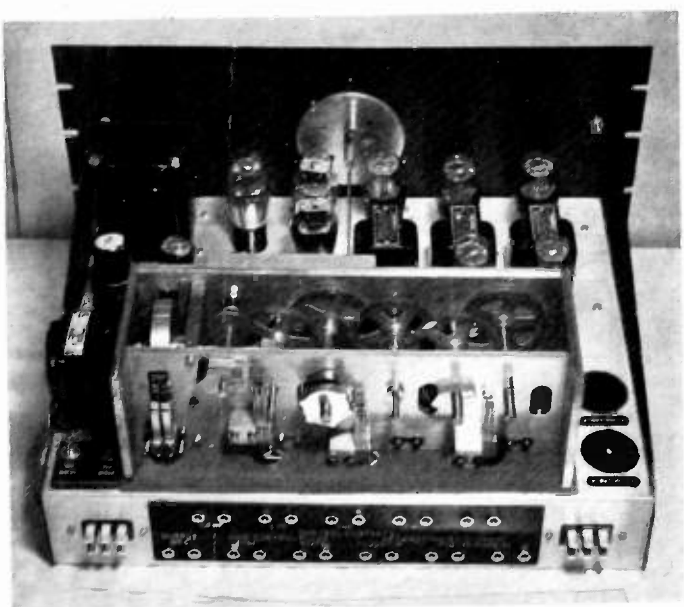
Proceedings of the I·R·E

A Journal of Communications and Electronic Engineering
(Including the WAVES AND ELECTRONS Section)



National Bureau of Standards

ELECTRONIC TIMEKEEPER OF HIGH PRECISION

Highly accurate time signals are transmitted continuously by station WWV of the United States National Bureau of Standards. The seconds-pulses generator and time-interval selector, shown above, provide the time controls. Three independent units are kept precisely in phase. The cam on the flywheel next to the driving motor opens a gate to permit highly accurate seconds pulses to be broadcast; longer intervals initiating station announcements are gated by succeeding cams.

August, 1947

Volume 35 Number 8

PROCEEDINGS OF THE I.R.E.

Waves and Electrons Section

TABLE OF CONTENTS PAGE FOLLOWS PAGE 32A

The Institute of Radio Engineers

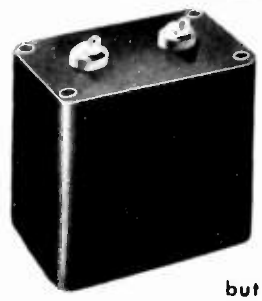
FOR HIGH Q TOROIDS

U. T. C. Permalloy dust core toroid coils combine the optimum type of core for each application with special U. T. C. winding methods to insure a maximum of Q and stability of characteristics. Having specialized in this field for many years, U. T. C. has developed a number of standardized types of coils and filters suited to virtually every application.

UTC HIGH Q TOROID COILS

HQA REACTOR

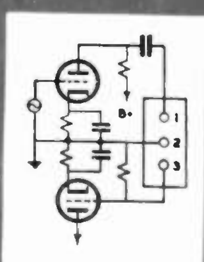
These reactors are designed for audio frequency operation with high Q and excellent stability. For a typical coil, (.14 Hy.), inductance varies less than 1% from .1 to 25 volts . . . Q is 120 at 5,000 cycles . . . hum pickup is low (toroidal structure), 70 Mv. per gauss at 60 cycles . . . variation in inductance less than ⅓ % from −60° C. to +85° C. . . . hermetically sealed in drawn case 1-13/16" diameter x 1- 3/16" high . . . weight 5 ounces . . . available in inductance values from 5 Mhys. to 2 Hys.

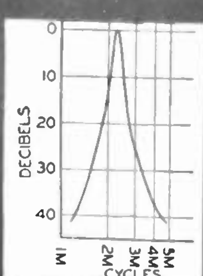


HQB REACTOR

The HQB reactors are similar to the HQA series, but provide higher Q. For a typical coil, (.45 Hy.), inductance varies less than 1% with applied voltage from .1 to 50 volts . . . hum pickup twice that of HQA . . . variation of inductance less than ⅓ % from −50° C. to +85° C. . . . Q is 200 at 4000 cycles . . . hermetically sealed in steel case 1⅝" x 2⅝" x 2½" high . . . 14 ounces . . . available in any inductance value from 5 Mhys. to 12 Hys.

UTC TOROID COIL INTERSTAGE FILTERS



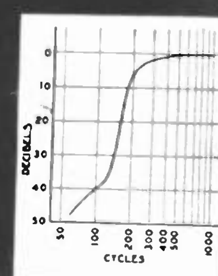


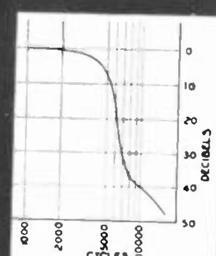
U. T. C. toroid interstage filters are designed to operate between vacuum tube stages and have a nominal impedance of 10,000 ohms. They are not stocked but are available from standardized components for any frequency from 200 to 30,000 cycles. Dimensions, including dual alloy shielding, are same as the HQB reactors.

BPI units have 2:1 gain. They are sharply peaked, having approximately 2 DB attenuation at plus or minus 3% from mean frequency and attenuations of approximately 40 DB per octave. They are adjusted to zero phase shift at mean frequency.

HPI units have loss of less than 6 DB at cutoff frequency. At .67 cutoff frequency the attenuation is 35 DB and at .5 cutoff frequency, 40 DB.

LPI units have loss of less than 6 DB at cutoff frequency. At 1.5 cutoff frequency the attenuation is 35 DB and at twice cutoff frequency, 40 DB.





For further details write for Bulletin PS-407

United Transformer Corp.

150 VARICK STREET NEW YORK 13, N. Y.

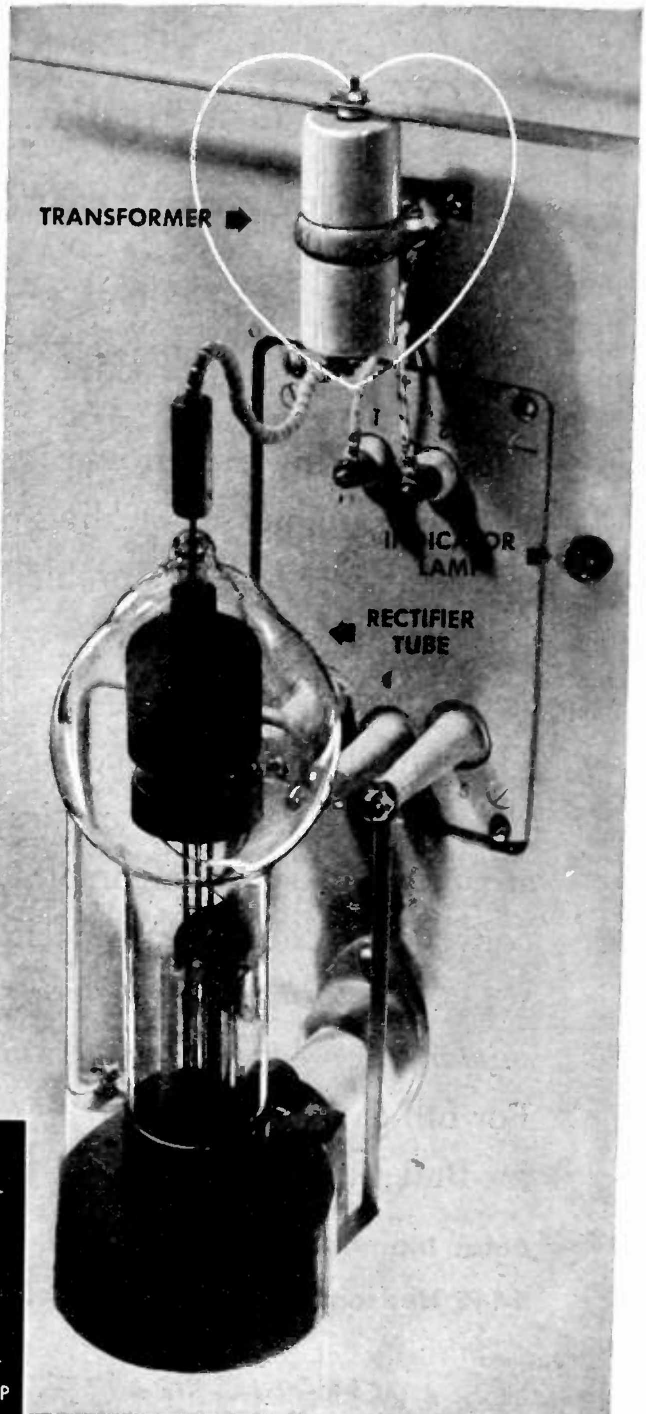
EXPORT DIVISION: 13 EAST 40th STREET, NEW YORK 16, N. Y., CABLES: "ARLAB"

PROCEEDINGS OF THE I.R.E., July, 1947, Vol. 35, No. 8. Published monthly in two sections by The Institute of Radio Engineers, Inc., at 1 East 79 Street, New York 21, N.Y. Price $1.50 per copy. Subscriptions: United States and Canada, $12.00 a year; foreign countries $13.00 a year. Entered as second class matter, October 26, 1927, at the post office at Menasha, Wisconsin, under the act of March 3, 1879. Acceptance for mailing at a special rate of postage is provided for in the act of February 28, 1925, embodied in Paragraph 4, Section 412, P. L. and R., authorized October 26, 1927.

Table of contents will be found following page 32A

Another "FIRST" for Western Electric

NEW Arc-Back Indicator in Western Electric FM Transmitters spots faulty mercury vapor rectifier tube surely . . . instantly!



Arc-backs in mercury vapor rectifier tubes are rare—but when one occurs it is *essential* that you locate the faulty tube *at once*.

And that is exactly the function of the new Arc-Back Indicator, an exclusive feature of Western Electric FM Transmitters of 10 kw and higher powers.

Gone is the uncertainty as to which tube is at fault, for the Arc-Back Indicator shows you *instantly* . . . enables you to get back on the air in a fraction of the usual time.

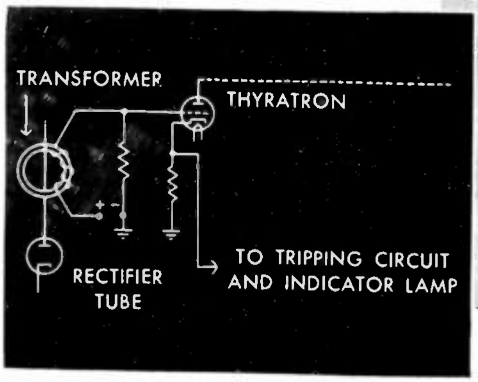
The new Indicator is only one of the *major* features which put Western Electric FM Transmitters in a class by themselves. The Power and Impedance Monitor—which gives an accurate, direct measurement of the actual RF power fed to the antenna system and, in addition, a method of measuring standing wave ratio under full power output—is another. The Frequency Watchman for precise, dependable frequency control is a third.

Investigate Western Electric before you buy any FM transmitter. The Western Electric line ranges from 250 watts to 50 kw in power. Call your local Graybar Broadcast Representative, or write Graybar Electric Co., 420 Lexington Ave., New York 17, N. Y., for full information.

Western Electric

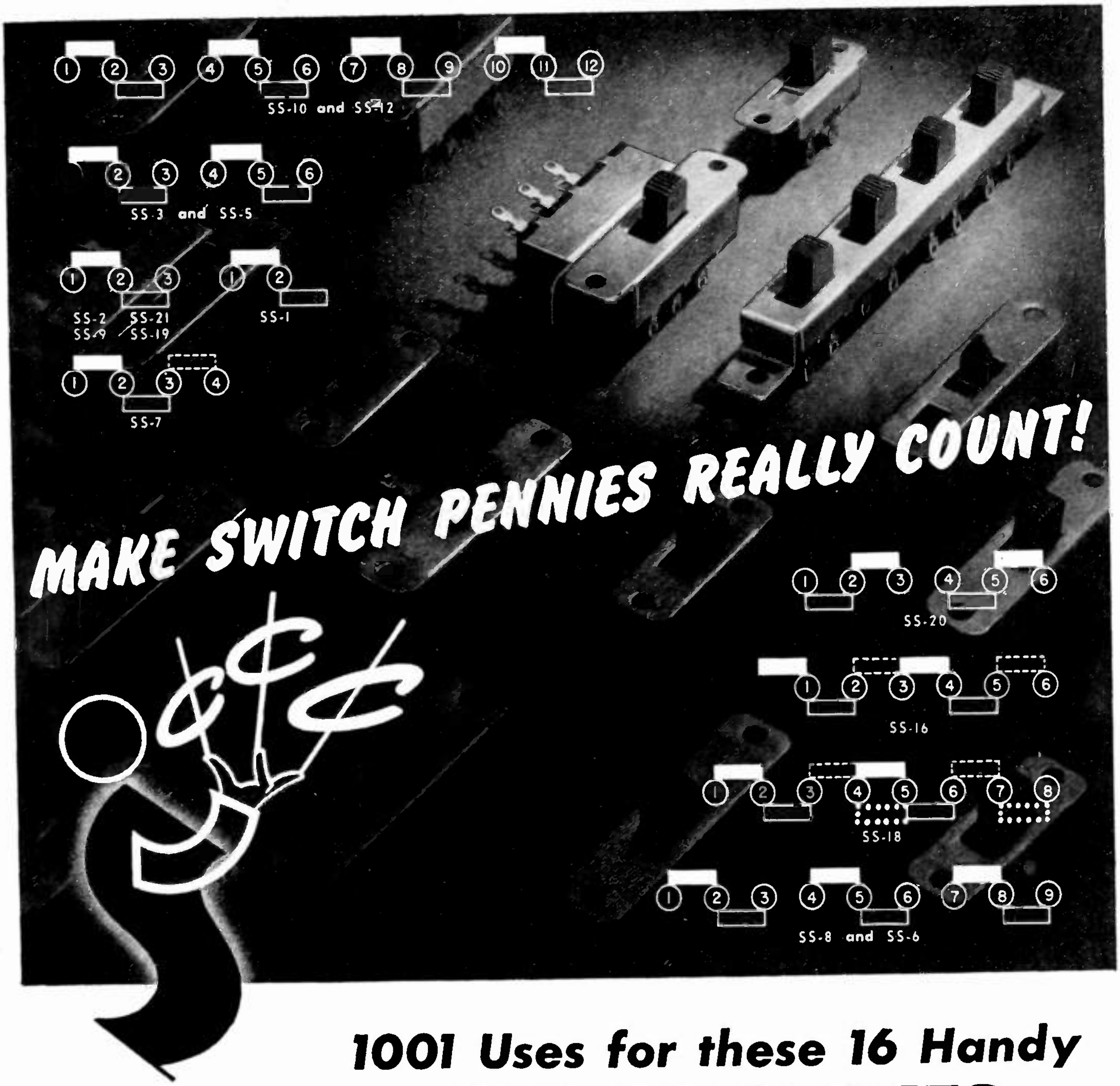
Distributed by GraybaR

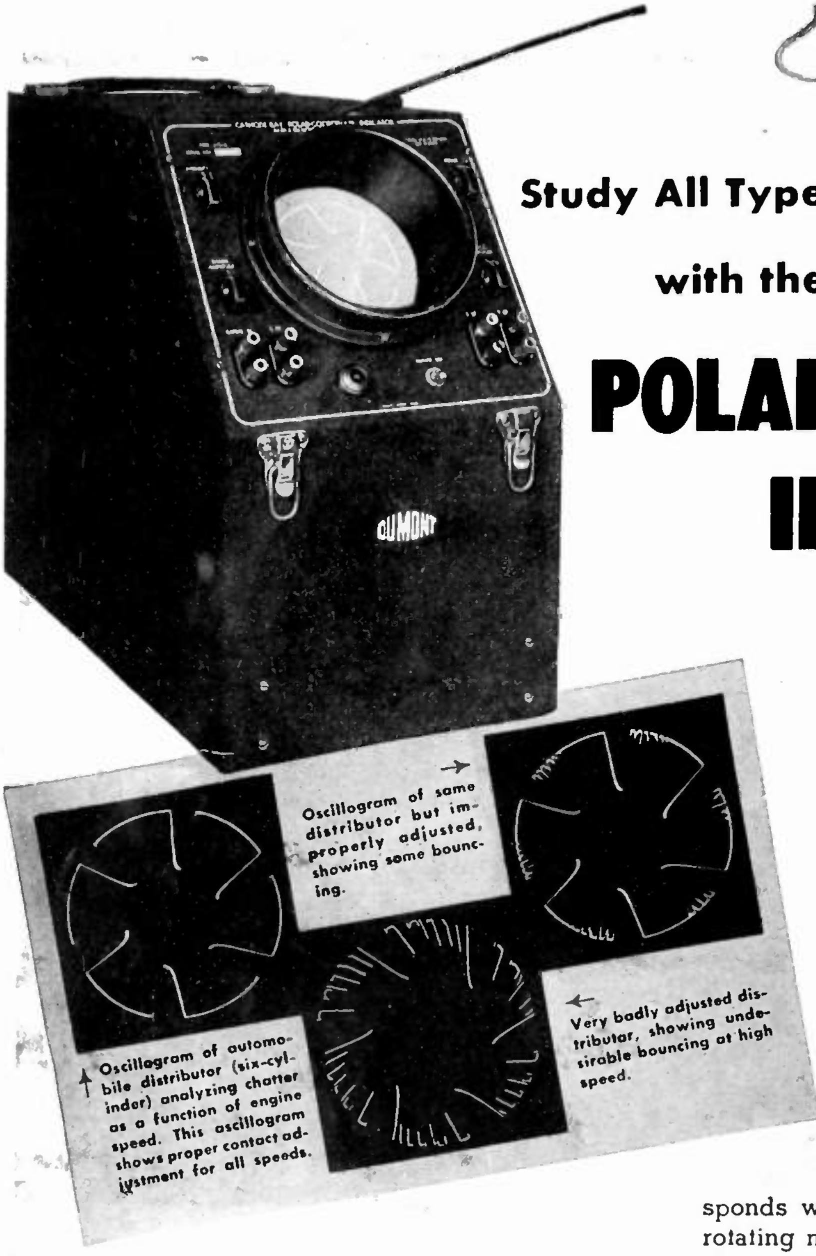
OFFICES IN 95 PRINCIPAL CITIES



Heart of the new and exclusive Arc-Back Indicator circuit is a saturated toroidal transformer which responds only to reverse current in its associated rectifier tube. When an arc-back occurs, the voltage from the transformer fires a small thyratron tube which removes high voltage and lights the proper indicator lamp, visible through the glass front door of the TRANSVIEW design transmitter. In case of a string of "sympathetic" arc-backs, only *one* indicator lamp is fired—the one associated with the rectifier in which the *original* arc-back occurred.

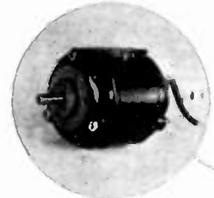
— *QUALITY COUNTS* —


SS-10 and SS-12
SS-3 and SS-5
SS-2 SS-21
SS-9 SS-19
SS-1
SS-7
MAKE SWITCH PENNIES REALLY COUNT!
SS-20
SS-16
SS-18
SS-8 and SS-6



Study All Types of Rotating Machinery with the *New* Type 275-A

POLAR-COORDINATE INDICATOR



- ✓ Fully portable; self-contained
- ✓ Type 5CP-A Cathode-ray Tube
- ✓ 3000 v. accelerating potential
- ✓ Continuous time base 100-3600 r.p.m.
- ✓ Automatic synchronization
- ✓ Frequency response of radial amplifier less than 10% down at 2 cps. and 30 kc.
- ✓ 0.4 v. R.M.S. sufficient to apply deflection to center

All types of rotating machinery can be studied with the new Du Mont Type 275-A Polar-Coordinate Cathode-ray Indicator. Likewise the plotting of phenomena on a circular time base.

This circular time base provides a *continuous time base* since no time is lost on retraces. Furthermore, a given spot position along this time base always corresponds with the same phase or rotation angle, regardless of speed of rotation.

Presentation on a circular or angular time base corresponds with methods customarily used in studying rotating machinery. The signal under examination is always synchronized with the circular sweep of the cathode-ray tube since the sweep is controlled directly by means of a two-phase generator coupled to the apparatus from which the signal is taken. This generator is supplied with the Type 275-A.

The Polar-Coordinate Indicator is designed for use in the laboratory or in the field. Major controls conveniently located on front panel; those for occasional adjustment, in recessed space accessible through top of unit. Cathode-ray tube set at 55° angle for ease of observation.

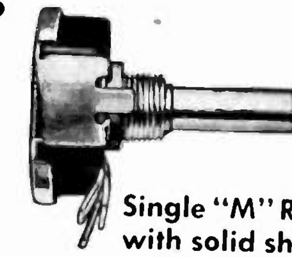
Write for further details . . .

DUMONT *Precision Electronics & Television*

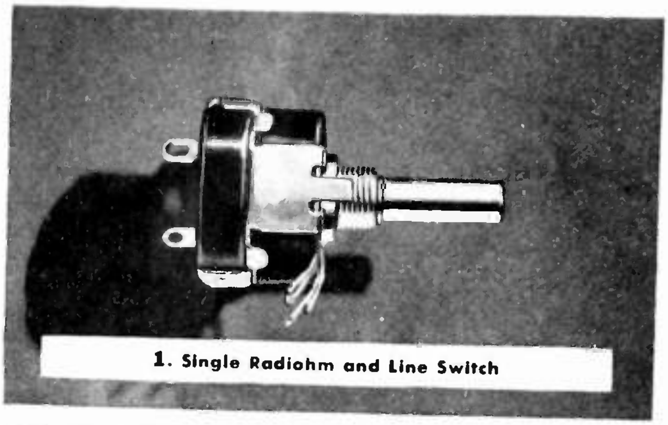
ALLEN B. DUMONT LABORATORIES, INC., PASSAIC, NEW JERSEY • CABLE ADDRESS: ALBEEDU, PASSAIC, N. J., U. S. A.

Want to simplify production?

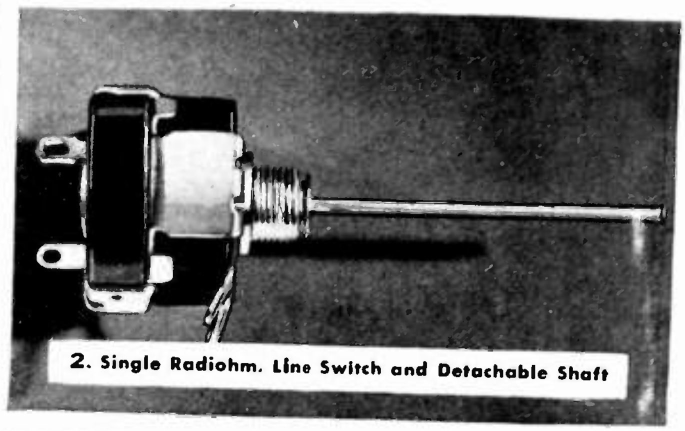
See how Centralab's model "M" Radiohm gives you wide range of possible mechanical variations . . . helps keep down your inventory, step up your production of electronic equipment.



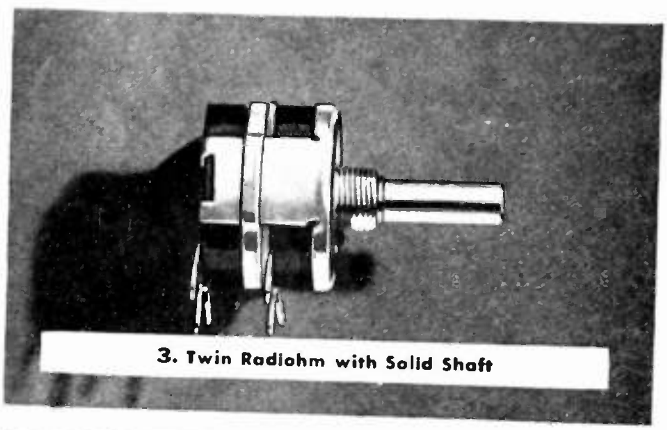
Single "M" Radiohm with solid shaft



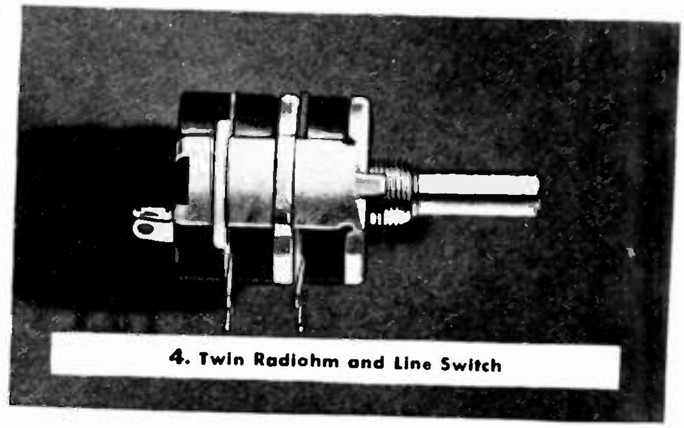
1. Single Radiohm and Line Switch



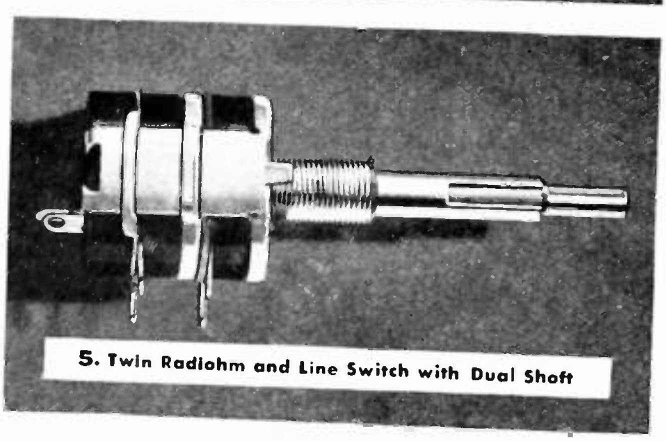
2. Single Radiohm. Line Switch and Detachable Shaft



3. Twin Radiohm with Solid Shaft



4. Twin Radiohm and Line Switch



5. Twin Radiohm and Line Switch with Dual Shaft

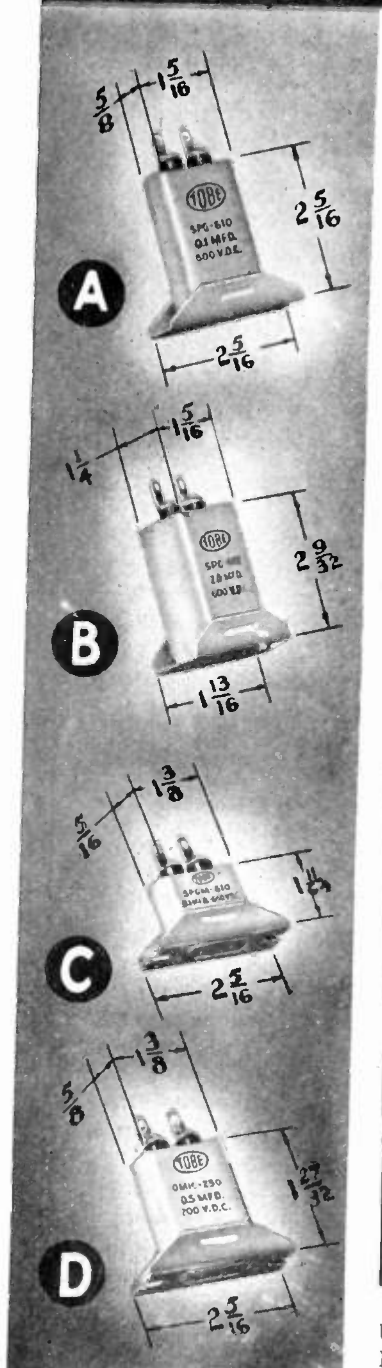
Your choice of detachable and dual shafts gives you new versatility, maximum convenience!

ONE LOOK at the many variations you can have from Centralab's single model "M" Radiohm, and you'll see why it's one of the most popular controls on the market today for cost-conscious manufacturers! Added to this: fine CRL engineering and research have given it a guaranteed minimum life test of 10,000 cycles (control resistance that is) . . . an average life expectancy of 20,000-25,000 cycles. Available with shaft and bushing lengths to meet your needs. For complete facts, send for Bulletin R697-A.

LOOK TO CENTRALAB IN 1947! First in component research that means lower costs for the electronic industry . . . pioneer manufacturer of Radiohms, switches, capacitors and ceramics.

Centralab CRL
Division of GLOBE-UNION INC., Milwaukee

CHECK *these* SPECIFICATIONS



These data explain the outstanding performance of Tobe "Oil-Mites" . . . demonstrate their qualifications for use under extreme humidity and temperature environment . . . show the diversity of mounting provisions, sizes, housings, and electrical ratings for convenient incorporation in electronic and electrical apparatus.

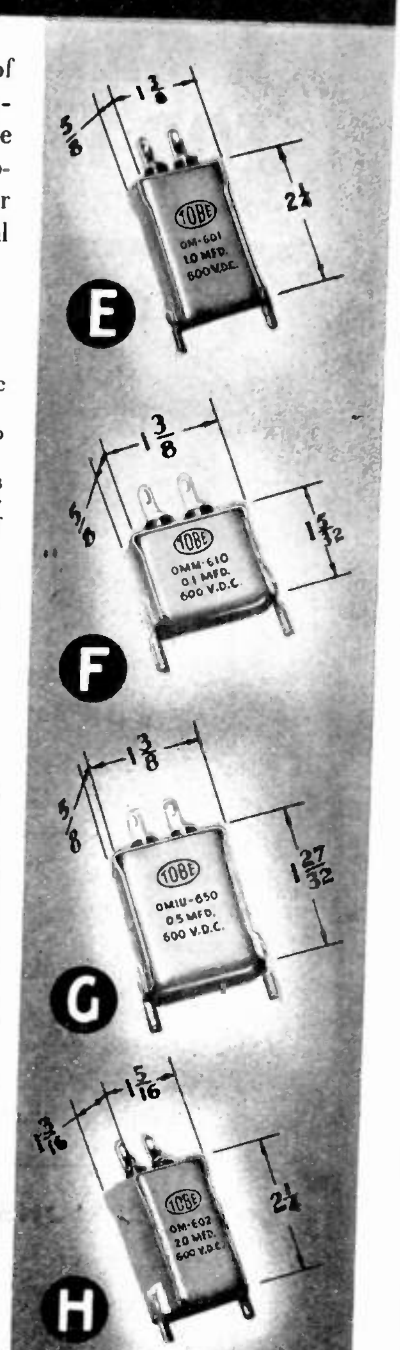
Winding: non-inductive.
Impregnation: mineral oil.
Case: seamless drawn steel, hermetically sealed; non-magnetic case (copper or brass) can be furnished.
Terminals: non-removable tinned copper solder lugs riveted to phenolic bushings.
Terminal Seal: oilproof gaskets between all adjacent surfaces in terminal assembly; terminal solder-sealed to assembly rivets; metal-to-glass-sealed terminals can be furnished if specified.
Case Finish: tinned all over.
Markings: type number, voltage and capacitance rating, and terminal identification ink-stamped on case.
Insulation Resistance: never less than 2,000 megohms.
Dissipation Factor: less than 0.008 at 1,000 cycles.
Operating Temperature: minus 55C to plus 85C.

With Attached Channel Bracket

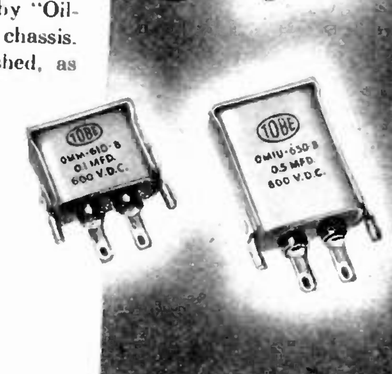
VDC	MFD			
	Case A	Case B	Case C	Case D
100	—	4.0	.01 — .25 2 x .05, 2 x .1	.01 — 1.0 2 x .05, 2 x .1
200	—	—		
400	—	2.0		.01 — .50 2 x .05, 2 x .1
600	.01 — 1.0			
1000	.05 — .50	1.0	.01 — .1	.01 — .25

With Reversible Hold-Down Bracket

VDC	MFD			
	Case E	Case F	Case G	Case H
100	—	.01 — .25 2 x .05, 2 x .1	.01 — 1.0 2 x .05, 2 x .1	4.0
200	—			—
400	—		.01 — .5 2 x .05, 2 x .1	2.0
600	.01 — 1.0			
1000	—	.01 — .1	.01 — .25	.05 — 1.0



Uniformity of size adds to the convenience afforded by "Oil-Mites," allowing gang installation above or below the chassis. Both upright and inverted mounting can be furnished, as illustrated. Where necessary, variation can be made in style and position of terminal lugs.

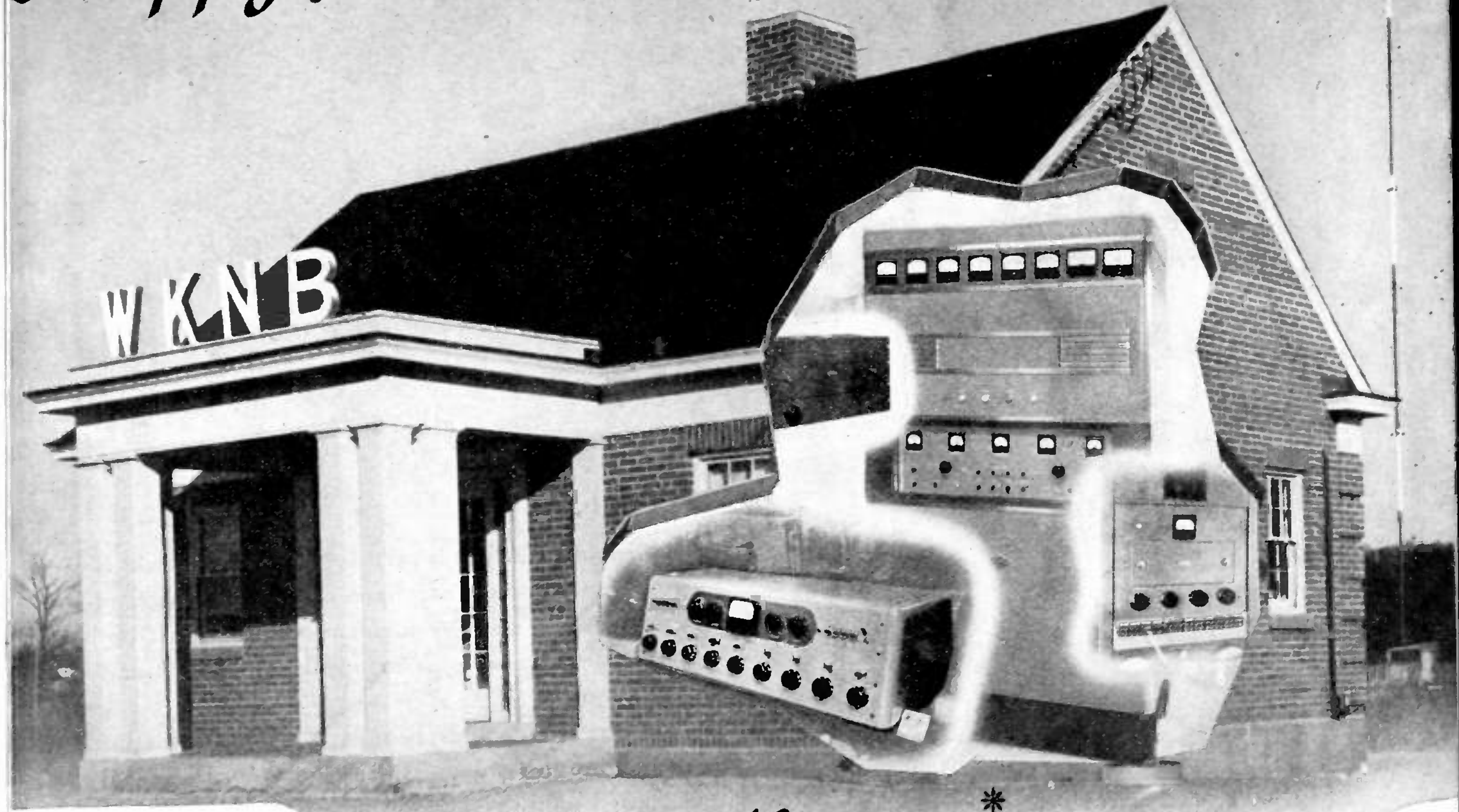


Reprints of this specification page are available and will be sent on request. For detailed data on "Oil-Mites" and other Tobe Capacitors ask for Catalog 477-RE

TOBE

TOBE DEUTSCHMANN *Corporation* CANTON, MASSACHUSETTS

Happy Anniversary, WKNB...



Raytheon equipment installed includes: RM 10 Monitoring Amplifier; RL-10 Limiting Amplifier; RC-10 Studio Console; R9 1000 Watt AM Transmitter.

AND *More Power** TO YOU!

Every day for twelve consecutive months New Britain's WKNB has been operating on the Raytheon equipment shown. Owner and engineers now *know from experience* that Raytheon is truly "the finest in broadcast equipment." Result: When WKNB is ready to use *more power, they will buy their equipment from Raytheon!

Users the country over are enthusiastic about the high fidelity, servicing accessibility and low-cost maintenance of Raytheon AM and FM broadcast equipment. They find it greatly facilitates setting up programs, with operation so simple and logical that errors are cut to a minimum.

Get the facts before you buy. Write for illustrated bulletins and technical data on the complete line of Raytheon Speech Input Equipment and AM and FM Transmitters ranging from 250 to 10,000 watts.

Meet Chris Brauneck . . .

Here's the chap who helped select and procure the Raytheon equipment and associated items for WKNB . . . and, incidentally for many other New England stations. He is typical of the high type Raytheon representatives who are ready to work with *you:*

CHRISTIAN BRAUNECK
1020 Commonwealth Ave.
Boston, Massachusetts
Tel. Aspinwall 6734

HENRY J. GEIST
60 East Forty-Second Street
New York 17, New York
Tel. Murray Hill 2-7440

W. B. TAYLOR
Signal Mountain
Chattanooga, Tennessee
Tel. 8-2487

ADRIAN VAN SANTEN
Fifth and Spring Streets
Seattle, Washington
Tel. Eliot 6175

COZZENS & FARMER
7475 North Rogers Avenue
Chicago 26, Illinois
Tel. Ambassador 0712

HOWARD D. CRISSEY
414 West Tenth Street
Dallas 8, Texas
Tel. Yale 2-1904

EMILE J. ROME
215 West Seventh Street
Los Angeles, California
Tel. Tucker 7114

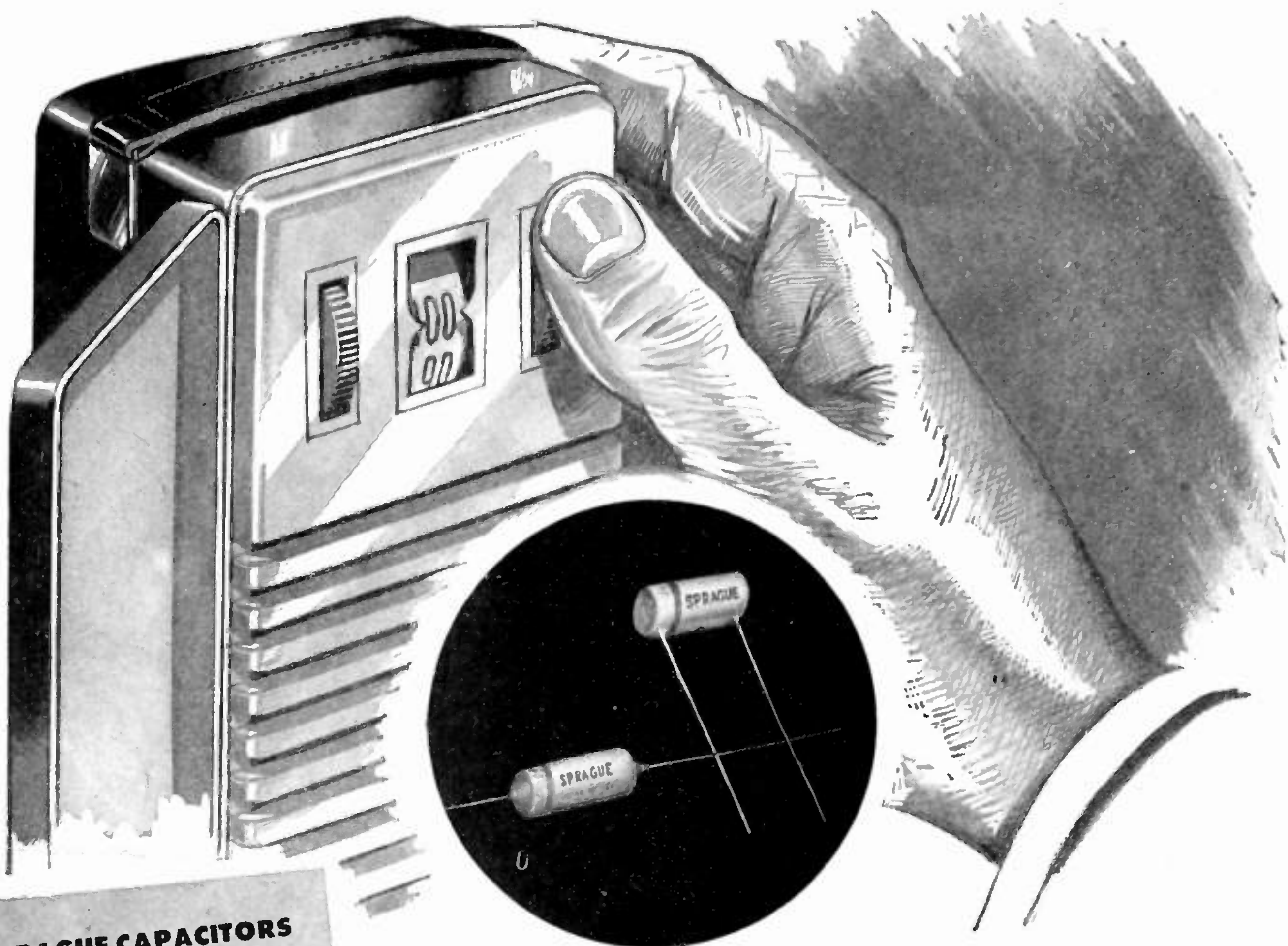
RAYTHEON

Excellence in Electronics

RAYTHEON MANUFACTURING COMPANY
COMMERCIAL PRODUCTS DIVISION
WALTHAM 54, MASSACHUSETTS

Industrial and Commercial Electronic Equipment, Broadcast Equipment, Tubes and Accessories

Sales offices: Boston, Chattanooga, Chicago, Dallas, Los Angeles, New York, Seattle

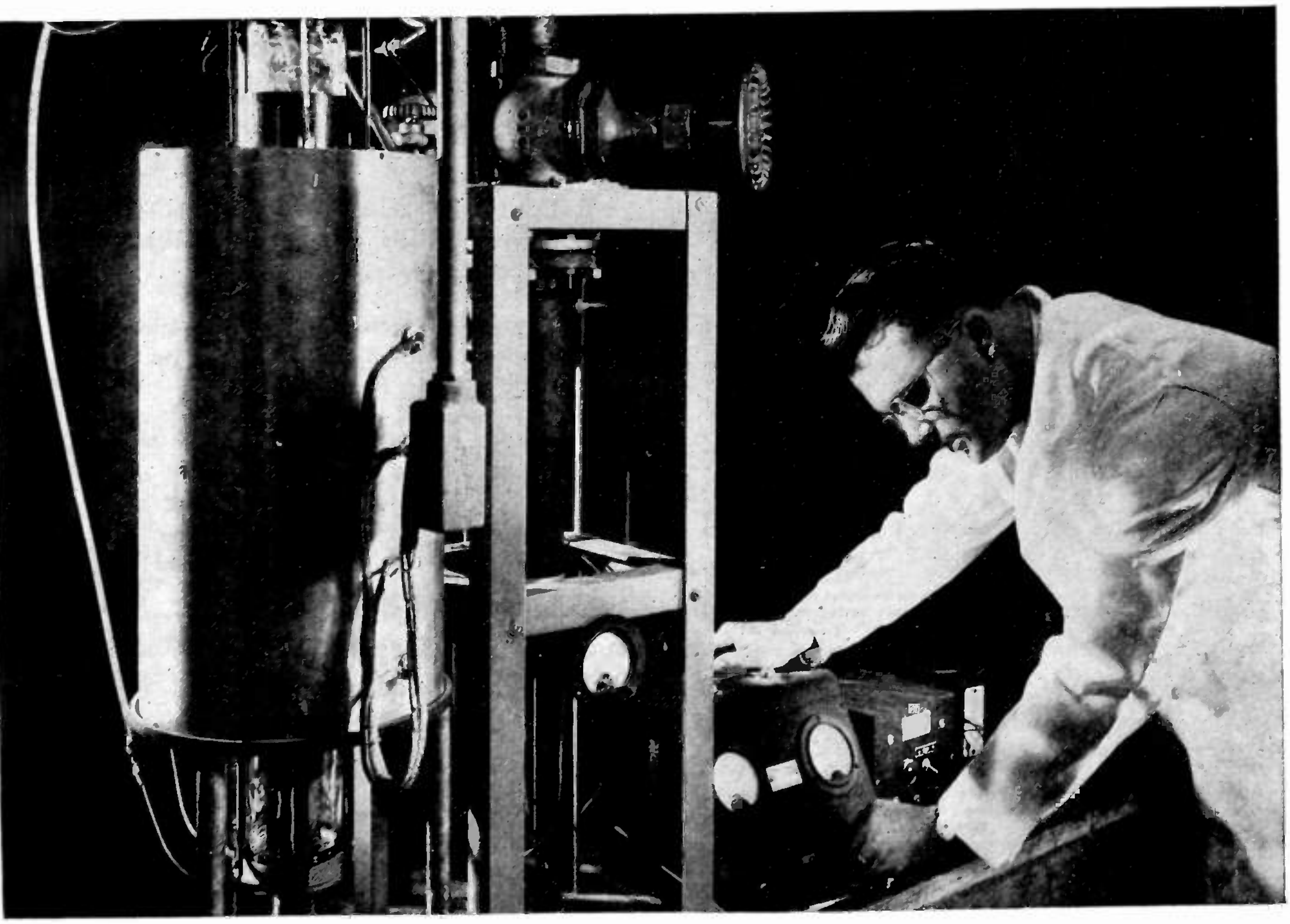


SPRAGUE
SPRAGUE

SYLVANIA RESEARCH NEWS

AUGUST *Prepared by* SYLVANIA ELECTRIC PRODUCTS INC., Bayside, L. I. 1947

ELABORATE SYLVANIA-DESIGNED APPARATUS AIDS IN RESEARCH OF RADIO TUBE WIRE THINNER THAN A HAIR



This High Temperature Vacuum Creep equipment—specially designed by Sylvania Metallurgical Research Laboratories—is one of the many developments Sylvania uses to insure the manufacture of radio tubes of unsurpassed quality.

It accommodates four specimens—suspended and weighted—which can be electrically heated in vacuum or gases, simulating actual tube conditions. Built-in micrometers at base of furnace chamber accurately measure the elongation or stretch of various alloy wires, under different temperatures and tensions.

Technician is examining Pirani Gage used to measure furnace vacuum—enabling testing finer-than-hair wire at various degrees of vacuum, as well. *Sylvania Electric Products Inc., 500 Fifth Avenue, New York 18, N. Y.*

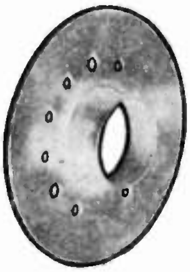
SYLVANIA ELECTRIC

MAKERS OF RADIO TUBES; CATHODE RAY TUBES; ELECTRONIC DEVICES; FLUORESCENT LAMPS, FIXTURES, WIRING DEVICES; ELECTRIC LIGHT BULBS

XLA
A low-loss socket for the 6F4 and 950 series acorn tubes for frequencies as high as 600 mc. By-pass condensers may be compactly mounted between contact terminals and chassis. Low contact resistance, short and direct leads, and low and constant inductance are features.
Net Price..........................$ .99

National
NC
EST. 1914

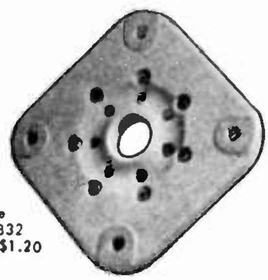
A TUBE IS NO BETTER THAN THE SOCKET IT FITS IN



XLA-S
An internal shield fitting the XLA socket and suitable for tubes such as the 956.
Net Price..$ .36

The most expensive tube available will fail to function properly if the socket it fits in is not made correctly.

That's why National sockets have come to be so widely used by hams, engineers and manufacturers in constructing new equipment.



HX-29
A low-loss wafer socket with steatite insulation for the popular 829 and 832 tubes. Net Price....................................$1.20

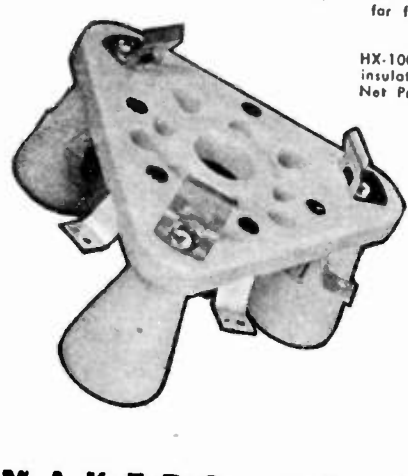
When you use a National socket, you know from experience that it will grip the tube perfectly and will stand up under heavy duty.

Send today for your copy of the 1947 National catalog, containing over 600 parts.

JX-51
A low-loss wafer socket for the 813 and other tubes having the Giant 7-pin base. Net Price............$ .81

National Company, Inc.
Dept. No. 12
Malden, Mass.

HX-100S
A low-loss wafer socket suitable for the type 4-125-A, 4-250-A and other tubes using the Giant 5-pin base. Shield grounding clips are supplied. Air holes are provided for forced air cooling.



HX-100S (with standoff insulators).
Net Price................$2.55

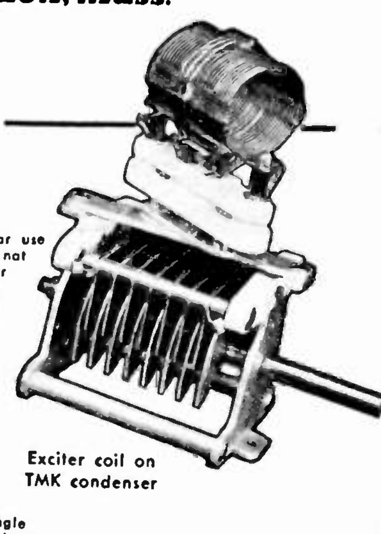
HX-100 (without standoff insulators).
Net Price
$1.98

Type AR-16 (Air-Spaced) Exciter Coils and Forms
These air-spaced coils are suitable for use in stages where the plate input does not exceed 50 watts and are available for the 6, 10, 20, 40 and 80 meter bands. All have separate link coupling coils and all include the PB-16 Plug, which fits the XB-16 Socket.

AR-16, Coils, End Link, Center Link or Swinging Link. Net Price....$1.15
(Include PB-16 Plug)

PB-16, Plug-in Base Only.
Net Price.........................$ .27

XB-16, Plug-in Socket Only.
Net Price.......................$ .33



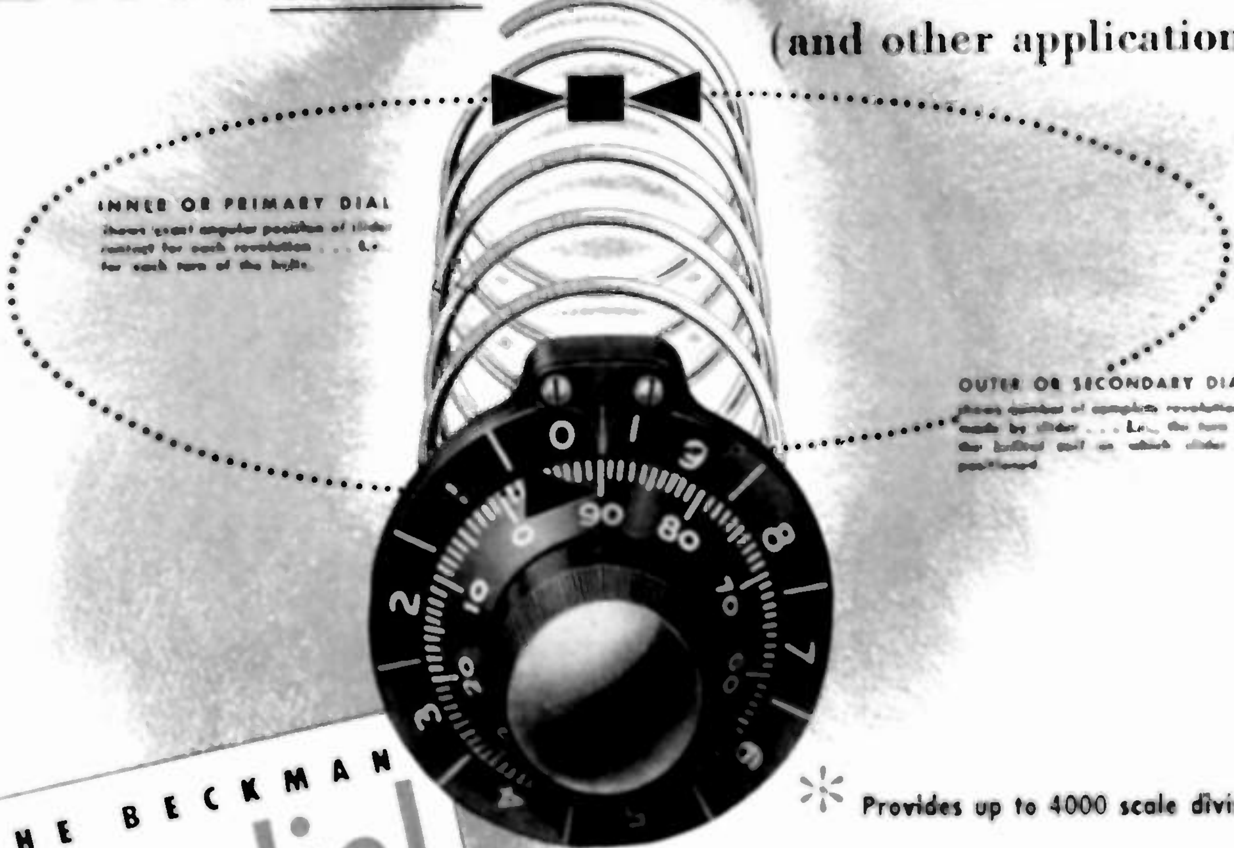
Exciter coil on TMK condenser

Type TMK Transmitting Condenser—An ideal condenser for exciters and low power transmitters. Available in single and double stator models. For panels or stand-off mounting. Steatite insulation. Net Price...........From $2.30 to $5.11

MAKERS OF LIFETIME RADIO EQUIPMENT

NEW! A *Multi-turn* Dial for Helical Potentiometers

(and other applications)



THE BECKMAN

Duodial

* Provides up to 4000 scale divisions
* Requires only 2″ diameter space

HERE'S A DIAL development entirely new in operating simplicity, convenience and versatility. It's the Beckman DUODIAL — a multi-turn rotational-indicating unit consisting of a primary knob-dial geared to a concentric turns-indicating secondary dial, and the entire unit so compact it requires a panel space only 2″ in diameter.

The DUODIAL permits extremely accurate vernier adjustment of driven controls and, when used with helically-wound devices such as the Beckman Helipot, it registers *both* the angular position of the slider contact on any given helix and the position of the slider along the helical winding. The DUODIAL is so designed that — as the primary dial is rotated through each complete revolution — the secondary dial moves one division on its scale.

Thus the secondary dial counts the number of complete revolutions ... or, when used with helical potentiometers, it indicates the helical turn on which the slider contact rests.

Although developed originally for use with the well-known Helipot Potentiometer, the DUODIAL is readily adaptable to other helically-wound devices of similar nature, as well as to many conventional gear-driven controls where extra dial length is desired without wasting panel space. Its compactness and simplicity — and unique advantage of providing an accurate rotational indication from a minute fraction of a turn through as many as 40 full turns — make the DUODIAL invaluable for many applications where maximum dial accuracy is essential.

Complete information on the DUODIAL can be secured from your nearest Helipot representative ... or write direct.

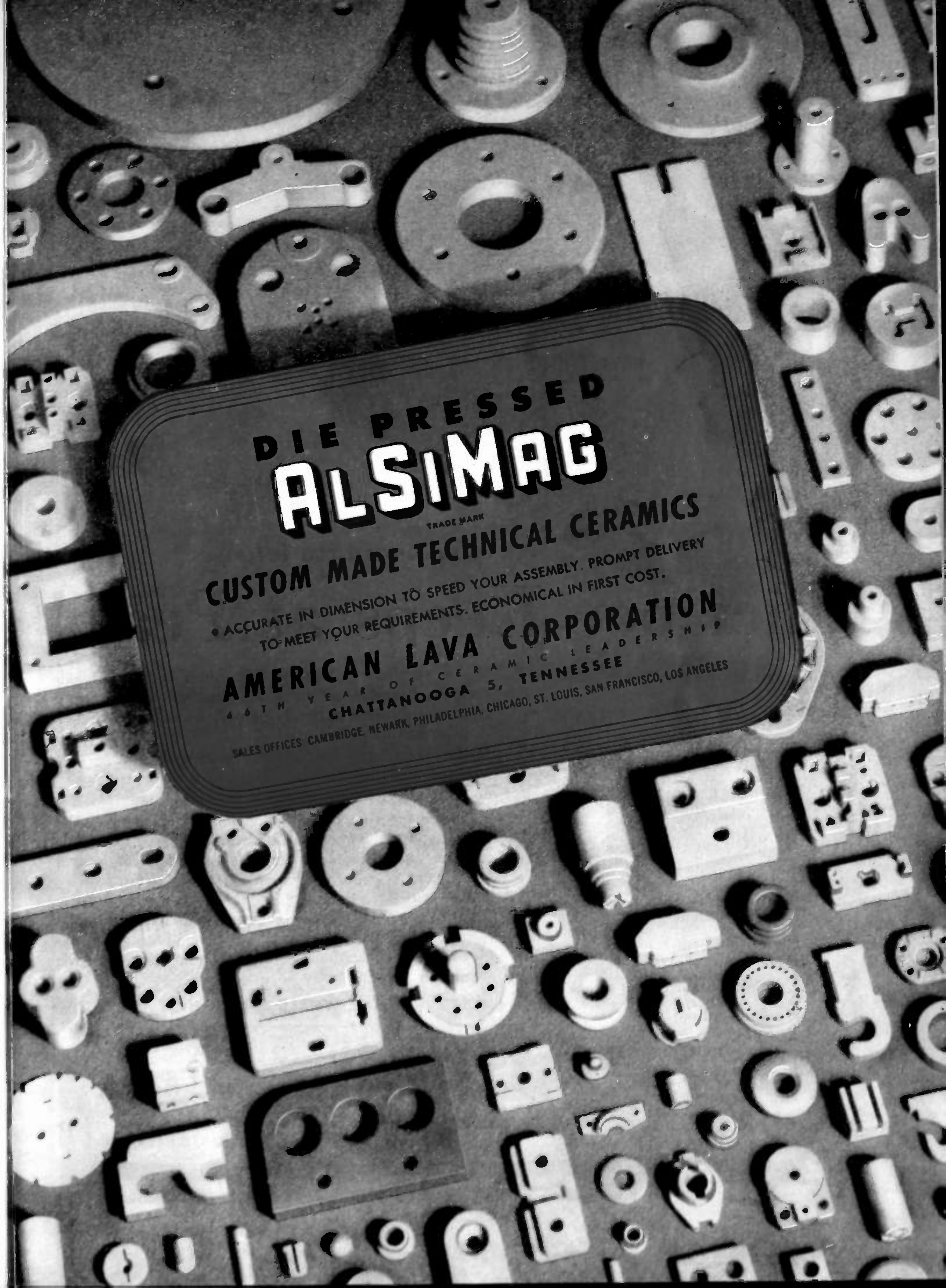
IMPORTANT DUODIAL FEATURES

- The DUODIAL contains only two moving parts. Mechanical wear and operating torque are reduced to an absolute minimum, ensuring long, trouble-free life. All parts, including knob itself, are made entirely of metal for maximum strength and durability.
- The primary scale, which indicates angular position, is an integral part of the knob, and, by means of a set-screw, is rigidly affixed to the shaft of the driven device. Thus, in contrast to most turns-indicating mechanisms, the scale readings are not subject to error from backlash of internal gears. For maximum convenience in making decimal notations, this dial is graduated 0 to 100.
- The DUODIAL cannot be damaged through jamming of the driven unit, or by forcing beyond any mechanical stop. The dial can readily be used with power-driven devices, because, due to the absence of worm gears, it can be operated from either the shaft or knob end.
- The DUODIAL is currently available in turns-ratios of 10:1, 15:1, 25:1 and 40:1 (ratio between primary and secondary dials). Other ratios can be provided on special order. The 10:1 ratio DUODIAL can be readily employed with devices operating fewer than ten revolutions and is recommended for the Model C three-turn Beckman Helipot. All ratio-types are identical in size and appearance except for the numbering of the secondary (turns-indicating) dial.
- The DUODIAL is designed for mounting directly on [illegible]″ diameter round shaft, and in all cases the primary dial and shaft operate with a 1:1 ratio.

* Range for 40:1 ratio DUODIAL.

THE HELIPOT CORPORATION

1011 MISSION ST. SOUTH PASADENA 6, CALIFORNIA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TRADE MARK
CUSTOM MADE TECHNICAL CERAMICS
• ACCURATE IN DIMENSION TO SPEED YOUR ASSEMBLY. PROMPT DELIVERY TO MEET YOUR REQUIREMENTS. ECONOMICAL IN FIRST COST.
AMERICAN LAVA CORPORATION
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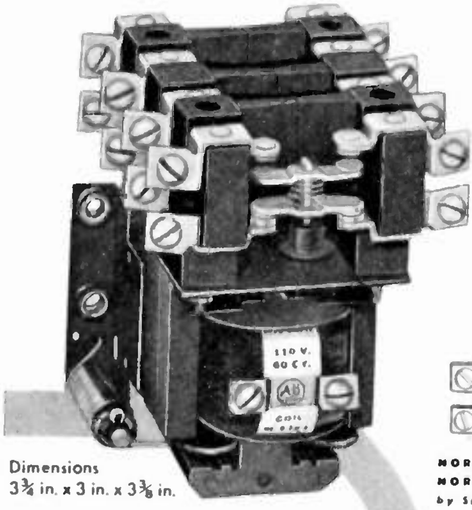
SALES OFFICES: CAMBRIDGE, NEWARK, PHILADELPHIA, CHICAGO, ST. LOUIS, SAN FRANCISCO, LOS ANGELES

RELAYS

for Electronic Circuits



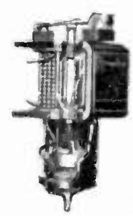
Dimensions
3¾ in. x 3 in. x 3⅜ in.

Change from NORMALLY-OPEN Contacts to NORMALLY-CLOSED Contacts by Simply Shifting Connections

BULLETIN 700 UNIVERSAL RELAYS are a new and important addition to the standard line of Allen-Bradley solenoid relays with a 10-ampere rating. These universal relays have two banks of contacts which permit quick and easy changes from NORMALLY OPEN TO NORMALLY CLOSED contacts ... or vice versa ... merely by shifting terminal connections. (See diagrams at left.) They are ideal for electronic applications in which circuit connections must be interchangeable to meet varied operating conditions. Available in 2, 4, 6, and 8 poles, with double break, silver alloy contacts which need no maintenance. There are no pins, pivots, bearings, or hinges to bind or stick. Hence, these relays are good for millions of trouble-free operations in electronic service. Send for bulletin, today.

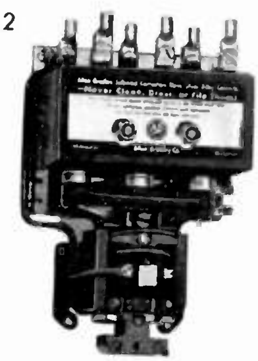
Typical Contact Connections

OTHER ALLEN-BRADLEY RELAYS & CONTACTORS



BULLETIN 810 TIMING RELAYS are ideal for any service requiring an adjustable delayed action relay. Have normally open or normally closed contacts.

Magnetic solenoid core is restrained from rising by the piston in oil dash-pot. Adjustable valve in piston regulates time required to pull piston through oil-seal and trip the contacts, which open or close with quick, snap action. Ideal for transmitter plate voltage control.



BULLETIN 702 SOLENOID CONTACTORS for heavy duty ratings up to 300 amperes. Arranged for 2- or 3-wire remote control with push buttons or automatic pilot devices.

Enclosing cabinets for all service conditions. Double break, silver alloy contacts require no maintenance. Solenoid mechanism is simple and trouble-free.

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Should your SHORT RUN instrument be specified for production quantities, we will be in a position to fulfill your requirements at low cost in our regular production plant. For additional details on our SHORT RUN PROGRAM, and for copies of the Marion SHORT RUN Specification Questionnaire, see your jobber — or write direct. A copy of the Marion catalog will also be sent upon request.

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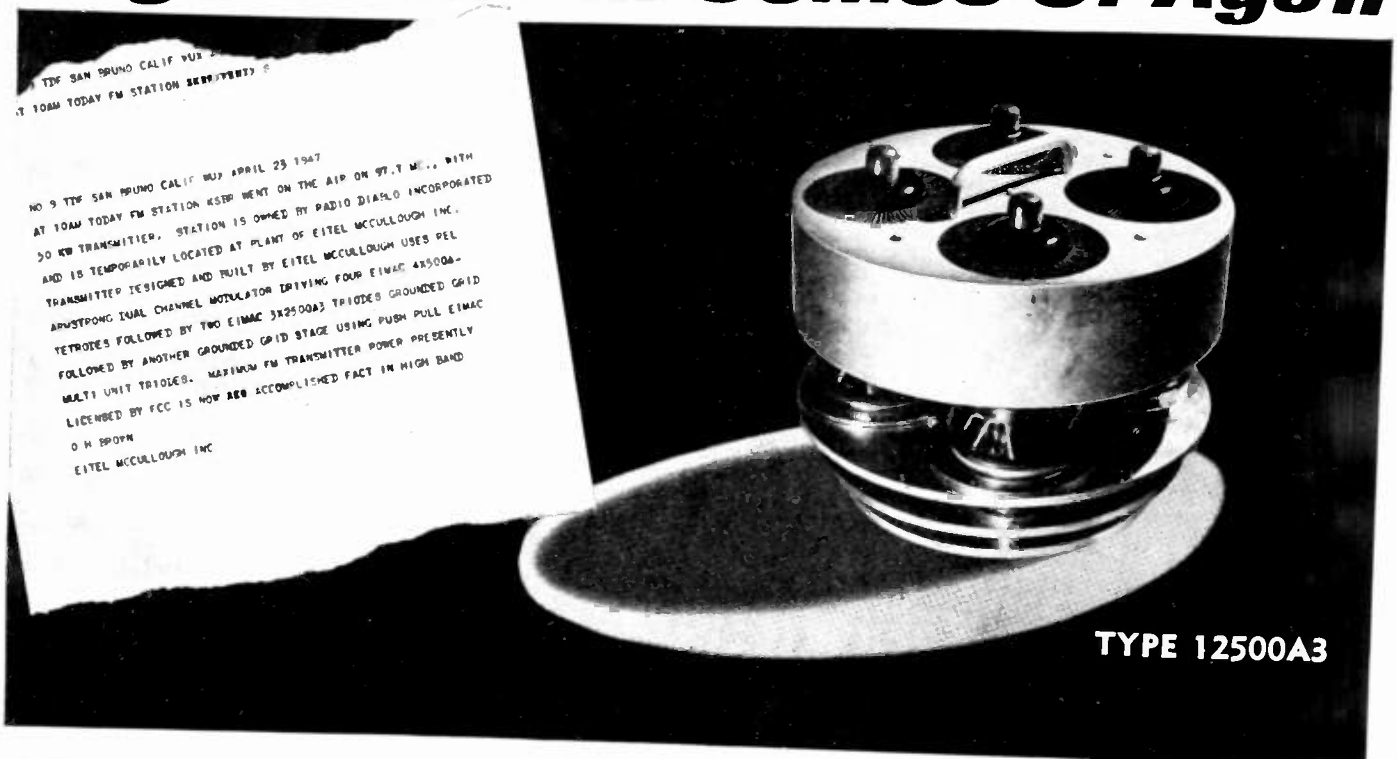
50kw. FM...

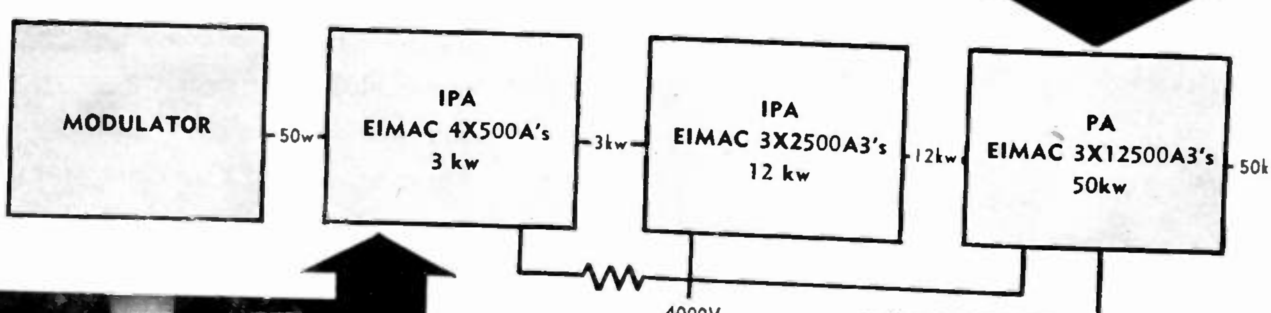
High Band FM Comes Of Age..


TDF SAN BRUNO CALIF WUX
T 10AM TODAY FM STATION SEVENTY

NO 9 TDF SAN BRUNO CALIF WUX APRIL 23 1947
AT 10AM TODAY FM STATION KSBR WENT ON THE AIR ON 97.1 MC., WITH
50 KW TRANSMITTER. STATION IS OWNED BY RADIO DIABLO INCORPORATED
AND IS TEMPORARILY LOCATED AT PLANT OF EITEL MCCULLOUGH INC.
TRANSMITTER DESIGNED AND BUILT BY EITEL MCCULLOUGH USES REL
ARMSTRONG DUAL CHANNEL MODULATOR DRIVING FOUR EIMAC 4X500A-
TETRODES FOLLOWED BY TWO EIMAC 3X2500A3 TRIODES GROUNDED GRID
FOLLOWED BY ANOTHER GROUNDED GRID STAGE USING PUSH PULL EIMAC
MULTI UNIT TRIODES. MAXIMUM FM TRANSMITTER POWER PRESENTLY
LICENSED BY FCC IS NOW AN ACCOMPLISHED FACT IN HIGH BAND
O H BROWN
EITEL MCCULLOUGH INC

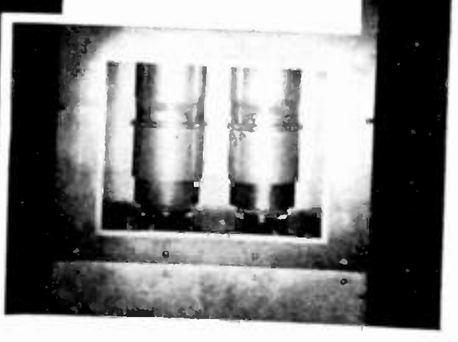
TYPE 12500A3

Here's How It Is Done . . .



Above. Four Eimac 4X500A tetrodes in push-pull parallel raise the power level from 50 watts to 3 kilowatts.

Right. A pair of Eimac 3X2500A3 triodes in a grounded-grid circuit provide 12 kilowatts of driving power for the final amplifier.



OPERATING CONDITIONS
(Two Tubes)

D-C Plate Voltage	4000 volts
D-C Plate Current	14.4 amperes
D-C Grid Voltage	-620 volts
D-C Grid Current	1.9 amperes
Driving Power (Approx.)	12 kilowatts
Plate Dissipation (total)	15.4 kilowatts
Plate Power Input	57.6 kilowatts
Useful Power Output	54.4 kilowatts
Apparent Efficiency	94 per cent

[1]Actual power delivered to water-cooled load. Amplifier output estimated to be 3 kw higher, due to resistance and radiation losses between amplifier and load.

ON THE AIR

...with Eimac Tubes, Of Course...

When KSBR put the first 50-KW high-band FM transmitter on the air Eimac tubes were in every important socket. This was only natural, as Eimac tubes have been associated with every FM transmitter development, including the original historic 1935 demonstration before the IRE.

KSBR's 50-KW amplifier was designed and built by Eimac to demonstrate the capabilities of the new Eimac 3X12500A3 multi-unit air cooled triode. A pair of these new triodes in a grounded-grid circuit easily delivers 50-KW at high-band FM frequencies, with power to spare. Performance of this sort is made possible by sound vacuum-tube engineering. Because of its unique multi-unit design, the 3X12500A3 combines high power capability with close electrode spacing and low lead inductance, thus making it possible to produce high power at VHF with low plate voltage and high over-all efficiency. These same features make the 3X12500A3 an outstanding performer at low frequencies.

Data on the 3X12500A3 and the 50-KW amplifier are available. Write to

EITEL-McCULLOUGH, INC.
176 San Mateo Ave., San Bruno, California

The final amplifier at KSBR—the amplifier that made FM history—consists of little more than two Eimac 3X12500A3 triodes and a pair of shielded, low-loss tank circuits.

The unit is extremely compact considering its power capabilities. Width 36"; Height 70"; Depth 25".

TYPE 3X12500A3
ELECTRICAL CHARACTERISTICS

Filament: Thoriated tungsten	
Voltage	7.5 v
Current	192 amp.
Amplification Factor (Aver.)	20
Direct Interelectrode Capacitances (Av.)	
Grid-Plate	95 µµf.
Grid-Filament	240 µµfd.
Plate-Filament	5 µµfd.
Transconductance (e_b = 3000 v, i_b = 4a)	80,000 µmhos

PRICE $700

TYPE 3X2500A3
ELECTRICAL CHARACTERISTICS

Filament: Thoriated tungsten	
Voltage	7.5 v
Current	48 amp.
Amplification Factor (Av.)	20
Direct Interelectrode Capacitances (Av.)	
Grid-Plate	20 µµf.
Grid-Filament	48 µµf.
Plate-Filament	1.2 µµf.
Transconductance (i_b = 830 ma, E_b = 3000 v)	20,000 µmhos

PRICE $165

TYPE 4X500A
ELECTRICAL CHARACTERISTICS

Filament: Thoriated tungsten	
Voltage	5.0 v
Current	13.5 amp
Screen-grid amplification (Av.)	6.2
Direct Interelectrode Capacitances (Av.)	
Grid-Plate	0.05 µµf.
Input	12.8 µµf
Output	5.6 µµf.
Transconductance (i_b = 200 ma., E_b = 2500 v, E_{c2} = 500 v)	5200 µmhos

PRICE $85

Follow the Leaders to

Eimac REG. U. S. PAT. OFF.
TUBES

The Power of FM

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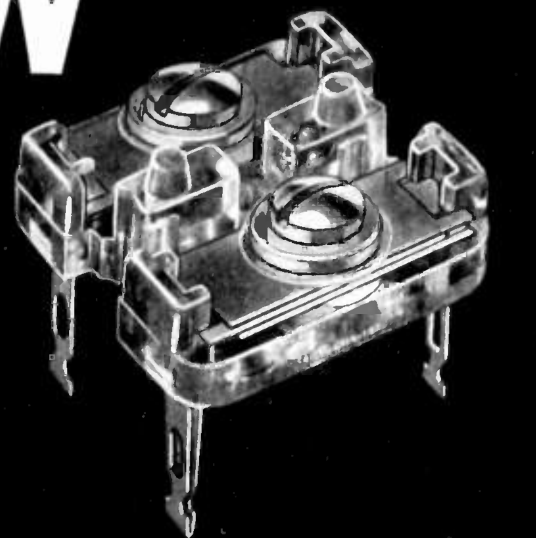
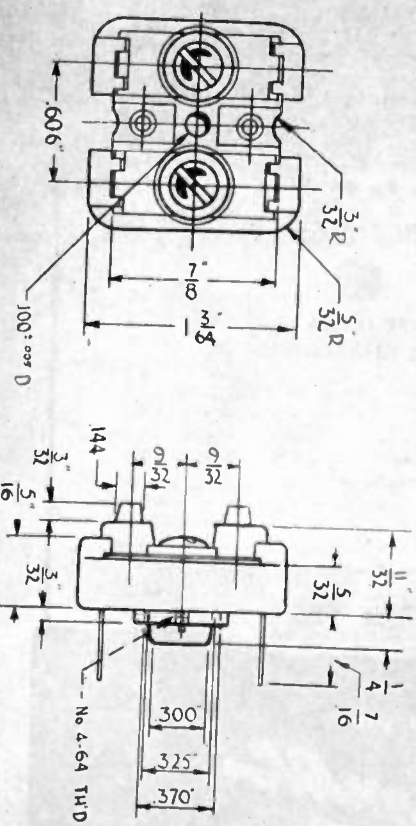
NEW



BETTER



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Range B 50 to 160 μμfds

AND AT A LOWER COST!

Automatic has applied the advanced techniques used in the K-TRAN to a plastic base dual trimmer for use in conventional I.F. Transformers.

Easier to use, better for drift, and lower in price, it is dimensionally interchangeable with the old ceramic trimmers.

It is made in two materials, Type L 64 for use up to 65° C and type L 74 up to 90° C.

K-TRAN

The modern Standardized I.F. Better, smaller, cheaper to use. Design your chassis to use it. 262 KC, 455 KC, 10.7 MC.

AUTOMATIC MANUFACTURING CORPORATION

MASS PRODUCTION COILS & MICA TRIMMER CONDENSERS

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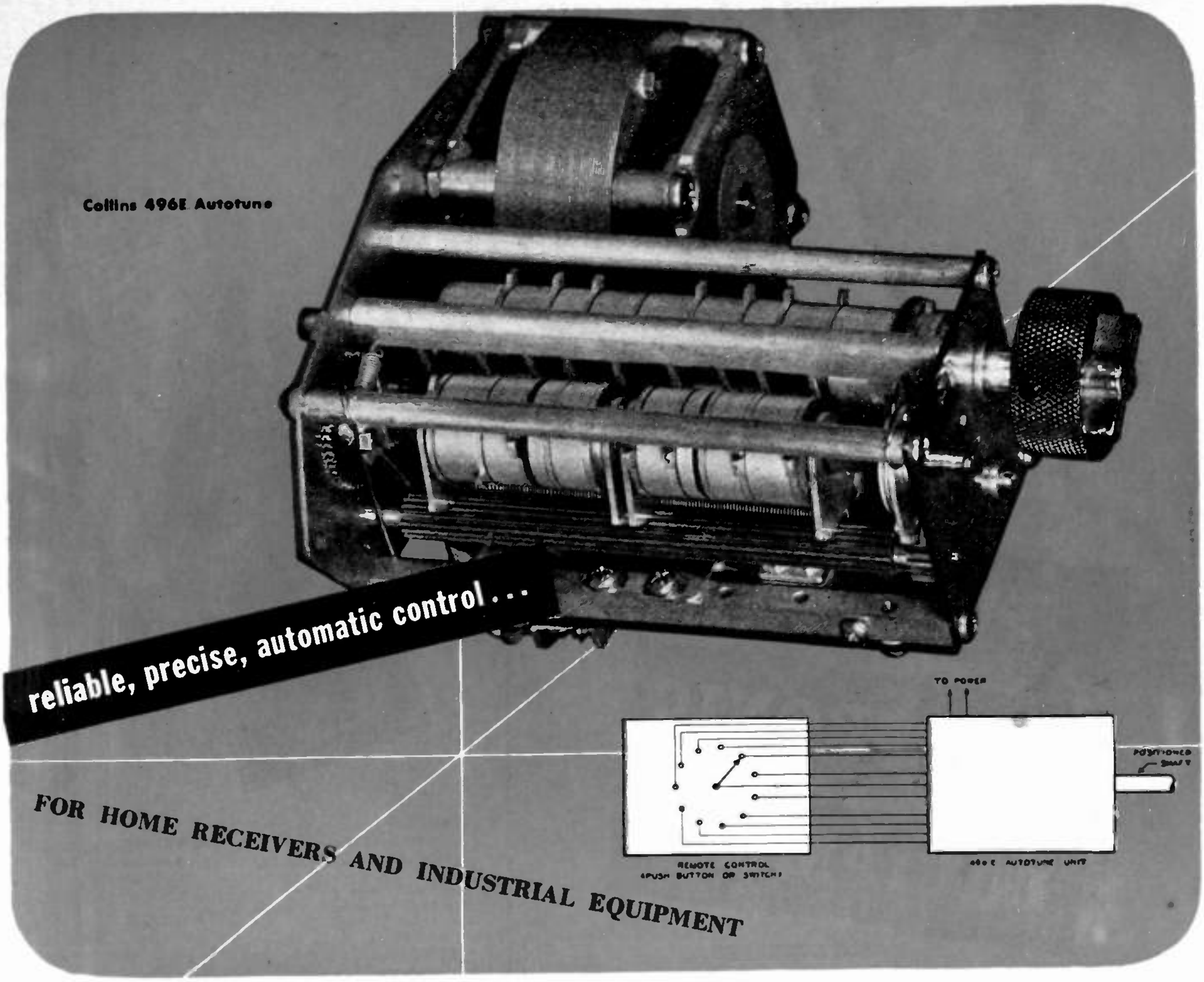

Automatic Tuning. The Collins Type 496E Autotune is an automatic repositioning mechanism designed specifically for tuning quality-built home radio receivers and for control of industrial equipment. Its guaranteed accuracy is one part in 36,000. Age, use, wear, and normal changes in operating conditions do not affect its precision or reliability.

The 496E is a commercial adaptation of the Collins Autotune system originated and patented more than a decade ago. The Autotune reached a high state of development during the war years and was a major contribution to the reliability of thousands of military radio communication equipments designed and built by Collins.

Remote Control. The 496E provides ten automatically reset positions and one position for unlimited manual adjustment of a rotating shaft. Each reset position is independently adjustable to any setting within the full range of ten revolutions of the shaft. Initial settings and desired changes can be performed by unskilled personnel. No tools are required. Control is by means of push-buttons or a tap switch located either at the unit or at any remote position. Only electrical connections are necessary between the 496E and its control unit.

Easy to Use. The operating time is a maximum of six seconds. Reset accuracy is 0.1 degree. This Autotune can be built for operation from any a-c or d-c source. Power consumption is very low. Installation is simple, requiring a single shaft coupler for connecting the Autotune to the positioned shaft.

* * *

We will be pleased to furnish engineering services to aid you in applying the Autotune to your needs. Engineering models of special designs are available at reasonable cost. Write us for further information.

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COLLINS RADIO COMPANY, Cedar Rapids, Iowa

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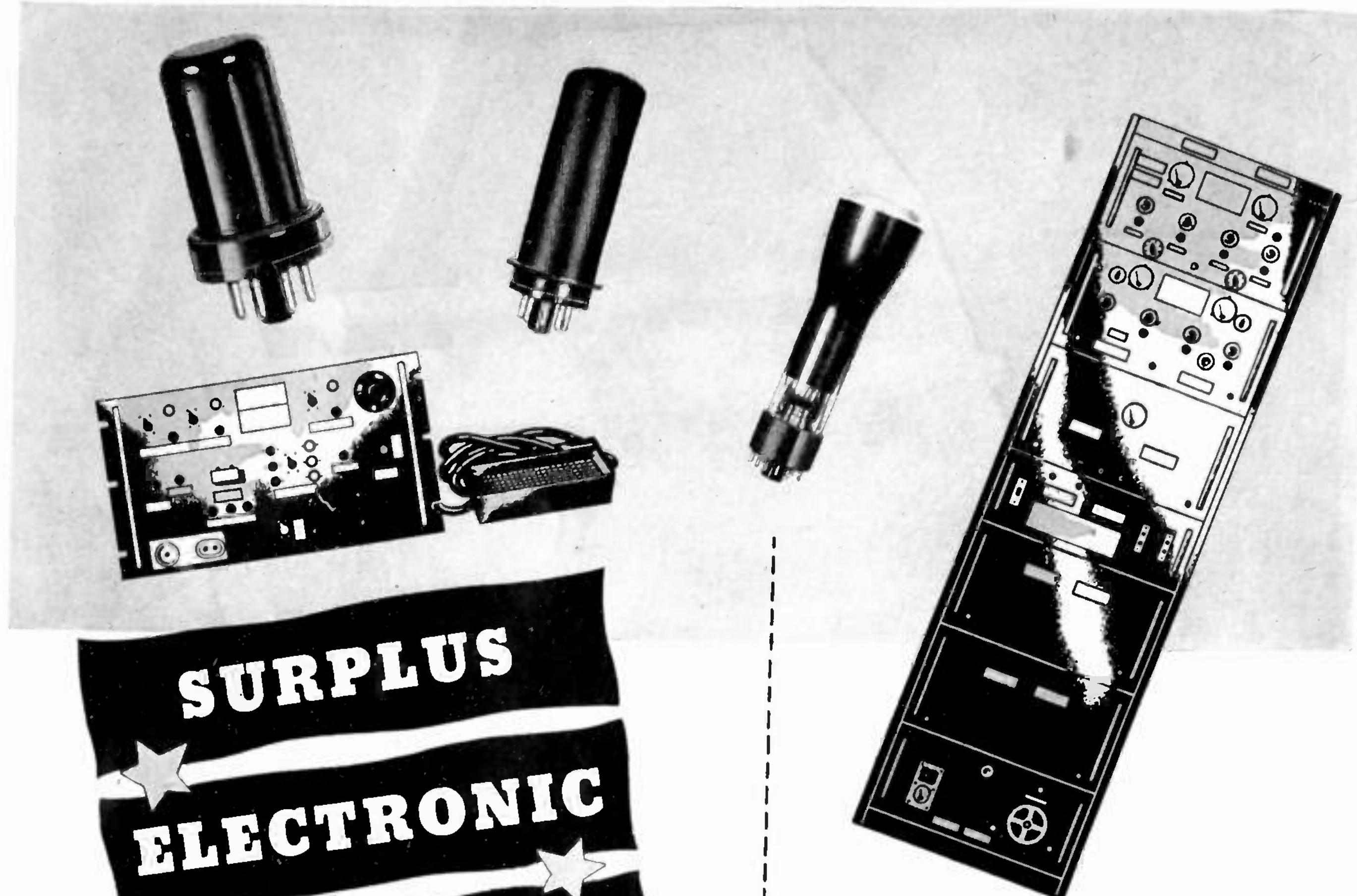
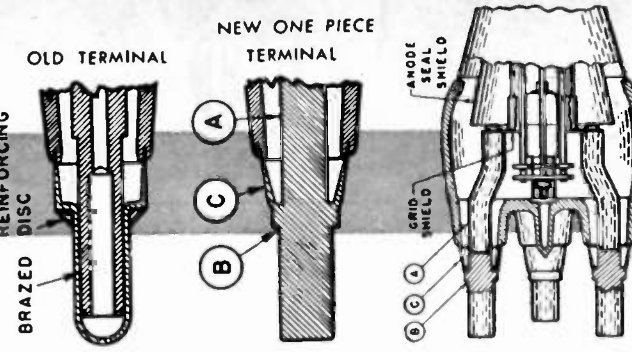
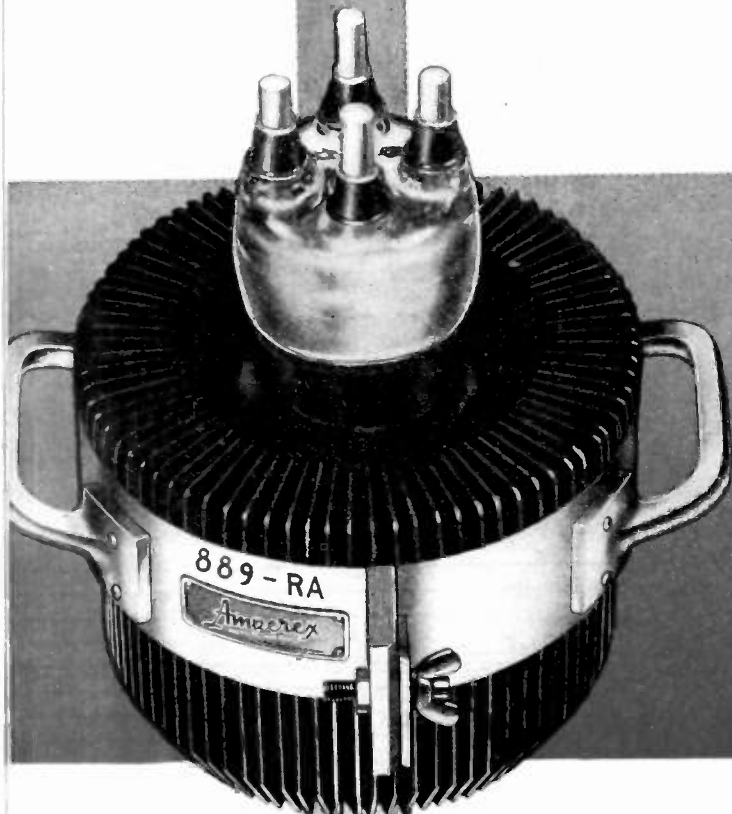


the **LITTLE** differences



(a) (b) (c)



There may be little visible physical difference between a good violin and a *great* violin. But, in their respective performances, these almost invisible differences may make *all* the difference. Similarly, while all transmitting tubes may look alike and be designed to serve the same purpose, the little "extras" are the things that give outstanding distinction to Amperex tubes.

For example, one of these "differences" is the one-piece contact pin, grid and filament support used in the Amperex 889R-A. Heretofore, the pin support and seal were a brazed assembly (a). Now, they are one unit, made of pure, oxygen-free copper which is non-magnetic, and has a very low RF resistance and high conductivity. A strong conical form replaces the less desirable cylindrical form at the seal, and the lack of brazing eliminates not only the weaker mechanical area but also its detrimental effects on the copper and the glass seal (b).

This new Amperex structure is stronger . . . much *stronger!* Where the old pins could be distorted by side pressure, the new ones resist that pressure up to the breaking point of the glass. Not only have we added strength where it is needed but the one-piece design has enabled us to relocate and redesign the anode and grid shields (c). This has reduced glass heating and resultant punctures. Laboratory tests also indicate a remarkable freedom from grid-filament shorts caused by thermal fatigue. Little differences, yes!—but they make the Amperex 889R-A *the tube to use when you re-tube.*

make the **BIG** difference

re-tube with Amperex

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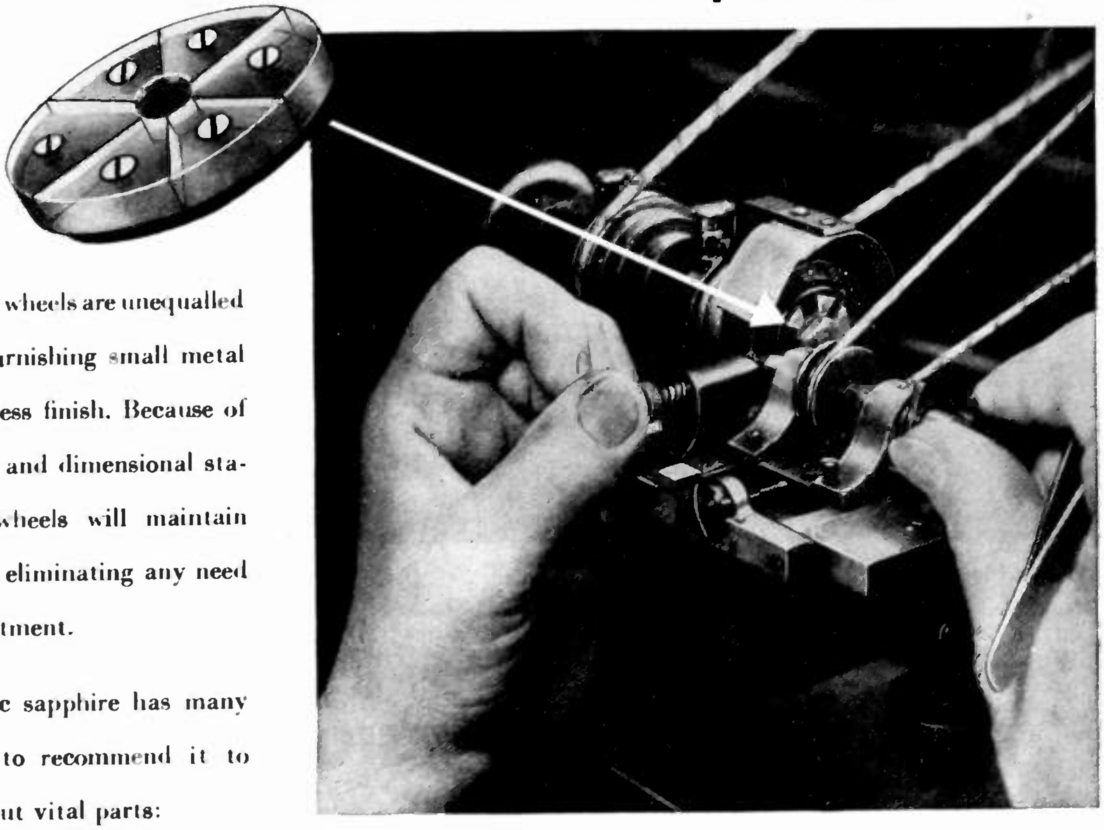

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(Including the WAVES AND ELECTRONS Section)

Published Monthly by

The Institute of Radio Engineers, Inc.

VOLUME 35 — *August, 1947* — NUMBER 8

PROCEEDINGS OF THE I.R.E.

INSTITUTE NEWS AND RADIO NOTES

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Sir Noel Ashbridge

Vice-President—1947

Sir Noel Ashbridge was born on December 10, 1889, at Wanstead, Essex, England. From Forest School at Snaresbrook, Essex, he went on to King's College, London University, taking the degree of B.Sc. in engineering in 1911.

The years 1911 to 1914 Sir Noel spent with Yarrow and Company, shipbuilders, in their works and drawing office; also with The British Thomson Houston Company, gaining practical experience with heavy plant on the test bed; and with the Lancashire Dynamo and Motor Company, supervising the erection of plant. From 1914 to 1919 he was with the British Army, in the Royal Fusiliers and attached to the Royal Engineers (Signals) in France, and later acting as an instructor on radio communication. In 1919, on demobilization, he returned to the Lancashire Dynamo Company. From 1920 to 1926 Sir Noel was with Marconi's Wireless Telegraph Company, engaged on the experimental design of wireless plant, and in charge of their Writtle experimental station.

In 1926 he joined the British Broadcasting Corporation as assistant chief engineer, was appointed chief engineer in 1929, and controller of engineering in 1935. In 1943 he became Deputy Director-General and Technical Adviser to the Board of Governors, the position he now holds. Sir Noel has been the B.B.C.'s representative at many international Wavelength Conferences.

Sir Noel became a Fellow of The Institute of Radio Engineers in 1938. He is a member of the Institution of Electrical Engineers (being president in 1941–42), a member of the Institution of Civil Engineers, and a Fellow of King's College, London. He was a member of the original government television committee (1934) and is a member of the present television committee set up in 1943. He is a member of the Radio Research Board, London, and a member of the executive committees of the National Physical Laboratory. He was president of the Radio Industries Club, London, in 1943 and 1944. Sir Noel became a Knight of the Royal Order of Dannebrog (Danish) in 1934, and was created a Knight Bachelor (Great Britain) in 1935.

The author of many technical papers in the field of broadcast transmission, he was awarded the James Watt Medal for "Modern Developments in Broadcasting Transmission and Television," given at the Institution of Civil Engineers in 1937.

LEWIS M. CLEMENT

The engineering leaders of today fully realize the importance of the human factors involved in their professional and executive activities. While in no wise depreciating the value of scientific and technical competence, they stress also the less tangible but highly significant matters of coherent and co-operative personal and organizational planning. These points are well treated in the following guest editorial by an eminent radio pioneer who is a Fellow of the Institute, and Director of Research and Engineering of the Crosley Division of Avco Manufacturing Corporation.—*The Editor.*

Importance of Proper Engineering Organization to Industry

LEWIS M. CLEMENT

It is not too strong a statement to say that the really successful industries of tomorrow will grow from the foundations of sound, resourceful, and well-trained engineering organizations. In the last analysis, the skill and ingenuity of the research function and the ability of the product development function to design high quality, competitive products at low cost, will determine the pace at which that company will march in competitive industry.

Proper organization is a prime requisite for a good engineering department. Establishment of the proper organization can only be effected by careful consideration of all the functions to be performed, the personal capabilities and potentials of the individuals selected to direct the functions, adequate facilities and equipment, and proper working conditions.

It is important that we go beyond the tangible factors of functions and men. A successful organization cannot be built merely with men, facilities, money, and instructions to proceed. These must be supplemented by leadership of supervision, delegation of authority to subordinates, and prompt action on decisions if the organization is to develop that spontaneous co-operation characterizing a live, aggressive group of capable, willing-thinking, and articulate people.

More than the essential profit motive, there must be pervading the organization from top to bottom, a deep-rooted spirit or desire to produce superior products and render the greatest services to the company and to mankind.

It is through unity of keen and alert minds working together, seeking out the knowledge where it lies and applying it to the design of products, that marked progress is made.

From the leader of an organization down, there must be evidence of an intense desire to further the interest of not mainly the person himself, but his company, his company's products, and the industry generally. Lukewarm interests or selfish motives, in an individual or a group, detract from the ideals of the entire organization.

Engineering organizations so constituted and directed will inevitably contribute to the success of many enterprises today and leave their mark in the years to come.

Electronic Computing Circuits of the ENIAC*

ARTHUR W. BURKS†, MEMBER, I.R.E.

Summary—The ENIAC (Electronic Numerical Integrator and Computer), the first electronic computing machine to be built, is a very large device (containing 18,000 vacuum tubes) compounded out of a few basic types of computing circuits. The design principles that were followed in order to insure reliable operation of the electronic computer are presented, and the basic types of computing circuits are analyzed.

Most of the design work on component circuits was devoted to constructing reliable memory circuits (flip-flops) and adding circuits (counters). These are treated in detail.

The ENIAC performs the operations of addition, subtraction, multiplication, division, square-rooting, and the looking up of function values automatically. The units which perform these operations, the units which take numerical data into and out of the machine, and those which control the over-all operation are described.

The technique of combining the basic electronic circuits to perform these functions is illustrated by three typical computing circuits: the addition circuit, a programming circuit, and the multiplication circuit.

I. Introduction

THE ENIAC (Electronic Numerical Integrator and Computer) is the first general-purpose computing machine in which the computation is done entirely electronically. It is the purpose of this paper to discuss the design of the various circuits used and to show how they are combined to make an automatically sequenced electronic computer. As an introduction, however, it is worth while to consider the general question: What is the function of the ENIAC? That is, what kinds of problems does it solve?

Very briefly, the answer to this question is that the ENIAC can solve any problem which can be reduced to numerical computation, i.e., to a finite sequence (of reasonable length) consisting of additions, subtractions, multiplications, divisions, square-rootings, and the looking up of function values. Hence, it can differentiate, integrate, solve systems of simultaneous algebraic and transcendental equations, partial differential equations, etc. The importance of high-speed electronic computation derives from the fact that there are many problems that the mathematical physicist can easily formulate but which can be solved only with great labor. The differential equations of exterior ballistics will serve as a good example of this, especially since the ENIAC was designed primarily to solve total differential equations of about this order of complexity.

It is well known[1] that the path of a projectile in motion is described by

$$y'' = -Ey' - g$$
$$x'' = -Ex'$$

where

$$E = \frac{\epsilon^{-hv}G(v)}{C}, \quad (v = \sqrt{(x')^2 + (y')^2}),$$

g and h are fixed constants, C is a constant for a given shell, and $G(v)$, the ballistic drag function, expresses the resistance of the air to the shell as a function of its velocity. The equations are thus easy to state, but since the drag function has no simple mathematical formulation (it is actually obtained from experimental measurements, i.e., firings of shells) an analytic solution of them (that is, a solution in terms of well-known functions) is impossible. Hence, the construction of a firing or bombing table requires the numerical solution of this pair of differential equations for each set of initial conditions (muzzle velocity, angle of fire) for each type of shell, and a transformation of the results into a form suitable for use in the field or in the construction of a gun director. Each solution is called a trajectory, and the production of a firing table requires the computation of hundreds of such trajectories and a processing of the results. A skilled computer with a desk machine can compute a 60-second trajectory in about twenty hours; a differential analyzer can produce the same results in about fifteen minutes; the ENIAC can do it in thirty seconds, that is, it can compute the trajectory of a shell faster than the shell itself flies! Moreover, the ENIAC, which can handle either ten- or twenty-digit numbers, is much more accurate than a differential analyzer, and is, in fact, 1000 times as fast as any machine which gives comparable accuracy.

II. General Circuit-Design Considerations

War circumstances made it imperative to construct the ENIAC out of conventional electronic circuits and elements with a minimum of redesign. This fact, together with the ordnance requirements for capacity, speed, and accuracy, led to an extremely large electronic machine. The ENIAC contains about 18,000 tubes,[2] 70,000 resistors, 10,000 capacitors, 6,000 switches, etc. It is 100 feet long, 10 feet high, and about 3 feet deep. The filaments require 80 kilowatts of power, the direct-current power supplies produce 40 kilowatts, and the blower system consumes 20 kilowatts of power.

It is clear that, if an electronic device with 18,000 tubes in it is to be successful, the component circuits must be extremely reliable. This is especially true of a

* Decimal classification: 621.375.2. Original manuscript received by the Institute, May 2, 1946; revised manuscript received, November 15, 1946. Presented, Princeton Subsection, Princeton, N. J., May 8, 1946.

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The ENIAC was designed and built at the Moore School of Electrical Engineering for the Ordnance Department of the United States Army. H. H. Goldstine was the Ordnance Department representative; J. G. Brainerd was the administrative supervisor; J. P. Eckert was the chief engineer; and J. W. Mauchly was the consulting engineer.

[1] G. A. Bliss, "Mathematics for Exterior Ballistics," John Wiley and Sons, New York, N. Y., 1944, chap. 2.

[2] Actually 18,000 envelopes, many of them containing two triodes.

digital computer, for the failure of a single tube can cause a digit to be erroneous and may vitiate the results. Two main principles were followed in the ENIAC design, in order to insure reliable operation. In the first place, the circuits were manufactured out of carefully selected and rigidly tested standard components which are operated considerably below their normal ratings. For example, the 6.3-volt filaments are operated at 5.7 volts and are rarely turned off (in order to increase their life), and plate and screen power are limited to 25 per cent of rated value.

The second general principle of design has to do with the method chosen for making the accuracy of the computations independent of the tolerances and variations of the components. The tolerances of vacuum tubes are especially poor (with plate-resistance variations of the order of ± 40 per cent, for example), so all tubes are operated as on-off devices: that is, either conducting (in which case the grid is driven slightly positive) or nonconducting (in which case the grid is driven considerably below cutoff, e.g., to -14 volts for a 6J5 with $+75$ volts on the plate). This means that numbers are never represented by the magnitudes of electrical signals, but only by their presence or absence on wires, and these signals are of sufficient magnitude (at least 3 volts, and on the average of 50 volts strength) that they are never destroyed by cross talk. The ENIAC operates as a timed or synchronous system controlled from a central clock (called the cycling unit), and ample safety factors are provided in the timing to cover changes in time constants due to parameter variations.

III. Types of Computing Circuits

It is, of course, impossible to discuss in detail within a paper of this scope all of the circuits of the ENIAC. Such is not necessary for a general understanding of how electronic computing is done, however, for all of the circuits of the ENIAC are compounded out of certain basic types or elements. Hence it will suffice to discuss these elements and to show how (by examples) they may be combined to form computing circuits.

The first general type of circuit needed in electronic computing is one capable of remembering. Both digital and programmatic information must be stored: the machine must be able to remember both the numbers that are operated on and the instructions for performing the operations. There are three types of remembering circuits in the ENIAC (exclusive of the relay circuits used for input and output), differing as to the speed with which information can be put into them and read out of them. The first consists of an Eccles-Jordan trigger circuit[3–5] or flip-flop (see Section IV); information can be both registered in it and read out of it electronically, and hence at high speed. This form of memory is costly in terms of equipment since it requires two triodes (one envelope) per binary digit. The function table,[6] consisting of a matrix of resistors so wired as to remember information (see Section VI-C and Fig. 7), is a more economical type of memory circuit. Since the connections must be established manually the registering of information is slow, although the output appears in electronic form and is relatively fast. Function tables are used in the ENIAC to remember the multiplication table and to remember arbitrary functions (in which case the interconnections are established by means of switches), such as the ballistic drag function.

The third kind of memory circuit used in the ENIAC consists of the wiring itself. This may seem to be a trivial observation, but if one were to set up a problem on the ENIAC by plugging in cables and setting switches he would see the force of the statement. The ENIAC is a flexible, general-purpose machine, capable of solving a wide variety of problems. The different units of the ENIAC (discussed in Section V) are permanently wired to do the specific operations of addition, subtraction, multiplication, division, square-rooting, and the looking up of function values, but the particular operations which these units perform in a given problem and the order in which they do them depend upon how they are interconnected and how the various switches on them are set. Because the setup of a problem is manual, it is slow (relatively to the speed of computation); and hence the ENIAC is best suited to solve problems that are highly repetitive in character as, for example, the production of firing tables.

The second general type of circuit needed in an electronic computer is one capable of adding numbers. Addition is performed in the ENIAC by electronic counters consisting of flip-flops interconnected so as to count groups of pulses representing digits (see Figs. 1 and 2). These will be described in Section IV.

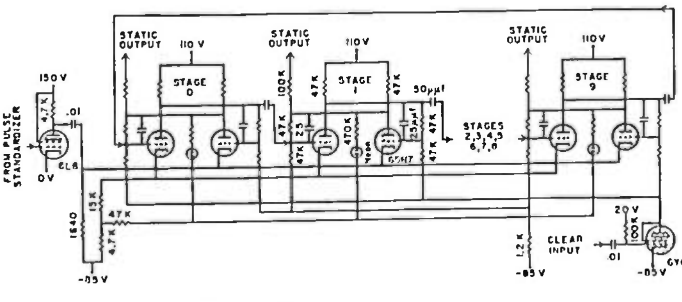

Fig. 1—Decade ring counter.

It is clear that, though electronic circuits for remembering and adding are basic components of a computer, other types of circuits must be employed as well. Electronic means are required for controlling the adding circuits so that they will subtract, divide, and square-root,

[3] W. H. Eccles and F. W. Jordan, "A trigger relay utilizing three-electrode thermionic vacuum tubes," *Radio Rev.*, vol. 1, pp. 143–146; December, 1919.

[4] J. G. Brainerd, G. Koehler, H. J. Reich, and L. F. Woodruff, "Ultra-High-Frequency Techniques," D. Van Nostrand Company, New York, N. Y., 1942, pp. 168–176.

[5] H. J. Reich, "Trigger circuits," *Electronics*, vol. 12, pp. 14–17; August, 1939.

[6] Invented independently by J. Rajchman and P. Crawford.

and for programming the various operations to be performed. These control circuits are compounded out of three very simple types of circuits: the electronic representations of the logical concepts of "and," "or," and "not." The "and" operation is performed by a "gating" or "switching" tube; for example, a pentagrid tube with the first and third grids used as the control elements (such as tube 9 of Fig. 3). A gate tube draws current only when both grids are brought to cathode potential, and hence one grid switches a signal applied to the other grid into and out of the plate circuit. Such a tube is symbolized in the block diagrams of Figs. 2 and 4 by a square with two inputs and one output (e.g., tube 2 of Fig. 2). Gating can also be done by means of a circuit which is the dual of this; a number of tubes connected to

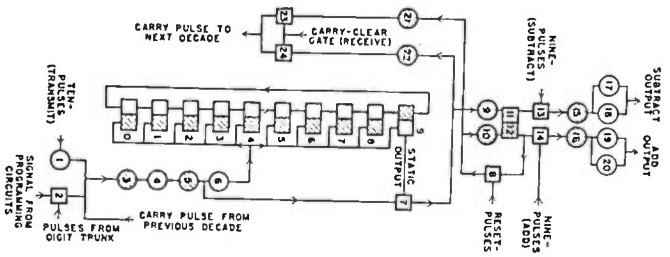

Fig. 2—Block diagram of accumulator decade circuit.

a common load resistor and so arranged that any one tube when conducting draws sufficient current to keep the following tube cut off is a representation of the concept "and," for only if *all* of these tubes are cut off will the following tube be operated.[7]

The "or" operation is performed by a "buffing" circuit. Such a circuit may consist of two or more normally nonconducting tubes with a common load resistor in either the plate circuit (see tube 8 of Fig. 3) or the cathode circuit (see tube 7 of Fig. 3). A positive input signal

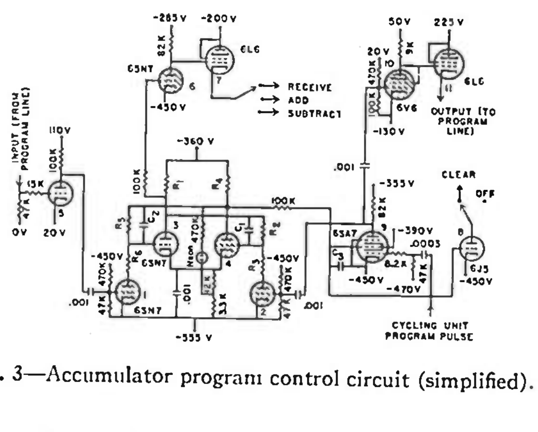

Fig. 3—Accumulator program control circuit (simplified).

to any of these tubes will be transmitted to the output without affecting the inputs of the other tubes. (If more than one tube is made conducting, the output signal is increased, but this has no effect on the computing since the following tube is not sensitive to differences in amplitude.) The dual of this circuit consists of a two-input tube (such as a pentagrid tube) which is kept on normally, so that a negative signal to either input will be transmitted to the output without affecting the other input. The "not" operation is, of course, performed by an inverter tube (such as tube 3 of Fig. 2 and tube 6 of Fig. 3). In all the figures, normally conducting tubes are shaded and normally nonconducting tubes are left unshaded.

[7] W. B. Lewis, "Electrical Counting," Cambridge University Press, Cambridge, England, 1942, p. 61.

IV. Flip-Flop and Counter Design

The flip-flop circuit used in the ENIAC is shown in Fig. 3 (tubes 1, 2, 3, and 4). In the design of such a circuit two aspects need to be considered: (1) the steady-state stability, depending upon the direct-current connections, and (2) the flipping or triggering action, depending upon the alternating-current connections as well. These will be discussed in turn.

(1) A flip-flop has two stable states because of the direct-current connections from the plate of each tube to the grid of the opposite tube (R_2, R_5 of Fig. 3) which cause the conducting tube to bias the nonconducting tube negatively, and the nonconducting tube to bias the conducting tube positively. The resistors R_2 and R_3 (similarly R_5 and R_6) form a direct-current voltage step-down circuit changing the direct-current level of the plate signal to the proper direct-current level for the grid, and must be selected so that the biases are correct. The difference between the voltage at the plate of tube 3 when it is conducting and nonconducting depends upon the sizes of R_1, R_2, and R_3, relative to the plate resistance of tube 3 (similarly for tube 4), and the amount of this signal that is applied to the grid of tube 4 depends on the ratio R_2/R_3. In designing the circuit the expected variations in resistor values and plate resistances of the tubes, and also the power-supply regulation, must be considered and the parameters selected so that the stability of the circuit will not be greatly affected by these variations. The stability needed in the ENIAC was attained by making these resistors roughly equal ($R_1 = R_4 = 39{,}000$ ohms and $R_2 = R_3 = R_5 = R_6 = 47{,}000$ ohms) and about six to eight times as large as the plate resistance of an average 6SN7 tube (as measured when the grid of the tube is driven positive).

(2) The design of the circuit from the point of view of dynamic operation leads to a compromise between two opposing factors; the actual flipping of the circuit and the recovery of the circuit so that it will be ready for resetting. Increasing the values of R_1, R_2, and R_3 will increase the gain of the circuit and hence accelerate the flipping action; and increasing the value of C_1 will decrease the alternating-current impedance from plate to grid and hence will accelerate the transfer of the plate signal to the grid. But large values of R_1, R_2, R_3, and C_1 will delay the return to the quiescent state (ready for the next operation) by making the time constant of the circuit large. The actual value chosen for C_1 (and C_2) was

25 micromicrofarads. In all cases where a flip-flop was used by itself (i.e., not in connection with other flip-flops as in the counter of Fig. 1), the flipping tubes 1 and 2 were built into it in order to speed up the action by amplifying the triggering pulse and by avoiding the additional capacitance of a long lead going into the grid circuit. The flip-flop shown in Fig. 3 can be set in about one microsecond and is ready to reset in about four microseconds; in the ENIAC it always has at least 2.5 microseconds in which to be set, and is never reset sooner than ten microseconds after being set.

The design of a vacuum-tube counter can be based on the flip-flop in either of two ways: (1) A counter can be made by using a flip-flop for each stage as in the circuit of Fig. 1.[8] Since a flip-flop is required for each stage, this type of counter is known as a two-tubes-per-stage counter. (2) A counter with only one tube per stage can be made by generalizing the flip-flop so that it has as many stable states as tubes.[9–12] In such a counter the static connections consist of resistors going from the plate of *each* tube to the grid of *every* other tube. This means that (in contradistinction to the two-tubes-per-stage counter) this type of counter becomes inherently more complicated as the number of stages increases. For this reason the other type was adopted for the decade counters (used for registering and storing decimal digits). For a binary counter (needed for storing the signs of numbers) the one-tube-per-stage type (Fig. 5) proved superior.

The action of the circuit of Fig. 1 may be explained with reference to the block diagram of Fig. 2. The counter of Fig. 2 registers the digit 9, since the last flip-flop has been triggered (similarly, Fig. 1 registers the digit 0). The triggered flip-flop is the only one to respond to an incoming positive pulse which is applied to all flip-flops; as it is reset it gives out a positive pulse which triggers the next stage. In this manner the counter advances one stage on receiving a pulse, and hence is an adder as well as a register. It may be cleared to zero by applying a negative pulse to the input of the 6Y6 clearing tube. Clear leads go from this tube and from the balancing 1200-ohm resistor to each stage, the connections to the zero stage being reversed so that this stage is left in a triggered state.

There are the following five basic considerations or principles which enter into the design of a counter circuit: (1) The first of these has to do with the prevention of oscillation. As Fig. 2 shows, in a ring counter there are a number of tubes connected from plate to grid repeatedly, making a closed loop. Consequently, if at any time all of the tubes in this loop are conducting, the circuit may oscillate. Though possible oscillation may be prevented by adjusting the circuit parameters so as to reduce the over-all gain per stage, such a solution slows

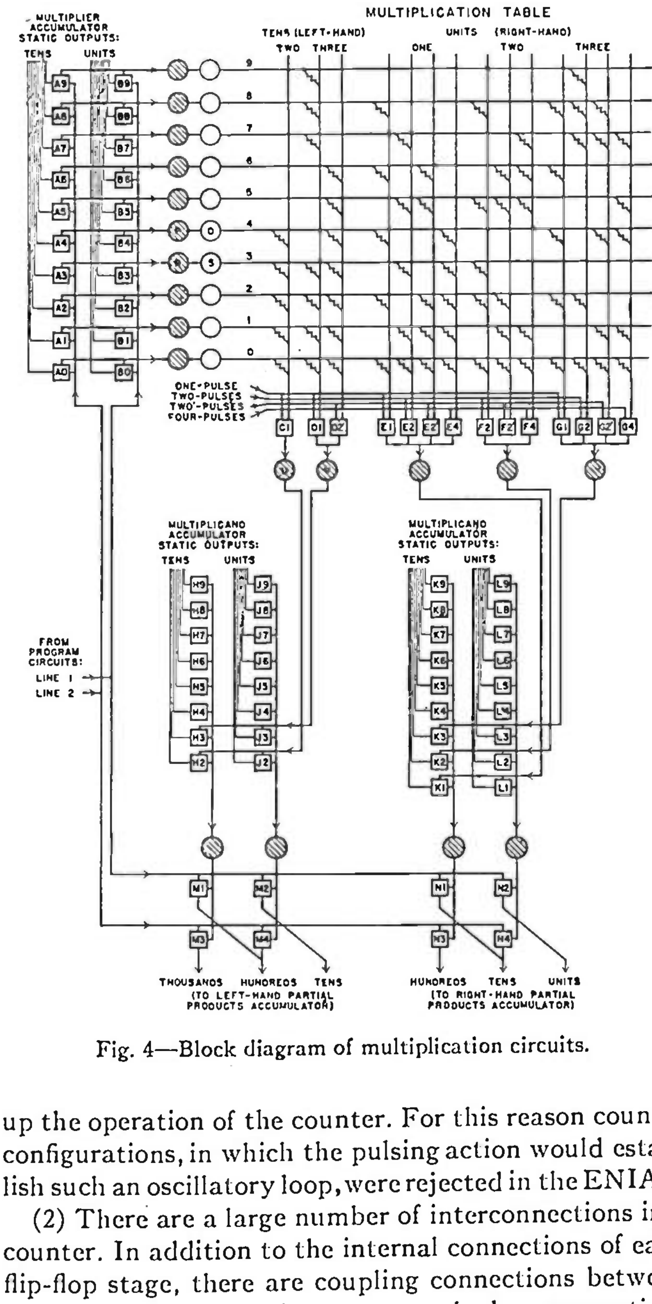

Fig. 4—Block diagram of multiplication circuits.

up the operation of the counter. For this reason counter configurations, in which the pulsing action would establish such an oscillatory loop, were rejected in the ENIAC.

(2) There are a large number of interconnections in a counter. In addition to the internal connections of each flip-flop stage, there are coupling connections between stages, connections to the common pulse bar, connections for clearing the counter to the zero position, and static output connections for operating indicating neon lamps and associated vacuum tubes. It is desirable to arrange the circuit so that there are a minimum of connections going to any one element of the tube. Hence it is disadvantageous to pulse the tubes on the grids, since these elements are already used for the internal connections of the flip-flop and for coupling connections between stages. The decade counter of Fig. 1 is pulsed on the cathode, while the binary counter of Fig. 5 is pulsed on the plate.

[8] This circuit is a modification of one suggested to us by RCA Laboratories, Princeton, N. J.

[9] See page 91 of footnote reference 6 for a five-stage one-tube-per-stage counter. The binary (scale-of-two) counter of Fig. 5 is the simplest case of a one-tube-per-stage counter.

[10] E. C. Stevenson and I. A. Getting, "A vacuum-tube circuit for scaling down counting rates," *Rev. Sci. Instr.*, vol. 8, pp. 414–416; November, 1937.

[11] H. Alfven, "A simple scale-of-two counter," *Proc. Phys. Soc.*, vol. 50, pp. 358–359; May, 1938.

[12] H. Lifschutz, "A complete Geiger-Müller counting system," *Rev. Sci. Instr.*, vol. 10, pp. 21–26; January, 1939.

(3) A cathode-pulsed decade counter has another advantage over one pulsed on the grid, e.g., it has no undesirable modes of operation. For a counter to operate correctly, only one flip-flop should be in the "set" position at any one time. In a counter pulsed on the grids, it is possible for several flip-flops to be in the "set" position at one time and for the counter nevertheless to count around. This is impossible in the cathode-pulsed counter

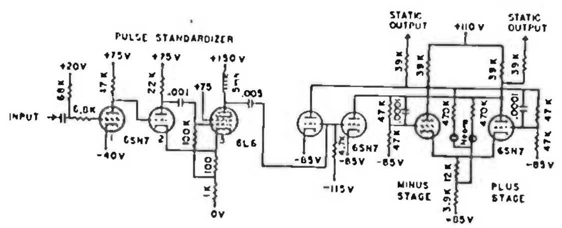

Fig. 5—Binary ring counter.

of Fig. 1, because the grid biases are obtained from the cathode resistors. If more than one stage were set, this would produce such a large negative bias that only one stage would remain set.

(4) The fourth design principle concerns the charging of grid capacitors. If a positive pulse is applied to a grid via a capacitor, the capacitor will acquire a charge. Now if the tube is conducting only while the pulse is present, the capacitor is charged through the low impedance of the (positive) grid to the cathode, but must be discharged through the relatively high bias resistor. Hence, under certain duty cycles, a charge may collect on the capacitor, changing the effective bias. The magnitude of this effect will clearly depend upon the duty cycle, and since a counter used in a computing machine has a variable duty cycle, the result would be for the effective bias to change with the conditions of operation. For this reason (and the same considerations hold true for all circuits in the ENIAC) direct rather than capacitive coupling is used with positive pulses under these circumstances.

(5) The last design principle has to do with the delicate timing involved in the operation of electronic counters. An input pulse affects only the flip-flop which is triggered; e.g., stage 9 in Fig. 2. As stage 9 is reset it produces a pulse which triggers the next flip-flop (stage 0), and if the input pulse is still present on the pulse bar, it opposes this action. A similar situation obtains in the binary counter of Fig. 5. When this counter is being flipped, there will be a point at which the currents in the two tubes are equal; at this point the previous state of the counter is not remembered in the tubes, but by means of the charges stored on the capacitors connecting the plate of one tube to the grid of the other, and the action of these charges is opposed by the input pulse. Thus the effects of the input pulse and the internal pulse going between the stages of a counter are opposed to one another, so that the counting action depends on the circuit's taking the difference between the two signals. The counting action can be made determinate by making the time constant of the input pulse circuit shorter than the time constant between stages (and that shorter than the period between pulses, of course), and this is done in the circuits of Figs. 1 and 5. Nevertheless, the operation of the counter depends very critically upon the shape of the incoming pulse, so that the pulse-forming circuit of Fig. 5 is used with all the counters of the ENIAC.

The counters of Figs. 1 and 5 will operate over a range of frequencies from a few pulses a second to 200,000 pulses per second. To provide a safety factor of two to one they are operated in the ENIAC at a maximum rate of 100,000 pulses per second. At this speed the decade counter will operate with a direct-power supply voltage variation of from 100 to 500 volts; the circuit voltage is actually maintained at 195 ± 10 volts. Altering the resistors and capacitors of the decade circuit as much as ± 20 per cent and replacing the tubes with others having six times the plate resistance (6SL7's) only reduces this voltage range to 190 to 370 volts. At a frequency of 200,000 pulses per second the binary counter will operate with a direct-current power-supply tolerance of from 10 to nearly 1000 volts.

V. Units of the ENIAC

The ENIAC consists of thirty separate units (in addition to the power supplies and power control equipment), each containing from 500 to 1500 vacuum tubes. There are nine different types of units, each type having electronic circuits capable of performing a certain operation, and circuits which locally control the operation of the unit. The particular operations which are to be carried out and the arrangement and number of these operations are determined by the setup of a problem on the machine. The units are arranged linearly in the shape of a U, with coaxial transmission lines passing by the front of each unit. A set of eleven such lines, capable of carrying simultaneously from one unit to another the groups of pulses representing a ten-digit signed number (these pulses are called "digit pulses"), is called a "digit trunk." A single line, used to carry a "program pulse" from one unit to another, is called a "program line."

The accumulators (of which there are twenty), the high-speed multiplier, and the divider-square-rooter, are units which perform arithmetic operations. Each accumulator is capable of storing a ten-digit (decimal) signed number,[13] of receiving such a number (in the form of pulses coming over a digit trunk) and adding it to its contents, and of transmitting (in pulse form) the number stored additively or subtractively with or without clearing[14] after the transmission. The addition of two numbers requires the simultaneous operation of two accumulators: one converts the digits held in its counters into pulse form and transmits them over a digit trunk to

[13] Provision is also made for interconnecting the accumulators and other units so that twenty-digit numbers can be handled.

[14] The accumulator may be cleared to zero, or to zero in nine decades and to five in one decade, for rounding off.

the other, which receives them and adds them to its contents (see Section VI-A). An addition takes only 1/5000 second; this period of 200 microseconds is called an addition time (see Fig. 6).

It should be noted that the accumulator combines the functions of an electronic adder with those of an electronic register; it is for this reason that there are twenty of them. In addition to being used for adders they are used by the high-speed multiplier for storing the multiplier and the multiplicand, and for accumulating the partial products; by the divider-square-rooter for storing the numerator, denominator, square-root, and quotient, and for shifting remainders; by the function table for storing the argument and receiving the function value; and by the printer for storing the numbers to be punched until they are transferred to relay (electromechanical) registers.

Accumulators may be used for subtracting as well as for adding. Since the counters of the accumulators operate in one direction only (they cannot count backwards), subtraction is done by counting the counters around through zero up to the position to which the counters would have gone, had they counted backwards. This is accomplished by means of a complement system of representation. A negative number $(-x)$ is represented as a complement with respect to 10^{10}; that is, $-x$ is expressed as $(10^{10}-x)$ with a sign indication to show that it is a complement. (If twenty-digit numbers are being handled, complements are taken with respect to 10^{20}.) When an accumulator is programmed to transmit subtractively, it will transmit, not the number it holds, but the complement of the number it holds. All units of the ENIAC are capable of handling both positive numbers and complements.

The high-speed multiplier is capable of multiplying two ten-digit numbers and producing a full twenty-digit product (if needed) in 13 addition times or 2.6 milliseconds. Its operation is described in Section VI-C. The divider-square-rooter is a unit which controls the operation of certain accumulators so that they form a quotient or a square root. It does this by a process of repeated subtractions and additions, so the time required is relatively long and depends upon the numbers involved; on the average, 125 addition times, or 25 milliseconds, are required for ten-digit numbers.

Although computation with the ENIAC is done exclusively by electronic means, numerical data are supplied to the machine and the answers are taken out by electromechanical methods. While a computation is in progress, numerical data are supplied to the ENIAC by means of an International Business Machine card reader in conjunction with the constant transmitter. The card reader reads standard punched cards and gives out electrical signals which set up relays in the constant transmitter. These relays in turn operate gate tubes which emit pulses that are transmitted over the digit trunks whenever needed. The results of a computation are punched on cards by an International Business Machine card punch operating with signals received from the printer. The static outputs of the decade and binary counters (see Figs. 1 and 5) activate triodes whose plate loads are relay coils. After the relays have stored the numbers to be punched (this requires 1/10 second), the rest of the ENIAC may proceed with the computation, while the relays supply signals to the card punch for the actual punching (which requires another 5/10 second).

The card reader can read 120 cards (each holding 80 digits) per minute, and the card punch can punch 100 cards per minute. Thus 960 ten-digit numbers can be supplied to the ENIAC per minute, and 800 ten-digit numbers can be recorded per minute. These input and output speeds are slow, relative to the speed of electronic computation within the machine (300,000 additions per minute, 23,000 multiplications per minute, etc.). Thus the ENIAC is best suited to those problems in which a large amount of computation is done with relatively little data and with relatively few quantities to be recorded. This limitation is accompanied by the restriction that the setup of problems, being manual, is slow; this fact makes the ENIAC best suited to problems in which a large number of iterated solutions are desired. The production of firing tables by repeated solution of the total differential equations of exterior ballistics is a good example of a problem well-matched to the ENIAC input, output, and setup speeds.

Three function tables provide a method of supplying numbers which remain fixed throughout a problem. Each function table holds 104 values of any arbitrary function; these values are set into a function table matrix manually, i.e., by turning switches which interconnect horizontal buses (representing the 104 values of the argument) to vertical buses (representing the digits of the function value) through resistors. When a two-digit number (argument) is sent to a function table, it will produce the corresponding function value (in the form of groups of pulses) in 1/1000 of a second. Though the numbers stored in a function table may represent programming instructions,[16] the chief use of a function table is to store arbitrary functions which have no simple mathematical formulation. As has already been pointed out, the ballistic drag function (stating the resistance of the air to a shell as a function of the shell's velocity) is of this type. A large class of scientific problems are difficult to solve (i.e., the actual solution process is complicated) solely because they involve such arbitrary functions, and hence they are well-adapted for solution on the ENIAC.

Each of the units described above contains, in addition to the circuits required to perform its operations, local programming circuits for controlling these operations. The programming circuits of a unit include a number of "program controls" which function in the following manner. A program control has associated with it some switches by means of which a given operation may

[16] In which case the function table emits program pulses, rather than digit pulses.

be selected; for example, an accumulator program control may be set to "add and clear," or to "receive," etc. (see Section VI-B). When a program control is stimulated by a program pulse, it directs its unit to perform the operation preset on the switches and emits a program pulse when this is completed. This output pulse

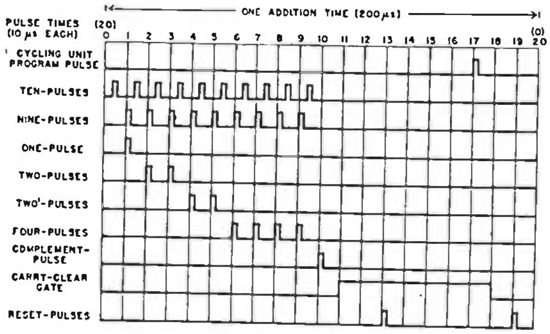

Fig. 6—Cycling-unit pulses.

then goes to the program control (or controls) which directs the next operation in the computation. To set up a problem on the ENIAC, one establishes chains or sequences of local program controls by interconnecting their inputs and outputs and setting the switches associated with them. For example, the following sequences occur in the solution of the exterior ballistic equations: (1) the reading of initial data; (2) the computation of a portion of a known trajectory and automatic comparison with known answers as a check on the ENIAC operation; (3) the integration of the unknown trajectory over one increment of the independent variable (e.g., over 1/10 of a second), involving a number of subsequences: (a) an interpolation sequence for data read from function tables, and (b) a number of subintegrations (depending upon the complexity of the integration method used); (4) a sequence to determine whether or not the projectile is at the summit or at the ground (in which case its co-ordinates are to be punched on cards); and (5) a punching sequence.

The solution of the exterior ballistic equations clearly requires a repeated use of these different sequences which have been set up on the local program controls, and the number of times that any sequence is to be iterated may be a function of the numbers produced by the arithmetic units (e.g., the integration sequence (3) is followed until the projectile reaches the summit and then the punching sequence (5) is followed, etc.). The over-all control of the sequences (and subsequences, supersequences, etc.) is handled by the master programmer. It contains ten six-stage counters, each of which routes incoming program pulses over any of six different output channels. The positions of these counters may be controlled either by the number of pulses which have been supplied to the various output channels or by pulses received (such as the pulses representing the digit of a number) on a special input terminal. In this way the schedule of sequences may be fixed in advance, or it may be made contingent on the results of the computation.

Although the programming of the ENIAC is completely automatic (once it is set up), it must be initiated by the operator. He accomplishes this by pushing a switch on the initiating unit, which causes a program pulse to initiate the first sequence of operations. When that sequence is finished, the program pulse coming from the last program control circuit used in the sequence is returned to the master programmer, which selects the next sequence to be performed. This process is then repeated until the problem, or set of problems, is completed.

The units of the ENIAC operate as a synchronized system, the operations of each unit being governed by a standard set of timed signals furnished by the cycling unit (see Fig. 6). A fundamental reason for this mode of operation has to do with reliability of operation. In the process of transmission from circuit to circuit, electrical pulses suffer degeneration both in amplitude and in phase. If pulses were retransmitted from one circuit to another, etc., progressive degeneration might result and adversely affect the reliability of operation. Transmitted pulses are thus always derived by gating pulses received from the cycling unit.

The ten different kinds of pulses produced by the cycling unit and transmitted to all other units are derived from a master oscillator which normally operates at 100,000 cycles per second, but which may be operated at other frequencies for checking and fault-detecting purposes. The pulses from the oscillator are used to step a twenty-stage ring counter and are (after passing through an electrical delay line) in turn gated by gate tubes operated by this counter. All pulses are of the same phase except the ten-pulses; they are shifted by being passed through another electrical delay line. All pulses are of about two microseconds duration (except for the carry-clear gate) and about fifty volts magnitude.

In the normal operation of the ENIAC, the cycling unit transmits these pulses to all other units continuously; the actual course of the computation is then controlled by the programming circuits. For purposes of checking a setup and localizing a fault, however, two discontinuous types of operation of the cycling unit are provided for. These are called the one-addition-time and one-pulse-time modes of operation and are selected by means of a manual switch. In the one-addition-time mode of operation, the cycling unit emits the complete set of pulses shown in Fig. 6 once every time a push button is pressed and then stops; but the pulses emitted have the same shape, duration, and spacing as during continuous operation, so that the operation of the ENIAC units during this 200-microsecond period is normal. All ENIAC circuits are designed so that they retain their information whenever the cycling unit stops. (This partly accounts for the large number—80—of direct-voltage levels in the ENIAC). By this means a problem can be solved by one-addition-time steps; the numbers and programming signals held in the flip-flops can be read by means of neon bulbs and the operation checked in that manner. When the error is localized to within a given addition time, the one-pulse-time mode of operation is used. This results in the cycling-unit counter's advancing one stage each time the push button is pressed, so that the signals for a given ten-microsecond period are emitted. In this way, the fault can be isolated to within a group of from one to about a dozen tubes.

VI. Analysis of Typical Circuits

In this section we will show how the basic circuit elements discussed in Sections III and IV are combined to form computing circuits. The accumulator decade circuit (Fig. 2) will show how a counter is used for addition and subtraction, the program control circuit of an accumulator (Fig. 3) will show how a local programming circuit governs the operation of its unit, and the multiplication circuit (Figs. 4 and 7) will show how a function table is employed in high-speed multiplication.

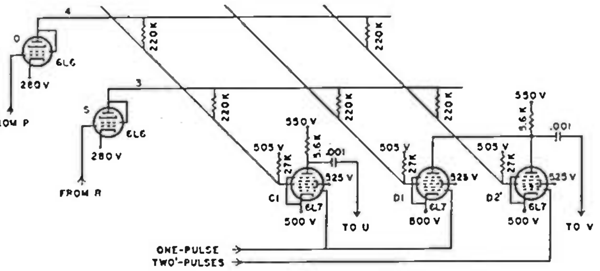

Fig. 7—Cross section of multiplication table.

A. Accumulator Decade Circuit

Each accumulator contains ten decade circuits like that of Fig. 2, in addition to a sign circuit (which uses the binary counter of Fig. 5 to store the sign of the number) and the programming circuits (of which Fig. 3 is a sample). Each decade counter stores a single decimal digit and adds to its contents a digit received in the form of pulses. Incoming pulses are first shaped by tubes 3, 4, and 5 (see tubes 1, 2, and 3 of Fig. 5 for the circuit) and then supplied by tube 6 to the counter.[16] Tubes 9, 10, 11, and 12 are connected as a flip-flop, called the carry flip-flop, which remembers whenever a carry takes place during the reception of a number and is used during transmission to control gates 13 and 14.

The addition of two numbers requires the simultaneous operation of the decades of two accumulators. The decades of the transmitting accumulator convert the digits held in them into groups of pulses which are transmitted to the receiving accumulator. The decades of the receiving accumulator receive these pulses and add them to their contents. We will discuss first the operation of the circuit of Fig. 2 when it is receiving a number arriving in pulse form on a digit trunk. Since

[16] Tube 6 is the 6L6 driving tube shown in Fig. 1. The clearing tube and clearing connections of the counter of Fig. 1 are not shown in Fig. 2, and only one static output lead (that coming from stage 9) is shown.

these digit pulses have been derived from the cycling-unit digit pulses (the nine-pulses, the one-pulse, the two-pulses, the two'-pulses, the four-pulses, and the complement pulse), they will arrive during pulse times one to ten inclusive.

When the problem is set up, one input of gate tube 2 is connected to a digit trunk. Since the same digit trunk is used by other ENIAC units, a gate tube is required here so that pulses passing over this digit trunk do not go into the decade counter, except during those addition times when the other input of gate tube 2 is opened by a signal from the programming circuits. As an example, suppose that the decade counter registers 8 and that five pulses pass over the digit trunk while gate tube 2 is open. These pulses pass through gate tube 2 to the pulse standardizer (tubes 3, 4, and 5), and thence into the counter, counting it from 8 around through 9 and 0 and up to 3. Since 5 plus 8 makes 13, i.e., 3 with 1 to carry, one pulse should have been supplied to the decade to the left when the counter went from 9 to 0. But since that decade may also be receiving pulses from the digit trunk during this period of time, the fact that a carry-over took place must be remembered, and the carry pulse sent to the next decade to the left later in the addition time. This fact is remembered by the carry flip-flop and the carrying is done during pulse times eleven to seventeen inclusive.

The method of setting the carry flip-flop when the counter passes from 9 to 0 is of some interest, since it illustrates the design rule (mentioned in Section V) that pulses are never generated in ENIAC units but are derived from cycling-unit pulses by means of gating circuits. The pulse for setting the carry flip-flop could have been taken from the number 9 stage of the counter except for this rule, for the number 9 stage gives out a pulse as the counter goes from 9 to 0. Instead, gate tube 7 was added. This gate tube receives every incoming pulse from tube 5 of the pulse standardizer on one input, and is turned "on" on the other input when the counter registers a 9. Thus when a counter registers a 9, the pulse which steps the counter to 0 also goes through gate tube 7 and sets the carry flip-flop, electronically recording the fact that a carry has occurred. (The pulse from tube 7 also goes through inverter tube 22 and to gate tube 24, but it is blocked here since the cycling unit carry-clear gate is not on during pulse times one to ten.) Thus, at the end of pulse time ten, each counter holds the sum of its original digit and the digit received (modulo 10), and each carry flip-flop records whether or not a carry took place.

The carrying takes place during pulse times eleven to seventeen, (i.e., after all possible pulses have arrived from the digit trunk). During this period, the carry-clear gate from the cycling unit is passed by the accumulator program controls through to gates 23 and 24, opening them up. At pulse time thirteen the first reset-pulse is applied to gate tube 8, which is open since (in this example) the carry flip-flop is set. The reset-pulse then passes through tube 8, resets the carry flip-flop (so it will be ready for the next operation), and goes through inverter 21 and gate tube 23 into the next decade to the left. In this way, the carry-over is effected.

One such carry-over may give rise to another carry-over, and this to another, etc.; for if a decade receiving a carry-pulse already holds a 9, a further carry must take place. This is accomplished by means of tubes 7, 22, and 24. Suppose, for an example, that the counter of Fig. 2 is registering 9 when a carry-pulse enters the pulse standardizer from the decade to the right. Since the counter is on stage 9, gate tube 7 is open, so that this pulse (in addition to stepping the counter from 9 to 0) passes through tubes 7, 22, and 24 and into the next decade. (This pulse will also set the carry flip-flop; the carry flip-flop is reset by the second reset-pulse at pulse time nineteen, i.e., after the carry-clear gate has gone, so that the pulse generated in this resetting process is blocked at gate 23.)

One may wonder why the carry-clear gate is on for fifty microseconds after the first reset-pulse initiates the carry-over. The reason for this is that in an extreme case twenty carry-overs may take place in sequence. Consider, for instance, the addition of +1 to −1, the numbers being stored in twenty-digit accumulators.[17] A negative number, such as −1, is stored as a complement, that is, −1 is stored as *M*99,999,999,999,999,-999,999, where the "*M*" means that the binary sign counter registers "minus." When the number +1 is added to the contents of this accumulator, 1 pulse is sent to the units decade and no pulses to any other decade. The single pulse going into the units decade counter will change it from a 9 to a 0 and set its carry flip-flop. When the carry-over is initiated, the first reset-pulse goes through tubes 8, 21, and 23 of the units decade into the tens decade; since the tens decade holds 9, this pulse goes on (after being reshaped by the pulse standardizer) through tubes 7, 22, and 24 of the tens decade into the hundreds decade; this process is then repeated for a total of twenty times, until the pulse has changed all decades from 9 to 0 (except the units decade, already at 0) and the binary sign counter from *M* to *P*, thus leaving the number 0 in the accumulator (1−1=0!). Experimental measurement showed that about twenty-five microseconds were required for such a complete twenty-place carry, so (to provide a two-to-one safety factor) fifty microseconds are allowed by the cycling unit.

Let us next consider the operation of the circuit of Fig. 2 during the transmission of a number. The problem here is to convert the number statically registered in the decade counter into pulse form. When addition takes place, the number of pulses emitted (through tube 16 and buffers 19 and 20) is equal to the digit held in the counter. When subtraction takes place, the number of pulses emitted (through tube 15 and buffers 17 and 18) is equal to the difference between the digit and 9.[18] Thus if the counter of Fig. 2 holds the digit 3, three pulses are transmitted from the addition output and six pulses from the subtraction output.

This could have been accomplished by connecting gate tubes to the static ouptuts of the counter and supplying the proper sets of pulses to these gates. (For example, the add gate connected to the third stage would be supplied with three pulses and the subtract gate with six pulses.) A method more economical of tubes is employed, however. It makes use of the ten-pulses from the cycling unit. These are introduced into the decade during the transmission process through buffer tube 1. They cycle the counter completely around through 9 and 0 and up to where it was at the beginning; that is, from 3 to 9 and 0 and to 3 again in the example we are considering. As the counter goes from 9 to 0, the carry flip-flop is set; this occurs during pulse time six in our example. Before the carry flip-flop is set the subtract gate (tube 13) is open, while after it has been set the add gate (tube 14) is open. Thus, in this example, the subtract gate is open from the middle of pulse time zero to the middle of pulse time six, while the add gate is open from the middle of pulse time six to the middle of pulse time nine. Hence, if the nine pulses from the cycling unit are supplied to the subtract gate during this addition time, six of them will be passed; whereas if they are supplied to the add gate, three of them will be passed. In this way the nine pulses are divided into two groups, one representing the digit stored in the decade at the beginning of the process, and the other representing the complement of that digit with respect to 9. The decade is left in its initial position (since no carry-overs are allowed to take place) and the carry flip-flop is reset at the end of the process (by the reset pulses). The digit pulses are transmitted onto digit trunks by means of the cathode-follower buffer tubes 17, 18, 19, and 20.

B. Program Control Circuit

As already stated, the various units of the ENIAC have local programming circuits which govern the operation of these units. At the particular time when a unit is to be used, a program pulse (derived from the cycling-unit program pulse and hence coming during pulse time 17) is sent to a program control of that unit. The program control selected causes the unit to perform the predetermined operation (set up on switches), and then emits a program pulse which is sent to another unit (or units) via a program line to cause the next operation in the sequence to be performed.

Fig. 3 is a somewhat simplified circuit of an accumulator program control. An accumulator has twelve pro-

[17] It will be remembered that two accumulators may be interconnected so as to form a twenty-digit accumulator.

[18] The taking of complements is achieved by complementing each digit with respect to 9 (i.e., taking the difference between that digit and 9) and adding one pulse in the units place, so that the units digit is effectively complemented with respect to 10. The cycling-unit complement-pulse is used for this extra pulse.

gram controls, on each of which may be set up a particular operation, e.g., add and clear, receive a number, subtract without clearing, etc., and each of which is used at a different time during the computation. All program controls operate certain common programming circuits, which in turn cause the decade circuits and sign circuit to act. For example, program control number 3 may direct the accumulator to receive at one point during a computation, and program control number 5 may direct the accumulator to receive at a different time. Since either program control must be able to control reception without the other's being affected, both are connected through buffers (such as tube 7 of Fig. 3) and switches (so that the operation can be selected manually in the setup of a problem) to the common programming circuits which, when stimulated by either program control, will open gate tube 2 and will pass the cycling-unit carry-clear gate to gate tubes 23 and 24 of Fig. 2.

Let us trace through the operation of the circuit of Fig. 3 from the time it receives a program pulse to the time it emits such a pulse. A positive program pulse received on the input terminal of the program control is amplified by tube 5 and sets the flip-flop (tubes 1, 2, 3, and 4). The flip-flop static outputs operate buffer tubes 7 (through amplifier tube 6) and 8 and one input of gate tube 9. Buffer tube 7 connects through a switch to the common circuits which may be operated by the buffer tubes of any program control; the setting of the switch controls whether the operation is transmission, additively or subtractively, or reception. Buffer 8 connects through a clear switch to the circuits which cause the accumulator to be cleared. The load resistors for these buffers are located in the common circuits.

Gate tube 9 receives the cycling-unit program pulse on the first grid every addition time. Hence, when its other input is activated by the flip-flop, it passes the pulse to transmitter tubes 10 and 11[19] and to the flip-flop, causing it to be reset. Thus, the program control emits a program pulse (which will go to stimulate the next operation in the sequence of operations) and is left in the reset condition (so that it may be used again when that sequence is repeated).

There is a timing problem in this operation which should be noted. As soon as the flip-flop is set by the program pulse coming from another program control, (and hence derived from the cycling-unit central program pulse) gate 9 will be opened. But if this action occurred within two microseconds (the duration of a pulse), the same cycling-unit program pulse from which the input was derived would be passed by gate 9, and the flip-flop would be reset immediately. This is prevented by means of capacitor C_3 (300 micromicrofarads), which slows up the operation of the circuit.

[19] The load resistor for tube 11 is not located in the program control, but is attached to the program line running around the front of the machine, since the number of such buffer tubes which are connected together to a given program line depends upon the particular problem set up on the ENIAC.

One further point of circuit design should be discussed. It will be noted that the grid of every conducting tube is driven positive. Thus, the grid of tube 10 normally draws about one-third milliampere of grid current, and when the flip-flop is set, the grids of tubes 8 and 9 are driven positive, with respect to the cathodes of these tubes. The purpose of this mode of operation is to increase the plate current of conducting tubes (and thus decrease the effective plate resistance), to reduce the effect of spurious signals picked up on the leads (since the gain of the tube is decreased when the grid is positive), and to make sure that the driven stage is operated, even if the driving tube is not completely turned off (and hence is drawing some plate current). The last factor is especially important in the high-speed multiplier, where twenty-four buffers (normally nonconducting tubes) are connected in parallel to a common load resistor.

C. Multiplication Circuit

In most problems, multiplication is the chief factor determining the duration of the computation. Though multiplication occurs less frequently than addition (a typical problem will have one multiplication for every four additions), it is a more lengthy process because it involves a number of additions. If multiplication is done by successive additions in sequence, a maximum of ninety addition times would be required for ten-digit numbers. To increase the over-all speed of computation within the ENIAC, it was decided to use a process of multiplication faster than that of successive additions, even at the cost of complicating the multiplier somewhat. The process chosen makes use of an electrical multiplication table; by means of it the complete multiplicand can be multiplied by a single digit of the multiplier in one addition time.

A description of the operation of the circuits of the high-speed multiplier, capable of handling ten-digit numbers, is too complicated for us to give here. Instead, we will consider a simplified version of the circuit, as shown in Fig. 4. The circuit of Fig. 4 can handle only two-digit multipliers and multiplicands (and hence will produce only four-digit products). Moreover, to effect further simplification, only part of the multiplication table is shown (and hence only some of the output gates), namely, that part used by multiplicand digits of one, two, or three. Thus, in our example, we will take a multiplicand of which neither digit exceeds three.

Tubes $A0$ through $A9$ and $B0$ through $B9$ form what is called the multiplier selector since, by means of this array of tubes, one digit of the multiplier can be selected at a time. On one input these gate tubes are connected in one-one correspondence with the static outputs of the stages of the decade counters of the accumulator holding the multiplier (called the multiplier accumulator). On the other input these gate tubes are connected in columns to lines coming from the programming circuits (lines 1 and 2). These lines are activated in sequence (one each addition time) so that one digit of the multiplier is selected at a time. The outputs of the selector gates are connected in rows to drive the multiplication table (through tubes P, Q, R, S, etc.).

The digit selected operates the multiplication table and associated output gates (the tubes lettered C, D, E, F, and G). The table is so wired up that when the incoming bus representing a digit from 0 to 9 is activated, all output gate tubes are turned off except those representing the products of that digit by the digits from 0 to 9. The output gate tubes are pulsed with pulses from the cycling unit, so that the whole network generates the products of the multiplier digit selected by *all* digits from 0 to 9. Since the product of two single-digit numbers is in general a two-digit number, the multiplication table is divided into two parts, the left-hand part (producing the tens digit of the product) and the right-hand part (producing the units digit of the product). For example, if the multiplier digit is 7, tube $D2'$ will pass two pulses and tube $G1$ will pass one pulse, since the product of 7 times 3 is 21, i.e., 2 in the tens place and 1 in the units place.

The units and tens outputs of the multiplication table are fed into two multiplicand selectors, called the left-hand multiplicand selector (the tubes lettered H and J) and the right-hand multiplicand selector (the tubes lettered K and L). Each selector consists of an array of gate tubes (certain rows are not needed) connected on one input in one-one correspondence with the static outputs of the stages of the decimal counters of the accumulator holding the multiplicand (called the multiplicand accumulator). On the other input these gate tubes are connected in rows to the lines coming from the multiplication table output gates (via inverters U, V, etc.), each row receiving pulses according to the digit it represents. Thus tubes $H3$ and $J3$ represent possible multiplicand digits 3 and hence receive pulses from the number 3 channel of the left-hand part of the multiplication table (from tubes $D1$ and $D2'$). The outputs of the selector gates are connected in columns and go to the shifters.

The electronic shifters (the tubes lettered M and N) consist of square arrays of gate tubes used to shift the partial products into position. On one input the gates of a shifter are connected together in columns which receive the outputs of the corresponding multiplicand selector. On the other input the gates of a shifter are connected to the lines coming from the programming circuits which are activated in sequence, one being on for each successive multiplier digit (lines 1 and 2). The outputs of a shifter are connected together diagonally, so that the pulses coming out of the shifter are moved over one place each time a different multiplier digit is used.

Suppose, for example, that the multiplier is 76 and the multiplicand is 21. As a consequence, one input of each of the following selector tubes is activated: $A7$, $B6$, $H2$, $K2$, and $L1$. The programming circuits energize line 1 and as a result two things happen. First, gate tube $B6$ goes on, causing the number 6 line of the multiplication table to be energized; this causes gate tubes $D2'$, $E1$, $E2'$, $F2'$, $F4$, and $G1$ to be turned off—the remaining tubes pass the pulses received from the cycling unit. Second, the shifter gate tubes $M1$, $M2$, $N1$, and $N2$ are activated on one input. The pulses coming from the multiplication table (representing the product of 6 times 1, 2, and 3) go to the multiplicand selectors. Tube $H2$ passes the one pulse received from the table, and tubes $K2$ and $L1$ pass 2 and 6 pulses, respectively. Thus pulses are emitted by the left-hand multiplicand selector representing 10, and pulses come from the right-hand selector representing 26. These come out of the shifters as 0100 and 0026 and go to the accumulators which collect the partial products.

The program controls activate line 2 during the next addition time, the multiplier digit 7 is selected, and pulses come out of the shifters representing 1000 and 0470 and go into the left-hand and right-hand partial products accumulators (producing the sums 1100 and 0496, respectively). After all of the multiplier digits have been used in this manner, corrections are made in case negative numbers (complements) are involved, and the left-hand partial products are then added to the right-hand partial products, producing the final answer.[20] In the example we have taken, the final sum will be 1596, which is the product of 76 and 21.

A more detailed view of one section of the multiplication table is shown in Fig. 7. When the table is in operation, the buses representing all the digits except the one selected are positive; the one selected is driven negative, turning off those output gate tubes which are connected to the selected bus through the 220,000-ohm resistors. Of course, because of the cross-connections via the various 220,000-ohm resistors, the nondriven buses will receive a certain amount of negative signal, and this will, in turn, have a tendency to turn off the gate tubes which are supposed to be on. This "parasitic" signal is overcome by driving the grids positive (the grid resistors go to 505 volts, whereas the cathodes are held at 500 volts). The design of the table must take into account the possible parasitic signals. These are a function of the matrix of connections and the resistances of the driving tubes, the cross-connecting resistors, and the grid resistors. The problem was particularly acute in the case of the tables used in the function tables, both because these were so large (over one hundred buses on each side), and because the matrix connections are variable; the parasitic signal was decreased in that case and the operating signal made less dependent upon the particular matrix connections set up by using plate load resistors in parallel with the load provided by the table itself. The multiplication table has, of course, fixed connections. It was further simplified by the use of a coded system; instead

[20] These operations take two addition times. At the beginning of the multiplication, an addition time is required for setting up the selector circuits. Hence, the multiplication of ten-digit numbers takes 13 addition times or 2.6 milliseconds.

of having an output gate tube for each digit from 1 to 9, gate tubes receiving the one-pulse, the two-pulses, the two′-pulses, and the four-pulses were used. This required fewer output gate tubes and made possible a better-balanced multiplication table.

VII. Conclusion

Since its dedication on February 15, 1946, the ENIAC has produced results of great value in both theoretical and applied fields, demonstrating unquestionably that electronic computation is practicable. Except for an initial period of testing, the rate of failures has been only about two or three per week, most failures being caused by heater-cathode short circuits and heater open circuits in tubes. These can usually be detected, localized, and corrected quickly, despite the complexity of the ENIAC, by an operator who is thoroughly familiar with all the details of ENIAC design and with the particular problem being solved. Under such an operator only a few hours per week are lost on account of failures.

Because the ENIAC combines the desirable features of speed and reliability, it is capable of solving problems hitherto beyond the scope of science. Thus it inaugurates a new era, an era of electronic computation.

Automatic Frequency Control of Microwave Oscillators*

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Summary—**A method for the automatic frequency control of any type of tunable microwave oscillator is described. In this method a servomechanism is used which includes a wave-guide discriminator circuit, a mercury-contact relay, a 60-cycle amplifier, and a small two-phase induction motor.**

Tests made on a preliminary model of a circuit of this type used with a 4000-megacycle oscillator showed that a stability of 1 part in 50,000 was obtainable. The manner in which such a control system may be used in a microwave repeater is described.

I. Introduction

THE AUTOMATIC-frequency-control circuit to be described was developed in connection with work on microwave repeaters. A mechanical servo was chosen because of considerations discussed under Sections V and VI below.

II. Description

Fig. 1 shows diagrammatically the components and connections in the servo loop. Part of the output power of a 4000-megacycle oscillator is fed into a wave-guide version of the well-known discriminator circuit.[1–3] The discriminator output is converted to a 60-cycle square-wave signal by means of a polarized mercury-contact relay also shown in Fig. 1. The fundamental component of this signal is amplified and applied to the control phase of a two-phase low-inertia induction motor. The

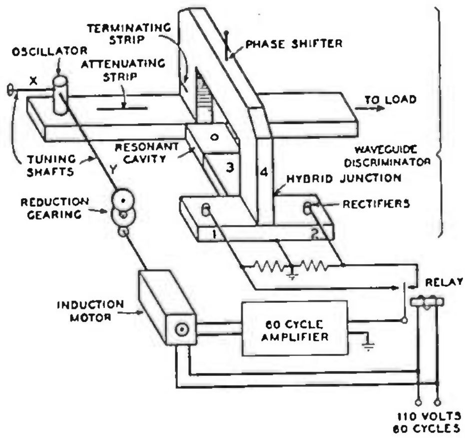

Fig. 1—Servomechanical automatic-frequency-control circuit.

motor is, in turn, connected to an oscillator tuning shaft through reduction gearing, thus completing the servo loop.

The various components of the loop will now be discussed in more detail.

1. *Wave-Guide Discriminator*

In the low-frequency phase discriminator shown in Fig. 2(a) the voltages e_a and e_b, if in phase quadrature, give the conjugate voltages e' and e'' across the rectifiers. If the phase of e_a or e_b is now changed, the voltage across one rectifier will increase, and that across the other will decrease. If e_a and e_b are derived from a com-

* Decimal classification: R355.6×R355.912. Original manuscript received by the Institute, May 1, 1946; revised manuscript received, December 16, 1946.

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[1] F. A. Polkinghorn and N. F. Schlaak, "A single side-band short-wave system for transatlantic telephony," Proc. I.R.E., vol. 23, pp. 701–718; July, 1935.

[2] U. S. Patent No. 2,041,855, 1936.

[3] D. E. Foster and S. W. Seeley, "Automatic tuning, simplified circuits, and design practice," Proc, I.R.E., vol. 25, pp. 289–313; March, 1937.

mon source, and a network whose phase shift varies with frequency is interposed between the source and one of the pairs of input terminals, the circuit becomes a frequency discriminator.

A phase discriminator in wave guide is based on the hybrid junction shown in Fig. 2(b). From a considera-

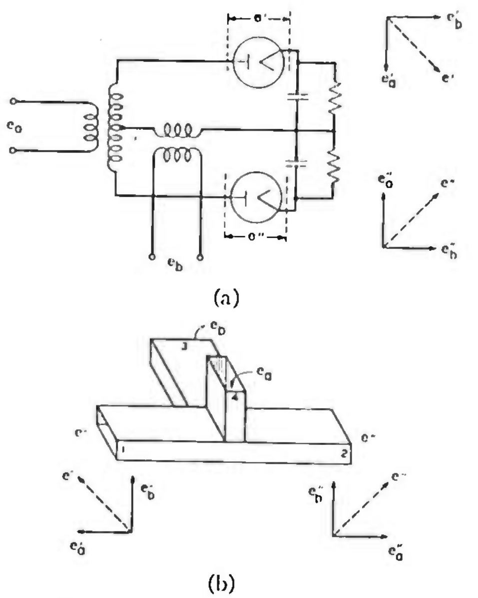


Fig. 2—Low-frequency and high-frequency phase discriminators.

tion of the voltage vectors in space in the wave guide, (here, always perpendicular to the large dimension of the guide), it will be seen that branch 3 is in parallel, and branch 4 is in series with branches 1 and 2. Thus the phase relationships of the voltages are the same as in the first circuit, and if rectifiers are placed across the guide in branches 1 and 2, the voltages across them will vary with the relative phase of e_a and e_b, as in the first circuit. Transformer ratios have been ignored for simplicity.

In Fig. 1 a resonant cavity has been added to the hybrid junction to make a frequency discriminator.[4] Power flows down the wave guide attached to the oscillator and develops voltages across two irises connected effectively in parallel and in series with the line. The iris in the small side of the guide forms part of a resonant cavity through which power flows to the parallel branch of the hybrid junction. The iris in the large side of the guide is connected through a phase shifter to the series branch of the hybrid junction. The terminating strip ensures a matched impedance looking back from the hybrid junction. The phase shifter is included so that the voltages from the two paths 3 and 4 can be put in phase quadrature at the resonant frequency of the cavity. The power flowing into the hybrid junction from each of the two paths is adjusted to be approximately equal at this frequency.

By means of an analysis based on the lumped-constant equivalent circuit it may be shown that the total voltage appearing across the rectifier load resistors is

$$V = K\left\{\frac{(f/f_0 - f_0/f)Q_L}{1 + (f/f_0 - f_0/f)^2 Q_L^2}\right\}.$$

Here Q_L is the loaded Q of the cavity, and f_0 is its resonant frequency. The constant K depends upon the power input, cavity transmission loss, and crystal sensitivity. Square-law rectifiers are assumed.

For most applications we can use the approximation

$$f/f_0 - f_0/f \doteqdot 2(f - f_0)/f_0 = 2F/f_0.$$

For small variations, therefore,

$$V \doteqdot K\left\{\frac{(2Q_L/f_0)F}{1 + (2Q_L/f_0)^2 F^2}\right\}.$$

Thus, for frequencies close to f_0, V is approximately linear with F, the variation from f_0. As $|F|$ increases, the second term in the denominator becomes of importance, and the slope of the curve decreases. Voltage maxima occur at $F = \pm f_0/2Q_L$.

In Fig. 3 the measured response curve for a wave-guide discriminator centered at $f_0 = 4200$ megacycles is

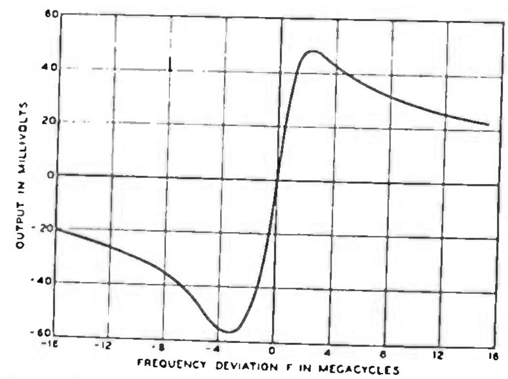


Fig. 3—Response of an experimental high-frequency wave-guide discriminator.

shown. The curve is not quite symmetrical, partly because of the different responses of the two rectifiers used, but the linear part of the curve is greater than that required.

2. *Amplifier*

The 60-cycle amplifier was designed to give linear output of motor speed versus input voltage, up to at least 40 revolutions per second with low-power tubes. This amplifier was designed largely by R. E. Graham, of the Bell Telephone Laboratories.

3. *Motor and Gearing*

The motor used in the experimental design is a two-phase Diehl induction motor, especially designed to have low inertia and linear characteristics. The total inertia is about 16.3 gram-centimeters squared.

The gear reducer had to be designed to have a gear ratio (input-to-output speed ratio) small enough so that

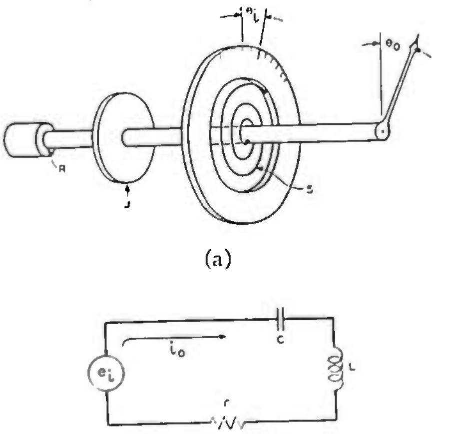
[4] This was first suggested by A. C. Beck and D. H. Ring of the Bell Telephone Laboratories.

the motor speed to follow maximum rate of frequency drift lay within the linear response region of the servo. Although a small gear ratio calls for less amplifier gain, a limit is reached where the frictional resistance of the load or the static-friction errors become too large. The gear ratio used in this system was selected to be in the range thus determined.

III. Elementary Servomechanism Theory

In the circuit of Fig. 1, two shafts[5] are shown, one of which (shaft X) may be hand controlled to introduce a known frequency variation to simulate an undesired frequency shift. Shaft Y, the servo-output shaft, is driven by the motor. Let it be assumed that they both change the oscillator frequency at the same rate.

The circuit of Fig. 1 is a servomechanism, by definition, if the introduction of an angle θ_i (corresponding to a frequency change F_i) at shaft X causes the servo-output shaft Y to change by an angle θ_0 such that the corresponding frequency change F_0 tends to cancel F_i. The net change $F_i - F_0$ at any given time is called the frequency error. It will be convenient to use the proportional angular error $\theta_i - \theta_0$.



(a)

(b)

Fig. 4—Simple circuit equivalents for the servomechanism of Fig. 1.

If we do not exceed the linear range of any of the servo components, this angular error appears successively as a proportional variation in frequency, phase, voltage, and motor torque. To a first approximation this may be assumed to happen instantaneously, because the inertia and the effective mechanical resistance of the motor are the dominant factors limiting the speed of response. Because a torque is produced which is proportional to the angular error, the relation between the error angle and the motor torque may be expressed as a stiffness analogous to a spring stiffness. The torque is then given by

$$T = S(\theta_i - \theta_0). \tag{1}$$

The effective stiffness S is increased if the amplifier gain is increased, or if the gear ratio is decreased.

[5] The reflex type of oscillator used in the experimental system actually has two independent frequency controls.

This torque is balanced by the retarding torques due to the motor inertia J, and the effective mechanical resistance of the motor R, according to the equation

$$S(\theta_i - \theta_0) = J \frac{d^2\theta_0}{dt^2} + R \frac{d\theta_0}{dt}. \tag{2}$$

The equivalent mechanical circuit is shown in Fig. 4(a), in which the input angle θ_i is the rotation of a ring which is coupled by a spring to the output shaft.

Equation (2) becomes the equation for the series circuit of Fig. 4(b), if we substitute the analogous electrical quantities as shown in (3).

$$\frac{1}{C}(q_i - q_0) = L \frac{d^2 q_0}{dt^2} + r \frac{dq_0}{dt}. \tag{3}$$

This may be written

$$\frac{q_i}{C} = e_i = L \frac{di_0}{dt} + r i_0 + \frac{1}{C}\int i_0 dt. \tag{4}$$

The response of this circuit to various types of input signals is well known. Commonly used parameters are the damping factor α and the natural frequency ω_n. In (4) these are

$$\alpha = \frac{r}{2L}, \qquad \omega_n = \sqrt{\frac{1}{LC}}. \tag{5}$$

In (2) they are

$$\alpha = \frac{R}{2J}, \qquad \omega_n = \sqrt{\frac{S}{J}}. \tag{6}$$

For critical damping, $\alpha = \omega_n$. If $\alpha > \omega_n$ either system gives nonoscillatory response, and for $\alpha < \omega_n$ the response is oscillatory.

For one-half critical damping ($\alpha = (\alpha_c/2)$) we have, in the mechanical system,

$$\frac{R}{2J} = \frac{1}{2}\sqrt{\frac{S}{J}}. \tag{7}$$

This is a commonly used design value for the damping in a simple servo, and gives a 16 per cent overshoot for an input step-function, but about half the time of rise of the critically damped case.

The time constant $\tau = J/R$ of the motor-amplifier combination was measured by opening the loop and determining the time needed for the motor to come up to $1 - 1/e = 0.632$ times its final speed after the application of an input step function of voltage.

For $\alpha = \alpha_c/2$ we have, from (7),

$$\tau = R/S. \tag{8}$$

In such a servo, for the constant velocity case (θ_i introduced at a constant rate), from (2),

$$S(\theta_i - \theta_0) = R \frac{d\theta_0}{dt}. \tag{9}$$

Therefore, the error for the constant-velocity case in a servo with one-half critical damping is

$$\theta_i - \theta_0 = \tau \frac{d\theta_0}{dt},$$

or

$$F = (F_i - F_0) = \tau \frac{dF_0}{dt}. \tag{10}$$

Similarly if the output shaft is opened and a small angle θ_i is introduced,

$$\theta_i = \tau \frac{d\theta_0}{dt}. \tag{11}$$

Thus, if the motor time constant is known, the damping can be set at one-half critical by opening the loop at the output shaft, introducing a known angle (or frequency change), and adjusting the amplifier gain or other variable until the output speed corresponds to that given by (11).

IV. Results of Tests

Tests were made on a laboratory model of an automatic-frequency-control circuit designed for use with a reflex oscillator operating at 4000 megacycles. The oscillator could be tuned electrically over ±7 megacycles by a motor-driven potentiometer which varied the repeller voltage. A resonant cavity with $Q_L = 800$ (giving the discriminator response shown in Fig. 3) was used.

The maximum drift rate to be followed was found to be 0.5 megacycle, and the motor-plus-amplifier time-constant, 0.068 second. The error expected at this drift rate was, therefore, 34 kilocycles (see 10)).

The coulomb friction, which gives a retarding torque independent of angular velocity, limits the servo accuracy at very low speeds. From measurements on the motor the error expected for $\alpha = \alpha_c/2$ was ±30 kilocycles. This error may be reduced by using a higher gear ratio (plus higher amplifier gain to maintain the same gain around the loop), provided the gear ratio still satisfies the conditions outlined in part 3 of Section II.

It was assumed in Section III that there were no limitations on the response due to the effects of gear backlash. In the experimental system, although the backlash did not cause mechanical oscillations or "hunting" to begin until optimum gain ($\alpha = \alpha_c/2$) had been exceeded, it was thought advisable to use slightly lower amplifier gain than optimum. For the gain used, the measured error for a 0.55-megacycle drift rate was 60 kilocycles, and the measured static error was ±40 kilocycles.

No attempt has been made as yet to use equalizing networks[6,7] to increase the accuracy of control of the servo, except for some special circuit features included in the amplifier, and some further improvement is possible by such means.

A resonant cavity of solid brass construction was used in the first tests. This type of cavity showed no observable change in resonant frequency after cycling between −70 and +70 degrees centigrade. The variation in resonant frequency with temperature was measured to be 0.07 megacycle per degree centigrade, which is close to the value calculated from the temperature coefficient of expansion for brass.

Thus, for a cavity of this type with the temperature controlled to ±0.5 degree centigrade, and with controlled humidity, the variation in resonant frequency could be expected to be held to ±35 kilocycles. For radio repeater use, therefore, where rates of drift and the occurrence of sudden variation can be minimized by proper attention to power supplies and to shielding of the reflex oscillator from sudden ambient temperature variations, the maximum frequency error should be of the order of ±75 kilocycles, except during the first minute of warm up.

V. Comparison With Other Methods of Automatic Frequency Control

There are two general methods of automatic frequency control; one in which the control is purely electrical, and the other in which a mechanical link is included, as described here. In the first type the error ordinarily varies with the amount of correction that has been called for, while in the second the error varies with the rate of change of frequency which is called for and has a fixed maximum value when this rate is zero.

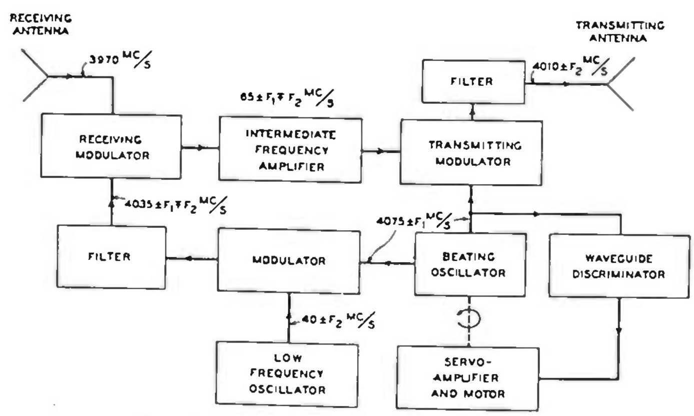


Fig. 5—Block diagram of radio repeater.

Because of its noncumulative error, the second or servomechanical type of control may be preferable where slow drifts over long periods of time are encountered. The direct-current amplifiers which are customarily used in the straight electrical type of control are often undesirable from the point of view of stability over long periods of time. The fact that in the case of a power failure a servomotor will stop, thus causing no detuning, may be of considerable importance.

[6] E. B. Ferrell, "The servo problem as a transmission problem," Proc. I.R.E., vol. 33, pp. 763–767; November, 1945.
[7] LeRoy A. MacColl, "Fundamental Theory of Servomechanisms," D. Van Nostrand Co., Inc., New York, N. Y., 1945.

On the other hand, the electrical type of control ordinarily has a much faster response. Thus it is usually preferable where very high stability of an oscillator is necessary over relatively short periods of time. It requires, of course, an oscillator which can be rapidly varied in frequency by means of a change in some electrical potential.

VI. Application to a Microwave Repeater

Fig. 5 shows a block diagram of a microwave repeater with an automatic-frequency-control system of the kind which has been described. This type of repeater involves only one ultra-high-frequency beating oscillator, which is held to the resonant frequency of a cavity. The main output of this oscillator beats with the 65-megacycle signal in the transmitting modulator to produce the output signal. An auxiliary oscillator produces power at comparatively low frequency which is used to beat against the ultra-high-frequency oscillator output to produce power at a frequency suitable for the conversion of the incoming signal to the intermediate frequency. If it is arranged that the receiving and the transmitting beating-oscillator frequencies are respectively on the same sides of the incoming and outgoing frequencies, the error in the transmitted frequency will exceed that in received frequency by only the error in the low-frequency oscillator ($\pm F_2$ in Fig. 5). This error may be made very small by the use of crystal control.

Thus, this method of microwave-repeater automatic frequency control puts the burden of control of the transmitted frequency mainly on the original transmitting terminal. Frequency control of the beating oscillators in each repeater is needed mainly to keep the intermediate frequency within given limits. The present types of intermediate-frequency amplifiers permit a variation of carrier frequency which is somewhat greater than the possible variation of ± 75 kilocycles quoted in Section IV.

VII. Conclusions

The servomechanical type of automatic frequency control described in this paper was designed to be used to control the ultra-high-frequency beating oscillators in radio-relay repeaters operating at about 4000 megacycles. In giving a possible accuracy of control of ± 75 kilocycles, or better than one part in 50,000 at this frequency, it more than meets the requirements of such a system. It is furthermore a general method of control applicable to many kinds of oscillators, and useful with ultra-high-frequency or intermediate-frequency discriminators. With some changes, this servomechanism may also be applied to automatic gain control.

Harmonic-Amplifier Design*

ROBERT H. BROWN†, MEMBER, I.R.E.

Summary—Two methods are presented for calculating the ideal performance of amplitude-variation-type harmonic amplifiers: (1), a slightly revised form of Terman's analysis, which is convenient for quickly obtaining approximate results, and (2), a graphical analysis which, while somewhat less rapid, is exact.

In a frequency-multiplier stage the actual performance may come short of the ideal because of degenerative effects due to grid-plate capacitance and cathode inductance. In many cases, with power tubes, these degenerative effects are so great as to render the stage impracticable. The degeneration due to grid-plate capacitance may be thought of as an output loading effect which is proportional to the mutual conductance and the grid-plate capacitance of the tube and inversely proportional to the total capacitance in the circuit between the grid and the cathode.

Inductance in the cathode circuit common to both grid and plate circuits has a loading effect on both input and output circuits which is proportional to the mutual conductance of the tube, the common inductance, the internal capacitance between the cathode and the input or output electrode as the case may be, and to the second power of the frequency. Circuit arrangements for overcoming these degenerative effects are discussed in theory and application.

Introduction

Modern applications requiring crystal stability of carrier frequencies of the order of 10^8 cycles and higher have emphasized a need for material on frequency-multiplier design more extensive than that which is usually available to the individual confronted with such design problems. This fact became especially evident during the development of the equipment later used as the "moon radar."

Various methods are known for obtaining frequency multiplication, but in the present state of the art only the locked oscillator and the harmonic amplifier are suitable for use at frequencies above approximately 10 megacycles. Harmonic amplifiers may be divided into two classifications: amplitude variation and velocity variation. Tubes suitable for the velocity variation type are not generally available at present, and the following discussion is confined to amplitude-variation harmonic amplifiers.

Graphical Analysis of Performance

The performance of a harmonic amplifier may best be

* Decimal classification: R357.1. Original manuscript received by the Institute, May 5, 1946; revised manuscript received, November 27, 1946. The work described herein was conducted under a subcontract with Major E. H. Armstrong as part of prime Signal Corps Contract No. W28-003-ac-248. The equipment supplied under this contract constituted the major portion of the "moon radar."

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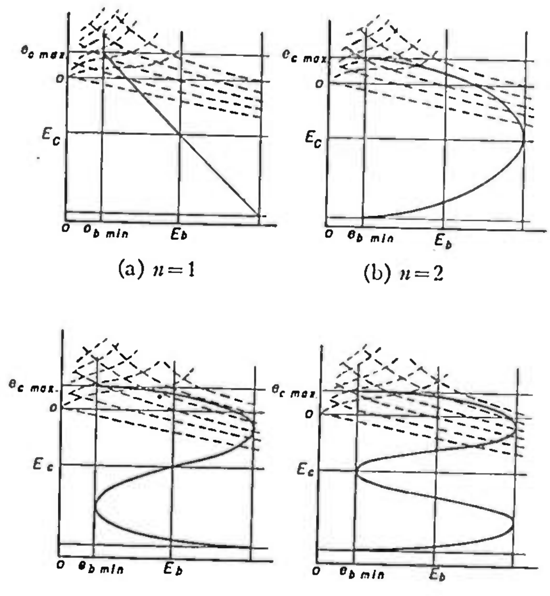
studied by a graphical analysis. Fig. 1 shows the nature of the operating paths of harmonic amplifiers when the paths are plotted on a constant-current characteristic. The operating path of the ordinary class-C amplifier, in which the frequency multiplication is unity, is shown in Fig. 1 (a). Figs. 1 (b), 1 (c), and 1 (d) show, respectively, the operating paths of a frequency doubler, tripler, and quadrupler. It will immediately be recognized that if the grid and plate signals are sinusoidal, these operating paths are Lissajou figures. Throughout this analysis it will be assumed that the grid and plate circuits are in tune and have Q values greater than ten, and that transit times are small, i.e., that the grid and plate signals are sinusoidal and 180 degrees, or an odd multiple thereof, out of phase at an arbitrary time $t=0$.



(a) $n=1$ (b) $n=2$ (c) $n=3$ (d) $n=4$

Fig. 1—Harmonic-amplifier operating paths. n = order of frequency multiplication. Ordinates are instantaneous grid voltage and abscissas are instantaneous plate voltage. E_c = grid bias and E_b = plate supply voltage. Dashed lines indicate constant-plate-current curves. Dotted lines indicate constant-grid-current curves.

Taking grid and plate voltages as cosine functions, current and voltage relations in the neighborhood of the time when plate current flows may be represented as in Fig. 2. The relation between the angular velocities of the grid and plate signals is $\omega_p = n\omega_g$ where n is the order of frequency multiplication. Integration yields the following relation between the phase angles of the plate and grid signals:

$$\Phi_p = n\Phi_g + \pi. \tag{1}$$

The crest value of the plate or output signal is given by

$$E_{pnm} = (E_b - e_{b\ \min}). \tag{2}$$

If θ is defined as the angle, measured in electrical degrees at the input or fundamental frequency during which plate current flows, the plate potential at plate-current cutoff is

$$e_{b_0} = E_b + E_{pnm} \cos\left(\pi + n\frac{\theta}{2}\right). \tag{3}$$

The crest value of the grid or input signal is given by

$$E_{g1m} = -(E_c - e_{c\ \max}), \tag{4}$$

and the grid potential at plate-current cutoff is

$$e_{c_0} = \left(E_c + E_{g1m}\cos\frac{\theta}{2}\right). \tag{5}$$

Eliminating E_{g1m} from (4) and (5) yields the following relation for the grid bias:

$$E_c = \left(e_{c_0} - e_{c\ \max}\cos\frac{\theta}{2}\right) \Big/ \left(1 - \cos\frac{\theta}{2}\right). \tag{6}$$

$e_{c_0} = e_{b_0}/\mu$ but since μ is considerably lower near cutoff than its published value for normal operating conditions, e_{c_0} should be taken as the ordinate of the point on the zero plate-current line whose abscissa is e_{b_0}.

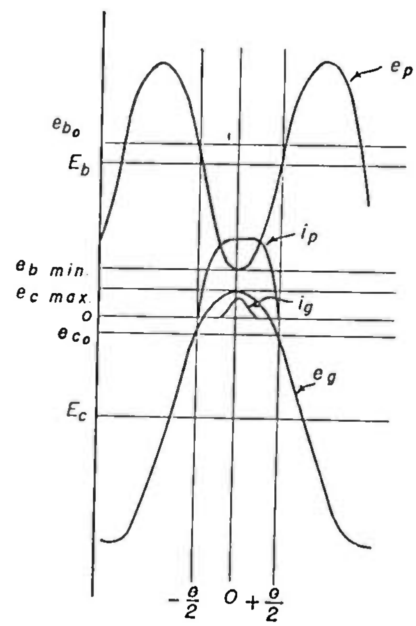


Fig. 2—Harmonic amplifier voltage and current relations.
e_{b_0} = plate voltage at plate current cutoff
e_{c_0} = grid voltage at plate current cutoff
E_b = plate supply voltage
E_c = grid bias voltage
θ = total angle of plate current flow.

Knowing E_c, E_{g1m}, E_b, and E_{pnm}, with the aid of (7) and (8) the operating path may be plotted on a constant-current-characteristic sheet.

$$e_c = E_c + E_{g1m}\cos\Phi_g. \tag{7}$$

$$e_b = E_b + E_{pnm}\cos(\pi + n\Phi_g). \tag{8}$$

Two points have already been determined ($e_{c\ \max}$, $e_{b\ \min}$) and (e_{c_0}, e_{b_0}), and it is usually only necessary to find two or three more in order to sketch the conduction region of the path with sufficient accuracy.

Having obtained the operating path, the direct and input-frequency components of the grid current and the direct and output-frequency components of the plate current may be determined to the desired degree of accuracy by whatever method of harmonic analysis the designer may prefer. A Fourier analysis based on the instantaneous values of grid and plate currents at ten-degree intervals (at the input angular velocity) should be adequate for any practical frequency multiplier of the type discussed here.[1-4] For doublers and many triplers an analysis based on currents taken at fifteen-degree intervals will usually be found adequate.

In many cases it may be desirable to use a more rapid but less accurate method for determining approximate operating conditions before applying the foregoing analysis. Such a method, based on Terman's analysis,[5] is described in Appendix I.

In the embodiment of a multiplier, coupling between the grid and plate circuits by means of interelectrode capacitance and/or cathode inductance may, because of degenerative effects, prevent realization of the performance predicted by the foregoing analysis. In a very-high-frequency multiplier employing power tubes these effects may be so great that, unless compensated for, they will render the stage unworkable.

Degenerative Effects

1. Degeneration Due to Capacitive Feedback

Because of the highly nonlinear operation of a harmonic amplifier, it is not convenient to obtain a complete

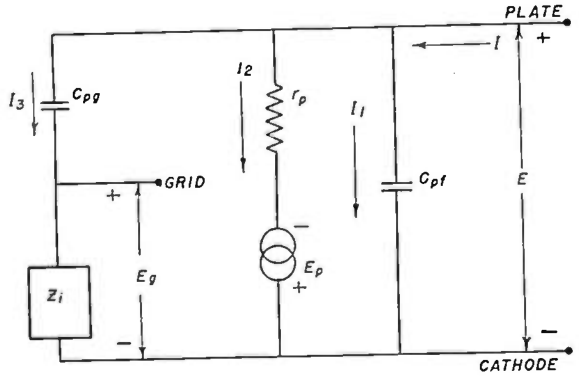


Fig. 3—Equivalent circuit for analyzing effect of grid-plate capacitance on output.
C_{pg} = grid-plate capacitance
C_{pf} = plate-cathode capacitance
r_p = dynamic plate resistance
Z_i = total impedance between grid and cathode
E_p = equivalent plate-circuit generator voltage due to signal E_g reaching grid from plate circuit.

general solution showing the effects of grid-plate capacitance. However, by assuming the equivalent plate-circuit theorem, a rough first-order approximation may be obtained which, while of little quantitative value, does reveal what we need to know here. The problem may be approached by solving for the admittance seen between the anode terminal and ground in a simple single-tube harmonic amplifier, when looking toward the tube at the output frequency. Fig. 3 shows the equivalent circuit seen looking toward the tube if lead inductances be neglected.

$$I = Ej\omega C_{pf} + (E - E_p)/r_p + E[j\omega C_{pg}/(1 + j\omega C_{pg}Z_i)]. \quad (9)$$

$$E_p = -\mu E_g = -\mu E[j\omega C_{pg}Z_i/(1 + j\omega C_{pg}Z_i)]. \quad (10)$$

For any given tube μ and r_p in the above expressions are functions of the operating conditions in the circuit, but it is not necessary here to be specific about their values. Combining (9) and (10) to eliminate E_p and substituting g_p for $1/r_p$ and g_m for μg_p gives for the output admittance:

$$Y_0 = g_p + j\left[\omega C_{pf} + \omega C_{pg}\left(\frac{1 + g_m Z_i}{1 + j\omega C_{pg}Z_i}\right)\right]. \quad (11)$$

If Z_i be represented by a parallel combination of L_i, C_i (which includes grid-filament capacitance) and R_{in}, then at the input frequency f, $\omega L_i = 1/\omega C_i$ and $Z_i = R_{i1}$ where $\omega = 2\pi f$. At the output frequency nf the reactance of L_i is n^2 greater in magnitude than the reactance of C_i, and Z_i may be represented with small error by a parallel combination of C_i and a resistance R_{in}. Since the magnitude of the reactance of C_i at the output frequency is usually much less than R_{in} and only approximate results are desired, for Z_i at the output frequency one may write $1/j\omega_n C_i$, in which case (11) becomes

$$Y_0 = g_p + g_m[C_{pg}/(C_{pg} + C_i)] + j\omega_n[C_{pf} + C_{pg}C_i/(C_{pg} + C_i)], \quad (12)$$

or

$$Y_0 = g_p[1 + \mu C_{pg}/(C_{pg} + C_i)] + j\omega_n[C_{pf} + C_{pg}C_i/(C_{pg} + C_i)]. \quad (13)$$

The values of g_m in (12) and μ in (13) depend upon the operating conditions in the circuit, but are related to the ordinary g_m and μ values of the tube.

The second term in (12) or the second part of the first term in (13) shows that, in a harmonic amplifier, capacitive coupling between grid and plate circuits gives rise to a degenerative effect which may be thought of as a loading of the output circuit. This loading effect is proportional to the mutual conductance and the grid-plate capacitance of the tube, and approximately inversely proportional to the total capacitance in the circuit between the grid and the cathode. It has been found by experience that power tubes with large values of g_m and C_{pg} are in many cases inoperative as practical harmonic amplifiers, if this output loading effect is not removed. Unless $C_i \gg \mu C_{pg}$ the coupling through C_{pg} must be eliminated in any harmonic amplifier, if full efficiency and power output are to be obtained. This can be accomplished by (a) balancing the undesired output frequency signal at the grid with a signal equal in amplitude but differing in phase by 180 degrees (Fig. 4(a)); (b) adding

[1] Electrical Engineering Staff, Massachusetts Institute of Technology, "Applied Electronics," John Wiley and Sons, New York, N. Y., 1944, pp. 569–578.
[2] "Reference Data for Radio Engineers," Federal Telephone and Radio Corp., New York, N. Y., 1943, pp. 162, 163.
[3] I. S. Sokolnikoff and E. S. Sokolnikoff, "Higher Mathematics for Engineers and Physicists," McGraw-Hill Book Co., New York, N. Y., 1941, pp. 545–550.
[4] E. L. Chaffee, "Simplified harmonic analysis," *Rev. Sci. Inst.*, vol. 10, p. 384; October, 1936.
[5] F. E. Terman, "Radio Engineering," McGraw-Hill Book Co., New York, N. Y., 1937, pp. 314–331 and 338–341.

inductive reactance between grid and plate to secure antiresonance in the feedback path (Fig. 4(b)); or (c) arranging the input circuit to present zero or inductive reactance between grid and cathode at the output frequency (Fig. 4(c)).

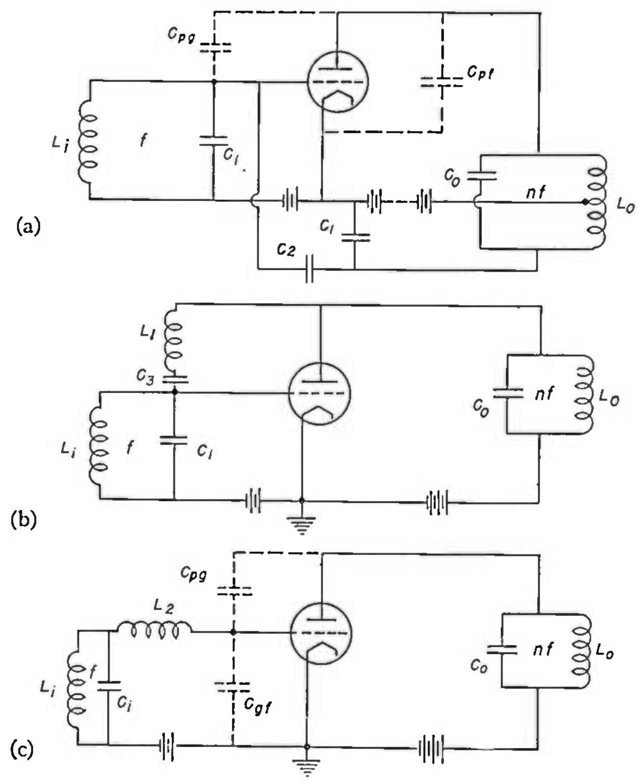


Fig. 4—Arrangements for neutralizing harmonic-amplifier output loading.
(a) Conventional balanced feedback arrangement. Neglecting lead inductances, $C_1 = C_{pf}$ and $C_2 = C_{pg}$.
(b) Antiresonant feedback path. $(2\pi nfL_1 - 1/2\pi nfC_3) = 1/2\pi nfC_{pg}$.
(c) Phase reversal of feedback voltage. L_2 taken to obtain series resonance between grid and ground at nf.

The arrangement of Fig. 4(a) is similar to the conventional scheme used for neutralizing regeneration, except that here it is used to neutralize a degenerative effect. It has been found by experience that for values of C_2 greater or less than optimum, the plate tuning is less sharp and the value of direct plate current at resonance is increased. (If C_2 is large compared with its optimum value an ultraudion oscillator may result, particularly if the grid circuit has a very high inductance-capacitance ratio.) It is most convenient to adjust C_2 for the minimum value of direct plate current, keeping the plate circuit resonant.

In the arrangement of Fig. 4(b), losses in L_1 and C_3 must be held to a minimum in order to make the impedance between grid and plate as large as possible.[6,7] Capacitance C_3 may be made variable or a small variable capacitance may be placed in parallel with C_3 and L_1 and adjusted in the same manner as C_2 in the arrangement of Fig. 4(a). This scheme is attractive in very-high-frequency multipliers because it does not add extra capacitance (neglecting strays) to the other resonant circuits. Elements L_1 and C_3 may be a well-shielded, open-ended transmission-line section between one-quarter and one-half an output wavelength long. With lumped elements for L_1 and C_3 there will be some input loading unless the circuit between plate and grid is antiresonant at both input and output frequencies, since at the input frequency the plate circuit is inductive and the grid-to-plate impedance will also be inductive. With an open-ended transmission-line section for L_1 and C_3 there will be a small amount of negative input loading at the input frequency because the grid-to-plate impedance will be capacitive.[8]

The arrangement shown in Fig. 4(c) was developed by C. R. Runyon in the early work on frequency-modulation transmitters at very high frequencies. In the grid lead is placed a small inductance L_2 which is large enough so that the combination of L_2 in series with L_i and C_i has at the output frequency either zero reactance or an inductive reactance $+X_i$. If $+jX_i$ be substituted for Z_i in (11) and $X_i \ll 1/\omega_n C_{pg}$, taking $C_{gf} \gtreqless C_{pg}$,

$$Y_0 = g_p - g_m\omega_n C_{pg} X_i + j\omega_n(C_{pf} + C_{pg}). \qquad (14)$$

Values of L_2 too small to make the combination of L_2 with L_i and C_i inductive have the effect of increasing C_1 in (12) or (13); hence, as L_2 is increased from zero, the stage first becomes less and less degenerative and then becomes increasingly regenerative until a point is reached at which self-oscillation takes place. When $X_i = 0$ the term containing gm or μ in (12), (13), and (14) becomes zero and G_0 is simply $1/r_p$.[9] In a very-high-frequency multiplier, L_2 may be merely a short piece of wire.

2. Degeneration Due to Inductive Feedback

Cathode inductance common to grid and plate circuits has an input loading effect and increases the driving power required[10]; that it also has an output loading or degenerative effect is shown by the following analysis. As in the previous case, the equivalent plate-circuit theorem will be assumed in order to obtain easily a rough first-order approximation. Fig. 5 shows the equivalent circuit seen looking from the external output circuit toward the tube, if plate-grid capacitance and the inductances of all leads except the cathode are neglected.

$$I_1 = (E - Ij\omega_n L_k) \times j\omega_n C_{pf}. \qquad (15)$$

[6] R. J. Kircher, "A coil-neutralized vacuum-tube amplifier at very-high frequencies," Proc. I.R.E., vol. 33, pp. 838–843; December, 1945.

[7] Many valuable and interesting suggestions are to be found in U. S. Patent No. 2,344,734, issued to Walter van B. Roberts, March 21, 1944.

[8] Electrical Engineering Staff, Massachusetts Institute of Technology, "Applied Electronics," John Wiley and Sons, New York, N. Y., 1944, pp. 402–407.

[9] Harry R. Summerhayes, Jr., U. S. Patent No. 2,352,455, issued June 27, 1944.

[10] F. E. Terman, "Radio Engineer's Handbook," McGraw-Hill Book Co., New York, N. Y., 1943, p. 472.

$$I_2 = [E - (-\mu E_g) - Ij\omega_n L_k]/r_p. \quad (16)$$

Taking $g_p = 1/r_p$ and $g_m = \mu g_p$ as before, since $I = I_1 + I_2$ and $E_g = -Ij\omega_n L_k$,

$$I = E(g_p + j\omega_n C_{pf})/[1 - \omega_n^2 L_k C_{pf} + (g_p + g_m)j\omega_n L_k]. \quad (17)$$

Dividing by E and taking $\omega_n L_k \ll 1/\omega_n C_{pf}$ and $g_m \gg g_p$, the output admittance is

$$Y_0 = \left(\frac{g_p + g_m\omega_n^2 L_k C_{pf}}{1 + g_m^2\omega_n^2 L_k^2}\right) + j\omega_n\left(\frac{C_{pf} - g_m g_p L_k}{1 + g_m^2\omega_n^2 L_k^2}\right). \quad (18)$$

Unless $\omega_n L_k$ is about 100 ohms or more, $g_m^2\omega_n^2 L_k^2$ is usually small enough so that one may write, with but little error,

$$Y_0 = g_p + g_m\omega_n^2 L_k C_{pf} + j\omega_n(C_{pf} - g_m g_p L_k). \quad (19)$$

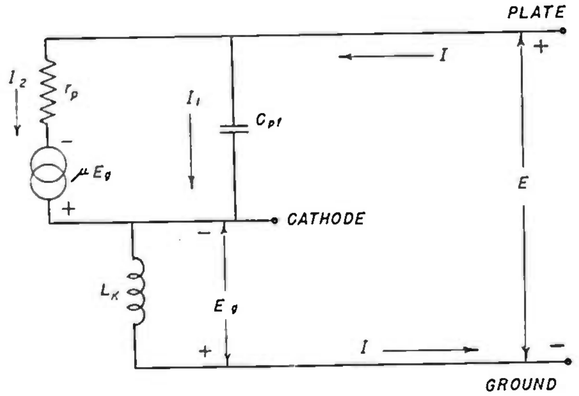


Fig. 5—Equivalent circuit for analyzing effect of cathode inductance on output.
L_k = inductance of cathode and cathode lead which is common to grid and plate circuits
r_p = dynamic plate resistance
C_{pf} = plate-cathode capacitance
$-E_g$ = signal across L_k at output frequency.

From the above expression one concludes that a degenerative effect equivalent to an output loading is produced by cathode inductance common to both grid and plate circuits, and that this effect is proportional to this inductance, the mutual conductance and the plate-cathode capacitance of the tube, and to the second power of the frequency.

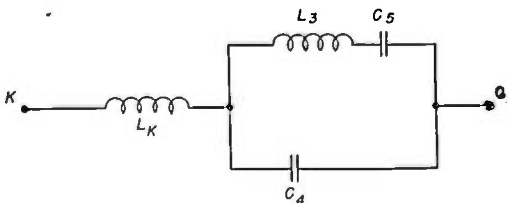


Fig. 6—Two-frequency series-resonant cathode circuit.
L_k = inductance of cathode and cathode lead.
L_3, C_4, and C_5 are elements used to obtain series resonance between K and G at both f and nf.

If optimum performance is to be obtained from a harmonic amplifier, the cathode-inductance effects must be neutralized for both the input and the output frequency. If the cathode is tied to the ground point through a series combination of inductance and capacitance shunted by a capacitor as shown in Fig. 6, series resonance may be obtained between the cathode and the ground point at both the input frequency f and the output frequency nf. If L_k is known, trial values of L_3 may be assumed and C_4 and C_5 determined by solution of (20).

$$\left.\begin{aligned} &[\omega^2 L_k]C_4 + [\omega^2(L_3 + L_k)]C_5 - [\omega^4 L_3 L_k]C_4 C_5 - 1 = 0,\\ &[n^2\omega^2 L_k]C_4 + [n^2\omega^2(L_3 + L_k)]C_5 - [n^4\omega^4 L_3 L_k]C_4 C_5 - 1 = 0. \end{aligned}\right\} \quad (20)$$

The solution gives,

$$n^2\omega^4 L_3(L_3 + L_k)C_5^2 - (1 + n^2)\omega^2 L_3 C_5 + 1 = 0, \quad (21)$$

$$C_4 = 1/n^2\omega^4 L_3 L_k C_5. \quad (22)$$

In a large number of cases, cathode inductance is not serious at frequencies below those at which transmission-line sections may conveniently be used as circuit elements. Fig. 7 shows a cathode-circuit arrangement which employs a balanced transmission-line section and

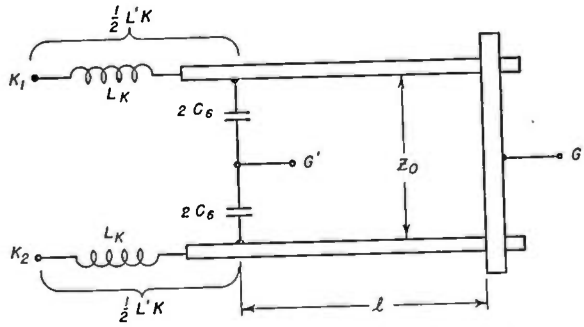


Fig. 7—Two-frequency series-resonant balanced-cathode circuit.
L_k = inductance of cathode and cathode lead
Z_0 = characteristic impedance of transmission-line element
C_6 = lumped shunting capacitance on transmission-line section for obtaining zero impedance between K_1 and K_2 at both f and nf
l = length of line section between C_6 and short
G and G' are neutral points.

is adapted to push-pull harmonic amplifiers. If the values of l and C_6 are properly selected and the currents in the two tubes are balanced, K_1, K_2, G', and G will be at the same potential for both f and nf. If L_k' is known, C_6 may be determined in terms of Z_0 from (23)

$$n\omega L_k'/[Z_0(n^2\omega^2 L_k' C_6 - 1)] = \tan\{n \tan^{-1}[\omega L_k'/[Z_0(\omega^2 L_k' C_6 - 1)]]\}. \quad (23)$$

Ordinarily Z_0 will be about 250 ohms in order that conduction losses in the line section may be minimized.[11,12]

Representing the wavelength at frequency f by λ,

$$l = (\lambda/2\pi)\tan^{-1}\{\omega L_k'/[Z_0(\omega^2 L_k' C_6 - 1)]\}. \quad (24)$$

Fig. 8 shows a cathode-circuit arrangement employing an image transmission-line section which is adapted to a single-tube harmonic amplifier. In a very-high-

[11] R. I. Sarbacher and W. A. Edson, "Hyper and Ultrahigh Frequency Radio Engineering," John Wiley and Sons, New York, N. Y., 1944, pp. 347–349.
[12] See pages 191 to 193 of footnote reference 10.

frequency doubler or quadrupler using two tubes—push-pull input and push-push output—each tube should have a cathode circuit similar to that described in Fig. 8 (or Fig. 6), since unbalanced currents are present. As a rule, only odd-order multipliers (triplers or quintuplers) are satisfactory at very-high frequency with power tubes, at least, because simple even-order multipliers are unbalanced.

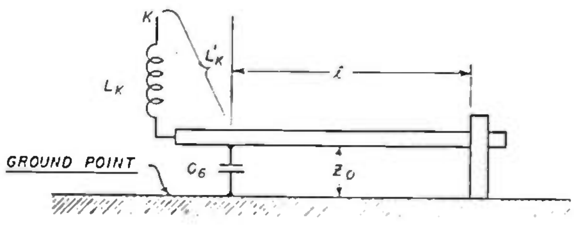


Fig. 8—Two-frequency series-resonant unbalanced-cathode circuit. K is at potential of ground point for f and nf. Symbols defined in Fig. 7.

The cathode inductance and cathode-lead inductance of the tube around which one is designing a frequency multiplier are usually not known, and the stray reactances in the circuit are very difficult to evaluate. Hence the cathode circuit must be adjusted by "cut and try." With the arrangement of Fig. 6, C_4 and C_5 may be made variable for purposes of adjustment. With the arrangement of Fig. 7 or Fig. 8, the position of the shorting bar and the position and value of C_6 may be made variable for initial adjustments. With constant driving power, optimum adjustment for the input frequency may be indicated by a maximum value of direct grid current, while for a constant value of grid current and driving power optimum, adjustment for the output frequency may be indicated by a minimum value of direct plate current.[13] Fortunately, in many wide-band applications some form of loading is needed in the grid circuit making it unnecessary and undesirable to neutralize cathode inductive reactance for the input frequency.

Conclusion

Where transit times are not large, the graphical analysis presented above provides a convenient method for the design of a frequency multiplier without recourse to guesswork or cut and try. To realize design performance, coupling between the input and output circuits must be rendered insignificant. In a well-arranged multiplier the only coupling between input and output circuits will be that due to capacitance between the output and the control electrodes, and/or inductance between the cathode and the point common to both input and output circuits. Either of these couplings has, as far as the output circuit is concerned, an effect equivalent to that of placing a positive conductance across the output circuit with a resulting decrease in Q and increase in power dissipated on the output electrode.

In a frequency multiplier using a medium-sized power tube (e.g., type 304-TH), if the total capacitance between control grid and ground is small (less than 50 micromicrofarads) the loading effect on the output circuit due to coupling through the grid-plate capacitance may be so great that almost 100 per cent of the plate input power is dissipated on the plate. If one of the arrangements of Fig. 4 is used, the performance of the multiplier may be made to correspond with that called for in the design. With large tubes and with output frequencies above approximately 10 megacycles, it may be necessary to neutralize the effects of the inductance between the cathode and the ground point by one of the arrangements shown in Figs. 6, 7, and 8.

By employing the principles set forth in this paper, any tube may successfully be employed in a frequency multiplier in which the output frequency is one at which the tube may be used as a straight amplifier.

Appendix I

Approximate Analytical Method for Determining Harmonic-Amplifier Performance

The method of analyzing harmonic amplifiers given by Terman[5] has been in general use and is very convenient, but unless certain minor modifications are made in the procedure, the performance predicted is apt to be too optimistic.

The ratio of the crest value of the n^{th} harmonic of the space current I_{sn} to the peak value of the space current I_{max} may be represented[14] by β_n, thus:

$$I_{sn} = \beta_n I_{max}. \tag{25}$$

Similarly, the direct component of space current I_0 is written

$$I_0 = \beta_0 I_{max}. \tag{26}$$

and the direct component of grid current I_{g0} will be

$$I_{g0} = kI_0. \tag{27}$$

The factor k may be determined to a fair degree of approximation in most cases from typical operating data. For example, in the typical radio-frequency power-amplifier operating data given by the manufacturer for the type 35T tube, the direct plate current is 125 milliamperes and direct grid current is 45 milliamperes. From this information k may be determined as being approximately 45/(125+45) or 0.26. The crest value of input-frequency grid current is, to a good degree of approximation, given by

$$I_{g1} = 2I_{g0}. \tag{28}$$

[13] This statement can be misleading because the cathode circuit may have a regenerative effect on the stage if its reactance is between 0 and $-\mu/\omega C_{gf}$. If this regeneration does not cause instability or make the bandwidth of the stage too narrow, it is desirable and the above statement is true.

[14] See pages 325 and 340 of footnote reference 5.

In order to determine the crest value of plate current at the output frequency I_{pnm}, it is important to know the crest value of grid current I_{gnm} at this frequency. While the grid-current pulse shape is quite different from the space-current pulse shape, for lack of a better, easily handled assumption, consider the components of the grid current to have the same relative values as the components of the space current; then

$$I_{gnm} = (\beta_n/\beta_1)I_{g1m}. \tag{29}$$

The remaining currents to be computed are I_{p0} and I_{pnm}, given by

$$I_{p0} = I_0 - I_{g0} \tag{30}$$

$$I_{pnm} = I_{nm} - I_{gnm}. \tag{31}$$

If the tube is a tetrode, one has expressions for the second grid similar to (27), (28), and (29); a corresponding factor for the screen grid may be determined from typical operating data in a manner similar to that suggested above for k. Corresponding to (31), for a tetrode $I_{pnm} = I_{nm} - (I_{gnm} + I_{sgnm})$. Because of the number and nature of the approximations involved, this analysis is much less reliable for tetrode than for triode harmonic amplifiers.

While rapid and convenient, this analysis is likely to underestimate the required grid driving power and the plate dissipation, and to overestimate harmonic power output, particularly if $n > 2$.

ACKNOWLEDGMENT

The author wishes to express appreciation for the stimulation and assistance received in the preparation of this material from R. M. Bowie, N. L. Harvey, G. D. O'Neill, and many others of the Sylvania Engineering Research Department.

Abstract of "A Method for Calculating Electric Field Strength in the Interference Region"*

HOMER E. NEWELL, JR.†

THE PAPER outlines a method and provides graphs which can be used to effect a rapid calculation of electric field strength from the formula

$$E = \frac{E_0}{d}\left[1 + (DR)^2 - 2DR\cos(\theta - C)\right]^{1/2}.$$

A brief review of the suggested method appears below.

As is well known, the formula arises from the interference of direct and reflected rays. Let ψ be the angle between the reflected ray and the horizontal. Select a convenient set of values for tan ψ covering the range of validity

$$\frac{0.0177737}{f_{mc}^{1/3}} \leqq \tan\psi \leqq 0.1$$

where f_{mc} is frequency in megacycles.[1] Let the antenna heights be h_1 and h_2. Let d_1 and d_2 be the distances along the earth from directly below the antennas to the point of reflection. From the specified value of $h_\nu(\nu = 1, 2)$ in feet, d_ν, in nautical miles, can be obtained for each value of tan ψ from graphs provided in the paper. The sum $d_1 + d_2$ is d, the distance along the earth from below one antenna to directly below the other.

Next, h_1 and h_2 are easily modified to h_1' and h_2' to account for the earth's curvature, and the parameter $w = h_1'h_2'/d$ is computed. The divergence factor D may now be read from curves of the paper in which D is plotted against w for various values of tan ψ.

The remainder of the calculation follows usual lines. R, C, θ, and E_0 can be obtained from commonly available graphs and familiar formulas, the calculation of E completed, and a plot of E versus d drawn.

The procedure outlined is new in that values of tan ψ, e.g., 0.1, 0.09, 0.08, . . . , are selected, and corresponding values of d are subsequently derived from suitable graphs. This affords a considerable saving of time over the usual procedure of selecting values of d first, and then calculating tan ψ. Also, the convenient values of tan ψ simplify the reading of divergence factors and reflection coefficients from their graphs.

Two illustrative sets of calculations are carried out in the paper, one for slowly varying field strength, and one for field strengths which oscillate rapidly as d varies. Also, the calculations which depend only on geometric factors are carried out and tabulated for various combinations of antenna heights from 15 and 15 feet to 20,000 and 20,000 feet. Starting with these, one can quickly complete the calculation and plotting of E versus d for specified frequency and ground constants.

All graphs and tables in the paper are based upon a standard atmosphere, the radius of the earth being taken as four thirds of its actual value to allow for refraction effects. The accuracy of the final results obtainable by the method of the paper is necessarily limited by the great number of graphical steps involved. Interpolations are, however, kept to a minimum and, in actual practice, curves drawn up by the procedure outlined above have proved to be very useful working estimates of actually existing field strengths.

* Decimal classification: R270. Report R-2638 Naval Research Laboratory. Original manuscript received by the Institute, March 27, 1947; abstract received, May 7, 1947.

† Naval Research Laboratory, Washington 20, D. C.

[1] K. A. Norton, "The calculation of ground wave field intensity over a finitely conducting spherical earth," FCC Report No. 39920, March 18, 1940.

Electron Reflectors with a Quadratic Axial Potential Distribution*

J. M. LAFFERTY†, MEMBER, I.R.E.

Summary—Trajectory equations are developed for accelerated electrons which enter a retarding, axially symmetric electrostatic field with a quadratic axial potential distribution. Neglecting space-charge effects of the electrons, such a field can be produced between two charged electrodes consisting of a cone and a hyperboloid. A focus criterion is established, and under these conditions the permissible angles of divergence and convergence which an incident electron may have and still be focused back through the entering aperture are determined. An equation for the transit time of the axial electrons in the reflector is derived. By proper adjustment of dimensions and voltages, various simple electrode shapes may be made to give an axial potential distribution which is nearly quadratic, and thus give comparable performances as electron reflectors.

Introduction

In accordance with the optical definition, an electron reflector is defined as an electrode system which reverses the direction of an electron beam. Only systems which bring the reflected beam to a spot focus will be considered. The image-producing properties, such as are obtained with electron mirrors, will not be considered. For producing electron reflectors, use will be made of strongly retarding electric fields which have axial symmetry and contain potentials lower than that of the cathode from which the electrons were emitted. These fields are formed between charged electrodes consisting of diaphragms, cylinders, and hemispheres.

Electrons entering such a field with a velocity corresponding to the potential of the positive electrode are gradually retarded and finally, on approaching the zero equipotential surface, are turned back and proceed in a direction indicated by the disposition of the equipotential surfaces.

Calculation of the Electron Trajectory

In the calculations to follow, cylindrical co-ordinates z and r will be used. Axial symmetry is assumed. A list of the more important symbols to be employed follows:

$V = V_{(r,z)}$ = potential of a point in space
$\Phi = \Phi_{(0,z)}$ = potential of a point on the z axis
V_0 = positive electrode potential
V_c = negative electrode (reflector) potential
$\dot{r}$, $\ddot{r}$, $\dot{z}$ = derivatives with respect to time
r', r'' = derivatives with respect to z
R_0 = electron beam radius
θ_0 = incident angle of electron
θ_e = exit angle of electron
m, e = mass and charge of the electron, respectively.

* Decimal classification: R138. Original manuscript received by the Institute, May 1, 1946; revised manuscript received, July 17, 1946.

† General Electric Company, Schenectady, New York.

Assuming that the electrons have a velocity at any point in the retarding field corresponding to the potential at that point, and that they have no rotational velocity about the z axis on entrance into the field, the radial acceleration is

$$m\ddot{r} = e\partial V/\partial r, \tag{1}$$

and for the total kinetic energy

$$\frac{m}{2}(\dot{r}^2 + \dot{z}^2) = eV. \tag{2}$$

From (2) is obtained

$$\dot{z} = \sqrt{\frac{2e}{m}}\sqrt{\frac{V}{1+r'^2}}. \tag{3}$$

Since $\ddot{r} = \dot{z}d(r'\dot{z})/dz$, substituting (1) and (3) gives

$$\sqrt{\frac{V}{1+r'^2}}\frac{d}{dz}\left[\sqrt{\frac{V}{1+r'^2}}r'\right] = \frac{1}{2}\frac{\partial V}{\partial r}. \tag{4}$$

A simple method of solving this equation has been given by Recknagel[1] and will be used here through the substitution

$$r' = W/\sqrt{V - W^2}. \tag{5}$$

Equation (4) then takes the form

$$\frac{dW}{dz} = \frac{1}{2\sqrt{V - W^2}}\frac{\partial V}{\partial r}. \tag{6}$$

Writing

$$\frac{dW^2}{dr} = 2W\frac{dW}{dr} = 2W\frac{dW/dz}{dr/dz},$$

and substituting (5) and (6) gives

$$\frac{dW^2}{dr} = \frac{\partial V}{\partial r}. \tag{7}$$

It is now desirable to find an expression for the right-hand member of this equation.

As is well known, the potential in the entire space of an axially symmetrical field can be completely determined in the absence of space charge, if the potential Φ along the axis and its derivatives are given.[2] An expression for this relation is

$$V = \sum_{n=0}^{\infty}\frac{(-1)^n}{(n!)^2}\left(\frac{r}{2}\right)^{2n}\frac{d^{2n}\Phi}{dz^{2n}}. \tag{8}$$

[1] A. Recknagel, "Zur theorie des elektronenspiegels," *Zeit. für Phys.*, vol. 104, pp. 381–394; February, 1936.

[2] L. M. Myers, "Electron Optics Theoretical and Practical," D. Van Nostrand Co., Inc., New York, N. Y., 1939, p. 37.

Thus

$$\frac{\partial V}{\partial r} = \sum_{n=0}^{\infty} \frac{(-1)^n n}{(n!)^2}\left(\frac{r}{2}\right)^{2n-1} \frac{d^{2n}\Phi}{dz^{2n}}. \quad (9)$$

In only a few rare cases can the axial potential distribution $\Phi(z)$ be computed analytically for a given electrode arrangement. Even in these cases, if it is expressed by a function whose second derivative is other than a constant, difficulty will be encountered in the integration of (7). From (9) it is seen that if the axial potential is expressed analytically by a function whose second derivative is constant, then $\partial V/\partial r$ is a function of r only, and the integration of (7) is easily performed, since the variables are separable.

Because the electron trajectory lends itself to easy calculation in the case of electric fields with axial symmetry and a quadratic potential distribution along the axis, electron reflectors with this type of field will be investigated. Although no claim can be made that such a field gives optimum focusing properties, the analysis which follows shows that useful electron reflectors can be made and that the results obtained serve as a guide in the construction of reflectors of other types.

Let the axial potential, then, be of the form

$$\Phi = V_c + B(z - C)^2. \quad (10)$$

Then from (8) the potential at any point off the axis is

$$V = V_c + B(z - C)^2 - \frac{B}{2} r^2, \quad (11)$$

and the radial field is

$$\frac{\partial V}{\partial r} = -Br. \quad (12)$$

Substituting (12) in (7) and integrating from $W = W_0$ to $W = W$ and from $r = r_0$ to $r = r$, the results are

$$W^2 + \frac{B}{2} r^2 = W_0^2 + \frac{B}{2} r_0^2 = K. \quad (13)$$

Substituting (11) and (13) in (5) gives

$$\frac{dr}{dz} = \frac{\sqrt{K - Br^2/2}}{\sqrt{(V_c - K) + B(z - C)^2}}.$$

Integrating this equation between the limits

$$\begin{cases} r = r_0 \\ z = 0 \end{cases} \text{ and } \begin{cases} r = r \\ z = z \end{cases} \quad (14)$$

yields

$$r = \frac{W_0}{\sqrt{B/2}} \sin \alpha + r_0 \cos \alpha \quad (15)$$

where

$$\alpha = \frac{\sqrt{2}}{2} \log \frac{C - z \pm \sqrt{(C - z)^2 + (V_c - K)/B}}{C - \sqrt{C^2 + (V_c - K)/B}}, \quad (16)$$

$$K = W_0^2 + Br_0^2/2, \quad (17)$$

and from (5),

$$W_0 = r_0' \sqrt{\frac{V_{(r_0,0)}}{1 + r_0'^2}}. \quad (18)$$

The ambiguity of the radical sign in the numerator of the logarithm term is subject to the following physical interpretation: Assuming the initial position of the electron to be $(r_0, 0)$, the negative sign is used when the electron is traveling in the positive direction of the z axis, and the positive sign when it is traveling in the reverse direction.

Criterion for Focus

In many applications the electrons enter the retarding field through a small circular aperture of radius R_0 in the positive electrode, and it is required that these electrons return passing back within the boundary of this same aperture. If the electrons enter with a large variety of incident angles, it may not be possible to focus all of them back through the aperture. It is evident that some criterion for focus must be established. The ideal solution would involve analyzing the angular distribution of the incident electron beam and adjusting the retarding field to focus the maximum number of electrons back through the aperture. For this work it will be assumed that the incident beam has most of its electrons parallel to the axis. With this in mind, the retarding-field conditions will be determined which are necessary so that an electron entering the field parallel to the axis at a radius R_0 will return passing through the center of the aperture. These conditions will be called the criterion for focus. With these conditions satisfied, the focusing quality of the reflector, and hence its general usefulness, will be determined by computing the magnitude of the positive and negative angles of incidence which the entering electrons may have, and still be focused back through an aperture of radius R_0.

For an electron entering the retarding field at a radius R_0 and parallel to the axis, $W_0 = 0$, and hence $K = BR_0^2/2$ and $r = R_0 \cos \alpha$. If this electron is to return passing through the origin, α must equal $\pi/2$ at $z = 0$. Making these substitutions in (16) and solving for C gives

$$C^2 = K_0^2\left(\frac{R_0^2}{2} - \frac{V_c}{B}\right) \quad (19)$$

where

$$K_0 = \cosh \frac{\sqrt{2}\,\pi}{4} = 1.683. \quad (20)$$

Now consider an electron which enters the field at radius R_0 and makes an angle $\theta_0 = \arctan r_0'$ with the axis. On substituting these conditions in (11), (18), and (19), imposing the focus condition (19) on the retarding field, and substituting the results in (16), the following value of α is obtained:

$$\alpha = \frac{\sqrt{2}}{2} \log \frac{1 - \left(\frac{z}{C}\right) \mp \left[\left(\frac{z}{C}\right)^2 - 2\left(\frac{z}{C}\right) + \tanh^2 (\sqrt{2}\pi/4) \cos^2 \theta_0\right]^{1/2}}{1 - \tanh (\sqrt{2}\pi/4) \cos \theta_0}. \quad (2$$

The radial distance of the electron from the z axis at any point throughout its flight is given by substituting (11), (18), and (19) in (15), thus giving

$$r = R_0 \cos \alpha + \sqrt{2} C \tanh (\sqrt{2}\,\pi/4) \sin \theta_0 \sin \alpha \quad (22)$$

where α now has the values given by (21). A plot of $\cos \alpha$ and $[\sqrt{2} \tanh (\sqrt{2}\pi/4) \sin \theta_0 \sin \alpha]$ is given in Figs. 1 and 2 as a function of z/C for various values of θ_0.

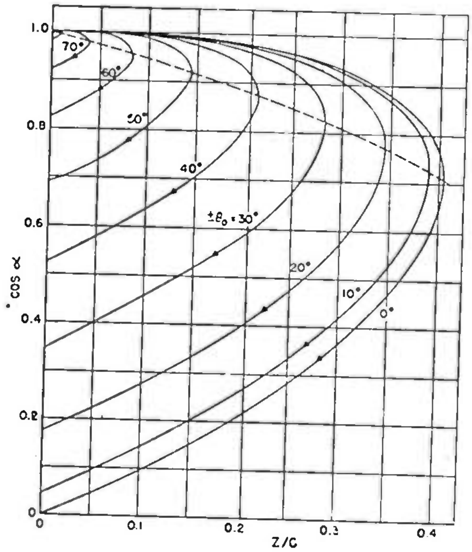


Fig. 1—Cos α as a function of z/C for various values of θ_0.

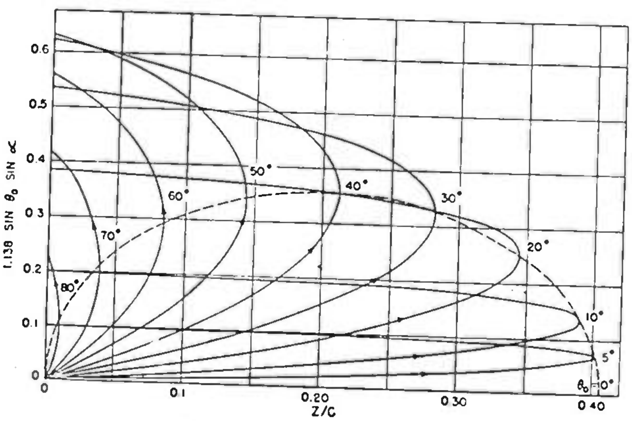


Fig. 2—$(1.138 \sin \theta_0 \sin \alpha)$ as a function of z/C for various values of θ_0.

Of interest also is the angle θ_s and radius r_s at which the electron leaves the retarding field. θ_s is found by evaluating the derivative of (22) at the point $z=0$ for the positive value of the radical in (21). The result is

$$\frac{dr}{dz} = \tan \theta_s = \frac{\sqrt{2}}{2} \frac{\sin \alpha}{(C/R_0) \cos \theta_0 \tanh (\sqrt{2}\,\pi/4)} - \tan \theta_0 \cos \alpha. \quad (23)$$

On eliminating C/R_0 from this equation by combinatic with (22), it appears that

$$\tan \theta_s = \tan \theta_0 \frac{1 - \frac{r_s}{R_0} \cos \alpha}{\frac{r_s}{R_0} - \cos \alpha}. \quad (24$$

This equation is plotted in Fig. 3 for various values of θ_0 Superimposed on this plot are contour lines of constan C/R_0, obtained by plotting (23). Each contour line cor responds to a given geometry. For any point on one o these lines the graph gives the radial distance r_s and th angle θ_s at which an electron leaves the field, having entered at radius R_0 with an angle of incidence θ_0.

The direction in which an electron traverses a given trajectory is immaterial, from a mathematical standpoint. Therefore, any point (r_s, θ_s) on a contour line in

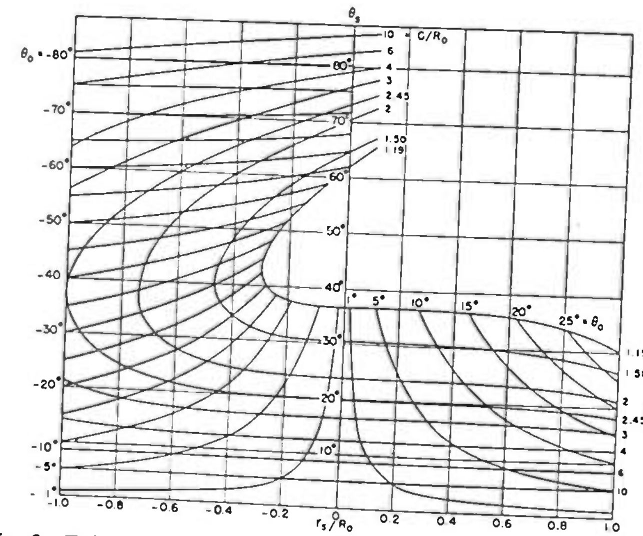


Fig. 3—Exit angle θ_s and radius r_s of electrons which enter the retarding field at a radius R_0 with an incident angle θ_0.

Fig. 3 may be interpreted as giving the radius and angle at which an electron must enter the field in order to leave at radius R_0 and angle θ_0.

Fig. 3 may also be interpreted to give the permissible angles of divergence and convergence with which an electron can enter the field at a given radius and still be focused back through the aperture of radius R_0. For any point r_s on a given contour line, the right-hand side of the graph gives the maximum angle of divergence θ_s with which an electron can enter at radius r_s and still be focused back within the aperture boundary. Now assume for the moment that in Fig. 3 the signs of the abscissa, ordinate, and θ_0 are reversed. Then on the left-hand side of the graph there will be, in general, two points on this contour which correspond to the same radius r_s. The electron may have any angle of convergence θ_s between 0 and −90 degrees except those between the two points corresponding to r_s. If there is no point on the contour line corresponding to r_s, then the angle of convergence may have any value between 0 and −90 degrees and the electron will be focused back within the aperture boundary. Fig. 4 shows these limiting trajectories for electrons entering at the two radii R_0 and $R_0/2$ for a geometry in which $C/R_0=5$.

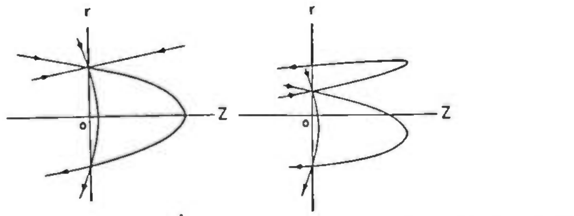


Fig. 4—Limiting trajectories for electrons entering the retarding field at radii R_0 and $R_0/2$ for a geometry in which $C/R_0=5$.

The limiting minimum value which C/R_0 may have is 1.190 because at this point the reflector voltage is zero (see Fig. 7) and the electrons are no longer reflected. From Fig. 3 it appears that beams with large angles of divergence or convergence require a geometry with a small value of C/R_0 for complete focusing. For perfectly focused incident beams (i.e., ones in which the radial velocity of the electrons is proportional to their distance from the axis), this type of reflector can, for $C/R_0=1.190$, focus beams which diverge as much as 30 degrees or converge as much as 71 degrees.

Transit Time

In many applications, the length of time spent by the electrons in the retarding field is of prime importance. For example, in the design of a reflector for a reflex oscillator it is convenient to express this time duration in cycles for some particular radio frequency f. Thus, if the transit time is t and period of the oscillation is T, the number of cycles spent by the electrons in the retarding field is $n=t/T=tf=tc/\lambda$ where λ is the wavelength of the oscillation and c the velocity of light.

The transit time of an electron in the retarding field will depend on the angle and radius at which it enters. Computing the transit time involves integrating the velocity of the electron over its entire trajectory. To simplify computations, only those electrons which travel along the axis will be considered. The transit time of these electrons will not differ appreciably from those which enter the field off the axis but parallel to it. This will be especially true for the cases where the electrons penetrate several beam diameters into the field.

The potential along the axis is given by (10) as $\Phi=V_c+B(z-C)^2$. An electron travels along the axis with a velocity v corresponding to this potential until the potential drops to zero at $z=C-\sqrt{-V_c/B}$.

At this point the electron reverses its direction and travels back along the axis again. The time of the return flight is just equal to the time of the forward flight, so that for the total transit time

$$t = 2\int_0^{C-\sqrt{-V_c/B}} \frac{dz}{v}.$$

Substituting the value of v, integrating, then introducing the expression $V_0=V_c+BC^2$ for the axial potential at $z=0$ and the focus condition given by (19), the transit time expressed in cycles becomes

$$\frac{n\lambda\sqrt{V_0}}{R_0} = \frac{2c}{\sqrt{2e/m}}\sqrt{\frac{1}{2}+\left(\frac{C}{R_0}\right)^2\left(1-\frac{1}{K_0^2}\right)}\times \log\frac{\sqrt{(C/R_0)^2-K_0^2/2}}{K_0(C/R_0)-\sqrt{(K_0^2/2)+(K_0^2-1)(C/R_0)^2}}. \quad (25)$$

A plot of this equation is given in Fig. 5 where V_0 is expressed in volts, n in cycles, and λ in R_0 in the same units. For large values of C/R_0 the logarithm term approaches the constant $\sqrt{2}\pi/4$, so that (25) becomes simply $n\lambda\sqrt{V_0}/R_0=905\ C/R_0$.

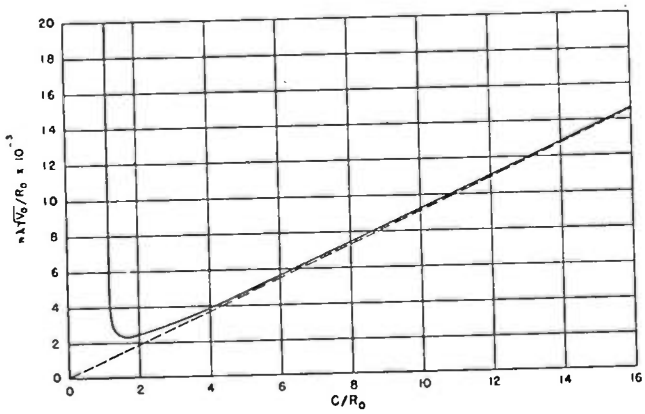


Fig. 5—Transit angle of axial electrons in the retarding field as a function of the reflector geometry and beam voltage.

The maximum distance which the electrons travel into the retarding field is found to be on the axis where they just reach the zero-potential point. This distance, subject to the condition of (19), is shown in Fig. 7.

Reflector Electrodes

If space charge due to the presence of the electron beam is not large enough to appreciably alter the potential distribution in the retarding field, either because the current density is low or because of the presence of positive ions, (11) may be used to determine the electrode shapes. A plot of (11) in Fig. 6 shows that the equipotential surfaces are hyperboloids. Any two of these equipotential surfaces may be replaced by conducting metal electrodes without changing the electric field between them, providing this space does not contain the singular point C. For convenience, the cone which is at potential V_c is selected for one electrode. For the other electrode, the equipotential surface is selected which passes through the origin. Its potential is

$$V_0 = V_c + BC^2, \qquad (26)$$

and the equation of its surface is

$$r = \pm\sqrt{2z(z-2C)}. \qquad (27)$$

These two electrodes are shown as heavy lines in Fig. 6. No deflection of the electrons is assumed in passing through the grid.

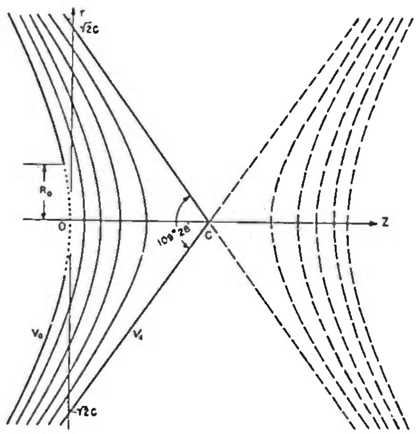


Fig. 6—Hyperbolic equipotential surfaces for producing a parabolic axial potential distribution.

In the theory presented above, it was assumed that the retarding field existed only to the right of the origin. For this electrode arrangement the outer edge of the beam enters the retarding field at a distance equal to $C-\sqrt{C^2+R_0^2/2}$ to the left of the origin. For large values of C/R_0 this distance is negligibly small. This difficulty is not encountered for the cylindrical and hemispherical geometries discussed below, since the positive electrode is a plane.

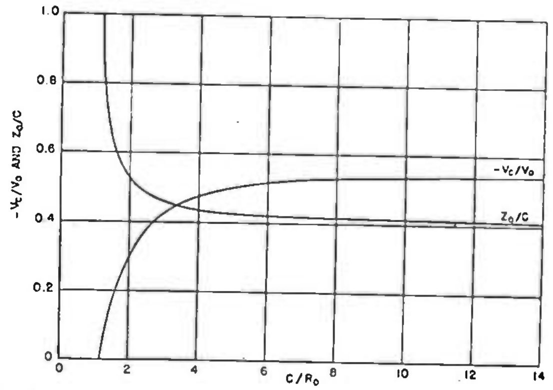


Fig. 7—Ratio of electrode voltages and depth of axial electron penetration into the reflector as a function of the reflector geometry.

To properly focus the beam, the potentials on the electrode arrangement shown in Fig. 6 must satisfy both (19) and (26). Eliminating B from these two equations gives

$$\frac{-V_c}{V_0} = \frac{(C/R_0)^2 - (K_0^2/2)}{(K_0^2-1)(C/R_0)^2 + (K_0^2/2)} \qquad (28)$$

for the ratio of the cone voltage to the hyperbolic electrode voltage. This equation is plotted in Fig. 7. For values of $C/R_0 < K_0/\sqrt{2}$ the cone voltage becomes zero or positive, and the electrons are no longer reflected back through the hyperbolic electrode.

Cylindrical and Spherical Geometries

It is of interest to compare the electron reflector just discussed with two others employing somewhat different electrode configurations. In Fig. 8(a) is shown a reflector system consisting of a flat plate and a long circular cylinder. If the plate is at a positive potential V_0 and the cylinder at a negative potential V_c, the potential along the axis of the cylinder[3] is, to a high degree of approximation, equal to

$$\Phi = V_0 - (V_0 - V_c)\tanh 1.32z/R. \qquad (29)$$

Fig. 8(b) shows a reflector consisting of a flat plate at potential V_0 and a hemisphere at a negative potential V_c. The potential along the axis for this case is

$$\Phi = V_0 + 2(V_0 - V_c)\sum_{n=1}^{\infty}\frac{n+1/2}{n}\left(\frac{z}{R}\right)^n P_{n+1}(0), \qquad (30)$$

where $P_{n+1}(0)$ is a Legendre polynomial of degree $n+1$.

The calculation of the electron trajectories for these two geometries would be quite difficult. However, it can

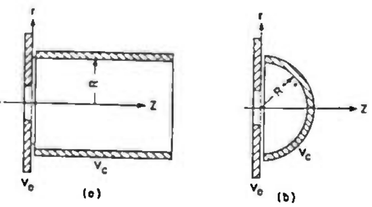


Fig. 8—Cylindrical and spherical electron-reflector systems.

be reasonably assumed that if the diameters and potentials of the cylinder and hemisphere could be adjusted to give approximately the same axial potential distribution as the hyperbolic geometry, the performance of all three systems should be comparable both as to focusing and transit time.

Numerical Example

Consider the problem of constructing an electron reflector in which $n\lambda = 3.45$ cycle centimeters for a 1625-volt electron beam 0.0428 centimeter in diameter. The axial potential is found to be $\Phi = -850 + 110{,}000(z-0.15)^2$, where Φ is in volts and z is in centimeters. Selecting the hyperboloid geometry, the shape of the positive electrode is given by substitution in (27):

[3] Frank Gray, "Electrostatic electron-optics," *Bell Sys. Tech. Jour.*, vol. 18, pp. 1–31; January, 1939.

$r = \pm\sqrt{2z(z-0.3)}$. The cone, with a total included angle of 109.5 degrees, is spaced 0.15 centimeter from the hyperboloid and operated at -850 volts.

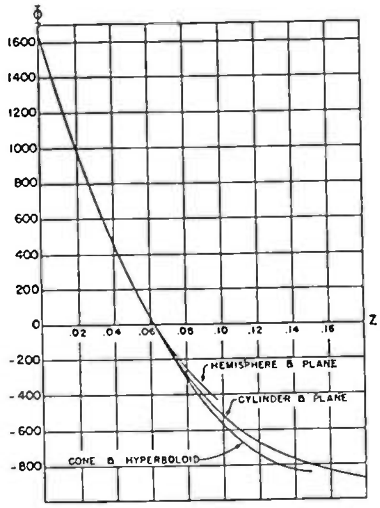


Fig. 9—Comparison of the axial potential for three different geometries.

A similar reflector can be made from the plate and cylinder by choosing the cylinder diameter and voltage such that the axial potential matches that given by the equation in the above paragraph at three points: $z=0$, 0.031, and 0.062 centimeter. This yields a diameter of 0.220 centimeter and a potential of -945 volts for the cylinder, thus giving for the axial potential $\Phi = 1625 - 2570 \tanh 12z$. Similarly, matching the axial potential of the hemisphere and plane at three points gives

$$\Phi = 1625 + 4110 \sum_{n=1}^{\infty} \frac{n+1/2}{n} \left(\frac{z}{0.097}\right)^n P_{n+1}(0)$$

where the hemisphere radius and voltage are 0.097 centimeter and -430 volts, respectively. Fig. 9 shows the close agreement of the axial potential distribution for the three geometries throughout the range traversed by the electrons.

Properties of Ridge Wave Guide*

SEYMOUR B. COHN†, MEMBER, I.R.E.

Summary—Equations and curves giving cutoff frequency and impedance are presented for rectangular wave guide having a rectangular ridge projecting inward from one or both sides. It is shown that ridge wave guide has a lower cutoff frequency and impedance and greater higher-mode separation than a plain rectangular wave guide of the same width and height. The cutoff frequency equation is fairly accurate for any practical cross section. The impedance equation is strictly accurate only for an extremely thin cross section. Values found by the use of this equation have, however, been found to check experimental values very closely. A number of uses for this type of wave guide are suggested.

I. Applications

THE CROSS-SECTIONAL shape of ridge wave guide is shown in Fig. 1. This type of wave guide is briefly described in a text by Ramo and Whinnery,[1] where a simple method of calculating the cutoff frequency is given. That method is used in this paper.

The lowered cutoff frequency, lowered impedance, and wide bandwidth free from high-mode interference obtainable with ridge wave guide make it useful in many ways. A few uses are listed below:

(a) It is useful as transmission wave guide, where a wide frequency range must be covered, and where only the fundamental mode can be tolerated. It will be shown that a frequency range of four to one or more can be easily obtained between the cutoff frequencies of the TE_{10} and TE_{20} modes, and six to one or more between those of the TE_{10} and TE_{30} modes. The attenuation is several times as great as that for ordinary wave guide, but is still much less than for ordinary coaxial cable. The reduced cutoff frequency of ridge wave guide also permits a compact cross section.

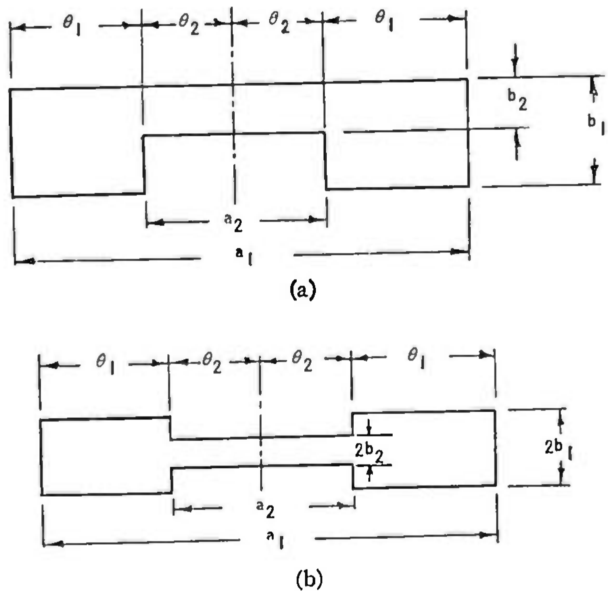


Fig. 1—Parameters for single-ridge (a) and double-ridge (b) wave-guide cross-sections.

* Decimal classification: R118.2. Original manuscript received by the Institute, May 9, 1946.

† Cruft Laboratory, Harvard University, Cambridge, Mass. The work reported in this paper was done at the Radio Research Laboratory under contract with the Office of Scientific Research and Development, National Defense Research Committee, Division 15.

[1] S. Ramo and J. R. Whinnery, "Fields and Waves in Modern Radio," John Wiley and Sons, New York, N. Y.; 1944.

(b) Ridge wave guide has been used successfully as matching or transition elements in wave-guide to coaxial junctions. In one type of junction, a quarter-wavelength section of ridge wave guide serves as a matching transformer from the impedance of the guide ("toll-ticket" wave guide, $2\frac{3}{4}\times\frac{3}{8}$-inch cross section) to the 50-ohm coaxial cable. In another junction, a tapered length of ridge wave guide gives a gradual match from standard $3\times1\frac{1}{2}$-inch rectangular wave guide to a 50-ohm coaxial line.[2]

(c) Various forms of ridge wave guide are useful also as filter elements, cavity elements, cavity terminations, etc. Wherever an element of line is needed having reduced cutoff frequency, reduced impedance, or wide mode separation, ridge wave guide provides a simple solution.

(d) The attenuation formula for ridge guide (8) shows that the attenuation may be made very high by making a_1 and $Z_{0\infty}$ as small as possible. If the guide, or just the ridges, are made of steel instead of copper, the attenuation may be made about 1000 times greater than that for ordinary copper wave guide without ridges. H. C. Early of the Radio Research Laboratory has made use of a length of such wave guide tapered to standard $3\times1\frac{1}{2}$-inch wave guide in the design of a broadband matched load.[3,4] The total length of the load and taper is only four feet.

(e) Another application, due to Early, is in a wide-band wattmeter,[3] in which a wave guide having nearly constant impedance over a wide band is required.

II. Design Data

The design equations use the notation of Fig. 1. a_1, a_2, b_1, and b_2 are inside dimensions in centimeters. θ_1 and θ_2 are the electrical phase lengths in terms of the cutoff wavelength in free space

$$\left(\text{e.g., } \theta_2 = \frac{a_2/2}{\lambda_c'} \times 360\right)$$

where λ_c' is the wavelength in free space at the ridge-guide cutoff frequency.

The cutoff of the TE_{10} mode occurs when the lowest root of the following equation is satisfied:

$$\frac{b_1}{b_2} = \frac{\cot\theta_1 - \dfrac{B_c}{Y_{01}}}{\tan\theta_2}. \qquad (1)^5$$

B_c is the equivalent susceptance introduced by the discontinuities in the cross-section, as explained in Appendix I.[6]

Equation (1) is accurate if proximity effects are taken fully into account in calculating B_c. In the curves of this paper, proximity effects are neglected, but the results are highly accurate so long as $(a_1-a_2/2)>b_1$.

In terms of θ_1 and θ_2, λ_c' is given by

$$\lambda_c' = \left(\frac{90°}{\theta_1+\theta_2}\right)\lambda_c \qquad (2)$$

where $\lambda_c = 2a_1$ is the cutoff wavelength of the guide without the ridge, and where θ_1 and θ_2 are values satisfying (1).

The TE_{10}-mode cutoff wavelength is plotted in Figs. 2 and 3 for a wide variety of ridge shapes in guide having cross-section ratios of $b_1/a_1=0.136$ ("toll-ticket" wave guide, $2\frac{3}{4}\times\frac{3}{8}$ inch) and 0.500, respectively. The ordinate $\lambda_c'/2a_1=\lambda_c'/\lambda_c=f_c/f_c'$ is the ratio of cutoff wavelength with the ridge to that without the ridge. The abscissa a_2/a_1 is the ratio of ridge width to guide width. Each solid curve corresponds to a constant value of b_2/b_1. As an example, if a particular ridge wave guide has $b_1/a_1=0.5$, $a_2/a_1=0.4$, and $b_2/b_1=0.1$, then from Fig. 3, $\lambda_c'/\lambda_c=f_c/f_c'=2.6$. If the cutoff frequency without the ridge is 2600 megacycles, the cutoff frequency with the ridge will be 1000 megacycles.

On comparing Fig. 2 and Fig. 3, it will be seen that there is not a great deal of difference between the corresponding constant b_2/b_1 curves. The only reason there is any difference is the size of the discontinuity susceptance term, B_c/Y_{01}, which is small for $b_1/a_1=0.136$, and fairly large for $b_1/a_1=0.5$. If b_1/a_1 has a value different from 0.136, or 0.5, Figs. 2 and 3 may still be used with little error. Fig. 2 should be used for values of b_1/a_1 between zero and about one-third, and Fig. 3 should be used for values of b_1/a_1 in the vicinity of 0.5.

The characteristic impedance at infinite frequency for the TE_{10} mode is given by

$$Z_{0\infty} = \frac{120\pi^2 b_2}{\lambda_c'\left\{\sin\theta_2 + \dfrac{b_2}{b_1}\cos\theta_2\tan\dfrac{\theta_1}{2}\right\}}. \qquad (3)^4$$

If $Z_{0\infty}$ and the cutoff frequency f_c' are known, the characteristic impedance at any frequency f is obtained by multiplying $Z_{0\infty}$ by the right-hand side of (4).

$$\frac{Z_0}{Z_{0\infty}} = \frac{\lambda_g}{\lambda} = \frac{1}{\sqrt{1-\left(\dfrac{f_c'}{f}\right)^2}}. \qquad (4)$$

The guide wavelength is also obtained by multiplying the space wavelength at the same frequency by the right-hand side of (4).

Equation (4) is plotted in Fig. 4.

Constant $Z_{0\infty}$ curves are plotted in Figs. 2 and 3 as dashed lines. In the example cited above, the impedance of a guide having $b_1/a_1=0.5$, $a_2/a_1=0.4$, $b_2/b_1=0.1$, and $\lambda_c'/\lambda_c=2.6$ would be 47 ohms at infinite frequency. At one and one-half times the cutoff frequency, the im-

[2] S. B. Cohn, "Design of simple broad-band wave guide-to-coaxial line junction," to be published in Proc. I.R.E.

[3] H. C. Early, "A wide-band wattmeter for wave guide," Proc. I.R.E., vol. 34, pp. 803–807; October, 1946.

[4] H. C. Early, "A wide-band directional coupler for wave guide," Proc. I.R.E., vol. 34, pp. 883–887; November, 1946.

[5] (1), (3), (6), and (8) are derived in the appendix.

[6] B_c may be calculated from the curves in a paper by J. R. Whinnery and H. W. Jamieson, "Equivalent circuits for discontinuities in transmission lines," Proc. I.R.E., vol. 32, pp. 98–116; February, 1944.

pedance is multiplied by the factor 1.34, found from Fig. 4, which gives $Z_0 = 47 \times 1.34 = 63$ ohms.

Equation (3) does not take the discontinuity susceptance fully into account, and consequently it is truly accurate only if b_1/a_1 is small. In addition to this, it has

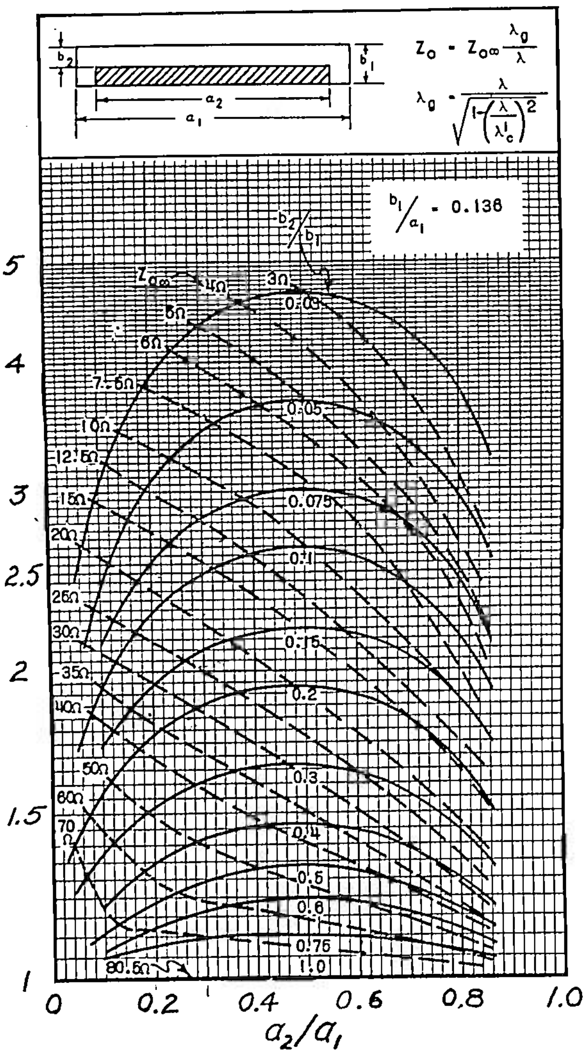


Fig. 2—Characteristic impedance and cutoff wavelength of ridge wave guide ($b_1/a_1 = 0.136$).

the same restrictions as (1). Experiments have given excellent checks of Fig. 2 ($b_1/a_1 = 0.136$), while for $b_1/a_1 = 0.5$ the impedance for the above example was found experimentally to be about 35 to 40 ohms. To obtain a 50-ohm impedance, b_2/b_1 has to be increased from 0.1 to about 0.133 (see Part III, below). But even for $b_1/a_1 = 0.5$ (3) is a useful approximation, and gives a good starting point in design work.

If b_1/a_1 is not equal to 0.136 or 0.5, $Z_{0\infty}$ may still be determined very closely from Figs. 2 and 3. For values of b_1/a_1 between about zero and one-third, multiply values of $Z_{0\infty}$ on Fig. 2 by the scale factor

$$\frac{b_1/a_1}{0.136}.$$

For values of b_1/a_1 between about one-third and two-thirds, multiply values on Fig. 3 by

$$\frac{b_1/a_1}{0.5}.$$

For example, if $b_1/a_1 = 0.2$, $b_2/b_1 = 0.3$, and $a_2/a_1 = 0.5$, Fig. 2 gives $Z_0 = 28$ ohms for $b_1/a_1 = 0.136$. Therefore,

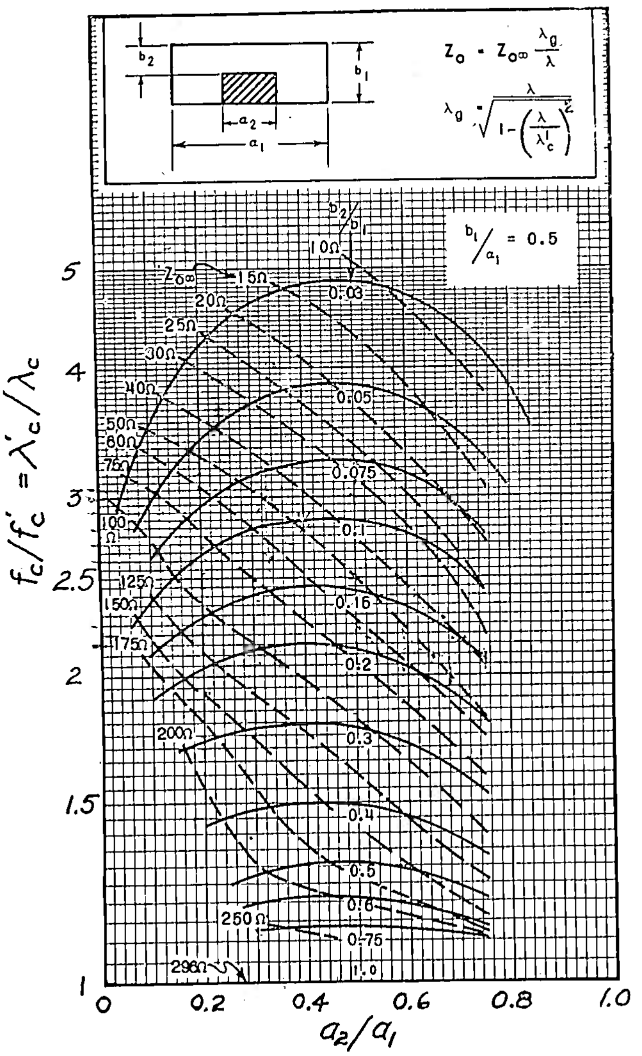


Fig. 3—Characteristic impedance and cutoff wavelength of ridge wave guide ($b_1/a_1 = 0.5$).

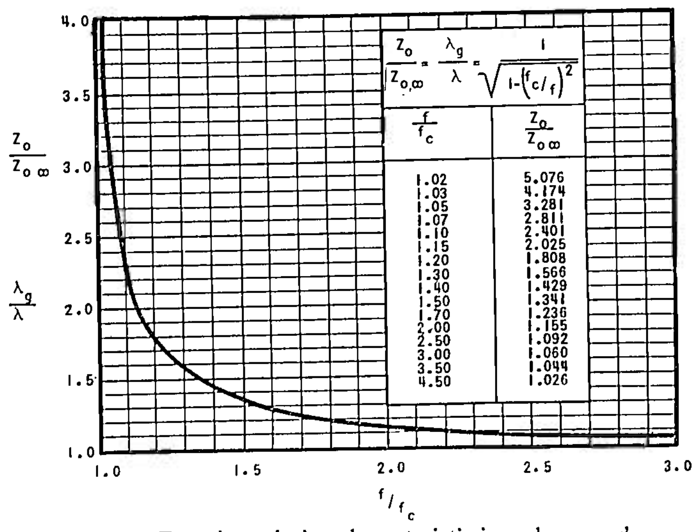


Fig. 4—Function relating characteristic impedance and guide wavelength to frequency.

for $b_1/a_1=0.2$, $Z_{0\infty}=28\times 0.2/0.136=41.1$ ohms. The characteristic impedance was checked experimentally for a cross section having $b_1/a_1=\frac{1}{4}$, and was found to be very close to the value calculated by the foregoing method.

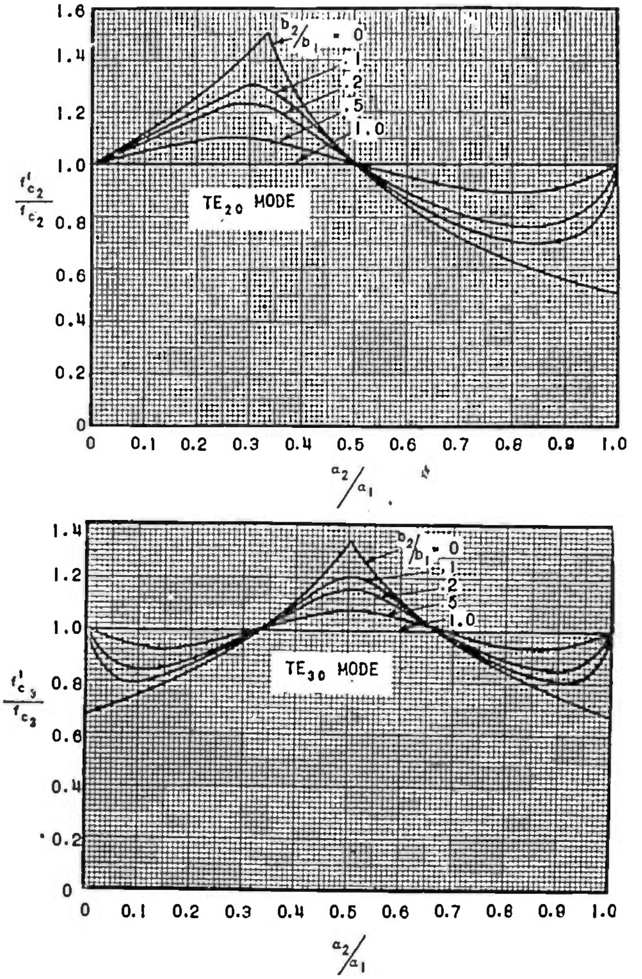


Fig. 5—Cutoff-frequency ratios for the TE_{20} and TE_{30} modes in ridge wave guide.

The higher roots of (1) give the cutoff frequencies of all the odd TE_{mo} modes. The TE_{30} mode is of considerable interest, since it is usually the lowest mode that can cause trouble in a transmission system having a symmetrical cross section in both E and H directions at every point including the ends. For $0\leqq\theta_1\leqq 90$ degrees, choose the root of θ_2 between 180 and 270 degrees. For 90 degrees $\leqq\theta_1\leqq 180$ degrees, choose the root of θ_2 between 90 and 180 degrees. For 180 degrees $\leqq\theta_1\leqq 270$ derees, choose the root of θ_2 between 0 and 90 degrees. Once a pair of values θ_1 and θ_2 have been determined, the ratio f_{c3}'/f_{c3} can be determined from the relation

$$\frac{f_{c3}'}{f_{c3}}=\frac{\theta_1+\theta_2}{270°} \tag{5}$$

where f_{c3}' and f_{c3} are the cutoff frequencies for the TE_{30} mode with and without the ridge, respectively. f_{c3}'/f_{c3} is plotted in Fig. 5 as a function of a_2/a_1 for several values of b_2/b_1, with B_c/Y_{01} neglected. Note that when a_2/a_1 is one-half, f_{c3}'/f_{c3} is a maximum, and the greatest separation of the TE_{10} and TE_{30} cutoff frequencies is obtained. It is easily shown that, for $a_2/a_1=\frac{1}{2}$, f_{c3}'/f_{c3} increases as b_2/b_1 decreases, and in the limit approaches 4/3.

The even TE_{mo}-mode cutoffs are given by solutions of the following equation in which the discontinuity susceptance term has been neglected:

$$\theta_2=\tan^{-1}(-n\tan\theta_1) \tag{6}$$ [5]

where $n=b_1/b_2$. For the TE_{20} mode, the θ_2 root lies between 90 and 180 degrees for $0\leqq\theta_1\leqq 90$ degrees, and the θ_2 root between 0 and 90 degrees for 90 degrees $\leqq\theta_1\leqq 180$ degrees. The cutoff frequency is given by

$$\frac{f_{c2}'}{f_{c2}}=\frac{\theta_1+\theta_2}{180°}. \tag{7}$$

This is plotted in Fig. 5 as a function of a_2/a_1 for several values of b_2/b_1. The maximum value of f_{c2}'/f_{c2} occurs between $a_2/a_1=\frac{1}{4}$ and $\frac{1}{3}$, depending upon b_2/b_1. As b_2/b_1 is made vanishingly small, the maximum value of f_{c2}'/f_{c2} approaches 3/2 at $a_1/a_2=\frac{1}{3}$.

Figs. 2, 3, and 5 show that when a wide frequency band free from TE_{20} and TE_{30} modes is desired, the ridge width should be between about $\frac{1}{3}$ and $\frac{1}{2}$ of the total guide width.

The formulas and curves for a single ridge in a wave guide are directly applicable to the double-ridge cross section shown in Fig. 1(b). In this case, the total height of the guide is $2b_1$ and the total spacing is $2b_2$. Thus, if the width is $2\frac{3}{4}$ inches and the height is $\frac{3}{4}$ inch, then $b_1/a_1=0.136$, and the cutoff curves in Fig. 1 apply exactly. The characteristic-impedance curves apply also, but their values must be doubled. Hence, for a double-ridge guide in which $b_1/a_1=0.136$, $a_2/a_1=0.35$, and $b_2/b_1=0.2$, the relative cutoff wavelength is $\lambda_c'/\lambda_c=1.9$, and the infinite-frequency characteristic impedance is $Z_{0\infty}=2\times 26=52$ ohms, by Fig. 2.

The attenuation constant in decibels per meter for copper single-ridge wave guide may be calculated fairly closely from the following approximate formula:

$$\alpha=6.01(10)^{-7}k\sqrt{f}\left\{\frac{\dfrac{1}{a_1}+\dfrac{2}{b_1}\left(\dfrac{f_c'}{f}\right)^2}{\sqrt{1-\left(\dfrac{f_c'}{f}\right)^2}}\right\}\frac{60\pi^2\left(\dfrac{b_1}{a_1}\right)}{Z_{0\infty}}$$

decibels per meter (8)

where a_1 and b_1 are in centimeters, and f is in cycles per second. k is a correction constant a little larger than unity, which takes account of the more crowded current distribution in ridge wave guide than in plain wave guide. If a_2/a_1 is larger than about $\frac{1}{3}$, this term is probably not greater than 1.5.

For double-ridge wave guide, b_1 should be replaced by the total guide height, $2b_1$. If any metal other than copper is used, α is proportional to $\sqrt{\mu/\sigma}$.

III. Experimental Verification

A three-foot length of ridge wave guide having the cross-sectional dimensions shown in Fig. 6(a) has been tested. For this symmetrical cross section, the design

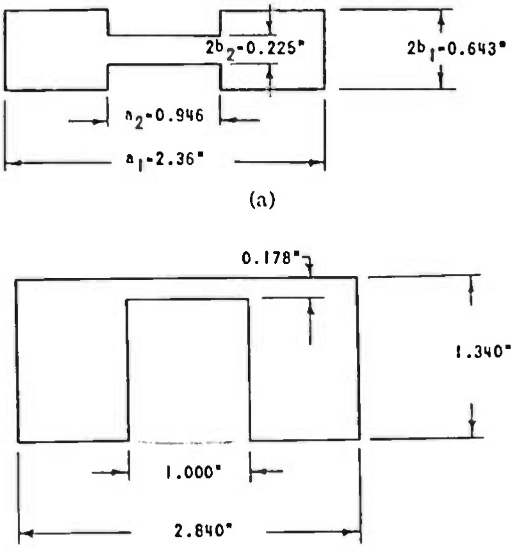


Fig. 6—Two experimental cross sections discussed in the text.

method of II is applicable. The parameters are $b_1/a_1 = 0.136$, $b_2/b_1 = 0.35$, and $a_2/a_1 = 0.40$. Without the ridges, the cutoff wavelength would be $2 \times 2.36 \times 2.54 = 12.0$ centimeters, and the cutoff frequency would be $30{,}000/12.0 = 2500$ megacycles. Fig. 2 gives $f_c/f_c' = 1.50$ and $Z_{0\infty}/2 = 37$ ohms. Therefore, $f_c' = 1670$ megacycles and $Z_{0\infty} = 74$ ohms. Fig. 5 gives approximately $f_{c2}'/f_{c2} = 1.10$ and $f_{c3}'/f_{c3} = 1.06$. Hence,

$$f_{c2}' = 2 \times 2500 \times 1.10 = 5500 \text{ megacycles, and}$$

$$f_{c3}' = 3 \times 2500 \times 1.06 = 7950 \text{ megacycles.}$$

The calculated and measured cutoff frequencies are tabulated below.

Mode Cutoffs

Mode	Calculated	Measured
TE_{10}	1670 megacycles	1675 megacycles
TE_{20}	5500 megacycles	5200 megacycles
TE_{30}	7950 megacycles	7900 megacycles.

Ridge wave guide has been used for elements in wide-band junctions between wave guide and coaxial line. In one type of junction designed for "toll-ticket" wave guide ($a_1 = 2.75$ inches, $b_1 = 0.375$ inch, $b_1/a_1 = 0.136$) a quarter-wavelength section of ridge wave guide is used as a matching transformer between the 103-ohm guide and the 50-ohm line. The experimental results checked the ridge wave guide calculated impedance within a few per cent. In another type of junction for $3 \times 1\frac{1}{2}$-inch wave guide, a tapered length of ridge guide is used to match the 50-ohm coaxial line. In this case, the impedance calculated for the ridge guide proved less accurate, because the approximations were less valid with this higher ratio of b_1 to a_1. The impedance in this case proved, however, to be about 25 per cent lower than the calculated value, and hence the impedance curves in Fig. 3, though not very accurate, serve as a valuable guide in the preliminary design of a piece of equipment. In a double-ridge type of junction for $3 \times 1\frac{1}{2}$-inch wave guide, the impedance curves checked very well. In this case the ratio of b_1 to a_1 was approximately 0.25.

A cross section in $3 \times 1\frac{1}{2}$-inch wave guide that has been found experimentally to have $Z_{0\infty}$ approximately equal to 50 ohms is shown in Fig. 6(b). Fig. 3 gives a value of 65 ohms for $b_1/a_1 = 0.5$, $b_2/b_1 = 0.133$, and $a_2/a_1 = 0.352$. For the above cross section, the impedance must be scaled by the factor 0.472/0.500, since b_1/a_1 is not quite 0.5. Therefore, the calculated impedance is 61.5 ohms, which is 23 per cent greater than the approximate measured impedance.

The paper now under preparation on wave-guide to coaxial-line junctions will give further details.[2]

APPENDIX

I. The Cutoff Equation

In the cross section of Fig. 1(a), the electromagnetic field at the cutoff frequency may be considered as the resultant of a wave traveling from side to side without any longitudinal propagation. As pointed out by S. Ramo and J. R. Whinnery,[1] such a cross section may be treated at cutoff by assuming it to be an infinitely wide, composite, parallel-strip transmission line short-circuited at two points. The TE_{10}-mode cutoff occurs at the frequency at which this strip transmission line has its lowest-order resonance. All the other TE_{m0} cutoffs occur at the corresponding m-order resonance frequencies. For m odd, the resonance must be of a type giving an infinite impedance at the center of the cross section. For m even, this impedance must be zero. A resonance condition may therefore be set up by setting the input admittance of half the cross section equal to zero or infinity (Fig. 7). The discontinuity susceptance B_c at the change in height must be included in the calculation.

If one examines the equivalent circuit, it is seen that it is a composite, dissipationless, passive line matched at both ends, and it is, therefore, matched at every point within. Hence, the sum of the admittances across $x-x$ must equal zero, and the following relation results:

$$-Y_{01} \cot\theta_1 + B_c + Y_{02} \tan\theta_2 = 0$$

$$\frac{Y_{02}}{Y_{01}} = \frac{Z_{01}}{Z_{02}} = \frac{\cot\theta_1 - \dfrac{B_c}{Y_{01}}}{\tan\theta_2}.$$

But in a strip transmission line, the characteristic impedance is proportional to the height. Therefore,

$$\frac{b_1}{b_2} = \frac{\cot\theta_1 - \dfrac{B_c}{Y_{01}}}{\tan\theta_2} \qquad (9)$$

which is the cutoff condition for the odd TE_{m0} modes (1).

For the even modes, the equivalent circuit is shown in Fig. 7(c).

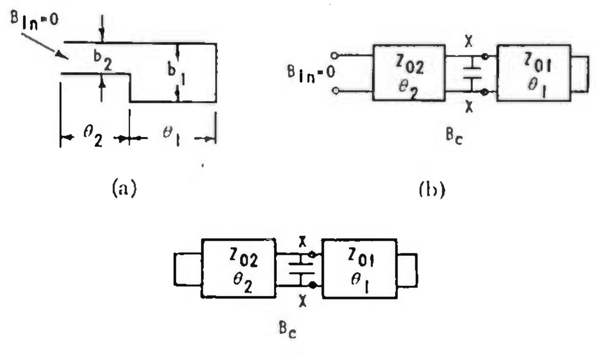


Fig. 7—Development of the equivalent circuit for ridge wave guide.

In this case, $-Y_{01}\cot\theta_1+B_c-Y_{02}\cot\theta_2=0$, and hence

$$\cot\theta_1+\frac{b_1}{b_2}\cot\theta_2=\frac{B_c}{Y_{01}}\cdot \tag{10}$$

Equation (6) follows readily from this.

The discontinuity-susceptance term B_c/Y_{01} is obtainable from a paper by J. R. Whinnery and H. W., Jamieson.[6]

II. Impedance Equation

In deriving the impedance equation for ridge wave guide, it will be assumed that b_1/a_1 is small, so that the discontinuity susceptance at the edges of the ridge may be neglected.

If the TE_{10} mode alone is set up in the wave guide, the E field distribution is the same at all frequencies, including $f=f_c$ and $f=\infty$. The E field can be calculated easily at the cutoff frequency by the approach used in deriving the cutoff equation. At $f=\infty$, the wave impedance is that of free space.[7] Hence, if the E field is known, the H field is given by $H=E/120\pi$. Both E and H are completely transverse at $f=\infty$, and the current on the top or bottom of the wave guide is completely longitudinal. The current per unit width is equal to the H field intensity at the surface of the conductor.

The guide impedance at infinite frequency will now be defined as the *ratio of voltage across the center of the guide to the total longitudinal current on the top face*

$$Z_{0\infty}=\frac{V_0}{I}=\frac{b_2E_0}{2\int_0^{a_1/2}i\,dx}=\frac{120\pi b_2E_0}{2\int_0^{a_1/2}E\,dx}\cdot \tag{11}$$

The impedance at any other frequency is related to $Z_{0\infty}$ by the expression

$$Z_0=\frac{Z_{0\infty}}{\sqrt{1-\left(\frac{f_c'}{f}\right)^2}} \tag{12}$$

where f_c' is the cutoff frequency of the ridge guide.

Since the guide has been assumed thin, the voltage across the step will be continuous. The voltage distribution in the right half of the cross section will therefore be the same as that along the shorted composite transmission line shown in Fig. 8.

Since the input impedance is infinite at the open end, the voltage across the guide is a maximum at that point. Transmission-line theory shows that the voltage distribution over the θ_2 range is given by $V=V_0\cos\theta$ from $\theta=0$ to $\theta=\theta_2$. Over the θ_1 range it is given by

$$V=V_1\sin\frac{(\theta_1+\theta_2-\theta)}{\sin\theta_1}=V_0\frac{\cos\theta_2}{\sin\theta_1}\sin(\theta_1+\theta_2-\theta),$$

from $\theta=\theta_2$ to $\theta=\theta_1+\theta_2$.

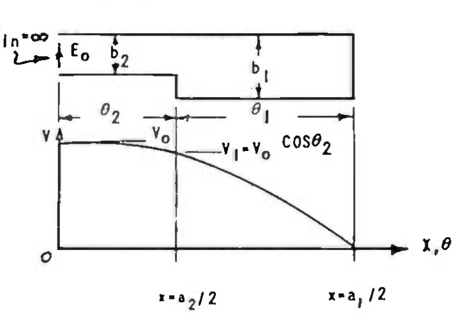


Fig. 8—Approximate voltage distribution across half of the cross section.

The E field is equal to V/b. Therefore,

$$E=E_0\cos\theta,\qquad 0\leqq\theta\leqq\theta_2 \tag{13}$$

$$E=\frac{b_2}{b_1}E_0\frac{\cos\theta_2}{\sin\theta_1}\sin(\theta_1+\theta_2-\theta),\qquad \theta_2\leqq\theta\leqq(\theta_1+\theta_2).$$

The integral in (11) may be evaluated as follows:

$$\int_0^{a_1/2}E\,dx=\frac{\lambda_c'}{2\pi}\int_0^{(\theta_1+\theta_2)}E\,d\theta$$

$$=E_0\frac{\lambda_c'}{2\pi}\left\{\int_0^{\theta_2}\cos\theta\,d\theta+\frac{b_2}{b_1}\frac{\cos\theta_2}{\sin\theta_1}\int_{\theta_2}^{\theta_1+\theta_2}\sin(\theta_1+\theta_2-\theta)\,d\theta\right.$$

$$=E_0\frac{\lambda_c'}{2\pi}\left\{\left|\sin\theta\right|_0^{\theta_2}+\frac{b_2}{b_1}\frac{\cos\theta_2}{\sin\theta_1}\left|\cos(\theta_1+\theta_2-\theta)\right|_{\theta_2}^{\theta_1+\theta_2}\right\}$$

$$=E_0\frac{\lambda_c'}{2\pi}\left\{\sin\theta_2+\frac{b_2}{b_1}\frac{\cos\theta_2}{\sin\theta_1}(1-\cos\theta_1)\right\}$$

$$=E_0\frac{\lambda_c'}{2\pi}\left\{\sin\theta_2+\frac{b_2}{b_1}\cos\theta_2\tan\frac{\theta_1}{2}\right\}.$$

Substituting this relation in (11) gives

$$Z_{0\infty}=\frac{120\pi^2b_2}{\lambda_c'\left\{\sin\theta_2+\frac{b_2}{b_1}\cos\theta_2\tan\frac{\theta_1}{2}\right\}}\cdot \tag{14}$$

[7] For background on this derivation, consult J. C. Slater, "Microwave-Transmission," McGraw-Hill Book Co. New York, N. Y., 1942; chap. 4.

Artificial Electrical Twinning in Quartz Crystals*

JAN J. VORMER†

Summary—**By local heating to temperatures below 573 degrees centigrade, localized twinning is easily produced in AT- CT-, and GT-cut quartz plates. This twinning is of the electrical or Dauphine type. Such twinning may result from manufacturing operations, but may be prevented.**

IT IS WELL known that piezoelectric α quartz, or low quartz, changes at 573 degrees centigrade into the β modification, or high quartz. This conversion is immediate, and completely reversible. If a piece of quartz, which has been raised to a temperature above 573 degrees centigrade, is later cooled below this temperature, it returns to the α quartz form. However, the performing of a complete temperature cycle leaves its marks.

If the original piece of quartz is righthanded, the end product will be the same, i.e., the handedness does not reverse throughout the temperature cycle; optical twins do not change their enantiomorphic form. However, if the original piece of quartz is perfect without any twinning whatsoever, this will, in general, not be the case with the end-product, i.e., the sense which the electrical axes will take in the inversion from high into low quartz depends upon circumstances which are usually not wholly controlled, circumstances which even do not seem to be the same for different parts of one piece of quartz. Thus, if a piece of quartz is heated above 573 degrees centigrade and afterwards cooled, electrical twinning will occur in places which cannot be predicted. This kind of twinning will be called "spontaneous" electrical twinning. (See Fig. 1.) It is to avoid spontaneous

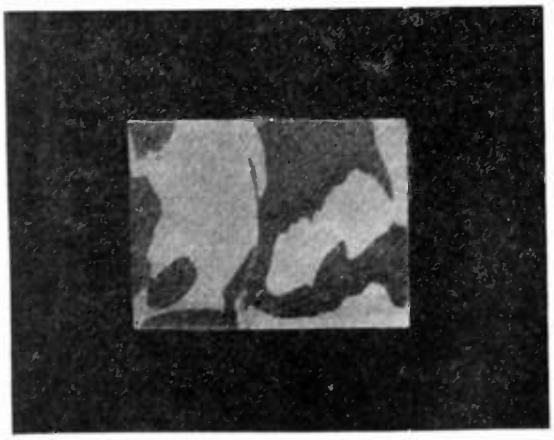


Fig. 1—"Spontaneous" electrical twinning.

twinning of this sort, when following the so-called ceramic procedure of manufacturing silvered quartz plates, that care must be taken not to raise the baking temperature to 573 degrees centigrade.

It is perhaps less well known that artificial electrical twins can also be obtained at temperatures below 573 degrees centigrade and even rather far below this temperature.[1,2] This effect first came to light here when observations on a number of CT-cut plates, to which wires had been soldered, showed properties differing from the normal. The plates had suffered a structural change under the point of soldering. Such a CT-cut plate, to which a wire had been soldered, is shown in Fig. 2 after the plate was etched in hydrofluoric acid. When a plate has been previously etched before the soldering operation, the surface must be fine ground before the second

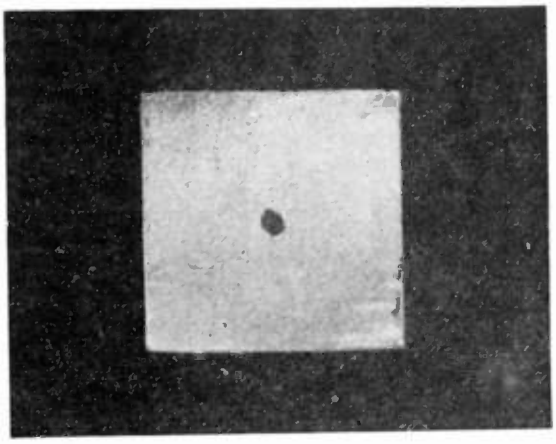


Fig. 2—Artificial twinning in CT-cut plate with soldered lead.

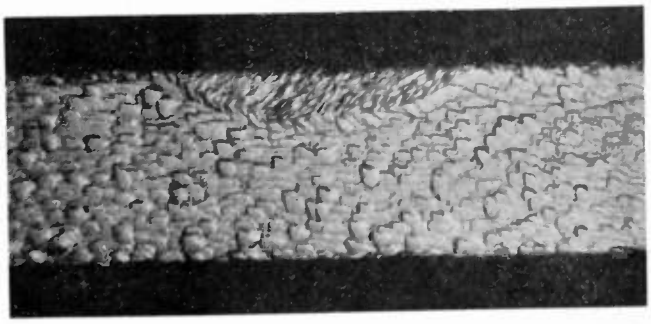


Fig. 3—Cross section of CT-cut plate with lead soldered on one side.

etching, in order that the latter shall develop unambiguous evidence of the twinning. That the transformation in form of the quartz may be quite superficial is proved by Fig. 3, which gives a photograph of a cross section

* Decimal classification: R214.3×537.65. Original manuscript received by the Institute, May 27, 1946; revised manuscript received, September 25, 1946.

† Radio Laboratory of the Dutch Postal Telegraph and Telephone Service, The Hague, Holland.

[1] Clifford Frondel, "Secondary Dauphine twinning in quartz," *American Mineralogist*, vol. 30, pp. 447–468; 1945.

[2] W. A. Wooster and Nora Wooster, "Control of electrical twinning in quartz," *Nature* (London), vol. 157, pp. 405–406; March 30, 1946.

through a plate to which a wire had been soldered on but one side. Fig. 4 shows a similar cross section etched after wires had been soldered to both sides of the plate, and indicates the development of a figure which is of characteristic diabolo shape.

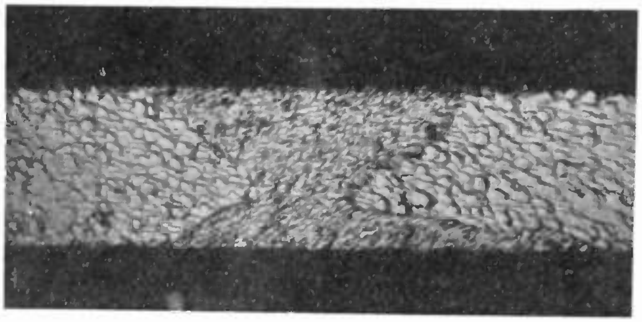


Fig. 4—Cross section of CT-cut plate with lead soldered on both sides.

The type of twinning with which we are concerned is electrical, as can be shown by a microscopic study of the form of the etch figures. A 25-fold magnification of an etched CT-cut plate is shown in Fig. 5, where the region of the artificial electrical twin is clearly seen. The change in structure may be shown also by the macroscopic light-figure which is developed when a luminous point is placed under the plate. In a 37 degree, 30 minutes CT-cut plate the light-figure of a −37 degree, 30 minutes cut appears in the changed region where the quartz has been transformed.

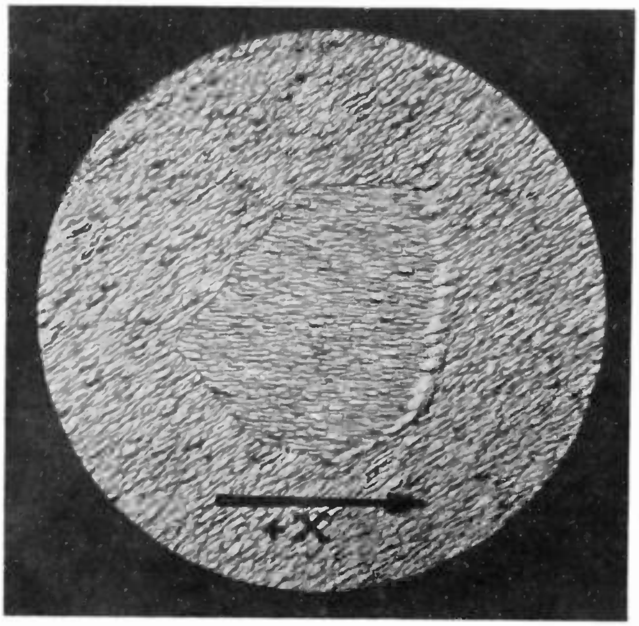


Fig. 5—Magnified view of region of artificial electrical twin.

The plates which were used to show this were made by coating the crystal with a thin layer of copper by evaporation, and then applying Woods metal or tin solder by means of a small soldering iron. These two solders melt at approximately 70 degrees centigrade and 220 degrees centigrade, respectively. The temperature of the iron during the soldering was determined by means of a thermocouple; the temperature of the iron for use with the Woods metal was about 150 degrees centigrade, while for soldering with tin certainly not more than 300 degrees centigrade. During the soldering, the temperature of the quartz plate was presumably lower than these values, but it is possible that for a very short time, and very locally, the above-mentioned temperatures did occur. Twinning occurred despite the low temperatures used.

The above observations point to a combined effect of temperature and mechanical stress. This hypothesis is confirmed by the fact that spontaneous twinning does not occur below 573 degrees centigrade if large temperature gradients in the quartz are avoided. For example, if solder is made to cover a plate by flowing as the plate is warmed in an electrical furnace to a temperature well up toward 573 degrees centigrade, and the plate then slowly cooled, no twinning will be found to have occurred.

It is natural to consider the possibility of removing local twinning produced by local heating to temperatures below 573 degrees centigrade. Success in this direction appears possible only when the local twinning penetrates only partly through the thickness of the plate, as in Fig. 3. Such twinning disappears entirely when the plate is heated to about 200 degrees centigrade. When the structural change has penetrated through the whole thickness of the plate, as in Fig. 4, it is usually impossible to bring about the detwinning with temperatures below 573 degrees centigrade, for the central part of the diabolo as a rule remains intact. In the case of the plate with the twinning on one side only, it is as if the close proximity of quartz in its original untwinned state is able to provide sufficient mechanical stress to cause the transformation of the locally twinned area back to its original state under heating to about 200 degrees centigrade.

One way of avoiding the difficulties of extreme temperature gradients in soldering wires to a plate is to warm up the entire plate during the soldering operation to a temperature slightly below the melting point of the solder. The slight additional rise in temperature at the point of soldering is, then, not sufficient to bring about the mechanical stresses for producing a structural transformation. Etching experiments have indicated that in plates treated in this way electrical twinning does not appear.

Whereas by local heating it is very easy to produce artificial electrical twins at well-defined places in AT-, CT-, and GT-cut plates, to date BT-, DT-, X-, Y-, and Z-cut plates have not shown similar effects. It appears that cuts in the vicinity of a z plane are in a favorable orientation for the production of artificial twinning.

Correspondence

Image Formation in Cathode-Ray Tubes

October 2, 1946*

G. Liebmann and H. Moss[1] discuss some questions relating to the image formation in cathode-ray tubes raised in an earlier paper[2] by the first author. It is hoped that the following remarks may help to clear up some common misapprehensions in this field.

Nature of the Crossover—The crossover is located at the point where the principal rays (corresponding to electrons leaving the cathode with zero initial velocity) intersect the axis. This point is quite definite for an aberration-free lens (Fig. 1). In the presence

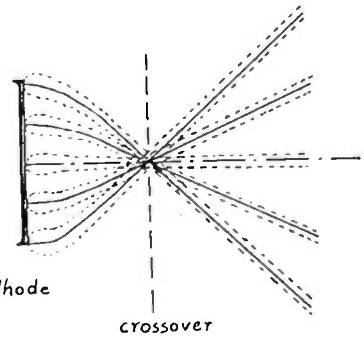


Fig. 1

of spherical aberration (Fig. 2) the crossover plane may be defined as the plane in which the bundle of principal rays experiences its narrowest constriction. In the first case, the diameter of the crossover is determined en-

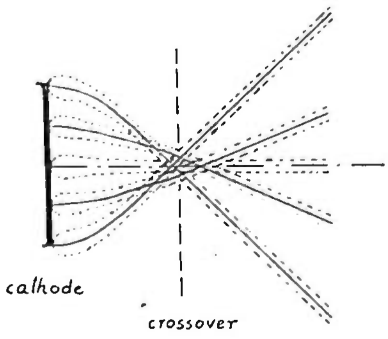


Fig. 2

tirely by the initial velocities of the electrons; in the second, both the initial velocities of the electrons and the spherical aberration of the first lens contribute to its size. Optically, the crossover corresponds to the pupil of the imaging system. The edge of the pupil is not defined, however, by a physical diaphragm, but by the maximum value of the lateral components of the initial velocities of the electrons. Since the position of the crossover is determined by the intersection of the principal rays with the axis, a crossover must necessarily lie between the cathode and a real image thereof, and a crossover image must lie between any two successive real images of the cathode. It should be emphasized that normally the electron velocities at the crossover are high and the interaction between the electrons negligible, so that the presence of the crossover in no way prevents the formation of sharp images of the cathode. The existence of the crossover in no way depends on either the nature or even the existence of the velocity distribution of the electrons.

Dependence of Spot Size on Anode Voltage for a Triode Gun—For a triode gun, i.e., a gun system which may adequately be represented by two lenses, such as guns 2 and 4 of Liebmann's paper[2] with aberration-free lenses, the simplified theory given by Zworykin and Morton[3] applies, and the spot size should be inversely proportional to the second-anode voltage. For a triode gun with aberrations it will still hold for low operating voltages, since the cross section at the cross over of an electron pencil leaving a single point of the cathode may be expected to be large compared with the narrowest constriction of the bundle of principal rays, which constriction is independent of the operating voltage. Insofar as this theory takes account only of the spreading of the individual imaging pencils arising from the initial velocities of the electrons which diminishes with increasing accelerating voltage, and not of the effects of spherical aberration of the first lens which is independent of the voltage, it must fail for voltages high enough to render the first factor small compared to the second. With increasing voltage of both the first and second anode, the ratio being kept constant, the spot size will not decrease indefinitely but approach a constant minimum value determined by the magnitude of the narrowest constriction of the bundle of principal rays. The position of the "knee" of the curve will move toward lower voltages as the effective cathode area (for fixed first-lens focal length) is increased.

Dependence of Spot Size on Anode Voltage for a Three-Lens Gun—If a second lens acting primarily simply as an accelerating field is placed between the crossover and the final lens and close to the former, increasing the final anode voltage, keeping the accelerating voltage constant, will decrease the beam cross section at the final lens in inverse proportion to the square root of the voltage, as derived by Liebmann, and will not affect spot size (in absence of aberrations). In actual three-lens guns, the action of increasing the voltage will be distributed over reducing the convergence angle and reducing the spot size in a manner determined by the precise gun geometry.

Cathode Image or Crossover Image—In principle, either the cathode or the crossover may be imaged on the screen. However, in most cathode-ray tubes—particularly, television viewing tubes—the first lens is much too weak to form a real image of the cathode a small distance from the latter. Liebmann's statement that the cathode image appeared inverted for underfocusing, right-side up for overfocusing, and that, hence, *the imaging pencils cross the axis at the point of sharp focus*, proves that his focused spot is, just as that of Moss, an image of the crossover and not the cathode.

E. G. Ramberg and D. W. Epstein
Radio Corporation of America
Princeton, New Jersey

* Received by the Institute, October 4, 1946.

[1] G. Liebmann and H. Moss, "The image formation in cathode-ray tubes and the relation of fluorescent spot size and final anode voltage," Proc. I.R.E., vol. 34, pp. 580–586; August, 1946.

[2] G. Liebmann, "The image formation in cathode-ray tubes and the relation of fluorescent spot size and final anode voltage," Proc. I.R.E., vol. 33, pp. 381–389; June, 1945.

[3] V. K. Zworykin and G. A. Morton, "Television," John Wiley and Sons, Inc., New York, N. Y., 1940, pp. 370–374.

Presentation of Technical Papers

October 18, 1946*

I have given some thought to the process of conveying information from the man who presents a technical paper at a meeting of a technical society to members of the audience. Numerous experiences in the past lead me to believe that there are a few elementary precautions that could increase the above-mentioned transfer greatly.

The management of the conference or meeting should provide for a good auditorium with satisfactory acoustical qualities and ample ventilation; a person familiar with the lighting system; a good reading lamp for the lecturer; several blackboards and an efficient pointer to point out details on both blackboards and projector screen; an efficient projector and a man familiar with it; a good sound system in good condition; a lapel or throat microphone giving the speaker sufficient freedom to move around; a call system to call persons to the information desk or telephone; and attendants in the audience equipped with portable mcirophones for discussion speakers.

The speaker should also prepare himself well, and a few points are here suggested. He should carefully time his paper and the speed of his delivery, and familiarize himself beforehand with the lecture room, the microphone, the reading light, and the pointer. If at all possible, mimeographed sheets should be prepared, giving all sketches, formulas, and tabulations the lecturer wants to be put on the blackboard or to project. They should all be carefully numbered. The lecturer can then refer to this material during his talk and it saves his audience the trouble of trying to take notes in the darkened room, while listening to the speaker at the same time. The notes should be distributed at the entrance to the room.

The proceedings of the conference, if any, should be ready for distribution at the earliest possible date so as to keep the impressions gained alive in the minds of the audience. I feel strongly that any time saved in this respect is very valuable indeed. I would greatly appreciate your printing these suggestions if you feel they are of any help.

Harald Schutz
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Waltham, Massachusetts

* Received by the Institute, October 21, 1946.

Equivalent Circuits for Plane Discontinuities

April 3, 1947*

Mr. Jamieson and I have read with much interest the recent and very valuable paper on "The Equivalent Circuit for a Plane Discontinuity in a Cylindrical Wave Guide"[1] by J. W. Miles, and would like to comment on the references to our work on this subject.[2] We believe that these references, although in no sense critical of our work, do not correctly state the procedure which we followed. Since the comments in Miles' paper are interpretable as a comparison of our procedure with his, this is of some importance. The method used by us in the main body of the paper and in a following paper[3] followed closely the procedure developed by W. C. Hahn,[4] and is fairly completely explained in Part VI of our first paper.[2] The procedure attributed to us following equation (92) of Miles' paper[1] is an approximate one which gives useful results over a wide range of conditions and which, we believe, has occurred to a number of people independently from physical considerations. For that reason a curve of this approximation was included for comparison with the results from our more detailed analysis in our Fig. 16. The result from conformal mapping was also included as a zero-frequency limiting-case check, but does not form a starting point for the series method which we used.

We believe also that the comments on page 739, in the paragraph following that containing equation (89), do not give a correct impression of the degree of approximation in the analyses of the several more complex discontinuities treated in our papers. The series method of Hahn may be used to obtain a high degree of accuracy for the equivalent networks of a variety of discontinuities, and it was so applied for several of these in our papers. Certain problems were solved to a lower degree of approximation, but I believe the distinction was made in the presentation of results.

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Department of Engineering
University of California
Berkeley, California

* Received by the Institute, April 11, 1947.
[1] Proc. I.R.E., vol. 34, pp. 728–742; October, 1946.
[2] J. R. Whinnery and H. W. Jamieson, "Equivalent circuits for discontinuities in transmission lines," Proc. I.R.E., vol. 32, pp. 98–114; February, 1944.
[3] J. R. Whinnery, H. W. Jamieson, and T. E. Robbins, "Coaxial-line discontinuities," Proc. I.R.E., vol. 32, pp. 695–709; November, 1944.
[4] W. C. Hahn, "A new method for the calculation of cavity resonators," Jour. Appl. Phys., vol. 12, pp. 62–68; January, 1941.

April 3, 1947*

In reply to J. R. Whinnery's comments on the author's paper,[1] an apology is due for the misleading implications made with reference to the work in the Whinnery and Jamieson paper.[2] As is stated in both the paper and Whinnery's letter, the results given in Fig. 16 of his paper were calculated by systematic analysis, and the approximate result stated in equation (93) of the author's paper was plotted for comparison.

Similarly, the more complex discontinuities were systematically analyzed, and the approximations stated in the various figures were inferred from these analyses. The point the author wished to make was that the approximations suggested by Whinnery and Jamieson are sufficiently accurate for most engineering work to justify calculating accurately only the asymmetrical change of cross section.

It should be clearly understood that the general method outlined in the author's paper, which culminates in the integral equation of equation (28) for the electric field in the plane of the discontinuity, although a more general formulation, leads to a set of simultaneous equations which are identical with those obtained using the method used by Hahn[3] and Whinnery,[2,4] when applied to parallel-plate and axially symmetrical coaxial-line discontinuities. It has been pointed out in a recent letter to the Editor[5] that Hahn's work[3] introduced the author to the analytical study of wave-guide discontinuities and was the basis of his later work, although it was greatly augmented by later contacts with Julian Schwinger, et al.[5] The most important advantages of the formulation used in the subject paper (see equations (16) to (34))[1] are that it suggests certain features which are expedient in the solution of more complex problems than those treated in the Whinnery and Jamieson paper. Among these are:

(1) The breakdown of the aperture field into the superposition of two linearly independent fields as suggested by Schwinger and expressed in equation (25).

(2) Through (1), the approximate approach of equations (35) to (38) and Fig. 3.[1]

(3) Schwinger's variational formulation (see (34)[1]) which leads to a variety of approaches and is particularly convenient in leading to approximate results for complex problems. However, when subjected to the condition that it be an extremal, Schwinger's variational formulation leads to the original integral equation, or to the set of simultaneous equations which represent the solution of the latter; it is therefore exact or approximate in exactly the same sense that Hahn's method[3] or, more generally, the Rayleigh-Ritz method is exact or approximate (although the usual Rayleigh-Ritz problem generally leads to an infinite, discrete set of solutions, whereas the former methods yield a unique solution).

(4) The formulation of approaches which give an exact treatment to a finite number of higher modes (see equations (84) to (87)).[1]

On the other hand, the formulation of the problem in terms of the current in the discontinuity plane (see equations (40) to (53)),[1] although analogous to the field approach, leads to a different set of equations than the method of Hahn when applied to the same problem. This approach was suggested to the author through the work of Condon and Smythe.[5]

Inasmuch as the work of Whinnery and Jamieson[2] was the first treatment of a large class of problems of great engineering importance (and is still the most generally accessible source of information),[6] it would be most unfortunate if the author's statements had cast any doubt on the validity or accuracy of this work.

John W. Miles
Department of Engineering
University of California
Los Angeles, California

* Received by the Institute, April 11, 1947.
[1] J. W. Miles, "The equivalent circuit for a plane discontinuity in a cylindrical wave guide," Proc. I.R.E., vol. 34, pp. 728–742; October, 1946.
[2] J. R. Whinnery and H. W. Jamieson, "Equivalent circuits for discontinuities in transmission lines," Proc. I.R.E., vol. 32, pp. 98–114; February, 1944.
[3] W. C. Hahn, "A new method for the calculation of cavity resonators," Jour. Appl. Phys., vol. 12, pp. 62–68; January, 1941.
[4] J. R. Whinnery, H. W. Jamieson, and T. E. Robbins, "Coaxial line discontinuities," Proc. I.R.E., vol. 32, pp. 695–709; November, 1944.
[5] John W. Miles, "Contributions to wave guide theory," Proc. I.R.E., vol. 35, pp. 378–379; April, 1947.
[6] Some of the work done at the Massachusetts Institute of Technology Radiation Laboratory is available through the United States Department of Commerce and a large amount of data will undoubtedly appear in the "Wave Guide Handbook," to be published in McGraw-Hill's Radiation Laboratory series.

The Steady-State Operational Calculus

January 13, 1947*

I have just read the paper by D. L. Waidelich[1] and should like to try to demonstrate how to arrive at a formula of easier application for the calculation of the steady state. The starting point for my deduction is the Heaviside formula. My deduction is as follows:

Given a voltage

$$1(t)\begin{cases} = 0 & t < 0 \\ = 1 & t > 0 \end{cases}$$

the corresponding current in the circuit is

$$i = \frac{1}{Z(0)} + \sum_i \frac{e^{\alpha_i t}}{\alpha_i Z'(\alpha_i)}$$

showing by α_i the roots of $Z(p)=0$.

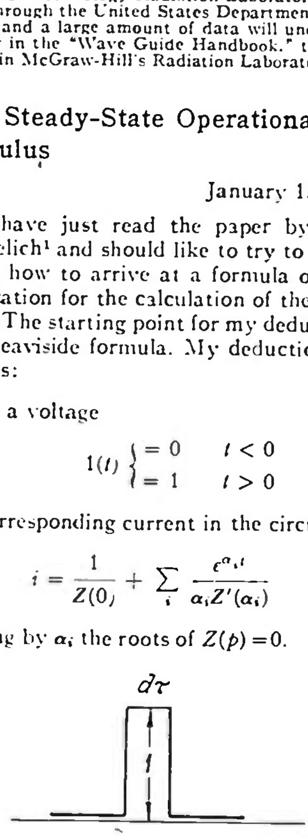


Fig. 1—Infinitesimal pulse $1d\tau$.

The infinitesimal pulse $1d\tau$ will be transformed, after a time t, in

$$di = \sum_i \frac{e^{\alpha_i t}}{Z'(\alpha_i)}\, d\tau,$$

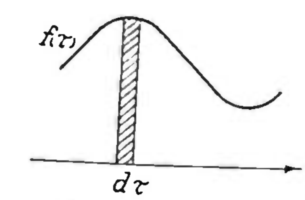


Fig. 2—Decomposition of $f(\tau)$ in pulses.

and if it is assumed that $f(\tau)$ is composed of a series of infinitesimal pulses, we obtain

* Received by the Institute, January 24, 1947.
[1] D. L. Waidelich, "The steady-state operational calculus," Proc. I.R.E., vol. 34, pp. 78P–83P; February, 1946.

$$i = \sum_i \frac{1}{Z'(\alpha_i)} \int_{-\infty}^{t} e^{\alpha_i(t-\tau)} f(\tau)\, d\tau;$$

but, as $f(t)$ is a periodic function,

$$\int_{t-T}^{t} e^{\alpha_i(t-\tau)} f(\tau)\, d\tau = e^{-\alpha_i T} \int_{t-2T}^{t-T} e^{\alpha_i(t-\tau)} f(\tau)\, d\tau.$$

Finally, as there is the limitation $e^{\alpha t} \xrightarrow[t\to\infty]{} 0$; we have

$$i = \sum_i \frac{1}{Z'(\alpha_i)(1 - e^{\alpha_i T})} \int_0^T e^{\alpha_i \tau} f(t - \tau)\, d\tau.$$

A. Colino
Marconi Espanola, S.A.
Madrid, Spain

Nomogram for Rosa Inductance Correction

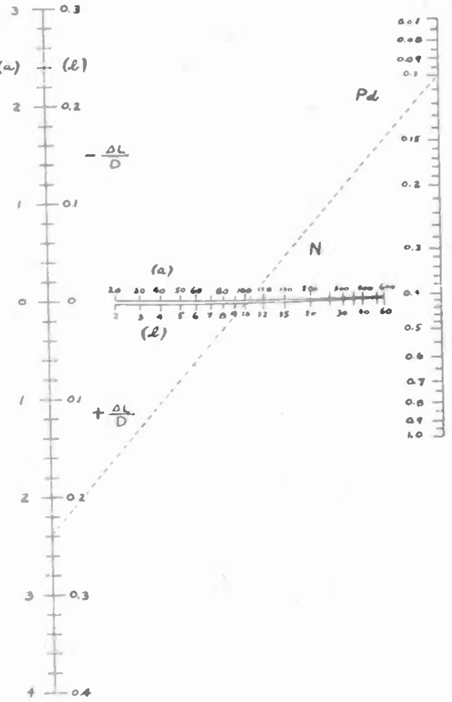
January 14, 1947*

Formulas for the calculation of the inductance of a solenoid are generally based on current-sheet theory. The current-sheet inductance supposes the winding to be an infinitely thin tape with the turns infinitesimally separated.

A correction of the current-sheet formula for the case of a coil wound with round wire has been derived by Rosa. The inductance formulas of Raleigh, Coffin, Lorenz, Nagaoka, and others, together with Rosa's correction, are described and discussed in the literature.[1]

Calculators and nomograms for quickly finding the current-sheet inductance of a solenoid have made their appearance. An example of such a calculator is one published by the American Radio Relay League, Inc., West Hartford, Connecticut, and an example of a nomogram is one incorporated in the catalogue of Barker and Williamson, Upper Darby, Pennsylvania.

In view of these aids, the calculation of the Rosa correction is much more time-consuming than finding the current-sheet inductance. A nomogram was therefore devised for finding the Rosa correction, and is presented herewith by permission of Barker and Williamson, for whom it was prepared. This nomogram allows a quick preliminary investigation of the order of this correction, and is accurate enough for most practical purposes.



Nomogram of Rosa Correction for Current-Sheet Inductance of a Solenoid.

$$L = L_0 + \Delta L$$

ΔL—correction in microhenries
L_0—current-sheet inductance in microhenries
L—true inductance in microhenries
D—diameter of coil in inches
N—total turns
P—winding pitch in turns per inch
d—bare wire diameter in inches.

Inspection of the nomogram brings out several important facts. When Pd is approximately equal to 0.42, the correction is generally small and is almost independent of N. Also, the correction is ordinarily negative for Pd greater than 0.42, and positive for Pd less than 0.42.

An example will be worked out illustrating the use of the nomogram. The current-sheet inductance will be determined by means of the ARRL calculator. Consider a coil in which $N=10$ turns, $P=1$ turn per inch, $d=0.1$ inch, and $D=5$ inches. The coil length is therefore 10 inches and Pd equals 0.1.

The value for P just given places the coil outside of the range of the ARRL calculator, since it is calibrated only as low as P equals 2 turns per inch. The principle of similitude can then be invoked by dividing all of the physical quantities by 2, with the number of turns remaining the same. The resulting inductance must then be multiplied by 2 in order to find the actual current-sheet inductance. Performing this operation gives the coil inductance as 5.0 microhenries.

The dotted line on the nomogram shows that the Rosa correction for this example is positive and equal to $0.235D$ or 1.175 microhenries. The actual inductance of this coil is therefore 5.0 plus 1.175, or 6.175 microhenries.

A slide-rule calculation by means of Nagoka's formula gives a value of 5.13 microhenries for the current-sheet inductance, and a similar calculation gives 1.18 microhenries for the Rosa correction. There is little practical difference in this case between the calculated values and those found by means of the chart and calculator.

Samuel Sabaroff
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Philadelphia 31, Pennsylvania

* Received by the Institute, January 16, 1947.
[1] Bureau of Standards, "Scientific Paper No. 169," pp. 116–135.

Contributors to the Proceedings of the I.R.E.

Robert H. Brown

Robert H. Brown (M'46) was born at Sioux Falls, South Dakota, on August 27, 1915. He received the B.A. degree in 1940 from Union College, Lincoln, Nebraska, where he majored in physics, and the M.S. degree in 1942 from the University of Nebraska.

On leaving the University of Nebraska, where he had been an assistant instructor in physics, he joined the research department of Sylvania Electric Products, Inc., where his work concerned training equipment for the SCR-268 radar, testing and measurement problems in the microwave region, and radiation problems connected with the proximity fuze. From 1943 until 1945 his efforts were largely devoted to the frequency-modulated radar equipment which was developed under a subcontract with Edwin H. Armstrong, later known as "moon radar." In 1946 and 1947 he taught physics and mathe-

Arthur W. Burks

Contributors to Proceedings of the I.R.E.

Seymour B. Cohn

matics at Canadian Union College, Lacombs, Alberta.

Mr. Brown is now assistant professor of physics at Walla Walla College, College Place, Washington, and is at present on leave of absence to do advance study and research at the University of Washington, Seattle. He is a member of the American Physical Society.

Arthur W. Burks (A'43–M'44) was born in Duluth, Minnesota, on October 13, 1915. He received the B.A. degree in mathematics and physics from DePauw University in 1936, and the M.A. and Ph.D. degrees in mathematical philosophy from the University of Michigan in 1937 and 1941, respectively. In the fall of 1941 he joined the staff of the Moore School of the University of Pennsylvania as instructor of electrical engineering and research engineer.

Dr. Burks was one of those who directed the designing of the ENIAC from its inception in the summer of 1943 until its completion in February, 1946. He then accepted an assistant professorship at the University of Michigan, his duties to begin in the fall of 1946. Until such time he was invited by Professor John von Neumann to participate in the initial design work of an electronic computing machine to be built at the Institute for Advanced Study. He is co-author with Professor von Neumann and Dr. H. H. Goldstine of a report on the logical design of this machine.

Dr. Burks is now at the University of Michigan teaching mathematical logic and philosophy of science. He is a member of the Institute of Electrical Engineers, the American Mathematical Society, Eta Kappa Nu Association, and the Society of Sigma Xi.

Seymour B. Cohn (S'41-A'44-M'46) was born at Stamford, Connecticut, on October 21, 1920. He received the B.E. degree in electrical engineering from Yale University in 1942. From 1942 through 1945 he was employed as a special research associate by the Radio Research Laboratory of Harvard University. While with this laboratory, he engaged in research and development on wide-band and wide-range very-high-frequency receivers for military purposes. Also he represented the Radio Research Laboratory during part of this time as a Technical Observer with the United States Army Air Forces in the Mediterranean Theater of Operations.

Upon completion of his work with the Radio Research Laboratory, Mr. Cohn undertook full-time graduate work at Harvard University on a National Research Council fellowship. In June, 1946, he received the M.S. degree in communication engineering, and is now continuing work toward a Ph.D. degree.

Mr. Cohn is a member of Tau Beta Pi and an associate member of Sigma Xi. He is on the Papers Review Committee of the I.R.E.

J. M. Lafferty

James M. Lafferty (M'46) was born in Battle Creek, Michigan, on April 27, 1916. He attended Western Michigan College and later transferred to the University of Michigan, where he received the B.S. degree in engineering physics in 1939; the M.S. degree in physics in 1940; and the Ph.D. degree in electrical engineering in 1946.

In 1941 Dr. Lafferty left the University to aid in the development of VT proximity fuzes at the Carnegie Institution in Washington, D. C. In 1942 he joined the staff of the General Electric Research Laboratory as a research physicist where he worked on microwave tubes. Later he went to the Radiation Laboratory at Berkeley, California, to work on the Manhattan District project. He returned to General Electric in May, 1945, where he completed the research work for his doctorate. Dr. Lafferty is a member of Sigma XI, Phi Kappa Phi, Iota Alpha, and the American Physical Society.

Vincent C. Rideout

Vincent C. Rideout (M'44) was born on May 22, 1914, in Alberta, Canada. He received the B.Sc. degree in engineering physics from the University of Alberta in 1938, and the M.S. degree in electrical engineering from California Institute of Technology in 1940. From 1939 to 1946, Mr. Rideout was a member of the technical staff of the Bell Telephone Laboratories, engaged in microwave radio and radar research. He has recently joined the staff of the University of Wisconsin. Mr. Rideout is a member of Sigma Xi.

Jan J. Vormer was born in The Hague Holland, on October 24, 1901. He received the degree of electrotechnical engineer from the Technical University at Delft in 1925. In this same year he was appointed an engineer of the Dutch Postal Telegraph and Telephone service at the Radio Laboratory in The Hague. He became chief engineer in 1941 and was appointed chief of the radio laboratory since 1945.

Jan J. Vormer

Institute News and Radio Notes

Air Force Day—August 1, 1947

Major General Harold M. McClelland

On August 1, 1947, Air Force Day was celebrated in the United States of America. The part played in the development of military aviation radio and guidance by the communications and electronic engineers, and their Institute, is admirably set forth in the following statement. The Institute is indebted to Major General Harold M. McClelland, Commanding General of the Airways and Air Communications Service, for his encouraging expression of viewpoint.
—*The Editor.*

HAROLD M. McCLELLAND

Fast, reliable transmission of intelligence and orders has always been important, often vitally so, in military operations. World War II saw a greater demand in this regard than ever before, particularly in air operations. The future need will be even greater. The work of members of The Institute of Radio Engineers formed the foundation and framework of the systems of electrical communications upon which the Air Forces relied in World War II, and upon which they must rely in the future.

Annual Meeting of the Institute

Article VIII of the Constitution, Section 2, states: "There shall be an annual meeting of the Institute as soon as practicable after the annual meeting of the Board of Directors at which general reports of the Secretary and Treasurer shall be presented."

The annual meeting of the Institute is called for September 3, 1947, at 1:30 P.M., Eastern Daylight Time. The meeting will be held at the Institute Headquarters, 1 East 79 Street, New York 21, N. Y.

Institute Policy

At a recent meeting of the Board of Directors it was decided to continue as Institute policy the following:

"The Institute welcomes to its membership, in each case in an appropriate member grade, all persons professionally active in the communications and electronic engineering field, or interested in that field. The meetings and publications of the Institute are exclusively of professional engineering nature and will remain of that character. The Institute offers all its members the opportunity to mingle with its professional engineering members, to participate in the technical meetings of the Institute, and to study the scientific and engineering publications of the Institute."

Student Branches

Petitions for the formation of Student Branches at Purdue University, Stanford University, and Northwestern University were approved by the Board of Directors at its May 7, 1947, meeting.

At the Board's June 4, 1947, meeting, similar petitions were approved from the following: University of Washington, University of Illinois, University of Texas, North Carolina State College, and Rutgers University.

Institute Representatives

Herman A. Moench, assistant professor of electrical engineering, Rose Polytechnic Institute, Terre Haute, Indiana, was appointed local Institute Representative at the May 7, 1947, Board of Directors meeting.

Carl S. Roys, professor of electrical engineering, Syracuse University, Syracuse, New York, was appointed local Institute Representative at the Board's June 4, 1947, meeting.

Sections

The petition from the Sacramento Section, approved by the San Francisco Section, that the portion of Solano County, California, north of a line drawn across the county east and west just below Elmira, be included in the territory of the Sacramento Section, the remaining portion of the county to remain as part of the San Francisco Section, was approved by the Board of Directors at its May 7, 1947, meeting.

Advanced Work at Stanford University

The Microwave Laboratory of the physics department of Stanford University announces that a number of Fellowships, Research Assistantships, Research Associateships, and Postdoctorate Research Fellowships are available to qualified graduate students for the academic year 1947–1948.

The Microwave Laboratory conducts research in microwave physics and engineering. Its present program includes the development of electron accelerators, klystrons, and the application of microwave techniques to physical measurements.

Fellowships with an annual value of $1000, sponsored by the Sperry Gyroscope Company, Inc., are offered to qualified students who are candidates for higher degrees. Research assistantships, available to graduate students, enable the student to earn from $900 up. Some of the research done under these assistantships can be used as thesis material toward higher degrees. Full-time research associateships, available to advanced graduate students who have completed most of their work toward doctorates, carry stipends of $2400 to $2700 per academic year, and the work done will be acceptable as thesis material toward doctors' degrees. Postdoctorate research fellowships, available for independent research either in microwave engineering or in application of microwaves to physics, are on an eleven-month basis and carry stipends up to $4000.

Further information may be obtained from and applications made to Professor William W. Hansen, Director, Microwave Laboratory, Stanford University, California.

West Coast

San Francisco, California,

Redwood Empire Association

Palace Hotel

The first postwar West Coast Convention of The Institute of Radio Engineers, sponsored by the San Francisco Section, will be held at the Palace Hotel, San Francisco, September 24 through 26. The West Coast conventions, which were well attended before the war, serve the fast-growing membership of the great Western Slope. This year's convention, having available the many recent technological advances, is expected to be outstanding and a large attendance is anticipated.

Professor Karl Spangenberg, convention chairman, promises not only a group of papers of outstanding caliber and value but an integrated program of events which will further enhance the convention.

Registration is set for Wednesday morning, September 24, and papers will be presented from Wednesday afternoon through Friday, September 26. There will be a get-together cocktail party Wednesday evening, September 24, a luncheon on Thursday, and a banquet Friday evening. Inspection trips to outstanding activities of interest in the Bay region will include the National Advisory Committee for Aeronautics installations at Moffett Field, the new University of California 184-inch cyclotron, the Microwave and Communications Laboratories at Stanford University, and several electronic manufacturing plants.

While the convention will not sponsor any exhibits, the West Coast Electronic Manufacturers Association's annual exhibition at the Hotel Whitcomb, San Francisco, September 26 through 28, will be open to I.R.E. members and guests. Its display of recently developed electronic devices will effectively supplement the I.R.E. convention activities.

A special block of rooms has been reserved for I.R.E. members and their families at the leading hotels in San Francisco. Reservations should be forwarded to J. H. Landells, Chairman of the Hotel Function Committee, c/o Westinghouse Electric Corporation, 1 Montgomery Street, San Francisco, California. In order to assure reservations, a $5.00 deposit should accompany the request. Checks should be made out to "1947 West Coast I.R.E. Convention."

PROGRAM

Wednesday, September 24, 1947

Registration

Military Applications

1. "Technical Problems of Military Radio Communications of the Future," John Hessel, Signal Corps Engineering Laboratories, Fort Monmouth, N. J.
2. "Some Applications of Electronics to Underwater Ordnance," Ralph D. Bennett, Naval Ordnance Laboratory, Washington, D. C.
3. "Some Experimental Determination of Mutual Impedance of Antennas," F. R. Abbott, Naval Electronics Laboratory, San Diego, Calif.
4. "A New Pulse-Time Telemetering System," James N. Davis, Sylvania Electric Products, Flushing, N. Y.
5. "Microwaves in Ordnance Work," Frederick G. Suffield, Allison Associates, Los Angeles, Calif.
6. "Telemetering Guided-Missile Performance," James C. Coe, United States Naval Air Missile Test Center, Point Mugu, Calif.

Cocktail Party

Frequency Modulation

1. "Frequency-Modulation Detectors," Stuart W. Seeley, Radio Corporation of America Industry Service Laboratory, New York, N. Y.
2. "A 50,000-Watt Frequency-Modulation Transmitter for 100.5 Mc.," Leigh Norton, Eitel-McCullough Inc., San Bruno, Calif.
3. "Susceptibility of Frequency-Modulation Receivers to Interfering Signals," D. E. Foster, Hazeltine Research Inc. of California, Los Angeles, Calif.
4. "Limiters and Discriminators in Frequency-Modulation Receivers," W. G. Tuller, Massachusetts Institute of Technology, Cambridge, Mass.

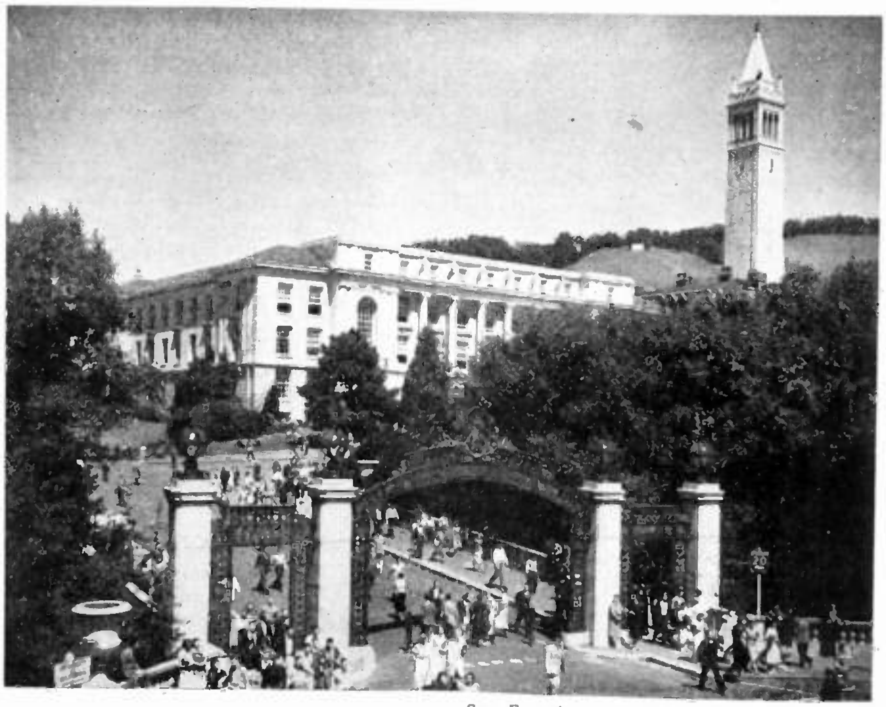
Thursday, September 25, 1947

Session I, Instrumentation

1. "A Very-High-Frequency Bridge for Impedance Measurements," Robert Soderman, General Radio Company, Cambridge, Mass.
2. "A Pulse-Counter-Type Frequency-Modulation Station Monitor," David Packard and Norman Schrock, Hewlett-Packard Company, Palo Alto, Calif.
3. "Supersonic Flaw Detection," Donald Erdman, Triplett-Barton Company, Burbank, Calif.
4. "Electronic-Gauge Methods and Apparatus," Robert L. Sink, Consolidated Engineering Corp., Pasadena, Calif.

Session II, Miscellaneous

1. "Equivalent Networks for Wave-Guide Problems," John R. Whinnery, University of California, Berkeley, Calif.
2. "The New York-Boston Radio Relay Experiment—A Progress Report," J. W. McRae, Bell Telephone Laboratories, New York, N. Y.



San Francisco Convention and Tourist Bureau

University of California

I.R.E. Convention

September 24, 25, 26

3. "High-Quality Loudspeakers and Their Adaptation to Systems Engineering," John K. Hilliard, Altec Lansing Corp., Hollywood, Calif.
4. "A New Solution of the Antenna Problem," Cornelius Lanczos, Boeing Aircraft Co., Seattle, Wash.

Luncheon

Electronic Devices

1. "The Proton Linear Accelerator," Louis Alverez, University of California, Berkeley, Calif.
2. "The Electron Linear Accelerator," W. W. Hansen, Stanford University, Palo Alto, Calif.
3. "Oscillation and Gain Properties in New Types of Traveling-Wave Tubes," Lester M. Field, Stanford University, Palo Alto, Calif.
4. "Resnatron Design," W. W. Salisbury, Collins Radio, Cedar Rapids, Iowa.

Redwood Empire Association

San Francisco s California Street, Near Chinatown

Friday, September 26, 1947

Frequency Modulation and Television

1. "Radio Wave Propagation in the Frequency-Modulation Broadcast Band," Kenneth A. Norton, National Bureau of Standards, Washington, D. C.
2. "A 5-Kilowatt Television Broadcast Transmitter," J. E. Keister, J. W. Downie, H. B. Sancher, and E. M. Ewing, General Electric Company, Syracuse, N.Y.
3. "Receiving Antennas for Frequency-Modulation and Television," Andrew Alford, Somerville, Massachusetts.
4. "A Modern Television Transmitter," C. D. Kentner, Radio Corporation of America, Camden, N. J.

Inspection Trips

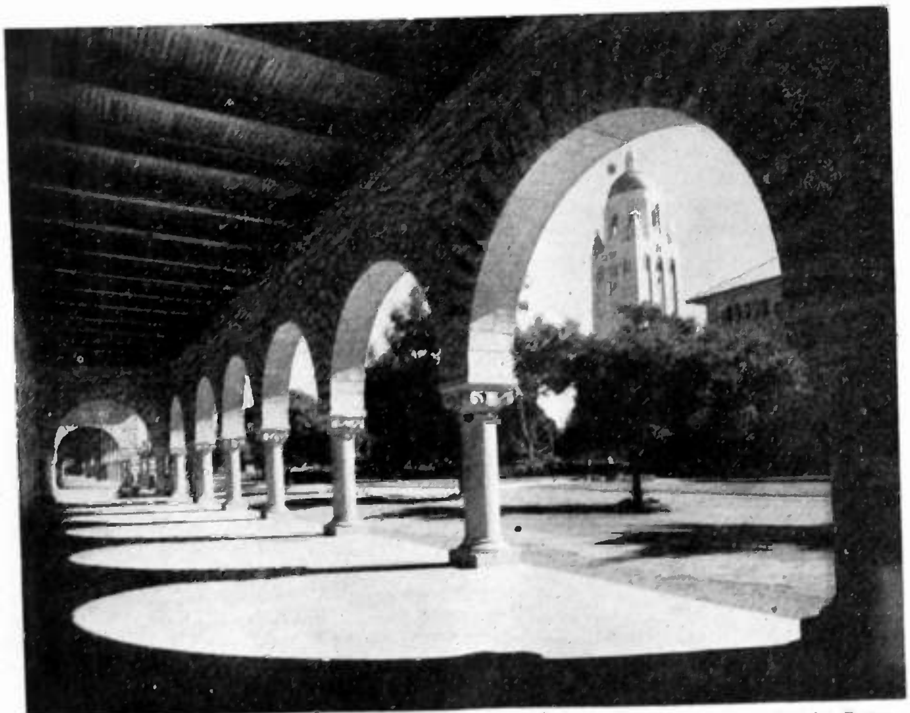
A. Moffett Field, Stanford University, and Hewlett-Packard Company.
B. Transoceanic Transmitter KWIX and KWID, San Francisco; and Eitel-McCullough Inc.

Convention Banquet

Saturday, September 27, 1947

Inspection Trips

C. University of California.



San Francisco Convention and Tourist Bureau

Stanford University, Showing Hoover War Library Through Arch

LADIES' PROGRAM

Wednesday, September 24, 1947

Registration—Wives and Children
Welcoming Tea by Institute

Thursday, September 25, 1947

Sight-seeing trip in San Francisco, Luncheon at famed Fishermans Wharf.

Friday, September, 26, 1947

Conducted visit through Gumps
Luncheon and broadcast, Sir Francis Drake Hotel
Informal trips and shopping tours about San Francisco
Convention Banquet.

In addition to the above, the United Air Lines will make available one of their most modern airplanes for a one-hour sight-seeing trip over San Francisco and the Bay area. Space will be limited and apportioned to visitors according to geographical location.

Memo to Members Acting as References

A Communication from the Membership Committee to All Members of the Institute

I.R.E. members have an important duty to perform whenever they are asked to act as reference for a new member, or to recommend a transfer to a higher grade. The Admissions Committee, acting as a jury for the Board of Directors, meets once a month and considers 100 applications for admission or transfer at each meeting. In the great majority of cases this committee has no way of deciding whether an applicant should be admitted or transferred except by studying the reference reports. Hence, the final responsibility for safeguarding the standards of the I.R.E. membership rests with members who supply references. The work of the Admissions Committee will be greatly facilitated if each reference indicates clearly and accurately in his report the full extent of his knowledge of the applicant's record and his professional standing.

For the guidance of members who are called upon to act as references, the following suggestions are offered:

1. References should have *direct knowledge* of the applicant's record and professional status. Occasionally references are selected by applicants whose records are not sufficiently well known to permit full and accurate statements. In such cases, the reference should not accept the responsibility of reporting on the applicant until he has verified any missing details with a third party who is more familiar with the applicant's record. In all cases the reference should indicate clearly in the space provided on the reference form the extent of his knowledge of, and association with, the candidate for membership or higher grade.

The applicant is expected to record his professional experience in sufficient detail to show that he has the necessary qualifications, particularly the time during which he was an engineer or scientist, and references are expected to confirm information of which they have knowledge.

The opinions of the references concerning the character of the applicant's work are most helpful to the Committee in deciding whether or not the applicant is qualified.

2. There is a natural tendency to recommend advancement to higher grades in borderline cases, not only as a personal favor to the applicant, but also because of the supposition that the Institute will benefit from increased membership in the higher grades. References should avoid recommending advancement in all cases where doubt exists. The higher grades of I.R.E. membership are badges of professional service and qualification as an engineer. Recommendations for advancement should be made only if the reference is *sure* the applicant is actively engaged in important work in radio or allied fields, or is supervising such work, and has been so engaged for the period of years specified by the Constitution. Each reference should review carefully the excerpts from the Constitution which are printed on the letter accompanying each reference report form.

3. References should encourage applicants who may approach them prior to submitting their applications to apply for the highest grade of membership for which the applicant is qualified.

4. References' comments should be *informative* and should be written with the understanding that the Admissions Committee has to base an important decision on the reference's report. In evaluating the applicant's record, the reference should draw a clear distinction between the performance of routine duties and the exercise of creative skill. Experience as radio station operator, in broadcast receiver service and repair or routine maintenance, is not generally accepted as qualifying for Member or Senior Member.

5. References should remember that action on an application cannot be completed until all references have replied, the Admissions Committee has acted, and notices prepared and sent by the Headquarters office. Applications for admission or transfer to the higher grades are seldom completed in less than three months. If the reference is interested in the action taken on a particular application, he should so indicate in a separate letter (not on the reference report form) addressed to the Headquarters office of the Institute. Such requests should be made only when knowledge of the action taken will serve a purpose other than mere curiosity, since the burden of correspondence is already heavy. References can assist materially in speeding action on applications by filling in and returning the sponsor form *promptly*. In those cases where the applicant is either very slightly known to the reference, or even unknown, a specific statement to that effect should be entered by the reference on the blank which should then be mailed back to headquarters immediately. The cases of many applicants are held up because references in the above category do not return the blanks promptly.

6. The space on the reference form for general comments should be filled out in all cases. Such comments are of particular value to the Admissions Committee. The space should be used for an accurate word-picture of the applicant, filling in gaps not covered by the standardized questions on the form. Whenever any of the latter questions are not answered, the reason should be stated in this space. Comments on the general character of the applicant (honesty, enthusiasm, industry, originality, and the like) are pertinent and should be made. But it should be remembered that these qualifications alone, in the absence of technical attainment, do not qualify for membership in the higher grades.

Suggestions for improvement in the operation of the reference system will be welcomed by the Membership Committee.

Electron Tube Conference

The Fifth Annual Electron Tube Conference, sponsored by the Electron Tube Committee of The Institute of Radio Engineers, was held at Syracuse University, Syracuse, New York, June 9 and 10, 1947. Attendance was about two hundred.

On the first day, the conference was opened with a welcoming address by Chancellor W. P. Tolley of Syracuse University. This was followed by a technical session entirely concerned with the beam traveling-wave tube, E. D. McArthur, chairman. The second session was a symposium on high-density space-charge problems, A. Nordsieck, chairman.

A stag banquet was held at the Hotel Syracuse on the evening of the first day. At the speakers' table were A. G. Clavier of Paris, R. Kompfner of Oxford; Dean Mitchell, Dean Bartlett, and Professor Fredrickson of Syracuse University; J. R. Pierce; H. W. Parker; W. R. G. Baker, president of the Institute and principal speaker; and G. D. O'Neill, conference chairman. The banquet was followed by informal gatherings with beer and singing.

About twenty-five women accompanied their husbands to Syracuse and enjoyed a program of local visits and bridge. Mrs. R. A. Galbraith was hostess.

The morning program of the second day consisted of a symposium on new microwave tube devices and signal-storage devices, L. Malter, chairman. At the conclusion of this session, four rump sessions were organized for the afternoon, some for the purpose of discussing problems brought up in the regular sessions. The principal topics were as follows: Noise and Oscillation Characteristics of Beam Traveling-Wave Tubes, J. A. Morton, chairman; Multi-Velocity Electron Streams, L. S. Nergaard, chairman; Magnetrons and Other Microwave Devices, G. R. Kilgore, chairman; Signal Storage Tubes, L. Malter, chairman.

The next I.R.E. Electron Tube Conference will be held June 28 and 29, 1948, at Cornell University, Ithaca, New York.

National Electronics Conference

The 1947 National Electronics Conference will be held at the Edgewater Beach Hotel, Chicago, Illinois, on November 3, 4, and 5, 1947. A program of between fifty and sixty technical papers, covering all phases of electronics, will feature engineers who are recognized authorities in their respective fields. The Institute of Radio Engineers is sponsor of one portion of this program. Another portion is being arranged by the Electronics Section of the American Institute of Electrical Engineers in connection with the A.I.E.E. Fall Meeting in Chicago. Exhibits of the latest in electronic equipment and developments are being planned by manufacturers.

Nationally-known speakers will address the banquet and the three luncheons, one of which is to be under the auspices of the I.R.E., while the A.I.E.E. will be in charge of another. As before, this Conference will serve to renew old acquaintances and make new ones among electronic engineers from all over the country.

New England Radio Engineering Meeting

The New England Radio Engineering Meeting, held May 17, 1947, at the Continental Hotel in Cambridge, Massachusetts, brought together the Boston Section and the Connecticut Valley Section of The Institute of Radio Engineers in a highly successful regional venture.

The Boston Section has suggested that Regional Meetings be held as a possible substitute for the Summer National Convention. The belief that such gatherings would be of maximum benefit to the membership was confirmed by the success of this meeting, which was attended by 606 registrants and New England exhibitors, and the North Atlantic Region is planning an annual affair.

Outstanding events were six technical papers; exhibits of thirty New England manufacturers; and the banquet, with Harold B. Richmond of General Radio Company the toastmaster, and William C. White of General Electric Company and George W. Bailey, I.R.E. executive secretary, the guest speakers. Mr. White presented a number of interesting microwave experiments under the title, "Radiation Without Frustration."

Many of the executive committee members of both Sections met with representatives from I.R.E. Headquarters and New England colleges to discuss the implementation of the regional representation plan and the Institute's Student activities

The New England Meeting was conducted by the following organization:

General Chairman	L. E. Packard
Co-Chairman	Dale Pollack
Papers Committee	D. B. Sinclair
Exhibits Committee	C. E. Worthen
Publicity Committee	J. M. Henry
Arrangements Committee	H. H. Dawes
Banquet Committee	J. G. Hildebrand
Treasurer	W. H. Radford

Titles, authors, and summaries of the technical papers presented were published on pages 386 and 387 of the April, 1947, issue of the PROCEEDINGS OF THE I.R.E.

TWO VIEWS OF EXHIBITS AT THE NEW ENGLAND RADIO ENGINEERING MEETING

BANQUET OF THE NEW ENGLAND RADIO ENGINEERING MEETING

Spring Technical Conference

CINCINNATI, OHIO, SATURDAY, MAY 3, 1947

The Spring Technical Conference held by the Cincinnati Section of The Institute of Radio Engineers on May 3, 1947, in Cincinnati, Ohio, was attended by more than 300 people.

Papers and speakers were selected with extreme care and scheduled in a morning and an afternoon session. Thirty minutes were allowed for presentation of each paper and ten minutes for discussion. Preprints were available for six out of the eight papers and were much appreciated.

Working models of television receivers were on demonstration during the Conference and a special program was furnished by W8XCT, the experimental television broadcasting transmitter of the Crosley Broadcasting Corporation. An inspection tour to the "Voice of America" transmitter in Bethany, Ohio, was arranged for Sunday, May 4.

The program of the Conference follows:

Television

MORNING SESSION

Chairman: R. J. Rockwell, The Crosley Broadcasting Corporation

1. "Antennas for Television Reception," Andrew Alford, Consulting Engineer.
2. "A New Approach to Television Input Circuits," Paul F. G. Holst, Crosley Division, Avco Manufacturing Corporation.
3. "Intermediate-Frequency Television Amplifier Design," Stuart Seeley, Radio Corporation of America.
4. "Television Receiver Synchronizing Circuits," Robert W. Sanders, Farnsworth Television and Radio Corporation.

Buffet Luncheon

AFTERNOON SESSION

Chairman: Professor W. C. Osterbrock, University of Cincinnati

1. Part I—"Cathode-Ray Tube Screens in Contact with Metal," Dr. C. S. Szegho, The Rauland Corporation.
   Part II—"Reflective and Refractive Optics for Projection Television Receivers," George K. Schnable, The Rauland Corporation.
2. "Inter-connecting Facilities for Television Broadcasting," W. E. Bloecker, American Telephone and Telegraph Company.
3. "The Future of Color in Television," Donald G. Fink, McGraw-Hill Publishing Company, Inc.

Cocktail Party

BANQUET

Presiding: L. M. Clement, Director of Research Engineering, Crosley Division, Avco Manufacturing Corporation

Speaker: K. W. Jarvis, Consultant

Don Foster

CHAIRMAN AND SPEAKERS AT THE MORNING SESSION OF THE CINCINNATI SPRING TECHNICAL CONFERENCE

Left to right: R. J. Rockwell, Andrew Alford, P. F. G. Holst, R. W. Sanders, Stuart Seeley

Don Foster

CHAIRMAN AND SPEAKERS AT THE AFTERNOON SESSION OF THE CONFERENCE

Left to right: C. S. Szegho, G. K. Schnable, W. C. Osterbrock, W. E. Bloecker, D. G. Fink

Don Foster

LEWIS M. CLEMENT ADDRESSING THE BANQUET

Left to right at the speakers' table are: Carl Gieringer, John Jordan, Kenneth Jarvis, Mr. Clement, John Reid, W. C. Osterbrock, R. J. Rockwell.

Minutes of Technical Committee Meetings

The following brief abstracts of I.R.E. technical committee minutes are intended to keep the membership informed as to the activities of such groups. Members having views or proposals of interest to the committees, or desiring possibly available information from them, should write directly to the chairman of the particular committee, sending a copy of the letter to Mr. Laurence G. Cumming, Technical Secretary, The Institute of Radio Engineers, 1 East 79 Street, New York 21, N. Y.

Railroad and Vehicular Communication

Date......April 18, 1947
Place......Hotel Stevens, Chicago, Illinois
Chairman..D. E. Noble

Present

D. E. Noble, *Chairman*
L. J. Biskner — W. A. Harris
G. M. Brown — G. H. Teommey
W. R. Young

The purpose of the meeting was to prepare definitions and test methods for various receiver and transmitter characteristics. The Sensitivity draft, prepared by Mr. G. M. Brown, and the Spurious Response draft, prepared by Mr. W. R. Young, were considered by the committee and approved with minor modifications. The committee as a whole prepared definitions and methods of measurements. The entire committee was requested to consider these definitions and methods and submit approval or suggestions for future modifications to Mr. Brown who is replacing Mr. Noble as Chairman.

Industrial Electronics

Date.......March 6, 1947
Place.......Hotel Commodore, New York, N. Y.
Chairman...H. C. Gillespie

Present

H. C. Gillespie, *Chairman*
G. P. Bosomworth — Eugene Mittelmann
G. H. Fett — F. W. Priebe
C. W. Frick — Julius Weinberger

A study of methods of measuring radiation above 200 megacycles was recommended as a project for the Research Committee. After some discussion, the committee decided that the field of high-frequency heating demanded early attention, regardless of other fields which might be brought within its scope. It was thought that the Institute might properly concern itself with the problem of interference with the various communications services by radiations from high-frequency generating equipment. The work of RTPB, NEMA, and A.I.E.E. committees on this subject was reviewed and the possibility of adding to their findings discussed. To obtain data on the tolerable interference levels, it was suggested that representatives be added to the committee to represent the various services. The Chairman of the committee should, it was decided, attend the meetings of the A.I.E.E. subcommittee on electronic heating to avoid duplication of its efforts.

Radio Transmitters

Date...............May 19, 1947
Place...............I.R.E. Headquarters, New York, N. Y.
Chairman...........E. A. Laport

Present

E. A. Laport, *Chairman*
L. T. Bird — A. E. Kerwien
M. E. Briggs — L. A. Looney
W. J. Cronin — Robert Serrell
I. R. Weir

The Subcommittees were reviewed and discussed briefly. It was decided to continue the subcommittee organization set up last year with Messrs. Weir, Serrell, and Brunetti as Chairmen. Mr. L. T. Bird accepted chairmanship of the Subcommittee on Frequency-Modulation Transmitters. Messrs. Knox and Punchard of Montreal are appointed to this group so that they can work as a geographical unit with such others as they may appoint from the Montreal Section. Copies of proposed definitions were given to all members present for study and comment before the next meeting.

Radio Wave Propagation and Utilization

Date...............June 2, 1947
Place...............I.R.E. Headquarters, New York, N. Y.
Chairman...........S. A. Schelkunoff

Present

S. A. Schelkunoff, *Chairman*
Stuart Bailey — M. C. Gray
C. R. Burrows — D. E. Kerr
T. J. Carroll — K. A. Norton
L. G. Cumming — George Sinclair
H. W. Wells

Dr. Carroll's list of Definitions of Recommended Terms on Tropospheric Propagation was discussed by the Committee. A letter dated May 26, 1947, received by the Chairman from Mr. J. C. Schelleng, with comments on the Definitions, was circulated. There was some discussion on the meanings of the terms "ground wave" and "tropospheric wave." The matter was referred to a Subcommittee. The list of Definitions on Ionosphere Terms, prepared by Mr. Wells, was discussed by the Committee. Dr. Schelkunoff appointed some members of the Committee to prepare material for the Annual Review.

SUBCOMMITTEES

Color Television

Date...............April 24, 1947
Place...............I.R.E. Headquarters, New York, N. Y.
Chairman...........H. T. Lyman

Present

H. T. Lyman, *Chairman*
F. J. Buigley — R. D. Kell
R. B. Dome — N. H. Young, Jr.

Individual reports to be prepared by contributing individuals and companies were to be submitted to the Chairman by May 1, 1947, who would edit the material and complete the finished report. A list of definitions submitted by the Chairman was reviewed by the committee and corrections made and agreed upon.

Power-Output High-Vacuum Tubes

Date...............April 25, 1947
Place...............I.R.E. Headquarters, New York, N. Y.
Chairman...........I. E. Mouromtseff

Present

I. E. Mouromtseff, *Chairman*
C. E. Fay — E. E. Spitzer
M. S. Glass — C. M. Wheeler
H. E. Mendenhall — A. K. Wing, Jr.

Emission Tests as corrected by Professor Reich was reviewed. The Chairman announced that Sections 4.0–4.3 had been returned for revision with the general comment that the definitions should be separated from methods of test. It was requested that members submit proposals for the revised sections. Messrs. Mouromtseff and Fay will confer on this matter. Mr. Wheeler will prepare an outline for work on definitions and methods of test for magnetrons. It was suggested that the attention of the parent committee be called to the fact that this subcommittee's proposed Section 6 had not yet been considered. It was requested that members submit suggestions regarding further work appropriate for this subcommittee.

Electron Tube Conference

Date...............May 9, 1947
Place...............I.R.E. Headquarters, New York, N. Y.
Chairman...........G. D. O'Neill

Present

G. D. O'Neill, *Chairman*
R. A. Galbraith — I. E. Mouromtseff
Louis Malter — L. S. Nergaard
E. D. McArthur — S. G. Schaffner

Mr. McArthur reported that Dr. W. R. G. Baker would attend the banquet as a guest. Professor Galbraith outlined a detailed entertainment program for the ladies who would attend. Dr. Nergaard reported that 350 invitations were mailed. Mr. Morton submitted the schedule of subjects, chairmen, and subject leaders. Dr. William P. Tolley would welcome the Conference at Marshall Hall at the beginning of the first session. Mr. G. D. O'Neill would give a short introductory talk.

Sections

Chairman		Secretary
P. H. Herndon c/o Dept. in charge of Federal Communication 411 Federal Annex Atlanta, Ga.	ATLANTA September 19	M. S. Alexander 2289 Memorial Dr., S.E. Atlanta, Ga.
H. L. Spencer Associated Consultants 18 E. Lexington Baltimore 2, Md.	BALTIMORE	G. P. Houston, 3rd 3000 Manhattan Ave. Baltimore 15, Md.
W. H. Radford Massachusetts Institute of Technology Cambridge, Mass.	BOSTON	A. G. Bousquet General Radio Co. 275 Massachusetts Ave. Cambridge 39, Mass.
A. T. Consentino San Martin 379 Buenos Aires, Argentina	BUENOS AIRES	N. C. Cutler San Martin 379 Buenos Aires, Argentina
R. G. Rowe 8237 Witkop Avenue Niagara Falls, N. Y.	BUFFALO-NIAGARA September 17	R. F. Blinzler 558 Crescent Ave. Buffalo 14, N. Y.
J. A. Green Collins Radio Co. Cedar Rapids, Iowa	CEDAR RAPIDS	Arthur Wulfsburg Collins Radio Co. Cedar Rapids, Iowa
Karl Kramer Jensen Radio Mfg. Co. 6601 S. Laramie St. Chicago 38, Ill.	CHICAGO September 19	D. G. Haines Hytron Radio and Electronics Corp. 4000 W. North Ave. Chicago 39, Ill.
J. F. Jordan Baldwin Piano Co. 1801 Gilbert Ave. Cincinnati, Ohio	CINCINNATI	F. Wissel Crosley Corporation 1329 Arlington St. Cincinnati, Ohio
W. G. Hutton R.R. 3 Brecksville, Ohio	CLEVELAND September 25	H. D. Seielstad 1678 Chesterland Ave. Lakewood 7, Ohio
C. J. Emmons 158 E. Como Ave. Columbus 2, Ohio	COLUMBUS October 10	L. B. Lamp 846 Berkeley Rd. Columbus 5, Ohio
Dale Pollack 352 Pequot Ave. New London, Conn.	CONNECTICUT VALLEY	R. F. Blackburn 62 Salem Rd. Manchester, Conn.
Robert Broding 2921 Kingston Dallas, Texas	DALLAS-FT. WORTH	A. S. LeVelle 308 S. Akard St. Dallas 2, Texas
E. L. Adams Miami Valley Broadcasting Corp. Dayton 1, Ohio	DAYTON	George Rappaport 132 E. Court Harshman Homes Dayton 3, Ohio
P. O. Frincke 219 S. Kenwood St. Royal Oak, Mich.	DETROIT	Charles Kocher 17186 Sioux Rd. Detroit 24, Mich.
N. J. Reitz Sylvania Electric Products, Inc. Emporium, Pa.	EMPORIUM	A. W. Peterson Sylvania Electric Products, Inc. Emporium, Pa.
F. M. Austin 3103 Amherst St. Houston, Texas	HOUSTON	C. V. Clarke, Jr. Box 907 Paradise, Texas
H. I. Metz Civil Aeronautics Administration 84 Marietta St., NW Atlanta, Ga.	INDIANAPOLIS	M. G. Beier 3930 Guilford Ave. Indianapolis 5, Ind.
C. L. Omer Midwest Eng. Devel. Co. Inc. 3543 Broadway Kansas City 2, Mo.	KANSAS CITY	Mrs. G. L. Curtis 6003 El Monte Mission, Kansas
R. C. Dearle Dept. of Physics University of Western Ontario London, Ont., Canada	LONDON, ONTARIO	E. H. Tull 14 Erie Ave. London, Ont., Canada
C. W. Mason 141 N. Vermont Ave. Los Angeles 4, Calif.	LOS ANGELES September 16	Bernard Walley RCA Victor Division 420 S. San Pedro St. Los Angeles 13, Calif.
L. W. Butler 3019 N. 90 St. Milwaukee 13, Wis.	MILWAUKEE	E. T. Sherwood 9157 N. Tennyson Dr. Milwaukee, Wis.
R. R. Desaulniers Canadian Marconi Co. 211 St. Sacrement St. Montreal, P.Q., Canada	MONTREAL, QUEBEC	R. Matthews Federal Mfg. Co. 9600 St. Lawrence Blvd. Montreal 14, P.Q., Canada
J. E. Shepherd 111 Courtenay Rd. Hempstead, L. I., N. Y.	NEW YORK October 1	I. G. Easton General Radio Co. 90 West Street New York 6, N. Y.
L. R. Quarles University of Virginia Charlottesville, Va.	NORTH CAROLINA-VIRGINIA	J. T. Orth 4101 Fort Ave. Lynchburg, Va.
K. A. Mackinnon Box 542 Ottawa, Ont. Canada	OTTAWA, ONTARIO September 18	D. A. G. Waldock National Defense Headquarters New Army Building Ottawa, Ont., Canada
P. M. Craig 342 Hewitt Rd. Wyncote, Pa.	PHILADELPHIA	J. T. Brothers Philco Radio and Television Tioga and C Sts. Philadelphia 34, Pa.
E. M. Williams Electrical Engineering Dept. Carnegie Institute of Tech. Pittsburgh 13, Pa.	PITTSBURGH OCTOBER 13	E. W. Marlow 560 S. Trenton Ave. Wilkinburgh PO Pittsburgh 21, Pa.
Francis McCann 4415 N.E. 81 St. Portland 13, Ore.	PORTLAND	A. E. Richmond Box 441 Portland 7, Ore.
N. W. Mather Dept. of Elec. Engineering Princeton University Princeton, N. J.	PRINCETON	A. E. Harrison Dept. of Elec. Engineering Princeton University Princeton, N. J.
A. E. Newlon Stromberg-Carlson Co. Rochester 3, N. Y.	ROCHESTER	J. A. Rodgers Huntington Hills Rochester, N. Y.
E. S. Naschke 1073-57 St. Sacramento 16, Calif.	SACRAMENTO	G. W. Barnes 1333 Weller Way Sacramento, Calif.
R. L. Coe Radio Station KSD Post Dispatch Bldg. St. Louis 1, Mo.	ST. LOUIS	N. J. Zehr Radio Station KWK Hotel Chase St. Louis 8, Mo.
Rawson Bennett U. S. Navy Electronics Laboratory San Diego 52, Calif.	SAN DIEGO October 7	C. N. Tirrell U. S. Navy Electronics Laboratory San Diego 52, Calif.
W. J. Barclay 955 N. California Ave. Palo Alto, Calif.	SAN FRANCISCO	F. R. Brace 955 Jones San Francisco 9, Calif.
J. F. Johnson 2626 Second Ave. Seattle 1, Wash.	SEATTLE October 9	J. M. Patterson 7200—28 N. W. Seattle 7, Wash.
C. A. Priest 314 Hurlburt Rd. Syracuse, N. Y.	SYRACUSE	R. E. Moe General Electric Co. Syracuse, N. Y.
H. S. Dawson Canadian Association of Broadcasters 80 Richmond St., W. Toronto, Ont., Canada	TORONTO, ONTARIO	C. J. Bridgland Canadian National Telegraph 347 Bay St. Toronto, Ont., Canada
O. H. Schuck 4711 Dupont Ave. S. Minneapolis 9, Minn.	TWIN CITIES	B. E. Montgomery Engineering Department Northwest Airlines Saint Paul, Minn.
L. C. Smeby 820—13 St. N. W. Washington 5, D. C.	WASHINGTON	T. J. Carroll National Bureau of Standards Washington, D. C.
L. N. Persio Radio Station WRAK Williamsport 1, Pa.	WILLIAMSPORT	R. G. Petts Sylvania Electric Products, Inc. 1004 Cherry St. Montoursville, Pa.

Sections

SUBSECTIONS

Chairman		Secretary
J. D. Schantz Farnsworth Television and Radio Company 3700 E. Pontiac St. Fort Wayne, Ind.	FORT WAYNE (Chicago Subsection)	S. J. Harris Farnsworth Television and Radio Co. 3702 E. Pontiac Fort Wayne 1, Ind.
F. A. O. Banks 81 Troy St. Kitchener, Ont., Canada	HAMILTON (Toronto Subsection)	E. Ruse 195 Ferguson Ave., S. Hamilton, Ont., Canada
K. G. Jansky Bell Telephone Laboratories Box 107 Red Bank, N. J.	MONMOUTH (New York Subsection)	L. E. Hunt Bell Telephone Laboratories Deal, N. J.
A. R. Kahn Electro-Voice, Inc. Buchanan, Mich.	SOUTH BEND (Chicago Subsection)	A. M. Wiggins Electro-Voice, Inc. Buchanan, Mich.
W. M. Stringfellow Radio Station WSPD 136 Huron Street Toledo 4, Ohio	TOLEDO Detroit Subsection	M. W. Keck 2231 Oak Grove Place Toledo 12, Ohio
W. A. Cole 323 Broadway Ave. Winnipeg, Manit., Canada	WINNIPEG (Toronto Subsection)	C. E. Trembley Canadian Marconi Co. Main Street Winnipeg, Manit., Canada

I.R.E. People

Jennings B. Dow

Jennings B. Dow (M'26–F'42), consulting engineer of Washington, D. C., was recently elected vice-president of the Hazeltine Electronics Corporation.

Born at Bowling Green, Ohio, on January 2, 1897, he was graduated from the United States Naval Academy in 1919 with the B.S. degree, and received the M.S. degree in electrical engineering from Harvard University in 1926.

On January 1, 1947, he retired from the Navy with the rank of commander, having served in many capacities since 1919. He was a radio and communications officer on various ships, a member of the staff of commander of battleship divisions from 1922 to 1924, Asiatic Fleet radio officer from 1926 to 1927, and radio matériel officer in the Navy Yard at Cavite, Philippine Islands, from 1927 to 1929. He went to the radio division of the Bureau of Engineering in 1930, where he served as division head from 1938 to 1939.

In 1940, Commander Dow became director of the Navy Radio and Sound Laboratory at San Diego, California, and was sent to Great Britain on special duty as observer of radio and radar in 1940 and 1941. Upon his return he was made head of the radio division of the Bureau of Ships, a post he held until January, 1945. At that time the Bureau's electronics division was established, with Commander Dow its director.

George C. Southworth

George C. Southworth (M'26–F'41) was recently awarded the Stuart Ballantine medal by the Franklin Institute "in consideration of his pioneer work in electromagnetic and microwave technique, a material contribution to the development of new systems of communication and reconnaissance."

Born at Little Cooley, Pennsylvania, on August 24, 1890, Dr. Southworth received the bachelor's and master's degrees from Grove City College.

After some advanced work at Columbia University and over a year at the Bureau of Standards, he became an instructor and assistant professor of physics at Yale University. Here he continued for the next five years, completing at the same time the requirements for a Ph.D. degree in physics.

In 1923 he became a staff member of the American Telephone and Telegraph Company, later transferring to the Bell Telephone Laboratories where he has specialized in communications research.

Dr. Southworth is a Fellow of the American Physical Society and the American Association for the Advancement of Science.

Underwood and Underwood

George C. Southworth

P. J. Selgin

P. J. Selgin (M'45), thirty-five-year old expert in high-frequency radiation and electronics, has been appointed to the staff of the National Bureau of Standards where he will work on the development of electronic ordnance for the military services in the Ordnance Development Division.

Dr. Selgin graduated from the Royal Engineering School of Milan with the degree of doctor of electrical engineering in 1933. He came to the United States in 1935 to continue the study of vacuum-tube theory at Harvard University, returning to Italy in 1936 to head the testing and control department of Fivre, manufacturers of radio tubes under Radio Corporation of America licence in Italy. The following year he joined the staff of the Italian associate of the International Telephone and Telegraph Company in Milan, heading a group of technicians formed to design special carrier telephony equipment.

In 1939, Dr. Selgin moved permanently to the United States, and obtained the S.M. degree in communication engineering from Harvard. He taught physics at the Newark College of Engineering in 1941, and electrical engineering and electronics at Brooklyn Polytechnic Institute in 1942 and 1943. During the war, he was active in the government agencies' specialized war training programs.

I.R.E. People

James F. White

James F. White (S'43–A'45) has been appointed assistant sales manager of Andrew Company, Chicago, Illinois, manufacturers of transmission-line and antenna equipment. Mr. White, who received the B.E. degree from Yale University in 1940, has been associated with the New Haven Railroad, the W. L. Maxson Corporation, and Hazeltine Corporation in engineering capacities. During the war he served as radar officer aboard an aircraft carrier and participated with the Seventh Fleet in the invasions of Palau, Leyte, Mindoro, and Luzon. Later, he was appointed project engineer at the Massachusetts Institute of Technology Radiation Laboratories, and remained in this position until placed on inactive duty by the Navy.

George F. Metcalf

George F. Metcalf (A'34–M'38–F'42) was decorated in Washington, D. C., recently by Lord Inverchapel, British Ambassador, for his wartime contributions to airborne radar. Mr. Metcalf, who headed the Aircraft Radar Laboratories at Wright Field, Ohio, while he was in the Service, was appointed an Honorary Officer of the Military Division of the Most Excellent Order of the British Empire, an honor conferred by King George VI.

The citation accompanying the decoration read: "Colonel Metcalf was associated with airborne radar, first in the War Department and later at Aircraft Radar Laboratories. Due to his enthusiasm and engineering appreciation, collaboration on detailed aspects of development of design of airborne radar equipment was effective in making an important contribution to the air war."

Mr. Metcalf was born on December 7, 1906, at Milwaukee, Wisconsin. He received the B.S. degree from Purdue University in 1928, and that same year took the General Electric Company's student engineering course. From 1929 to 1931 he was in the research laboratory of that company and was later in the vacuum-tube engineering department. He is now manager of their Electronics Laboratory at Syracuse, N. Y.

Ellery W. Stone

Ellery W. Stone, U.S.N.R., (A'14–M'16–F'24) has been elected a vice-president of the International Telephone and Telegraph Corporation. Admiral Stone has just returned to this country following a distinguished war career during the past four years in the Mediterranean theater. Most recently he served as Chief Commissioner of the Allied Commission for Italy with headquarters in Rome.

A native of Oakland, California, Admiral Stone attended the University of California where he specialized in electrical and radio engineering. He was a pioneer in the radiotelegraph field and organized the Federal Telegraph Company on the Pacific Coast, which company was later acquired by I. T. and T. and became the Mackay Radio Company of California. He successively held a variety of executive posts with I. T. and T. including the executive vice-presidency of Mackay Radio, vice-president of All America Cables and Radio, and he was also in charge of all I. T. and T.'s radio operations. He joined the Postal Telegraph Company in 1937 as vice-president and was elected president in 1942. On May 24, 1943, he was recalled to active duty with the United States Navy.

In addition to his various campaign decorations during World Wars I and II, including the Naval Reserve Medal with two bronze stars, Admiral Stone also holds both the United States Navy and the United States Army Distinguished Service Medals. He is a Knight Commander of the British Empire, a Knight of the Grand Cross of St. Maurice and St. Lazarus (Italy), a Grand Officer of the Crown of Italy, and a Knight of the Grand Cross of San Marino.

Fabian Bachrach

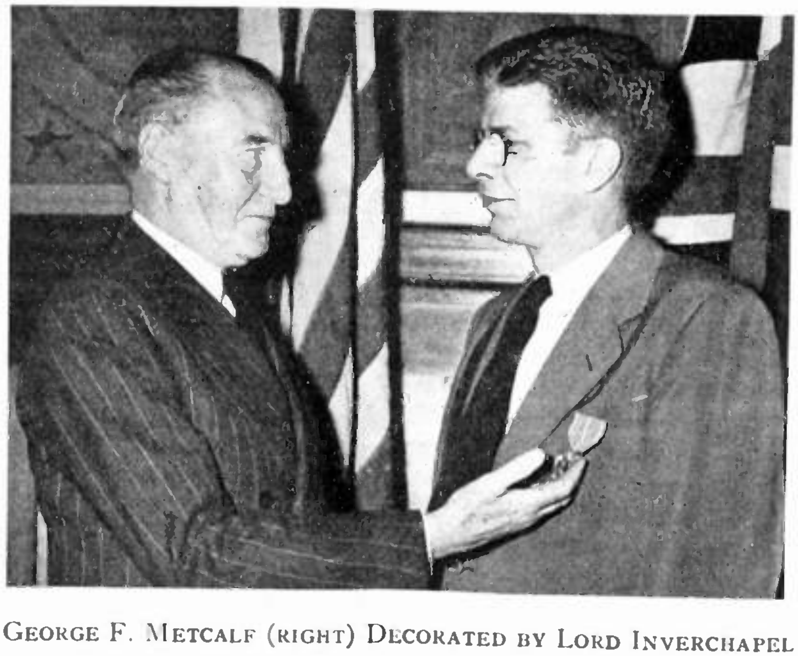
Ellery W. Stone

A. M. Wiggins

A. M. Wiggins (A'42), research director of Electro-Voice, Inc., has recently returned from a survey of electroacoustic developments in Germany.

During his stay, he toured the country, visiting factories and laboratories, to check on various phases of German progress in this field.

Prior to his present affiliation, Mr. Wiggins had done research work with Seismic Explorations, Inc., and the Radio Corporation of America. He is a member of Sigma Xi and the Acoustical Society of America, and has been a contributor to the Proceedings of the I.R.E.



George F. Metcalf (right) Decorated by Lord Inverchapel

Books

Proceedings of the National Electronics Conference, Volume II, edited by R. E. Beam, assisted by R. R. Buss, T. J. Higgins, R. R. Johnson, E. W. Kimbark, and A. H. Wing, Jr.

Published (1947) by the National Electronics Conference, Inc. Available (Vols. 1 and 2) from R. E. Beam, Secretary (for 1947), c/o Electrical Engineering Department, Northwestern University, Evanston, Illinois. 741 pages + x pages. 488 figures. 6×9 inches. Price, $3.50.

Since the contents of this book are fairly obvious, it being the record of the technical papers delivered at the Second National Electronics Conference, a statistical approach is the best way to describe the volume.

It is a book of almost 750 pages, its format is 6 by 9 inches, and there are 66 papers (most are complete but some in abstract only), divided into 16 general divisions as follows: General Papers, Television, Antennas and Wave Propagation, Infrared and Microwave Systems, Spectroscopy and Medical Applications, Industrial Applications, Air Navigation Systems, Theoretical Developments, Electronic Instrumentation, Induction and Dielectric Heating, Radio Relay Systems, Frequency Modulation, Recording and Facsimile, Microwave Generators, Mobile Radio Communication, and Nuclear Physics.

The volume also contains biographical sketches of the authors, a catalog of the registrants at the conference, a catalog of the exhibitors, list of conference committees, etc.

The few typographical errors noted by the reviewer are such that little confusion will be created, and in a book of such magnitude and produced so soon after the event it is to the credit of the editors that there are not more of them. The format is convenient, the paper stock good, the articles easy to read.

KEITH HENNEY
Electronics
McGraw-Hill Publishing Co., Inc.
New York, N. Y.

The Physical Principles of Wave-Guide Transmission and Antenna Systems, by W. H. Watson

Published (1947) by Oxford University Press, 411 Fifth Avenue, New York 11, N. Y. 207 pages+1-page index+xiv pages. 96 illustrations. 6¼×9¼ inches. Price, $7.00.

This book deals with the physical properties of wave guides as a practical means of transmission and radiation of microwaves. The author has taken active part in the research program on radar under the National Research Council of Canada during the war, and made many fundamental contributions towards the art of radar design. This book represents a documentary report covering mostly the theoretical work on wave guides and slots done in Canada similar to the forthcoming Radiation Laboratory series, and should be viewed as such.

The first three chapters deal with conventional transmission-line theory as applied to simple wave guides and microwave measurement techniques. The impedance concept and matrix algebra are introduced at the outset. Multimode propagation and the discontinuity and excitation in rectangular wave guides are discussed in the next two chapters. Chapters VI and VII cover the properties of slots in wave guides and the applications to wave-guide arrays. Most of the work here was originally carried out by the author at McGill University. Because of the vast ground which the author covers, most of the results are given without proofs. The last chapter, on Field Representations, treats in sufficient detail the general methods used for the mathematical analysis of electromagnetic problems associated with wave guides. Many formulas are given for design purposes. It is not particularly suitable for classroom use on account of the lack of proofs of many "laws" and "principles" dealt with in the text.

The material is systematically developed, leading gradually toward the subject of wave-guide arrays. As a whole, the book is easily readable, despite the fact that it was written by a theoretical physicist for engineers.

L. J. CHU
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Television Techniques, by Hoyland Bettinger

Published (1947) by Harper and Brothers, 49 East 33rd Street, New York 16, N. Y. 229 pages+7-page index+ix pages. 47 illustrations. 5¼×8¼ inches. Price, $5.00.

In "Television Techniques" Mr. Bettinger has prepared a manual covering television operations from the basic technical system to the finished program. The basic technical system is described in simple terms with line illustrations, and is written to provide program personnel with some working knowledge of technical equipment. The text deals mainly with production techniques and problems, and these are treated with great detail.

The book should appeal to sound broadcasters and beginners in television, and be of real value to the small station operator who is planning to get into the business. For such readers this publication will be a good text book and will provide an understanding of the complex problems to be met in producing a finished program. The outline of a productions preparation is thorough and, if absorbed and used, may eliminate many of the pitfalls that will beset the path of new television producers.

The information presented is basic and clear, but in its reading requires considerable checking with drawings and illustrations.

While there will be differences of opinion regarding some of Mr. Bettinger's statements on lighting, the book is recommended as a contribution to television programming and production.

O. B. HANSON
National Broadcasting Company,
New York 20, New York

Guide to the Literature of Mathematics and Physics, by Nathan Greer Parke III

Published (1947) by McGraw Hill Book Company, 330 W. 42 Street, New York 18, N. Y. 178 pages+27-page index+xv pages. 8 figures. 6×9 inches. Price, $5.00.

This book has been written to provide information and guidance for students, scientists, engineers, and librarians who are desirous of obtaining a general acquaintance with the subject matter of mathematics and physics, or who seek information relevant to definite research problems.

The first part of the book includes chapters on the general principles of reading and study and the methods appropriate for successful literature search. The author, who is a member of the faculty of the Massachusetts Institute of Technology, has evidently in mind the direction of college students in methods of approach to research problems and in gaining experience in independent study. Very complete information is provided regarding sources useful for orientation, such as dictionaries, encyclopedias, and handbooks, and methods of library classification are discussed sufficiently to give aid in finding material in the special case of a definite research problem. With respect to the wide field of periodical literature, attention is paid to the abstract journals and indices of classified articles.

Part II of the book, which deals with the literature in particular, is a list of some 2300 titles of books, arranged under 150 subject headings, with an introductory descriptive paragraph for each heading. The list of text-books can, naturally, hardly be all-inclusive. The reader, expert in a restricted branch of research, will of course note omissions in his own subject. However, the titles included give a judicious coverage of a wide variety of branches of mathematical and physical knowledge. In this list are included the most recent publications, not only of books in English, but in French and German also.

The whole work shows much thoroughness and attention to detail. It should be most helpful in directing the study and research of students in these branches.

FREDERICK W. GROVER
Union College
Schenectady, N. Y.

Books

An Introduction to Engineering Plastics, by D. Warburton Brown and Wilbur T. Harris

Published (1947) by Murray Hill Books, Inc., 252 Madison Avenue, New York 16, N. Y. 256 pages+viii pages+6-page index+10-page appendix. 153 figures. 6×9 inches. Price, $4.00.

This is a new and up-to-date book that presents in a clear and concise manner, aided by many useful tables and curves, the specific information and data required by engineers, industrial designers, manufacturers, and technicians. It covers plastic materials: their elementary chemistry and methods of manufacture; their physical properties, including fatigue and creep; and their test methods and specifications. In addition to the usual applications for plastics, there are chapters on gears, bearings, transparent models, metal coatings for plastics, machining, adhesives, laminations, high-frequency heating, welding, fillers, mold design, and plant equipment. Formulations and specific methods are clearly explained. These subjects are covered adequately for the purpose of the book and there are many tables giving a wide range of data.

It is to be regretted that the halftones are not better, but this is a fault in the printing.

A topic that is not covered is service testing which brings out the effects of organic deterioration induced by humidity, light, and chemical instability. Perhaps this is expecting too much from an elementary treatment.

This is an excellent book for an introduction to the engineering of plastics.

John R. Townsend
Bell Telephone Laboratories
New York, N. Y.

Most-Often-Needed 1947 Radio Diagrams and Servicing Information, compiled by M. N. Beitman

Published (1947) by Supreme Publications, 9 South Kedzie Avenue, Chicago 12, Illinois. 189 pages+3-page index. 347 figures. 8½×11 inches. Price, $2.00.

This book contains an accumulation of varied wiring diagrams and service information on radio-receiver models of approximately forty-one manufacturers, produced during the latter part of 1946 and early 1947.

Although not complete in its coverage, some models are included from most of the major manufacturers. This information varies in completeness from simple wiring diagrams to alignment procedures and voltage readings, with specific service information, such as location of coil lugs and wire color, dial-cord arrangement, and parts lists, on some models.

In a publication of this type there always seems to be incompleteness, as all types of receivers made by the manufacturer cannot be listed, and a gap develops, thus limiting its usefulness. It is to be taken into consideration that the limited size and price of this book, and the amount of information supplied by the manufacturer, contribute to this shortcoming.

For the small service shop or for the serviceman who is unable to obtain information from the manufacturer of the models listed, it will be of assistance.

Because the binding on this book is permanent, there has been no provision for loose-leaf supplements of service information of the new radio receivers as they appear on the market. It is the reviewer's opinion that if this were prepared in loose-leaf form, it would be more valuable.

Lewis M. Clement
The Crosley Corporation
Cincinnati, Ohio

Electric Contacts, by Ragnar Holm

Published (1946) by Almquist and Wiksells Akademiska Handbocker, Hego Gebers Forlag, Stockholm, Sweden. 359 pages+31 pages of indexes+8 pages of appendixes+xvi pages. 141 figures. 6½×9½ inches. Price, $12.50.

"Electric Contacts" is a revised and re-edited material of the 1941 publication of "Die technische Physik der Elektrischer Kontake." This book is a comprehensive and authoritative contribution to the subject of electric contacts, and will be useful to both the producers and the users of electric contacts.

The contents cover the physical principles of contact phenomena and related formulas and matter constants for contacts as used on circuit breakers, relays, terminals, microphones, current collectors, and commutators. The handling of large currents—100 amperes and above—and the frictional electrification and thermoelectric effects caused by the junction of unlike materials are omitted. The author has been intensely interested in this subject for a number of years, and the book is based upon an immense amount of data which he has accumulated during this period.

The subject is treated under three general divisions, namely: stationary contents, sliding contacts, and electric phenomena in switching contacts. In the first division, the author discusses the constriction through which the current must flow when it is conducted from one metal conductor to another, and the various characteristics of this constriction under the conditions of pressure, hardness, temperature, and tarnish. Many formulas are developed to show how these factors can be correlated and the performance of various contact materials under assumed conditions be anticipated.

Sliding contacts, the second subject division, have many of the same phenomena as do the stationary contacts described in the first subject division, but they also have mechanical friction which, in turn, affects the contact surfaces, such as the tarnishes and the epilaments. The subject of brushes for commutators has received much attention by development laboratories, and the author points out the basic principles of current conduction between a carbon brush and a copper ring or commutator, together with the rates of wear with and without current.

The third subject division, the electric phenomena in switching contacts, is limited to short arcs or a low-energy circuit, the discharge of which can be absorbed by a medium size capacitor. Real power interruption is not discussed at any length. The short-arc phenomena is discussed under three heads: corona, glow discharge, and the arc. It is shown how the discharge builds up and reaches the arc stage, and also the characteristics of these several stages, including the extinguishing of the arc by the use of capacitance. The usual arc duration is then discussed with its resultant oxidation, erosion, and material transfer, and it is shown how this erosion or wear can be greatly reduced by the use of the right-size discharge capacitors. Formulas are developed which can be used for determining the size of capacitors which will result in a minimum of material transfer or wear on frequently operated contacts.

The reader can learn much from this book without delving into the extensive mathematics which the author uses, but if he is both inclined and has the required background for following the entire context, he will find the book very valuable. Therefore, either type of reader who is interested in electric contacts will find this unusual book well worth the effort.

B. W. Jones
General Electric Company
Schenectady, N. Y.

1945–1947 Post-War Automatic Record Changers and Servicing Information, compiled by M. N. Beitman

Published (1947) by Supreme Publications, 9 South Kedzie Avenue, Chicago 12, Illinois. 144 pages. 232 figures. 8½×11 inches. Price, $1.50.

This manual is a compilation of the services notes on automatic record changers issued by various radio set manufacturers. About a dozen set manufacturers are represented, but all the types of record changers used by a given manufacturer are not necessarily included. Furthermore, the manual covers only changers used in regularly manufactured assemblies and does not cover those most commonly available as component parts in the retail market.

The accuracy, completeness, and clarity of the information is a function of the original source material which has been duplicated more or less verbatim. It varies from the minimum of operating instructions to very complete maintenance and adjustment data. The presentation ranges from poor to excellent, as do the illustrations and the type face. If the service man finds that the contents of the manual cover those machines he frequently encounters, it may appeal to him as a conveniently bound collection of manufacturers' service notes.

Howard A. Chinn
Columbia Broadcasting System
New York, 22 N. Y.

Officers, Philadelphia Section—May 1946-May 1947

Samuel Gubin

Chairman

Samuel Gubin was born on July 28, 1907, at Sebastopol, Russia. He received the B.S. degree in 1929 and the M.S. degree in electrical engineering in 1931, from Yale University. After a few months as student engineer with Westinghouse Electric Company, he became a member of their transmitter engineering department.

In 1933 Mr. Gubin joined the engineering department of the Radio Corporation of America where he was engaged in design and installation work on transmitters varying widely in power, frequency, and application. He was designated vacuum-tube co-ordinator in 1936, and in 1939 added the activity of project engineer in a government equipment of advanced design. During the war Mr. Gubin was engaged in supervising an engineering training program, co-ordinating government projects, supervising advance development work, and promoting postwar planning. In 1944 he was placed in charge of the microwave beacon development group.

Since February, 1946, Mr. Gubin has been connected with Spectrum Engineers, Inc., of Philadelphia, Pennsylvania, a firm of consulting electronic and mechanical engineers which he helped to organize.

Mr. Gubin joined The Institute of Radio Engineers in 1941 as an Associate, becoming a Senior Member in 1944. He has been a member of the I.R.E. membership committee for several years. He is also a member of the Franklin Institute.

Palmer McFadden Craig was born on January 29, 1904, in Cherry Hill, Maryland. After graduation from the University of Delaware with a B.S. degree in 1927, he was first connected with the engineering department of Westinghouse Electric Company, and later he became employed by the RCA Victor Division of the Radio Corporation of America as a radio engineer, where he did extensive development work on home radio receivers.

Joining the Philco Corporation in 1933, Mr. Craig became a senior engineer responsible for many phases of radio receiver design. Promoted to the position of chief engineer of the radio division in 1943, he was responsible for engineering the designs for production of important airborne search radar systems. Under his supervision new radio receivers and radio-phonographs, as well as postwar engineering developments in radar and microwave electronics for the War and Navy Departments, are being designed.

Palmer M. Craig

Vice-Chairman

Mr. Craig became an Associate Member of The Institute of Radio Engineers in 1935 and transferred to Senior Member in 1945. He is chairman of the Radio Manufacturers Association engineering committee dealing with broadcast and international short-wave receivers.

Arthur N. Curtiss

Secretary-Treasurer

Arthur N. Curtiss was born on March 27, 1906, in Buffalo, N. J. He received the B.S. degree in electrical engineering from the University of Pittsburgh in 1927. During his undergraduate days he participated in a co-operative training program with Westinghouse Electric Company and in 1927 joined the radio engineering section.

In 1930 Mr. Curtiss went to the Radio Corporation of America. He was in charge of electrical design at the Indianapolis plant from 1939 to 1943, following which he was made responsible for all design activities in the Photophone division. He continued in this position until his appointment on September 1, 1945, as manager of the newly formed standards engineering section at Camden.

During his sojourn with Westinghouse, Mr. Curtiss was a member of the staff of the graduate school at the University of Pittsburgh. Later, while residing in Indianapolis, he served on the staff of the graduate school of Purdue University.

Mr. Curtiss joined The Institute of Radio Engineers as an Associate in 1936, and became a Senior Member in 1944. He was chairman of the Indianapolis Section of the Institute during 1942–44. He is vice-chairman of the sound equipment section of Radio Manufacturers Association and chairman of the amplifier committee of the same section, as well as a member of several other RMA and American Standards Association committees in engineering fields.

Among the identifying characteristics of a young and thoroughly healthy organism are its normal growth and its ready adaptation to its environment. The Institute of Radio Engineers has shown these characteristics in large measure. But it is opportune, in these rapidly changing times, to devote careful thought to any possible further steps which the Institute might take to meet proper demands upon it. The following guest editorial by an active patent-legal worker in the communications and electronic field, who is past Chairman of the Chicago Section of the Institute, clearly analyzes the general history and present trends of the Institute.—*The Editor.*

Evolution

ALOIS W. GRAF

Nearly a century ago the first national engineering society was organized for the purpose of advancing engineering and architectural knowledge and practice, and for establishing "a central point of reference and union for its members." Subsequently, other national societies were organized in particular branches of engineering. They included as their purpose the promotion of the welfare of those employed in their arts and sciences, and the maintenance of a high professional standing among their members.

The first activity of the engineering society was the presentation of papers on fundamental discoveries. These papers and their discussions were published by the society. Soon after, engineers joined in order to obtain the publication, even though they were unable to attend the meetings.

Subsequently, localized groups of members held meetings for the presentation of their own papers. This led to the formation of branches, sections, or chapters. Societies soon recognized the need for broadening their scope as evidenced by amendments to constitution and by-laws to include the education and professional status of the engineer.

Concomitantly with the growth of societies and their technical publications came the commercial technical press which covered the commercial aspect and practical application of fundamental discoveries to new products. While this supplements the societies' activities, there still are certain phases of engineering activity which require attention and which are not within the scope of either the engineering society or commercial technical press. Certain social, political, and economic problems require united action of all engineers. Until the majority of the members of the societies join an organization which has for its primary objective the consideration of these problems, it is the duty of each society to present impartially information pertaining to any situations, problems, laws, or organizations which directly or indirectly affect any of its members.

More than a generation ago The Institute of Radio Engineers was organized to advance the art and science of radio communication, and since then its charter and constitution have been amended to broaden its scope into the allied branches of engineering and of the related arts and sciences. The presentation of papers at the section meetings is not limited to those setting forth only fundamentally new discoveries or advances. Often they deal with specific applications of the fundamentals.

We must not cling too tenaciously to the original concept of presenting only those papers which set forth fundamentally new discoveries or advances, and object whenever any paper is published in the PROCEEDINGS which illustrates advances in the arts and sciences by giving specific examples which quite naturally identify the participating commercial interests. Granted that we should not duplicate the efforts of the commercial technical press, such purist policy nevertheless definitely restricts the Institute's service to its members.

Let us avoid and suppress any fear of encroachment by commercial interests since we already co-operate with the American Standards Association, the Radio Technical Planning Board, the Radio Manufacturers Association, and other bodies. We cannot exist without commercial organizations, nor can they exist without engineers. Perhaps much could be gained by constantly showing the industry how we co-operate with them, and how the activities of our members benefit industry. We might inform officials in industry whenever an individual is elected to an office in the Section, and whenever anyone is appointed to serve on sectional or national committees. Such appointment develops the individual and benefits both the Institute and industry.

Originally, the majority of society members were located at Headquarters, so it was natural for the Sections to be supported and guided by Headquarters. Now the majority of members are located in the various Sections which want to participate in guiding the activities of the Institute. The Regional representation plan will facilitate this, but it must not be forgotten that each new privilege is accompanied by its responsibility. Whereas in the past the Sections have expected assistance from Headquarters, they now should expect to assist Headquarters as well. Much can be done by Sections, such as supplying the nucleus for a committee, accepting subcommittee work, and drafting plans for improved operation or activity of the Institute.

The Institute has grown because of a progressive evolution so that we now embrace the electronic and other fields directly contributory to or derived from radio. Still, too many of us speak only of the radio engineer, and a few purists shudder at the suggestion that the initials I.R.E. could denote: "Institute of Radio and Electronics." However, not so long ago, many Sections barely managed to hold the minimum required number of meetings; now practically every Section holds more than ten meetings per year. The evolution in the Institute is evident in its activities, management, and scope. Our objective of the advancement of the theory and practice of our arts and sciences can best be attained by encouraging this natural progressive evolution so as to benefit the individual member, the Institute, and our industry.

Electronics at Peace*

An Address by

PRESIDENT W. R. G. BAKER†, FELLOW, I.R.E.

WHEN man learned to organize his efforts he began to obtain some degree of control over nature. Within our memory he has gained in control over nature more than in the preceding 300 years. There is no evidence to indicate that this is due to some peculiar genius of modern man. On the contrary, there is strong evidence pointing to the fact that this acceleration of our progress is due to our faith in the organized efforts of ordinary men.

We need not look far for proof of this statement. Spurred by our entry into World War II, there took place in a period of five years tremendous advances in the field of electronics. Under peacetime conditions these advances would have taken certainly ten and perhaps twenty years.

We know that these advances were not made possible because there happened to be available a group of geniuses. The fact is that the brilliant war achievements were deeply rooted in the peacetime accumulation of fundamental knowledge of individuals and organizations. Further, the effective utilization and application of this knowledge was possible only through the organized efforts of scientists and just ordinary engineers.

Science is certainly as old as mankind. It is equally true that the effective organization of science is the essence of modernity.

Science during the dark ages found some truths but unorganized science lost many of them. The total wealth of knowledge increased slowly.

Science began to have power when it began to be cumulative, when organized groups began to pool their efforts and experiences and—perhaps more important—when so-called scientific truths were subject to critical analysis and scrutiny.

Science began to be effective when just ordinary men made the winning of knowledge and the application of this knowledge a distinctive profession. When this took place there followed the evolution of the specialist. Then the fragments of knowledge were broken into smaller and smaller pieces so that highly organized effort could work each fragment more intensively.

The age of specialization has implemented the diffusion of knowledge, the exchange of experience, the codification of practice, and the standardization of usage. It is in connection with these functions and services that The Institute of Radio Engineers acts as the catalyst. This organization, comprising 20,000 scientists and engineers scattered throughout the world, is without question pre-eminent in the field of radio and electronics. Such a position carries with it great honors, as well as grave responsibilities and obligations.

"Electronics at peace" is the keynote of this convention. It is indeed well chosen. I think it is more than a keynote. It is a challenge—a challenge to every one of the 20,000 members of The Institute of Radio Engineers individually and collectively.

What is this challenge? Let me give you my interpretation.

The Institute recognizes that power without responsibility is an unsound philosophy. As a democratic body it must provide a vehicle of expression for every engineer associated with the organization. It must associate with itself the student engineers, who, tomorrow, will hold the key positions in industry; and it must provide a common meeting place for those interested in the theory or practice of radio engineering or of the allied arts or sciences, that is, the great body of associate members.

It is the business of the scientist to find the fundamental means for the mastery of nature. It is the responsibility of the engineer to make these truths of use to mankind.

It is the business of the engineer to find ways and means for preserving and in fact advancing the prosperity of our country and of our people. Prosperity comes not from subsidies, wage and price increases, bonuses, and unemployment relief. Prosperity comes only from production.

The foundation for the maintenance of a high standard of living is a high level of productivity. A high level of productivity must rest upon a firm foundation of engineering. There is nothing new in this statement. It is as fundamental as any law of nature.

The engineers of our industry have proved their ability to meet such a challenge. The facts and figures pertaining to the growth of sound broadcasting offers ample evidence. Our war record with its tremendous accomplishments is further evidence, if such is needed.

The engineers of our industry are fully cognizant of the impact on our people and on our economy of such new systems and services as frequency modulation and television. They are fully aware that unborn systems still in the hands of the scientists may well transcend in terms of a higher standard of living those services with which we are familiar.

The Institute of Radio Engineers and the radio industry can look forward to the future with confidence, knowing that the accomplishments to date are but a preview of the future.

* Decimal classification: R040. Original manuscript received by the Institute, March 21, 1947. Presented, 1947 I.R.E. National Convention, March 5, 1947, New York, N. Y.

† General Electric Company, Syracuse, New York.

A Test for a Successful Institute Section*

FREDERICK B. LLEWELLYN†, PAST PRESIDENT AND FELLOW, I.R.E.

THIS YEAR the address of the outgone President departs somewhat from tradition. Rather than a report on "The State of the Institute," which will appear, complete with statistics, in the published Report of the Secretary, I want to talk for a few minutes on a subject that is close to all of us who have the interest of the Institute at heart. I shall talk on the subject: "A Test for a Successful Institute Section."

All Institute Sections are successful, but some find that success comes to them while others have to go after it. My visits to the Sections last year afforded an opportunity for evaluating the things that make it easier for some Sections than for others, and I came to the conclusion that a reliable test for easy success is whether the Section leans for support upon some research group. This group may be connected with a government laboratory, the Army or the Navy, or with a university, or with an industrial laboratory—it makes little difference which. And why should not this be so; why should not the Sections depend upon the research workers for their main support?

Radio engineering was built upon planned research as perhaps no other engineering field was. Look at engineering in general. One branch deals with a new dam in Venezuela; another with new power plants in the West; a third with a new bridge in Africa. The dam, the plant, and the bridge are new, but the engineering that

* Decimal classification: R060. Original manuscript received by the Institute, April 2, 1947. Presented, 1947 I.R.E. National Convention, March 5, 1947, New York, N. Y.

† Bell Telephone Laboratories, New York, N. Y.

went into them seldom involves new principles—only new applications. Now look at the I.R.E. Take any issue of the PROCEEDINGS. Nearly all of the papers are about some new idea. The resulting apparatus and equipment often are not described at all. We have been criticized for this, and perhaps rightly. One would like to see descriptions of new equipment in the PROCEEDINGS. However, *as long as the disclosure of new ideas continues, I,* for one, *will not worry about the direction the Institute is facing.* It is the right one. As this research background applies to the PROCEEDINGS, so also it applies to the Sections individually, and, because it is the collective organ of the Sections, to Headquarters as well.

Look at the Institute meetings that create the greatest interest. I remember, many years ago, when Hartley's paper on carrier and sidebands was given. That was a big meeting for those days. I remember the other meetings where papers were given which described new ideas. Events such as those stand out and have made the Institute what it is today—a forum for new ideas. The people who are responsible for the new ideas are the ones who have built the Institute, and, wherever they are found, in the north, south, east, or west, the meetings they engineer and run will always have the same kind of interest.

Meetings concerned with description of a new type of apparatus are fine. It has been said that we need more of them, and perhaps that is so. This does not mean, though, that we want them at the expense of meetings and papers that tell about new ideas.

New ideas are something like mathematics. I once had a professor who used a great deal of mathematics. One day he startled the class with the statement, "Mathematics is a crutch for feeble minds." When our astonishment had become apparent, he glared at us and continued, "How many of you think you can get along without it?" *New ideas are the scaffolding by means of which new apparatus can be developed.* When the apparatus is complete, the scaffolding may be removed and a child can operate the equipment without knowledge of the ideas from which it was built. But the ideas were needed to produce it in the first place, and without them nothing new would result.

From all this it may be concluded that in the enthusiasm of starting a new Section, the first thing is to insure that it has the backing and support of whatever research groups are located in the vicinity. Ordinarily this is not difficult, for it is the research people themselves who, in many cases, are promoters of new Sections. It is much more difficult when no research is located within the proposed Section. In such cases some very strong compensating influence is usually needed to insure success.

Finally, the same conclusions apply to the broad policy operations of Headquarters and the Board. *Let the Institute keep its structure supported by the research worker,* and, despite the ups and downs of the times, despite the possibility of pressure to move us this way and that way, we shall be in a position to progress—keeping always the attributes of youth, even as research itself is always new—and to move in new ways and new paths, but with the fundamental soundness that goes with a good research job. I have every confidence that this will always be the aim and outlook of the Institute, even as it reflects today the adherence to the research tradition which has been ours through the years gone by.

Relation of the Engineering Profession to World Affairs*

C. B. JOLLIFFE†, FELLOW, I.R.E.

In a world devastated by war and torn by political and social dissensions, the engineer finds himself in a confused environment strangely different from the productive surroundings and logically analytical atmosphere of the laboratory and shop. Amid the chaos of present-day so-called civilization, the constructive aims of the engineer are too often thwarted by misapplication of his contributions. He may find want and misery where his work might be expected to breed prosperity and happiness. There follows a paper which squarely faces this problem. The pertinent and constructive views in this paper originate from an author who is a former Chief Engineer of the Federal Communications Commission and a director of the I.R.E. As the executive head of a large research laboratory, he is in a position correctly to appraise the problems he here analyzes.—*The Editor.*

I AM GRATEFUL for the opportunity to participate in a symposium on the engineering profession. Much good can be accomplished by an exchange of experiences and by a discussion of our technical work as well as our aims and ambitions.

As engineers and scientists, we have contributed greatly to the rise of science and industry as dominant forces in modern life. Yet, when the results are integrated into the life of the nation, there remain broad areas in the field of human relations in which our services to society have been more potential than real.

The gears of the machinery of living are not meshing properly, and the over-all operation is less efficient than we like to admit. Our efforts to fix up this machine and make it run smoothly are too often ineffectual. The oil of expediency is not solving the problem.

World conditions are most extraordinary and paradoxical. The earth contains sufficient resources to provide food and shelter for all mankind, yet the greater portion of the world's population lacks these necessities of life. Knowledge and education are rightfully the common property of all men, but most of the world lives in relative ignorance. Industry and commerce can provide wealth for all nations, yet there are the "haves" and the "have-nots."

Finally—and most important—we have the precepts of philosophy and religion by which man can live peacefully and happily with his fellowmen; but nations quarrel, go to war, and create indescribable misery and destruction.

The brutal devastation of World War II and the awesome reality and possibilities of atomic energy have shocked the world from its complacency as nothing has ever done before. Leaders of science and industry were quick to take advantage of this opening wedge in the public consciousness.

They have told us that man has dangerously overdrawn the balance between the physical and the social sciences. Materialism has been too long in the ascendency. Moral and spiritual values have dropped low on the scale of life. Consequently, we find ourselves unprepared to deal adequately with the great physical powers we now possess.

That does not mean that a solution lies in a decrease in our efforts to advance

* Decimal classification R010×R071. Original manuscript received by the Institute, March 11, 1947. Presented, 1947 I.R.E. National Convention, March 5, 1947. New York, N. Y.
† RCA Laboratories Division, Radio Corporation of America, Princeton, N. J.

science. On the contrary, our labor in this direction must be unremitting; for from such efforts will continue to come new means of employment and wealth for all men. It is by this means that the standard of living throughout the world can be raised steadily. What is needed is a new emphasis on the social sciences.

Inherent in the warnings voiced by top men in science and industry is a challenge to act—to do something beyond the limits of our own profession. The program of The Institute of Radio Engineers recognizes this fact with this symposium which gives us the opportunity to take stock of ourselves as engineers. The time is well chosen, for on all sides human behavior is being subjected to critical analysis. If our own inventory is carefully made, we may find ways of vastly increasing our usefulness.

I have been asked to discuss the engineering profession in relation to industry, with emphasis on the engineer's responsibilities, his opportunities for growth, and the requirements he must meet for leadership. This calls for a substantial amount of introspection—a weighing of values we seldom think of in a work-a-day world.

Modern life is complex because man has made it that way. Every advance in the physical sciences, with its consequent spread of industrialization, has brought new complications. The many advances have resulted in far-reaching changes in home life, the ways of earning a living, and in the practices of government, business, and commerce.

Ours is an industrial world, wherein technological development is a principal factor. The wealth and power of nations is based on the ability to manufacture, to distribute, and to use the products and services created by science.

Science has taught us to use heat, water, electricity and, now, atom fission, as sources of power. It has given us steam, electricity, gas engines and turbines, and jet propulsion engines. It has given us mass production, fast and efficient transport on land and sea and in the air, instantaneous communication around the earth, and mass communication by broadcasting. It has developed chemistry, medicine, and other fields of knowledge to an extent undreamed of only a generation ago.

Upon the continuing development of science and engineering rests the industrial might of the United States. Moreover, all of our economic, political, and social activities are closely geared to the industrial wheel. Let this wheel cease to turn and the results would be chaos.

When it is remembered that substantially more than half of our national economy is dependent upon industrial activity, the responsibility of the engineering profession assumes a new order of magnitude.

To state the obvious, the high standard of living we have achieved, particularly here in America, is almost entirely due to industrial progress. In our own industry, this progress is based on scientific research and development. It is our responsibility as scientists and engineers to see that this research and development is not reduced.

Industry depends upon us and has shown its willingness to support our activity. It has confidence that important results will be forthcoming. The growth in the number and importance of industrial laboratories during the past twenty years reflects this confidence. Industry, I am sure, will not be disappointed in the results it obtains.

The industrial scientists should constantly explore new areas of knowledge, developing information upon which new or better products and services may eventually be based. A portion of his work must be free and unguided investigation of pure science—a seeking of knowledge for knowledge's sake. Progress depends upon this type of effort.

Industrial laboratories have drawn heavily on the bank of fundamental scientific knowledge. Due to the demands of war, our account in this bank of knowledge has dropped very low and the balance needs to be restored. Here, industry and its scientists have a definite responsibility Only through their efforts added to those of American scientists working in other laboratories can America hold her place of world leadership in science and industry.

It is also necessary for industrial engineers to carry research and development directed to the creation of products and services which can be adapted to immediate or future practical use. Were this not done, industry would inevitably slow down due to a lack of new and better products. The steady rise in the standard of living would halt, gradually to slip backward and downward.

The general public judges the results of scientific discovery on the basis of the products and services that are delivered to it. A profound discovery that stops with discovery cannot be appreciated outside the world of science. A good example of this is found in our own field. The mathematical work of Maxwell was a wonderful achievement, but it lay dormant, as far as the general public was concerned, for more than twenty years. It took the work of Hertz, Marconi, and the many hundreds of radio scientists and engineers of more recent years to translate Maxwell's mathematics into world-wide communications, radio broadcasting, television, radar, facsimile, and the many other services of radio and electronics that are within the common experience of people today.

World War II gave science a new meaning to the average man. Science and engineering provided the instruments with which the war was fought and won. We, the radio scientists and engineers, made an enviable record in the war. Radio was the only means capable of providing the kind of communications necessary in a war of speed and movement, fought on a global scale. Radar helped beat back the enemy in the air, and sonar stopped him at sea. Shoran enabled our armed forces to make pin-point bombing attacks in darkness and through overcast. Loran guided our planes to tiny islands lost in the vastness of ocean space. The proximity fuze brought destruction and consternation to enemy land forces and aircraft, and television gave long-range eyes to airplanes and projectiles.

These and the accomplishments of engineers working in other fields were a remarkable demonstration of the power of science and engineering to supply the technical basis of industry. The release of atomic energy, overshadowing as it did all other wartime developments, was positive proof that science had stepped into a more dominant role in the affairs of man. With this more dominant role the responsibilities of the engineer have been greatly increased.

Unlimited horizons of technological progress stretch ahead through scientific investigation. It has been demonstrated, time and time again, that the scientific method is the key to unlocked doors of the future. For this reason, it is all the more regrettable that, knowing this to be true, we have not applied it more extensively to the solution of purely human problems.

In the application of science to industry the engineer has played the principal role, but his technological accomplishments often have not been properly applied. It is proper to place the chief blame for this unsatisfactory application on those leaders of business and government who guide and direct national and world affairs. However, the engineer can take small comfort from this fact, for he has failed to develop the all-important quality of leadership outside of his profession. He has left in other hands, often hands less skilled than his, the job of controlling the benefits of his creative work.

The results of our purely engineering efforts are manifest in the many material assets we have today. But we, as engineers, have done little to see that these benefits are distributed in a way that will do the most good for the greatest number of people. We have, in general, been satisfied with developing the tools for a better life but have taken little or no responsibility for their use and applications by society.

Now, the engineer must reorient his thinking. He must act in a way that will give his special training and abilities greater influence on industry and on society. He must adjust his ideas to a new set of standards for personal conduct. The responsibilities that go with any type of engineering are enormous, and now more than at any other time in the world's history the "man in the street" should be able to look to the engineer for guidance in a scientific world. I am confident that application of the orderly thinking and the precise methods of science to the problems of society would pay as high dividends as they have in the production of material wealth.

Considered strictly from the engineering viewpoint, any man who engages in this profession must assume certain basic obligations. To begin with, before even taking up the study of engineering, he must analyze his own nature to determine whether he is responsive to the exacting demands of scientific endeavor. He must acknowledge the rigid discipline of intellectual attainment, and he must place truth, with regard to humanity as well as to science, above all other considerations.

Today's engineer owes it to his profession to acquire as much education and basic training as it is within his power to obtain. It is not enough, however, to study the physical sciences alone. The modern engineer, in addition to his special training, must know the broad principles of psychology, economics, and political science. He must know something of ethics, as well as of logic. In other words, he must be a citizen as well as a scientist, for he needs to relate his achievements in science to the whole of human endeavor.

Some years ago, it was sufficient if an engineer possessed the requisite technical knowledge to do his job; qualities of leadership were not a necessary attribute. Gradually, as industry expanded, however, it became necessary to find members of the profession who could exercise guidance over other engineers, groups of technicians, and other workers.

With this new demand, it became evident that many engineers had to have something more than technical competency. Additional requirements included the ability to handle men, to understand the motives that actuate them, and to plan programs of research, development, and production that would bring the greatest benefit to the organization for which the work was being done.

Now, it is equally evident that this new responsibility must be extended beyond the relatively narrow limits of the engineering laboratory. The present period has been called the Age of Science. If the description is apt, then we need more scientists and engineers in positions of leadership. They must extend their influence into the levels of management in both business and government and accept the responsibilities that go with leadership.

This thought brings us back to the field of human relations. Many scientists and engineers feel that they do not have time, as men of other professions do, to participate in activities unrelated to their work. I disagree with that idea completely. I see no reason why an engineer cannot take as much part in business and public affairs as lawyers, physicians, and educators. We should break out of our professional shell and become better citizens. In fact, I think a broadening of interest would make us better engineers.

Here is the most fertile field for the growth of our profession. By finding ways and means of impressing the proved methods of science upon the many other forms of human activity, we can make a significant contribution toward the development of a better life.

It is axiomatic that knowledge precedes understanding. We are constantly amazed, however, at the small amount of knowledge, analysis, or understanding that enters into what are called "solutions" to some of the major problems of business and government. But, you ask, what can we, as engineers, do about it?

In reply, let me first ask a question. What do you do, as an engineer, when confronted with a complicated problem in the laboratory or workshop? You gather all the information on the subject that is obtainable and you study it in relation to your problem. If more information is needed, you do research. You find out the facts—all of them, not just some of them. You analyze the facts, evaluate them, test their effects, and calculate the results. By these orderly and often laborious processes, you arrive at a solution. Seldom are you so fortunate as to find the answers by a "flash of genius."

Few people outside of scientific circles know about this simple formula—the "scientific method." Fewer still use it. I can think of no valid reason why this formula should not be just as successful in solving other problems of industry and even the problem of organized society as it is in dealing with the problems of physical science.

This situation holds the answer to our original question of what to do. There is a clearly indicated need in nearly all levels of business and society for the well-disciplined mental processes of the engineer. As an advocate of the "scientific method," in circles outside of your profession you can exert a profound influence on community life, business, and government. But first you must convince others of your availability for expert counsel and leadership. You must abandon the "ivory tower."

Most of you have probably noted how the art of public relations is moving rapidly into the front rank of management circles. Here is an art that recognizes the high value of developing good impressions. Its practitioners specialize in examining management's policies to determine their public relations aspects, and, where necessary and desirable, to interpret them in the most effective manner possible.

Industrial management's increasing use of public relations methods, particularly in recent years, reflects its acceptance of a wider responsibility to society. Without loss to private enterprise and individual initiative, there is greater recognition of the interdependence of the various forces involved in community life.

Why is management accepting this wider responsibility? The answer is, I believe, that management—on an ever-rising scale—is giving greater consideration to human values—values that are assuming larger importance as this civilization of ours grows more complex.

Science is in the public eye as it never was before, and we should take advantage of it. A few scientific and technical men have recently become articulate in the world of public affairs, but if science is to continue to deserve respect many others must do likewise. We must not let the new voice of science die out, for it is one of the most effective means of achieving sound public relations for engineering.

I know of no time in the history of science and engineering when conditions were more favorable for our professional growth and leadership. In the radio industry, we are particularly fortunate. The new radio services of frequency-modulation broadcasting and television are just getting started as great new services to the public, and the many miracles of wartime research are available for application to peacetime uses. The development and use of these and other scientific discoveries yet to be made are a challenge to our ability as engineers; they also represent new opportunities for leadership.

The requirements for leadership are simple, yet exacting. In the engineering field, they call for a broadening of interest, and an exercise of duty over and beyond the technical limits of our profession.

We must acquire a greater knowledge of human behavior, business operations, and social institutions. Only by doing so can we be prepared to accept greater responsibilities.

We must develop a feeling for leadership and a confidence in our ability to provide it. We must emerge from our laboratories to take a greater part in community affairs. We must extend our influence into the level of management in both business and government, and we must be ready to accept positions of leadership at that level. We must be articulate in the expression of our ideas and concepts, and we must learn to speak in words free of technical terminology. Above all else, we must maintain the integrity of the engineering profession.

I have noted, with deep concern, a few instances in which false engineering concepts have been supported by men of supposedly good professional standing. This is both dangerous and unrealistic; for science permits no compromise with truth.

As competition grows, engineers will be subjected more and more to commercial and political pressures for the sake of expediency. These pressures must be resisted with all of our power. Dishonest engineering counsel can have ill effects of far-reaching significance and can do great harm to our profession. It can even damage our economic structure and weaken national security.

As professional men, zealous of our position in society, we must be prepared to deal summarily with those who would lower our standards. In engineering, there is no substitute for intellectual honesty. We must insist on the "scientific method" in our every undertaking.

In conclusion, I want to emphasize that society for too long a time has tolerated inefficiencies in human relations that we, as engineers, would never countenance in the laboratory. There is the challenge to leadership! I urge you to accept it. Only by acceptance of higher responsibility with the engineer fulfill the great promise of his profession.

Magnetic Deflection of Kinescopes*

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Summary—This paper investigates some basic principles in the operation of systems for magnetic deflection of television tubes. In the first part, the energy of the deflecting field is calculated for various deflection angles and beam voltages. It is found that sweep amplifiers are preferably operated with a positive rate of change of plate current. This causes a considerable plate-voltage drop, for which expressions are given. The efficiency of sweep generators is discussed and a method is indicated to determine the power dissipation in the sweep output amplifier.

The second part deals with the transients during the retrace and their elimination. A theory is given for resistance damping. Practical results are presented for a special method of damping by secondary emission within the sweep amplifier.

In part three, some basic forms of sweep distortion are discussed and means for their correction are indicated. Two characteristic distortions are found to be due to the resistive components of either the tube or the load. These distortions are of opposite sign. Nonlinearity of the tube characteristic is found equivalent to an emphasis of low-frequency components in the spectrum of a sawtooth wave.

The fourth part describes a sweep circuit of improved efficiency. This circuit operates with power feedback and uses a diode as switching element. Flyback energy is rectified and the resulting direct-current power added to the plate power supply.

PART I

General Properties of Deflection Circuits

In designing a sweep supply for magnetic deflection, the question of power requirements and efficiency is of primary importance. Power input, efficiency, and the number and size of tubes in the output amplifier vary widely in receivers of different design. It is therefore desirable to have general expressions for the energy of the deflecting field as a starting point from which the total power input, and thus the efficiency, can be calculated.

Equation (1) indicates the peak-to-peak amplitude of a magnetic field of a length l_0 which deflects a cathode ray of given voltage E from $-\frac{1}{2}\alpha$ through the axis of symmetry to $+\frac{1}{2}\alpha$:

$$H = \frac{5.3\sqrt{E}}{l_0} \sin\left(\frac{\alpha}{2}\right) \text{ (ampere turns per centimeter).} \quad (1)$$

In this equation the dimensions are volts, centimeters' and ampere-turns per centimeter. From this field strength at full deflection the maximum energy content of the deflecting field may be estimated:

$$\mathcal{E}_f = 0.63 \cdot 10^{-8} \cdot H^2 \cdot V \text{ (joule).} \quad (2)$$

This assumes that the volume V comprised by the yoke is filled by a homogeneous field H. In practice this condition holds to a good approximation if the density of the windings is distributed along the neck-periphery according to a cosine law.

If the field energy is dissipated at the end of each cycle, the power supply to the yoke follows from (2) by multiplication with the sweep frequency:

$$W_f = \mathcal{E}_f \cdot f \text{ (watt).} \quad (3)$$

This value may be expressed in terms of the yoke inductance L_0 and the peak-to-peak amplitude I_0 of the sweep current:

$$W_f = 1/2 L_0 I_0^2 f. \quad (3a)$$

All of this power must be supplied only in the theoretical case of complete energy dissipation in a yoke damping resistor. If a periodic tuning is used (Part II-A), there is a useful overswing of 13.4 per cent which reduces the power-supply requirements for a given sweepwidth to 77 per cent of (4). With modern reactance scanning[1] this overswing becomes almost 100 per cent, and the field is maintained chiefly by circulating power at one-fourth of the wattage given in Table I.

The sweep frequency enters into the power equation as a linear factor. This accounts for the fact that line deflection requires about 250 times more power than field deflection. It also indicates that horizontal deflection for sequential color television requires more than twice the power input needed for black-and-white receivers. Additional power is necessary at these higher frequencies to compensate for increasing losses in circuit components and in the core material of the sweep transformers.

Table I presents data for three commercial television tubes which are representative for: (1) the narrow-angle direct-viewing type of prewar receivers (12AP4); (2) the modern wide-angle direct-viewing type (10PB4); and (3) a typical projection-receiver tube (5TP4). The plate voltages for the first and second types are of the

TABLE I

Field Energy and Power Values for Horizontal Deflection

Tube Type	Symbol Dimension	12AP4	10BP4	5-inch Proj. 5TP4
Deflection angle	degree	30°	50°	50°
Yoke length	l_0 centimeter	8	5	5
Yoke diameter	D_0 centimeter	5	5	5
Yoke volume	V centimeter³	150	100	100
Plate voltage	E volt	7000	8000	30000
Field strength	H AT per centimeter	15	44	85
Ampere turns		60	230	425
Deflection current	I_0 amperes peak to peak	0.5	1.8	3.6
Field energy	$\mathcal{E}_f$ joules	2.22×10^{-4}	12.2×10^{-4}	45×10^{-4}
Field power supply for black and white Television (15.75 kilocycles)	W_f watt	3.5	19	70
for color Television (31.5 kilocycles)	W_f watt	7.0	38	140
Plate bucking voltage for 100 micromicrofarad plate capacitance (7)	e_- volt	−149	−276	−500
Peak retrace voltage	e_+ volt	+1650	+3000	+5500

* Decimal classification: R583.6. Original manuscript received by the Institute, July 16, 1946; revised manuscript received, December 9, 1946. Presented, I.R.E. New York Section, October 2, 1946.

Patentable subject matter included in this paper is, or will be, protected by applications for Letters Patent.

† Columbia Broadcasting System, Inc., New York 22, N. Y.

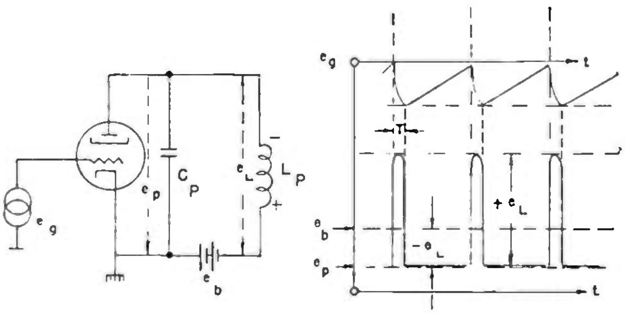
[1] See 4 of Additional References.

same order, about 8000 volts, while the projection tube operates at 30,000 volts.

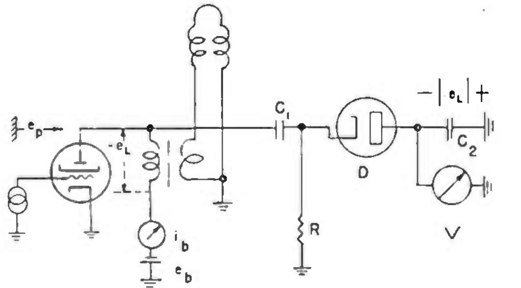
The main difference between prewar and postwar systems lies in the magnitude of angular deflection, which increased from 30 to 50 degrees. The length and volume of the deflecting yoke have been reduced correspondingly, but this is more than outweighed by the increase in the angle of deflection and higher anode voltages. Accordingly, field energies have increased from 6 to 20 times, and power requirements are growing at an even faster rate as special applications, such as color television, make higher sweep frequencies necessary.

Fig. 1 shows a typical circuit arrangement for a sweep amplifier. Damping means are not shown. A pentode is used as constant-current generator. The grid-voltage input has approximately sawtooth wave form, but may have to be slightly predistorted to correct for distortions in the plate circuit. (See Part III.) The plate load L_p is predominantly inductive, and may be either the yoke inductance itself or the input impedance of a sweep transformer. The size of this inductance is limited by the condition that the half-period of the resonant plate circuit should not exceed the flyback time:

$$\pi\sqrt{L_pC_p} \leqq T. \tag{4}$$



(a)



(b)

Fig. 1—Sweep amplifier: measurements of bucking voltage and efficiency.

Under these conditions, the load may be considered as a pure inductance for the forward stroke of the sweep. At a constant rate of change of the plate current, there will then be a constant voltage drop across this inductance. This voltage drop will be either subtractive or additive with respect to the plate supply e_b, depending on whether the sawtooth input has a positive or negative rate of change. At first glance it may therefore appear advantageous to have the plate current decrease during the sweep period so that the voltage across L_p may become series-aiding. This mode of operation is impracticable, however, because the retrace is slowed down excessively by lack of plate voltage during the flyback. The oscillograms (Fig. 12 (a) and (b)) show the output current of the same sweep amplifier for both types of operation. The superiority of a grid input with positive rate of rise is clearly evident. By virtue of these same facts, push-pull operation is not advisable for high-frequency sweep generators, because operating conditions are quite dissimilar in the two phases of the circuit.

The following discussion is limited to systems with positive rate of rise of plate current during the sweep. (See Fig. 1.) The bucking voltage e_- may then be written as follows:

$$e_- = -\frac{1}{1-p}\cdot L_p i_p f \tag{5}$$

where $p = T\cdot f$ is the flyback ratio, and i_p is the amplitude of the plate-current sawtooth. This voltage seems to increase with sweep frequency. However, if the relation (5) between the plate inductance and flyback speed is taken into account, the bucking voltage proves to be *independent* of frequency. Instead, it is the plate-current amplitude i_p which has to be increased in proportion to the sweep frequency in order to keep the field energy and picture size the same. By combination of (2), (5), and (6) there results

$$e_- = -\frac{\sqrt{2}}{\pi}\cdot\frac{p}{1-p}\sqrt{\mathcal{E}_f/C_P}\ \text{(volt)}. \tag{6}$$

This expression contains only the field energy and plate capacitance, but not the sweep frequency. Numerical values for this counter electromotive force are listed in Table I. They are calculated under the assumption of a total plate capacitance of 100 micromicrofarads and a flyback ratio of 1 to 7. As compared to prewar receivers, the plate-bucking voltage is found to have increased from −150 to about −300 and −500 volts for direct viewing and projection receivers, respectively. The plate-voltage supply has to exceed these values by about 100 volts, which becomes rather unwieldy. Modern developments are therefore striving to reduce the actual voltage of the B-supply by generating additional direct voltages during the flyback period.

The positive voltage peak during retrace given in Table I is calculated from:

$$e_+ = \tfrac{1}{2} i_p\sqrt{L_p/C_p}. \tag{7}$$

The ratio of the coil voltages during the two phases of the sweep follows from (7), (5), and (4) in terms of the flyback ratio:

$$\frac{e_+}{e_-} = \frac{\pi}{2}\left(\frac{1}{P} - 1\right). \tag{8}$$

Multiplying the plate voltage by plate current and averaging over 1 cycle yields the following power balance:

$$W_p = i_b e_b - 1/2 \cdot L_p i_p^2 f/(1-p) = W_s - W_f$$

where i_b is the average plate current. This shows how the field energy W_f is deducted from the power supply W_s to yield plate dissipation W_p of the tube. The efficiency of the sweep generator may then be formulated for circuits which dissipate all of the field energy at the end of each sweep:

$$\eta = \frac{W_f}{W_s} = 1 - \frac{W_p}{W_s} = \frac{e_-}{e_b}. \tag{9}$$

In Fig. 1(b), the plate bucking voltage e_- is indicated at the peak-reading diode voltmeter V. This permits the measurement of the plate dissipation W_p, knowing the average plate current i_p.

Measurements of this type were made with a sweep generator for color television (31,500 cycles per second) which used resistance damping across the yoke. The plate dissipation of three type 807 tubes in parallel was found to be 50 watts. The field power was of the same order, 45 watts (see Table I, column 2). Hence, the over-all efficiency of a system of this type is less than 50 per cent. Methods for improvement are discussed in Part IV of this paper.

PART II

Damping of Flyback Transients

At the end of each sweep, magnetic energy is stored within the deflecting yoke. If the flow of current is suddenly stopped, and if no means for dissipation of the stored field energy are provided, oscillations are bound to occur. Persistence of these transients during the next forward stroke is harmful to the picture presentation. The traditional procedure was to dissipate the field energy completely during, or immediately after, each retrace. To this end, a damping resistor may be connected across the yoke, through a small series capacitor or through a diode. The latter method secures the highest retrace speed and good deflection efficiency by allowing a complete reversal of the coil current. Finally, in modern high efficiency circuits with power feedback, the damping resistor is replaced by the plate impedance of the sweep amplifier itself (see Part IV).

A. Resistance Damping

The basic circuit for resistance damping is shown in Fig. 2(a). It has a damping resistance-capacitance network in parallel to the transformer output. The output system then becomes a resonant circuit with low Q factor. The damping resistor renders this system aperiodic. In contrast to diode damping, which operates immediately *after* completion of the retrace, resistance damping is active *during* the flyback.

For the purpose of analysis, the system in Fig. 2(a) is redrawn and shown in Fig. 2(b) as it appears looking in from the load inductance L_0. The tube is shown as the generator of a current mi_p, having a source impedance of R_p/m^2 where m is the turns ratio of the sweep transformer.

The actual yoke current may then be found for any matching condition $x=\sqrt{L_2/L_0}$ by multiplying the plate current i_p by the factor

$$i_0/i_p = m/2 \cdot \frac{2x}{1+x^2} \tag{10}$$

which reaches an optimum of $m/2$ for equality of L_2 and L_0, in an ideal transformer. In practical transformers with a coupling coefficient $k<1$, the optimum of current step-up lies nearer $L_2=2L_0$.

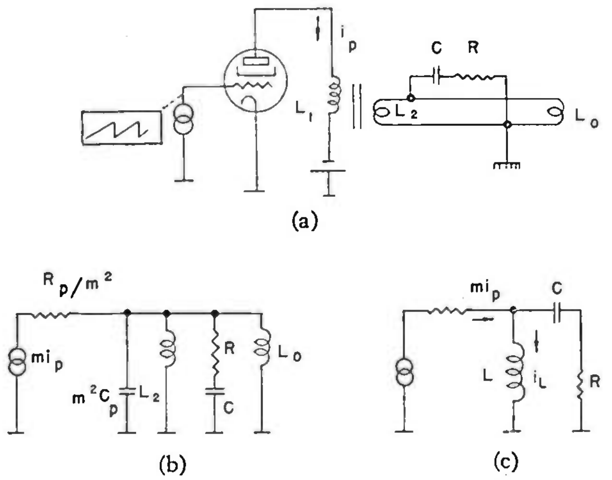


Fig. 2—Resistance damping of transients.

In Fig. 2(c), the inductances L_2 and L_0 are lumped into L, and the yoke shunt resistance R'_p and capacitance C'_p are neglected. These simplifications are justified if the tube is cut off during flyback, and if the damping resistance R is small enough to prevent oscillations at the natural frequency of the yoke:

$$R < \tfrac{1}{2}\sqrt{\frac{L}{C'_p}}. \tag{11}$$

If the system of Fig. 2(c) is exposed to a current input of unit step wave form, oscillatory transients are set up in the coil as described by (12):

$$i_L = 1 - e^{-\delta t}(\cos \cdot \Omega t - \delta/\Omega \cdot \sin \cdot \Omega t) \tag{12}$$

where

$$\delta = R/2L \tag{13}$$

is the decrement of the system. The actual frequency $\Omega=\sqrt{\omega^2-\delta^2}$ is always lower than the frequency $\omega=1/\sqrt{LC}$ of the circuit without losses. The condition for this circuit to be aperiodic may then be written as follows:

$$R = 2\sqrt{\frac{L}{C}}. \tag{14}$$

For unit current input, the deflection current through the coil then becomes

$$i_L = 1 - e^{-\delta t}(1 - \delta t). \tag{15}$$

The voltage across the coil and the current through the damping resistor are given by the following equations:

$$e_L = 1 \cdot R \cdot e^{-\delta t}(1 - \tfrac{1}{2}\delta t) \tag{16}$$

$$i_R = 1 \cdot e^{-\delta t}(1 - \delta t). \tag{17}$$

All of these functions are shown in Fig. 3. This graph yields the interesting result that the current through the yoke exceeds the current input by 13.4 per cent ($0.134 = 1/\epsilon^2$). Aperiodic tuning thus offers an actual gain of deflection sensitivity due to "flyback-resonance."

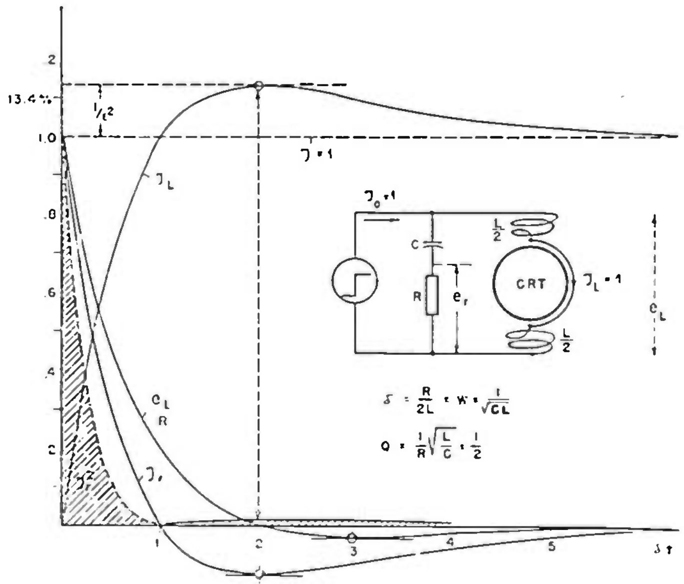


Fig. 3—Voltage, power, and current wave forms for unit step current input.

Fig. 4 shows further that the flyback is complete at a time when

$$\delta T = 2. \tag{18}$$

Combining this with (13) and (14) yields

$$T = RC. \tag{19}$$

The flyback time equals the time constant of the damping network. By combination of (14) and (19) we are now in a position to obtain the following optimum values for the damping resistance and capacitance:

$$R = 4L/T \tag{20}$$

$$C = T^2/4L. \tag{21}$$

These expressions contain the yoke circuit inductance and the flyback time as the only variables. They are in good agreement with experience.

The theory gives further information about the flyback voltage across the coil. The voltage peak is found to be the product of the deflection current amplitude and the damping resistor:

$$(\text{yoke})\ e_+ = I_0 R, \tag{22}$$

or, in terms of the yoke inductance and flyback time,

$$(\text{yoke})\ e_+ = I_0 \cdot 4L/T. \tag{23}$$

From (11) and (20) it may be deduced that the retrace time T_{RC} of a yoke with resistance damping is

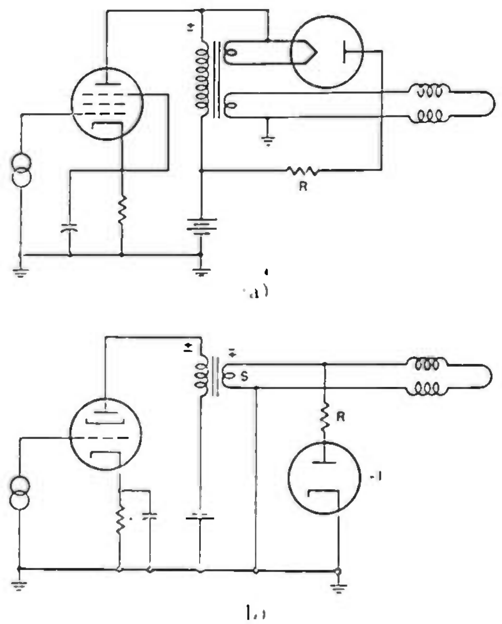


Fig. 4—Diode damping: grounded-plate and grounded-cathode circuits. A bypass capacitor may be connected across the damping resistor R.

considerably longer than its free flyback, T_0. Comparison with (4) shows this ratio to be:

$$T_{RC}/T_0 = \frac{8}{\pi} = 2.56. \tag{24}$$

From (23), (24), and (4) it follows that the back-kick voltage of the loaded yoke has the same peak value, though not the same waveform, as for free retrace (see (7)).

Fig. 5 shows the results of a more complete theory for a current input with gradual cutoff. The graphs show the flyback voltage, the deflection current, and the actual retrace time for various values of the parameter θ/T_0. θ is the retrace time of the actual current input and T_0 is the flyback time of the field for a unit step input. It will be seen from the graphs that the deflection current stays practically constant regardless of the input retrace time. However, the flyback voltage across the yoke depends in a large measure on the cutoff rate of the input. If the input and output flyback are equal, the back-kick voltage drops to about one fourth of the value for the unit step input. This indicates that a grid-voltage wave form with fast flyback is desirable if it is intended to extract high direct voltage from the sweep generator. Fig. 5 also shows how the flyback speed of the field depends on the input retrace. Apparently the field flyback is slowed down somewhat, but this influence is moderate. The actual flyback time increases about 70 per cent if the retrace time of the drive and of the yoke circuit are equal.

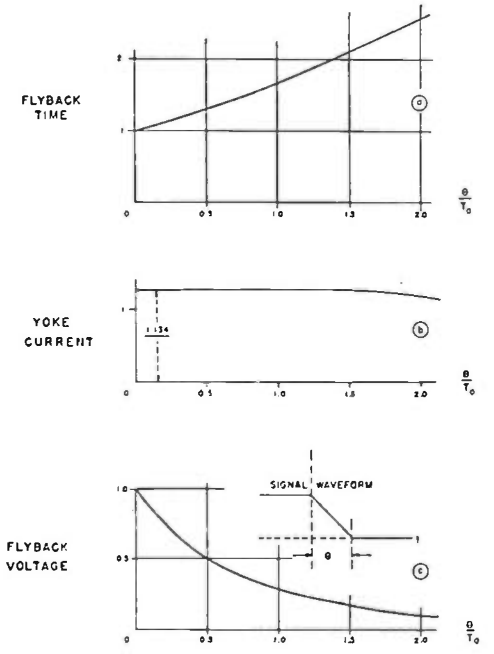


Fig. 5—Yoke current, flyback time, and voltage as functions of current cutoff rate.

B. Diode Damping

If diodes are used as damping elements they have to be conductive during the forward stroke but nonconductive during the retrace, so that deceleration of the flyback is avoided. Damping of the primary of the sweep transformer, as shown in Fig. 4(a), is quite efficient. However, it necessitates a separate filament winding which adds capacitance and requires high-voltage insulation. The pulse polarity may be reversed and the diode cathode grounded, if the secondary winding is used to energize the diode as shown in Fig. 5(b). The damping action may be adjusted at a resistor R in series with the diode. The diode then acts as a switching element which connects R across the load during the forward stroke and disconnects it during the retrace. The flyback speed will then be as high as the circuit capacities permit (see (4)) and is unimpaired by the damping resistor. Satisfactory operation of these circuits requires very close coupling between the various windings of the sweep transformer. Such coupling is not too readily obtained at the higher harmonics of the scanning frequency.

C. Damping by Secondary Emission

In Fig. 6 there is shown a very attractive method which is especially suitable for high-frequency deflection at high power levels. The system operates with damping by secondary emission from the plate of a tetrode output stage. During the forward stroke, the power amplifier operates with screen potential above plate potential. This condition is easily obtained due to the inductive voltage drop across the sweep transformer. As a result, secondary emission passes freely from plate to screen and establishes during the forward stroke a shunt resistance across the transformer which is sufficiently low to render the output system aperiodic. During the retrace period the plate potential reaches a positive peak value far in excess of the screen bias. This stops any secondary emission temporarily, so that a fast flyback is achieved due to the absence of conductivity across the transformer input. No cutoff is employed at the No. 1 grid.

Fig. 12(d) shows the wave forms of plate and screen current. The screen current stops completely during the flyback but recurs at peak value immediately after completion of the retrace. This current pulse extracts sufficient power from the plate circuit to absorb its transients. The oscillograms (Fig. 12(b) and (c)) are taken with the same circuit arrangement using a pentode, type 8001, with separate leadout for the No. 3 grid (suppressor). In Fig. 12(b), the No. 3 grid was tied to the screen, thus converting the pentode into a tetrode. The plate current is found to be free from transients. In Fig. 12(c), the No. 3 grid is connected to cathode, and the transients reappear.

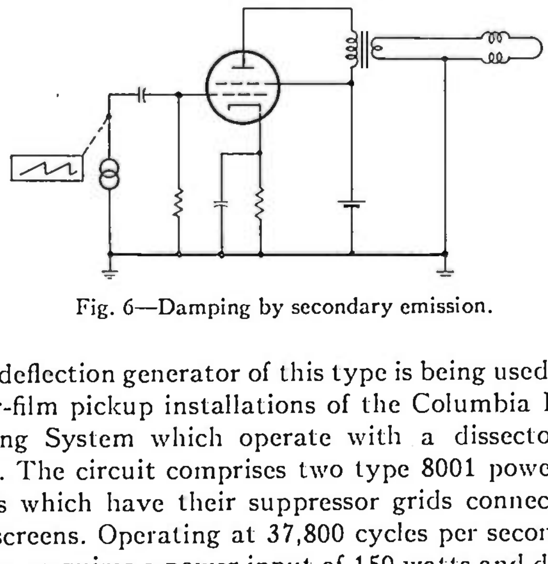


Fig. 6—Damping by secondary emission.

A deflection generator of this type is being used in the color-film pickup installations of the Columbia Broadcasting System which operate with a dissector-type tube. The circuit comprises two type 8001 power pentodes which have their suppressor grids connected to the screens. Operating at 37,800 cycles per second, the system requires a power input of 150 watts and delivers 100 watts into the yoke. Due to the low plate capacitance, a current step-up transformation of 25 to 1 is possible, with a flyback ratio of 11 per cent. Regardless of the usual instability associated with secondary emission, systems of this type have yielded trouble-free operation over a considerable period of time.

PART III

LINEARIZATION OF THE SWEEP

In a sweep amplifier using a pentode with linear grid-voltage wave form, some typical distortions of the yoke current are caused by the resistive components of either the tube or the load. The first influence prevails in high-frequency systems, the second in low-frequency systems. The resulting speed variation of the sweep is of the nature of an acceleration or deceleration, respectively, during each sweep period. Both distortions may be corrected by suitable predistortion of the plate-current wave form, as will be shown.

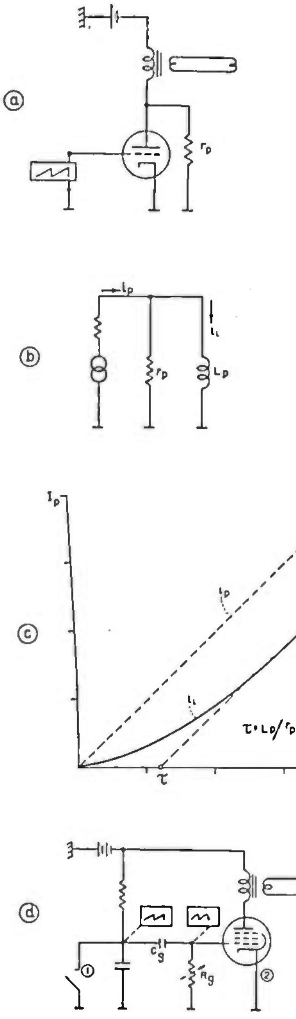


Fig. 7—Distortion by tube resistance and its correction.

Fig. 7(a) shows the output amplifier of a horizontal sweep generator. In such a system, the plate reactance becomes comparable to the plate resistance of the tube. In Fig. 7(b) the tube is replaced by an equivalent constant-current generator which is loaded by the plate resistance r_p in parallel to the input impedance L_p of the sweep transformer. Assuming a plate current with constant rate of rise:

$$i_{p(t)} = I_p \cdot \frac{t}{H}, \tag{25}$$

the current i_L through the load inductance then becomes

$$i_L = I_p \frac{t - \tau(1 - \epsilon^{-t}/\tau)}{H}; \qquad \tau = L_p/\gamma_p \tag{26}$$

or in series form:

$$i_L = I_p \frac{\tau}{H}\left[\frac{\left(\frac{t}{\tau}\right)^2}{2!} - \frac{\left(\frac{t}{\tau}\right)^3}{3!} + \frac{\left(\frac{t}{\tau}\right)^4}{4!} - \cdots\right]. \tag{27}$$

This is shown in Fig. 7(c) for the case of $\tau = 1/3 \cdot H$. It is found that the scanning speed is too slow at the start, but reaches its correct value at the end of the sweep. The lack of high-frequency response in the sweep amplifier is thus responsible for a scanning nonlinearity of the nature of an *acceleration*.

This type of distortion may be corrected by suitable predistortion of the plate-current wave form in the sweep amplifier. Fig. 7(d) shows one such method of linearization. A high-pass filter C_gR_g is inserted between the sawtooth voltage generator *1* and the sweep amplifier *2*. The time constant R_gC_g of the correcting network is of the same order as, or smaller than, the sweep period H. By itself, such a network introduces sweep deceleration along each line as indicated. The over-all nonlinearity may thus be conveniently corrected by variation of R_g.

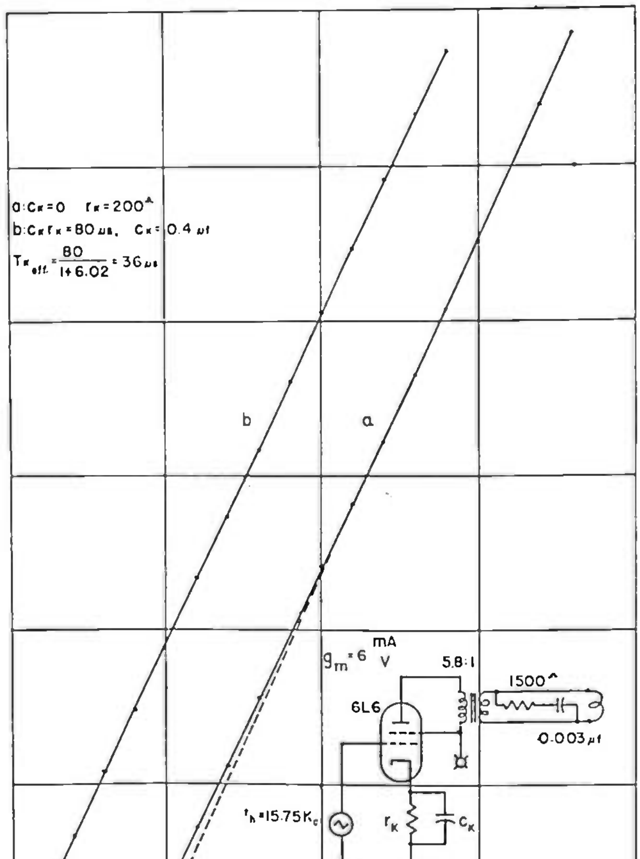


Fig. 8—Distortion through nonlinearity of tube characteristic and its correction.

Another method for correcting for sweep acceleration is shown in Fig. 8. Here, the high-frequency emphasis is obtained by a cathode-bypass capacitor of critical size. The graph indicates the position of vertical bars as observed on the face of a kinescope. The bars were keyed at equal time intervals and were obtained from a signal generator operating at the 15th harmonic of the horizontal sweep frequency. Graph (a) is taken with grounded cathode (infinite bypass capacitor). It shows a small degree of sweep acceleration at the start of each line. Curve (b) is obtained with a cathode time constant of approximately one-half the line period. The correcting action of this high-pass filter is clearly evident.

It is worth mentioning that a similar type of sweep distortion may be caused by nonlinearity of the tube characteristic. This factor produces a sweep acceleration, i.e., it acts as though the lower Fourier components of the sweep were better transmitted than its higher harmonics. Tube nonlinearity may thus be corrected by high-frequency compensation as described. Using this technique, it becomes possible to operate sweep systems as class A-B amplifiers. In so doing, plate current and power input can be markedly reduced. The nonlinearity of the tube characteristic may also be utilized to correct for the opposite type of distortion, known as sweep deceleration. This distortion is frequently encountered in systems for low-frequency deflection, and will be considered below.

An example of the deceleration type of distortion is given in Fig. 9. This distortion occurs if the frequency response is deficient at low frequencies. Fig. 9 shows the typical circuit of a low-frequency sweep amplifier with output transformer. At the low sweep frequencies, the reactance in the yoke circuit L_0 is no longer large as compared to the yoke resistance R_0. The equivalent schematic of Fig. 9 shows a constant-current generator loaded by a pure inductance L_2 in parallel with the lossy inductance L_0/r_0. The frequency response of this system shows a drop at low frequencies. The wave form of the resulting sweep was calculated in a similar manner as above. If the current input rises linearly with time:

$$i_p = I_p \cdot t/V, \tag{28}$$

the yoke current becomes

$$i_0 = I_p \cdot \frac{L_2}{r_0} \cdot \frac{1}{V} \cdot \left[1 - \epsilon^{-t/\tau}\right]; \qquad \tau = \frac{L_2 + I_0}{r_0} \tag{29}$$

or in series form,

$$i_0/I_p = \frac{L_2}{L_2 + L_0} \frac{t}{V} - \frac{L_2}{r_0 V}\left[\frac{\left(\frac{t}{\tau}\right)^2}{2!} - \frac{\left(\frac{t}{\tau}\right)^3}{3!} + \cdots\right]. \tag{30}$$

This is shown in the graph of Fig. 9 for the case $\tau/V = 0.6$. Apparently, the speed of the scanning movement decreases during the sweep, and would reach zero after a sufficiently long time. Thus, *deceleration* is found to result from a lack of low-frequency response in sweep amplifiers. The correcting predistortion of the grid voltage may be found in the following manner. The Heaviside function of the system in Fig. 9 is

$$h = \frac{L_2}{L_2 + L_0} \cdot \epsilon^{-t/\tau}, \tag{31}$$

i.e., the load current i_0 for a unit step current input. If some predistorted plate current with unknown wave form i_p is fed into the system, the resulting load current will be

$$i_0 = \int_0^t i_{p(\theta)}' \cdot h_{(t-\theta)} d\theta. \tag{32}$$

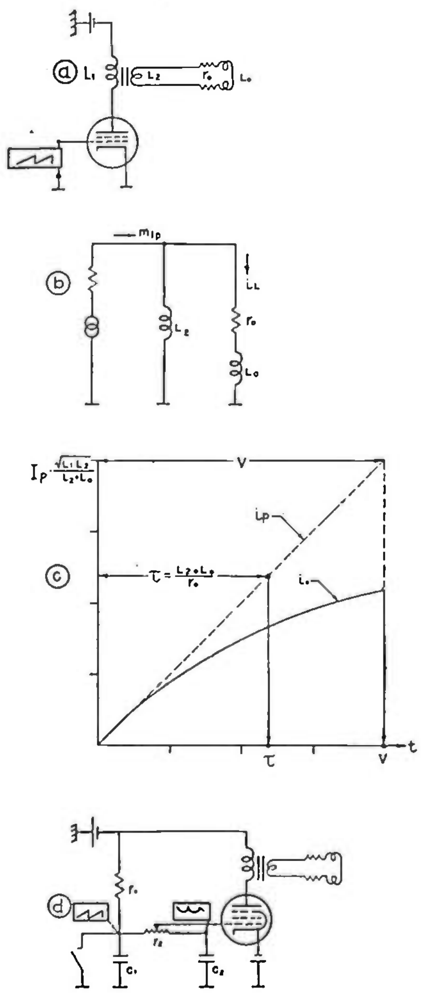


Fig. 9—Distortion by yoke resistance and its correction.

By postulating that this becomes a linear function of time, an integral equation is obtained for the plate current[2]:

$$\int_0^t \frac{di_p}{d\theta} \cdot \epsilon^{(\theta - t)/\tau} d\theta = Kt; \quad K = \text{constant}. \tag{33}$$

The solution is a wave form which contains only the first and second powers of time:

$$i_p = Kt\left(1 + \frac{1}{2}\frac{t}{\tau}\right). \tag{34}$$

[2] This is an integral equation of the Volterra type. See E. T. Whittacker and G. N. Watson, "A Course of Modern Analysis," 1944, p. 221, section 11.31.

This signal is readily generated with a circuit of the type shown in Fig. 9(d). This circuit comprises two integrating networks in tandem. A linear-voltage sawtooth appears across the first capacitor C_1, while a parabolic-voltage wave form is obtained across the second capacitor C_2 by integration of the current sawtooth through r_2. At a tap along r_2, it is thus possible to extract any desired proportion of linear and quadratic terms of t as required by (34). In this way linearity correction of low-frequency sweep transformers may be carried out successfully.

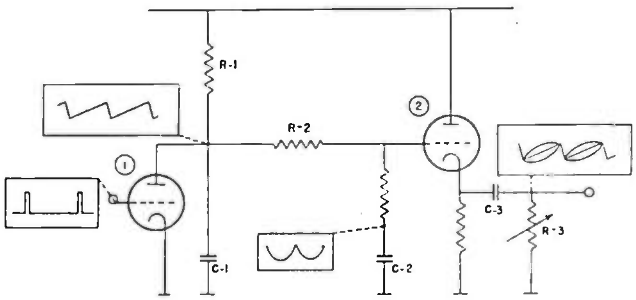


Fig. 10—Linearization circuit for sweep amplifiers.

A practical driver circuit for general linearity control of sweep amplifiers is shown in Fig. 10. This system produces a voltage sawtooth of constant amplitude, but with an adjustable degree of acceleration or deceleration, including zero distortion. The circuit combines the double-integration feature of Fig. 9 and the variable hi-pass from Fig. 7. Triode *1* is a pulsed discharge tube while a cathode-follower stage *2* is used as isolation amplifier. The variable high-pass filter R_3C_3 counteracts the integrator system R_2C_2 to a degree which may be adjusted at the resistor R_3. The wave forms at various points of the circuit are indicated in Fig. 10. The oscillograms (Fig. 12 (e) and (f)) show actual output wave forms as obtained from the same input for two different adjustments of this system.

PART IV

A Sweep Circuit of Improved Efficiency

To overcome the need for a power supply of high voltage and wattage in color receivers, a special sweep system was developed in the Columbia Broadcasting System laboratories.

This circuit is based on the principle of reclaiming rather than dissipating the energy of, the magnetic field at the end of each cycle and feeding it back into the B-supply for the sweep amplifier. In this way, the flyback energy will assist the direct-current power supply in raising the plate voltage for the output tube, and thus aid in driving plate current through the tube. While this happens, the energy stored in the yoke is rapidly used up and the unwanted transients are eliminated. Conversion of the field energy into the plate circuit of the power stage acts much like an equivalent step-up of the B-supply voltage, so that operation of the system may be maintained with a direct-current power supply operating at a reduced voltage.

If a system of this type reclaims K per cent of the field energy for its direct-current supply, the over-all efficiency improves from η_0 without feedback (9) to

$$\eta = \frac{\eta_0}{1 - K\eta_0}. \qquad (35)$$

The power feedback acts like a battery of

$$\Delta e = K \cdot \eta_0 \cdot e_0 \text{ volt} \qquad (36)$$

in series with the power supply voltage e_0.

The high-efficiency circuit for sweep generation is shown in Fig. 11. The system contains no resistive elements whatever in the deflection circuit *1* and *2*. Instead, energy is extracted, after the retrace period, from the transformer field by the use of a separate damper coil *3* which is connected to a low-impedance diode *4*. The polarity of the pulse output from the damper coil is such that the diode is conductive only during the sweep period, but not during the flyback. (See Fig. 12(g).) Positive charges are thus accumulated across the capacitors *5* and *6*, which are connected by an inductance *7*. The oscillogram (Fig. 12(g)) shows in three consecutive lines the wave forms of plate voltage, sweep current, and diode current as they occur in this sweep generator. It is apparent that the plate voltage is constant during the sweep

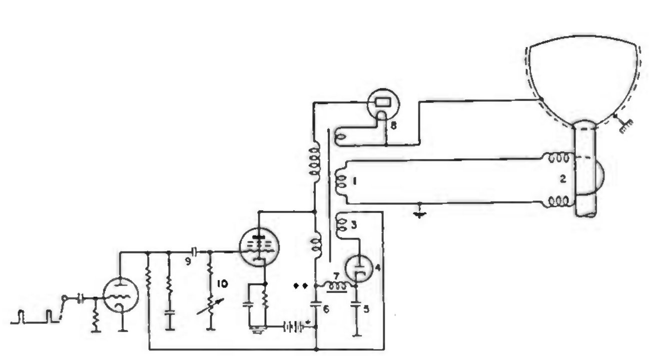


Fig. 11—High efficiency system for wide angle deflection combined with high-voltage generation.

and has a positive peak during the flyback. By transformation and rectification of this peak in a separate diode *8*, an anode voltage of 8000 is obtained for operation of the kinescope. The current through the efficiency diode *4* is nearly constant during the sweep and ceases during the retrace. Immediately after the flyback, however, the diode current reappears at a peak value which is about three times the average direct current supply. During this part of the cycle, the accumulated energy of the field is converted into pulsating direct-current energy across the capacitor *5*. If close coupling is achieved between the damper coil *3* and the secondary coil *1*, this system is capable of eliminating transients, while additional direct voltages of the order of 100 volts are built up across the capacitors *6* to assist the flow of plate current.

Figs. 12(h) and (i) show the pulsating component of the rectified voltage across the first and second filter capacitors, *6* and *8* respectively. Between input and output voltage, a delay of almost an entire line period is observed. This appears plausible if the network *5-6-7* is considered as one section of a low-pass filter with a cutoff frequency at about one-half of the sweep frequency. ($C_5 = C_6 = 0.02$ microfarad, $L_7 = 20$ millihenries.) The parabolic ripple of the plate-supply voltage leaving the filter is used as correction for sweep distortions introduced by the damper circuit. The only distortion left is a slight deceleration which is readily corrected by a variable grid-coupling element *9–10*, with relatively short time constant.

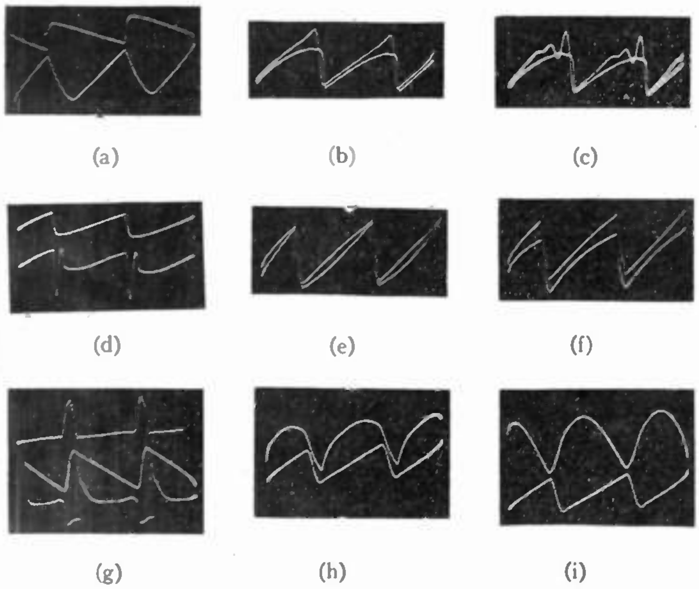


Fig. 12—Oscillograms of wave forms in sweep generators.
(a)—Sawtooth drive with negative rate of change. Plate current shows sluggish retrace.
(b)—Tetrode damping. Grid voltage and plate current with suppressor connected to screen. Sawtooth drive with positive rate of change. No transients.
(c)—Tetrode damping. Grid voltage and plate current with suppressor grid to ground. Transients in plate circuit are shown.
(d)—Damping by secondary emission. Tetrode sweep amplifier. Suppressor at screen voltage. Plate current and screen current are shown.
(e)—Linear sawtooth drive. Output shows acceleration distortion.
(f)—Linear sawtooth drive. Output shows deceleration distortion.
(g)—High-efficiency circuit: wave forms of plate voltage, sweep current, and diode current.
(h)—Rectification of flyback power. Voltage at first filter capacitor.
(i)—Rectification of flyback power. Voltage at second filter capacitor.

With this system, it is possible to obtain wide-angle deflection at a sweep frequency of 37,800 cycles per second, using less than 70 watts input at 350 volts. The direct-voltage increase was measured as 80 volts, so that the output amplifier tube, type 815, was operating with an actual plate supply of 430 volts. The direct-current feedback power amounted to 18 watts, which is almost one-half of the total field energy. The over-all efficiency of this type of scanning supply has therefore been improved from 45 to about 65 per cent. The additional high-voltage supply brings the over-all economy of the system close to 70 per cent.

Additional References

At the time this work was done (1944 to 1945), very little published information about deflection was available. Listed below are several excellent papers which have appeared more recently:

1. W. T. Cocking, "Electromagnetic deflection," *Wireless World*, pp. 217–222; July, 1946, and pp. 289–291, September, 1946.
2. A. W. Friend, "Television deflection circuits," *RCA Rev.*, vol. 8, pp. 98–138; March, 1947.
3. R. Rawcliffe and R. W. Dressell, "Magnetic focusing and deflection," *Electronic Ind.*, vol. 5, p. 51; October, 1946.
4. G. C. Sziklai, "Current oscillators for television sweep," *Electronics*, vol. 19, pp. 120–124; September, 1946.

Electronic Indicator for Low Audio Frequencies*

A. E. HASTINGS†, ASSOCIATE, I.R.E.

Summary—**An instrument which indicates the frequencies of the components in a periodic complex electrical waveform is described. The frequencies are displayed on four parallel linear scales on a cathode-ray tube. The scales can be set up, without frequency calibration and with an accuracy of 3 per cent, from design equations developed in this paper. The range of indication is from 1 cycle to 1 kilocycle per second. The performance is described, and limitations on the rate of sweeping the frequency bands and the effects of transients are discussed.**

* Decimal classification: R371.1. Original manuscript received by the Institute, March 8, 1946; revised manuscript received, January 6, 1947.

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Introduction

In the solution of a particular problem, a need has arisen for the rapid analysis of complex audio wave forms. The component frequencies may be as low as a few cycles per second. The frequencies and amplitudes of the complex wave form may vary with time, so that it is desirable to analyze the wave form as rapidly as possible. The required analysis amounts to the rapid display of amplitude versus frequency.

A number of methods of obtaining this display suggest themselves. The arrangement allowing the most rapid analysis consists of a large number of resonant elements, with a means for displaying the amplitudes of oscillation against frequency. The reed type of frequency meter is an example of this method. The disadvantages are the bulkiness of the large number of elements, particularly for the lower frequencies, the difficulty in maintaining equal amplitude response from element to element, and the difficulty in obtaining suitable selectivity for each element.

A second general method is that of sweeping the resonant frequency of a single element through a frequency band and displaying the amplitude response against frequency. There is a finite response time inherent in any resonant circuit which limits the rate of sweep, and since here a single element has to cover a range of frequencies, this method of analysis then is necessarily slower than the one first described. There is the simplicity of a single resonant element only, and certain other advantages depend on the type of tuned circuit employed and on the method of its use.

Two types of electrical elements exist with variable resonant frequency. The common inductance-capacitance circuit is impractical at low frequencies, as it is difficult to vary its resonant frequency and to obtain very great selectivity. The second type,[1] an amplifier with bridge-controlled feedback, has the advantages of widely adjustable selectivity and of constant Q over any frequency range.

A third general method of analysis is that used in the superheterodyne wave analyzer. Here the single element is operated at fixed frequency, and the frequency band is made to sweep over this frequency. This frequency can be much higher than the frequencies to be measured, an advantage when these frequencies are low. The single element can be carefully designed as to response characteristics. Features of the heterodyne method include the complexity of the circuits, the variation of Q with frequency, and the slowness of analysis, since the sweep rate is limited by response time as in the second method.

The design of instrument chosen for this work combines the first two methods. The required frequency range is divided into four parts, each part swept simultaneously with the others by a single selective circuit using a bridge-controlled feedback amplifier. The amplitude responses of the four selective circuits are displayed on four scales simultaneously as a function of frequency on a single cathode-ray tube. By sweeping the beam of the cathode-ray tube in a particular manner, linear scales are obtained. Each scale may be made to cover a range of frequencies within certain limits independently of the others.

In the work for which this instrument was designed, only a rough measurement of amplitudes of the frequency components was desired. While the sensitivity of the instrument could be obtained by calibration, the limited amplitude scales do not allow much accuracy of reading. Accordingly the instrument is called simply a frequency indicator.

Description of Indicator

Fig. 1 is a block diagram of the arrangement. The audio input drives four channels, each covering a range of frequencies and including a tuned amplifier, a clipper, and a mixer.

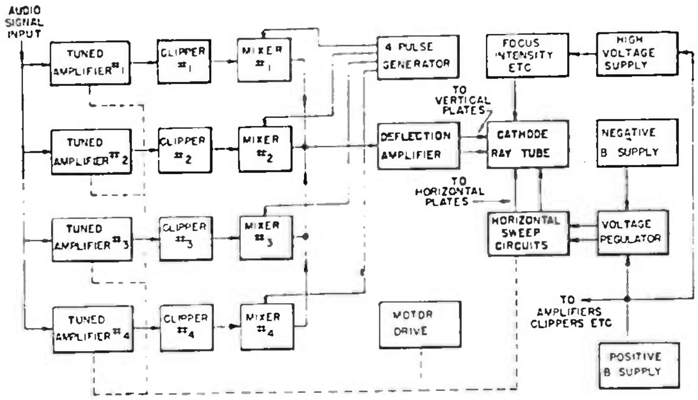

Fig. 1—Block diagram of frequency indicator.

The tuned amplifier consists of an amplifier with inverse feedback through a Wien bridge. The bridge balances to a null in output at one frequency only. At this frequency the feedback is zero and the amplifier operates with full gain, while at other frequencies the feedback is so degenerative that the amplifier output is sensibly zero. This provides a tuned amplifier with variable selectivity and variable frequency, controlled by variable resistors in the amplifier and bridge. The clipper, or rectifier, removes one half of the amplifier output, essentially a sine wave, to obtain an upward deflection only on the screen of the cathode-ray tube. The mixer allows the clipped signal to deflect the beam of the cathode-ray tube for one quarter of the time and from a particular base line.

The outputs of the four channels are displayed on a single cathode-ray tube. This display is accomplished by a four-pulse generator and the four mixers. The generator has four output channels, with a square pulse occurring in each in succession. All square pulses are of equal length, following each other in time with no overlapping and with no gaps between them. Each pulse drives one mixer, which allows the clipped audio signal in its channel to pass, together with a voltage which forms a base line, for the duration of the pulse. All four mixer outputs are combined and passed through a deflection amplifier to the vertical deflecting plates of the cathode-ray tube. The square pulses are short relative to the period of the frequencies to be measured, so that many of them occur during a single cycle of the signal frequency. The cathode-ray beam is swept slowly in a horizontal direction by a voltage derived from motor-driven variable resistors ganged with the variable resistors in the bridge circuits, so that a particular null fre-

[1] H. H. Scott, "A new type of selective circuit and some applications," Proc. I.R.E., vol. 26, pp. 226–236; February, 1938.

quency of any bridge, and a maximum gain in the associated amplifier, always occurs at the same horizontal position on the cathode-ray screen. The cathode-ray The cathode-ray tube is blanked between sweeps. The sweep rate can be varied by changing gears in the motor drive.

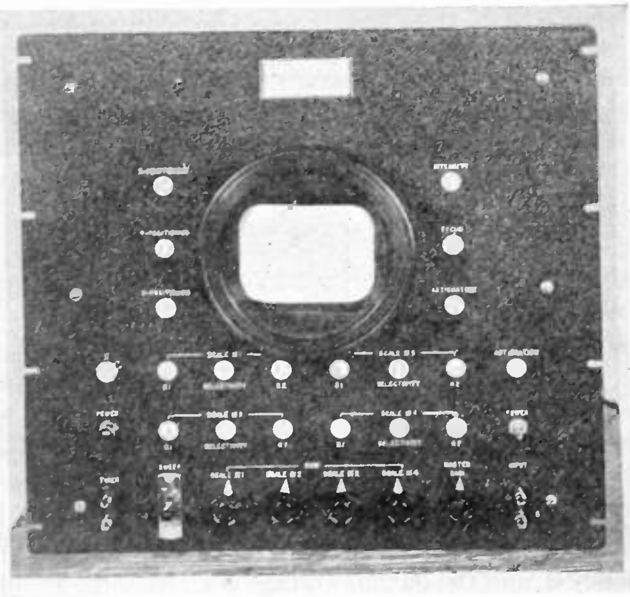

Fig. 2—Panel view of indicator.

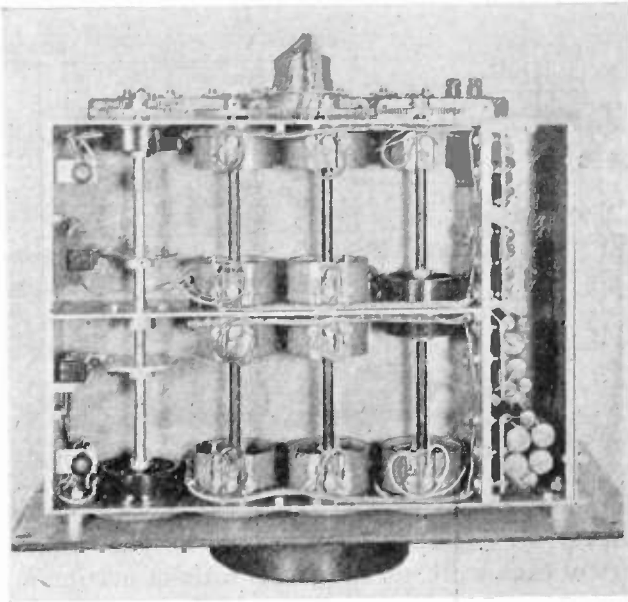

Fig. 3—View showing variable resistors for sweep and bridge circuits.

beam, then, traces out a part of the output signal from one channel above the lowest base line, rises to the next base line and traces out a part of the signal from the second channel, and so on to the fourth line, when it

If the cathode-ray tube is swept with a voltage which changes at a constant rate, the resulting frequency scales are nonlinear. The indicator has a resistance net-

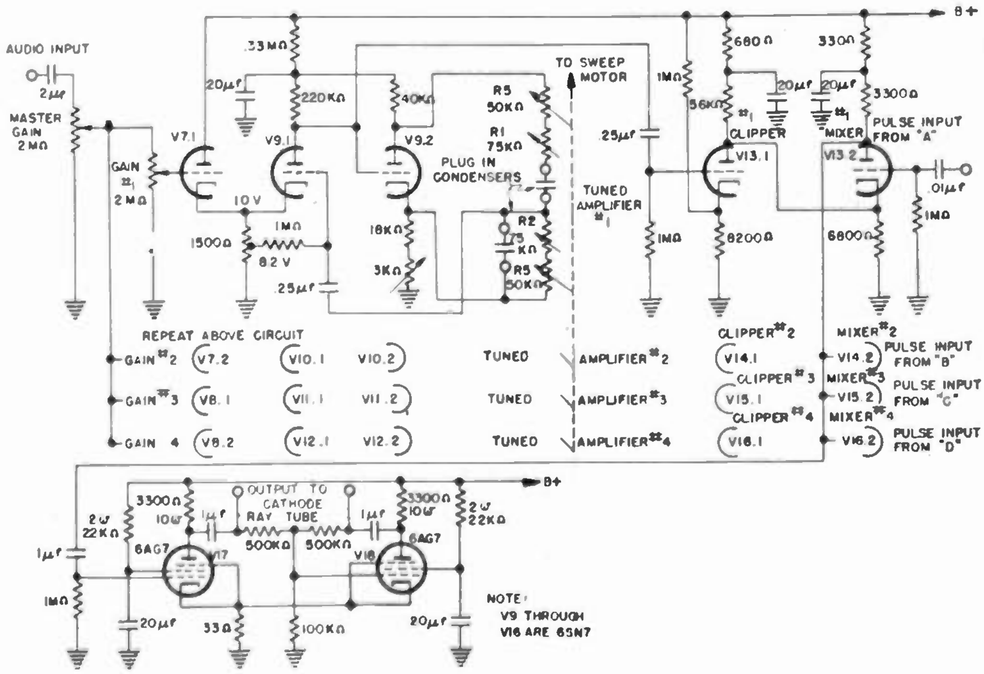

Fig. 4—Circuit for amplifiers and electronic switches.

drops and traces a successive part of the signal from the first channel. The resulting pattern appears as a continuous display of frequency against amplitude for the four channels, each above the other. Since the sweep rate is low, a long-persistence screen aids in visual observation.

work, including the motor-driven resistors, which provides a sweep voltage varying with time in such a manner as to produce linear frequency scales. The voltage supplied to this network and the network resistance values depend on the scale ratio of maximum to minimum frequency, which is chosen the same for each scale. A simple voltage regulator holds the supply voltage at the required value. Equations are given which allow calculation of the supply voltage and resistance

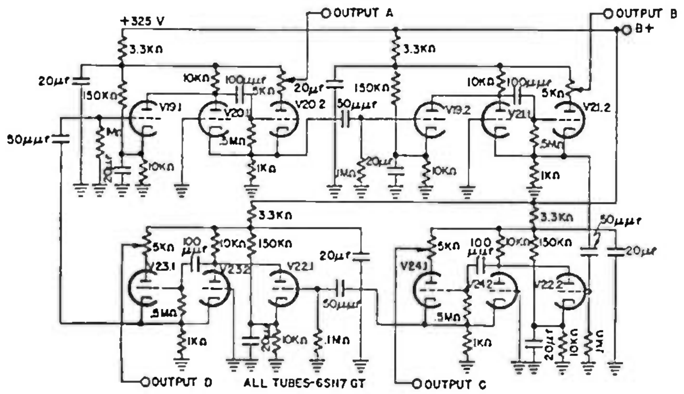

Fig. 5—Four-pulse generator.

values in the sweep circuit and of the resistance values in the bridge circuits for any scale ratio. The frequency range of each scale, except for its ratio of maximum to minimum, is independent of that of the others and can be determined by plug-in capacitors of value calculated from a given equation.

Fig. 2 is a front view of the frequency indicator. The cathode-ray tube, its controls, scale ratio and selec-

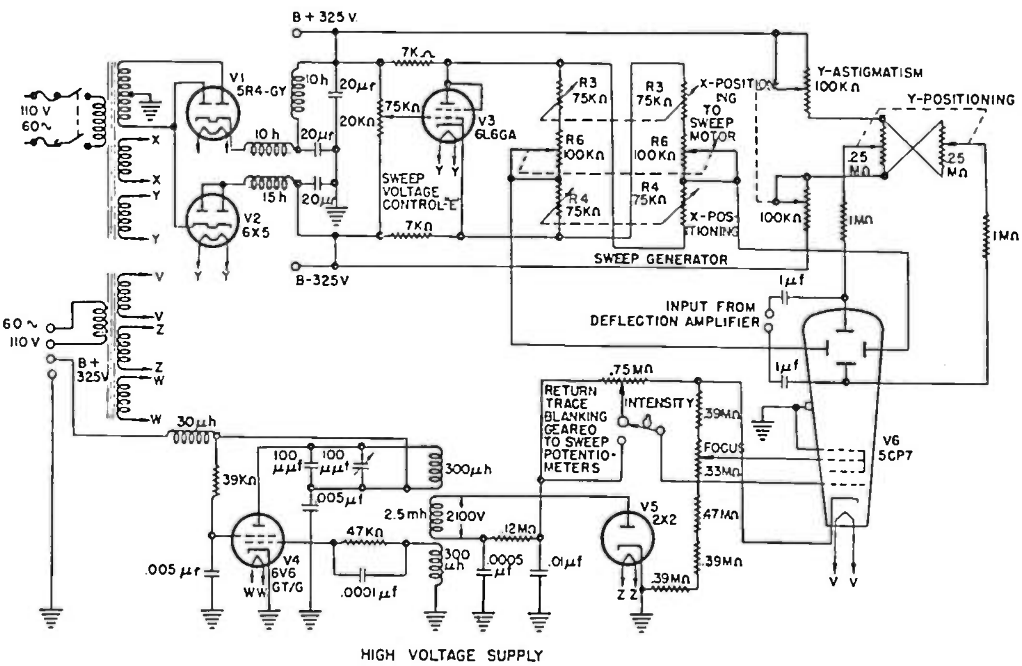

Fig. 6—Power-supply and cathode-ray-tube circuits.

tivity controls for each scale, and terminals for a time switch appear on the panel. The switch can be used for operating a camera shutter after every sweep. Fig. 3 shows the gear drive, the variable sweep and bridge resistors, the cam-operated blanking and timing switches, and the plug-in capacitors for each range. Figs. 4, 5, and 6 show the circuit details.

Analysis

The Wien bridge, the tuned amplifier, and the sweep circuit used in the frequency indicator are best understood by circuit analysis.

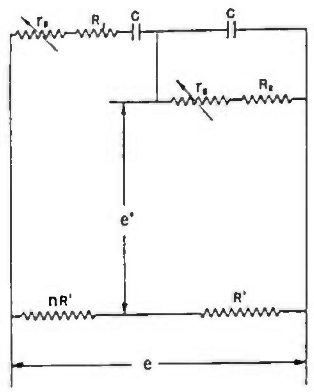

Fig. 7—Circuit of Wien bridge used in amplifiers.

The form of the Wien bridge used is shown in Fig. 7. The input voltage to the bridge is e with angular frequency ω, and the output voltage is e'. At some angular frequency of the input voltage, e' will be zero. It can be shown that the conditions for this null are

$$\omega_0 = 2\pi f_0 = \frac{1}{C\sqrt{(r_5 + R_1)(r_6 + R_2)}} \quad \text{and} \quad n = 2.$$

If the two r_6's are ganged and varied together, the null frequency can be varied continuously. The variation is inverse, resulting in a very nonlinear scale if the variation is over too wide a range. If the range is restricted on a single scale, substitution of fixed values C gives a means of changing scales. The scale range of 2.2 to 1 used gives harmonically related scales with sufficient overlapping and allows the linearization described later. The other condition for a null requires $n=2$. It is convenient to use n as a means of introducing positive or negative feedback which is independent of frequency, giving control of selectivity, and n is made variable.

If e is made the output of an amplifier and e' the inverse feedback to its input, and if there is no signal input to the amplifier, the input and output are related through the gain μ without feedback by

$$e + \mu e' = 0.$$

It may be shown by a comparison of differential equations of the circuits that this arrangement is equivalent to a resistance-inductance-capacitance circuit in which the parameter n determines the damping. For $n=1/(\mu-1)$ the circuit is critically damped. For higher values of n the circuit becomes oscillatory with angular frequency ω_0. This is the condition of operation employed in order to realize high selectivity. Sustained oscillation may occur if n exceeds the value $(2\mu+3)/(\mu-3)$. The Q of the circuit is given by

$$Q = \frac{f}{\Delta f} = \frac{\mu + n + 1}{3n + 3 + 2\mu - \mu n}$$

where Δf is the bandwidth. A Q of about 15 used is a compromise for high selectivity and reasonably small response time. The selectivity is constant along the scale and on any scale. The time constant of the circuit is

$$\tau = \frac{Q}{\pi f}. \quad (1)$$

With $Q=15$ and $f=5$, this time constant is about 1 second. The gain μ is not a critical quantity in this circuit, since variation of n also determines the damping and selectivity. The μ used is about 60, and n is 2.09. R_1 and R_2 are here considered equal; they are used to compensate for variations in the r_5's in the practical application.

R_1 and C are fixed, and the two r_5's are ganged and rotated at a constant angular velocity. Let

T = time required to sweep cathode-ray beam across full scale (3 to 20 seconds)
t = time required to sweep cathode-ray beam along scale to distance x
f_0 = value of null frequency at beginning of scale ($t=0$) (2.5 to 20 cycles per second)
af_0 = value of null frequency at end of scale ($t=T$)
x = distance of beam along scale, measured from f_0 to any distance f
l = length of scale (4 inches)
R_5 = maximum value of r_5 ($t=0$) (75,000 ohms)
a = scale ratio f_l to f_0 (2.2).

It can be shown that if

$$R_1 = \frac{R_5}{a - 1} \quad (2)$$

then

$$f_0 = \frac{a - 1}{2\pi a C R_5} \quad (3)$$

and the frequency for a maximum in amplifier output varies according to the law

$$f = \frac{f_0 a}{(a - 1)\left(1 - \frac{t}{T}\right) + 1}. \quad (4)$$

For a linear scale under the above conditions, it is required that

$$f = f_0\left[1 + \frac{x}{l}(a - 1)\right]. \quad (5)$$

If f is eliminated from (4) and (5),

$$x = \frac{l\frac{t}{T}}{a - (a - 1)\frac{t}{T}}. \quad (6)$$

Then a voltage, varying with time in such a manner that the deflection as given by this equation is obtained, must be applied to the horizontal deflecting plates of the cathode-ray tube. The circuit of Fig. 8 has been devised to produce this voltage e_2 balanced to ground. R_3 and R_4 are fixed and the r_6's are variable resistors ganged and rotated synchronously with those in the

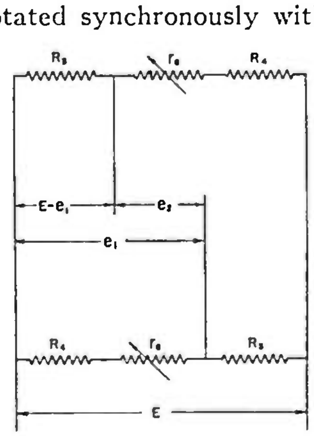

Fig. 8—Circuit producing nonlinear sweep voltage.

Wien bridge, the r_6's varying from zero to R_6 (100,000 ohms). The position of the beam of the cathode-ray tube along the scale may be found as

$$x = \frac{R_6 R_3 l \frac{t}{T}}{(R_4 + R_6)^2 - R_3^2 - (R_4 R_6 + R_6^2 - R_3 R_6)\frac{t}{T}} \quad (7)$$

providing the supply voltage to the sweep circuit is maintained at the value

$$E = \frac{kl}{2}\left[\frac{R_4 + R_6 + R_3}{R_4 + R_6 - R_3}\right]. \quad (8)$$

k is the sensitivity of the cathode-ray tube in volts per unit deflection (about 70 volts per inch). Comparing (6) and (7), it is seen that these relations must hold:

$$\frac{(R_4 + R_6)^2 - R_3^2}{R_3 R_6} = a \tag{9}$$

and

$$\frac{R_4 R_6 + R_6^2 - R_3 R_6}{R_3 R_6} = a - 1. \tag{10}$$

These give the following conditions on R_3 and R_4 in terms of the maximum value R_6 of r_6:

$$R_3 = \frac{aR_6}{a^2 - 1} \tag{11}$$

and

$$R_4 = \frac{R_6}{a^2 - 1}. \tag{12}$$

Substituting (11) and (12) in (8) gives

$$E = \frac{kl}{2}\left[\frac{a+1}{a-1}\right]. \tag{13}$$

In the indicator used, $R_3 = 57{,}000$ ohms, $R_4 = 26{,}000$ ohms, and $E = 370$ volts. The instrument can be set up for a variety of scales within the practical limits on f_0 and a. If these two quantities are given, the required values of R_1, C, R_3, R_4, and E can be determined from (2), (3), (11), (12), and (13).

In an instrument of this type, where one selective circuit sweeps a frequency band, it is obvious that the circuit must accept any one frequency for a limited time. Suppose a sine-wave signal with a frequency f. A Fourier analysis carried out by any method would give the amplitude of the single-frequency component, in this signal, assuming the signal continuous from $-\infty$ to $+\infty$. If only a limited number of periods of the signal exist, however, the Fourier analysis gives an amplitude-frequency spectrum with a maximum at f. Any device which carries out this same analysis over a limited number of periods must produce at best a broadened response, no more selective than that given by the spectrum of the Fourier analysis. In the indicator under consideration, the time during which the selective circuit is exposed to a single-frequency signal decreases as the rate of sweep is increased. At relatively high rates, the circuit is exposed to the signal only for a few signal periods, and accordingly the normal amplitude-frequency response is much broadened.

It has been shown that the indicator requires a certain time to respond to a change in input signal. Thus when the frequency of the tuned amplifier is swept continuously over the fixed frequency of an input signal, the resulting resonance curve of amplitude versus time is distorted. This distortion increases with rate of sweep, and since reading the input frequency involves locating the peak of the resonance curve, the rate of sweep is limited by the scale accuracy desired. Walther[2], who has considered this problem in a general way, concludes that the maximum rate of sweep must be less than the square of the bandwidth. Here the rate of sweep is a maximum at the end of the scale. If this condition is used, it can be shown that the minimum time of sweep for the linear scale becomes

$$T_{\min} = \frac{Q^2(a-1)}{af_0} \tag{14}$$

which requires longer periods for low-frequency scales. This relation gives order of magnitude only.

Another limitation on the rate of sweep occurs when the individual cycles of the amplifier output, as displayed on the screen of the cathode-ray tube, are much extended. Suppose that a maximum in the resonance curve can be located within one period of the output frequency. It can be shown that if ϵ is the allowable error of location expressed as a fraction of full-scale value, the time of sweep is given by

$$T = \frac{1}{f_0 \epsilon}. \tag{15}$$

Table I shows calculated values of these sweep times and measured errors for typical adjustments of the parameters.

TABLE I

EFFECT OF TIME OF SWEEP ON ACCURACY

Sweep time (seconds)	Indicated frequency (cycles per second)	Error (per cent)	$\epsilon = 1/f_0T$ (per cent)	$T_{\min}$ (seconds)
Scale, 2.5 to 5.5 cycles per second. Input frequency, 4.5 cycles per second.				
3	5.4	16	14	48
7	4.8	6	6	
20	4.6	2	2	
Scale 5 to 11 cycles per second. Input frequency, 9.0 cycles per second.				
3	10.2	9	6	
7	10.1	9	3	24
20	9.1	1	1	
Scale, 10 to 22 cycles per second. Input frequency, 18 cycles per second.				
3	20.0	9	3	
7	19.0	5	2	12
20	18.5	2	1	
Scale, 20 to 44 cycles per second. Input frequency, 36 cycles per second.				
3	37	2	2	
7	36	0	1	6
20	36	0	0	

$$T_{\min} = \frac{Q^2(a-1)}{af_0} \qquad Q = 15, \quad a = 2.2$$

PERFORMANCE

The peak corresponding to any frequency can be located on the scale with an accuracy of 1 per cent of full scale. The indicator can be arranged for a particular set of linear scales, setting the sweep supply voltage and the resistance values and choosing the correct capacitor

[2] C. H. Walther, "Über die grenzen der analyziergeschwindigkeit bei frequenzgemischen," *Wissenschaftliche Veröffentlichungen aus dem Siemens-Konzern*, vol. 14, no. 1, pp. 56–63; 1935.

values according to the design equations, with a maximum error of 3 per cent of full scale. A variation of 10 per cent in line voltage has no effect on accuracy. With the gain controls at maximum, the minimum signal required to produce full-scale deflection of ¾ inch is about 0.05 volt, varying less than 30 per cent between scales and along any one scale. The lower limit of frequency is set by the coupling circuits at about 1 cycle per second. The higher limit is somewhat indefinite. Since the rate of the four-pulse generator is 5 kilocycles per second, only small parts of a high-frequency sine wave from the tuned amplifiers are displayed, and component frequencies much over 1 kilocycle are so poorly displayed as to distort the peak locating the frequency.

As has been shown, the time required to sweep a scale increases as the scale is lowered in frequency. Table I shows the correlation of the errors in performance with the errors predicted by the analysis for one setup of the indicator. Equation (15), which gives one error in locating the frequency peak, expresses the actual error quite well. Equation (14), intended to give only order of magnitude, predicts much better than this.

Since the tuned amplifiers operate like high-Q circuits, they have response and decay times given by (1). For a given Q, τ becomes relatively large at low frequencies and may be an appreciable part of the time of sweep. If a high-level transient, such as a sudden surge of input voltage or of line voltage, is applied to a tuned amplifier operating at low frequency, the time required to damp the resulting response may extend over an appreciable part of the scale. If these transient disturbances occur very frequently, a low-frequency scale may be quite obscured by the responses. Close regulation of power supplies would be advantageous in removing disturbances due to line transients, but all power supplies must then be regulated to make the calibration independent of line voltage. There are compensating features which accomplish this result if no supplies are regulated.

ACKNOWLEDGMENT

J. B. Stickney, W. S. Sunderlin, and J. J. Myers carried out the development, construction, and testing of the frequency indicator.

A Coaxial Load for Ultra-High-Frequency Calorimeter Wattmeters*

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Summary—A design is described for a broad-band coaxial water load suitable for use in ultra-high-frequency calorimeter wattmeters. The load utilizes a water-filled coaxial line as an attenuating section. The low input impedance of this line is matched to the standard transmission-cable impedance in a broadband matching section using a tapered dielectric composed of titanium dioxide.

Several requirements influenced the design: the needs for broad-band impedance characteristics, sturdy construction, small physical size, and for the ability to measure low powers quickly, being of prime importance. As a practical illustration, a brief description is given of a unit designed to operate in the 1000- to 3000-megacycle frequency ranges and the 5- to 150-watt power range.

INTRODUCTION

A COMMON method for obtaining an accurate absolute measurement of ultra-high-frequency energy is that in which the electrical energy is changed to heat energy which can be measured by ordinary calorimetric methods.

The initial problem in the design of such a calorimeter wattmeter is that of converting the electrical energy to heat energy. This is done invariably by dissipating the electrical energy in a resistive circuit element of a nature appropriate to the frequency of the power to be measured. At ultra-high frequencies, coaxial circuit elements are commonly used and a coaxial load is normally desired.[1]

The ideal load element would combine small physical size and sturdy construction, with an electrical design resulting in an input impedance that is a real quantity, constant in value over the frequency range in which measurements are desired. It is possible to realize this goal to a practical degree with two general types of load elements. In the first, energy is dissipated in a lossy material and the resultant heat is transferred to an air or liquid coolant in which it can be measured. Water-cooled carbon resistances or lengths of "lossy" cable are examples. In the second, the electrical energy is converted to heat directly in the liquid which forms a dissipative medium. An example is a salt-water load. Such circuit elements find uses other than in connection with power measurement, particularly as broad-band terminations.

The power converted to heat in the load element is

* Decimal classification: R245.6. Original manuscript received by the Institute, May 23, 1946; revised manuscript received, October 8, 1946. This paper is based on work done at the Radio Research Laboratory of Harvard University, under contract OEMsr-411 with the Office of Scientific Research and Development, National Defense Research Committee, Division 15.

† Formerly, Radio Research Laboratory, Harvard University, Cambridge, Mass.; now, Airborne Instruments Laboratory, Mineola, New York.

[1] R. C. Shaw and R. J. Kircher, "A coaxial-type water load and associated power-measuring apparatus," PROC. I.R.E., vol. 35, pp. 84–87; January, 1947.

measured by the rate of change of temperature in a fixed mass of coolant, or by the temperature rise in a given flow of coolant. Actually, the heat energy can be measured by a number of conventional techniques, and this discussion will be limited to the design of a particular type of coaxial load.

General Description

The load to be described is divided into two series sections: an attenuating line in which the radio-frequency energy is dissipated, and an untuned matching line which transforms the input impedance of the attenuating section to match the normal characteristic impedance of the coaxial transmission lines used in the ultra-high-frequency range. A simplified cross-sectional view is shown in Fig. 1.

The diameters of the metallic inner and outer conductors are constant throughout, are identical in the two sections, and are chosen consistent with those of the connectors and cables with which the load is to be used. This is done to minimize discontinuities that would be introduced by sudden changes in diameters even though the ratios were to remain constant.

As a dielectric, ordinary tap water is used in the attenuating line, and it is in this that the radio-frequency energy is dissipated. In the matching sections, a tapered dielectric composed of titanium dioxide performs the functions of transforming the input impedance of the attenuating section to the transmission-cable impedance. Since there is no reduction in clearances between inner and outer conductors, as would exist if metallic tapers or quarter-wave sections were used for matching, the peak power that can be handled in the load is limited only by the cable itself. The properties of the dielectric do not impose a practical limit.

The incorporation of the load in a circulating water system permitting calorimeter measurements is simple in that it is only necessary to provide means for introducing the water at the input end of the line and removing it at the shorted end. Small holes in the outer conductor are satisfactory. No glass is used; this, coupled with the durability of the titanium dioxide, makes for a sturdy unit.

Attenuating-Section Considerations

The input impedance of the attenuating line will be an essentially real value approximating its characteristic impedance if the total attenuation in decibels is large and if the attenuation per electrical wavelength along the line is small. The relatively low loss in tap water in the ultra-high-frequency range[2] satisfies the latter condition. On the other hand, the high dielectric constant of water reduces the velocity of propagation in a completely water-filled line so that a long electrical length, and large attenuation, can be obtained in a physically short section.

[2] The loss tangent for water at 25 degrees centigrade and at 3000 megacycles is 0.15.

The attenuation in a given line can be calculated from transmission-line equations and will be found to vary with frequency both from the change in electrical length of the line and because the loss of ultra-high-frequency energy in water is not constant with frequency. In the practical case, a line whose length in air approaches one wavelength at the lowest frequency to be measured provides ample attenuation for most purposes. From the electrical standpoint, the longer the line, the better.

The impedance of the line is affected also by the dielectric constant of water, which varies with temperature.[3] It is advisable, therefore, in order to maintain matching, to restrict temperature changes to the minimum required to provide a satisfactory indication on the calorimeter thermometers or thermocouples. For a given maximum power to be measured, this is done by regulating the rate of flow of water.

Little time is required for such a system to stabilize enough to permit a calorimeter measurement. This is the result of the small quantity of water to be heated, and the fact that the radio-frequency energy is dissipated directly in the water coolant. The water capacity in the attenuating section in Fig. 1 is small in practical lines, and can be reduced still further by tapering the outer conductor of this coaxial section toward the short-circuit point. At low frequencies the improvement usually does not justify the trouble of making long tapers.

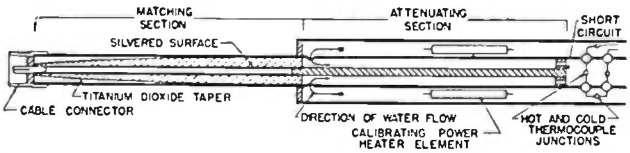

Fig. 1—Coaxial water load (simplified cross section; not to scale).

Matching Section

While the attenuating-line input impedance is nearly constant and real, it is also low because of the high dielectric constant of water. It is usually necessary to match this low impedance to 50 ohms, and to do so in an untuned matching section if frequency sensitivity is to be avoided. This is done in a coaxial line of uniform conductor dimensions, but with an exponentially tapered dielectric. This dielectric is composed of a titanium-dioxide compound so mixed and fired as to produce a material of very low loss,[4] of extremely high imperviousness to water, and with a dielectric constant approximating that of the water in the attenuating section.[5]

In order to realize fully the dielectric properties of

[3] For example, the dielectric constant of water at 3000 megacycles varies from 79 at 0 degrees centigrade to about 60 at 80 degrees centigrade.

[4] The loss is a function of both frequency and the mixture. A typical value of loss tangent for the dielectric, used in the example described in the next section, is 0.0004.

[5] The titanium-dioxide mixture used in the test loads was prepared and fired by the Laboratory for Insulation Research at the Massachusetts Institute of Technology.

the titanium dioxide, it is essential to have excellent contact between dielectric and conductor. It was found impractical to mold the dielectric around a platinum center conductor because of different coefficients of expansion. Metals, other than platinum, of good electrical conductivity would melt in the high temperatures reached during the firing cycle for the dielectric. A satisfactory solution lay in extruding the titanium-dioxide sample with a hole along the axis of the unfired cylinder. After the firing process, the surface of the hole was silvered by drawing a silver paste through it and then baking to deposit a silver coating in very close contact with the dielectric.

Titanium dioxide, when fired, has a hardness in the order of 9 on the Brinnel scale; this precludes the possibility of fashioning a taper, after firing, in any manner other than grinding with a diamond wheel, a laborious process. It was found much simpler to machine an exponential taper on a lathe, using a template as a guide in place of the normal taper attachment, while the titanium dioxide was in an unfired state and of a "chalky" composition. Thus, a cylinder of the material was first extruded from a dough with the inner conductor hole down the center axis. Then the outer surface was tapered while the substance was still in a green condition, with allowances left for shrinkage in the firing process, and the unit was then packed in sand and fired. Following this, the inner hole was silvered, as was a band around the outer surface at the large diameter end. The outer band may then be soldered directly into the outer conductor of the coaxial line, thus not only providing a water-tight joint between matching and attenuating lines but also guaranteeing a nearly perfect impedance match because of the similarity of line dimensions and dielectric constants at the junction point. The center conductor of the attenuating section can be soldered into the silvered hole in the dielectric.

The exponentially tapered dielectric provides an impedance match in which a constant change of impedance per wavelength down the line is maintained. The actual change per wavelength can be kept small to provide a nearly reflectionless match even in a line of short physical length. This is the result of the long electrical length of a line having the high average dielectric constant of the air and titanium-dioxide combination. In cases where the required impedance change is small, a linear taper may be substituted for the exponential taper with little loss in impedance-matching properties. If it is desired to use an exponential taper, its dimensions may be calculated by determining a characteristic impedance and velocity of propagation along the line under the assumption that the line inductance is uniform and determined by conductor dimensions, and that the capacitance per unit length is the series sum of the two varying capacitances whose dielectrics are of air and titanium dioxide.

As was the case with the attenuating line, the longer the taper, the better. With reasonable conductor dimensions the impedance of the attenuating line may run as low as 10 to 12 ohms, requiring an impedance transformation in the matching section of 4 or 5 to 1 to match the normal 50-ohm cable impedance. To keep the voltage-standing-wave ratio introduced on a 50-ohm line under 2 to 1 at the lowest frequency to be transmitted, the taper should have a physical length in the order of a half wavelength. As the frequency is increased, the standing-wave ratio improves rapidly. A practical case is cited in the next section.

Application

The development of this water load was undertaken to satisfy the need for an accurate wattmeter operating in the 1000- to 3000-megacycle range capable of measuring continuous-wave powers in the order of 50 watts and with impedance characteristics without external tuning at least as good as the available broad-band antennas.

The final load utilized a 9-inch attenuating line with a maximum diameter of $\frac{3}{8}$ inch. The length of the titanium-dioxide taper was 6 inches. The inner-conductor diameter was held to 0.05 inch, a Cromax wire being used in the attenuating section.[6] The unit was assembled as previously described; no glass was used, and hence no glass-to-metal seals were required.

Measurements of the voltage-standing-wave ratio introduced on a 50-ohm line terminated in this load showed a maximum value of 2 to 1 at 1000 megacycles and an average of less than 1.5 to 1 between this frequency and 3100 megacycles, the highest at which measurements were made. The impedance variations that did exist fluctuated rapidly with frequency due to the long electrical length of the matching section. An increase in matching-section and attenuating-line lengths would reduce the standing-wave ratio.

The total volume of water in the load is less than 15 cubic centimeters, so that the dissipation of only a few watts of power provides a readable temperature rise in a water flow sufficiently rapid to reduce the required reading time to from 10 to 15 seconds. If desired, a crystal probe inserted in the matching line will provide an instantaneous indication of relative power suitable for equipment-tuning purposes.

The radio-frequency power-handling capabilities are determined by permissible temperature rise and rate of flow of water. Dissipations in the order of 150 watts can be handled without trouble. An attenuating line 30 inches in length and 1 inch in diameter easily handled continuous-wave powers of 1 to 2 kilowatts.

[6] While some loss occurs in the water-cooled resistive center conductor, the principal radio-frequency loss still takes place in the water dielectric.

Charts for Resonant Frequencies of Cavities*

R. N. BRACEWELL†

Summary—Six charts are given which may be used for designing cylindrical resonant cavities whose cross sections are circles, concentric circles, squares, or rectangles. A new method of representing multiple-resonance phenomena is used, to which the name "mode lattice" has been given. The mode lattice is an alignment chart which relates the size and shape of a cavity with resonant wavelength for a large number of modes. Points distributed on a lattice represent the modes. The equations involved, the method of use, and the special advantages of each chart are described, together with the method of construction.

A set of equations has been derived for calculating the effect of small changes in dimensions or wavelength for resonators of all the above shapes.

Introduction

THE APPLICATION of resonant cavities to microwave apparatus has reached a stage where a great bulk of known results relating to higher modes of vibration should be made available in numerical form to designers. Early papers on cavity resonators, for example those of Hansen,[1] Borgnis,[2,3] and Ledinegg,[4] were concerned solely with lower modes because they were the ones to be put to immediate use, and many formulas given for numerical calculations were suitable only for the fundamental modes. Increasing use of ringing cavities has required detailed, quantitative knowledge of higher modes both for direct utilization and to enable steps to be taken to suppress or avoid unwanted modes. The present work was initiated by the need to design a ringing cavity.

Nomography,[5] the art of graphical representation of formulas, provides the means of displaying the behavior of resonant cavities. Each problem in nomography has to be considered with the object of finding the chart most suitable for the purpose. Advantage should be taken of the peculiarities of the problem, and the first solution which suggests itself should not be accepted without a comparison with alternatives. Hansen[1] has given a chart which finds the natural frequencies of transverse magnetic modes in circular cylinders whose length and diameter are equal. It could readily be elaborated to deal with cylinders of any length and diameter, but although ingenious it is already clumsy in view of the simple operation it performs. A completely new means must be sought.

Attention to the problem has resulted in the development of the "mode lattices." These charts preserve simplicity and reduce the mechanical operations of getting a solution to a minimum. The clear visual presentation which has been achieved results in easy picturing of the spectral distribution in cavity resonators and reduces likelihood of errors. An alignment system is used whereby a set of allowed values of the variables corresponds to a set of collinear points. The continuous variables are distributed continuously along lines while isolated points scattered over the plane reflect the presence of discontinuous quantities. An attractive feature of the present method is the representation of the natural modes as a lattice of discrete points, a property which is appropriate to an eigenvalue problem.

A graph, in common use, consists of a family of families of straight lines in addition to the co-ordinate families. This, of course, results in great congestion so that this means of representation is at a disadvantage in comparison with a mode lattice for charts of moderate size. For very large charts of unusual accuracy, and for charts concerned with a single mode, the straight line graph is suitable, but for a 10-×-7-inch chart covering many modes the simplicity of the mode lattice commends it. There is a close geometrical relationship between the two types of chart, which are in fact dual figures.

In this paper a cylinder is defined as a homogeneous dielectric region bounded by two perfectly conducting parallel planes and a conducting surface, which is generated by a straight line moving normal to the planes and passing through a closed curve. Thus, prisms and coaxial cylinders are included in the definition. Shapes not treated are the elliptic cylinder,[6] sphere,[7] spheroid, and ellipsoid. All these shapes are susceptible of representation by mode lattices except the sphere, which is trivial.

The idea of a lattice chart is applicable to vibration problems other than electrical, such as the acoustic resonances of rooms and the mechanical vibrations of plates.

As it is necessary, in dealing with resonant cavities, to have a good grasp of the subscript notation, full definitions of the three indexes are given in the list of

* Decimal classification: R084×R119.32. Original manuscript received by the Institute, March 15, 1946; revised manuscript received, July 21, 1946.

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[1] W. Hansen, "A type of electrical resonator," *Jour. Appl. Phys.*, vol. 9, pp. 654–663; October, 1938.

[2] F. Borgnis, "Die elektrische grundschwingung zylindrischer hohlräume," *Hochfrequenz. und Elektroakustik.*, vol. 54, pp. 121–128; October, 1939.

[3] F. Borgnis, "Die konzentrische leitung als resonator," *Hochfrequenz. und Elektroakustik.*, vol. 56, pp. 47–54; August, 1940.

[4] E. Ledinegg, "Das feldlinienbild der dem kreiszylindrischen hohlraum zugeordneten schwingungstyps," *Hochfrequenz. und Elektroakustik.*, vol. 62, pp. 38–44; August, 1943.

[5] Greek νόμος = law and γραφω = write. The exhaustive work of M. d'Ocagne, "Traité de Nomographie," Gauthier Villars, Paris, 1899, second edition, 1921, does not seem to have been superseded.

[6] L. J. Chu, "Electromagnetic waves in elliptic hollow pipes of metal," *Jour. Appl. Phys.*, vol. 9, pp. 583–591; September, 1938, from which mode constants may be obtained for a few modes as functions of eccentricity.

[7] R. L. Lamont, "Wave Guides," Methuen, London, 1942, p. 77.

symbols. The subscripts refer in order to the .gular, radial, and axial co-ordinates. There are two ays of regarding the number triplet (l, m, n) spec ying a mode: first, as certain quantities appearing in a particular solution of the field equations, and secc dly, as properties of a physically pictured field pattern A definition based on the first outlook can be made precise bu y be difficult to frame a rule which ads to th result when the field pattern is k. quali-tatively well enough to sketch it roughly, bu not to write the equations. Definitions of the second pe for circular and coaxial cylinders have been given y Barrow l Mieher.[8] Kirkman and Kline[9] have sh n that t ven for m does not hold f radial patt that in coaxial resonators th inition may lea to different values for different rati of the radii. The definition cannot be interpreted tly in other cases, e.g., the TM_{010} in a circular ler. A fur lifficulty arises with TE mode coaxial cy over the proper serial numb ot, i.e., whether the counting should start fron unity. Barrow and Mieher have counted fr ut the advantage of the second method, w l here, is that corresponding modes for coaxial cylinders receive the same name. T ence is such that one mode passes contin other as the diameter of the inner coax shrinks to zero Borgnis[3] has used the pr taking t pts from the associa empty cy Kirkman and Kline ha avor of the present system. In the list of defini-tions of the subscripts have been e diffi-culty of counting "half-period var periodic fun s is avoided by a sel eme ros of a fi ponent.

How to Use the Charts

Circular Cylinders

m of the present set of charts lify the c ns relating to th gths of cavities so that their design t confi-dently and quickly, and with the minim n risk of arithmetical error. Choice of units, a major urdle in numerical work, has been eliminated by a oing, on the face of the charts, the symbols ϵ, μ, c and ung only dimensionless quantities such as D/λ. The charts, therefore, work equally well with inches, centimeters, or meters, and confine themselves strictly to the elevant design quantities, viz., shape, wavelength, a d mode. Thus, there is no mention on the charts of oots of Bessel functions.

The accuracy obtainable is of the order of 1 er cent. If four-figure accuracy is required, e.g., to costruct a fixed wavemeter with a predetermine following formula (Lamont[7]) may be

$$f_{lmn} = \frac{v}{2}\sqrt{\left(\frac{x_{lm}}{a\pi}\right)^2 + \ldots}$$

where, for TM waves, x_{lm} is the and for TE waves x_{lm} is the mth r the velocity of a plane wave in the length and a the radius of the cylinder

This formula may be rewritten

$$\left(\frac{D}{\lambda}\right)^2 = \left(\frac{x_{lm}}{\pi}\right)^2 + \frac{n^2}{4}\left(\frac{D}{L}\right)^2$$

where D is the diameter of the cylinder.

The form of the wavelength equation apply cylinders having any shape of cross section

$$\left(\frac{D}{\lambda}\right)^2 = K_{lm} + \frac{n^2}{4}\left(\frac{D}{L}\right)^2.$$

K_{lm} is called the mode constant, and possesses two series of values, one for TE and one for TM modes for a given shape of cross section. D is a specified transverse dimension.

TABLE I

MODE CONSTANTS FOR CIRCULAR CYLINDERS

	TE Modes			*TM* Modes	
	K_{lm}	x_{lm}		K_{lm}	x_{lm}
TE_{11}	0.3435	1.841	TM_{01}	0.5859	2.405
TE_{21}	0.9452	3.054	TM_{11}	1.4878	3.832
TE_{01}	1.488	3.832	TM_{21}	2.672	5.136
TE_{31}	1.788	4.201	TM_{02}	3.087	5.520
TE_{41}	2.865	5.317	TM_{31}	4.124	6.380
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where D is the diameter of the cylinder.

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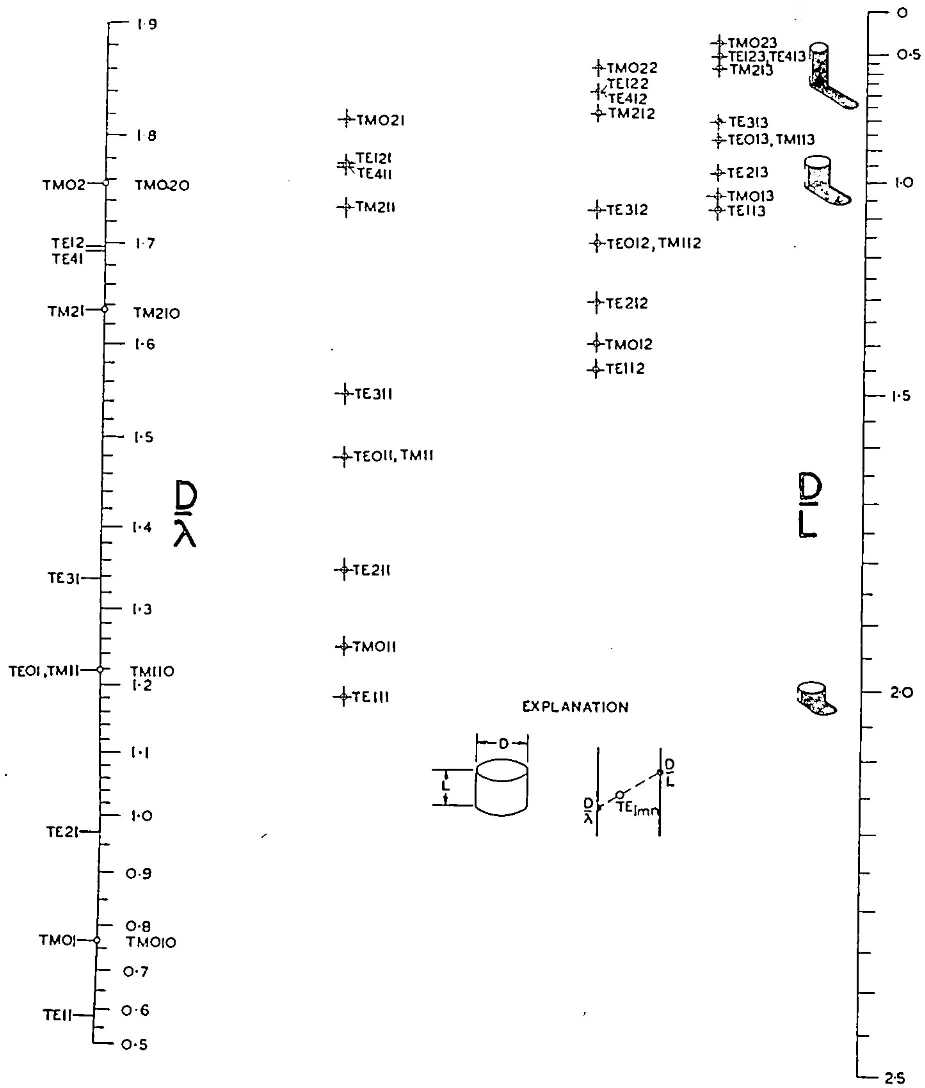

Chart I—Mode lattice for cylinder resonators.

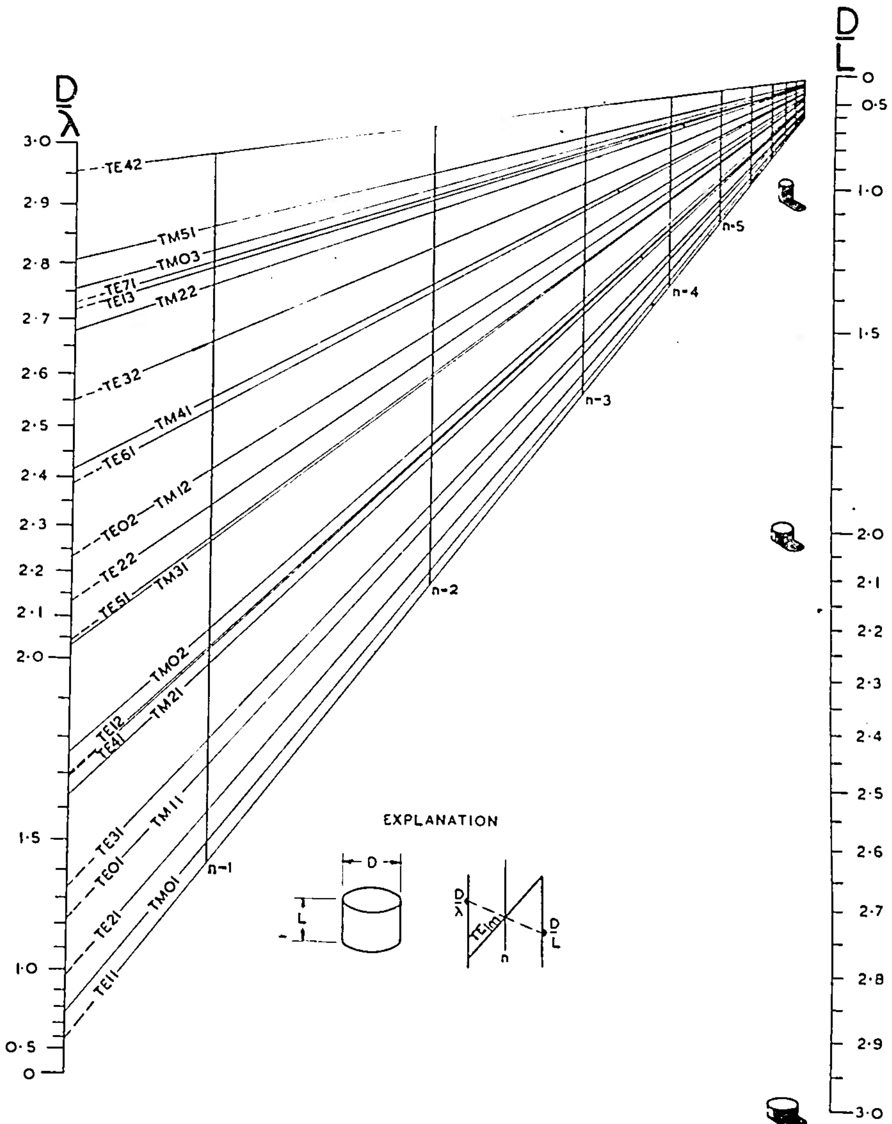

Chart II—Circular cylinder resonator lattice for the first 200 modes.

and II, we come to their actual use. Typical problems which they handle are as follows:

(a) Given dimensions and wavelength at resonance, what mode is excited?
(b) Given the dimensions and desired mode of oscillation, what should the wavelength be?
(c) Given mode and wavelength, find the dimensions.
(d) Find the line spectrum of a given cylinder.
(e) What is the critical wavelength for transmission in a given mode through a circular cylinder?

Inspection of the charts makes the solution of the first four problems clear. Critical diameters may be read off in wavelengths on the D/λ scale (against the column of modes on its left in the case of Chart I), or at the intersections with the D/λ scale of the labeled mode lines TE_{11}, TM_{01}, etc., for Chart II.

Note that at the critical wavelength

$$\left(\frac{D}{\lambda_c}\right)^2 = K_{lm}. \tag{5}$$

If the cavity is filled with material of dielectric constant k, λ is taken to be the wavelength of a plane wave in that medium, viz.,

$$\lambda = \frac{c}{fk^{1/2}}.$$

Points of interest which appear from the charts are these: the TE_{0mn} and TM_{1mn} modes coincide; there are no TE_{lm0} modes; there are no TE_{00n} or TM_{00n} modes; the fundamental may be either the TM_{010} or TE_{111} according to the shape—the former for squat, the latter for long cylinders; square cylinders ($D=L$) have the fundamental modes equal; TM_{010} is called the fundamental transverse magnetic (or fundamental electric) mode; and the TE_{12n} and TE_{41n} modes are very close together.

Transversals are best drawn across a chart by the use of a line engraved on celluloid, or a taut thread. Opaque straight edges are not recommended. In ringing-cavity design it is good to rule permanent transversals for reference purposes. A typical use to which the mode lattice may be put is seen in the case of a ringing cavity which is tuned by moving an endplate. The scales of Fig. 1 have been directly graduated in wavelength and length of cavity. Dashed lines indicate the extreme tuning positions in the desired TE_{011} mode. The undesired modes which may give responses within the same band of frequencies can be found by counting the mode points enclosed in the heavy boundary.

Chart II gives a bird's-eye view of over 200 modes in the circular cylindrical resonator. Consequently it shows at a glance the line spectrum of a cylinder, where the modes are congested, and what happens if a resonant cavity is used in a band other than that for which it was intended. Instead of marking the mode points individually as in Chart I, the complete lattice has been drawn and lattice intersections mark the mode points. Apart from this difference, this chart is identical in use with the first.

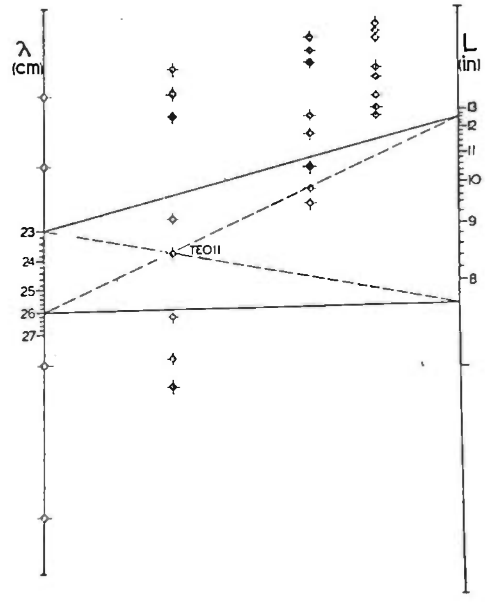

Fig. 1—A direct reading mode lattice.
-------- Nominal limits of band.
———— The cavity will respond to modes enclosed within this boundary at frequencies within the operating band.

Universal Nomogram

Cylinder resonators possess a curious property. If a cavity is resonant at a given length and wavelength, then the wavelength at which it will resonate, if the length is changed, can be calculated without knowledge of the transverse dimensions or the mode of oscillation. Cross section and mode are assumed constant save that a change in the axial subscript n can be taken into account.

It is, thus, possible to construct a chart valid for elliptical cylinders, hexagonal prisms, and quite irregular cylinders, which performs the very useful function of directly indicating the variation of length with wavelength. The tunable ringing cavity provides an example where the chart may be used to examine the effect of axial motion of an endplate. Again, it may be desired to adjust the wavelength of an existing cavity which is not amenable to calculation or which for some reason does not behave as predicted. Utilizing the experimental information regarding wavelength, the correction to be made to the length is obtained directly from the chart.

Of course, some sacrifice has to be made to obtain such versatile nomograms. In this case the initial information required includes knowledge of one solution of the wavelength equation. This may be obtained from another chart of this series or it may be experimental. If the latter, the transverse dimensions are not required; it is not even necessary to know the mode of operation.

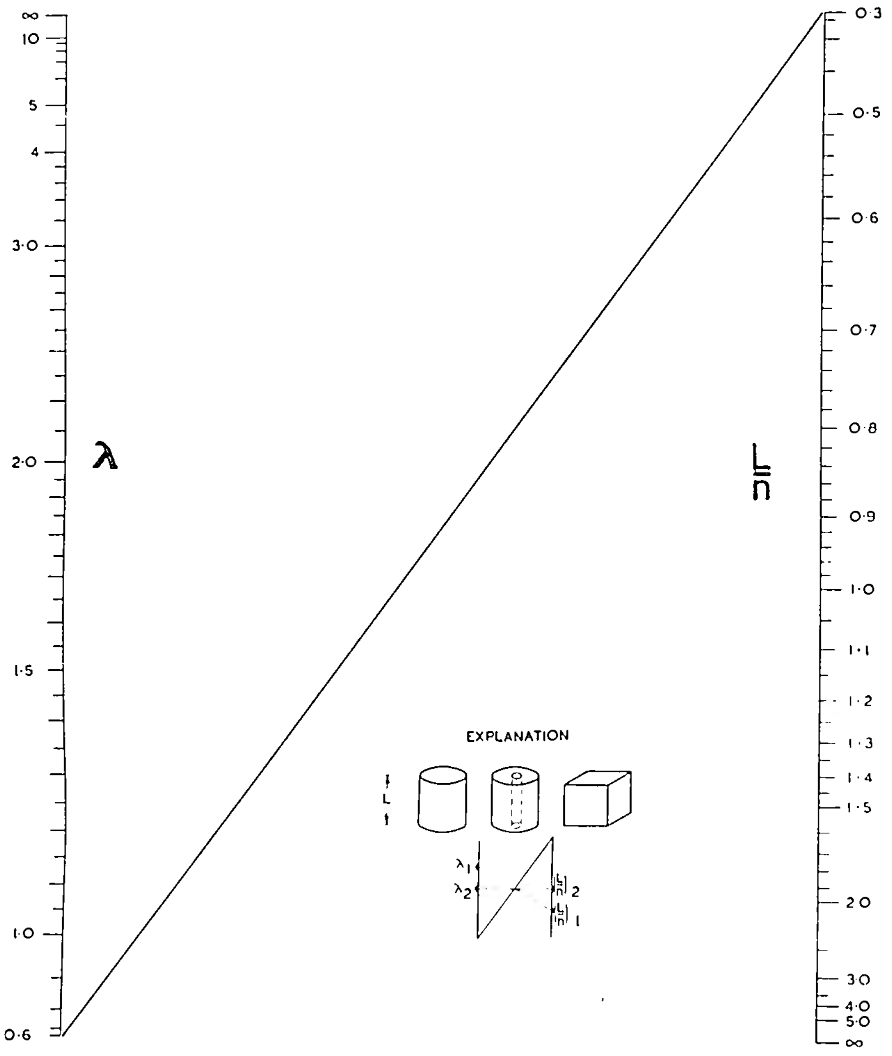

Chart III—Universal nomogram for cylinder resonators.

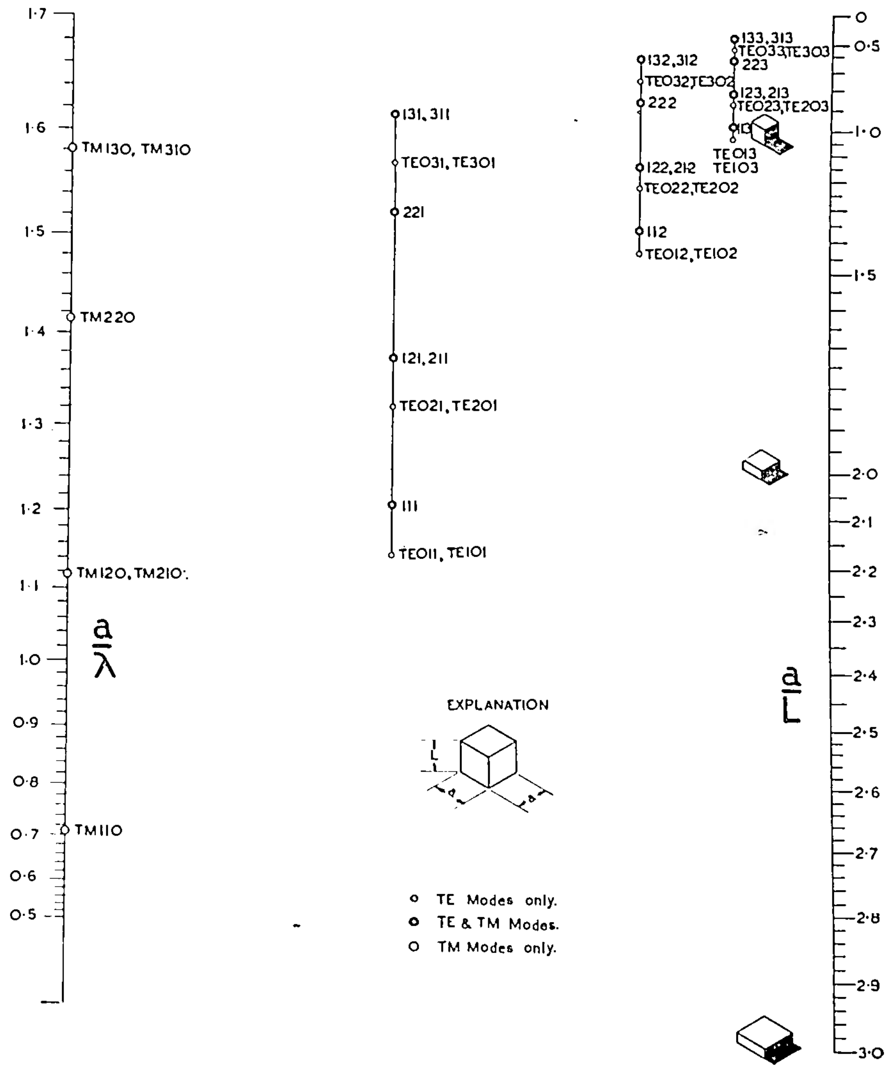

Chart IV—Mode lattice for square prism resonators.

To see why this property exists, consider the general wavelength equation for cylinders.

$$\left(\frac{D}{\lambda}\right)^2 = K_{lm} + \frac{n^2}{4}\left(\frac{D}{L}\right)^2 \quad (6)$$

where the mode triplet is (lmn), L = length of cylinder, λ = wavelength, the mode constant K_{lm} is a function of the mode, and the shape of the cross section D is a transverse dimension.

Keeping the mode and transverse dimensions constant, this may be rewritten

$$\frac{1}{\lambda^2} - \frac{1}{4}\left(\frac{n}{L}\right)^2 = \text{constant.} \quad (7)$$

Hence, if a solution of the wavelength equation is given in the form of a pair of corresponding values of λ and L/n, then further pairs may be deduced at once.

To use Chart III, mark off on the vertical scales the pair of values corresponding to a known resonance. Join these points by a straight line, and let it intersect the reference axis in a point P. Then all straight lines through P connect values of L and λ for which resonance will occur.

Any units may be used provided the same unit is used for both L and λ. If it is desired to read L in inches and λ in centimeters, this may be arranged in the obvious way by providing one of the axes with additional graduations on its blank side. As the units are quite arbitrary, the user may diminish or increase L and λ by any convenient factor which makes the chart easier to use.

Square Prism

Except for the disposition of the mode points in the plane, Chart IV is identical with those for circular cylinders. Many more modes, however, are nonexistent. In the circular cylinder the only impossible modes are the TE_{lm0} and the TEM. In the prism they are the TE_{lm0}, TE_{00n}, and TM_{0mn}, TM_{l0n}, and TEM. A good deal of degeneracy is visible on this chart. Because of the square cross section, f_{cba} is equal to f_{abc} for both TE and TM modes, but in practice slight departures from squareness will cause the modes to separate. A further degeneracy, through which the TE_{lmn} and TM_{lmn} modes have the same frequency, occurs also in rectangular prismatic cavities.

If the dimensions of the prism are $a \times a \times L$, the wavelength equation is

$$\left(\frac{a}{\lambda}\right)^2 = K_{lm} + \frac{n^2}{4}\left(\frac{a}{L}\right)^2 \quad (8)$$

where the mode constant is given for both classes of modes by

$$K_{lm} = \tfrac{1}{4}(l^2 + m^2). \quad (9)$$

Coaxial Cylinders

Much more complicated mathematical equations have to be solved in the case of coaxial cylinders. Bessel functions of the second kind, which were excluded from hollow cylinders because they possess a singularity at the origin, are now allowed since the origin is no longer in the cavity. The wavelength equation is as above:

$$\left(\frac{D}{\lambda}\right)^2 = K_{lm} + \frac{n^2}{4}\left(\frac{D}{L}\right)^2 \quad (10)$$

where the mode triplet is (lmn), L = length of cylinder, D = outside diameter, λ = wavelength, and the mode constant $K_{lm} = (x_{lm}/\pi)^2$, but the need for satisfying boundary conditions over two circles introduces an involved equation for x_{lm} which is the mth root of

$$\frac{J_l(qx)}{Y_l(qx)} = \frac{J_l(x)}{Y_l(x)} \quad \text{for } TM_{lmn}, \quad (11)$$

and of

$$\frac{J_l'(qx)}{Y_l'(qx)} = \frac{J_l'(x)}{Y_l'(x)} \quad \text{for } TE_{lmn} \quad (12)$$

where $q = d/D$, d = diameter of the inner cylinder.

The roots of these equations have not been adequately tabulated. In order to plot them as a function of q on Chart V, some values were obtained from Jahnke and Emde[11] and some were calculated by the Mathematical Group at Radiophysics Laboratory.

An explanatory diagram shows how the chart is to be used. Each mode point is to be constructed separately by drawing a line from a point on the D/λ axis determined by d/D and the subscripts lm to the origin of the D/L scale, and marking its intersection with the required n axis. Corresponding values of D/L and D/λ are now indicated by straight lines through this intersection as with the circular cylindrical charts.

If interest is centered on resonators having a particular value of d/D, the complete pencil through the origin of the D/L scale may be drawn to give a mode lattice for that shape of resonator. For this and similar purposes the mode lattice blank of Chart VII may be used.

The transverse electromagnetic or conventional modes of vibration of the coaxial resonator, for which

$$L = \frac{n\lambda}{2}, \quad (13)$$

are independent of the ratio of diameters, and therefore the mode points TEM_{00n} may be permanently marked on the chart. These are modes which cannot be supported in the absence of an inner conductor. Although often referred to as the fundamental mode, it

[11] E. Jahnke and F. Emde, "Tables of Functions," Dover Publications, New York, N.Y., 1943.

will be clear by inspection of the chart that the TEM_{001} mode is not necessarily the mode with the lowest or even the second lowest frequency. In squat resonators for which $D/L > 1.531$ the fundamental transverse-magnetic mode (TM_{010}) will have a lower frequency. The fundamental conventional mode thus behaves like the fundamental transverse-electric mode of the circular cylinder without inner conductor.

Nomogram for Rectangular Prism Resonators

Just as Chart V was developed from Chart I to accommodate a shape parameter in the transverse section, so is Chart VI related to the chart for square prisms (Chart IV). Advantage has been taken of the simple algebraic expression for the mode constant to replace the families of curves of Chart V by an alignment system.

If the dimensions of the prism are $a \times b \times L$, the wavelength equation is

$$\left(\frac{a}{\lambda}\right)^2 = K_{lm} + \frac{n^2}{4}\left(\frac{a}{L}\right)^2 \tag{14}$$

and

$$K_{lm} = \tfrac{1}{4}(l^2 + q^2 m^2) \tag{15}$$

where

$$q = \frac{a}{b} \cdot \tag{16}$$

The wavelength equation is probably more familiar in the form

$$\lambda = \frac{2}{\sqrt{\left(\frac{l}{a}\right)^2 + \left(\frac{m}{b}\right)^2 + \left(\frac{n}{L}\right)^2}} \cdot \tag{17}$$

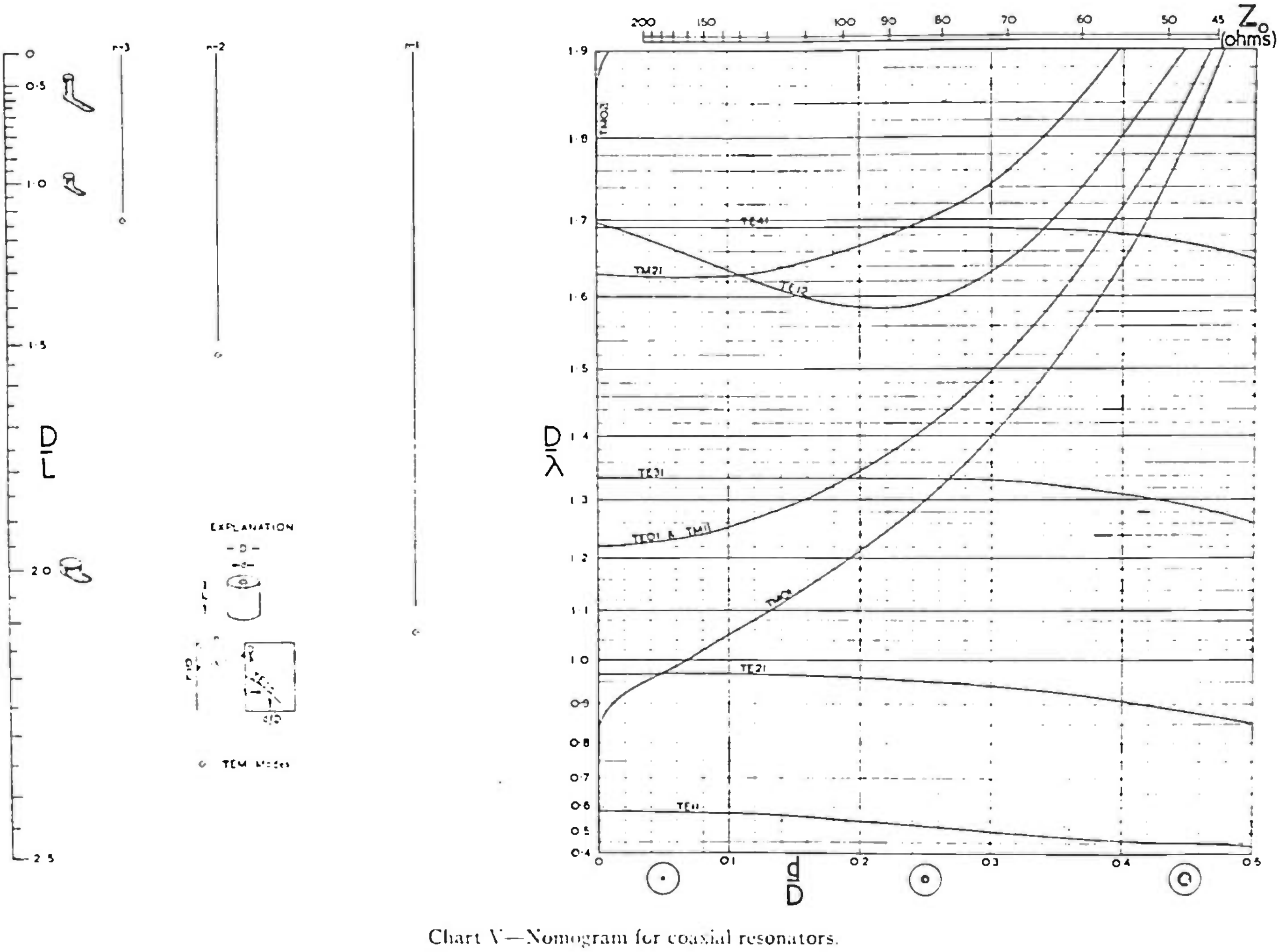

Chart V—Nomogram for coaxial resonators.

An explanatory diagram shows the method of obtaining single solutions for a prism. To construct a complete mode lattice for prisms with a particular cross-section shape (a/b), proceed as follows. With the desired point on the (a/b) axis as center, project all the points in the lower part of the chart on to the (a/λ) axis. Join all the projected points to the origin of the (a/L) scale. This pencil, together with the n lines already existing, constitutes the required lattice.

How the Charts are Constructed

The charts presented with this paper have been designed for general utility. Charts are often required with

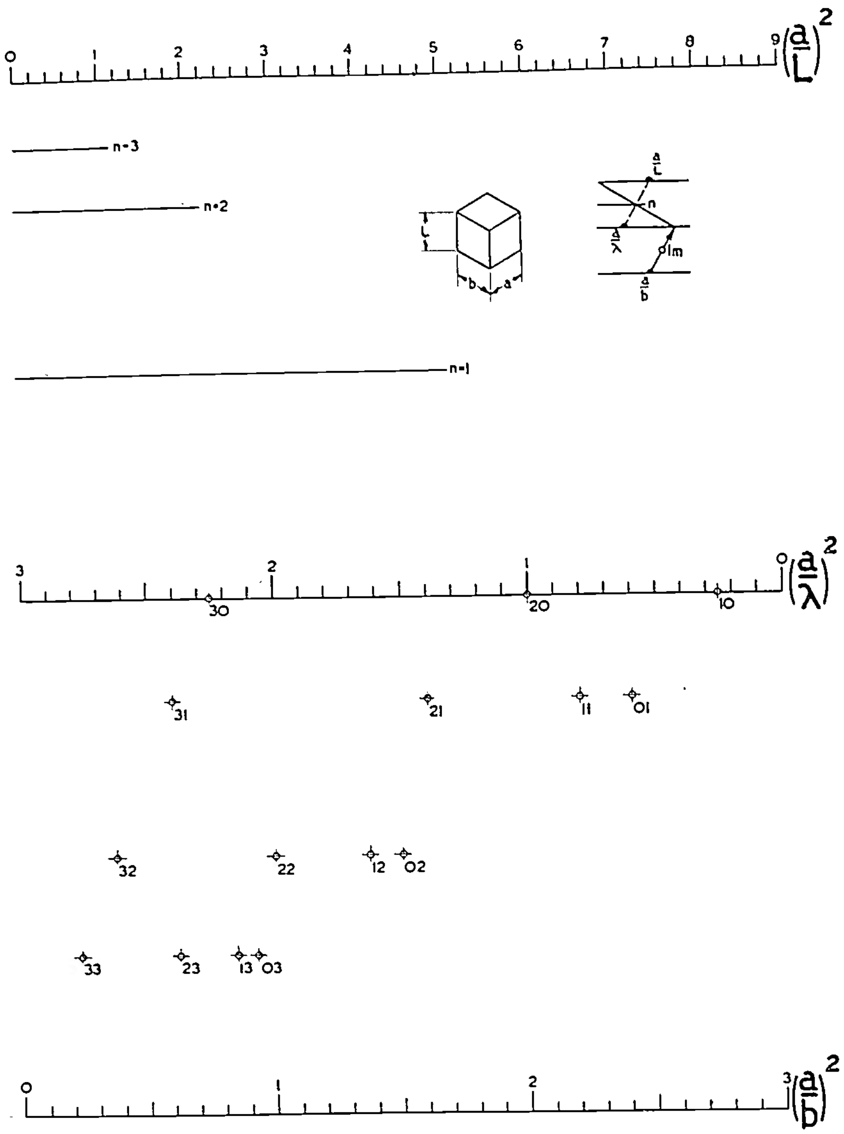

Chart VI—Nomogram for rectangular prism resonators.

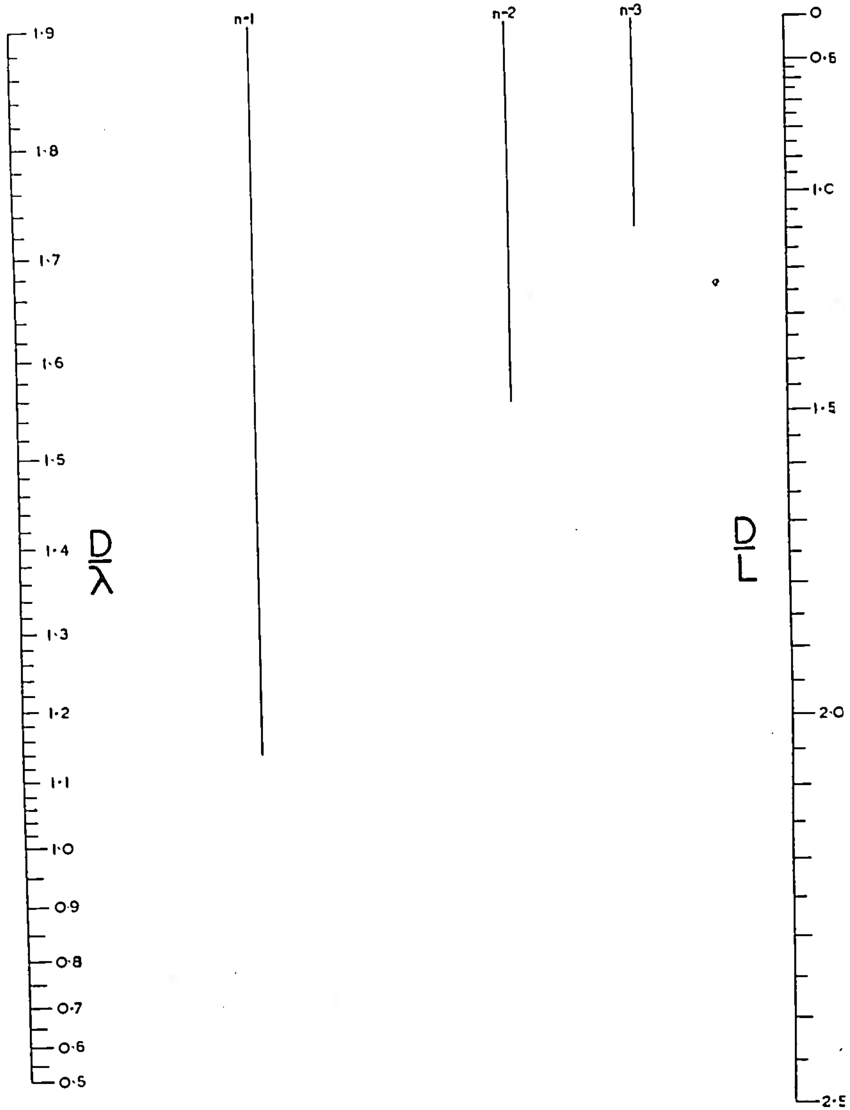

Chart VII—Mode lattice blank.

special characteristics such as higher accuracy over a restricted range of variables and fewer modes, and scales reading directly in terms of D, L, or λ.

Circular Cylinders

Three sets of information are required to construct Charts I and II: the scale equations, the terminal points of the convergent pencil on the D/λ scale, and

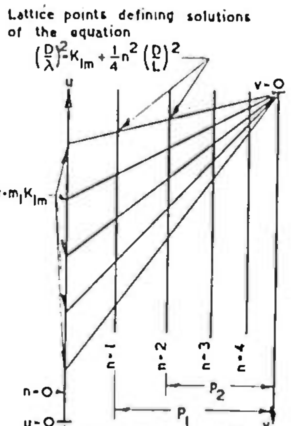

Fig. 2—The basis of Chart I.
$u = m_1(D/\lambda)^2$
$v = m_2(D/L)^2$
$p_n/q = 1/[1 + n^2m_1/4m_2]$.

the position of the n supports. Referring to Fig. 2, the lengths u and v are measured in opposite directions along the parallel D/λ and D/L scales from arbitrary origins. The scale equations which enable the scales to be graduated are

$$u = m_1\left(\frac{D}{\lambda}\right)^2 \tag{18}$$

$$v = m_2\left(\frac{D}{L}\right)^2 \tag{19}$$

where m_1 and m_2 are the scale moduli which are chosen so as to make the scales approximately equal in length for the desired ranges of variables. From the origin of the v axis, which may not always be on the chart, a pencil of lines is drawn to points on the u axis for which

$$u = m_1K_{lm}.$$

Table I gives the values of K_{lm}. If q is the separation of the scales and p_n is the distance of the lines of constant n from the v axis, then

$$\frac{p_n}{q} = \frac{1}{1 + \dfrac{n^2m_1}{4m_2}}. \tag{20}$$

There is a quick graphical method of placing the n supports, by constructing their points of intersection with the line (0, 0), which does not require explicit knowledge of the scale moduli. Draw the line (0, 0) and choose values of D/λ and D/L such that $(D/\lambda) \div (D/L) = N/2$ where N is an integer. The line joining these values cuts the line (0, 0) at a point lying on the required line $n = N$. The point so constructed is simply the position the lattice points TEM_{00n} (for which $L/\lambda = n/2$) would have if this mode existed. If it were desired to incorporate a scale of L/λ = constant in the chart, it could thus be done by properly graduating the line (0, 0).

It is possible to construct a skeleton chart, such as Chart VII on which the D/λ and D/L scales and the n = constant family are marked, before the cross section of the cylinder is specified. As soon as the series of mode constants K_{lm} is given, the chart may be completed, but even if only incomplete information is available, such a chart can immediately utilize it to the maximum. An irregular cylinder may be under consideration for which it is feasible to calculate one or two roots. One or two ways of the convergent pencil can then be drawn, and a useful number of lattice points established. Conversely, an experimental result relating to a noncircular cylinder of particular size and shape may be incorporated in the chart to deduce resonant frequencies for other sizes and aspect ratios, and even some other modes.

In the charts here presented, the principle described above has been applied to construct charts for coaxial cylinders and rectangular prisms, cases where the series of constants K_{lm} is a function of the shape of the cross section. A skeleton chart is given, in each case leaving the shape of the cross section unspecified. An additional chart is incorporated on the same sheet which automatically marks off the mode constants along the D/λ axis as soon as the cross section is chosen. This device enables the lattice to be constructed wholly or in part according to requirements. Alternatively, a set of complete lattices might have been presented for an assortment of cross-section shapes. With the present arrangement the user is placed in the position of being able to do this easily himself, on the skeletons provided, for the shapes which interest him.

The charts have now developed without undue complexity to the stage of handling eight variables. These are, for the coaxial cavity resonator, diameter of outer cylinder; diameter of inner cylinder; length; class of mode (TE or TM); angular, radial, and axial subscripts; and resonant wavelength. Advantage has been taken of the discrete nature of some of the variables, and some dimensionless parameters have been introduced to achieve this on what would normally be a five-variable chart.

Universal Nomogram

Two parallel axes, along which lengths are measured in opposite directions by the co-ordinates u and v, together with the line joining their origins, form the basis of Chart III (Fig. 3). The scale equations are:

$$u = m_1 \text{ antilog} \left(-\frac{1}{\lambda^2} \right) \tag{21}$$

$$v = m_2 \text{ antilog} \left(-\frac{n^2}{4L^2} \right). \tag{22}$$

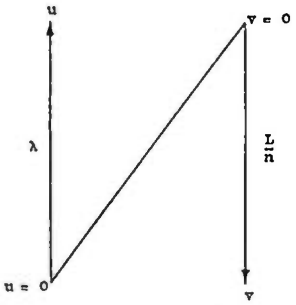

Fig. 3—The basis of Chart III.
$u = m_1 z_1$
$v = -m_2 z_2$
$z_1 = \text{antilog}\,(-1/\lambda^2)$
$z_2 = \text{antilog}\,(-n^2/4L^2)$
$\log (z_1/z_2) = -1/\lambda^2 + n^2/4L^2.$

Square Prism

The scale equations are

$$u = m_1 \left(\frac{a}{\lambda} \right)^2 \tag{23}$$

$$v = m_2 \left(\frac{a}{L} \right)^2, \tag{24}$$

and the position of the n supports is given by

$$\frac{p_n}{q} = \frac{1}{1 + \dfrac{n^2 m_1}{4 m_2}}. \tag{25}$$

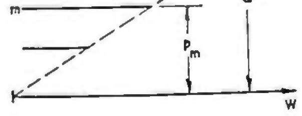

Fig. 4—The basis of Chart VII.
$u = m_1(a/\lambda)^2$
$v = -m_2(a/L)^2$
$w = -m_3(a/b)^2$
$p_n/q = 1/[1 + n^2 m_1/4m_2]$
$p_m/Q = 1/[1 + n^2 m_1/4m_3].$

Coaxial Cylinders and Rectangular Prism

The left part of Chart V is identical with Chart I, and the right side fulfills the auxiliary function of representing graphically the roots of (11) and (12) as functions of d/D. The y axis of this graph is graduated with a functional scale such that ordinates are proportional to the mode constant K_{lm}. This allows the two halves to be united by causing the y and u axes to coincide to form a composite chart.

In the case of Chart VI, which is similarly conceived, the explicit expression for K_{lm} suggests combining two alignment systems, one similar to Chart IV, the other to project values of K_{lm} on to the a/λ axis according to (15). Fig. 4 shows the co-ordinate system used, and the scale equations are

$$u = m_1 \left(\frac{a}{\lambda} \right)^2 \tag{26}$$

$$v = m_2 \left(\frac{a}{L} \right)^2 \tag{27}$$

$$w = m_3 \left(\frac{a}{b} \right)^2. \tag{28}$$

The position of the supports is given by

$$\frac{p_n}{q} = \frac{1}{1 + \dfrac{n^2 m_1}{4 m_2}}, \tag{29}$$

and

$$\frac{p_m}{Q} = \frac{1}{1 + \dfrac{n^2 m_1}{4 m_3}}. \tag{30}$$

Some Differential Formulas

A number of differential expressions may be derived from the wavelength equation for cylinder resonators. These enable various rates of change to be calculated and the effect of small deformations or changes in design to be estimated.

In the following relations, which apply to circular cylinders, coaxial cylinders, and prisms, the mode and the shape of the cross section remain constant. Thus, if the outside diameter of a coaxial cavity is changed, the inner diameter is assumed to change in the same proportion.

Diameter Constant

$$\frac{\partial \lambda}{\partial L} = \frac{n^2}{4} \left(\frac{\lambda}{L} \right)^3 \tag{31}$$

$$\frac{\delta \lambda}{\lambda} = \frac{n^2}{4} \left(\frac{\lambda}{L} \right)^2 \frac{\delta L}{L}. \tag{32}$$

Wavelength Constant

$$\frac{\partial L}{\partial D} = \frac{L}{D} - \frac{4L^3}{n^2 \lambda^2 D} \tag{33}$$

$$\frac{\delta L}{L} = \left\{ 1 - \left(\frac{L/n}{\frac{1}{2}\lambda} \right)^2 \right\} \frac{\delta D}{D}. \tag{34}$$

Length Constant

$$\frac{\partial\lambda}{\partial D} = \frac{\lambda}{D} - \frac{n^2\lambda^3}{4L^2D} \qquad (35)$$

$$\frac{\delta\lambda}{\lambda} = \left\{1 - \left(\frac{\frac{1}{2}\lambda}{L/n}\right)^2\right\}\frac{\delta D}{D}. \qquad (36)$$

Summary of Formulas

Circular Cylinder

$$f_{lmn} = \frac{v}{2}\sqrt{\left(\frac{x_{lm}}{a\pi}\right)^2 + \frac{n^2}{L^2}}$$

$$\left(\frac{D}{\lambda}\right)^2 = \left(\frac{x_{lm}^2}{\pi}\right) + \frac{n^2}{4}\left(\frac{D}{L}\right)^2$$

$$\left(\frac{D}{\lambda}\right)^2 = K_{lm} + \frac{n^2}{4}\left(\frac{D}{L}\right)^2$$

x_{lm} is the mth root of $J_l(x) = 0$, for TM waves
x_{lm} is the mth root of $J_l'(x) = 0$, for TE waves

$K_{lm} = (x_{lm}/\pi)^2$ = mode constant for circular cylinder. (See Table I.)

When the wavelength is critical,

$$\left(\frac{D}{\lambda_c}\right)^2 = K_{lm}.$$

Rectangular Prism

$$\left(\frac{a}{\lambda}\right)^2 = K_{lm} + \frac{n^2}{4}\left(\frac{a}{L}\right)^2$$

$$K_{lm} = \tfrac{1}{4}(l^2 + q^2m^2)$$

$$q = \frac{a}{b}$$

$$\lambda = \frac{2}{\sqrt{\left(\frac{l}{a}\right)^2 + \left(\frac{m}{b}\right)^2 + \left(\frac{n}{L}\right)^2}}.$$

Coaxial Cylinders

$$\left(\frac{D}{\lambda}\right)^2 = \left(\frac{x_{lm}}{\pi}\right)^2 + \frac{n^2}{4}\left(\frac{D}{L}\right)^2$$

x_{lm} is the mth root of $T_l(qx) = T_l(x)$ for TM_{lmn}
x_{lm} is the mth root of $U_l(qx) = U_l(x)$ for TE_{lmn}

$$T_l(x) \equiv \frac{J_l(x)}{Y_l(x)} \qquad U_l(x) \equiv \frac{J_l'(x)}{Y_l'(x)}$$

$$q = \frac{d}{D}$$

$$\left(\frac{D}{\lambda}\right)^2 = K_{lm} + \frac{n^2}{4}\left(\frac{D}{L}\right)^2$$

$$K_{lm} = \left(\frac{x_{lm}}{\pi}\right)^2.$$

The essential equations for constructing the charts are summarised on Figs. 2, 3, and 4.

List of Symbols

a = side of square prism, side of rectangular prism in the x direction, radius of circular cylinder
b = side of rectangular prism in the y direction
a, b = constants
d = smaller diameter of coaxial cylinders
D = diameter of circular cylinder, larger diameter of coaxial cylinders, any transverse dimension of a general cylinder or prism
E = electric field intensity
E_z = axial component of electric field
f_{lmn} = natural frequency of the mode TE_{lmn} or TM_{lmn}
$J_l(x)$ = Bessel function of first kind of order l
H = magnetic field intensity
H_z = axial component of magnetic field
K_{lm}, K = mode constant, determined by transverse field pattern and shape of section
L = length of circular cylinder, length of coaxial cylinders, length of prism
(l, m, n) = number triplet specifying mode of resonance
(lm) = number pair specifying field pattern in transverse plane
l = (for circular and coaxial cylinders) the coefficient of the angular co-ordinate θ in the circular function describing the variation of a field component in the angular direction, *or* the number of full period variations undergone by any non-zero field component as θ varies from 0 to 2π
= (for prisms) the integer specifying the number of half-wave variations through which a standing wave pattern extends in the x direction
m = (for circular and coaxial cylinders) the serial number of the root equal to the value assumed at the wall by the argument of the Bessel function or derived function describing the variation of angular component of electric field along a radius, *or* the number of zeros of angular component (in the case of TE modes) or of axial component (in the case of TM modes) of electric field lying on any non-nodal radius, counting that at the wall but not that which may occur at the center. For coaxial cylinders m takes the value of the associated simple cylindrical mode into which the field pattern passes as the radius of the inner cylinder approaches zero
= (for prisms) the integer specifying the number of half-wave variations through

which a standing-wave pattern extends in the y direction

n = integer specifying the number of half-wave variations through which a standing-wave pattern extends axially; this definition applies to all cylinders and prisms

m_1, m_2, m_3 = scale moduli

p_n = the distance of an n support from the v axis

p_m = the distance of an m support from the w axis

$q = d/D$ for coaxial cylinders, a/b for rectangular prisms, separation of u and v axes

Q = separation of u and w axes

TE = transverse electric, $E_z = 0$

TM = transverse magnetic, $H_z = 0$

(u, v) = line co-ordinates

v = the velocity of a plane wave in a dielectric medium

w = line co-ordinate axis

x_{lm} = the mth root of an equation containing Bessel functions of order l

$Y_l(x)$ = the Bessel function of the second kind of order l

z_1, z_2 = variables

(r, θ, z) = cylindrical co-ordinates

(x, y, z) = cartesian co-ordinates

λ = the natural wavelength of a cavity, i.e., the wavelength of a plane wave traveling in an unbounded dielectric medium similar to that in the medium, at the natural frequency of the cavity; $\lambda = v/f$

λ_c = the free-space wavelength corresponding to the critical frequency for transmission through a cylinder.

ACKNOWLEDGMENT

The work described in this paper was carried out as part of the program of the Division of Radiophysics, Council for Scientific and Industrial Research, and the author wishes to thank Dr. J. L. Pawsey, under whose direction it was carried out, for his encouragement and advice during the course of the work.

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C. B. Jolliffe (M'25–F'30) was born in Mannington, West Virginia, on November 13, 1894. He received the B.S. degree in 1915, and the M.S. degree in 1920 from West Virginia University; the Ph.D. degree from Cornell University in 1922; and the honorary degree of LL.D. from West Virginia University in 1942.

From 1917 to 1918 and from 1919 to 1920 he was an instructor in physics at West Virginia University, and from 1920 to 1922 he taught that subject at Cornell University. He was a physicist in the radio section of the National Bureau of Standards from 1922 to 1930, engaged in research on radio wave propagation and development and maintenance of standards of frequency. In 1930 Dr. Jolliffe was appointed chief engineer of the Federal Radio Commission and continued in that capacity until 1935, when he resigned to accept a position with the Radio Corporation of America, as engineer in charge of the RCA Frequency Bureau. In 1942 he was elected vice-president and chief engineer of the RCA Manufacturing Company, Inc., and from 1943 to 1945 he was chief engineer of the RCA Victor Division.

C. B. JOLLIFFE

Dr. Jolliffe was elected a vice-president of the Radio Corporation of America on March 2, 1945, in charge of RCA Laboratories. This was followed in December, 1945, by his promotion to executive vice-president in charge of the RCA Laboratories Division, the position he now holds. He has attended many international and other radio conferences as a delegate of the United States or as an expert adviser. From September, 1940, until April, 1944, he was chief of the Electrical Communications Division of the National Defense Research Committee. He was Chairman of Panel 2 on Frequency Allocations of the Radio Technical Planning Board.

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R. N. Bracewell was born in Sydney, New South Wales, Australia, in 1921. He entered Sydney University in 1938, obtaining the B.Sc. degree in mathematics and physics in 1941, and the B.E. degree in mechanical and electrical engineering, with honors, in 1943. During the last four years of the war he was attached to the Radiophysics Laboratory of the Commonwealth Council for Scientific and Industrial Research, which was engaged on radar research, and worked on the design and development of microwave equipment. Mr. Bracewell is now working in the Cavendish Laboratory, Cambridge, England.

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Frederick B. Llewellyn (A'23–F'38) was born September 16, 1897, in New Orleans, Louisiana. Between 1915 and 1922 he spent a total of three years as a radio operator with the United States Navy and on ships of the merchant marine. In 1922 he was graduated from Stevens Institute of Technology with the degree of Mechanical Engineer, and in 1928 received the degree of Doctor of Philosophy in Physics from Columbia University.

Joining the engineering department of the Western Electric Company in 1923, he was transferred to the Bell Telephone Laboratories when that company was formed in 1925 and has remained with them ever since.

Dr. Llewellyn has been primarily concerned with radio and circuit research which has extended to the analysis of the electronic behavior of vacuum tubes at high frequencies.

FREDERICK B. LLEWELLYN

Several papers by Dr. Llewellyn have appeared in the PROCEEDINGS OF THE I.R.E., and in 1935 he was awarded the Morris Liebmann prize for his outstanding original work on constant-frequency oscillators and on vacuum-tube electronics at high frequencies.

Kurt Schlesinger (A'41) was born on April 20, 1908, in Berlin, Germany. In 1928 he received the engineer's diploma, and in 1929 the degree of Doctor of Applied Physics, both from Technische Hochschule in Berlin. From 1929 to 1930 he was a research physicist in Ardenne Research Laboratory, Berlin, and from 1931 to 1937 he was chief engineer in the television department of Loewe Radio Company, also in Berlin.

KURT SCHLESINGER

In 1938 Dr. Schlesinger became affiliated with the Radio and Cables-Grammont in Paris, France, where he devoted his time to television development. From 1941 to 1944 he was a research engineer for the Radio Corporation of America, attached to the laboratory at Purdue University. He is now associated with the Columbia Broadcasting System in New York City.

A. E. Hastings (A'42) was born in Massachusetts on April 11, 1909. He received the B.S. degree in electrical engineering in 1934 and the Ph.D. degree in physics in 1938 from Brown University.

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A. E. HASTINGS

For a photograph and biography of W. R. G. BAKER, see the frontispiece on page 3 of the January, 1947, issue of the PROCEEDINGS OF THE I.R.E.

William R. Rambo (S'39-A'40-SM'46) was born on September 3, 1916, at San Jose, California. He received the B.A. and E.E. degrees from Stanford University in 1938 and 1941, respectively. He was engaged in broadcast station engineering from 1939 to 1942. In 1942, Mr. Rambo joined the staff of the Radio Research Laboratory in Cambridge, Massachusetts, and was engaged in radar countermeasures work until the end of 1945, when he became affiliated with the Airborne Instruments Laboratory at Mineola, New York. He is a member of Sigma Xi.

WILLIAM R. RAMBO

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Prepared by the National Physical Laboratory, Teddington, England, Published by Arrangement with the Department of Scientific and Industrial Research, England, and *Wireless Engineer*, London, England

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Factors Governing the Intelligibility of Speech Sounds—N. R. French and J. C. Steinberg. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 90–119; January, 1947.) Characteristics of speech, hearing, and noise are discussed in relation to intelligibility. It is shown that intelligibility can be related to a quantity called "the articulation index" which can be computed from the intensities of speech and unwanted sounds received by the ear, both as a function of frequency.

534.78 1980
Premodulation Clipping in A.M. Voice Communication—K. D. Kryter, J. C. R. Licklider, and S. S. Stevens. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 125–131; January, 1947.) Saving of 14 decibels in carrier power can be achieved, without loss in intelligibility, by 24 decibels of premodulation peak clipping followed by 24 decibels of linear gain to obtain 100 per cent modulation.

534.78 1981
More on Speech Clipping—W. W. Smith. (*QST*, vol. 31, pp. 18–22; March, 1947.) Stresses the importance of design and operating details and gives some new circuits, including a full-wave series clipper maintaining constant load on a resistance-capacitance driving circuit and a high-level half-wave clipper-filter system for use with 8000- to 10,000-ohm loads and anode voltages up to 2000. For an earlier article see 1724 of 1946; see also 933 of April.

534.78:621.317.35 1982
Waveform Analysis of Speech—J. Dreyfus-Graf. (*Helv. Phys. Acta*, vol. 19, pp. 404–408; December 18, 1946.) The nature of speech and hearing are expressed as far as possible in terms of analogous electrical circuits of which a block diagram is given.

534.78(23.03) 1983
Effects of Distortion on the Intelligibility of Speech at High Altitudes—G. A. Miller and S. Mitchell. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 120–125; January, 1947.) Using mask-microphone equipment at altitudes of 40,000 feet intelligibility can be improved by amplitude limitation; it may also be desirable to filter out frequencies below 500 cycles. A summary was abstracted in 3522 of January.

534.833.4–8 1984
Absorption of Supersonic Waves in Water near One Megacycle—L. W. Labaw and A. O. Williams, Jr. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 30–34; January, 1947.) Absorption measurements between 1.09 and 1.30 megacycles do not confirm earlier measurements indicative of a strong absorption peak near 1 megacycle, but a fairly reliable upper limit of the absorption coefficient has been obtained.

534.851 1985
Improved Theory of the Light Pattern Method for the Modulation Measurement in Groove Recording—J. Hornbostel. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 165–169; January, 1947.)

534.851 1986
Sound Embossing at the High Frequencies—M. Morse. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 169–172; January, 1947.) Optimum loading, stylus dimensions, etc., for embossing at 5000 cycles.

534.851:621.395.813 1987
Wire Recorder Wow—A. W. Sear. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 172–178; January, 1947.)

551.596.1 1988
Calculation of Sound Rays in the Atmosphere—P. Rothwell. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 205–221; January, 1947.)

551.596.1:534.22–8 1989
Ultrasonic Propagation in Open Air—H. K. Schilling, M. P. Givens, W. L. Nyborg, W. A. Pielemeier, and H. A. Thorpe. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 222–234; January, 1947.) Absorption and scattering properties at frequencies up to 30 kilocycles.

621.395.623 1990
A General Theory of Passive Linear Electroacoustic Transducers and the Electroacoustic Reciprocity Theorem. Part 2—H. Primakoff and L. L. Foldy. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 50–58; January, 1947.) Continuation of 264 of 1946. If a transducer is considered to consist of media characterized by appropriate linear relations between stress, strain, electric and magnetic polarization, charge and current density, and electric and magnetic field intensity, the validity of the linear relations and the "reciprocity relations" assumed in part I can be established provided certain sufficient conditions are satisfied. These conditions are: (a) that the coefficients in the constitutive relations satisfy certain "symmetry conditions;" (b) that no magnetostrictive media and no static magnetic field, or no piezoelectric media and no static charge density, are present in the transducer; and (c) that the transducer does not radiate electromagnetic waves from its surface.

621.395.623.64.08 1991
Headphone Measurements and Their Interpretation—D. W. Martin and L. J.

Anderson. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 63–70; January, 1947.) Fundamental headphone data are presented in a form suitable for users; the importance of analysis of the performance on different wearers is emphasized. Requirements for an improved artificial ear are outlined.

621.395.623.8 1992
Radio Translation—(*Wireless World*, vol. 53, no. 3, p. 96; March, 1947.) At Lake Success six low-power transmitters on frequencies of about 120 megacycles radiate the original speech and translations in five languages. United Nations General Assembly delegates carry small receivers, with simple dial switches. These have a working range up to 200 yards.

621.395.625 1993
Lateral Recording: Part 1—W. H. Robinson. (*Communications*, vol. 27, pp. 26, 28; February, 1947.) The first of a series of papers giving a general discussion of average electromagnetic and crystal cutters, groove depths, disks, volume indicators, measuring equipment, frequency runs, styluses, cutting angles, scratch filters, and pickups.

621.395.625.3 1994
Recent Developments in the Field of Magnetic Recording—S. J. Begun. (*Jour. Soc. Mot. Pic. Eng.*, vol. 48, pp. 1–13; January, 1947.) A new type of magnetic tape recorder is described using 8-millimeter coated paper tape. Frequencies up to 5000 cycles can be recorded with a tape speed of 7.5 inches per second.

621.395.625.3 1995
A Magnetic Sound Recorder of Advanced Design—R. J. Tinkham and J. S. Boyers. (*Jour. Soc. Mot. Pic. Eng.*, vol. 48, pp. 29–35; January, 1947.) "Characterized by good frequency response, low distortion, freedom from 'wow' and flutter, and lock-in synchronous drive."

621.395.625.3 1996
Magnetic Sound Recording on Coated Paper Tape—H. A. Howell. (*Jour. Soc. Mot. Pic. Eng.*, vol. 48, pp. 36–46; January, 1947. Discussion, pp. 46–49.) The factors affecting the choice of magnetic material and backing medium are considered; this leads to a discussion of the performance of paper tape recording systems. The properties of a recently developed tape are shown graphically.

621.395.625.3:778.5 1997
Magnetic Sound for Motion Pictures—M. Camras. (*Jour. Soc. Mot. Pic. Eng.*, vol. 48, pp. 14–24; January, 1947. Discussion, pp. 25–28.) Advantages and disadvantages of magnetic sound recording on motion picture film. High-quality recording apparatus is described and curves showing frequency response and distortion are given.

621.395.625.6:621.383.49 1998
The Use of Sulphur-Thallium Photocells in Sound Pictures—Kolomiec. (*See* 2199.)

AERIALS AND TRANSMISSION LINES

621.392+537.291 1999
Study of the Simultaneous Propagation of a Guided Wave and of an Electron Beam of Approximately Equal Velocity—P. Lapostolle. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, pp. 268–270; January 27, 1947.) For the system of a cylindrical guide formed of a dielectric of high permittivity, metalized on the outside and with an axial hole through which the electron beam passes, three waves are found to be propagated in the direction of the beam, one slightly faster than the beam and without change of amplitude, the others slightly slower, one increasing in amplitude and the other decreasing. See also 1317 and 1330 of June and 2003 below.

621.392.029.64 2000
On Propagation in Curved Guides of Circular Cross Section—M. Jouguet. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, pp. 549–551; February 24, 1947.) A summary of the results and conclusions of previous papers noted in 1320 of June and back references, 1005 of May, and 1667 and 1668 of July.

621.392.029.64+621.396.611]:621.384.6 2001
Cavities and Waveguides Associated with Charged Particle Accelerators—Kahan. (*See* 2200.)

621.392.029.64:535.231.2 2002
The "Black Body" for Radio Waves—Malov. (*See* 2059.)

621.392.029.64:621.385.029.64 2003
Study of the Various Progressive Guided Waves Capable of Propagation in Interaction) with an Electronic Beam—P. Lapostolle. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, pp. 558–560; February 24, 1947.) An extension of the work described in 1999 above to the case where the electron velocity may have any value whatever. Only E_0 waves are considered. Certain waves are propagated with neither attenuation nor gain, others with either attenuation or gain. Conditions are given for the various possible types.

621.392.1 2004
Equations for Generalized Transmission Lines—S. Frankel. (*Elec. Commun.*, vol. 23, pp. 329–331; September, 1946.) The differential equations for voltage and current at points not near discontinuities of a two-wire lossless line are extended to lossless lines consisting of a multiplicity of conductors of arbitrary cross section.

621.392.2.025.3 2005
Propagation along an Electrically Long Symmetrical Three-Phase Line when a Transmitter is Applied Between One Phase and Earth—A. Chevallier. (*Compt. Rend. Acad. Sci.* (Paris), vol. 219, pp. 89–90; July 17, 1944.)

621.392.2.025.3 2006
Attenuation of High-Frequency Waves along an Electrically Long Symmetrical Three-Phase Line—A Chevallier. (*Compt. Rend. Acad. Sci.* (Paris), vol. 219, pp. 157–158; July 31, 1944.)

621.392.3 2007
Directional Couplers—W. W. Mumford. (Proc. I.R.E., vol. 35, pp. 160–165; February, 1947.) Describes the principles governing the independent measurement of the direct and reflected waves in an unmatched transmission line. The use of multielement "tapered-current" couplers is considered as a means of increasing the bandwidth. Application of the method to give a known attenuation and to enable power to be measured is also discussed.

621.392.4.08:621.397.5:621.396.67 2008
Application of Transmission Line Measurements to Television Antenna Design: Parts 1 and 2—Hamilton and Olsen. (*See* 2262.)

621.392.5 2009
Spiral Delay Lines—K. H. Zimmermann. (*Elec. Commun.*, vol. 23, pp. 327–328; September, 1946.) A brief discussion of design and applications with particular reference to the K-71 line which has a characteristic impedance of 950 ohms and a delay time of 0.042 microseconds per foot.

621.396.621.2 2010
Receiver Aerial Couplings for Medium Wavelengths—S. W. Amos. (*Jour. Brit. I.R.E.*, vol. 6, pp. 144–161; July–August, 1946. Discussion, pp. 161–164.) A discussion of the electrical nature of an outdoor aerial and the problems arising when it is coupled to the aerial input circuit of a receiver. Equations and curves are given to show the variation of gain and selectivity with various types of aerial coupling. The two desirable features, high voltage transfer and high selectivity, are mutually conflicting, but it is possible to obtain 80 per cent efficiency in gain and in selectivity at half optimum coupling. Appendixes give a detailed mathematical analysis of mutual inductance coupling, and a tabulation of exact and approximate formulas derived in the paper.

621.396.67 2011
The Antenna Laboratory—(*Eng. Exp. Sta. News*, vol. 18, pp. 3–24 and 33–40; December, 1946.) A series of papers describing successful wartime methods and equipment for testing the performance of airborne and other aerials by the use of scale models. The papers are entitled: "The Antenna Laboratory," by E. E. Dreese; "Miniature Antennas—A New Tool for the Antenna Designer," by G. Sinclair; "Equipment for Determining Aircraft Antenna Characteristics," by D. C. Cleckner; "Simulation of the Characteristics of Direction Finder Antennas," by W. E. Rife; "Accuracy of Antenna-Pattern Measurements," by R. A. Fouty; "Construction of Models," by P. H. Nelson; and "Antennas Mounted on Vehicle [Radiation Pattern Determined by Model Technique]," by E. A. Jones.

621.396.67 2012
Recent Theories of the Aerial: Parts 1 and 2—E. Roubine. (*Onde Élect.*, vol. 27, pp. 32–37 and 57–64; January and February, 1947.) An elementary treatment intended for non-specialists. To be continued.

621.396.67.011.2 2013
Note on the Expression for Mutual Impedance of Parallel Half-Wave Dipoles—K. J. Afanasiev. (Proc. I.R.E., vol. 35, p. 48; January, 1947.) Additional note to 23 of February.

621.396.674.011.2 2014
Special Aspects of Balanced Shielded Loops—L. L. Libby. (*Elec. Commun.*, vol. 23, pp. 332–338; September, 1946.) Reprint of 25 of February.

621.396.677 2015
Metal Lenses for Radio—"Cathode Ray." (*Wireless World*, vol. 53, pp. 84–88; March, 1947.) A concise account of the properties and construction of the directive lenses designed at the Bell Telephone Laboratories. For a more detailed description see 1013 of May.

621.396.677 2016
Radiation Patterns of Ground-Based Antennas—R. B. Jacques. (*Eng. Exp. Sta. News*, vol. 18, pp. 24–33; December, 1946.) The output of the aerial to be tested was compared with that of an aerial of known pattern, using a moving airborne transmitter.

621.396.677 2017
Fundamental Beam Patterns—D. C. Cleckner. (*QST*, vol. 31, pp. 23–26; March, 1947.) A simplified method of plotting aerial characteristics.

621.392 2018
An Introduction to Transmission Lines [Book Review]—C. J. Mitchell. Harrap and Co., London, 64 pp., 3s. 6d. (*Wireless World*, vol. 53, p. 83; March, 1947.) A simple approach to the subject that "can be thoroughly recommended."

CIRCUITS AND CIRCUIT ELEMENTS

537.525.72:621.396.6 2019
Electrodeless Discharges and Some Allied Problems—G. I. Babat. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 27–37; January, 1947.) "Electrodeless discharges in high-frequency electromagnetic fields were investigated

in conditions where the ratio of linear dimension l of the discharge space to the electromagnetic wavelength λ in air was $10^{-3}<l/\lambda<10^{-1}$ at frequencies between 10^6 and 10^8 cycles. The power introduced into the discharge space varied from fractions of a watt to 100 kilowatts, and the electric field strength was varied between tens and hundreds of volts per centimeter. There are two different types of discharge: "*E*-discharges," in which the elementary conductance currents are continued by dielectric currents, and "*H*-discharges," with elementary conductance currents in the form of closed curves."

537.533.7 2020
Interruption of Electron Beams—P. Selme. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 992–993; June 26, 1944.) A combination of two pentodes and two thyratrons giving establishment and suppression times which are negligible in comparison with the short exposure time.

538.244+621.3.013.1 2021
Theory of Ferromagnetic Inductances: Production and Use of Harmonics—P. Bricout. (*Gen. Elec. Rev.*, vol. 55, pp. 61–74; February, 1946.) A theory based on the method of representation of hysteresis cycles previously given (1746 of July). Tables and graphs permit rapid harmonic analysis of the current intensity. Practical methods are described of isolating odd harmonics and of using them for local deformation of sinusoidal currents. This technique has proved useful in improving the operation of triphase dry or contact rectifiers.

621.3.078.3 2022
A Generalization of the Nyquist and Leonhard Stability Criteria—W. Frey. (*Brown Boveri Rev.*, vol. 33, pp. 59–65; March, 1946.) For Nyquist's rule for stability, see 1932 Abstracts, p. 279; for Leonhard's see 567 of 1946. In the present paper, the underlying principles are considered mathematically; the conditions under which the zeros of a function $f(z)$ of a complex variable z all have negative real parts are derived, where $f(z)$ has a finite number of poles of any order. A more general form of the Nyquist and Leonhard criteria, whose application is not restricted to electric circuits, is then deduced.

621.314.3 2023
Some Considerations Concerning the Internal Impedance of the Cathode Follower—H. Goldberg. (Proc. I.R.E., vol. 35, pp. 168–169; February, 1947.) Discussion of 42 of 1946.

621.316.722 2024
Regulator of Effective Alternating Voltage—L. LeBlan. (*Comp. Rend. Acad. Sci.* (Paris), vol. 224, pp. 643–645; March 3, 1947.) A Wheatstone bridge has two opposite constant-resistance arms while the other two arms are fine nickel wires in vacuo. It is connected across the resistive load and balanced for a particular voltage. The out-of-balance voltage, due to a change of the supply voltage, is amplified and applied to the grids of a balanced triode system. The anodes of this system are fed from the two halves of a transformer secondary whose primary is included in one supply lead. The variation of the primary impedance acts as an automatic rheostat. Supply voltage variations are divided by a factor of the order of 1000. A circuit diagram is given.

621.316.722.2:621.314.632 2025
Some Notes on the Copper-Oxide Rectifier and the Thermionic Tube in the Voltage-Doubling Circuit—R. R. Gilmour. (Proc. I.R.E., vol. 35, pp. 213–216; February, 1947.) Discusses the relative merits of the two rectifiers for a particular application requiring portability, 40 milliamperes output into 500 to 5000 ohms, ability to withstand short circuits and low ripple.

621.317.757:518.4 2026
Second Harmonic Calculator—W. L. Detwiler. (*Communications*, vol. 27, pp. 16–17, 28; January, 1947.) Permits rapid graphical determination of harmonic distortion.

621.318.4:621.316.974:538.532 2027
The Field of a Coil between Two Parallel Metal Sheets—Moullin. (*See* 2077.)

621.318.7 2028
Conditions for Common Frequencies in Ladder Networks, of Any Length, Terminated by Identical Circuits Differing from the Intermediate Circuits—M. Parodi. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 965–967; June 19, 1944.)

621.319.4:621.315.614.63 2029
Metallized Paper Capacitors—J. I. Cornell. (*Communications*, vol. 27, p. 22; January, 1947.) A short account of self-healing capacitors produced by high vacuum vaporization of aluminium, the coatings being 25 to 100 millicrons in thickness. Breakdown at a weak spot in the dielectric vaporizes the film there and redeposits it as oxide, which is a good insulator. A noninductive winding method is used for the larger capacitors, which are considerably smaller than those of similar value built from metal foil and paper. A 0.1-microfarad capacitor for a direct-current working voltage of 200 being only $\frac{5}{8}$ inch long and $\frac{3}{8}$ inch in diameter while the corresponding metal-foil capacitor is approximately $1\frac{5}{8}$ inches long and $\frac{1}{2}$ inch in diameter. Summary of Rochester Fall Meeting paper.

621.392:003.62 2030
Shorthand Circuit Symbols—A. W. Keen. (*Wireless World*, vol. 53, pp. 99–101; March, 1947.) Details of a simplified system, supplementary to existing practice, to save time in drawing circuit diagrams. It could be used with advantage to distinguish equivalent circuits from actual circuit diagrams.

621.392.4 2031
A Note on Phase Correction in Electrical Delay Networks—A. J. Ferguson. (*Canad. Jour. Res.*, vol. 25, sec. A, pp. 68–71; January, 1947.) By means of mutual inductance between the coils and capacitance across them, the third and fifth order terms in the expression for the variation of phase shift with frequency can be eliminated. A simple relation between the circuit constants is found for this case.

621.392.5 2032
Geometrical Considerations in Connection with the Theory of Electric Four Terminal Networks [Thesis]—J van Slooten. N. V. Philips' Gloeilampenfabrieken Research Laboratory, Eindhoven. Reprints are available. (*Philips Tech. Rev.*, vol. 8, p. 287; September, 1946.) The first part discusses the properties of quadripoles as impedance transformers. The second gives methods of determining the characteristics of the resultant quadripole obtained by connecting in series or parallel two lossless quadripoles whose transformer properties are known. A Cayley diagram is given for the series connection. Brief summary only.

621.392.52.011.2 2033
The Direct Setting-Up of $Z_{\alpha\beta}$ for Closed Mesh Networks from the Network Diagram: Part 1—S. A. Stigant. (*Beama Jour.*, vol. 54, pp. 28–36; January, 1947.) The impedance tensor, $Z_{\alpha\beta}$, of a mesh network can be written down directly in full detail from the network diagram. The $\alpha\beta$ axes may be either loop or branch currents. In the present article loop currents are considered. To be continued.

621.392.52.015.33 2034
Transition Time and Pass Band—C. C. Eaglesfield. (Proc. I.R.E., vol. 35, pp. 166–167; February, 1947.) Fourier transforms are used to define two functions which may be regarded as definitions of pass band and transition time for a network subjected to a step-function voltage. The numerical relation between these functions is that usually quoted, but this approach avoids the "ideal filter."

621.392.52.015.33 2035
Transient Response of Filters—V. Belevitch: W. E. Thomson. (*Wireless Eng.*, vol. 24, pp. 93–94; March, 1947.) Criticisms of a statement in a letter by E. T. Emms (662 of April) that when a voltage cos $\omega_0 t$.1 is applied to a band-pass filter the envelope of the output transient is the same as the output voltage produced by a unit step in the equivalent low-pass filter. This statement is shown to be untrue, in general, being valid only for a narrow-band filter.

621.394/397].645 2036
Capacitance-Coupled Intermediate-Frequency Amplifiers—M. J. Larsen and L. L. Merrill. (Proc. I.R.E., vol. 35, pp. 71–74; January, 1947.) Discusses the design and performance of attenuating traps for television intermediate-frequency amplifiers above 20 megacycles, using double-ended damping to minimize changes in response due to component variations.

621.394/.397].645.3 2037
Cathode-Excited Linear Amplifiers—J. J. Muller. (*Elec. Commun.*, vol. 23, pp. 297–305; September, 1946.) The advantages of cathode-excited power amplifiers are outlined. "The use of neutralizing capacitances, having values which differ from the internal capacitances of the vacuum tubes, in combination with appropriate reactances between the grids of symmetrical stages, permits control of power amplification, stability and feedback." The distortion characteristics of a cathode-excited stage are illustrated by reference to intermodulation measurements made on a 60-kilowatt two-channel transmitter.

621.395/.396].645.36 2038
The Twin Triode Phase-Splitting Amplifier—J. D. Clare. (*Electronic Eng.*, vol. 19, pp. 62–63; February, 1947.) A practical circuit modification used to operate the twin triodes under optimum conditions and to give a flat "gain versus frequency" response over a very wide audio band.

621.396.611.1:621.316.5 2039
The Energy O tput of an Oscillatory Circuit Excited by a Periodically Interrupted Continuous Current—J. Cayrel. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 109–111; January 17, 1944.) Experiments show that when a mercury interrupter is used, the output efficiency approximates to 100 per cent proving that the current break occurs in a time very short with respect to the natural frequency of the oscillatory circuit. Interrupters with solid contacts gave anomalous results.

621.396.611.4:534.2 2040
New Method for Calculating the Properties of Electromagnetic Resonators—P. Grivet. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 71–73; January 10, 1944.) An adaptation to the case of electric vibrations of Rayleigh's method for mechanical vibrations. For applications of this method see 2041 below.

621.396.611.4:534.2 2041
The Natural Wavelength of Certain Electromagnetic Resonators—P. Grivet. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 183–185; January 31, 1944.) The method described in 2040 above is applied to calculate the natural wavelengths of a cylinder, a ring of rectangular section, a rhumbatron, and a sphere.

621.396.615 2042
The Calculation of Triode Oscillators—J. Queffelec. (*Compt. Rend. Acad. Sci.* (Paris), vol. 219, pp. 449–451; November 6, 1944.)

Calculation based on the assumptions that the triode operates well below saturation, that the characteristic is linear, and that grid current is negligible.

621.396.615.14:621.385.029.63/.64 2043
The Traveling-Wave Tube as Amplifier at Microwaves—Kompfner. (*See* 2286.)

621.396.615.142 2044
A Wide-Tuning-Range Microwave Oscillator Tube—Clark and Samuel. (*See* 2291.)

621.396.615.142 2045
Transit-Time Effects in Ultra-High-Frequency Class-C Operation—Dow. (*See* 2290.)

621.396.645 2046
Cathode-Coupled Triode Amplifiers—N. I. Korman. (PROC. I.R.E., vol. 35, p. 48; January, 1947.) Comment on 3811 of 1945 (Sziklai and Schroeder).

621.396.645:621.318.572 2047
Photo-Counters and Poisson's Law—A. Blanc-Lapierre. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 188–190; January 31, 1944.) A study of the output fluctuations of an amplifier excited by equal, short, and random impulses of low density. The series of discharges of a photocounter can be satisfactorily used, and Poisson's law is in general obeyed. For high densities, see 2048 below.

621.396.645:621.38 2048
Shot Effect and Fluctuations at the Output of a Linear Amplifier—A. Blanc-Lapierre. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 272–274; February 14, 1944.) Extension of 2047 above to high impulse densities, using a photoelectric multiplier tube instead of a photocounter. Two formulas are given from which the output law for any input density may be deduced; the limiting form of this law as the density increases indefinitely is Gaussian.

621.396.645.36 2049
Push-Pull Amplifier with Direct Coupling—S. Petralia and R. Ricamo. (*Nuovo Cim.*, vol. 3, pp. 185–197; June 1, 1946. In Italian with English summary.) A battery-fed push-pull amplifier with linear frequency response to 6000 cycles and gain of the order of 1.5×10^6. The output is connected to a cathode-ray oscilloscope. Drift is low after 5 minutes operation.

621.396.645.371 2050
The Anode Follower—B. H. Briggs. (*R.S.G.B. Bull.*, vol. 22, pp. 138–143; March, 1947.) A full account of the properties of a circuit in which negative feedback is applied to a single tube amplifier. Practical details of design are given, with several applications.

621.396.645.371.029.4 2051
The Parallel-T Bridge Amplifier—A. B. Hilan. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 42–51; January, 1947.) A discussion on the design and performance of low-frequency amplifiers using negative feedback through a parallel-T bridge network to obtain selectivity. "Two basic forms of the circuit giving symmetrical selectivity are analyzed, and a method of varying the selectivity, while maintaining the magnitude and frequency of the peak amplification constant, is indicated."

621.396.662.2 2052
Guillotine Tuner for F.M.—(*Electronics*, vol. 20, p. 136; February, 1947.) A variable inductance tuning system in which a blade is inserted between the turns of a two-turn coil to change their self-inductance and mutual inductance.

621.396.662.34.029.3 2053
An RC Audio-Frequency Filter—P. N. Nield. (*R.S.G.B. Bull.*, vol. 22, pp. 144–145; March, 1947.) A ladder-type filter with a pass band centered usually at about 1000 cycles.

621.39.09 2054
Electrical Transmission in Steady State [Book Review]—P. J. Selgin. McGraw-Hill Book Co., New York, N. Y., 427 pp., $5.00. (*Communications*, vol. 27, p. 33; January, 1947.) Fundamental circuit, field, and network principles, with detailed analysis of circuit characteristics. Field theory and Maxwell's equations are considered for ultra-high-frequency, where lumped circuit concepts cease to apply, and coupled circuits and three-conductor systems are studied.

621.396.69 2055
Radio Components for Export. [Book Review]—Radio Component Manufacturers Federation, London. (*Elec. Times*, vol. 111, p. 211; February 13, 1947.) A new catalogue giving a comprehensive survey of the products of leading British firms. Printed in English, French, and Spanish.

GENERAL PHYSICS

534.213 2056
Propagation of Plane Elastic Waves in a Heterogeneous Medium—M. Parodi. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 69–71; January 10, 1944.) The propagation of such waves in an infinite heterogeneous medium satisfies the quadripole equation. The case of propagation along an arbitrary line was discussed in 2149 of 1944.

534.213:548.0:537 2057
Propagation of Elastic Waves in a Piezoelectric Medium—M. Cotte. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 445–447; March 13, 1944.)

535.13 2058
On the Ellipsoidal Theory of Wave Propagation [Liaisons Ondulatoires]—J. Dreyfus-Graf. (*Helv. Phys. Acta*, vol. 19, pp. 399–404; December 18, 1946. In French.) A new theory based on the principles of Fermat, of Huyghens, and of superposition, leads to the replacement of the Poynting energy vector by an ellipsoid with focuses at the transmitter and receiver (ellipsoïde de liaison). This enables the problem of diffraction of a spherical wave front to be solved by elementary mathematics. For the case of diffraction by an absorbing screen, the new theory gives much simpler formulas than the Fresnel integrals. If this theory is correct, all the classical theories based on that of Maxwell involve a fundamental phase error of 45 degrees. Correction of this error is necessary for the solution of problems such as that of the diffraction of a spherical wave front at the edge of a screen. The hope is expressed that competent critics will comment on the new theory.

535.231.2:621.392.029.64 2059
The "Black Body" for Radio Waves—N. Malov. (*Jour. Phys.* (U.S.S.R.), vol. 10, no. 4, pp. 383–385, 1946.) Southworth has indicated that in order to obtain a pure traveling wave in a wave guide closed by a metallic piston, a slightly absorbing plate should be placed in front of the piston. This plate together with the space between it and the piston acts as a "black body." This gives a new method (for which formulas are derived) for investigating the electrical properties of materials at very-high-frequency. See also *Zh. Eksp. Teor. Fiz.*, vol. 16, no. 6, pp. 495–498; 1946. In Russian.)

535.329-15:535.81 2060
Dispersion of Several Optical Glasses in the Near Infra Red—J. Ramadier. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, pp. 555–557; February 24, 1947.)

535.33.072-15:539.2 2061
Infra-Red Spectrographic Study of Molecular Groups—J. Lecomte, G. Champetier, and P. Clément. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, pp. 553–555; February 24, 1947.)

535.376 2062
Cathodo-Luminescence—A. V. Moskvin. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 9, nos. 4–5, pp. 429–462; 1945. In Russian.) The most important properties of substances which become luminescent, when excited by an electron beam, are discussed, and a number of experimental curves are given. A theoretical interpretation of the phenomenon is offered.

535.376 2063
On Cathodo-Luminescence of Solid Phosphors—E. A. Ab. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 9, nos. 4–5, pp. 467–468; 1945. In Russian.) Experiments were conducted with $CaWO_4$, Zn_2SiO_4Mn, and ZnB_4O_7Mn. Curves are plotted showing the spectral distribution of radiation and the effect of temperature on the performance of these substances.

537.291 2064
The Motion of Positive Ions in the Electric Field in a Gas—L. Sena. (*Zh. Eksp. Teor. Fiz.*, vol. 16, no. 8, pp. 734–738; 1946. In Russian.) An English version was noted in 1405 of June.

537.523.4 2065
The Strong Current Stage of an Electric Spark in a Gas at Atmospheric Pressure. Parts 1 and 2—I. S. Marshak. (*Zh. Eksp. Teor. Fiz.*, vol. 16, no. 8, pp. 703–717 and 718–727; 1946. In Russian, with English summary.) Current-versus-time and voltage-versus-time curves calculated from energy considerations are obtained. The nature of the limitation of current density increase at a later stage of the discharge is explained.

537.525 2066
On the Oscillation of the Electron Plasma—L. Landon. (*Zh. Eksp. Teor. Fiz.*, vol. 16, no. 7, pp. 574–586; 1946. In Russian.) Equations are derived determining the oscillations arising in a plasma owing to the initial unbalanced distribution of electrons. It is shown that these oscillations decrease with time. The penetration of an external oscillating field into the plasma is also considered.

537.525.5 2067
Spontaneous Electrical Oscillations in Low-Pressure Arc Discharge—B. Granovsky and L. Bykhovskaya. (*Jour. Phys.* (U.S.S.R.), vol. 10, no. 4, pp. 351–359; 1946.) Four different modes of oscillation depend upon discharge conditions and especially upon whether the cathode spot is free or anchored. Graphs show the dependence of the frequency and peak amplitude of these oscillations upon pressure, current, and arc length.

537.525.5 2068
Rate of Growth of Current in Arc Discharges—K. D. Froome. (*Nature* (London), vol. 159, p. 129; January 25, 1947.) Discusses the characteristics of the high-intensity, short-duration type of discharge through small gas tubes. A fuller account will be published later.

537.531:535.341 2069
Measurement of X-Ray Absorption Coefficients—J. Devaux and A. Guinier. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 318–320; February 21, 1944.) A monochromatic beam passes successively through two ionization chambers to which voltages of opposite sign are applied. These chambers are separated by the absorbing material; the first has low sensitivity which is controlled by the displacement of a screen, with micrometer adjustment, in front of the collecting electrode. In equilibrium the ionization currents in the two chambers are equal and opposite. The apparatus is calibrated by noting the micrometer reading corresponding to absorbing material of known composition and thickness. A thickness variation of 1 micron in sheet aluminum 0.25 millimeter thick causes a galvanometer spot deflection of 4 centimeters.

537.533.9:778.3 2070
A New Method for Studying the Mechanism of the Photographic Action of Electrons—P. Selme. (*Compt. Rend. Acad. Sci.* (Paris), vol. 219, pp. 60–62; July 10, 1944.)

537.562:551.510.535 2071
On the Mean Energy of Electrons Released in the Ionization of Gas—G. Drukarev. (*Zh. Eksp. Teor. Fiz.*, vol. 16, no. 6, pp. 483–488; 1946. In Russian, with English summary.) As an electron released by ionization gives up its energy during a large number of collisions, the mean energy of the electron is larger, under certain conditions, than the thermal energy of the remainder of the gas. The conditions under which the electrons may be regarded as a gas having a temperature are considered, a formula for this temperature is derived and applied to the ionosphere. An English version appears in *Jour. Phys.* (U.S.S.R.), vol. 10, no. 1, pp. 81–84; 1946.)

538.114:539.23/.24 2072
Theory of the Structure of Ferromagnetic Domains in Films and Small Particles—C. Kittel. (*Phys. Rev.*, vol. 70, pp. 965–971; December 1–15, 1946.) Discussion of "the theory of the domain structure of ferromagnetic bodies whose smallest dimension is comparable with the thickness of the Weiss domains as found in crystals of ordinary size."

538.22 2073
Thermoremanence and the Theory of Metamagnetism—É. Thellier. (*Compt. Rend. Acad. Sci.* (Paris), vol. 223, pp. 319–321; August 12, 1946.) Recent researches on the thermoremanence of $Fe_2O_3\alpha$ and certain baked earths show that these substances are metamagnetic, i.e., paramagnetic and ferromagnetic, simultaneously. The essential characteristics of this condition are described by J. Becquerel (Congrès de Strasbourg, "Le Magnétisme," vol. 1, pp. 97–139, 1939; see 3597 of 1946). Three important differences are noted between isothermal remanence and thermoremanence; theory must allow for these.

538.221 2074
On the Exchange Interaction of the Valence and Inner Electrons in Ferromagnetic (Transition) Metals—S. Vonsovsky. (*Jour. Phys.* (U.S.S.R.), vol. 10, no. 5, pp. 468–475; 1946.)

538.245 2075
On the Connection between the Magnetization and Hysteresis Curves of Polycrystalline Ferromagnetic Bodies—N. Poptzov and L. Tchernikova. (*Zh. Eksp. Teor. Fiz.*, vol. 16, no. 6, pp. 513–522; 1946. In Russian, with English summary.) The connection is considered between the magnetization and hysteresis curves of soft polycrystalline ferromagnetic substances having a small degree of magnetic anisotropy, such as permalloy and alsifer. Specimens of polycrystalline cobalt were also examined.

The experimental hysteresis curves agree with theoretical curves computed from E. Kondorsky's formula (591 of 1944) over the whole range of magnetic-field values from zero to the coercive force of the specimen concerned. Full English translation in *Jour. Phys.* (U.S.S.R.), vol. 10, no. 1, pp. 85–91; 1946.

538.245:539.185.9 2076
Neutron Polarization and Ferromagnetic Saturation—F. Bloch, R. I. Condit, and H. H. Staub. (*Phys. Rev.*, vol. 70, pp. 972–973; December 1–15, 1946.)

538.532:621.316.974:621.318.4 2077
The Field of a Coil Between Two Parallel Metal Sheets—E. B. Moullin. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 78–84; January, 1947.) An investigation of the problem of a circular coil of any radius with its plane parallel to two infinite and perfectly conducting planes separated by any distance. The exact expression for the field when the sheets are close together is derived, giving the absolute calibration for an "attenuator" of this type. The results obtained are applicable to the case of a coil enclosed in a cylindrical screening can with closed ends. See also 821 of 1941.

538.56:535.42 2078
On a Problem of Diffraction of Electromagnetic Waves at the Surface of Separation of Two Media—L. Robin. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 135–136; January 24, 1944.) A treatment of the case of an infinite diffracting plane. The solution is not limited to sinusoidal functions of the time; the two media are conductors, and the scalar equation of propagation of spherical waves is valid. See also 2079 below.

538.56:535.42 2079
A Problem of Propagation and of the Diffraction of Electromagnetic Waves at the Surface of Separation of Two Media—L. Robin. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 989–990; June 26, 1944.) An application of Maxwell's equations to the case treated in 2078 above.

538.56:535.421 2080
On a Theorem in the Theory of Diffraction and Its Application to Diffraction by a Narrow Slit of Arbitrary Length—M. Leontovitch. (*Zh. Eksp. Teor. Fiz.*, vol. 16, no. 6, pp. 474–479; 1946. In Russian, with English summary.) The problem of a plane electromagnetic wave incident on a thin plane perfectly conducting screen with an aperture of arbitrary shape can be reduced to that of a similar wave incident on a perfectly reflecting lamina of the same shape as the aperture. In the special case of a narrow slot, it can be solved completely.

538.566 2081
The Field of a Plane Wave Near the Surface of a Conducting Body—V. Fock. (*Jour. Phys.* (U.S.S.R.), vol. 10, no. 5, pp. 399–409; 1946.) Expressions are derived for the field at any point on or near the surface of a convex body of finite conductivity. From a knowledge of the distribution of the currents induced by an incident plane wave, an approximate solution can be obtained for the case of diffraction by a conducting convex body of arbitrary shape.

538.691:531.553 2082
The Hodoscope—J. Loeb. (*Onde Élec.*, vol. 27, no. 238, pp. 27–31; January, 1947.) A discussion of the principles and possible applications of an instrument by means of which the trajectory of an electrified particle in a stationary magnetic field can be traced without calculation.

541.183.26:621.352.36.011.2 2083
The Effect of Physical Adsorption on the Electrical Resistance of Activated Carbon—R. McIntosh, R. S. Haines, and G. C. Benson. (*Jour. Chem. Phys.*, vol. 15, pp. 17–27; January, 1947.) Measurements of resistance changes due to adsorption of various vapours.

537.228.1 2084
Piezoelectricity [Book Review]—W. G. Cady. McGraw-Hill Book Co., New York and London, 806 pp., $9.00 or 45s. (*Elec. Rev.* (London) vol. 139, p. 1028; December 20, 1946; *Jour. Appl. Phys.*, vol. 17, pp. 1130–1131; December, 1946.) A detailed survey of the whole domain of crystal physics that centers around piezoelectricity. "To the mature physicist and serious research student the work will be invaluable. . . . The technical applications are only treated insofar as they illustrate the scientific side of the subject."

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.5:621.396.82 2085
The Giacobinid Meteor Shower, 1945—J. S. Hey. (*Nature* (London), vol. 159, pp. 119–121; January 25, 1947.) A more detailed account of the observations discussed in 1753 of July.

523.53 2086
Derivation of Meteor Stream Radiants by Radio Reflexion Methods—J. S. Hey and G. S. Stewart. (*Nature* (London), vol. 158, pp. 481–482; October 5, 1946.) With 150 kilowatt peak power on vertical pulse transmission (wavelength of 4 to 5 meters), definite correlation is found between echo reception peaks and the Quadrantid and Lyrid meteor showers in January and April, 1946. The echoing source is sensitive to aspect and a technique is described whereby the activity and radiant directions of the main meteor streams can be observed both by day and night in all weathers.

523.7:621.396.822.029.62 2087
On the Radio-Frequency Emission from the Sun: Part 1—J. V. Garwick. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, pp. 377–379; February 10, 1947.) Deductions from the hypothesis attributing the emissions to the rotation of electrons round the lines of force of a magnetic field H are discussed and compared with Appleton's results (323 of 1946). Agreement between the theoretical and experimental curves indicates that for wavelengths above 5 meters the radiation intensity is proportional to $H^{2/3}$. Possible explanations are suggested for the discrepancies between theory and experiment for wavelengths from 2 to 5 meters. For part 2 see 1758 of July.

523.72:621.396.822 2088
Origin of Radio Emissions from the Disturbed Sun—D. F. Martyn. (*Nature* (London), vol. 159, pp. 26–27; January 4, 1947.) A theory accounting for solar radio emissions associated with sunspots. Radiation may occur by virtue of an "extraordinary" mode of oscillation of the ionized gases above the chromosphere.

523.745:550.384 2089
Relations between Solar Activity and Fluctuations in the Magnetic Declination at Lyons—J. Dufay and P. Flajolet. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 46–48; January 4, 1944.) A graph of the mean amplitude A of declination fluctuations and the Wolf-Wolfer relative number S for sunspot activity for the years from 1884 to 1933 gives a correlation coefficient between A and S of $+0.45$ for the decreasing phase and of $+0.76$ for the increasing phase. At Paris Brazier has found, for the years 1884 to 1917, a mean value of $+0.33$. See also 2090 below.

523.745:550.384 2090
The Annual Variation of the Magnetic Declination Fluctuations at Lyons and Its Relations with Solar Activity—J. Dufay and P. Flajolet. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 162–164; January 24, 1944.) Detailed analysis of the data for the period 1884 to 1933 confirms the results of Kostitzin regarding the retardation of the autumn maximum and its large amplitude during the increasing phase of solar activity. During the decreasing phase, on the contrary, there is a tendency for the maxima to be displaced in the opposite sense and the spring maximum becomes the more important. This can be attributed to two causes: (a) solar activity generally increases more rapidly than it decreases; and (b) the progressive diminution of the latitude of the sunspots during the cycle makes them more and more effective. See also 2089 above.

523.746 2091
Structure of Sunspots—G. J. Odgers. (*Mon. Not. R. Astr. Soc.*, vol. 106, no. 2, pp. 101–107.) "The possibility that a sunspot is merely a region in which the product of the absorption coefficient and the density is higher than that of the disk is examined." Solution of the equations of radiative equilibrium shows that the

observed contrast between spot and disk can be explained by increased density inside the spot. Other features of spots are explained similarly.

523.78"1945.07.09":621.396.812:551.510.535 2092

Radio Observations during the Solar Eclipse of July 9, 1945—N. D. Papalxsi. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 10, no. 3, pp. 237–242; 1946. In Russian.) The following preliminary conclusions were obtained from a general survey of the observations: (a) the predominant role of the ultraviolet radiation from the sun in the ionization of all layers of the ionosphere is confirmed; (b) the density of the ionization of the F_2 layer diminished by 20 to 30 per cent of the average value some 40 to 50 minutes after totality; (c) during the photon eclipse the direction of the signals reflected from the F_2 layer was altered, which indicates curvature of this layer; and (d) during the period corresponding to the corpuscular eclipse for particles, with velocities of the order of 500 kilometers per second, peculiar perturbation effects were observed in the state of ionization of the whole depth of the ionosphere from the F_2 layer to the E layer.

523.78"1945.07.09":621.396.812:551.510.535 2093

On Radio Observations during the Solar Eclipse of July 9 1945—Ya. L. Al'pert and B. N. Gorozhankin. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 10, no. 3, pp. 245–251; 1946. In Russian.) Observations were carried out near Moscow to determine the effects of the ultraviolet and corpuscular radiations from the sun on the ionization of the upper layers of the atmosphere and to investigate the possible curving of the reflecting regions of the ionosphere during the photon eclipse.

The main results were: (a) it was confirmed that the ultraviolet radiation from the sun determines the ionization of the E layer, and the measured azimuth values of reflections from the F_2 layer are consistent with the assumption that a certain curvature of the layer takes place during the ultraviolet eclipse of sun; and (b) the ionosphere appears to be affected by the corpuscular radiation from the sun and in particular by particles with velocities of 400 to 600 kilometers per second.

523.78"1945.07.09":621.396.812:551.510.535 2094

On the Results Obtained in the Investigation of the Ionosphere during the Solar Eclipse of July 9, 1945—A. N. Kazantseff. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 10, no. 3, pp. 261–267; 1946. In Russian.) Observations were made at a temporary ionosphere station near Leningrad. The field intensities of the Leningrad and Kuibisheff radio-telephone stations (at frequencies of the order of 7 megacycles) were also compared at this point.

The observations have confirmed the predominant role of the ultraviolet radiation from the sun in the ionization of the ionosphere. Thus an abrupt diminution of the absorption, and therefore of the ionization of the lower layers, was observed during the optical eclipse, together with a decrease in the ionization of the F region. The effects of the corpuscular eclipse were much less obvious, but the gradual increase in the field intensity two hours before the eclipse was probably due to the corpuscular eclipse for fast particles in accordance with Milne's calculations.

523.78."1945.07.09":621.396.812.029.62/.63 2095

Observations of the Ultra-Short-Wave Propagation during the Solar Eclipse of July 9, 1945—N. I. Kabanoff. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 10, no. 3, pp. 275–278; 1946. In Russian.) Army radar stations were used for observing signals reflected from obstacles such as hills, tall buildings, or masts. Observations were carried out at hundreds of places in the zone of the eclipse over distances up to several tens of kilometers. The main preliminary conclusions reached from a statistical analysis of the data are as follows: during the total eclipse an increase of 15 to 20 per cent in signal amplitude was observed for distances of 20 to 60 kilometers at decameter and meter wavelengths, but for distances of 15 to 20 kilometers the corresponding increase was much smaller; no increase was observed for distances 2 to 10 kilometers at meter and decimeter wavelengths.

523.78"1945.07.09":621.396.812.029.64 2096

Observations of the Variations of the Ultra-Short-Wave Intensity during the Solar Eclipse of July 9, 1945—N. V. Osipoff. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 10, no. 3, pp. 281–284; 1946. In Russian.) Observations were carried out at wavelengths of 1.44 and 4.00 meters over a distance of 55 kilometers due south of Moscow. Preliminary studies were made during the six months preceding the eclipse. During the eclipse the expected increase in the field intensity was observed, accompanied by rather strong fading. The maximum field intensity did not quite coincide with totality; this was probably due to the presence of the fading. It was thus established that during the eclipse the conditions of radio transmission approached for a short period those prevailing at night.

535.338.4:551.593.9 2097

A New Method of Molecular Spectrum Analysis with Application to the Spectrum of the Night Sky—D. Barbier. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, pp. 385–397; February 10, 1947.)

537.591 2098

Showers of Mesotrons and of Slow Particles—J. Daudin. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 192–193; January 31, 1944.) Apparatus for observation comprises three counters in a mass of lead and a Wilson chamber with lead partition. Results are discussed. For further results see 2099 below.

537.591 2099

Showers of Mesotrons and of Slow Particles—J. Daudin. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 275–276; February 14, 1944.) A discussion of further results obtained with the apparatus described in 2098 above.

537.591 2100

Probable Existence of a Particle of Mass 990 m_0 in Cosmic Radiation—L. Leprince-Ringuet and M. Lhéritier. (*Compt. Rend. Acad. Sci.* (Paris), vol. 219, pp. 618–620; December 13, 1944.)

537.591 2101

Some Mesotron Observations by Simultaneous Registration at Two Stations—F. A. Benedetto. (*Phys. Rev.*, vol. 70, pp. 817–820; December 1–15, 1946.) Mean life range near sea level was estimated at 9.7±3 kilometers. By correlating ground values of mesotron intensity with variations in the heights at which pressures from 1000 to 100 millibars occur, it is inferred that two production levels for mesotrons exist at approximately 5.5 to 16 kilometers.

537.591 2102

Multiple Scattering and the Mass of the Meson—H. A. Bethe. (*Phys. Rev.*, vol. 70, pp. 821–831; December 1–15, 1946.) Multiple scattering by the atoms of the gas in a cloud chamber can cause large apparent curvature of tracks. An analysis shows that all published meson tracks are compatible with a unique mass of about 200 electron masses. See also 1428 and 1429 of June.

537.591 2103

On the Fine Structure of Zenithal Curves of the Cosmic Radiation—G. Cocconi and V. Tongiorgi. (*Phys. Rev.*, vol. 70, pp. 850–852; December 1–15, 1946.)

537.591 2104

The Mean Lifetime of the Meson—G. Cocconi and V. Tongiorgi. (*Phys. Rev.*, vol. 70, pp. 855–859; December 1–15, 1946.)

537.591 2105

On the Mean Life of Slow Mesons—M. Conversi and O. Piccioni. (*Phys. Rev.*, vol. 70, pp. 859–873; December 1–15, 1946.)

537.591 2106

On the Disintegration of Slow Mesons—M. Conversi and O. Piccioni. (*Phys. Rev.*, vol. 70, pp. 874–881; December 1–15, 1946.)

537.591 2107

A Note on the Proton Hypothesis of the Primary Component of Cosmic Rays—N. Arley. (*Phys. Rev.*, vol. 70, pp. 975–976; December 1–15, 1946.)

537.591.15 2108

The Density Spectrum of the Extensive Cosmic-Ray Showers of the Air—G. Cocconi, A. Loverdo, and V. Tongiorgi. (*Phys. Rev.*, vol. 70, pp. 841–846; December 1–15, 1946.)

537.591.15 2109

Experimental and Theoretical Evaluation of Density Spectrum of Extensive Cosmic-Ray Showers—H. Cocconi, A. Loverdo, and V. Tongiorgi. (*Phys. Rev.*, vol. 70, pp. 846–849; December 1–15, 1946.)

537.591.15 2110

Penetrating Particles in Air Showers—G. Cocconi, A. Loverdo, and V. Tongiorgi. (*Phys. Rev.*, vol. 70, pp. 852–854; December 1–15, 1946.)

537.591.15 2111

The Density Spectrum and the Origin of Extensive Atmospheric Cosmic-Ray Showers—G. Cocconi. (*Phys. Rev.*, vol. 70, p. 975; December 1–15, 1946.)

537.591.15 2112

The Main Results Obtained by the Pamir Expedition for the Investigation of Cosmic Rays—D. V. Skobel'tsyn. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 9, no. 3, pp. 250–258; 1945. In Russian.) A brief report on the work of the expedition whose main task was the investigation of showers and nuclear fission at a height of about 3800 meters. See also 1441 of June.

537.591.15 2113

The Problem of Fluctuations in Cosmic Radiation Showers—M. Della Corte. (*Nuovo Cim.*, vol. 3, pp. 142–151; June, 1946. In Italian, with English summary.)

538.566.3 2114

Measurements of Changes of the Phase Paths of Radio Waves in the Ionosphere—J. W. Findlay. (*Nature* (London), vol. 159, pp. 58–59; January 11, 1947.) A modification of the pulse method is described whereby both the magnitude and the sense of a change of the phase path can be determined. The method was used to study the changes of the phase path of pulses reflected from the E and F layers, using wavelengths of 150 and 75 meters. On 20 occasions during observations of the *E* layer Dellinger fade-outs occurred, their start being marked by a rapid reduction of the phase path, of the order of 1 kilometer in about a minute. The recovery of the echo corresponded with a slower increase of the phase path. The results are discussed and possible explanations given.

538.7+[523.7:538 2115

A Theoretical Interpretation of Terrestrial and Solar Magnetism—J. Mariani. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 585–586;

April 3, 1944.) A new geometrical interpretation based on a Riemann torsion space.

551.508.19 2116
Pressure and Temperature Measurements in the Upper Atmosphere—N. R. Best, E. Durand, D. I. Gale, and R. J. Havens. (*Phys. Rev.*, vol. 70, p. 985; December 1–15, 1946.) A description of experiments using a V-2 rocket in New Mexico. Measurements were made up to 90 kilometers above sea level.

551.510.535+523.746+621.396.812 2117
Ionosphere Review—T. W. Bennington. (*Wireless World*, vol. 53, pp. 108–111; March, 1947.) A discussion of the correlation between solar activity and ionosphere effects, with predicted sunspot numbers to 1951 and details of working frequencies for radio transmission during 1947.

551.510.535:537.562 2118
On the Mean Energy of Electrons Released in the ionization of Gas.—Drukarev. (*See* 2071.)

551.593.9 2119
Altitude of Emission of the Light of the Night Sky—P. Abadie, É. Vassy and Mme. É. Vassy. (*Compt. Rend. Acad. Sci.* (Paris), vol. 218, pp. 164–166; January 24, 1944.) The results obtained at the Pic du Midi can be explained by the assumption of two thin emitting layers, one at a height of 900 to 1000 kilometers and another at 65 to 70 kilometers, the zenith emission of the lower layer being slightly the weaker. A single thin or thick layer will not explain the results.

551.594.12 2120
Ionic Equilibrium in the Lower Atmosphere—J. Gilbert. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, pp. 584–587; February 24, 1947.) Discussion of the results of various investigators shows that (a) the equilibrium relations of Gish and Sherman are applicable if account is taken, apart from Aitken nuclei, of centers not acting as condensation nuclei; (b) the number of supplementary centers at Chambon is sensibly constant (about 30,000); and (c) the number of centers at Paris is much higher in winter than in summer.

551.594.21:539.16.08 2121
On the Application of Wilson's Mechanism to Thunder-Clouds—J. Bricard. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, pp. 487–489; February 17, 1947.) The presence in the cloud of large particles and the operation of Wilson's mechanism can account for the local field increments responsible for luminous discharges.

551.594.6:523.746.5 2122
Ionospheric Fluctuations of Sudden Origin and the Eleven-Year Solar Cycle—R. Bureau. (*Compt. Rend. Acad. Sci.* (Paris), vol. 219, pp. 461–463; November 6, 1944.) Observations from 1930 to 1944 of sudden increases of the mean level of atmospherics on a wavelength of 11,000 meters, show a close connection between the frequency of their occurrence and the changes of solar activity. Both curves show the 11-year cycle, with no phase difference.

551.594.6:621.39.029 2123
Effect of Wavelength on the General Level of Atmospherics—R. Bureau. (*Compt. Rend. Acad. Sci.* (Paris), vol. 219, pp. 349–351; October 9, 1944.) Automatic recording of Atmospherics on wavelengths from 25,000 to 115 meters and observations on shorter waves (85 to 20 meters) show that the range of sources of atmospherics decreases from over 3000 kilometers for 25,000-meter waves to about 46 kilometers for 26-meter waves. Special features of the effects observed on the shorter waves are discussed and also a crevasse sometimes found in the atmospherics curve for 11,000-meter wavelength.

537.591 2124
Les Rayons Cosmiques: Les Mésotons. [Book Review]—L. Leprince-Ringuet. Editions Albin Michel, Paris, 373 pp., 330 fr. (*Rev. Sci.* (Paris), vol. 84, pp. 432–433; October 15, 1946.)

LOCATION AND AIDS TO NAVIGATION

621.396.824 2125
Lateral Deviation of Radio Waves at Sunrise—W. Ross and E. N. Bramley, (*Nature* (London), vol. 159, p. 132; January 25, 1947.) An account of observations made at Slough on the 6.05-megacycle, British Broadcasting Corporation transmitter in Cumberland during April and May, 1946; the sunrise line being then approximately along the transmission path. "The bearings immediately following the maximum usable frequency condition were usually some 10 or 20 degrees to the east of the true direction, which was afterwards gradually approached." Calculations of bearing deviation based on changes with time of the equivalent height of reflection agreed with the directional observations.

621.396.93 2126
Radio Direction-Finding—(*Electrician*, vol. 137, pp. 1213–1215; November 1, 1946.) Summaries of the following papers read before the Institution of Electrical Engineers Radio Section:—"The Use of Earth Mats to Reduce the Polarization Error of U-Type Adcock Direction-Finders," by R. L. Smith-Rose and W. Ross; "The Development and Study of a Practical Spaced-Loop Radio Direction-Finder for H.F.," by W. Ross; "Site and Path Errors," by W. Ross; "Experiments on Conducting Screens for a U-Type Spaced-Aerial Radio Direction-Finder in the Frequency Range 600–1200 Mc/s," by R. R. Pearce; and "The Location of Thunderstorms by Radio Direction-Finding," by F. Adcock and C. Clarke.

621.396.93:621.396.663 2127
The Design of Electromagnetic Radiogoniometers for Use in Medium-Frequency Direction-Finding—J. H. Moon. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 69–77; January, 1947.) An investigation into the causes of errors and an account of modifications designed to reduce them. The more important results obtained with a new and improved design are tabulated; this design is shown to be 6 decibels better in signal-to-noise ratio than any existing design and has a maximum instrumental error of less than $\pm\frac{1}{2}$ degree.

621.396.933+621.396.96 2128
Radar Navigation—(*Jour. I.E.E.* (London), part IIIA, vol. 93, no. 2, pp. 511–512; 1946.) A discussion led by H. B. Law on 1789 to 1791 and 1793 of July. Dippy and Jones: Woods and Carter.

621.396.933 2129
A Review of Radio Aids in Aviation—C. B. Bovill. (*Jour. I.E.E.* (London), vol. 6, pp. 250–272; December, 1946.) An introduction to the applications of the radio art to aeronautics, with a discussion of some of the technical and practical problems involved.

621.396.96 2130
The Maximum Range of a Radar Set—K. A. Norton and A. C. Omberg, (PROC. I.R.E., vol. 35, pp. 4–24; January, 1947.) Formulas are developed for calculating the maximum range. The parameters considered are atmospheric attenuation, transmitted power, aerial gains, transmission-line losses, noise factor of the receiver, visibility of the pulse depending on the pulse width, receiver bandwidth, pulse recurrence frequency and type of display, externally generated noise including fluctuation noise from space or the sun, and position of the aerials with respect to the ground as it affects the polar diagrams and the effective echoing area of the target. The effective area of spherical reflectors is considered in detail in terms of Fresnel zones and the derived formulas are applied to calculate the intensity of radio reflections from the moon. A table gives values of the various parameters for twenty different radar equipments together with the derived range indexes. An appendix gives formulas for the characteristics of elliptical ground-reflection Fresnel zones on a plane earth.

621.396.96:535.39 2131
Frequency Dependence of the Properties of Sea Echo—Goldstein. (*See* 2218.)

621.396.97:621.396.664]:621.392.029.64 2132
High-Speed Waveguide Switch—Bishop. (*See* 2253.)

621.396.96(71)
Radar Development in Canada—F. H. Sanders (PROC. I.R.E., vol. 35, pp. 195–200; February, 1947.) A brief survey of the visit of the Canadian group to England in 1939, of the visit of the Tizard Mission to North America in 1940, and the subsequent development and production of radar in Canada.

621.396.96 2134
Radar—What It Is [Book Review]—J. F. Rider and G. C. B. Rowe. J. F. Rider, New York, N. Y., 1946, 80 pp. $1.00. (PROC. I.R.E., vol. 35, p. 190; February, 1947.) For the average nontechnical reader.

MATERIALS AND SUBSIDIARY TECHNIQUE

535.37 2135
Decay of Zinc Sulphide Type Phosphors—H. A. Klasens and M. E. Wise. (*Nature* (London), vol. 158, pp. 483–484; October 5, 1946.) A calculation of luminescence intensities over the whole decay period. See also 1808 of 1946.

535.37 2136
On the Mechanism of the Luminescence of Phosphors—V. V. Antonov-Romanovski. (*Bull. Acad. Sci.* (U.R.S.S.), sér, phys., vol. 9, nos. 4–5, pp. 369–390; 1945. In Russian.) A critical survey of the present state of knowledge, including some of the author's results.

538.114:669.15.24 2137
Magnetoresistance and Domain Theory of Iron-Nickel Alloys—R. M. Bozorth. (*Phys. Rev.*, vol. 70, pp. 923–932; December 1–15, 1946.) Domain theory is applied to iron-nickel alloys to predict the ratio of tension to magnetic field at which the resistivity is equal to that of a normal unmagnetized alloy. The theory is accurately confirmed by measurements. The difference between the resistances measured in (a) a transverse, and (b) a longitudinal magnetic field is independent of the domain distribution in the normal state.

538.221 2138
Ferromagnetic Properties of the Compounds $MnMi_3$ and Fe_3C—C. Guillaud. (*Compt. Rend. Acad. Sci.* (Paris), vol. 219, pp. 614–616; December 13, 1944.)

538.3:539.215.2 2139
The Electrical Constants of a Material Loaded with Spherical Particles—L. Lewin (*Jour. I.E.E.* (London), part III, vol. 94, pp. 65–68; January, 1947.) A theoretical investigation of the permittivity and permeability of a mixture consisting of a homogeneous material in which particles are embedded. Air bubbles as "particles" in dielectrics and iron-dust cores are considered. The permeability may depart from unity or be complex even when none of the substances is ferromagnetic.

546.287+679.5 2140
Plastics and Silicones—(*Gen. Elec. Rev.*, vol. 50, pp. 47–48; January, 1947.) A list of new developments.

549.514.1:537.228.1 2141
A Theory of the Control of Twinning in Quartz—W. A. Wooster. (*Nature*, (London), vol. 159, pp. 94–95; January 18, 1947.) The theory accounts for the production of substantially single-crystalline specimens by the application of a torque at temperatures somewhat lower than the $\alpha-\beta$ transition point. See also 1874 of 1946.

620.2:621.396.69(213) 2142
Choice of Materials for Tropical Radio Equipment—D. F. Livingstone and J. W. Whitehead. (*Jour. I.E.E.* (London), vol. 6, pp. 172–176; September–November, 1946.) A brief guide intended to assist in the examination of materials and radio equipment to decide whether or not they are suitable for tropical use. No details of tropicalization methods or specific tropical components are included.

621.314.63:621.315.59 2143
The Thermal Energy of Rectification—H. I. Amirhanov. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 5, nos. 4–5, pp. 447–456; 1941. In Russian with English summary.) A semiconductor placed between two electrodes becomes a rectifier if the electrodes are kept at different temperatures. Experiments with Cu_2O and PbS are described and the results tabulated and curves plotted. The direction of rectification depends on whether the conductivity of the sample is of the electron or hole type. The distribution of resistivity in the barrier layer was also investigated. A theoretical interpretation of the results is given.

621.315.6:621.396 2144
New Dielectric and Insulating Materials in Radio Engineering—(*Jour. I.E.E.* (London), part III, vol. 94, pp. 58–59; January, 1947.) Summary of Institution of Electrical Engineers Radio Section discussion led by J. C. Swallow and C. P. Britton.

621.315.616.018.14 2145
A Note on the Effect of Combined Carbon Monoxide on the Power Factor of Polythene—W. Jackson and J. S. A. Forsyth. (*Jour. I.E.E.*, (London), part III, vol. 94, pp. 55–57; January, 1947.) Slight concentrations of carbon monoxide in the original ethylene gas are sufficient to cause an appreciable increase in the power factor of the polymer. Power factors of pure and impure polythene are shown graphically. For previous work see 2768 of 1945.

621.315.616.9.015.5 2146
Intrinsic Electric Strength of Polythene—W. G. Oakes. (*Nature*, (London), vol. 159, pp. 29–30; January 4, 1947.) Measurements of the direct-current electric strength support the predictions of Fröhlich's theory.

621.318.23 2147
The Design and Application of Modern Permanent Magnets—A. J. Tyrrell. (*Jour. I.E.E.* (London), vol. 6, pp. 178–213; September–November, 1946.) A short account is given of the development of permanent magnetic alloys, with a table of the properties of many commercial magnet materials. Methods of measurement of the magnetic properties and performance are discussed. Manufacturing problems, heat treatment, stabilization, and methods of magnetization are fully treated. The general principles of design are considered and detailed design procedure is given for the types of permanent magnets required in loudspeakers, meters, motors, generators, etc. The design of magnetron magnets requires special treatment and is only mentioned briefly. Applications are considered with particular reference to the use of Ticonal-G alloy, for which magnetic characteristic graphs are given.

621.318.23 2148
Discussion on the Design and Application of Modern Permanent Magnets—G. L. Hamburger. (*Jour. I.E.E.* (London), vol. 6, pp. 247–248; December, 1946.) A discussion with special reference to Tyrrell's paper (2147 above.)

621.318.323.2.042.14:621.317.331 2149
Measurement and Control of Interlaminar Resistance of Laminated Magnetic Cores—Franklin (*See* 2170.)

621.357.6 2150
Electroforming for Precision—H. R. Clauser. (*Sci. Amer.*, vol. 176, pp. 15–17; January, 1947.) The outstanding characteristics of electroforming are the extremely high surface smoothness attainable, the very close dimensional tolerances possible, and the ability to produce intricate shapes accurately.

621.357.9 2151
Electrolytic Polishing and Superfinishing—R. Mondon. (*Tech. Mod.* vol. 38, pp. 281–286; December 1–15, 1946.) Dissolving the successive surface layers makes it possible to examine their properties. Electrolytic polishing may be of considerable value in studying fatigue in metals.

621.791.353:669.018.21 2152
Metallic Joining of Light Alloys: Parts 1 and 2—(*Light Metals*, vol. 10, pp. 20–32 and 103–108; January and February, 1947.) General discussion of methods of joining thin lightweight alloys, and of the metallurgical aspects of soft-soldering. Details are given of the many different soft solders which have been suggested for aluminum. The lack of coordinated investigation and of field test results is stressed. To be continued.

621.798:621.396.694 2153
General Principles of Valve-Crate Design—R. A. L. Cole. (*Elec. Commun.*, vol. 23, pp. 320–326; September, 1946.)

669.018.58:621.318.22 2154
Formable Magnets—(*Sci. Amer.*, vol. 176, p. 36; January, 1947.) Two new magnetic alloys, Cunico and Cunife, are soft enough to be machined and can be punched or even drawn into wire, thus allowing magnets to be made of any size or shape.

669.3.019.2 2155
Micrographic Study of Copper. Detection of Inclusions, Hardening, Recrystallization and Micro-cracks—P. A. Jacquet. (*Tech. Mod.*, vol. 38, p. 280; November 15, 1946.) Summary of a paper published in *Bull. Soc. Franç. Métal.*, 1945 (first half of year). See also 648 of 1946 (Jacquet).

669.721.891+669.721.5.891. 2156
Rates of High-Temperature Oxidation of Magnesium and Magnesium Alloys—T. E. Leontis and F. N. Rhines. (*Metals Technol.*, vol. 13, tech. publ. no. 2003, 28 pp.; June, 1946. Discussion, vol. 14, tech. publ. no. 2039, pp. 7–9; January, 1947.) The linear oxidation was measured in the temperature range 412 to 575 degrees centigrade. The rate was found to vary exponentially with the absolute temperature. Alloying increases the rate of the melting point is appreciably lowered. A protective oxide film is formed at low temperatures, a nonprotective loose scale at higher temperatures. These results are explained theoretically.

669.738:620.193.23 2157
Comparison of Electro-Plated Finishes Under Humidity Tests—E. E. Halls: F. Taylor. (*Metallurgia, Manchr*, vol. 35, pp. 137–139; January, 1947.) Comment on 1485 of June, and Taylor's reply. A table is given of the comparative behavior of relatively thin electroplate coatings, with and without passivation, on soft iron, when subjected to cycles of the W. T. Board K 110 test. *Note.* Universal Decimal Classification of 1485 should read 620.193.23.

678.1.001.5(773) 2158
Rubber Laboratory—(*Sci. Amer.*, vol. 176, pp. 33; January, 1947.) A short account of research activities at the University of Illinois.

678.7:539.31:534.213 2159
Acoustic Determination of the Physical Constants of Rubber-Like Materials—A. W. Nolle. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 194–201; January, 1947.)

679.5 2160
Taking the Stress out of Styrene—C. A. Breskin. (*Sci. Amer.*, vol. 176, pp. 11–14; January, 1947.) Details of annealing processes for removing thermally or mechanically induced strains from moulded parts.

679.5:621.3 2161
The Growing Importance of Plastics in the Electrical Industry—G. Haefely. (*Beama Jour.*, vol. 54, pp. 14–19; January, 1947: *Electrician*, vol. 137, pp. 1760–1762; December 20, 1946.) Summaries of a paper presented before the Institute of Electrical Engineers Installations Section. For another account see 1122 of May.

679.5:621.365.92 2162
Pre-Heating by High-Frequency Currents Maddock.—(*See* 2196.)

678.1:62 2163
Rubber in Engineering [Book Notice]—H. M. Stationery Office, London. 10s. (*Govt. Publ.* (London), p. 14; November, 1946.) Joint publication of the Ministry of Supply, the Admiralty and the Ministry of Aircraft Production.

MATHEMATICS

518.5 2164
Machines Speed Science—(*Sci. News Let.* (Washington), vol. 51, pp. 51–52; January 25, 1947.) Discusses the operational principles of the Harvard Mark II automatic sequence-control calculator, built for use at the Naval Proving Grounds, Dahlgren, Virginia, to solve problems of guided missile flight and of bomb and shell trajectories.

518.5:621.317.733 2165
Bridge Type Electrical Computers—W. K. Ergen. (*Phys. Rev.*, vol. 71, p. 138; January 15, 1947.) Based on the Wheatstone bridge, with the resistances of three arms proportional to different quantities. Developments include a bridge used for the solution of the quartic equation of a line in bipolar co-ordinates. Summary of American Physical Society paper.

517.564.4(083.5) 2166
British Association for the Advancement of Science. Mathematical Tables. Part-Volume A: Legendre Polynomials [Book Review]—Committee for the calculation of Mathematical Tables. Cambridge University Press, Cambridge, 1946, A42 pp., 8s. 6d. (*Nature* (London), vol. 159, p. 46; January 11, 1947.) $P_n(x)$ is tabulated for integers n from 2 to 12, and for the range $x=0$ to 6 at intervals of 0.01.

518.61 2167
The Escalator Method in Engineering Vibration Problems [Book Review]—J. Morris. Chapman and Hall, London, 270 pp., 21s. (*Jour. Sci. Instr.*, vol. 24, p. 140; May, 1947.) The solution by this method of simultaneous linear equations and Lagrangian frequency equations is fully investigated, with special reference to stiffness and vibration problems. This is the comprehensive account referred to in 463 of March.

MEASUREMENTS AND TEST GEAR

621.3.087:621.38 2168
Electronic Recording Instruments—(*See* 2248.)

621.317.323.027.7:537.533.73 2169
Diffraction of Non-Monokinetic Electrons; Application to the Measurement of High Alternating Voltages—J. J. Trillat. (*Compt. Rend. Acad. Sci.* (Paris), vol. 223, pp. 322–324; August 12, 1946.) With a nonmonokinetic beam of electrons and a sinusoidal accelerating voltage, the usual spots given by a thin sheet of mica are replaced by "comets" with bright heads near the center of the diffraction pattern and tails thinning out radially, finally vanishing completely. Knowing, from X-ray measurements, the constants of the mica sheet, the radial length of the tail of a comet of known order terminating nearest the center of the diffraction pattern can be used to determine the peak value of the accelerating voltage, from about 10 to 100 kilovolts.

621.317.331:621.318.323.2.042.14 2170
Measurement and Control of Interlaminar Resistance of Laminated Magnetic Cores—R. F. Franklin. (*A.S.T.M. Bull.*, no. 144, pp. 57–61; January, 1947.) An instrument is described for testing, under simulated operating conditions, films applied to sheet steel. A number of individual multiple contacts to which voltage is applied are pressed against the insulating surface under predetermined conditions of voltage, pressure, and temperature; and the total current through the contacts is measured. The results obtained have been found more useful than those given by the present American Society for Testing Materials test; the new test has proved of great value in the study of insulating films and their application to steel sheets and punchings.

621.317.336.029.63 2171
Impedance Measurements with a Non-Tuned Lecher System—J. M. van Hofweegen. (*Phillips Tech. Rev.*, vol. 8, pp. 278–286, September, 1946.) From voltage measurements along the Lecher wires when loaded by the impedance to be measured, the reflection factor is determined. The impedance can then be calculated: a graphical method is described. Details are given of apparatus suitable for use with decimeter waves.

621.317.382.08:621.392.3 2172
A Coaxial-Type Water Load and Associated Power-Measuring Apparatus—R. C. Shaw and J. R. Kircher. (PROC. I.R.E., vol. 35, pp. 84–87; January, 1947.) Describes its design, construction and use with a thermistor bridge for measuring peak pulse powers of a megawatt at wavelengths of 10 to 40 centimeters with an accuracy of 5 to 10 per cent.

621.317.4 2173
A.C. Measurements of Magnetic Properies—H. W. Lamson. (*Communications*, vol. 27, p. 19; January, 1947.) An iron-cored inductor should be represented by a reactance ωL carrying the magnetizing current, and in parallel with a core-loss resistance R carrying the loss current, the combination being in series with a copper-loss resistance R_c carrying the full exciting current. A method is described for the study of magnetic cores which enables all necessary data to be obtained, including the hysteresis angle, which is the phase lag of the magnetizing current with reference to the exciting current. Summary of a Rochester Fall Meeting paper.

621.317.651.029.3 2174
Tachometric Audio-Frequency Meter—E. Kasner. (*Electronics*, vol. 20, pp. 121–123; February, 1947.) "Eccles-Jordan scale of two trigger circuits divide the audio input frequency and produce two-phase output for driving a synchronous motor and magnetic-drag tachometer. Frequencies from 30 to 450 cycles are indicated directly by a pointer, with 0.5 per cent accuracy."

621.317.715.5 2175
Equipment and Appliances: High-Sensitivity Mirror Galvanometer—(*Electrician*, vol. 137, p. 1202; November 1, 1946.) A low-resistance instrument with a period of 15 to 20 seconds and negligible zero creep, particularly suitable for permeability and magnetic measurements. With an 850-ohm coil, the sensitivity at 1-meter scale distance is 16,000 millimeters per microampere or 100 millimeters per microvolt.

621.317.726 2176
An Automatic-Slideback Peak Voltmeter for Measuring Pulses—C. J. Creveling and L. Mautner. (PROC. I.R.E., vol. 35, pp. 208–211; February, 1947.) Automatic slideback is provided by the amplified and rectified output from a diode in series with the pulse source. The error is less than ±6 per cent for repetition frequencies of 50 to 5000 cycles and pulse durations of ½ to 15 microseconds. An improved version has an error of less than ±2 per cent over the range 25 to 10,000 cycles.

621.317.738 2177
Finding the Inductance of R.F. Coils—R. M. Crotinger. (*QST*, vol. 31, pp. 54–56; March, 1947.) The circuit and details of a mains-operated electron-coupled oscillator having a frequency range of 2 to 16 megacycles. A grid current meter is used as an indicator.

621.317.76 2178
An Instrument for Short-Period Frequency Comparisons of Great Accuracy—H. B. Law. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 38–41; January, 1947.) Phases of the two 100-kilocycle inputs are compared in a phase discriminator, the output of which controls a trigger circuit. Trigger pulses operate an accurate chronometer which thus measures the time period between consecutive beats. Comparison of frequencies differing by 1 part in 10^6 can be made to an accuracy of 1 part in 10^{11} over the period of a single beat.

621.317.761 2179
A Frequency Meter for the 100-kc to 50-Mc Range—A. J. Zink, Jr. (*Communications*, vol. 27, pp. 10–11, 37; January, 1947.) Containing an internal calibrating oscillator using a 100-kilocycle crystal, a calibrated oscillator with tuning range from 1 to 2 megacycles in five 200-kilocycle stages, and flexible coupling for external signals.

621.317.761:621.396.621 2180
A 100-kc Frequency Standard for Receivers—J. N. Whitaker. (*Communications*, vol. 27, pp. 24, 39; February, 1947.) A small unit, with 100-kilocycle crystal oscillator in aperiodic circuit, adjustable to zero beat of harmonics with Bureau of Standards transmissions. Marker signals are obtained at 100-kilocycle intervals throughout the receiver tuning range.

621.317.79:621.396.611 2181
The Design of a Universal Automatic Circuit Tester, and Its Application to Mass-Production Testing—R. C. G. Williams, J. E. Marshal, H. G. T. Bissmire, and J. W. Crawley. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 20–26; January, 1947.) A differential tube amplifier circuit compares impedances in the unit under test with standard impedances, alternating and direct currents being used successively. Connection into the unit is made through the tube-holders. Operation is automatic and small transmitter-receivers have been tested at a rate of 20 per hour.

621.392.4.08:621.397.5:621.396.67 2182
Application of Transmission Line Measurements to Television Antenna Design. Parts 1 and 2—Hamilton and Olsen. (*See* 2262.)

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

518.5:621.317.733 2183
Bridge Type Electrical Computers—Ergen. (*See* 2165.)

534.321.9:620.179.1 2184
Supersonic Applications—M. E. Hutter. (*Elec. Times*, vol. 111, pp. 162–165; February 6, 1947.) Use of supersonic waves for flaw detection and marine depth sounding.

536.48 2185
On the Possible Use of Brownian Motion for Low Temperature Thermometry—J. B. Brown and D. K. C. MacDonald: A. W. Lawson and E. A. Long. (*Phys. Rev.*, vol. 70, pp. 976–978; December 1–15, 1946.) Criticism of 483 of March, and the authors' reply.

537.533.7 2186
Interruption of Electron Beams—Selme. (*See* 2020.)

537.533.8 2187
Simple Means of Observing Electron Images—S. Goldsztaub. (*Compt. Rend. Acad. Sci.* (Paris), vol. 219, pp. 445–446; November 6, 1944.) The X-rays emitted when electrons strike a very thin anticathode are observed either by coating it with fluorescent material or by applying photographic paper. A resolving power of the order of 0.1 millimeter is obtainable. Considerably larger images can be obtained by using Lenard window technique.

621.3:629.1.001.4 2188
Little Shakers Test Big Structures—J. Markus. (*Sci. Amer.*, vol. 176, pp. 6–10; January, 1947.) For another account see 1147 of May.

621.3.013.2:544 2186
Amplified Radio Frequencies Identify Chemical Elements—(*Sci. News Let.* (Washington), vol. 51, p. 71; February 1, 1947.) A new method developed by F. Bloch, W. W. Hansen, and M. Packard at Stanford University. Substances are rotated in a powerful magnetic field and the atomic resonance frequencies are used for identification.

621.318.572:531.76 2190
An Electronic Decimal Counter Chronometer—S. S. West (*Electronic Eng.*, vol. 19, pp. 3–6 and 58–61; January and February, 1947.) The counter uses a set of scale-of-ten units which enable time intervals to be read directly to five significant figures on a row of meters scaled from 0 to 9. Each unit comprises a scale-of-two and a scale-of-five circuit, whose operation is described in some detail, with a circuit diagram but no component values. The pulse-shaping circuit used to convert an arbitrary input signal to the waveform required by the counter consists essentially of a two-tube trigger circuit giving an output of discontinuous steps even when the input waveform is continuous. Two such trigger pairs are used in the switching circuit which introduces and cuts out a crystal-controlled 100-kilocycle oscillator at the start and finish of the time interval to be measured. The number of cycles counted in the interval is shown by the positions taken up by the meter pointers, which remain stationary until the reset push button is pressed. The tubes used are EF50 high-frequency pentodes. Considerable numbers of these chronometers have been manufactured and they have found many applications in the accurate measurement of short time intervals. A modified version provides a time-interval generator of high accuracy.

621.318.572:539.17 2191
Electronic "Stopwatch" Times Atomic Particles—(*Sci. News Let.* (Washington), vol. 51, p. 61; January 25, 1947.) Operation depends upon the synchronization of electrical counters

which serve as pulse detectors. Timing to 10^{-9} seconds is accomplished by measuring the delay inserted in order to synchronize the counters.

621.318.572:621.396.645 2192
Photo-Counters and Poisson's Law—Blanc-Lapierre. (*See* 2047.)

621.365:621.396.615.141.2 2193
High-Frequency Heating—(*Gen. Elec. Rev.*, vol. 50, pp. 25–26; January, 1947.) Development of magnetron equipment for industrial applications.

621.365.92 2194
The High-Frequency Heating of Nonconducting Materials—F. J. Jolly. (*Trans. A.S.M.E.*, vol. 69, pp. 155–162; February, 1947.) An explanation of the theoretical basis and practical limitations of high-frequency dielectric heating, and brief descriptions of its applications in various industries.

621.365.92:62 2195
High-Frequency Induction Heating—E. May. (*Engineer* (London), vol. 183, pp. 178–180; February 14, 1947.) Survey of industrial applications: melting, surface hardening, brazing, soldering, etc. About 500 kilowatt hours is needed per ton of metal melted; equipment cost is about £100 per kilowatt output; running cost about £1 per 100 kilowatt hours.

621.365.92:679.5 2196
Pre-Heating by High-Frequency Currents—A. J. Maddock. (*Elec. Commun.*, vol. 23, p. 291–296; September, 1946.) The advantages to be gained by the pre-heating of plastic preforms are discussed in relation to high-frequency heating. The effect of the physical properties of the material on equipment design is considered. The variation of heating time with specimen thickness is shown graphically for various types of phenolic thermosetting materials.

621.38.001.8:62 2197
Electronics in the Caterpillar Tractor Plant—A. A. McK. (*Electronics*, vol. 20, pp. 104–109; February, 1947.) A general description of nearly 50 different applications of electronics, used with the object of improving safety of personnel, or quality or speed of production.

621.38.001.8:621.313.2 2198
Electronic D.C. Motor—(*Gen. Elec. Rev.*, vol. 50, p. 28; January, 1947.) A power supply using sealed ignitrons gives zero to full-speed regulation by armature-voltage control, or zero to base-speed regulation by armature-voltage control with field control above base speed, for drives from 75 to 600 horsepower.

621.383.49:621.395.625.6 2199
The Use of Sulphur-Thallium Photocells in Sound Pictures—B. T. Kolomiec. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 5, nos. 4 and 5, pp. 506–509; 1941. In Russian with English summary.) Sulphur-thallium photocells can be used for the reproduction of sound. When they were tested in three Leningrad cinemas, it was found that: (a) amplifier photocascades were unnecessary, (b) the sound-reproduction apparatus was simplified and the rectifier requirements became less stringent, (c) the photocells produced no noise, and (d) the low input resistance removed the influence of electrostatic induction on the amplifier output stage. Sound reproduction was thus improved.

621.384.6:[621.392.029.64+621.396.611 2200
Cavities and Waveguides Associated with Charged Particle Accelerators—T. Kahan. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, pp. 548–549; February 24, 1947.

621.385.833 2201
"Shadow-Cast" Replicas for Use in the Electron Microscope—H. Thielsch. (*Metals Technol.*, vol. 13, tech. publ. no. 1977, 10 pp.; February, 1946. Discussion, vol. 14, tech. publ. no. 2039, pp. 1–2; January, 1947.) Transparent replicas of collodion or formvar are coated with a thin metallic film by vacuum evaporation. Manganese has been found to give excellent results. For most evaporations the angle between the replica surface and the line from filament to replica should be about 40 to 50 degrees. Numerous photographs show the results obtained.

621.385.833 2202
On the Disturbing Potential Due to Ellipticity of Electrostatic Lenses—F. Bertein. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, pp. 560–562; February 24, 1947.) A method is given for calculating the corrective potential appropriate to the ellipticity defect of the system. See 1521 of June.

621.386.1 2203
X-Ray Tube with Great Intensity and Point Focus—S. Goldsztaub. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, pp. 458–459; February 17, 1947.) The electron beam is focused by means of electronic lenses and a spot of diameter only 0.2 millimeters is obtained. With a beam current of 1 milliampere at 30 kilovolts, the brightness is of the order of 475 watts per millimeter squared.

621.386.1:539.4 2204
X-Ray Method of Measuring Poisson's Ratio—R. F. Hanstock and E. H. Lloyd. (*Engineering* (London), vol. 163, pp. 68–70; January 17, 1947.) An electron diffraction method. Some results obtained for hiduminium RR56 alloy are given.

621.386.1.032.2 2205
X-Ray Tube with Movable Anticathode—A. J. Rose. (*Compt. Rend. Acad. Sci.* (Paris), vol. 224, p. 460; February 17, 1947.) Uses a flexible metallic tube to permit displacement of the anticathode. Short exposures with high-energy beams are thus obtained.

621.386.84:620.179.1 2206
20 Million-Volt X-Ray Machine Penetrates Heavy Steel Sections—(*Materials and Methods*, vol. 25, p. 138; January, 1947.) A betatron specially designed for industrial radiography and capable of detecting flaws from $\frac{1}{32}$ to $\frac{1}{16}$-inch in diameter in forgings, welds, etc., up to 2 feet thick.

621.389:535.61–15 2207
Infra-Red Equipment for "Night" Vision—(*Engineer* (London), vol. 183, p. 170; February 14, 1947.) Brief reference to wartime applications by British Services; midget submarine attacks on the "Tirpitz," the sinking of the Bergen floating dock, identification of friendly aircraft, etc. The complete signaling equipment weighs 1½ pounds; the equivalent German "Seehund" weighs 16 pounds.

621.39.001.8:61 2208
Electromedical Equipment. Berman Locator—(*Gen. Elec. Rev.*, vol. 50, p. 37; January, 1947.) Audible signals rise in pitch as the probe approaches a metallic foreign body.

PROPAGATION OF WAVES

551.510.535+523.746+621.396.812 2209
Ionosphere Review—Bennington. (*See* 2117.)

551.594.6:523.746.5 2210
Ionospheric Fluctuations of Sudden Origin and the Eleven-Year Solar Cycle—Bureau. (*See* 2122.)

621.396.11.029.64:517.942 2211
Asymptotic Solutions for the Normal Modes in the Theory of Microwave Propagation—C. L. Pekeris. (*Jour. Appl. Phys.*, vol. 17, pp. 1108–1124; December, 1946.) Several extensions of the "W.K.B." method for the asymptotic solution of differential equations are considered, particularly in the case of solutions to the normal-mode theory of microwave propagation. An outline is given of this theory for propagation in an atmosphere with a horizontally stratified refractive index, the case of a surface duct being emphasized. In a study of "leaky modes" the "aim has been to obtain explicitly the terms after the leading one in the asymptotic expansion of the solution, in order to have an estimate of the order of magnitude of the error introduced by the use of the leading term only."

Equations are given for the first correction terms to the phase-integral solution for the characteristic values of the normal modes. An alternative asymptotic solution for the case of leaky modes, which includes first correction terms, is also given. See also 507 of March.

621.396.619.029.6 2212
Propagation of Amplitude- and Frequency-Modulated Short-Wave Oscillations—Hölzler, Gecks, and Kamphausen. (*See* 2236.)

621.396.81.029.6 2213
Very-High-Frequency and Ultra-High-Frequency Signal Ranges as Limited by Noise and Co-Channel Interference—E. W. Allen, Jr. (PROC. I.R.E., vol. 35, pp. 128–136; February, 1947. Discussion, pp. 136–152.) "Theoretical ground-wave ranges for smooth-earth and standard-atmosphere conditions are shown for frequency-modulation and television broadcast services and for mobile services for frequencies between 30 and 3000 megacycles. Practical limits of antenna size and antenna gain are discussed. The effects of external noise, terrain, and penetration of buildings are considered and their probable trends with frequency are indicated, together with the need for comprehensive data for their evaluation.

"A comparison is made between theoretical ground-wave and tropospheric ranges computed for 50 megacycles and the results of continuous field-intensity measurements made at various distances, from which it is concluded that theoretical ground-wave curves can be used as reliable measures of service ranges. Theoretical ground-wave curves are found not to be direct measures of probable ranges of tropospheric interference and it is suggested that a factor of 2 be applied to the station-separation distances obtained from such curves at 50 megacycles, with the probability of larger factors for higher frequencies.

"Two families of curves, one for sporadic-E-layer and one for F-layer transmission, showing skip distances as a function of frequency for the frequency band under consideration, are derived from the National Bureau of Standards' measurements of layer characteristics at Washington, D. C., for the purpose of estimating the occurrence of interference from one other co-channel station. The effect of increasing the number of stations is investigated, and estimates of five times the single-station interference for sporadic-E-layer and three times for F-layer interference are made.

"Combining the above factors, an estimate is made of comparative service areas at 46 and 105 megacycles for frequency-modulation broadcast stations of 1 kilowatt and 340 kilowatts effective power, and the reduction in area due to the effects of external noise, hills, and station interference by bursts and sporadic-E- and F-layer propagation."

In the discussion C. M. Jansky points out the importance of the paper in that it records the evidence on which the Federal Communications Commission decided to assign to frequency-modulation broadcasting, frequencies of about 100 instead of 50 megacycles. He quotes Dellinger who considers that ionospheric interference on both frequency bands is very small.

Armstrong considers that calculations of fields based on propagation in a standard atmosphere are inadequate as fading is not considered. He points out that interference due to sporadic-E is greater than that predicted by the author.

Carnahan and Brown also stress the serious effects of fading at points beyond the horizon.

De Mars gives graphs of theoretical signal variation with distance for different transmitting aerial heights assuming a standard atmosphere, and also of observed signal variations, and shows that the author's estimates are "not in accord with observations and measurements in any portion of the frequency band under consideration." The author's reply is given.

621.396.81.029.62 2214
Field Intensities beyond Line of Sight at 45.5 and 91 megacycles—C. W. Carnahan, N. W. Aram, and E. F. Classen, Jr. (PROC. I.R.E., vol. 35, pp. 152–159; February, 1947.) The effects of tropospheric propagation conditions on the median value of the field strength and on fading are compared for the two frequencies over a path of 76 miles.

621.396.812:523.78"1945.07.09":551.510.535 2215
Various Papers on the Solar Eclipse of July 9, 1945 and Its Effects on Propagation and the Ionosphere (*See* 2092 to 2096.)

621.396.824 2216
Lateral Deviation of Radio Waves at Sunrise—Ross and Bramley. (*See* 2125.)

621.396.945 2217
Radio-Geological Conditions for Radio Communication in Mines—V. Fritsch. (*Radio Welt*, vol. 1, pp. 39–43 and 59–64, November and December, 1946.) A discussion of the effects of different types of strata, the occurrence of faults, etc., on underground radio field strengths.

621.396.96.029.64:535.39 2218
Frequency Dependence of the Properties of Sea Echo—H. Goldstein. (*Phys. Rev.*, vol. 70, pp. 938–946; December 1–15, 1946.) Measurements were made at 9.2, 3.2, and 1.25 centimeters at grazing incidence over a wide range of sea states. The wavelength dependence of a quantity termed the "sea-echo cross section per unit area of the sea surface" was found to lie between λ^0 and λ^{-4}, and a modified drop theory is proposed which assumes the presence of drops whose diameter is of the order of λ.

RECEPTION

551.594.6:621.39.029 2219
Effect of Wavelength on the General Level of Atmospherics—Bureau. (*See* 2123.)

621.396.619.13/.14 2220
Technical Topics—N.F.M. Reception—G.G. (*QST*, vol. 31, pp. 30–32; March, 1947.) A discussion on narrow-band frequency-modulation reception in the amateur bands, pointing out some of the advantages of phase modulation.

621.396.619.13 2221
Some Investigations on Oscillations with Frequency Modulation [Thesis]—F. L. H. M. Stumpers. N. V. Philips' Gloeilampenfabrieken Research Laboratory, Eindhoven. Reprints are available. (*Philips Tech. Rev.*, vol. 8, pp. 287–288; September, 1946.) The frequency spectrum occurring with different kinds of modulation is calculated. Interference, noise, and disturbances are investigated. Distortion is calculated by Fourier analysis and the series of Carson and Fry, and by the author's alternative method. Results are compared with experiment. "A new method for determining the distortion of the measuring emitter directly from the spectrum deserves attention." Brief summary only.

621.396.62.029.6 2222
Design of Communication Receivers for the Naval Service with Particular Consideration to the Very-High-Frequency and Ultra-High-Frequency Ranges—T. McL. Davis and E. Toth. (PROC. I.R.E., vol. 35, pp. 201–207; February, 1947.) Owing to the close proximity of many transmitting and receiving aerials on a ship, mutual interference is probable. Methods of avoiding this by suitable design of the high- and intermediate-frequency stages are discussed.

621.396.621.029.62 2223
An Improved Receiver for Two Meters—C. F. Hadlock. (*QST*, vol. 31, pp. 35–40; March, 1947.) Details and circuit diagram of a superheterodyne receiver having an intermediate frequency of 10.7 megacycles and a superregenerative second detector.

621.396/.397.621.004.67 2224
The Servicing of Radio and Television Receivers—R. C. G. Williams. (*Jour. I.E.E.* (London), vol. 94, part III, pp. 11–19; January, 1947.) A comprehensive survey of the responsibilities, personnel, and equipment problems of the service organization and the interrelationship between service and design. All relevant statistics are shown graphically. See also 222 of February.

621.396.621(492)"1943/1945" 2225
Secret Production of Radio Receivers in Occupied Territory—"One out of many." (*Philips Tech. Rev.*, vol. 8, pp. 337–340; November, 1946.) An account, with photographs, of many ingenious methods of construction used in Holland.

621.396.645:621.38 2226
Shot Effect and Fluctuations at the Output of a Linear Amplifier—Blanc-Lapierre. (*See* 2048.)

621.396.822:621.317.7.089.6 2227
Factors affecting the Accuracy of Radio Noise Meters—H. E. Dinger and H. G. Paine. (PROC. I.R.E., vol. 35, pp. 75–81; January, 1947.) Experimental work is needed to make an increase in the absolute accuracy of noise measurements possible, though some of the more serious errors can be avoided by proper design, construction, calibration, and operation.

621.396.822:621.396.621 2228
Input Circuit Noise Calculations for F.M. and Television Receivers—W. J. Stolze. (*Communications*, vol. 27, pp. 12–13, 51; February, 1947.) Discusses the three factors—total noise, sensitivity, and signal-to-noise ratio—that must be taken into consideration in efficient design of the input stages of such receivers and presents formulas for calculating thermal agitation noise, shot noise, and induced grid noise. Total noise calculations are made for the grid of a frequency-modulation receiver radio-frequency amplifier stage.

621.396.822:621.396.621.029.64 2229
A Note on Noise and Conversion-Gain Measurements—W. M. Breazeale. (PROC. I.R.E., vol. 35, pp. 31–34; January, 1947.) "The development of microwave receivers, with a low-gain converter as the first stage, has made it desirable that the noise level and the conversion gain be determined independently of the following intermediate-frequency amplifier. Often this converter is a crystal with a conversion gain less than one. This paper discusses some of the general procedures that have been used to measure microwave-converter noise levels and conversion gains."

621.396.823 2230
Interference Problems Arising from Industrial Electronic and Electromedical Apparatus—(*Jour. I.E.E.* (London), part III, vol. 94, pp. 57–58; January, 1947.) Summary of Institution of Radio Engineers' Radio Section discussion led by M. R. Gavin.

621.396.823:621.327.43 2231
Radio Interference by Fluorescent Lamps—(*Light and Lighting*, vol. 40, p. 40; February, 1947.) A summary of a paper by L. F. Shorey and S. M. Gray at the recent convention of the American Illuminating Engineering Society. The authors conclude that interference can be reduced to a negligible amount by a combination of screening and filtering.

621.396.96.029.62:523.3 2232
Radio Reflection from the Moon [at 120 Mc]—Z. Bay. (*Electronics*, vol. 20, pp. 196, 198; February, 1947.) An electrochemical method of cumulation was used to distinguish the signal from noise. The equipment is being used to measure solar radiation at 2.6 meters.

STATIONS AND COMMUNICATION SYSTEMS

621.3 (494) "1945" 2233
High-Frequency, Communications, and Remote Control Engineering—(*Brown Boveri Rev.*, vol. 33, pp. 43–47; January—February, 1946.) Progress in 1945 in the design of beam and multichannel telephony and telegraphy equipment, ultra-high-frequency, frequency-modulation radio systems for the police and fire services, short-wave telephone and telegraph transmitters of 1 to 10 kilowatts, broadcasting transmitters, high-frequency heating, carrier telephone, and remote control equipments.

621.391.63 2234
Transmission with Light—R. H. Milburn. (*Radio Craft*, vol. 18, pp. 62–63, 139; January, 1947) For short-range communication a NE-30 neon tube is used as the light source, with a suitable lens system for focusing the light on the receiving photoelectric cell. Modulation of the light is effected by a 3-stage amplifier of conventional design fed from a microphone or gramophone pickup. With a simple resistance-capacitance amplifier following the photocell, good reproduction is obtained at short distances.

621.394.44:621.396.619.16 2235
The Basic Principles of Multi-Channel Transmission with Modulated Impulses—H. J. v. Baeyer. (*Brown Boveri Rev.*, vol. 33, pp. 65–69; March, 1946.) By modulating periodic pulses several channels can be "multiplexed" on the same carrier and resolved at the receiver by phase-discriminating equipment; the pulse recurrence frequency must be at least twice the highest frequency in the intelligence to be communicated.

621.396.619.029.6 2236
Propagation of Amplitude- and Frequency-Modulated Short-Wave Oscillations—E. Hölzler, F. H. Gecks, and G. Kamphausen. (*Elektrotech. Zeit.*, vol. 65, pp. 133–138; April 20, 1944.) Single sideband transmission with carrier suppression, as used between Berlin and New York, reduces very considerably the distortion and signal variations often found in short-wave communication. The use of frequency-modulation for further noise reduction introduces new disturbances whose origin is explained by multipath transmission. The technical aspects of such effects are discussed. Results with model equipment indicate the possibility of evaluating directly the disturbing effect of neighboring transmitters.

621.396.619.13 2237
Frequency Modulation—K. R. Sturley. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 84–88; January, 1947.) Discussion of 4047 of 1945.

621.396.619.13 2238
Frequency-Modulation in Broadcasting—(*Nature* (London), vol. 159, pp. 15–16; Janu-

ary 4, 1947.) Summary of 3751 of January (Kirke).

621.396.619.13 2239
A New System of Frequency Modulation—R. Adler. (Proc. I.R.E., vol. 35, pp. 25–31; January, 1947.) Describes the development of the phasitron modulator in which a radial electron stream in a concentric structure is shaped into a wavelike pattern which progresses continuously around the cathode. The axial-modulating magnetic field curves the paths of the electrons in the plane of rotation so that the streams of electrons reaching the segmented anode are advanced or retarded according to the magnetic field. The faults of early models and the steps taken to correct them are analyzed.

621.396.619.13 2240
Some Investigations on Oscillations with Frequency Modulation (Thesis)—Stumpers. (*See* 2221.)

621.396.619.13:621.396.712 2241
B.B.C. and F.M.—(*Wireless World*, vol. 53, p. 95; March, 1947.) The British Broadcasting Corporation has invited tenders for a frequency-modulation transmitter for experimental transmissions; such transmissions are at present being radiated each evening from 6 P.M. to midnight on 90.3 megacycles from the Alexandra Palace.

621.396.65 2242
Two Multichannel Microwave Relay Equipments for the United States Army Communication Network—R. E. Lacy. (Proc. I.R.E., vol. 35, pp. 65–70; January, 1947.) Sets AN/TRC-5 and AN/TRC-6 use pulse-position modulation of 1-microsecond pulses giving 8 channels with a pulse rate of 8000 pulses per second. Audio performance and radiation characteristics are given.

621.396.65 Vanguard 2243
Radio Facilities in H.M.S. Vanguard—(*Elec. Times*, vol. 111, p. 151; January 30, 1947.) A long-range duplex transmitter, Type DS10, provides continuous waves and telephone channels for two-way communications with Great Britain and South Africa. For another account see *Electrician*, vol. 138, pp. 346–347; January 31, 1947.

621.396.72 2244
Planning and Constructing a 1-kw Studio-Transmitter Building—H. G. Stephenson, Jr. (*Communications*, vol. 27, pp. 9–11, 51; February, 1947.) Details of a station erected at Centralia, Illinois, including studios isolated from external noise, with baffles in the forced ventilating system, soundproof teletype room, etc.

621.396.72.029.62 2245
H.F. A.M. Broadcasting for Small Communities—S. Tarzian, A. Valdettaro, and M. Weigel. (*Communications*, vol. 27, p. 27; January, 1947.) A report of results obtained in hilly limestone country around Bloomington, Indiana. The aerial consisted of 8 coaxial units mounted vertically and hanging from the top of a 200-foot tower. With a radiated power of 200 watts on a frequency of 87.75 megacycles, field strengths of 120 microvolt per meter have been measured at a point 21 miles from the transmitter. The advantages of such systems for local broadcasting are stated. Summary of a Rochester Fall Meeting paper.

621.396.931 2246
The Development of Police Communications—S. C. Austin. (*Proc. I.R.E.* (Australia), vol. 8, pp. 4–12; January, 1947.) A comprehensive account of methods of radio communication from early to present day systems, as used in Australia. The general communications networks of the chief cities are described, with more detailed accounts of the mobile equipment for patrol cars, launches, motor cycles, and for personal use; descriptions and photographs of the equipment are given and the frequencies used are stated. Early types were continuous-wave only, but this has been superseded by telephony. The chief difficulties encountered, such as the elimination of frequency drift, and the methods used to overcome them, are described. Initial frequency-modulation experiments on very-high frequency are mentioned.

621.396.931.029.6 2247
V.H.F. Space Radio Train Communication—L. G. Sands. (*Teleg. Teleph. Age*, vol. 65, pp. 10, 12, 31; February, 1947.) Frequency bands of 158 to 162 and 186 to 216 megacycles are used. Experiments have been carried out with frequencies near 2600 megacycles. Train-to-train range varies between 4 and 12 miles and station-to-train range between 10 and 30 miles, the transmitter power being about 10 watts.

SUBSIDIARY APPARATUS

621.3.087:621.38 2248
Electronic Recording Instruments—(*Elec. Eng.*, vol. 66, pp. 36–44; January, 1947.) Summary of the following talks given at a session of the 1946 American Institute of Electrical Engineers Summer Convention in Detroit devoted to electronic recording instruments for potentiometric and bridge-type measurements: "A Brief History [of Electronic Recording Instruments]," by W. R. Clark; "Electronically Operated Instruments for Industrial Measurements," by A. J. Hornfeck; "D.C. to A.C. Conversion Systems," by W. P. Wills; "The Input Transformer Problem," by A. J. Williams, Jr. "A New High-Speed Recording Potentiometer," by V. L. Parsegian; and "Sweep-Balance Recorders," by G. Keinath and R. K. Hellmann.

621.316.53.029.5/.6 2249
A Design of Heavy-Current Contact, Particularly for Radio-Frequency Use—A. J. Maddock. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 52–54; January, 1947.) A high-pressure, small-area type, capable of carrying 75 amperes at 20 megacycles and 150 amperes at power frequencies.

621.316.546.032.43:621.317.329 2250
Potential Distribution at the Igniter of a Relay Valve with Mercury Cathode—N. Warmoltz. (*Philips Tech. Rev.*, vol. 8, pp. 346–352; November, 1946.) Curves are given showing the field strength at the mercury surface for different thicknesses of the igniter wall. The measurements were made of a 100-to-1 scale-model. The mechanism of the ignition is discussed.

621.317.79.087.6 2251
New Statistical Recorders of Electromagnetic Variations—F. Carbenay. (*Compt. Rend. Acad. Sci.* (Paris), vol. 219, pp. 443–445; November 6, 1944.) Pen recorders based on the method of multiple time constants previously noted (1336 of 1942). Three identical elements are generally included for recording either on three wavelengths or for three components of an electromagnetic field. Each element comprises a coil suspended by a steel wire in the air-gap of a magnet, with oil damping. Such an arrangement has a principal time constant τ and a much smaller secondary constant τ_1, which is equal to the ratio of the moment of inertia of the system to the damping coefficient. If T is the period of natural oscillations, $T=2\pi\sqrt{\tau\tau_1}$. A sensitivity of 1 millimeter per microampere can be obtained with a restoring couple of $0.6+10^6$ centimeter gram second units per radian, a coil resistance of 15,500 ohms, magnet flux 1.14×10^{10} maxwells and natural period 17 seconds.

621.394.324:629.135 2252
Airborne Teletype Printer—R. A. Vanderlippe. (*Telegr. Teleph. Age*, vol. 65, pp. 6–8; February, 1947.) Model 31, weight 35 pounds, can be used in any two-way voice installation. Operation of the keyboard modulates a radio-frequency signal at a frequency between 1615 and 1275 cycles. Some of the energy is fed back into the receiver giving a local copy of the message. On reception the signal is passed through a band-pass filter and an amplitude limiting circuit to a frequency discriminator yielding a positive voltage for marking and a negative voltage for spacing.

621.396.664:621.396.96]:621.392.029.64 2253
High-Speed Waveguide Switch—D. K. Bishop. (*Wireless Eng.*, vol. 24, pp. 67–70; March, 1947.) Alternate radio-frequency pulses are switched at a rate of 500 per second into the two aerials of a radar installation. Thee switch consists of a T-junction in a rectangular wave guide transmitting the H_{10} mode, the side arms being closed alternately by vanes on two disks rotated in synchronism with the pulses. The effective open time of the switch 1550 microseconds, is long enough to receive reflected pulses from targets at ranges up to 150 miles. The switch operates on wavelengths of 9.8 to 10.2 centimeters and will handle a peak power of 500 kilowatts.

621.396.665.029.64 2254
An Attenuator of "S"-Band Energy—H. R. Meahl. (Proc. I.R.E., vol. 35, pp. 211–213; February, 1947.) A 4-inch length of concentric line has, in its inner conductor, a 1-inch gap which can be partly bridged by a hollow metal cylinder sliding on the inner conductor. The gap acts as a wave guide whose dimensions can be varied to give attenuations from 6 to 50 decibels.

621.396.682:621.314.634 2255
Voltage Multiplier Circuits with Selenium Rectifiers—E. W. Chadwick. (*Communications*, vol. 27, p. 14; January, 1947.) Selenium rectifiers have a lower impedance than corresponding tubes in a high-voltage supply unit and may be used with larger capacitors, thus giving better regulation. Voltage doubler and tripler circuits permit television sets to be run from a 115-volt mains supply without a mains transformer.

TELEVISION AND PHOTOTELEGRAPHY

621.396/.397].621.004.67 2256
The Servicing of Radio and Television Receivers—Williams. (*See* 2224.)

621.397 2257
The Development of Photo-Telegraphy—W. C. Lister. (*Electronic Eng.*, vol. 19, pp. 37–43; February, 1947.) Apparatus of historical interest is briefly described with illustrations. Transmitting and receiving processes used in various workable systems are compared, and possible methods of synchronization are discussed.

621.397 2258
New Phototelegraph Equipment: Part 1—A Picture System for the Press—(*Electronic Eng.*, vol. 19, pp. 46–48; February, 1947.) A Muirhead-Jarvis equipment, including the mechanical design of the scanning and optical systems and the electrical arrangements for synchronization and phasing. Selection of scanning rate and drum speed gives a choice of time of transmission and quality of reproduction for a given picture size.

621.397 2259
New Phototelegraph Equipment: Part 2—Cable and Wireless Facsimile Equipment—(*Electronic Eng.*, vol. 19, pp. 49–50; February, 1947.) A brief description of a crystal-controlled system using frequency modulation of an audio-frequency subcarrier. The terminal

equipment is designed for alternative reception or transmission. Details of the scanning mechanism and the optical system are given. Transmission may be over any line or radio-telephone channel.

621.397.26 Vanguard 2260
Picture Transmission by Radio—(*Elec. Times*, vol. 111, p. 145; January 30, 1947.) Apparatus installed in *H.M.S. Vanguard* and working with the ship's transmitter. A constant-speed motor drives the drum carrying the picture and the traversing head gives a 135 lines per inch scan. For another account see *Electrician*, vol. 138, pp. 346–347; January 31, 1947.

621.397.335 2261
Television Synchronizing—W. T. Cocking. (*Wireless World*, vol. 53, pp. 90–94; March, 1947.) A survey of some of the problems, with a detailed discussion of the action of a slicer, or double limiter, circuit to minimize the effect of pulling on whites.

621.397.5:621.392.4.08:621.396.67 2262
Application of Transmission Line Measurements to Television Antenna Design: Parts 1 and 2—G. E. Hamilton and R. K. Olsen. (*Communications*, vol. 27, pp. 8–9, 36 and 32, 40; January and February, 1947.) The first two of a series of papers. Analysis is given for the case of a transmission line terminated by a complex impedance, with particular reference to standing-wave ratio, angular position of voltage maximum and minimum, and the surge impedance of the line. Actual measurement techniques are described, with practical details.

621.397.5:621.396.619.16 2263
Transmission of Television Sound on the Picture Carrier—G. L. Fredendall, K. Schlesinger, and A. C. Schroeder. (Proc. I.R.E., vol. 35, p. 46; January, 1947.) Discussion by E. R. Kretzmer of 1382 of 1946, analyzing pulse-width modulation when the time shift of a pulse edge varies as the instantaneous modulating signal at the instant at which the pulse edge actually occurs.

621.397.5:778.5 2264
Television and the Motion Picture Theater—L. B. Isaac. (*Jour. Soc. Mot. Pic. Eng.*, vol. 47, pp. 482–486; December, 1946.) A discussion, from the exhibitors' standpoint, of the various problems involved.

621.397.5(44) 2265
Television in France—A. Ory. (*Wireless Eng.*, vol. 24, p. 93; March, 1947.) Correction of a statement in an article abstracted in 270 of February to the effect that the equipment of the R.D.F. television studio is all of German manufacture. This statement is erroneous, as the whole of the equipment was both designed and manufactured in France.

621.397.5(71) 2266
Television and F.M. Plans for Canada—G. W. Olive. (*Communications*, vol. 27, pp. 20–21; January, 1947.) Discussion of problems and future possibilities.

621.397.6 2267
Some Special Tubes used in Television—(*Télév. Franç.*, no. 10, pp. 12–13; February, 1946.) Diagrams and brief descriptions of principal characteristics.

621.397.62 2268
Television Receiving Equipment [Book Review]—Iliffe and Sons, London, second edition, 354 pp., 12s 6d. (*Wireless World*, vol. 53, p. 89; March, 1947.) Brought up to date, with many chapters rewritten and some additional material.

TRANSMISSION

534.78 2269
More on Speech Clipping—Smith. (*See* 1981.)

621.317.761:621.396.61 2270
The BC-221 Frequency Meter as a V.F.O.—H. W. Johnson. (*QST*, vol. 31, pp. 43–47; March, 1947.) Details of its adaptation without impairing its use as a frequency meter. See also 3099 of 1946.

621.396.61.029.62 2271
Low-Cost Six-Meter 'Phone—C. V. Chambers. (*QST*, vol. 31, pp. 13–17; March, 1947.) A description and circuit diagram of a 15-watt 50-megacycle transmitter. The second harmonic of a 25-megacycle crystal is obtained from a triode-tetrode oscillator with sufficient output to drive directly a low-power amplifier.

621.396.615.142 2272
Current and Power in Velocity-Modulation Tubes—L. J. Black and P. L. Morton. (Proc. I.R.E., vol. 35, p. 43; January, 1947. Discussion by P. J. Wallis and S. G. Tomlin of 3843 of 1944.

621.396.619.13/.14 2273
Development of the Cascade Phase Shift Modulator [for F.M. Transmitters]—(*Radio*, vol. 31, pp. 11–15; January, 1947.) Distortion in phase-shift modulators may occur as nonlinearity of phase modulation or as the result of amplitude modulation of the signal. The paper describes in detail a circuit employing a 100-kilocycle crystal oscillator and six pentode-triode resistance controlled modulators.

621.396.619.14 2274
Wide-Angle Phase Modulator—H. K. Bradford. (*Electronics*, vol. 20, pp. 100–103; February, 1947.) "Technique for phase modulating a crystal-controlled carrier, whereby two components of fixed phase difference are amplitude modulated and added to give the output, is described. Circuit can be used to give frequency modulation, or modified to give amplitude modulation."

621.396.619.231.029.62 2275
Investigations on Suppressor Grid Modulation at Ultra-High Frequency—S. K. Chatterjee. (*Electrotech.*, no. 19, pp. 41–51; December, 1946.) An experimental investigation at 40 megacycles. Main results are high over-all efficiency (20 per cent) and good linearity of the modulation characteristic.

VACUUM TUBES AND THERMIONICS

621.314.632:546.289 2276
Properties of Welded Contact Germanium Rectifiers—H. Q. North. (*Jour. Appl. Phys.*, vol. 17, pp. 912–923; November, 1946.) Construction and tests of these rectifiers are described. Welded contact has advantages of mechanical stability, very-low-forward and high-backward resistance, low contact capacity at zero bias, logarithmic direct-current characteristic over wide current range, and high harmonic power output as microwave generator. Loss- and noise-ratio measurements are also described.

621.316.722.1:621.384.5 2277
A Voltage Stabilizing Tube for Very Constant Voltage—T. Jurriaanse. (*Philips Tech. Rev.*, vol. 8, pp. 272–277; September, 1946.) By using a carefully prepared molybdenum cathode and depositing a thick layer of molybdenum on the tube walls by cathode sputtering, the stabilized voltage varies by not more than a few volts for different samples of the same type and the variation with time is not more than ½ volt per 1000 working hours. Ambient temperature, also, has little effect on the working voltage.

621.383 2278
Elimination of the Residual Current in Photoelectric Cells—A. Lallemand. (*Compt. Rend. Acad. Sci.* (Paris), vol. 223, pp. 856–857; November 18, 1946.) Difficulties due to residual current can be very considerably reduced by using only a small portion of the cathode, with electrostatic or magnetic lenses between it and the corresponding portion of the anode, which can be pierced and provided with a small collecting disk behind the hole. A 5-stage multiplier on this principle has been constructed, with magnetic lenses forming an electronic image of the photocathode successively on each multiplier, the residual current from the small collecting electrode being 80 times less than from the guard electrode. With this device it has been possible to show that the light reflected or diffused by a photoelectric layer is by no means negligible, and also to measure the gain realized by giving the photosensitive layer in an ordinary cell the form of a black body.

621.383:537.533.8 2279
Application of Secondary Emission of Electrons to Multiplier Tubes—A. Lallemand. (*Rev. Sci.* (Paris), vol. 84, pp. 131–136; August, 1946.) A review of the phenomena of secondary emission from pure metals, alloys, and complex layers, and their practical use in electron multipliers.

621.383.42 2280
Parallel Operation on Several Barrier-Layer Selenium Photocells—M. Delattre. (*Comp. Rend. Acad. Sci.* (Paris), vol. 218, pp. 112–113; January 17, 1944.)

621.383.42:535.215.4 2281
Investigation of Uniformity of Sensitivity Distribution over the Surface of Selenium Photocells—I. A. Vladimirov. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 5, nos. 4–5, pp. 499–502; 1941. In Russian with English summary.) Apparatus is described for recording this sensitivity distribution.

621.383.42:535.215.6 2282
On the Gaseous Nature of the Non-Conducting Layer in Selenium Photocells—D. I. Arkadiev. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 5, nos. 4–5, pp. 503–505; 1941. In Russian with English summary.) If a selenium rectifier photocell is placed in a high vacuum, the only way in which its electrical and photoelectric properties can be changed is by the formation of selenium amalgam when the mercury vapor is not completely frozen out. Previous suggestions that the rectifier layer consists of adsorbed gaseous molecules or other volatile compounds are not supported by these experiments.

621.383.5:620.196 2283
The Influence of Impurities on the Rectifier Photo Effect of Cuprous Oxide—V. E. Laskarev and K. M. Kosonogova. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 5, nos. 4–5, pp. 478–493; 1941. In Russian with English summary.) If cuprous oxide cells are prepared by reduction during tempering in salt solutions (of Li, Na, K, Be, Zn, Pb, U) an extra maximum occurs in the red and infrared region of the spectrum (0.75 to 1 micron). The position of the maximum is determined by the content of the metallic impurities introduced and is the same for all the above metals. For large impurity contents the principal maximum at wavelengths = 0.54 micron disappears. The introduction of impurities causes an abrupt increase in the absorption by cuprous oxide in the red region of the spectrum; it has a marked effect on the dissociation work of the barrier layer. A thermoprobe method reveals, in Cu_2O photocells, the existence, between the upper electrode and the barrier layer, of a layer of oxide which has electronic conductivity. Analysis of the results suggests a new structural scheme for Cu_2O cells. The stability of these cells when temperature varies is increased if impurities are introduced. For relatively large amounts of impurity this stability is of the order of fifty times that for photocells prepared by cathode sputtering. All the observed

phenomena can be explained on the assumption that the electropositive impurities result in localized levels whose height is greater than that of the oxygen levels in Cu_2O.

621.385.029.63/.64 2284
Theory of the Beam-Type Travelling-Wave Tube—J. R. Pierce. (Proc. I.R.E., vol. 35, pp. 111–123; February, 1947.) The theory is developed assuming small signals. The equations predict three forward waves, one increasing and two attenuated, and one backward wave which is little affected by the electron beam. The dependence of the wave propagation coefficients on voltage, current, circuit loss, and other properties of the transmission mode, together with expressions for gain, noise, and power are given and illustrated graphically. Appendixes deal with (a) the field in a uniform transmission system due to impressed current (such as an electron stream) in terms of the parameters of the transmission modes, and (b) wave propagation along a helix.

621.385.029.63/.64 2285
Traveling-Wave Tubes—J. R. Pierce and L. M. Field. (Proc. I.R.E., vol. 35, pp. 108–111; February, 1947.) Describes a tube with a gain of 23 decibels at 3700 megacycles and power output of 0.2 watt. The bandwidth between the 3 decibel points is 800 megacycles. A qualitative account of its operation is included; for theory see 2284 above.

621.395.029.63/.64:621.396.615.14 2286
The Traveling-Wave Tube as Amplifier at Microwaves—R. Kompfner. (Proc. I.R.E., vol. 35, pp. 124–127; February, 1947.) The inner conductor of a concentric line consists of a wire helix such that the velocity of propagation is about one-tenth of the velocity of light. If an electron beam of voltage of the order of 2500 and about the same velocity as that of the traveling field is shot along the axis of the helix, the line acts as an amplifier of radio-frequency power passing along it. A description of the early development of these tubes in England and expressions for power gain and noise factor are given.

621.385.1 2287
Time Constant of the Ignition of the Discharge in Rarefied Gases—J. Moussiegt. (*Compt. Rend. Acad. Sci.* (Paris), vol. 223, pp. 659–661; October 28, 1946.) A simple theory is given, with formulas, in general agreement with the results previously reported (940 and 941 of April) for the effect of various factors on the value of the current maximum for intermittent gas discharges.

621.385.1.029.62/.63+621.396.6 2288
Radar Vacuum-Tube Developments—J. J. Glauber. (*Elec. Commun.*, vol. 23, pp. 306–319; September, 1946.) The development, and factors influencing the design, of high-power transmitting triodes for pulsed- and continuous-wave operation in the 200 to 600 megacycle band are discussed. Brief details of air-cooled tubes suitable for pulsed operation are given below: L200: operating frequency 200 megacycles; power output per pair 150 kilowatts (duty cycle 0.01); directly heated thoriated tungsten cathode; squirrel-cage type grid connecting to a ring seal; re-entrant anode. L400: operating frequency 400 megacycles; generally similar to L200 but shorter anode. L600E: operating frequency 600 megacycles; power output 25 kilowatts. 8C22: operating frequency 400 megacycles; directly heated cathode specially arranged to reduce electromechanical force between adjacent elements thereof; filament power 1.35 kilowatts; power output 500 kilowatts. 6C23: operating frequency 600 megacycles; power output 600 kilowatts; indirectly heated cathode requiring lower filament power input than 8C22.

Brief details of tubes suitable for continuous-wave operation are given below: 6C22: directly-heated water cooled tube, having smaller grid-to-filament spacing than L600E and larger filament area; output power 250 watts as an oscillator at 600 megacycles and 500 watts as an amplifier with a driving power of 100 watts. L600NR: air-cooled version of 6C22. 8C23: an improved tube developed from 8C22, having modified grid structure and reduced anode diameter. Incomplete tests using forced air cooling indicate a power output of 500 watts at 400 megacycles with an anode dissipation of 1 kilowatt: with water cooling, power outputs of 2.7 kilowatts and 1 kilowatt (anode dissipation 5 kilowatts) are anticipated at 400 and 600 megacycles, respectively. 6C23: early tests on this tube under continuous-wave operating conditions are described.

621.385.1.032.216 2289
Periodic Variations of Anode Current in Vacuum Tubes with Oxide Cathodes—R. Champeix. (*Compt. Rend. Acad. Sci.* (Paris), vol. 223, pp. 786–788; November 13, 1946.) The anode current in some of these tubes varies periodically, the periods observed ranging from 15 minutes to 4 hours. In some cases the current curves are approximately sinusoidal, but more frequently the maxima, which may be three times the minima, are sharply peaked. The effect is observed much more often with low than with high cathode temperatures and appears to be related to modifications of the cathode saturation current. See also 3810 of January.

621.396.615.142 2290
Transit-Time Effects in Ultra-High-Frequency Class-C Operation—W. G. Dow. (Proc. I.R.E., vol. 35, pp. 35–42; January, 1947.) "Effects discussed are electron-transit reactance; electron-transit phase-delay angle; cathode back-heating; use of a screen grid to improve efficiency; changes in optimum shunt impedance; secondary emission; and anode back-heating by secondary electrons. It is pointed out that by increasing voltage and current density, simultaneously, the frequency and power can be raised without sacrificing efficiency or bandwidth. An equivalent circuit is described which takes account of certain important transit-time effects."

621.396.615.142 2291
A Wide-Tuning-Range Microwave Oscillator Tube—J. W. Clark and A. L. Samuel. (Proc. I.R.E., vol. 35, pp. 81–83; January, 1947.) Describes the design of the 2K48 reflex velocity-modulation tube and its associated cavity resonators tuning from 3000 to 6000 megacycles and 5000 to 10,000 megacycles, respectively.

621.396.615.142 2292
Current and Power in Velocity-Modulation Tubes—Black and Morton. (*See* 2272.)

621.397.6 2293
Some Special Tubes used in Television—(*Télév. Franç.*, no. 10, pp. 12–13; February, 1946.) Diagrams and brief descriptions of principal characteristics.

MISCELLANEOUS

001.4:621.38 2294
Is "Electronics" Overworked?—"Cathode Ray." (*Wireless World*, vol. 53, pp. 43–45; February, 1947.)

061.31 2295
British Commonwealth Scientific Official Conference, London, 1946. Report of Proceedings [Book Review]—H. M. Stationery Office, London, 73 pp., 1s. 3d. Terms of reference: "To consider the best means of ensuring the fullest possible collaboration between Civil Government Scientific Organizations of the Commonwealth and to make formal recommendations for the approval of the Governments represented."

061.6 2296
20th Annual Report of the Council of the [British] Institution [of Radio Engineers]—(*Jour. Brit. I.R.E.*, vol. 6, pp. 130–142; July–August, 1946.)

061.6:[526+55] "1946.0729/.08.2" 2297
Summary Report on the Extraordinary General Assembly of the International Union of Geodesy and Geophysics (IUGG), Cambridge, England, July 29 to August 2, 1946—J. M. Staff. (*Terr. Mag. Atmo. Elec.*, vol. 51, pp. 509–515; December, 1946.)

371.3.621.3 2298
I.E.E. and Further Education Grants—(*Electrician*, vol. 137, p. 1292; November 8, 1946.) The Ministry of Labour scheme enables university or Institution of Electrical Engineers graduates, whose war service has prevented completion of practical training, to take a specially designed course.

371.3:621.3 2299
E. R. A. Apprenticeships—(*Elec. Rev.* (London), vol. 140, p. 342; March 7, 1947.) This scheme, involving attendance at college for one or two days each week, while not a substitute for full-time university training, makes a useful contribution to the training of electrical engineers.

384:654.196(73) 2300
U. S. Radio Statistics, 1947—(*Tele-Tech.*, vol. 6, p. 59; January, 1947.) A table of output of broadcast receiving sets from 1922 to 1946, and of economic statistics for 1946.

519.283:62 2301
Engineering and Quality Control—P. L. Alger. (*Elec. Eng.*, vol. 66, pp. 16–19; January, 1947.) Describes a systematic procedure for taking samples, measuring them, and plotting the results on charts so that variations of importance can be noted before they become serious. The fundamental laws of chance on which this procedure is based are briefly discussed. See also 2421 of 1946.

621.38(083.72) 2302
"Tron"—(*Toute la Radio*, vol. 14, p. 43; January, 1947.) Short definitions of 30 of the "tron" family, many of which are simply trade names.

621.396.621.004.67 2303
Manual of Radio Practice for Servicemen [Book Review]—E. G. Beard. Philips Electrical Industries of Australia, Sydney, 496 pp. (Proc. I.R.E. (Australia), vol. 7, p. 33; November, 1946.) A comprehensive treatment which should prove useful both to the serviceman and the radio engineer.

621.396.97:06.013 2304
Broadcasting. Copy of the License and Agreement Between His Majesty's Postmaster General and the British Broadcasting Corporation, November 29, 1946. [Book Notice]—H.M. Stationery Office, London, 3d. (*Govt. Publ.* (London), p. 6, December, 1946.)

621.396.97:06.013 2305
Broadcasting. Draft of Royal Charter for the Continuance of the British Broadcasting Corporation for which the Postmaster General Proposes to Apply [Book Notice]—H.M. Stationery Office, London, 2d. (*Govt. Publ.* (London), p. 6; December, 1946.)

SECTION MEETINGS

Baltimore

"Radio Heating in Industry," by C. P. Bernhardt, Westinghouse Electric Corporation; April 22, 1947.

"A New Microwave Communication System," by C. Bath and H. Goldberg, Bendix Radio Division; May 27, 1947.

Boston

"Sofar," by W. F. Saars, United States Navy; May 22, 1947.

Election of officers; May 22, 1947.

Buffalo-Niagara

"Micro-Micro Wave Radar," by M. G. Nicholson, Jr., Colonial Radio Corporation; May 21, 1947.

Election of officers; May 22, 1947.

Cedar Rapids

"Importance of Stylus and Groove Fit in Record Reproduction," by D. A. Andrews, Radio Corporation of America; May 7, 1947.

Cincinnati

Spring Technical Conference; May 3, 1947.

Chicago

"Interconnecting Facilities for Television Broadcasting," by W. E. Bloecker, American Telephone and Telegraph Company; May 16, 1947.

Election of Officers; May 16, 1947.

Cleveland

"Mathless Microwaves," by P. Nelson, University of Florida; May 22, 1947.

Election of Officers; May 22, 1947.

Columbus

"Helical Antennas," by J. D. Kraus, Ohio State University; May 16, 1947.

"Dielectric Antennas," by G. E. Miller, Ohio State University; May 16, 1947.

Election of Officers; June 18, 1947.

Dallas-Fort Worth

"Electronics as Applied to Industrial Instruments," by T. C. Dudley, Foxboro Company; May 8, 1947.

"Western Electric Company F.M. Broadcast Transmitters," by J. B. Bishop, Bell Telephone Laboratories; May 22, 1947.

Dayton

"Instruments for the Detection of Nuclear Radiations," by J. Heyd, Monsanto Chemical Company; May 8, 1947.

Election of Officers; May 8, 1947.

Emporium

"New Research Facilities in the Engineering School at Penn State," by E. Walker, Pennsylvania State University; May 9, 1947.

Houston

"Recent Trends in Vacuum-Tube Design and Manufacture," by C. E. Atkins, Tungsol Lamp Works, Inc.; May 29, 1947.

Election of Officers; May 29, 1947.

London (Ontario)

"Cathode-Ray Oscillography," by R. Wilton, Bach-Simpson Limited; May 23, 1947.

Election of Officers; May 23, 1947.

Los Angeles

"Radar in War and Peace," by L. A. DuBridge, California Institute of Technology; May 20, 1947.

SECTION MEETINGS

Montreal

"Theory of F.M. Broadcast Antennas," by G. Glinski, Northern Electric Company, Ltd.; May 28, 1947.

"Premodulation Speech Clipping," by W. W. H Dean, Radio Corporation of America Victor Company, Ltd.; May 28, 1947.

Election of Officers; May 28, 1947.

New York

"Television Receivers," by A. Wright and E. Clark, Radio Corporation of America; April 2, 1947.

"New Techniques in Television Synchronizing Signal Generators," by E. Schoenfeld, Industry Service Laboratory; May 7, 1947.

"Instrumentation for Television Receiver Development," by W. F. Bailey, Hazeltine Electronics Corporation; May 7, 1947.

Election of Officers; June 4, 1947.

Pittsburgh

"Color Television," by D. Balthis, Westinghouse Radio Division; March 10, 1947.

"The University of Pittsburgh Cyclotron," by A. J. Allan, University of Pittsburgh; April 14, 1947.

Election of Officers; June 9, 1947.

Portland

"The Lanac System of Air Control and Navigation," by E. E. Harper, Hazeltine Electronics Corporation; May 22, 1947.

"The Work of the Bell Telephone Laboratories," by M. J. Kelly, Bell Telephone Laboratories; May 27, 1947.

"Some Practical Applications of Slotted Line Measurements," by R. R. Ehiger, KGW-FM; June 5, 1947.

Rochester

"The Mobile Radio Telephone System," by D. S. Dewire, New York Telephone Company; May 15, 1947.

Election of Officers; May 15, 1947.

Sacramento

"Magnetic Tape Recording," by N. D. Webster, McClatchy Broadcasting Company; May 20, 1947.

Election of Officers; May 20, 1947.

St. Louis

"Train Communication Systems," by I. E. Verbarg, The Missouri Pacific Railroad Company; May 22, 1947.

Election of Officers; May 22, 1947.

San Diego

"Split Anode Magnetrons," by J. L. Bowers, Consolidated-Vultee Aircraft Corporation; May 6, 1947.

"The Design of Glass-B Amplifiers," by D. C. Kalbfell, Kalbfell Laboratories; May 16, 1947.

"Application of Carrier-Type Communication to Power Lines," by W. U. Dent; June 3, 1947.

Seattle

"Tracking Submarines With Sonar," by C. K. Stedman, Boeing Aircraft Company" April 18, 1947.

"Principles of Servomechanisms," by G. L. Hoard, University of Washington; May 9, 1947.

Toronto

"Facsimile," by F. A. Hester, Radio Inventions Inc.; May 19, 1947.

Twin Cities

"Design Considerations of a Pulse Time Modulation Multichannel Telephone System," by A. M. Levine, Federal Telecommunication Laboratories; March 11, 1947.

(Continued on page 36A)

SECTION MEETINGS

(Continued from page 35A)

"Loudspeaker Design Considerations," by M. R. Jones, Cinaudagraph Speakers, Inc., April 16, 1947.

Election of Officers; July 1, 1947.

WASHINGTON

"A Consideration of the Factors Affecting the Design of Turnstile Antennas," by G. H. Brown, Radio Corporation of America Laboratories; May 23, 1947.

"Electronic Heating," by F. M. Rives, General Electric Company; June 16, 1947.

SUB-SECTIONS

FORT WAYNE

"High-Frequency Amplitude Modulation," by S. Tarzian, Consulting Engineer; May 19, 1947.

MONMOUTH

"Recent Advznces in the field of Infrared," by R. A. Weiss, Evans Signal Laboratory; April 16, 1947.

"Cathode-Ray Flying Spot Scanner for Television Signal Generator," by G. C. Szlikal, Radio Corporation of America Laboratories; May 21, 1947.

PRINCETON

"Television Today," by D. B. Smith, Philco Corporation; May 7, 1947.

Election of Officers; May 7, 1947.

MEMBERSHIP

The following transfers and admissions were approved on July 1, 1947, to be effective August 1, 1947:

Transfer to Senior Member

Andresen, E. H., 6530 N. Bosworth Ave., Chicago, Ill.
Caplan, R. S., 1712 Hutchins St., Houston 3, Texas
Coe, R. L., Radio Station KSD, St. Louis 1, Mo.
Gardner, F. H., 11600 Sherman Way, North Hollywood, Calif.
Gunn, R., 4437 Lowell St., N.W., Washington, D. C.
Harris, F., Olleros 3738, Buenos Aires, Argentina
Harvey, R. L., RCA Laboratories, Princeton, N. J.
Honnell, M. A., Electrical Engineering Department, Georgia School of Technology, Atlanta, Ga.
Jasik, H., 867 South St., Roslindale, Mass.
Kennedy, M. E., 415 West Lexington Dr., Glendale, Calif.
Kihn, H., 30 Green Ave., Lawrenceville, N. J.
Kulikowski, E. F., 4212—28 St. Mt. Rainier, Md.
Lapham, E. G., R. F. D. 2, Rockville, Md.
Mautner, L., 103 Rhoda Ave., Nutley, N. J.
Mayer, H. F., 17 E. Oneida St., Baldwinsville, N. Y.
McCachren, W. S., R.F.D. 2, Box 271, Alexandria, Va.
Morf, F. P., R.F.D. 1, Box 36, Little Silver, N. J.
Oldfield, H. R., Jr., 109 Rugby Rd., Syracuse, N. Y.
Parker, C. V., 118 Forrester St., S.W., Washington 20, D. C.
Pensak, L., RCA Laboratories, Princeton, N. J.
Rea, W. T., 180 Varick St., New York 14, N. Y.
Reash, C. W., Box 11, Emporium, Pa.
Robinson, E. B., 3436 Zola St., San Diego 6, Calif.
Schlafly, H. J., 702 Danforth St., Syracuse 8, N. Y.
Schooley, A. H., 4035 Nichols Ave., S.W., Washington 20, D. C.
Siegelin, C. O., 1406 W. Fourth St., Plainfield, N. J.
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(Continued on page 38A)

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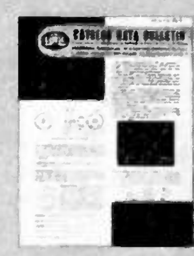

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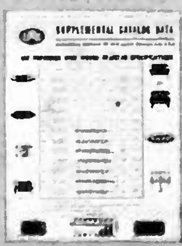

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Sundius, H. W., c/o The Southern New England Telephone Co., 227 Church, New Haven 6, Conn.
Tarzian, S., 537 S. Walnut St., Bloomington, Ind.
Trolese, L. G., 3569 Promontory St., San Diego 9, Calif.
Warner, S. E., 17 Lafayette Ave., East Hartford 8, Conn.
Wells, L. V., 617 W. Lawrence Ave., Charlotte, Mich.
Wiener, F. M., Bell Telephone Laboratories, Inc., Murray Hill, N. J.

Admission to Senior Member

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Hall, N. I., Bell Telephone Laboratories, Inc., 463 West St., New York 14, N. Y.
Hopkins, P. E., 336 N. Edison St., Arlington, Va.
Martin, S. T., 20-B-103, Massachusetts Institute of Technology, Cambridge 39, Mass.
Marvin, P. R., c/o Milwaukee Gas Specialty Company, 722 N. Jackson, Box 461, Milwaukee 1, Wis.
Pernice, J. R., 4801 Connecticut Ave., Washington, D. C.
Toulon, P., 221 Park Ave., New York 17, N. Y.
Weil, R. T., Jr., 2162 Schenectady Ave., Brooklyn 3, N. Y.

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Banks, F. A. O., 81 Troy St., Kitchener, Ont., Canada
Bauer, F., 1209 S. Weller, Springfield, Mo.
Bauman, H. W., 5123 N. Nagle, Chicago 30, Ill.
Bigler, R. R., Collins Radio Co., Cedar Rapids, Iowa
Blinzler, R. F., 558 Crescent Ave., Buffalo 14, N. Y.
Bliss, P., 68 Theodore St., Newington, Conn.
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Bond, F. E., Coles Signal Laboratory, Red Bank, N. J.
Bromall, J. M., Hampton Rd. and Crefeld St., Philadelphia 18, Pa.
Buegler, J. A., 94 Maple Ave., Red Bank, N. J.
Cannon, J. F., 227 Church St., New Haven 6, Conn.
Carter, H. T., 48 Maple Ave., Madison, N. J.
Comstock, G. C., 160 Old Country Rd., Mineola, L. I., N. Y.
Crothers, M. H., c/o Electrical Engineering Department, University of Illinois, Urbana, Ill.
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Dubbs, B., 1151 Stratford Ave., New York 59, N. Y.
Duszak, H., 341 S. Washington Ave., Moorestown, N. J.
Fisk, R. E., 43 Granada Ave., Long Beach 3, Calif.
Frank, R. L., 142 W. 62 St., New York 23, N. Y.
Fristoe, H. T., Electrical Engineering Department, Oklahoma Agricultural and Mechanical College, Stillwater, Okla.
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Henry, E. A., 37 N. Dudley St., Camden, N. J.
Hollander, G. L., 6147 Kingsbury Ave., St. Louis, Mo.

MEMBERSHIP

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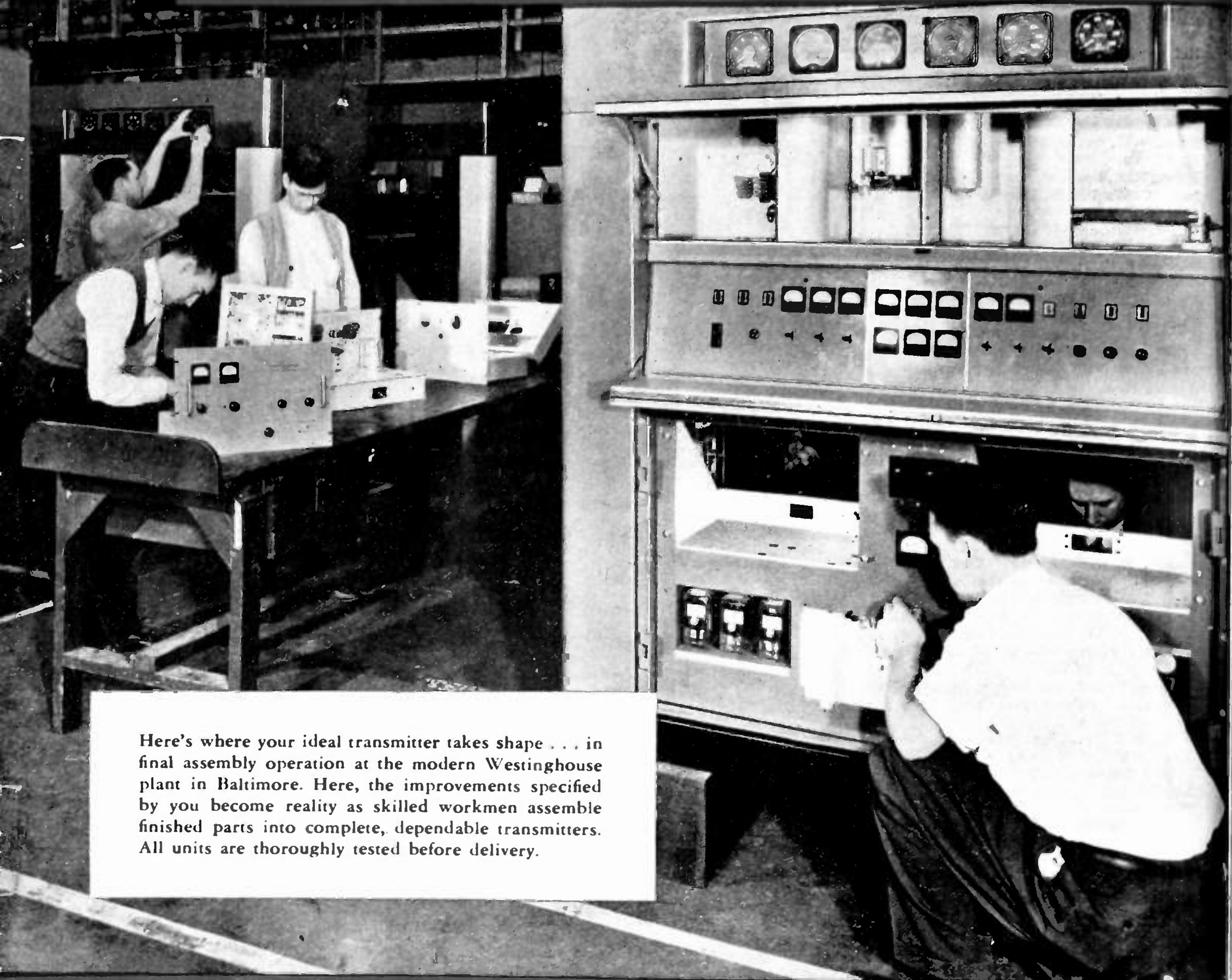
Jacobi, T. E., 17 E. Browning Rd., Collingswood, N. J.
Jarvis, J., 29 Forest Rd., Dumont, N. J.
Jenny, H. K., c/o Rudy Herr, R.F.D. 5, Lancaster, Pa.
Jensen, K. S., Box 1663, Santa Fe, New Mexico
Jones, C. W., Box 85, Fairview Ave., Robertson, Mo.
Kaiser, H. R., c/o WWSW, Inc., Box 1555, Pittsburgh 30, Pa.
Karman, R. B., Pte. Zayas—519, Box 647, Havana, Cuba
Kenigson, R. R., 15 Crawford St., Alfred Vail Homes, Eatontown, N. J.
Ketcham, A. R., 1846 Mansfield Rd., Toledo 12, Ohio
Klaus, G. H., 723 Sunset Court, San Diego 8, Calif.
Knauss, H. C., 30 Lancaster St., Cambridge 40, Mass.
Koch, J. F., Jr., 39 E. Knowles Ave., Glenolden, Pa.
Kraus, C. R., The Bell Telephone Company of Pennsylvania, 1835 Arch St., Philadelphia 3, Pa.
Kucera, F. L., c/o Skodaworks, Ltd., Box 3108, Johannesburg, South Africa
Lafferty, R. E., 415 Pleasant Ave., Ogdensburg, N. Y.
Lane, R. N., 2210 San Gabriel, Austin, Texas
Leff, B., 1930 N. Humboldt Blvd., Chicago 47, Ill.
Leslie, D. A., Box 237, Suva, Fiji
Levey, A. W., 1083 Fox St., New York 59, N. Y.
Loutit, J. A., 119 Oxford St., Cambridge, Mass.
Malone, J. P., Jr., 3431—91 St., Jackson Heights, L. I., N. Y.
Maloney, T. E., 13 Crawford St., Eatontown, N. J.
Mendez, L., Radio Station HPX, Republic of Panama
Miller, R. C., 121 Barnett St., Brookville, Pa.
Minton, M., 54 Moreland Court, Finchley Rd., London N.W. 2, England
Mitchell, J.H., Route 4, Box 1254, Tampa 7, Fla.
Nienaltowski, W., c/o Electronics Division, Engineering Department, Northern Electric Company, Ltd., Box 369, Montreal, Que., Canada
Osorio, A. E., Acoyte 443, Buenos Aires, Argentina
Oyster, D. E., 533 Wiltshire Blvd., Dayton 9, Ohio
Paramasivayya, G. S., Principal, Lingaraj College, Belguam, India
Pennie, D. F., Box 114, Cranbury, N. J.
Rice, C. I., 2163 James Ave., St. Paul 5, Minn.
Robbins, L. G., 2505 Palmer Pl., S.E., Washington, D. C.
Rothschild, R. F., 40 Cameron Ave., Hempstead, L. I., N. Y.

Admission to Member

Andrews, D. R., 514 Dwight Ave., Collingswood, N. J.
Baer, C. E., 305 Williams St., Osborn, Ohio
Barbier, M. P., Albisriederstr 369, Zürich, Switzerland
Benfield, A. B., Westford Rd., R.F.D. 1, Concord, Mass.
Benoit, R. C., Jr., 620 Maple St., Brooklyn, N. Y.
Blumberg, M., 45 William St., Rochelle Park, N. J.
Bowen, R. G., 1886 S. Humboldt St., Denver 10, Colo.
Bridgman, J. M., Photographic Survey Co., Ltd. DeHavilland Airport, Postal Station L., Toronto, Ont., Canada
Chu, C., 43 Linden Lane, Princeton, N. J.
Cohen, J., 1616 Fitzgerald Lane, Alexandria, Va.
Corbell, P. I., Jr., 551 Eaton Ave., Redwood City, Calif.
Cram, C. C., 4763 Lamont St., San Diego 9, Calif.

(Continued on page 42A)

Building the Transmitter



Here's where your ideal transmitter takes shape . . . in final assembly operation at the modern Westinghouse plant in Baltimore. Here, the improvements specified by you become reality as skilled workmen assemble finished parts into complete, dependable transmitters. All units are thoroughly tested before delivery.

SERVICE EVERYWHERE.....

Westinghouse has 17 parts warehouses, a staff of service engineers on 24-hour call and 35 maintenance and repair shops conveniently located . . . as close as your telephone. Factory trained communications sales engineers in your area are also ready to serve you.

More Information?

These new books will give you a complete picture of the operating advantages built into Westinghouse transmitters. Ask for B-3829 (1 and 3 kw, FM) or B-3850 (10 kw, FM).

WESTINGHOUSE

Westinghouse

PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE

Electronics at Work

1, 3 and 10 kw FM Transmitters

...of your ideas!

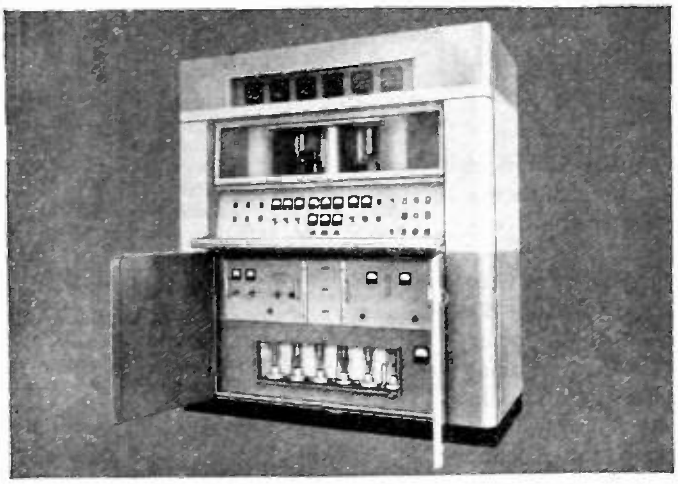
. . . a truly modern design based on the recommendations of your industry and the years of experience of our own engineers in operating five FM stations.

Now you can throw away the "can opener". You won't need one to get at the tubes—they're all within reach of your finger tips, from the front of the transmitter. This is what you asked for . . . and get . . . in all Westinghouse FM transmitters. And here are a few more of those "examples" which help to make your operating and maintenance job easier.

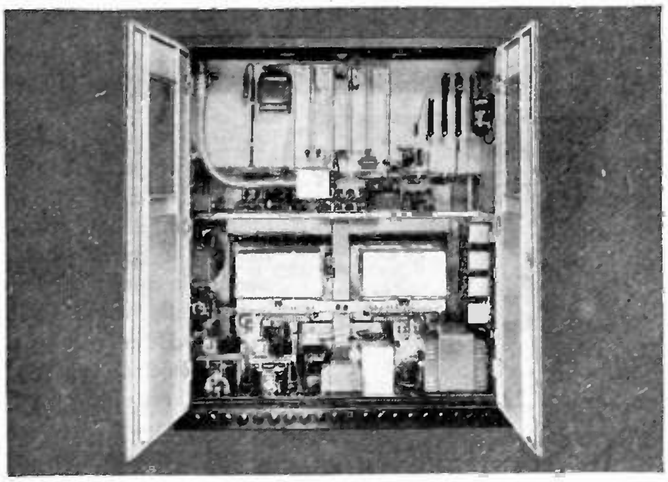
- **New 270° meters at eye level.**
  (You can see the grid and plate currents in all stages simultaneously.)
- **Visible, conventional-type tubes—nothing tricky.**
- **Fuseless overload protection and excellent shielding, lead covered wire.**
  ("De-ion" circuit breakers used throughout.)
- **No ¼-watt receiver resistors.**
  (Only heavy-duty resistors are used throughout.)
- **Individual voltage regulators for bus voltage and high-voltage rectifier.**

This "duo of experience" . . . yours and ours . . . assures these features, and more, in all Westinghouse FM transmitters—1, 3, 10, and 50 kw.

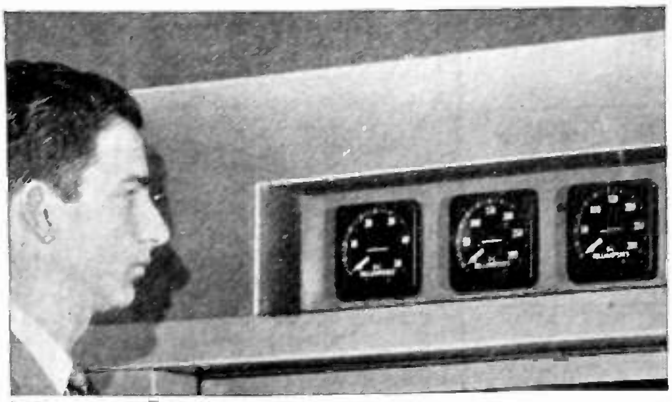
Your Westinghouse office will give you more details or you can write to us at P.O. Box 868, Pittsburgh 30, Pa. J-02105-A



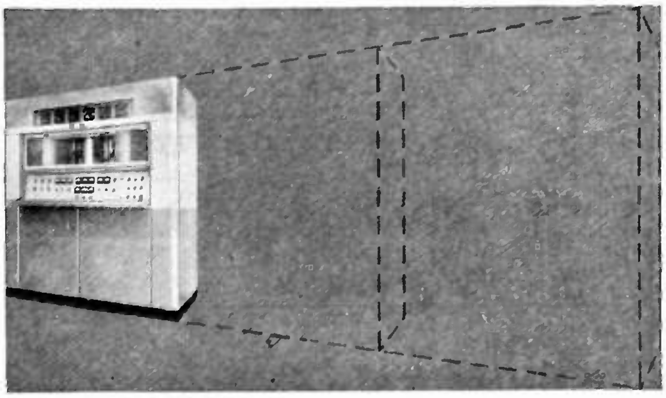
CENTRALIZED CONTROLS . . . all major controls are located on the front panel to make simultaneous adjustments easy. All tubes are replaceable from the front of the cubicle.



EASY TO MAINTAIN . . . full-opening doors, open vertical arrangement of components and power outlets, facilitate inspection and maintenance. All access doors are electrically and mechanically interlocked for safety of service personnel.



ONE-JOB, EYE-LEVEL METERS . . . new 270° circular scale meters are at eye level for easy reading. Each instrument operates in but one circuit, eliminating instrument switching.



BUILDING BLOCK DESIGN . . . your Westinghouse 3 kw, FM transmitter, a complete unit in a single cubicle, can be stepped-up to 10 or 50 kw simply by adding cubicles. Each added cubicle is a complete rectifier or amplifier within itself. Thus, a minimum of inter-cubicle wiring . . . your assurance of a quick, easy change-over.

MEMBERSHIP

(Continued from page 39A)

Danner, O. G., 4874 Montrose Dr., Fort Worth, Texas
Davis, A., 53 Barker Ave., Eatontown, N. J.
Duckwitz, W. G., 100 Victor Ave., Dayton 5, Ohio
Elkins, C. C., Jr., 3103 Douglas St., Dallas 4, Texas
Elliott, A. G., 19 West 91 St., New York 24, N. Y.
Fees, F. K., 404 Rutherford Ave., Trenton, N. J.
Felsenheld, R. A., 67 Broad St., New York 4, N. Y.
French, L. E., Collins Radio Co., Cedar Rapids, Iowa
Gibbons, T. J., 707 Patterson Rd., Dayton 9, Ohio
Given, I. K., 561 W. 163 St., New York 32, N. Y.
Greene, G. G., 66 Needham St., Newton Highlands 61, Mass.
Handelsman, M., 400 W. Siebenthaler Ave., Dayton 5, Ohio
Hixson, J. D., 33 Holly Rd., West Belmar, N. J.
Howard, F. E., Jr., Compound Gate, NATTC, Ward Island, Corpus Christi, Texas
Hunt, T. W., 49 Park Lane, Frodsham, Via Warrington, Lancs., England
Kadenacy, J., c/o Association of Polish Engineers, 9 Sussex Square, London W. 2, England
Kearse, G. P., 3844 Maypole Ave., Chicago 24, Ill.
Kenniger, A., 8 Galt St., Ottawa, Ont., Canada
Lawrence, T. B., Box 2509, Beaumont, Texas
Phillips, D. J., 28 Barrow Rd., Odd Down, Bath, Somerset, England
Placek, J. H., 226 N. 82, Belleville, Ill.
Pree, W. G., 2500 W. 66 St., Minneapolis, Minn.
Richards, G. F., 117 St. Paul's Pl., Hempstead, L.I., N. Y.
Sandlin, G. L., 6308 Malvey St., Fort Worth, Texas
Sherman, R., 235 Mt. Hope Pl., New York, N. Y.
Sigvaldson, J. M., 4815 Holly, Kansas City, Mo.
Smith, C. P., 34 Linnaean St., Cambridge 38, Mass.
Sperring, F. E., 26 Shinfield Rd., Reading, Berkshire, England
Stegner, V. J., R.F.D. 3, Box 188, Dayton 3, Ohio
Swantz, F. W., 204 S. Jackson St., Belleville, Ill.
Taylor, D. R., 371 Winchester St., Winnipeg, St. James, Manitoba, Canada

The following admissions to Associate were approved on July 1, 1947 to be effective August 1, 1947:

Adison, J. C., 1343 Eddy, Chicago 13, Ill.
AhSam, J., G.P.O. Box 77, Suva, Fiji
Allen, F. H., Western Electric Co., 120 Broadway, New York, N. Y.
Allison, L. P., 406 Tennessee Ave., Alexandria, Va.
Andrews, J. S., c/o Radio Station WBLJ, Dalton, Ga.
Arispe, J. S., San Martin 379, Buenos Aires, Argentina
Arnold, D. C., 4200 Gardenia Ave., Long Beach 7, Calif.
Avery, W. B., Troy, Missouri
Benedict, G. R., 417 Glen Echo Circle, Columbus, Ohio
Bennett, D. J., 27 Evans Ave., Toronto, Ont., Canada
Bloom, W. E., 1840 Bryant Ave., New York 60, N. Y.
Boyer, W. H., 484 Lincoln St., York, Pa.
Boyle, B., 263 Flatbush Ave., Brooklyn 17, N. Y.
Branen, S. M., Box 428, Lake Charles, La.
Braun, C. G., 221 Washington St., Boonton, N. J.
Brock, W. T., 112-20—178 Place, St. Albans, N. Y.
Bruna, R. F., 3901 Sheridan Rd., Chicago 13, Ill.
Bugg, K. W., 9 St. Charles Ave., Montgomery 7, Ala.
Callihan, E. S., 520 W. Pierce St., Houston 6, Texas
Capilla, A., Corrientes 1237-B, Villa Maria, F.C.C.A., Argentina
Castro, S., Vidal 2243, Buenos Aires, Argentina
Cerrato, E., Pasaje Los Territorios 2778, Buenos Aires, Argentina
Clark, J. B., 1257 E. Drive, Beaumont, Texas
Clough, L. D., Box 562, Galveston, Texas

MEMBERSHIP

Conti, C., 669 E. 30 St., Paterson, N. J.
Cooke, W. H., 2501 Kenilworth Ave., Los Angeles, Calif.
Copello, D. H., Seccion Comunicaciones, Base Naval, Puerto Belgrano, Rca., Argentina
Crain, J. T., 2356 Fishcanyon Rd., Monrovia, Calif.
Crawford, E. W., 1644 Columbia Rd., Washington, D. C.
Curry, W. H., 2655 N. E. Saratoga St., Portland, Ore.
Eachus, E. D., 605 Union St., Schenectady, N. Y.
Elterman, L., 56 Barker Ave., Eatontown, N. J.
Epprecht, G., Wiedingstrasse 3, Zürich 3, Switzerland
Feick, J. C., Jr., U. S. Naval Station, Norfolk 11, Va.
Fender, K. L., 930 S. Davis St., McMinnville, Ore.
Foster, F. H., 1537—46 St., Des Moines 11, Iowa
Forster, H. F., 26 Warwick Ave., Buffalo 15, N. Y.
Fuller, C. A., 1113 E. 107 St., Los Angeles 2, Calif.
Gellman, H. D., 2298 Bedford Ave., Brooklyn 26, N. Y.
Ghosh, S. R., 71 Ramapura, Benares (U.P.), India
Gloor, B., Kurlistrasse 40, Oberwinterthur, Switzerland
Graziani, E. D., Rivadavia 829, Buenos Aires, Argentina
Green, J. W., 7781 W. Moreland Lane, San Diego 11, Calif.
Guardado, W., Florida 1065-8E, Buenos Aires, Argentina
Gusler, F. C., 4319 Holland Dr., Des Moines, Iowa
Hajduk, E. C., 5150 N. Mulligan St., Chicago 30, Ill.
Harhat, T., 715 N. Elizabeth St., Chicago 22, Ill.
Hastie, E. G., 2010 Pierce Mill Rd., N.W., Washington, D. C.
Held, R. W., 1441 North Ave., Bridgeport 4, Conn.
Hiskin, J., Corrientes 3955 Dto. 3, Buenos Aires, Argentina
Hoffman, L. E., 1100 Glendale Blvd., Los Angeles 26, Calif.
Hogin, P. E., 36 Axtell Dr., Scarsdale, N. Y.
Hollis, R. H., 635 Cascade Rd., Forest Hills, Pittsburgh 21, Pa.
Housenfluck, T. H., Jr., Box 178, Nederland, Texas
Hulteen, C. K., 1242B—24 St., Santa Monica, Calif.
Hutton, J. E., 400 N. Madison, Siloam Springs, Ark.
Hyde, C. M., 2112 Emmaus Ave., Zion, Ill.
Ireland, G. B., 3901 N. Kilbourne, Chicago, Ill.
Jones, H. W., c/o Westinghouse International Co., 40 Wall St., New York, N. Y.
Justus, J. R., 318 S. Elizabeth St., Angola, Ind.
Kent, T. A., 3803 Cottage Terr., Cottage City, Md.
Konigstein, M., Franklin Airloop Corporation, 43-20—34 St., L. I., N. Y.
Krejcar, J. R., 9 Zapova, Prague 16, Czechoslovakia
Krulee, R. L., 19 Wilson Ave., Belmont 79, Mass.
Landis, J. J., 1151—23 St., Des Moines 11, Iowa
Lawrence, J. G., 170 E. Hartsdale Ave., Studio E, Hartsdale, N. Y.
Leavitt, W. E., 4214 Nichols Ave., S.W., Washington, D. C.
LeBoeuf, M. L., 611 D, Marysville, Calif.
Lulck, G. W., 1414—57 St., Des Moines 11, Iowa
Mack, A., 1349 Stratford Ave., New York, N. Y.
Maitland, C. E., 46 Kenton Rd., Harrow, County of Middlesex, England
Malagamba, R. A., Santa Rosa 1459, Vicente Lopez-F.C.C.A., Buenos Aires, Argentina
Mannino, A. J., 7230 Hilltop Rd., Upper Darby, Pa.
Martinez, J., Chacabuco 1525, Buenos Aires, Argentina
McCall, E. A., 3504 E. 26 St., Kansas City 1, Mo.
McCall, W. A., 215 W. 23 St., New York 11, N. Y.
McComas, A. D., Jr., 1016 E. North Ave., Baltimore, Md.
McGinness, C. C., 3430 Euclid, Kansas City 3, Mo.
Merkel, H. E., 712 North Nelson St., Arlington, Va.
Mignorance, F., Libertad 257-4, piso. R., Buenos Aires, Argentina

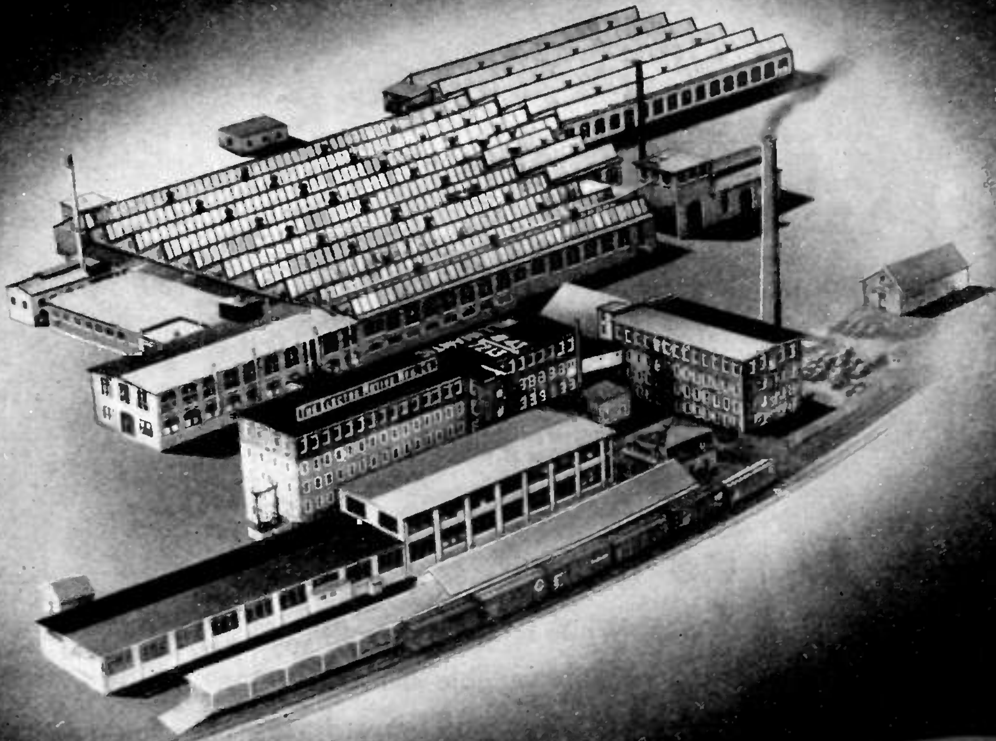
(Continued on page 44A)

MEMBERSHIP

(Continued from page 43A)

Mishra, N. D., Podar College, Naivalgarh, Jaipur State, India
Moehring, W. D., 432 S. Cochran St., Charlotte, Mich.
Morley, L. N., 5640 N. Fifth St., Arlington, Va.
Mosler, G. M. F., R. L. Falcon 4923, Buenos Aires, Argentina
Murdock, R. H., Radio Station KPBX, Beaumont, Texas
Narasimham, T., Radio Wing, I.M.T.C., T. Nagar, Madras, S. India
Newman, M. M., 239 Plymouth Bldg., Minneapolis 2, Minn.
Norris, S. F., 32 Hillsdale Ave., Long Branch, N. J.
Odino, C. A., Laprida 2363, Florida, Buenos Aires, Argentina
Olson, A. L., 918 Webster St., Fort Wayne 2, Ind.
Patel, M. B., International House, 500 Riverside Drive, New York 27, N. Y.
Pedemenyou, M. L. F., Casilla de Correos 3762, Buenos Aires, Argentina
Pellegrinelli, G. L., 4048 Park Ave., New York 57, N. Y.
Pritchett, W. A., 519 S. Church St., Florence, S. C.
Pucalik, A. T., 2917 W. Adams St., Chicago 12, Ill.
Rao, R., 5 Veeranna's Garden St., A, Cleveland Town, Bangalore, India
Rehberg, J. C., 5047 W. Fulton St., Chicago 44, Ill.
Rench, C. F., 259 Highland Pk. Dr., Tory, Ohio
Ribe, M. L., 314 Broad St., Eatontown, N. J.
Richardson, L. E., 450 Murray St., North Bay, Ont., Canada
Rodberg, B. A., Cangallo 1286, Buenos Aires, Argentina
Rogers, C. L., 3012 N. Park Drive, East St. Louis, Ill.
Rolf, P., Sonneggstrasse 63, Zürich 6, Switzerland
Saunders, D. H., 4408 Klingle St., N.W., Washington, D. C.
Schoolberg, H., Box 17, Gibsonia, Pa.
Sheker, E. B., c/o Mrs. B. F. Baer, Gladyne, Pa.
Sherman, J., 1414 Pennington Rd., Trenton 8, N. J.
Shoucair, S. F., 2515 K St., N.W., Washington, D. C.
Skocpol, C. L., 916 Snyder, Akron 7, Ohio
Smith, A. E., Alliance Manufacturing Co., Alliance, Ohio
Smith, R. T., 12 Frazer Ave., Collingswood, N. J.
Steffen, R. V., 4095 N. Sixth St., Milwaukee 12, Wis.
Stenhouse, J. M., 545 W. Belden Ave., Chicago 14, Ill.
Stramazzo, L. A., Calle San Martin 3970, Rosario, Prov. Santa Fe, Argentina
Teodori, D. C., Salta 211, Buenos Aires, Argentina
Tippings, C. C., Jr., 622 Center Point Rd., Cedar Rapids, Iowa
Turner, E. S., 1718 E. Fifth Ave., Columbus 3, Ohio
Verbanec, W. R., 2908 N. Troy St., Chicago 18, Ill.
Walding, N. N., 362 Karangahape Rd., Auckland, New Zealand
Waldorf, L. E., 103 North University, Vermillion, S. D.
Warreck, A., Carnegie Institute of Technology, Pittsburgh 13, Pa.
Washburn, W. M., Room 114, Humble Oil Refining Co., Houston 1, Texas
Watschke, M. V., 1011 Mohawk, Royal Oak, Mich.
Wayne, C. R., 1810 W. Genessee, Syracuse, N. Y.
Wharton, R. H., 703 Johnson St., Gary, Ind.
Whittle, O. W., 4219 S. Benton, Kansas City 4, Mo.
Williams, D. G., 839 Edmund Ave., St. Paul 4, Minn.
Williams, M., Radio Station KCKN, Kansas City 6, Mo.
Wixson, F. C., 16 Garrabrant Rd., Clifton, N. J.
Young, A. R., 1100 N St., Lewis Apt., Sacramento, Calif.

this is the house . . . . .



. . . . . that El-Menco built!

Size is not necessarily a sign of greatness. But when size is the result of consistently steady growth, based on an ever-widening demand for a product, then it is truly indicative of outstanding quality.

Year after year, in more and more instances, El-Menco Capacitors become first choice with manufacturers who are proud of their products.

Send for samples and complete specifications.

Foreign Radio and Electronic Manufacturers communicate direct with our Export Department at Willimantic, Conn., for information.

THE ELECTRO MOTIVE MFG. CO., Inc., Willimantic, Conn.

Write on firm letterhead for samples and catalog.

ARMY E NAVY

MOLDED MICA **El-Menco** **MICA TRIMMER**

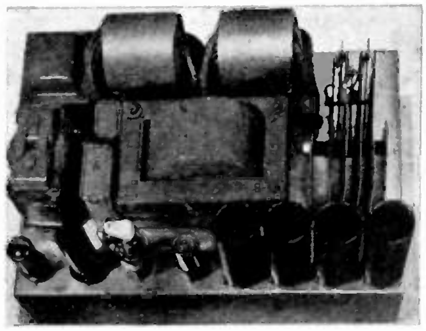
CAPACITORS

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

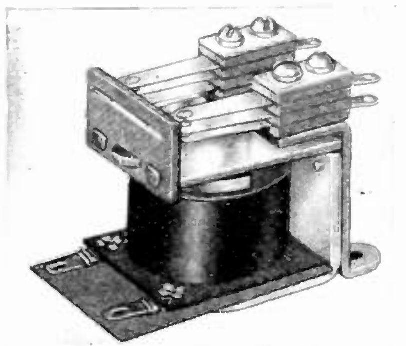
Voltage Regulators

Regulated direct current voltages at high stable currents are available by utilizing a new line of voltage regulation units, called Nobatrons, which have been announced by **Sorenson & Company, Inc.,** 37 5Fairfield Ave., Stamford, Conn.



Nobatrons, available in six standard models provide currents of 5, 10 or 15 amperes with output voltages of 6, 12, or 26 volts respectively. It is stated that regulation accuracy of 0.5%, maximum ripple voltage (root-mean-square) of 1%, and recovery time of one-fifth second make Nobatrons ideally suited for critical applications where constant direct-current voltages are required.

Midget Relay



Designed to meet industrial needs for a small, compact, low-cost relay, the **Guardian Electric Manufacturing Co.,** 1628 W. Walnut Street, Chicago 12, Ill., has recently announced its Series 600 Relay. It can be furnished with numerous contact-switch combinations, up to and including four pole, double throw. Suitable coils provide many AC and DC operating voltages. The maximum contact current is 8 amperes. It is stated that the short contact blades in the switch assembly eliminate contact "bounce."

(Continued on page 48A)

TWO POPULAR RECTIFIER TUBES

for broadcast, communications, and other work

•

. . . better built for more hours of topgrade performance!

RATINGS

	GL-8008	GL-673
Cathode voltage	5 v	5 v
current	7.5 amp	10 amp
Typical heating time	30 sec	30 sec
Anode peak inverse voltage	10,000 v	15,000 v
peak current	5 amp	6 amp
avg current	1.25 amp	1.5 amp

Heavy-duty bases, with large pin-contact area, are one of many features that give these mercury-vapor phanotrons the dependability needed for 24-hour broadcast-station use—extra reliability for police-radio, aviation, and other exacting communications work—the steady efficiency required to convert power for small d-c industrial equipment operating on full schedule.

Minimum temperature rise is an especially valuable characteristic of Types GL-8008 and GL-673. Installation of these tubes reduces the cooling problem for broadcast-station and factory engineers.

Less mounting space needed . . . this is an important result of the straight-side envelope design in contrast to the bulb shape of older types. Maintenance men, too, report that the straight-side contour makes Types GL-8008 and GL-673 easier to handle, and helps ward off accidental tube breakage.

Sturdy, shock-resistant . . . these qualities stem from the modern structural design of the GL-8008 and GL-673—their strongly braced cathodes, and their nickel anodes which, lighter in weight than others, put less strain on the seal above them, enabling the latter to withstand shocks and vibration better.

General Electric builds a complete line of phanotron rectifier tubes—15 types in all, matching every broadcasting, communications, or industrial need. Your nearby G-E tube distributor or dealer will be glad to give you prices and full details. Phone him today! *Electronics Department, General Electric Company, Schenectady 5, N. Y.*

G.E.'s new Transmitting Tube Manual is the most complete book in its field! Profusely illustrated; packed with application data. Over 600 large pages. Price $2, with an annual service charge of $1 for new and revised pages to keep the manual up-to-date. Order direct from General Electric Company.

GENERAL ELECTRIC

161-F3-8086

FIRST AND GREATEST NAME IN ELECTRONICS

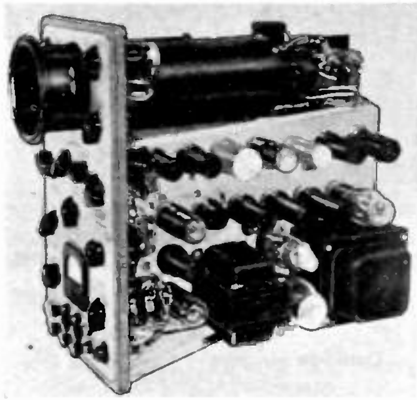
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 46A)

Portable Oscilloscope

A new portable three-inch oscilloscope with laboratory refinements is now in production, according to the Engineering Products Department of the **Radio Corporation of America,** Camden, N. J. This oscilloscope's frequency range and high gain characteristics permit close examination of high-speed transients up to six megacycles, and pulsed voltages of the order of one micro-second for test analysis.



The major electrical components of the new oscilloscope, Type WO-79A, include calibrated horizontal and vertical input attenuators, high-gain horizontal and vertical amplifiers, a synchronizing amplifier, a time-base oscillator and sweep generator, intensifying amplifier, low- and high-voltage power supplies, and a three-inch high-contrast cathode-ray oscilloscope.

The triggered sweep feature makes the unit particularly suitable for photographic study of transient waveforms, for television signal expansion for checking square-wave time, and for checking irregularly timed pulses.

Recent Catalogs

. . . What a large financing organization advises its customers on radios will interest most manufacturers. "Better Buymanship—Use and Care of Radios" is No. 25 in series offered by *Household Finance Corporation,* 919 North Michigan Avenue, Chicago 11, Ill. Mailing cost 5 cents.

. . . On alternating- and direct-current relays, stepping relays and contact switch assemblies, Catalog 10-A by *Guardian Electric Manufacturing Company, Inc.,* 1621 W. Walnut Street, Chicago 12, Ill.

. . . On Cannon "Quick Disconnect" Plugs for the Electric Industry, a 76 page illustrated catalog by *Cannon Electric Development Company,* 3209 Humboldt Street, Los Angeles 13, Calif.

(Continued on page 56A)

POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. . . .

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.
I East 79th St., New York 21, N.Y.

PHYSICISTS AND ELECTRICAL ENGINEERS

For vacuum tube research. Apply by letter stating qualifications to Director of Research, National Union Radio Corporation, 350 Scotland Road, Orange, New Jersey.

ELECTRICAL ENGINEERING TEACHERS

Instructors, assistant and associate professors to teach electrical engineering at state university in the southeast. Salaries $2,800 to $4,500 for nine months, depending upon qualifications. Write full details of education and experience. Box 467.

RF-IF TRANSFORMER ENGINEER

Radio engineer with theoretical and practical knowledge and experience in design of RF-IF transformers. Familiar with modern practice and requirements in FM and television receivers. Excellent opportunity with established growing company. Write giving full details. Box 468.

ENGINEER

A mid-western manufacturer has an opening for a graduate engineer with a broad background in electronic circuit design and instrumentation. Experience with pulse technique, servo-systems or telemetering procedure is particularly desirable. Unlimited opportunity in a specialized and highly interesting field is offered. A complete résumé should be submitted. Box 469.

ELECTRONICS ENGINEER

Electronics engineer wanted for a responsible position in development of instruments for radiation measurements. Degree and several years experience plus initiative and ability to follow through desired. Background in instrumentation, electronics associated with nuclear physics is advantageous. Box 470.

CHIEF ENGINEER

Chief engineer and works manager by first company to deliver projection television. Heavy experience Ultra High Frequency circuit characteristics and mechanical layout in engineering required. Mechanical layout of radio chassis, production and testing techniques. Resourcefulness, initiative, foresight, sound judgment, willingness to assume responsibility for own decisions. Ability to enforce discipline, to locate and eliminate unnecessary overhead. Salary high—only heavy weights need apply. United States Television Manufacturing Corporation, 3 West 61st Street, New York 23, N.Y.

(Continued on page 51A)

POSITIONS OPEN

(Continued from page 50A)

ELECTRONICS ENGINEER

A large research and manufacturing company has openings for men with B.S. or M.S. in physics or engineering. Ages between 28 and 35 years. Must have 2 years experience on the development of electronic measuring instruments. Experience in the design of radar circuits or in servo-mechanism techniques. Box 471.

RADIO COMPONENT ENGINEER

Experienced in design of RF and IF components and FM circuits essential. Excellent opportunity for qualified man. Please send a complete résumé. Automatic Manufacturing Corporation, 900 Passaic Ave., East Newark, New Jersey.

ENGINEERS—PHYSICISTS

Graduate engineer or physicist for design and development of electronic instruments is required by a large research laboratory. At least three years' experience in the field, familiarity with pulse technique and broad band amplifier design is essential. Living accommodation arranged. Address: National Research Council, Chalk River, Ontario.

ELECTRONICS ENGINEER

Electronics engineer capable of designing and supervising construction of oscillator circuits from 15 kilocycles to 500 megacycles for use in quartz crystal networks and testing equipment. College graduate preferred. Mid-western university town. Salary open. Send full details of education and experience. Write Box 473.

ENGINEERS—PHYSICISTS

Highly qualified engineers and physicists needed in development of electronic circuits, microwave components, UHF and VHF antenna, and servomechanisms. Highly qualified talent is also needed for analytical study of dynamical systems, complex electric circuits, and complex electronic systems. Opportunities are unlimited for the right men who are capable of assuming responsibility. Write to Personnel Manager, Boeing Aircraft Company, Seattle 14, Washington.

ENGINEERS—PHYSICISTS

Eastern tube manufacturer has openings for experienced men for electronic tube and circuit research and development work. Box 474.

COMMUNICATIONS ENGINEER OR PHYSICIST

The National Geophysical Company, Inc. has an opening on its engineering staff for a communications engineer, or physicists with electronic training, who is interested in research and development work. Projects cover all phases of geophysical work. This position is permanent. Salary open. Write National Geophysical Company, Inc. Research Laboratory, 8806 Lemmon Avenue, Dallas, Texas.

RADIO ENGINEER

Radio engineer development of military receivers for low frequency and microwave regions. Must have 3 to 4 years experience in receiver design. Location New York City. Salary up to $4,500. Box 476.

(Continued on page 52A)

POSITIONS OPEN

(Continued from page 51A)

INSTRUCTOR OR ASSISTANT PROFESSOR

Instructor or assistant professor to teach courses in wire and radio communication and ultra-high-frequency techniques at a small New England University. Prefer man 25–35 with advanced degree and industrial experience. Work begins Oct. 1, 1947. Salary dependent upon qualifications. Box 477.

★ ★ ★ ★

Positions Wanted By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants, and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The Institute publishes free of charge notices of positions wanted by I.R.E. members who are now in the Service or have received an honorable discharge within a period of one year. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion and the maximum number of insertions is three per year. The Institute necessarily reserves the right to decline any announcement without assignment of reason.

INVENTOR—ELECTRICAL ENGINEER

Training in theoretical mechanics and electronics. Diversified experience. Harvard 1929. Desires part time position, research and development, preferably on unusual project requiring best fundamental training and initiative. Location preferred, Washington or East coast. Box 82W.

JUNIOR ENGINEER

B.E.E., Cornell University, 1946. Age 21. Single. Desires position in radio, television or electronics. Prefer Detroit area. Box 83W.

SALES ENGINEER

M.S. in E.E., Boston College, 1940. B.S., Boston College, 1938. Age 30. Two years teacher, public schools, college physics. Fellowship, Boston College. Desires position in technical sales or application engineering field. Has had experience as research physicist, production engineer, assistant sales engineer. Prefers New England location. Box 85W.

ENGINEER

B.E.E., Rensselaer, Army officer, Harvard and M.I.T. training, teaching electronics at night, college level, 3 years ex-

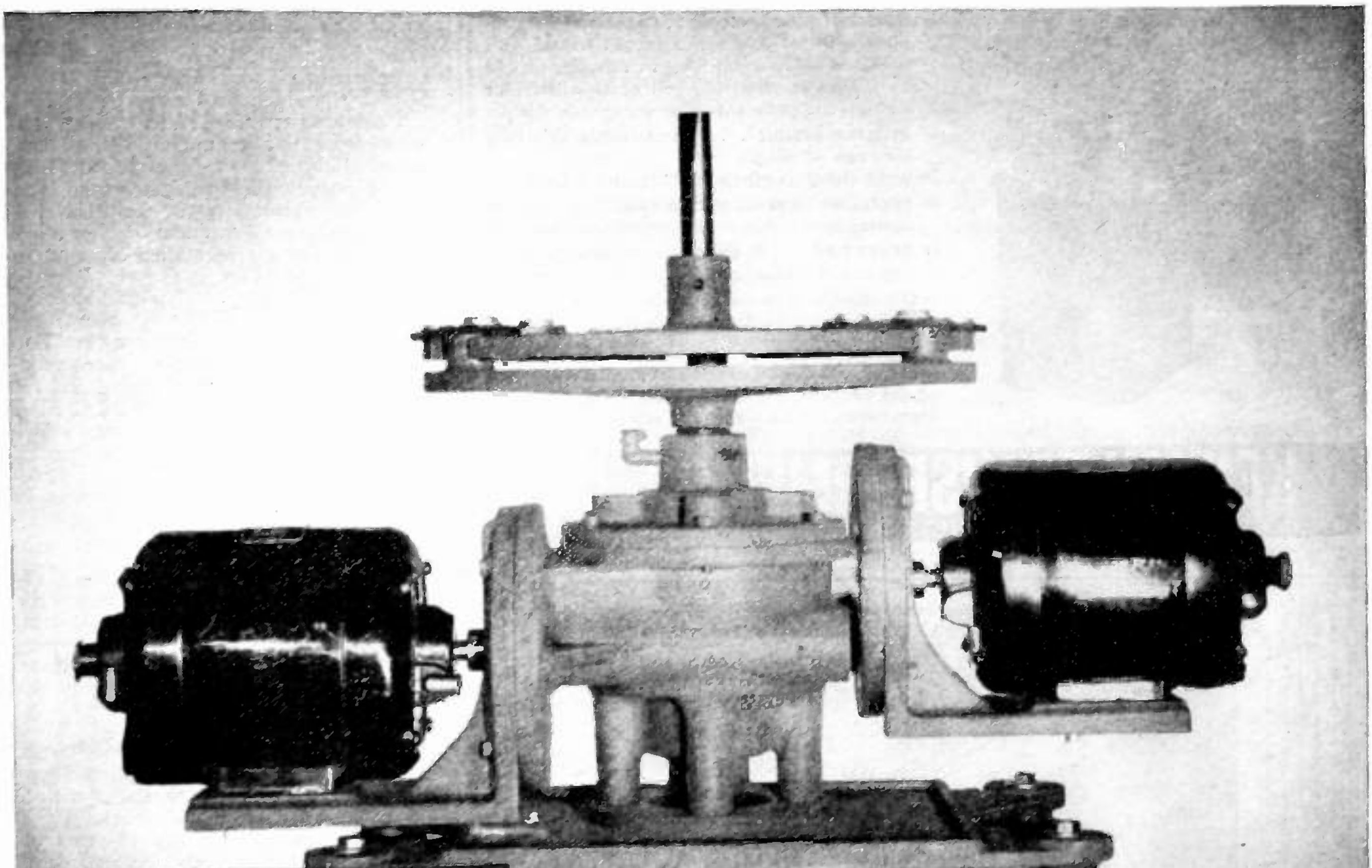
(Continued on page 54A)

NEW! Presto's Dual-Motor, Direct Drive!

▶ The new Presto 64-A transcription unit combines a number of radical improvements which are of first importance to broadcast stations, recording studios, and industrial and wired music operators.

▶ The turntable is directly gear-driven at both 33⅓ and 78.26 rpm and two separate motors are employed — one for each speed. Speed may be changed instantly at any time by turning a mercury switch, without damage to the mechanism. *No frictional, planetary, or belt operated elements are used in this new drive mechanism.*

▶ The following points are of interest: *Motors*—Two 1800 rpm synchronous. *Speed*—Total speed error is zero. *Noise*—At least 50 db below program. *Starting*—Table on speed in less than one-eighth revolution at 33⅓ rpm. *Adjustment*—Construction is very rugged and no attention whatsoever is required—except lubrication.



Brand of reproducer is at the customer's discretion

PRESTO RECORDING CORPORATION

242 West 55th Street, New York 19, N. Y. • Walter P. Downs, Ltd., In Canada

WORLD'S LARGEST MANUFACTURER OF INSTANTANEOUS SOUND RECORDING EQUIPMENT & DISCS

Positions Wanted

(Continued from page 52A)

perience with LORAN, Countermeasures equipment, and servos. 1 year experience in the coke industry. Desires association with the electronic industry in Boston, Mass. Box 86W.

JUNIOR ENGINEER

Completing Junior Engineering, two non-electrical courses for B.E.E. degree N.Y.U. Desires work in industrial electronics or sales engineering in metropolitan area. Age 29. Details on request. Box 87W.

ELECTRONICS ENGINEER

Experienced receiver and transmitter design and production, F.M., A.M.; B.S., London. Age 31. 1934–37, RX designer large British radio firm; 1937-39 Air Ministry production of airborne RX and TX equipment; 1935–45 R.A.F. pilot, 3500 hours, transatlantic Captain; 1945 to date, technical director of large broadcasting station designing FM equipment, and color television. Speak French, well traveled. Desire position Connecticut or New York area. Consider representation or sales engineering. Box 88W.

ENGINEER

B.S. in E.E.; Graduate work, Ohio State University, Princeton. Three years civilian with A.G.F. development and research engineer on H.F. and V.H.F., F.M. and A.M. Mobile communications equipment. One and a half years with A.A.F., microwave R.C.M. development. Desires equivalent position or sales engineer in New York. Box 104W.

RADIO ENGINEER

B.S.E.E. Age 24. Married. Some graduate work, 2 years high frequency oscillator and antenna design, development, RCA. Half year radio frequency engineer, CBS. Half year microwave relay advisor, Army Signal Corps. Desires highly responsible position. Box 105W.

AVIATION RADIO ENGINEER

I am interested in making another long term affiliation in Aviation Radio with a progressive and reputable company who can advantageously use my 18 years of pilot, receiver design and domestic and foreign sales engineering experience. Box 106W.

JUNIOR ENGINEER

Graduating Michigan in June, 1947 with B.S.E.E., Tau Beta Pi, Eta Kappa Nu. One year Army experience with receivers, radioteletype, low power transmitters (all up to 30 MC). Speaks French, German and English. HAM, first phone license. Interested in production or development work. Details on request. Box 107W.

SENIOR ELECTRONICS ENGINEER

Graduate engineer. 20 years experience, receiver development, sound systems, university teaching, sales promotion, advertising, editing electronics magazine. War experience, airborne radar, some experience guided missiles. Interested in development or application engineering, liaison, advertising, personnel or editorial position. Box 108W.

ELECTRONICS ENGINEER

Since 1922 in many phases; 10 years in broadcasting, 5 years a Chief Engineer, 5 years Naval Electronics (Commander). Radiophone first license. Experienced writer, speaker. Personable. Résumé of experience on request. Box 109W.

Positions Wanted

RADIO ENGINEER

B.S.E.E. 1943, University of Michigan. Eight years radio service; 10 years amateur, Class A; 1st Class radio-phone; 1 year industrial electronics research; Harvard-M.I.T. radar; New London, submarine sonar and radar; 1 year instructing; present manager of manufacturing concern, design, setup, sales and advertising. Box 110W.

ELECTRONICS ENGINEER

B.S.E.E., Northeastern University in September, 1947. Age 23. One and one-half years experience with all types of Naval Airborne radio and radar equipment. Hold 1st Class radio-telephone license. Member Tau Beta Pi. Desires position as Junior Engineer in electronic design, research or development. Further details on request. Box 113W.

ENGINEER

Schools—N.C.E., Harvard and M.I.T. Flying Air Corps officer. Presently engineer in development laboratory. Familiar with radio, radar, G.M., microwave techniques. Desires industrial engineering position in laboratory or plant. Box 114W.

JUNIOR ENGINEER

B.S. in mathematics 1944. B.S.E.E., June, 1947, University of Michigan. Member Eta Kappa Nu. Two years Signal Corps. Age 24. Single. Desires development or production work in radio or electronics. Box 116W.

JUNIOR ENGINEER

B.E.E., 1947, Polytechnic Institute of Brooklyn. Age 30. Married. One child. Two years Army Radar Officer, Harvard-M.I.T. radar school. Eta Kappa Nu. Desires position as a Junior Engineer in electronic design, development. Anywhere in U.S. Box 118W.

ELECTRICAL ENGINEER

Electrical engineer, age 21, single, interested in a position with opportunities for advancement, either industrial or academic. Good mathematical training. Some teaching ability. B.S. in E.E., Columbia. Expect M.E.E., Cornell, in September. Box 119W.

ENGINEER (CANADIAN)

B.S. Electrical engineering, 1939. Six years experience in maintenance and installation of Naval radar and radio equipment. Last 3 years in administration and supervision. Present rank Lieutenant Commander (Electrical). Licensed amateur since 1932. Age 30, married, 1 child. Interested in engineering, sales or representative position particularly in maritime provinces or Newfoundland. Box 120W.

ELECTRONICS ENGINEER

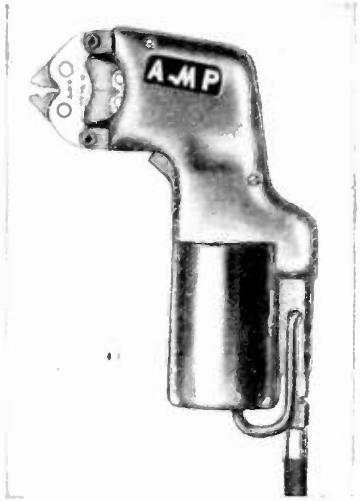
B.S.E.E., 1936. Five years civilian experience radar circuit design; one year development and design of computer circuits and guided missile controls. Half of required graduate credits for M.S.E.E. Age 32, married. Now employed in radar system design. Box 121W.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

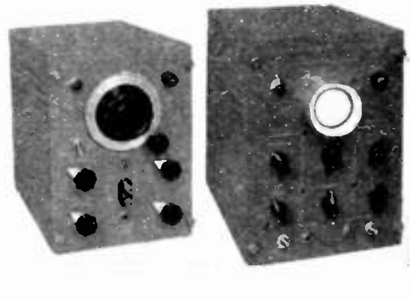
(Continued from page 48A)

Pneumatic Hand Tool for Solderless Wire Terminals



A trigger-type controlled, fast-acting pneumatic-powered hand tool for production line assembly of solderless electrical terminals was presented by **Aircraft-Marine Products Inc.**, 1613 N. Fourth Street, Harrisburg, Pa., at the 1947 Radio Engineering Show. Made for wire sizes 22 to 14 and using the various solderless terminals manufactured by the company, this tool completes connections as fast as an operator can insert the wire and pull the trigger, and provides 2000 lb. crimping pressure from 85 lbs. air pressure with extremely low air consumption, the manufacturer states. The Show demonstrations proved high speed even for unskilled operators, and ease in handling tight and hard-to-reach connections.

Visual Alignment Unit



Harvey Radio Laboratories, Inc., 456A Concord Avenue, Cambridge 38, Mass., has announced two new units which, when used together, provide a precise method of visually aligning intermediate frequency and tuned-coupled circuits in the range of 20 to 500 kilocycles. A linear sweep deviation, adjustable from 0 to 70 kilocycles peak to peak, is incorporated in the instrument. The signal generator is Type 204-TS and the oscilloscope is Type 188-TS.

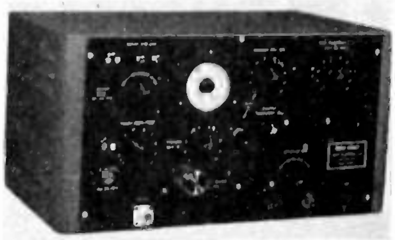
(Continued on page 58A)

NEWS—NEW PRODUCTS

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 56A)

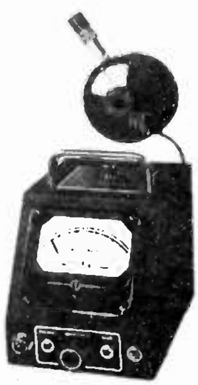
Mega-Sweep Oscillator—Model No. 2



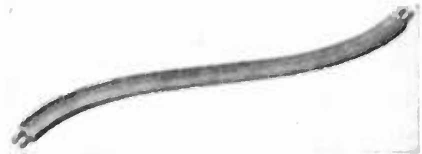
Announced by **Kay Electric Company,** East Orange, N. J., this new model incorporates several new features. Carrier frequency may be increased to 1000 megacycles to cover color television bands. Low amplitude modulation while sweeping is now less than 1 decibel per megacycle. An improved wavemeter provides metering from 1000 megacycles to 1 megacycle. This model, as well as model No. 1, has a frequency sweep from 30 megacycles to 30 kilocycles. Both models feature a continuously variable attenuator.

Megacycle Meter

The **Measurements Corporation** of Boonton, N. J., now offers Model 59 for determining resonant frequency of tuned circuits, antennas, resonant transmission lines, or any resonant circuits. It is a compact oscillator connected to its power supply by a flexible cord. The tuned-circuit coil is mounted externally so that it can be easily coupled to other circuits. Essentially a "grid-dip meter," it adds many new and improved features.



Twin Lead



Recognizing the need for a quality transmission line at reasonable cost, **American Phenolic Corporation,** 1830 So. 54 Avenue, Chicago 50, Ill., has announced the development of its Type 14-023 Polyethylene Twin-Lead. The use of polyethylene as a superior insulation with low radio-frequency loss and desirable characteristics of resistance to moisture and most solvents, provides an ideal dielectric for this 75-ohm transmission lines. With proper matching and a standing wave ratio in voltage of less than two to one, this new conductor will safely handle two kilowatts. According to the manufacturer, this new heavy-duty transmission line has loss characteristics which are as much as ten times better than the prewar transmission lines normally used.

Decade Amplifier

Known as Model 102-A, the new Decade Amplifier recently announced by **Kalbfell Laboratories,** 1076 Morena Blvd., San Diego 10, Calif., is designed to have higher gain and more power output than units previously available.

This instrument has an output impedance of less than 25 ohms and can be used as a pre-amplifier for copper-oxide-type voltmeters as well as for vacuum-tube voltmeters. It is built to deliver up to 50 volts at 10 ma. r.m.s., incorporates negative feedback in addition to a fully regulated power supply, and is flat within 1 decibel from below 10 cycles to 1 megacycle. The amplification factors are ×100, ×1000 and ×10,000 on its three ranges.

(Continued on page 59A)

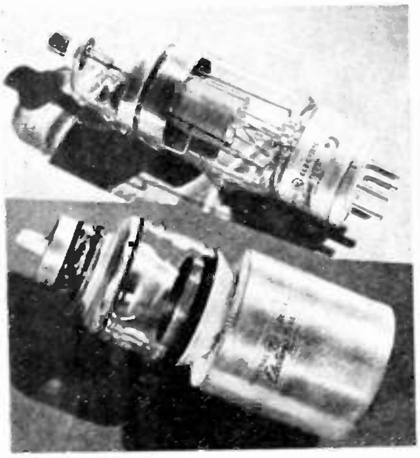
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 58A)

New Electron Tubes

Two new electronic tubes, Types GL-5545 (upper) and GL-5513 (lower) have been announced by the Tube Division of **General Electric Company's** Electronics Department, Thompson Road, Syracuse, N. Y. The GL-5545 has three major industrial uses: for 220-volt direct-current motor-control work; in grid-controlled rectifier service; in separate-excitation ignitor circuits. Called "climate-proof" because of its ambient temperature ranges from minus 55° to plus 70°C., the new tube has a peak-to-average current ratio of 80 to 6.4 amperes and a high peak voltage of 1,500 volts. Its inert-gas content makes possible the short heating time of one minute.



The very-high-frequency power tube, Type GL-5513, with an output ranging to 2 kilowatts, has been designed for television and frequency-modulation applications under Class B and C conditions, and with a frequency range up to 220 megacycles it may be adapted to dielectric heating services employing the higher frequencies. When used as a grounded-grid amplifier in Class C telegraphy, the GL-5513 has a tube output of over 2 kilowatts with a power gain of ten. In Class B video service under synchronizing peak conditions in a grounded-grid circuit, output exceeds one kilowatt, with an approximate power gain of 8.

Plant Expansions

• • •At New Haven, Conn., by **Eastern Industries, Inc.**, to take over the production rights of the McIntyre Company, manufacturers of precision pumps and fluid motors.

• • •At Springfield, Illinois, by the **Gothard Manufacturing Company,** for dynamotor, inverter, and motor-generator production, facilities for which were perchased from Pioneer Gen-E-Motor, Chicago, who are discontinuing the manufacture of these items.

(Continued on page 60A)

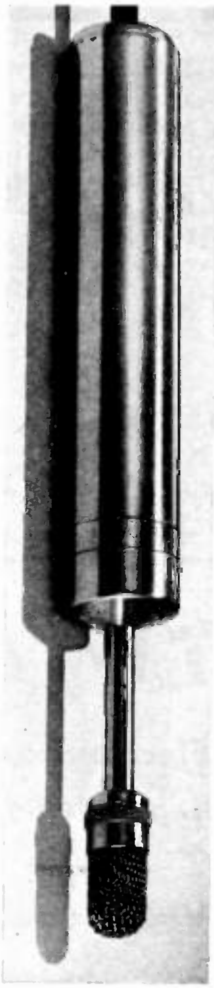
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 59A)

Hydrophone

Designed as a standard for underwater sound-pressure measurements and acoustic measurements in air, the Model BM-101 Hydrophone has been announced by the **Brush Development Company, 3405 Perkins Ave., Cleveland 14, Ohio.** The frequency range in water is from 100 cycles to 100 kilocycles and in air from 100 cycles to 20 kilocycles. The unit consists of a sound-pickup head connected to the preamplifier housing by means of a short length of metal tubing.



The sound-pickup head consists of a sensitive crystal assembly surrounded by castor oil and enclosed in a rubber housing. The absence of mechanically coupled elements contributes greatly to the extended frequency range to which it is responsive.

When used as a microphone, the unit is equivalent to a Rayleigh disc as far as diffraction errors are concerned, and it can be used with the same degree of facility as any other general purpose microphone. Due to the small dimensions of the sound-pickup head, this unit can be used as a probe for investigating sound-pressure distribution inside a pipe carrying sound, or inside exponential horns and other sound transmission systems.

Contact Modulated Amplifier

For the measurement of d.c. and low-frequency a.c. voltage in the microvolt range and below, **The Perkin-Elmer Corporation,** Glen Brook, Connecticut, announces that they are now manufacturing a Geiger-Muller type contact-modulated amplifier. This amplifier is suitable for

(Continued on page 61A)

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 60A)

replacing sensitive suspension type galvanometers in circuits of between 5 and 100,000 ohms resistance. It is not subject to vibration, and its output is suitable for actuating standard recorders, relays or rugged d.c. meters. The manufacturer states that it responds much faster than sensitive galvanometers, being useful for measuring current changes as fast as 10 cycles per second.

The amplifier has numerous specific applications in addition to general laboratory use. In association with a radiation thermopile, it is suited for the measurement and recording of radiant energy, particularly in infrared spectrometers. When used with an iron-contantan thermocouple, temperature differences as low as 0.001 degree Centigrade can be measured and controlled. It may also be used with photronic cells for the measurement of minute quantities of radiant energy in the visible region.

The amplifier can be supplied for either 110-volt, 60-cycle operation or for 6-volt battery operation. Its size is 10"×8"×8", and it weighs 25 pounds. Where 100-volt operation is desired, an external power-supply unit is furnished. This unit measures 14"×6"×9".

Noise-Canceling Microphone

A new hand microphone with special characteristics, called Model 15-D-NC, has been introduced by **The Turner Company**, Cedar Rapids, Iowa. It is a hand-held dynamic microphone which is designed to cancel out background noise, permitting only close-talking speech to be transmitted. A unique arrangement of the diaphragm balances out random sound arriving at a distance, yet allows pickup of ordinary speech directed at the front.

If desired, a "push-to-talk" thumb switch is built into the handle. The microphone is available in 50, 200, 500 ohms or high impedance input.

(Continued on page 63A)

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 61A)

Recent Catalogs

• • •On "Flowrater" instruments for measuring flow rate of liquids, by **Fischer & Porter Company,** Hatboro, Pa. Write Dept. 8Z-C, Catalog Sec. 25-E for Bulletin No. 700.

• • •On coils, by **The Pioneer Electric & Research Corp.,** Forest Park, Ill. Bulletin 1947 Perco.

• • •On controls and resistors, by **Clarostat Mfg. Co., Inc.,** 285–7 No. Sixth St., Brooklyn, N. Y. Catalog No. 47.

• • •On electronic receiving tubes, 700-page technical manual for electronic equipment manufacturers and designers, by **General Electric Company,** Electronic Dept., Tube Div., Bldg. 267, Schenectady, 5, N. Y. Price $5.00.

• • •On "Getters and Gettering Methods for Electronic Tubes," a 28-page booklet by **Kemet Laboratories Co., Inc.,** Madison Avenue and West 117th St., Cleveland 1, Ohio.

• • •On Ultra High Speed D.C. Relay, by **Stevens-Arnold Co.,** 22 Elkins St., So. Boston, Mass. Catalog 214.

• • •On transmitting and special-purpose tubes, by the **Newark Electric Company, Inc.,** 242 West 55th St., New York 19, N. Y.

• • •On "20 Steps to Perfect Amplification," by the **Amplifier Corporation of America,** 398-1 Broadway, New York 13, N. Y. Booklet 4802. Send 3¢ to cover postage,

• • •On a new wire recorder, by **Magnecord, Inc.,** 304 West 63rd St., Chicago, Illinois. Descriptive bulletin on Model SD-1.

• • •On a Pres-to-Heat soldering tool, by **Triton Manufacturing Company, Inc.,** East Haddam, Conn. Catalog No. 7.

• • •On power wire-wound resistors, by **International Resistance Company,** 401 No. Broad St., Philadelphia 8, Pa. Bulletin C-2.

• • •On the Simpson Model 260 volt-ohm-milliammeter, an Operator's Manual, by the **Simpson Electric Company,** 5200–18 West Kinzie St., Chicago 44, Ill. In Canada, Bach-Simpson Ltd., London, Ontario.

• • •On a new plug-in type of "Megger" Insulation Tester, by the **James G. Biddle Co.,** 1316 Arch St., Philadelphia 7, Pa. Preliminary Bulletin 21-46-46.

• • •On physical, chemical, and technical matters, Philips Research Reports edited by the Research Laboratory of N. V. Philips' Gloelampenfabrieken, Eindhoven, Netherlands. Address subscription inquiries to Elsevier Publishing Co., Inc., 215 Fourth Ave., New York 3, N. Y. Subscription, six issues, $5.00; single copies 1.00.

(Continued on page 63A)

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(*Continued from page 62A*)

Antenna for F.M. Broadcast Stations

It may look like a radio rocket of the future but actually the unit shown above is a "doughnut" antenna for f.m. broadcast stations being built by **General Electric Company** at its electronics plant in Syracuse, N. Y. Helen Dydyk, G-E employee, helps display its trim, symmetrical styling. The circular antenna serves to increase the power of the broadcast transmitter. Some f.m. stations use up to eight of these circular units on their antenna structure and increase the power gain over seven times.

Interesting Abstracts

• • •To **Sorenson & Company, Inc.**, of Stamford, Conn., comes Edward R. McCarthy as General Sales Manager. Mr. McCarthy is a graduate of Carnegie Tech (B.S.) and had sales and engineering experience with Pneumatic Products, Inc., General Motors, and with Sikorsky.

• • •The Vacuum Equipment Division of **Distillation Products, Inc.**, Rochester, N. Y. opens a sales and service office for the central states at 135 South LaSalle St., Chicago 5, Ill. Tom C. Comer is in charge.

• • •A recently inaugurated publication, "C.E.C. Recordings" for quarterly distribution has been announced by the **Consolidated Engineering Corporation**, 620 North Lake Avenue, Pasadena 4, Calif.

• • •A license has been issued to the Bell System and Western Electric Company covering patents on the cathode-follower circuit which are controlled by **Remco Electronic, Inc.**, of 33 West 60 Street, New York, N. Y. This cathode-follower circuit was widely used during the war in radar, loran navigation systems, industrial electronic controls and is an essential part of the microwave wireless-telephone system now being constructed.

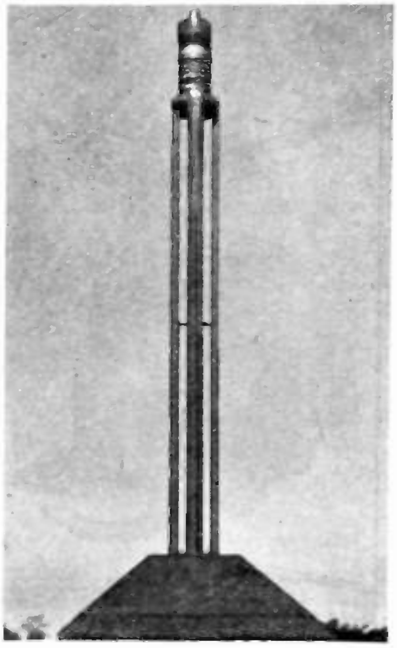
• • •To provide additional space required for the expansion of facilities, the **Solar Mfg. Corp.** has moved its general offices from New York City to its main Eastern plant at 1445 Hudson Blvd. North Bergen, N. J.

(*Continued on page 64A*)

The manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 63A)

F.M. "Tower" Transmitting Antenna



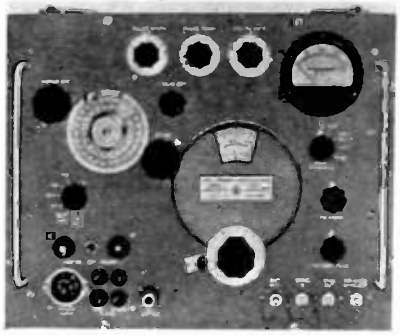
The Workshop Associates, Inc., 66 Needham St., Newton Highlands 61, Mass., announce a new type of f.m. transmitting antenna pictured above. Clean-cut performance is claimed for this new f.m. "Tower" antenna which eliminates complicated feed systems and elaborate mechanical structures.

It provides a mounting for a standard 300-mm. beacon. The single self-supporting tower structure is the antenna, with no protruding elements to increase wind and ice load. Weight of 183 pounds allows use of lighter and less expensive supporting structures; sections reduce installation problems.

The manufacturer claims highest gain per antenna height, equal or superior in gain to a 3-bay ½ wave spaced array of conventional types. Horizontally polarized by use of a new "wave-guide" principle of radiation; two short wave-guide sections arranged and fed at 90°. The azimuth pattern is circular to better than a ratio of 1.1 to 1 in power.

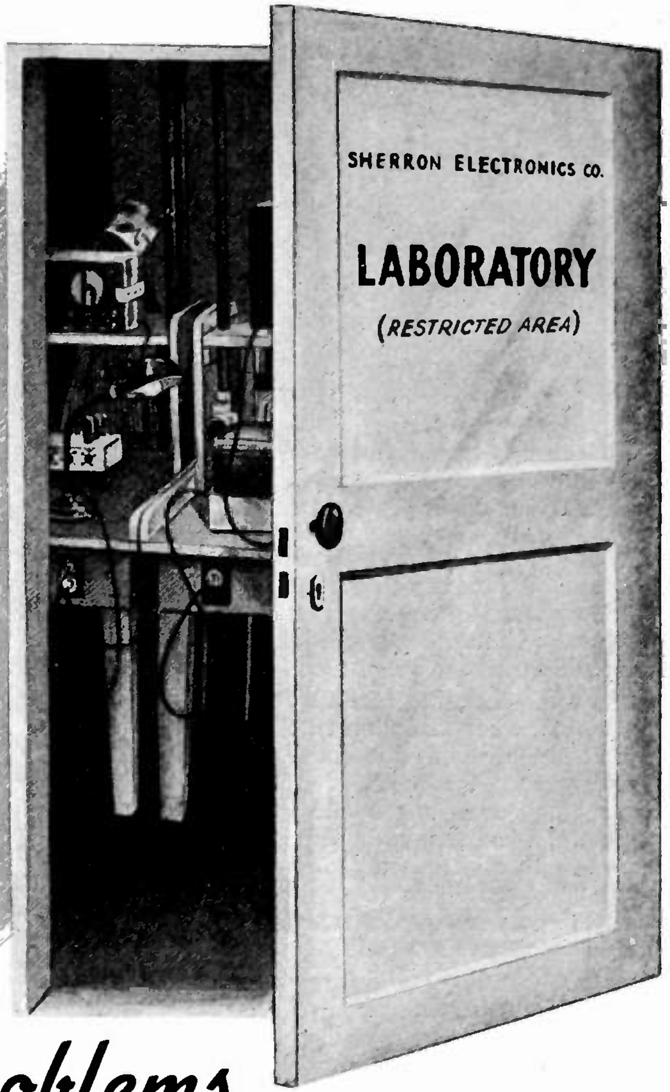
Ultra High Frequency Signal Generator

The **Hewlett Packard Company,** Palo Alto, California, is manufacturing a wide-band laboratory-standard signal generator in the range between 1800 and 4000 megacycles. It is stated to be the first instrument of its kind to provide direct-reading frequency and voltage scales, simplified controls, c.w., f.m., pulsed or delayed pulse output, in one small unit.



The generator utilizes a resonant-cavity, reflex-klystron oscillator. Radio-frequency output from this oscillator may be directly set and directly read, either in microvolts or decibels, on a simplified output dial. Any frequency between 1800 and 4000 megacycles is available on the large central tuning dial. It is not necessary to make voltage adjustments when frequency is changed, because of a coupling device which causes oscillator repeller voltage to automatically track all frequency changes. Accuracy of frequency calibration is within plus or minus 1%, and stability is of the order of 0.005% per degree centigrade in ambient temperature, the manufacturer reports. Identified as Model 616A UHF Signal Generator, the instrument is designed for almost any ultra-high-frequency measuring purpose.

(Continued on page 66A)



DOORWAY TO SOLUTIONS FOR *Electronics Problems*

America's destiny may well be determined by the vision, resourcefulness and researches of electronics scientists. The implications of the development of electronic applications are clear, even without definition. Speed, therefore, is a crucial factor in the evolution of electronics, whether as a tool or weapon . . . Keenly alert to this urgency, Sherron's scientists, physicists and mathematicians are massed in an ever-pressing assault on electronics problems. At their command is the most advanced equipment. Theirs is the experience of a host of different electronics enigmas clarified, of specialized electronics applications worked out to meet difficult and unusual operating conditions.

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1. ULTRA AND HYPER HIGH FREQUENCY TECHNIQUES
2. ELECTRONIC BALLISTICS
3. THERMIONIC EMISSION
4. HIGH VACUUM ELECTRONIC TUBES TECHNIQUES
5. RADAR: — (DETECTION — NAVIGATION)
6. ELECTRONIC CONTROL FOR DRONE AND GUIDED MISSILES

Sherron Electronics W2XDK

SHERRON ELECTRONICS CO.

Division of Sherron Metallic Corporation

1201 FLUSHING AVENUE • BROOKLYN 6, NEW YORK

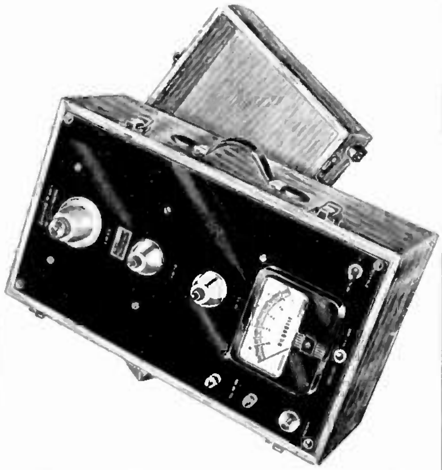
NEWS—NEW PRODUCTS

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 63A)

New High-Sensitivity Kilovoltmeters

Pictured below is the new #760-A kilovoltmeter, a typical unit of the new series of high-sensitivity kilovoltmeters specifically adapted for measurements in television and similar electronic circuits announced by the **Shallcross Manufacturing Company**, Collingdale, Pa.

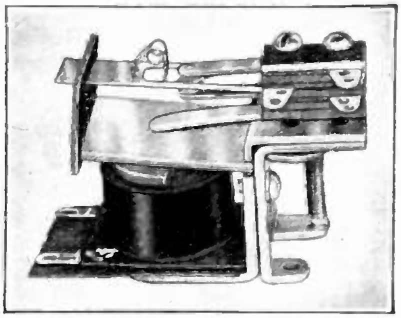


All of the eight instruments are portable and designed to draw little current from the circuits in making high-voltage measurements, and the line provides both d.c. types as well as a.c.–d.c. types in practically any required voltage combination.

The unit here shown has three scales of 5, 10, and 20 kilovolts, with a sensitivity of 10,000 ohms per volt. Thus, the instrument only draws 100 microamperes at full scale. A polarity-reversing switch is supplied and provision is made for connecting an external meter where required.

Snap-Action Switches

A complete line of snap-action switches is offered by **Guardian Electric Manufacturing Co.**, 1628 West Walnut St., Chicago 12, Illinois, in conjunction with the standard Guardian relays.



The snap-action feature is particularly suited to control applications that involve slow-moving mechanical devices or where a given stroke is required to provide quick, positive "make" or "break" contact action. It is claimed that chattering, arcing, intermittent contact pressure, and many other circuit and operating problems are eliminated with snap-action switches.

New Cathode-Ray Tube

The Tube Division of the Electronics Department, **General Electric Company**, Schenectady, N. Y., has announced a new cathode-ray electronic tube known as Type 7GP4 for direct-view television receivers and industrial oscilloscopes.

The new tube features a high deflection sensitivity rate. The deflection factor for two of the 7GP4 electrodes is 108 volts d.c. per inch, while the two remaining electrodes function at 89 volts d.c. per inch.

Both the focusing and deflecting methods employed by the 7GP4 are electrostatic. Maximum ratings of the new tube apply to 4000 volts. Grid-circuit resistance is 1.5 megohms.

Typical operating conditions of teh 7GP4: Anode No. 1 voltage, 1000 volts, plus or minus 20 per cent; Anode No. 2 voltage, 3000 volts; Grid No. 1 voltage 60 volts plus or minus 40 per cent; Anode No. 1 current—15 microamps, plus or minus 10 per cent.

(Continued on page 68A)

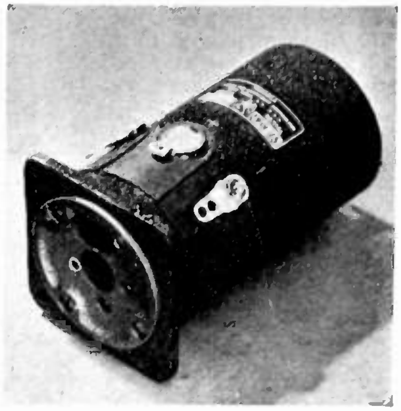
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 66A)

Servo Motors

The **Fairchild Camera and Instrument Corporation**, 88-06 Van Wyck Blvd., Jamaica 1, N. Y., has announced two servo motors, of either ½ inch or 1 inch corestack, designed for thyratron control operation from 115 volt/60 or 400 cycle a.c. Both motors feature 72-to-1 built-in gear reduction, armature resistance of approximately 100 ohms, and field excitation of 28 volts d.c.



Torque output of the ½-inch type at approximately 150 r.p.m. is 69 inch-ounce; 1-inch type, 150 inch-ounce. Field current is 0.15 and 0.23 ampere, respectively. The armature and gear box are mounted in ball bearings, and the backlash of the gear box is very low. Overall dimensions are 2″×2″×3″ and 2″×2″×3½″. Weight is less than a pound.

These servo motors are for use in all types of equipment where control is required for metering purposes, proportional follow-up systems, computing mechanisms, and stabilization systems.

New Enterprises

• • • A new enterprise, **Industrial Television, Inc.**, has been established at 36 Franklin Avenue, Nutley, N. J., to manufacture a direct-viewing television receiver with large screen for public viewing. Officers are: Horace Atwood, Jr., President and Chief Engineer; Robert L. Ringer, Jr., Secretary-Treasurer; Louis Rehak, Factory Manager; and Charles M. Puckette, Jr., Production Engineer.

• • • A new plant has been opened at Riverside, Calif. by **Colonial Radio Corporation** for the production of radios for West Coast distribution. Colonial is a subsidiary of Sylvania Electric Products, Inc.

• • • A new manufacturer, the **Kullman Manufacturing Company**, has commenced operations at 4307 Winona Court, Denver 12, Colo., for the production of a complete line of stock decalcomania transfers with application to radio and electronics. Write the company for descriptive booklet, "Decals for Electronics."

(Continued on page 69A)

News—New Products

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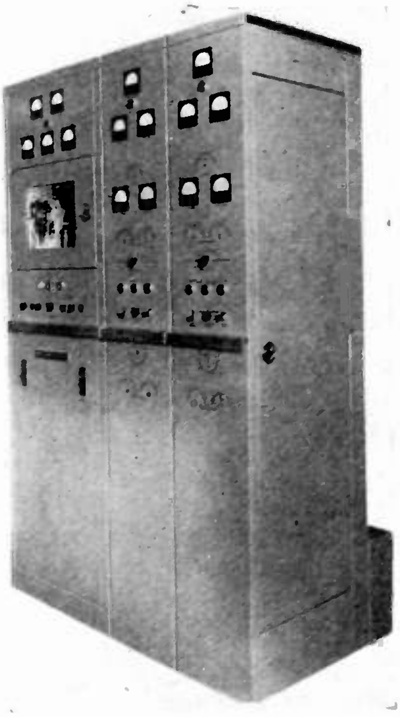
H.F. Point-to-Point Radio Transmitter



This new radio transmitter, rated at 3 kw. on c.w. operation and 2.5 kw. on voice operation, is designed for use in public service, private net, shore-to-ship, press service and government service communication. It is of all-aluminum cubicle construction consisting of a radio-frequency unit, modulator, and rectifier which may be assembled in a variety of combinations suitable to individual station requirements, and is available from the **Westinghouse Electric Corporation**, Box 868, Pittsburgh 30, Pa. Telegraph, voice, teleprinter, facsimile, or tone modulation are available using standard components.

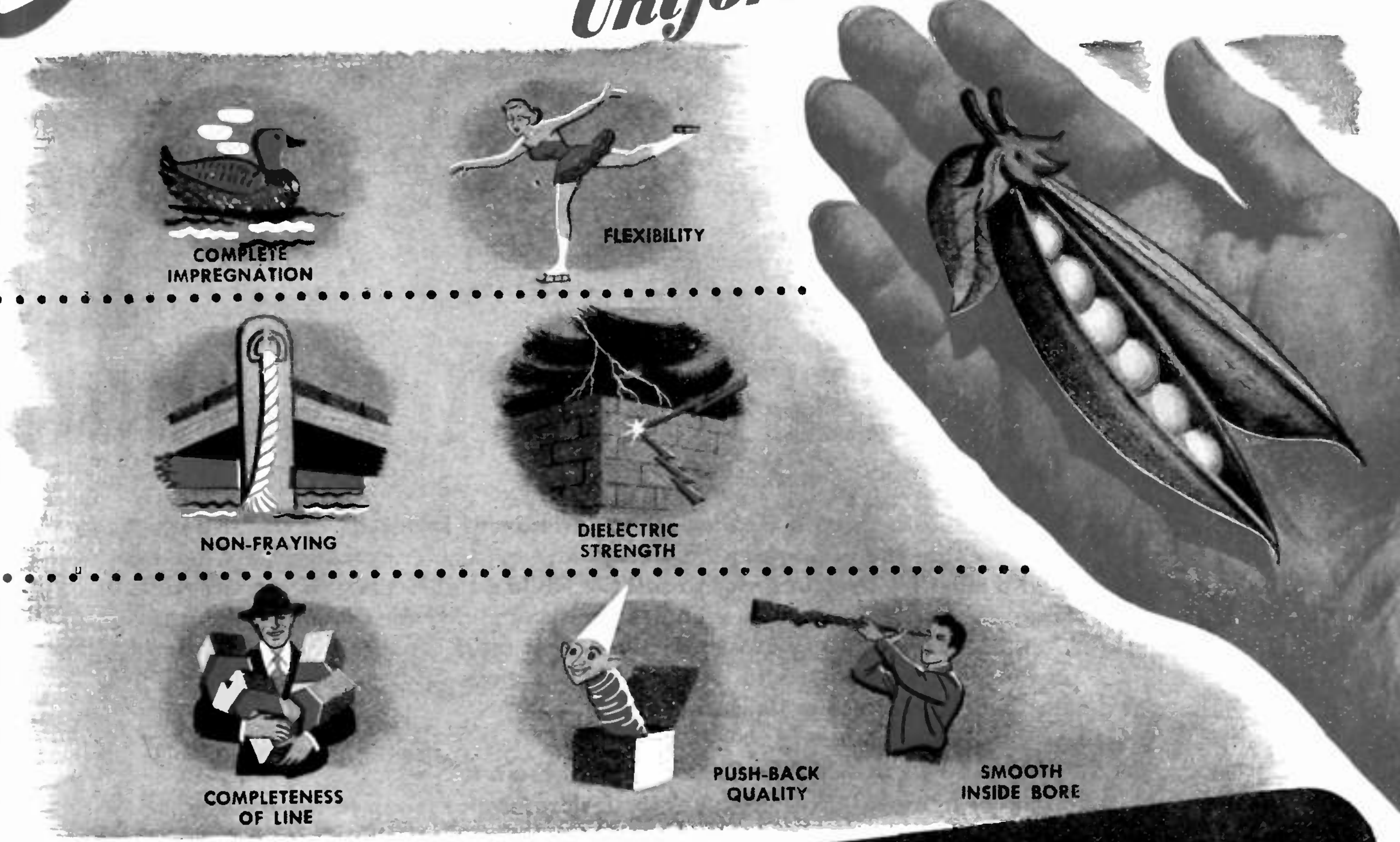
Moisture-proofed for operation under humid conditions, this point-to-point transmitter also features hermetically sealed chokes and vacuum capacitors, and low-loss insulation materials not subject to deformation at high temperatures.

The radio-frequency unit designed for an output load resistance of 60–80/600–800 ohms, operates at frequencies from 2 to 20 megacycles on the radio-frequency-amplifier principle. The excitation is supplied from a separate crystal oscillator or a frequency-shift exciter through a 70-ohm coaxial cable. The modulator provides an audio fidelity of plus or minus 1 decibel over the range of 200 to 4500 cycles. The rectifier, operating from a power supply of 210/230/250 volts, 3-phase, 50/60 cycles, is designed for continuous operation at rated power of two radio transmitters and two modulators at 100% modulation or equivalent.

INDEX AND DISPLAY ADVERTISERS

DISPLAY ADVERTISERS

8th among the features of DIEFLEX VARNISHED TUBING PRODUCTS is . . *Uniformity of Product*



LIKE two peas in a pod, every piece of Dieflex varnished tubing or sleeving is like the next one in its faithful adherence to the high standards of quality that have made this product a time and money saver for electrical manufacturers. Such features as ability to be cut evenly and cleanly, rapid return to roundness after cutting, and excellent flexibility, make Dieflex varnished tubing products an important factor in cutting manufacturing costs.

Dieflex varnished tubing and saturated sleeving, of finely braided cotton or inorganic glass fiber, have these helpful characteristics in all VTA and ASTM grades. They will help you because they will speed your production and cut assembly costs. Insist on Dieflex and be sure you are using the best.

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VTA Grade A-1 Magneto Grade Varnished Tubings—VTA Grade B-1 Standard Grade Varnished Tubings—VTA Grades C-1 and C-2 Heavily Coated Saturated Sleevings—VTA Grade C-3 Lightly Coated Saturated Sleevings—Heavy Wall Varnished Tubings and Saturated Sleevings.

MADE WITH BRAIDED GLASS SLEEVING BASE

VTA Grade A-1 Magneto Grade Varnished Fiberglas Tubings—VTA Grade C-1 Extra Heavily Saturated Fiberglas Sleevings—VTA Grade C-2 Heavily Saturated Fiberglas Sleevings—VTA Grade C-3 Lightly Saturated Fiberglas Sleevings — Silicone-Treated Fiberglas Varnished Tubings and Saturated Sleevings.

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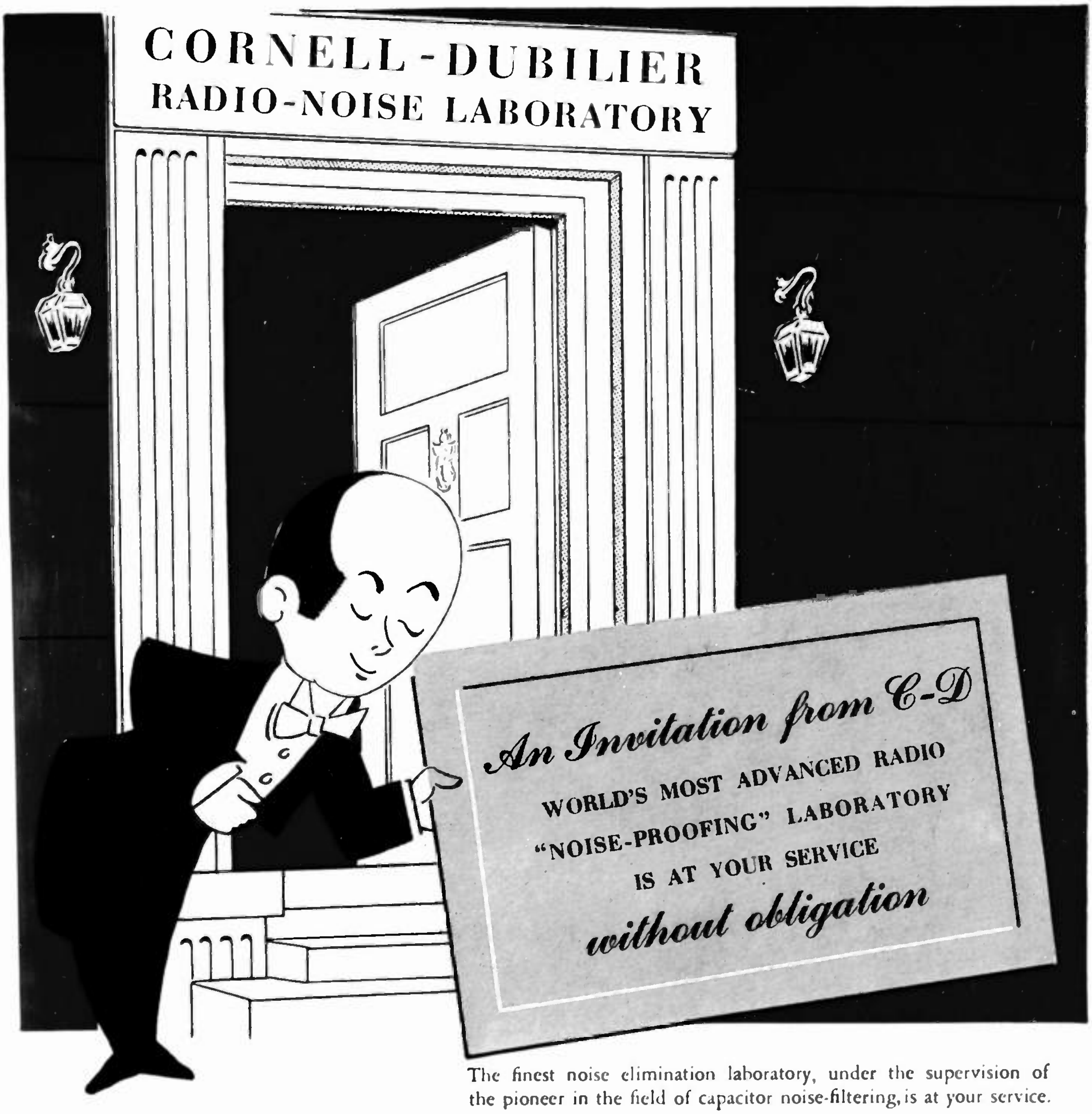

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For SIMPLE CONVERSION to A-C OPERATION

SEVERAL G-R instruments, equipped with a battery block to secure the maximum portability for field use, are often operated continuously for many hours in the laboratory, in testing and in production. For such uses an a-c operated power supply to replace the battery is a great convenience.

The Type 1261-A Power Supply was designed for this use. Mechanically and electrically it is interchangeable with a BA48 battery, supplying the same voltages and current. It is interchangeable with the BA48 battery in the Type 759-A or -B Sound Level Meter, the Type 720-A Heterodyne Frequency Meter and the Type 1231-A Amplifier & Null Detector.

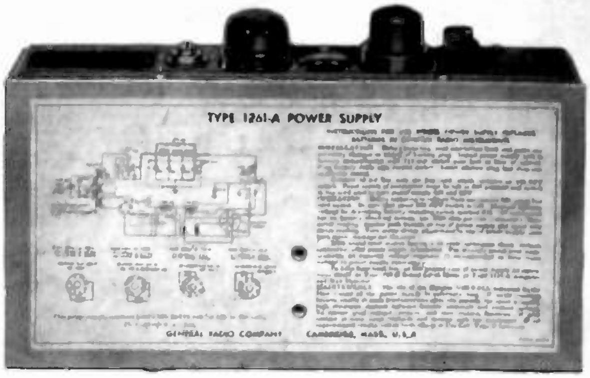
It also can be used as a general-purpose substitute for a BA48 battery. Its output is: FILAMENT SUPPLY: 1.5 or 3.0 volts up to 350 ma; PLATE SUPPLY, when used on a 115-volt 60-cycle line with normal filament current of 300 ma: 133 volts, open circuit; 107 volts at 3 ma; 89 volts at 5 ma; 72 volts at 7 ma; maximum output current of 8 ma.

A selenium rectifier and L-C filter with two flashlight cells floating across the output provide a low-impedance, well-filtered and regulated d-c filament supply. A relay opens the circuit when the instrument is not in use so that the life of the batteries is equivalent to their shelf life.

A conventional vacuum-tube rectifier and R-C filter provide the plate supply. A 4-terminal output socket fits the plug on the battery cable of the instruments which use the BA48 battery; octal selector plugs inserted into a socket on the power supply make it possible to select filament and plate voltages for various needs.

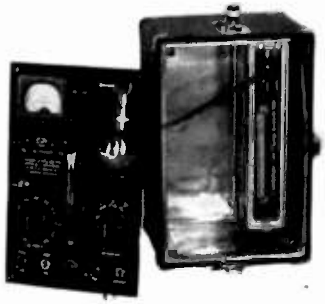
IMPORTANT — When ordering be sure to specify type and serial number of any of the three G-R instruments with which the supply is to be used; otherwise we will ship a selector plug which the user can wire to meet his individual requirements.

TYPE 1261-A POWER SUPPLY $95.00



TYPE 759-B SOUND-LEVEL METER

For all types of Noise Measurements. Accurate, very sensitive, anyone can operate.

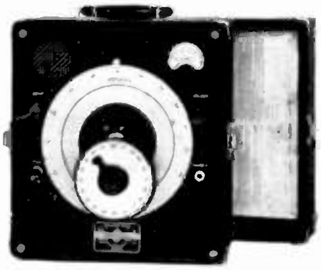


TYPE 1231-A AMPLIFIER & NULL DETECTOR

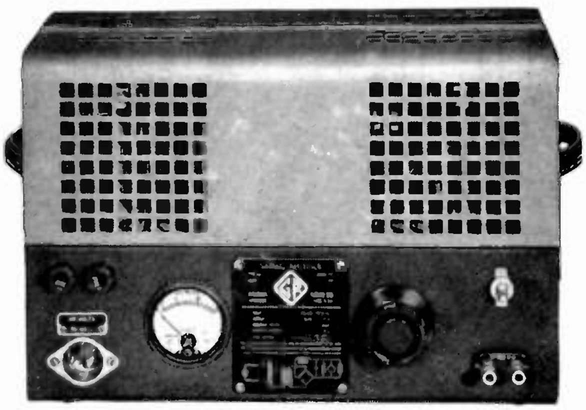
A high gain general-purpose laboratory amplifier and a sensitive visual null detector for bridge measurements.

TYPE 720-A HETERODYNE FREQUENCY METER

For measurement of frequencies by harmonic methods between 10 and 3,000 megacycles.



A-C SUPPLY TO REPLACE STORAGE BATTERIES



● The Type 1260-A VARIAC*-RECTIFIER effectively replaces the usual storage battery for general laboratory use. It is a convenient variable d-c voltage source for use in many types of experimental circuits for operation from 115-volt, 60-cycle lines.

Essentially this supply consists of a transformer with VARIAC*-controlled input, a selenium rectifier, an output filter and a d-c output meter.

The output voltage range is 0-10 volts at 4 amperes; maximum power of 40 watts; maximum current 4 amperes; no-load voltage 15. The power input at full 40-watt load is about 75 watts; the hum voltage at 10 volts, 4 amperes, is less than 100 millivolts or 1% of the output voltage, when the supply is operated on a 60-cycle line.

This supply is a very convenient unit for operating battery-driven equipment at voltages up to 10 volts. The ability to set the d-c voltage at any desired value between 0 and 10 is an added advantage in many cases.

TYPE 1260-A VARIAC*-RECTIFIER $125.00

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