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AUTHORITY
EO 10501 dtd 5 Nov 1953; Navy ltr dtd 1 Apr 1968

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BIMONTHLY PROGRESS REPORT
R-222.21-52, PIB-167.21

ON

ATTENUATORS

October 1952 - November 1952

Prepared for

BUREAU OF SHIPS

CONTRACT NObsr-43360

MRI

POLYTECHNIC INSTITUTE OF BROOKLYN
MICROWAVE RESEARCH INSTITUTE

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Report R-222.21-52, PIB-167.21
Contract No. NObsr-43360
Index No. 100-402

BIMONTHLY PROGRESS REPORT
For the Months of
October 1952 - November 1952
on
Navy Contract NObsr-43360
"Attenuators"

Title Page
10 Pages of Text
4 Pages of Tables
10 Pages of Figures

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Brooklyn 1, New York
December 31, 1952

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I. Scope of the Program

The present phase of the program is based upon a technical proposal which was submitted to the Navy Department, Bureau of Ships, as a basis for extension of Contract NObsr-43360 beyond the expiration date of October 31, 1952. The proposal included the following data:

A. Objectives

The present contract phase which commenced on November 1, 1951, was initiated in order to realize the following objectives.

1. Development of a broadband variable attenuator for 7/8" coaxial line.
2. Design of fixed attenuators for 3/8" coaxial line.
3. Improvement of high-power probe attenuators for 7/8" coaxial line.
4. Development of a high-power probe attenuator for 1 5/8" coaxial line.
5. Measurement of phase-shift characteristics of waveguide attenuators developed for the frequency range of 2600-10,000 mc/sec.
6. Design of 20db and 70db metallized-glass plates for guide size 1 1/2" x 3/4".

The main emphasis has been to conceive improved and new types of attenuators essential for the determination of accurate data intrinsic to the development of radars and guided missiles.

B. Current Status

1. Broadband Variable Coaxial Attenuator

The principle employed is to insert a resistance element through a slot milled in the outer conductor into the 7/8" coaxial line parallel to the electric field.

Theoretical and experimental investigations have been performed to understand the effect of eccentricity, the nature of the coupling between inner and outer conductors, and the action of surface resistivity and geometry of the resistance element on attenuation and VSWR characteristics. Promising results have been obtained for an attenuator consisting of a coaxial line without eccentricity in which a resistance element of non-uniform resistivity is introduced. It appears that such an attenuator

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can be designed to have a maximum attenuation of at least 30db with a VSWR of not greater than 1.4 in the bandwidth of 1000 to 4000 mc/sec.

2. Fixed Attenuators for 3/8" Coaxial Line

A complete set of series element type attenuators covering the range from 0.1 to 0.7db in 0.1db steps has been fabricated whose attenuation values at d-c lie well within 2% tolerance limits under operating conditions. In order to measure low attenuations accurately at microwave frequencies, various methods have been studied. The scheme decided upon utilizes a broadband choke-bucket type and non-contacting short-circuit which has been designed and constructed.

A complete set of shunt metallized mica-disk type attenuators has been prepared. In addition, units of the chimney type have been constructed. These are being tested over a broad frequency range for attenuation values within a 2% tolerance limit.

The aim is to make available fixed attenuators over the frequency limits of 0-4000 mc/sec in the following attenuation range:

0 - 1.0db:	in steps of 0.1db
3.0 - 12.0db:	in steps of 1.0db
10db - 40db:	in steps of 10db

In addition, these attenuators can be combined in a suitable arrangement to realize a precision decade attenuator to be used as a reference standard in the frequency bandwidth of 1-1500 mc/sec. Such a decade attenuator capable of distinguishing differences in attenuation of 0.1db is not commercially available.

3. High-Power Probe Attenuators

A probe attenuator designed for 7/8" coaxial line has been shown to possess a power handling capacity of 300,000 watts peak or one kilowatt average. Modification of this design has led to a high power probe attenuator where the breakdown strength between the inner conductor of the probe line and the inner conductor of the main line is approximately 10 kilovolts corresponding to better than 3.5 megawatts peak power. Further efforts to improve the breakdown strength become valueless since the breakdown strength between the main line and the probe line exceeds that of the main line itself.

A preliminary design of a 50db 1 5/8" coaxial probe attenuator has been completed and submitted for fabrication. This larger coaxial unit will have a higher peak power handling capacity and consequently broader applications.

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4. Phase-Shift Characteristics

Various components have been constructed for measuring the phase-shift characteristics of the $1\frac{1}{4}" \times \frac{5}{8}" \times 0.064"$ waveguide attenuator. The method employs a twin-line in a bridge arrangement. Further evaluations are being made before measurements are undertaken.

The four attenuators of interest in the frequency range of 2600-10,000 mc/sec. are $3" \times 1\frac{1}{2}" \times 0.080"$, $2" \times 1" \times 0.064"$, $1\frac{1}{2}" \times \frac{3}{4}" \times 0.064"$, and $1\frac{1}{4}" \times \frac{5}{8}" \times 0.064"$.

5. Special 20db and 70db Attenuators

The development of a 20db and 70db attenuator plates for guide size $1\frac{1}{2}" \times \frac{3}{4}"$ over the frequency range of 5,400-5,900 mc/sec. has been completed. These plates will be used in special casings for guided missile research at the Johns Hopkins University.

C. Proposed Extension

The following program is proposed for extension of the contract from November 1, 1952 through October 31, 1953.

1. Broadband Variable Coaxial Attenuator

Design of a broadband variable $\frac{7}{8}"$ coaxial attenuator in the frequency range of 1000 to 4000 mc/sec. incorporating an element of non-uniform resistance.

2. Fixed Attenuators for $\frac{3}{8}"$ Coaxial Line

- (a) Measurements of attenuation of less than one db are to be refined to permit accurate calibration of these attenuators.
- (b) Completion of $\frac{3}{8}"$ fixed attenuators in the range of 0 - 40db.
- (c) Design of a mechanism for a precision decade attenuator utilizing the $\frac{3}{8}"$ fixed attenuator series.

3. High-Power Probe Attenuators

- (a) Fabrication and test of $1\frac{5}{8}"$ coaxial probe attenuator.
- (b) Development of a high-power probe attenuator in L-Band Waveguide.

4. Phase-Shift Characteristics

Continuation of measurement of phase-shift characteristics of waveguide attenuators from 2600 mc/sec. to 10,000 mc/sec.

II. Detailed Data*

A. Fixed Attenuators for 3/8" Coaxial Line

In connection with this program, three measurement systems are being assembled to determine the attenuation values of the units at d-c, 200 megacycles/sec., and at discrete frequencies in the 1000 - 4000 megacycle/sec. region. Modification of the coaxial impedance meter for use in attenuation measurements at 200 megacycles, and described in the last progress report, is near completion. In addition further work was required on the broadband short circuit after testing wherein it was discovered that the VSWR presented at the input terminals of the short circuit was too low to be satisfactory for use in the precision measurements of the low db value attenuators.

As was indicated in the last report, a complete new set of attenuators is being prepared. Units of the shunt-metallized mica disk type, including a 10db, 11db, 12db, 20db and 30db attenuators have been completed and are presently being measured for VSWR and attenuation. Most of the other units, including the series element and chimney type covering the lower ranges of attenuation values, are either near completion or being assembled. It is anticipated that VSWR and attenuation data for these units will be presented in the next progress report.

B. Probe Attenuators

Arrangements are being made with the Microwave Tube Section, Code 924, Materials Laboratory, N.Y. Naval Shipyards, Brooklyn, New York, for high power RF testing of the 7/8" coaxial probe attenuator. It is expected that pulsed power up to 1 megawatt peak in the S-band region will be available for use in breakdown testing of the unit.

Fabrication of the preliminary design of a 1 5/8" coaxial probe attenuator is near completion. At the same time, measurements are under way at the present to specify optimum configuration of 1 5/8" coaxial teflon bead supported broadband couplings.

Further work on the L-Band probe attenuator includes the design of a test unit to determine the parameters of the equivalent circuit of the probe attenuator structure in the waveguide system.

*Principal contributors to this report include Mr. M. Wind, Mr. H. Rapaport, and Dr. L. M. Vallese.

C. Magnetic Attenuators

1. Visit to Naval Research Laboratory

On November 24, 1952, a visit was made to the Naval Research Laboratory for the purpose of becoming acquainted with its program on Ferrite research. A discussion held with Messrs. H. N. Chait and N. G. Sakiotis and Dr. M. L. Kales revealed the usefulness of Ferrites as attenuation media in microwaves. Much was learned regarding companies manufacturing Ferrites. They include

General Ceramics and Steatite Corp., Keasbey, N. J.

Ferroxcube Corporation of America, New York, N. Y.

Henry L. Crowley and Co., West Orange, N. J.

However, very little data appears to be available on the broadband attenuation characteristics of Ferrites.

2. Polyiron Attenuators

A Polyiron Attenuator was described in the August, 1951, issue of the Technical News Bulletin of the National Bureau of Standards. The dissipation of energy associated with a propagating electromagnetic wave within a coaxial line was accomplished by the placement of a highly permeable and resistive ferromagnetic material, such as, Polyiron, along the axis of propagation.

This principle was utilized at MRI in an effort to produce a variable 3db coaxial attenuator for use from 1000 - 4000 mc/sec. in connection with precision measurement of low db valued attenuators. In the course of this development, various effects were observed, details of which are as follows:

Experiment a

The first experiment was performed using a 7/8" rigid coaxial line. A 0.356" O.D. center conductor of Polyiron D 1.5" long was made and inserted into the 7/8" line replacing the original center conductor. An external permanent magnet of the horseshoe type was oriented so that the field was either in a longitudinal direction in the direction of power propagation or in a transverse direction at right angles to the direction of power propagation.

(1) With the magnetic field longitudinal and at a frequency of 2000 mc/sec. an increase of attenuation of approximately 1/2 db was noted.

(2) With the magnetic field transverse and at a frequency of 2000 mc/sec. an increase of attenuation of approximately 1/2 db was again noted.

In both cases, the magnitude of the variation depended on the orientation and proximity of the magnet.

Experiment b

The device described in Experiment a was used as the core of a 1200 turn coil of No. 20 wire. This magnetizing coil was 1.5" long and 3.5" O.D. wrapped on the 7/8" coaxial outer conductor. With 1 ampere D.C. through this coil and at a frequency of 2000 mc/sec. an attenuation of 1/2 db was noted. This attenuation was an increase.

Experiment c

(1) In order to obtain stronger fields and to enhance the attenuation observed in Experiment b, a unit to approximate 3/8" coaxial line was constructed. A brass outer conductor with an I.D. of 0.356" was selected. A cylinder of Polyiron D 1.5" long which filled the brass cylinder was inserted. Two type N male connectors were used as end pieces for the brass cylinder. The center conductors of 0.120" Diam. were butted against the ends of the Polyiron. A coil of 1200 turns of No. 22 wire, 1-3/4" long and 1-3/4" O.D., was wrapped around the brass cylinder. With this specimen and at a frequency of 2000 mc/sec. the insertion loss was too high for measurements to be taken.

(2) By experiment, the length of the Polyiron cylinder was reduced to 1/2". Attenuation measurements were taken using a Ballantine VTVM and bolometer technique. Alternating current (60 c.p.s.) was used as the magnetizing coil supply. The data given in Table I was obtained and the curves of Fig. MRI-12933 show the variations in transmitted power as a function of magnetizing coil current.

(3) The Polyiron cylinder length was reduced to 1/4" and the experiment described in (2) was repeated. The data given in Table II was obtained and the curves of Fig. MRI-12934 show the variations in transmitted power as a function of magnetizing coil current.

(4) To determine the effect of recessing the center conductors, the 1/4" cylinder described in (3) was removed and replaced with a cylinder of Polyiron D 11/16" long with recessed holes for the center conductors. These holes were 1/4" deep producing 3/16" between center conductors. Again the experiment described in (2) was performed. The data is given in Table III and the curves of Fig. MRI-12935 and Fig. MRI-12936 illustrate the variations in transmitted power as a function of magnetizing coil current.

(5) The 11/16" specimen described in (4) was next drilled through so that the center conductor was continuous. The experiment described in (2) was repeated and the data is given in Table IV. The curves of Fig. MRI-12937, Fig. MRI-12938, and Fig. MRI-12939 show the variations of power as a function of magnetizing coil current.

V.S.W.R. Data

While no formalized design was attempted for these specimens described under Experiment c, some VSWR measurements were taken. In all cases the system was matched to better than a VSWR of 1.05 before insertion of the device.

Butted Center Conductors

<u>Frequency (mc/sec.)</u>	<u>VSWR</u>
980	6
1285	9
1500	7
2000	10

1 - 1/4"

Recessed Center Conductors

<u>Frequency (mc/sec.)</u>	<u>VSWR</u>
980	2.5
1500	2.0
2000	1.5
2500	3.0
3500	3.8
4000	4.2
4500	3.0

1 - 11/16"

Continuous Center Conductor

<u>Frequency (mc/sec.)</u>	<u>VSWR</u>
980	2.8
1500	1.8
2000	2.9
2500	3.0
3000	2.6
3500	2.6
4000	2.4
4500	3

1 - 11/16"

Other measurements indicated that the VSWR changed as a function of coil current. The above readings are with zero magnetizing current.

Measurement of Magnetic Field

In order to measure the field produced by the magnetizing coil at the center of the specimen (Experiment c (1), (2), (3), (4) and (5)), a search coil was made. Using a Ballantine V.T.V.M. the calibration curve for the magnetizing coil, Fig. MRI-12940, was produced.

Conclusions

(1) Although the extent of the data obtained at this time is limited and precludes a general analysis, certain conclusions seem to be evident from the curves.

(a) It is possible to vary the power transmitted along a coaxial line by applying an A.C. longitudinal magnetizing field to a polyiron bead in the line.

(b) The variations in transmitted power may be increases or decreases from the reference power level. Thus, attenuations and "deattenuations" are both possible.

(c) The polyiron bead may be in the form of: bead with butted center conductors, bead with recessed center conductors, and bead with continuous center conductor.

(2) It is to be noted that in all cases with the use of polyiron as the bead and alternating current in the magnetizing coil, the original reference levels were reproduced when the coil current was returned to zero.

(3) Because of equipment limitations it was not possible to obtain a set of comparative D.C. magnetizing coil readings. However, preparation is being made so that both D.C. and A.C. readings may be taken and the results compared. A unit to hold the specimens and provide quick interchange of inserts is also in preparation. In the construction of this unit, a more formalized design for VSWR and impedance matching will be attempted. In addition to the present specimen material, other ferromagnetic materials, such as the ferrites, are to be examined and tested.

D. 7/8" Coaxial Variable Attenuator

In the previous progress report, a unit was described which presented favorable attenuation and VSWR results in the range of frequencies 1500 - 4000 mc/sec. The dissipative element used in this unit consisted of a Bakelite strip of length 9", coated with a layer of graphite of resistivity 50 ohm/square. The graphite layer, which was cut with a convex form of large radius of curvature, was provided with vertical slits in the outer thirds of

its length and was protected with cellophane scotch-tape. As a result of the presence of these slits, the surface resistivity varied from 50 ohm/square in the central portion to ~60 ohm/square in the outer portions. The change in resistivity is computed with the formula $\rho' = 50/1 - n\delta$ where δ is the width of each slit and n the number of slits per unit square. In the range of frequencies indicated, this type of attenuator presents VSWR values less than 1.3. However, the attenuation varies at large rate with the penetration and is a function of frequency. In addition, a very small reactive effect still is present and produces small steps in the attenuation-versus-penetration curves. Further experimentation is now directed towards the investigation of the effect of the law of variation of the resistivity.

A temporary shortage of the type of IRC resistance card described has resulted in the use of a slightly different dissipative element. This one consists of a Bakelite strip, coated with a layer of graphite, which in turn is covered with baked enamel. The enamel cannot be removed without removing at the same time the graphite and for this reason it is not possible to establish ohmic contact between the graphite layer and the outer conductor of the coaxial line as it was done in the case of the previous successful attenuator unit. As a result, disturbing reactive phenomena take place after the insertion reaches a certain value. Fig. MRI-12931 shows the attenuation and VSWR values versus insertion obtained with a card of convex form, radius of curvature 40" and resistivity 50 ohm/square in the central portion and 52 ohm/square in the outer thirds. Fig. MRI-12932 shows the attenuation and VSWR measurements obtained with a card of convex form, radius of curvature 40", resistivity varying from 50 to 54 ohm/square from the central portion outward. Other measurements were taken with a card of convex form and radius of curvature 23"; these, however, are not recorded here because they present very pronounced reactive phenomena even at small values of the insertion.

The experimentation with the type of card just described has not given satisfactory results in the whole. However, rather good values of attenuation and VSWR were obtained in certain cases and a number of interesting conclusions could be drawn. For instance, the importance of the ohmic contact between the dissipative element and the outer conductor of the coaxial line and the critical dependence of the VSWR values upon the curvature of the convex form of the card have been placed in evidence. On the other hand, it has been found necessary to design a new improved mechanical drive for the insertion of the card because of the steepness of the attenuation-versus-insertion curves. For this design we shall utilize the fundamental criteria used in the drive of a slotted section.

To continue the investigation of the effect of variable resistivity, a new dissipative element is being prepared in which the variation of the resistivity is uniform. The element consists of a glass plate with a continuous metallic coating of variable thickness, protected with a layer of silicon monoxide.

E. Phase-Shift Measurements

A phase-shift standard has been calibrated in order to measure the phase-shift properties of the $1\text{-}1/4"$ x $5/8"$ x $0.064"$ attenuator. The curves are shown by Fig. MRI-12954. The maximum attenuation introduced by the loss characteristic of the dielectric at the wavelengths of interest are:

Wavelength (cm)	Maximum Attenuation (db)
3.00	1.35
3.51	1.56
3.74	1.80
4.26	1.35

III. Program for the Next Period

1. Completion of measurement systems to determine the attenuation values of the fixed attenuators at various frequencies.
2. Completion of the fabrication of designed fixed attenuators and $1\text{-}5/8"$ coaxial probe attenuator.
3. Design of L-Band probe attenuator.
4. Further considerations of magnetic attenuators.
5. Design of a metallized glass plate for the $7/8"$ coaxial variable attenuator.
6. Measurement of phase-shift characteristics of $1\text{-}1/4"$ x $5/8"$ x $0.064"$ attenuator.

TABLE I

Power Change as a Function of Coil Current
For Polyiron D, Length 1/2", O.D. .356";
Inner Conductor Ends Butted to Polyiron

Freq.	Insertion Loss	<u>Power Change in Decibels</u> <u>At A.C. Current in Amperes</u>					
		0 amp.	1 amp.	2 amp.	3 amp.	4 amp.	5 amp.
Mc/S	db						
1200	26db	0 db	-0.3db	-0.8db	-1.3db	-1.7db	-2.1db
2100	22	0	-1.2	-4.7	-7.0	-9.4	-11.0
3000	22	0	0	-0.5	-2.0	-4.0	-6.5
4030	22	0	+2.0	+3.4	+3.7	+3.2	+2.5
9424	23.5	0	-0.5	-4.7	-8.0	-10.5	-12.0

TABLE II

Power Change as a Function of Coil Current
For Polyiron D, Length 1/4", O.D. .356";
Inner Conductor Ends Butted to Polyiron

Freq.	Insertion Loss	VSWR	<u>Power Change in Degrees</u> <u>At A. C. Current in Amperes</u>								
			0amp.	0.5amp.	1amp.	1.5amp.	2.0amp.	2.5amp.	3amp.	4amp.	5amp.
Mc/S	db										
980	26.8	6	0	-0.1	-0.3	-0.5	-0.8	-1.1	-1.5	-2.5	-3.5
1285	22.4	9	0	-0.03	-0.03	-0.03	-0.03	-0.05	-0.1	-0.2	-0.3
1500	20.7	7	0	-0.1	-0.3	-0.5	-0.8	-1.0	-1.3	-1.8	-2
2000	22.2	10.5	0	-0.1	-0.4	-0.9	-1.4	-1.9	-2.3	-3.1	-3.9

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TABLE III

Power Change as a Function of Coil Current for Polyiron D, Length 11/16", O.D. .356";

Center Conductor is Recessed

Power Changes in Decibels																		
At A. C. Current in Amperes																		
Freq. Mc/S	Insertion Loss db	VSWR	0 Amp.	0.5 Amp.	1.0 Amp.	1.5 Amp.	2.0 Amp.	2.5 Amp.	3.0 Amp.	3.25 Amp.	3.5 Amp.	3.75 Amp.	4.00 Amp.	4.25 Amp.	4.50 Amp.	4.75 Amp.	5.00 Amp.	
980	32.4	2.5	0	-0.15	-0.5	-0.9	-1.3	-1.8	-2.3				- 3.4				- 4.9	
1500	31.4	2.0	0	-0.6	-1.8	-3.0	-4.3	-5.0	-6.0				- 6.9				- 7.2	
2000	32.3	1.5	0	-0.7	-2.1	-4.0	-5.0	-7.6	-9.0				-11.4				-13.0	
2500	42.5	3.0	0	+1.3	+3	+4.4	+5.3	+5.8	+6.0				+ 5.8	+5.5	5.1	4.6	3.9	
3500	44.5	3.8	0	+1.0	+2.0	+3.3	+3.5	+3.6	+3.7	+3.8	+3.3	+2.8	+ 2.3	+1.9	+1.0	+3.0	- 1.0	
4000	46.0	4.2	0	+0.6	+2.4	+4.4	+5.8	+5.9	+6.3	+6.3	+6.2	+6.0	+ 5.8	+5.4	+5.0	+4.4	+ 3.5	
4500	48.0	3.0	0	-1.3	-2.3	-4.5	-5.6	-6.0	-6.4				7.0				- 6.3	

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TABLE IV

Power Change as a Function of Coil Current for Polyiron D, Length 11/16", O.D. .356"; Center Conductor Continuous

		Power Changes in Decibels At A. C. Current in Amperes																
Freq. Mc/S	Insertion Loss	VSMR	0 Amp.	0.5 Amp.	1.0 Amp.	1.5 Amp.	2.0 Amp.	2.5 Amp.	2.75 Amp.	3.0 Amp.	3.25 Amp.	3.5 Amp.	3.75 Amp.	4.0 Amp.	4.25 Amp.	4.5 Amp.	4.75 Amp.	5.0 Amp.
980	14.3	2.8	0	-0.3	-0.6	-1.0	-1.3	-1.6		-1.9				-2.0				-2.1
1500	13.3	1.8	0	-0.4	-1.1	-2.0	-2.8	-3.5		-4.1				-5.8				-6.0
2000	21.1	2.9	0	-0.2	-0.7	-1.8	-2.5	-3.4		-4.2				-5.9				-7.1
2500	21.5	3.0	0	-0.3	-0.9	-1.6	-2.3	-2.8		-3.3				-4.0				-4.5
3000	41.5	2.6	0	+0.4	+1.1	+1.7	+2.0	+2.2	+2.3	+2.2				+ .8				-1.0
3500	34.5	2.6	0	+0.5	+2.5	+3.8	+4.3	+4.8	+4.9	+4.7				+3.8				+1.3
4000	40.5	2.4	0	+1.2	+3.0	+4.8	+5.5	+6.3		+6.5			+7.0	+6.5				+4.5
4500	43.5	3.0	0	+1.0	+2.9	+4.4	+5.6	+6.5		+7.1				+7.8				+8.3

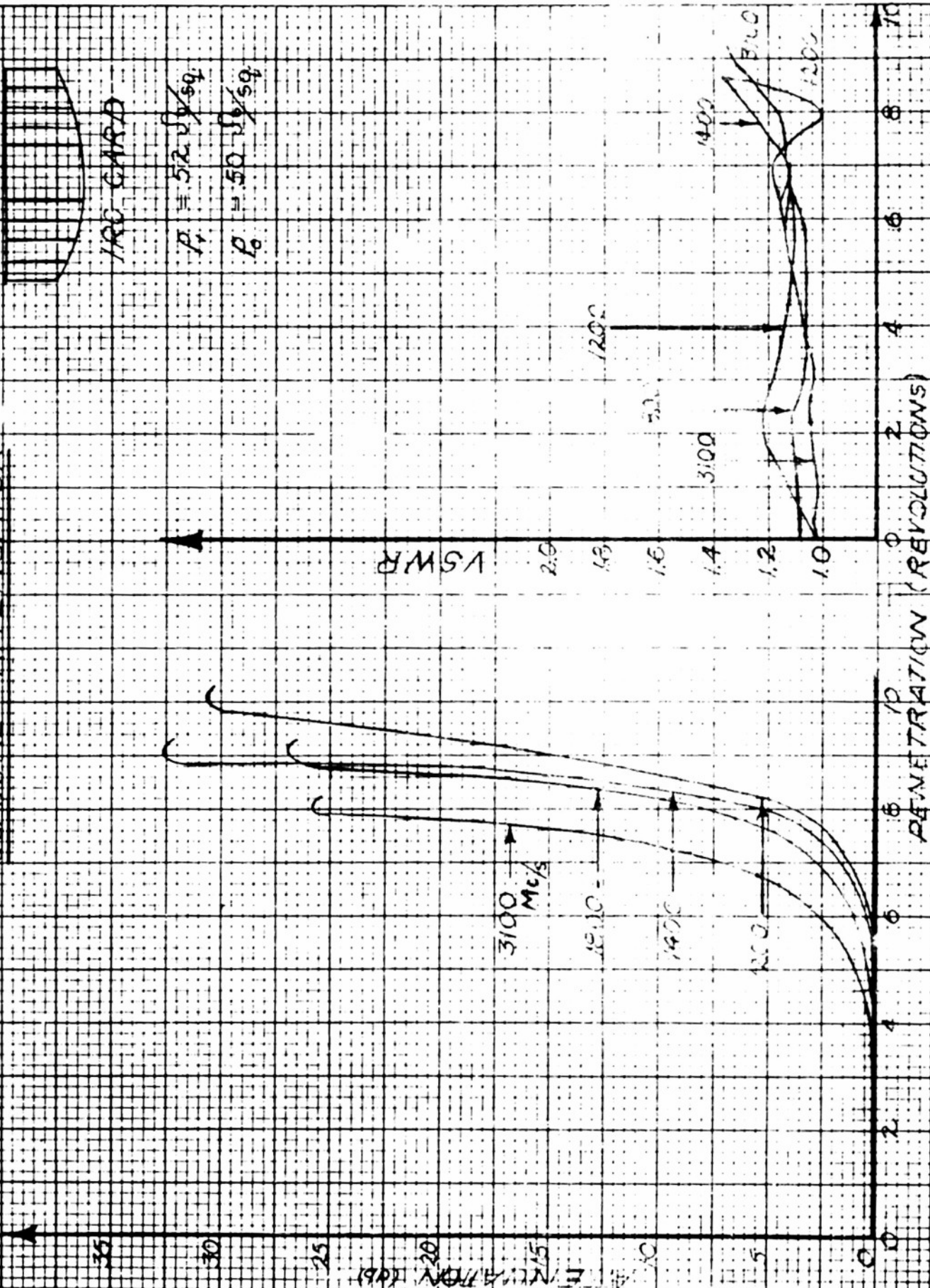
COAXIAL ATTENUATOR



100 CARD

$P_1 = 52 \text{ dB/sq}$

$P_0 = 50 \text{ dB/sq}$



COAXIAL ATTENUATOR

P₁ P₂ P₃ P₄ P₅ P₆ P₇



ARC CARD

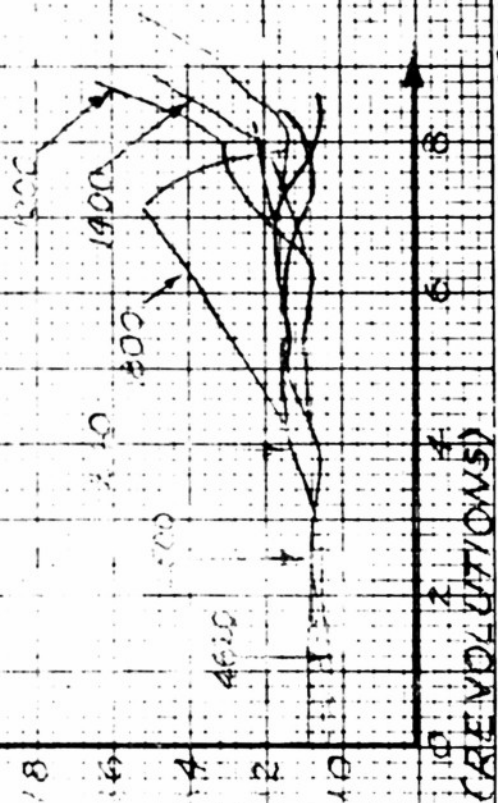
$$P_1 = 54 \frac{dB}{50}$$

$$P_2 = 52 \frac{dB}{50}$$

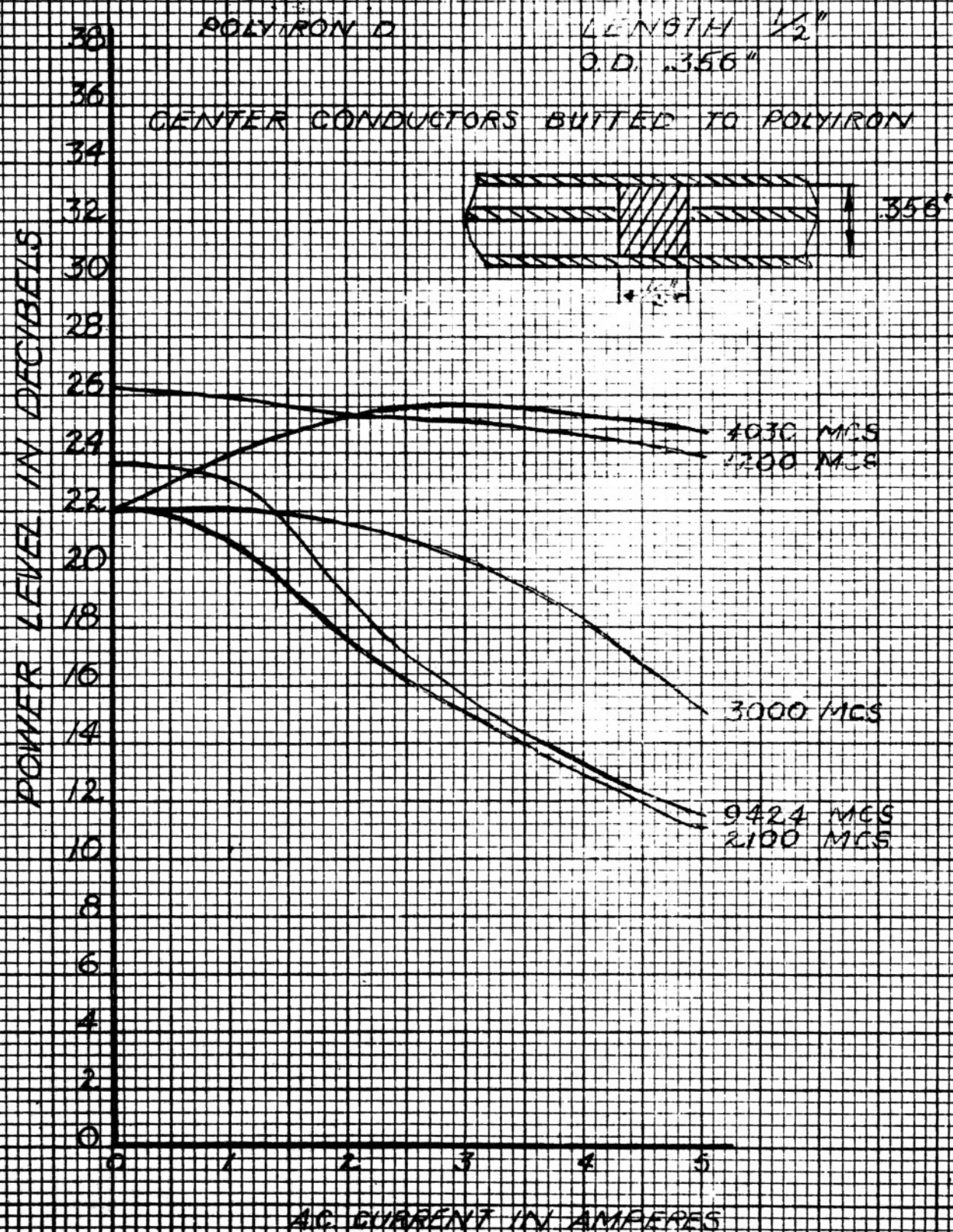
$$P_3 = 50 \frac{dB}{50}$$



VSWR



POWER CHANGE AS A FUNCTION OF COIL CURRENT



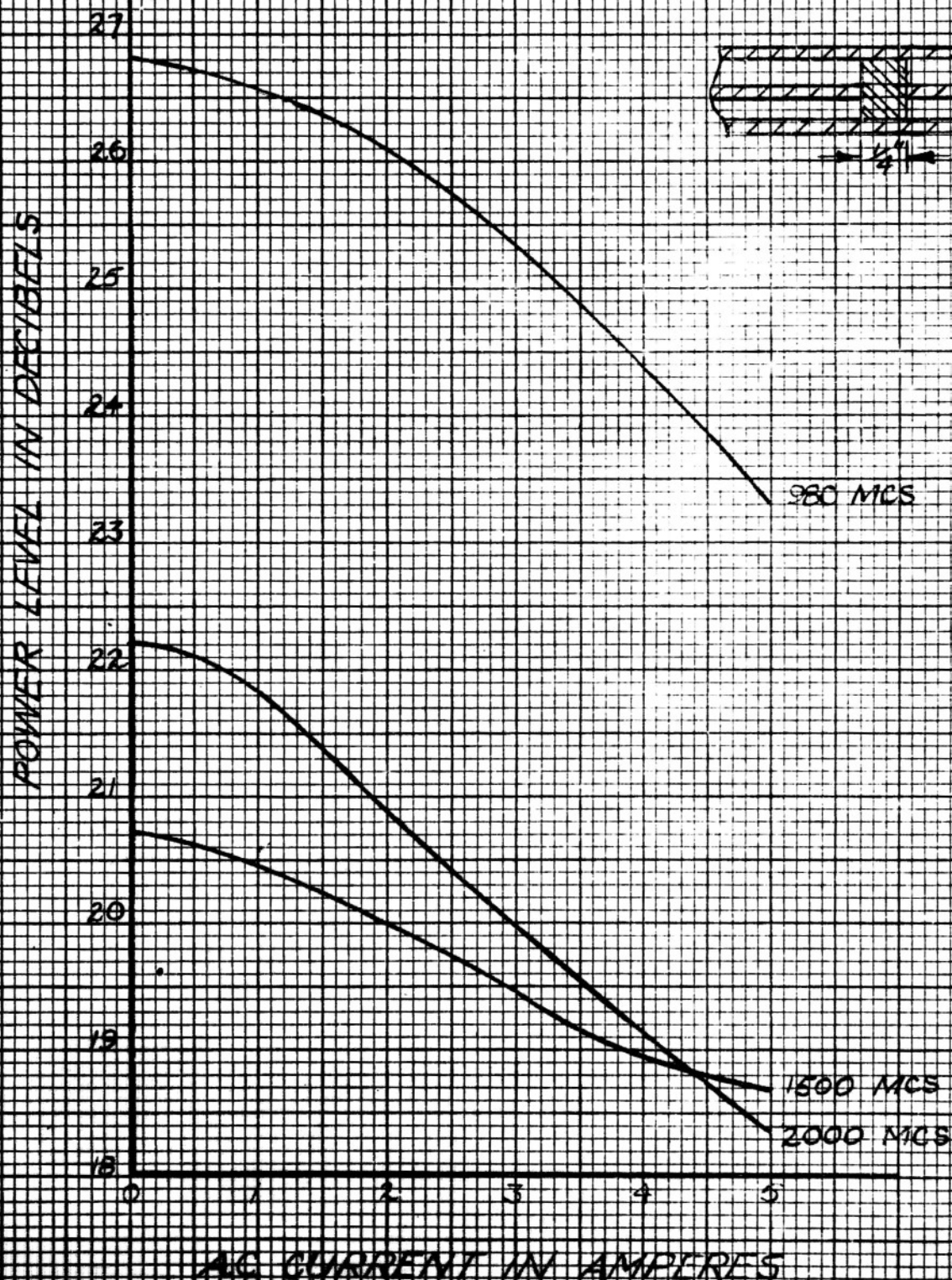
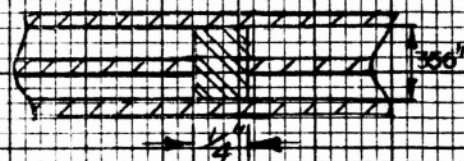
POWER CHANGE AS A FUNCTION OF COIL CURRENT

POLYIRON D

LENGTH $\frac{1}{4}$ "

O.D. .356"

CENTER CONDUCTOR BUTTED TO POLYIRON



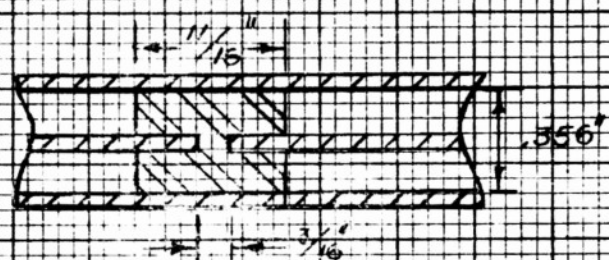
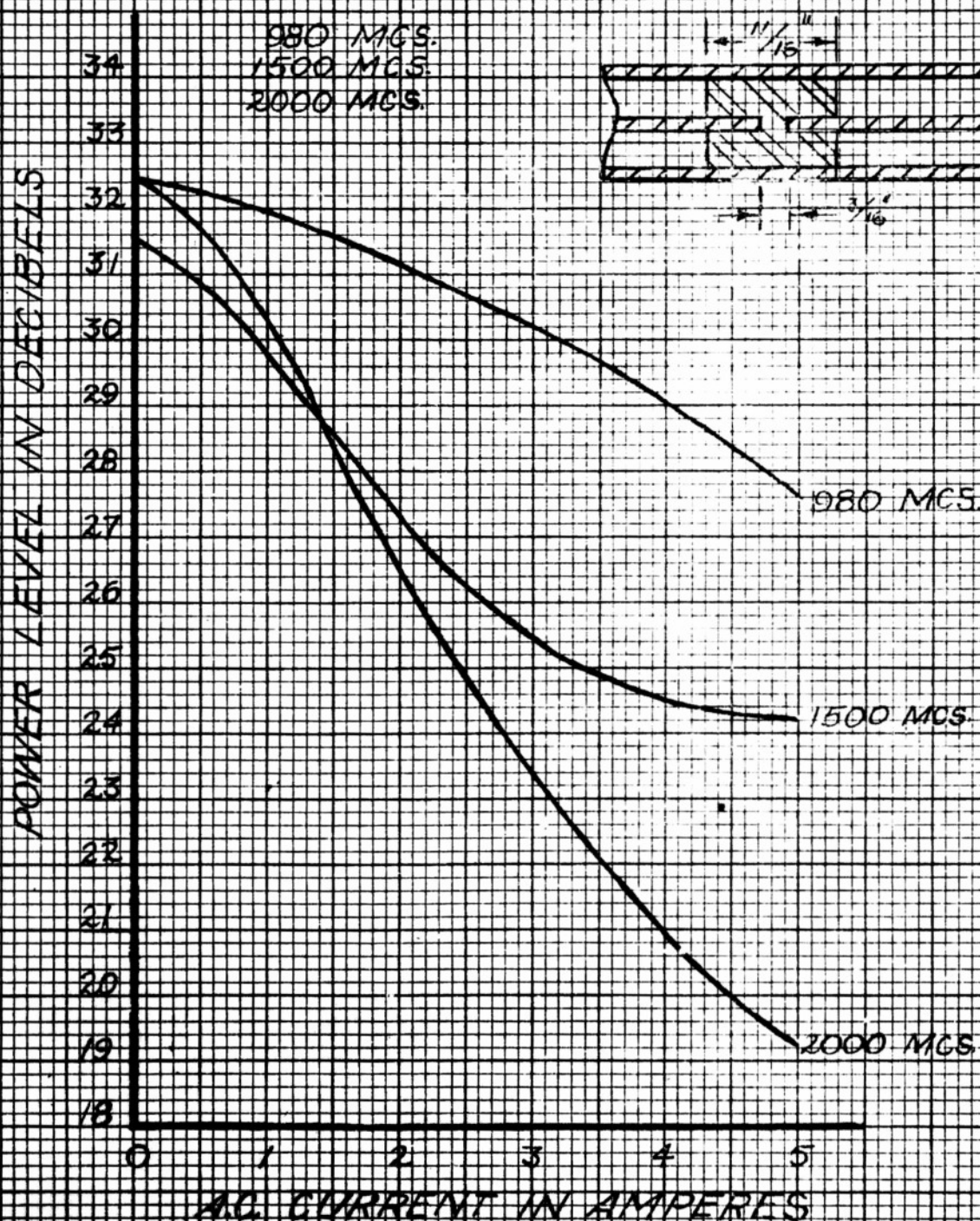
POWER CHANGE AS A FUNCTION OF COIL CURRENT

POLYIRON D

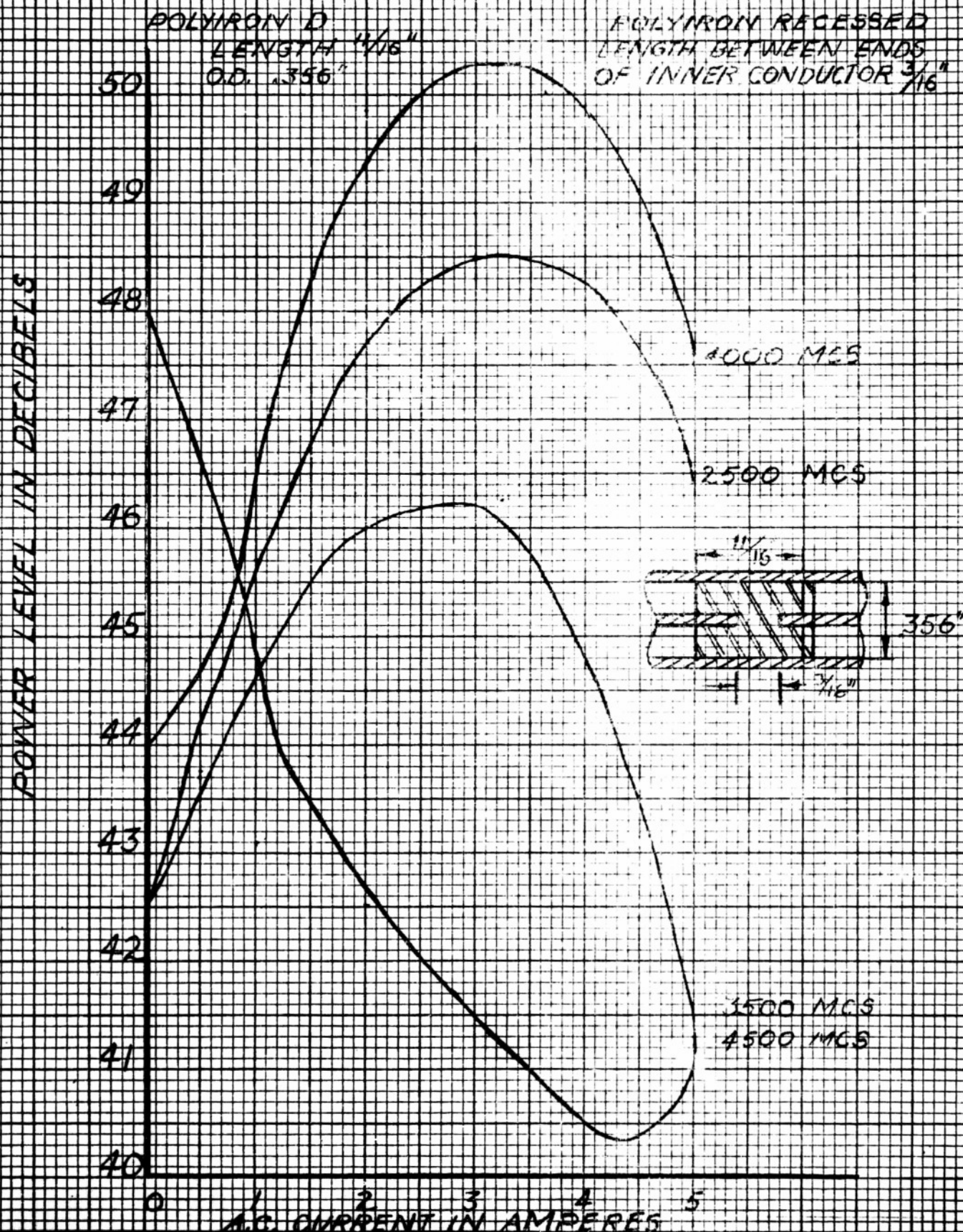
LENGTH $\frac{11}{16}$ "
O.D. .356"

POLYIRON RECESSED

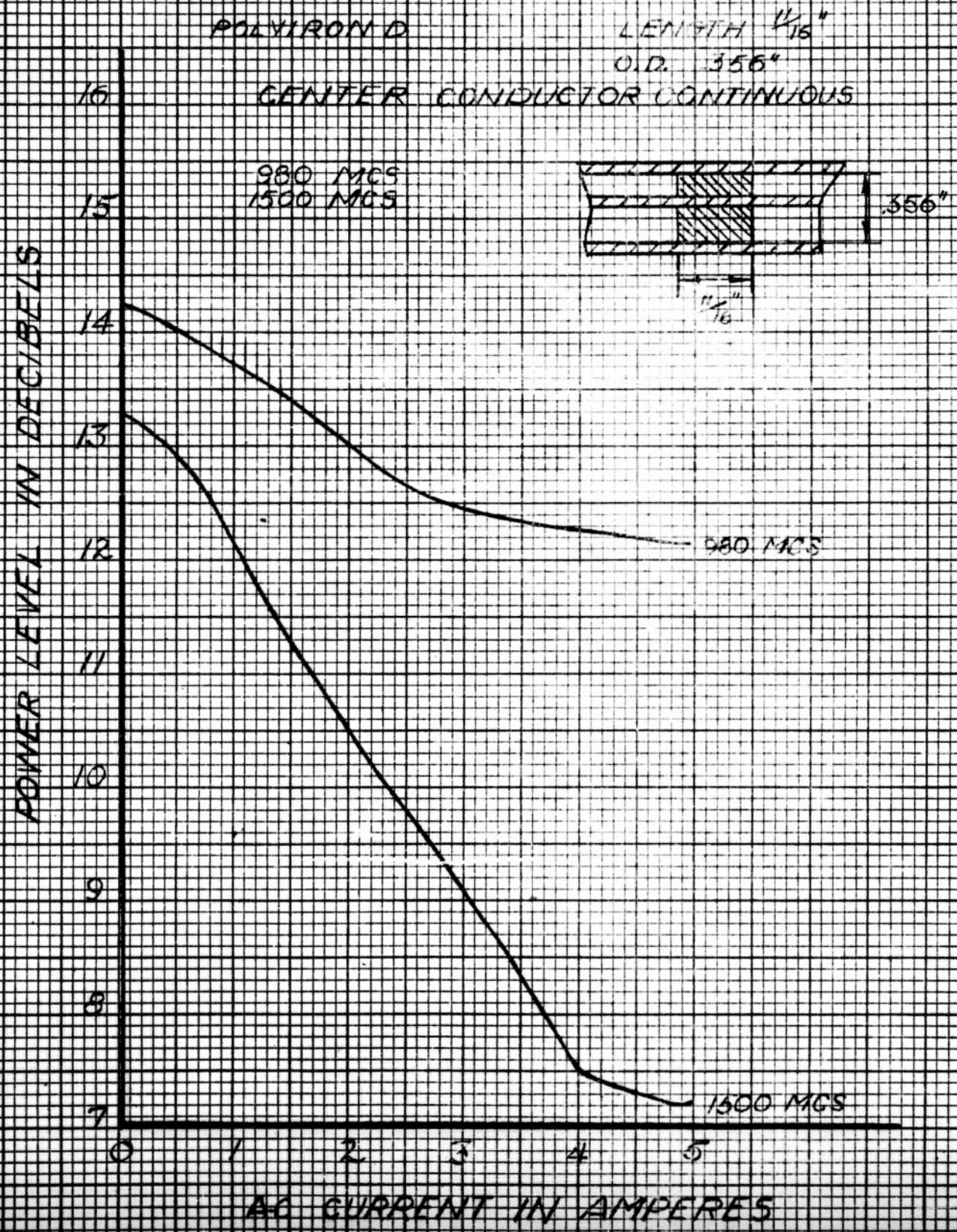
LENGTH BETWEEN ENDS
OF INNER CONDUCTOR $\frac{3}{16}$ "



POWER CHANGE AS A FUNCTION OF COIL CURRENT



POWER CHANGE AS A FUNCTION OF COIL CURRENT



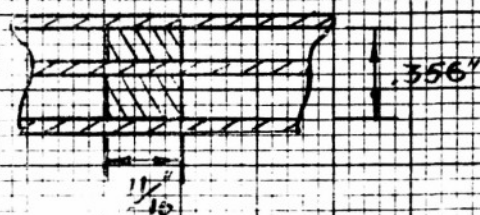
POWER CHANGE AS A FUNCTION OF COIL CURRENT

POLYIRON D

LENGTH $\frac{11}{16}$ "
O.D. .356"

CENTER CONDUCTOR CONTINUOUS

2000 MCS
2500 MCS



POWER LEVEL IN DECIBELS

22
21
20
19
18
17
16
15
14
13

2500 MCS

2000 MCS

AC CURRENT IN AMPERES

0 1 2 3 4 5

RESTRICTED

SECURITY INFORMATION

CALIBRATION CURVE FOR MAGNETIZING COIL

MAXIMUM FIELD INTENSITY OERSTEDS

3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0

0

1

2

3

4

5

AC. MAGNETIZING CURRENT AMP.

RESTRICTED

MRI 12940