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SATURABLE REACTOR CONSIDERATIONS
by F. H. Shepard, Jr.
DEDICATION OF 1BCG MEMORIAL
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Volume 27 1950 No. 3

SATURABLE REACTOR CONSIDERATIONS

by

F. H. Shepard, Jr.*

Presented before the Radio Club, January 13, 1950

Saturable reactors have been known and used for many years. In fact, at one time they were the only means for the modulation and control of large amounts of high frequency energy. Back in 1909 and 1910 Dr. Alexanderson of General Electric Co. used such devices for modulating the output of his alternator.

The advent of the vacuum tube and the lack of good magnetic materials has caused the saturable reactor to be relegated to relative obscurity for many years. Much of the reluctance of engineers to use the saturable reactor has been due to the lack of a simple concept as to its mechanism of operation. In general, the explanation of operation has been passed off by a statement that the AC permeability of an iron core can be changed by DC saturation, hence the inductance of a coil can be varied. While this is a true statement, it is far from satisfying - just as a similar statement about vacuum tubes would be. The detailed, mathematical analysis, although correct, leaves the practical engineer without a physical concept of/ or "feel" for the subject.

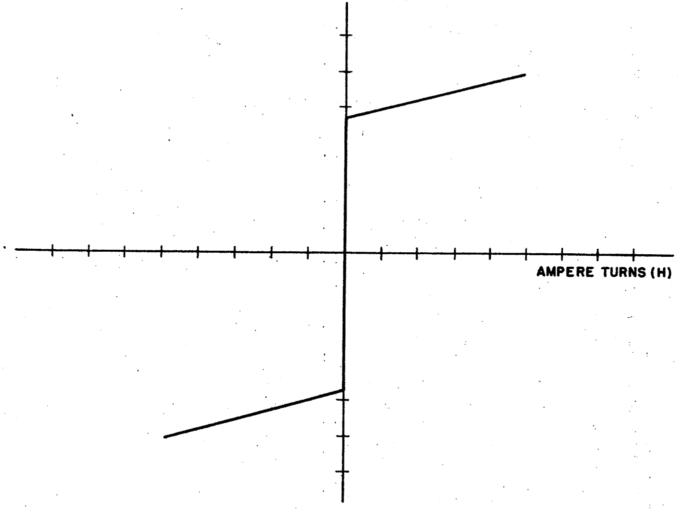
The Author will endeavor to condense saturable reactor operation down to a few simple transfer curves, of the type we are used to working with in vacuum tube practice, to give the practical engineer a basis for thinking about reactors in much the same way he now thinks about vacuum tubes.

The two basic parameters to be considered in connection with reactors are:

Ampere turns or magnetizing force (H) and flux density (B). All other parameters are expressible in terms of these two.

Permeability is equivalent to mu in a vacuum tube, i.e. - flux change per unit of magnetizing force. Voltage, as is the case in all pure inductors, is the time derivative of flux. Because of this, it is imperative that our basic thinking about saturable reactors be done first in terms of ampere turns and flux.

The basic transfer characteristic for consideration of saturable reactors is the B-H or ampere turns versus flux curve for the core materials used.



IDEAL B-H CHARACTERISTIC
FIG. I

Fig. #1 shows the B-H characteristic of an ideal magnetic material. Since the use of an ideal material simplifies consideration of the problem and since commercially available materials, such as grain oriented, magnetically annealed cores, approach the ideal, this is a reasonable assumption.

It will readily be seen that when a core material with a sharply non-linear magnetization curve (such as is shown for "Deltamax" in Figure #2) is used as a transfer curve, large amounts of current can be controlled by relatively small changes in D.C. current bias level. This advantage is clearly shown in the curves of Figures #22 and #23.

Fig. #2 shows the B-H curve for Deltamax, a 50% iron-50% nickel alloy.

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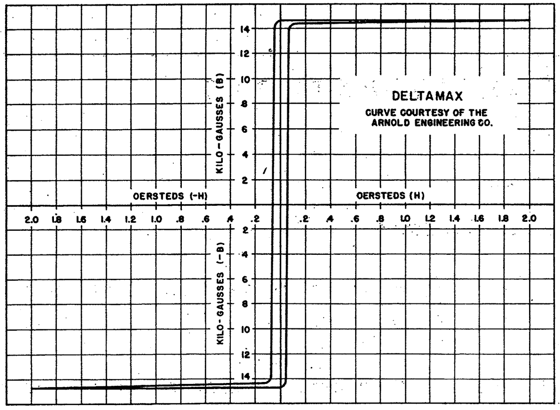
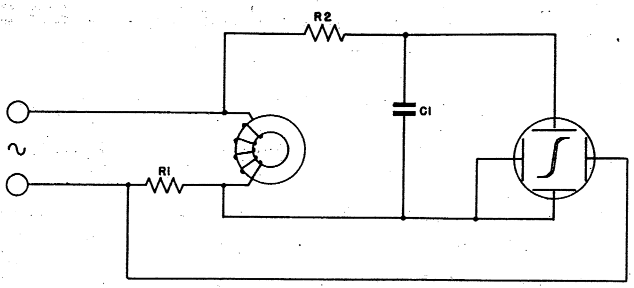
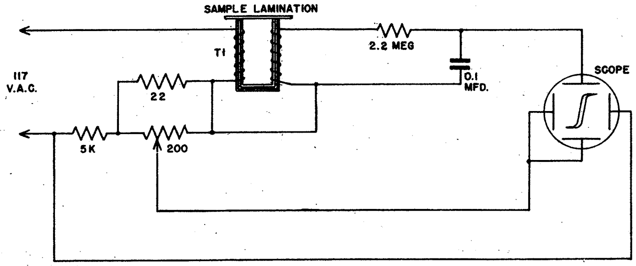


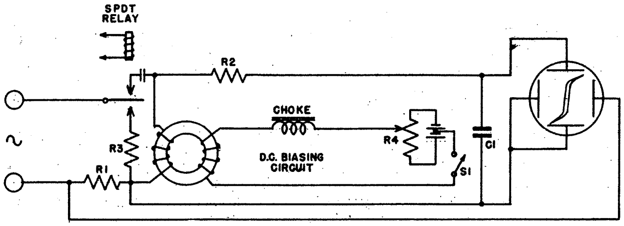
FIG. 2



CIRCUIT FOR SHOWING B-H(MAGNETIZATION) CHARACTERISTICS
FIG. 3



MAGNETIC MATERIALS TESTER
FIG. 4



CIRCUIT FOR INSERTING ZERO MAGNETIZING FORCE FLUX BASE LINE ON B-H CURVE.
FIG. 5

Fig. #3 is a basic circuit for presentation of the B-H (current versus flux curve), since in a zero resistance coil, voltage is the time derivative of flux, and since flux is not directly observable, the RC network shown effectively intergrates the voltage, and hence this integral can be taken as a true representation of flux.

Fig. #4 shows a setup for observing the B-H curve of individual laminations. An open core of substantially larger cross-section than the lamination to be tested is used. Voltage or flux due to the leakage across the open ends of the core is neutralized by balancing the leakage flux induced voltage by a voltage proportional to the exciting current. The resultant curves, when laminations are placed across the gap, are characteristic of the samples being observed.

It should be noted that the above mentioned methods of presentation do not show the exact position of the base line or zero magnetizing force level of the flux. Practically, a differential has no continuing DC component; a practical integrating circuit cannot restore the DC. In order to show the base line and to show how its level changes as an external magnetizing force is applied, the AC input to the reactor is applied periodically by means of the relay circuit shown in Fig. 5. When the AC input circuit to the reactor is open, the magnetizing force is zero and the flux drops back to its normal level. If the spot on the scope is deflected horizontally during this time, a base line is created. To avoid rectification in the relay circuit, an exact integral number of cycles must be included in the time the contacts are closed.

Fig. 6 shows a multivibrator relay drive circuit operating at 30 times per second synchronized with the line and adjustable as to phase of opera-

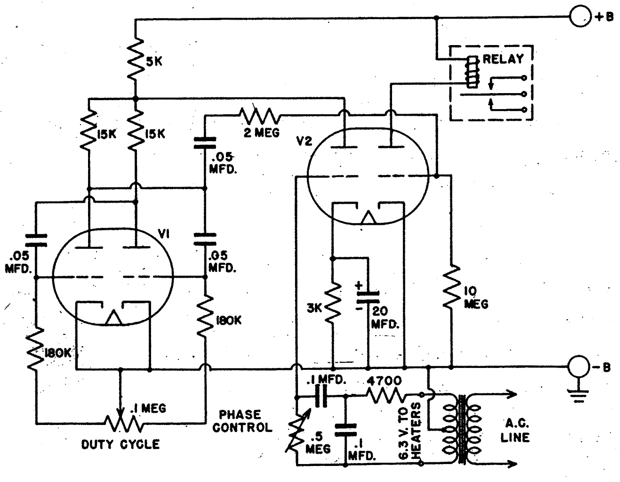


FIG. 6

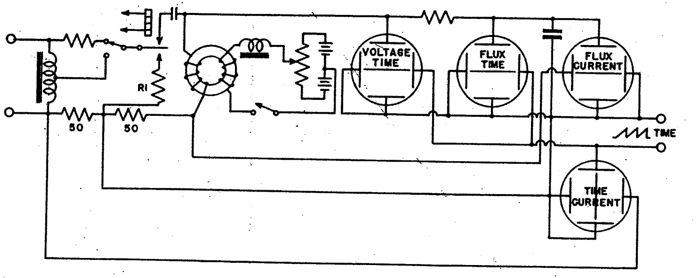


FIG. 7

tion and as to the duration of the relay energization.

Fig. #7 shows a multiple oscilloscope set up for showing simultaneously voltage versus time, flux versus time, the portion of the B-H curve being traversed, and the resultant time versus current characteristics of a reactor under various values of externally excited DC magnetizing force. A high impedance choke is used in the DC control circuit to keep the AC flux changes in the core and hence the induced AC voltage in the DC winding from causing any appreciable AC component of magnetizing current in this winding.

It should be noted that since the back voltage of a reactor is the time derivative of flux, it can have no continuing DC component, even though the flux may have a DC value. It follows that since the current is controlled by this induced back voltage, which has no DC component, the current can have no DC component either. Flux rectification, however, does take place and can be explained as follows:

When DC is applied to a winding on a core, a DC flux bias results, and the AC back voltage of the primary winding, as explained above, can have no DC back voltage component. However, equal amounts of current produce different amounts of flux change in opposite directions, due to the non-linear current vs flux characteristic of the iron core. Therefore, the integrated mean flux level will be changed by the flow of AC currents, i.e., flux rectification is present. By reference to the curves, it can be seen that for an ideal core material taking negligible magnetizing current, the flux rectification is just equal and opposite to the externally applied DC flux, and the AC magnetizing ampere turns will be equal to the externally applied DC ampere turns. If an ideal reactor is used, i.e., one which magnetizes on negligible current and one which has negligible DC resistance, negligible power will be required to establish and maintain the DC flux bias in the reactor itself. However, current may be fed momentarily by transformer action through the reactor into the AC source. This effect is a primary factor in limiting the speed of response of single or parallel saturable reactors. In the series connection the induced voltage in the AC windings balances out and no current results when operating at balance.

Figs. 8, 9, and 10 show the curves as they appear when the reactor is fed by a substantially zero impedance sine wave source of AC voltage. In these cores the flux time curves must be sinusoidal but they may have a DC component due to flux rectification.

Figs. 11, 12, and 13 show the curves as they appear when the reactor is fed from a substantially infinite impedance source of AC current. In this case the time-current curves appear as sinusoidal while the flux and voltage time curves are distorted.

In actual practice it is inconvenient to use a single reactor with a large choke in series with the DC magnetizing winding. It is more convenient to connect two reactors with their AC windings in series or in parallel and their magnetizing windings in series, connected so that their induced AC voltages tend to cancel.

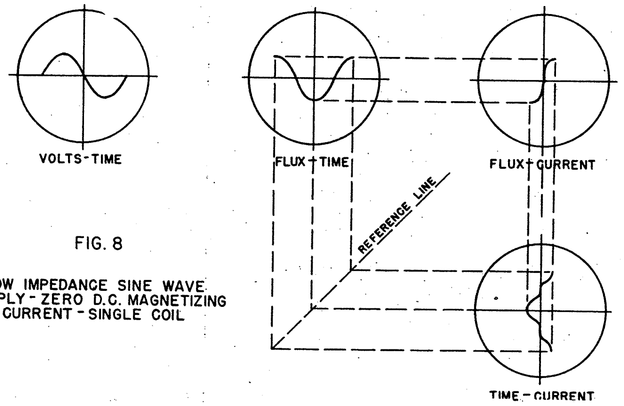


FIG. 8

LOW IMPEDANCE SINE WAVE SUPPLY - ZERO D.C. MAGNETIZING CURRENT - SINGLE COIL

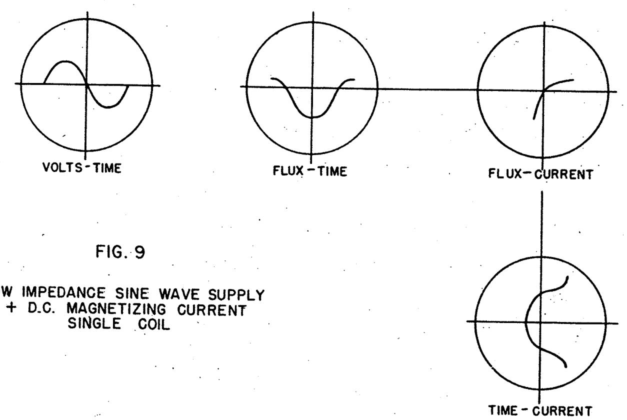


FIG. 9

LOW IMPEDANCE SINE WAVE SUPPLY + D.C. MAGNETIZING CURRENT SINGLE COIL

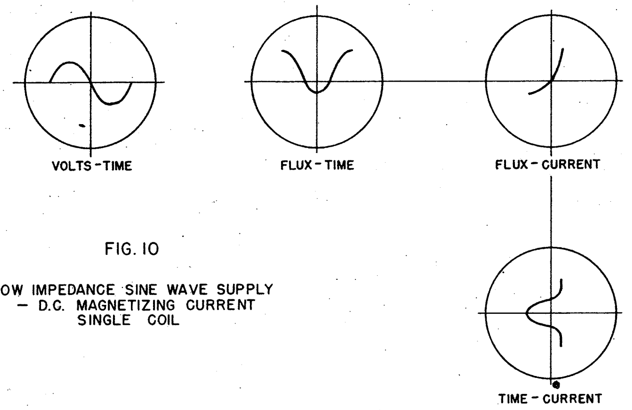


FIG. 10

LOW IMPEDANCE SINE WAVE SUPPLY
- D.C. MAGNETIZING CURRENT
SINGLE COIL

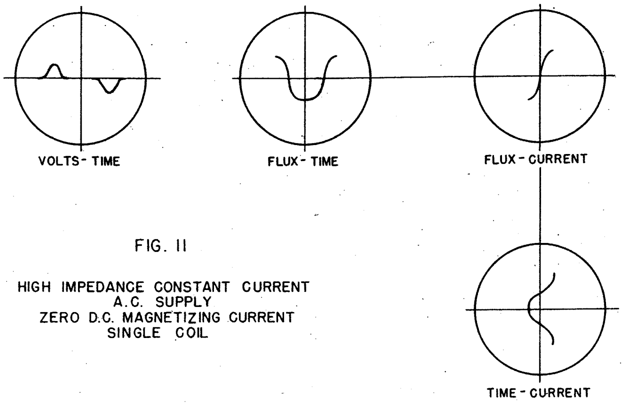


FIG. 11

HIGH IMPEDANCE CONSTANT CURRENT
A.C. SUPPLY
ZERO D.C. MAGNETIZING CURRENT
SINGLE COIL

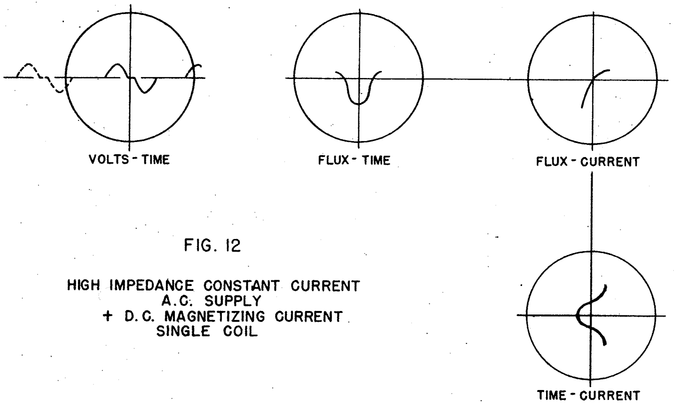


FIG. 12

HIGH IMPEDANCE CONSTANT CURRENT
A.C. SUPPLY
+ D.C. MAGNETIZING CURRENT
SINGLE COIL

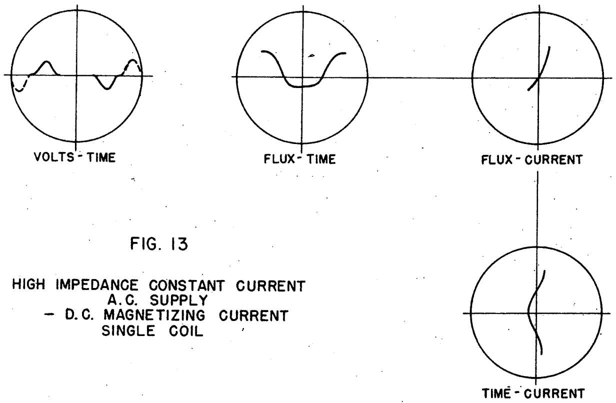


FIG. 13

HIGH IMPEDANCE CONSTANT CURRENT
A.C. SUPPLY
- D.C. MAGNETIZING CURRENT
SINGLE COIL

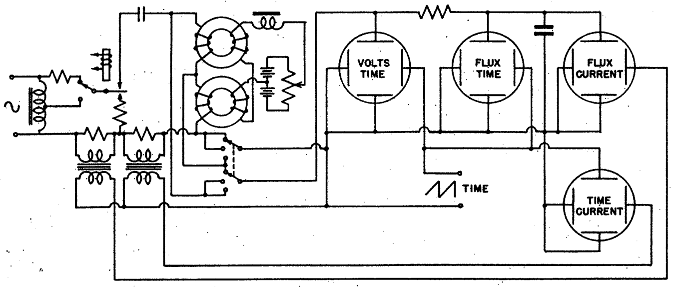


FIG. 14

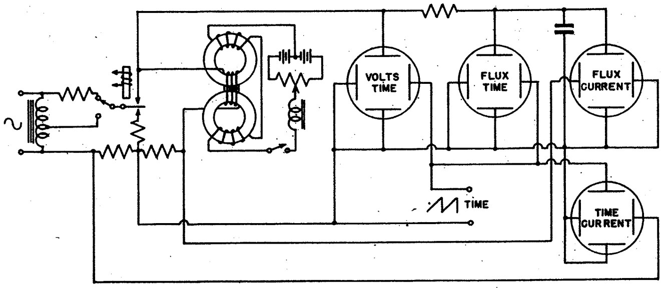


FIG. 15

SERIES CONNECTIONS:

When the AC windings are connected in series, the voltages and/or fluxes are effectively additive. While the DC magnetizing force is the same for both cores, it is in series opposition in the two cores with respect to the AC windings. In the case of the series connected reactors shown in Fig. 14, this means that not only does the AC flux and induced **voltage** from the AC supply tend to cancel or buck **out in the** DC windings, but the induced voltages **from DC bias** flux changes tend to balance out in the **AC windings** so that circulating currents are mini**mized and** higher speeds of response are obtained.

Fig. 14 also shows a set up whereby the fluxes, voltages, and currents, in series connected reactors may be studied. The switches may be thrown so as to observe the voltages and fluxes of each reactor individually or of the pair in series.

Fig. 15 is essentially the same as Fig. 14 except that a single AC winding is wound around both cores. The characteristics of this type of saturable reactor pair are identical to the pair with separate windings as shown in Fig. 14. This connection is shown and demonstrated to illustrate this fact.

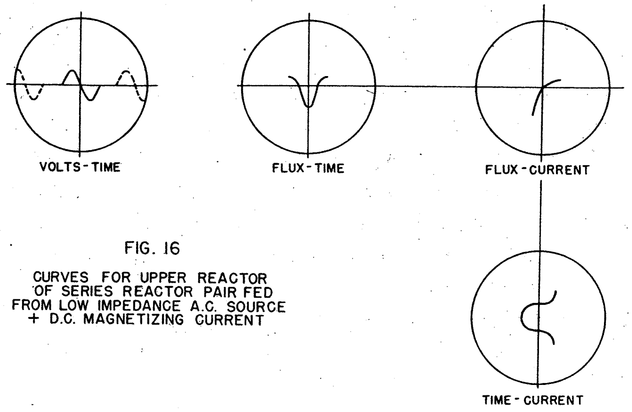


FIG. 16

CURVES FOR UPPER REACTOR OF SERIES REACTOR PAIR FED FROM LOW IMPEDANCE A.C. SOURCE + D.C. MAGNETIZING CURRENT

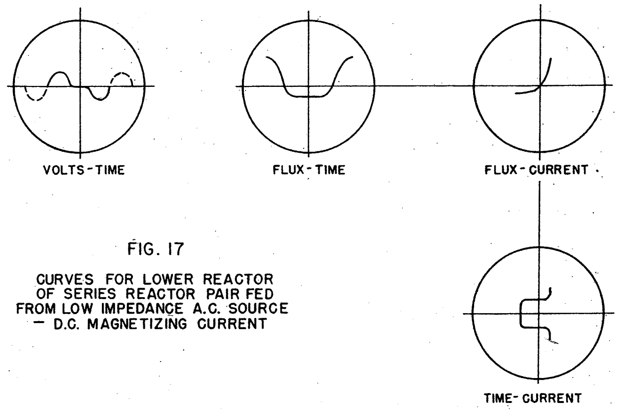


FIG. 17

CURVES FOR LOWER REACTOR OF SERIES REACTOR PAIR FED FROM LOW IMPEDANCE A.C. SOURCE – D.C. MAGNETIZING CURRENT

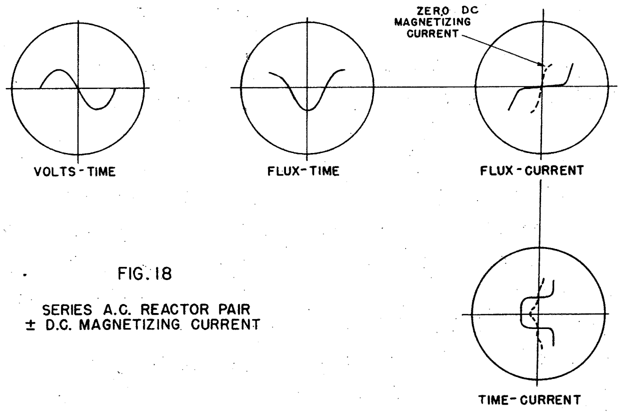


FIG. 18

SERIES A.C. REACTOR PAIR
± D.C. MAGNETIZING CURRENT

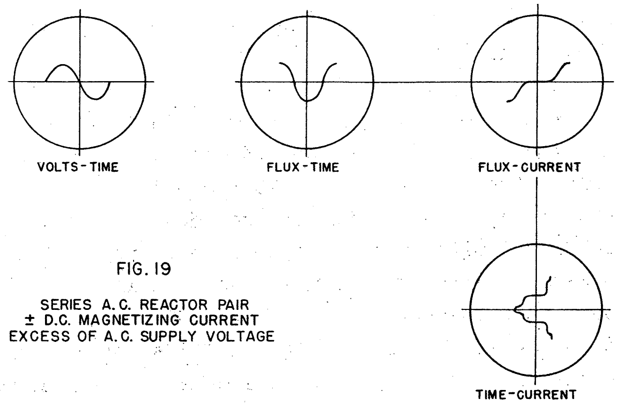


FIG. 19

SERIES A.C. REACTOR PAIR
± D.C. MAGNETIZING CURRENT
EXCESS OF A.C. SUPPLY VOLTAGE

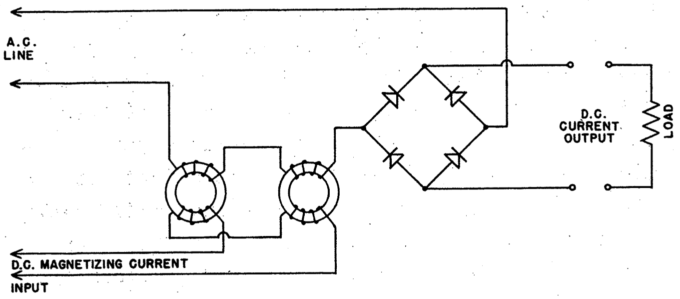


FIG. 20

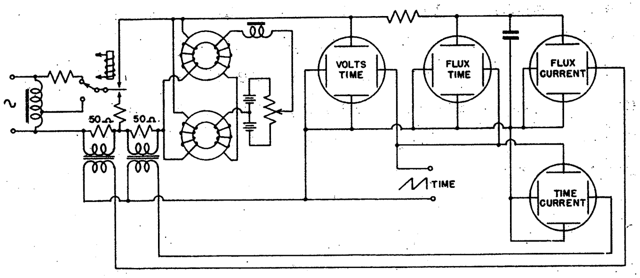


FIG. 21
PARALLEL REACTORS

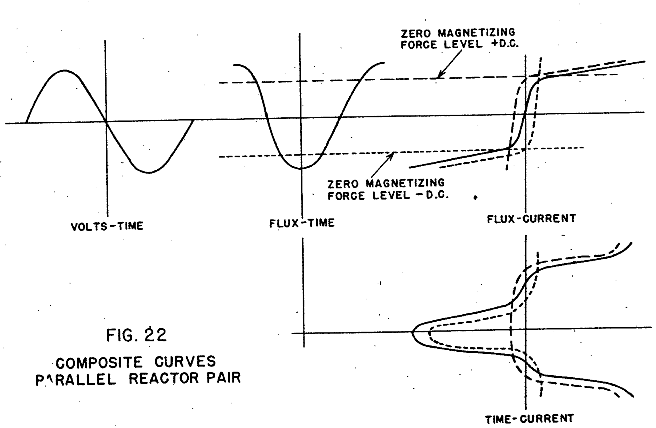


FIG. 22

COMPOSITE CURVES PARALLEL REACTOR PAIR

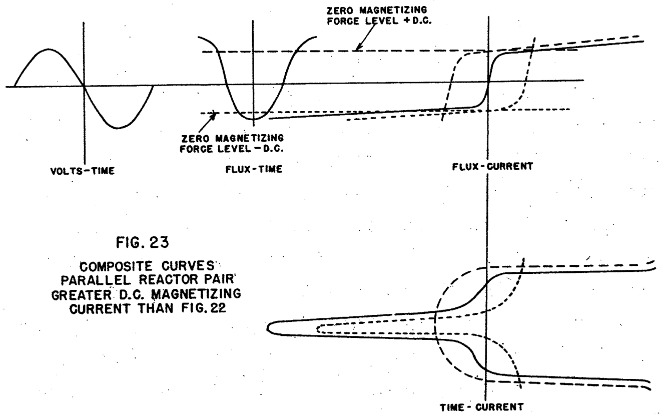


FIG. 23

COMPOSITE CURVES PARALLEL REACTOR PAIR GREATER D.C. MAGNETIZING CURRENT THAN FIG. 22

On again examining the circuit shown in Fig. 14, when no DC magnetizing current is present, we see that the voltage, flux, and current curves are similar to the curves for both reactors together except that the effective voltage and flux values are doubled. These curves are essentially the same shape as the ones shown in Fig. 8. When DC is caused to flow in the DC windings, the characteristics are as shown in Fig. 16 for the upper core and as shown in Fig. 17 for the lower core, when the two in series are fed from a substantially zero impedance AC source. When the fluxes or voltages of the two cores are added together, the curves of Fig. 18 are obtained. It should be noted that the curves of Fig. 18 obtain for either polarity of DC magnetizing current.

When the AC supply voltage is increased so that the flux increases beyond the AC saturation limits, the curves of Fig. 19 are obtained. It is interesting to note that in the ideal case within the flux limits of the device, the output current in ampere turns of a series reactor pair is exactly equal to the ampere turns in each DC coil. This is an instantaneous phenomenon and holds for currents in the input windings over a frequency range from DC to many times the AC supply frequency. If the output current is rectified as shown in Fig. 20, it will have a wave form identical to the wave form of the DC magnetizing input. If the polarity of the DC input is reversed, the polarity of the output is not. The power consumed by the DC winding increases with input frequency until at carrier frequency all the output power is supplied from the signal source.

When the AC windings of the reactor are in parallel as shown in Fig. 21, the impedances of the two windings are not in series but are effectively in shunt with each other, the currents add and the characteristic curves of Figs. 22 and 23 are obtained when DC is present in the DC windings.

The fluxes and currents in each reactor individually are as shown in Figs. 8, 9, and 10 when fed from a low impedance AC source. When the two reactors are placed in parallel, the voltages across the two reactors are identical, hence the integrals of these voltages or AC core fluxes have the same identical AC wave forms. However, the AC currents flowing to produce this flux wave form may be different. The total current flowing in the pair of reactors is simply the sum of currents in the two individual reactors. Fig. 22 shows the curves for a pair of parallel reactors. It can be seen that the AC flux is the same in both reactors. However, the instantaneous zero magnetizing force level due to the external DC magnetization of the core and due to flux rectification in the core is shown for both cores, and the currents flowing in the AC winding of each reactor. The curve showing the sum of instantaneous currents flowing for each value of AC flux is also shown as is the total current versus time curve. Fig. 23 shows curves similar to those of Fig. 22 but for greater DC magnetization.

In the case of a high impedance source of AC current, the voltage across each reactor in the pair and hence the AC core fluxes are identical. However, since the total current is limited, the actual flux value is limited by the nonlinearity of the cores.

In the above modes of operation a biasing current or flux applied to the saturating reactors results in a quantity of AC current flow that will cause sufficient flux rectification to balance out the original bias flux. If ideal core materials were used, the AC current in ampere turns would exactly equal the DC biasing current in ampere turns.

Fig. 24 shows the instantaneous current flux curve for a core externally biased. If a low impedance AC supply voltage is suddenly applied to the primary, the current build-up will be as shown. Note that the first few cycles of current have a DC component. This DC current component soon subsides as flux rectification causes a shift of the flux base line. Note that it is the small practically zero reverse current flow over the steep part of the flux current curve that provides the flux base line shift or degeneration. If this

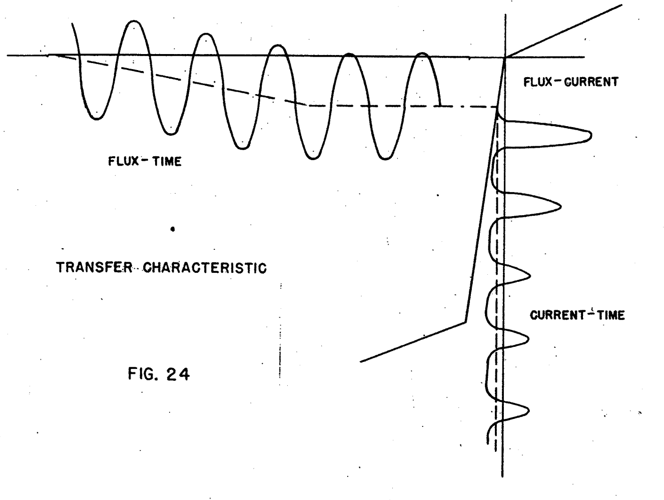


FIG. 24

small reverse current is prevented from flowing by means of a rectifier in series with the reactor, the degenerative flux base line shift is prevented; the current transformer action of the reactor is spoiled; and if an ideal (infinitely permeable) core material could be used, infinite current amplification could be obtained.

From the above, it can be seen that saturable reactors are simple non-linear elements that can be used in connection with rectifier, resistive, inductive or saturable reactor loads to form the elements of bridges, amplifiers, modulators, etc. The reactor amplifier may be cascaded to provide high gains or power amplification. It may be used with either positive or negative feedback through resistive, integrating, and/or differentiating networks to obtain constant gain, constant current, constant voltage, differential, or integral outputs. Although a detailed discussion of specific circuits is beyond the scope of this paper, it is interesting to note that reactor amplifiers have found practical use as DC repeater amplifiers, as differentiating and integrating elements in analogue type computors, as servo and industrial process control amplifiers; providing error integration (reset) and several orders of differential stabilization, in arc and resistance welding controllers, and in many other types of regulators and control devices.

Fig. 25 shows the circuit of a universal demonstration unit that has facilitated the actual observation of the reactor characteristics discussed above.

The use of high permeability core materials is not necessary for the initial study and use of saturable reactors. The experimenter can take almost any pair of identical audio or power transformers and get the "feel" of the subject. (It may be desirable but not imperative to restack the cores of these transformers interleaving 100% to eliminate all possible air gaps.)

EDITORIAL NOTE: The demonstration accompanying the presentation of this paper consisted of the following:

Four 5" Cathode Ray Oscilloscopes were set up in the positions shown in Figure #7 and operated from the "Black Box", the circuit for which is shown in Figure #25. The voltage-time, flux-time, flux-current, and time-current curves shown in the various figures were actually shown simultaneously on the scopes.

A two-stage magnetic amplifier was demonstrated, operating directly from a Weston self-generating photo-cell, to drive a two-phase motor. Mounted on the motor shaft was a target arranged to interrupt the light beam to the photo-cell, thereby reversing the motor to again uncover the light beam again reversing the motor, etc.

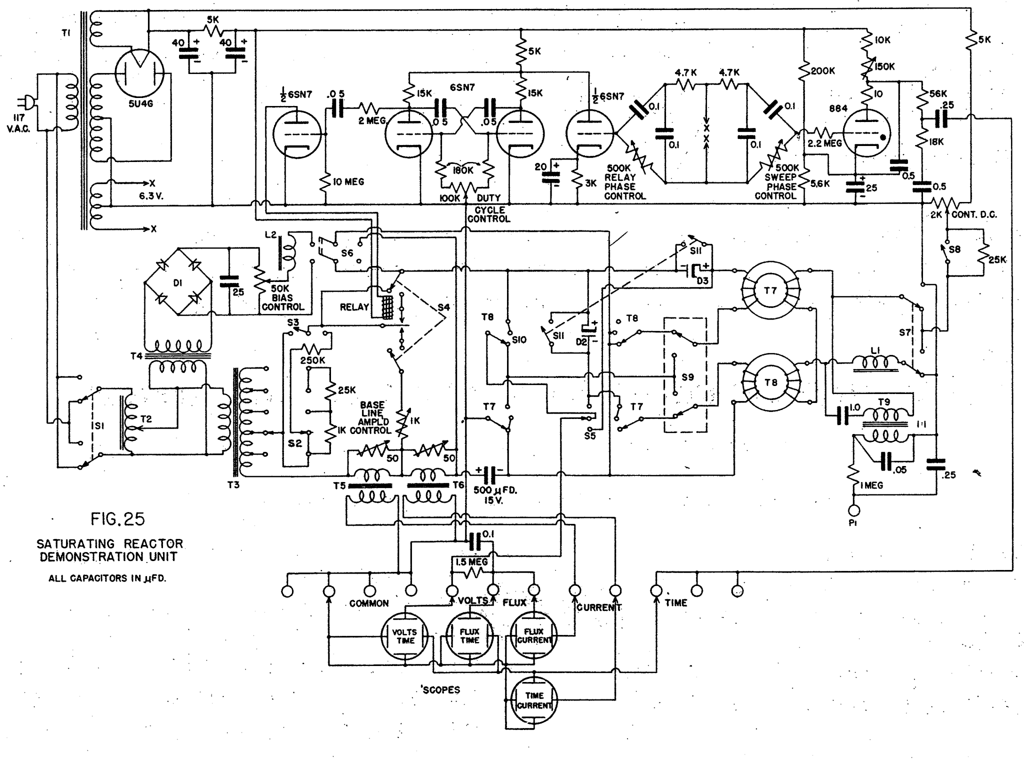


FIG. 25

SATURATING REACTOR DEMONSTRATION UNIT

ALL CAPACITORS IN μFD.

ANNUAL RADIO CLUB BANQUET

The annual banquet of The Radio Club of America was held on December 1st at the Advertising Club of New York.

Celebrating the 41st anniversary of the founding of the Club, those present enjoyed an excellent program which featured Rear Admiral Redmond, USN, Director of Naval Communications as guest speaker; an informal but informative talk by Major Edwin H. Armstrong, in his inimitable manner; a tape recording of the 1BCG ceremonies by Jerry B. Minter and movies of that historical event by O.F. Masin. President O. James Morelock presided with John V.L. Hogan as toastmaster.

Choosing as his theme "The Navy's Interest In LF and VLF Radio", Admiral Redmond explained a part of the Navy's program in that field. He first outlined the basic service requirements which include broadcasts to ships at sea, ship-to-shore terminals and point-to-point circuits linking major radio stations.

Emphasizing the importance of broadcast methods, he reviewed the use of LF and VLF by the Navy starting with the well-known NAA at Arlington, Va. operating at 100 KW. Then the Admiral told of Navy stations in New Brunswick, N.J., Bordeaux, San Diego, Cavite, Pearl Harbor, Canal Zone, Annapolis, Lualualei, Haiku and finally spoke in detail of the Navy's new "Radio Arlington" located in the State of Washington. This ultra-modern transmitter with catenaries up to 8700 feet long, radiators nearly a mile long and down-leads 1200 feet in length, will have a power output of 1000 KW.

Space here does not permit a full report of the complete data given by Admiral Redmond, but he left no doubt in the minds of those present that the magnitude of the Jim Creek station, as the new installation is known, is dramatic proof that LF and VLF radio have vital roles to play in naval communications.

The banquet committee headed by F.A. Klingenschmitt, chairman, included J.L. Callahan, H.W. Houck and D.H. Miller.

ACKNOWLEDGMENT

Grateful acknowledgment is made to the following sponsors who by their contributions have helped make possible the 1BCG Commemorative Issue:

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While a letter of solicitation was sent to a large list of concerns, some were inadvertently missed who would have wanted to take part. Contributions are still being accepted and may be forwarded to the Club Treasurer. Acknowledgment will be made in a future edition of Proceedings.

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HISTORY OF 1BCG, Ernest V. Amy, George E. Burghard

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STATION 1BCG, George E. Burghard

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THE STORY OF THE TRANSATLANTICS, Reprinted from Feb. 1922 QST

OFFICIAL REPORT ON THE SECOND TRANSATLANTIC TESTS, Paul F. Godley

THE RADIO CLUB OF AMERICA, W.E.D. Stokes, Jr.

MEMBERSHIP LIST OF THE RADIO CLUB OF AMERICA

ALSO MANY INTERESTING PICTURES

IN MEMORIAM

LAWRENCE C. F. HORLE

1892-1950

Mr. Horle, well known to Radio Club members and prominent in the engineering profession, died on October 28 after a brief illness, at Newark, N.J. His age was 58.

He started pioneering in radio in his early boyhood. When only 14 years of age he operated an amateur station and later became one of the organizers of the New Jersey Wireless Association.

A graduate of the Stevens Institute of Technology, he taught for two years at that institution before becoming affiliated with the Navy Department as a radio engineer. During World War I he was largely responsible for the planning of the Navy's Anacosta, Maryland radio research laboratory.

In the following years he was chief engineer for the DeForest Radio Telephone and Telegraph Company, a Vice-President of the Federal Telephone Manufacturing Company, an engineering consultant and chief engineer and director of the Data Bureau of the Radio Manufacturers Association.

Mr. Horle was elected as a member of The Radio Club of America in November 1913, and became a Fellow in 1926. He held the offices of Vice President in 1921 and 1931, Recording Secretary in 1922 and President in 1932. In 1922, 1924, 1930 and from 1933 to 1949, he served as a Director of the Club. Mr. Horle was most active in club affairs serving on many committees; he was Chairman of the Awards Committee and originated the 1BCG Memorial which was dedicated just one week prior to his death.

He joined the Institute of Radio Engineers in 1914 and became a Fellow in 1925. In 1940, the IRE elected him as President and in 1948 that organization awarded him the IRE medal for "contributions to standardizations both in peace and war".

WILLIAM D. LOUGHLIN

1893-1950

Mr. Loughlin, a resident of Mountain Lakes, N.J. for the past twenty years died on November 12th, at Boonton, N.J. He was born in Philadelphia, Pa. January 22, 1893, the son of the late Dr. Dennis J. Loughlin and Katherine Loughlin.

A pioneer in the electronic industry, Mr. Loughlin was graduated from St. Joseph's College of Philadelphia in 1912, where he conducted numerous early experiments in wireless telegraphy and operated a 5KW transmitter, 3XJ.

As an electronic engineer at the U.S. Naval Laboratory at Philadelphia during World War I, he was associated with the late Stuart Ballantine in the development of the radio compass and succeeded Mr. Ballantine, as director of the project when he resigned to join the Radio Frequency Laboratories at Boonton, N.J. In 1923, Mr. Loughlin also joined the RFL organization to work on the developments of new circuits for broadcast receivers. He became vice-president of RFL in 1928 and was elected its president in 1931.

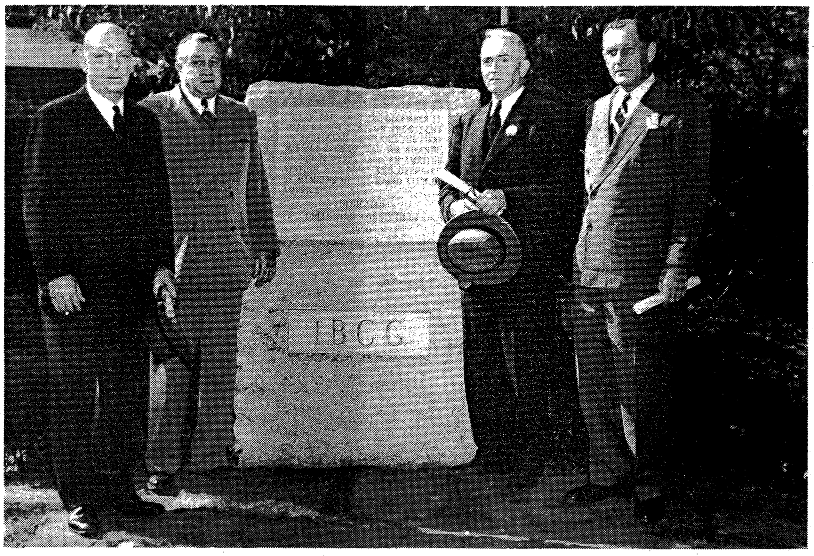
Mr. Loughlin formed the Boonton Radio Corporation in 1934 to specialize in the research, design and manufacture of electronic measuring equipment. Probably one of the best known of the many instruments produced by his company is the Boonton "Q" Meter.

The Radio Club of America elected Mr.Loughlin to its membership in November 1929 and he became a Fellow in March 1937. He was also a Fellow of the Institute of Radio Engineers, a member of the executive committee of the Northern New Jersey Section of the IRE and a member of the Franklin Institute.

The Radio Club of America mourns the recent passing of two members, who, in separate fields of endeavor, became outstanding in the art and have brought honor to our organization by their membership. The Club joins with their families and friends in their bereavement. -- EDITOR.

DEDICATION OF IBCG MEMORIAL

Greenwich, Connecticut - October 21, 1950

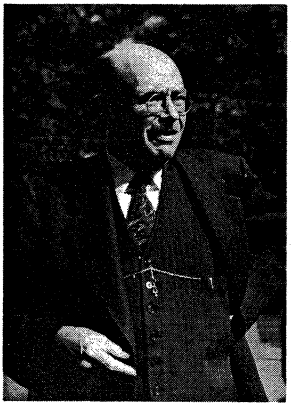


Near this spot on December 11, 1921, Radio Station 1BCG sent to Ardrossan, Scotland, the first message even to span the Atlantic on short waves. 1BCG, an amateur station, was built and operated by members of The Radio Club of America.

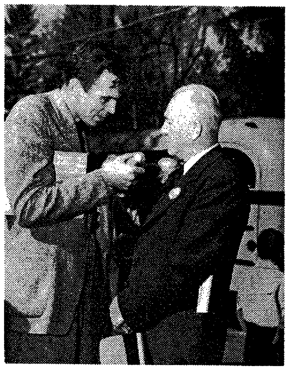
THE 1BCG STAFF

Left to right: Major Edwin H. Armstrong, George E. Burghard, Paul Godley and Ernest V. Amy, recipients of 1BCG Medallions and Radio Club Citations.

Others honored but not present were Minton Cronkhite, John F. Grinan and Walker P. Inman.



The late Larry Horle, chairman of the Awards Committee and originator of the 1BCG Memorial.



Paul Godley records for the Voice of America how he heard 1BCG in Scotland.

Dr. Orestes H. Caldwell delivering the Dedication address. Recordings were made for WGCH and the Voice of America.

Radio Club President O. James Morelock presenting a 1BCG Medallion and Citation to George E. Burghard.

Major Armstrong is greeted by Wilbur M. Peck, First Selectman of Greenwich, who accepted the Memorial for his community.

IBCG MEMORIAL CEREMONIES AN OUTSTANDING EVENT IN RADIO CLUB HISTORY

An epoch in the history of radio communications was fittingly commemorated on Saturday, October 21st at Greenwich, Connecticut when The Radio Club of America dedicated a granite memorial to 1BCG, the first radio station to transmit a message across the Atlantic on short waves.

Club members and others interested in the historic event gathered at the monument site on Clapboard Ridge Road and North Street in beautiful Greenwich, to participate in an excellent program that had been expertly planned by a special committee of the Club. It was truly a beautiful setting for the affair with the Autumn foliage at its brightest and warm sunshine taking the chill from the mid-morning air. The Greenwich High School Band, in its colorful uniforms, entertained with musical selections and there was much reminiscing by old friends who met again for the first time in years as they waited for the ceremonies to get underway.

Promptly on schedule at 11:00 AM, George E. Burghard, Chairman of the Memorial Committee introduced O. James Morelock, Club president. Mr. Morelock welcomed all present for the occasion and gave a brief history of The Radio Club and the story of 1BCG. He described how construction of the station, located only a few hundred feet from the monument site, was started in late November 1921 and completed, less than one month later, just in time to participate in the tests that were climaxed by the historic message transmitted to Ardrossan, Scotland on December 11th. It was this accomplishment by a group of radio amateurs which opened the way for the many commercial communications facilities in service today.

To personally honor the original operators of 1BCG, special medallions and citations were presented on behalf of The Radio Club by President Morelock. Of the recipients, Major Edwin H. Armstrong, George E. Burghard, Ernest V. Amy and Paul F. Godley were present; Minton Cronkhite, John F. Grinan and Walker Inman were unable to attend. With the exception of Mr. Godley who operated the receiving equipment in Scotland, the others were responsible for the design, construction and successful operation of 1BCG.

Honorable Wilbur M. Peck, First Selectman of Greenwich accepted the monument on behalf of his community and assured the Club of its perpetual care. He told of the careful preparation of the monument site by the town and of the special selection of shrubbery to form a beautiful background for the granite memorial. Selectman Peck, spoke of the pride his community felt in having had 1BCG within its boundaries.

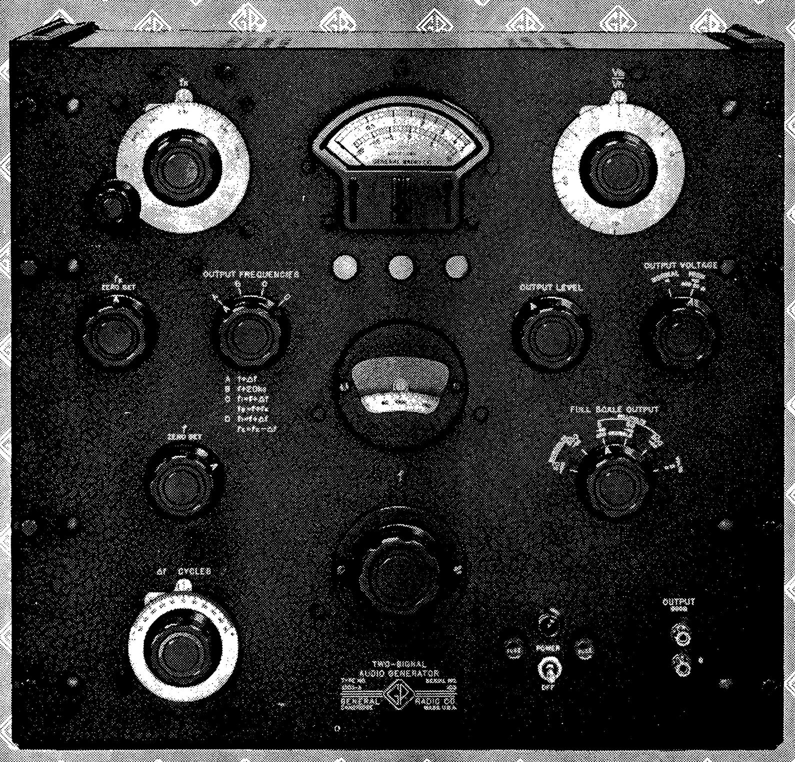
Dr. Orestes H. Caldwell delivered the dedication address which proved most interesting because he, as a native of Connecticut, has a wealth of information about Greenwich and its environs. Speaking first about 1BCG, Dr. Caldwell stressed the true significance of that first trans-Atlantic transmission and how a group of amateurs, with limited equipment and pressed for time, accomplished a feat which heretofore the commercial services had deemed impractical.

Greenwich, explained Dr. Caldwell, had also been the scene of other early technical experiments, one of the most outstanding being the first illumination by electricity of a private residence. He further informed his audience of many of the legends of the area, how Lafayette visited the town during the Revolution and of the escape by way of Greenwich of the notorious Boss Tweed. In summarizing Dr. Caldwell's fascinating address, it may be said that he eloquently told of how a neighborhood already rich in historical events was honored by still another recognition - the 1BCG Dedication.

He also commended the Radio Club on its membership and the important part taken in the development of the field of electronics by such men as Armstrong, Houck, Horle, Beverage, Hogan, Amy, Burghard, Godley, Grinan, Inman, Sadenwater, Van Dyke, Morelock and Cronkhite.

During the ceremonies countless pictures were taken by both amateur and professional photographers anxious to record the event for posterity. Tape recordings were made by Walter S. Lemmon, president of World Wide Broadcasting Co., for FM station WGCH and for the Voice of America. Past-president Jerry B. Minter, also made a recording which he presented at the Club's 40th Anniversary Banquet in New York on December 1st.

After the formalities were over many groups retired to the Greenwich Arms for refreshment and lunch. In this famous old hostelry, radio talk was heard on all sides far into the afternoon as stories were told and experiences swapped by those who have helped make radio what it is today. For the newer members and visitors outside the club, it was an enjoyable experience to just sit and listen, for the day will long be remembered as one that is worthy of a page in the world's history of communications.



TYPE 1303-A
TWO-SIGNAL GENERATOR
$1050

a *New* Two-Signal Audio Generator

Ideal for Non-Linear Tests On: ☆ *Audio Amplifiers* ☆ *Hearing Aids* ☆ *Filter Networks* ★ *Noise Suppressors* ★ *High-Efficiency Speech Reproducing Systems* ★ *Loudspeakers* ☆ *F-M Systems with Pre-Emphasis* ★ *Recording Systems* ★ *Any System of Restricted Frequency Range*

The new G-R Type 1303-A Two-Signal Audio Generator supplies signals by the beat-frequency method. Three oscillators and three mixers are used to provide a number of output-signal combinations. The output of the mixers are combined in a linear adding network and then amplified through a very low-distortion power amplifier. The output from the amplifier is fed into a 600-ohm attenuator system, with a voltmeter to monitor the level at the input of the attenuator. The harmonic content and inter-modulation products in the final output are at a very low level. High stability of voltage and frequency are provided. The frequency drift from cold start is only a few cycles.

This A-F Signal Generator will supply the following signals:

- A single low-distortion sinusoidal voltage, adjustable in frequency from 20 cycles to 40 kilocycles, in two ranges.
- Two low-distortion sinusoidal voltages, each separately adjustable, one to 20 kc and the other to 10 kc.
- Two low-distortion sinusoidal voltages with fixed difference in frequency maintained between them as the frequency of one is varied. The fixed difference frequency is adjustable up to 10 kc, and the lower of the two frequencies is adjustable up to 20 kc.

The output is continuously adjustable and is calibrated both in volts and in db with respect to 1 mw into 600 ohms. The frequency calibration can be standardized within one cycle at any time. Its accuracy is ± (1% + 0.5 cycle).

This generator is an excellent and versatile signal source for the three standard non-linear distortion tests:

1. The widely used harmonic distortion test.
2. The intermodulation method that evaluates distortion in terms of the resultant modulation of a high-frequency tone by a low-frequency tone.
3. The difference-frequency intermodulation test, which evaluates distortion in terms of the amplitude of the difference-frequency components produced by intermodulation of two sinusoidal test signals of equal amplitude.

Write for Complete Information

GENERAL RADIO COMPANY Cambridge 39, Massachusetts

90 West St., New York 6   920 S. Michigan Ave., Chicago 5   1000 N. Seward St., Los Angeles 38

New television microphone, developed at RCA Laboratories, virtually vanishes when in active use.

Vanishing Microphone lets the stars shine

Now you see it, now you don't! RCA's new "vanishing microphone" is plainly visible when standing alone—but let a television performer stand before it and it seems to disappear.

Called the "Starmaker," this RCA microphone is little larger than a big fountain pen . . . and principles of design based on modern camouflage blend it with an artist's clothing. There's no clumsy "mike" to distract your attention from the artist—and it's also a superbly sensitive instrument.

Through research carried out at RCA Laboratories, the "Starmaker" microphone picks up sound from all directions—hears and transmits every sound the human ear can detect. It's not only small and almost invisible, but it's also one of the most efficient microphones ever devised.

* * *

See the latest wonders of radio, television, and electronics at RCA Exhibition Hall, 36 West 49th Street, New York. Admission is free. Radio Corporation of America, RCA Building, Radio City, New York 20, New York.

Known for brilliant pictures, RCA Victor's 1951 home television receivers also have the finest of sound systems—RCA Victor's "Golden Throat."

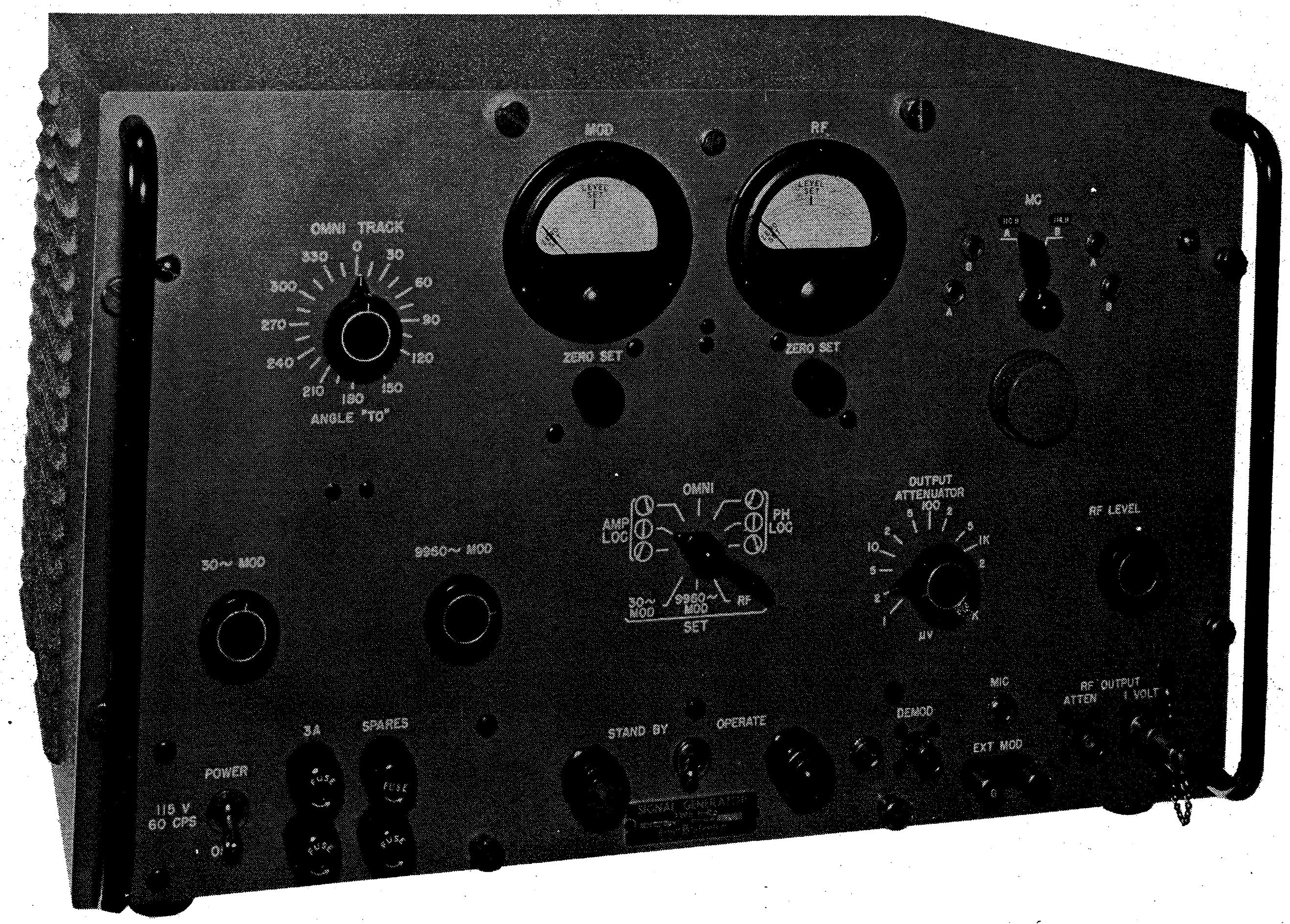
RADIO CORPORATION of AMERICA

World Leader in Radio — First in Television

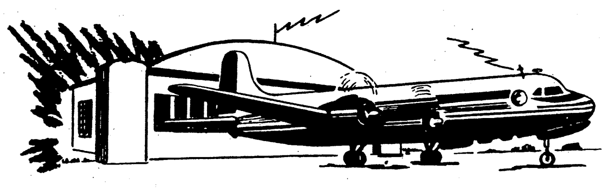
Type H-14 Signal Generator

108-118MC

A TEST SET FOR AIRBORNE VHF NAVIGATIONAL RECEIVING EQUIPMENTS



1. PURPOSE OF THE INSTRUMENT



TESTING OF EQUIPMENT IN AIRCRAFT

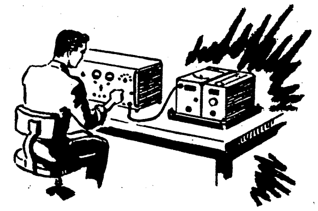
The H-14 Signal Generator provides simulated omni, phase localizer, and tone localizer signals for testing of VHF navigational equipment in one aircraft, or in a squadron of aircraft simultaneously. The instrument will check:

24 omni courses
Left-center-right on 90/150 cps localizer
Left-center-right on phase localizer
Omni course sensitivity
Operation of TO-FROM meter
Operation of flag-alarms

Simultaneous voice instructions to pilots may be transmitted with the test signals. A limited "go-no go" check requires less than one minute for one aircraft or for a squadron of aircraft.

TESTING OF EQUIPMENT ON THE BENCH

The H-14 Signal Generator provides signals of accurately known frequency, amplitude, and modulation for quantitative tests of VHF navigational receiving equipments on the bench.



AIRCRAFT RADIO CORPORATION
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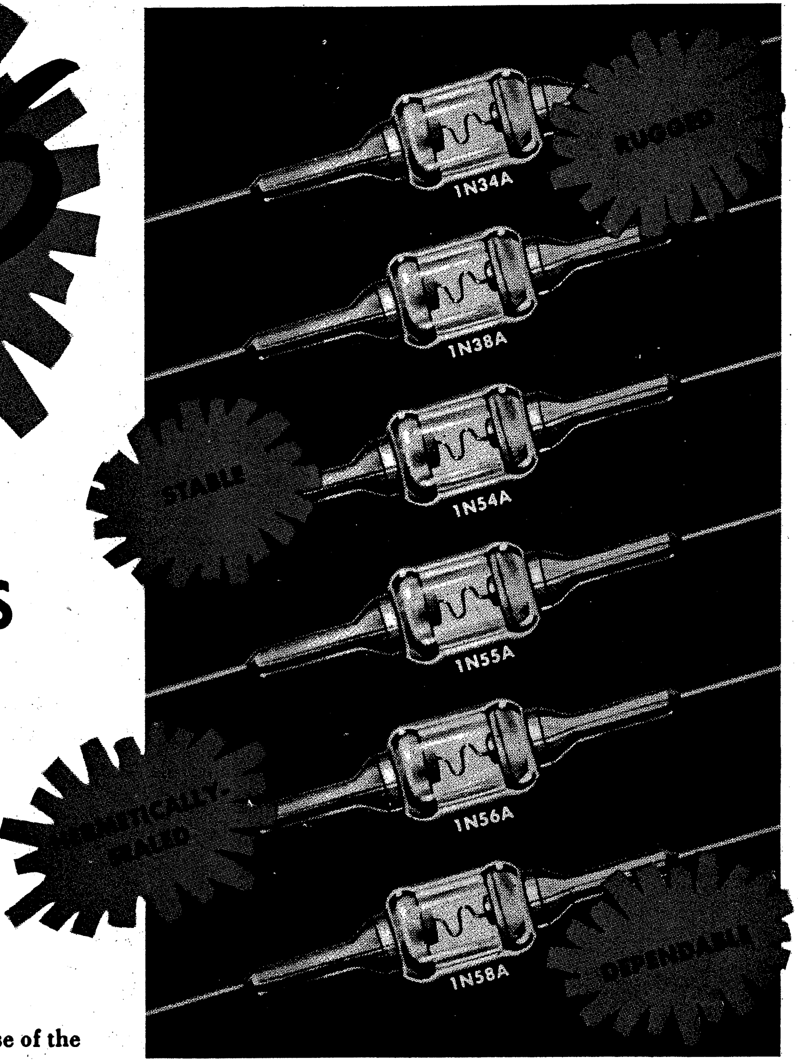
Now 6

SYLVANIA GERMANIUM DIODES SEALED-IN-GLASS

They're individually engineered to meet YOUR circuit requirements



1N34A—General Purpose Diode. The workhorse of the Sylvania line. *New* higher quality standards guarantee back resistance higher than ⅓ megohm at −10 volts.

1N38A—High-Resistance, 100-Volt Diode. *Now* specially engineered to guarantee still higher back resistance at both high and low voltage levels. 0.6 megohm at −3 volts; 0.2 megohm at −100 volts.

IN54A—Here's a real high back resistance crystal. *Now* guaranteed to show at least 1.4 megohms at −10 volts—averages better than 2! Use it for high efficiency in high load resistance circuits.

1N55A—150-Volt Diode. *New* more rigid specifications guarantee at least 0.3 megohm back resistance at −150 volts.

1N56A—Low Forward Impedance Diode. Average forward resistance less than 60 ohms at one volt. Ideal for high efficiency operation into low impedance loads.

1N58A—General Purpose 100-Volt Diode. *Now* guaranteed to have resistance of at least 0.16 megohm at −100 volts. Use it for gating or clamping circuits where dependable high voltage hold-off is required.

Try these new, finer-quality Sylvania "Sealed-in-Glass" Germanium Diodes. You'll find them ideal for scores of applications calling for low power rectification at frequencies up to several hundred megacycles.

Mail the coupon today for a new FREE, 8 page booklet describing Sylvania's complete line of both glass and ceramic style Germanium Diodes and for Varistor types.

ELECTRONIC DEVICES; RADIO TUBES; TELEVISION PICTURE TUBES; ELECTRONIC TEST EQUIPMENT; FLUORESCENT TUBES, FIXTURES, SIGN TUBING, WIRING DEVICES; LIGHT BULBS; PHOTOLAMPS; TELEVISION SETS

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Please send me full information concerning the complete line of Sylvania Germanium Diodes.

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Company __________
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City ______ *Zone* ____ *State* ______

INTERMODULATION METER *Model 31*

- *Completely Self-Contained*
- *Direct Reading For Rapid, Accurate Measurements*

To insure peak performance from all audio systems; for correct adjustment and maintenance of AM and FM receivers and transmitters; checking linearity of film and disc recordings and reproductions; checking phonograph pickups and recording styli; checking record matrices; adjusting bias in tape recordings, etc.

GENERATOR

LOW FREQUENCY: 60 cycles.*
HIGH FREQUENCY: 3000 cycles.*
LF/HF VOLTAGE RATIO: Fixed 4/1.
OUTPUT VOLTAGE: 10v. max. into high impedance or +5 DBM matched to 600 ohms.
OUTPUT IMPEDANCE: 2000 ohms.
RESIDUAL IM: 0.2% max.
*(*Other frequencies on special order)*

ANALYZER

INPUT VOLTAGE: Full scale ranges of 3, 10 and 30 volts RMS. Less than one volt of mixed signal is sufficient for operation.
INPUT IMPEDANCE: Greater than 400 K ohms.
INTERMODULATION: Full scale ranges of 3, 10 and 30%.
ACCURACY: ±10% of full scale.
OSCILLOSCOPE connection at meter.

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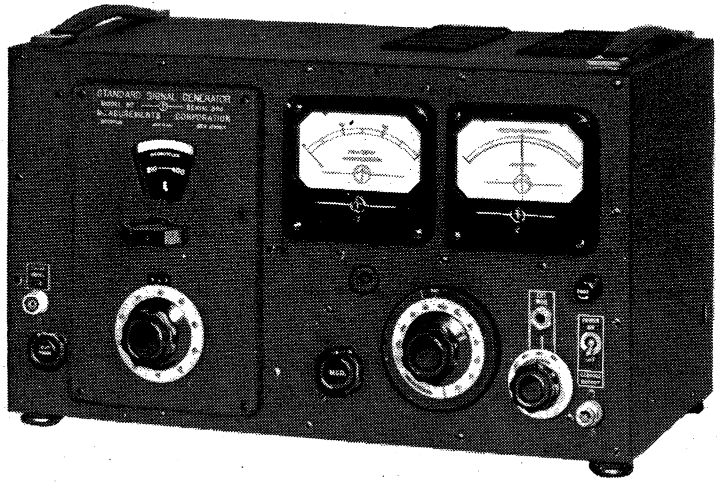
BOONTON NEW JERSEY

MEASUREMENTS CORPORATION *MODEL 80*

STANDARD SIGNAL GENERATOR



2 to 400 MEGACYCLES

MODULATION: Amplitude modulation is continuously variable from 0 to 30%, indicated by a meter on the panel. An internal 400 or 1000 cycle audio oscillator is provided. Modulation may also be applied from an external source. Pulse modulation may be applied to the oscillator from an external source through a special connector. Pulses of 1 microsecond can be obtained at higher carrier frequencies.

FREQUENCY ACCURACY ±.5%

OUTPUT VOLTAGE
0.1 to 100,000 microvolts

OUTPUT IMPEDANCE
50 ohms

MANUFACTURERS OF
Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
UHF Radio Noise & Field Strength Meters
Capacity Bridges
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Phase Sequence Indicators
Television and FM Test Equipment

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

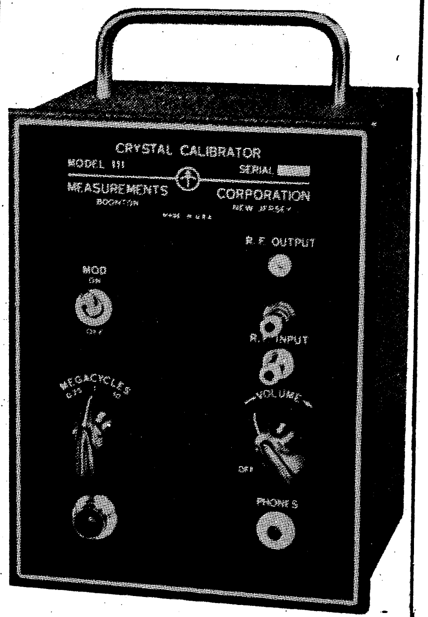
CRYSTAL CALIBRATOR

MEASUREMENTS CORPORATION

Model 111

FREQUENCY RANGE: .25Mc.—1000 Mc.

FREQUENCY ACCURACY:
±0.001%



A Dual-Purpose Calibrator

- **CRYSTAL-CONTROLLED OSCILLATOR**
- **BUILT-IN DETECTOR**
  2 Microwatt Sensitivity

Designed for the Calibration and Frequency Checking of Signal Generators, Transmitters, Receivers, Grid-Dip Meters and other equipment where a high degree of frequency accuracy is required.

Harmonic Range:

.25 Mc. Oscillator:	.25-450 Mc.
1 Mc. Oscillator:	1-600 Mc.
10 Mc. Oscillator:	10-1000 Mc.

117 volts, 50/60 cycles; 18 watts, 6" wide, 8" high, 5" deep; 4 lbs.

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MEASURING INSTRUMENTS
FOR ACCURATE, DEPENDABLE SERVICE

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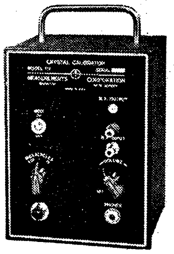
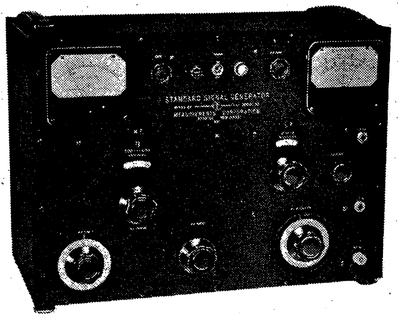
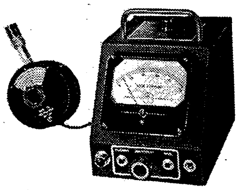


CRYSTAL
CALIBRATOR
Model 111
250 Kc. to 1000 Mc.

U. H. F. OSCILLATOR
Model 112
300 Mc. to 1000 Mc.



STANDARD SIGNAL GENERATOR
Model 82
20 Cycles to 50 Mc.



MEGACYCLE
METER
Model 59
2.2 Mc. to 400 Mc.

STANDARD SIGNAL GENERATORS

MODEL	FREQUENCY RANGE	OUTPUT RANGE	MODULATION
65-B	75 Kc.-30 Mc.	0.1 microvolt to 2.2 volts	AM. 0 to 100% 400 cycles or 1000 cycles External mod., 50-10,000 cycles
78	15-25 Mc.; 195-225 Mc. 15-25 Mc.; 90-125 Mc. other ranges on order	1 to 100,000 microvolts	AM. 8200-400 cycles 625-400 cycles Fixed at approximately 30%
78-FM	86 Mc.-108 Mc.	1 to 100,000 microvolts	Deviation 0-300 kc, 2 ranges FM. 400-8200 cycles External modulation to 15 Kc.
80	2 Mc.-400 Mc.	0.1 to 100,000 microvolts	AM. 0 to 30% 400 cycles or 1000 cycles External mod., 50-10,000 cycles.
82	20 cycles to 200 Kc. 80 Kc. to 50 Mc.	0-50 volts 0.1 microvolt to 1 volt	Continuously variable 0-50% from 20 cycles to 20 Kc.
84	300 Mc.-1000 Mc.	0.1 to 100,000 microvolts	AM. 0 to 30%, 400, 1000, or 2500 cycles. Internal pulse modulator. External mod., 50-30,000 cycles.
90	20 Mc.-250 Mc.	0.3 microvolt to 0.1 volt	Continuously variable, 0 to 100% Sinusoidal modulation 30 cycles-5 Mc. Composite TV modulation.

U. H. F. OSCILLATOR

MODEL	FREQUENCY RANGE	OUTPUT RANGE	OUTPUT IMPEDANCE
112	300 Mc. — 1000 Mc.	Maximum varies between 0.3 volt and 2 volts. Adjustable over 40 db range.	50 ohms

PULSE GENERATOR

MODEL	FREQUENCY RANGE	PULSE WIDTH	OUTPUT
79-B	60 to 100,000 cycles	Continuously variable from 0.5 to 40 microseconds	Approximately 150 volts positive with respect to ground. "Sync Output" 75 volts positive with respect to ground.

SQUARE WAVE GENERATOR

MODEL	FREQUENCY RANGE	WAVE SHAPE	OUTPUT
71	Continuously variable 6 to 100,000 cycles	Rise time less than 0.2 microseconds with negligible overshoot	Step attenuator: 75, 50, 25, 15, 10, 5 peak volts fixed and 0 to 2.5 volts continuously variable.

U.H.F. RADIO NOISE and FIELD STRENGTH METER

MODEL	FREQUENCY RANGE	INPUT VOLTAGE RANGE
58	15 Mc. to 150 Mc.	1 to 100,000 microvolts in antenna. 1 to 100 microvolts on semi-logarithmic output meter, balanced resistance attenuator with ratios of 10, 100 and 1000 ahead of all tubes.

VACUUM TUBE VOLTMETERS

MODEL	VOLTAGE RANGE	FREQUENCY RANGE	INPUT IMPEDANCE
62	0-1, 0-3, 0-30 and 0-100 volts AC or DC	30 cycles to over 150 Mc.	Approximately 7 mmfd.
62-U.H.F.	0-1, 0-3, 0-30 and 0-100 volts AC or DC	100 Kc. to 500 Mc.	Approximately 2 mmfd.
67	.0005 to 300 volts peak-to-peak	5 to 100,000 sine-wave cycles per second	1 megohm shunted by 30 mmfd.

MEGACYCLE METER

MODEL	FREQUENCY RANGE	FREQUENCY ACCURACY	MODULATION
59	2.2 Mc. — 400 Mc.	Within ± 2%	CW or 120 cycles fixed at approximately 30%. Provision for external modulation

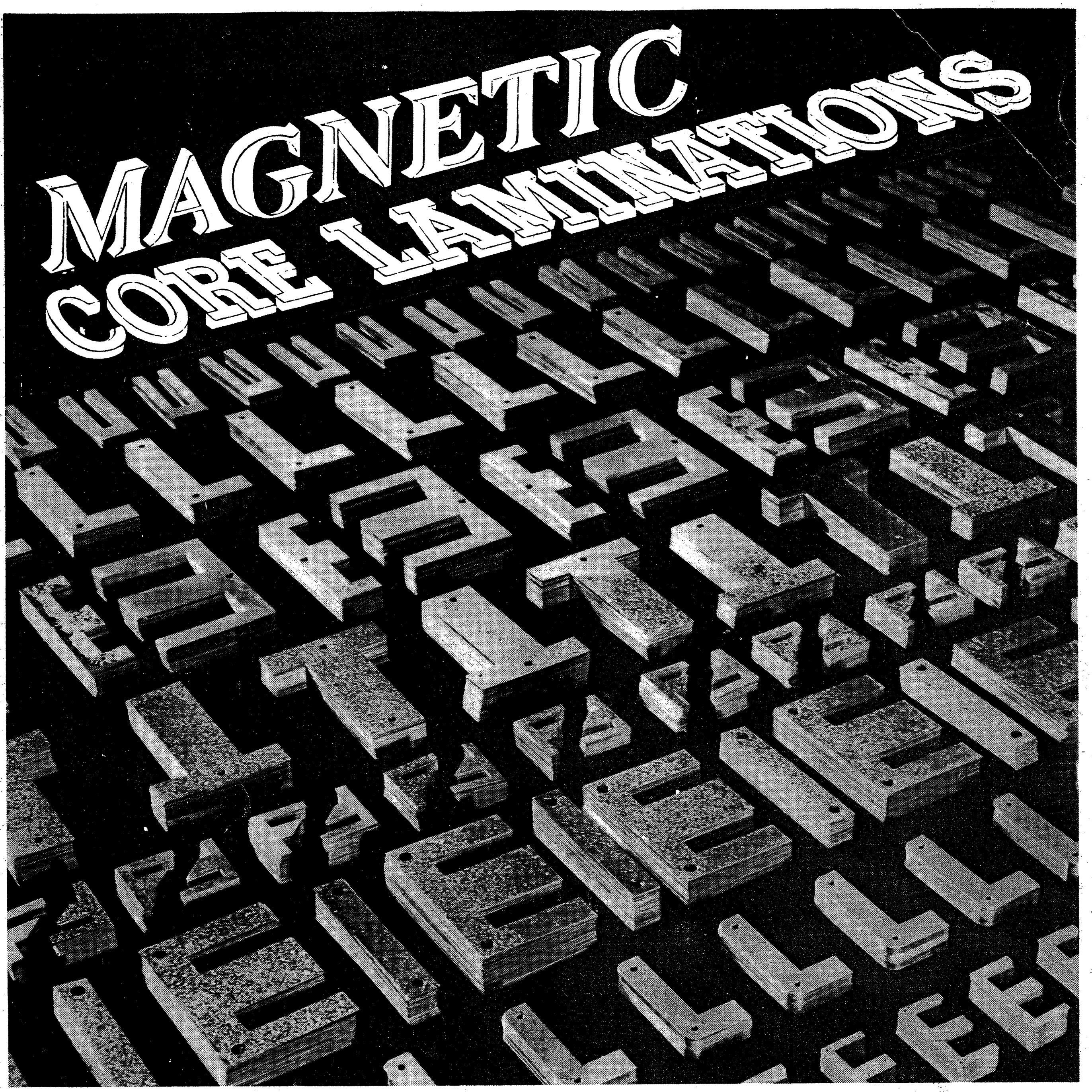
CRYSTAL CALIBRATOR

MODEL	FREQUENCY RANGE	FREQUENCY ACCURACY	HARMONIC RANGE
111	250 Kc. — 1000 Mc.	0.001%	.25 Mc. Oscillator: .25-450 Mc. 1 Mc. Oscillator: 1-600 Mc. 10 Mc. Oscillator: 10-1000 Mc.

BRIDGES

MODEL	INDUCTANCE (L)	CAPACITANCE (C)	AC RESISTANCE (R)
102	0.5 microhenry to 110 henries	1 mmf. to 110 mfd. Power factor 0-30%	1 ohm to 11 megohms

MEASUREMENTS CORPORATION • BOONTON, N. J.


MAGNETIC
CORE LAMINATIONS