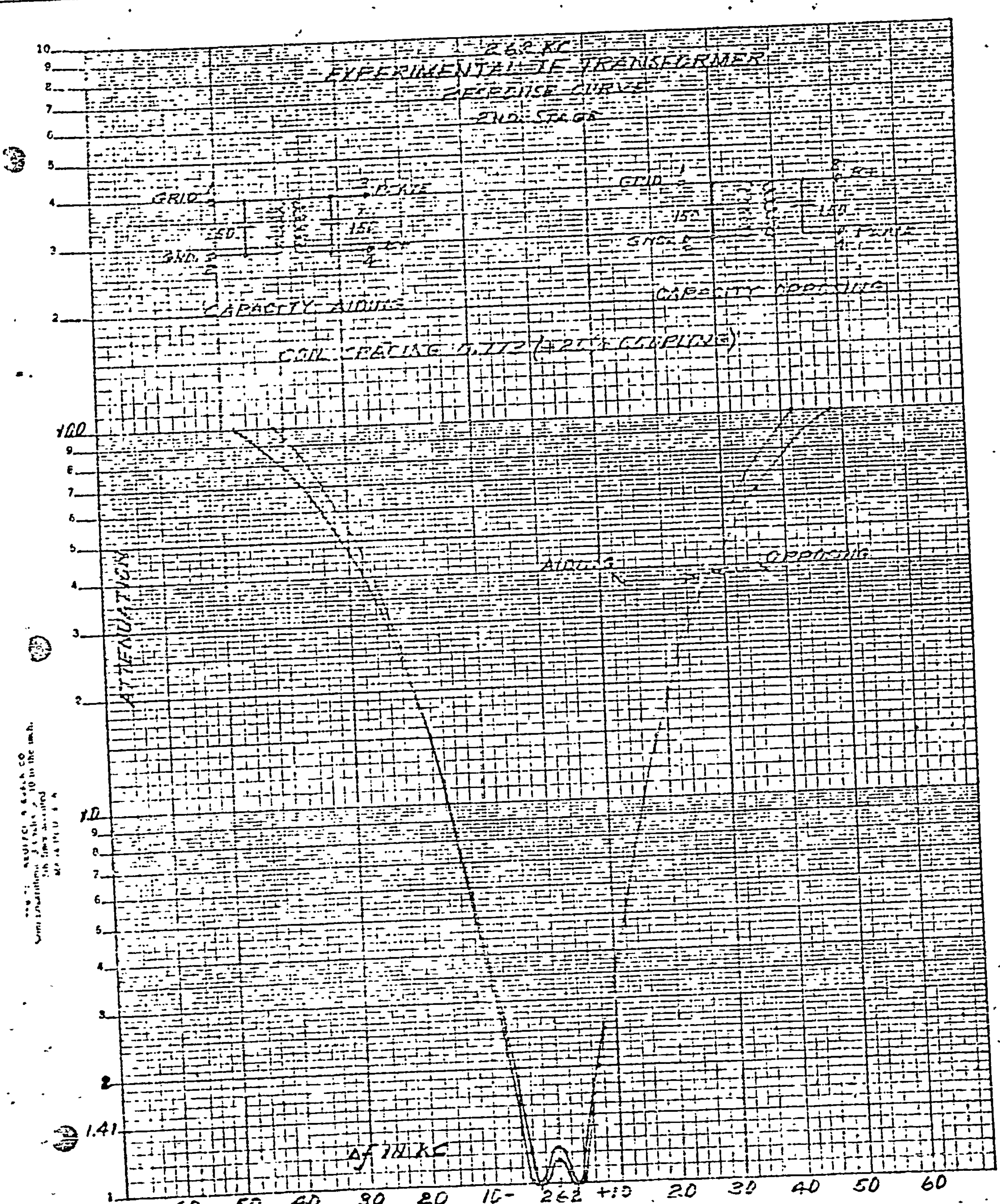

EXPERIMENTAL I.F. TRANSFORMER
RESPONSE CURVE
1st. STAGE
GRID
PLATE
B+
GND.
CAPACITY AIDING
CAPACITY OPPOSING
OPPOSING
ATTENUATION
100
10
60 50 40 30 20 10- 262 +10 20 30 40 50 60


262 KC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
1 st. STAGE
GRID
PLATE
150
150
B+
GND.
CAPACITY AIDING
CAPACITY OPPOSING
OPPOSING
AIDING
ATTENUATION
100
10
1.41
60 50 40 30 20 10 - 262 +10 20 30 40 50 60


EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
1ST STAGE
GRID
PLATE
150
150
GND.
B+
CAPACITY AIDING
GRID
PLATE
B+
CAPACITY OPPOSING
100
10
1.41
60
50
40
30
20
10
262
10
20
30
40
50
60
IN KC.

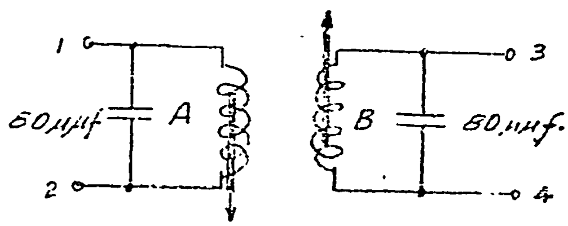

EXPERIMENTAL TRANSFORMERS
RESPONSE CURVE
GRID
PLATE
150
GRID
PLATE
CAPACITY AIDING
CAPACITY OPPOSING
COIL SPACING
COUPLING)
ATTENUATION
OPPOSING
AIDING
100
10
1.41
Δf IN KC
60 50 40 30 20 10 - 262 +10 20 30 40 50 60


262 KC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
2ND. STAGE
GRID
PLATE
150
GND.
B+
CAPACITY AIDING
CAPACITY OPPOSING
COIL SPACING 0.237 (CRITICAL COUPLED)
ATTENUATION
OPPOSING
AIDING
Δf 11.5 KC
60 50 40 30 20 10 262 10 20 30 40 50 60

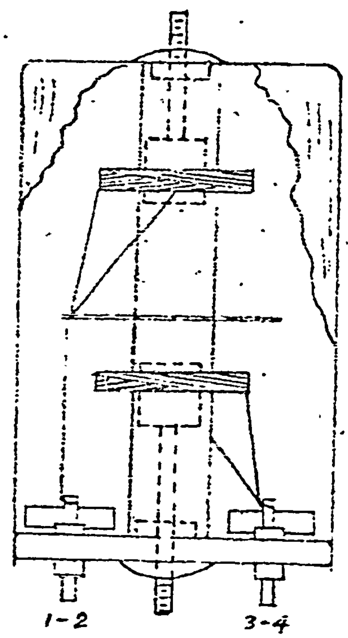

262 KC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
2ND STAGE
GRID
PLATE
GND
CAPACITY AIDING
CAPACITY OPPOSING
ATTENUATION
AIDING
OPPOSING
1.41
60 50 40 30 20 10 262 +10 20 30 40 50 60

EXPERIM... TAL 1400 KC IF TRANSFORMER

WIRE 3/41 SSE
GEARS 28/58
CAM 5/32
TURNS A 75 - B 75
FORM 1/2 OD. - 3/8 ID. - 3/4 L.
SHIELD CAN 3 1/2 X 2 X 2
CORE 3/8 OD. X 1/2 L.
SK-132, G3



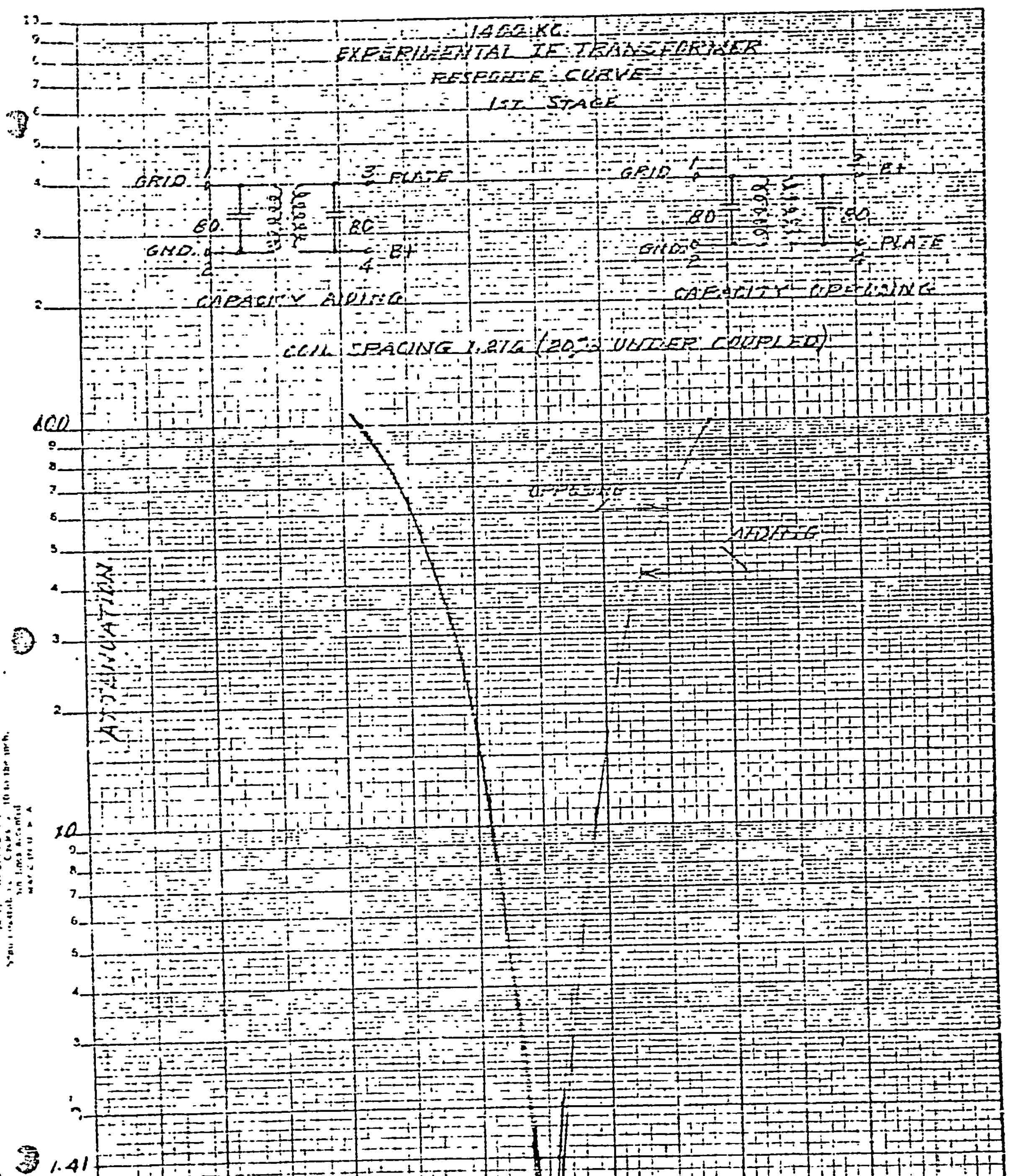
COIL AFTER IMP. WITH CORE		COIL AFTER IMP. WITHOUT CORE	
IN CAN	OUT OF CAN	IN CAN	OUT OF CAN
f = 1400 KC	f = 1400 KC	f = 1400 KC	f = 1400 KC
C = 88	C = 87	C = 124	C = 123
Q = 64	Q = 84	Q = 74	Q = 75

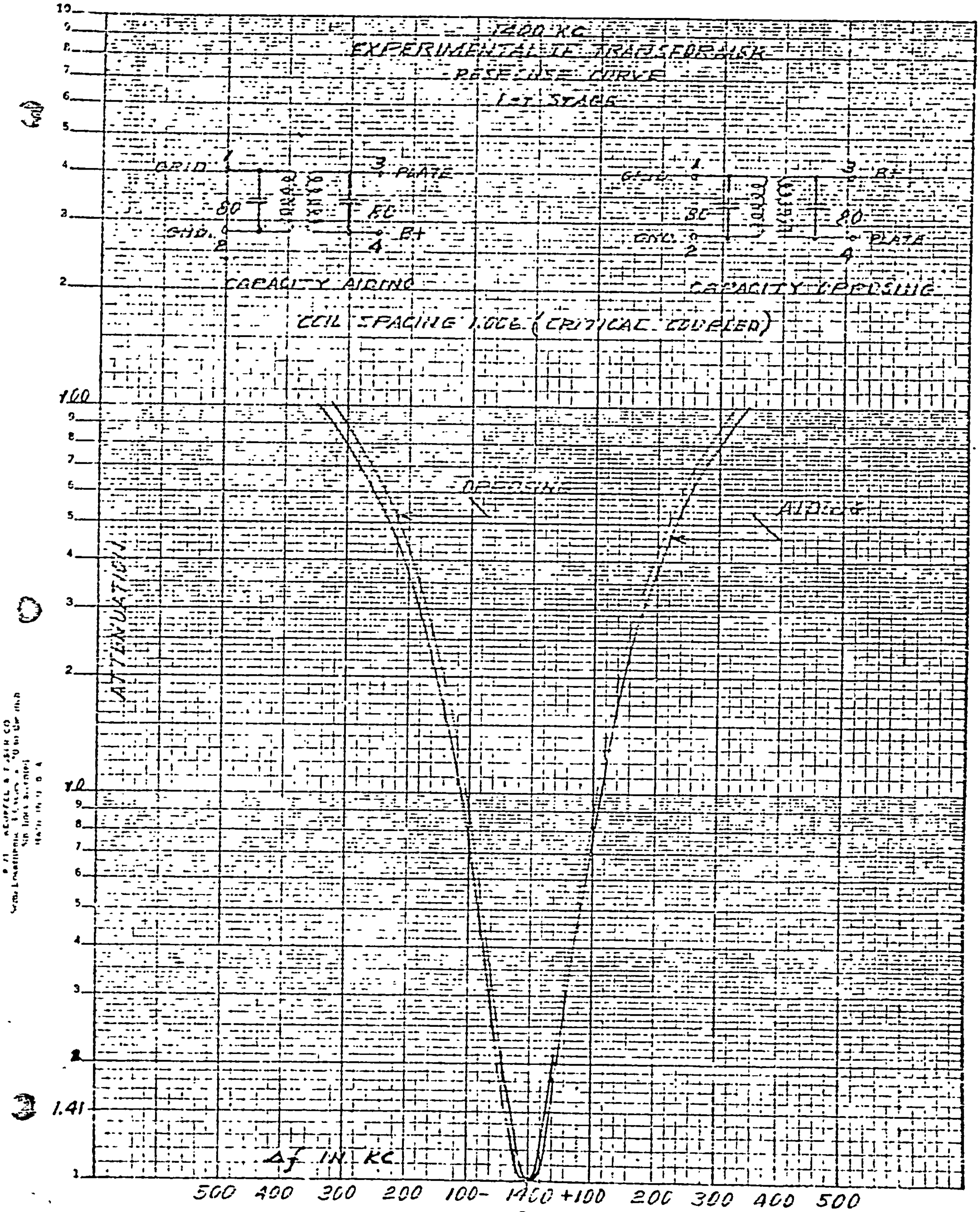


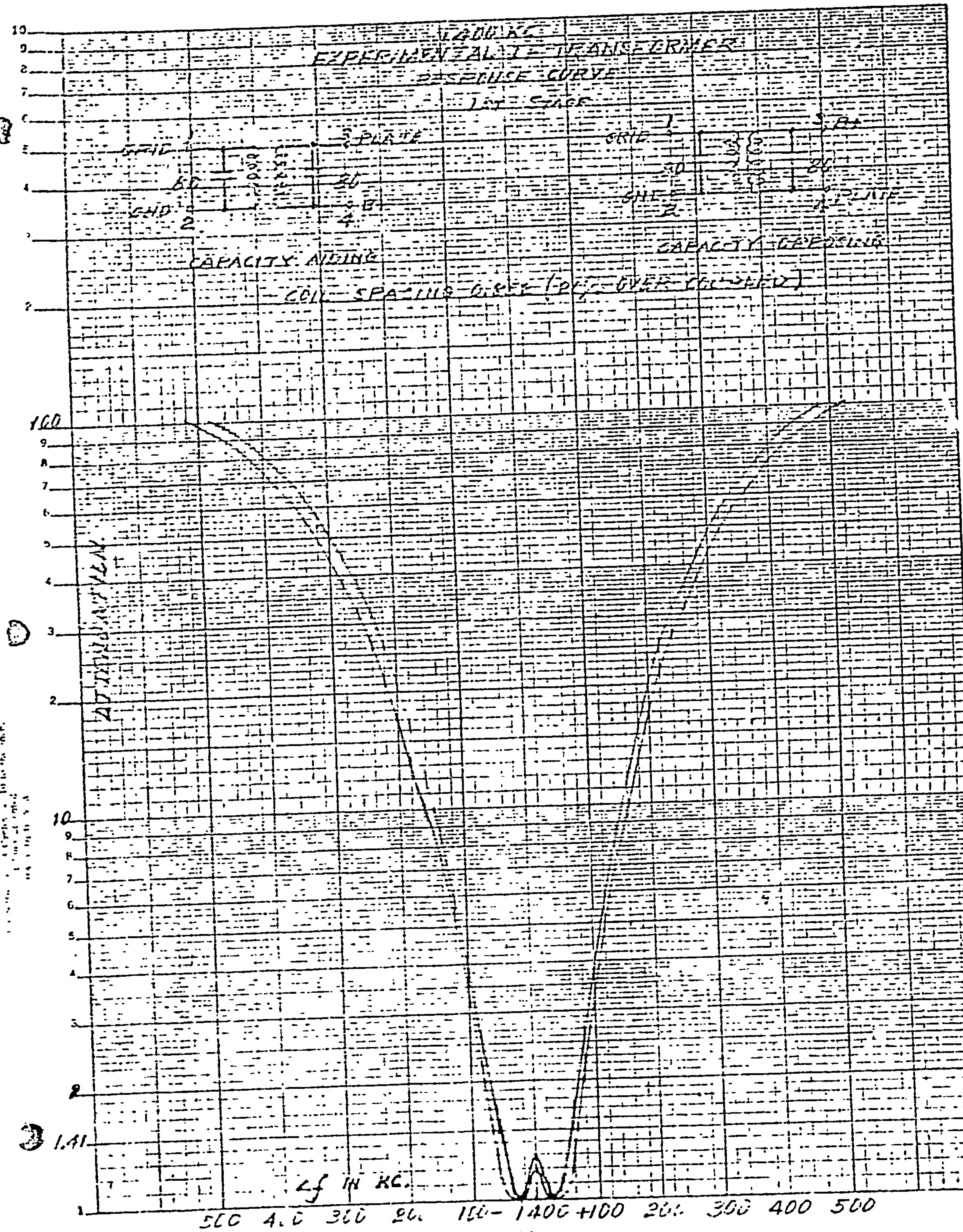
ASSEMBLED TRANSFORMER

NOTE:
TRANSFORMER TUNED ON
Q-METER WITH C = 88 μμf.
i.e. 80 μμf. BASE CAPACITY
+ 8 μμf STRAY CAP.

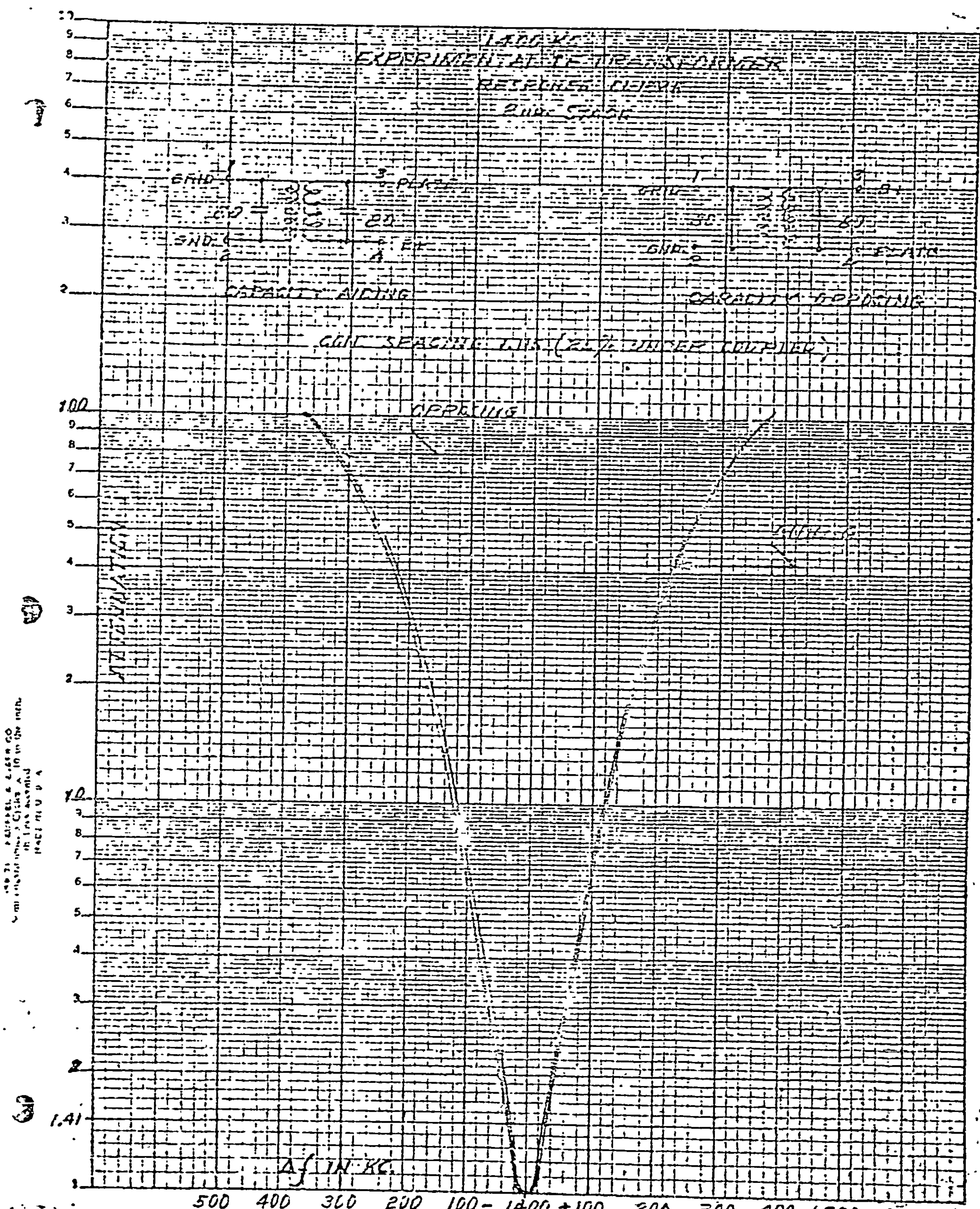
BASE CAP. ARE SILVER MICA.

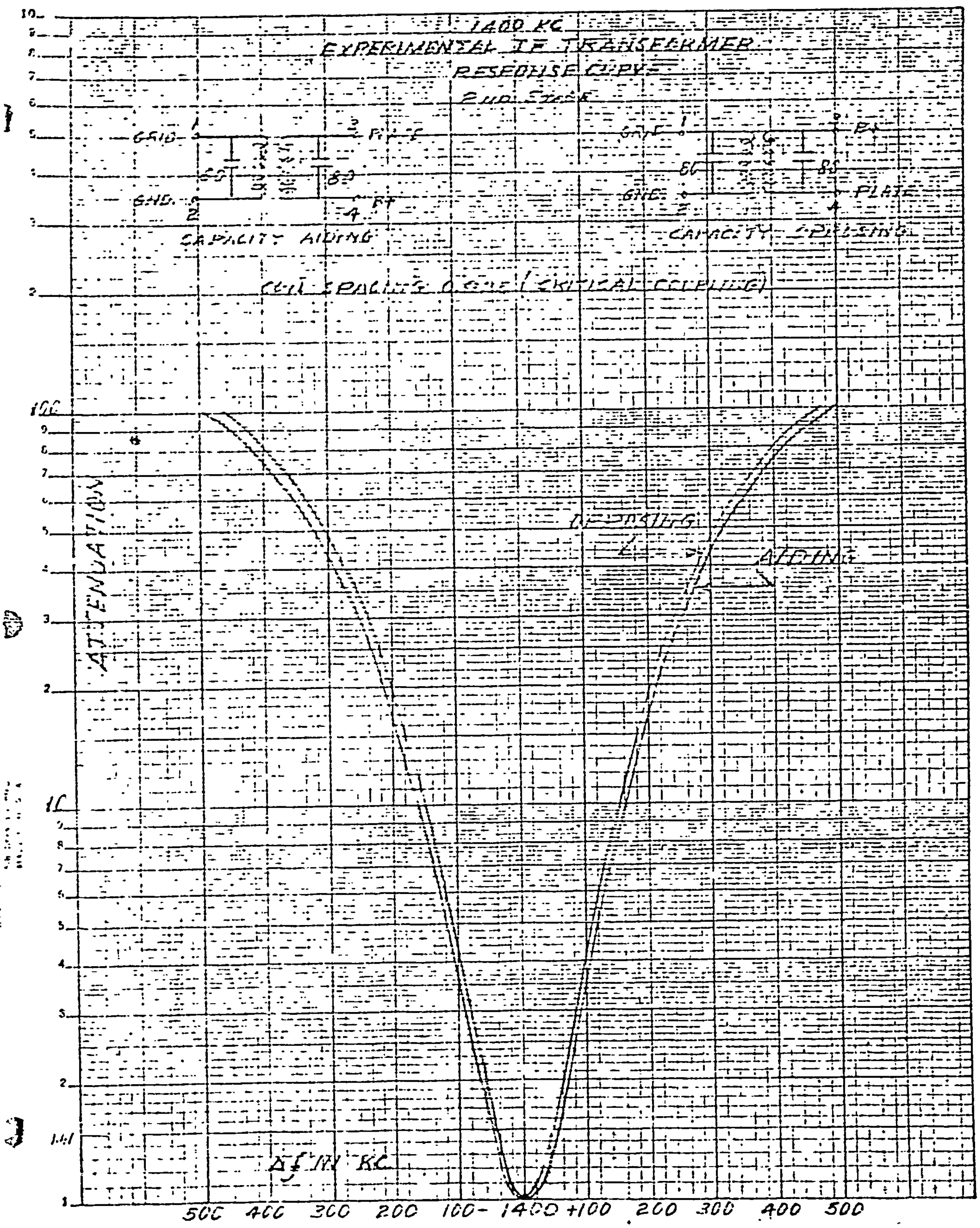

1400 KC.
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
1ST. STAGE
GRID
PLATE
80
GND.
B+
CAPACITY AIDING
GRID
80
GND
PLATE
CAPACITY OPPOSING
COIL SPACING 1.276 (20% UNDER COUPLED)
OPPOSING
AIDING
ATTENUATION
100
10
1.41
Δf IN KC
500 400 300 200 100- 1400 +100 200 300 400 500


1400 KC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
1ST STAGE
GRID
PLATE
GND.
B+
80
CAPACITY AIDING
CAPACITY OPPOSING
COIL SPACING 1.006 (CRITICAL COUPLED)
OPPOSING
AIDING
ATTENUATION
1.41
Δf IN KC
500 400 300 200 100- 1400 +100 200 300 400 500

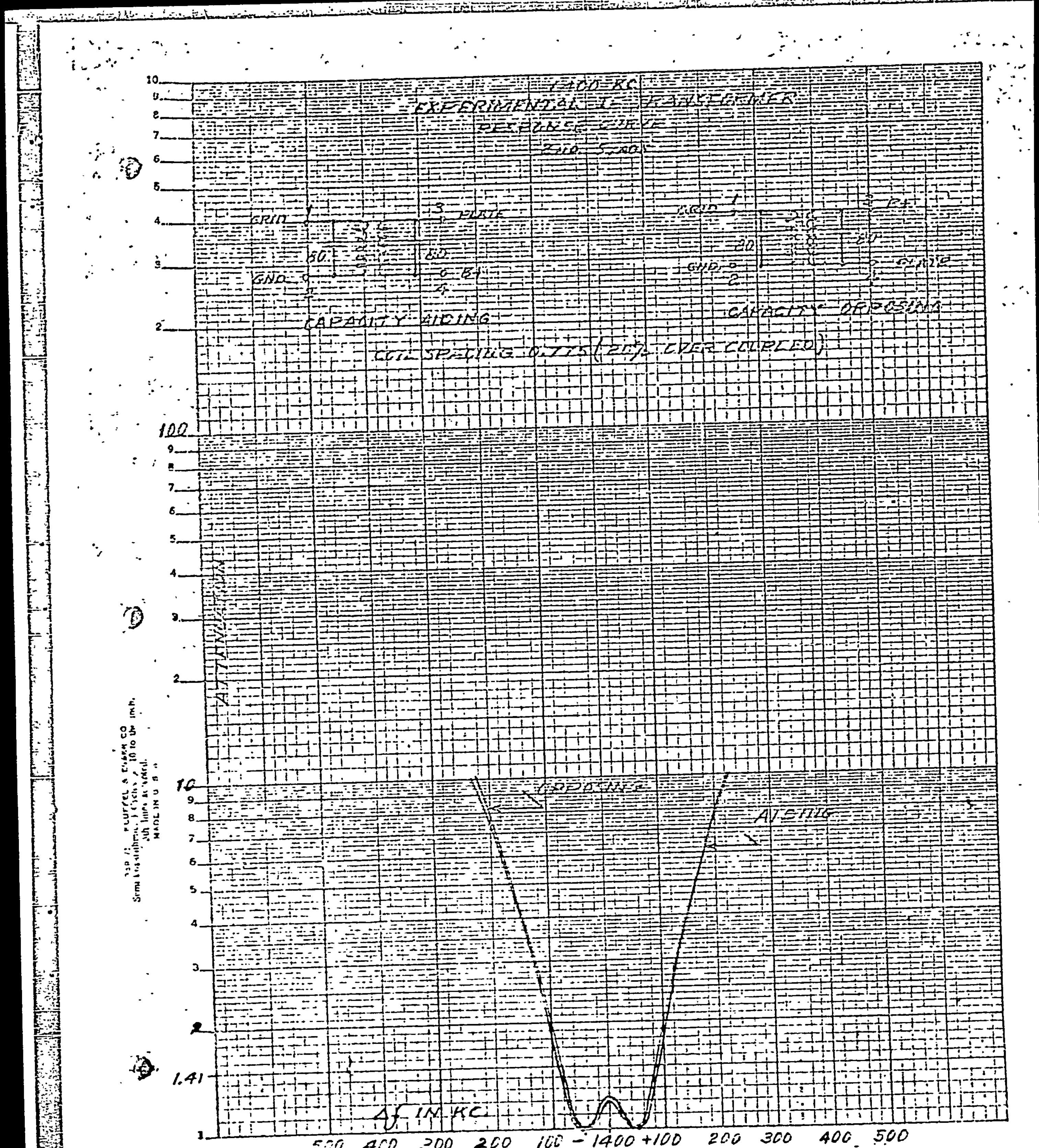

1400 KC
EXPERIMENTAL I.F. TRANSFORMER
RESPONSE CURVE
1st STAGE
PLATE
GRID
GND
CAPACITY AIDING
CAPACITY OPPOSING
ATTENUATION
100
10
2
1.41
1
Δf IN KC.
500 400 300 200 100 - 1400 + 100 200 300 400 500

POOR ORIGINAL



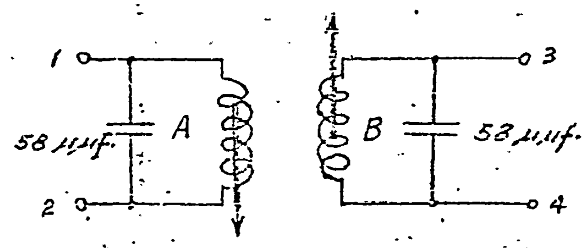


1400 KC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
2ND STAGE
GRID
PLATE
CAPACITY AIDING
CAPACITY OPPOSING
ATTENUATION
OPPOSING
AIDING
Δf IN KC
500 400 300 200 100- 1400 +100 200 300 400 500


1400 KC
EXPERIMENTAL I.F. TRANSFORMER
RESPONSE CURVE
GRID
PLATE
GND
B+
CAPACITY AIDING
CAPACITY OPPOSING
COIL SPACING 0.775 (20% OVER COUPLED)
OPPOSING
AIDING
1.41
Δf IN KC
500 400 300 200 100 - 1400 + 100 200 300 400 500

EXPERIMENTAL 4.3 MC IF TRANSFORMER

WIRE 5/44 SSE.
GEARS 101/66.
CAM 1/8.
TURNS A 26 – B 26.
FORM 1/2 OD. 3/8 ID. 3 1/4 L.
SHIELD CAN 3 1/8 x 2 x 2
CORE 3/8 OD. x 1/2 L
SK-133, G3

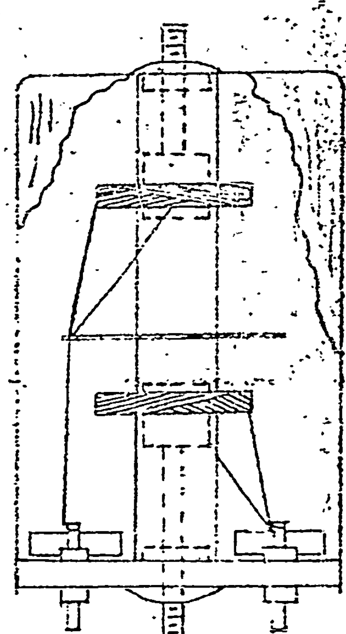


COIL AFTER IMP. WITH CORE

IN CAN	OUT OF CAN
f = 4.3 MC	f = 4.3 MC
C = 65	C = 65
Q = 82	Q = 83

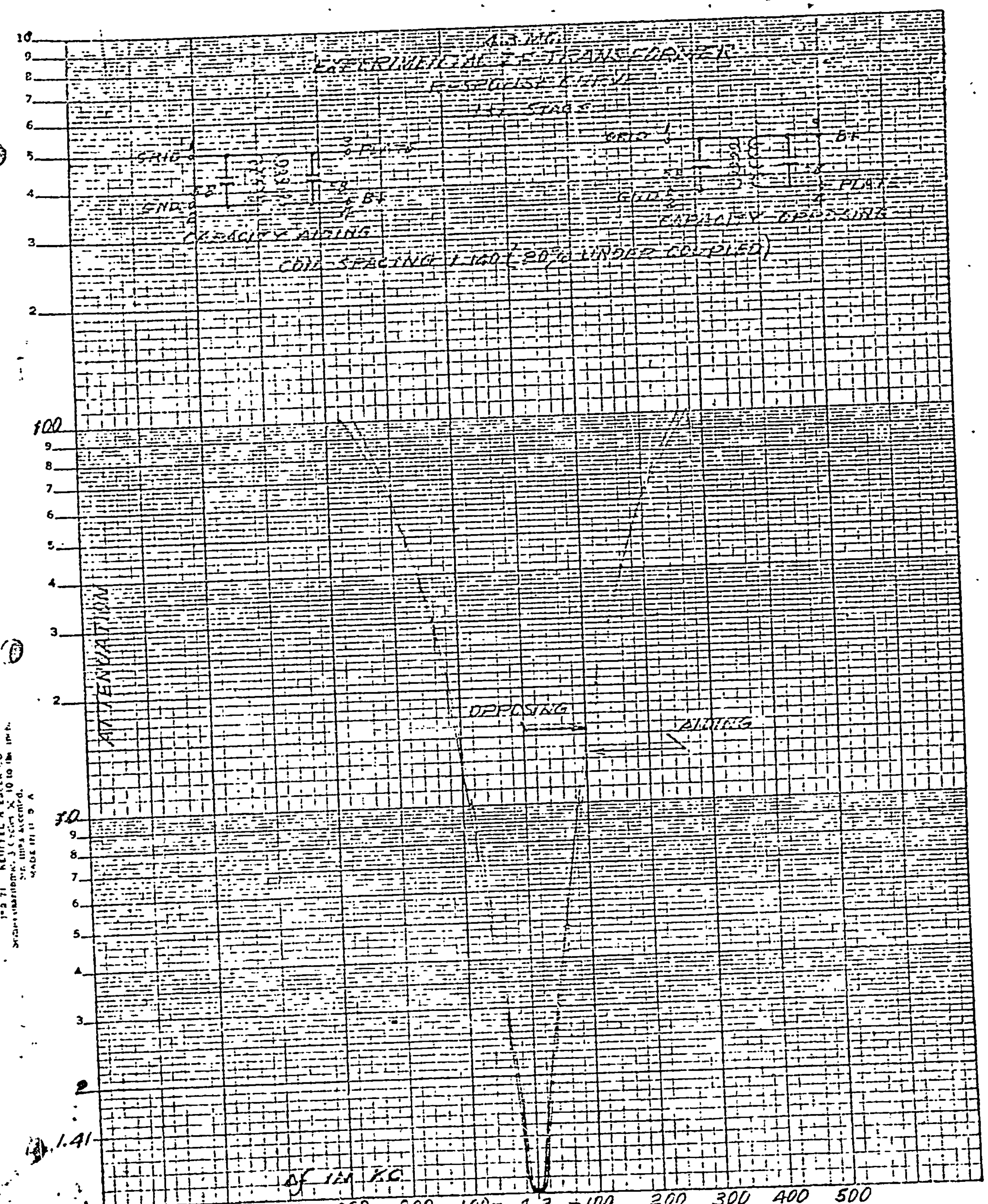
COIL AFTER IMP. WITHOUT CORE

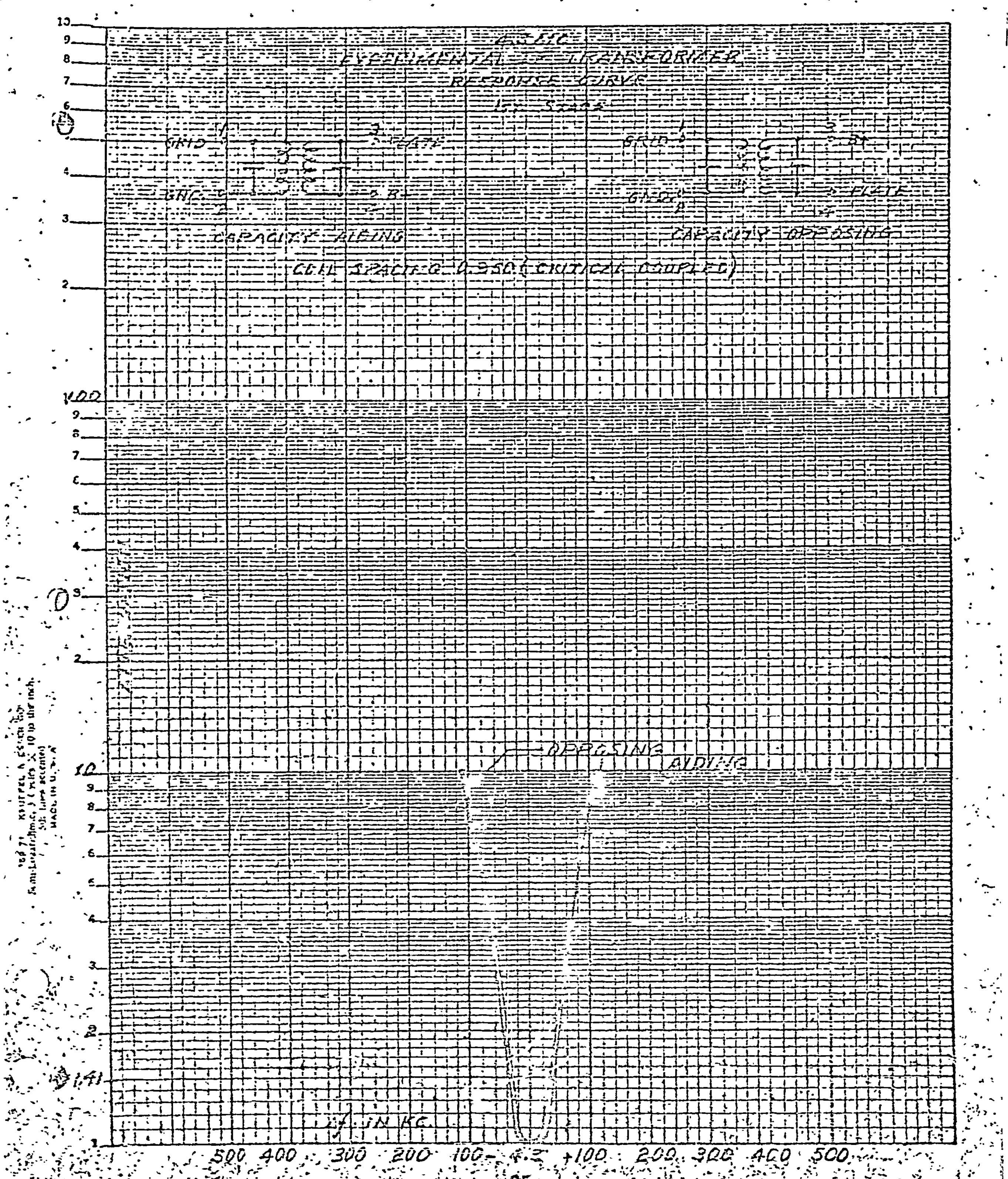
IN CAN	OUT OF CAN
f = 4.3 MC	f = 4.3 MC
C = 97	C = 96
Q = 67	Q = 68

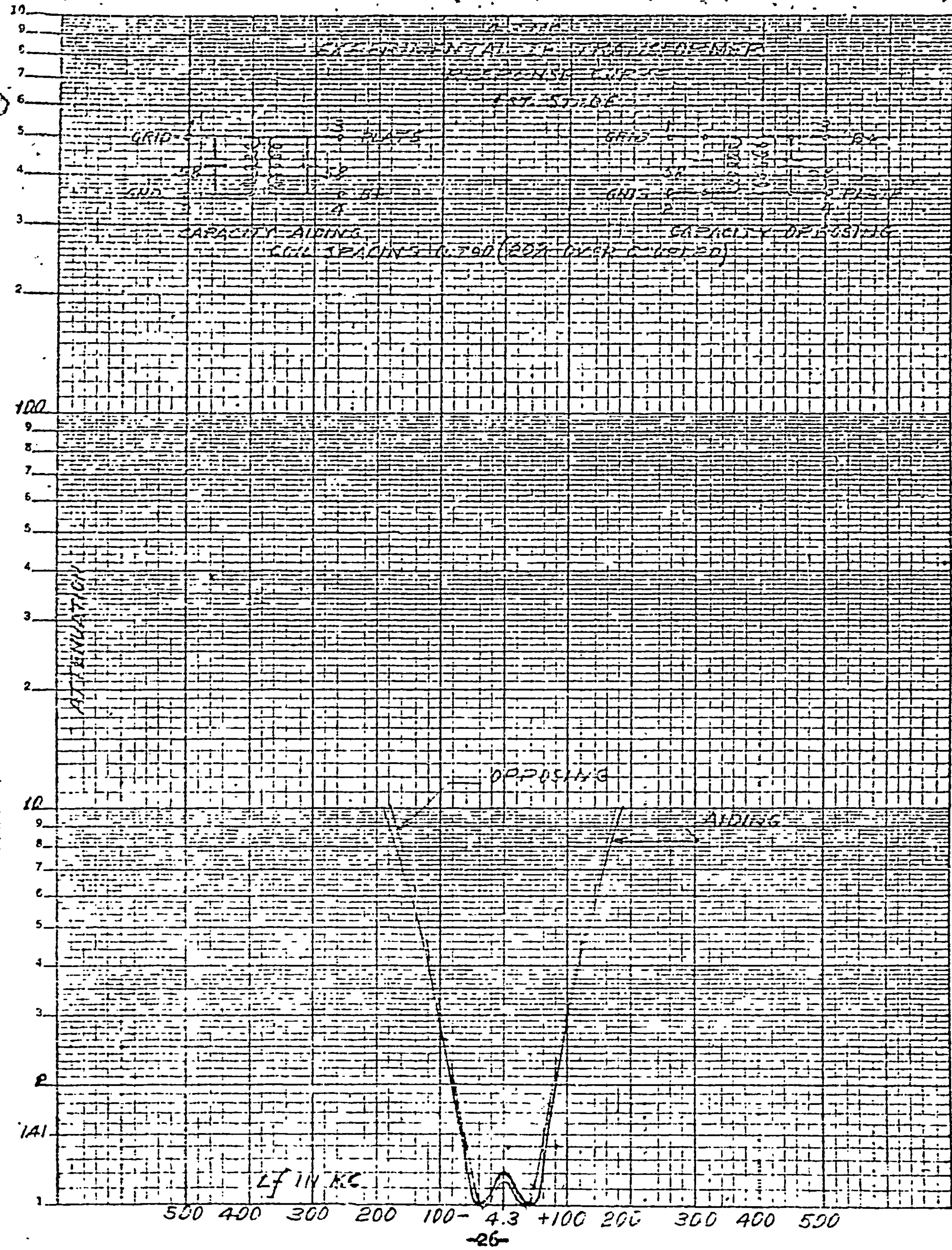


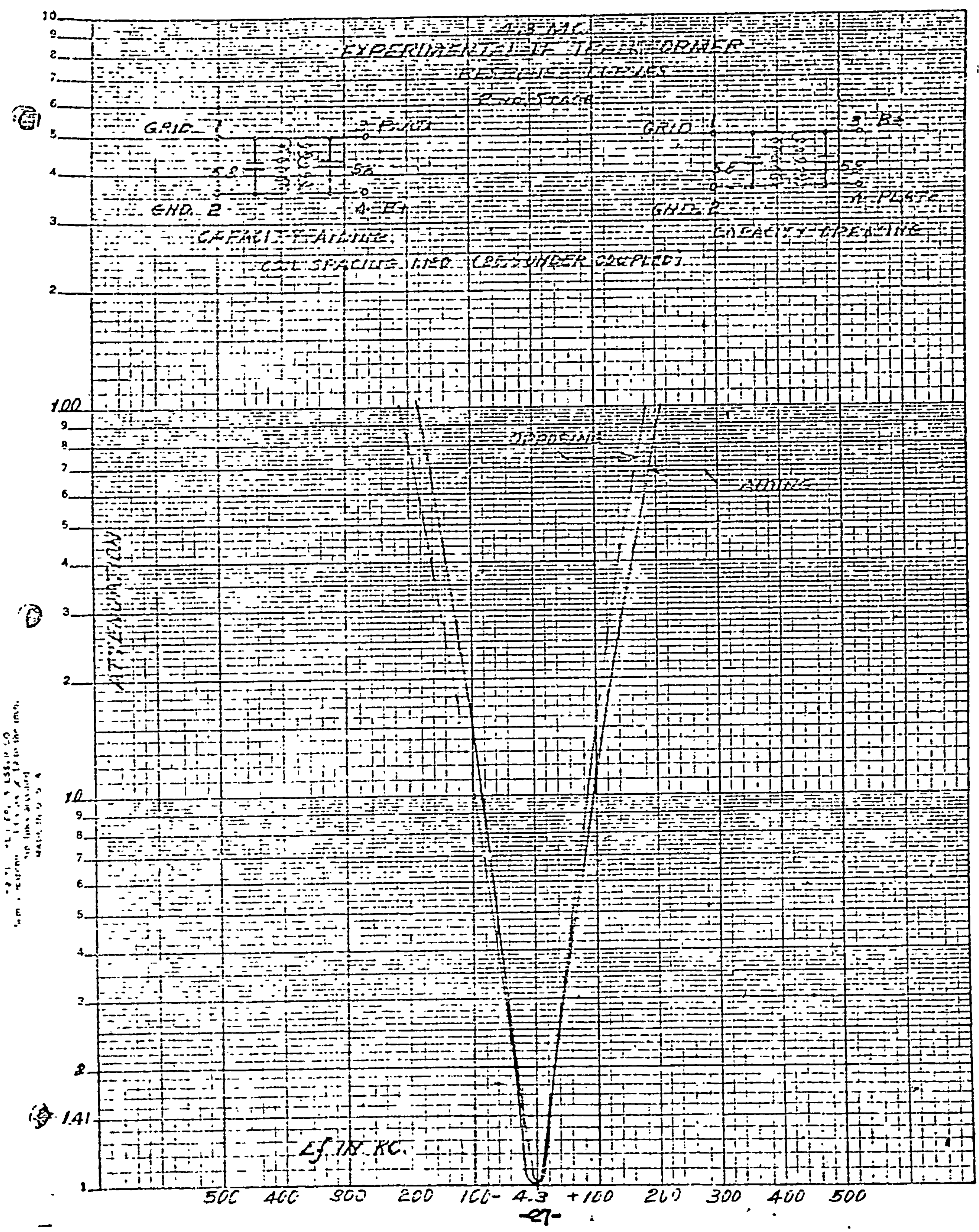
ASSEMBLED TRANSFORMER

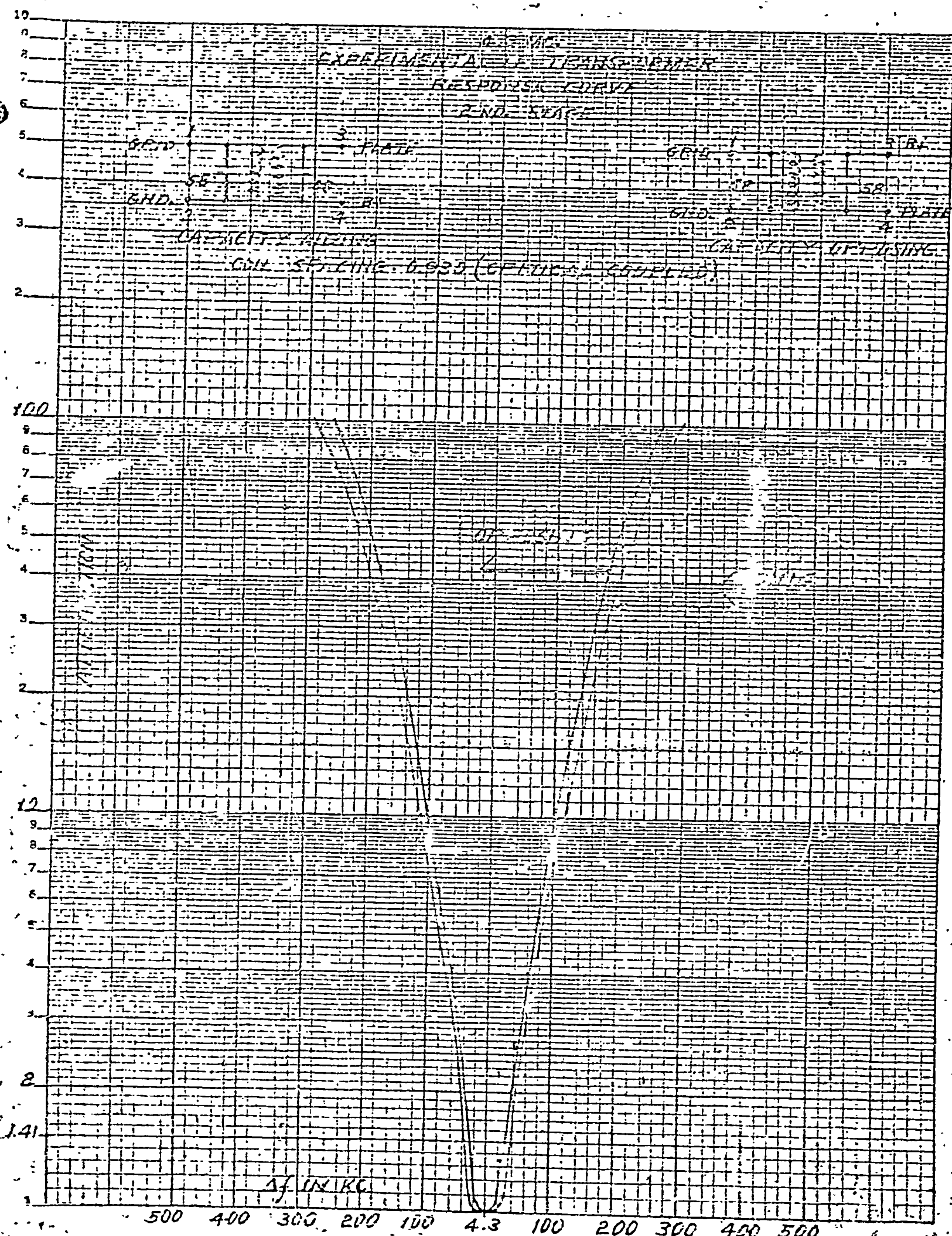
NOTE:
TRANSFORMER TUNED ON Q-METER WITH C = [illegible] μμf.
i.e.; 58 μμf BASE CAP.
+ 8 μμf STRAY CAPACITY.
BASE CAP. ARE SILVER MICA.

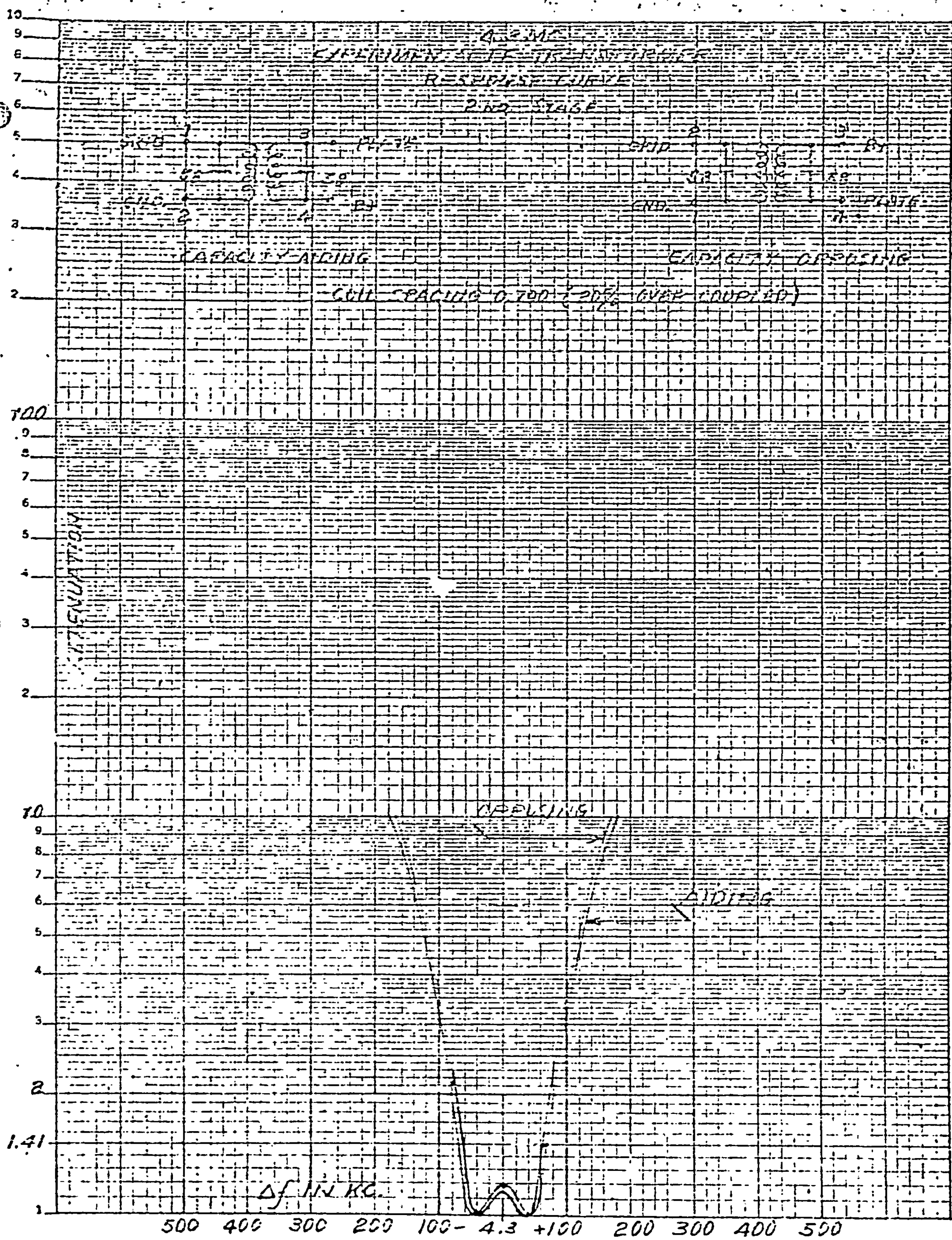

4.3 MC.
EXPERIMENTAL I.F. TRANSFORMER
1st STAGE
GRID
PLATE
GND.
B+
CAPACITY AIDING
GRID
B+
PLATE
GRID
CAPACITY OPPOSING
COIL SPACING 1.160 (80% UNDER COUPLED)
ATTENUATION
OPPOSING
AIDING
Δf IN K.C.
1.41
100
10
500 400 300 200 100 - 4.3 + 100 200 300 400 500


RESPONSE CURVE
GRID
PLATE
CAPACITY AIDING
CAPACITY OPPOSING
OPPOSING
AIDING
500 400 300 200 100 +100 200 300 400 500


GRID
GND
CAPACITY AIDING
CAPACITY OPPOSING
ATTENUATION
OPPOSING
AIDING
Lf IN KC
500 400 300 200 100 - 4.3 +100 200 300 400 500


4.3 MC.
EXPERIMENTAL IF TRANSFORMER
2nd STAGE
GRID
PLATE
GND. 2
4 B+
GRID
B+
A PLATE
GND. 2
COIL SPACING
ATTENUATION
OPPOSING
AIDING
1.41
500 400 300 200 100 4.3 +100 200 300 400 500


RESPONSE CURVE
2 ND. STAGE
PLATE
GND.
58
B+
PLATE
58
Δf IN KC
500 400 300 200 100 4.3 100 200 300 400 500
100
10
2
1.41


4.3 MC
RESPONSE CURVE
2ND STAGE
GRID
PLATE
B+
CAPACITY AIDING
CAPACITY OPPOSING
COIL SPACING 0.700 (20% OVER COUPLED)
ATTENUATION
OPPOSING
AIDING
Δf IN KC
1.41
100
10
500 400 300 200 100 - 4.3 + 100 200 300 400 500

TEMPERATURE STABILITY

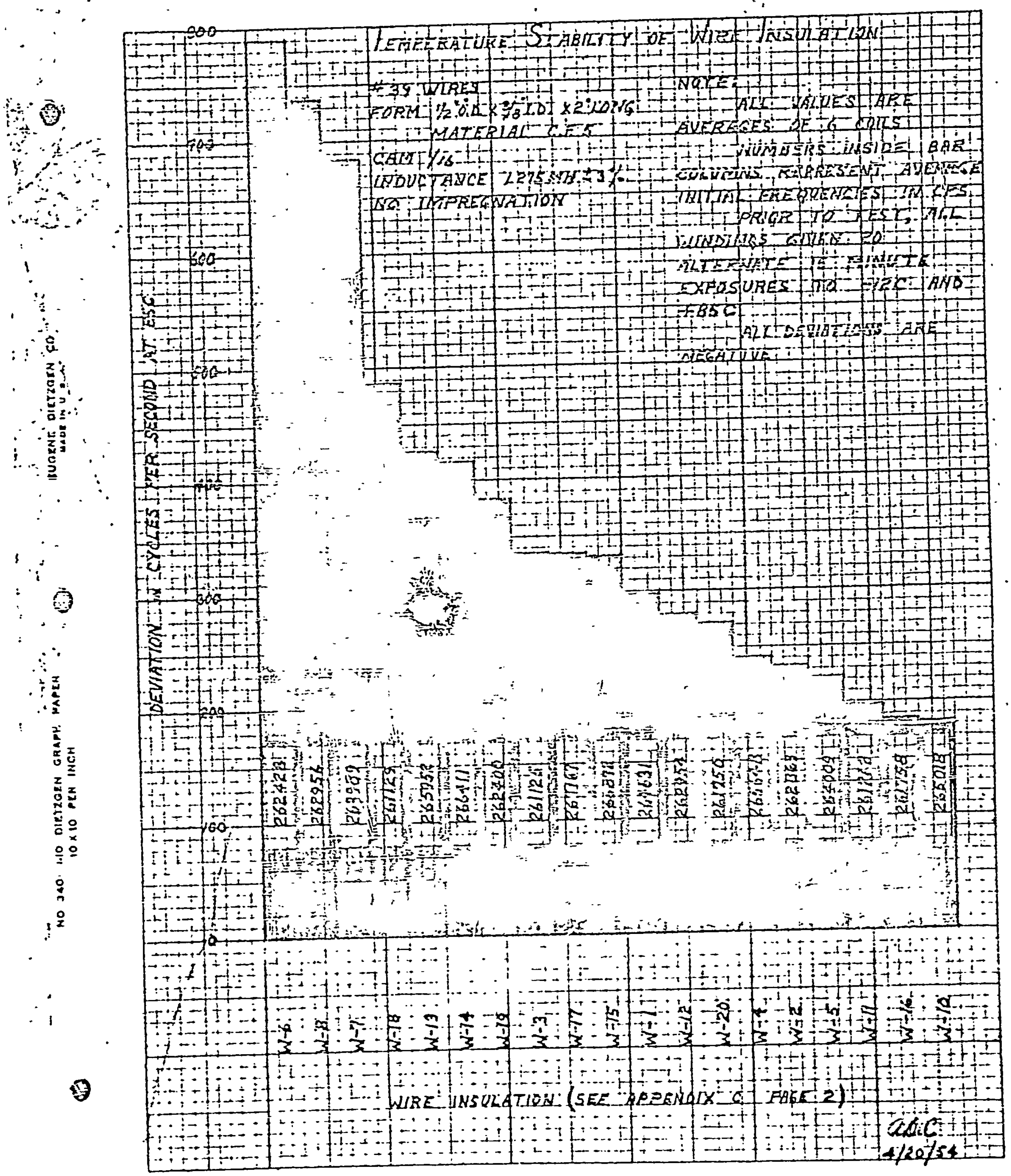
$$T.C. = \frac{2\Delta f}{f} \times \frac{10^6}{\Delta t}$$

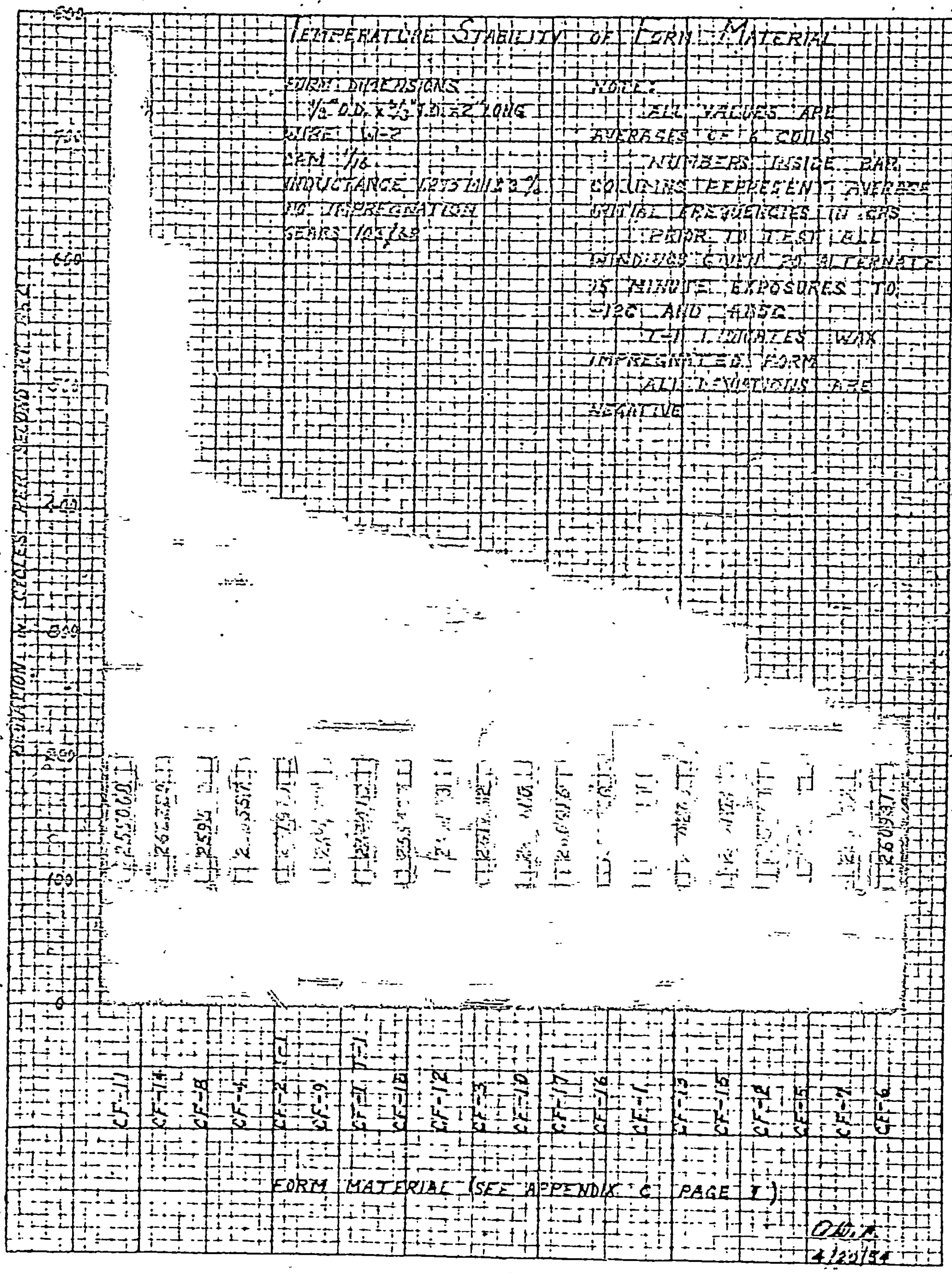
WIRE INSULATIONS	COIL FORM MATERIAL
Form: 1/2 inch OD x 3/8 inch ID x 2 inches long	Form: 1/2 inch OD x 3/8 inch ID x 2 inches long
Material: C.F.-5	Cam: 1/16 No impregnation
Cam: 1/16 No impregnation	Gears: 103/68
Inductance: 1.275 mh ± 3 per cent	Inductance: 1.275 mh ± 3 per cent
Wire Size: No. 39	Wire Size: No. 39
Insulation: Various	Insulation: Various

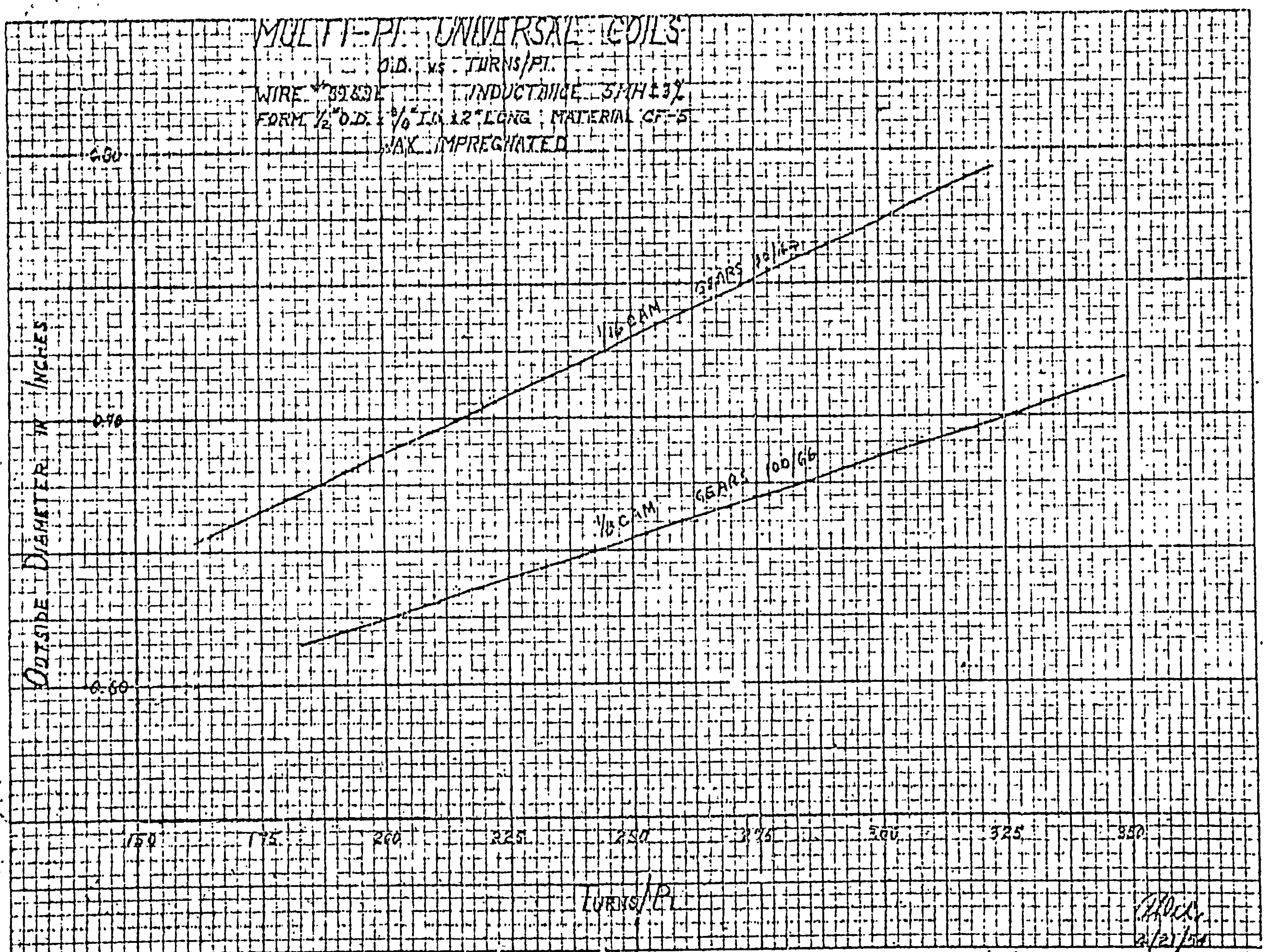
Wire Insulation (See Appendix C Page 2)	ppm/°C @ 85 C	Coil Form Material (See Appendix C Page 2)	ppm/°C @ 85 C
W-10	21	CF-6	28
W-16	22	CF-7	29
W-11	24	CF-5	30
W-5	27	CF-2	31
W-2	28	CF-15	37
W-4	29	CF-13	38
W-12	33	CF-1	38
W-20	33	CF-16	40
W-1	35	CF-17	41
W-15	38	CF-3	44
W-17	39	CF-12	44
W-3	41	CF-10	45
W-19	47	CF-18	45
W-14	48	CF-1 T-1	46
W-13	50	CF-9	47
W-18	58	CF-2 T-1	48
W-7	80	CF-4	49
W-8	93	CF-8	50
W-6	96	CF-14	72
		CF-11	94

NOTE: 1. All values are averages of 6 coils.

2. Prior to test all windings given 20 alternate 15 minute exposures to -12 C and +85 C


TEMPERATURE STABILITY OF WIRE INSULATION
#39 WIRES
FORM ½" O.D. x ⅞" I.D. x 2" LONG
MATERIAL C.F.5
CAM 1/16
INDUCTANCE 1275 MH ±3%
NO IMPREGNATION
NOTE:
ALL VALUES ARE AVERAGES OF 6 COILS
NUMBERS INSIDE BAR COLUMNS REPRESENT AVERAGE INITIAL FREQUENCIES IN CPS PRIOR TO TEST. ALL WINDINGS GIVEN 20 ALTERNATE 15 MINUTE EXPOSURES TO -72C AND +85C
ALL DEVIATIONS ARE NEGATIVE
DEVIATION IN CYCLES PER SECOND AT 85C
800
700
600
500
400
300
200
100
0
W-6
W-8
W-7
W-18
W-13
W-14
W-19
W-3
W-17
W-15
W-1
W-12
W-20
W-4
W-2
W-5
W-11
W-16
W-10
WIRE INSULATION (SEE APPENDIX C PAGE 2)
A.C.C.
4/20/54
EUGENE DIETZGEN CO.
MADE IN U.S.A.
NO. 340-110 DIETZGEN GRAPH PAPER
10 X 10 PER INCH


TEMPERATURE STABILITY OF FORM MATERIAL
FORM DIMENSIONS
NOTE:
ALL VALUES ARE AVERAGES OF 6 COILS
NUMBERS INSIDE BAR COLUMNS REPRESENT AVERAGE INITIAL FREQUENCIES IN KCS PRIOR TO TEST. ALL WINDINGS GIVEN 20 ALTERNATE 15 MINUTE EXPOSURES TO -12C AND +85C.
WAX IMPREGNATED FORM
ALL DEVIATIONS ARE NEGATIVE
DEVIATION IN CYCLES PER MEGACYCLE
CF-11
CF-14
CF-8
CF-4
CF-2
CF-9
CF-18
CF-12
CF-3
CF-10
CF-17
CF-16
CF-1
CF-13
CF-15
CF-5
CF-7
CF-6
FORM MATERIAL (SEE APPENDIX C PAGE 1)



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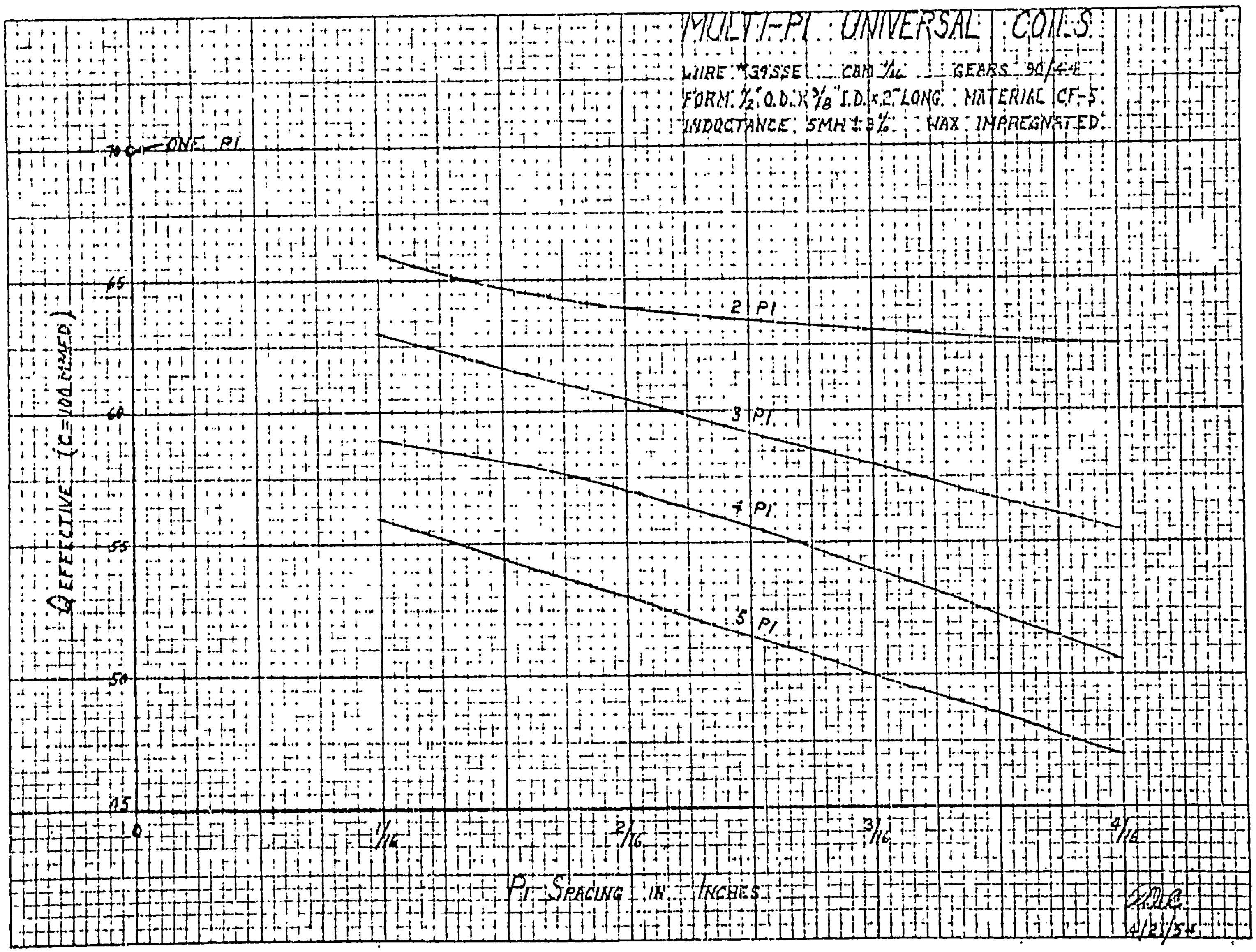
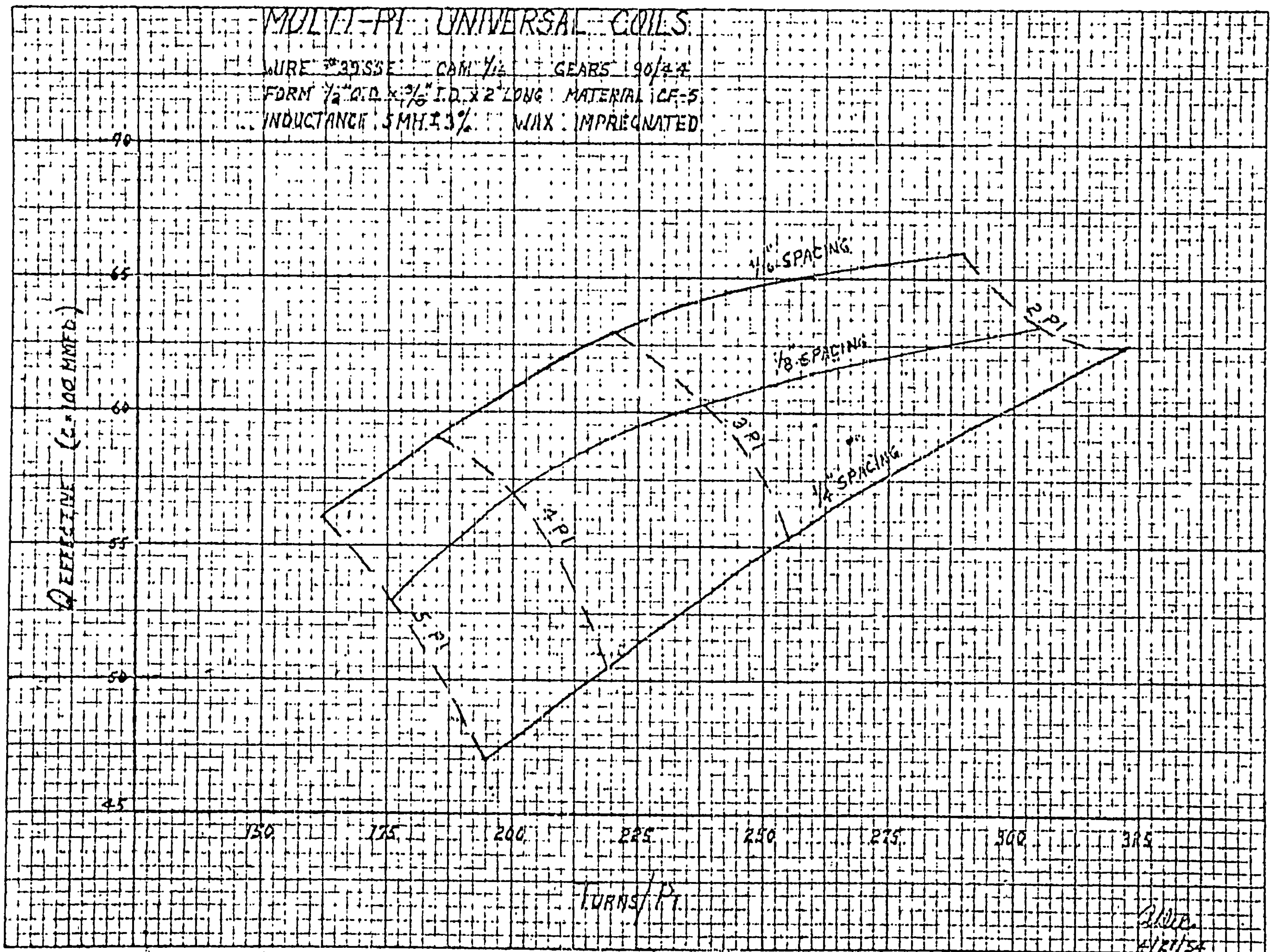

MULTI-PI UNIVERSAL COILS
WIRE #39SSE CAM 1/16 GEARS 90/44
FORM: 1/2" O.D. X 3/8" I.D. X 2" LONG. MATERIAL CF-5
INDUCTANCE 5MH ± 3%. WAX IMPREGNATED.
70 ONE PI
65
60
55
50
45
2 PI
3 PI
4 PI
5 PI
Q EFFECTIVE (C=100 MMFD)
0
1/16
2/16
3/16
4/16
PI SPACING IN INCHES
4/23/54

NO 340 110 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO
MADE IN U. S. A.



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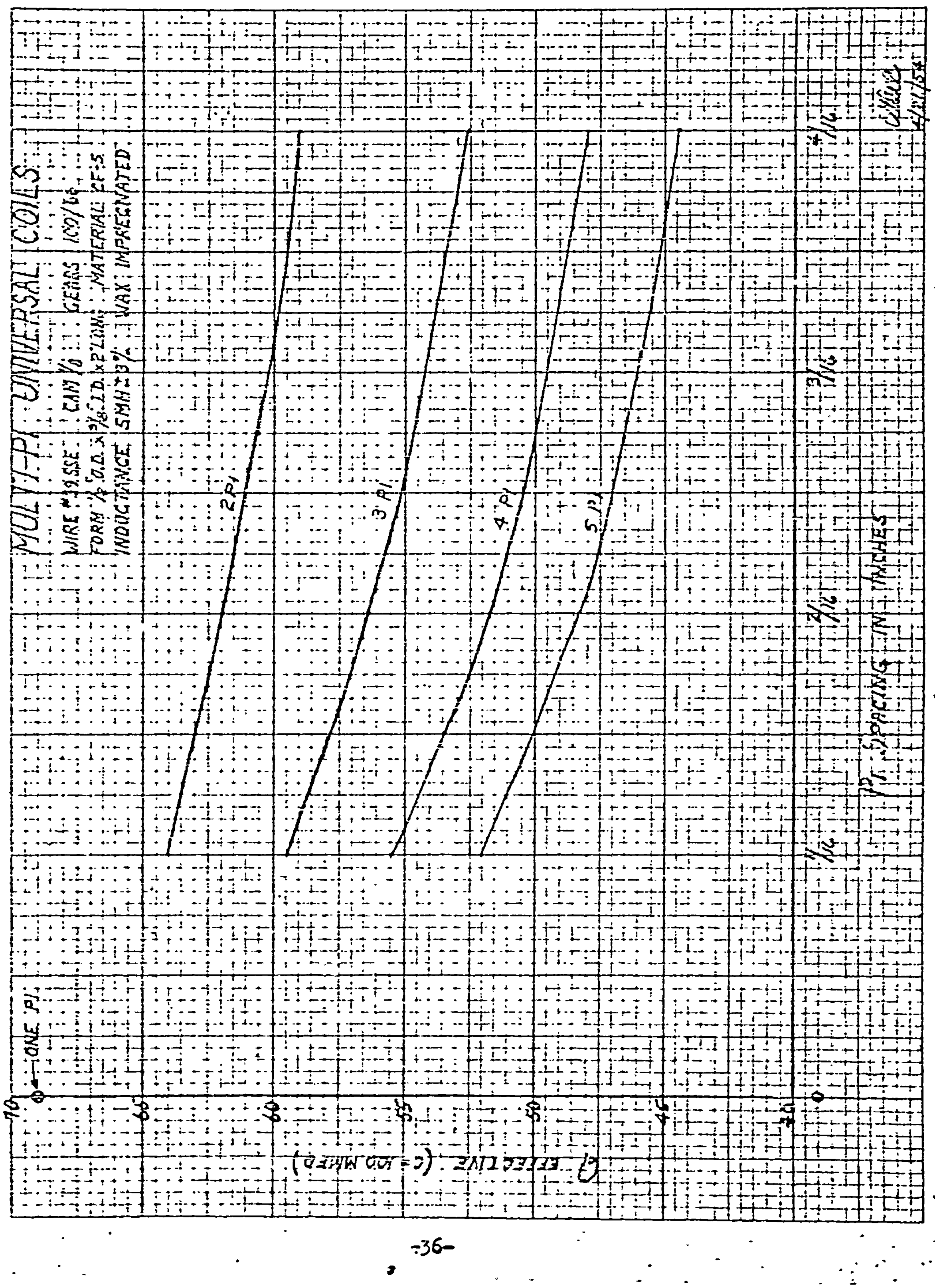
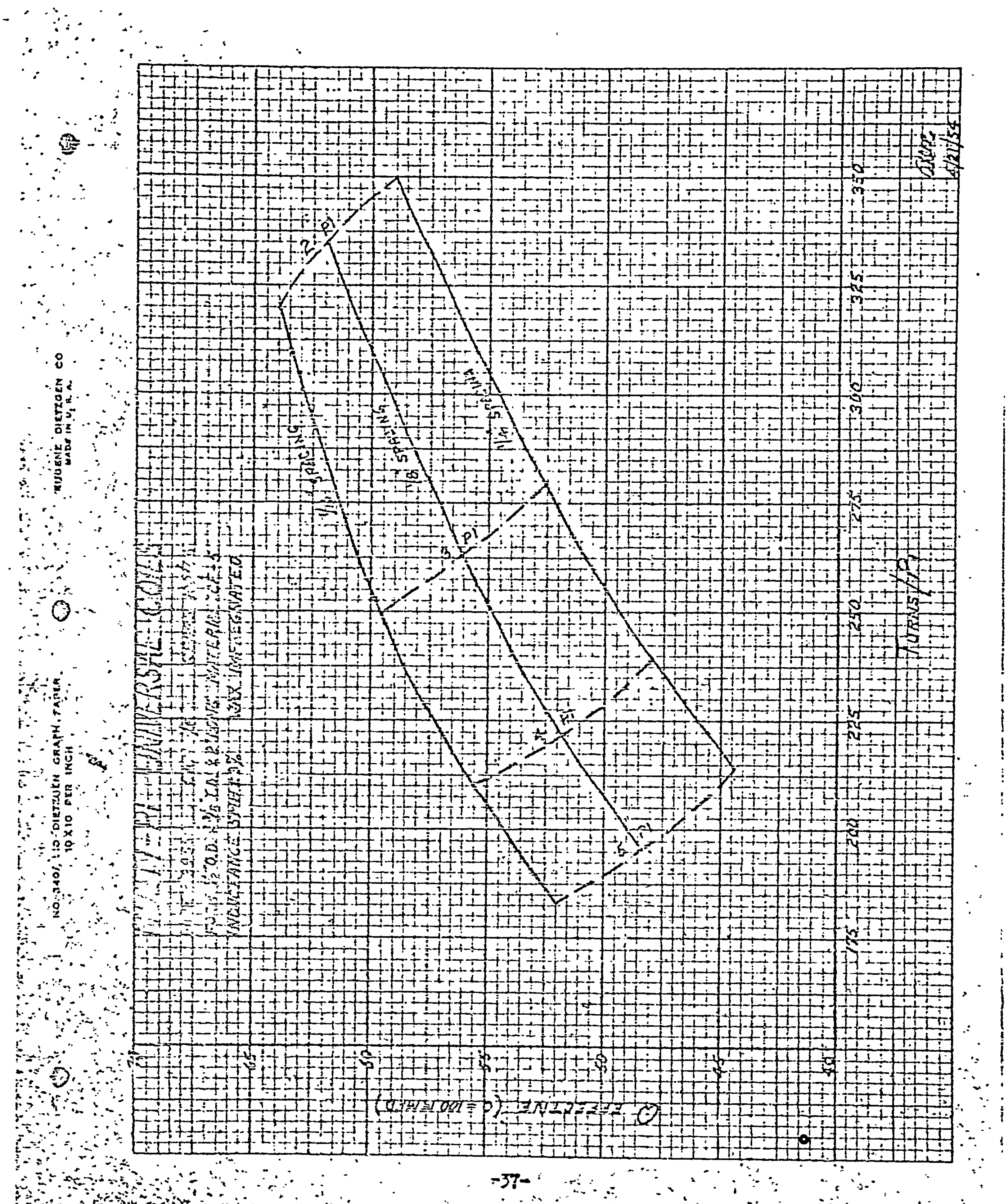
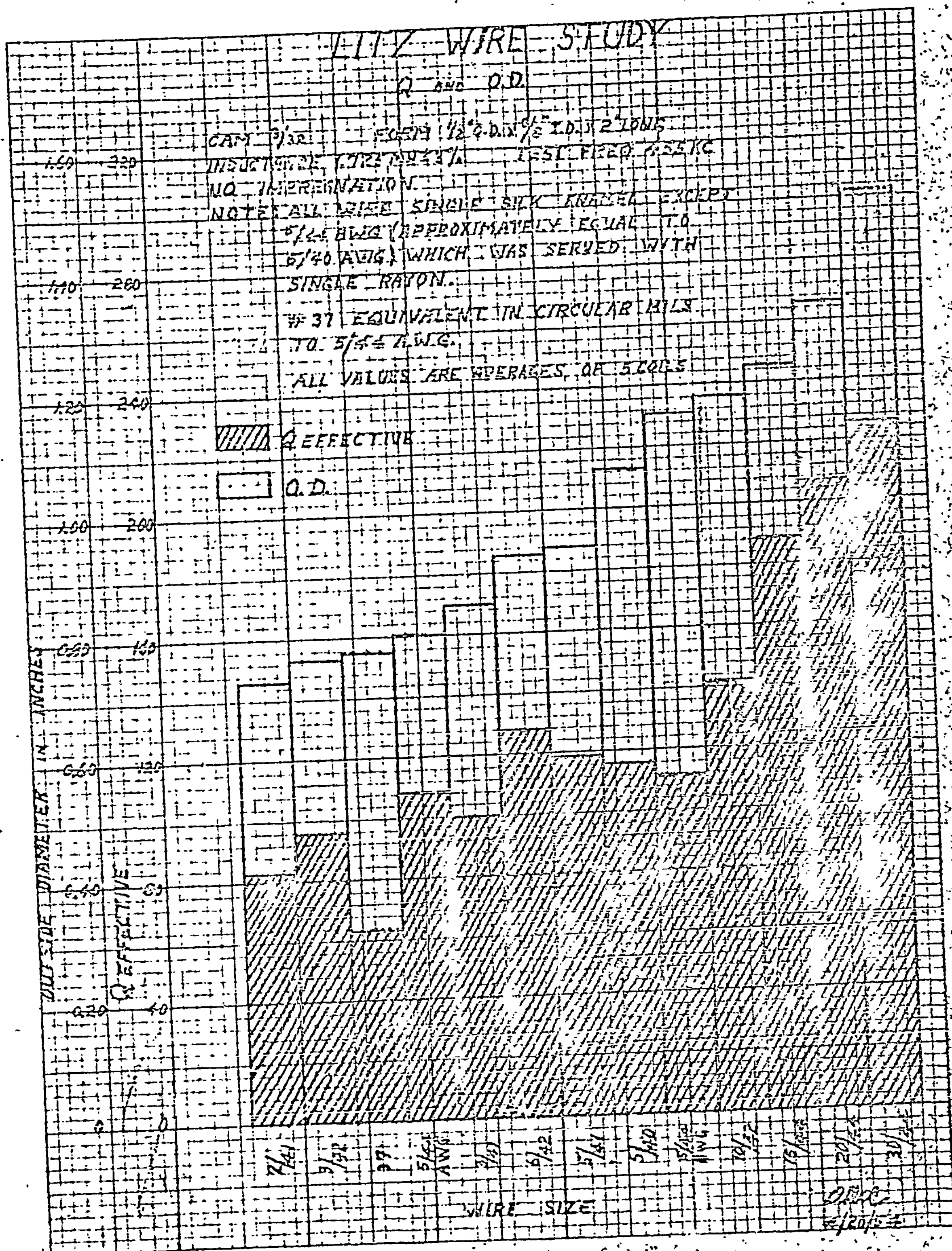

MULTI-PI UNIVERSAL COILS
WIRE #39 SSE CAM 1/8 GEARS 109/66
FORM 1/2" O.D. x 3/8" I.D. x 2" LONG MATERIAL CF-5
INDUCTANCE 5MH ±3% WAX IMPREGNATED
2 PI
3 PI
4 PI
5 PI
ONE PI
0
1/16
2/16
3/16
4/16
PI SPACING IN INCHES
70
65
60
55
50
45
40
Q EFFECTIVE (C = 100 MMFD)


UNIVERSAL COILS
INDUCTANCE SHIFT 5%
WAX IMPREGNATED
1/16 SPACING
1/8 SPACING
1/4 SPACING
65
60
55
50
45
40
175
200
225
250
275
300
325
350
TURNS/P
4/21/54


LITZ WIRE STUDY
Q and O.D.
CAM 9/32 FORM ½" O.D. x ⅝ I.D. x 2" LONG
NO IMPREGNATION
NOTE: ALL WIRE SINGLE SILK KNAPEL EXCEPT 5/44 AWG (APPROXIMATELY EQUAL TO 5/40 AWG) WHICH WAS SERVED WITH SINGLE RAYON.
#37 EQUIVALENT IN CIRCULAR MILS TO 5/44 A.W.G.
ALL VALUES ARE AVERAGES OF 5 COILS
Q EFFECTIVE
O.D.
OUTSIDE DIAMETER IN INCHES
Q EFFECTIVE
1.60 320
1.40 280
1.20 240
1.00 200
0.80 160
0.60 120
0.40 80
0.20 40
0 0
7/41
9/42
37
5/44 AWG
6/42
5/41
5/40
15/44 AWG
10/42
WIRE SIZE

LITZ WIRE STUDY

No. 5/44 SSE Twists/Ft.	Cam 1/4 Gears 54/106 Form 1/2 inch OD		Cam 3/32 Gears 67/44 Form 1/2 inch OD				Cam 1/16 Gears 51/48 Form 0.178 OD			
	Q f=110 kc	L (mh) @ 79 kc	Q f=376 kc	L (mh) @ 250 kc	Q f=455 kc	L (mh) @ 250 kc	Q f=738 kc	L (mh) @ 790 kc	Q f=455 kc	L (mh) @ 790 kc
Commercial- As normally supplied	89	19.75	106	1.72	113	1.72	95	0.468	76	0.468
Parallel	84	19.75	102	1.74	108	1.74	94	0.477	75	0.477
18	87	19.70	101	1.72	109	1.72	94	0.476	74	0.476
65	85	19.45	102	1.73	110	1.74	94	0.465	76	0.465

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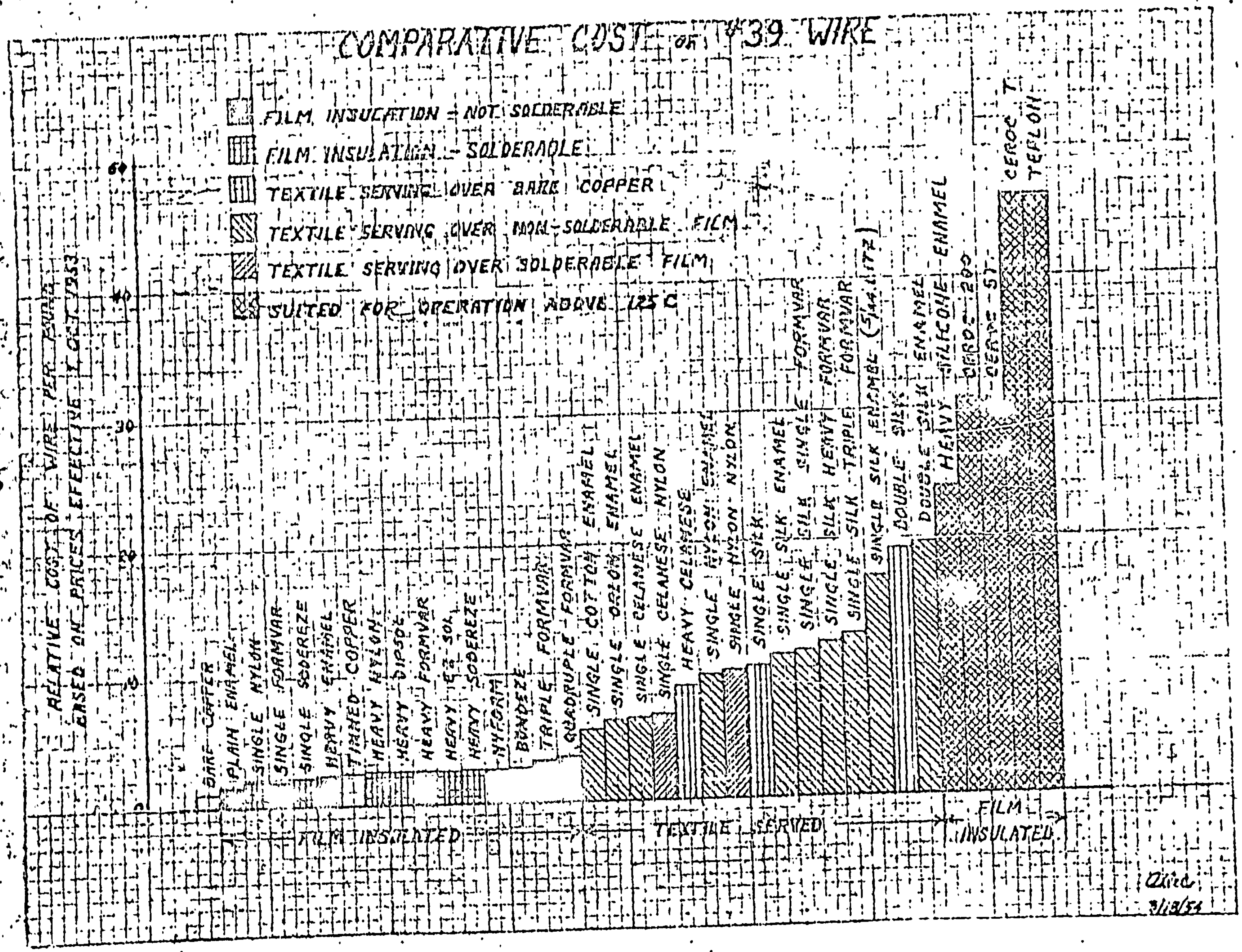
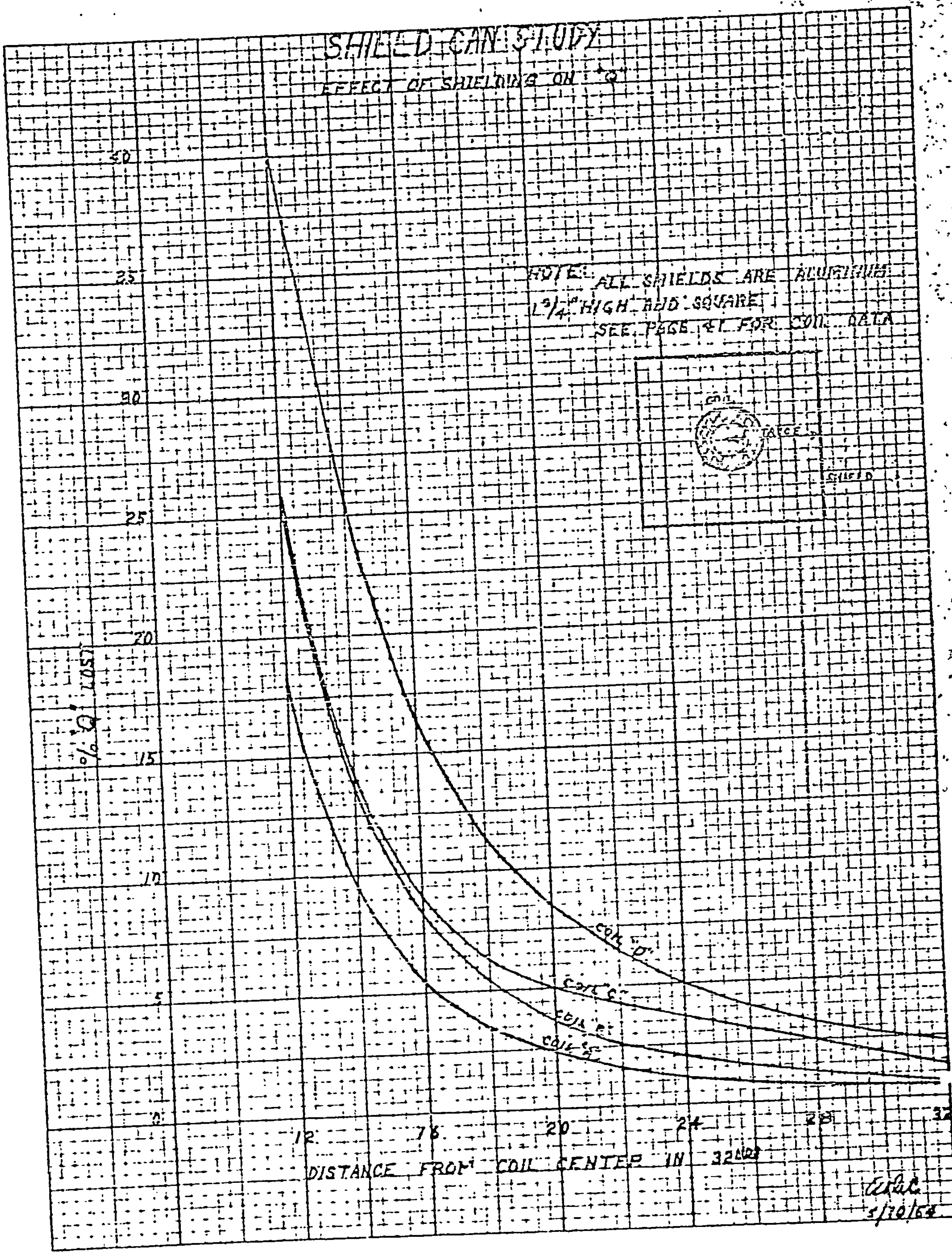

COMPARATIVE COST OF #39 WIRE
FILM INSULATION - NOT SOLDERABLE
FILM INSULATION - SOLDERABLE
TEXTILE SERVING OVER BARE COPPER
TEXTILE SERVING OVER NON-SOLDERABLE FILM
TEXTILE SERVING OVER SOLDERABLE FILM
SUITED FOR OPERATION ABOVE 125 C
RELATIVE COST OF WIRE PER POUND
BASED ON PRICES EFFECTIVE 1 OCT 1953
0
10
20
30
40
60
BARE COPPER
PLAIN ENAMEL
SINGLE NYLON
SINGLE FORMVAR
SINGLE SODEREZE
HEAVY ENAMEL
TINNED COPPER
HEAVY NYLON
HEAVY DIPSOL
HEAVY FORMVAR
HEAVY EZ-SOL
HEAVY SODEREZE
NYFORM
BONDEZE
TRIPLE FORMVAR
QUADRUPLE FORMVAR
SINGLE COTTON ENAMEL
SINGLE ORLON ENAMEL
SINGLE CELANESE ENAMEL
SINGLE CELANESE NYLON
HEAVY CELANESE
SINGLE NYLON ENAMEL
SINGLE NYLON NYLON
SINGLE SILK
SINGLE SILK ENAMEL
SINGLE SILK SINGLE FORMVAR
SINGLE SILK HEAVY FORMVAR
SINGLE SILK TRIPLE FORMVAR
SINGLE SILK ENAMEL (5/44 LITZ)
DOUBLE SILK
DOUBLE SILK ENAMEL
HEAVY SILICONE ENAMEL
CEROC 200
CEROC 51
CEROC T
TEFLON
FILM INSULATED
TEXTILE SERVED
FILM INSULATED

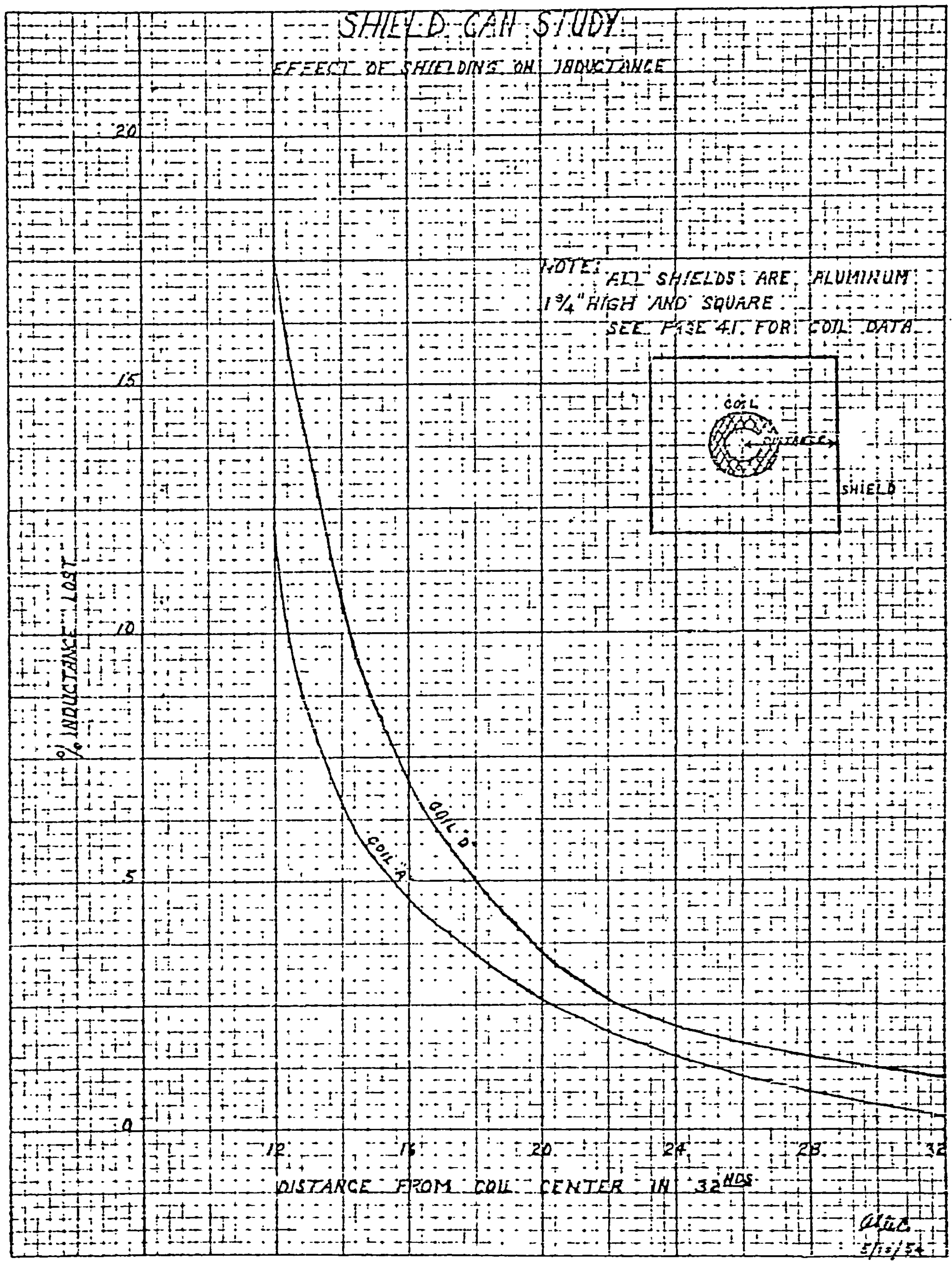
SHIELD CAN STUDY

COIL DATA

	COIL "A"	COIL "B"	COIL "C"	COIL "D"
Wire	No. 39 H.F.	No. 39 H.F.	No. 5/44 SSE	No. 5/44 SSE
Cam	3/32	3/32	3/32	3/32
Gears	56/74	56/74	51/67	51/67
Turns	500	500	225	225
End Spacing	0.425"	0.425"	0.425"	0.425"
OD	0.516"	0.516"	0.523"	0.523"
Coil Width	0.115"	0.115"	0.120"	0.120"
Coil Form OD	0.285"	0.285"	0.285"	0.285"
Core	None	Plast-Iron D-451	None	Carbonyl E
Impregnation	Wax	Wax	Wax	Wax
Frequency	455 kc	455 kc	455 kc	455 kc
Coil "Q" (No Shield)	59	74	79	122
C	46.91 uuf	27.95 uuf	252.09 uuf	155.91 uuf
Calculated Inductance	2610 uh	4380 uh	485 uh	785 uh

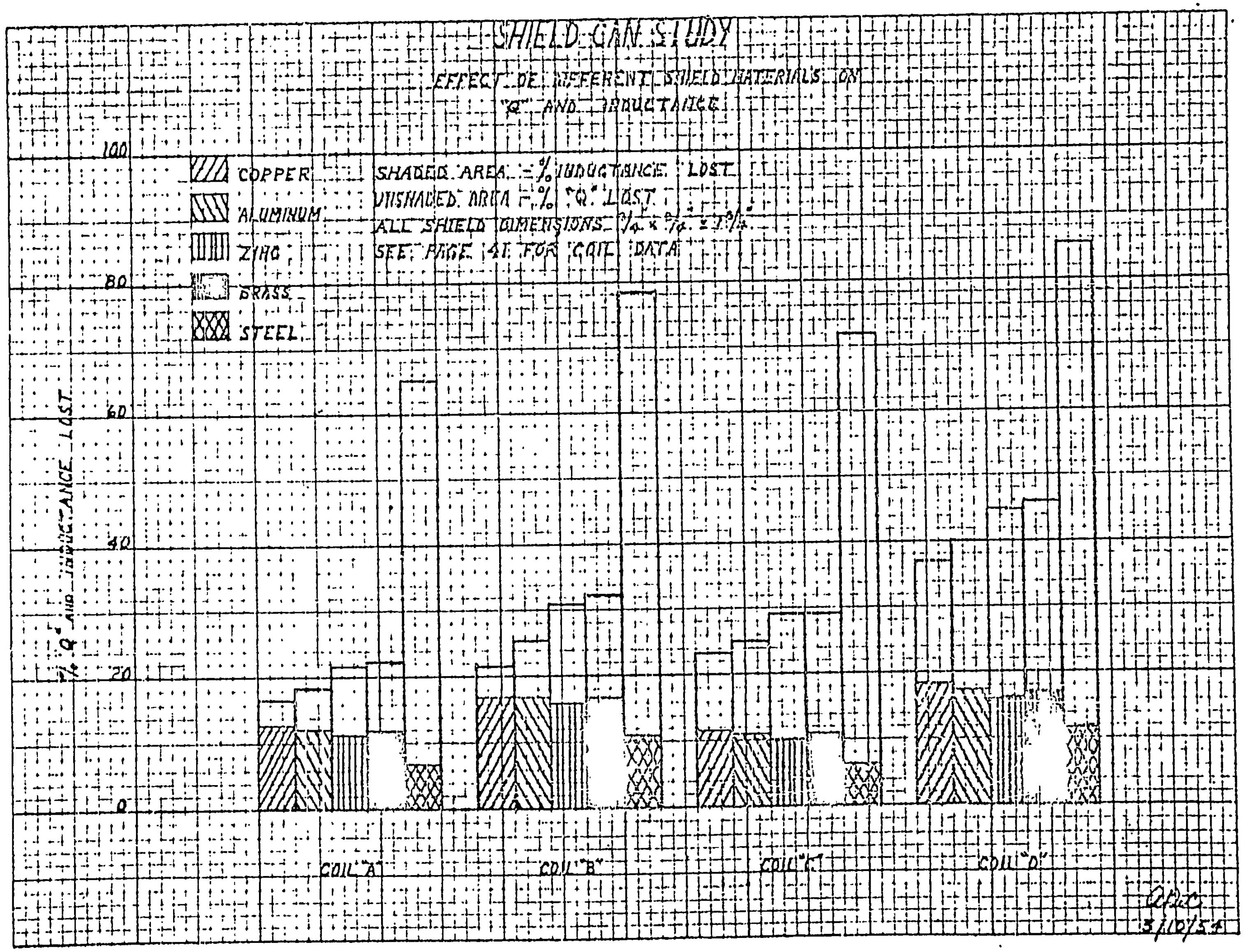


SHIELD CAN STUDY
EFFECT OF SHIELDING ON "Q"
NOTE: ALL SHIELDS ARE ALUMINUM
1 3/4" HIGH AND SQUARE
SEE PAGE 41 FOR COIL DATA
COIL
SHIELD
% "Q" LOST
30
25
20
15
10
5
0
12
16
20
24
28
32
DISTANCE FROM COIL CENTER IN 32NDS
COIL "D"
COIL "C"
COIL "B"
COIL "A"


SHIELD CAN STUDY
EFFECT OF SHIELDING ON INDUCTANCE
NOTE: ALL SHIELDS ARE ALUMINUM
1¾" HIGH AND SQUARE
SEE PAGE 41 FOR COIL DATA
COIL
SHIELD
COIL "B"
COIL "A"
% INDUCTANCE LOST
20
15
10
5
0
12
16
20
24
28
32
DISTANCE FROM COIL CENTER IN 32NDS

NO 340 I-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.



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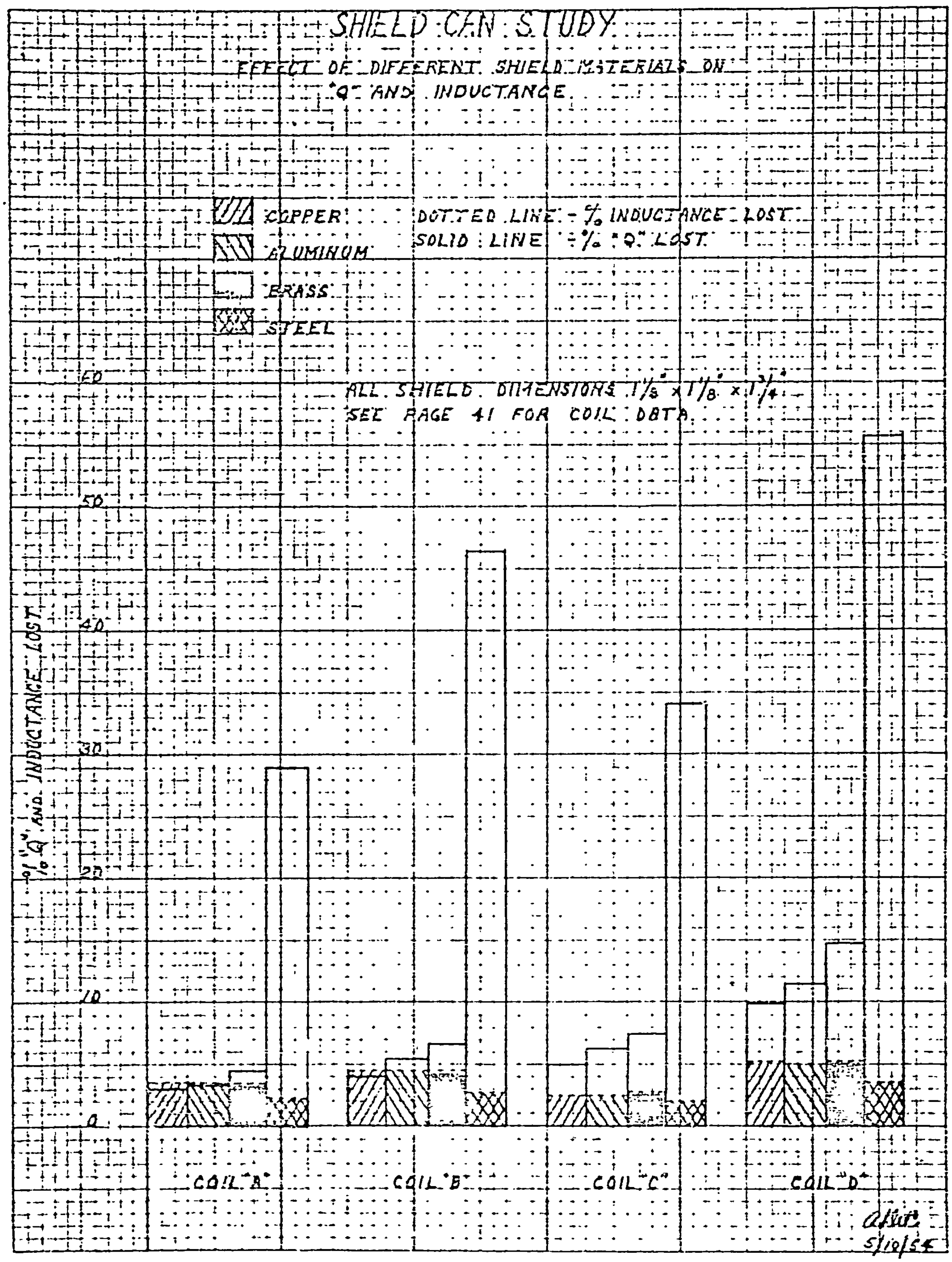
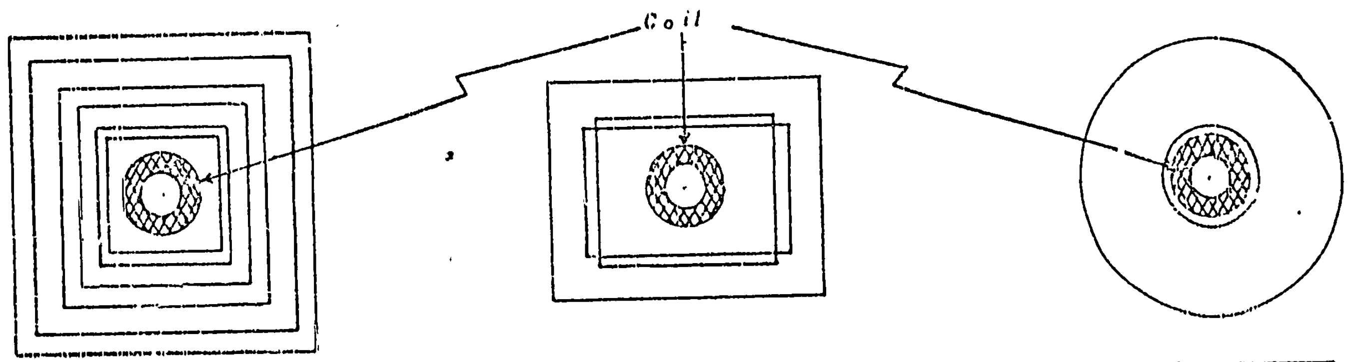

SHIELD CAN STUDY
EFFECT OF DIFFERENT SHIELD MATERIALS ON "Q" AND INDUCTANCE
COPPER
ALUMINUM
BRASS
STEEL
DOTTED LINE - % INDUCTANCE LOST
SOLID LINE - % "Q" LOST
ALL SHIELD DIMENSIONS
SEE PAGE 41 FOR COIL DATA
% "Q" AND INDUCTANCE LOST
0
10
20
30
40
50
60
COIL "A"
COIL "B"
COIL "C"
COIL "D"
5/10/54

POOR ORIGINAL

PERCENTAGE "Q" LOST DUE TO SHIELD SIZE



	¾ x ¾"	7/8 x 7/8"	1-1/8x1-1/8"	1-3/8x1-3/8"	1½x1½"	2 x2"	13/16x1-3/8"	15/16x 1-3/16"	1-3/8 x 13/16"	5/8" OD	1¼" OD
COIL "A"	19.1%	10.4%	4.4%	2.6%	1.7%	1.6%	8.0%	5.9%	1.7%	55.7%	2.6%
COIL "B"	25.5%	13.5%	5.4%	2.6%	1.7%	0.6%	10.7%	6.1%	2.0%	63.5%	1.3%
COIL "C"	25.3%	13.9%	7.5%	3.7%	2.5%	1.2%	11.4%	8.1%	2.5%	63.9%	2.5%
COIL "D"	41.0%	25.4%	12.2%	6.5%	3.2%	[illegible]	[illegible]	15.5%	4.8%	75.6%	4.8%

ALL SHIELDS ARE ALUMINUM 1-3/4 inches HIGH AND 0.017-0.024 inches THICK

SEE PAGE 41 FOR COIL DATA

SCALE 1:1

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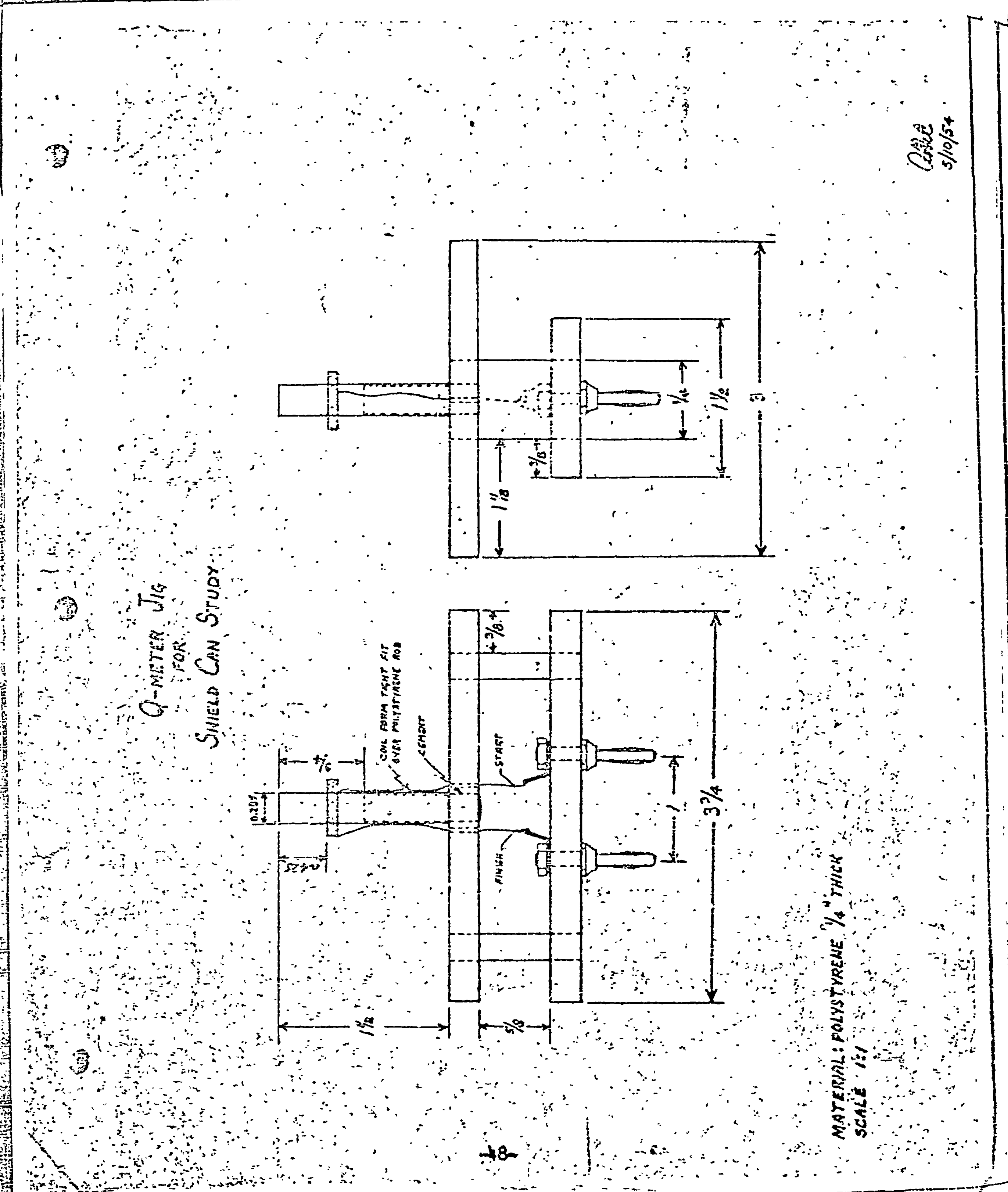
SHIELD CAN STUDY

Shield Dimension	COIL "A" % Inductance Lost Grounded	COIL "A" % Inductance Lost Not Grounded	COIL "A" % Q Lost Grounded	COIL "A" % Q Lost Not Grounded	COIL "D" % Inductance Lost Grounded	COIL "D" % Inductance Lost Not Grounded	COIL "D" % Q Lost Grounded	COIL "D" % Q Lost Not Grounded
5/8" OD	35.0%	34.3%	55.7%	53.6%	44.0%	43.6%	75.6%	75.3%
1-3/4" OD	1.2%	2.0%	2.6%	1.0%	2.1%	2.2%	4.8%	4.0%
3/4 x 3/4"	12.2%	12.5%	19.1%	18.8%	17.6%	17.5%	41.0%	40.1%
7/8 x 7/8"	6.6%	7.2%	10.4%	9.5%	10.5%	10.8%	25.4%	25.4%
1-1/8 x 1-1/8"	3.5%	3.6%	4.4%	3.4%	5.0%	5.2%	12.2%	12.2%
1-3/8 x 1-3/8"	2.0%	2.3%	2.6%	1.5%	2.6%	2.9%	6.5%	6.5%
1-3/4 x 1-3/4"	0.8%	1.1%	1.7%	0.8%	1.5%	1.7%	3.2%	3.2%
2 x 2"	0.3%	0.8%	1.6%	0.5%	1.1%	1.1%	2.3%	2.3%
13/16 x 1-3/8"	5.0%	5.7%	8.0%	7.0%	7.9%	8.1%	20.5%	20.5%
15/16 x 1-3/16"	4.2%	4.2%	5.9%	4.6%	6.3%	6.3%	15.5%	14.7%
1-3/8 x 1-13/16"	1.0%	1.7%	1.7%	1.2%	1.8%	2.2%	4.8%	4.8%

ALL SHIELDS ALUMINUM 1-3/4" HIGH AND 0.017"-0.024" THICK

SEE PAGE 41 FOR COIL DATA


Q-METER JIG
FOR
SHIELD CAN STUDY
COIL FORM TIGHT FIT OVER POLYSTYRENE ROD
CEMENT
START
FINISH
MATERIAL: POLYSTYRENE 1/4" THICK
SCALE 1:1
5/10/54

APPENDIX C

Code Numbers for Materials Tested

Treatment Materials

Additions to:

Wire
Coil Form Materials

Treatment Materials

T-1	Wax
T-2	Synthetic Baking Varnish
T-3	Synthetic Baking Varnish
T-4	Synthetic Baking Varnish
T-5	Silicone Baking Varnish
T-6	Coil Impregnant (Composition unknown)
T-7	Casting Material (Styrene base)
T-8	Casting Material (Epoxy base)
T-9	Air Drying Lacquer
T-10	Polyester Resin
T-11	Polyester Resin
T-12	Epoxy Resin
T-13	Varnish Thinner

Wire

W-20	Silicone Enamel

Coil Form Materials

CF-17	XX Bakelite (Molded)
CF-18	XXX Bakelite (Rolled)

ppm/°C occupied the other end of the scale. It may surprise some readers to learn that forms of untreated Kraft paper from two suppliers were worsened by approximately 50 per cent when subjected to wax impregnation—a procedure made necessary in practice by the hygroscopic properties of the paper.

A check of the coefficients of linear expansion of the various materials shows reasonably good correlation with the temperature coefficients of coils wound on these materials. This may possibly be interpreted as pointing to the advisability of having at hand complete information on the physical as well as the electrical properties of materials under consideration for use in transformers of maximum stability characteristics.

As has been said before, no attempt was made to take absolute measurements in the above mentioned testing program. Results are given in ppm/°C because of a desire to conform to accepted practice. Since the basic conditions under which the tests were conducted were held uniform and because the operating personnel made every effort to avoid deviations from established practice, it is felt that the indications obtained may be considered as representative of the materials and that they may safely be used as guides to good design practice.

To conclude this phase of the program it is proposed to evaluate in similar fashion both treatment materials and their methods of application. The final step will be to check the validity of the findings by combining the best wire, the best coil form, and the best treatment and then to compare coils thus constituted with others representative of the average and the poorest of the three basic materials.

with a 3/8 inch cam is split up into three windings each made with a 1/8 inch cam but having a total inductance equal to that of the original winding, it will be found that the Q of the multi-pi winding will be higher and the distributed capacity lower than that of the original winding. A definite advantage of multi-pi windings appears in the smaller OD's which lessen the losses caused by shielding.

4.5 Litz Wire Studies

It is well known that the use of multi-strand wire of the type commonly known as Litz offers substantial advantages, particularly in that portion of the frequency spectrum from around 300-kc upwards to about 1500-kc. One feature of this type of wire about which there is not complete uniformity of understanding is the effect of varying the twists per foot of the individual conductors. Genuine Litzendraht wire, which is not made commercially in the United States, is more than a twisted wire in that it has the individual conductors so arranged that each conductor appears on the outside of the stranding as often as it appears on the inside. This is to say that not only are the individual strands twisted but in addition they are displaced in a manner similar to braiding thus insuring accurate placement of the strands. By contrast to this rather complicated manufacturing process, American Litz wire is supplied in a number of forms ranging from no twists other than those resulting from the passing of the individual strands through the serving machine to a probable maximum of 18 twists per foot in the case of one supplier. Even higher numbers of twists per foot are frequently supplied on special order at the request of specific customers.

this particular point.

Through the efforts of the Signal Corps, a sample of 5/44 European type Litz wire was procured for evaluation in this program. This wire was received marked as 5/44 single Rayon enamel, but a check revealed this marking to be in accordance with British wire gauge instead of American wire gauge making it more nearly comparable to our 5/40 Litz and it is upon this basis that comparisons were made. Test coils were wound using a 5/32 inch cam in a winding of 290 turns which at 455-kc produced an average Q of 112 on the British Litz compared to a 295 turn winding made with the same setup on 5/40 single silk enamel American Litz where the test coils had a Q averaging 116. It is unfortunate that the serving on the British Litz was of a synthetic yarn since it makes impossible a direct comparison with silk but in view of the recognized fact that rayon served wires give lower Q's than silk served wires it seems safe to assume that European Litz might show a slight Q advantage if provided with the same type of serving.

It is generally accepted that the number of twists per foot has a definite influence upon the Q of Litz coils. Because our findings did not support this premise, it was decided to try windings having a different form factor in order to establish whether the coils first selected had some peculiar characteristic which lessened the importance of the twists per foot of the conductors. New coils were wound, also on a 1/2 inch form, using 5/48 gears and a 1/16 inch cam. Four 5/44 Litz wires—parallel, 18 twists per foot, 40 twists per foot, and 65 twists per foot—were selected for the test. The Q of all windings was found to range between 94 and 95. The situation was further checked by the use of windings made with a 1/4 inch cam and 54/106 gears. Here the range of Q was found to be between 84 and 87. It therefore appears that the effect of twists per foot upon Q is less pronounced than is commonly believed.

In Appendix B Page 58 will be found a graph showing the effect upon Q and OD of various wires—all single silk enamel—ranging from No. 37 solid (equal in cross section to 5/44) through various Litz wires from 2/41 up to 50/44. All readings were taken at 455-kc.

4.6 Shielding Study

In this phase of laboratory activity the primary purpose was to determine the effect of variations in shield can size, shape, and material upon windings having relatively low and relatively high Q's and of air core and iron core construction.

A fixture shown in the sketch in Appendix B Page 46 was built to fit the Model 260A Q meter and provide a firm base upon which the coils could be mounted and the shields placed for studying their effect upon the coils.

To keep conditions as constant as possible all shields were cut to a length of 1-3/4 inches. Round, square, and rectangular cross-sections were checked as were shields made of aluminum, copper, brass, steel, and zinc. An end spacing between coil and top of shield of approximately 0.426 inch was maintained in all tests. Measurements were made with shields grounded and ungrounded.

Page 47 of Appendix B shows the results of these measurements and points out the effect upon Q and L of shields of varying sizes and different materials. From these results it is apparent that grounding the shield has only a slight effect upon the readings when compared to the same shield ungrounded.

The material of which the shield is composed has a considerable effect upon the enclosed coil. It is well recognized that placing a metallic shield about a winding which is energized by an a-c current produces what is effectively a transformer, the untuned secondary of which consists of the shield can. It follows naturally that the better the conductivity of the shield material, the higher the degree of shielding afforded the coil and less the losses that will be reflected to the inductor.

Reference to Appendix B Page 44 will show this premise to be supported inasmuch as copper--the best conductor--had the least effect upon Q and L of all materials tested while steel--the poorest conductor--lowered both Q and L to the greatest degree. Since aluminum has only a slightly lower conductivity than copper, it shows only minor differences in its effect upon enclosed coils when all other factors are held constant.

The effect of shield shape and proximity is shown on Page 45 of Appendix B where the old adage that "a shield can should never be closer to a coil than a distance equal to the coil diameter" appears to be well supported.

It is worthy of note that the effect of a shield upon a coil of moderately high Q is substantially greater than it is upon coils of lower Q's. Whether or not the coil is of the air core type or has a powdered iron core does not seem to be of much importance so long as the Q is approximately equal in both cases.

It is planned to continue this study of shielding in the vicinity of 11 Mc and again around 50 Mc and to explore the effect of copper foil liners in steel shield cans. From the results of these studies it is planned to include in the Design Manual concrete recommendations for shield design based upon the effect of such shields upon the inductances which they enclose.

4.7 Writing

Substantial progress in this phase of the work has been accomplished during this quarter.

The portion of the manual devoted to materials of construction has been completely revised and rewritten. Accumulation of visual material has been started as has work leading to the arrangement of material within the chapters where, insofar as is possible, supporting visual material (including tables, graphs, photographs, nomographs, etc.) will be located in close proximity to the related text.

The second portion of the manual dealing with theory and design is well under way. Greatest progress has been in that portion devoted to the theory of coils and coupled circuits. Here such subjects as inductance, capacitance, resonance, phase, impedance, Q, amplification, and those other terms closely associated with high frequency transformers are discussed in sufficient detail and with sufficient supporting mathematics to enable a person with engineering training to quickly review basic principles--or a beginner to acquire a background.

It is felt that this manual will achieve maximum value only if it is so arranged that it may be used efficiently by two distinct methods and by two distinct classes of readers.

For that group who are interested only in producing a transformer whose performance will fulfill stated requirements, there will be a chapter complete within itself, in which a step-by-step procedure will outline the means whereby a coil may be designed and produced and which will also suggest courses to be followed if the end product falls short of expectations. There will be no mathematical derivations of theoretical explanations in this chapter but footnotes or other references will tie this portion to the main section of the manual.

In the main section will be the background material which will provide engineering-trained personnel with sufficiently detailed explanations of fundamentals to serve either as a review for a graduate engineer or as a text for an engineering trainee. It is proposed to make this portion complete while at the same time employing every means possible to keep the presentation simple, logical, direct, and well illustrated.

The task will not be an easy one. It is obvious that in a field so large and so complicated it will be difficult to avoid errors and omissions. The goal of the contractor continues to be to include as much pertinent information on coils and transformers as is necessary to provide that uncluttered background from which may be drawn design principles which are basically sound. Stated another way, it is hoped that this manual will be a definite step towards converting the art of coil design to the science of coil design.

5. CONCLUSIONS

While but little of the data accumulated in the course of this study has been completely evaluated, it is possible to once more extract certain findings and to arbitrarily assign to those findings the importance usually attached to conclusions.

From the work of the third quarter, the following findings are presented:

1. Multiple pi coils do not necessarily have higher Q's than single pi coils of the same inductance.
2. Multiple pi windings of a specific inductance require more turns per pi as the spacing between pi's is increased.
3. Coil forms of ceramic materials show greatest temperature stability.
4. The greater the coefficient of linear expansion, the less the temperature stability of a coil form material.
5. The addition of a textile serving adds materially to the cost of magnet wire.
6. Magnet wire film insulations showing the greatest temperature stability over the room to 85 C range are those insulations intended for high temperature operation.
7. In general, the most stable coils are wound with film insulated rather than textile-served magnet wires.
8. The effect upon Q of twists per foot of Litz wire does not appear to be as great as is generally believed.
9. Universal windings containing large amounts of magnet wire do not appear to be more sensitive to temperature changes

than windings containing substantially less wire.

10. The effect of a shield is proportionally greater upon coils of relatively high Q's than it is upon coils of low Q's.

11. The effect of shielding upon a coil does not seem to be influenced by the presence of an iron core so long as the Q in air of the coil is unchanged.

12. Overcoupled transformers show definite double peaks while critically coupled and undercoupled transformers show only one peak.

13. Increasing the coupling of a transformer broadens its response curve.

14. Transformers designed to operate into a diode require higher couplings than units designed for interstage operation.

5. PLANS FOR FOURTH QUARTER

The laboratory phases of this project may be expected to conclude well within the coming quarter. It is inevitable that as data is collected and evaluated the need may arise for further explorations along specific lines in order to fully clarify or explain certain observed characteristics, an explanation of which seems necessary for the manual. For this reason it is planned to review all test data early in this quarter. In this way the findings of the laboratory program may be fairly evaluated in advance of the time when results must be incorporated in the text and if work must be repeated or expanded, time will thus be available.

The activities of those who are serving as consultants to this project will be accelerated. Their contributions will be fitted into the text in a manner such that their particular specialties will assume optimum values in the overall project.

The major activity of the Project Supervisor and his assistant will necessarily be devoted to the assembly of the text of the manual along with the charts, graphs, sketches, photographs, nomographs, and other related visual materials which will support the text. In this phase of activity, the McGraw-Hill Book Company—particularly Mr. Keith Henney, Editorial Director—will work closely with the contractor to see that the resulting text is as complete and readable as possible.

Following the completion of the portion of the manual dealing with the theory of coils and transformers, a design method (or methods) will be extracted and prepared as a separate section.

7. ESTIMATE OF PROGRESS

Continuing the policy of estimating progress on each phase of activity associated with this project, the following is believed a fair statement of progress achieved as of 1 April 1954:

PART I - MATERIALS OF CONSTRUCTION

1. Introduction. 20%
2. Shields 75%
3. Conductors 0%
4. Plastics 30%
5. Ceramics 75%
6. Magnetic Cores 5%
7. Electronic Hardware. 70%
8. Waxes, Varnishes, Lacquers and Cements. 75%
9. Tapes & Film Insulations . 60%

PART II - DESIGN TECHNIQUES

10. Introduction 25%
11. Windings 60%
12. Types of Construction. . . 40%
13. Methods of Testing 15%
14. Tricks of the Trade. . . . 10%
15. Methods of Design 20%

APPENDIX

16. Bibliography 40%
17. Standards of the Industry. 40%
18. Buyer's Guide . . . . Work suspended at request of Service Representative

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8. MANHOURS EXPENDED

Manhours expended during the third quarter

1 January 1954 to 31 March 1954

A. M. Hadley.	494.5 Hours
A. DoCarlo	474.0 "
C. Kruczek	286.5 "
W. O'Connell.	244.7 "
E. McCormick.	432.5 "
P. Dolan	177.5 "
C. Burgin	164.5 "
TOTAL	2274.2 Hours

9. IDENTIFICATION OF TECHNICIANS

Bert E. Smith is Vice President of the Corporation.

Joseph R. Mazzola, Director of Engineering, is a graduate of the New York University Engineering College with a degree of Bachelor of Science in Electrical Engineering. Mr. Mazzola has been in radio engineering since 1928, and has been with Automatic Manufacturing Corporation since 1936, having been successively Chief Production Engineer, Assistant Chief Engineer, Chief Engineer, and Director of Engineering. He is a member of the Consultants Group on RF and IF Transformers of the Research and Devlopment Board, and a Senior Member of the Institute of Radio Engineers.

In his capacity as Director of Engineering he is in close touch with this project and through consultation and supervision is making substantial contributions to the various phases of the development.

John P. Tucker holds an E.E. degree from the University of Cincinnati, and the rank of Lieutenant Colonel, United States Army Reserve. Mr. Tucker has been employed by General Motors Corporation, Crosley Radio Corporation, and from 1934 to 1941 was Chief Engineer of the Gen-Ral Manufacturing Company, later the General Coil Division of the Muter Company. From 1941 to 1942 he was employed by Henry L. Crowley and Company in development and application of high frequency powdered metal cores. From 1942 to 1945 he served as Staff Officer in the Production Division of Army Service Forces, Washington, D. C. Since 1945, he has been Assistant Chief Engineer of Automatic

Manufacturing Corporation.

He has been intimately connected with this project since its beginning. Together with the Project Leader, he formulated the general plan of attack and remains active in the dual roles of advisor and consultant.

Allan M. Hadley holds a Bachelor of Arts degree from Clark University. He has attended the Graduate Schools of Clark University and the University of Massachusetts. Following sixteen years of teaching Chemistry, Physics, and Photography in the public schools of New York and Massachusetts he became, in 1942, a Civilian Instructor in Mathematics and Basic Electricity at the Signal Corps Enlisted Reserve School at Springfield, Massachusetts.

In September 1943 he joined the Engineering Staff of the F. W. Sickles Company of Chicopee, Massachusetts as Senior Research Engineer. From then until July 1947 he was engaged in research and development, mostly in connection with RF and IF coils. He holds several patents on IF Transformers, permeability tuners, and iron cores. From July 1947 until October 1951 he served as Manufacturing Engineer with responsibility for Production Engineering, Methods, Test and Inspection, Treatments, and Quality Control. Incidental duties included Engineering Control of Incoming Inspection, Technical Advisor to Purchasing Department in matters pertaining to the quality of purchased materials, and Engineer-in-Charge of Magnet Wire.

Forced by ill health to resign his position, he was inactive until March 1952 at which time he joined the Engineering

Staff of Automatic Manufacturing Corporation as Engineer-in-Charge of Research and Special Projects.

He is an Associate Member of the Institute of Radio Engineers.

As Project Leader, he is presently devoting full time to this development and is directly responsible for all phases of the work.

Zenobius Szulczynski graduated in June 1951 from Seton Hall University with a degree of Bachelor of Science in Mathematics (Magna Cum Laude). His degree was accompanied by a departmental gold medal award in mathematics. From 1943 to 1946 he served in the U. S. Infantry where he participated in the Army Specialized Training Program, later becoming an instructor in Radio Theory and Practice. His first industrial employer was the Electronics Division of Curtiss-Wright in Carlstadt, New Jersey, where he was employed as a specifications Engineer between August 1951 and March 1952.

He joined the Engineering Staff of Automatic Manufacturing Corporation in March 1952 as a Coil Engineer. His duties involve all phases of coil development including winding, impregnation and treatment, testing, and general development on RF and IF transformers. In addition, he is continuing his Engineering education and is an Evening School Instructor at Seton Hall University in Trigonometry and Calculus.

His assignments in this project are of a research nature, particularly those where mathematic interpretation is necessary.

Ray J. Zeliff entered Upsala College in 1938. During summer vacations he worked on Police Radio Communications Equipment at Link Radio in New York City. In 1941 he left college and accepted a position as Final Systems Tester on telephone carrier and teletype equipment with the Kearny Works of Western Electric Company. During 1943 he transferred to the Bell Telephone Laboratories at Murray Hill, New Jersey for development work on classified electronic equipment, later returning to Western Electric to assist in the production of this equipment. In 1945 he became a Cost Planning Engineer associated with the production of 400 cycle power and pulse transformers, IF transformers, and chokes for radar equipment. He later served as Equipment Engineer for telephone apparatus and as Equipment Engineering Analyst.

In September 1948 he left Western Electric Company to complete his final year at Upsala College, graduating in June 1949 with a Bachelor of Science degree in Physics. He then joined the Engineering Staff of Automatic Manufacturing Corporation where he is now Group Leader responsible for the design and application of high frequency RF and IF coils for FM, television, and associated fields.

In 1952 he completed a course in measurements and testing in radio and television at New York University. He has been a licensed amateur radio operator since 1938 (Class A since 1939) and has held two commercial licenses which have now expired. He is a member of the American Radio Relay League and an Associate Member of the Institute of Radio Engineers.

In this development he has been largely responsible for planning the high frequency portion of the work program and will assist in its supervision and in the interpretation of the resulting experimental data.

Chester R. Kruczek attended Newark College of Engineering, leaving for the Navy in 1945. While in service, he completed the Electronics Technicians Program and became an instructor in the Navy's Chicago Training School. Following his discharge he enrolled in the RCA Institute in New York City where he studied Advanced Technology, graduating in 1949. From 1949 to 1952 he served as television technician with a private service organization.

In 1952 he joined the Engineering Department of Automatic Manufacturing Corporation where he has been associated with television tuner developments and with related test equipment in both the UHF and VHF bands.

Since mid-September he has been assigned full time to this project. His responsibilities include coil and transformer measurements, design of special equipment, and supervision of temperature coefficient tests.

Anthony DeCarlo received his Bachelor of Science degree in Electrical Engineering at Rutgers University in 1951, having completed four years of electrical engineering and one year of industrial engineering. From 1943 to 1946 he served in the Army - first as radio operator in the Field Artillery and later as Traffic Analyst in Radio Intelligence in the European theater. In 1951 he joined the Engineering

Department of Automatic Manufacturing Corporation as Design Engineer on IF transformers, RF chokes, and special coils. He is an Associate Member of the Institute of Radio Engineers.

Assigned full time to this project in September, he is presently responsible for coil winding and transformer design.

Estelle McCormick is a graduate of Drake's Business College of Newark, New Jersey. She has been in the employ of Utility Electronics Corporation, Link Radio Corporation, Wright Aeronautical Division-Curtiss Wright Corporation, and Peter Pan Manufacturing Corporation.

Her business career has been largely spent in engineering work where she has collected, recorded, and interpreted engineering data. She assisted in the FRC-8, 9, 10 standardization and test programs and has done intensive work in the preparation of graphs based on engineering data.

She joined the Engineering Department of Automatic Manufacturing Corporation in September 1953 as Engineering Assistant assigned to this program. She will actively assist the Project Leader in all phases of the development - particularly in the preparation of the manual, the translation of experimental and engineering data into visual forms, and in the general coordination of the project.

Philip J. Dolan Jr. attended the public schools of Union City, New Jersey. Enlisting in the U. S. Navy in 1949, he graduated from the Class A Electronic Technicians School

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before serving as electronic technician with the Atlantic Fleet.

His industrial experience includes work for the Electronics Division of Curtiss-Wright Corporation and Vitro Corporation of America. He is presently enrolled in the Newark College of Engineering where he is studying electrical engineering.

He is assigned to this project as laboratory technician with responsibilities including coil measurements, temperature coefficient testing, coil impregnation, and other general laboratory duties.

Cecil B. Burgin attended the Illinois Institute of Technology. During World War II at Northwestern University and University of Chicago he took numerous E.S.M.W.T. courses in ultra-high frequency techniques, vacuum applications at ultra-high frequencies, higher mathematics for engineers and physicists, and other subjects.

His professional experience includes seven years in the Engineering Dept. of Stewart Warner Corporation where he designed and developed radio receivers. During World War II he did engineering and developing work on loop antennas for aircraft, altimeters, and direction finders. Since 1945 he has worked on weather observation equipment and has participated in research and development work on r-f and i-f coils and their applications to electronic equipments.

His responsibilities on this project are primarily in the field of coupled circuit measurements.

APPENDIX A

SQUIER SIGNAL LABORATORY

COMPONENTS AND MATERIALS BRANCH

COMPONENT PARTS SECTION

FORT MONMOUTH, NEW JERSEY

TECHNICAL REQUIREMENTS

For PR&C No. 53-ELS/D-3438

8 January 1953

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DESIGN METHOD
for
HIGH FREQUENCY TRANSFORMERS

I. Objectives and Scope

These requirements cover research and development related to design, fabrication and test of high frequency transformers such as i-f and low power rf. Classes to be included are: untuned, single tuned, double tuned, triple tuned, and tapped versions of all these types. Research and development is to cover the following phases:

A. Study and research into the theoretical and material requirements for optimum electrical, magnetic, and mechanical design of high frequency transformers.

B. The establishment of prescribed methods of design of these transformers.

II. Requirements

A. Electrical and Mechanical

The method of design to be established should take into account the various operating parameters that could be specified because of the circuit applications, as well as those which are necessary for the proper design of r-f transformers. The following factors which are considered essential to such design will be considered in the course of this development:

1. Inductance
2. Q
3. Impedance (input and output)

4. Distributed capacity
5. DC resistance
6. Bandwidth
7. Gain
8. Resonant frequency
9. Temperature rise
10. Protection
11. Coefficient of coupling (k), mutual inductance, and coupling factor.

B. Environmental

The design method shall include design procedures for r-f transformers operating on ambient temperatures of the following ranges:

1. -55°C to +85°C
2. -55°C to +125°C
3. -55°C to +200°C

The r-f transformer should be capable of withstanding static storage for three days at -65°C with no physical damage or adverse effect on electrical performance within the operating temperature range.

C. Shielding

Present types of electromagnetic and electrostatic shielding shall be studied to determine their effectiveness. Possibility of recommending a standard series of transformer can should be investigated. Proper spacing of the shield from the coil for optimum performance should also be considered.

D. Windings

Various types of conductors and windings shall be studied to find those most suitable for use based on temperature ranges of operation and electrical considerations. To be included are insulated wire, bare wire, Litz wire and tubing as well as wire size and factors of space winding, space factor and methods of obtaining optimum "Q". Types of windings shall include space winding, universal winding, duo-lateral winding, and Pi winding.

E. Dielectric Materials

The temperature and moisture resistant properties of the dielectric materials used for coil forms, base plates, supports, wire insulation, etc., shall be investigated. Types of wire insulation should include silk, cotton, nylon, enamel, and various types of resin coatings.

F. Mounting and Core Locking Devices

The types of mountings and core locking devices presently available shall be evaluated to determine which will meet service requirements, particularly in regard to vibration and shock.

G. Methods of Measurement

All methods of measurement used to evaluate design, construction, and performance shall be presented in detail.

H. Methods of Design

The design method shall be presented step-by-step in a clear, concise manner. The presentation shall be made in a manner readily understandable by electrical engineers not normally associated with the r-f transformer industry. The use of tables, charts, graphs, and nomographs may be used and is encouraged where such use permits simplification of design procedures. Reference to readily available technical literature where derivations of all formulas and discussions of the technical concepts used may be found should be included. Some articles of direct interest are "Band Pass Monographs" published by Federal Tel. & Radio Corp., and "Practical Aspects of Design of R-F transformers" by C. E. S. Ridgers (British). An outline of the design method shall be included as well as design examples for typical r-f transformers. All necessary formulas, charts, curves, tables and nomographs shall be included. The design method should include the following pertinent information:

1. Methods of selecting the core material including characteristic curves, losses, frequency limitations.
2. Design of coils, including insulation choices, type of winding (single layer, universal, bank), size and type of wire, number of turns, etc.
3. Methods of determining inductance, Q, coefficient

of coupling, bandwidth, etc., and other pertinent electrical parameters.

I. Electrical Ratings

High frequency transformers shall include units operating between 30 MC and 200 MC.

Low power r-f transformers shall include units having electrical ratings up to and including 5 watts.

J. Tests

The "Proposed" Specification on "Coils R-F, Transformers I-F, and Transformers R-F', ASESA Project 146, in whole or in part (as applicable) shall be used as a guide in the design, choice of materials of construction, and test of R-F transformers.

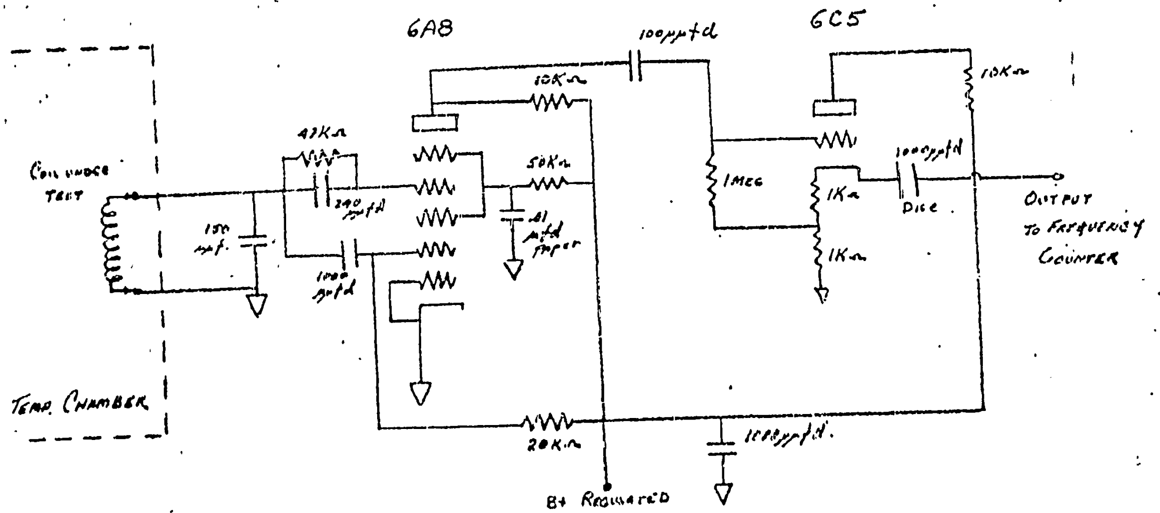
K. Design Examples

The principles of design established shall be illustrated by examples. Construction and testing of models based on these design examples may be used, if necessary, to prove out the design principles. Items so constructed need not be submitted, but full documentation of construction and test data should be included in the reports. The choice of design examples shall be as mutually agreed upon between the Contractor and the Contracting Officer's Representative and will be predicated upon the extent of progress achieved (or anticipated) at the time of agreement.

APPENDIX B

Circuit Diagrams
Test Data
Curves and Graphs

CKT. C



Coil Test Oscillator

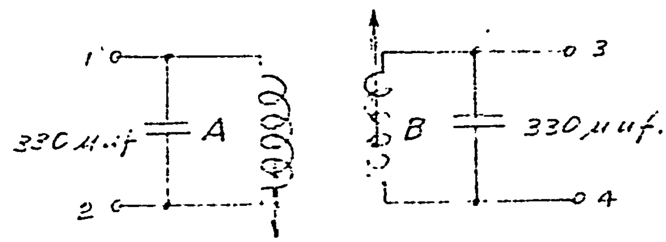
(Negative Transconductance)

All Capacitors are Silver Mica Except when otherwise stated.

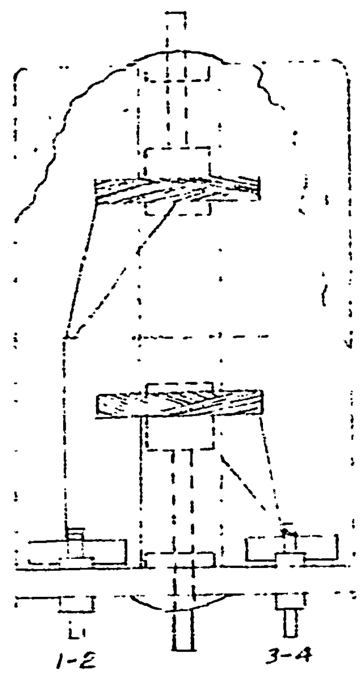
CRK
Feb 2, 1954

EXPERIMENTAL 135 KC IF TRANSFORMER

WIRE 3/41 SSE.
GEARS 42/82.
CAM 3/16.
TURNS A 460 - B 460.
FORM 1/2 OD. 3/8 ID. 3 1/4 L.
SHIELD CAN 3 1/2 x 2 x 2.
CORE 3/8 OD. x 1/2 L.
SK-133, G3.



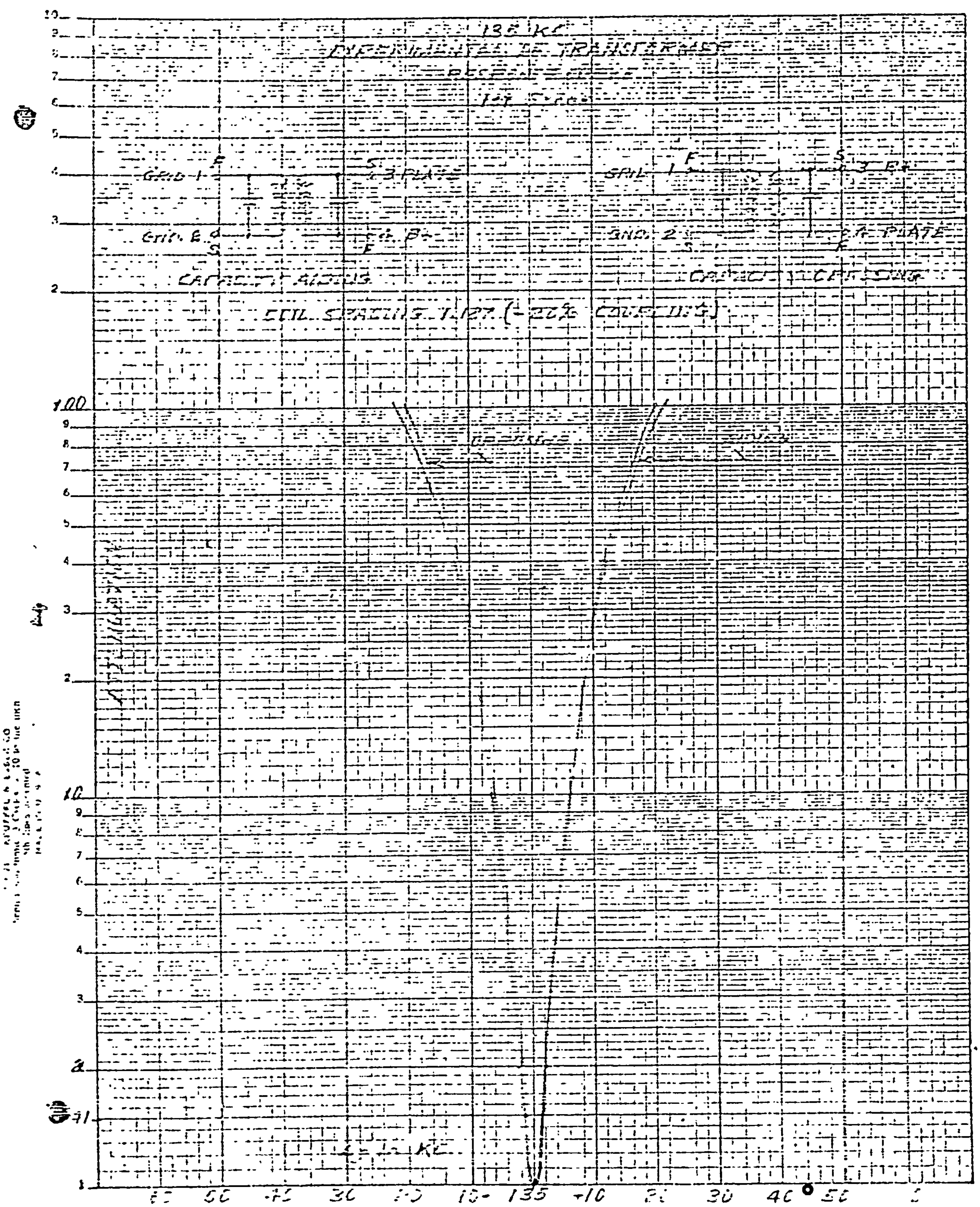
COIL AFTER IMP. WITH CORE		COIL AFTER IMP. WITHOUT CORE	
IN CAN	OUT OF CAN	IN CAN	OUT OF CAN
f = 135 KC	f = 135 KC	f = 135 KC	f = 135 KC
C = 338	C = 325	C = 376	C = 369
Q = 75	Q = 79	Q = 69	Q = 72

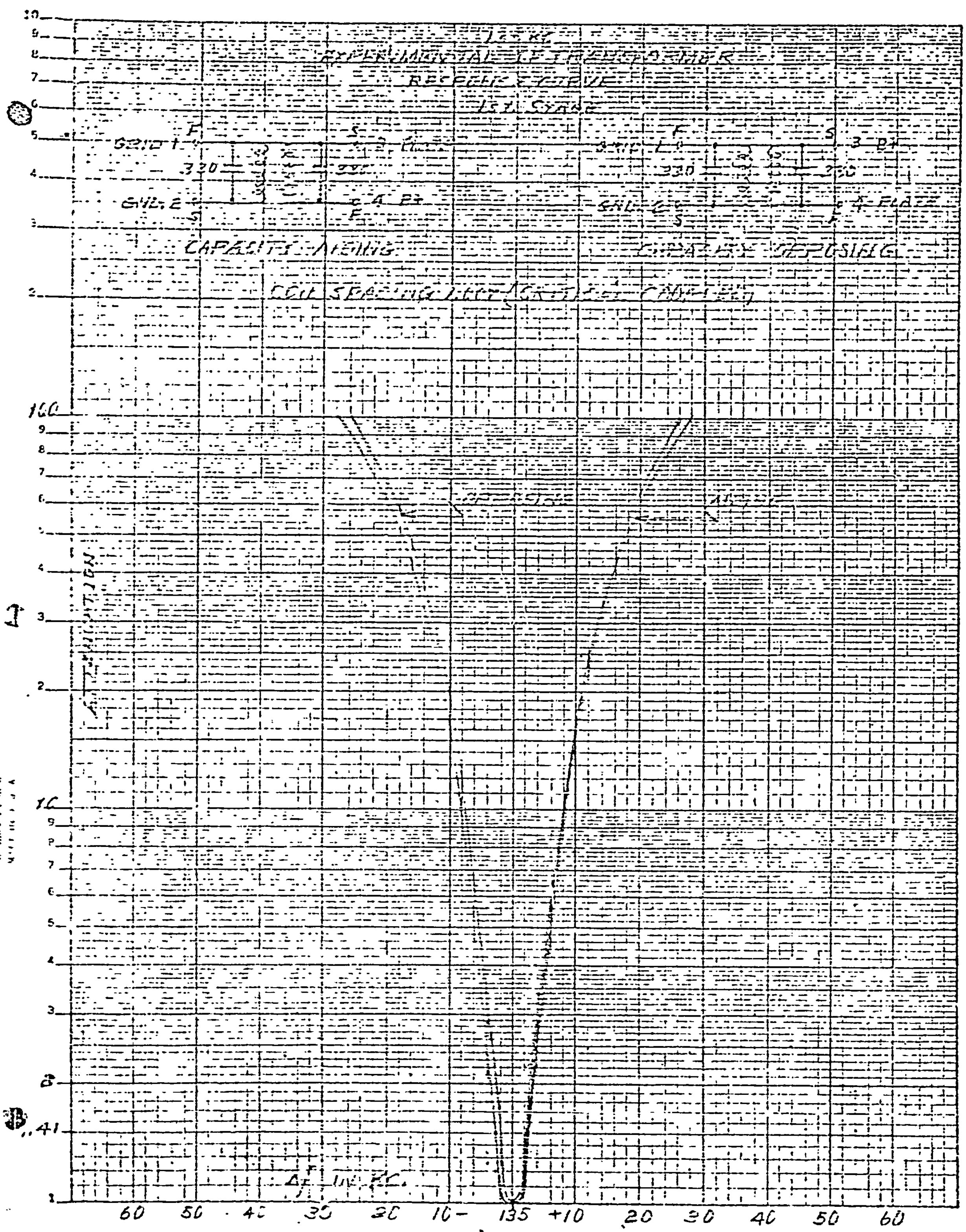


ASSEMBLED TRANSFORMER

NOTE:
TRANSFORMER TUNED ON Q-METER WITH C = 335 μμf. i.e. 330 μμf BASE CAP + 5 μμf. STRAY CAPACITY.

BASE CAP. A [illegible] MICA.


135 KC
GRID 1
GRID 2
PLATE
100
10
135



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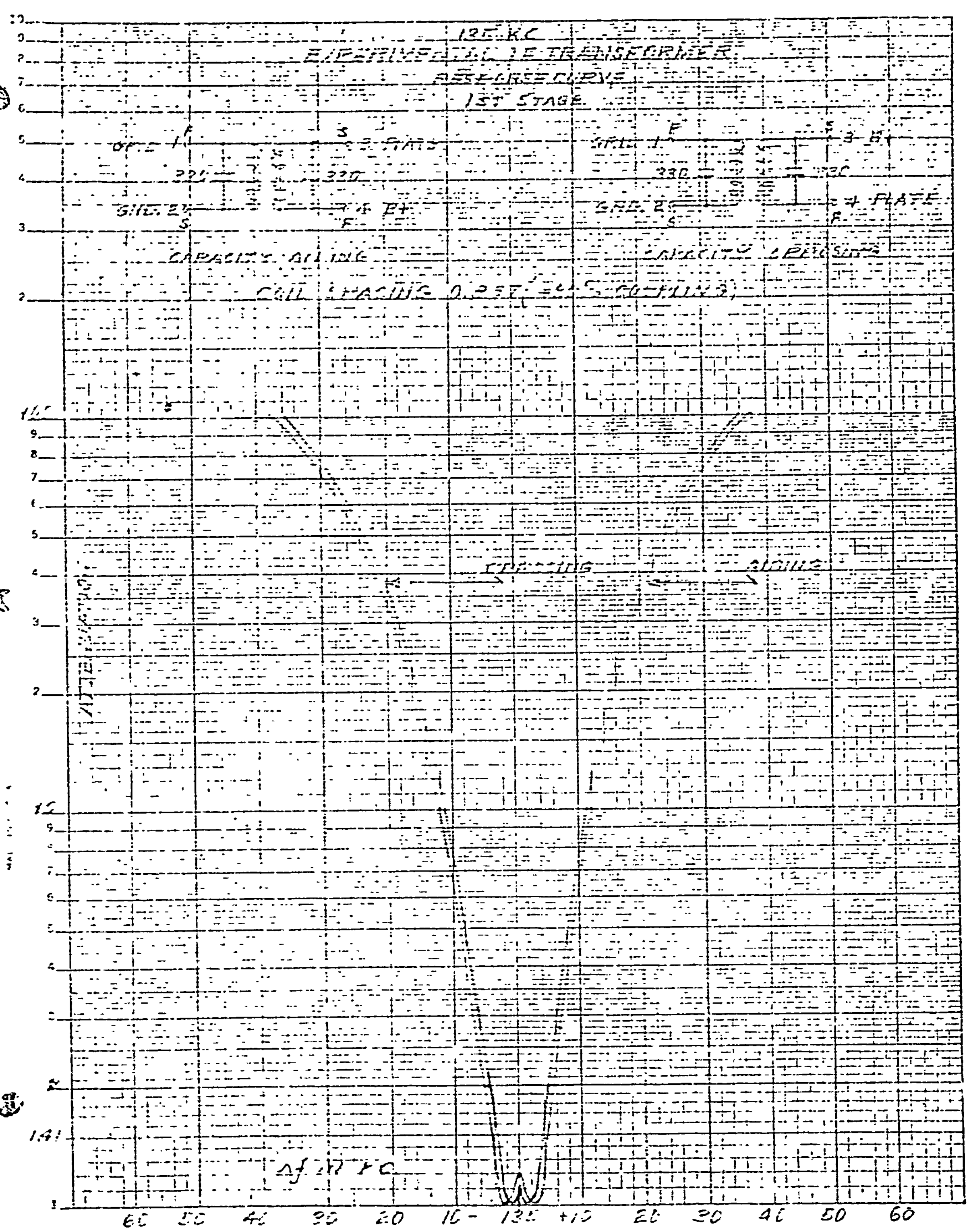
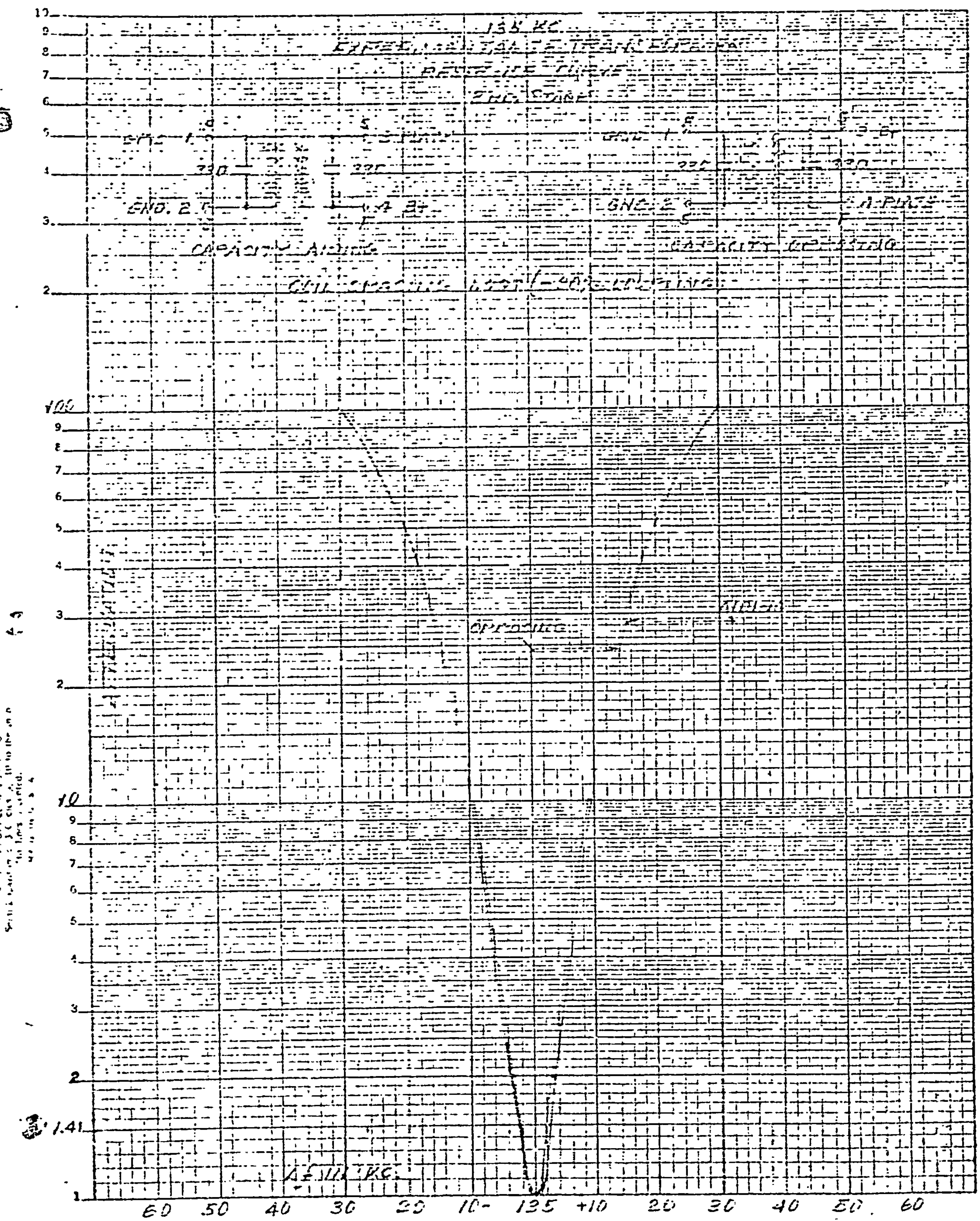
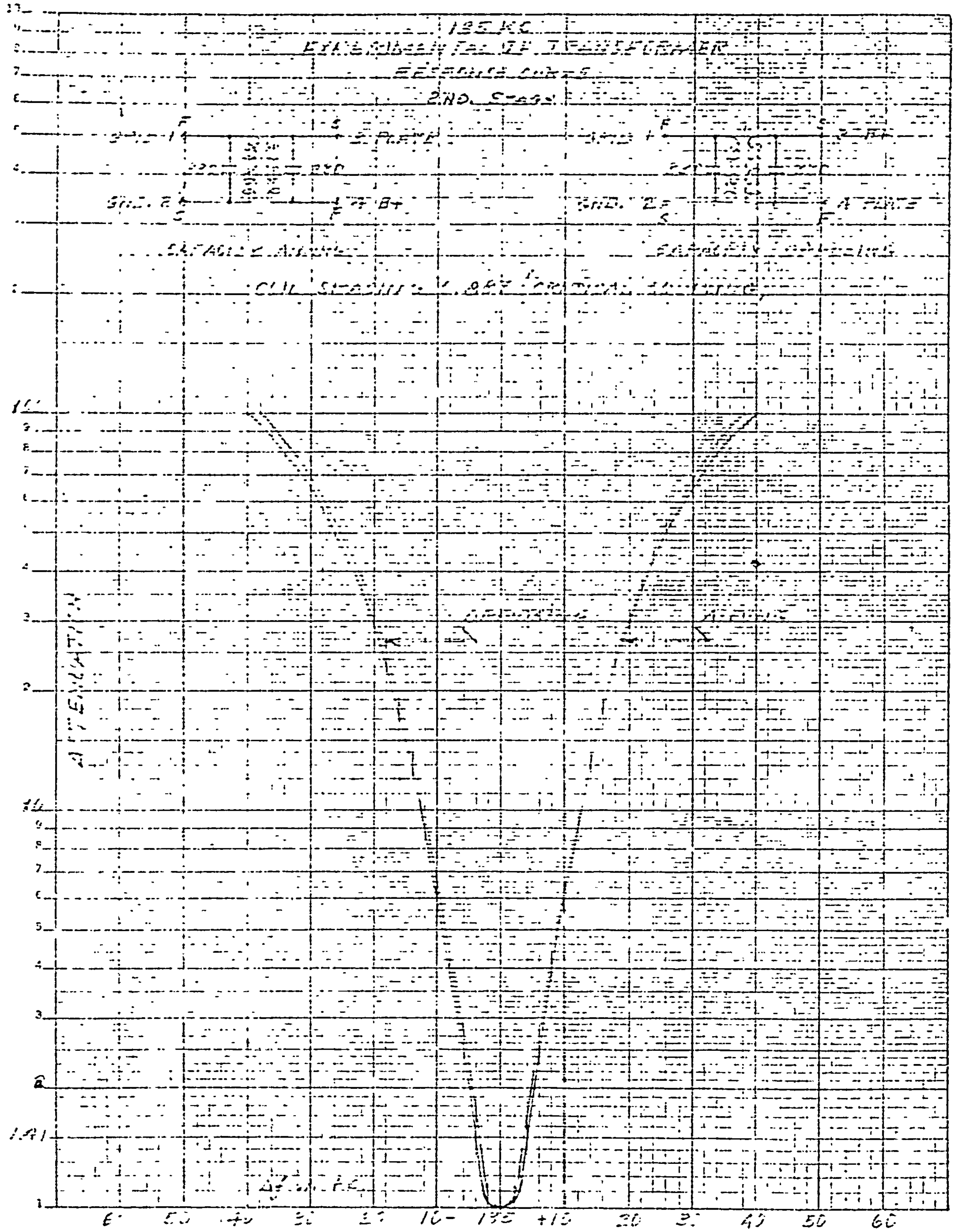
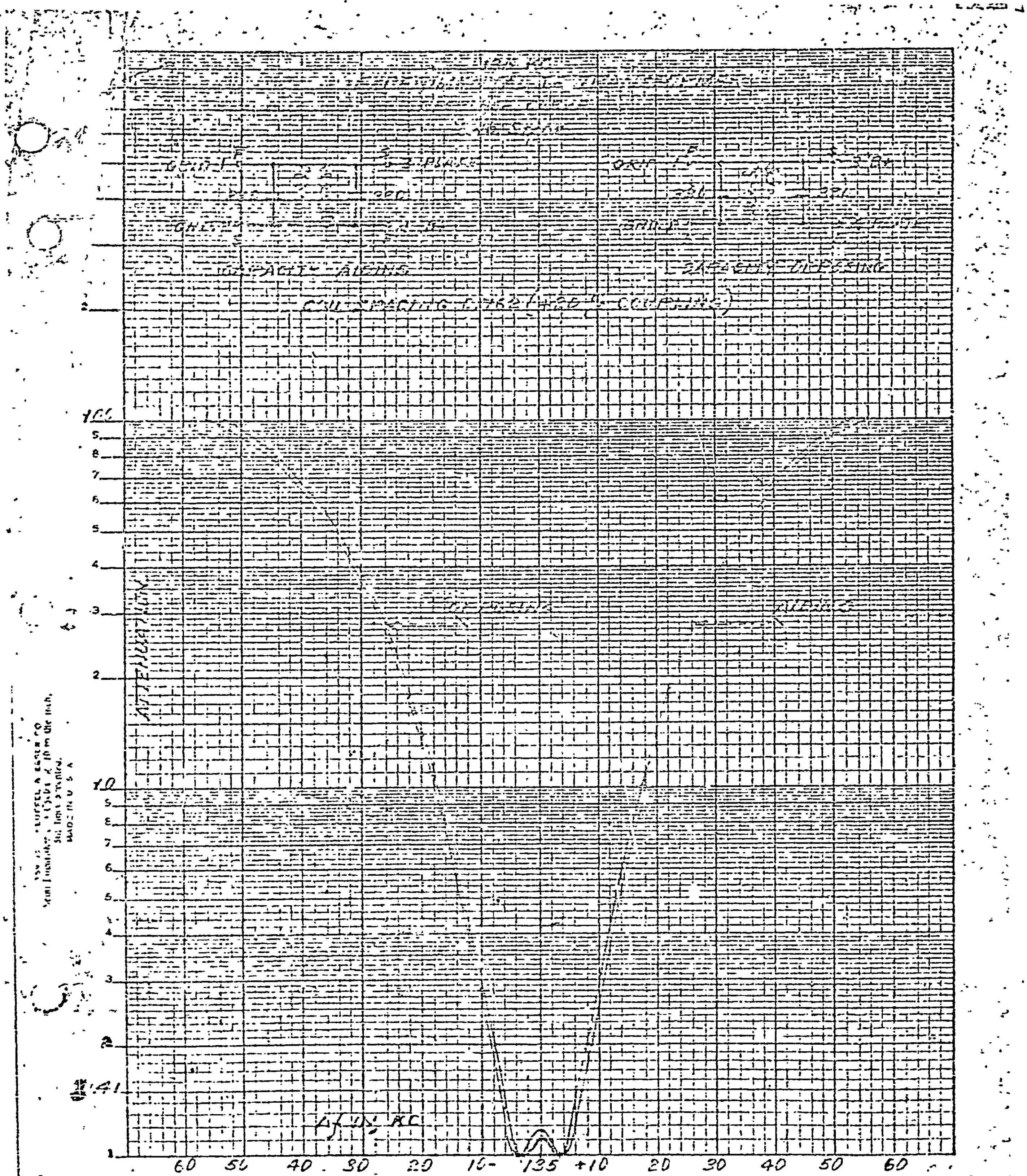

135 KC
1ST STAGE
60 50 40 30 20 10 135 +10 20 30 40 50 60

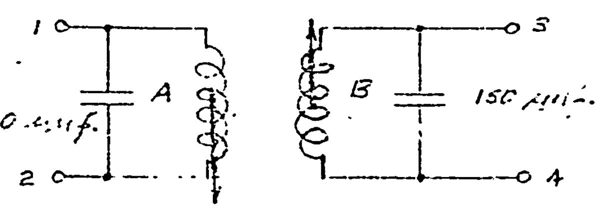

135 KC
CAPACITY AIDING
CAPACITY OPPOSING
AIDING
OPPOSING
1.41
60 50 40 30 20 10- 135 +10 20 30 40 50 60


135 KC
2ND. STAGE
ATTENUATION
135
+10
20
30
40
50
60


ATTENUATION
60 50 40 30 20 10 135 +10 20 30 40 50 60

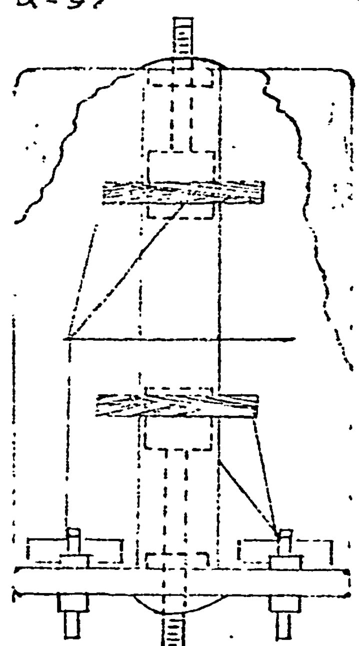
EXPERIMENTAL 262 KC IF TRANSFORMER

WIRE 3/41 SSE.
GEARS 42/22.
CAM 3/16.
TURNS A 350 - B 350.
FORM 1/2 OD. 3/8 ID. 3 1/4 L.
SHIELD CAN 3 1/2 x 2 x 2.
CORE 3/8 OD. x 1/2 L.
SK-133, G3.



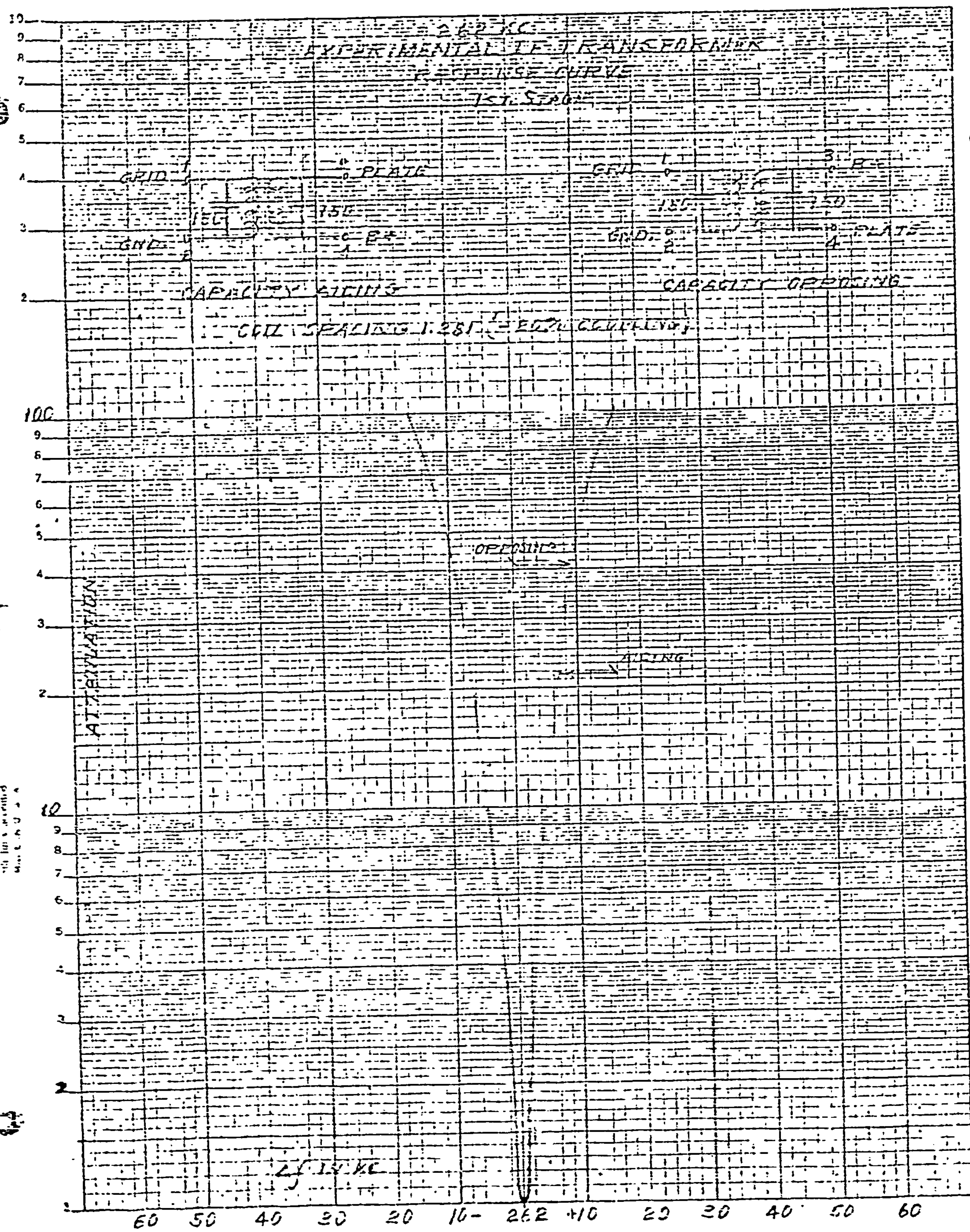
COIL AFTER IMP. WITH CORE	
IN CAN	OUT OF CAN
f = 262 KC.	f = 262 KC.
C = 158	C = 154
Q = 93	Q = 97

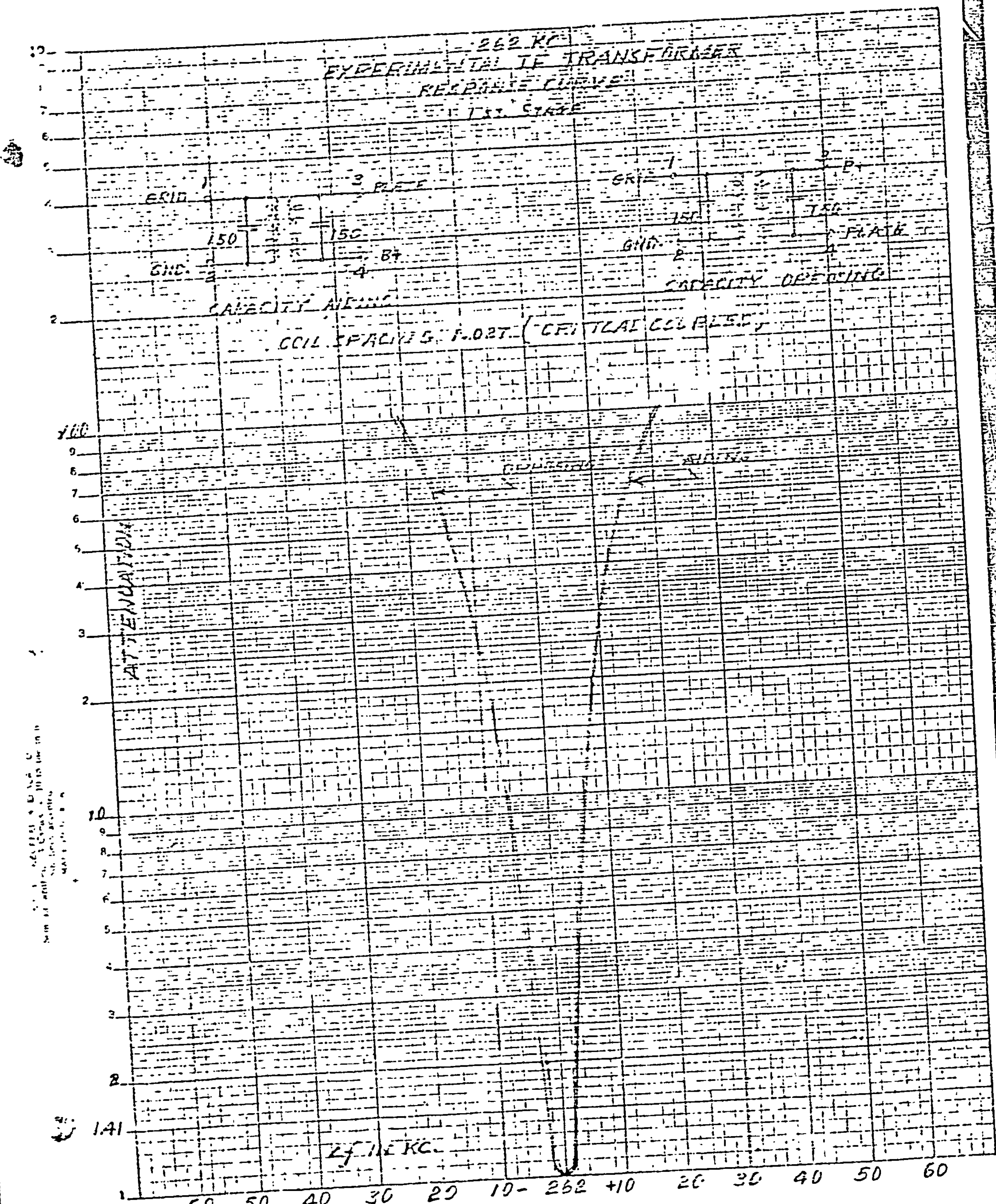
COIL AFTER IMP. WITHOUT CORE	
IN CAN	OUT OF CAN
f = 262 KC.	f = 262 KC.
C = 195	C = 192
Q = 82	Q = 85

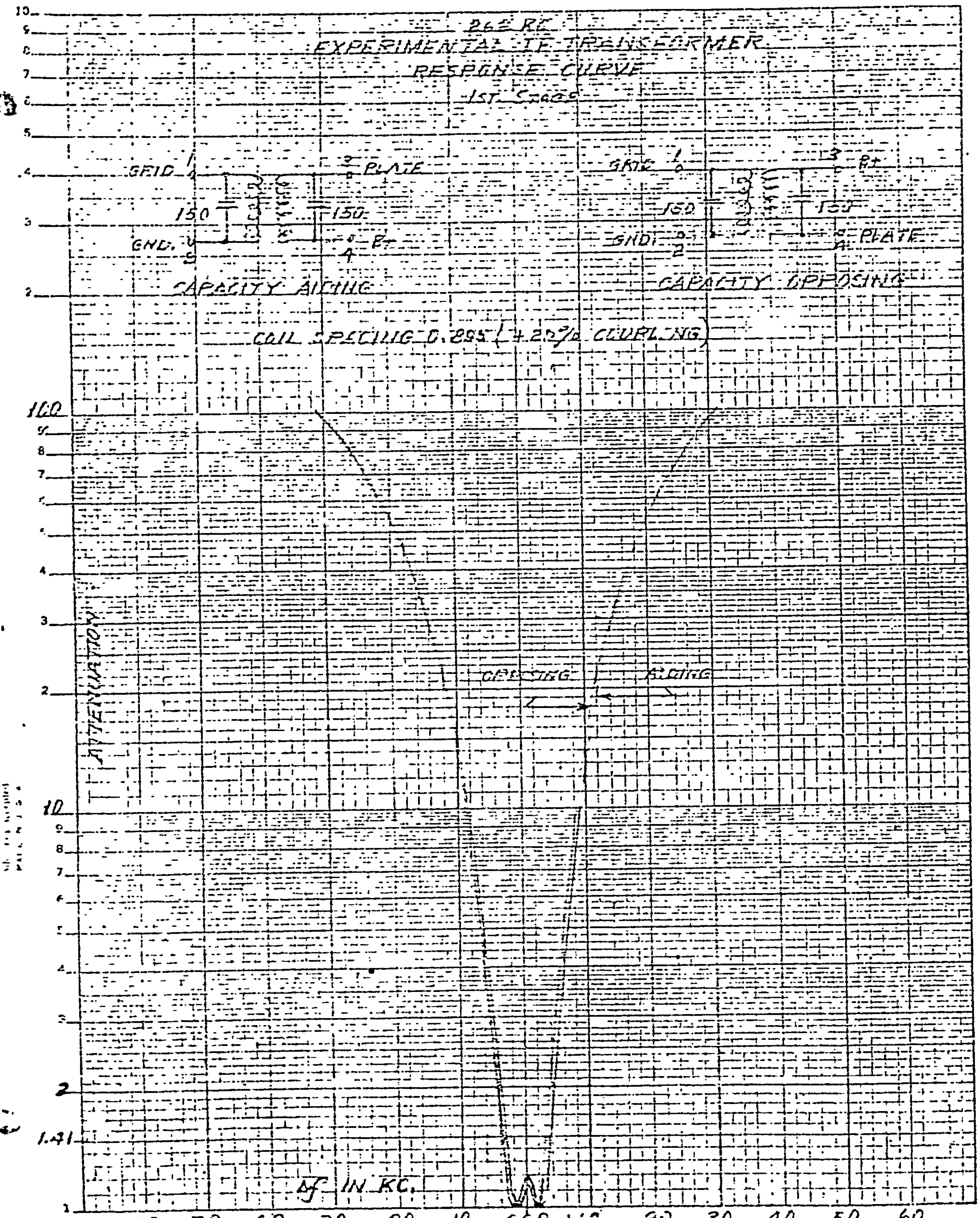


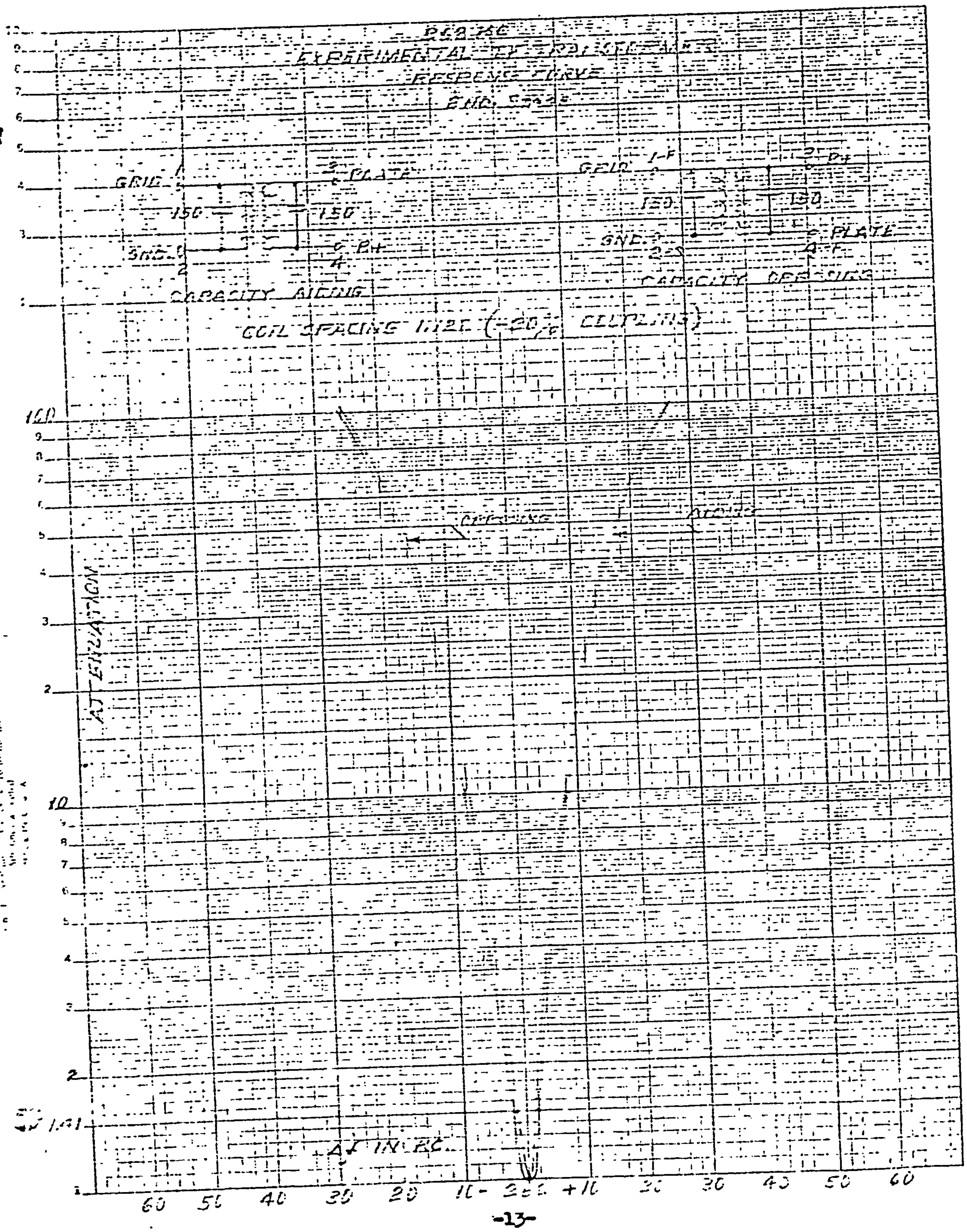
ASSEMBLED TRANSFORMER

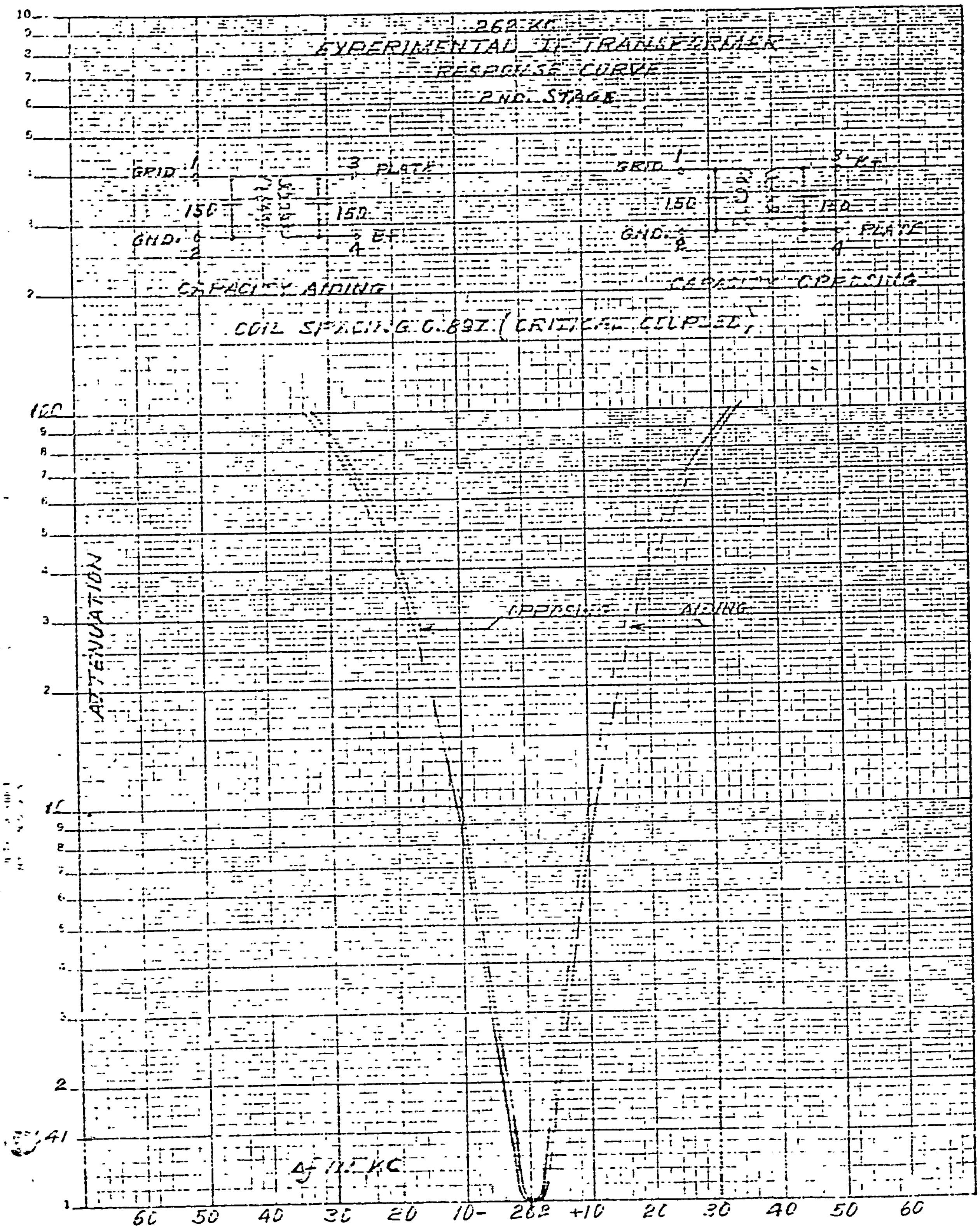
NOTE:
TRANSFORMER TUNED ON Q-METER WITH C = 158 μμf.
ie. 150 μμf BASE CAP.
+ 8 μμf STRAY CAP.
BASE CAP. ARE SILVER MICA.

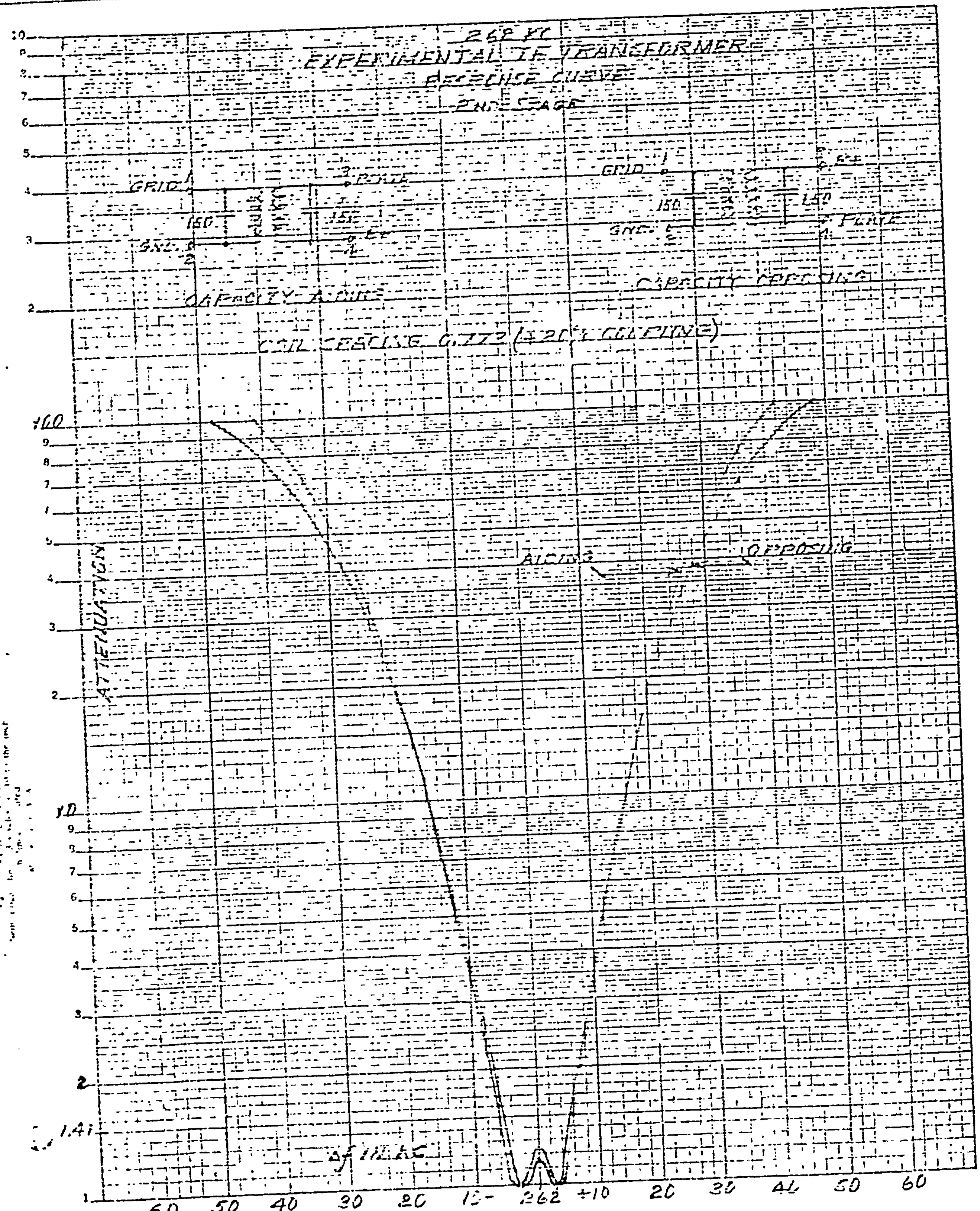

262 KC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
1st STAGE
GRID
PLATE
GND
B+
150
CAPACITY AIDING
CAPACITY OPPOSING
OPPOSING
AIDING
ATTENUATION
60 50 40 30 20 10 - 262 +10 20 30 40 50 60


262 KC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
1st STAGE
GRID
PLATE
150
GND
B+
CAPACITY AIDING
CAPACITY OPPOSING
COIL SPACING .027 (CRITICAL COUPLING)
ATTENUATION
OPPOSING
AIDING
100
10
1.41
Δf IN KC
60 50 40 30 20 10 - 262 +10 20 30 40 50 60


262 KC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
1ST STAGE
GRID
PLATE
150
150
GND.
B+
CAPACITY AIDING
GRID
B+
150
150
GND.
PLATE
CAPACITY OPPOSING
COIL SPACING 0.295 (+20% COUPLING)
ATTENUATION
OPPOSING
AIDING
Δf IN KC.
60 50 40 30 20 10 262 +10 20 30 40 50 60
100
10
2
1.41

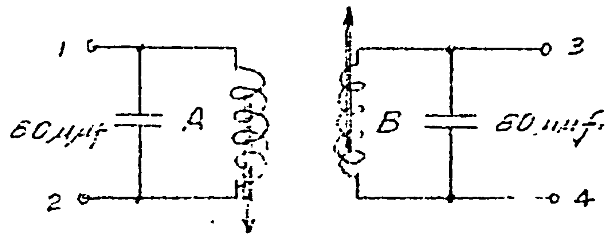

RESPONSE CURVE
GRID
PLATE
150
GND
CAPACITY AIDING
COIL SPACING
CAPACITY OPPOSING
ATTENUATION
AF IN KC
60 50 40 30 20 10 +10 20 30 40 50 60


262 KC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
2ND. STAGE
GRID
PLATE
150
GND.
B+
CAPACITY AIDING
CAPACITY OPPOSING
ATTENUATION
OPPOSING
AIDING
50 50 40 30 20 10- 262 +10 20 30 40 50 60


262 KC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
2ND STAGE
GRID
PLATE
150
GND.
CAPACITY AIDING
CAPACITY OPPOSING
AIDING
OPPOSING
ATTENUATION
100
10
2
1.41
1
60 50 40 30 20 10 262 +10 20 30 40 50 60

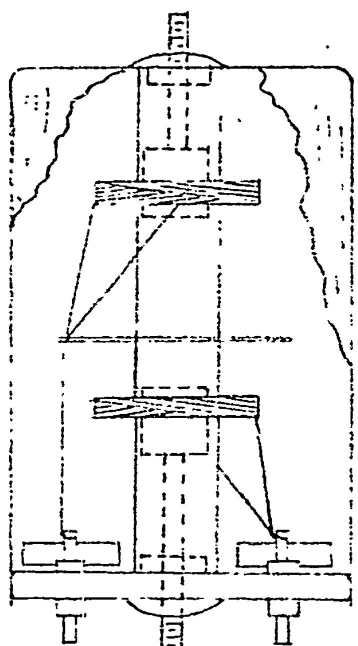
EXPERIMENTAL 1400 KC IF TRANSFORMER

WIRE 3/41 SSE
GEAR 28/55
CAM 5/32
TURNS A 75 - B 75
FORM 1/2 OD. - 3/8 ID. - 3/4 L.
SHIELD CAN 3 1/2 X 2 X 2
CORE 3/8 OD. X 1/2 L.
SK-132 ; G3



COIL AFTER IMP. WITH CORE	
IN CAN	OUT OF CAN
f = 1400 KC	f = 1400 KC
C = 88	C = 87
Q = 64	Q = 84

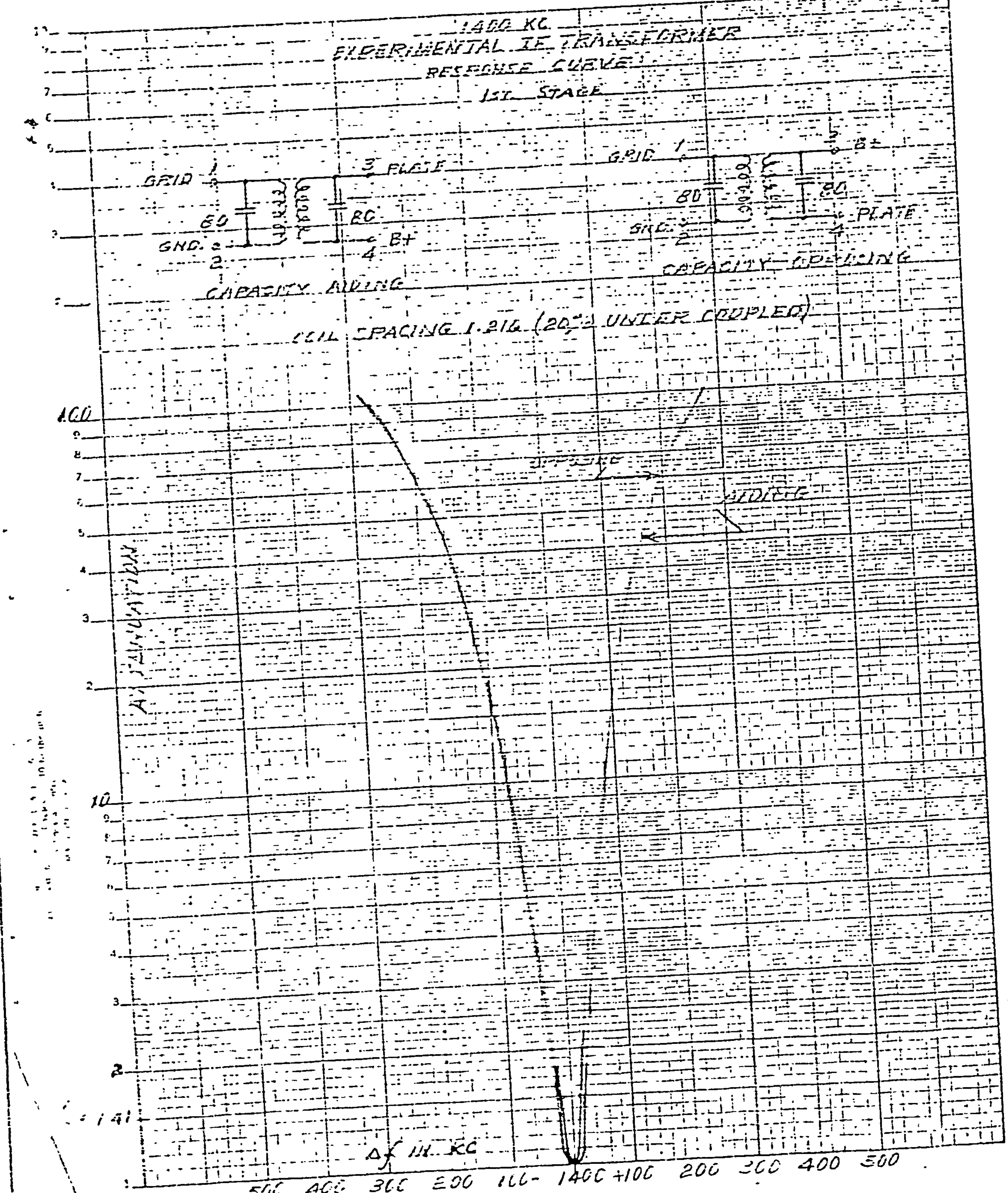
COIL AFTER IMP. WITHOUT CORE	
IN CAN	OUT OF CAN
f = 1400 KC	f = 1400 KC
C = 124	C = 123
Q = 74	Q = 75

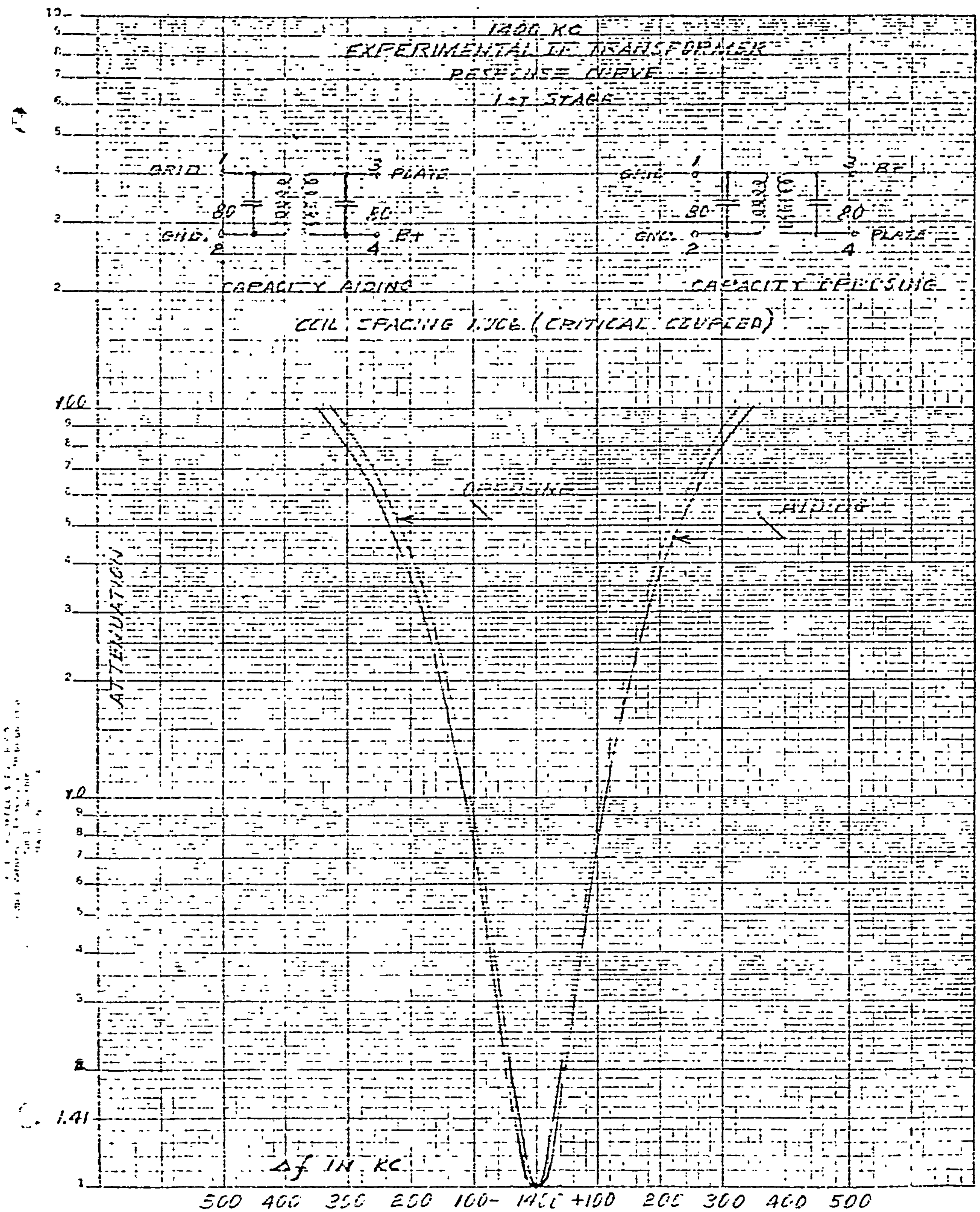


ASSEMBLED TRANSFORMER

NOTE:
TRANSFORMER TUNED ON
Q-METER WITH C = 88 μμf.
i.e.; 80 μμf BASE CAPACITY
+ 8 μμf STRAY CAP.

BASE CAP. ARE SILVER MICA.


1400 KC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
1ST STAGE
GRID 1
3 PLATE
80
80
GND. 2
4 B+
CAPACITY AIDING
GRID 1
5 B+
80
80
PLATE
GND. 2
4
CAPACITY OPPOSING
COIL SPACING 1.21 (20% UNDER COUPLED)
100
10
2
1.41
Δf IN KC
500 400 300 200 100 1400 +100 200 300 400 500



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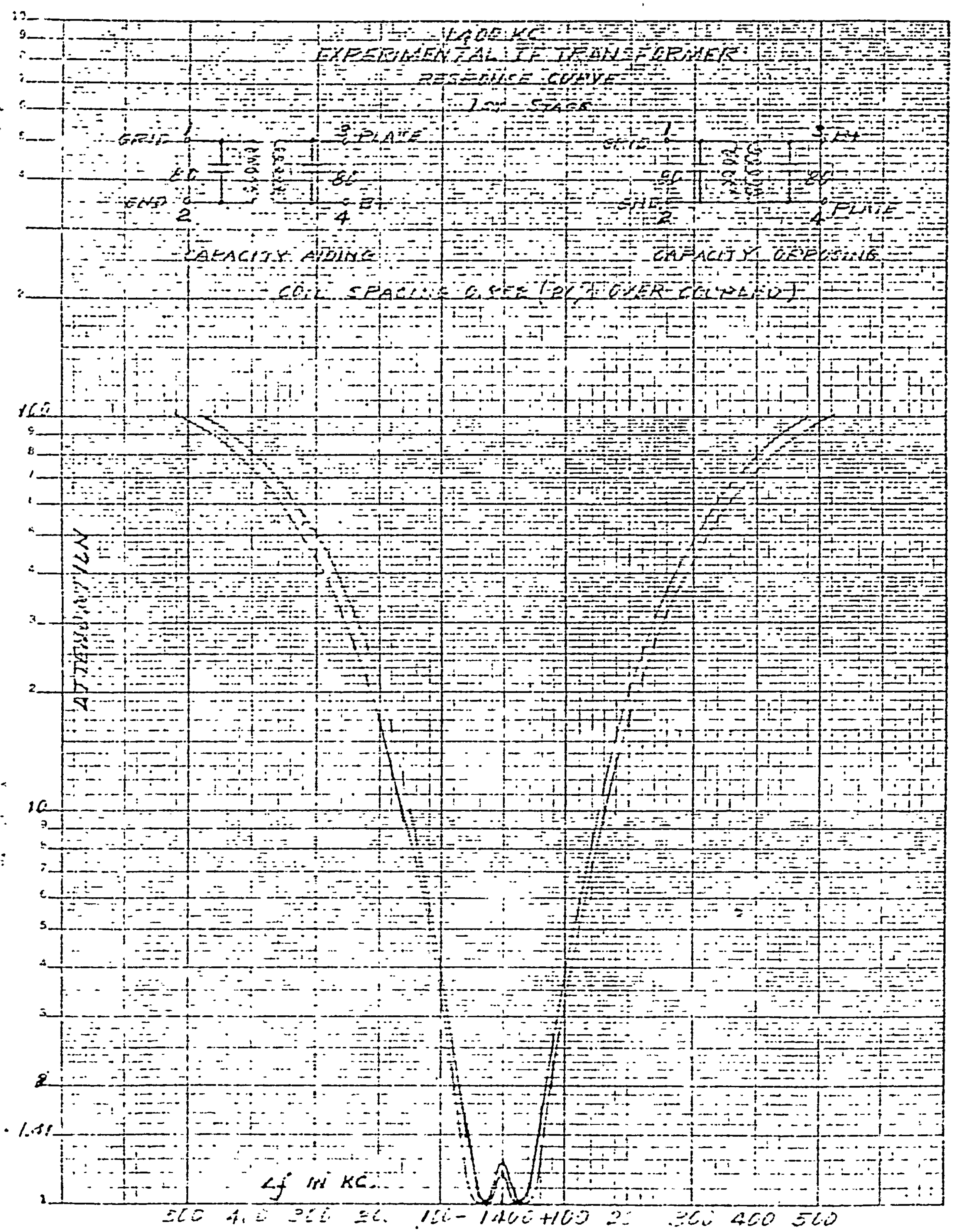
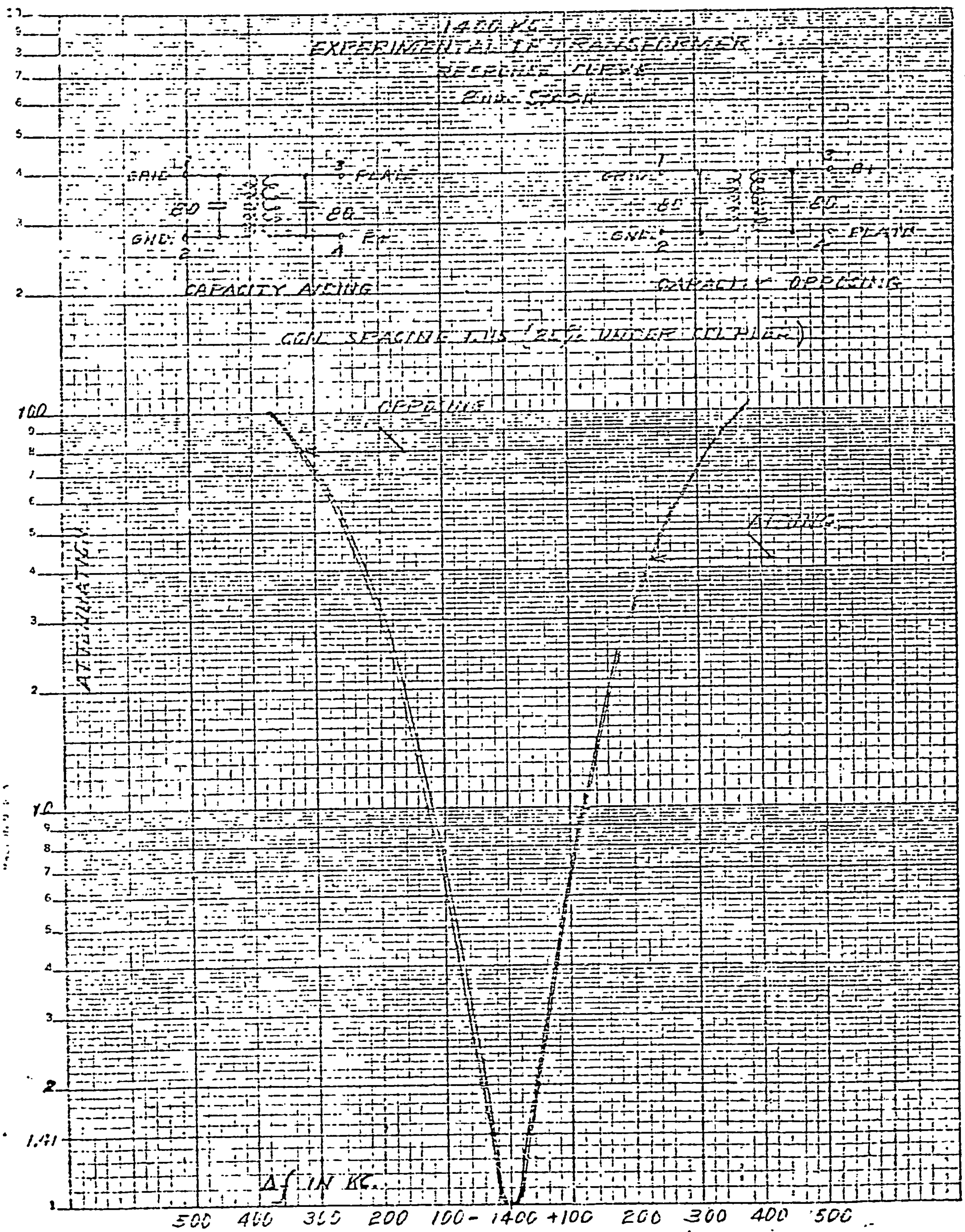
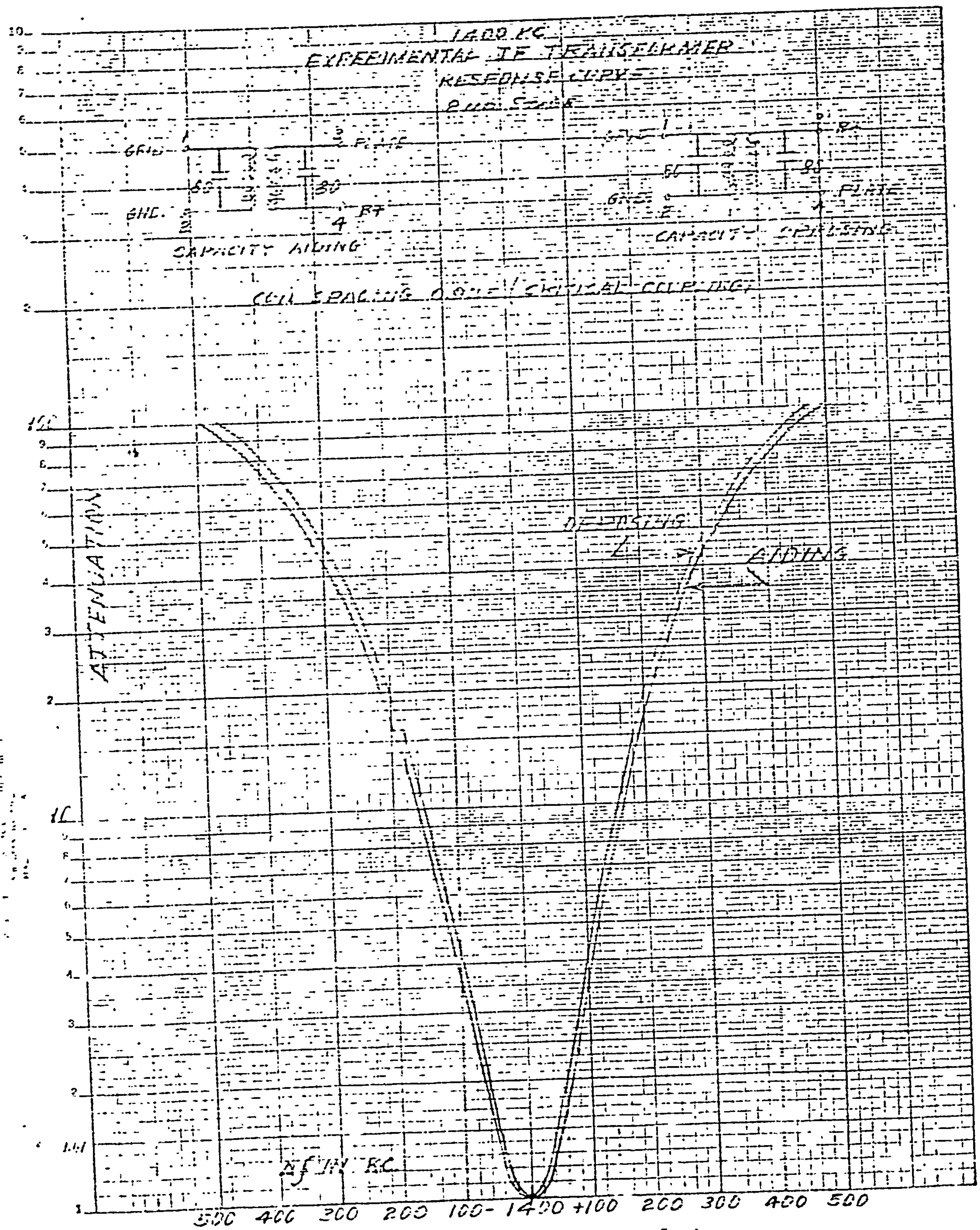


1400 KC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
1st STAGE
GRID
PLATE
B+
GND
CAPACITY AIDING
CAPACITY OPPOSING
COIL SPACING
ATTENUATION
Δf IN KC
1400


1400 KC
EXPERIMENTAL IF TRANSFORMER
GRID
PLATE
GND
B+
80
CAPACITY AIDING
CAPACITY OPPOSING
OPPOSING
AIDING
ATTENUATION
100
10
1.41
1
Δf IN KC.
500 400 300 200 100 - 1400 +100 200 300 400 500



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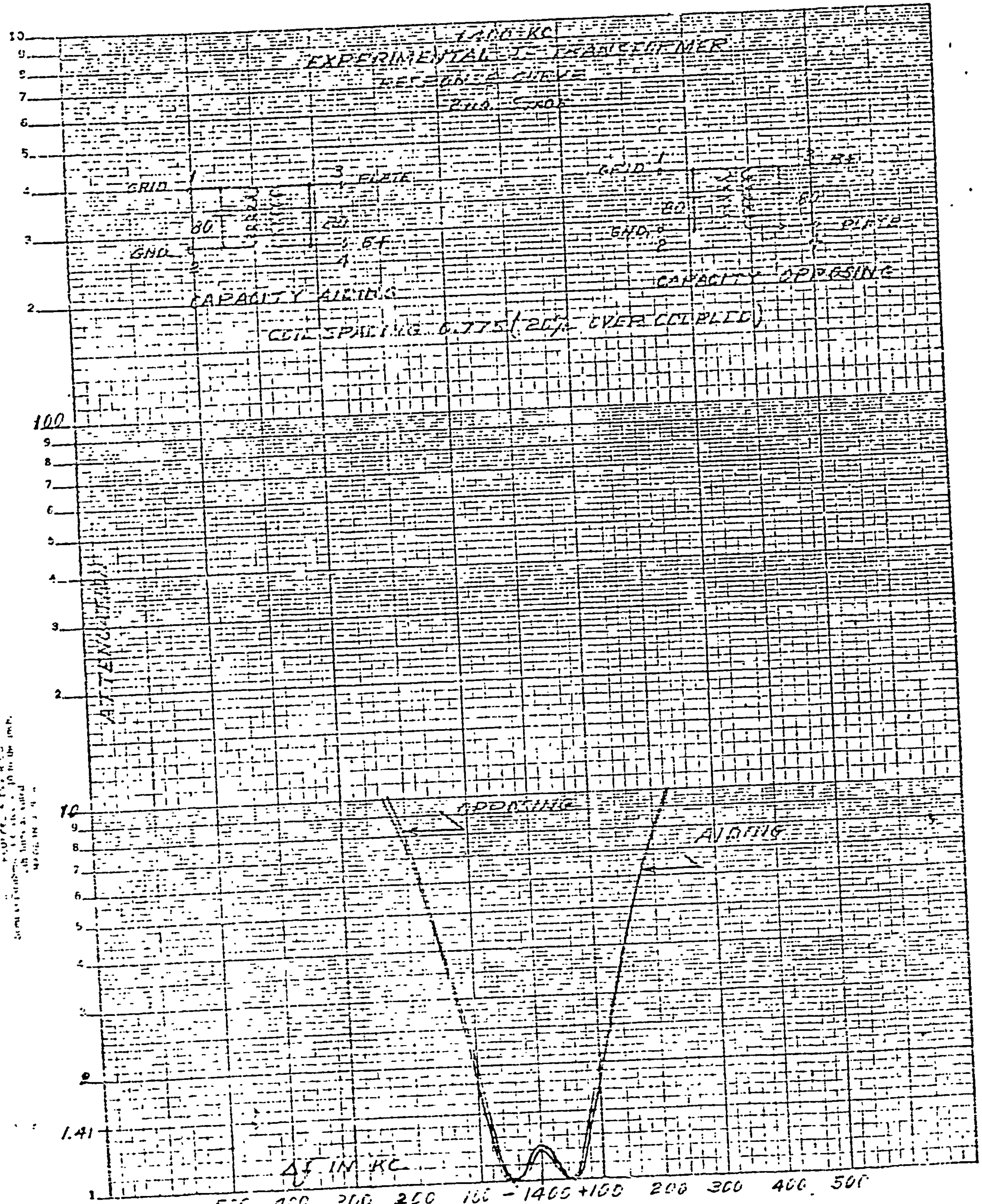
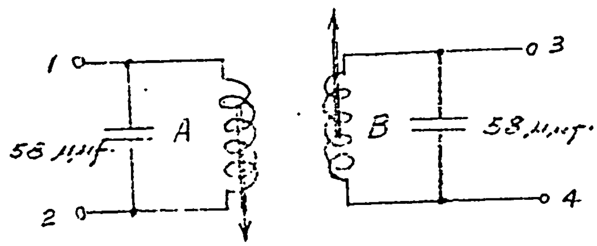
POOR ORIGINAL



EXPERIMENTAL 4.3MC IF TRANSFORMER

WIRE 5/44 SSE.
GEARS 101/66.
CAM 1/8.
TURNS A 26 - B 26.
FORM 1/2 OD. 3/8 ID. 3 1/4 L.
SHIELD CAN 3 1/2 × 2 × 2
CORE 3/8 OD. × 1/2 L
SK-133, G3

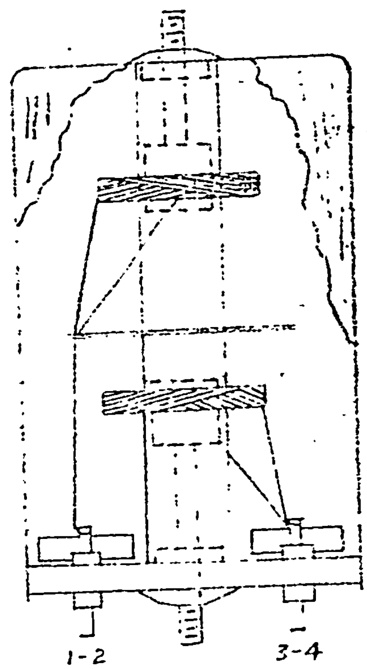


COIL AFTER IMP. WITH CORE

IN CAN	OUT OF CAN
f = 4.3 MC	f = 4.3 MC
C = 66	C = 65
Q = 82	Q = 83

COIL AFTER IMP. WITHOUT CORE

IN CAN	OUT OF CAN
f = 4.3 MC	f = 4.3 MC
C = 97	C = 96
Q = 67	Q = 68



ASSEMBLED TRANSFORMER

NOTE:
TRANSFORMER TUNED ON
Q-METER WITH C = 66 μμf.
i.e. 58 μμf BASE CAP.
+ 8 μμf STRAY CAPACITY.
BASE CAP. ARE SILVER MICA.

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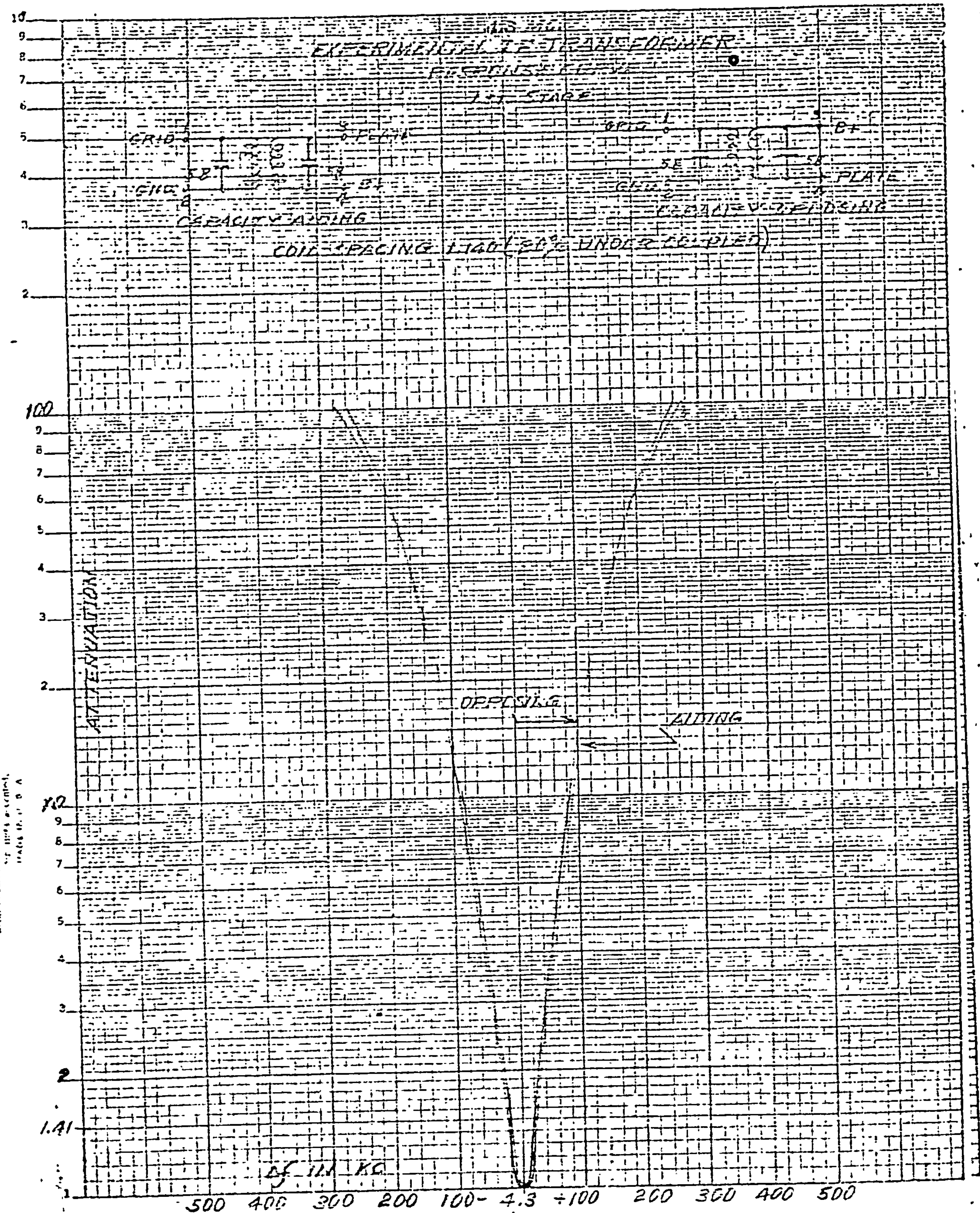
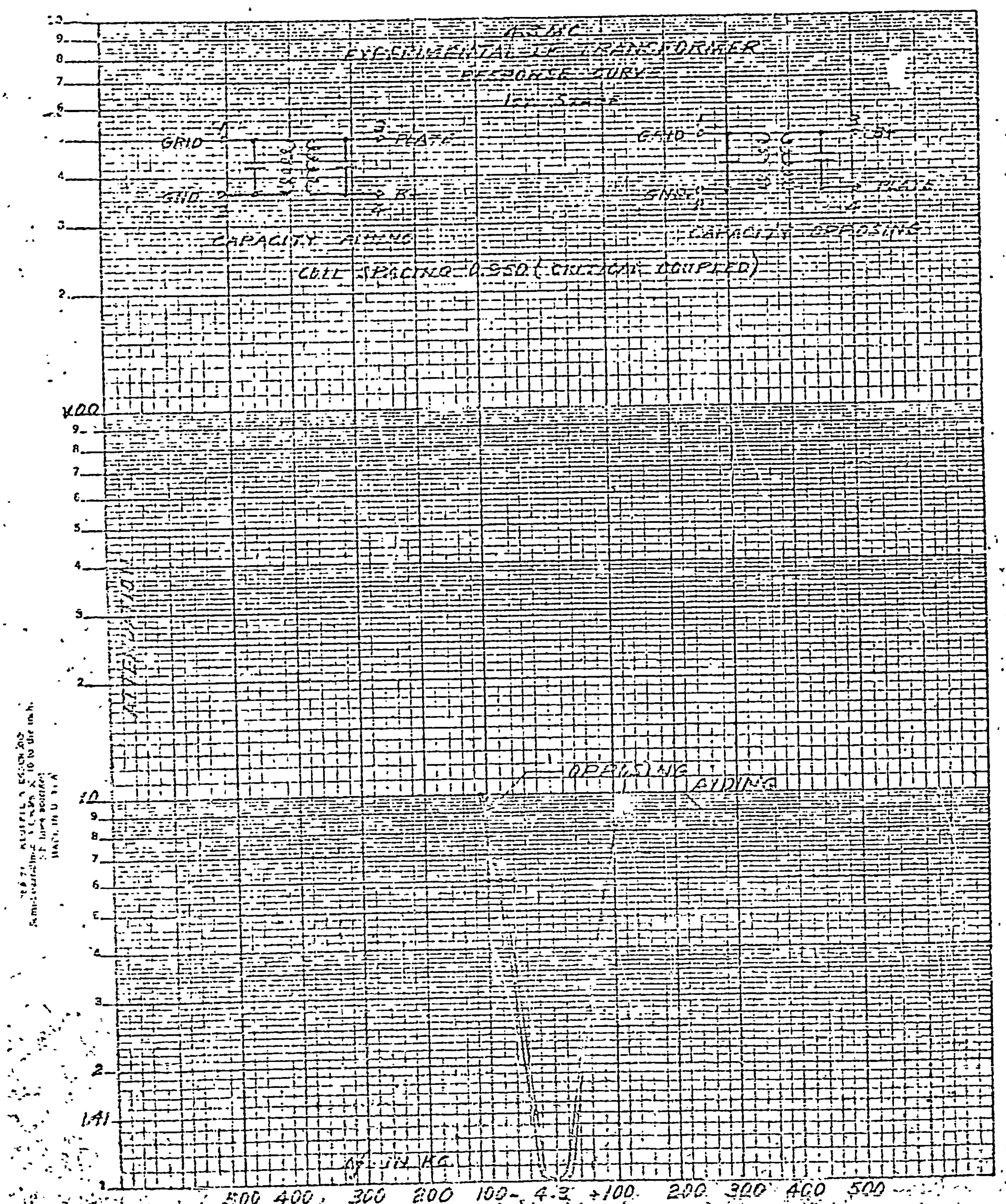
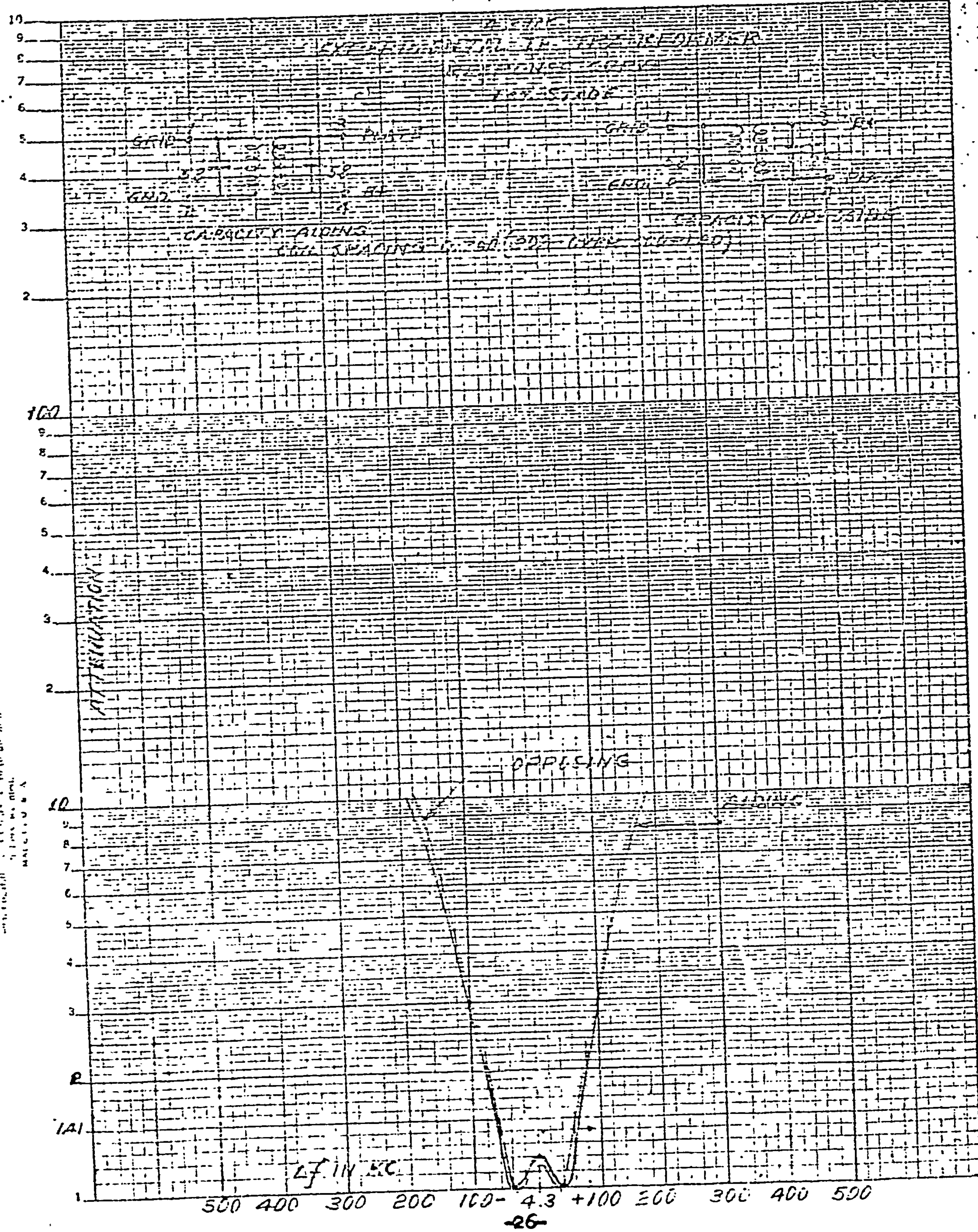
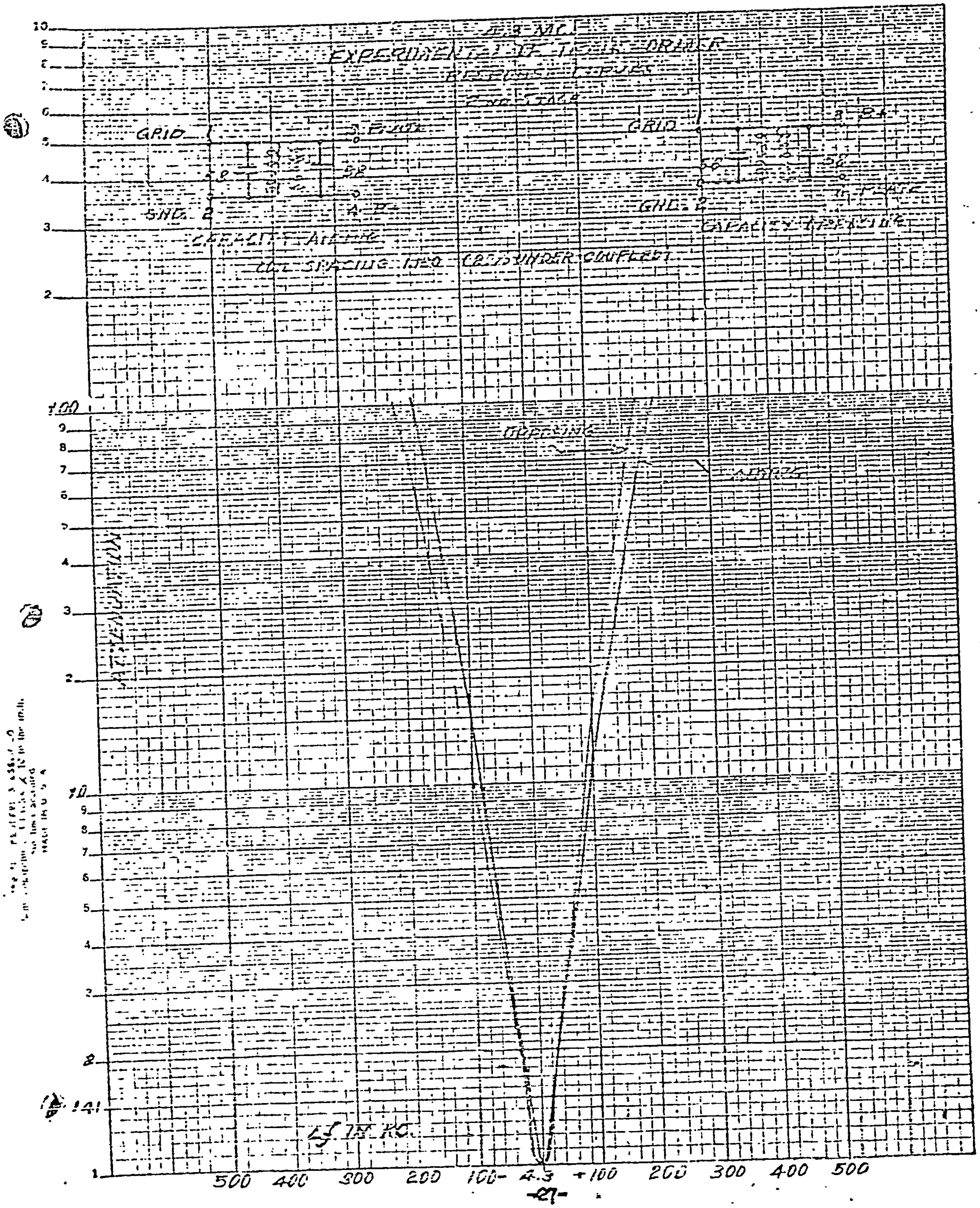

EXPERIMENTAL IF TRANSFORMER
1st STAGE
GRID
PLATE
GND
B+
CAPACITY AIDING
CAPACITY OPPOSING
COIL SPACING
UNDER COUPLED
ATTENUATION
OPPOSING
AIDING
100
10
2
1.41
500 400 300 200 100 4.3 100 200 300 400 500


4.3 MC
EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
GRID
PLATE
B+
CAPACITY AIDING
CAPACITY OPPOSING
COIL SPACING 0.550 (CRITICAL COUPLED)
ATTENUATION
OPPOSING
AIDING
1.41
Δf IN KC
500 400 300 200 100 4.3 100 200 300 400 500


1ST STAGE
GRID
PLATE
GND
GRID
CAPACITY AIDING
CAPACITY OPPOSING
OPPOSING
AIDING
ATTENUATION
Δf IN KC
500 400 300 200 100 - 4.3 + 100 200 300 400 500



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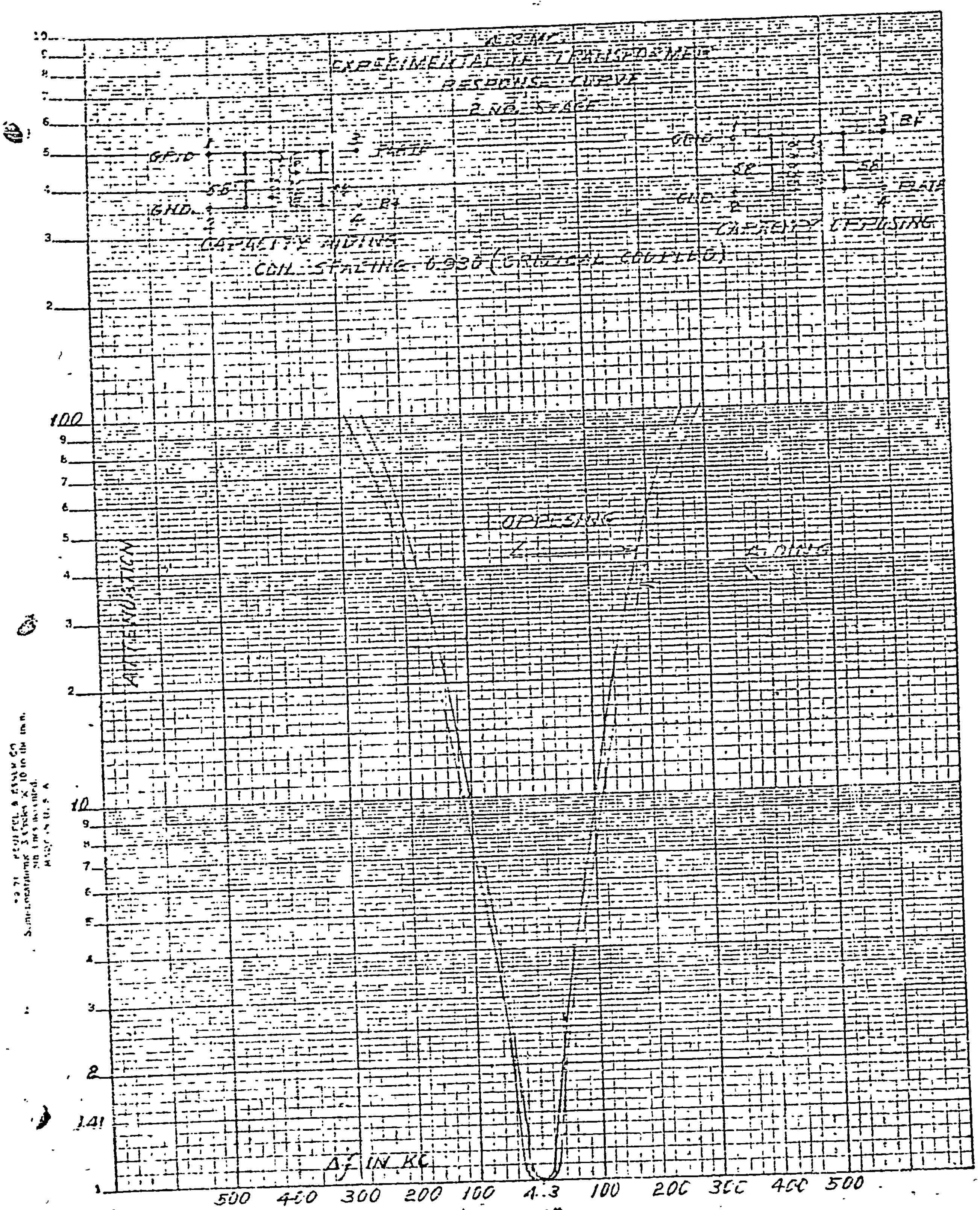
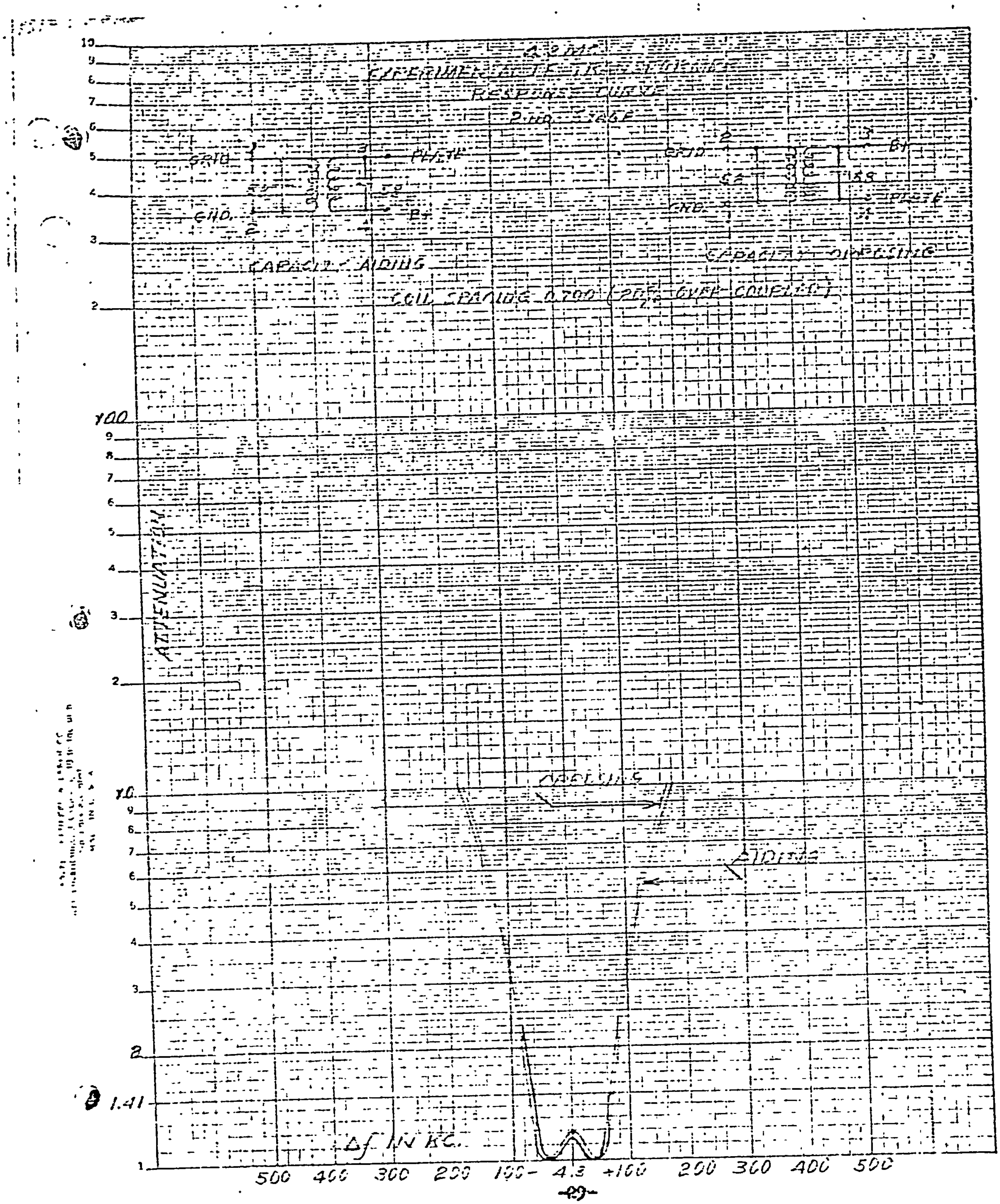

EXPERIMENTAL IF TRANSFORMER
RESPONSE CURVE
2ND. STAGE
GRID
GND.
PLATE
B+
CAPACITY AIDING
COIL SPACING 0.930 (CRITICAL COUPLED)
CAPACITY OPPOSING
OPPOSING
AIDING
ATTENUATION
100
10
2
1.41
Δf IN KC
500 400 300 200 100 4.3 100 200 300 400 500



2ND STAGE
GRID
PLATE
GND.
B+
CAPACITY AIDING
COIL SPACING 0.700 (20% OVER COUPLED)
ATTENUATION
AIDING
1.41
Δf IN KC.
500 400 300 200 100 - 4.3 +100 200 300 400 500

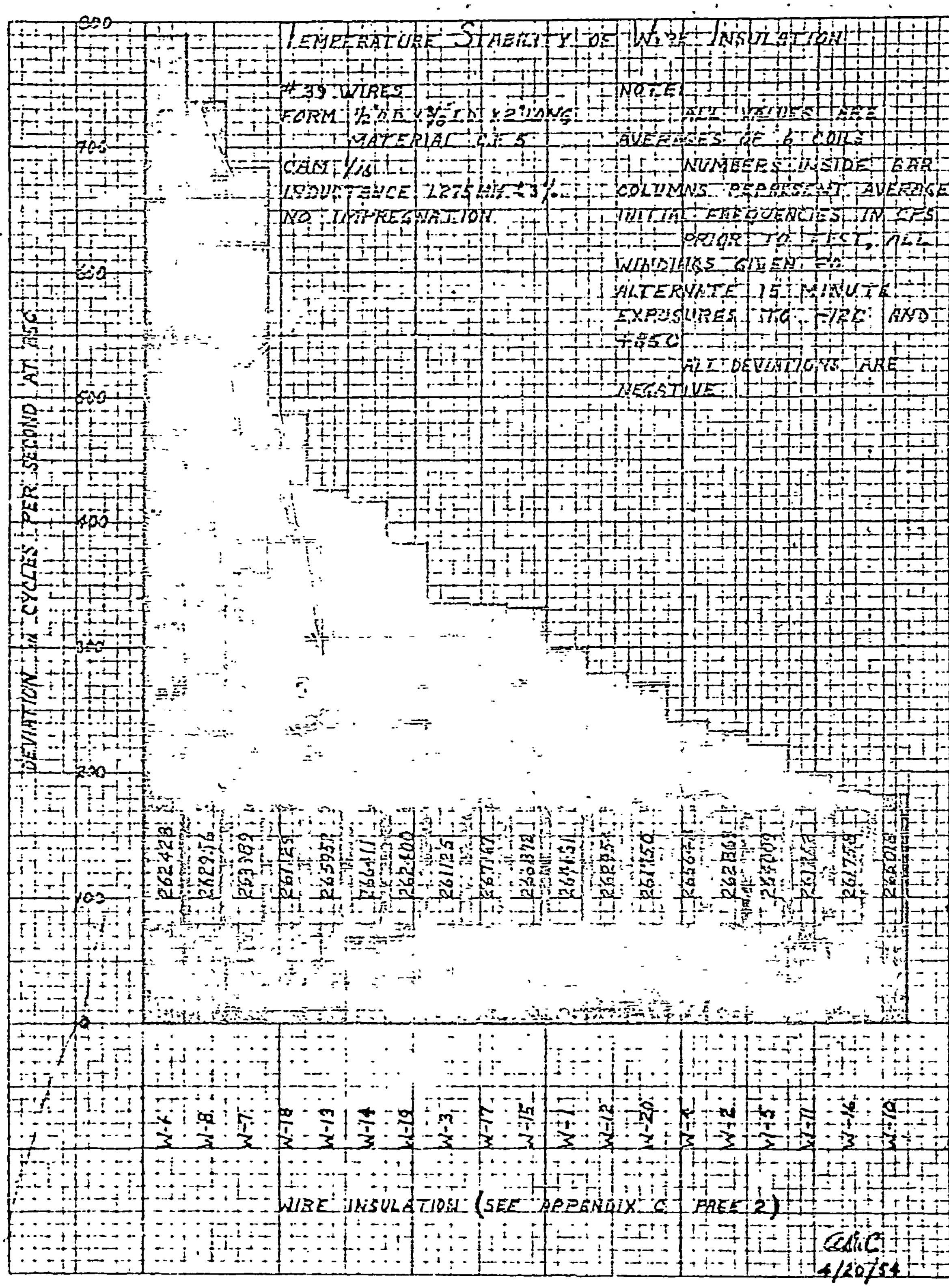
TEMPERATURE STABILITY

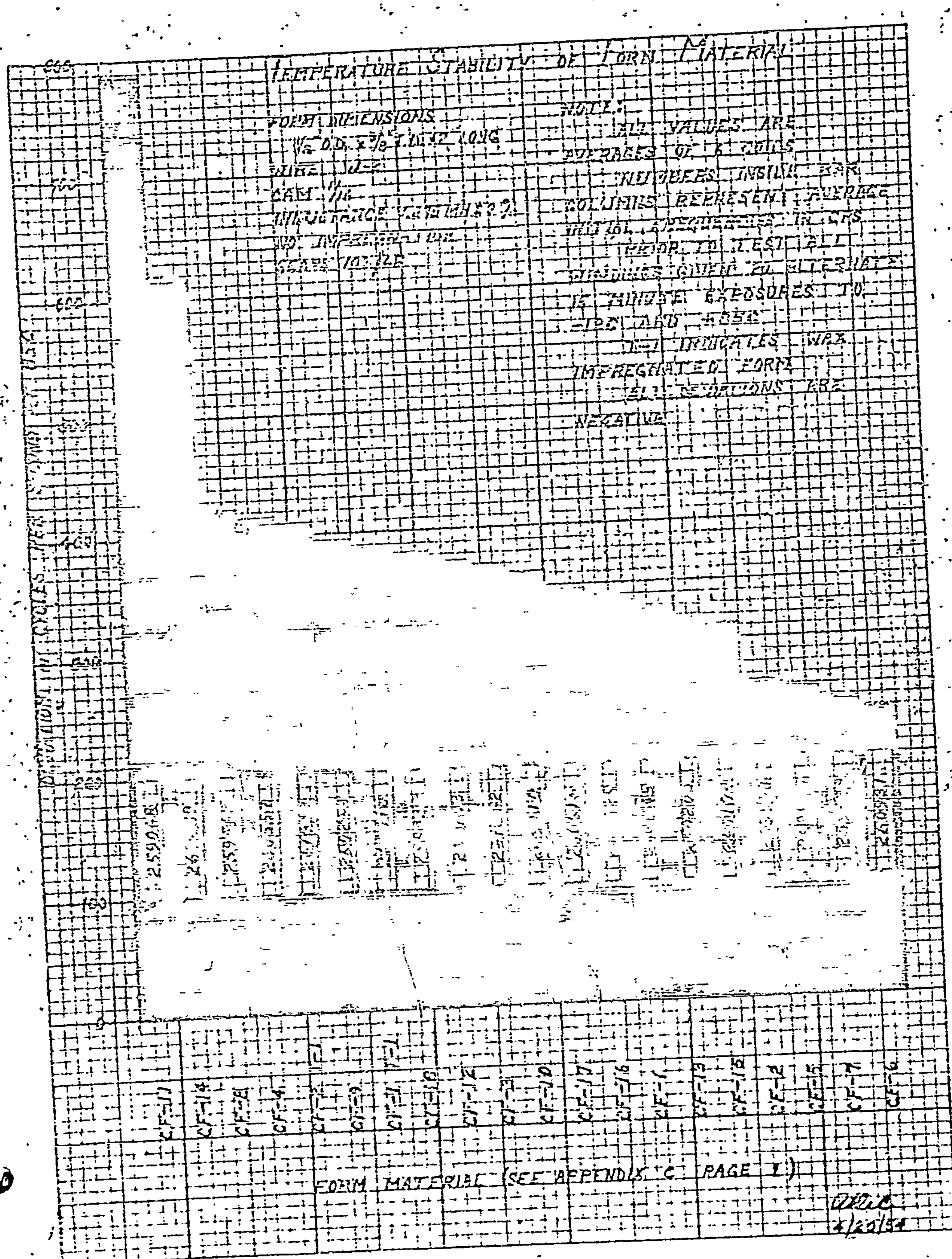
$$T.C. = \frac{\Delta f}{f} \times \frac{10^6}{\Delta t}$$

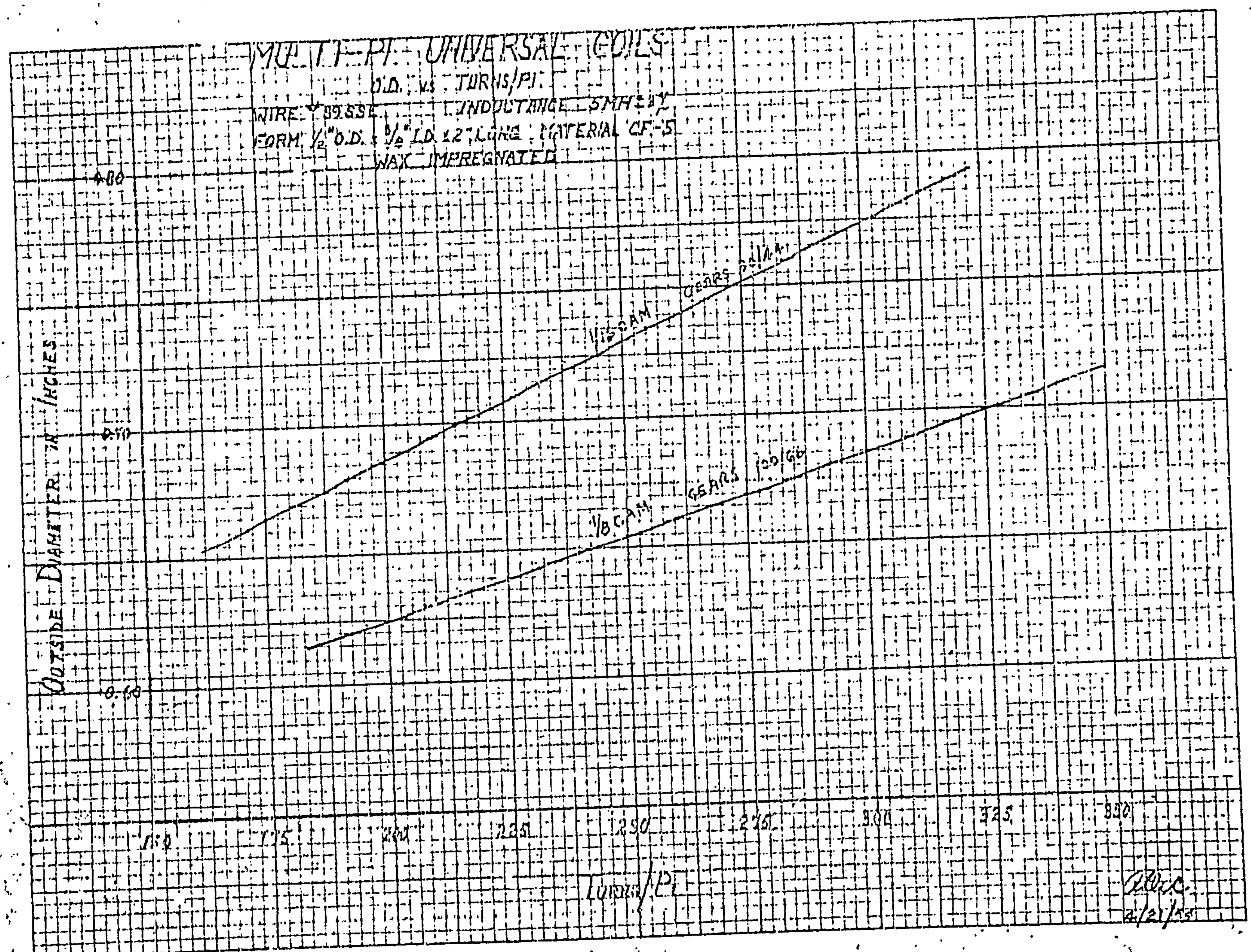
WIRE INSULATIONS		COIL FORM MATERIAL	
Form: 1/2 inch OD x 3/8 inch ID x 2 inches long Material: C.F.-5 Cum: 1/16 No impregnation Inductance: 1.275 mh ± 3 per cent Wire Size: No. 39 Insulation: Various		Form: 1/2 inch OD x 3/8 inch ID x 2 inches long Cum: 1/16 No impregnation Gears: 103/68 Inductance: 1.275 mh ± 3 per cent Wire Size: No. 39 Insulation: Various	
Wire Insulation (See Appendix C Page 2)	ppm/°C @ 85 C	Coil Form Material (See Appendix C Page 2)	ppm/°C @ 85 C
W-10	21	CF-6	28
W-16	22	CF-7	29
W-11	24	CF-5	30
W-5	27	CF-2	31
W-2	28	CF-15	37
W-4	29	CF-15	38
W-12	33	CF-1	38
W-20	33	CF-16	40
W-1	35	CF-17	41
W-15	38	CF-3	44
W-17	39	CF-12	44
W-3	41	CF-10	45
W-19	47	CF-18	45
W-14	48	CF-1 T-1	46
W-13	50	CF-9	47
W-18	58	CF-2 T-1	48
W-7	80	CF-4	49
W-8	93	CF-8	50
W-6	96	CF-14	72
		CF-11	94

NOTE: 1. All values are averages of 6 coils.

2. Prior to test all windings given 20 alternate 15 minute exposures to -12 C and +85 C


#39 WIRES
NOTE:
ALL VALUES ARE AVERAGES OF 6 COILS
NUMBERS INSIDE BAR COLUMNS REPRESENT AVERAGE INITIAL FREQUENCIES IN CPS PRIOR TO TEST. ALL WINDINGS GIVEN 20 ALTERNATE 15 MINUTE EXPOSURES AND +85C
ALL DEVIATIONS ARE NEGATIVE
DEVIATION IN CYCLES PER SECOND AT 85C
800
700
600
500
400
300
200
100
0
W-1
W-8
W-7
W-18
W-13
W-14
W-19
W-3
W-17
W-15
W-1
W-12
W-20
W-2
W-12
W-5
W-11
W-16
W-10
WIRE INSULATION (SEE APPENDIX C PAGE 2)


TEMPERATURE STABILITY OF FORM MATERIAL
FORM DIMENSIONS
NOTE:
ALL VALUES ARE AVERAGES OF 6 COILS
WAX IMPREGNATED FORM
NEGATIVE
FORM MATERIAL (SEE APPENDIX C PAGE I)
CF-11
CF-14
CF-4
CF-12
CF-10
CF-17
CF-16
CF-13
CF-15
CF-6
4/20/54



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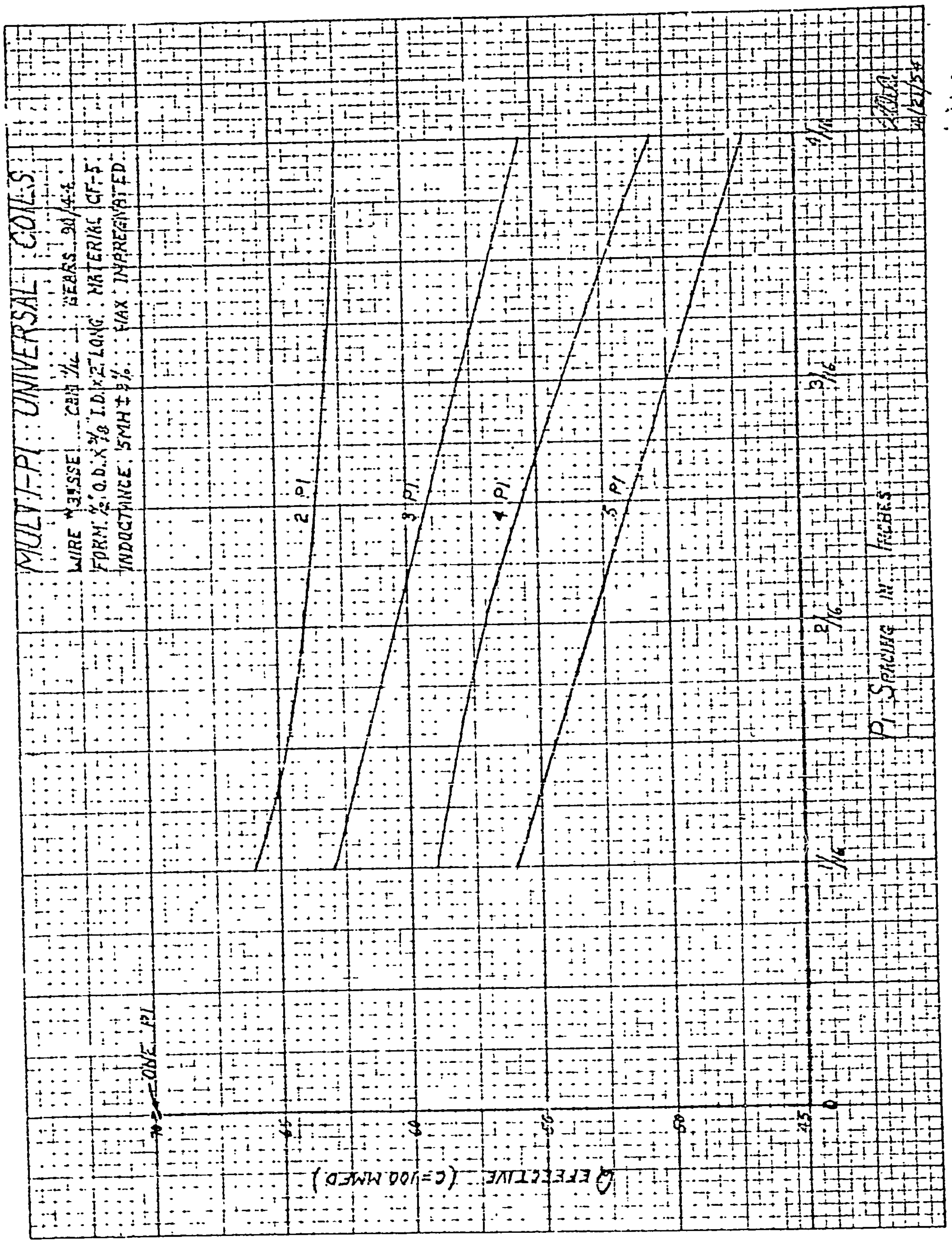

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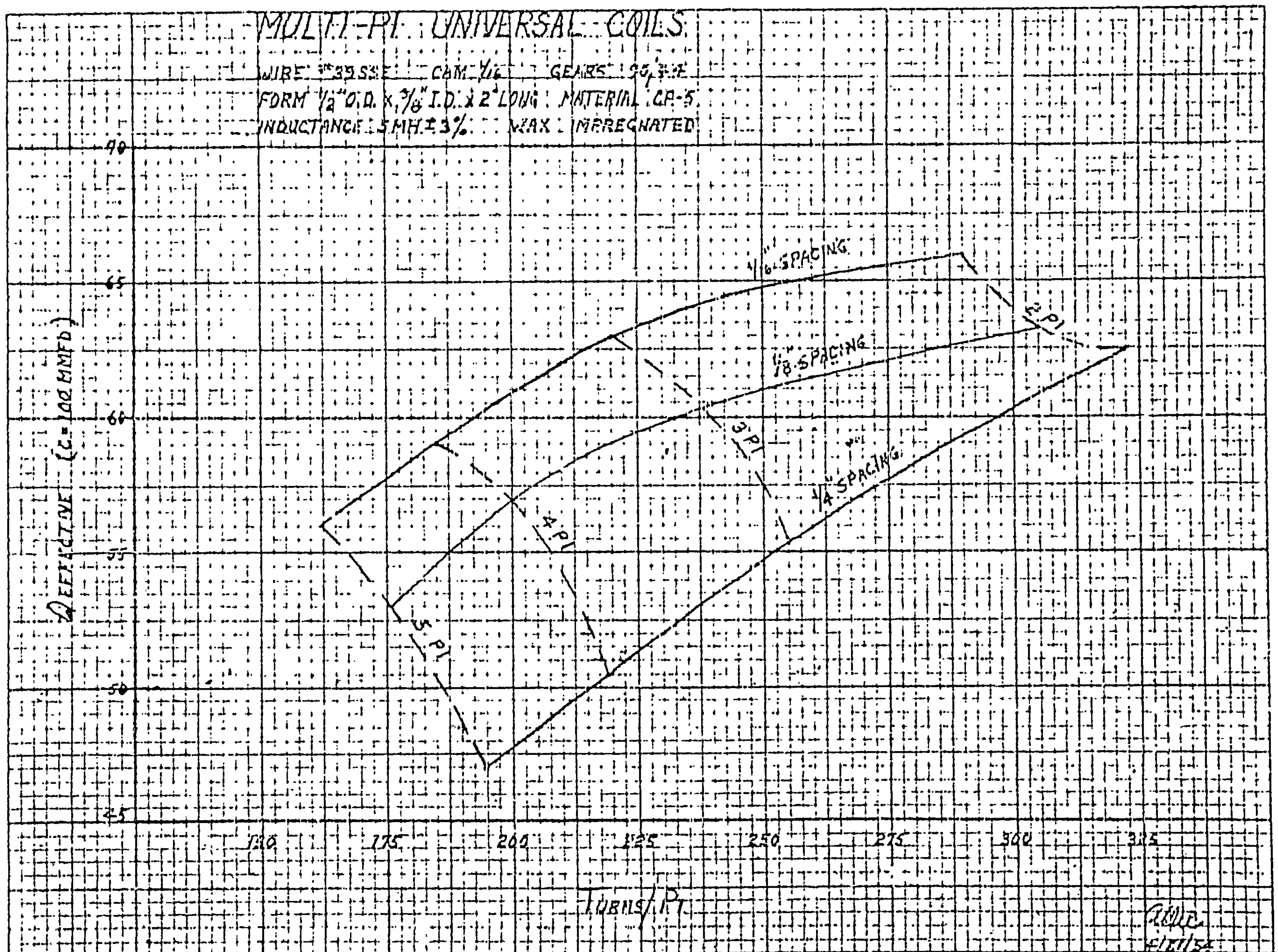

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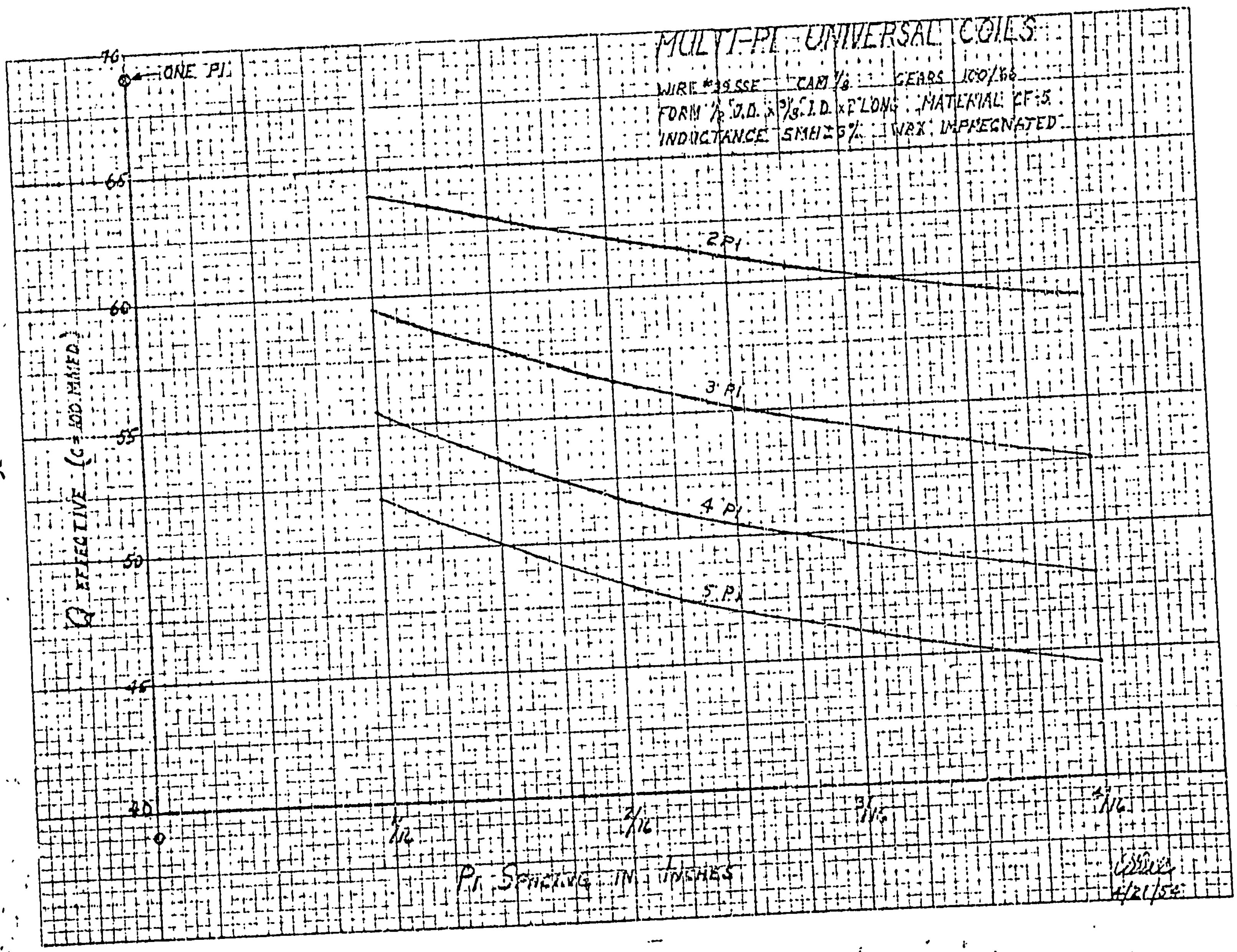
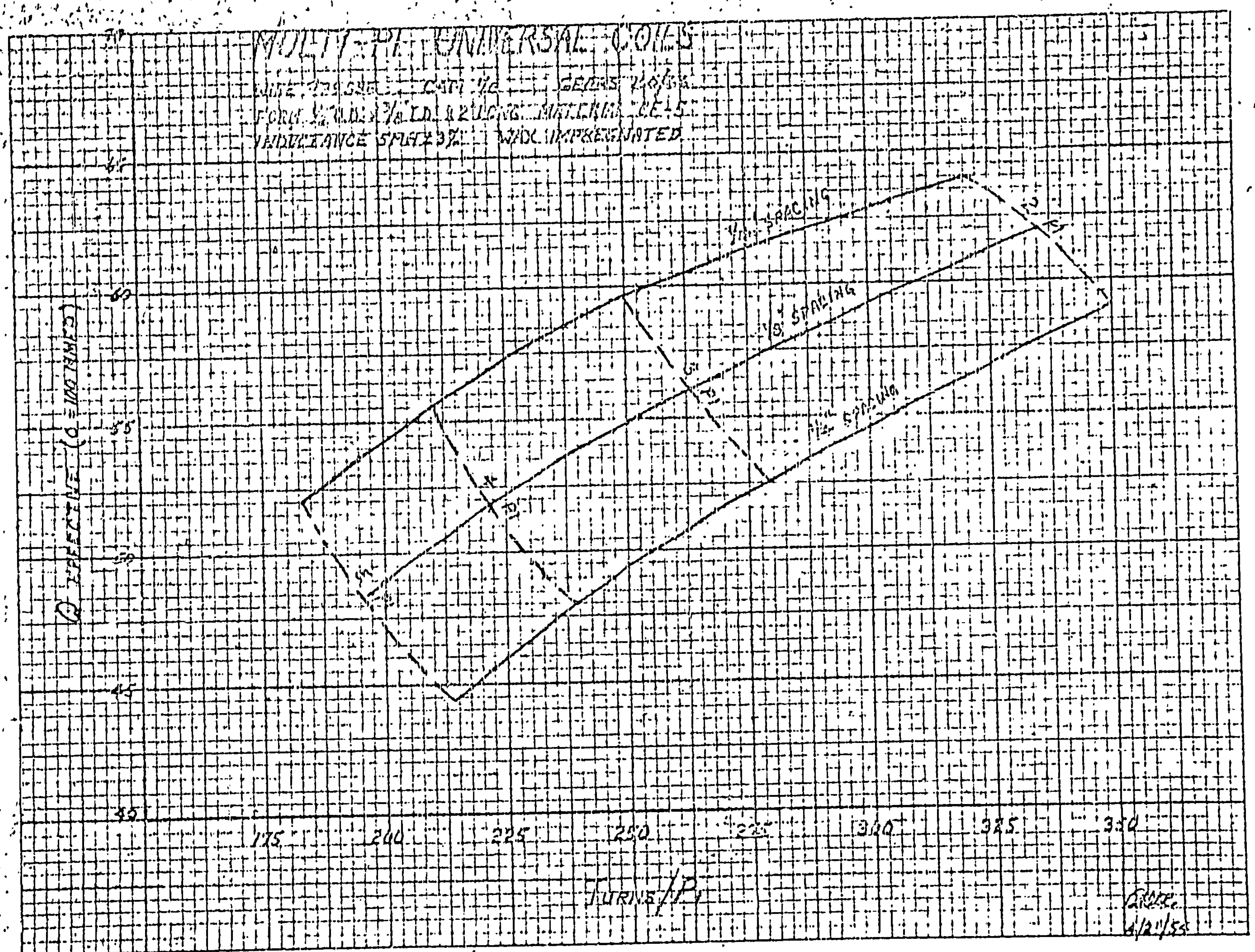

MULTI-PI UNIVERSAL COILS
WIRE #39 SSE CAM 1/8 GEARS
FORM 1/2" O.D. x 3/8" I.D. x 2" LONG MATERIAL CF-5
INDUCTANCE 5MH±5% WAX IMPREGNATED
ONE PI
2 PI
3 PI
4 PI
5 PI
70
65
60
55
50
45
40
0
1/16
2/16
3/16
4/16
Q EFFECTIVE (C = 100 MMFD.)
PI SPACING IN INCHES
4/21/54

NO. 340 10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO
MADE IN U. S. A.



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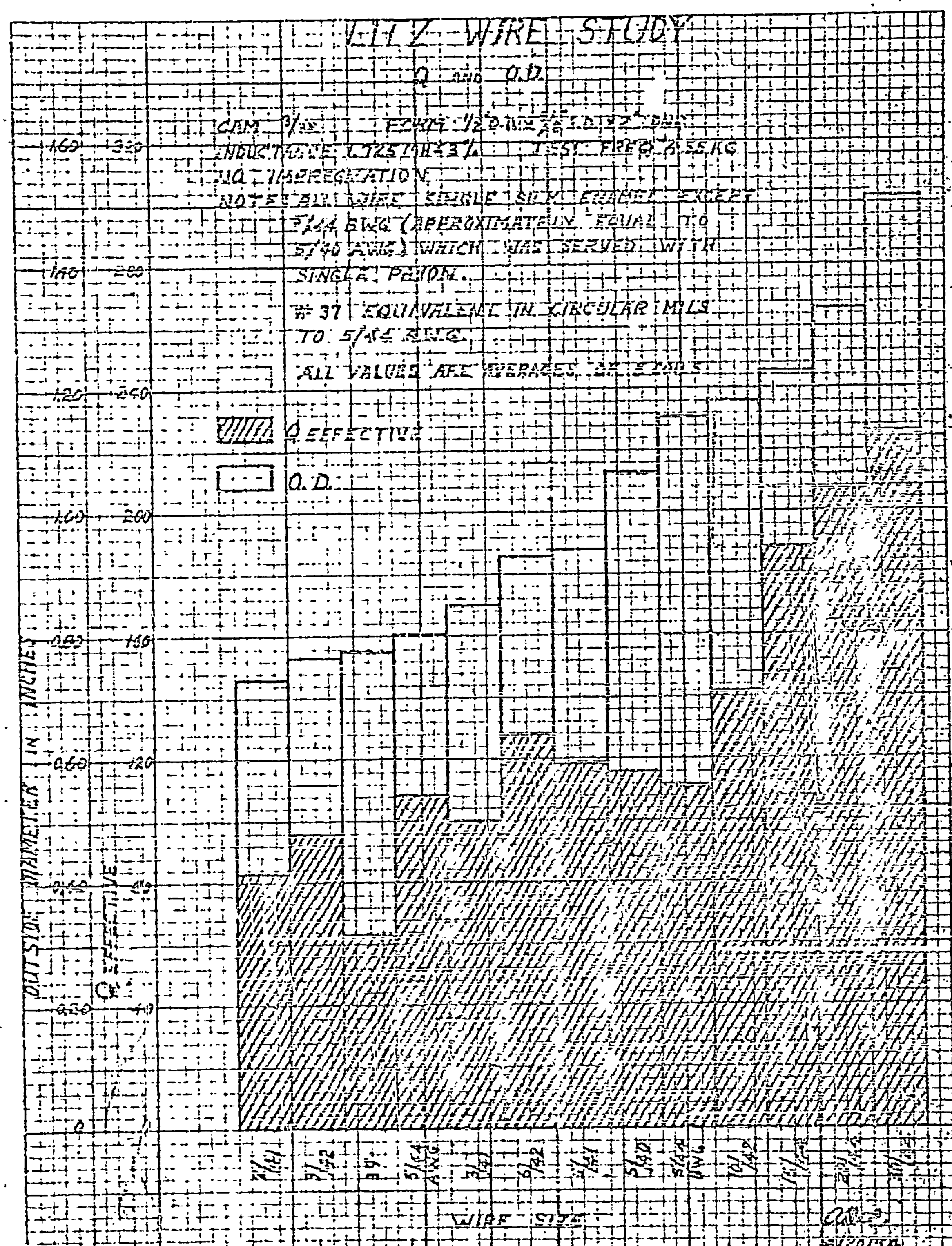
LITZ WIRE STUDY
Q and O.D.
SINGLE PEION.
#37 EQUIVALENT IN CIRCULAR MILS
TO 5/44 B.W.G.
Q EFFECTIVE
O.D.
OUTSIDE DIAMETER IN INCHES
Q EFFECTIVE
WIRE SIZE

LITZ WIRE STUDY

No. 5/44 SSE Twists/Ft.	Core 1/4 Gears 54/106 Form 1/2 inch OD		Core 3/32 Gears 67/44 Form 1/2 inch OD				Core 1/16 Gears 51/48 Form 0.176 OD			
	Q f=110 kc	L (mh) @ 79 kc	Q f=376 kc	L (mh) @ 250 kc	Q f=455 kc	L (mh) @ 250 kc	Q f=738 kc	L (mh) @ 790 kc	Q f=455 kc	L (mh) @ 790 kc
Commercial-As normally supplied	89	19.75	106	1.72	113	1.72	95	0.468	76	0.468
Parallel	84	19.75	102	1.74	108	1.74	94	0.477	75	0.477
18	87	19.70	101	1.72	109	1.72	94	0.476	74	0.476
65	85	19.45	102	1.73	110	1.74	94	0.465	76	0.465

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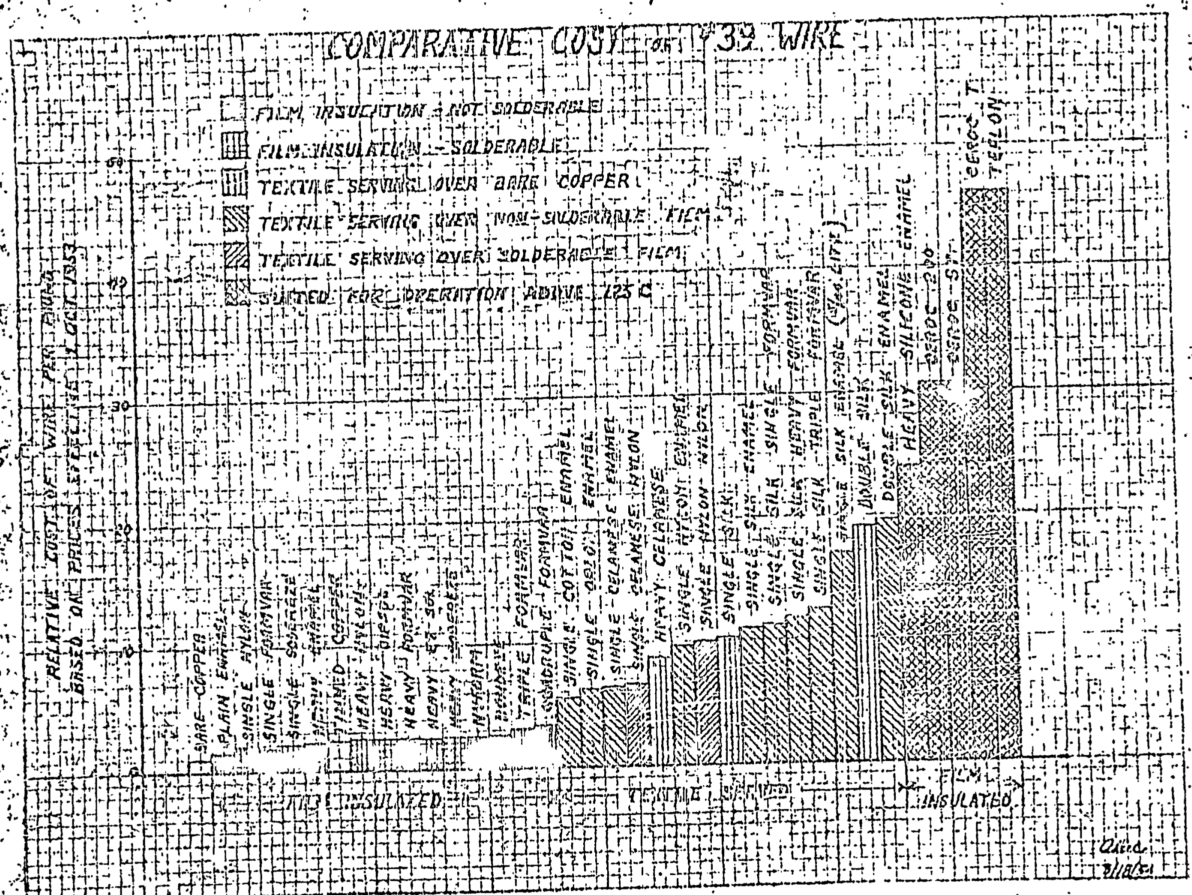


POOR ORIGINAL

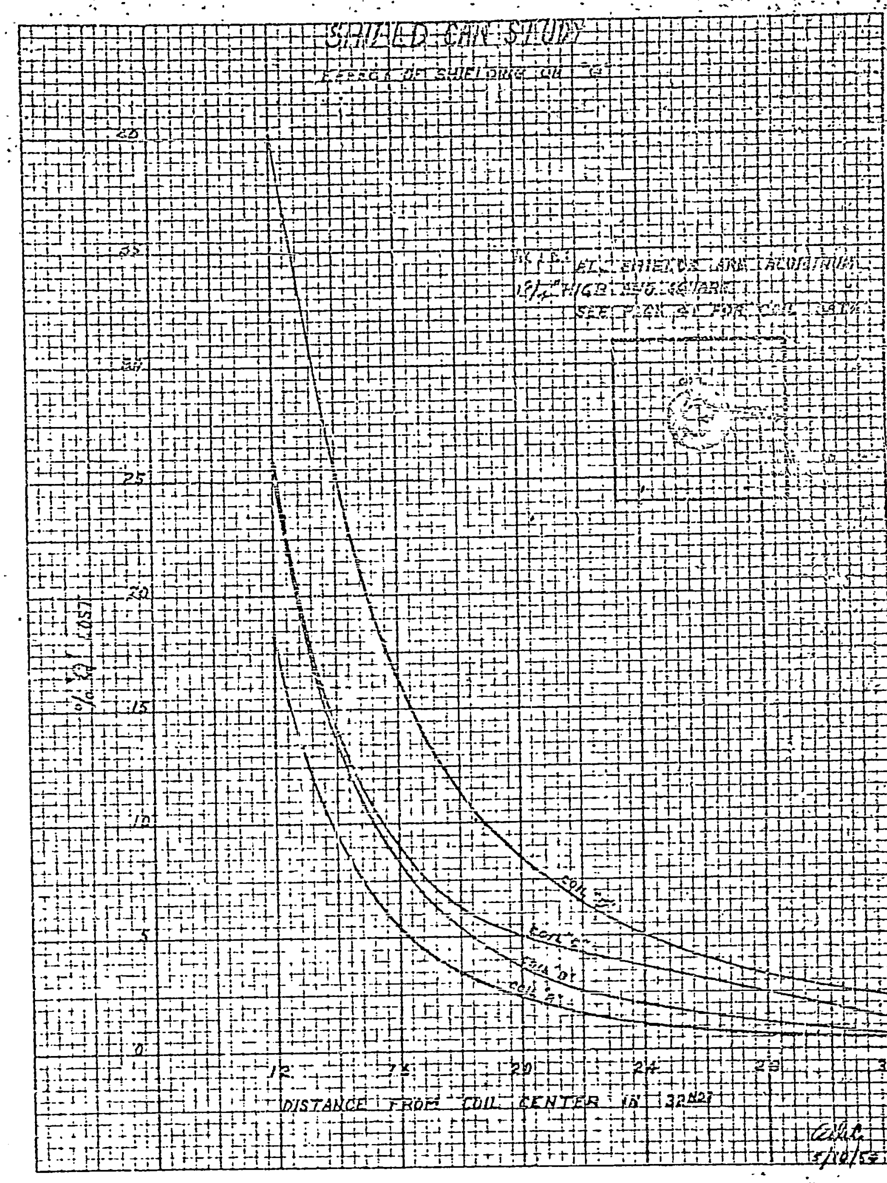
SHIELD CAN STUDY

COIL DATA

	COIL "A"	COIL "B"	COIL "C"	COIL "D"
Wire	No. 39 H.F.	No. 39 H.F.	No. 5/44 SSE	No. 5/44 SSE
Cam	3/32	3/32	3/32	3/32
Gears	56/74	56/74	51/67	51/67
Turns	500	500	225	225
End Spacing	0.425"	0.425"	0.425"	0.425"
OD	0.516"	0.516"	0.523"	0.523"
Coil Width	0.115"	0.115"	0.120"	0.120"
Coil Form OD	0.285"	0.285"	0.285"	0.285"
Core	None	Plast-Iron E-231	None	Carbonyl E
Impregnation	Wax	Wax	Wax	Wax
Frequency	455 kc	455 kc	455 kc	455 kc
Coil "Q" (No Shield)	59	74	79	122
C	46.91 muf	27.93 muf	252.09 muf	155.91 muf
Calculated Inductance	2610 uh	4380 uh	485 uh	785 uh

NO 340, 1-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

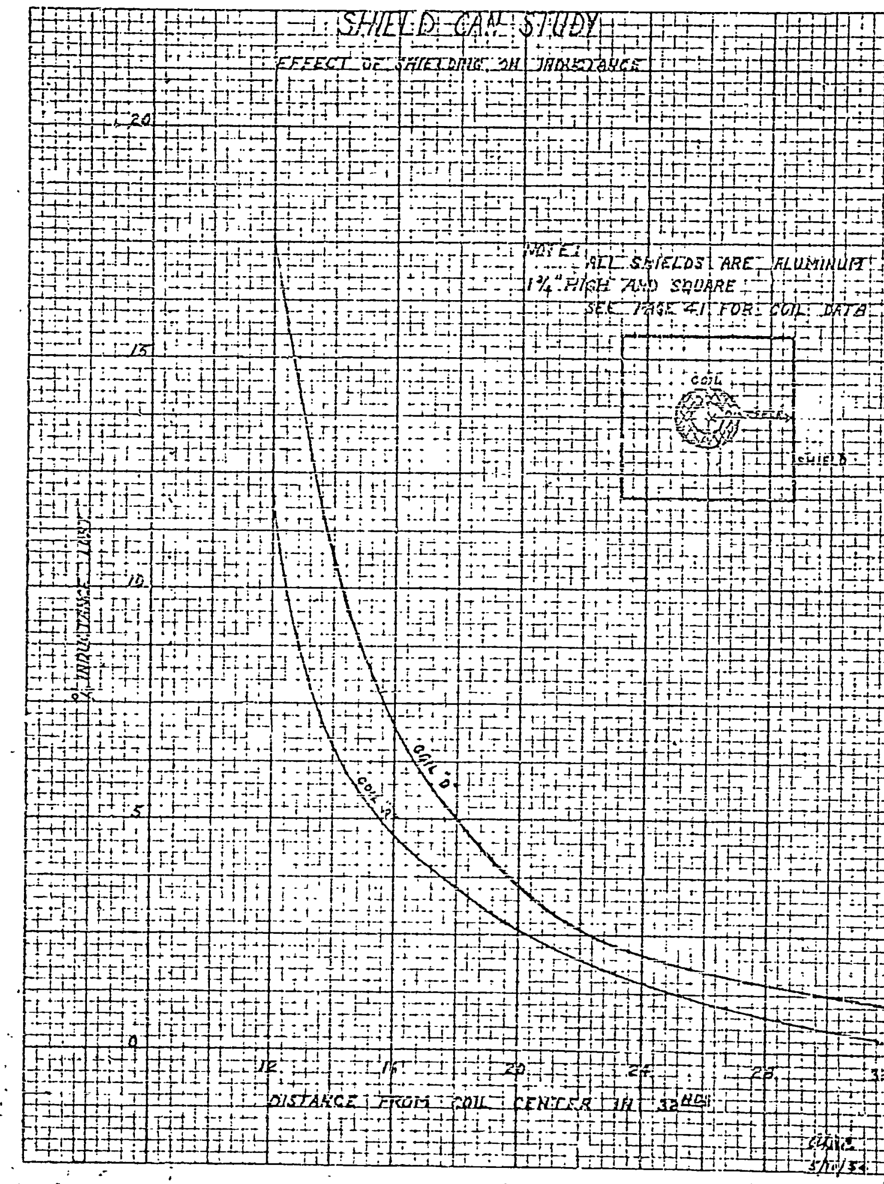
EUGENE DIETZGEN CO.
MADE IN U. S. A.



-42-

NO 340 I-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO
MADE IN U. S. A.



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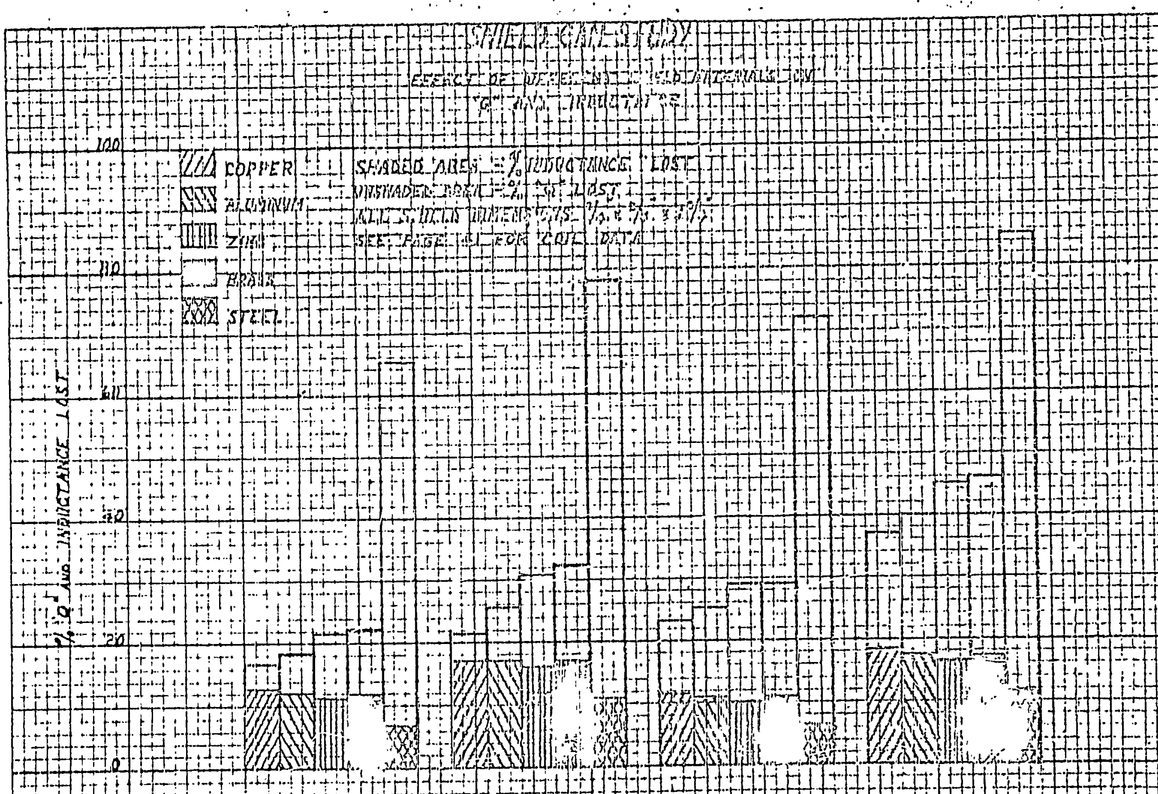
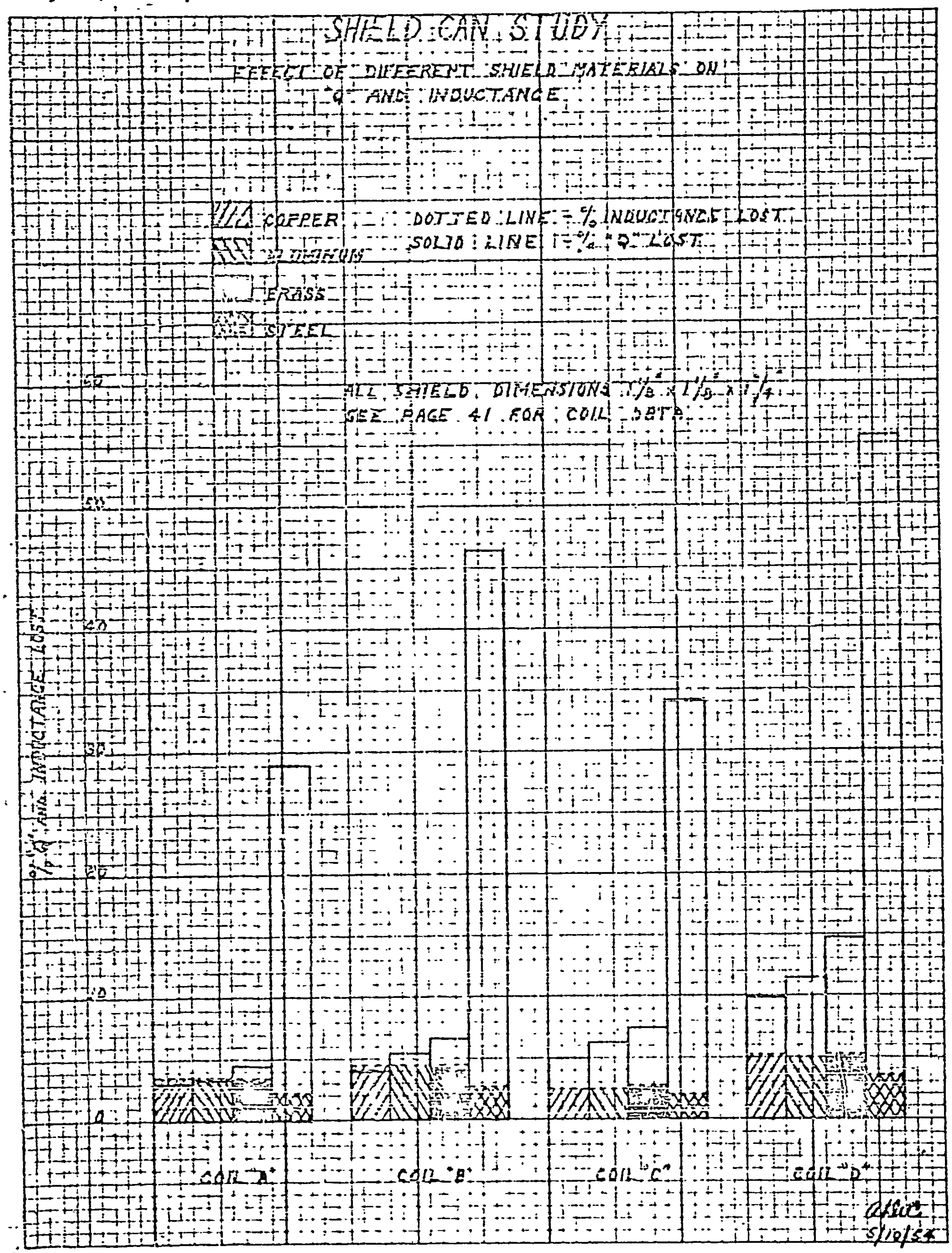
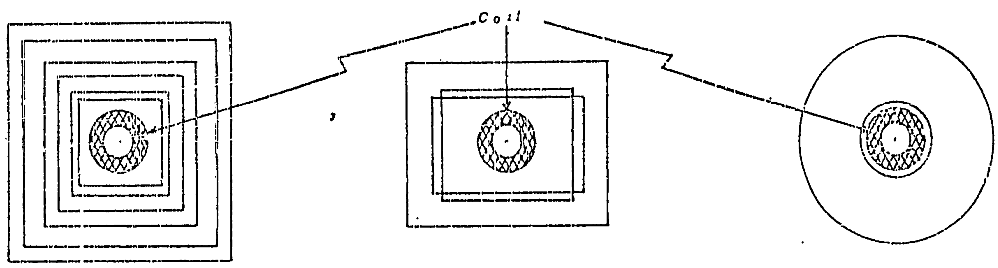

COPPER
ALUMINUM
ZINC
BRASS
STEEL
SHADED AREA = % INDUCTANCE LOST
SEE PAGE FOR COIL DATA
% Q AND INDUCTANCE LOST
100
20
0
COIL "A"
COIL "B"
COIL "C"
COIL "D"


SHIELD CAN STUDY
EFFECT OF DIFFERENT SHIELD MATERIALS ON "Q" AND INDUCTANCE
COPPER
BRASS
STEEL
DOTTED LINE = % INDUCTANCE LOST
SOLID LINE = % "Q" LOST
ALL SHIELD DIMENSIONS
SEE PAGE 41 FOR COIL DATA
% Q AND INDUCTANCE LOST
60
50
40
30
20
10
0
COIL "A"
COIL "B"
COIL "C"
COIL "D"
5/10/54

PERCENTAGE "Q" LOST DUE TO SHIELD SIZE



	¾ x ¾"	7/8 x 7/8"	1-1/8x1-1/8"	1-3/8x1-3/8"	1½x1½"	2 x2"	13/16x1-3/8"	15/16x 1-3/16"	1-3/8 x 13/16"	5/8" OD	1¼" OD
COIL "A"	19.1%	10.4%	4.4%	2.6%	1.7%	1.6%	8.0%	5.9%	1.7%	55.7%	2.6%
COIL "B"	25.5%	13.5%	5.4%	2.6%	1.3%	0.6%	10.7%	6.7%	2.0%	63.5%	1.3%
COIL "C"	25.3%	13.9%	7.5%	3.7%	2.5%	1.2%	[illegible]	8.1%	2.5%	63.7%	2.5%
COIL "D"	41.0%	25.4%	12.2%	6.5%	3.2%	[illegible]	20.7%	15.5%	4.8%	75.6%	4.8%

ALL SHIELDS ARE ALUMINUM 1-3/4 inches HIGH AND 0.017-0.024 inches THICK

SEE PAGE 41 FOR COIL DATA

SCALE 1:1

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SHIELD CAN STUDY

Shield Dimension	COIL "A" % Inductance Lost Grounded	COIL "A" % Inductance Lost Not Grounded	COIL "A" % Q Lost Grounded	COIL "A" % Q Lost Not Grounded	COIL "D" % Inductance Lost Grounded	COIL "D" % Inductance Lost Not Grounded	COIL "D" % Q Lost Grounded	COIL "D" % Q Lost Not Grounded
5/8" OD	35.0%	34.3%	55.7%	53.6%	44.0%	43.6%	75.6%	75.3%
1-3/4" OD	1.2%	-2.0%	2.6%	1.0%	2.1%	2.2%	4.5%	4.0%
3/4 x 3/4"	12.2%	12.5%	19.1%	18.8%	17.6%	17.5%	41.0%	40.1%
7/8 x 7/8"	6.6%	7.2%	10.4%	9.5%	10.5%	10.8%	25.4%	25.4%
1-1/8 x 1-1/8"	3.5%	3.6%	4.4%	3.4%	5.0%	5.2%	12.2%	12.2%
1-3/8 x 1-3/8"	2.0%	2.3%	2.6%	1.5%	2.6%	2.9%	6.5%	6.5%
1-3/4 x 1-3/4"	0.8%	1.1%	1.7%	0.8%	1.5%	1.7%	3.2%	3.2%
2 x 2"	0.3%	0.8%	1.6%	0.5%	1.1%	1.1%	2.3%	2.3%
13/16 x 1-3/8"	5.0%	5.7%	8.0%	7.0%	7.9%	8.1%	20.5%	20.5%
15/16 x 1-3/16"	4.2%	4.2%	5.9%	4.6%	6.3%	6.3%	15.5%	14.7%
1-3/8 x 1-13/16"	1.0%	1.7%	1.7%	1.2%	1.6%	2.2%	4.8%	4.8%

ALL SHIELDS ALUMINUM 1-3/4" HIGH AND 0.017"-0.024" THICK

SEE PAGE 41 FOR COIL DATA

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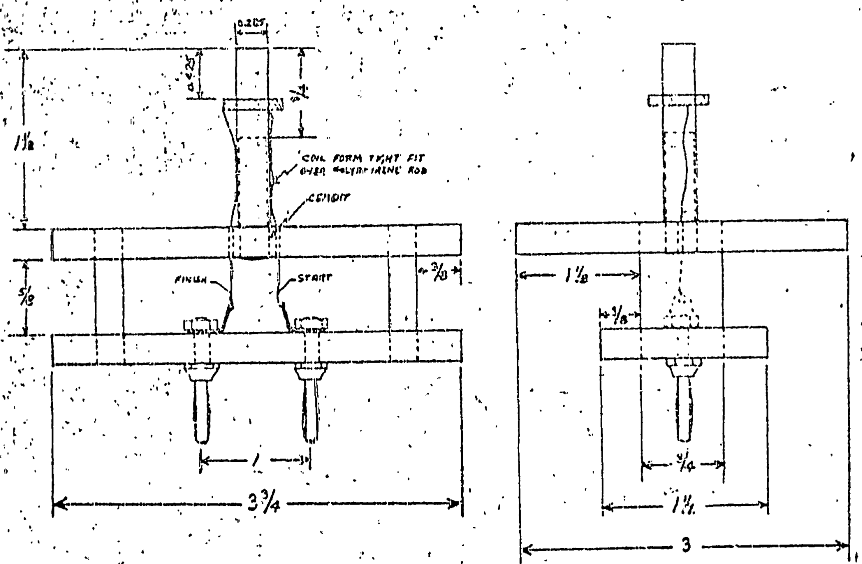
Q-METER JIG
FOR
SHIELD CAN STUDY



MATERIAL: POLYSTYRENE 1/4" THICK
SCALE 1:1

[illegible]
5/10/54

APPENDIX C

Code Numbers for Materials Tested

Treatment Materials

Additions to:

Wire
Coil Form Materials

Treatment Materials

T-1	Wax
T-2	Synthetic Baking Varnish
T-3	Synthetic Baking Varnish
T-4	Synthetic Baking Varnish
T-5	Silicone Baking Varnish
T-6	Coil Impregnant (Composition unknown)
T-7	Casting Material (Styrene base)
T-8	Casting Material (Epoxy base)
T-9	Air Drying Lacquer
T-10	Polyester Resin
T-11	Polyester Resin
T-12	Epoxy Resin
T-13	Varnish Thinner

Wire

W-20	Silicone Enamel

Coil Form Materials

CF-17	XX Bakelite (Molded)
CF-18	XXX Bakelite (Rolled)