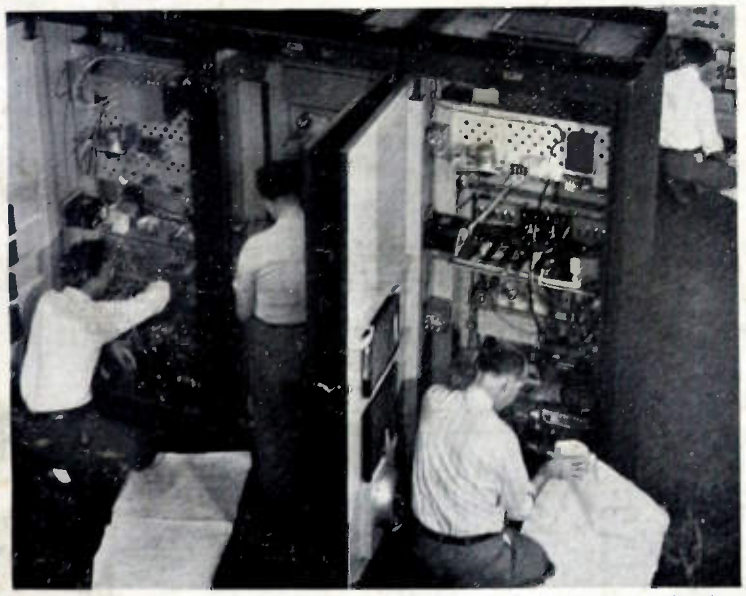
Proceedings of the I·R·E

A Journal of Communications and Electronic Engineering

April, 1951
Volume 39 Number 4



Allen B. DuMont Laboratories, Inc.

TELEVISION TECHNOLOGY AT WORK

The individual television transmitter—a complex electrical structure—requires the attention of a group of engineers during the assembly operations.

PROCEEDINGS OF THE I.R.E.

The Standards on Abbreviations for Radio-Electronic Terms, 1951, appear in this issue.

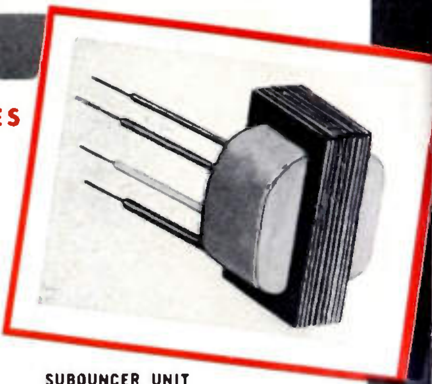
Table of Contents, Indicated by Black-and-White Margin, Follows Page 32A

The Institute of Radio Engineers

MINIATURE COMPONENTS FROM STOCK...

SUBOUNCER UNITS

FOR HEARING AIDS...VEST POCKET RADIOS...MIDGET DEVICES

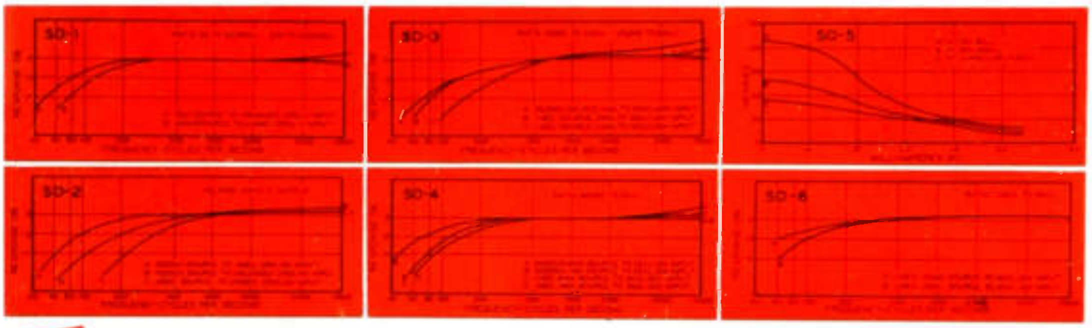


SUBOUNCER UNIT
Dimensions....9/16" x 5/8" x 7/8"
Weight .... .03 lb.

UTC Sub-Ouncer units fulfill an essential requirement for miniaturized components having relatively high efficiency and wide frequency response. Through the use of special nickel iron core materials and winding methods, these miniature units have performance and dependability characteristics far superior to any other comparable items. They are ideal for hearing aids, miniature radios, and other types of miniature electronic equipment. The coils employ automatic layer windings of double Formex wire . . . in a molded Nylon bobbin. All insulation is of cellulose acetate. Four inch color coded flexible leads are employed, securely anchored mechanically. No mounting facilities are provided, since this would preclude maximum flexibility in location. Units are vacuum impregnated and double (water proof) sealed. The curves below indicate the excellent frequency response available. Alternate curves are shown to indicate operating characteristics in various typical applications.

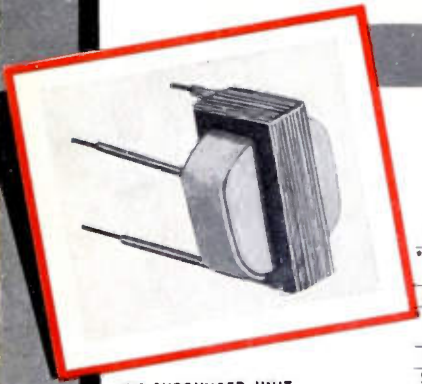
Type	Application	Level	Pri. Imp.	D.C in Pri.	Sec. Imp.	Pri. Res.	Sec. Res.	List Price
*SO-1	Input	+ 4 V U	200 50	0	250,000 62,500	16	2650	$6.50
SO-2	Interstage/3:1	+ 4 V.U	10,000	0	90,000	225	1850	6.50
*SO-3	Plate to Line	+ 20 V U	10,000 25,000	3 mil 1.5 mil.	200 500	1300	30	6.50
SO-4	Output	+ 20 V U	30,000	1.0 mil	50	1800	4.3	6.50
SO-5	Reactor 50 HY at 1 mil D.C 3000 ohms D.C. Res							5.50
SO-6	Output	+ 20 V U	100,000	.5 mil.	60	3250	3.8	6.50

*Impedance ratio is fixed, 1250:1 for SO-1, 1:50 for SO-3 Any impedance between the values shown may be employed.



SUB-SUBOUNCER UNITS

FOR HEARING AIDS AND ULTRA-MINIATURE EQUIPMENT

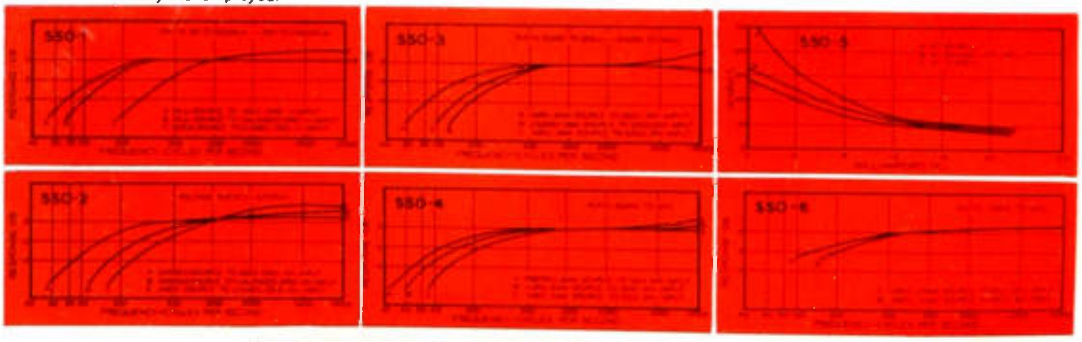


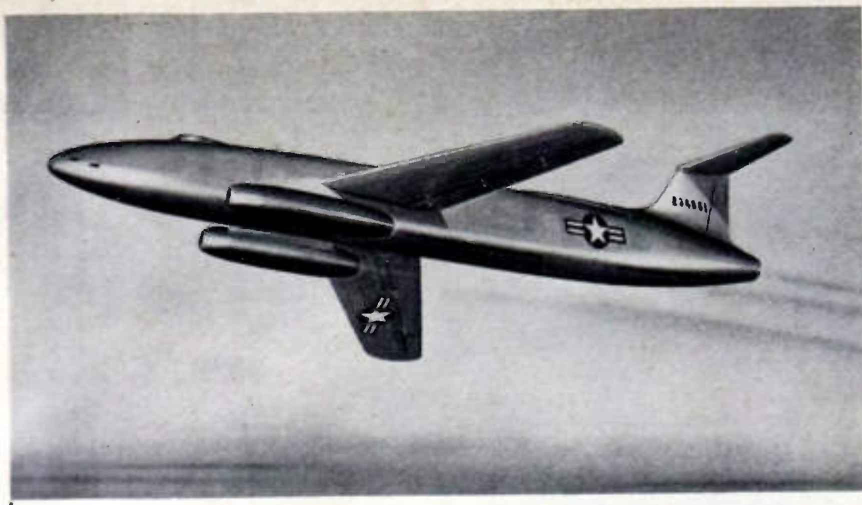
SUB-SUBOUNCER UNIT
Dimensions....7/16" x 3/4" x 5/8"
Weight .... .02 lb.

UTC Sub-SubOuncer units have exceptionally high efficiency and frequency range in their ultra-miniature size. This has been effected through the use of specially selected Hiperm-Alloy core material and special winding methods. The constructional details are identical to those of the Sub-Ouncer units described above The curves below show actual characteristics under typical conditions of application.

Type	Application	Level	Pri. Imp.	D.C. in Pri.	Sec. Imp.	Pri. Res.	Sec. Res.	List Price
*SSO-1	Input	+ 4 V U.	200 50	0	250,000 62,500	13.5	3700	$6.50
SSO-2	Interstage/3:1	+ 4 V.U	10,000	0	90,000	750	3250	6.50
SSO-3	Plate to Line	+ 20 V U	10,000 25,000	3 mil. 1.5 mil	200 500	2600	35	6.50
SSO-4	Output	+ 20 V U	30,000	1.0 mil.	50	2875	4.6	6.50
SSO-5	Reactor 50 HY at 1 mil D.C. 4400 ohms D.C Res.							5.50
SSO-6	Ouptut	+ 20 V.U.	100,000	.5 mil.	60	4700	3.3	6.50

*Impedance ratio is fixed, 1250:1 for SSO-1, 1:50 for SSO-3. Any impedance between the values shown may be employed.





NATIONAL CONFERENCE ON AIRBORNE ELECTRONICS

The IRE Professional group on Airborne Electronics joins with the Dayton Section in sponsoring the 1951 NATIONAL CONFERENCE ON AIRBORNE ELECTRONICS to be held at the BILTMORE HOTEL IN DAYTON, OHIO May 23-25, 1951. The Conference committee, working with research laboratories, universities, and electronic and aircraft industries have made arrangements for the largest and best Conference held to date! Over 70 papers will be presented covering over 14 general topics including communication, navigation, propagation, computers, instrumentation, antennas, components and vacuum tubes. Some of the titles to be presented are:

- Reliability Testing of Airborne Electronic Systems and Components
- Rating of Electronic Tubes at Very High Altitudes
- Long-Range Navigation Instrumentation
- Radiosonde Telemetering System
- The Use of Feedback Theory on the Remote Control of Aircraft
- Audio Problems in Aircraft Communication
- The Electronics Systems Engineer
- Fin Cap Zero-Drag Loran Antenna

In addition to a high-powered technical conference, complete with a display of commercial equipment, there will be an excellent social program.

For information write the Dayton Section, IRE c/o Far Hill, P. O. Box 44, Dayton 9, Ohio

NEW ENGLAND RADIO ENGINEERING MEETING

The 5th annual Radio Engineering Meeting of the North Atlantic Region will be held on Saturday, April 12, 1951 at the Copley Plaza Hotel, Copley Square, Boston.

Featuring the radio engineer's role in the present emergency, the technical program for this one-day event will include papers on Test Instruments, Color Television, High Frequency, Instrumentation and Radiation.

SOUTHWESTERN I.R.E. CONFERENCE

The Southwestern I.R.E. Conference will be held in Dallas on April 20-21 at Southern Methodist University.

Technical papers by outstanding feature speakers will be presented. Here is a partial list: "The Radiation of a Cylindrical Antenna," "Microwave Refractometer and Its Application to the Studies of the Structure of the Lower Atmosphere," "Instrumentation for Radiation Assay," "Radio Astronomy."

Write for further information

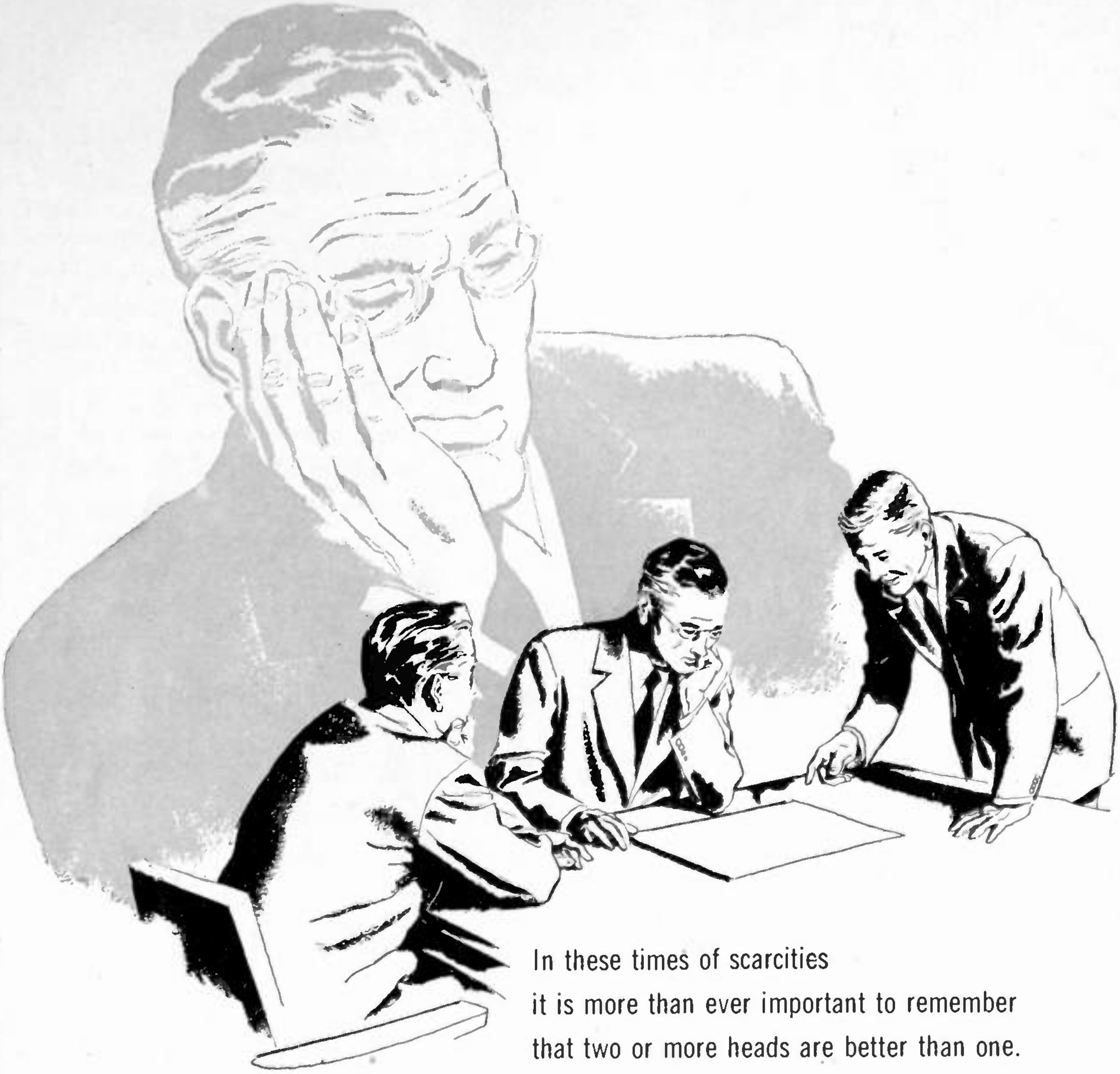
SPRING TECHNICAL CONFERENCE - CINCINNATI SECTION INSTITUTE OF RADIO ENGINEERS

The Spring Technical Conference will be held Saturday, April 14, 1951 at the Engineering Society Headquarters Building, Woodburn and McMillan Street, Cincinnati, Ohio. Advance registration and reservations for hotel accommodations and for the Luncheon and Banquet may be made by mail. Registration may also be made at the door the morning of the conference. Papers concerning UHF Television, Color Television and the Megacycle Meter will be presented.

ELECTRONIC MEETINGS

Proceedings of the I.R.E. April, 1951, Vol. 39, No. 4. Published monthly by The Institute of Radio Engineers, Inc., at 1 East 79 Street, New York 21, N.Y. Price per copy: members of the Institute of Radio Engineers $1.00; non-members $2.25. Yearly subscription price: to members $9.00; to non-members in the United States, Canada and U.S. Possessions $18.00; to non-members in foreign countries $19.00. 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



In these times of scarcities
it is more than ever important to remember
that two or more heads are better than one.
Your suppliers, for example, know a great deal
about their materials, how to select, specify and fabricate them.
No matter what you buy, it will pay you
to draw upon this knowledge.
It may be able to make scarce materials go further,
reduce costs, perhaps even speed up production.
AND of course for close and confidential collaboration
on copper and its alloys, and aluminum alloys,
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ACE HIGH

. . for miniaturization, mounting, and temperature problems

Here they come, right off the top of the deck, to fill in what's been needed—new ways of mounting subminiature capacitors in military electronic equipment!

You'll find side stud, end stud, threaded neck, and two types of side bracket capacitors in Sprague's new 16 page Engineering Bulletin 213-A.

These new Sprague-pioneered designs make even broader the world's most complete line of solder-seal terminal metal-encased subminiature paper capacitors.

And they're now available as standard in a 125°C. temperature rating Vitamin Q® capacitor series. Voltage ratings range from 100 to 1000 volts in both inserted tab and extended foil constructions.

And remember, Sprague Capacitors are the standard of dependability for critical electronic circuits. Write for your copy of Bulletin 213-A which gives the complete Sprague Subminiature Story.

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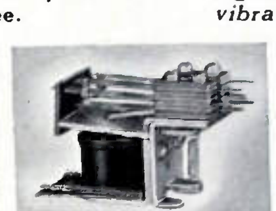
The Series 335 D.C. Guardian Relay shown above is available with the A.N. Connector Plug, Octal Plug and Lug Header hermetic seal *containers. Packs loads of power over a wide operating range, withstands the rigors of dust, moisture, salt air, temperature changes, vibration and impact.*

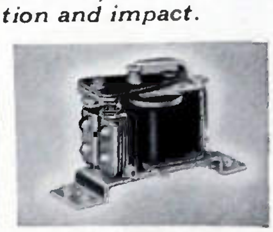
A.N. CONNECTOR PLUG HERMETIC SEALED CONTAINER

NEW CATALOG on Hermetically Sealed Guardian Relays with various containers is yours for the asking, cost-free.

Series 30 A.C.

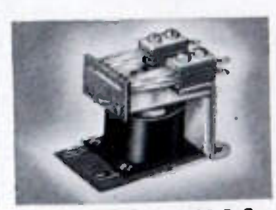


Series 210 A.C.—215 D.C.



Series 220 A.C.

Series 595 D.C.



Series 610 A.C.—615 D.C.

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GUARDIAN G ELECTRIC

1628-D W. WALNUT STREET CHICAGO 12, ILLINOIS

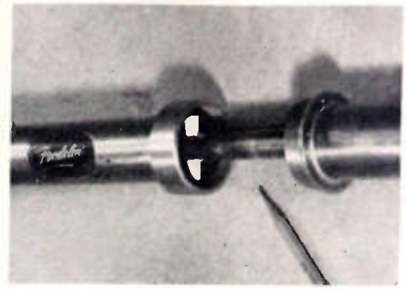
A COMPLETE LINE OF RELAYS SERVING AMERICAN INDUSTRY

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

Coaxial Transmission Line

The development of the "Series 800" reflectionless broadband rf air dielectric coaxial transmission lines is announced by the **Product Development Co., Inc.,** 507 Elm St., Arlington, N. J.



This line is supplied in standard twenty-foot assemblies in sizes up to $3\frac{1}{8}$ inches diameter with an "Air-tite" coupling designed for use in broad-band transmission service. Previous objections to coaxial systems which could not tolerate insulator discontinuities are now eliminated by the use of a new *Prodelin* compensated insulator structure supporting the center conductor and without projecting through the surface of the outer conductor.

"Series 800" line has been serving in commercial and military systems handling higher powers and providing lower VSWR values in applications up to 3,500 Mc for television, telephone, navigation, radar, and other critical transmission systems.

Replaceable Power Resistor

A new Greenohm power resistor with insulated safety knob and convenient Edison screw base is available from **Clarostat Mfg. Co., Inc.,** Washington St., Dover, N. H. This Type H3ON Greenohm is being used as an easily replaceable resistor or heater, particularly in the tropics and where high humidity is a working condition.

This replaceable resistor is characteristic of the flexibility of the Greenohm line with its wide range of wattages and resistances, terminals and mountings, whereby the user can select such features as will best meet his particular requirements. The general specifications for Greenohms are contained in Engineering Bulletin 113.

(Continued on page 7A)

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 6A)

Mobile Radio Equipment

A mobile radio unit has been announced by **Bendix Radio Div., Bendix Aviation Corp.**, Baltimore 4, Md.

Designed for adjacent channel operation, the MRT-5B communications unit combines a 10–12 watt FM transmitter, receiver, and power supply in a single wrap around housing. A shockmount is provided with this new unit which will operate on any one of two radio channels in the 152- to 162-Mc band.

The MRT-5B is adaptable for use by construction contractors, railroads, the petroleum industry, the maritime industry, and bus lines because of its design, which will permit installation on machines and vehicles where heavy shocks and vibration will be encountered. The same unit may be used at base stations as well as in mobile applications.

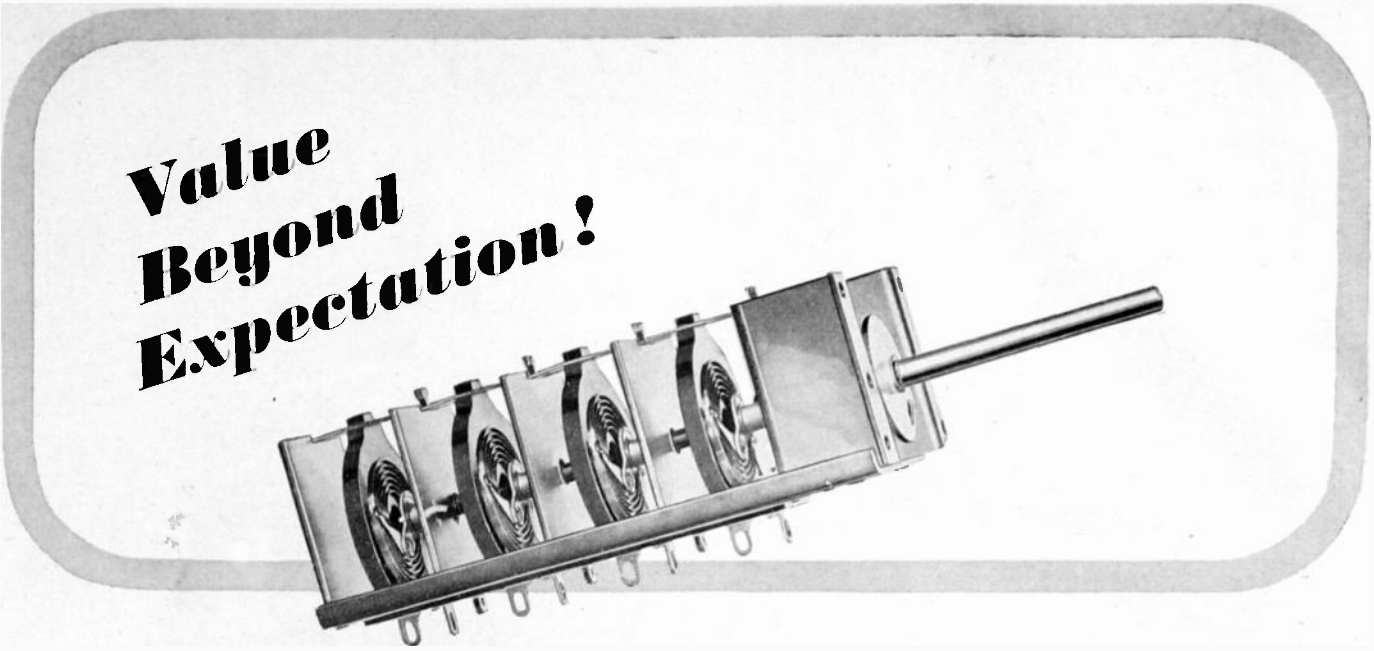
Additional information may be obtained by contacting R. B. Barnhill at Bendix.

Dynaural Amplifier

The 210-B Dynaural amplifier, an improved version of the 210-A, is available at a lower price from **Hermon Hosmer Scott, Inc.**, 385 Putnam Ave., Cambridge 39, Mass.

Technical specifications are: frequency response flat from 12 to 22,000 cps; harmonic distortion less than 0.5 per cent at full 20-watts output; first-order difference-tone intermodulation less than 0.1 per cent at full output; automatic loudness control to compensate for the insensitivity, of the ear at low volumes; hum level 84 db, or more, below full output; and the dynaural noise suppressor which virtually eliminates record scratch and rumble without affecting the music response.

(Continued on page 20A)



New Mallory Inductuner* Tunes All TV Channels In Three Revolutions

A modification in the mechanical arrangement of the Mallory Inductuner makes possible a wider application of the performance advantages of the continuous tuning principle. Now, even more TV manufacturers will be able to capitalize on the simplicity and economy of the Inductuner design.

Depending upon the requirements of your receiver, you can make your selection from . . .

1. The new three-turn Skip Band Mallory Inductuner—available in two, three or four sections. It tunes continuously from 50 to 88 mcs, then skips to 172 and tunes again to 220.
2. The new four-turn Skip Band Mallory Inductuner—available in two, three or four sections. It tunes continuously from 50 to 110 mcs, including FM bands, then skips to 170 and tunes again to 220.
3. The standard six-turn Mallory Inductuner—available in two, three or four sections. It tunes continuously from 50 to 220 mcs, covering TV channels and the FM bands.

That's value beyond expectation!

Write for detailed information on the Inductuner that meets your specific requirements . . . and for technical data on the new front end designs developed around the Inductuner by Mallory engineers.

Outstanding Advantages of the new Mallory Spiral Inductuner:

1. A single control for easy selection and fine tuning of any television or FM channel.
2. Easily adapted to UHF converter use.
3. Excellent stability eliminates frequency drift.
4. Supplied in three- or four-section designs.
5. Far more quiet operation; permits high signal-to-noise ratio in front end designs.
6. Free from microphonics.
7. Greater selectivity on high frequency channels.
8. Eliminates "bunching" of high band channels.
9. Simplifies front end design and production.
10. Reduces assembly costs.

**Reg. trade mark of P. R. Mallory & Co., Inc., for inductance tuning devices covered by Mallory-Ware patents.*

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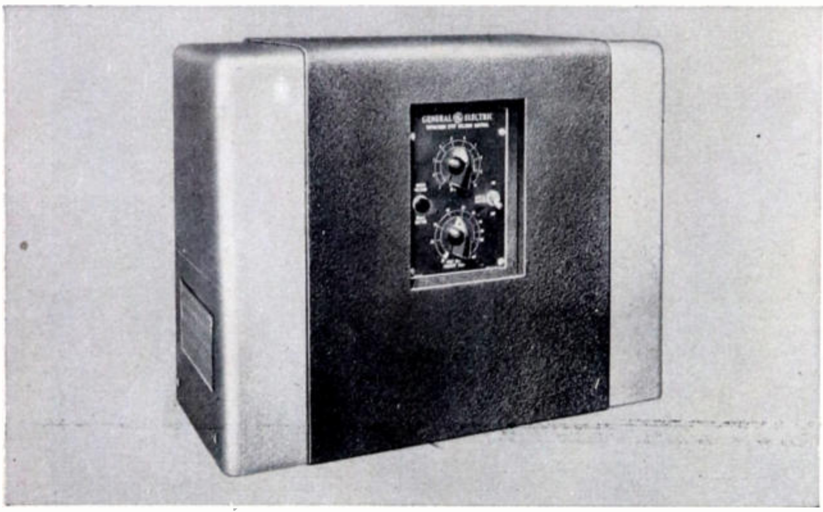
ELECTRONICS

Designers



MAKE 16 GROUND CONNECTIONS IN 1 MINUTE!

Low-resistance joints that hold at over 125°C easily made with

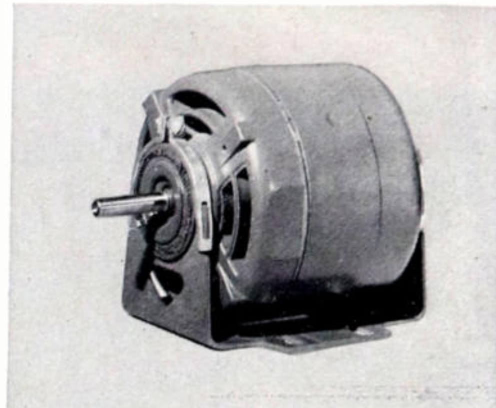
G-E PRECISION CONTROL FOR RESISTANCE WELDERS

Operators are making sixteen ground connections a minute to a television-receiver chassis with G. E.'s precision-control resistance welding method.

The compact electronic spot-welding control shown here has been specifically designed for use in conjunction with small bench welders or tongs and thus is ideally suited for many of the otherwise expensive assembly operations encountered in the manufacture of electronic equipment.

The panel provides for welding-current to control the amount of heat produced in the welds. Once set, successive welding currents remain constant to assure accurate and consistent welding of connections.

Complete data in Bulletin GEA-4175.



NEW! Unit-Bearing Motor for fans and blowers

- all angle operation
- improved appearance
- provision for 4-way mounting
- quiet operation
- requires no additional lubrication
- adjustable-speed operation available

Available in ratings from 25 millihorsepower to 1/12 horsepower to match many fan or blower sizes, this new G-E unit-bearing motor uses a new lubrication system and bearing design that permit reliable operation in any position. For extremely quiet operation, resilient cradle-base or end-ring mounting may be supplied. Suitable control is available for two-speed or adjustable-speed operation. More data in Bulletins GEA-5338 and GEC-219A.

GENERAL ELECTRIC

667-11

Digest

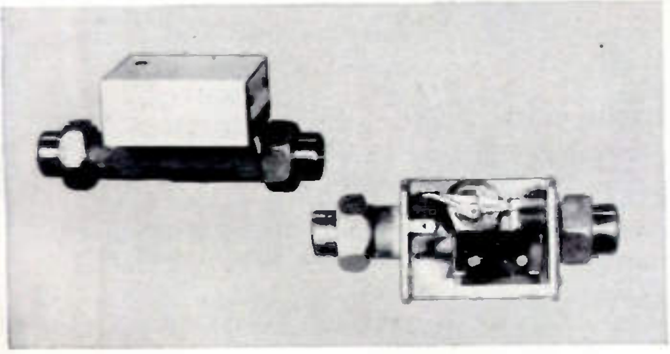
TIMELY HIGHLIGHTS ON G-E COMPONENTS

replace tubes BEFORE THEY FAIL! —record life with G-E time meters

A vacuum tube can usually be replaced *before* it fails if you have an accurate indication of operating time on the electronic device on which the tube is used.

G-E time meters, with dependable Telechron* motor drive, record operating time in hours, tenths of hours, or minutes, and are supplied for 115-, 230-, or 460-volts. The molded Textolite† case harmonizes with other G-E 3½-inch instruments mounted on the same panel. For more information, including dimensions, write for Bulletin GEC-472.

*Reg. T. M. Telechron, Inc. †Reg. T. M. General Electric Co.

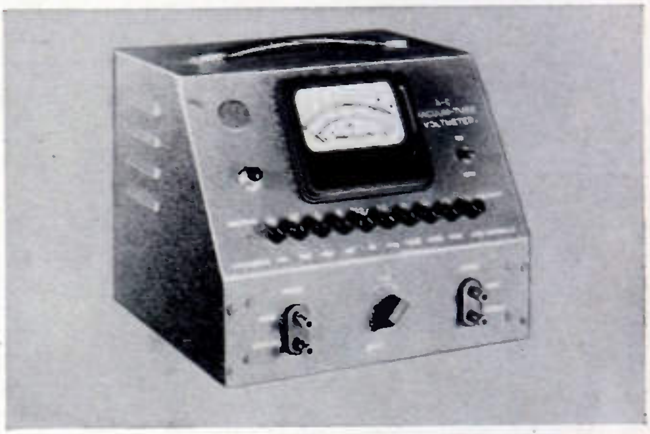


sure protection against overheating!

This G-E flow interlock opens the electric circuit of your water-cooled components when water flow is lower than a preset minimum, closes it when flow is above this point.

Depending on adjustment, the interlock will actuate the electric contact for any flow between ½ and four gallons per minute. Cut-in, cut-out differential is 0.1 gpm.

Ratings: 10 amps, 120 or 240 volts a-c; maximum water-line pressure is 125 lb./sq. in. Unit is bronze with standard ½-inch fittings, is easy to install and adjust. See Bulletin GEC-411.



select 10 ranges INSTANTLY with this HIGH SENSITIVITY VTVM

CALIBRATED RANGES: .001 to 300 volts (10 cycles to 1.5 mc.); −52 to +52 db (ref. level −1 mw at 600 v.)

Just about everything you could ask for in a high-sensitivity vacuum tube voltmeter! Frequency range of this G-E Type AA-1 instrument is substantially flat from 10 cycles to one megacycle with voltage ranges of 0-.01, 0-.03, 0-0.1, 0-0.3, 0-1.0, 0-3.0, 0-10, 0-30, 0-100, 0-300, decibels from −52 to +52 in 10 ranges.

Ten-position pushbutton switch instantly selects range without passing through intermediate stages. This vacuum-tube voltmeter is stable, has high impedance input, uses full-wave rectification, and has an amplifier output of 3 volts. More in Bulletin GEC-461.

General Electric Company, Section F 667-11
Apparatus Department, Schenectady 5, N. Y.

Please send me the following bulletins:

Indicate
V for reference only
X for planning on immediate project

- ☐ GEA-4175 Welding control
- ☐ GEA-5338 Fan motors
- ☐ GEC-219A Fan motors
- ☐ GEC-411 Flow interlock
- ☐ GEC-461 Vacuum-tube voltmeter
- ☐ GEC-472 Time meters

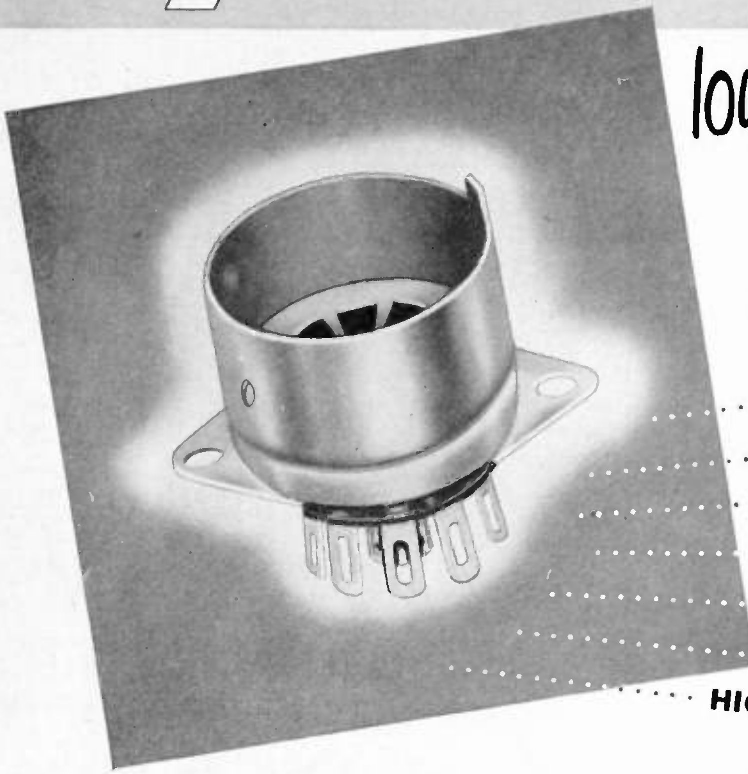
Name ____________________

Company ____________________

Address ____________________

City ____________________ State ____________________

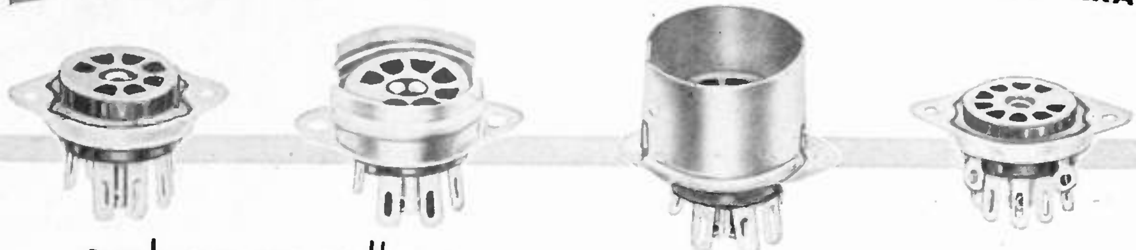
MYCALEX



low loss miniature
TUBE SOCKETS

OFFER ALL THESE ADVANTAGES:

- CLOSER TOLERANCES
- LOWER DIELECTRIC LOSS
- HIGH ARC RESISTANCE
- HIGH DIELECTRIC STRENGTH
- GREAT DIMENSIONAL STABILITY
- IMMUNITY TO HUMIDITY
- HIGH SAFE OPERATING TEMPERATURE



-cost no more than
PHENOLIC TYPES

These glass-bonded mica sockets are produced by an exclusive MYCALEX process that reduces their cost to the level of phenolic sockets. Electrical characteristics are far superior to phenolics while dimensional accuracy and uniformity exceed that of ceramic types.

MYCALEX miniature tube sockets, available in 7-pin and 9-pin types, are injection molded with great precision and fully meet RTMA standards. They are produced in two grades, described as follows, to meet diversified requirements.

MYCALEX 410 is priced comparable to mica-filled phenolics. Loss factor is only .015 at 1 mc., insulation resistance 10,000 megohms. Conforms fully to Grade L-4B under N.M.E.S. JAN-1-10 "Insulating Materials Ceramic, Radio, Class L."

MYCALEX 410X is low in cost but insulating properties greatly exceed those of ordinary materials. Loss factor is only one-fourth that of phenolics (.083 at 1 mc.) but cost is the same. Insulation resistance 10,000 megohms.

MYCALEX TUBE SOCKET CORPORATION
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CORPORATION OF AMERICA
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Telephones have changed....

...and in this era of engineering progress MODERN ELECTRONICS LOOK TO HI-Q*

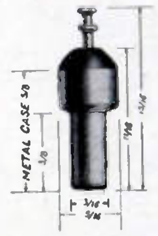
Capacitors • Trimmers • Choke Coils • Wire Wound Resistors

Yes, telephones have changed, and countless developments have played a part in electronic progress since the day of those old stem winders on the wall. Compactness, engineering precision and never-failing dependability are now demanded where the only question once was, will it work at all? In meeting these modern demands of modern electronics for modern ceramic components, **HI-Q** has led the way.

The **HI-Q** trademark is unquestioned assurance of capacitors, trimmers, choke coils and wire wound resistors that are uniformly dependable in every respect and rigidly meet specifications and tolerances. As the leading specialists in the ceramic field, **HI-Q** has come to be regarded by producers of radio, television, communications and other electronic equipment, as their best source of technical assistance in developing new components to meet the special needs of any circuit. **HI-Q** engineers are at your service any time you see fit to call them.

JOBBERS—ADDRESS: 740 Belleville Ave., New Bedford, Mass.

METAL CLAD STANDOFF



(Illustration Actual Size)

Ceramic tube of this quick mounting capacitor is enclosed in Cadmium plated metal case with special end seal for protection against humidity and temperature changes. Capacity 1500 mmf ± 500 mmf.

BETTER 4 WAYS

- PRECISION
- UNIFORMITY
- DEPENDABILITY
- MINIATURIZATION

HI-Q*

* Trade Mark Registered, U. S. Patent Office

Electrical Reactance Corp.
OLEAN, N. Y.

SALES OFFICES: New York, Philadelphia, Detroit, Chicago, Los Angeles

PLANTS: Olean, N. Y., Franklinville, N. Y. Jessup, Pa., Myrtle Beach, S. C.

Presenting hp PRECISION EQUIPMENT

...THE BASIC TOOLS YOU

–hp– 608A VHF SIGNAL GENERATOR

SPECIFICATIONS

FREQUENCY RANGE: 10 to 500 mc. in 5 bands.
ACCURACY: Calibration ±1%. Re-setability better than 1 mc, at high frequencies. Total scale length approx. 90″.

OUTPUT: 0.1 μv to 1.0 v. continuously variable. Calibrated in volts and dbm.
IMPEDANCE: 50 Ω. Maximum VSWR 1.2.
ACCURACY: ±1 db entire range.

MODULATION:
AMPLITUDE: From 0 to 90% indicated by front panel meter.
ENVELOPE DISTORTION: 1% to 30% modulation.
INTERNAL: Fixed modulation at 400 and 1,000 cps.
EXTERNAL: Any frequency 50 cps to 1 mc. 4.0 v. input.

EXTERNAL PULSE: Positive, 4 v. peak. Good pulse shape. Square wave to 1 μsec length (At 100 mc. and above).

LEAKAGE: Less than 1 μv.

RESIDUAL FM: Not over .0025% at 30% modulation.

POWER: 115/230 v. 50/60 cps. 150 watts.

SIZE: 12″ x 14″ x 18″ deep. –hp– grey finish. Cabinet mounting.

PRICE: $850.00 f.o.b. Palo Alto.

Data Subject to Change Without Notice

VHF SIGNAL GENERATOR

10 to 500 mc

High power output...Constant internal impedance...Wide frequency range...Broad modulation capabilities...Master oscillator power amplifier circuit...Microsecond pulses ...Small residual FM...CW, AM or pulsed output

Here is a new general purpose laboratory generator of broadest application. It offers a directly calibrated output from 0.1 μv. to 1 v. for measuring gain, selectivity, sensitivity or image rejection of receivers, I-F amplifiers, broad band amplifiers and other VHF equipment. The 1 v. output (to a 50 ohm load) is available throughout the entire frequency range for driving bridges, slotted lines, antennas, filter networks, etc. The output circuit is directly calibrated in volts and dbm for fast reading. No charts are necessary.

DIRECT CALIBRATION

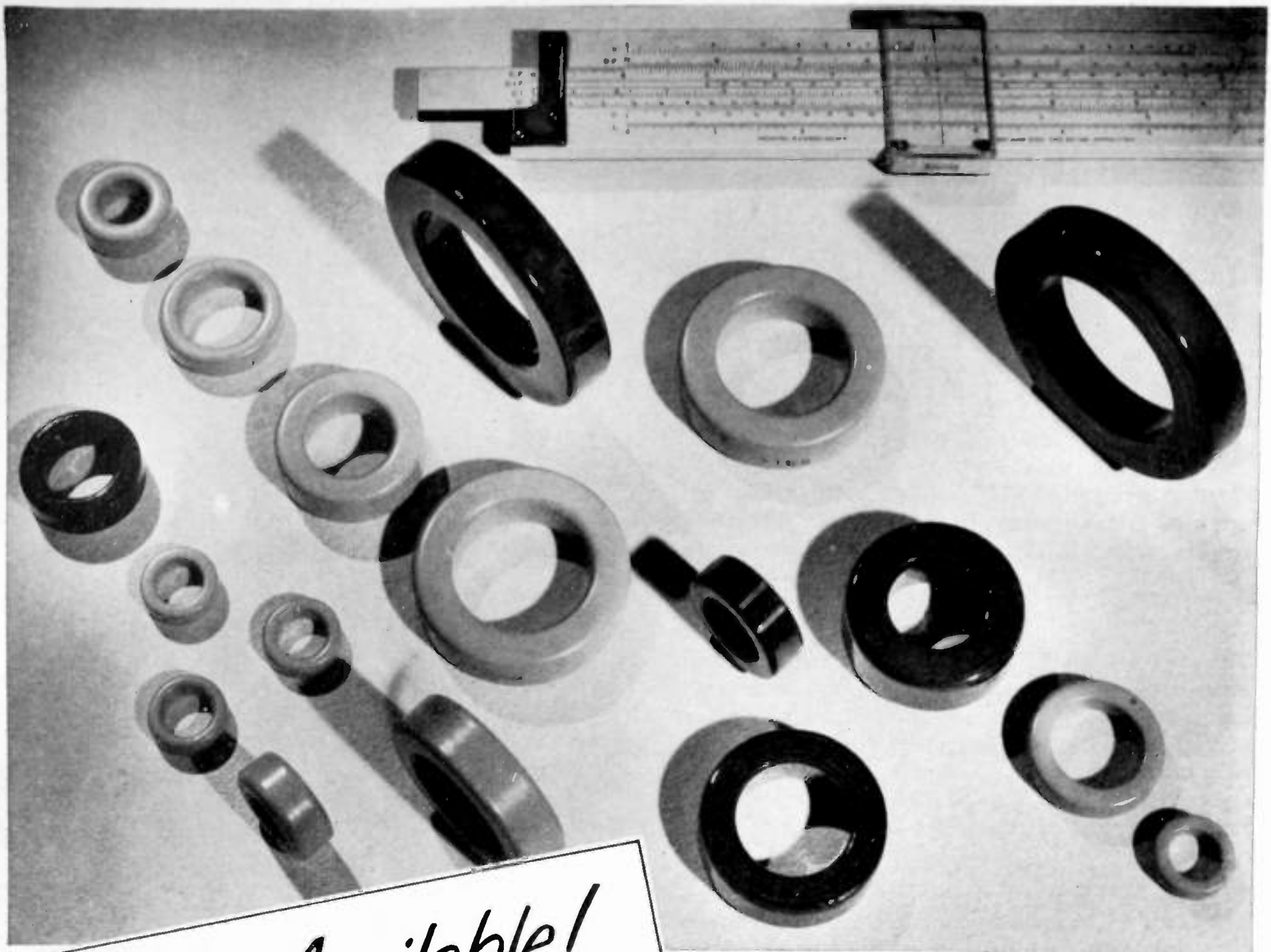
Frequencies from 10 to 500 mc. are covered in 5 bands, and calibrated directly in mc. on a drum-type dial having effective scale length of 90″. The single-dial, ball-bearing frequency control insures maximum convenience and accuracy in tuning and re-setting.

Master oscillator and power amplifier circuits are enclosed in a heavy cast aluminum shield, insuring high stability and low electrical leakage.

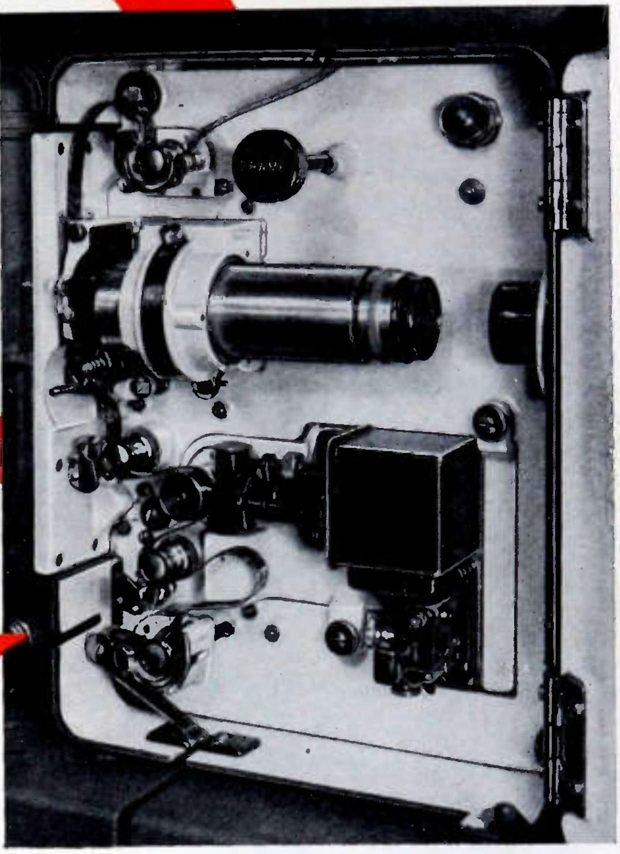
–hp– 417A VHF DETECTOR

This new *–hp–* instrument is a super-regenerative (AM) receiver covering all frequencies between 10 and 500 mc. in 5 bands. It is designed for use with the *–hp–* 803A VHF bridge. It offers 5 μv sensitivity over entire band, quick, easy operation, and a direct-reading frequency control. The instrument is thoroughly shielded, and is suitable for general laboratory use; for making approximate frequency checks, determining noise, interference, etc. Price $200.00 f.o.b. Palo Alto.

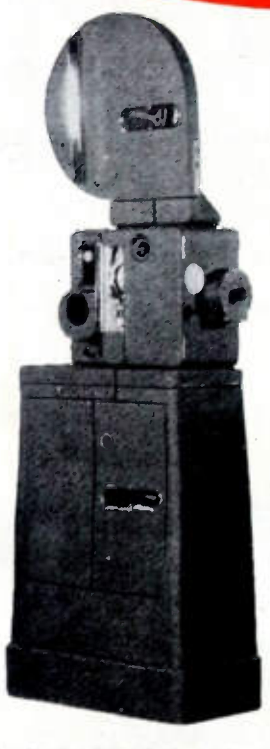
HEWLETT hp PACKARD



Look into this PROFESSIONAL Telecast Projector *and see years of Dependable Service*



The GPL Model PA-100—a 16-mm Studio Projector



The Model PA-100 is a 16-mm projector consistent with the professional character of television station operation. Its enclosed 4,000 foot film magazine provides for 110 minutes of projection—an entire feature.

Sharper Pictures . . . Finer Sound From Any Film in Your Studio

The importance of 16-mm film in television programming has called for new standards of projection quality and dependability. The GPL Model PA-100 is the first projector designed and built specifically for television studio use. It is a heavy-duty film chain projector for operation with any full-storage type film pick-up.

The professional, sprocket-type intermittent, similar to that used in the finest 35-mm equipment, is quiet and trouble-free. It provides a vertical stability of better than 0.2% over years of service. Film is protected—tests show more than 4,000 passages without noticeable film wear.

The high quality optical system resolves better than 90 lines per mm, with illumination so uniform that corner brightness is at least 90% of center. With a 1,000 watt light source, the projector delivers 100 foot-candles to the camera tube. The sound system provides a frequency response truly flat to 7,000 cps, with flutter less than 0.2%.

The Model PA-100 is one of a complete line of GPL 16-mm television studio and theatre projectors built to highest 35-mm standards.

WRITE, WIRE OR PHONE FOR DETAILS

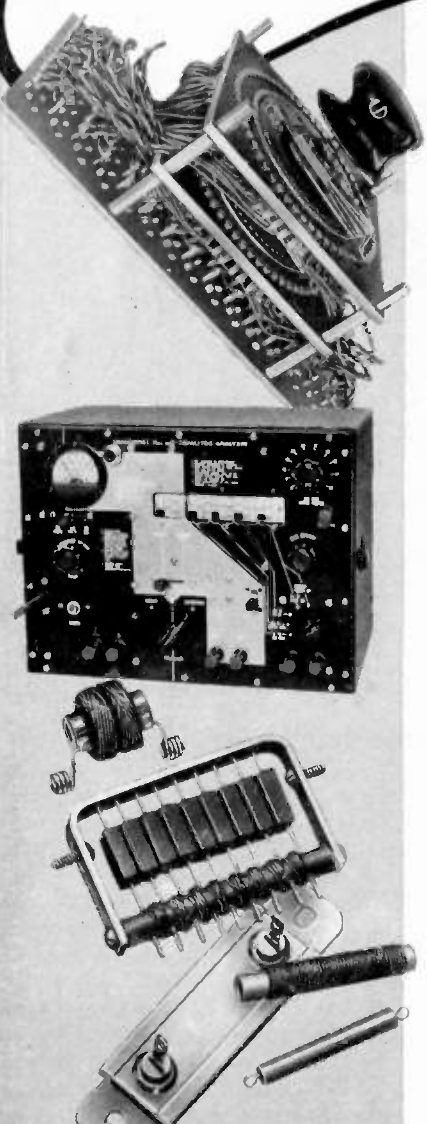
General Precision Laboratory
INCORPORATED
PLEASANTVILLE NEW YORK

TV Camera Chains • TV Film Chains • TV Field and Studio Equipment • Theatre TV Equipment

A RELIABLE SOURCE FOR YOUR

Custom Built

Electric-Electronic Specialties



Leading equipment manufacturers find that it pays to turn specialized assignments over to Shallcross for development, design or production . . .

From critical components to sub-assemblies and instruments, Shallcross' broad experience and precision facilities assure better results . . .

Often, they assure an appreciable cost saving as well.

- A capable staff of electrical, electronic, mechanical, chemical and instrumentation engineers . . .
- A fully equipped plant . . .
- Plus over 20 years of specialization in high quality products for military, industrial and public utility use . . . are here at your disposal.

AMONG RECENT SHALLCROSS CUSTOM-BUILT ASSIGNMENTS HAVE BEEN:

ROTARY SWITCHES
POTTED AND THERMALLY-CONTROLLED R-C NETWORKS
PRECISE DECADES AND NETWORKS FOR COMPUTER DEVICES
CALIBRATING INSTRUMENTS FOR STRAIN GAUGE BRIDGES
HIGH RESISTANCE STANDARDS
CRITICAL COIL ASSEMBLIES
HERMETICALLY SEALED CHOKES
HIGH-VOLTAGE MEASURING EQUIPMENT, ETC.

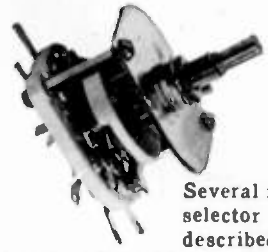
SHALLCROSS

ENGINEERS
DESIGNERS
MANUFACTURERS

SHALLCROSS MANUFACTURING CO.

COLLINGDALE, PA.

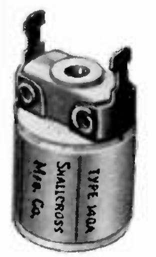
Something New



NEW OVAL SELECTOR SWITCHES

Several new oval rotary selector switches are described in Bulletin L13 just issued by the Shallcross Manufacturing Co., Collingdale, Pa. Six basic plates and three rotor types produce switches having from one to three poles per deck or gang and with other desired mechanical and electrical details. As many as 18, 9 or 6 positions may be obtained in single-, double-, or triple-pole types respectively. These may be single-, double-, or triple-pole decks exclusively or a combination of different types.

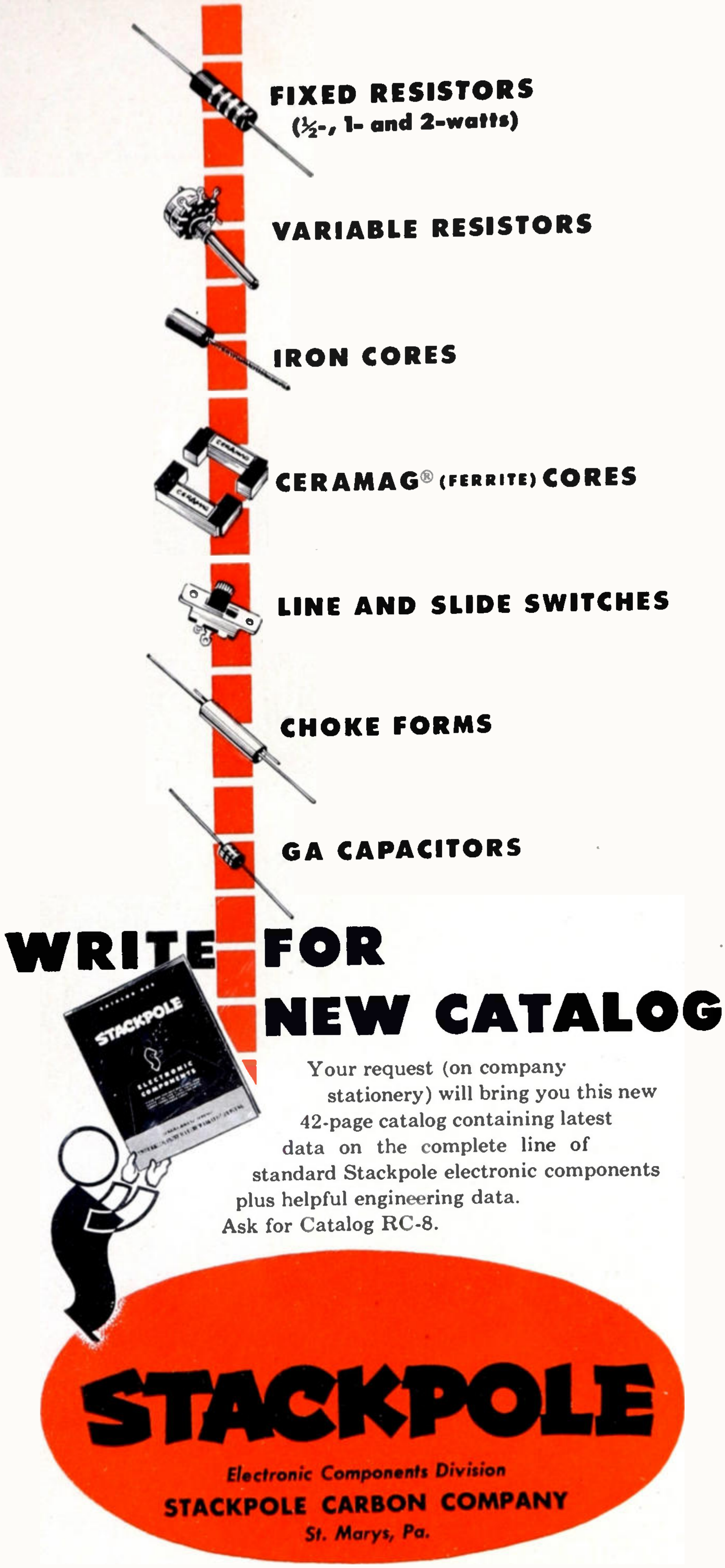
VERTICAL STYLE PRECISION RESISTORS FOR JAN USES



Improved vertical style precision wire-bound resistors for use where mounting requirements make it desirable to have both terminals at the same end of the resistor have been introduced by the Shallcross Manufacturing Co., Collingdale, Pa. These units provide a longer leakage path from the mounting screws to the terminals. Known as Shallcross Types BX120, BX140, and BX160, they are designed to meet JAN requirements for styles RB40B, RB41B and RB42B respectively. For commercial uses, the resistors carry somewhat higher ratings than for JAN applications. Wire leads instead of terminals can be furnished if desired. Complete details will gladly be sent on request to the manufacturer.

FLAT, METAL-ENCASED WIRE-WOUND RESISTORS

Flat, metal-encased, Type 265A wire-wound power resistors introduced by the Shallcross Manufacturing Company, Collingdale, Pa., are space wound, have mica insulation, and are encased in aluminum for mounting flat against a metal chassis. At 175° C. continuous use they are conservatively rated for 7½ watts in still air and 15 watts when mounted on a metal chassis. Write for Bulletin 122.



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 7A)

Simplified Camera Chain

A new type of image orthicon camera chain designed to increase the efficiency and quality of TV camera work is announced by **General Precision Laboratory, Inc.**, 63 Bedford Ave., Pleasantville, N. Y.

Four basic elements, instead of the normal six, make up a single camera chain: image orthicon camera (above), camera control unit, synchronizing pulse generator and camera power unit.

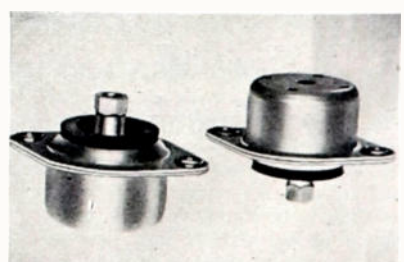
Camera weighs 75 pounds and measures $10\frac{3}{4}$ inches × $12\frac{1}{2}$ inches × 22 inches. Motor controlled iris permits instant adjustment to changing light conditions and eliminates reaching around camera. Iris can be controlled from rear of camera, beneath integral view finder, or from camera control unit.

All cameraman controls are located on rear panel, plus right-hand side. Operating controls used only infrequently have been moved out of the way.

Fast focusing of the camera results from coordinating turret control and focus adjustment on concentric shafts. Focus adjustment of all lenses is uniform; the same rotation of focus control produces the same shift in plane of focus for all lenses.

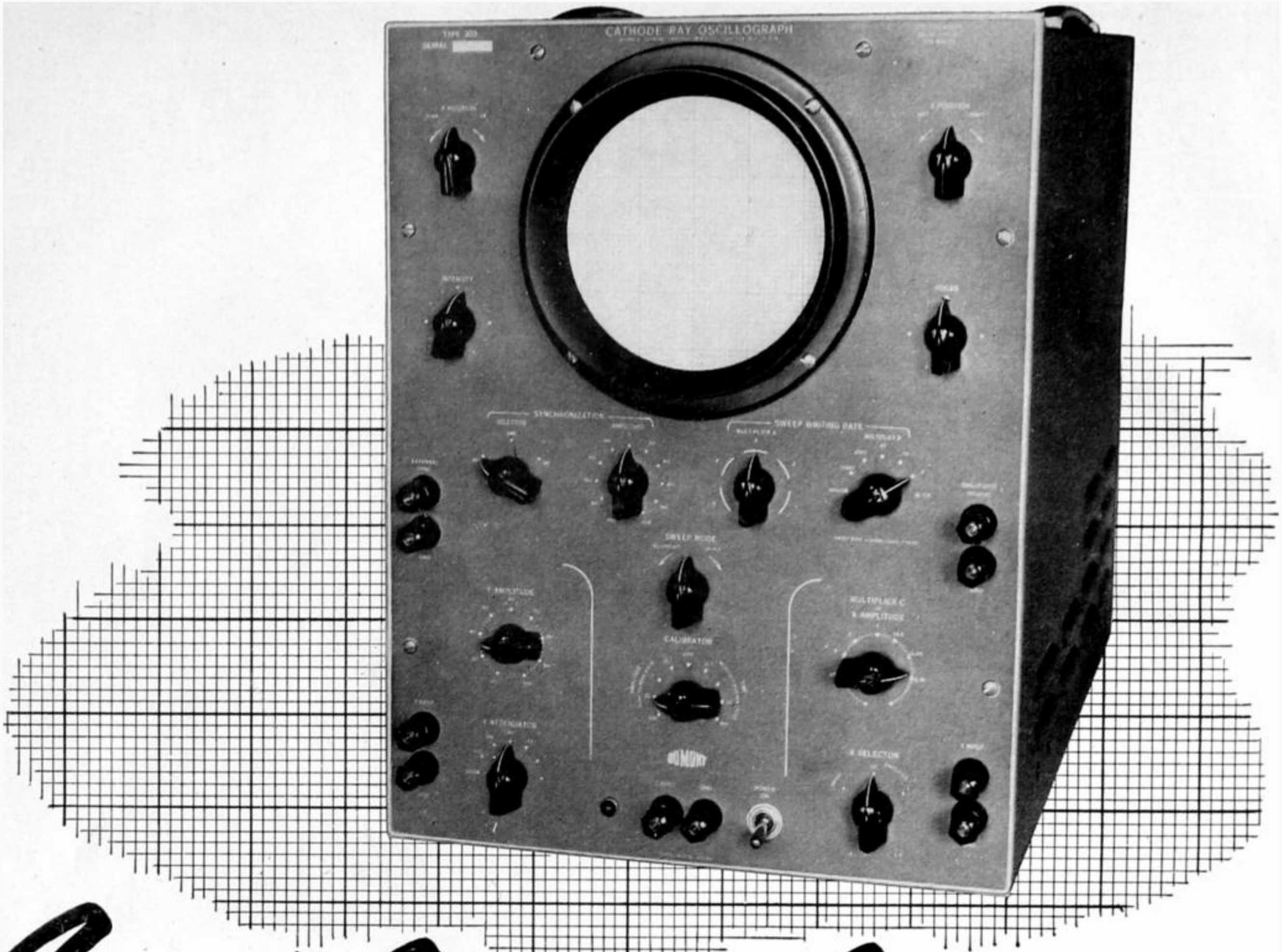
Compact Shock and Vibration Isolator

For use with light-weight airborne equipment installed in restricted space, the new Series 6475 air-damped Barrymounts provide vibration isolation with all the advantages of air damping. Equipment supported on these new mountings is raised only 1/2 inch above the mounting surface, according to the manufacturer **The Barry Corp.**, 179-R Sidney St., Cambridge, Mass.



(Continued on page 28A)


Save time by contacting
UNITED
for the wide range of
JAN APPROVED
GAS RECTIFIERS
& THYRATRONS
Complete Technical Data
Sent On Request
Type 4B32
Rectifier
Max. Dimen.: Ht. 8-1/2" Diam. 2-5/16"
Ratings: Ef 5.0 volts If 6.75 amps. epx 10 KV Io 1.25 amps. ib 5.0 amps.
Atmosphere: Xenon Gas
Type 323B
Thyratron
Max. Dimen.: Ht. 6-9/16" Diam. 2-3/16"
Ratings: Ef 2.5 volts If 7.0 amps. epx 1250 volts Io 1.5 amps. ib 6.0 amps.
Atmosphere: Argon-Mercury
Type 3B28
Rectifier
Max. Dimen.: Ht. 6-5/32" Diam. 2-1/16"
Ratings: Ef 2.5 volts If 5.0 amps. epx 10 KV Io 250 ma ib 1.0 amp.
Atmosphere: Xenon Gas
Type 393A
Thyratron
Max. Dimen.: Ht. 6-10/16" Diam. 2-1/16"
Ratings: Ef 2.5 volts If 7.0 amps. epx 1250 volts Io 1.5 amps. ib 6.0 amps.
Atmosphere: Argon-Mercury
Type 3C23
Thyratron
Max. Dimen.: Ht. 6-1/8" Diam. 2-1/16"
Ratings: Ef 2.5 volts If 7.0 amps. epx 1250 volts Io 1.5 amps. ib 6.0 amps.
Atmosphere: Argon-Mercury
Type 355A
Thyratron
Max. Dimen.: Ht. 9-1/2" Diam. 3-3/16"
Ratings: Ef 2.5 volts. If 16.0 amps. epx 350 volts Io 4.0 amps. ib 16.0 amps.
Atmosphere: Argon-Mercury
Type 354A
Thyratron
Max. Dimen.: Ht. 9-1/2" Diam. 2-5/16"
Ratings: Ef 2.5 volts If 16.0 amps. epx 1500 volts Io 4.0 amps. Ib 16.0 amps.
Atmosphere: Mercury Vapor
Type 575A
Rectifier
Max. Dimen.: Ht. 11-1/16" Diam. 3-1/16"
Ratings: Ef 5.0 volts If 10.0 amps. epx 15 KV Io 1.5 amps. Ib 6.0 amps.
Atmosphere: Mercury Vapor
UNITED ELECTRONICS, 42 Spring Street, Newark 2, N. J.
(TRANSMITTING TUBES EXCLUSIVELY Since 1934)



Exceeds Everyone's Expectations

by outperforming its own specifications...

Read the specifications of the Type 303 and you'll call it a 10-megacycle, quantitative instrument: operate the Type 303 and you'll realize you've sold it short. You'll find performance beyond the exacting limits of its specifications!

An exceptionally fine, medium-priced cathode-ray oscillograph, the Type 303 employs the new Type 5YP- Cathode-ray Tube. High sensitivity and an unusually wide range of sweep speeds make the Type 303 especially well suited for the study of high-frequency phenomena.

Using the equivalent of five inches of undistorted deflection on the Y axis, and six times full-screen expansion on the X axis, qualitative analyses can be highly detailed with the Type 303. Time and amplitude calibration add quantitative precision to this analysis, making the performance of the Type 303 unrivaled in the medium-price field.

Specifications

CATHODE-RAY TUBE — Type 5YP-

Y AXIS:

Sensitivity — 0.1 peak-to-peak volt per inch (down 30% at 10 cycles per second and 10 mc.) down 50% at 15 mc.

Pulse Rise Time — 0.03 microsecond.

Available Undistorted Deflection — 5" for symetrical signals and 2½" for unidirectional signals.

Signal Delay — Sufficient to allow for sweep-starting time.

X AXIS:

Sensitivity — 0.35 peak-to-peak volt/in. (flat to d-c down 30% at 500 kc).

Available Undistorted Deflection — 5"

SWEEP SPEEDS — up to 6" /μsec. obtained by expansion.

SWEEP DURATION — Continuously variable from 0.1 sec. to 2 μsecs. Driven or Recurrent operation.

VOLTAGE CALIBRATION — Square wave with peak-to-peak amplitudes of 0.1, 1, 10, and 100 volts. Accuracy ± 5%.

TIME CALIBRATION — Pulsed oscillations corresponding to time intervals of 100, 10, 1, or 0.1 μsec. Accuracy better than ± 3%.

INTENSITY MODULATION — 15 volts peak will blank the beam.

DuMont for Oscillography

INSTRUMENT DIVISION • ALLEN B. DU MONT LABORATORIES, INC., 1000 MAIN AVENUE, CLIFTON, N. J.

50th YEAR

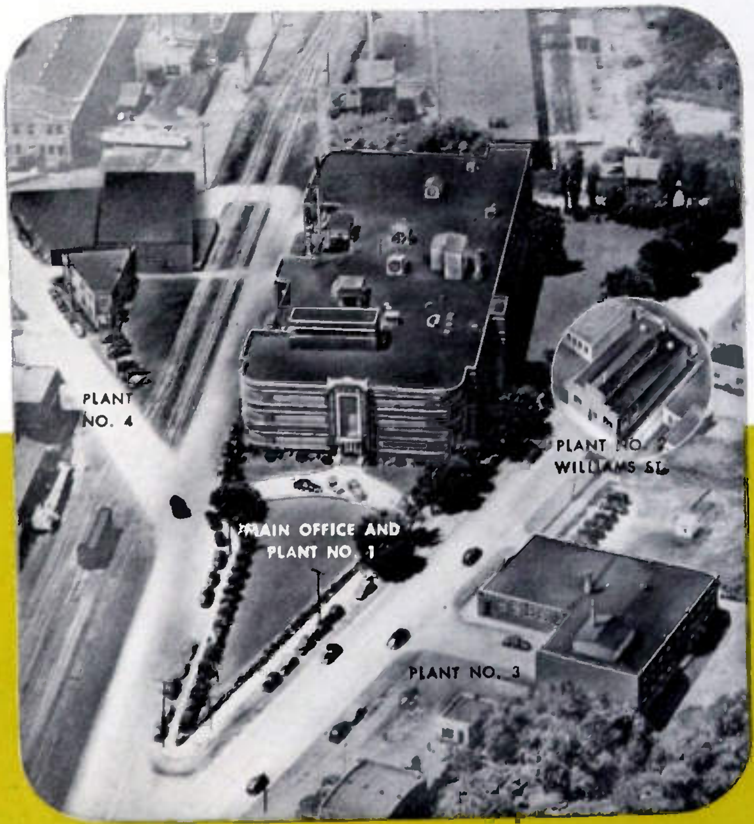
OF CERAMIC LEADERSHIP

APRIL, 1951, marks the beginning of the 50th year of American Lava Corporation's ever growing services to users of custom made technical ceramics. We are proud of this record and are genuinely grateful to the customers who have made this growth possible. To our customers we dedicate our future to a continuance of the type of services and quality of products that will contribute to the success of expanding American industries.

AMERICAN LAVA CORPORATION

PHILADELPHIA • ST. LOUIS • CAMBRIDGE • CHICAGO • LOS ANGELES • NEWARK

CHATTANOOGA 5, TENNESSEE



ALSIMAG®

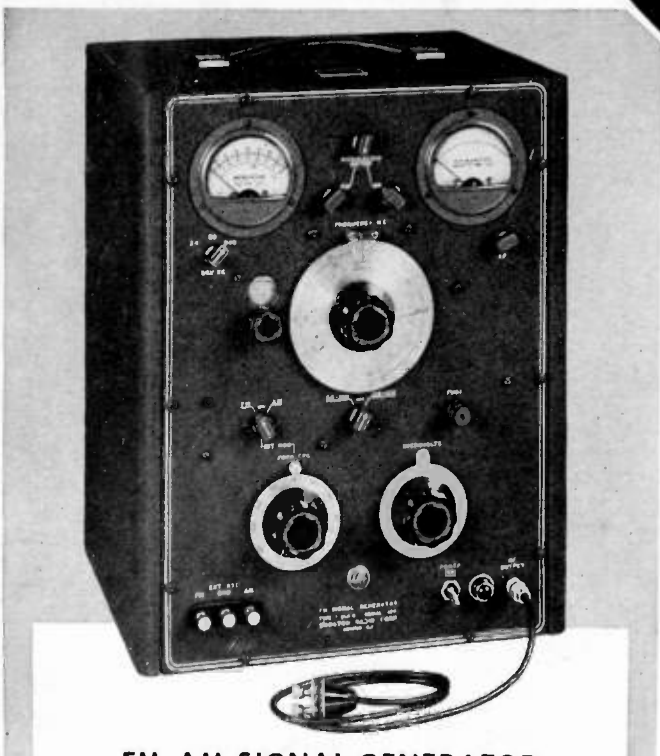
Announcing a *NEW* UNIVERTER

Continuous Coverage 0.1 to 216 mc.

Accessory for the

FM-AM SIGNAL GENERATOR

TYPE 202-B



FM-AM SIGNAL GENERATOR

TYPE 202-B

This instrument has become the standard signal source for the FM and Television Industry.

The Type 207-A Univerter described at the right was developed to extend its useful frequency range down to 100 kc. without changing the signal level or modulation characteristics shown below.

SPECIFICATIONS:

RF RANGES: 54-108, 108-216 mc.
FREQUENCY DEVIATION: 0-24 kc., 0-80 kc., 0-240 kc.
FM DISTORTION: Less than 2% at 75 kc. deviation
AMPLITUDE MODULATION: Continuously variable 0-50%.
RF OUTPUT VOLTAGE: 0.1 microvolt to 0.2 volt.

UNIVERTER

TYPE 207-A

The Type 207-A Univerter fills the widespread need for an FM-AM source in the frequency range of from 0.1 to 55 mc. This instrument is a unity gain frequency converter which subtracts 150 mc. from a signal derived from the Type 202-B FM-AM Signal Generator to produce an output of from 100 kc. to 55 mc. This is accomplished without change of signal level or of modulation and with negligible spurious frequencies. Thus the Type 207-A Univerter when used with the Type 202-B Signal Generator shown at the left will provide complete FM-AM Signal Generator coverage from 100 kc. to 216 mc.

In addition to the unity gain output, the Type 207-A Univerter provides a high level output of about 7.5 times the input thus making about 1.5 volts available for high level tests.

In order to facilitate band-width measurements, the Univerter is provided with an incremental frequency dial which is calibrated in 5 kc. increments over a range of ± 300 kc. This permits selectivity curves to be taken on even the most selective mobile receivers.

The power supply is well regulated to prevent change of gain or output frequency with line voltage variation from 95 to 130 volts.

Complete specifications, price, and delivery information will be furnished on request.

BOONTON RADIO *Corporation*
BOONTON·N·J·U·S·A·
BRC

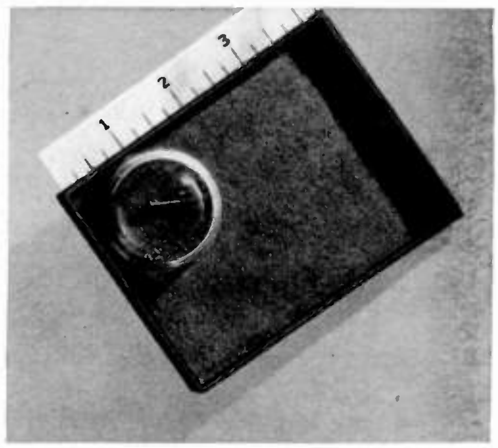
DESIGNERS AND MANUFACTURERS OF THE Q METER · QX CHECKER
FREQUENCY MODULATED SIGNAL GENERATOR · BEAT FREQUENCY
GENERATOR AND OTHER DIRECT READING INSTRUMENTS

OHMITE
Has Just the Resistor You Need
Ohmite offers fixed, adjustable, tapped, non-inductive, and precision resistors in more than 60 sizes and 18 types of terminals, in a wide range of wattages and resistances.
These rugged resistors have proved their dependability under the toughest conditions. Write on company letterhead for Catalog 40.
Be Right with
OHMITE
Reg. U. S. Pat. Off.
RHEOSTATS · RESISTORS · TAP SWITCHES
OHMITE MANUFACTURING COMPANY
4860 Flournoy St., Chicago 44, Ill.

Disc Cathode Speeds Assembly-Improves Performance

Expanded Facilities . . . more space, equipment and trained co-workers help to meet growing demand.

Inspection and Gaging . . . equipment for checking "E" dimensions of Disc Cathodes.



52,600 Seamless Nickel Cathodes, compared under a lens with an ordinary pin.

● Electronics manufacturers find it pays to be a customer of Superior. They receive good service, quality products and the benefits of Superior's methods and metals research that constantly improves upon already good products.

An example is the new, improved Disc Cathode. Investigation proved that a slight flaring of the open end minimized the danger of heater cathode "shorts" caused by scraping of the heater wire coating during insertion, while speeding the operation.

This feature added to an already excellent cathode, resulted in a part that does a better job at a lower cost.

The Disc Cathode is only one of the hundreds of products which Superior supplies . . . but the same program of product improvement is applied to all of them. That's why most manufacturers in the electronics field are already friends and customers. If you are one of the exceptions, it will pay you to find out more about Superior and Superior products. For information, consultation about production problems, design help or research assistance, write today to Superior Tube Company, 2506 Germantown Ave., Norristown, Pennsylvania.

Which Is The Better For Your Application . . .

SEAMLESS . . . ? The finest tubes that can be made. Standard production is .010" to .121" O.D. inclusive, with wall thicknesses of .0015" to .005". Cathodes with larger diameters and heavier walls will be produced to customer specification.

Or LOCKSEAM* . . . ? Produced directly from thin nickel alloy strip stock, .040" to .100" O.D. in standard length range of 11.5 mm to 42 mm. Round, rectangular or oval, cut to specified lengths, beaded or plain.

Superior

THE BI E IN SMALL TUBING

All analyses .010" to 5/8" O.D.

Certain analyses (.035" max. wall) Up to 1⅛" O.D.

**Mfd. under U.S. Pats.—Superior Tube Company • Electronic Products for export through Driver-Harris Company, Harrison, New Jersey • Harrison 6-4800*

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 20A)

Unit mounts are 1 inch in diameter and have an over-all height of 1 inch under minimum rated load. Load ratings range from 0.3 to 3.0 pounds-per-mount. Two mounting styles are available. Series 6475 with two hole mounting on 1.414-inch centers, and Series 6695 for four-hole mounting on one-inch centers. The center stud is tapped to a depth of 1/4 inch with an 8/32 thread.

Mounting bases utilizing these new inverted air-damped mountings can be furnished to government requirements. A data sheet giving dimensions and load ratings is obtainable from Barry.

Output Power Meter

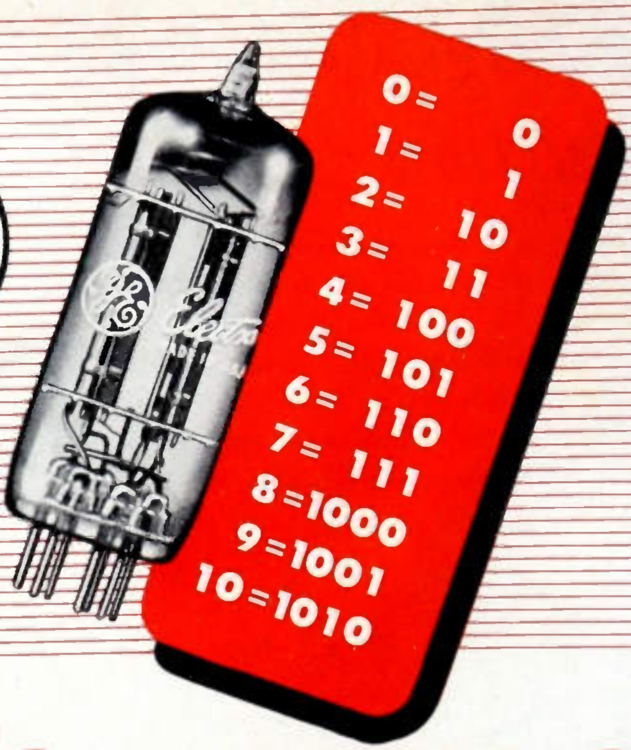
The Daven Co., 191 Central Ave., Newark 4, N. J., announces the addition of Type OP-962 to its line of output power meters. The meters are designed to measure the actual power delivered by an audio signal system to a given load. However, because of the characteristics of the circuit, they are suited to other applications such as determination of characteristic impedance of an ac source, effects of load variation on a signal system, transmission line equalization measurements, measurement of insertion loss in multichannel mixer and other complex circuits, filter and transformer measurements, and radio receiver measurements.

Type OP-962 output power meter, features a large meter, provision for the use of a calibrated external amplifier to extend the power range below 0.1 mw, and provision for connecting an oscilloscope in the circuit. Type OP-962 covers the range from 0.1 mw to 100 watts.

Impedance: 40 selected impedances between 2.5 and 20,000 ohms. Accuracy ±2 per cent over frequency range 30 to 10,000 cps.

Power: 0.1 mw to 100 watts in 0.1 mw steps.

(Continued on page 76A)



GL-5844 Twin Triode

For "flip-flop" service in binary-system calculators

(Over-all tube length 2⅛")

HERE'S A NEW G-E TUBE FOR COMPUTER USE

GL-5844, first of a series, is specially designed for computers . . . and priced economically!

- ✔ **Replaces Type 6J6 in most computer applications—but requires much less heater power.**
- ✔ **Is a true twin triode, specially designed for dependability.**

Here's a great new twin triode engineered for *you* as builder or designer of computers, whether for business or research purposes. Superior reliability, meaning fewer replacements, makes the tube a preferred investment.

You can rely on the GL-5844! This binary-counter type outscores the 6J6 in five important ways:

1. Regular GL-5844 production is 100-percent tested for service in computers. It is not necessary to specially select individual tubes for sharp-cut-off performance.
2. Plate output exceeds that of the 6J6, because of higher perveance.
3. Failure to function after periods of non-conduction while biased to cut-off (often called tube "sleeping sickness") is corrected in the GL-5844 by special cathode design.
4. Cut-off voltage for the two triodes balances within a 1-v limit—a boon to the circuit designer.
5. Heater requirement is a third less than with the 6J6. In a 600-tube computer, this can save more than ½ kw of power . . . important economy . . . plus helping to assure cool operation.

Wire or write for technical-data folder ETD-154. Get the *full* story about this G-E tube "first" in a field of expanding importance! *General Electric Company, Sec. 2, Electronics Department, Schenectady 5, New York.*

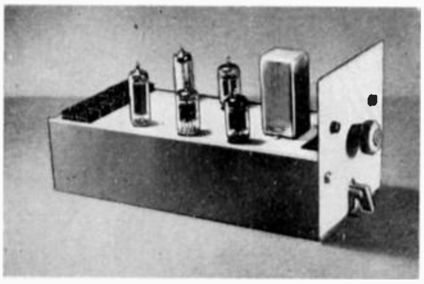
GENERAL ELECTRIC

160-KB

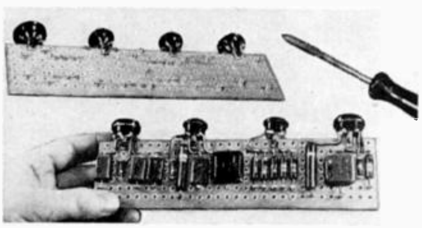
No Blocks to High Velocity Production

It is extremely important to get equipment out and through to the user fast, and yet, the design should be kept economically feasible. Alden Products Company announces a new Basic Chassis Design that does away with extreme techniques to give rapid delivery in large or small volume . . . provide's the manufacturer with a chassis assembly ideally suited to high-velocity production methods . . . the user with an accessible plug-in chassis that makes equipment easier to operate and maintain.

PLUG-IN DESIGN BRINGS WORK OUT INTO THE OPEN



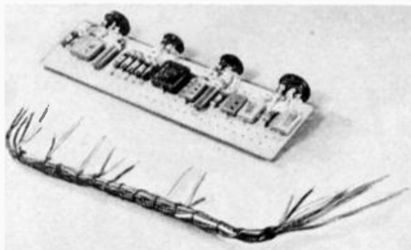
Specifically here is how the Alden Basic Chassis Design and Terminal Card Mounting System can help to eliminate obstacles and really pick up production. . . . Simplifying operations by bringing the work out into the open is the keynote. . . . Most



components and circuit elements are laid out and mounted on the Alden Terminal Cards. These cards come with holes prepunched and allow the engineer to select optimum component layout. Miniaturized Alden Terminals are then staked in this layout. These terminals developed on a government miniaturization contract save space and speed production. . . . Components snap or push in and are held without twisting—cross-wires, buss bars and feed throughs are soldered with ease . . . related circuits are wired rapidly in open as straight line bench work.

CABLING IS NEAT UNIT PACKAGE

The next step—cabling is made as a unit sub-assembly—no mess or fuss—connectors and lead-ins are a neat package. Again, because the work is out in the open and is easily accessible, connections are made to the terminal mounting board with speed and facility. Unit cabling allows instant continuity checks, rapid replacement

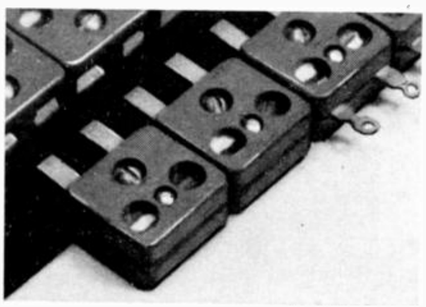


in the field and eliminates problems of malfunctions and excessive production costs.

While the component sub-assemblies are being processed, back connectors, sockets, switches, dial lights, meters, etc., can all be mounted on the basic chassis and front panel, ready for joining to the sub-assemblies. The front panel can be detached to facilitate production. When joined to the chassis, it is hinged and opens forward for clear inspection and service in the field.

COMPONENTS ASSEMBLED FAST

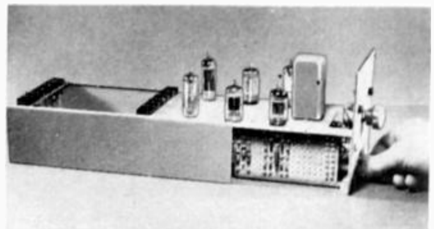
Then the completely pre-wired terminal cards are quickly and easily mounted on the open-sided chassis. Unit cable is wired to terminal cards, circuit elements and to the Alden color-coded back connectors.



These Alden back connectors are individual units which can be mounted where desired to provide the most direct cabling from connector to component. Solder terminals are out in the open so unit cable is easily attached. Color coding instantly identifies circuits for immediate check, whether equipment is operative or on the bench.

COMPLETED ASSEMBLY NEAT AND EFFICIENT

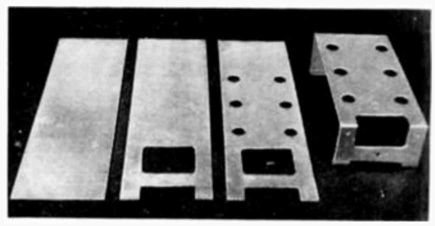
The finished assembly is an efficient, neat, plug-in, slide-in unit. Mounted in cabinet or panel rack in horizontal or vertical succession, chassis elements are always instantly accessible for check, service, or replacement. Quick, positive insertion and removal is smooth and effortless. A simple twist of the handle and the Serve-A-Unit Lock backs the chassis off with



fingertip ease. For re-assembly, chassis is slid in and piloted into locked position with the same facility. Make and break of electrical contacts is efficient and clean because chassis go together and come apart easily.

CHASSIS MANUFACTURED AS STRAIGHT-LINE OPERATION

The Alden Basic Chassis Design makes possible a wonderfully simple method of construction so that with the least possible sizes of stock, orders—large or small—can be started and with a minimum of stocking or storing, proceed rapidly to completion. The design principles allow fabrication that parallels the operation of a progressive



die. The work proceeds as a flat piece as it is sheared and blanked, and, since the operations are principally bending, the work moves to plating or painting and assembly with little or no lost effort—no waste material—no unnecessary physical material handling—no complicated time consuming operations come into play.

This manufacture as a straight-line operation, gives speed and economy to completing the chassis. Ease of manufacture gives us the ability to move into volume production fast, assuring you of chassis when you need them.

"Write to Department I for detailed booklet 'Components for Plug-in Unit Construction.'"

NA-ALD

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...to conserve critical materials

RCA engineering has once again taken the lead by developing an improved method of electrostatic focusing that offers the television industry important savings in critical materials. Incorporating this new RCA development are three new rectangular picture tubes that require no focusing coil or focusing magnet. The tubes provide high-quality pictures on a par with those obtained from kinescopes employing electromagnetic focus.

Featuring electrostatic focusing, the RCA types 14GP4, 17GP4, and 20GP4 use an electron gun of improved design that provides good uniformity of focus over the entire picture area. Furthermore, focus is maintained automatically with variation in line voltage and with adjustment of picture brightness. Need for alignment of a focusing magnet is eliminated and, therefore, tube installation and adjustment for optimum performance are simplified.

Because the electron gun is designed so that the focusing electrode takes negligible current, the voltage for the focusing electrode can be provided easily and economically. In other respects, the RCA 14GP4, 17GP4, and 20GP4 are similar to magnetically focused types—the 14EP4, 17CP4, and 20CP4.

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* Numerals in parenthesis following Directors' names designate Region number.

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Harry F. Dart

REGIONAL DIRECTOR, 1951–1952

Harry F. Dart, section engineer in the electronics engineering department of the Westinghouse Electric Corporation, Bloomfield, N. J., and a pioneer in the development of radio and industrial electronics, was born at Forrest, Ill., on October 20, 1895. He studied electrical engineering at Purdue University, receiving the B.S. degree in 1917, and later the professional degree of electrical engineer.

Upon graduation, he joined the staff of the Hawthorne plant of the Western Electric Company in Chicago, and then enlisted in the Signal Corps where he served as a second lieutenant during World War I. His work in the Army included assignments at College Park, Md., Fort Monmouth, N. J., and at Indiana University. After his discharge he spent another year with the Western Electric Company, and then joined the Internation Correspondence Schools at Scranton, Pa., whose first course on radio he organized and prepared. Later he taught electrical engineering for one year each at Rice Institute and at Harvard University.

In 1922 Mr. Dart joined Westinghouse Electric in Bloomfield, N. J., where he engaged in the development of the early types of receiving tubes. When transmitting tube manufacture was transferred from East Pittsburgh to Bloomfield in 1926, he was placed in charge of transmitting tube testing and rating.

At various times he headed the design and engineering on transmitting and industrial tubes, and the commercial engineering on electron tubes, as well as specification and drafting work on all types of power, industrial, and X-ray tubes. At present he has charge of life testing and handling of technical data on electron tubes such as transmitting, industrial, radar, and X-ray types.

Mr. Dart joined the Institute in 1920, becoming a Member in 1926, and a Senior Member in 1943. When the New York Section was organized in 1942, he was elected the first Secretary, and became its Chairman in 1949. He has served on numerous Committees, including Admissions, Broadcast, Meetings and Papers, Membership, Associations, Standardization Technical Committee No. 3—Vacuum Tubes, Symbols, Professional Recognition, and Tellers. In addition to his IRE activities, he is a member of several committees of the Joint Electron Tube Engineering Council of NEMA and RTMA.

Mr. Dart's name first appeared in *Who's Who in Engineering* in 1922, and in *Who's Who in the East* in 1940. He belongs also to the American Institute of Electrical Engineers, the Montclair (N. J.) Society of Engineers, the Radio Pioneers, and is a Fellow of the Radio Club of America. He has prepared a "Radio Handbook for the ICS," and is the author of several booklets and articles on radio subjects.

National Bureau of Standards Fiftieth Anniversary

The National Bureau of Standards of the United States of America has completed its first fifty years of notable achievement. In recognition of this service, The Institute of Radio Engineers has presented a scroll to the Bureau, the actual presentation being carried out by the President of the IRE, Mr. I. S. Coggeshall.

In handing this scroll to Dr. E. U. Condon, Director of the Bureau, President Coggeshall delivered the following informal but significant address:

"Roger Bacon, medieval herald of science, correctly said: 'There are two methods in which we acquire knowledge—argument and experiment.'

"Seven hundred years later we have Congress arguing and the White House experimenting.

"This wry jest is based upon the incongruity of experiment without means of precise measurement.

"For fifty years the National Bureau of Standards has put celestial calipers on the centimeter, the gram, and the second. In return, scientists and engineers of the universities and industrial laboratories, banded together in societies like The Institute of Radio Engineers, have shown how to produce all manner of devices to lock space, mass, and time into the most extraordinary relationships, involving the measured behavior of elements of the atom and the speed of light among the stars.

"The crystals, tubes, other circuit components, and measuring devices so produced have gone back into the Bureau of Standards, there to be used further to refine the standards of measurement. Today, the rotation of the earth and the fix of the stars—once standard above all standards—yield up their vagaries, by methods of microwave spectroscopy derived from radar techniques, to the constant frequency with which electrons spin about their nuclei.

"It is tragic that the effects of social experiment, the philosophies, and the 'isms' have so long resisted similar exact measurement. While philosophers can prove that Marxism smells, not even the Bureau of Standards on its fiftieth birthday can tell how bad.

"The world will be further in debt to the Bureau if, perhaps in the early part of its second half-century, it brings forth an analog computer upon which may be set up philosophical problems, and answers obtained which may be duplicated at will at any point in time and geography. Its use might be limited by law to international problems, thus not interfering with the two-party system in the United States.

"I hope I may be pardoned for having spoken in a lighter vein, as befitting the well-founded happiness of this luncheon celebration. In all seriousness, however, I now turn to the presentation of the scroll which will constitute the permanent record of the occasion, and acceptance of which by you, Doctor Condon, will do honor to the Institute and its President."

The text of the scroll was as follows:

"TO THE NATIONAL BUREAU OF STANDARDS

"GREETING

"Upon the occasion of the Fiftieth Anniversary of the founding of the National Bureau of Standards

The Institute of Radio Engineers, Incorporated

"In Recognition of the valuable scientific and engineering services rendered by the Bureau to the people of the United States; its establishment and maintenance of standards for electrical measurements at all frequencies; pioneering of precision measurements in all fields of physics and engineering; its improvement of calibration methods; its constructive accomplishments in advancing high-frequency measurement techniques, and its long co-operation with the engineering profession

"Presents this scroll at the Second Joint Conference on High Frequency Measurements, held at Washington, D.C., this eleventh day of January in the year 1951."

What's Behind IRE?*

JOHN V. L. HOGAN†, FELLOW, IRE

MY ASSOCIATION with radio goes considerably back of the date on which IRE was formed. Let me tell you a little bit about how difficult it was for radio engineers to get together in those early days. There were several "wireless" companies engaged either in radio communication or in manufacturing radio equipment or both. I remember most of the successive De Forest Companies (including the De Forest Wireless Telegraph Co., American De Forest, and Atlantic De Forest) which, about the time that De Forest broke off with them, became the United Wireless Telegraph Company. I also remember the Collins Wireless Telephone Company, a very different Collins from the company of that name that we know today. Of course, there were also the Marconi Wireless Telegraph Company of America and Harry Shoemaker's company in Jersey City, which I think was called International something or other. There doubtless were others, but those are the only ones that come to mind at the moment. Oh, yes, there was one more, the United States representative of German radio. That organization was originally called Telefunken Wireless Telegraph Company of America, but later became the Atlantic Communications Company.

In these pre-IRE days, each of the wireless companies was an exceedingly self-contained and closely guarded unit. A man working for one of them could easily lose his job if his boss found out that he had had lunch with a man working for another one of them. It was the day of secrets and of what we would now call unethical competition. You all have probably heard the story of how the Marconi Company tried to report the International Yacht Races from a ship-borne transmitter in lower New York Bay, and how the Shoemaker company tried to prevent the success of that demonstration by jamming the Marconi receiver. Radio countermeasures existed even in the early 1900's.

Fessenden's National Electric Signaling Company and the Stone Wireless Telegraph Company in Boston were probably the two organizations which first initiated reasonable, well-planned development programs, and recognized that wireless telegraphy was actually a matter of engineering. I give Fessenden credit for being the first realistic electrical engineer to apply the principles of electrical engineering to the development of radio. At the very least, we must credit him with recognizing that what was needed in a radio transmitter was a continuous radio-frequency alternating current developed in a tuned antenna. John Ambrose Fleming, the great British scientist and the man who wrote the first bible of radio engineering in our language, was so imbued with the contrasting Marconi spark techniques that, in the first edition of his famous "Principles of Electrical Wave Telegraphy," he expressed doubt that the Fessenden continuous-wave system would in fact radiate electromagnetic waves. That criticism was based on Fleming's view that no energy would be radiated unless there was what he called an electrical "whip crack" to snap the waves off the antenna. Of course, the criticism was eliminated from later editions of Fleming's book.

ROBERT H. MARRIOTT—First IRE President

The engineer is human, and like other humans, he is gregarious. In spite of the 1900 type of "classification" that was placed on those early radio engineers by their employers, they did meet from time to time, and they did not hate each other just because they were employed by different organizations. Gradually over the period running from approximately 1900 to 1908, the desire to get together and to discuss their puzzles became stronger and stronger. They commenced to realize that the answers to their technical problems depended upon matters of fact, many of which could not be determined without experiment, and that these problems were generally common to all of the companies, rather than individual to any one of them.

With this background, and under a date line of May 14, 1908, more than 42 years ago, Robert H. Marriott, who was then Assistant Scientific Manager of the United Wireless Telegraph Company, sent out a circular letter to a number of engineers in the various wireless companies of that day. I think that that was the first specific attempt to form a radio engineering society drawing its membership from any and all companies. In any event, I believe you would be interested in the contents of Bob Marriott's 1908 letter. It reads as follows:

"Dear Sir:

"You have often thought no doubt that Wireless Telegraphy would be developed faster if those engaged in it would work together more.

"The Electrical Engineers have come together in the United States by forming the American Institute of Electrical Engineers. This institution has helped to make better Electrical Engineering, better Electrical Engineers, and better feeling between competitive firms.

"Why should not we form the Institute of Wireless Engineers and pattern it after the American Institute of Electrical Engineers. The American Institute of Electrical Engineers' plan as applied to Wireless people would be briefly as follows:

First: Any person interested in Wireless with proper recommendations, etc., would be eligible to associate membership.

Second: Any person having done valuable, original work in Wireless would be eligible to full membership.

Third: Any person whom the Society, by vote, should decide upon would be eligible to honorary membership.

Fourth: Meetings would be held once a month, at which papers on Wireless subjects would be read and criticized.

Fifth: Every member and associate would receive a copy of the paper read, together with the criticisms, thus giving absent members the same information as those present.

Sixth: A library of Wireless publications would be accumulated as rapidly as the funds of the Institute would permit. Each member or associate member would have access to this library.

Seventh: The Officers and Committees would be about as follows: President, Vice-President, Manager, Treasurer, and Secretary.

Committees: Executive Committee, Committee on Finances, Committee on Papers, Board of Examiners, Library Committee, Editing Committee, and necessary special committees appointed from time to time.

Eighth: The dues would be possibly about $10.00 per year.

"I believe an organization formed on a plan similar to the above would materially improve Wireless, increase the knowledge and ability of members, avoid friction between employees, between employees and employers, and to some extent between Wireless companies.

"Would you join such an organization as outlined? If so, please write me and give full expression of your views in regard to the matter in order that an organization may be formed on the right lines. Also such an organization might contemplate the establishment of a beneficiary association in connection with the Institute.

Yours very truly,
R. H. Marriott
Ass't., Scientific Manager
United Wireless Telegraph Co.
42 Broadway, New York"

Bob's efforts to get the engineers together on a common meeting ground produced results. He got about sixty replies to his letter and only one or two of those who wrote to him were negatively inclined. In

* Decimal classification: R060×R090. Original manuscript received by the Institute, September 27, 1950. Presented, National Electronics Conference Luncheon, Chicago, Ill.; September 27, 1950.
† Hogan Laboratories, Inc., New York, N. Y.

January of 1909 he was able to form a temporary organization and in March of that year a meeting was held in the Engineering Societies Building, New York, N. Y., when a constitution was adopted. The name of the organization thus founded was "The Wireless Institute," and Bob Marriott was elected its first President.

At the second meeting of the Wireless Institute, in April of 1909, Bob Marriott presented a paper on the plans and purposes of the society. In that lecture he gave a list of suggested subjects for papers to be presented at future meetings. To give you an idea of what radio engineering was in those days, his list of 26 proposed topics is presented below:

1. "The Recent Wireless Bills Before Congress"
2. "The Berlin Convention"
3. "The Regulation of Amateur Stations"
4. "Unnecessary Interference"
5. "Static"
6. "How to Get Business on the Boat"
7. "How to Handle Messages Rapidly"
8. "The Present Field for Wireless"
9. "How Business Can Best Be Handled in Case of Distress"
10. "How to Prevent Wireless Stations from Damaging Property"
11. "The Care of the Motor-Generator"
12. "The Care of the Storage Battery"
13. "The Key, Vibrator, and Switches"
14. "The Induction Coil and Transformer"
15. "The Condenser"
16. "The Helix; Coupling and Tuning"
17. "Aerials"
18. "Receivers"
19. "Tuners, Jiggers, Syntonizers, Selectors, Etc."
20. "Wireless Waves"
21. "The Wireless Telephone"
22. "How to Make the Wireless Institute of the Greatest Benefit"
23. "How and What Wireless Operators Should Be Taught"
24. "How Weather Conditions Affect Wireless"
25. "Simple Methods for the Operator to Test and Repair Instruments"
26. "Telephone Receivers."

Papers relating to almost all, if not all, of these topics have since been presented and published.

The Wireless Institute continued its activities, with New York headquarters, holding meetings and publishing proceedings until it joined with the Society of Wireless Telegraph Engineers to form our present Institute of Radio Engineers.

The Society of Wireless Telegraph Engineers had been formed earlier in Boston, Mass., on February 25, 1907, but I understand that membership in the SWTE was first recruited only from the technical staff of the Stone Wireless Telegraph Co. Later that Society admitted men who worked for Fessenden and for other wireless organizations. When the Fessenden Company moved from Brant Rock to Brooklyn, the Society of Wireless Telegraph Engineers lost a substantial part of its membership, but, by the same token, the potential membership of the Wireless Institute in New York was increased. I think that this situation, together with the idea that the members of both societies were intensely loyal to their fledgling organizations, may well have been the mainspring that drove them into consolidation and the organization of The Institute of Radio Engineers. Looking at the Institute today, it is hard to realize what the membership situation was in 1912. It is difficult to believe that when The Institute of Radio Engineers was formally established on May 13, 1912, its membership comprised 22 men from the Society of Wireless Telegraph Engineers, 22 men from the Wireless Institute, and one man (Greenleaf Whittier Pickard) who belonged to both. The original list of only 45 members included a number of people who are still active in radio engineering, among them Lee De Forest, Lloyd Espenschied, Alfred N. Goldsmith, Arthur Van Dyck, and myself. The Organization Committee comprised Bob Marriott, Alfred N. Goldsmith, and myself, and the first President of The Institute of Radio Engineers was Bob Marriott.

As you all know, Alfred Norton Goldsmith has been Editor, not only of the PROCEEDINGS OF THE I.R.E. from the date of the first issue, January, 1913, but also of the *Wireless Institute Proceedings* that was still earlier. We owe him great tribute for the way in which he has developed our publication. There is no doubt that very soon after its appearance in 1913, it became recognized as having the stature of an important engineering periodical, and, of course, today it is accepted as the leading publication in the electronics field. Similarly, Bob Marriott rates our gratitude for his persistent effort, in the face of many difficulties, to get a radio engineering organization started. Unless someone else had done what Bob did, we would have no Institute of Radio Engineers today. I think that we should all recognize our debt to him, and that we should take every opportunity to express our appreciation of his services to the profession of radio engineering. Bob, at present, is healthy, but because he spends most of his time at his home in Brooklyn, his present activities in our field are mainly confined to writing. He is almost as young as I am, having been born in 1879.

In closing, let me answer a question that has come up from time to time. That question is, "How did it happen that the Radio Engineers started an organization of their own instead of joining with the American Institute of Electrical Engineers as a subdivision of some kind?" The answer is that the radio men, even in those earlier days, felt that they had so many problems of mutual interest that they would need to have monthly meetings of their own. They were not satisfied with the idea of perhaps one or two radio papers per year, sandwiched in between meetings devoted to what the Germans call "heavy-current" electrical engineering. The matter was discussed with the American Institute of Electrical Engineers, but the charter members of The Institute of Radio Engineers felt that they needed and that they could develop a successful professional society of their own. I think you will agree that succeeding events have proved that they were correct.

Supplemental Note on "What's Behind IRE?"

In a brief discussion which followed my presentation of the talk "What's Behind IRE?" I was asked why The Institute of Radio Engineers had not been named the "American Institute of Wireless Engineers." In the first place, the adjective "American" was omitted from the name because the founders desired to have the IRE a truly international organization. As you all know, we have Sections outside of the United States, we have many non-American members, and we have long made it a policy to elect a Vice-President from some nation other than the United States of America. For this reason, among others, the Institute has attained international recognition.

As to the use of the word "Radio" instead of "Wireless," my recollection is that the the new word "Radio" was coined at a meeting of the group which later became the Institute's Standardization Committee. For some years it had been recognized that wireless telegraphy utilizing waves radiating from an antenna was entirely different in character from the early forms of wireless telegraphy (for example, as used by Preece and Lodge) which were based on magnetic or electrostatic induction or on ground conductivity. Since the members of the Institute were interested in *radiated* waves, the title of the organization was chosen so as to indicate that fact.

Incidentally, in the preliminary report of the Committee on Standardization of the Institute, issued to members on September 10, 1913, there appears the following definition:

> "Radio Telegraphy and Radio Telephony: Further divisions of radio communication. It is proposed that the term 'Wireless' shall be entirely eliminated, as inaccurate and inappropriate."

The same report defined radio frequencies as those above 20,000 cycles per second and audio frequencies as "the normally audible frequencies lying between 20 and 20,000 cycles per second." The definition of radio frequencies carries the following rather interesting footnote:

> "It is not implied that radiation cannot be secured (at) lower frequencies and the distinction from audio frequencies is merely one of convenience."

The membership of the first Committee on Standardization comprised the following:

Robert H. Marriott
Alfred N. Goldsmith
John V. L. Hogan
A. E. Kennelly
Roy A. Weagant
Greenleaf W. Pickard.

The Committee had held more than fifty meetings prior to the publication of its preliminary report in the fall of 1913.

The Characteristics and Some Applications of Varistors*

FRANK R. STANSEL†, SENIOR MEMBER, IRE

A study of editorial correspondence and verbal comments from readers of these PROCEEDINGS has shown that many of them desire the publication of tutorial papers on matters of current and major importance to the communications and electronic engineers. Such papers should be prepared by experienced and recognized workers in the corresponding field, and should be both clear and comprehensive. They should form a "refresher course" for the practicing engineer, and should be of further value as source material to active engineering workers and as advanced texts for the use of student members.

Accordingly the Board of Directors, upon recommendation of the Administrative Committee of the Board of Editors, has authorized the publication of such papers in the PROCEEDINGS. These papers are in each case procured and approved by the Subcommittee on Tutorial Papers, under the Chairmanship of Professor Ernst Weber, of the IRE Education Committee, under the Chairmanship of Professor H. J. Reich.

The following paper is of the type here described and deals with one of the newer and valuable instrumentalities used in the branches of engineering served by the Institute.—*The Editor.*

***Summary*—Varistors, circuit elements whose resistance is a function of the voltage applied, represent one important commercial application of semiconductors. They may be divided into two classifications: nonsymmetrical and symmetrical varistors. The first classification includes both metallic rectifiers such as copper oxide, selenium, and copper sulfide, and point contact rectifiers such as silicon and germanium. The only commercial varistor of the symmetrical class is the silicon carbide varistor, although a symmetrical characteristic may be obtained by connecting two nonsymmetrical varistors in parallel with proper polarity.**

Each varistor has its volt-ampere characteristic and at each point on this characteristic two different values of resistance may be defined, namely the dc resistance, defined as the ratio of voltage to current, and the dynamic or ac resistance, defined as the ratio of *dE* to *dI*. The former is important in problems dealing with steady-state dc or large-signal applications, while the latter is important when dealing with small applied signals.

Because of the state of the art, varistors as manufactured commercially are less uniform than many other circuit elements and required uniformity is often obtained by special selection. Economical use of these elements therefore requires the circuit engineer to recognize clearly which of the several properties are important in his application and to specify special selection for only those properties and to the extent necessary for his application.

Other properties of varistors which may be of importance are capacitance, maximum inverse voltage, effect of temperature and frequency on any of the other characteristics, long and short time stability, and noise.

Of the many applications of varistors three are discussed which illustrate how different properties may be determining factors in different applications. In power rectifiers the limiting factors are those which may physically damage the unit, energy dissipated within the varistor, and inverse voltage across the varistor. As a result such items as ventilation, duty cycle, and the like, are important. In bridge- and ring-(lattice) type modulators the problem of protecting the varistor against physical breakdown is seldom present, but the limiting factor is the extraneous modulation products introduced into the circuit. It is therefore necessary to make detailed analyses of the spectrum of the sum and difference products involved. In the compandor (compressor plus expandor), operating economies are obtained by a device which is dependent on the uniformity of the dynamic characteristic of the varistor in its forward direction. A selected bibliography is included.

INTRODUCTION

WHILE THE rectifying properties of certain metallic sulfides were known as early as 1874, the first commercial application of semiconductors was probably the crystal detector used in radio telegraphy during the first portion of this century. With the advent of the vacuum tube the crystal detector was supplanted, only to be recently reinstated in an improved version as a detector for microwaves. In the meantime, the copper-oxide rectifier was introduced about 1925 as a power rectifier. About 1936 this same copper-oxide unit was introduced as a modulator in carrier telephone circuits. This application was so successful that the copper-oxide modulator (later supplemented by silicon and germanium modulators) soon became an essential portion of the long-distance telephone plant. Although a selenium rectifier was described as early as 1883, the commercial selenium rectifier was slow to develop and was not introduced on a wide-spread commercial scale until after the copper-oxide rectifier. Because of its lighter weight, smaller bulk, and lower cost, the selenium rectifier has supplanted the copper-oxide rectifier in many, but by no means all, applications. Microwave development during the recent war was responsible for the silicon and germanium rectifiers which today have been used for a wide variety of functions, many not related to their original purposes.

Despite the wide diversity of origin and usage, these devices—the early crystal detector, the copper-oxide rectifier and modulator, the selenium rectifier and the silicon and germanium rectifiers—all are but applications of the same basic principle, nonsymmetrical conduction at the junction between a conductor and a semi-

* Decimal classification: R282.12. Original manuscript received by the Institute, February 1, 1951.

† Bell Telephone Laboratories, Inc., Murray Hill, N. J.

conductor, or between two differing semiconductors. With this idea in mind the term "varistor" was coined about 1934 and is now defined as "a two-terminal circuit element composed of an electronic semiconductor and suitable contacts, which has a markedly nonlinear volt-ampere characteristic."[1]

While the varistor was the first, and is still from the production viewpoint, the largest application of semiconductors, it is not the only application. Other applications include the thermistor (circuit elements whose resistance varies with temperature), the transistor (the semiconductor amplifier), and various photoelectric devices. None of these later applications will be discussed in this paper, as each is important enough to warrant a separate treatment.

The commercial varistors of today may be divided into two mechanical classes—the area contact type, and the point contact type. The first classification includes copper-oxide, selenium, and copper-sulfide units, and also silicon carbide disks or rods (more familiar to some engineers by trade names such as "Thyrite"). Point contact devices include the silicon and germanium varistors. Basically, area and point contact varistors have similar properties, and frequently both may be used for the same application. It is therefore planned to discuss both of these types together, pointing out their similarities and in some cases their differences.

Besides these commercial types, there are a large number of materials also known to have similar properties, such as the natural crystals used in early crystal detectors and many chemical compounds, particularly oxides and sulfide. It is therefore quite possible that in the future additional commercial types of varistors may be made available to the circuit engineer.

Electrically all varistors, either of the area or the point contact type, may be divided into two classes—symmetrical and nonsymmetrical varistors. The only symmetrical varistors commercially available today are of silicon carbide, although a symmetrical characteristic can be obtained by properly connecting two nonsymmetrical varistors. In this paper it is proposed first to discuss the characteristics of nonsymmetrical varistors, reserving the discussion of the symmetrical type for a later section.

Nonsymmetrical Varistors

All nonsymmetrical varistors, be they of the area or point contact type, consist of three essential elements, a body of a semiconductor and two electrodes. One of these electrodes makes an intimate contact with the semiconductor and this junction is ideally a purely ohmic connection. Between the second electrode and the semiconductor is a barrier layer which is capable of passing current easier in one direction than in another. The mechanism of this barrier layer is more fully treated in various articles on the theory of semiconductors.[2]

The direction of easy current flow through the barrier layer is dependent on the type of semiconductor in the varistor. Two basic types, designated as *P*-type material and *N*-type material, exist. For varistors using *P*-type material, the direction of easy flow is obtained by making the body of the semiconductor positive. For those using *N*-type material, it is obtained by making the body of the semiconductor negative. Of the present-day commercial varistors, all are made of *P*-type material except germanium varistors, which are made of *N*-type material.[3]

In point contact varistors the barrier layer is always located at the point contact, but in area type varistors the location of the barrier layer is not self-evident. To help avoid this confusion Figs. 10 through 14 show simplified cross sections of each of the commercial types of varistors with the direction of easy current flow indicated.

Before considering the properties of any type of varistor in detail it will be well to emphasize their nature. First, because of their nonlinear characteristic, varistors cannot be characterized by a single dimensional adjective as we do when we specify, for example, a 50-microfarad condenser or a 10-ohm resistor. Rather, a varistor must be specified by its properties at several points on its characteristics, such as the current at one volt in forward direction, the current at five volts in reverse direction, and so forth. In general, the current at one point bears little and in many cases no relation to the current at another point, so that it is essential that the characteristic desired be completely specified at all points.

Second, because of the nature of the manufacturing processes now employed, varistors are not inherently uniform. Nonsymmetrical varistors bearing the same manufacturer's designation often differ in forward current at the same voltage by as much as 4 to 1, while the reverse current sometimes differ by even greater ratios. Any better uniformity, at the present state of the art, is obtained largely by selection. Fortunately, in many applications a high degree of uniformity is not necessary, so that the expense of such selection can be eliminated. It is therefore quite important for the circuit engineer to understand which properties are critical in the particular application at hand, so that the most economical selection of units can be made. The practice recently initiated by one manufacturer of publishing not only

[1] Tentative definition of ASA C42 subcommittee on communication definitions. The qualification "composed of an electronic semiconductor" excludes such devices as the electrolytic rectifier, popular with the radio amateurs in the 1920's, and the electrolytic condenser. Electronic processes differ from electrolytic processes in that no polarization voltages are produced nor is there any chemical decomposition of any of the elements of the device. As a result, the life of an ideal varistor is theoretically infinite.

[2] See references (1) through (6) in the Bibliography.

[3] It is well known that many semiconductors, particularly germanium and silicon, may exist in either the *N* type or the *P* type. Hence this statement must be restricted to commercial varistors, since it is sometimes possible to construct units in the laboratory which have the reverse direction of easy current flow.

average curves but also curves showing the limits between which 80 per cent of the units may be expected to be found is to be commended. The more widespread publication of such data will eliminate much confusion that has existed in the minds of engineers wishing to use varistors.

The most commonly published characteristic for a varistor is the relation between the voltage across the varistor and the current through it. Such a characteristic is shown in Fig. 1(a). In one direction a small impressed voltage causes a relatively large flow of current. This is the so-called forward direction or direction of easy current flow. The usual convention symbol for a nonsymmetrical varistor shown in the upper left-hand corner of Fig. 1(a) is arrow-shaped, with the arrow pointing in the direction which current flows when operating on the forward portion of the characteristic.[4]

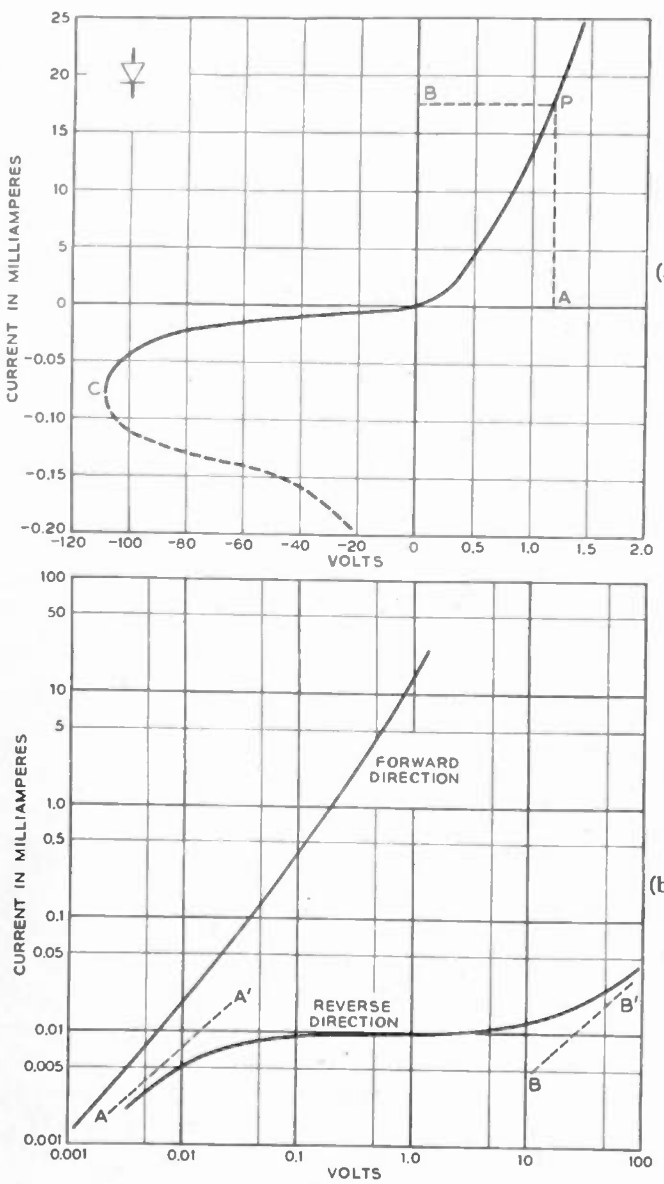


Fig. 1—Voltage-current characteristic of a typical nonsymmetrical varistor.
(a) Characteristic plotted using a linear scale. Note that the scale for the reverse portion of the characteristic differs from that of the forward portion.
(b) Characteristic plotted using a logarithmic scale.

In the forward direction, this characteristic may be approximated by the empirical equation:[5]

$$I = AE^n \tag{1}$$

where I and E are the current and voltage, respectively, and A and n are empirical constants. The exponent n depends on the type of varistor and on the portion of the characteristic curve to which this empirical equation is fitted. For most varistors n is greater than 2, and in some cases may be as high as 4, or even higher. This is in contrast to the vacuum-tube diode, which has an exponent of the order of 3/2.

In all cases the characteristic curve passes through the origin. Unlike the vacuum-tube diode, there is no current at zero voltage due to contact potential.

In the reverse direction there is always a measurable current which increases as the reverse voltage is increased. In Fig. 1(a) both the voltage and current scales are different in the reverse direction. This is a quite common practice in plotting varistor characteristics and is generally necessary because of the large difference in magnitude between the forward and reverse currents.

When the reverse voltage reaches the point C, the reverse current increases very fast and in some varistors a region is reached where as the current is increased still further the voltage decreases. This negative resistance region[6] is readily observed in germanium varistors. The voltage at point C is often designated as the "maximum inverse voltage" or "voltage for zero dynamic resistance." The exact value of this voltage is dependent on many factors, including ambient temperature and local heating produced during its measurement. Consequently its exact value is seldom specified but rather varistors are specified to have a "maximum inverse voltage" not less than a given value.

In types of varistors other than germanium the question of the existence of this maximum inverse voltage is of academic interest. With these varistors the reverse current becomes so great that the characteristic of the

[4] The method of marking the forward direction on commercial varistors has not been standardized and some confusion exists because of the different points of view of the designs. For example, some germanium varistors have been marked with a "+" sign at the terminal corresponding to the upper end of the symbol in Fig. 1(a) to indicate that if the positive terminal of a battery is connected to this terminal current will flow in the forward direction. On the other hand, on some single-element selenium varistors the "+" designation is on the terminal corresponding to the lower end, because it is presumed that these units will be used as power rectifiers and hence this terminal will be the positive pole of the output.

[5] The forward characteristic may also be approximated by other equations. One such equation of exponential form may be derived theoretically (see bibliography reference (1), chapter 4). However, these other equations are usually too cumbersome for ready engineering application.

[6] While it is possible to operate germanium varistors in this negative resistance region in the laboratory, this portion of the curve is in general too unstable for commercial applications. Negative resistance regions have also been reported in the forward direction, but these regions are practically never found in normal operating ranges. It is interesting to note that W. H. Eccles is reported to have demonstrated an oscillator using a negative-resistance region in a galena crystal before the Physical Society of London in 1910.

varistor is permanently altered by internal heating before any negative resistance region is reached.

A varistor's characteristic inherently extends over a wide range of voltage and current, and so it is sometimes advantageous to plot this curve on a logarithmic scale. Fig. 1(b) shows the curve of Fig. 1(a) replotted, using logarithmic scales for both the voltage and current. Since in a plot of this type neither scale reaches zero, it is necessary to show different curves for the forward and reverse characteristics. As the scales are extended to the left to show smaller quantities, the forward and reverse characteristic curves both approach asymptotically the dotted line AA' shown in Fig. 1(b).

When dealing with a nonlinear device such as a varistor, one may define two different resistances and it is important when using the term "resistance" to specify which is referred to. The first is the ratio of voltage to the current at any point, such as the ratio OA/OB at the point P in Fig. 1(a). This frequently is referred to as the dc resistance and is of importance in problems involving the application of dc voltages to varistors.

In many applications the varistor is biased by a dc voltage, and a small ac voltage is superimposed on this dc bias. If we assume OA is such a bias, the ac voltage will see a resistance not of OA/OB but rather the reciprocal of the slope at the point P, that is, dE/dI. This resistance is called the dynamic or ac resistance. This dynamic resistance can be measured directly by a special bridge so arranged that the required dc bias can be superimposed on the varistor and the ac measuring voltage kept low, in the order of a few hundredths of a volt.

When a large ac voltage is applied to a varistor, the term resistance has no universal meaning. For a sinusoidal impressed voltage, the current wave is usually quite distorted and it is not possible to define resistance in terms of any simple ratio.

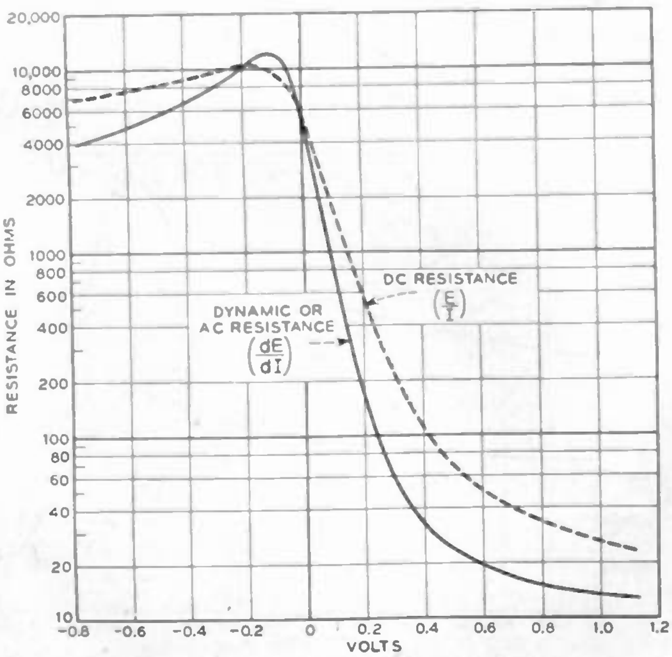


Fig. 2—Resistance-voltage characteristic of a silicon varistor.

Both the dc and the ac resistances are functions of the operating point. Fig. 2 shows the values of these two resistances for a silicon varistor plotted as a function of the dc voltage. At any point in the forward direction, the dc resistance is larger than the ac resistance, both resistances decreasing rapidly as the bias voltage increases. In the negative direction, both resistances reach a maximum, as in the case of the silicon varistor in Fig. 2 when the bias is only a fraction of a volt negative, and then decrease as the reverse voltage is increased.

The general relation between the dc and ac resistance is

$$R_{ac} = \frac{R_{dc}}{K} \tag{2}$$

where K is the slope of the volt-ampere curve when plotted on logarithmic co-ordinates as in Fig. 1(b). The dc and ac resistance will therefore be equal whenever this curve has a 1-to-1 slope, that is, when it is tangent to a 45° line. This occurs twice as shown in Fig. 1(b), the first time at zero voltage where both the direct and reverse characteristic curves are tangent to the 45° line AA' and second at the point on the reverse characteristic at which the curve is tangent to the 45° line BB'.

In a logarithmic plot of this type these 45° lines sloping from upper right to lower left form a co-ordinate system for E/I, that is, the dc resistance. Hence BB' is the maximum value of dc resistance, and from these curves it may be seen that the dc and ac resistances of a varistor are equal at two points, at zero voltage and at the point on the reverse characteristic where the dc resistance is maximum.

Effect of Temperature

When considering the effect of temperature on varistors, one must distinguish between temperature limitations imposed because of possible damage to impregnating compound or other parts of the varistor and temperature limitations which result because of changes in the characteristics of the varistor itself. While limitations of the first type lend themselves to simple blanket statements such as "maximum operating temperature—°C," such statements rarely tell the whole story. Basically, almost all properties of semiconductors are dependent on temperature and no simple general rule can be given. In each application the effect of variations in operating temperature must be carefully considered.

In the forward direction the dc resistance of a varistor decreases with an increase in temperature. This decrease in dc resistance (or increase in current) is greatest at low voltages and diminishes as the voltage is raised. Consequently, when the varistor can be operated with large applied current, the effect of changes in operating temperature is minimized. At a given operating voltage, the temperature variation from unit to unit of the same type is relatively uniform.

In the reverse direction, as the temperature increases the dc resistance also decreases (or current increases).[7] This change is gradual at low temperatures, but as the temperature is increased a point is often reached at which the rate of change is greatly accelerated. At extremely high temperatures (in the order of 250°C) most varistors no longer act as rectifiers. Unfortunately, the allowable temperature for a given degradation in reverse characteristic is often not uniform with varistors of the same type.

The effect of temperature on the dynamic or ac resistance can be seen from the volt-ampere characteristic of a germanium varistor shown in Fig. 3. As the temperature increases the whole curve moves to the left. Except in the immediate vicinity of the origin, the curves tend to remain parallel to each other. Thus the change with temperature of the dynamic or ac is often less than the change in dc resistance. When dealing with dynamic resistance one must differentiate between the case in which operation is at constant bias voltage, as, for example, along line AB, and the case where the bias current is held constant, as along the line CD in Fig. 3.

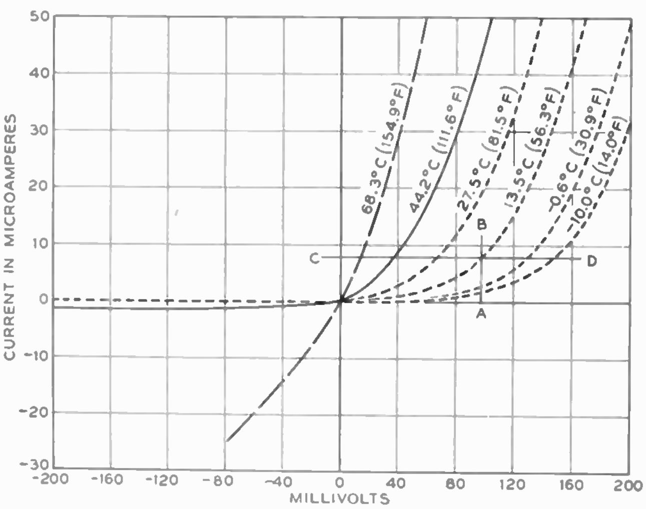
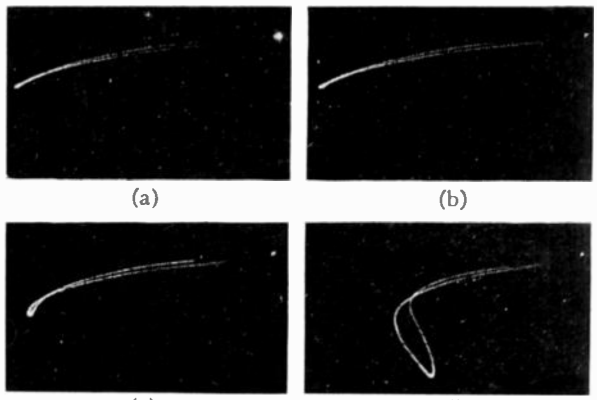


Fig. 3—Voltage-current characteristic of a germanium varistor in the vicinity of the origin showing the effect of changes in the ambient temperature.

Characteristics of a varistor are affected not only by changes in the ambient temperature but also by heat generated within the unit itself. This is illustrated by the oscillograms on a germanium varistor shown in Fig. 4. These oscillograms show the reverse half of the volt-ampere characteristic of the varistor and were taken after the varistor had been passing various amounts of forward current. The curve in Fig. 4(a) was taken before any forward current was applied. Fig. 4(b) was taken after application of 16 milliamperes in the forward direction. This current is well within the normal operating range of the varistor, and a comparison of Figs. 4(a) and 4(b) shows no appreciable change in the reverse characteristic. For Figs. 4(c) and 4(d), increasingly larger forward currents, well beyond the normal operating values, were applied before the oscillographs were taken. In Fig. 4(c) the increase in reverse current is noticeable. In Fig. 4(d) not only has the heating due to the previous forward current increased the reverse current, but it has also decreased the maximum reverse voltage.

In this test, when the unit was allowed to stand with no forward current for an appreciable length of time, the reverse characteristic returned to that shown in Fig. 4(a). In other similar tests in some cases such overloads have caused a permanent increase in the reverse current.



(a) (b) (c) (d)

Fig. 4—Oscillograms showing the effect of heat produced by prior forward current on the reverse portion of the voltage-current characteristic of a germanium varistor.

Capacitance

In any area-type varistor there is appreciable capacitance in parallel with the dynamic resistance. This capacitance is a function of the polarity and magnitude of the bias voltage and of the frequency. It may be measured using a bridge of the type described for measuring ac resistance. Fig. 5 shows the capacitance of a 3/16-inch copper-oxide varistor at both 10 and 200 kc.

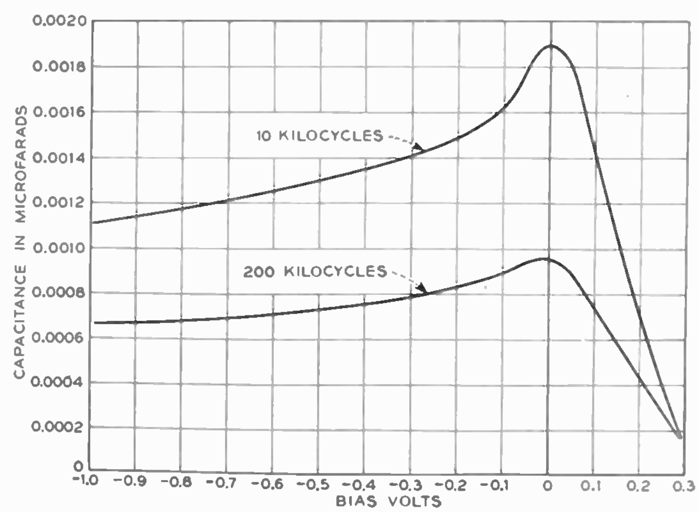


Fig. 5—Capacitance of a 3/16-inch copper-oxide varistor.

[7] Selenium is an exception to this statement. At lower temperatures the dc resistance decreases as the temperature decreases. The temperature for maximum dc resistance depends on the reverse voltage and lies in the range between freezing and usual indoor ambient temperatures. This temperature characteristic may depend on the processing of the unit, as published data from various sources are somewhat contradictory.

As the bias in the reverse direction is decreased the capacitance is increased, reaching a maximum at or near zero bias. As the bias is increased in the forward direction, the capacitance drops quite sharply, reaching a low value at high forward bias voltages.

At higher frequencies the curve has the same general shape, but the value of the capacitance is lower as shown by the curve for 200 kc in Fig. 5.

At large reverse bias voltage the capacitance of selenium is less than that of copper oxide, but as the bias voltage decreases, the rate of increase is larger in selenium than in copper-oxide varistors. As a result, at zero bias the capacitance of selenium varistors is larger than of copper-oxide varistors of the same area.

For point contact varistors it is probable that the capacitance acts in much the same manner, but measurements are more difficult to make because of the small magnitude of this capacitance, and because it is paralleled by a linear capacitance through the case of the same order of magnitude or greater. Since the total capacitance, barrier capacitance plus that through the case, is of the order of one to two micromicrofarads, it can be neglected in many applications.

Effect of Frequency on Impedance of Varistors

Both the effective capacitance and the effective resistance of a varistor[8] are functions not only of bias, but also of frequency. The effect of frequency on the capacitance was as discussed in the preceding section. In general, as the frequency increases the resistance of a varistor may be expected to decrease. Fig. 6 shows two sets of data taken on small copper-oxide varistors. Curve *A* is for 3/16-inch disks and is taken from Caruthers'[9] paper on modulators, while curve *B* is for 4-mm disks and is taken from a similar paper published in France by P. Moll.[10] Both curves show that for copper-oxide varistors the dynamic resistance decreases quite rapidly, with frequency falling from a value of over 10,000 ohms at low frequencies to a value of in the order of 200 ohms at 2 mc.

For negative bias the dynamic resistance is larger than at zero bias as shown in Fig. 2, and the curve of dynamic resistance versus frequency is approximately parallel to that at zero bias. At positive bias the dynamic resistance is much smaller, and as the value of resistance decreases, the variation with frequency decreases. Moll's article shows a curve for 4- mm copper-oxide varistor at +0.5 volts bias in which the dynamic resistance has a value of approximately 43 ohms for all values of frequency from 2 to 6 mc.

At first glance it would appear that these large changes in resistance with frequency would preclude the use of copper-oxide varistors above more than a few hundred kilocycles. Actually, modulators have been designed to work satisfactorily to frequencies over 2 mc using 3/16-inch copper-oxide varistors. The methods used and the results obtained are discussed in more detail in a later section.

The frequency characteristic of a germanium varistor is similar to copper oxide, except that the zero bias dynamic resistance is still above 10,000 ohms at 10 mc and the varistor does not reach low values until much higher frequencies. Consequently, germanium varistors are useful at much higher frequency than copper oxide, both because their capacitance component is much less and because their dynamic resistance does not drop as rapidly with frequency.

Silicon varistors in general have lower dynamic resistance than germanium, and, in contrast to germanium varistors, their resistance is almost constant for frequencies up to at least 50 mc. For this reason silicon varistors are well suited for broad-band applications.

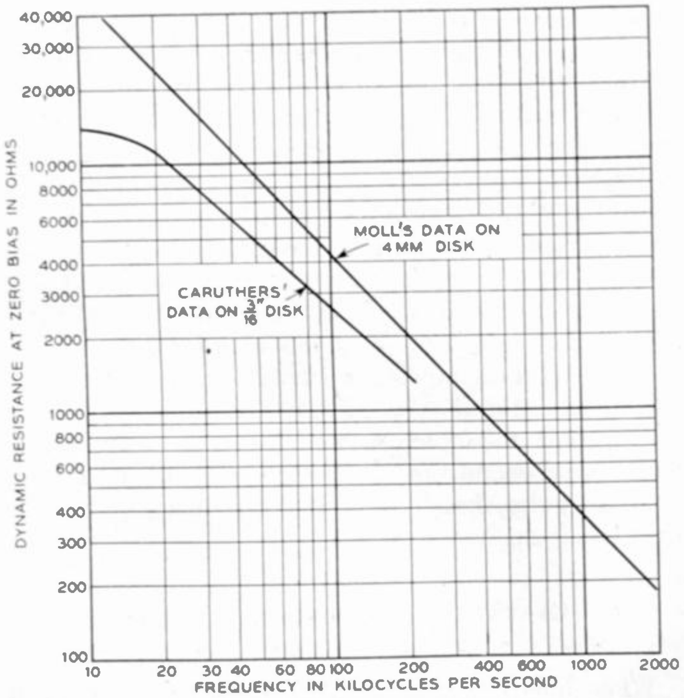


Fig. 6—Dynamic resistance at zero bias of copper-oxide varistors.

[8] A number of equivalent circuits are used in the discussion of varistors. For simplicity in this paper the equivalent circuit of a varistor is considered as a resistance in parallel with a capacitance. Obviously all resistances in the section are dynamic or ac resistance.

Stability and Aging of Varistors

One major problem in the development of varistors has been the reduction of instability. Two particular types of instability are well known—gradual changes or aging in the characteristics of a unit over periods of months or even years, and short time drift or creep in the current during the first few minutes when potential is applied.

Aging in varistors is due to many causes, some of which appear at this time to be inherent in the varistor itself and some of which can be eliminated by changes in design or processing. In the former class are aging processes that take place within the body of the semi-

[9] See bibliography reference (24).

[10] P. Moll, *Cables et Trans.* (Paris), vol. 6, pp. 24–46; 1950.

conductor and the barrier layer. The mechanisms of these changes are as yet only partly understood. In the latter class are such causes as changes due to lack of mechanical stability of parts, deterioration of contacts, and the like. The efforts of all manufacturers to eliminate causes of these latter types have resulted in marked improvement in the stability of varistors since the first introduction of copper-oxide units about twenty-five years ago, and there are reasons to believe further improvements will be made in the future.

Aging in varistors in general results in a decrease in forward current (increase in forward dc resistance) and usually[11] an increase in reverse current (decrease in reverse dc resistance). The rate of these changes gradually decreases, and after a period of one or two years the rate of aging is only a fraction of the initial rate of change.

The magnitude of this aging usually increases both as the ambient temperature is increased and as the current through the varistor is increased. Since increased current causes increased internal heating, it is possible that the effect may be entirely due to temperatures. For large copper-oxide disks operating at their full rated current, the aged value of forward dc resistance (measured at constant current) may be as high as double the initial value.

The rate of change is often accelerated by increased ambient temperatures. For example, with copper-oxide varistors it has been found that ten days' storage at 60°C is roughly the equivalent of one year's storage at average room temperature. For applications which demand extreme stability, a pre-aging process of this type can sometimes be used to eliminate a large portion of the subsequent aging of the unit.

Two different approaches are used in the solution of the problem of aging. In power rectifiers, where aging may be expected to reduce the output of the rectifier as much as 20 per cent during its life, the circuit may be designed to operate satisfactorily at the reduced output, or taps may be provided on the transformer so that the applied voltage may be increased to compensate for aging. In the later case the design of the unit must allow for the increased losses when the units are aged.[12]

In communication applications generally the amount of aging is less, as the varistors are usually operated at only a small fraction of their rated current. However, stability is much more important, particularly as it is desirable to reduce maintenance to a minimum. As a result of developments in production of varistors and careful circuit design, thousands of varistor modulators are today in operation in long-distance telephone circuits without any provision for routine maintenance tests. More detailed data on long time stability studies in communication circuits will be given in the sections on application of varistors to modulators and compandors.

In addition to long time aging, investigators in the field of varistors sometimes, but not always, encounter a drift or creep in current during the first few minutes that potential is applied. This drift may occur in either the forward or reverse current, but it is more frequently observed when measuring reverse current. While this drift is quite annoying when attempting to measure the volt-ampere characteristic of a unit, it may go unnoticed in many applications, its effects being part of the warming-up period of apparatus.

Short time drift may be due to any one of a variety of causes. When operating at high reverse or high forward current, power losses within the varistor itself are sometimes sufficient to produce internal heating and thus change the varistor characteristic as it warms up. Drift of this type is inherent in the unit and cannot be avoided. Other types of drift may be due to faulty processing. For example, in at least one case drift in the reverse direction was traced to chemical deterioration in the impregnating compound used. Other cases probably involve mechanisms of conduction in semiconductors not yet fully understood.

Noise

The fact that resistors have an inherent background noise due to thermal agitation (the so-called Johnson noise) is well known. Varistors also possess a background noise, but much less is known about the cause or nature of this noise. Unlike Johnson noise, which for a constant bandwidth is uniform throughout the frequency spectrum, varistor noise tends to vary inversely as the frequency. The noise in varistors probably is a function of the bias, appearing to be greater in absolute magnitude when biased in the reverse direction, although complete measurements are lacking. The comparison of the noise of different types of varistors is complicated by the problem of how the noise shall be expressed. The familiar designation "so many db above thermal noise" cannot be used in a circuit whose resistance (and hence theoretical thermal noise) varies with bias.

Noise becomes important when it is necessary to operate a modulator at very low levels. Field experience has shown that the quietest modulators are constructed with copper-oxide varistors.[13] However, the data available are quite sketchy and it is by no means certain that this is the final answer.

Operation of Varistors in Series or Parallel

When identical varistors are connected in series or parallel there is no particular problem. Random selected

[11] An exception is selenium varistors in which the reverse dc current frequently decreases during the first six months or so of their life.

[12] See bibliography reference (9).

[13] Early copper-oxide modulators had a high noise level but with the development of these varistors, particularly with the improvement in their contacts, the noise level has been reduced to a low value.

varistors are seldom identical, which may introduce problems in parallel or series operation. Fig. 7 shows the reverse characteristic of two dissimilar varistors. If these two varistors are to be connected in series, a new volt-ampere characteristic can be drawn for the combination by noting that the same current always flows through each varistor, and that at any value of current the total voltage across the two units in series (that is the point on the new curve) must be the sum of the voltages at this current for each of the varistors. The two varistors in Fig. 7 have quite dissimilar reverse characteristics, and this figure illustrates the situation of an engineer who finds that for his application the reverse current at some voltage is too high. He adds a second varistor, hoping to cut the reverse current in half, but instead because of the dissimilar nature of the two varistors, the reverse current is only reduced by a very small amount. Hence the basic law, two random selected varistors will be no worse than a single varistor, but may be little better. For series varistors to approximately divide the reverse voltage, they must have approximately identical characteristics.

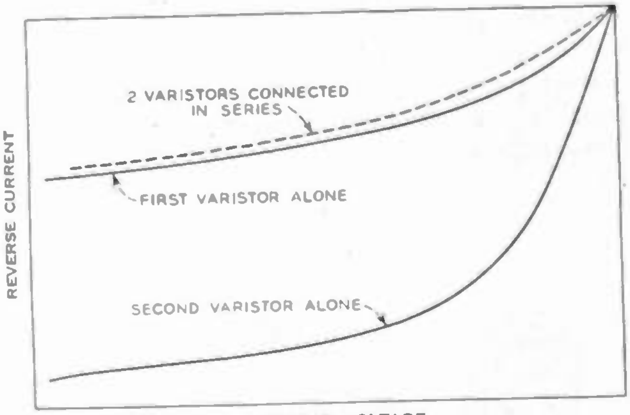


Fig. 7—Reverse portion of the voltage-current characteristic of two dissimilar varistors connected in series.

When varistors are connected in parallel, the same type of reasoning applies to the current. When varistors are connected in parallel, they divide the current equally only when they are identical.

The Symmetrical Varistor

The symmetrical varistor differs from the nonsymmetrical varistor in that the volt-ampere characteristic is the same in both directions as shown in Fig. 8. Essentially this characteristic can be obtained by connecting two identical nonsymmetrical varistors in parallel with the polarity as shown in Fig. 9. This connection suggests the convention symbol shown in the upper left corner of Fig. 8 for the symmetrical varistor.

Except for the absence of a high resistance reverse characteristic, symmetrical varistors are in many respects similar to nonsymmetrical varistors. Their application at present is almost entirely confined to some type of protective circuit, such as lightning arrestors, click or thump reducers, and voltage limiters. In these applications the varistor presents a high impedance to the low voltages normally applied. The application of

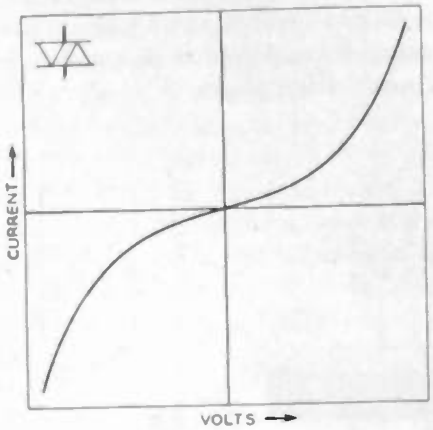


Fig. 8—Voltage-current characteristic of a typical symmetrical varistor.

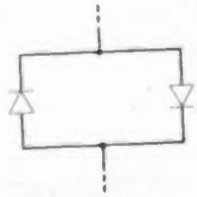


Fig. 9—Circuit connections for two nonsymmetrical varistors to obtain a symmetrical voltage-current characteristic.

abnormal higher voltages reduces the impedance of the varistor, thus limiting the amplitude of surge voltages.

Characteristics of Commercial Varistors

In this section, the general characteristics of various types of commercial varistors will be discussed and compared. While some data on units will be given, these figures are intended only to illustrate orders of magnitude, and are not intended as design data. For any application the necessary design data should be obtained from the manufacturer.

Copper-Oxide Varistors

Copper-oxide varistors are today manufactured in a wide variety of sizes, ranging from disks as small as 1/16 inch in diameter up to rectangular plates of at least $4\frac{3}{8}$ by 12 inches. The smaller units are used in meter rectifiers, modulators, and similar devices, while the larger plates are used for power rectifiers.

Basically these varistors consist of a copper plate on which a layer of cuprous oxide is produced by heat treatment. This cuprous oxide is the semiconductor and the barrier layer is located at the junction of the cuprous oxide and the mother copper (see Fig. 10(a)).

Contact to the cuprous oxide layer may be made in a variety of ways. In the early copper-oxide varistors this contact was made by a lead washer clamped under pressure against the face of the cuprous oxide. With this method of contact, the properties of the varistors are influenced to some extent by the pressure exerted on the lead washer. This type of contact is still used in units of the order of one to two inches in diameter, but has been generally superseded in smaller units and in the large copper-oxide plates.

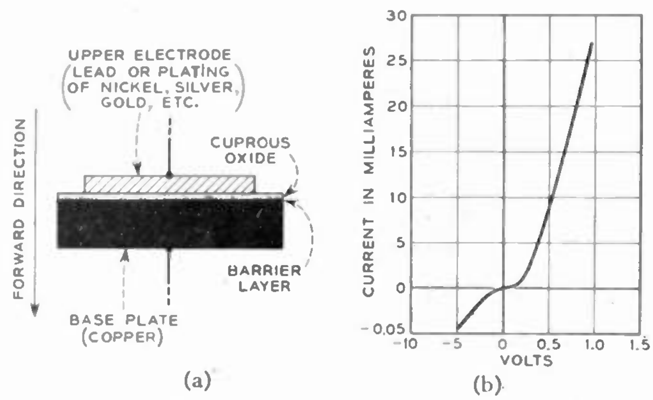


Fig. 10—Copper-oxide varistor.

In smaller varistors, contacts to the cuprous oxide layer is frequently made by evaporating a layer of silver or of gold on the oxide layer. This type of contact has been found to produce the greater degree of stability required for modulator and other nonpower applications. In large copper-oxide plates, contact is generally made by reducing the top surface of the cuprous oxide to metallic copper and then nickel-plating this surface.

The forward direction of current flow is from the top electrode to the cuprous oxide to the copper base, as shown by the arrow in Fig. 10(a). For a constant applied voltage the current in this direction is proportional to the area of the varistor. For a 3/16-inch disk the forward current at one volt is from 10 to 50 milliamperes, of the same order of magnitude as for silicon varistors and a little greater than for germanium varistors. Fig. 10(b) shows the volt-ampere characteristic of a 3/16-inch copper-oxide varistor.

In the reverse direction the current is proportional to the area with an added component, due to leakage around the periphery. This leakage component is generally minimized by careful control in manufacture. The reverse current does not show any negative resistance region. Continuous reverse voltage must be limited to the order of six volts[14] to prevent damage to the unit, although copper-oxide varistors will withstand as much as 40 to 50 volts for infrequent transients. Both the reverse ac and dc resistance are moderately high, reaching maximum values of the order of 100,000 ohms at a reverse voltage of a few volts for a 3/16-inch disk.

Most copper-oxide varistors are made using a copper base of high purity, but there are also available varistors whose base plate contains a small amount of thallium. In general, these varistors have higher dc and dynamic resistance at low-voltage levels and are used for special applications such as click reducers and other types of voltage limiters.

Selenium Varistors

As with copper oxide, selenium varistors are manufactured in a variety of sizes, ranging from disks one inch in diameter to large plates. Smaller size units are also available, but these have found much more limited application than small size copper-oxide units. Selenium varistors are made (see Fig. 11(a)) by depositing a layer of metallic selenium on a suitable base plate, generally of steel or aluminum. After suitable heat treatment, this selenium layer is covered by a layer of some low melting point alloy which forms the upper electrode. The melting point of the alloy frequently is one limitation in the operating temperature of selenium varistors.

In these varistors the semiconductor is the metallic selenium and the barrier layer is located between it and the top electrode. The forward direction of current is from the base electrode through the selenium to the top electrode, as shown by the arrow in Fig. 11(a).

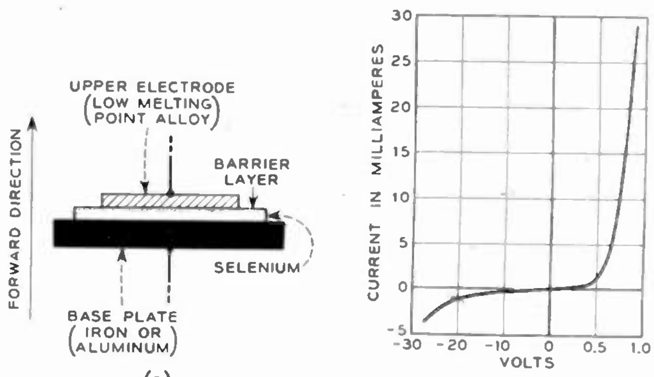


Fig. 11—Selenium varistor.

Fig. 11(b) shows the volt-ampere characteristic of a one-inch-square selenium varistor. For a given area at low forward voltages the forward current is less than for a copper-oxide varistor, as may be seen by comparing Fig. 10(b) for a 3/16-inch diameter copper-oxide varistor and Fig. 11(b) for a one-inch-square selenium varistor. These two figures also show the difference in the types of the forward characteristics. In copper-oxide varistors the forward current increases relatively fast as the forward voltage is raised, while in selenium varistors the first few tenths of a voltage cause very little increase in current.

[14] At least one manufacturer offers high reverse-voltage copper-oxide varistors rated at from 2 to 3 times this figure.

In the reverse direction the characteristics of selenium varistors are less definite than copper-oxide, due to the tendency for the reverse characteristic to deteriorate when the varistor is standing idle. On the application of reverse voltage the unit is re-formed, generally within a few cycles or, at the most, a few seconds. This re-forming process is not objectionable in power applications, but limits the usefulness of selenium varistors in other fields.

The allowable reverse voltage for selenium varistors exceeds that of copper oxide. While copper-oxide units are generally rated in rectifier circuits at $4\frac{1}{2}$ volts applied ac per unit, at least two distinct types of selenium rectifiers are available with a rating of 22 and 33 volts applied ac per unit. This increased voltage rating reduces the number of varistors required in series, producing a lighter and cheaper rectifier.

Selenium varistors may be damaged by mercury vapor, and should not be used in any application where there is a possibility of such contamination.

In general, the use of selenium varistors is confined to power applications in which light weight, small bulk, and low cost are important, and in which stability with life and large overload capacity are of secondary importance.

Copper-Sulfide Varistors

As compared to copper oxide and selenium, the production of copper-sulfide varistors is quite small. These units are also produced in a variety of sizes ranging from disks 19/32 inch in diameter to large plates. These varistors (see Fig. 12(a)) consist of a base plate of magnesium on which is placed a layer of cupric sulfide and a top electrode. The cupric sulfide is the semiconductor and the barrier layer is located between this sulfide and the magnesium base. Forward direction of current is from the top electrode through the cupric sulfide to the magnesium base, as shown by the arrow in Fig. 12(a).

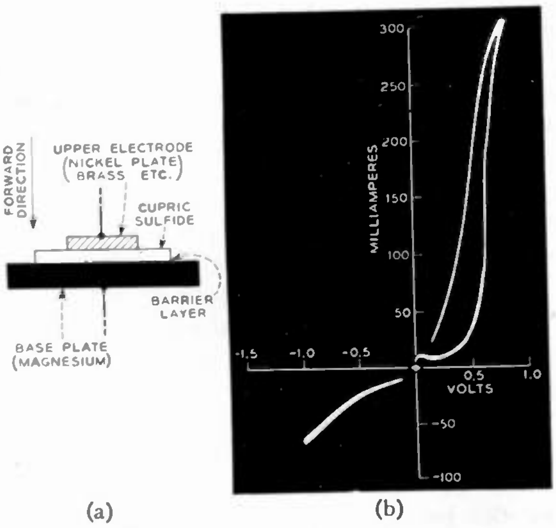


Fig. 12—Copper-sulfide varistor.

Only a limited amount of information has been published on the volt-ampere characteristics of copper-sulfide varistors, but it is generally reported that the forward current frequently is different for increasing and decreasing voltage as shown in the oscillogram in Fig. 12(b). In the reverse direction the current is much higher than that of either copper-oxide or selenium varistors, and the reverse voltage is quite limited. The two outstanding characteristics of copper-sulfide varistors are the current density at which they may be operated and their temperature characteristics. One authority reports that these units may be operated at current densities of 35 amperes per square inch in contrast to densities of about 1 ampere per square inch for copper oxide. Published curves of temperature versus dc resistance in both forward and reverse direction show a relatively much smaller change than for copper-oxide and selenium varistors. As a result, copper-sulfide rectifiers can be operated at much higher temperatures than other rectifiers.

Present uses of copper-sulfide varistors are almost entirely as power rectifiers in applications requiring low voltages and high currents. Their use in other fields where their reported superior temperature characteristics may make them desirable will depend upon whether greater stability of their volt-ampere characteristic can be obtained.

Silicon Varistors

The use of silicon as a radio detector is quite old, but the modern silicon varistor is essentially the outcome of microwave developments. As a result most silicon varistors are housed in either of the two standardized mountings shown in Figs. 13(a) and 13(b) which were originally designed to plug into microwave equipment. Fig. 13(a) is a ceramic case assembly first produced for use as a

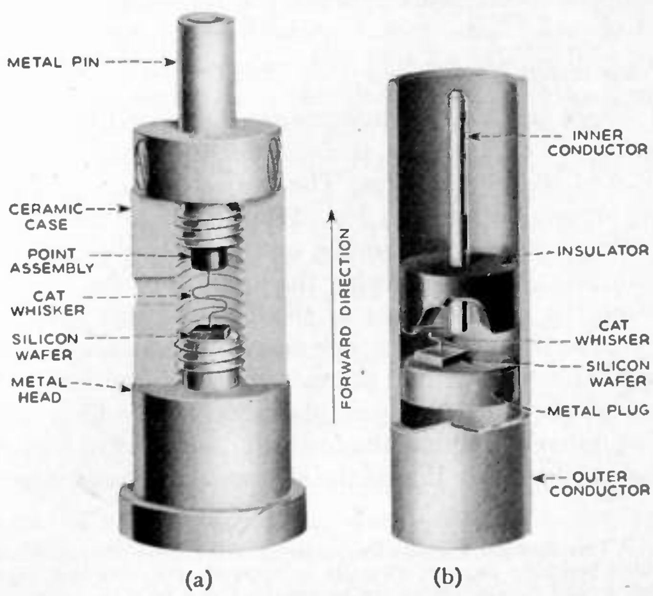


Fig. 13—Two types of silicon varistors originally designed for microwave applications.

mixer at 3,000 to 9,000 mc. Fig. 13(b) is a coaxial design produced for operation in the 24,000-mc region and also used at lower frequencies. In each of these units a small wafer of metallic silicon, generally about 50 mils square and 10 mils thick, is soldered to a brass pin. The "catwhisker," a wire of tungsten, platinum, phosphor bronze, and the like, from 3 to 15 mils in diameter, is soldered to another pin. During the process of manufacture these two pins are advanced until contact is made between the silicon wafer and the catwhisker.

Forward direction of current flow in this varistor is from the silicon to the catwhisker[15] as shown by the arrow in Fig. 13(a).

In the forward direction the silicon varistor has the lowest dc resistance of any of the point contact type of varistors, the forward current at one volt being between 10 and 60 milliamperes. At zero bias its dynamic resistance is much lower than that of germanium and somewhat lower than for most 3/16-inch copper-oxide varistors. In the reverse direction the resistance (both dc and ac) reaches its maximum value at less than $\frac{1}{4}$ volt as shown in Fig. 2. For reverse voltages of the order of one to three volts the reverse current is quite low, but beyond this the reverse current increases quite fast so that reverse voltages must be limited to this order of magnitude to prevent damage to the unit.

In general, silicon varistors have not received the attention they deserve in the past, probably because of the fact that the cost of most commercial units includes an expensive microwave test which is not necessary if the unit is to be used at lower frequencies. In addition to their superior performance at microwaves, they are well suited for many lower frequency applications, particularly where wide frequency bands are to be covered and medium impedance levels are desired.

Germanium Varistors

While germanium varistors are the newest variety of point contact varistors, their production greatly exceeds that of silicon varistors. The basic structure of most commercial units (see Fig. 14(a)) is quite similar to silicon units except that the case is generally equipped with pigtail leads, allowing the units to be mounted in much the same manner as small 1-watt size resistors. As in the silicon varistor, one metal pin has a small wafer of metallic germanium soldered to it and another pin a "catwhisker" of tungsten, platinum, or the like, wire. One difference is that the forward direction[16] of current flow is opposite to that of the silicon varistor, and is from catwhisker to the germanium as shown by the arrow in Fig. 14(a).

In the forward direction, germanium varistors pass from 3 to 25 milliamperes at 1 volt. In the reverse directions, these varistors are unique in the high reverse voltage which they will withstand. The maximum dc resistance does not occur until the unit is biased 5 to 10 volts in the reverse direction. This maximum resistance is practical always over 100,000 ohms and frequently is one or more megohms.

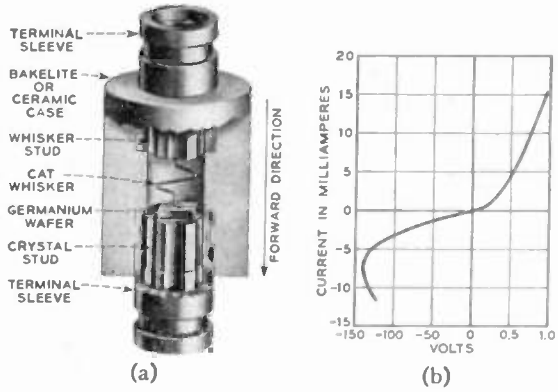


Fig. 14—Germanium varistor.
(a) Cross section of one type of germanium varistor.
(b) Voltage-current characteristic of a germanium varistor.

In the reverse direction these varistors show the characteristic maximum voltage and negative-resistance region as discussed in connection with Fig. 1(a) and as shown in the volt-ampere characteristic in Fig. 14(b). Except for one special type to be mentioned later, in practically all commercial units, this maximum is greater than 75 volts and many units will withstand voltages of 150 volts and greater.

Almost every manufacturer of germanium varistors today offers several types, all of which are of the same construction and manufacture, differing only in the values of minimum forward current, maximum reverse current, and peak reverse current at which the units are tested. If one examines a tabulation of these values he is impressed by the lack of any apparent systematic classification. One wonders if many codes have not been established because of the failure of the design engineer to understand his own requirements and particularly that these dc requirements do not always completely specify the performance of the unit. Recently units have been made available which are selected for use as detectors at 40 Mc in a specified circuit. This code will undoubtedly meet the need for which it was designed, but it leaves unsolved the problem of the design engineer who requires a unit for use at a different frequency or in a different circuit.

In addition to the standard type of germanium varistor, a second distinctly different type is now available

[15] This statement holds for varistors made from P-type silicon which probably includes all units in commercial production. Since both P- and N-type silicon can be prepared, it is possible to make a silicon varistor in which the direction of the forward current is reversed.

[16] This direction is for N-type germanium of which most, if not all, commercial germanium varistors are made. As in the case of silicon, metallic germanium can be prepared in either the N- or P-type, so a germanium varistor can be made with the opposite direction of forward current.

for use at ultra-high frequencies. In this unit the forward characteristic curve is steeper than the usual type unit and the maximum peak inverse voltage is appreciably less, generally of the order of 10 volts. The frequency characteristic of these units is superior to the characteristics of the usual units, making possible their application up into the hundreds of megacycles.

The large portion of germanium varistors manufactured today are used in communication circuits for such purposes as final detectors, clippers and other limiters, clamp circuit (so-called dc reinsertion circuits), modulators, gating and switching circuits, and the like. While not intended primarily for power use, their ability to withstand high reverse voltage and their ability to pass forward currents of 40 to 60 milliamperes make them quite suitable for small rectifiers for bias supply and similar purposes.

Silicon Carbide

Silicon-carbide disks and rods are today the only symmetrical varistors available commercially. The statement may appear as an anomaly, as it is well known that silicon-carbide crystals display marked rectifying properties. In fact, carborundum, or silicon carbide, crystals were once extensively used as crystal detectors in radio telegraphy.

The present-day silicon-carbide varistor consists of silicon-carbide granules mixed with suitable binding material and fired to form a ceramic-like rod or disk. In this form the silicon-carbide crystals are essentially connected in series-parallel with random polarity and, as a result, all nonsymmetry in conduction is lost. Contacts to these rods or disks, which may vary from ¼ to 6 inches in diameter, are generally made by plating the opposite faces.

In general, the field of application of silicon carbide lies in the higher voltage range. The exponent n of equation (1) for silicon carbide has a value of from 3.5 up to as high as 7.0, but these values can only be obtained when the potential gradient within the varistor is at least 100 to 300 volts per inch. When the potential gradient falls below this order of magnitude, the value of the exponent is markedly reduced. This generally restricts the application of silicon carbide to voltages somewhat greater than used with other types of varistors.

The major field of application of silicon carbide is in protective devices, particularly lightning arrestors, click and thump reducers, and the like.

Application of Varistors

In the application of varistors, the first step is to analyze the problem at hand in order to determine which of the properties of the proposed varistors will determine their operation in the proposed application. This step is important because properties which have little or no effect on the operation in one application may be of determining importance in another application. To demonstrate this fact, in this section three applications will be discussed, each of which requires a different viewpoint. In power rectification one important problem is to prevent the destruction of the varistors due to internal power losses. In modulators, physical failure of the varistors is almost never a problem, but considerable attention must be paid to the magnitude of distortion products generated. In the compandor, successful operation depends on the uniformity of the slope of the forward characteristic.

Application of Varistors to Power Rectifiers

In power rectification one major problem is to keep internal losses low enough so that the varistor will not be damaged by overheating. Two different losses are present: (1) those due to the low series resistance during the forward portion of the cycles, and (2) those due to the leakage through the high reverse resistance during the reverse half of the cycle. The first is a function of the current through the varistor and decreases as the temperature rises, while the second is a function of the voltage across the varistor and increases as the temperature rises. As a result the total loss may either increase or decrease with temperature, depending on whether the varistor is operated with high reverse voltage and low forward current, or with low reverse voltage and high forward current.

The problem is to operate the varistor elements so that the heat generated within each element by these losses does not exceed the amount which the element can dissipate at the maximum allowable operating temperature. Forward losses are reduced by using larger area varistors or by operating varistors in parallel. Reverse losses are reduced by operating with more varistors in series. In addition to the limit imposed by losses in the reverse direction, it is sometimes also necessary to limit the reverse voltage to a value that will prevent the unit from failing due to voltage breakdown.

When operated at high ambient temperature the heat dissipation is reduced so ratings based on normal operating temperatures must be decreased.[17] Similarly the power handling capacity may be greatly increased by forced ventilation or by intermittent operation. An example of the second type of service is the use of relatively small-size copper-oxide rectifiers to close circuit breakers. Here the rectifier is energized only occasionally and only for a short interval, hence the continuous duty rating of the rectifier can be greatly exceeded.

In practice, most power rectifiers are full-wave because of increased efficiency and better wave shape in the output. Fig. 15 shows two single-phase, full-wave rectifier circuits which externally are equivalent in all respects. Which of these circuits is used generally depends on the characteristics of the rectifying element. With vacuum tubes, except for high-voltage applica-

[17] For example, see curve in bibliography reference (15).

tions, voltage in the reverse direction is not a limiting factor. Hence the center-tapped circuit of Fig. 15(a) is generally preferred because only two rectifying elements are required and because a single filament supply can be used. In a varistor rectifier, except for low-voltage applications, the reverse voltage requires more than one

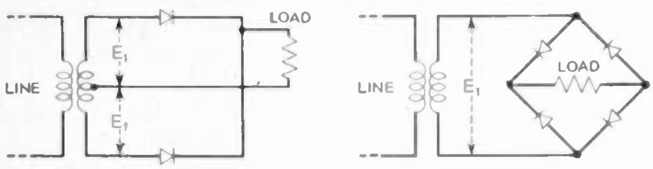


Fig. 15—Single-phase full-wave rectifier circuits.

varistor unit in series. Hence the bridge connection of Fig. 15(b) with its simpler transformer is generally preferred. In this circuit the total reverse voltage during each half of the cycle is impressed across one diagonally opposite pair of the varistors in the bridge. Similar rectifier circuits are available for polyphase operation.

Application of Varistors in Bridge- and Lattice-(Ring) Type Modulators

The extent that varistors have been utilized in bridge- and lattice-type modulators[18] is probably little realized by engineers other than those directly connected with long-distance telephone service. The copper-oxide modulator was introduced in carrier telephone service about 1936 and very quickly supplanted the vacuum tube because of its simplicity, higher degree of stability, longer life, lower maintenance costs, absence of power drain during stand-by periods, and ability to act as a bilateral device.

Prior to the close of the second World War, all varistor modulators installed were of the copper-oxide type. These were initially installed in systems where the frequency translation was from voice frequency up to carrier frequencies of less than 100 kc. This range was then expanded into the hundreds of kilocycles, and finally in the coaxial system super-group modulators were developed which work at frequencies up to 2 mc.

Since the close of World War II, both silicon and germanium varistors have been used as modulators in carrier systems. While it is doubtful that it would be economical to replace copper-oxide modulators with silicon or germanium modulators in systems already installed or even already designed, it is probable that the future trend will be away from copper-oxide modulators except for low-frequency applications, and possibly for applications in which a low noise level is necessary.

The outstanding problem in modulators is the reduction of undesired modulation products. If two signals, such as a signal S and a carrier C, are impressed on any nonlinear device an infinite number of new components whose frequencies are $NC \pm MS$ are generated. Here N and M are integers having any value including zero. One of these new products, generally $C+S$ or $C-S$, is the desired new frequency, while others represent extraneous products which must be eliminated by selective circuits or must be reduced to acceptable values by circuit design.

All of this infinite number of modulation products may be divided into four groups, namely:

$$N_oC \pm M_oS \quad \text{(A)}$$

$$N_eC \pm M_oS \quad \text{(B)}$$

$$N_eC \pm M_eS \quad \text{(C)}$$

$$N_oC \pm M_eS \quad \text{(D)}$$

in which N_e and M_e are any even integer, including zero, and N_o and M_o are any odd integer. The spectra of these four groups of modulation products are shown in Fig. 16.

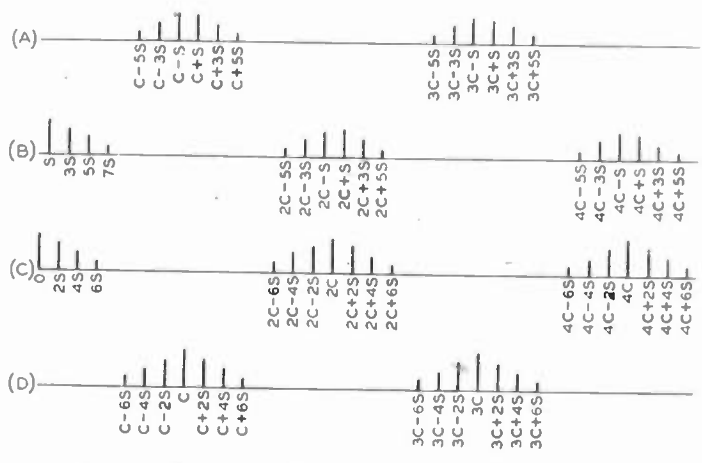


Fig. 16—Spectra of modulation products formed from a carrier of frequency C and a signal of frequency S.

When a single varistor or vacuum tube is used in a modulator circuit, all of these four groups of modulation products are present in the output. If, however, a multiple-unit modulator is used, certain of these groups can be eliminated from the output. Three circuits frequently used for this purpose are shown in Figs. 17(a), 17(b), and 17(c). Assuming perfect balance in the bridge-type modulator of Figs. 17(a) and 17(b), only the modulation products of groups (A) and (B) appear in the output. In the lattice- or ring-type modulator of Fig. 17(c) there is an additional degree of balance. Here only the

[18] A modulator is a device which is used to translate a band of frequencies from one portion of the spectrum to another. This shift may be either upwards, as when transferring a message band from its original position to a new position in the spectrum, or downwards, as when the message band is restored to its original position. In the second case, the translation is sometimes referred to as demodulation, but since the processes are identical it is simpler here to group all such translations under the general term of modulation.

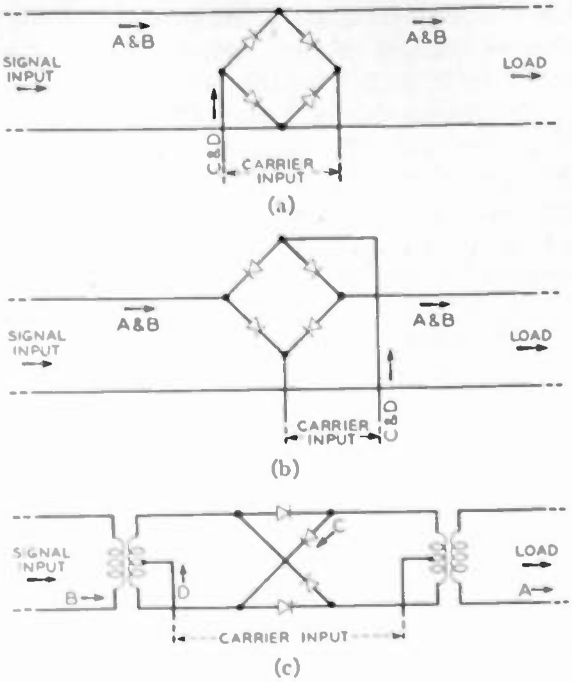


Fig. 17—Balanced modulator circuits. The letters *A*, *B*, *C*, and *D* in each circuit indicate the spectra (according to Fig. 16) appearing in various branches of these modulators.

TABLE I

Modulation Products in Output of Lattice-Type Modulator Using Western Electric Co. 3/16-Inch Copper-Oxide Varistors

Carrier Input: 15 db above 1 milliwatt
Sideband Output: 10 db below 1 milliwatt

Product	Order of Modulation	Is Product Affected by Balance?	Amplitude of Product in db below $(C-S)$
$C \pm S$	2nd	No	0
S	1st	Yes	20
$2S$	2nd	Yes	40
$3S$	3rd	Yes	70
C	1st	Yes	0
$2C$	2nd	Yes	10
$3C$	3rd	Yes	5
$4C$	4th	Yes	13
$5C$	5th	Yes	8
$6C$	6th	Yes	15
$7C$	7th	Yes	10
$2C \pm S$	3rd	Yes	20
$3C \pm S$	4th	No	5
$4C \pm S$	5th	Yes	23
$5C \pm S$	6th	No	8
$6C \pm S$	7th	Yes	25
$7C \pm S$	8th	No	10
$C \pm 2S$	3rd	Yes	45
$C \pm 3S$	4th	No	50
$2C \pm 2S$	4th	Yes	50
Noise	10 db above thermal noise		

Note: Above values are probable worst values. Only a moderate degree of balance is assumed and those products affected by balance can be reduced to greater extent if the balance is improved.

products of group (A) appear in the output. In each of the modulators, the products which are not present in the output appear elsewhere, as indicated in Figs. 17(a), 17(b), and 17(c).

Of the unwanted products falling in the output, some such as $3C \pm S$ are so widely separated in frequency from the desired output that there is no difficulty in eliminating these products by selective circuits. Other undesired products, particularly those of the $C \pm 3S$ type, are more difficult to eliminate, especially as they may fall within the pass band of the output filter. Such products must be reduced in magnitude by correct adjustment of the operating levels.[19] The magnitude of extraneous products permissible is dependent on the requirements of the system and is determined by such factors as permissible noise, distortion, and crosstalk between channels. In long-distance telephone circuits the limits imposed on single modulators may be quite severe, as these systems often contain several modulators in tandem, each of whose extraneous products contribute to the degradation of the circuit.

As an example of the order of magnitude of these various products, Table I indicates the worst value to be expected when using four Western Electric 3/16-inch copper-oxide varistors in a lattice-type circuit. In this table, it is assumed that the balance of the varistor suppresses carrier, and so forth, by only 25 db. This represents only a moderate degree of selection of the varistor elements and greater suppression can be obtained.

The degree of balance obtained is inherently dependent on the effort used in selecting the individual varistors of the modulator assembly. With purely random selection one cannot expect better than 10-to-1 reduction.[20] With a reasonable degree of selection, reductions as high as 50 to 1 can be obtained. For special application, even higher reduction can be obtained, particularly if auxiliary balancing circuits may be used. Once the balance is obtained, it is quite stable, in marked contrast to the balance obtained when using balanced vacuum-tube modulators.

The maintenance of the balance in a modulator is a severe test of the stability of varistors. Either the varistors must show no aging, or the aging from unit to unit must be extremely uniform. The degree to which this balance can be maintained, without any adjustments, is illustrated in Fig. 18, which shows the results of two surveys on approximately 600 bridge-type modulators using 3/16-inch copper-oxide varistors located in toll centers in the eastern part of the United States. At the time of installation in 1938 to 1940 all modulators having a carrier leak greater than 33 db below the level of the carrier supply were rejected. The dotted curve

[19] See bibliography reference (24).

[20] These figures are for the ratio of carrier voltage across a bridge modulator to carrier voltage in output. Because of difference in impedance levels, the ratio of power at these points is greater.

shows the percentage of installed units having carrier leak equal to or greater than the value given on the abscissa. Carrier leak value ranging all the way from 33 to 63 db below the level of the carrier supply were obtained, with 50 per cent of the modulators having a carrier leak of 43.4 db below carrier level or less. During 1949 the second survey was made on these same units and the results are shown by the solid line. This survey showed that while some changes had occurred in the individual modulators, from a statistical viewpoint there has been little change in the group of modulators as a whole.

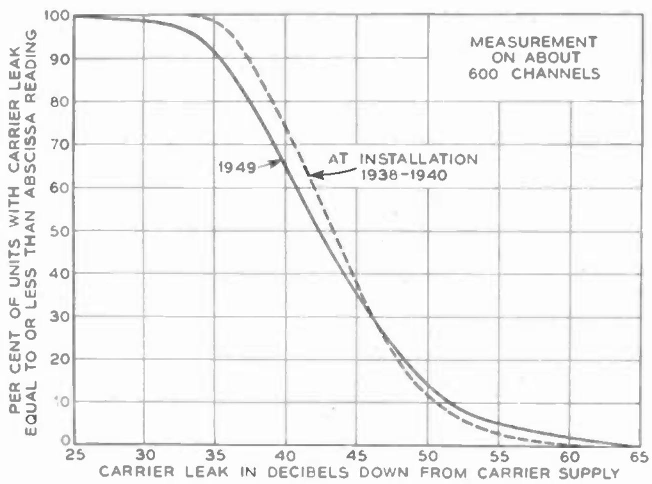


Fig. 18—Results of two surveys showing the stability of balance in copper oxide modulators.

In a preceding section it was pointed out that the dynamic resistance of a copper-oxide varistor drops rapidly as the frequency is increased. This plus the shunting effect of the capacitance would indicate that copper-oxide modulators are limited to audio and perhaps the lower carrier frequencies. That this is not the case may be seen by experience on the type-L1 coaxial system. In this system a total of 60 message channels are assembled to form a super-group occupying the frequency space from 312 to 552 kc. Eight such super-groups are assembled, and then each is translated to its position on the coaxial line using a lattice modulator such as shown in Fig. 17(c).[21] In each of these modulators, the input transformer has a ratio of 72 to 66 ohms, while the ratio of the output transformer is progressively reduced so that as the frequency is increased the varistor lattice operates into a lower and lower impedance. By this means it has been found possible to operate copper-oxide modulators to 2 mc with only the small increase in loss shown in Table II.

[21] There is no modulator for super-group No. 2 as the line frequency of this super-group is the same as the frequency band in which the super-group is assembled.

Since the original design of the L1 system, two additional super-groups have been added at 2,172 to 2,408 kc and 2,552 to 2,788 kc. By the time this addition was made, silicon varistors were available and for these two higher-frequency super-group silicon varistors operating at impedance levels of about 400 ohms are now used.

Modulators are one application of varistors which in practice are relatively free from troubles due to ambient temperature variations, except where high degree of balance is desired. This is because the carrier voltage applied is sufficient to drive the varistor into that portion of the characteristic where temperature effects are of negligible magnitude.

TABLE II

SUPER-GROUP MODULATORS FOR TYPE-L1 CARRIER

Super-Group No.	Line Frequency kc	Carrier Frequency kc	Impedance Ratio of Output Trans.	Modulator Loss—db
1	68 to 308	620	75 to 72	6.5
2	312 to 552	—	—	—
3	564 to 804	1,116	46 to 72	6.7
4	812 to 1,052	1,364	46 to 72	6.8
5	1,060 to 1,300	1,612	33 to 72	7.2
6	1,308 to 1,548	1,860	33 to 72	7.3
7	1,556 to 1,796	2,108	25 to 72	7.6
8	1,804 to 2,044	2,356	25 to 72	8.0

Application of Varistors in Compandors

In communication circuits the distance between repeater points is determined by the rate of attenuation of the medium, the maximum power available at the output of each repeater, and the noise level at the input of each repeater. When the signal to be transmitted varies in amplitude, as it will in a commercial telephone circuit due not only to normal variations in amplitude present in speech but also to variation in level of differ-

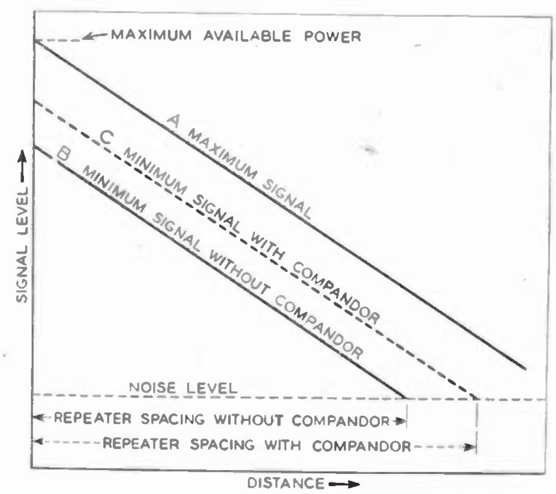


Fig. 19—Signal levels between two repeater stations showing the effect of a compandor on repeater spacing.

ent talkers, the situation is as shown in Fig. 19. At the first repeater the output must be adjusted so the maximum signal does not exceed the maximum available power. The minimum signal is then attenuated according to curve *B* and the next repeater must be located before this signal falls below the noise level. If the ratio of maximum to minimum signal could be decreased so that the minimum signal is that shown in curve *C*, it would be possible to increase the distance between repeaters.

One way to accomplish this is to pass the signal at the transmitting end through a circuit which acts as a compressor. At the far end of the circuit the signal is passed through an expandor which restores the signal to its original shape. This combination of a compressor followed by an expandor has been termed a "compandor."

The compandor was first introduced to combat static on hf transoceanic radio circuits.[22] Later it was applied to wire lines[23] in special locations where the improvement in noise and crosstalk was needed. More recently the compandor has been engineered as an integral part of new carrier telephone systems.

Fig. 20 shows a block diagram of one type of compandor. At the transmitting end the speech is passed through a variable pad or vario-losser whose loss is controlled by a dc current derived by rectifying the output of the signal. The time constant of the circuit is such that this dc current varies at syllabic rate, rather than following the instantaneous values of speech. When a loud signal is applied, the large dc control current effectively increases the attenuation of the vario-losser and

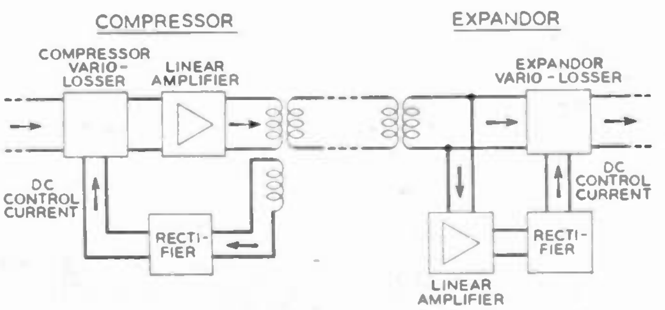


Fig. 20—Block diagram of a compandor system.

reduces the output. In this manner, the peaks of the slow variations in the speech are reduced in amplitude in proportion to their amplitude, thus obtaining a signal having a smaller ratio of maximum to minimum signal.

At the received end a portion of the incoming signal is rectified and another dc control current obtained. This control current is applied to a second vario-losser, which performs the reverse function of the vario-losser in the transmitting end restoring the signal to its original condition.

[22] See bibliography reference (27).
[23] See bibliography reference (28).

The heart of the compandor is the two vario-lossers. These are passive networks composed of varistors and resistors. In this application the property of the varistor used is its ability to change its dynamic or ac resistance in accordance with variations of a dc bias. In selecting varistors for this application a much greater stress must be placed on uniformity than in most other applications, as the operation of the vario-losser at the receiving end must exactly complement that of the one at the transmitting end. Temperature variations are also important, particularly as the two ends of the circuit may be located as much as one hundred miles or more apart. In the first compandor this temperature problem was solved by placing the copper-oxide varistors in a miniature oven which was maintained at constant temperature. More recently a vario-losser has been developed using germanium varistors which does not require an oven.

It will be noted that while both germanium and copper-oxide varistors have been used in this application, in neither case is the reverse characteristic used. The dc control current always biases the varistor to a point on the forward portion of its curve. There is no reason why varistors of the symmetrical type should not be used for this service, except that to date the characteristics of types available have not fitted practical designs.

The manufacturing problem of vario-lossers for a compandor system requires a high degree of control of uniformity of the product, especially since it is desirable from an operating viewpoint that any expandor vario-losser be suitable to operate with any compressor vario-losser. As an initial step the germanium varistors are classified in accordance with their dynamic resistance at two different dc biases. Following this, a vario-losser pad is made from the selected varistors and its transmission characteristic measured at several values of dc control current. In the case of the compressor vario-losser, an additional test for balance is required to insure against singing around the amplifier-rectifier-control circuit path.

To study the stability of germanium varistors in compandor service, eight vario-lossers were placed on life test in a circuit in which the dc control current was the maximum value encountered in service. At intervals an ac input was applied to each vario-losser and its output was measured. This life test was conducted for over 14,000 hours. During this period, variations in output were of a random nature, the greatest total variation being 0.5 db. Most of the units showed total variations not exceeding 0.3 db with at least half of this variation, probably due to variations in the measuring circuit.

Other Applications

In addition to these three applications, there are many other uses for varistors, each of which has its own peculiar set of requirements. For protective circuits, such as the lightning arrestors in power distribution circuits or the click reducers connected across telephone operators' headsets, it is important that the varistor present a high shunt impedance to the normal low voltages and instantaneously offer a low impedance path to any high-voltage surge. In some such applications ability to dissipate the energy in the surge is an important factor in the design, as illustrated by the use of large size silicon carbide disks in lightning arrestors.

Computers sometimes contain a large number of parallel circuits, each having a varistor normally biased in the reverse direction. By reversing the bias on one varistor so that it works on the forward portion of its characteristics, a gate is opened and a pulse is admitted to the circuit. In this application the dc resistance of the varistor in the reverse direction is often of major importance, as the total dc resistance of all varistors in parallel determines the impedance level for which the computer circuit may be designed. This impedance level in turn has a major influence on the total power consumption of the computer.

In conclusion, the writer hopes to have shown that all varistors, whether they be copper-oxide rectifiers, silicon carbide disks, crystal diodes, or the like, possess many common properties, and that the engineering application of varistors requires not only an understanding of these properties but also an appreciation of which of the properties play dominant roles in the application at hand.

Acknowledgments

A survey paper of this type can never be the work of one person. The writer wishes to acknowledge many references to published literature, and considerable indebtedness to many colleagues in the Bell Telephone Laboratories, Inc., for information as to the construction and characteristics of various types of varistors and for details of various applications. Special acknowledgment is made to J. R. Flegal, M. C. Waltz, and R. E. Crane. The test set used to obtain the oscillograms was designed and constructed by R. R. Blair.

Bibliography

This bibliography, which is by no means complete, lists some of the more important readily accessible references in the English language. A more complete bibliography, including foreign references, may be found in reference (2).

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(2) H. K. Henisch, "Metal Rectifiers," Oxford University Press, England; 1949.
(3) W. Shockley, "Electrons and Holes in Semi-Conductors," D. Van Nostrand, Inc., New York, N. Y.; 1950.
(4) G. L. Pearson, "The physics of electronic semi-conductors," *Trans. AIEE*, vol. 66, pp. 209–214; 1947.
(5) S. J. Angello, "Semi-conductor rectifiers," *Elec. Eng.*, vol. 68, pp. 865–872; October, 1949.
(6) J. A. Becker, "Photo effects in semi-conductors," *Elec. Eng.*, vol. 68, pp. 937–942; November, 1949.
(7) K. Lark-Horovitz, "Conductivity in semi-conductors," *Elec. Eng.*, vol. 68, pp. 1047–1056; December, 1949.

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(9) E. A. Harty, "Aging in copper oxide rectifiers," *Gen. Elec. Rev.*, vol. 39, pp. 244–245; May, 1936.
(10) A. L. Williams and L. E. Thompson, "Metal rectifiers," *Jour. IEE*, vol. 88, part I, pp. 353–371; 1941.
(11) L. O. Grondahl, "Twenty-five years of copper oxide rectifiers," *Trans. AIEE*, vol. 67, pp. 403–410; 1948.
(12) I. R. Smith, "The copper oxide rectifier," *Elec. Eng.*, vol. 67, pp. 1051–1058; November, 1948.

Selenium Varistors

(13) E. A. Richards, "The characteristics and applications of the selenium rectifier," *Jour. IEE*, vol. 88, part II, pp. 423–438; 1941. Also, vol. 88, part III, pp. 238–253; 1941. Abridgement, vol. 88, part I, pp. 384–387; 1941.
(14) J. E. Yarmack, "Selenium rectifiers and their design," *Trans. AIEE*, vol. 61, pp. 488–495; 1942.
(15) W. H. Falls, "Rectifiers—selenium and copper oxide," *Gen. Elec. Rev.*, vol. 50, pp. 34–38; 1947.

Copper-Sulfide Varistors

(16) C. A. Kotterman, "The magnesium-copper sulfide rectifier battery charger for railroad passenger cars," *Trans. AIEE*, vol. 58, pp. 260–265; 1939.
(17) C. A. Kotterman, "The copper sulfide rectifier as a source of power for projection arc," *Jour. Soc. Mot. Pic. Eng.*, vol. 32, pp. 558–565; 1939.

Silicon Varistors

(18) J. H. Scaff and R. S. Ohl, "Development of silicon crystal rectifiers for microwave radar receivers," *Bell Sys. Tech. Jour.*, vol. 26, pp. 1–30; 1947.
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Germanium Varistors

(20) W. C. Dunlap, Jr., "Germanium—important new semiconductor," *Gen. Elec. Rev.*, vol. 52; pp. 9–17; 1949.
(21) S. Benzer, "High inverse voltage germanium rectifiers," *Jour. Appl. Phys.*, vol. 20, pp. 804–815; 1949.

Silicon-Carbide Varistors

(22) K. B. McEachron, "Thyrite, a new material for lightning arresters," *Trans. AIEE*, vol. 49, pp. 410–417; 1930. Also, *Gen. Elec. Rev.*, vol. 33, pp. 92–99; 1930.
(23) F. Ashworth, W. Needham, and R. W. Sellars, "Silicon carbide non-ohmic resistors," *Jour. IEE*, vol. 93, part I, pp. 385–401; 1946.

Application of Varistors to Power Rectification

See references under copper oxide, selenium, and copper sulfide, especially references (13), (14), and (15).

Application of Varistors as Modulators

(24) R. S. Caruthers, "Copper oxide modulators in carrier telephone systems," *Trans. AIEE*, vol. 58, pp. 253–260; 1939. Also, *Bell Sys. Tech. Jour.*, vol. 18, pp. 315–337; 1939.
(25) V. Belevitch, "Linear theory of bridge and ring modulators circuits," *Elec. Commun.*, vol. 25, pp. 62–73; 1948.
(26) D. G. Tucker, "Rectifier modulators with frequency selective terminations," *Jour. IEE*, vol. 96, part III, pp. 422–428; 1949.

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(27) R. C. Mathes and S. B. Wright, "The compandor—an aid against static in radio telephony," *Bell Sys. Tech. Jour.*, vol. 13, pp. 315–332; 1934.
(28) C. W. Cater, Jr., A. C. Dickieson, and D. Mitchell, "Application of compandors to telephone circuits," *Trans. AIEE*, vol. 65, pp. 1079–1086; 1946.

Radio Progress During 1950*

Introduction

TELEVISION received more widespread attention in the United States during 1950 than any other radio-electronic subject. This attention was focused primarily on consideration by the Federal Communications Commission of color-television systems. Hearings and demonstrations started in 1949 disclosed active proponents of three fundamental methods based on field-, line-, and dot-sequential repetitions of three primary colors to build a picture in full color. Considerable light, accompanied by much heat, was cast on these methods by their proponents and opponents in both the public and technical press.

The Commission decided in favor of the field-sequential method and offered to delay official adoption if the manufacturers would promptly redesign their receivers to accept the concommitant new color scanning standards, as well as those for the existing black-and-white system. Failure of the manufacturers to agree to this resulted in the official adoption of the field-sequential system. The matter is now in the courts, a stay having been issued against commercial service pending review by the Supreme Court.

Black-and-white television broadcasting has expanded greatly. There are now more than one hundred broadcasting stations interconnected by 15,000 channel-miles of wire and radio links in the United States alone. Activities elsewhere have progressed to the point where international standards on fundamental features of transmission are being developed.

The microphone designer has met the need of television broadcasting by producing ever-smaller units that shrink into the unidentified "background" of a performance. The duplication of magnetic tape records by contact printing from a master record should aid immeasurably in the commercialization of this type of recording.

An interesting glossary of terms used in identifying various flaws in sound reproduction should prove useful to those who must describe these queer noises.

The propagation of radio waves, particularly in the microwave region, has shown discrepancies in equations based on a fictitious smooth earth having a radius of fourth-thirds the actual sphere. Transmission is much better than present theory predicts.

The use of radio "telescopes" for astronomical purposes has permitted the successful observation of a solar eclipse during a torrential rainstorm and hurricane. Thus do the longer centimeter waves penetrate barriers that are opaque to light waves.

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As has been true for a decade or more, the advances in receivers, particularly those for broadcasting, have been dominantly based on improvements and new developments in vacuum tubes. Although no startling inventions have been disclosed this year, there has been steady progress in adapting designs to specific problems, with understandably greatest emphasis on reducing the number of tubes in television receivers.

While there have been few of the headline type of developments during 1950, there has been consistent progress in the persistent whittling away of the barriers that mark the limit of our knowledge and the extent of our activities. It represents much more a consolidation of gains than a spearhead into new and unpredictable ventures.

Antennas and Waveguides

Antenna Theory

Several new books on antennas were published during 1950, including the following:

(1) D. W. Fry and F. K. Howard, "Aerials for Centimetre Wavelengths," Cambridge University Press; 1950.
(2) E. C. Jordan, "Electromagnetic Waves and Radiating Systems," Prentice-Hall, Inc., New York, N. Y.; 1950.
(3) J. D. Kraus, "Antennas," McGraw-Hill Book Co., Inc., New York, N. Y.; 1950.

Theoretical investigations on the approximate theorem that the pattern of an antenna is the Fourier transform of its aperture distribution have been examined critically and formulated in more precise terms.

(4) H. G. Booker and P. C. Clemmow, "The concept of an angular spectrum of waves and its relation to that of polar diagram and aperture distribution," *Jour. IEE* (London), vol. 97, part 3, pp. 11–17; January, 1950.

A summary of German developments in artificial-dielectric media and their applications to microwave radiators was published. Several articles described theoretical and experimental investigations of the properties of various artificial dielectrics to determine design data for applications.

(5) O. M. Stuetzer, "Development of artificial microwave optics in Germany," Proc. I.R.E., vol. 38, pp. 1053–1056; September, 1950.
(6) J. Brown, "Design of metallic delay dielectrics," *Jour. IEE* (London), vol. 97, part 3, pp. 45–48; January, 1950.
(7) C. A. Cochrane, "An experimental verification of the theory of parallel-plate media," *Jour. IEE* (London), vol. 97, part 3, pp. 72–76; March, 1950.
(8) G. Estrin, "The effective permeability of an array of thin conducting disks," *Jour. Appl. Phys.*, vol. 21, pp. 667–670; July, 1950.
(9) S. B. Cohn, "Electrolytic-tank measurements for metallic delay lens media," *Jour. Appl. Phys.*, vol. 21, pp. 674–680; July, 1950.
(10) A. E. Heins, "The reflection of an electromagnetic plane wave by an infinite set of plates III," *Quart. Appl. Math.*, vol. 8, pp. 281–291; October, 1950.

The calculation of the radiation from single- and multiple-wire transmission lines received some attention. Also, an approximate theoretical treatment of the radiation from conical horn antennas was published, together with an experimental verification of the patterns.

(11) M. Jenssen, "On radiation from overhead transmission lines," *Jour. IEE* (London), vol. 97, part 3, pp. 166–178; May, 1950.
(12) M. G. Schorr and F. J. Beck, Jr., "Electromagnetic field of the conical horn," *Jour. Appl. Phys.*, vol. 21, pp. 795–801; August, 1950.

The theory of radiation from a slot of arbitrary configuration in the surface of an infinite circular cylinder was presented and applied to the calculation of the distant field of a narrow rectangular slot. Experimental tests confirmed the theoretical patterns.

(13) S. Silver and W. K. Saunders, "The external field produced by a slot in an infinite circular cylinder," *Jour. Appl. Phys.*, vol. 21, pp. 153–158; February, 1950.
(14) S. Silver and W. K. Saunders, "The radiation from a transverse rectangular slot in a circular cylinder," *Jour. Appl. Phys.*, vol. 21, pp. 745–749; August, 1950.

A theoretical and experimental investigation of dielectric-tube antennas showed that they acted more as lenses than as leaky waveguides, and therefore the suggestion was advanced that they are fundamentally different from dielectric-rod antennas.

(15) D. G. Kiely, "Factors governing the radiation characteristics of dielectric-tube aerials," *Jour. IEE* (London), vol. 97, part 3, pp. 311–321; September, 1950.

Two papers discussed the theory of transmission and reception of waves of arbitrary (elliptical) polarization by using a complex-vector effective length.

(16) G. Sinclair, "The transmission and reception of elliptically polarized waves," Proc. I.R.E., vol. 38, pp. 148–151; February, 1950. Correction, p. 1216; October, 1950.
(17) E. Roubine, "Les proprietes directives des antennes de reception," *Onde elect.*, pp. 259–266; June, 1950.

Equivalent circuits for describing the effects of input configuration on the impedance of an antenna and approximate methods for determining them have been described.

(18) J. R. Whinnery, "The effect of input configuration on antenna impedance," *Jour. Appl. Phys.*, vol. 21, pp. 945–956; October, 1950.

Antenna Measurements

Progress in antenna measurements has been mainly in the refinements that have been made in the measurements of antenna impedance using slotted-line methods. Methods were developed for applying corrections to measurements made with equipments having imperfections.

(19) M. H. Oliver, "Discontinuities in concentric-line impedance measuring apparatus," *Jour. IEE* (London), vol. 97, part 3, pp. 29–38; January, 1950.
(20) A. M. Winzemer, "Methods for obtaining the voltage standing-wave ratio on transmission lines independently of the detector characteristics," Proc. I.R.E., vol. 38, pp. 275–279; March, 1950.
(21) R. G. Medhurst and S. D. Pool, "Correction factors for slotted measuring lines at very high frequencies," *Jour. IEE* (London), vol. 97, pp. 223–230; July, 1950.
(22) W. B. Wholey and W. N. Eldred, "A new type of slotted line section," Proc. I.R.E., vol. 38, pp. 244–248; March, 1950.

The patterns of antennas may be measured indoors by a method in which a large metal lens is used to produce a uniform illumination of the antenna.

(23) G. A. Woonton, R. B. Borts, and J. A. Carruthers, "Indoor measurement of microwave antenna radiation patterns by means of a metal lens," *Jour. Appl. Phys.*, vol. 21, pp. 428–430; May, 1950.

A theoretical investigation of the effect of a circular ground plane on the impedance and pattern of a quarter wavelength antenna mounted on it has been carried out, using oblate spheroidal wave functions.

(24) A. Leitner and R. D. Spence, "Effect of a circular groundplate on antenna radiation," *Jour. Appl. Phys.*, vol. 21, pp. 1001–1006; October, 1950.

Amplitude-Modulation Broadcast Antennas

Progress in antennas for amplitude-modulation broadcasting was limited largely to refinements of existing techniques. There has also been some development leading toward the simplification of directional-antenna calculations and improved equipment for the maintenance of existing installations.

(25) H. Brueckmann, "Antifading broadcast antenna," *Electronics*, vol. 23, pp. 82–85; May, 1950. Correction, p. 228; August, 1950.
(26) A. C. Todd, "An antenna analyzer," *Electronics*, vol. 23, pp. 82–87; September, 1950.

Frequency-Modulation Broadcast Antennas

The requirements for antennas for frequency-modulation and television broadcasting are more often structural than electrical.

(27) A. G. Kandoian, "A survey on FM and TV broadcast antenna problems," (Abstract) Proc. I.R.E., vol. 38, p. 958; August, 1950.

Television Antennas

Progress in television transmitting antennas has been in the direction of improved gain and in the development of efficient designs for the ultra-high-frequency band.

(28) L. J. Wolf, "High gain and directional antennas for television broadcasting," *Broadcast News*, pp. 46–53; March–April, 1950.
(29) O. O. Fiet, "A supergain u.h.f. TV transmitting antenna," *RCA Rev.*, vol. 11, pp. 212–227; June, 1950.

A relatively large number of papers were published on television receiving antennas. One of these reflects the growing tendency for manufacturers to furnish receivers with built-in antennas. Another indicates progress toward an improved ratio of wanted-to-unwanted signals in fringe areas. General trends in receiver antenna design are discussed in another paper.

(30) K. Schlesinger, "Built-in antenna for TV receivers," *Electronics*, vol. 23, pp. 72–77; January, 1950.
(31) G. N. Carmichael, "TV antenna phase control," *Radio and Electronics*, vol. 21, pp. 54–56; June, 1950.
(32) I. Kamen, "Trends in TV receiver antenna design," *TV Engineering*, vol. 1, pp. 8–11; January, 1950.

Microwave Antennas

Advances were made in microwave radiators capable of scanning over a wide angle. These radiators made use of lenses, a reflector and phased line source feed, and a unique type of lense that is capable of being scanned over a 360-degree angle. Further results were reported on the radiation characteristics of conical horn antennas.

(33) J. Ruze, "Wide-angle metal-plate optics," PROC. I.R.E, vol. 38, pp. 53–59; January, 1950.
(34) R. C. Spencer, C. J. Sletten, and J. E. Walsh, "Correction of spherical aberration by a phase line source," *Proc. NEC* (Chicago), vol. 5, pp. 320–333; September, 26, 27, 28, 1949.
(35) S. S. D. Jones, "A wide-angle microwave radiator," *Jour. IEE* (London), vol. 97, part III, pp. 255–258; July, 1950.
(36) A. P. King, "The radiation characteristics of conical horn antennas," PROC. I.R.E., vol. 38, pp. 249–251; March, 1950.

Waveguides and Transmission Lines

A group of articles dealt with the excitation of waveguides by arbitrary impressed currents and gave expressions for the resulting radiation resistance and reactance.

(37) W. Z. Chien, L. Infeld, J. R. Pounder, A. F. Stevenson, and J. L. Synge, "Contribution to theory of waveguides," *Canad. Jour. Res.*, vol. 27, pp. 69–129; July, 1949.
(38) J. J. Freeman, "Field generated by an arbitrary current distribution within a waveguide," *Jour. Res. Nat. Bur. Stand.*, vol. 44, pp. 193–198; February, 1950.

The method of conformal mapping introduced by Rice leads to the problem of a guide filled with inhomogeneous dielectric, which received further consideration. This method has also been used to reduce the wave problem in the case of cylindrical symmetry to that of propagation between parallel plates.

(39) R. Piloty, Jr., "The field in inhomogeneous rectangular tubes with H_{10}-wave excitation," *Z. angew. Phys.*, vol. 1, pp. 490–502; October, 1949.
(40) H. H. Meinke, "A general process of solution for inhomogeneous cylindrically symmetrical wave fields," *Z. angew. Phys.*, vol. 1, pp. 509–516; October, 1949.

A vibrating-membrane model was described that, not only demonstrates some principles of waveguide propagation, but can also be used for design purposes, such as bevelling of a bend.

(41) K. S. Knol and G. Diemer, "A model for studying electromagnetic waves in rectangular wave guides," *Philips Tech. Rev.*, vol. 11, pp. 156–163; November, 1949.

The perturbation due to a bend in a two-wire line has been obtained by a vector potential method and shows good agreement with experiments.

(42) K. Tomiyasu, "The effect of a bend and other discontinuities on a two-wire transmission line," PROC. I.R.E., vol. 38, pp. 679–682; June, 1950.

The guiding of a wave by a single wire was shown to be practical either in the case of a conductor coated with dielectric or of a pure dielectric. A surface wave exists that has relatively little attenuation.

(43) G. Goubau, "Surface wave transmission line," *Radio-Electronic Eng.*, vol. 14, pp. 10–11, 29–30; May, 1950.
(44) C. H. Chandler, "An investigation of dielectric rod as wave guide," *Jour. Appl. Phys.*, vol. 20, pp. 1188–1192; December, 1949.
(45) W. M. Elsasser, "Attenuation in a dielectric rod," *Jour. Appl. Phys.*, vol. 20, pp. 1193–1196; December, 1949.

Propagation in cylindrical media, including plasma, and lossy dielectrics was considered. The stability of modes in circular waveguides also received attention.

(46) W. O. Schumann, "On the propagation of electric waves along a dielectric cylinder surrounded by another dielectric when either or both media are made of plasma," *Z. Naturf.*, vol. 5A, pp. 181–191; April, 1950.
(47) D. L. Hetrick, "Propagation of the TM_{01} mode in a metal tube containing an imperfect dielectric," *Jour. Appl. Phys.*, vol. 21, pp. 561–564; June, 1950.
(48) R. Muller, "On the stability and attenuation of guided waves of same cutoff frequency and of magnetic or electric type," *Z. Naturf.*, vol. 4A, pp. 218–224; June, 1949.
(49) S. P. Morgan, Jr., "Mode conversion losses in transmission of circular electric waves through slightly non-cylindrical guides," *Jour. Appl. Phys.*, vol. 21, pp. 329–338; April, 1950.

The propagation in a composite waveguide formed of two guides coupled by a narrow longitudinal slot shows interesting characteristics that can be exhibited analytically when the composite guide has an elliptical section.

(50) P. E. Krasnushkin and R. V. Khokhlov, "Spatial beats in coupled waveguides," *Jour. Tech. Phys.* (*USSR*), vol. 19, pp. 931–942; August, 1949.

The design and calibration of piston attenuators was considered by various authors.

(51) A. C. Gordon-Smith, "Calibrated piston attenuator for millimeter wave," *Wireless Eng.*, vol. 26, pp. 322–324; October, 1949.
(52) J. Brown, "Corrections to the attenuation constants of piston attenuators," *Proc. IEE* (London), vol. 96, part III, pp. 437–490; November, 1949.
(53) A. Briot, "Waveguides below the cut-off frequency. Application to piston attenuators," *Onde elect.*, vol. 30, pp. 57–63; January, 1950.

Tapered lines used as a matching transformer or matching termination, and exponential lines improved by compensation devices have been described.

(54) A. Niutta, "Impedance matching by means of a particular type of exponential line," *Telecomunicazioni* (Rome), vol. 2, pp. 417–423; August, 1949.
(55) G. J. Clemens, "A tapered line termination at microwaves," *Quart. Appl. Math.*, vol. 7, pp. 425–432; January, 1950.
(56) A. Ruhrmann, "Improvement of the transformation properties of exponential lines by compensation arrangements," *Arch. elect. Ubertragung*, vol. 4, pp. 23–32; January, 1950.

Filters using periodic structures with systematic variation in the loading reactances were investigated. One with sections made of coaxial line with two inner conductors was also described.

(57) A. W. Lines, G. R. Nicoll, and A. M. Woodward, "Some properties of waveguides with periodic structure," *Proc. IEE* (London), vol. 93, part III, pp. 263–276; July, 1950.
(58) J. J. Karakash and D. E. Mode, "A coupled coaxial transmission line band-pass filter," PROC. I.R.E., vol. 38, pp. 48–52; January, 1950.

The problem of the termination of a shielded pair and the determination of its unbalance by standing-wave measurements was treated in the following paper.

(59) K. Tomiyasu, "Unbalanced terminations on a shielded-pair line," *Jour. Appl. Phys.*, vol. 21, pp. 552–556; June, 1950.

Audio Techniques

The year was marked generally by steady progress in audio design techniques. One report concerned with the frequency-band versus energy-content characteristics of sounds, described a method of measuring such characteristics and showed some experimental results. Another discussed a means of checking qualitatively the transient response of audio systems, using white noise as a test-signal source. Reports were presented to discuss further the intermodulation method of distortion measurement on audio systems.

(60) K. H. Davis, "The cathode ray sound spectroscope," *Bell Lab. Rec.*, vol. 28, pp. 263–267; June, 1950.
(61) E. Cook, "White noise testing methods," *Audio Eng.*, vol. 34, pp. 13–15; March, 1950.

(62) R. S. Fine, "An intermodulation analyzer for audio systems," *Audio Eng.*, vol. 34, pp. 11–13, 42, 43; July, 1950.
(63) J. van Beuren, "Simplified intermodulation measurements," *Audio Eng.*, vol. 34, pp. 24–25, 56–58; November, 1950.

A great amount of work is being carried out on the improvement and standardization of disk and magnetic-tape recording and reproducing systems. The use of such recording media has increased immeasurably during 1950, particularly in the sound broadcasting field.

(64) F. O. Viol, "Some problems of disk recording for broadcasting purposes," PROC. I.R.E., vol. 38, pp. 233–238; March, 1950.
(65) H. E. Haynes and H. E. Roys, "A variable speed turntable and its use in the calibration of disk reproducing pickups," PROC. I.R.E., vol. 38, pp. 239–243; March, 1950.
(66) R. C. Moyer, D. R. Andrews, and H. E. Roys, "Methods of calibrating frequency records," PROC. I.R.E., vol. 38, pp. 1306–1313; November, 1950.
(67) H. E. Roys, "Recording and fine groove technique," *Broadcast News*, vol. 60, pp. 8–17; July, 1950.
(68) F. L. Hopper, "Noise considerations in sound recording transmission systems," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 54, pp. 129–139; February, 1950.
(69) F. P. Hernfeld, "Flutter measuring set," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 55, pp. 167–172; August, 1950.

The impact of television broadcasting on sound techniques was substantial. For one thing, there was created a demand for smaller, less noticeable microphones, two of which are reported on below. Due to greater-than-usual distance from artist to microphone, the problems of obtaining pleasing sound pickups have been greatly aggravated. The use of automatic-gain-control amplifiers increased in broadcasting work. Two such amplifiers were described in detail.

(70) L. J. Anderson and L. M. Wigington, "The bantam velocity microphone," *Audio Eng.*, vol. 34, pp. 12–14; January, 1950.
(71) H. F. Olson and J. Preston, "Unobtrusive pressure microphone," *Audio Eng.*, vol. 34, pp. 18–20; July, 1950.
(72) A. C. Davis, "Steps to improve TV audio," *Audio Eng.*, vol. 34, V14–V18; March, 1950.
(73) J. L. Hathaway, "Automatic audio gain controls," *Audio Eng.*, vol. 34, pp. 27–29; October, 1950.
(74) G. A. Singer, "New limiting amplifier," *Audio Eng.*, vol. 34, pp. 18–19, 69–70; November, 1950.

Another effect of television in broadcasting has been to increase the difficulties in the design and installation of public-address systems in audience-type studios, due mainly to the higher-than-normal level difference required between loudspeakers and microphones. An historical paper reported performance of a previously described system. A general report on sound reinforcing systems appeared.

(75) H. Burris-Meyer and V. Mallory, "Sound in the theatre," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 256–259; March, 1950.
(76) A. W. Schneider, "Sound reinforcing systems," *Audio Eng.*, vol. 34, pp. 27–28, 53–55; November, 1950.

A report covers the variations in the response-frequency characteristics of rooms of several sizes and shows specific examples and results of tests.

(77) L. L. Beranek, "Developments in studio design," PROC. I.R.E., vol. 38, pp. 470–474; May, 1950.
(78) L. L. Beranek, "Acoustic Measurements," John Wiley and Sons, Inc., New York, N. Y., 1st Ed.; 1949.
(79) R. H. Bolt and R. W. Roop, "Frequency response fluctuations in rooms," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 280–289; March, 1950.

Several reports covered new installations, designs, or equipment units of interest to the audio engineer. One described a program control console, another a compact field-type audio mixer-amplifier, and others covered audio systems used in television broadcasting.

(80) S. H. Simpson, Jr., R. E. Hammond, and M. P. Rehm, "Program control console for international program service," *RCA Rev.*, vol. 11, pp. 233–254; June, 1950.
(81) J. L. Hathaway and R. C. Kennedy, "The brief-case amplifier," *RCA Rev.*, vol. 11, pp. 411–417; September, 1950.
(82) W. L. Lyndon, "Audio systems for TV service," *Audio Eng.*, vol. 34, pp. V9–V11; May, 1950.
(83) R. B. Monroe and P. E. Fish, "CBS-TV sound effects console," *Audio Eng.*, vol. 34, pp. V12–V19; March, 1950. Also, pp. V12–V15; May, 1950.
(84) W. I. McCord, "Audio coordination in remote television broadcasting," *Audio Eng.*, vol. 34, pp. V6–V7; July, 1950.

The purchase of separate-unit high-fidelity equipment for home reproduction of sound increased and many articles appeared, describing such installations. A report described a two-loudspeaker system to simulate stereophonic reproduction. Typical home-type custom installations of sound reproducing equipment were also described.

(85) I. Lode, "Stereophonic reproduction," *Audio Eng.*, vol. 34, pp. 15–16; January, 1950.
(86) E. T. Flewelling, "The Flewelling audio system," *Audio Eng.*, vol. 34, pp. 15–17, 46; November, 1950.

Electroacoustics

An important application of the Schwinger-Levine method of approximations was made to the problem of the diffraction of a plane harmonic sound wave by an aperture in an infinitely thin rigid plane screen. This problem was also attacked by developing the theory for the acoustic field produced by a freely vibrating rigid disk, and by analysis based on integral equations obtaining an expression equally applicable to the diffraction of plane scalar waves incident normally upon a circular disk or aperture.

(87) H. Levine, "Variational principles in acoustic diffraction theory," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 48–55; January, 1950.
(88) C. J. Bouwkamp, "On the freely vibrating circular disk and diffraction by circular disks and apertures," *Physica, 's Grav.*, vol. 16, pp. 1–16; January, 1950.

Proof was given that a linear system is always equivalent to a viscoelastic system and that in a linear system steady-state response to a sinusoidal stress cannot have a unique dynamic modulus and phase shift, but that these quantities must be related to creep and frequency.

(89) M. Cini, "Response characteristics of linear systems," *Jour. Appl. Phys.*, vol. 21, pp. 8–10; January, 1950.

Room Acoustics

A practical guide to good acoustical designing written primarily for architects and others who wish a non-mathematical but comprehensive treatise was published. Illustrations of the manner in which certain European broadcasting houses have expressed essential design features architecturally have been summarized.

90) C. M. Harris and V. O. Knudsen, "Acoustical Designing in Architecture," John Wiley and Sons, Inc., New York, N. Y.; 1950.
91) L. L. Beranek, "Developments in studio design," PROC. I.R.E., vol. 38, pp. 470–474; May, 1950.

A simple source emitting short tone pulses has been ɩed to study the propagation of sound in rooms by the i age method and to provide a basis for work in more eneral cases. A study of transient sound waves in one- d three-dimensional regions was made by means of lplace transform methods. Further studies were made the response-frequency fluctuations in transmission sound between arbitrarily selected points in rooms of ırious sizes and shapes.

(92) R. H. Bolt, P. E. Doak, and P. J. Westervelt, "Pulse statistics analysis of room acoustics," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 328–340; May, 1950.
(93) D. Mintzer, "Transient sounds in rooms," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 341–352; May, 1950.
(94) R. H. Bolt and R. W. Roop, "Frequency response fluctuations in rooms," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 280–289; March, 1950.

The general problem of absorption coefficients was viewed from the viewpoint of the manufacturer of coustical materials and measurements of materials ade in Italy was presented graphically. A new inter- etation of the Sabine formula and a reverberation con- ant establishes an acoustic power formula for rooms. he Eyering formula for reverberation time has been sed to plot reverberation-time charts, and a broadcast- ıg studio with variable reverberation characteristics as been described.

(95) H. J. Sabine, "Review of the absorption coefficient problem," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 387–392; May, 1950.
(96) M. Nuovo, "Coefficient of acoustic absorption for materials made in Italy," *Ricerca Sci.*, vol. 19, pp. 1327–1331; November and December, 1949.
(97) E. de Gruyter, "Nachhallzeit und Notwendige schalleistung fuer gebraeuch-liche raeme," *Bull. Assoc. Suisse Elec.*, vol. 40, pp. 757–761; September 17, 1949.
(98) L. S. Goodfriend, "Simplified reverberation time calculation," *Audio Eng.*, vol. 34, pp. 20–21; May, 1950.
(99) P. Arni, "Rooms with reverberation time adjustable over a wide frequency band," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 353–354; May, 1950.

oudspeakers

Objective measurements of loudspeakers increased in cope to give new criteria for acceptable performance.)irect measurements showed that at frequencies at vhich the envelope delay has a pronounced peak or dip, he response from a tone burst is distorted and has an dditional "tail." It has also been shown that it is not lesirable to obtain high sensitivity at the expense of mooth response and low distortion. The uselessness of educing the source impedance below 10 to 20 per cent f the voice coil impedance by means of negative feed- ack was confirmed.

(100) C. A. Ewaskio and O. K. Mawardi, "Electro-acoustic phase shift in loudspeakers," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 444–448; July, 1950.
(101) H. F. Olson, "Sensitivity, directivity and linearity of direct radiator loudspeakers," *Audio Eng.*, vol. 34, pp. 15–17; October, 1950.
(102) J. Moir, "Transients and loudspeaker damping," *Wireless World*, vol. 56, pp. 166–180; May, 1950.

Investigation showed that the principal effect of a cabinet is on the resonant frequency of the loudspeaker with very little higher mode trouble. Useful for the design of finite horns, is a method for locating the peaks in response without the necessity of computing the whole curve.

(103) W. F. Meeker, F. H. Slaymaker, and L. L. Merrill, "The acoustical impedance of closed rectangular loudspeaker housings," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 206–210; March, 1950.
(104) C. T. Molloy, "Response peaks in finite horns," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 551–557; September, 1950.

New designs in loudspeakers ranged from one small enough to be incorporated in a complete four-tube radio receiver, having a content of 25 cubic inches yet attaining an efficiency of 25 per cent with a combination horn and phase inverter system, to the first unitary three-channel system produced on a single frame. The choice of three channels to cover the complete audio spectrum is dictated by band-pass theory and proper integration is required for correct phasing so that single mounting provides the most satisfactory answer to the problem of providing a wide-range loudspeaker. Other systems were also described in which the emphasis was placed on extending the low or high end uniformly.

(105) H. F. Olson, J. C. Bleazey, J. Preston, and R. A. Hackley, "High efficiency loudspeakers for personal radio receivers," *RCA Rev.*, vol. 11, pp. 80–98; March, 1950.
(106) D. J. Plach and P. B. Williams, "A 3-channel unitary loudspeaker," *Radio and Telev. News*, vol. 44, pp. 66–67, 120, 122, 124; November, 1950.
(107) W. E. Gilson and J. J. Andrea, "A symmetrical corner speaker," *Audio Eng.*, vol. 34, pp. 16–17; March, 1950.
(108) B. H. Smith and W. T. Selsted, "A loudspeaker for the range from 5 to 20 kc," *Audio Eng.*, vol. 34, pp. 16–18; January, 1950.

Microphones

By admitting sound to both sides of a single diaphragm from spaced and oriented entrances, a close-talking microphone was developed with signal-to-noise ratio increased over that obtained in a first-order gradient microphone. Two velocity microphones were also described.

(109) W. A. Beaverson and A. M. Wiggins, "A second-order gradient noise cancelling microphone using a single diaphragm," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 592–601; September, 1950.
(110) L. J. Anderson and L. M. Wigington, "Bantam velocity microphone," *Audio Eng.*, vol. 34, pp. 12–14, 31; January, 1950.
(111) L. J. Anderson and L. M. Wigington, "KB-3A high fidelity noise-cancelling microphone," *Audio Eng.*, vol. 34, pp. 16–17, 30, 32; April, 1950.

Application of up to 32 db of negative feedback was used to improve the response of a reversible electrodynamic microphone. The low-frequency sensitivity of a condenser microphone was increased 20 db or more by using it as a variable impedance element in an oscillatory circuit. By mechanically coupling a carbon microphone to a telephone receiver, a considerable increase in either sensitivity or fidelity resulted.

(112) P. Chavasse and P. Poincelot, "On the application of negative feedback to electroacoustic systems," *Compt. Rend. Acad. Sci.* (Paris), vol. 230, pp. 529–530; February 6, 1950.
(113) J. Henry, "Sensitivity and fidelity of microphones," *Radio franç.*, no. 11, pp. 17–20; November, 1949.

Acoustic Measuring Devices

Three standards were published by the American Standards Association. These cover laboratory pressure microphones suitable for calibration in a primary manner, description of a method for securing this primary calibration, and a method of evaluating the performance of earphones. Abridged versions of these standards were published, as well as an informative description of the use of the three as a whole.

(114) "Laboratory Standard Pressure Microphones," Z24.8-1949, American Standards Association, New York, N. Y.; abridged version, *Jour. Acous. Soc. Amer.*, vol. 22, pp. 609–610; September, 1950.
(115) "Method for Pressure Calibration of Laboratory Standard Microphones," Z24.4-1949, American Standards Association, New York, N. Y.; abridged version, *Jour. Acous. Soc. Amer.*, vol. 22, pp. 611–613; September, 1950.
(116) "Method for Coupler Calibration of Earphones," Z24.9-1949, American Standards Association, New York, N.Y.; abridged version, *Jour. Acous. Soc. Amer.*, vol. 22, pp. 602–608; September, 1950
(117) L. L. Beranek, "How well does an earphone work," *Standardization*, vol. 21, pp. 170–172, 187, 188; July, 1950.

A reference volume was published that includes calibration of microphones, audiometry, and speech articulation tests, in addition to details of the more usual acoustic measurements.

(118) L. L. Beranek, "Acoustic Measurements," John Wiley and Sons, New York, N. Y.; 1949.

A refinement was made in the reciprocity pressure-response formula by including the effect of the chamber load on the motion of transducer diaphragms when only two of the three transducers are coupled to the chamber at one time.

(119) M. S. Hawley, "Reciprocity pressure response formula which includes effect of chamber load on the motion of the transducer diaphragms," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 56–58; January, 1950.

A review of methods of producing artificial speech sounds for technical purposes was published and an electroacoustic apparatus that records the spoken word in written characters was described. A system was installed in Geneva for developing and maintaining the proposed new international standards of telephone transmission based on articulation measurements. An artificial ear and mouth for use in tests of communication equipment was developed.

(120) H. Koschel, "The reproduction of natural speech sounds," *Fernmeldetech, Z.*, vol. 3, pp. 48–53; February, 1950.
(121) J. Dreyfus-Graf, "The phonetic steno-sonograph," *Tech. Mitt. Schweig. Telegr.-Teleph. Verw.*, vol. 28, pp. 89–95; March 1, 1950.
(122) J. Swaffield and R. H. de Wardt, "A reference telephone system for articulation tests," *P. O. Elec. Eng. Jour.*, vol. 43, pp. 1–7; April, 1950.
(123) P. Chavasse, "An artificial mouth for acoustic tests," *Compt. Rend. Acad. Sci.* (Paris), vol. 230, pp. 436–438; January 30, 1950.
(124) P. Chavasse, "The artificial ear of the Centre National d'Etudes des Télécommunications," *Compt. Rend. Acad. Sci.* (Paris), vol. 230, pp. 1390–1392; April 12, 1950.

An acoustic method of measuring fluid velocity by utilizing the Doppler effect between a transmitter and four receivers equally spaced at cardinal points from transmitter was developed. The system provides instantaneous indication of wind velocity and direction on a cathode-ray-tube screen. Another method utilizing the change in phase of acoustic signals at two receivers up and down stream from a transmitter measures the speed of a rapidly changing blast of air. By measuring the intensity at various distances and extrapalating back to the source, as is done in light measurements, the true intensity of various audible fog signals is determined. Utilizing the variation of velocity of sound with temperature, the temperature of furnace gases was determined.

(125) R. E. Corby, "Acoustic anemometer-anemoscope," *Electronics*, vol. 23, pp. 88–90; January, 1950.
(126) J. G. Dawes, "The acoustic blastmeter," *Jour. Sci. Instr.*, vol. 27, pp. 123–127; May, 1950.
(127) W. M. Hampton and W. H. Willott, "Transmission of sound and light," *Engineering* (London), vol. 170, pp. 118–120; August 4, 1950.
(128) W. H. Rigg, "Electronic high-temperature measurement," *Wireless World*, vol. 56, pp. S.9–S.12; June, 1950.

Ultrasonics

Industrial applications of ultrasonics continued to increase and many papers are of interest to workers in that particular field. A bibliography of over 600 references was published. Also, a good review article stressing the need for efficient generators of high-intensity sound has appeared.

(129) B. Curry and E. Hsi, "Bibliography—Supersonic or ultrasonic 1926 to 1949," Okla. Agric. and Mech. College, Stillwater, Okla., 1949.
(130) P. Alexander, "Powerful acoustic waves," *Research* (London), vol. 3, pp. 68–73; February, 1950.

Of particular interest to workers in the communications field should be the description of the use of ultrasonics for the storage and reuse of pulse information.

(131) W. P. Mason, "Sound transmission in solids at ultrasonic frequencies," *Bell. Lab. Rec.*, vol. 27, pp. 421–425; December, 1949.

Fundamental investigations continued into the techniques of producing and measuring ultrasonic waves, as well as the effects produced on the media.

(132) F. M. Leslie, "The relative output from magnetostriction ultrasonic generators," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 418–421; July, 1950.
(133) A. E. Bakanowski and R. B. Lindsay, "A crystal pick-up for measuring ultrasonic wave velocity and dispersion in solid rods," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 14–16; January, 1950.
(134) H. J. McSkimin, "Ultrasonic measurement techniques applicable to small solid specimens," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 413–418; July, 1950.
(135) J. L. Hunter, "New ultrasonic interferometer for liquids," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 243–246; March, 1950.
(136) E. Ribchester, "A new frequency-modulation method for measuring ultrasonic absorption in liquids," *Nature* (London), vol. 165, p. 970; June 17, 1950.
(137) A. Weissler, H. W. Cooper, and S. Snyder, "Chemical effect of ultrasonic waves: oxidation of potassium iodide solution by carbon tetrachloride," *Jour. Amer. Chem. Soc.*, vol. 72, pp. 1769–1775; April, 1950.
(138) L. Liebermann, "Sound propagation in chemically active media," *Phys. Rev.*, vol. 76, pp. 1520–1524; November 15, 1949.

Physiological and Psychological Acoustics

Important to the theory of communication is the development of functions that permit calculation of articulation in systems having various response-frequency characteristics and of noise conditions and types of distortion. Observed values were used to develop the critical bandwidth of a masking noise and the relation between the amount of masking to the effective level of the masking noise, thereby giving two basic functions. The effects on the intelligibility of speech of interruptions and interaural phase angles were investigated. Further investigations of the techniques used in hearing tests disclosed that the discrepancies sometimes observed may be partly due to errors in measuring the stimuli and to beats between a primary tone and a probe tone. Very important in hearing aid design is the disclosure that a binaural system has the ability to "squelch" reverberation and background noise.

(139) H. Fletcher and R. H. Galt, "The perception of speech and its relation to telephony," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 89–151; March, 1950.
(140) J. E. Hawkins, Jr., and S. S. Stevens, "The masking of pure tones and of speech by white noise," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 6–13; January, 1950.
(141) G. A. Miller and J. C. R. Licklider, "The intelligibility of interrupted speech," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 167–173; March, 1950.
(142) I. J. Hirsh, "Relation between localization and intelligibility," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 196–200; March, 1950.
(143) W. A. Munson and F. M. Wiener, "Sound measurements for psychophysical tests," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 382–386; May, 1950.
(144) W. A. Munson and M. B. Gardner, "Loudness patterns—a new approach," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 177–190; March, 1950.
(145) W. Koenig, "Subjective effects in binaural hearing," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 61–62; January, 1950.

The further step toward developing criteria for the rational design of auditoriums for speech was made by the development of a general statistical theory in which speech is regarded as a series of discrete pulses.

(146) R. H. Bolt and A. D. MacDonald, "Theory of speech masking by reverberation," *Jour. Acous. Soc. Amer.*, vol. 21, pp. 577–580; November, 1949.

The interrelationship of room and talker was emphasized by a series of tests showing that both rate and intensity of reading were affected by the size and reverberation time of the room, but not by its shape. Recent results of hearing tests of a large heterogeneous population as related to age, sex, musical training, exposure to noise, and awareness of hearing difficulties were reported. Subjective data were developed on the desirability of stereophonic music and acceptable level changes between broadcast speech and music.

(147) J. W. Black, "The effect of room characteristics upon vocal intensity and rate," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 174–176; March, 1950.
(184) J. C. Webster, H. W. Himes, and M. Lichtenstein, "San Diego County Fair hearing survey," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 473–483; July, 1950.
(149) J. P. de Visser van Bloemen, "Stereophonic music in the cinema," *Philips Tech. Rev.*, vol. 11, pp. 129–130; October, 1949.
(150) T. Somerville and S. F. Brownless, "Listeners' sound-level preferences: Part 2," *BBC Quart.*, vol. 5, pp. 57–66; Spring, 1950.

Miscellaneous

General formulas were developed for the radiation from a rigid sphere when subjected to external unit impulse and sinusoidal forces. A theory of passive linear electroacoustic transducers was developed in which the surface velocity distribution is independent of the manner of excitation of the transducers.

(151) J. Brillouin, "Transient radiation from sound sources, and related problems," *Ann. Telecommun.*, vol. 5, pp. 160–172 and 179–194; April and May, 1950.
(152) L. L. Foldy, "Theory of passive linear electroacoustic transducers with fixed velocity distribution," *Jour. Acous. Soc. Amer.*, vol. 21, pp. 595–604; November, 1949.

Data supplementing a study of vehicle noise in New York were provided by a survey in Chicago of over-all and octave levels of noise inside and outside of street, elevated and subway cars; diesel, steam, and electric trains; motor buses; trucks; and automobiles.

(153) G. L. Bonvallet, "Levels and spectra of transportation vehicle noise," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 201–205; March, 1950.

To facilitate oral or written descriptions of reproduced sounds, a body of terms suggestive of the sensations experienced was classified, defined, and illustrated. This imagery is the means by which a trained auditor may assess the extent to which the desired type of reproduction of sound has been achieved.

(154) V. Salmon, "Imagery for describing reproduced sound," *Audio Eng.*, vol. 34, pp. 14–15, 28 and 14, 29, 30, 32–35; August and September, 1950.

Sound Recording and Reproducing

Improvements have been made on measuring recording and reproducing techniques, with a continued trend toward fine-groove recording.

(155) R. C. Moyer, D. R. Andrews, and H. E. Roys, "Methods of calibrating frequency records," Proc. I.R.E., vol. 38, pp. 1307–1313; November, 1950.
(156) R. S. John, "A strain-sensitive phono pickup," *Radio and Telev.*, vol. 43, pp. 40–41; February, 1950.
(157) "Disc recording system development," *Tele-Tech*, vol. 9, pp. 14–15; January, 1950.
(158) G. H. H. Wood, "Record and stylus wear," *Wireless World*, vol. 56, pp. 245–248; July, 1950.
(159) J. G. Woodward, "A feedback-controlled calibrator for phonograph pickups," *RCA Rev.*, vol. 11, pp. 301–309; June, 1950.
(160) B. B. Bauer, "All-purpose phonograph needles," *Electronics*, vol. 23, p. 74; June, 1950.
(161) E. J. and M. V. Marcus, "The diamond as a phonograph stylus material," *Audio Eng.*, vol. 34, pp. 25–27; July, 1950.
(162) W. S. Buchanan, "The Columbia hot stylus recording technique," *Audio Eng.*, vol. 34, pp. 11–13; June, 1950.
(163) E. Schwandt, "Improved disk records," (In German) *Electrotech. Z.*, vol. 71, pp. 426–427; August, 1950.
(164) H. E. Roys, "Recording and fine-groove technique," *Audio Eng.*, vol. 34, pp. 11–13; September, 1950.
(165) E. S. Mallett, "The determination of gramophone pick-up tracking weights," *Electronic Eng.*, vol. 22, pp. 196–198; May, 1950.
(166) J. Simon, "New audio development," *Radio and Telev.*, vol. 44, pp. 43–45; December, 1950.
(167) J. D. Goodell, "Problems in phonograph record reproduction," *Radio and Telev.*, vol. 44, pp. 39–41; November, 1950.
(168) "High-quality reproduction," *Wireless World*, vol. 56, p. 132; April, 1950.
(169) K. E. Forsberg, "Phono equalizer design plus preamplifier data," *Radio and Electronics*, vol. 21, pp. 40–41; April, 1950.
(170) R. H. Dorf, "Custom-built phonograph," *Radio and Electronics*, vol. 21, pp. 46–48; February, 1950.
(171) C. G. McProud, "Phonograph reproduction," *Audio Eng.*, vol. 34, pp. 24–31, pp. 20–22; February and March, 1950.
(172) R. L. West, "Gramophone speed conversion," *Wireless World*, vol. 56, pp. 325–326; September, 1950.
(173) "Record changer, 3-speed automatic," *Gen. Elec. Rev.*, vol. 53, p. 43; January, 1950.
(174) J. D. Healy, "Processing radio transcriptions," *Radio and Telev.*, vol. 43, pp. 31–34; February, 1950.

In the field of sound-on-film, additional standards have been agreed on and published. Some work has been done on producing synthetic sound tracks.

(175) "American standards: (1) Sound focusing test film for 35 mm motion picture sound reproducers; (2) Buzz-tract test film for 35 mm motion picture sound reproducers," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 54, pp. 107–108; January, 1950.
(176) "Synthetic sound on film—1949 engineering developments," *Elec. Eng.*, vol. 69, p. 25; January, 1950.

Magnetic Recording

The professional use of magnetic recording has accelerated. There has been particular emphasis on schemes for achieving lip synchronism between pictures and magnetic sound tracks in motion-picture work.

Improvements in magnetic recording and playback heads and erasing devices have been described.

A new method has been described for duplicating magnetic records by contact printing from a master record with the assistance of a transfer or bias field. This appears to promise economics in producing multiple copies of recorded tapes.

(177) D. G. C. Hare and W. D. Fling, "Picture-synchronous magnetic tape recording," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 54, pp. 554–566; May, 1950.
(178) W. T. Selsted, "Synchronous recording on $\frac{1}{4}$ in magnetic tape," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 55, p. 279; September, 1950.
(179) M. Rettinger, "Magnetic recording in motion pictures," *Audio Eng.*, vol. 34, pp. 9–12 and 18–20; March and April, 1950.
(180) M. Camras, "Magnetic sound on 8 mm film," *Tele-Tech*, vol. 9, pp. 25–27; May, 1950.
(181) L. B. Hust, "A two-channel magnetic recording amplifier," *Radio and Telev.*, vol. 44, pp. 45–47; November, 1950.
(182) "New audio trends," *Electronics*, vol. 23, pp. 68–71; January, 1950.
(183) T. A. Hildebrand, "A magnetic tape eraser," *Television Eng.*, vol. 1, p. 21, June, 1950.
(184) M. Rettinger, "A magnetic-record-reproduce head," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 55, pp. 377–390; October, 1950.
(185) "Magnetic tape 'contact prints,'" *Radio and Electronics*. vol. 21, p. 52; February, 1950.

Studio and Field Sound-Recording Techniques and Facilities

Techniques and equipment for the solution of sound-recording problems encountered by the engineer in radio broadcast work have received considerable attention. Stereophonic recording is a matter of continued interest to workers in the sound-recording field, despite lack of commercialization.

An attempt has been made to define a vocabulary for the psychological effects of various flaws in sound reproduction.

(186) E. Beal, "A new sound-effects console," *FM-TV*, vol. 10, pp. 14–15; January, 1950.
(187) W. W. Pauly, "Studio tape recorder," *FM-TV*, vol. 10, p. 25; February, 1950.
(188) F. L. Hopper, "Noise considerations in sound-recording transmission systems," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 54, p. 129; February, 1950.
(189) "A new mobile recording van for radio-Luxembourg," *Electronic Eng.* (London), vol. 22, p. 126; April, 1950.
(190) J. Toll, "The art of tape recording," *Audio Eng.*, vol. 34, p. 13; May, 1950.
(191) C. P. Smith, "A new technique for reducing distortion in sound recording," *Audio Eng.*, vol. 34, p. 28; April, 1950.
(192) T. Lode, "Stereophonic reproduction," *Audio Eng.*, vol. 34, p. 15; January, 1950.
(193) "Sound reproduction," *Wireless World*, vol. 56, pp. 255–258; July, 1950.
(194) Q. G. Cumeralto, "Console modifications provide audio flexibility," *Tele-Tech*, vol. 9, pp. 24–26; July, 1950.
(195) E. Aisberg, "Improved stereophony," *Wireless World*, vol. 56, pp. 327–330; September, 1950.
(196) V. Salmon, "Imagery for describing reproduced sound," *Audio Eng.*, vol. 34, p. 14; September, 1950.
(197) "Recorder specifications for 1950," *Tele-Tech*, vol. 9, pp. 34–36; April, 1950.
(198) L. M. Dezettel, "The auditioner," *Radio and Telev.*, vol. 44, pp. 50–51; November, 1950.
(199) G. Southworth, "A versatile recording and playback amplifier," *Radio and Telev.*, vol. 43, pp. 62–63; March, 1950.
(200) H. Matthews, "Design consideration for high quality reproducing systems," *Radio and Telev.*, vol. 43, pp. 52–53; April, 1950.
(201) G. Southworth, "Linearity distortion in audio equipment," *Radio and Telev.*, vol. 43, pp. 54–55; April, 1950.
(202) H. Matthews, "Design considerations for high quality reproducing systems II," *Radio and Telev.*, vol. 43, pp. 69–72; May, 1950.
(203) J. C. Hoadley, "A self-equalizing preamp," *Radio and Telev.*, vol. 44, pp. 48–49; November, 1950.

Circuit Theory

Linear Lumped-Constant Passive Circuits

Increasing use of the methods of linear vector algebra in the treatment of network problems made possible some interesting generalizations of the theory. Professor Le Corbeiller's book provides a useful introduction to the vector concept, utilized by Oono and Bayard to fill a very old gap in the theory.

(204) P. Le Corbeiller, "Matrix Analysis of Electric Networks," Harvard University Press, Cambridge, Mass., and John Wiley and Sons, Inc., New York, N. Y., p. 108; 1950.
(205) Y. Oono, "Synthesis of a finite $2n$-terminal network by a group of networks each of which contains only one ohmic resistance," *Jour. Math. Phys.*, vol. 29, pp. 13–26; April, 1950.
(206) M. Bayard, "Synthesis of passive networks with any number of pairs of terminals, given their impedance or admittance matrices," *Bull. Soc. franç. elect.*, vol. 9, pp. 497–502; September, 1949.

Certain more specialized handlings of the synthesis problem, for the most part aimed at particular engineering needs, are represented by the following papers:

(207) V. A. Taft, "Construction of quadripoles and multiples with given frequency characteristics," *Bull. Acad. Sci. (URSS)*, no. 2, pp. 216–232; February, 1950.
(208) I. L. Bower and P. F. Ordung, "The synthesis of resistor-capacitor networks," PROC. I.R.E., vol. 38, pp. 263–269; March, 1950.
(209) M. Leroy, "Quadripoles," *Bull. Soc. franç. elect.*, vol. 10, pp. 128–134; March, 1950.
(210) S. Darlington, "Realization of a constant phase difference," *Bell Sys. Tech. Jour.*, vol. 29, pp. 94–104; January, 1950.
(211) A. P. Brogle, Jr., "The design of reactive equalizers," *Bell Sys. Tech. Jour.*, vol. 28, pp. 716–750; October, 1949.

The year contributed little new to the formulation of network properties and capabilities. To this, Fano's work on broad-banding was an outstanding exception.

(212) R. M. Fano, "Theoretical limitations on the broadband matching of arbitrary impedances," *Jour. Frank. Inst.*, vol. 249, pp. 57–83; January, 1950. Also pp. 139–154; February, 1950.

Linear Varying Parameter and Nonlinear Circuits

The concept of a steady-state admittance function was applied to linear variable systems by generalizing the methods used in the constant-coefficient case for composition of the total response in terms of responses to individual spectral components of the driving force. The appropriate generalized-admittance function depends on both frequency and time, and it is specified by a linear differential equation in time having variable coefficients. Since the original problem is also specified by the same kind of equation, there is no guarantee of simplification in the general case. There are, however, cases in which the coefficients of the admittance equation vary so slowly that they may be regarded as constants, and a good first approximation thus obtained by in effect freezing the variable network at the instant of consideration. Study of the admittance equation offers possibilities of evaluating and improving the accuracy of such quasi-steady-state approximations.

(213) L. A. Zadeh, "Frequency analysis of variable networks," PROC. I.R.E., vol. 38, pp. 291–299; March, 1950.

An exceptionally extensive and detailed development of the power-series method in nonlinear circuit theory appeared. In addition to the usual calculations of modulation products for sinusoidal input components, applications were given to free oscillations and subharmonic production.

(214) A. W. Gillies, "The application of power series to the solution of nonlinear circuit problems," *Proc. IEE* (London), vol. 96, part III, pp. 453–475; November, 1949.

The following publications dealt with more specialized problems within the field of nonlinear and varying-parameter systems.

(215) H. Kämmerer, "The frequency dependence of the distortion for coils with laminated-iron cores," *Arch. elekt. Ubertragung* vol. 3, pp. 249–256; October, 1949.
(216) M. E. Levenson, "Harmonic and subharmonic response for the Duffing equation," *Jour. Appl. Phys.*, vol. 20, pp. 1045–1051; November, 1949.
(217) H. Rosenhammer, "Contribution to the theory of the mathematical treatment of nonlinear phenomena," *Bull. schweiz. elektrotech. Ver.*, vol. 40, pp. 5–18; January 8, 1949.
(218) A. Klemt, "On mixing with detectors," *Frequenz*, vol. 4, pp. 50–54; February, 1950.
(219) F. Feil, "The nonlinearity of vacuum tube circuits caused by the voltage dependence of the tube input capacity," *Arch. elekt. Ubertragung*, vol. 4, pp. 65–70; February, 1950.
(220) V. Belevitch, "Nonlinear effects in rectifier modulators," *Wireless Eng.*, vol. 27, pp. 130–131; April, 1950.
(221) R. J. Duffin, "Nonlinear networks, IV," *Proc. Amer. Math. Soc.*, vol. 1, pp. 233–240; April, 1950.
(222) C. P. Gadsden, "An electrical network with varying parameters," *Quart. Appl. Math.*, vol. 8, pp. 199–205; July, 1950.
(223) F. E. Bothwell, "Transients in multiple periodic nonlinear systems," *Quart. Appl. Math.*, vol. 8, pp. 247–254; October, 1950.

Time-Domain Analysis and Synthesis

Various criteria for the optimum response characteristic of filters were considered. The matched-filter criterion for obtaining the greatest ratio between peak amplitude of the signal and the root-mean-square noise at the output were generalized to include input noise that is colored. The least-square error criterion of Wiener and Kolmogoroff were lucidly developed by a new method based on physical considerations and electric circuit theory, and were extended to include a new class of signals.

(224) B. M. Dwork, "Detection of a pulse superimposed on fluctuation noise," PROC. I.R.E., vol. 38, pp. 771–774; July, 1950.
(225) W. Bode and C. E. Shannon, "A simplified derivation of linear least-square smoothing and prediction theory," PROC. I.R.E., vol. 38, pp. 417–425; April, 1950.
(226) L. A. Zadeh and J. R. Ragazzini, "An extension of Wiener's theory of prediction," *Jour. Appl. Phys.*, vol. 21, pp. 645–655; July, 1950.

The fact that many physical systems may be treated and described by the well-developed techniques and viewpoints usually associated with electric circuits is emphasized in a recent book. This approach has called attention to the general problem of determining the system function from data obtained under actual operating conditions.

(227) J. D. Trimmer, "The Response of Physical Systems," John Wiley and Sons, Inc., New York, N. Y.; 1950.
(228) J. B. Wiesner and Y. W. Lee, "Experimental determination of system functions by the method of correlation," 1950 I.R.E. National Convention.
(229) Y. W. Lee and J. B. Wiesner, "Correlation functions and communication applications," *Electronics*, vol. 23, pp. 86–92; June, 1950.
(230) W. H. Huggins, "System-function analysis of speech sounds," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 765–767; November, 1950.
(231) L. A. Zadeh, "Determination of the impulse response of variable networks," *Jour. Appl. Phys.*, vol. 21, pp. 642–645; July, 1950.

Linear Active Circuits

In the continuing consolidation of feedback-amplifier theory, the criterion of stability was examined critically by several investigators with more general viewpoints being sought. There was also some effort directed toward the correlation of the background theory of control and feedback-amplifier applications. Among the reported applications of feedback, the largest area of interest appeared to be centered about the design of selective or filter amplifiers.

(232) G. F. Montgomery, "IF gain stabilization with inverse feedback," PROC. I.R.E., vol. 38, pp. 662–667; June, 1950.
(233) W. H. Horton, J. H. Jasberg, and J. D. Noe, "Distributed amplifiers; practical considerations and experimental results," PROC. I.R.E., vol. 38, pp. 748–753; July, 1950.
(234) G. E. Tisdale, "Continuously adjustable electronic filter networks," PROC. I.R.E., vol. 38, pp. 796–798; July, 1950.
(235) C. H. Miller, "*RC*-amplifier filters," *Wireless Eng.*, vol. 27, pp. 26–29; January, 1950.
(236) W. Reichardt, "Control, positive and negative feedback and negative resistance coordinated," *Elektrotechnik* (Berlin), vol. 4, pp. 47–53 and 73–80; February and March, 1950.
(237) J. M. Miller, Jr., "Combining positive and negative feedback," *Electronics*, vol. 23, pp. 106–109; March, 1950.
(238) J. Peters, "When is Nyquist's stability criterion valid?" *Arch. elect. Ubertragung*, vol. 4, pp. 17–22; January, 1950.
(239) K. Feher and G. Kurtze, "Selective *RC* audio-frequency amplifier," *Frequenz*, vol. 4, pp. 72–76; March, 1950.
(240) S. W. Punnett, "Audio frequency selective amplifiers," *Jour. Brit. I.R.E.*, vol. 10, pp. 39–59; February, 1950.
(241) J. C. West, "The Nyquist criterion of stability," *Electronic Eng.* (London), vol. 22, pp. 169–172; May, 1950.
(242) A. W. Keen, "Negative resistance characteristics," *Wireless Eng.*, vol. 27, pp. 175–179; June, 1950.
(243) W. T. Duerdoth, "Some considerations in the design of feedback amplifiers," *Proc. IEE* (London), vol. 97, pp. 138–155; May, 1950.
(244) E. E. Ward, "Feedback amplifiers and servo systems," *Wireless Eng.*, vol. 27, pp. 146–153; May, 1950.
(245) D. M. Tombs and M. F. McKenna, "Amplifier with negative resistance load," *Wireless Eng.*, vol. 27, pp. 189–193; June, 1950.
(246) J. E. Flood, "Negative-feedback amplifiers," *Wireless Eng.*, vol. 27, pp. 201–209; July, 1950.
(247) D. H. Parnum, "Transmission factor of differential amplifiers," *Wireless Eng.*, vol. 27, pp. 125–129; April, 1950.
(248) D. H. Picken and J. N. Van Scoyoc, "Phase shift band-pass filters," *Electronics*, vol. 23, pp. 96–99; May, 1950.
(249) J. N. Van Soyoc and G. F. Warnke, "A d-c amplifier with cross-coupled input," *Electronics*, vol. 23, pp. 104–107; February, 1950.

Servomechanisms

Advances in the field of servomechanisms and feedback control systems were noteworthy in the areas of analysis, components, and industrial applications. Theoretical contributions on the subject of stability, networks, and steady-state and transient performance have appeared in the literature. The magnetic fluid clutch was described as a noteworthy component development for servomechanisms of ratings of one horsepower or over. The sampling control system was further investigated from the theoretical point of view and both domestic and foreign papers on the subject have appeared. Greatly increased applications of feedback control systems to industrial control were reported. As systems become more complicated, the use of analogue computers to obtain design parameters for servomechanisms has increased.

(250) H. Chestnut and R. W. Mayer, "Comparison of steady-state and transient performance of servomechanisms," *Trans. AIEE*, vol. 68; 1949.
(251) W. R. Evans, "Control system synthesis by root locus method," AIEE Technical Paper 50-11 (To be printed in *Trans. AIEE*).
(252) F. H. Raymond, "Analyse du functionnement des systemes physiques discontinus, (et son application aux servomecanismes)," in 3 parts, *Ann. Telecommun.*, vol. 4, July, August–September, October, 1949.
(253) K. S. Miller and R. J. Schwarz, "Analysis of a sampling servomechanism," *Jour. Appl. Phys.*, vol. 21; April, 1950.
(254) V. B. Baker and J. F. Kovalsky, "Electronic speed regulators for sectional paper machine drive," *Trans. AIEE*, vol. 67; 1948.
(255) W. J. M. Moore, "An electronic synchronous speed regulator," AIEE Technical Paper No. 50–25.
(256) C. M. Edwards and E. C. Johnson, "An electronic simulator for nonlinear servomechanisms," *Trans. AIEE*, vol. 68; 1949.
(257) A. C. Hall, "Analogue computer for flight simulator," *Trans. AIEE*, vol. 69; 1950.

Electron Tubes and Solid-State Devices

Small High-Vacuum Tubes

A unified theory of traveling-wave tubes has been given, including a discussion of various electronic and circuit waves, the fitting of boundary conditions to obtain over-all gain, noise figure calculations, transverse motions of electrons, and field solutions appropriate to broad electron streams. Circuits for the tube have been discussed and it has been shown that gain will be highest for low group velocities and low stored energies.

(258) J. R. Pierce, "Traveling Wave Tubes," D. Van Nostrand & Sons, Inc., New York, N. Y.; 1950.

A new type of traveling-wave amplifier tube utilizing crossed electrostatic and magnetic fields has been described and further analyses of the phenomenon of increasing waves have been made.

(259) R. R. Warnecke, W. Kleen, A. Lerbs, O. Dohler, and H. Huber, "The magnetron-type traveling-wave amplifier tube," Proc. I.R.E., vol. 38, pp. 486–495; May, 1950.
(260) L. Brillouin, "The traveling wave tube," *Jour. Appl. Phys.*, vol. 20, pp. 1196–1206; December, 1949.
(261) J. R. Pierce, "Increasing space charge waves," *Jour. Appl. Phys.*, vol. 20, pp. 1060–1066; November, 1949.

Work on microwave triodes was continued. Factors which dictated the design parameters of the close-spaced BTL 1553 (WE 416A) type microwave triode are discussed in detail. A systematic procedure is outlined whereby figures of merit can be optimized for particular system needs. Derivation of the gain-band and power-band figures of merit are given. A ten-stage amplifier with 90 db of gain and 44 mc of bandwidth was described. A sweeping oscillator using this tube produces continuous oscillations from 3,600 to 4,500 mc.

(262) J. A. Morton and R. M. Ryder, "Design factors of the B.T.L. triode," *Bell Sys. Tech. Jour.*, vol. 29, pp. 496–530; October, 1950.
(263) A. E. Bowen and W. W. Mumford, "A new microwave triode: its performance as a modulator and as an amplifier," *Bell Sys. Tech. Jour.*, vol. 29, pp. 531–552; October, 1950.
(264) M. E. Hines, "A wide range microwave sweeping oscillator," *Bell Sys. Tech. Jour.*, vol. 29, pp. 553–559; October, 1950.
(265) G. Diemer and K. S. Knol, "Low-level triode amplifier for microwaves," *Philips Res. Rep.*, vol. 5, pp. 153–154; April, 1950.

A special klystron tube (SAC-19) has been developed using the phase modulation technique for mixer application at 6,000 Mc with 1-watt output.

(266) V. Learned, "Klystron mixer applied to television relaying," Proc. I.R.E., vol. 38, pp. 1033–1035; September, 1950.

The effect of space charge on the electron stream in the drift space was analyzed by examining the two fundamental differential equations governing electron flow. From this analysis may be predicted at what point overtaking occurs, at which time the expressions used are no longer valid.

Another study shows that beam-loading effects in reflex klystrons measured by the use of electronic tuning data are greater than that predicted by published analysis. Secondary emission effects may account for the discrepancy.

(267) B. Meltzer, "Two-cavity klystron, effect of space charge," *Wireless Eng.*, vol. 26, pp. 365–369; November, 1949.
(268) W. W. Harman and J. H. Tillotson, "Beam-loading effects in small reflex klystrons," Proc. I.R.E., vol. 37, pp. 1419–1423; December, 1949.

An experimental tube was described in which a secondary-emission stage is added to a conventional grounded-grid triode. This gives an exceedingly high figure of merit which makes the tube useful as a broadband amplifier. It was found that the secondary-emission stage added to the noise figure although there was evidence of space-charge smoothing.

(269) G. Diemer and J. L. H. Jonker, "Secondary-emission valve—wide band amplifier for decimeter waves," *Wireless Eng.*, vol. 27, pp. 137–145; May, 1950.

Focused electron beams have been used in a two-grid miniature tube to obtained step-shaped control characteristics for frequency-modulation limiter-discriminator and other applications.

(270) R. Adler and A. P. Haase, "The 6BN6 gated beam tube," *Proc. NEC* (Chicago), vol. 5, pp. 408–426; 1949.

Improvements were reported in planar triodes.

(271) R. H. Rheaume, "A miniature ceramic 'lighthouse' triode," Machlett Cathode Press, vol. 7, pp. 6–9; Summer, 1950.

(272) H. D. Doolittle, "The planar triode 2C39A . . . a progress report," Machlett Cathode Press, vol. 7, pp. 20, 21, 36; Summer, 1950.

In a survey of various power-output-tube constructions, two new methods of achieving a low distortion were given, which produce I_b-E_b characteristics that are practically linear around the normal operating point and lower the distortion by a factor of two below that of present tubes.

(273) G. Diemer and J. L. H. Jonker, "Low-distortion power valves," *Wireless Eng.*, vol. 26, pp. 385–390; December, 1949.

To save heater supply power, the use of two cathodes alternately, each being heated by bombardment by the other, was suggested.

(274) E. G. Hopkins, "Vacuum tubes with mutually bombarding oxide cathode," *Jour. Appl. Phys.*, vol. 21, p. 841; October, 1950.

A secondary-emission amplifier tube has been developed which overcomes the poisoning effect on the secondary-emitting surface by the evaporated products from the cathode. This has been accomplished without shielding by the use of a 1.4-volt filament operated with a 40 per cent reduction of filament voltage.

(275) C. W. Mueller, "Receiving tubes employing secondary electron emitting surfaces exposed to the evaporation from oxide cathodes," Proc. I.R.E., vol. 38, pp. 159–164; February, 1950.

Oscillations tunable from 1,000 to 4,000 mc can be obtained by changing current and voltage between parallel planes immersed in a plasma.

(276) G. Wehner, "Plasma oscillator," *Jour. Appl. Phys.*, vol. 21, p. 62; January, 1950.

Tube Characteristic Studies. A pulse method may be used in obtaining static characteristics of tubes in regions where power inputs are destructive to the tube.

An experimental determination of current-density distribution in the electron beam of an aligned grid tube has shown that the proper position for the screen grid laterals is not necessarily at the focus of the electron beam, but that a better screen-to-plate current ratio may be achieved with the screen grid plane lying between the focus and the control grid plane.

(277) J. Leferson, "The application of direct-current resonant-line type pulsers to the measurement of vacuum-tube static characteristics," Proc. I.R.E., vol. 38, pp. 668–670; June, 1950

(278) D. C. Rogers, "Aligned-grid valves," *Wireless Eng.*, vol. 27, pp. 39–46; February, 1950.

Investigations made on the upper limit of time delay in a secondary emission dynode at the maximum oscillating frequency and admittance gave an upper limit of about 10^{-11} seconds. Theoretical estimates from transit-time effects within the secondary-emitting material gave an upper limit of 10^{-14} to 10^{-15} seconds.

A study made of the ratio of the positive ion current per milliampere of ionizing electron current for various tubes showed wide variations which are distinctive for tubes of a similar type from a common source. However, after a period of operation these values fall to an approximately constant value in the range 300 to 900 $\mu\mu$a/ma. A theory for this effect is proposed.

(279) G. Diemer and J. L. H. Jonker, "On the time delay of secondary emission," *Philips Res. Rep.*, vol. 5, pp. 161–172; June, 1950.

(280) G. H. Metson, "Vacuum factor of the oxide-cathode valve," *Brit. Jour. Appl. Phys.*, vol. 1, pp. 73–77; March, 1950.

A theoretical evaluation was made of the limiting upper frequency of a triode oscillator, considering the triode as a four-pole network. Relations were derived between the four-pole coefficients and the properties of the electron stream, series resistance in the electrode leads, resistance of the emissive coating, and the dielectric losses. Experimentally, the theoretical calculations gave a limiting frequency 15 per cent above the value observed. A nondestructive method for determining which element of a planar triode produces microphonism has been found mathematically and verified experimentally.

(281) K. Rodenhuis, "The limiting frequency of an oscillator triode," *Philips Res. Rep.*, vol. 5, pp. 46–77; February, 1950.

(282) J. A. Wenzel and A. H. Waynick, "Microphonism in the dynamically operated planar triode," Proc. I.R.E., vol. 38, pp. 524–552; May, 1950.

(283) E. H. Gamble, "The high frequency response of cylindrical diodes," *Proc. NEC* (Chicago), vol. 5, pp. 387–402; 1949.

(284) A. H. Taub and N. Wax, "Theory of the parallel plane diode," *Jour. Appl. Phys.*, vol. 21, pp. 974–980; October, 1950.

Electron transit-time effects at high frequencies may be simulated in the use of the rubber diaphragm model for studies of tube design. Another investigation has shown that the limit of oscillation is reached when the period is from approximately 3 to 4 times the total time of transit of electrons from the cathode to the anode. A modified transit time expression involving the effects of alternating voltages on the grid and anode is derived and compared to experimental results. A summary of information disclosed by many authors concerning the various types of electron multiplier tubes and their desirable characteristics has been made.

(285) J. W. Clark and R. E. Neuber, "A dynamic electron trajectory tracer," Proc. I.R.E., vol. 38, pp. 521–524; May, 1950.

(286) S. K. Chatterjee and B. V. Sreekantan, "Electron transit time—effect on negative-grid oscillators," *Wireless Eng.*, vol. 28, pp. 59–63; February, 1950.

(287) P. L. Copeland and D. N. Eggenberger, "Electron transit time in space charge limited current between coaxial cylinders," *Jour. Appl. Phys.*, vol. 20, pp. 1148–1151; December, 1949.

(288) J. S. Allen, "Recent applications of electron multiplier tubes," Proc. I.R.E., vol. 38, pp. 346–358; April, 1950.

Further studies of the properties of oxide cathodes were made, including a study from retarding fields through zero, up to accelerating fields of 50,000 volts per cm.

Experiments have shown that small amounts of certain impurities in a standard oxide-cathode coating have relatively no effect on contact difference of potential. Deposition of cathode products during life on the anode cause a reduction of contact potential. Heating a carbonate coating of a cathode results in a loosely sintered oxide coating. Conduction in this coating is of two kinds acting in parallel: through the grains at temperatures below 800°K, and through electron gas in the pores between grains at temperatures above 800°K. At temperatures above 1,000°K, conduction lags behind emission. The fact that the curvature of the *J-V* curves disappear in this temperature region is probably due to the effect of space charge upon the field in the pores.

(289) C. S. Hung, "Thermionic emission from oxide cathodes: retarding and accelerating fields," *Jour. Appl. Phys.*, vol. 21, pp. 37–43; January, 1950.
(290) T. E. Levy, "The measurement of contact difference in potential on certain oxide-coated cathode diodes," Proc. I.R.E., vol. 38, pp. 774–776; July, 1950.
(291) R. Loosjes and H. J. Vink, "Conduction processes in the oxide-coated cathode," *Philips Tech. Rev.*, vol. 11, pp. 271–278; March, 1950.

A new cathode, designated *L*, has a mixture of barium and strontium oxides contained behind a wall of porous tungsten. At the working temperature of the cathode (900°–1,350°C) the oxides are gradually reduced due to the fairly high vapor pressure of barium, strontium, and barium oxide. These substances escape through pores in the wall and form monatomic layers of barium and strontium with some oxygen in between. The layer reduces the work function for tungsten from 4.5 volts to 1.6–2. This is not as low as that of an oxide-coated cathode (1–1.5 volts) so that the required temperature is higher and the thermal efficiency lower, but, owing to its construction, the *L* cathode can withstand heavy loads of some hundreds of amperes per square centimeter with reasonable life (measured under pulse conditions).

A microanalysis has been made of gases liberated from nickel cathode sleeves in a vacuum. The quantitative differences in the various gases liberated as affected by preliminary processes, for both coated and uncoated sleeves, were measured and explained.

(292) H. J. Lemmens, M. J. Jansen, and R. Loosjes, "Thermionic cathode for heavy loads," *Philips Tech. Rev.*, vol. 11, pp. 341–350.
(293) H. Jacobs and B. Wolk, "Analysis of gas in cathode coating assemblies," Proc. I.R.E., vol. 37, pp. 1247–1251; November, 1941.

Noise. It was shown that under favorable conditions there is an exact relationship between the mean-square noise currents induced at the grid of a triode and the space-charge component of input capacitance measurable at that point. This provides a convenient tool for estimating the mean-square induced noise from easily measured parameters. It was found that the available three-halves power law treatments of this phenomena are inadequate to explain the shot noise induced at the control grid, but that measurement of certain low-frequency characteristics may yield very close estimates of induced grid noise at moderate transit angles.

Measurements and theoretical calculations were made of the noise of a symmetrical double-cathode tube with two hot cathodes opposite each other. The measurements and calculations agree and show that the equivalent noise temperature of such tubes does not exceed the cathode temperature.

(294) R. L. Bell, "Induced grid noise," *Wireless Eng.*, vol. 27, pp. 87–94; March, 1950.
(295) K. S. Knol and G. Diemer, "Theory and experiments on electrical fluctuations and damping of double-cathode valves," *Philips Res. Rep.*, vol. 5, pp. 131–152; April, 1950.

Special Purpose Tubes. A new tube adapted to the control and stabilization of frequency in uhf and vhf oscillators has been described. A bimetal anode, whose curvature is determined by slow changes in frequency, is mechanically linked to a capacitor within the tube.

(296) R. W. Slinkman, "Variable capacitance tube for frequency control," *Sylvania Technologist*, vol. 3, pp. 18–20; July, 1950.

Gas-Filled Tubes

Cold-Cathode Stepping Tubes. Several designs of cold-cathode stepping tubes have been described. These tubes offer a simple means of providing a scale-of-ten counter in a single tube which operates at greater speeds than mechanical devices.

(297) J. J. Lamb and J. A. Brustman, "Polycathode glow tube for counters and calculators," *Electronics*, vol. 22, p. 92; November, 1949.
(298) R. C. Bacon and J. R. Pollard, "The Dekatron," *Electronic Eng.* (London), vol. 22, p. 173; May, 1950.
(299) M. A. Townsend, "Construction of cold-cathode counting or stepping tubes," *Elec. Eng.*, vol. 69, p. 810; September, 1950.
(300) G. H. Hough and D. S. Ridler, "Multicathode gas tube counters," *Elec. Commun.* (London), vol. 27, p. 214; September, 1950.

Gaseous Discharge Phenomena. The availability of fast-sweep oscilloscopes has permitted studies of the afterglow period in gas discharges. It has been found that thyratron grid current during the afterglow period retains the character of grid current during conduction, namely, dependence on ionization within the tube, and constancy independent of applied grid voltage and grid resistance.

New equipment for measuring deionization time of gas tubes using the pulse method is described. This equipment was used to measure the effect of current-pulse duration, magnitude of peak current, grid parameters, and tube dimensions on the deionization time of particular types of thyratrons.

(301) L. Malter and E. O. Johnson, "Studies on thyratron behavior," *RCA Rev.*, vol. 11, p. 165; March, 1950.
(302) H. H. Wittenberg, "Pulse measuring of deionization time," *Elec. Eng.*, vol. 69, pp. 823–827; September, 1950.

A series of articles outlining the various fields of application of gaseous-conduction phenomena describe the difference between nonself-sustained discharges and self-sustained discharges. Geiger counters, gas-filled photoelectric cells, and ionization gauges are applications of the first class. Rectifiers and control tubes, circuit breakers, arc furnaces, and gas-discharge lamps are applications of the second class.

(303) J. D. Cobine, "Gaseous-conduction phenomena and their application," *Elec. Eng.*, vol. 69, pp. 499–504; June, 1950.

The theory involved in the phenomena occurring in gas-filled rectifier tubes is discussed. It is shown how the two basic laws of electronics, the Richardson-Laue-Dushman equation of thermionic emission and the Child-Langmuire space-charge law, affect the behavior of these tubes. High-pressure diodes or tungar tubes, low-pressure diodes or phanotrons, and thyratrons including the developmental caesium-vapor tubes, mercury-arc rectifiers and ignitron tubes, are discussed.

(304) A. W. Hull, "Fundamental processes in gaseous tube rectifiers," *Elec. Eng.*, vol. 69, pp. 695–700; August, 1950.

The basic phenomenon of microwave gas discharge is described and compared with the direct-current discharge and low-frequency alternating-current discharge. Processes active in such discharges are discussed, and a formula is developed for the complex conductivity of the discharge from the known properties of elections and ions.

(305) M. A. Biondi, "Microwave gas discharges," *Elec. Eng.*, vol. 69, pp. 806–809; September, 1950.

The technique of study of gas discharges by means of probes immersed in the plasma indicates that a system of two floating probes has important advantages over the usual single probe.

(306) E. O. Johnson and L. Malter, "A floating double probe method for measurements in gas discharges," *Phys. Rev.*, vol. 80, pp. 58–68; October 1, 1950.

A survey of the main factors affecting the characteristics and life of thyratrons was made, based on experimental results. Such factors include electron emission from the cathode, ionization and current buildup, grid control, current-carrying capacity, the decay of ionization at the end of conduction, and the provision of suitable operating conditions. The control characteristics of different types of grids are discussed. A method of measuring deionization time is described. Results are given showing how this time varies according to the nature of the filling gas and its pressure.

(307) H. B. DeKnight, "Hot cathode thyratrons: practical studies of characteristics," *Proc. IEE* (London), vol. 96, pp. 361–378. Discussion, pp. 379–381; September, 1949.

End of Life Criteria—Hot-Cathode Gas Tubes. In order to predict the end of life of gas-filled tubes, measurement of voltage drop during operation yields useful data. As tube voltage drop increases rapidly near the end of their useful life, these tests may be used to indicate when tube replacement should be made to prevent emergency shutdowns. Several ways of measuring tube voltage drop are described, including the use of the wattmeter, the vacuum-tube voltmeter, and various cathode-ray oscilloscope methods. The relationship of peak arc drop, average arc drop, and tube life are discussed and illustrated.

(308) E. K. Smith, "Measurement of tube voltage drop in hot-cathode gas tubes," *Elec. Eng.*, vol. 69, pp. 419–422; May, 1950.

Cold-Cathode Tubes. The use of potassium metal on the cathodes of cold-cathode tubes has been found to lead to great uniformity of characteristics and to reduced values of breakdown voltage.

(309) A. L. Chilcot and F. G. Heymann, "Potassium-activated cold-cathode tubes," *Jour. Sci. Instr.*, vol. 26, pp. 289–294; September, 1949.

Certain types of gas tubes used in relay or trigger applications are limited in sensitivity by the high value of grid current required to fire them, which normally makes the tubes unsuitable for use with high-grid-resistance circuits. This limitation is overcome by superimposing a train of voltage pulses, from a source independent of the signal, on the grid voltage.

(310) R. J. Hercock and D. M. Neale, "The use of cold cathode relay valves with grid-cathode circuits of high resistance," *Brit. Jour. Appl. Phys.*, vol. 1, pp. 53–55; February, 1950.

Cathode-Ray and Television Tubes

The trend toward larger television pictures continued. Both 16- and 19-inch tubes are in large-scale production and 24-inch or larger tubes have been produced. Trends are in the direction of making the over-all tube as small as possible for a given picture size by increasing the deflection angle and using rectangular shapes. Great efforts and much ingenuity have been expended in the development of a single picture tube for use in color television. Cathode-ray tubes with deflection systems suitable for high frequencies using traveling-wave techniques were described.

(311) L. E. Swedlund and H. P. Steier, "Short 16 in. metal cone kinescope development," *Tele-Tech*, vol. 9, pp. 40–43, 59–60; August, 1950.
(312) "RCA color kinescope demonstrated," *Tele-Tech*, vol. 9, pp. 20–21, 61–63; May, 1950.
(313) C. S. Szegho, "Experimental tri-color cathode-ray tube," *Tele-Tech*, vol. 9, pp. 34–35; July, 1950.
(314) C. S. Szegho, "Color cathode-ray tube with three phosphor bands," *Jour. Soc. Mot. Pic. Eng.*, vol. 55, pp. 367–376; October, 1950.
(315) J. R. Pierce, "Travelling-wave oscilloscope," *Electronics*, vol. 22, pp. 97–99; November, 1949.
(316) K. Owaki, S. Terahata, T. Hada, and T. Nakamura, "The traveling wave cathode-ray tube," Proc. I.R.E., vol. 38, pp. 1172–1180; October, 1950.

A new and simple camera tube called the Vidicon was introduced. It uses a photoconductive target and low-velocity orthicon-type scanning. The target is sensitive to light throughout the entire frame time, permitting full storage of charge. No electron multiplier section is required. The tube is particularly suitable for industrial application, due to its small size and simplicity of operation.

Light transfer characteristics of image orthicons were studied with respect to effects caused by redistribution of secondary electrons. The particular redistribution causing ghosts was discussed in detail in published papers.

(317) P. K. Weimer, S. V. Forgue, and R. P. Goodrich, "The Vidicon photoconductive camera tube," *Electronics*, vol. 23, pp. 70–73; May, 1950.
(318) R. B. Janes and A. A. Rotow, "Light transfer characteristic of image orthicons," *RCA Rev.*, vol. 11, pp. 364–376; September, 1950.

Several new storage tubes were investigated and analyzed. The fundamental theory of electrostatic storage was discussed in one paper, and dot-circle patterns for storing charges were described in another. Memory is extended by a systematic regeneration process. Another paper dealt with a beam-deflection electrostatic tube to store binary-coded information.

Reading can be accomplished without disturbing the information written into the tube with the recording storage tube, and an analysis has been made of the storage tube operating as an integrator.

(319) J. P. Eckert, Jr., H. Lukoff, and G. Smoliar, "A dynamically regenerated electrostatic memory system," Proc. I.R.E., vol. 38, pp. 498–510; May, 1950.
(320) S. H. Dodd, H. Klemperer, and P. Youtz, "Electrostatic storage tube," *Elec. Eng.*, vol. 69, pp. 990–996; November, 1950.
(321) R. C. Hergenrother and B. C. Gardner, "The recording storage tube," Proc. I.R.E., vol. 38, pp. 740–747; July, 1950.
(322) J. V. Harrington and T. F. Rogers, "Signal-to-noise improvement through integration in a storage tube," Proc. I.R.E., vol. 38, pp. 1197–1203; October, 1950.
(323) J. V. Harrington, "Storage of small signals on a dielectric surface," *Jour. Appl. Phys.*, vol. 21, pp. 1048–1053; October, 1950.

Theoretical approaches were made in calculating the properties of electron lenses. Application of relaxation methods was made and numerical ray tracing performed. A more direct approach was made in a description of a dynamic device for obtaining electron trajectories. Magnifications between 1,000 and 100,000 times can be covered continuously in a new three-stage electron microscope.

(324) M. B. Hesse, "The calculation of magnetic lens fields by relaxation methods," *Proc. Phys. Soc.* (London), vol. 63B, pp. 386–401; June, 1950.
(325) G. Liebman, "An improved method of numerical ray tracing through electron lenses," *Proc. Phys. Soc.* (London), vol. 62B, pp. 753–772; December, 1949.
(326) P. A. Lindsay, "Certain properties of electrostatic fields encountered in electron lenses," *Proc. Phys. Soc.* (London), vol. 63B, pp. 699–702; September, 1950.
(327) U. F. Gianola, "Reduction of the spherical aberration of magnetic electron lenses," *Proc. Phys. Soc.* (London), vol. 63B, pp. 703–708; September, 1950.
(328) J. W. Clark and R. E. Neuber, "A dynamic electron trajectory tracer," Proc. I.R.E, vol. 38, pp. 521–524; May, 1950.
(329) M. E. Haine, R. S. Page, and R. G. Garfit, "A three-stage electron microscope with stereographic dark field and electron diffraction capabilities," *Jour. Appl. Phys.*, vol. 21, pp. 173–182; February, 1950.

A review of cathode-ray tube progress, electron lenses, field plotting, and ray tracing in electron optics and cathodoluminescence has been published.

(330) L. Marton, "Advances in Electronics," Vol. II, Academic Press, Inc., New York, N. Y.; 1950.

Power Tubes (High-Vacuum)

Triodes and Tetrodes. One development was a super-power triode capable of producing 500-kw output in the medium- and high-frequency range. It consists of 48 beamed triode structures arranged for convenient water cooling.

(331) "Super-power beam triode," *Broadcast News*, no. 38, pp. 8–9; March–April, 1950.

Continued interest in triodes of the disk-seal type for ultra-high frequencies was evident. One paper described a 30-watt tube having cylindrical electrodes that is useful up to 700 mc. Other papers considered the use of conventional tubes at higher frequencies.

(332) L. Liot, "New triodes for metre and decimetre waves," *Radio franç.*, no. 11, pp. 3–6; November, 1949.
(333) R. Suart, "Technology of electronic valves used for uhf," *Radio franç.*, no. 4, pp. 1–9; April, 1950.
(334) "A survey of V.H.F. valve developments," *Electronic Eng.* (London), vol. 22, pp. 310–315; August, 1950.
(335) K. W. Reusse, "On the physics and technics of modern transmitting valves for ultra high frequencies," *Elektrotechnik Berlin*, vol. 4, pp. 33–42, 81–90; February and March, 1950.

The alignment of grids was the subject of some study both in regard to reducing screen current and to improving the linearity of the characteristics.

(336) J. L. H. Jonker, "The computation of electrode systems in which grids are lined up," *Philips Res. Rep.*, vol. 4, pp. 357–365; October, 1949.
(337) J. L. H. Jonker, "Low distortion power valves," *Wireless Eng.*, vol. 26, pp. 385–390; December, 1949.
(338) D. C. Rogers, "Aligned-grid valves," *Wireless Eng.*, vol. 27, pp. 39–46; February, 1950.

Magnetrons. Much of the interest in magnetrons was still concentrated in the improvement and better understanding of conventional types used in military applications.

(339) O. Buneman, "Generation and amplification of waves in dense charged beams under crossed fields," *Nature* (London), vol. 165, pp. 74–476; 1950.
(340) "NBS develops electron-optical methods for mapping electric field of magnetron," *Elec. Eng.*, vol. 69, p. 661–662; 1950. Also, *Electronics*, vol. 23, p. 120; August, 1950.
(341) "Electron-optical mapping of the space charge field in a magnetron," *Tech. Nat. Bull. Bur. Stand.*, vol. 34, pp. 57–58; 1950.
(342) W. E. Willshaw and R. G. Robertshaw, "The behaviour of multiple circuit magnetrons in the neighborhood of the critical anode voltage," *Proc. Phys. Soc.* (London), vol. 63, pp. 41–45; 1950.

There was proposed a radically different magnetron design in which a ring cathode lies within a concentric toroidal anode with radial slots and the magnetic field circles around the cathode.

(343) O. Buneman, "Atoroidal magnetron," *Proc. Phys. Soc.* (London), vol. 63, pp. 278–288; 1950.

Continued interest in and development work on the interdigital structure was shown.

(344) "Development of turbator for radio relay equipment," *Brown-Boveri Rev.*, vol. 36, pp. 405–409; December, 1949.
(345) J. F. Hull and L. W. Greenwald, "Modes in interdigital magnetrons," Proc. I.R.E., vol. 37, pp. 1258–1263; November, 1949.

A magnetron amplifier was described in which separation of the incoming and amplified wave was secured by means of a directional coupler. It utilizes three-phase transmission in which the anode segments are divided into three groups.

(346) P. Marie, "A new type of magnetron amplifier," *Onde elect.*, vol. 30, pp. 13–22, 79–90, 200–202; 1950.

Two versions of the magnetron-type traveling-wave amplifier were described.

(347) J. R. Pierce, "A magnetron amplifier," *Bell Sys. Tech. Jour.*, vol. 29, pp. 653–659; October, 1950.
(348) R. R. Warnecke, W. Kleen, A. Lerbs, O. Döhler, and H. Huber, "A magnetron-type traveling wave amplifier tube," Proc. I.R.E., vol. 38, pp. 486–495; May, 1950.

Cathodes. The development of high-current-density cathodes of interest in magnetron and power-tube development was discussed.

(349) M. F. Amsterdam and W. E. Danforth, "High power pulsed magnetron with replaceable cathode," *Rev. Sci. Instr.*, vol. 21, p. 398; 1950.
(350) H. J. Lemmens, M. J. Jansen, and P. Loosjes, "A new thermionic cathode for heavy loads," *Philips Tech. Rev.*, vol. 12, pp. 341–350; June 1950.
(351) R. L. Jepsen, "Thermionic and secondary emission properties of magnetron cathodes and their influence on magnetron operation," *Phys. Rev.*, vol. 78, p. 354; May 1, 1950.

Traveling-Wave Tubes. The development of the traveling-wave tube gave promise of a means for obtaining wide-band power at frequencies above those at which more conventional tubes are useful. The highest power so far reported from this type of tube is 1,200 watts at frequencies in the vicinity of 500 mc. The beam voltage was about 5,000 volts and the current approximately 1 ampere.

(352) S. E. Webber, "1000 watt traveling-wave tube," *Electronics*, vol. 23, pp. 100–103; June, 1950.

Geiger-Müller Counter Tubes

Considerable progress was made toward an understanding of Geiger-Müller tubes and there was an evident trend to attach more importance to the role of the cathode than heretofore.

Some counters suitable for probing within the body were described. Details were given of a thin-window tube that can be used in a vacuum box as in a beta-ray spectrometer. Also reported was a metal-gauze cathode superior to a solid metal in that the probability of secondary emission was decreased.

(353) C. V. Robinson, "Small probing Geiger-Müller counters," *Rev. Sci. Instr.*, vol. 21, p. 82; January, 1950.
(354) E. R. Rae, "A thin-windowed miniature Geiger-Müller counter," *Jour. Sci. Instr.*, vol. 27, p. 143; May, 1950.
(355) O. Parkash, "A note on perforated cathode self-quenching G.M. counters," *Current Science*, vol. 18, p. 337; September, 1949.

A few papers appeared concerning the properties of various gas fillings, particularly with respect to life. Preliminary results were given on counters using ammonia as a self-regenerating quenching agent, and with mixtures of argon, xenon, oxygen, and nitrogen. In contrast to some previous work, recovery phenomena can be satisfactorily explained without invoking a variation in ion mobility. The influence of the quenching gas on plateau slopes was studied and gave evidence that spurious counts were due to the production of negative ions at the cathode. Spurious pulses were used to infer secondary-emission ratios for various cathode materials using alcohol quench. A method was developed for measuring spurious pulses using a pulsed X-ray beam. Results calling attention to the role of cathode work function were reported.

(356) S. A. Korff and A. D. Krumbein, "Tests of self-regenerating fillings for Geiger counters," *Phys. Rev.*, vol. 76, p. 1412; November 1, 1949.
(357) L. G. Shore, "Long-lived self-quenching counter filling," *Rev. Sci. Instr.*, vol. 20, p. 956; December, 1949.
(358) H. den Hartog and F. A. Müller, "Ion mobilities in Geiger-Müller counters," *Physica*, vol. 15, p. 789; September, 1949.
(359) S. C. Brown and C. Maroni, "Study of plateau slopes in self-quenching Geiger-Müller counters," *Rev. Sci. Instr.*, vol. 21, p. 241; March, 1950.
(360) E. Beretta and A. Rostagni, "Scariche secondarie nei contatori di Geiger e Müller e coefficiente di liberazione d'elettroni," *Nuovo Cim.*, Ser. 9, vol. 6, p. 391; September 17, 1949.
(361) D. Willard and C. G. Montgomery, "Method of measuring spurious counts in Geiger-Müller counters," *Rev. Sci. Instr.*, vol. 21, p. 520; June, 1950.
(362) I. Nonaka, "On a phenomenon observed with Geiger-Müller counters in ultraviolet measurement," *Jour. Phys. Soc. Japan*, vol. 3, p. 322; September–December, 1948.
(363) D. Blanc, "Etude de la deterioration des compteurs de Geiger-Müller a cathode externe remplis de methane," *Jour. Phys. Radium*, Ser. 8, vol. 10, p. 411; December, 1959.
(364) B. Tanyel, "Improvement effect of the plateau in xylene- and argon-filled Geiger counters," *Phys. Rev.*, vol. 77, p. 843; March 15, 1950.

Several authors studied the time lags and speed of breakdown in counter tubes. One gave data on drift times and propagation along the anode for numerous fillings. Others studied velocity of propagation for tank gases with external quench, and measured velocities were compared with Wilkinson's theory with satisfactory agreement except at the higher velocities (large over-voltages). Success was reported in devising a quench circuit fast enough to limit the discharge to a portion of the wire, which markedly reduces the dead time and should extend the life of a counter. Also reported was the use of a fast-quenching circuit on a hydrogen-filled counter to get very fast counting and long life.

(365) A. R. Laufer, "Time lags in Geiger counters," *Rev. Sci. Instr.*, vol. 21, p. 244; March, 1950.
(366) C. Balakrishnan and J. D. Craggs, "On the velocity of discharge propagation in externally quenched Geiger counters," *Proc. Phys. Soc.* (London), Sec. A, vol. 63, p. 358; April 1, 1950.
(367) H. Saltzmann and C. G. Montgomery, "Velocity of propagation of the discharge in Geiger-Müller counters," *Rev. Sci. Instr.*, vol. 21, p. 548; June, 1950.
(368) B. Collinge, "Dead times of self-quenching counters," *Proc. Phys. Soc.* (London), Sec. B, vol. 63, p. 15; January 1, 1950.
(369) B. Collinge, "Hydrogen-filled Geiger counters," *Proc. Phys. Soc.* (London), Sec. B, vol. 63, p. 665; September 1, 1950.

The effects of temperature on the characteristics of Geiger-Müller tubes, particularly of the self-quenching variety, received considerable attention. An external-cathode (Maze) tube was compared with a conventional type and reported better behavior of the former at low temperatures. Most of the findings were confirmed, but investigators disagree on the suitability of the external-cathode tube because of the increased resistance of the glass at low temperatures. Attention was called to the desirable properties of ethyl formate as a quenching agent, and tests were reported on temperature dependence of several types of commercial argon-alcohol tubes, indicating that the nature of the cathode is important.

(370) O. Parkash and P. L. Kapur, "On the temperature dependence of counter characteristics in self-quenching Geiger-Müller counters," *Proc. Phys. Soc.* (London), Sec. A, vol. 63, p. 457; May 1, 1950.
(371) W. R. Loosemore and D. Taylor, "Temperature dependence of counter characteristics in self-quenching Geiger-Müller counters," *Proc. Phys. Soc.* (London), Sec. B, vol. 63, p. 728; September 1, 1950.
(372) R. O. Jenkins and R. W. Taylor, "Ethyl formate as a quenching agent in Geiger-Müller counter tubes," *Jour. Sci. Instr.*, vol. 27, p. 254; September, 1950.
(373) O. Parkash, "On the temperature dependence of counter characteristics in self-quenching G.M. counters," *Current Science*, vol. 19, p. 273; September, 1950.

Sonoda published calculations of the efficiency of thick-walled counter tubes for high-energy gamma rays.

(374) M. Sonoda, "The efficiency of the G-M counter," *Jour. Phys. Soc. Japan*, vol. 5, p. 53; March–April, 1950.

Solid-State Devices

Continuing under the impetus of the transistor, the semiconductor field has been quite active with the greatest amount of reported work in the theoretical phase. Although there was strong evidence of very active device and circuit studies, such devices have not received large-scale application as yet. Published papers included an introductory article about the physics of the transistor.

(375) W. Shockley, "Holes and electrons," *Physics Today*, vol. 3, pp. 16–24; October, 1950.

Physical Theory and Experiment. Studies of Hall coefficient and mobilities in germanium were continued, both theoretically and experimentally, with some agreement among workers.

(376) W. Shockley and J. Bardeen, "Energy bands and mobilities in monatomic semiconductors," *Phys. Rev.*, vol. 77, pp. 407–408; February 1, 1950.
(377) W. Shockley, "Energy band structures in semiconductors," *Phys. Rev.*, vol. 78, pp. 173–174; April 15, 1950.
(378) G. L. Pearson, J. R. Haynes, and W. Shockley, "Comments on mobility anomalies in germanium," *Phys. Rev.*, vol. 78, pp. 295–296; May 1, 1950.
(379) V. A. Johnson and K. Lark-Horovitz, "Theoretical Hall coefficient expressions for impurity semiconductors," *Phys. Rev.*, vol. 79, pp. 176–177; July 1, 1950.
(380) W. C. Dunlap, "Some properties of high resistivity *p*-type germanium," *Phys. Rev.*, vol. 79, pp. 286–292; July 15, 1950.
(381) V. A. Johnson and K. Lark-Horovitz, "Electronic mobility in germanium," *Phys. Rev.*, vol. 79, pp. 409–410; July 15, 1950.
(382) J. Bardeen and W. Shockley, "Deformation potentials and mobilities in non-polar crystals," *Phys. Rev.*, vol. 80, pp. 72–80; October 1, 1950.

Experiments on resistivity and Hall effect at very low temperatures indicate the need for a more comprehensive theory of the behavior of these parameters over a wide range of temperatures.

(383) H. Y. Fan, "Temperature dependence of energy gap in monatomic semiconductors," *Phys. Rev.*, vol. 78, pp. 808–809; June 15, 1950.
(384) E. Conwell and V. F. Weisskopf, "Theory of impurity scattering in semiconductors," *Phys. Rev.*, vol. 77, pp. 388–390; February 1, 1950.
(385) C. S. Hung and J. R. Gliessman, "The resistivity and Hall effect of germanium at low temperatures," *Phys. Rev.*, vol. 79, pp. 726–727; August 15, 1950.
(386) C. S. Hung, "Theory of resistivity and Hall effect at very low temperatures," *Phys. Rev.*, vol. 79, pp. 727–728; August 15, 1950.

Continued experiments with neutron-bombarded germanium resulted in a redetermination of the effective cross section of the isotopes of germanium and a consequent agreement of experimental and theoretical results. Important conclusions were that there is one current carrier released per impurity center and that chemical doping is a substitutional process.

(387) J. W. Cleland, K. Lark-Horovitz, and J. C. Pigg, "Transmutation produced semiconductors," *Phys. Rev.*, vol. 78, pp. 814–815; June 15, 1950.
(388) J. H. Crawford, Jr., and K. Lark-Horovitz, "Fast neutron bombardment effects in germanium," *Phys. Rev.*, vol. 78, pp. 815–816; June 15, 1950.

Optical properties of bulk silicon and germanium were reported and indicate excellent possibilities for infrared lenses. One paper, reference (392), reported a coated germanium lens with 90 per cent transmission and a speed of $f/1.5$.

(389) K. Lark-Horovitz and K. W. Meissner, "Optical properties of semiconductors, I—The reflectivity of germanium," *Phys. Rev.*, vol. 76, p. 1530; November 15, 1949.
(390) M. Becker and H. Y. Fan, "Optical properties of semiconductors, II—Infra-red transmission of germanium," *Phys. Rev.*, vol. 76, pp. 1530–1531; November 15, 1959.
(391) M. Becker and H. Y. Fan, "Optical properties of semiconductors, III—Infra-red transmission of silicon," *Phys. Rev.*, vol. 76, pp. 1531–1532; November 15, 1949.
(392) H. B. Briggs, "Optical effects in bulk silicon and germanium," *Phys. Rev.*, vol. 77, p. 287; January 15, 1950.
(393) H. B. Briggs, "Infra-red absorption in silicon," *Phys. Rev.*, vol. 77, pp. 727–728; March 1, 1950.

It was shown (within experimental error) that the photonic yield in germanium is one electron-hole pair per photon absorbed, at wavelengths less than the cutoff.

(394) F. S. Goucher, "The photon yield of electron-hole pairs in germanium," *Phys. Rev.*, vol. 78, p. 816; June 15, 1950.

The theory of noise in semiconductors continued both to plague and to interest investigators.

(395) F. K. duPre, "Suggestion regarding the spectral density of flicker effect noise," *Phys. Rev.*, vol. 77, p. 615; January 1, 1950.
(396) J. M. Richardson, "The linear theory of fluctuations arising from diffusional mechanisms—an attempt at a theory of contact noise," *Bell Sys. Tech. Jour.*, vol. 29, pp. 117–141; January, 1950.
(397) A. Van der Ziel, "On the noise spectra of semiconductor noise and of flicker effect," *Physica*, vol. 16, pp. 359–372; April, 1950.
(398) G. C. Macfarlane, "Theory of contact noise in semiconductors," *Proc. Phys. Soc.* (London), vol. 63B, pp. 807–814; October 1, 1950.

Device Development. The development of a semiconductor amplifier having high input impedance was announced. The physical mechanism is deemed most likely to be the electrostatic field control of conductance; the success of the device is based on a new "microspacer" technique that enables the production of field intensities of the order of 10^4 volts per cm. As reported, power levels are low; gain is approximately unity; maximum frequency response approaches 10^4 or 10^5 cps; the dc input resistance is greater than 100 megohms; the shunting input capacitance is 1 to 3 $\mu\mu$f; noise is about the same as other transistors.

(399) O. M. Stuetzer, "A crystal amplifier with high input impedance," Proc. I.R.E., vol. 38, pp. 868–871; August, 1950.

Transistors were made with materials other than the historical *n*-type germanium, such as with *p*-type germanium in which the anomalous carriers are electrons as opposed to holes in the *n*-types. Characteristics of *p*-type germanium are quite similar to those of *n*-type except for a higher frequency response, which is claimed to be as high as 26 mc.

Lead sulfide also a deficit or *p*-type semiconductor has been employed. Operation was limited to low voltages, and no current gains were found. Power gains of 4 and voltage gains of 13 were obtained. Forming techniques affected the results. Frequency response was found to be related to collector voltage, with a reported cutoff at 610 kc at +8 volts bias. Transverse fields, poled for the *p*-type semiconductor, enhanced the response as originally disclosed by Brown, reference (411).

(400) W. G. Pfann and J. H. Scaff, "The *p*-germanium transistor," Proc. I.R.E., vol. 38, pp. 1151–1154; October, 1950.
(401) H. A. Gebbie, P. C. Banbury, and C. A. Hogarth, "Crystal diode and triode action in lead sulfide," *Proc. Roy. Soc. B*, vol. 63, p. 371; 1950.
(402) P. C. Banbury and H. K. Henish, "On the frequency response of PbS transistors," *Proc. Roy. Soc. B*, vol. 63, p. 540; 1950.

Progress was made in the understanding of transistors with contributions on the natures of forming, soldered contacts, and hole storage effects; the optical behavior of *p-n* junctions; a suggested controlled artificial preparation of *p-n* junctions; and the design theory for transistors. Hall and Dunlap reported the artificial preparation of *p-n*-junction diodes by the diffusion of appropriate impurities from the opposite sides of a germanium wafer. Diodes so prepared were similar in characteristics to those of selenium or copper-oxide rectifiers, except that current densities were about 1,000 times greater.

(403) J. Bardeen and W. G. Pfann, "Effects of electrical forming on the rectifying barriers of *n*- and *p*-germanium transistors," *Phys. Rev.*, vol. 77, pp. 401–402; February 1, 1950.
(404) W. Shockley, "Theories of high values of alpha for collector contacts on germanium," *Phys. Rev.*, vol. 78, pp. 294–295; May 1, 1950.
(405) J. I. Pantchechnikoff, "On the nature of a soldered contact on a semiconductor," *Phys. Rev.*, vol. 79, pp. 1027–1028; September, 1950.
(406) L. A. Meacham and S. E. Michaels, "Observations of the rapid withdrawal of stored holes from germanium transistors and varistors," *Phys. Rev.*, vol. 78, pp. 175–176; April 15, 1950.
(407) M. Becker and H. Y. Fan, "Photovoltaic effects of *p-n* junctions in germanium," *Phys. Rev.*, vol. 78; pp. 301–302; May 1, 1950.
(408) R. N. Hall and W. C. Dunlap, "*p-n* junctions prepared by impurity diffusion," *Phys. Rev.*, vol. 80, pp. 467–468; November 1, 1950.
(409) J. Bardeen, "Theory of relation between hole concentration and characteristics of germanium point contacts," *Bell Sys. Tech. Jour.*, vol. 29, pp. 469–495; October, 1950.
(410) W. van Roosbroeck, "Theory of the flow of electrons and holes in germanium and other semiconductors," *Bell Sys. Tech. Jour.*, vol. 29, pp. 560–607; October, 1950.

Circuit Properties and Applications. The use of a transverse magnetic field to improve frequency response and reduce variations between transistors was suggested. An intermediate-frequency amplifier using this method was also described, along with suggestions for general circuit design. Automatic-gain-control properties were also suggested through an observed variation of gain with collector voltage.

(411) C. B. Brown, "High frequency operation of transistors," *Electronics*, vol. 23, pp. 81–83; July, 1950.
(412) C. B. Brown, "Magnetically biased transistors," *Phys. Rev.*, vol. 76, p. 1736; December 1, 1949.

The use of the transistor as a reversible amplifier, *not* a bilateral amplifier, through the interchange of the roles of collector and emitter was suggested.

(413) W. G. Pfann, "The transistor as a reversible amplifier," Proc. I.R.E., vol. 38, p. 1222; October, 1950.

The analysis of relations of current, voltage, power, and time in the application of thermistors to control networks lead to design criteria.

(414) J. H. Bollman and J. G. Kreer, "The application of thermistors to control networks," Proc. I.R.E., vol. 38, pp. 20–26; January, 1950.

An unusual application of thermistor bolometers was also reported.

(415) J. R. Leslie and J. R. Waite, "Bolometer detection of line temperature rise," *Elec. Eng.*, vol. 68, pp. 969–973; November, 1949.

Electronic Computers

Digital Computers

The National Bureau of Standards eastern automatic computer (SEAC) was assembled and began useful calculations during 1950. It is a serial binary electronic computer with an acoustic-delay-line memory that holds 512 45-bit words. An average multiplication requires three milliseconds. The four-address instructions are retained in the memory with the data so that the computer can control and modify its own program.

(416) National Bureau of Standards Electronic Laboratory Staff, "The operating characteristics of the SEAC," *Math. Tables and Aids to Comp.*, vol. 4, pp. 229–230; 1950.
(417) National Bureau of Standards Machine Development Laboratory Staff, "The incorporation of subroutines into a complete problem on the NBS eastern automatic computer," *Math. Tables and Aids to Comp.*, vol. 4, pp. 164–168; July, 1950.
(418) "SEAC, National Bureau of Standards eastern automatic computer," *Tech. Bull. Nat. Bur. Stand.*, vol. 34, pp. 121–127; September, 1950.

The electronic delay storage automatic computer (EDSAC) was put in service at the University Mathematical Laboratory, Cambridge, England, during 1949. It is a serial binary computer with an acoustic-delay-line memory that holds 1,024 17-bit words. The memory is used to retain both the data and the single-address instructions.

(419) D. J. Wheeler, "Programme organization and initial orders for the EDSAC," *Proc. Roy. Soc.*, vol. 202, pp. 573–589; 22 August 1950.
(420) M. V. Wilkes and W. Renwick, "The EDSAC—an electronic calculating machine," *Jour. Sci. Instr.*, vol. 26, pp. 385–391; December, 1949.
(421) M. V. Wilkes and W. Renwick, "The EDSAC (electronic delay storage automatic calculator)," *Math. Tables and Aids to Comp.*, vol. 4, pp. 61–65; April, 1950.

The Maddida, which was described in oral reports at various meetings during the year, represents a refreshingly new idea. It is a differential analyzer with 22 variables that are represented as 22-bit binary numbers retained on a magnetic drum. The adders and integrators are digital and the machine is controlled by a novel form of stored program. It was demonstrated in operation, but without adequate input or output facilities.

Work continued on the several dozen other large-scale electronic computers that are in progress in various laboratories here and abroad. At least one, and probably more, large-scale computers with electrostatic memory were put in operation. However, no reports of actual useful calculations on these machines have appeared in print.

(422) "The Aberdeen Proving Ground computers," "The Institute for Advanced Study computer," "SEAC (Formerly called NBS interim computer)," "Institute for Numerical Analysis computer (SWAC)," "Project Whirlwind," "Maddida," "Raytheon computers," "The EDSAC, Cambridge University, England," *Digital Computer Newsletter*, vol. 2, pp. 1–4; August, 1950.
(423) "Naval Proving Ground calculators," "Ratheon computers," "Univac," "Aberdeen Proving Ground computers," "California digital computer," "Institute for Advanced Study computer," "Project Whirlwind," "Maddida computer," "Institute for Numerical Analysis computer," NBS computer," "Computers, Manchester University, England," "Telecommunications Research Establishment computer,"

"BARK computer, Sweden," *Digital Computer Newsletter*, vol. 2, pp. 1–4; May, 1950.
(424) "Institute for Advanced Study computer," "Whirlwind I," "Raytheon SDC computer," "CALDIC, University of California, Berkeley," "Institute for Numerical Analysis computer," "NBS interim computer," "The Bell computer—Model VI," "Data conversion equipment," "The EDSAC, Cambridge University, England," "Computer, Manchester University, England," "Digital computers, Birkbeck College, University of London," "Digital computers in Sweden," "Computer at Mathematisch Entrum, Amsterdam," *Digital Computer Newsletter*, vol. 2, pp. 1–4, January, 1950.
(425) H. D. Huskey, "Characteristics of the Institute for Numerical Analysis computer," *Math. Tables and Aids to Comp.*, vol. 4, pp. 103–108; April, 1950.
(426) L. Couffignal, "Report on the machine of the Institute Blaise Pascal," *Math. Tables and Aids to Comp.*, vol. 4, pp. 225–229; October, 1950.
(427) E. G. Andrews and H. W. Bode, "Use of the relay digital computer," *Elec. Eng.*, vol. 69, pp. 158–163; February, 1950.
(428) D. R. Brown and P. L. Morton, "Development of the California digital computer," (Abstract) Proc. I.R.E., vol. 38, p. 202; February, 1950.

Extensive work was carried on in development of components for computers. The problem of how to devise an adequate memory continued to have the greatest emphasis and significance.

(429) An Wang and Way Dong Woo, "Static magnetic storage and delay line," *Jour. Appl. Phys.*, vol. 21, pp. 49–54; January, 1950.
(430) P. L. Morton, "A compact magnetic memory," (Abstract) Proc. I.R.E., vol. 38, pp. 211; February, 1950.
(431) R. F. Shaw, "Arithmetic operations in a binary computer," *Rev. Sci. Instr.*, vol. 21, pp. 687–693; August, 1950.
(432) J. H. Knapton and L. D. Stevens, "Gate-type shifting register," *Electronics*, vol. 22, pp. 186, 192; December, 1949.
(433) J. Katz, "A new class of switching tubes for digital applications," (Abstract) Proc. I.R.E., vol. 38, p. 202; February, 1950.
(434) R. C. Hergenrother and B. C. Gardner, "The recording storage tube," Proc. I.R.E., vol. 38, pp. 740–747; July, 1950.
(435) J. P. Eckert, Jr., H. Lukoff, and G. Smoliar, "A dynamically regenerated electrostatic memory system," Proc. I.R.E., vol. 38, pp. 498–510; May, 1950.
(436) S. H. Dodd, H. Klemperer, and P. Youtz, "MIT electrostatic storage tube," (Abstract) Proc. I.R.E., vol. 38, p. 202; February, 1950.
(437) I. L. Cooter, "Pulse packing in magnetic recording wire," *Jour. Res. Nat. Bur. Stand.*, vol. 44, pp. 163–174; February, 1950.
(438) A. A. Cohen, "Magnetic drum for digital information processing systems," *Math. Tables and Aids to Comp.*, vol. 4, pp. 31–39; January, 1950.
(439) Tung Chang Chen, "Diode coincidence and mixing circuits in digital computers," Proc. I.R.E., vol. 38, pp. 511–514; May, 1950.
(440) E. W. Bivans and J. V. Harrington, "An electronic storage system," (Abstract) Proc. I.R.E., vol. 38, p. 205; February, 1950.
(441) R. C. Bacon and J. R. Pollard, "The Dekatron," *Electronic Eng.*, vol. 22, pp. 173–177; May, 1950.

The problem of how to construct a computer that practically never makes a mistake stimulated much discussion and some ideas and investigations.

(442) N. H. Taylor, "Marginal checking as an aid to computer reliability," Proc. I.R.E., vol. 38, pp. 418–421; December, 1950
(443) R. W. Hamming, "Error detecting and correcting codes," *Bell Sys. Tech. Jour.*, vol. 26, pp. 147–160; April, 1950.

There was a great deal of miscellaneous activity in connection with electronic digital computers. Some of it may be merely curious and entertaining, while some will undoubtedly lead to important new things.

(444) H. E. Singleton, "A digital electronic correlator," (Abstract) Proc. I.R.E., vol. 38, p. 204; February, 1950.
(445) W. B. Floyd, "Electronic machines for business use," *Electronics*, vol. 23, pp. 66–69; May, 1950.
(446) C. E. Shannon, "Programming a computer for playing chess," *Phil. Mag.*, vol. 41, pp. 256–275; March, 1950.

Analogue Computers

The analogue computer art during the past year has been marked by their greatly increased use, and the development of new techniques and components.

(447) E. C. Koenig, "An electric analog computer using the photo cell as a nonlinear element," AIEE Technical Paper, 50–263.
(448) A. D. Moore, "The further development of fluid moppers," AIEE Technical Paper, 50–267.
(449) E. S. Van Valkenburg and N. W. Matthews, "Analog techniques for turbo-jet thrust instrumentation," AIEE Technical Paper, 50–212.
(450) E. L. Harder and J. T. Carleton, "New techniques on the anacom—electric analog computer," AIEE Technical Paper, 50-85.
(451) D. L. Whitehead, "Analog computer—new techniques, new components," *Westinghouse Eng.*, November, 1950.
(452) H. Zangor, "Engineering applications of electronic analog computers," A.C.M. Conference; March, 1950.
(453) M. G. Scherberg, "An analog series computer," A.C.M. Conference; March, 1950.
(454) D. L. Whitehead, "The Anacom—a large-scale general-purpose analog computer," A.C.M. Conference; March, 1950.
(455) J. T. Carleton, "Fluid flow problems on the Anacom," AIEE Conference Paper.
(456) R. E. Langworthy and R. M. Byrne, "A special purpose analog computing system for radar triangulation problems," AIEE Conference Paper.
(457) B. N. Locanthi, "A high-speed multiplier for analog computers," AIEE Conference Paper.

These references give little idea of the extent of the application of analogue computer techniques to military and industrial control on a smaller scale and to individually constructed analogues for special-problem solutions as was evident from visits, to a large number of schools, factories, and research institutes.

The Maddida described in the digital-computer section is a digital computer using analogue-computer logic and this development is of considerable interest and significance.

(458) F. G. Steele, "Maddida, general theory," AIEE Conference Paper.
(459) D. E. Eckdahl, "Maddida, design features," AIEE Conference Paper.

Facsimile

A facsimile link has been found suitable for transmitting weather maps from recording stations to airports and other points. A plan to multiplex facsimile weather information on a frequency-modulated broadcast channel was described.

(460) C. A. Kettering and G. F. Montgomery, "How the U. S. Weather Bureau uses fax and telemetering," *FM and Telev.*, vol. 10, pp. 17, 40–41; October, 1950.
(461) J. V. L. Hogan and C. V. Olson, "High-speed fm facsimile; modern facsimile equipment operated at the Chicago Weather Bureau has proved fast and dependable," *FM and Telev.*, vol. 10, pp. 18–20, 40; October, 1950.
(462) "Facsimile to help cotton crops; Weather Forecasting and Research Co. buys WMC-FM time," *Broadcasting*, p. 48; September 11, 1950.

The application of facsimile to commercial telegraph systems progressed. New equipment designs in this field were described. A newly developed machine "cuts" a mimeograph stencil which is a facsimile of the copy scanned.

(463) A. W. Breyfogel and others, "Telegraph office desk-fax concentrator," *Elec. Eng.*, vol. 69, pp. 406–408; May, 1950.

(464) A. W. Breyfogel, "Western Union 50-line desk-fax concentrator," *Western Union Tech. Rev.*, vol. 4, pp. 1–9; January, 1950.
(465) J. H. Hackenberg, "A vertical drum telefax transmitter," *Western Union Tech. Rev.*, vol. 4, pp. 10–15; January, 1950.
(466) F. G. Hallden, "Three-stylus facsimile recorder for concentrator service," *Western Union Tech. Rev.*, vol. 4, pp. 16–18; January, 1950.
(467) "New business machine cuts stencils electronically," *Telegr. Teleph. Age.*, p. 27; November, 1950.

Industrial Electronics

During the last year, the scope of industrial electronics expanded to include a number of techniques for measurements and analysis heretofore confined to the laboratory. The phenomenon of nuclear induction saw its first application to industry in the measurement and control of magnetic fields.

(468) R. H. Varian, "Industrial application of nuclear induction," Gordon Research Conference on Instrumentation, Colby Junior College.

There were some uses of the mass spectrometer for monitoring continuous processes.

(469) C. F. Robinson, H. W. Washburn, C. E. Berry, and G. D. Perkins, "A mass spectrometer for monitoring continuous processes," Paper 50-14-1, Fifth National Instrument Conference.

Television came into increasing use as an industrial tool.

(470) R. W. Sanders, "Closed circuit industrial television," *Electronics*, vol. 23, p. 88; July, 1950.

Radioactive isotopes saw more use in industry, and special instruments in this field were being developed.

(471) E. T. Clarke, "Application of radioactive isotopes in industry and the instruments required for their application," Gordon Research Conference on Instrumentation, Colby Junior College.

Electronics found new applications to old problems of measurement and control in a number of diverse fields.

(472) M. S. Fred and E. G. Rauh, "Liquid air level control," *Rev. Sci. Instr.*, vol. 21, p. 258; March, 1950.
(473) R. D. Miller and J. S. Hopkins, "Electronic water level control," *Rev. Sci. Instr.*, vol. 21, p. 263; March, 1950.
(474) H. Munro and G. A. Larsen, "The penetron—its application to liquid level and metal thickness measurement," Paper 50-7-3, Fifth National Instrument Conference.
(475) G. L. Mellen, "Gas flow speedometer," *Electronics*, vol. 23, p. 80; February, 1950.
(476) A. Guthrie, "Leak detectors for industrial vacuum systems," *Electronics*, vol. 23, p. 96; September, 1950.
(477) E. C. Evans, and K. E. Burmaster, "A Philips-type ionization gauge for measuring of vacuum from 10^{-7} to 10^{-1} mm. of mercury," Proc. I.R.E., vol. 38, pp. 651–654; June, 1950.
(478) M. G. Turkish, "Electronic inspection of engine cam contours," *Electronics*, vol. 23, p. 74; October, 1950.
(479) W. T. Marchment, "Some developments in electronic instrumentation," 1950 Symposium on Process Industries, Texas A & M College. *Instruments*, vol. 24, pp. 42–44, 50–54; January, 1951.

An old discovery of the emission of positive ions from hot bodies has been utilized in a new type of leak detector. The device is extremely sensitive to the halogens.

(480) W. C. White, "Positive-ion emission, a neglected phenomenon," Proc. I.R.E., vol. 38, pp. 852–858; August, 1950.
(481) P. O. Engelder, "Continuous electronic recording of the water content of oil field emulsions," Paper 50-11-1, Fifth National Instrument Conference.
(482) S. A. Lippman and K. A. Ferguson, "Tire tread noise analyzer," *Electronics*, vol. 23, p. 84; November, 1950.

Work in the field of radio-frequency heating was limited to special applications.

(483) W. K. Halstead and L. D. Jaffe, "Quench controller for steel," *Electronics*, vol. 23, p. 109; November, 1950.
(484) R. H. Wittenberg, "Phototube controls, r. f. welding," *Electronics*, vol. 23, p. 91; January, 1950.

A large amount of attention was paid to the problems of reliability and dependability of industrial electronic instruments. A conference on the problems inherent with obtaining improved reliability was held at Washington, D. C., in May. A survey of means for obtaining reliability in industrial circuits was presented at the Fifth National Instrument Conference in Buffalo, N. Y.

(485) "Proceedings of Symposium—Improved Quality Electronic Components," published by Trielectro Company, 1 Thomas Circle, Washington, D. C.

Measurements

Progress in the field of basic standards and calibration methods include the following: good agreement was obtained from three independent sources on a predictable annual periodic fluctuation (approximately 0.001 second) in the length of the day, as deduced with reference to crystal clocks. It is of importance in defining and obtaining more uniformly accurate frequency and time standards.

(486) H. F. Finch, "On a periodic fluctuation in the length of the day," Monthly Notices, Royal Astronomical Society, vol. 110, pp. 1–14; 1950.

Accurate generation and measurement of frequency was enhanced by continued development of adjustable constant-frequency generators, frequency composition units, or frequency synthesizers. These instruments in general are stabilized by a single known frequency. A pulse and counter method of measuring frequencies to 5 mc in 200 microseconds was described. An additional experimental standard-frequency broadcast, station MSF in England, was commenced.

(487) L. F. Koerner, "A variable frequency oscillator stabilized to high precision," *Bell Lab Rec.*, vol. 28, pp. 66–71; 1950.
(488) W. D. Hershberger and L. E. Norton, "Servo theory applied to frequency stabilization with spectral lines," *Jour. Frank. Inst.*, vol. 249, pp. 359–366; 1950.
(489) R. L. Chase, "Measuring a varying frequency," *Electronics*, vol. 23, pp. 110–112; 1950.

The practical legal units of electrical and photometric measurement in the U. S. A. were defined by Public Law 617—81st Congress. An excellent symposium of papers appeared supporting the now widely used mks system of units. Basic standards for all physical measurements with reference to atomic or molecular properties were proposed.

(490) "Symposium of papers on the MKS system of units," *Proc. IEE*, vol. 97, part I, pp. 235–265; 1950.
(491) R. D. Huntoon and U. Fano, "Atomic definition of primary standards," *Nature*, vol. 166, pp. 167–168; 1950.

Additional progress on standardization and measurement of radio-frequency voltage and field intensity was reported. Accuracies within a few per cent may now be expected over a limited amplitude range, through vhf, in calibrating signal generators and field intensity sets.

(492) F. M. Greene, "The influence of the ground on the calibration and use of vhf field-intensity meters," Proc. I.R.E., vol. 38, p. 650; June, 1950.
(493) M. C. Selby and L. F. Behrent, "A bolometer bridge for standardizing radio-frequency voltmeters," *Jour. Res. Nat. Bur. Stand.*, vol. 44, pp. 15–30; 1950.

Precision measuring lines and guides with new techniques continued as the best absolute standard in determining impedance. An easily constructed slab line, having excellent microwave characteristics, was developed in theory and practice. An impedometer, admittance comparator, and vhf bridge became commercially available. The latter instruments, while less accurate than slotted lines, will certainly improve the efficiency or ordinary measurement and calibration methods. Quantitative checks on newly developed bridges in the range 100 to 500 mc could not be carried out because of lack of standards.

(494) A. M. Winzemer, "Methods for obtaining the voltage standing-wave ratio on transmission line independently of detector characteristics," Proc. I.R.E., vol. 38, pp. 275–279; March, 1950.
(495) W. B. Wholey and W. N. Eldred, "A new type of slotted line section," Proc. I.R.E., vol. 38, pp. 244–248; March, 1950.
(496) D. D. King, "Two simple bridges for very-high-frequency use," Proc. I.R.E., vol. 38, pp. 37–39; January, 1950.

The piston-attenuator (waveguide-below-cutoff attenuator, reactive attenuator, etc.), is becoming well established as a primary standard of attenuation.

(497) A. B. Giordano, "Design analysis of a *TM*-mode piston attenuator," Proc. I.R.E., vol. 38, pp. 545–550; May, 1950.

Magnetic Measurements

The subject of magnetic measurements is inextricably related to the many phases of research, development, application, and inspection of magnetic materials, and apparatus employing them.

The outstanding activity in the field of magnetic materials during the past year has been centered around the ferromagnetic ferrites. The manufacture of ferrite has developed on a large scale for application in television deflection coils and transformers, and more recently for magnetic antennae for radio receivers. Further material improvements and applications have been made in high-quality inductors and transformers for carrier and radio-frequency ranges and in small tuning coils and intermediate-frequency transformers for radio. Higher Q's and smaller sizes are possible in these designs than with those using cores of iron and permalloy powders or thin metal tapes.

The attainment of high resistivity coupled with high permeability in these ferromagnetic nonmetals has not only made them advantageous for use at comparatively high frequencies, but has opened entirely new areas of investigation for improvements in magnetic properties and for explanation of the mechanisms of ferromagnetic behaviors. High-frequency losses, not explained by conventional eddy-current concepts, are attributed by various observers to ferromagnetic resonance, and dimensional resonance associated with a high dielectric constant. Studies on measuring and evaluating the high-frequency properties in ferrites have led to an extension of bridge and series resonance LC circuit methods to the use of coaxial lines and resonant cavities, with some attempts to express the results in terms of transmission line theory.

Advancements were reported on the techniques of using fine magnetic powders of high coercive force in the fabrication of permanent magnets. More advanced theories of permanent magnetism were proposed. Interest increased in the applications of magnetic amplifiers and in the magnetic types of storage and trigger circuits. Various positive feedback circuits to increase sensitivity were studied. The development of methods of predicting steady-state and transient performance in magnetic amplifiers were noted. The domain theory of magnetism has been quite well developed.

At the Symposium on Ferromagnetic Materials conducted by the Measurements Section of the Institution of Electrical Engineers in November, 1949, a number of papers were presented covering methods of measurements, data, and applications of metal sheets and tapes, powders, and ferrites. Several of these were so-called "integrating" papers. Most of them were published in the *Proc. IEE* (London) vol. 97, part 2, April, 1950, which makes this issue a useful reference.

Several papers presented at the Magnetic Symposia of the American Institution of Electrical Engineers and the American Physical Society dealt largely with modern magnetic theory. A large number of papers on magnetics were given at a conference in Grenoble, France, in July, 1950, but have not yet reached publication.

Ferrites

(498) J. L. Snoek, "New Developments in Ferromagnetic Materials," Elsevier Publishing Company, Amsterdam, N. Y.; 1947.
(499) D. Polder, "Ferrite materials," *Proc. IEE*, (London), vol. 97, part 2, p. 246; April, 1950.
(500) K. E. Latimer and H. B. MacDonald, "A survey of the possible applications of ferrites," *Proc. IEE* (London), vol. 97, part 2, pp. 257–267; April, 1950.
(501) C. Guillaud, "Magnetic properties of ferrites," (in French), *Jour. des Recherches*, CNRS, #12, pp. 113–122; 1950.
(502) C. Guillaud and A. Barbezat, "MnZn Ferrite," (in French), *Jour. des Recherches*, CNRS, #11, p. 83; 1950.
(503) F. G. Brockman, P. H. Dowling, and W. G. Staneck, "Dimensional effects resulting from a high dielectric constant found in ferromagnetic ferrite," *Phys. Rev.*, vol. 7, pp. 85–93; January 1, 1950.
(504) V. D. Landon, "Use of ferrite cored coils as converters, amplifiers and oscillators," *RCA Rev.*, vol. 10, pp. 387–396; September, 1949.
(505) C. L. Snyder, E. Albers-Schoenberg, and H. A. Goldsmith, "Magnetic ferrites, core materials for high frequencies," *Elec. Mfg.*, vol. 44, pp. 86–91; December, 1949.

Measurements, Data, General Information

(506) P. P. Cioffi, "Recording fluxmeter of high accuracy and sensitivity," *Rev. Sci. Instr.*, vol. 21, pp. 624–628; July, 1950.
(507) H. W. Lamson, "Alternating current measurements of magnetic properties," Proc. I.R.E., vol. 36, pp. 266–277; February, 1948.
(508) R. A. Chegwidden, "Review of magnetic materials especially for communication systems," *Metal Progress*, vol. 54, pp. 705–714; November, 1948.
(509) R. J. Halsey, "Laminated ferromagnetic cores at very low inductions for use in line communication," *Proc. IEE*, (London), vol. 97, Part 2, pp. 141–157; April, 1950.
(510) H. J. Williams, "Ferromagnetic domains," *Elec. Eng.*, vol. 69, pp. 817–822; September, 1950.

(511) M. Kornetzki, "The magnetic characteristics of coils with shielded compressed iron cores" (in German), *Frequency*, vol. 4, pp. 105–113; May, 1950.
(512) E. E. Richards, S. E. Buckley, P. R. Bardell, and A. C. Lynch, "Some properties and tests of magnetic powders and powder cores," *Proc. IEE* (London), vol. 97, part 2, pp. 236–245; April, 1950.

Magnetic Amplifiers, Magnetic Triggers, and the like

(513) R. Feinberg, "The magnetic amplifier, transductor theory," *Wireless Eng.*, vol. 27, pp. 118–124; April, 1950.
(514) F. N. McClure, "Application of magnetic amplifiers," *Elec. Eng.*, vol. 69, pp. 538–543; June, 1950.
(515) N. R. Castellini, "The magnetic amplifier," Proc. I.R.E., vol. 38, pp. 151–158; February, 1950.
(516) W. S. Melville, "Measurement and calculation of pulse magnetization characteristics of nickel irons from 0.1 to 5 microseconds," *Proc. IEE* (London), vol. 97, part 2, pp. 165–198; April, 1950.
(517) A. G. Milnes, "A new theory of magnetic amplifiers," *Proc. IEE* (London), part 2, pp. 460–474; August, 1950.
(518) W. C. Johnson and F. W. Latson, "An analysis of transients and feedback in magnetic amplifiers," AIEE Technical Paper 50-94; December, 1949.
(519) A. Wang, "Magnetic triggers," Proc. I.R.E., vol. 38, pp. 626–629; June, 1950.

Permanent Magnets

(520) W. H. Neumann, "Definitions and physical bases of measurements for the coercive force *Hc*" (In German), *Arch. fur Elecktrotech.*, vol. 39, pp. 534–543, 1949; and vol. 39, pp. 578–600, 1950.
(521) A. H. Geisler, "Structure and properties of the permanent magnet alloys," *Elec. Eng.*, vol. 69, pp. 37–44; January, 1950.
(522) F. G. Spreadbury, "Permanent Magnets," Pitman and Sons, Ltd. London, England; 1949.
(523) E. A. Nesbitt and H. J. Williams, "Mechanism of magnetization in Alnico 5," *Phys. Rev.*, vol. 80, pp. 112–113; October 1, 1950.

Dielectrics

Considerable interest in the field of dielectrics was evident from the large attendance at a symposium on dielectrics held in New York, N. Y., on February 3, 1950, under joint sponsorship of the American Institute of Electrical Engineers and the American Physical Society. One paper considered dielectrics from the viewpoint that they are any material into which electric magnetic or electromagnetic fields penetrate; another paper described the action of dipoles in a dielectric by means of simple models; and a third paper dealt with relaxation phenomena in liquids and solids.

(524) A. Von Hippel, "Dielectrics in electrical engineering," *Elec. Eng.*, vol. 69, pp. 771–773; 1950.
(525) J. C. Slater, "Structure and polarization of atoms and molecules," *Elec. Eng.*, vol. 69, pp. 872–875; 1950.
(526) J. C. Slater, "Dielectric relaxation phenomena in liquids and solids," *Elec. Eng.*, vol. 69, pp. 975–980; 1950.

Numerous papers appeared on the properties of barium titanates and ferroelectricity. One report summarized this work at Massachusetts Institute of Technology and discussed the mechanisms of ferroelectricity in the titanates and piezoelectric effect in ceramics.

(527) A. Von Hippel, "Ferroelectricity, domain structure and phase transitions of barium titanate," *Rev. Mod. Phys.*, vol. 22, pp. 221–237; 1950.

Random noise in high polymerdielectrics has been reported. Current fluctuations with frequencies in the range of 60 to 1,000 cycles per second last for several minutes after the material has been subjected to a change of dc potential. These fluctuations are approximately 1,000 times the noise level of the circuit and apparently are a function of the moisture content.

(528) R. F. Boyer, "Random noise in dielectric materials," *Jour. Appl. Phys.*, vol. 21, pp. 469–477; 1950.

Instrumentation to record simultaneously the changes in dielectric constant and dissipation factor as a function of various parameters was accomplished. One system measures the dielectric constant of gases as a function of temperature, pressure, or humidity changes. The instrument in this form permits investigation of the atmosphere as a function of time. Such information is of interest in microwave propagation problems. Other instrumentation was developed which automatically computes and records dielectric constant and power factor as a function of frequency or temperature.

(529) George Birnbaum, "A recording microwave refractometer," *Rev. Sci. Instr.*, vol. 21, pp. 169–176; February, 1950.
(530) E. B. Baker, "Automatic computing and recording bridge for sonic and supersonic frequencies," Delivered before National Research Council 1950 Annual Conference on Electrical Insulation.

Methods for measuring the dielectric properties of thin films received serious consideration. The usual methods do not produce reliable results because the adhesive for the electrodes is frequently of the same order of thickness as the film to be measured. The thickness of the film itself cannot be accurately determined. It has been reported that the old method of immersing the unknown in a liquid and adjusting the dielectric of the liquid until it is the same as the unknown will produce satisfactory results on thin films. In this method the geometry of the specimen need not be known and specimen electrodes are not required. Except for the possibility of interfacial polarization and other solution effects, reliable results should be obtained. Thus by the proper choice of liquids, valuable data can be had which otherwise might not be available.

(531) W. F. Springate and H. S. Endicott, "Measurements of the dielectric constants of thin films." Delivered before National Research Council 1950 Annual Conference on Electrical Insulation.

Present-day equipment does not lend itself readily to the measurement of low-loss materials at radio frequencies. For example, the power factor of polystyrene is of the same order as the sensitivity of most bridges and Q meters. One suggested solution employs positive feedback to compensate for the circuit losses. By this means stable Q's of the order 50,000 are readily achieved. It becomes easy to obtain a 50 per cent voltage change by introducing the losses of polystyrene into such a circuit and to determine its power factor to an accuracy considerably better than 5 per cent.

(532) J. L. Dalke, "Considerations in making low-loss measurements around one megacycle." Delivered before National Research Council 1950 Annual Conference on Electrical Insulation.

Telemetering Systems and Techniques

During the year the FM/FM system of telemetering was accorded detail standardization by the RDB through a panel of the Committee on Guided Missiles. In the FM/FM system the intelligence value is converted to a frequency that modulates a subcarrier which in turn frequency modulates the radio carrier. Outstanding reliability figures achieved in actual flight testing have led to the widespread adoption of this system for radio telemetering. Eighteen basic subcarriers have been chosen, of which any number up to twelve may be selected to form a system. Audio deviations of ± 7.5 per cent or ± 15 per cent can be employed, and each subcarrier may be modulated in time sequence by a number of information channels through a commutator switch. The system operating practice is as follows:

A chopper is used to convert the intelligence signals from a number of dc low voltage sources, such as strain gauge bridges and thermocouples, into an ac square-wave carrier, amplitude-modulated by the intelligence. This signal is converted into a frequency-modulated wave and used to modulate an FM transmitter. After transmission over the radio link, detection, and discrimination the resulting output is impressed on a magnetic strain recording galvanometer as an amplitude-modulated square wave whose deviation (between a positive maximum and the following negative maximum) is proportional to the intelligence, and independent of any zero shift. Calibration is effected by inserting a known signal periodically.

The technique of telemetering vibration effects has been improved. New pickups, provide high-impedance sources for the low voltage ac signals which may or may not be commutated before amplification and conversion to a frequency-modulated subcarrier. At the receiving station this subcarrier is recorded in real time on a magnetic tape. Sections of the tape recording may be played back into a sonagraph for frequency and amplitude analysis. Improvement of calibration techniques has continued.

Low-pass filters having cutoff characteristics similar to the Gaussian error distribution curve have been designed for use between the audio discriminator and recorder, which reduce appreciably the ringing of commutated signals which result for the use of the presently employed circuits.

Magnetic tape recorders have been produced to record frequencies as high as 40 kc within ± 3 db, and improved models to record 80 kc are nearing completion. The advantages or FM over AM for this purpose have been shown, and compensating circuits have been built which reduce frequency errors to less than ± 1 per cent. New techniques, including the use of a tuning fork power supply, are expected to match this figure without the necessity of compensation.

Automatic data-analysis machines have been designed to convert the multiband recordings from a magnetic-string galvanometer into intelligence function time graphs and tabulated data, after all calibrations and zero corrections have been applied.

The PWM/FM System has been miniaturized and continues to be successfully employed where a low-performance system is adequate. It can show a 900 rating, where rating equals the number of intelligence channels times the frequency response of each.

One PAM/FM System employs a novel resistor-crystal which generates gating pulses. This system, however, requires a bandwidth to transmit the rectangular pulses 3.0 mc.

In general, radio telemetry is replacing wire carrier and other line systems because it minimizes problems of congestion, maintenance, and reliability. This is true in the file of power engineering and certain other commercial uses.

RF Units

Several radio-frequency FM transmitters, employing subminiature tubes and components, have been flight tested. Reactance-tube and reactance-switching modulators have been used. A packaged unit $3\times2\times1$ inches delivers 2 watts at approximately 219 mc.

A number of FM receivers were developed. One, using the spiral inductance in the radio-frequency section, has found wide-spread approval. Its powerful AFC characteristics minimize the risk of loss of signal due to transmitter carrier frequency drift.

Pickups

Reduced size and weight requirements, coupled with greater accuracy and reliability under severe physical conditions has stimulated greater use of inductance types. A very small ($1/4\times7/16$ inch) dynamic air-pressure gauge employing a strain gauge element was announced. This unit enabled pressures to be measured without the use of pickup tubing which would introduce phase errors.

Several successful accelerometers and vibration pickups using barium-strontium titanate crystals were designed and tested which gave a linear output with g changes and operated over frequency bands 320–10,000 cps. The progress of miniaturization, especially in connection with potentiometer and strain gauge types of pickups, has been hastened by the development of new materials rather than the employment of radically different principles. A very small accelerometer of the strain-gauge type, weighing 23 grams, is available.

Several new resistance-type-temperature pickups have been built, and a study on thermocouple housing and orientation has revealed the importance of these criteria when measuring the temperature of fast-moving air stream. A national conference on telemetering held in 1950 helped crystallize standardization of techniques and introduce new principles.

(533) "Joint AIEE-NFT Conference on Telemetering," Program papers. Published by AIEE (33 W. 39 St., New York, N. Y.); August, 1950.

Mobile Radio

Progress in the field of mobile radio was recorded in four specific categories; equipment design, system engineering, propagation, and applications.

Emphasis was on improvements in equipment design tended to permit more communication channels in a given frequency spectrum with less interference from other channels. This was accomplished both by selective calling and by reducing receiver bandwidth and transmitter radiation outside of the minimum band necessary for satisfactory communication.

Systems design articles dealt with somewhat similar problems, with emphasis on obtaining more usable communication channels by engineering and maintenance. Studies and tests of propagation in the uhf region, (particularly in the vicinity of 450 mc) were reported which are of particular value in this service. Many articles appeared dealing with the application of mobile radio communication, particularly in railroad operations.

At a national conference in Detroit, Mich., by the IRE Professional Group on Vehicular Communications, all phases of the problems in this field were discussed. It was brought out that the application of microwaves systems are expected to influence the design of vhf mobile communication systems. Point-to-point circuits using vhf replaced with microwave systems make additional frequencies available for the mobile service. A limitation in extending the frequency is attenuation due to heavy rain fall which begins to be an important factor above 8,000 mc.

Vhf-FM radio systems have been installed in several railroads on an experimental basis. Nine 250-watt transmitters and 12 receivers in the 40-mc band are employed. Experiments on 152 mc disclosed a noise level 25 db above set noise, while the transmitter was on the air and the train was in motion, caused by movement of metal parts in the field of the receiver.

A radio-frequency relay system wherein no audio demodulation or remodulation occurs in the repeaters except at terminal stations was installed in Cuba to carry programs to the network of AM broadcasting stations. Frequencies between 163 and 170.2 mc were used, although the same principles are being applied to other vhf and uhf bands. Circuit outages have been negligible and the performance of the system is superior to wire lines formerly used. Additional circuits are now planned.

The co-ordination of operations in large and wide spread production areas, installation, operation and maintenance of pipe lines extending from production fields to markets makes radio an ideal solution to a complex communication problem.

Applications

(534) "Radio expedites freight trains on the Santa Fe," *Railway Age*, vol. 128, pp. 16–19; January 14, 1950.

(535) "Radio for road train communication on the Santa Fe," *Ry. Signaling*, vol. 43, pp. 42–46; January, 1950.

(536) E. C. Brown, "Metropolitan police radio communication system," *Electronic Eng.*, vol. 22, pp. 316–322; August, 1950.

(537) J. H. Battison, "Erie Railroad traffic control operations aided by vhf-fm," *Tele-Tech*, vol. 9, pp. 25–26, 45; August, 1950.

Propagation and Its Effects on Mobile Radio

(538) K. Bullington, "Radio propagation variations at vhf and uhf," Proc. I.R.E., vol. 38, pp. 27–32; January, 1950.

(539) W. R. Young and L. Y. Lacy, "Echoes in transmission at 450 megacyles from land-to-car radio units," Proc. I.R.E., vol. 38, pp. 255–258; March, 1950.

(540) A. J. Aikens and L. Y. Lacy, "A test of 450-megacycle urban area transmission to a mobile receiver," Proc. I.R.E., vol. 38, pp. 1317–1319; November, 1950.

System Engineering and Operation

(541) E. Cook, "Small-town mobile fm operation," *Tele-Tech*, vol. 9, pp. 26–28, 54; February, 1950.

(542) E. R. Burroughes, "Planning vhf mobile systems," *Marconi Rev.*, vol. 13, pp. 37–46; January–March, 1950. Also *Electronic Eng.*, vol. 22, pp. 298–304; August, 1950.

(543) T. Luke, "Maintenance suggestions for railroad radio," *Railroad Signaling and Comm.*, vol. 43, pp. 356–360; June, 1950.

(544) I. Queen, "Mobile radio service," *Radio and Electronics*, vol. 21, pp. 71–75; June, 1950.

(545) C. A. Priest, et al, "Narrow-band fm doubles number of vhf channels for mobile use," *Tele-Tech*, vol. 9, pp. 30–32, pp. 34–35; September and October, 1950.

(546) R. C. Shaw, P. V. Dimock, W. Strack, and W. C. Hunter, "A six-system urban mobile telephone installation with 60-kilocycle spacing," Proc. I.R.E., vol. 38, pp. 1320–1323; November, 1950.

Equipment Design

(547) J. K. Kulanski, "Privacy for mobile phones," *FM-TV*, vol. 10, pp. 18–20, 37; January, 1950.

(548) D. C. Pinkerton and N. H. Shepherd, "Reducing unwanted radiation in mobile transmitters," *Electronics*, vol. 23, pp. 96–99; April, 1950.

(549) J. L. Kulanski, "Low-cost mobile fleet control," *FM-TV*, vol. 10, pp. 20–21, pp. 22–23; March and April, 1950.

(550) D. Samuelson, "Advance design details of single-channel mobile radio unit," *FM-TV*, vol. 10, pp. 18–19, 33; July, 1950.

(551) W. C. Babcock and H. W. Nylund, "Antenna systems for multichannel mobile telephony," Proc. I.R.E., vol. 38, pp. 1324–1329; November, 1950.

General information released by the FCC indicated that, of the over 300,000 nonbroadcast radio authorizations (including more than 80,000 amateur stations) about 12,000 were land and fixed stations and about 200,000 portable or mobile units, including over 40,000 for ships and aircraft. There was substantial activity also in the field of Public Safety, Industrial and Public Mobile Radio Communication. The general development of mobile radio equipment has been toward the improvement of those characteristics which permit 60-kc channel spacing in the 152- to 162-mc range and thus lead to the ultimate use of all of the available channels allocated in this part of the spectrum.

(552) C. A. Priest, C. M. Heiden, and D. C. Pinkerton, "Narrow-band fm doubles number of vhf channels for mobile use," *Tele-Tech*, pp. 30–32, September, 1950; and pp. 34–45, October, 1950.

(553) D. C. Pinkerton and N. H. Shepherd, "Reducing unwanted mobile radiation," *Electronics*, vol. 23, pp. 96–99; April, 1950.

(554) G. S. Ferguson, "Design trends in modern car radio," *IRE Australia Bull.*, vol. 10, pp. 338–342; December, 1949.

(555) J. D. Braak, "Mobile radio equipment, type SRR-192," *Commun. News*, vol. 10, pp. 120–125; April, 1950.

(556) L. W. D. Sharp, "Design problems of uhf mobile equipment," *Electronic Eng.* (London), vol. 22, pp. 331–337; August, 1950.

(557) D. R. Ripani, "Mobile two-way radio," *Radio and Telev.*, vol. 44, pp. 29–32; July, 1950.

(558) R. A. Beers, W. A. Harris, and A. D. Zappocosta, "Mobile radio sets on 152–174 Mc," *Elec. Eng.*, vol. 69, pp. 235; March, 1950.

(559) D. Samuelson, "Advance design details of single-channel mobile radio unit," *FM and Telev.*, vol. 10, pp. 18–19, 33; July, 1950.

Modulation Systems

Attempts are being made to devise practical coding systems that will permit communication over available channels at a rate near the maximum theoretically possible. Published material disclosed a study of certain coding schemes that approach ideal performance as the length of the coded message becomes very large. It appears that the codes so far examined approach this ideal very slowly, and may not be suitable for practical applications. These results emphasize the difficulty that is to be expected in devising efficient coding systems.

(560) S. O. Rice, "Communication in the presence of noise: probability of error for two encoding schemes," *Bell Sys. Tech. Jour.*, vol. 29, pp. 60–93; January, 1950.
(561) M. J. E. Golay, "Note on the theoretical efficiency of information reception with PPM," Proc. I.R.E., vol. 37, p. 1031; September, 1949.
(562) R. M. Fano, "The transmission of information—II," Technical Report No. 149, MIT Research Laboratory of Electronics; February 6, 1950.

Communication theory was applied to the study of secrecy systems and cryptography. The problem of deciphering an intercepted cryptogram was shown to be closely related to the problem of communication in the presence of noise, and in studying the problem use was made of the concepts of entropy and equivocation.

(563) C. E. Shannón, "Communication theory of secrecy systems," *Bell Sys. Tech. Jour.*, vol. 28, pp. 656–715; October, 1949.

The theory of optimum-mean-square linear filters and predictors was presented from a more physical point of view than that originally adopted by Wiener.

(564) H. W. Bode and C. E. Shannon, "A simplified derivation of linear least-square smoothing and prediction theory," Proc. I.R.E., vol. 38, pp. 417–425; April, 1950.

Maximizing the ratio of peak signal to root-mean-square noise was employed as a criterion to determine the optimum linear filter for a pulse signal of prescribed shape.

(565) B. M. Dwork, "Detection of a pulse superimposed on fluctuation noise," Proc. I.R.E., vol. 38, pp. 771–774; July, 1950.

Filtering in the time domain, either by correlation or integration, received considerable attention as a method of detecting a periodic waveform in the presence of random noise.

(566) Y. W. Lee and J. B. Wiesner, "Correlation functions and communication applications," *Electronics*, vol. 23, pp. 86–92; June, 1950.
(567) W. J. Cunningham, J. C. May, and J. G. Skalnik, "Integration noise reducer for radar," *Electronics*, vol. 23, pp. 76–78; September, 1950.
(568) Y. W. Lee, T. P. Cheatham, Jr., and J. B. Wiesner, "Application of correlation analysis to the detection of periodic signals in noise," Proc. I.R.E., vol. 38, pp. 1165–1171; October, 1950.
(569) J. V. Harrington and T. F. Rogers, "Signal-to-noise improvement through integration in a storage tube," Proc. I.R.E., vol. 38, pp. 1197–1203; October, 1950.

A general theory of the synthesis of optimum nonlinear filters and detectors was given.

(570) H. E. Singleton, "Theory of nonlinear transducers," Technical Report No. 160, MIT Research Laboratory of Electronics; August 12, 1950.

The study of interference phenomena continued. A new receiver for multipath frequency modulation, incorporating a wide-band limiter and discriminator, was developed. The receiver separates two interfering signals if they differ in amplitude by as much as approximately one-half decibel. Interference in amplitude-modulation systems and in pulse-modulation systems also received attention, the latter being studied analytically by statistical methods. For the reduction of cochannel television interference, carrier synchronization was demonstrated to be advantageous; the use of offset carrier operation was found to give still better results.

(571) L. B. Arguimban and J. G. Granlund, "Sky-wave f.m. receiver," *Electronics*, vol. 22, pp. 101–103; December, 1949.
(572) I. H. Gerks, "An analysis of distortion resulting from two-path propagation," Proc. I.R.E., vol. 37, pp. 1272–1277; November, 1949.
(573) E. G. Hills, "Multipath television reflections," Proc. I.R.E., vol. 37, pp. 1043–1046; September, 1949.
(574) R. M. Wilmotte, "Interference caused by more than one signal," Proc. I.R.E., vol. 38, pp. 1145–1150; October, 1950.
(575) E. R. Kretzmer, "Interference characteristics of pulse-time modulation," Proc. I.R.E., vol. 38, pp. 252–255; March, 1950.
(576) "A study of cochannel and adjacent-channel interference on television signals," *RCA Rev.*, vol. 11, pp. 99–120, March, 1950; and pp. 287–295, June, 1950.

The product-phase method of modulation was discussed, and a special tube was proposed for producing it. The outphasing system of producing amplitude-modulated signals, avoiding high-power modulators and high-power linear amplifiers, was suggested as being especially applicable to television.

(577) D. B. Harris, "Product phase modulation and demodulation," Proc. I.R.E., vol. 38, pp. 890–895; August, 1950.
(578) W. E. Evans, Jr., "Phase-to-amplitude modulation for uhf-tv transmitters," *Electronics*, vol. 23, pp. 102–106; September, 1950.

Several special pulse communication systems were investigated. It was pointed out that for multiplexing asynchronous pulse signals it is possible to add redundancy to the signals prior to mixing in a way that permits improved separation.

(579) A. E. Ross, "Theoretical study of pulse-frequency modulation," Proc. I.R.E., vol. 37, pp. 1277–1286; November, 1949.
(580) W. D. White, "Theoretical aspects of asynchronous multiplexing," Proc. I.R.E., vol. 38, pp. 270–275; March, 1950.

Activity in the field of modulation systems for television, especially color television centered around dot interlace, frequency interlace, and the mixed-highs method of color transmission, provides techniques for improving black-and-white pictures.

(581) "Six-megacycle compatible high-definition color television system," *RCA Rev.*, vol. 10, pp. 504–524; December, 1949.
(582) W. Boothroyd, "Dot systems of color television," *Electronics*, vol. 22, pp. 89–92, December, 1949; and vol. 23, pp. 96–99, January, 1950.
(583) "An analysis of the sampling principle of the dot-sequential color television system," *RCA Rev.*, vol. 11, pp. 255–286, June, 1950; and pp. 431–445, September, 1950.
(584) "Improvements in dot-sequential color tv," *Electronics*, vol. 23, pp. 154–156; August, 1950.
(585) R. B. Dome, "Frequency interlace color television," *Electronics*, vol. 23, pp. 70–75; September, 1950.
(586) A. V. Bedford, "Mixed highs in color television," Proc. I.R.E., vol. 38, pp. 1003–1009; September, 1950.

Navigation Aids

Radio aids to aerial navigation may be divided into classes applying to four zones of operation. These are the long-distance en route zone, the short-distance en route zone, the approach and landing zone, and the airport zone. The marine navigational aids are classified as long distance, medium distance, and harbor aids. Marine classification also includes an "anticollision" group.

The classifications listed in the foregoing form a suitable means whereby the navigational developments of the past year may be discussed.

Immediately after the second World War, the increase in air traffic made evident the need for navigational aids that would apply to the high-density areas; that is, the short-distance en route zone and the approach and landing zone. At this time, a large number of new systems were invented and described. Some of the systems were approved by using agencies and work has continued on their development, manufacture, and installation. Thus, the technical literature of the year relating to these devices is largely a progress report.

(587) J. P. Griffin, "Radio navigation equipment," *Radio and Telev.*, part 1, vol. 44, pp. 3A–5A, 29A; September, 1950. Part 2, vol. 44, pp. 11A–14A, 31A; October, 1950.
(588) W. L. Webb, "Flying with vhf," *Aero Digest*, vol. 61, pp. 80–83; July, 1950.
(589) H. L. Lubin and J. Starr, III, "Air-traffic control through radar," *Aero Digest*, part 1, vol. 60, pp. 56–60, 102–103, April, 1950; and part 2, vol. 60, pp. 48–52, 92–96, May, 1950.
(590) "Electronic aids to air navigation," *Electronics*, vol. 23, pp. 66–71; February, 1950.
(591) W. D. Perreault, "New omni-range design gives greater approach accuracy," *Amer. Aviation*. vol. 13, pp. 34–35; February 1, 1950.
(592) S. H. Dodington, "Crystal control at 1000 megacycles for aerial navigation," *Elec. Commun.*, vol. 26, pp. 272–278; December, 1949.
(593) "Dual-pattern omni-range system solves air traffic jams," *Tech. News*. vol. 21, p. 153; April, 1950.
(594) R. A. Hampshire and B. V. Thompson, "ILS-2 instrument landing equipment," *Elec. Commun.*, vol. 27, pp. 112–122; June, 1950.
(595) C. J. Hirsch, "Pulse-multiplex system for distance-measuring equipment (DME)," Proc. I.R.E., vol. 37, pp. 1236–1242; November, 1949.
(596) L. F. Jones, H. J. Schrader, and J. N. Marshall, "Pictorial display in aircraft navigation and landing," Proc. I.R.E., vol. 38, pp. 391–400; April, 1950.
(597) J. H. Dellinger, "The common system of air navigation and traffic control—the transition program," *Jour. Inst. Nav.*, vol. 2, pp. 103–109; March, 1950.

An interesting device applicable to the approach and landing zone is the so-called "Zero Reader."

(598) G. L. Christian, "Applications extended for zero reader," *Aviation Week*, vol. 52, pp. 21–24; June 12, 1950.

That the industry has turned its attention to long-range navigation is indicated in the following papers.

(599) W. D. Perreault, "Long range navigation target . . . world coverage with five-mile accuracy," *Amer. Aviation*, vol. 14, pp. 28–33; August 1, 1950.
(600) V. I. Weihe, "World wide coverage radio navigation for aviation and marine services using land based facilities in the I.T.U. (100 Kc-s) band," *Jour. Inst. Nav.*, vol. 2, pp. 200–201; September, 1950.
(601) A. R. Cottle, "The use of two Decca chains to obtain accurate fixes at long ranges," *Jour. Inst. Nav.*, vol. 3, pp. 34–38; January, 1950.

Some excellent papers on long-distance navigation aids were given at the joint meeting of the Institute of Navigation and the Radio Technical Commissions for Aeronautics and Marine Services.

(602) D. G. C. Luck, "Elementary factors and procedures in navigation—scientific aspects."
(603) W. Q. Crichlow, "The influence of radio propagation phenomena upon the selection of frequencies for radio navigation functions."
(604) H. Davis, "Azimuthal type electronic position determining systems."
(605) W. Palmer, "Hyperbolic types of electronic position determining systems."

These papers represent a serious study of the limitations of long-range-navigation devices. The problem, as defined by a committee, was to provide a system that would give worldwide coverage with an accuracy of within five miles. This stringent requirement caused an examination of the possibilities and limitations of radio devices and propagation phenomena involved. Regardless of the practical outcome of the analysis, the summary of the problem constitutes an important contribution to technical literature on this subject.

(606) Radio Technical Commission for Aeronautics, "Report of phase A of RTCA SC-50," Paper 84-49/EC-91; Sept. 13, 1949.

The Radio Technical Commission for Marine Services appointed a committee to consider medium-distance aids. These devices tend to overlap the short-distance aids of the aeronautical field as well as some of the lower-frequency devices that would not be admissible under the aeronautical classification of "short distance." Interest also continued in the field of direction finding.

(607) P. Bodez, "Aerien tournant pour radiogoniometre automatique," *Ann. Telecommun.*, tome 4, pp. 341–346; October, 1949.
(608) F. Horner, "Some experiments on the accuracy of bearings taken on an aural-null direction finder," *Proc. IEE* (London), vol. 97, pp. 359–361; September, 1950.
(609) B. C. Pressey and G. E. Ashwell, "Fixed H-Adcock direction finder for vhf," *Wireless Eng.*, vol. 27, pp. 54–58; February, 1950.

Piezoelectric Crystals

The following extensive bibliography, which attempts to be fairly complete for the period, indicates increasing activity in the field and great expansion in certain directions. The study of the properties of barium titanate is notable as providing a very large field in itself. An especial mark of progress in the year is the growing of synthetic quartz in sizes suitable for resonator use. The inclusion of a number of technical reports to the U. S. Army Signal Corps is suggestive of the extent of technical research in this field under their financial support, though the present bibliography makes no attempt to list even the majority of such reports. Their listing in the *Technical Information Pilot* has in most cases been taken as the criterion for inclusion.

(610) L. Bergmann, "Der Ultraschall und Seine Anwendung in Wissenschaft und Technik," (Ultrasonics and Its Application in Science and Technology), S. Hirzel Verlag, Zurich, 5th ed.; 1949.

(611) W. P. Mason, "Piezoelectric Crystals and Their Application to Ultrasonics," D. Van Nostrand Co., Inc., New York, N. Y.; 1950.
(612) K. S. Van Dyke and G. D. Gordon, "A Manual of Piezoelectric Data," 2nd ed. U. S. Army Signal Corps; 1950.
(613) E. Buehler and A. C. Walker, "Growing quartz crystals," *Sci. Mon.*, vol. 69, p. 148; 1949.
(614) W. G. Cady, "Crystals and electricity," *Sci. Amer.*, vol. 181, pp. 46–51; December, 1949.
(615) K. Hausser, "Seignette electrics," *Z. angew. Phys.*, vol. 1, pp. 289–294; January, 1949.
(616) A. R. von Hippel, "Dielectrics, made to order," ONR, Washington (NAVEXOS P-510); *Research Reviews*, pp. 1–6; August, 1950.
(617) F. A. Levi, "Effect of ultrasonics on crystal development," *Nature* (London), vol. 165, p. 264; February 18, 1950. Also, *Jour. Acous. Soc. Amer.*, vol. 22, p. 527; July, 1950.
(618) R. Taylor, R. Bechmann, and M. C. Lynch, "Crystals for electrical filters," *Research* (London), vol. 2, pp. 414–417; September, 1949.
(619) A. W. Ziegler, "Mechanical development of edt crystal units," *Bell Lab. Rec.*, vol. 27, pp. 245–250; July, 1949.
(620) A. B. Arons and R. H. Cole, "Design and use of piezoelectric gauges for measurement of large transient pressures," *Rev. Sci. Instr.*, vol. 21, pp. 31–38; January, 1950.
(621) A. E. Bakanowski and R. B. Lindsay, "A crystal pick-up for measuring ultrasonic wave velocity and dispersion in solid rods," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 14–16; January, 1950.
(622) E. Bergstrand, "A determination of the velocity of light," *Ark. Fys.*, vol. 2, pp. 119–150; 1950.
(623) J. Bugosh, E. Yeager, and F. Hovorka, "A high frequency barium titanate hydrophone," *Phys. Rev.*, vol. 76, p. 1890; December 15, 1949.
(624) F. Conrad, "On the monitoring of the rate of quartz clocks by means of time signals," *Frequenz*, vol. 3, pp. 270–273; September, 1949.
(625) H. W. Cooper, "A small crystal probe transducer for ultrasonic studies," *Jour. Acous. Soc. Amer.*, vol. 22, p. 86; January, 1950.
(626) S. H. Dodington, "Crystal control at 1,000 megacycles for aerial navigation," *Elec. Commun.*, vol. 26, pp. 272–278; December, 1949.
(627) L. Duqueroix, "Quartz clocks," *Ann. Franc. Chronom.*, vol. 3, pp. 145–156; 1949.
(628) W. A. Edson, "High frequency crystal controlled oscillator circuits," *Technical Information Pilot*, p. 1340; February 10, 1950.
(629) W. A. Edson, "High frequency crystal controlled oscillator circuits," *Technical Information Pilot*, p. 1769; July 12, 1950.
(630) L. Fein, "Ultrasonic radiation from curved quartz crystals," *Jour. Acous. Soc. Amer.*, vol. 21, pp. 511–516; September, 1949.
(631) J. A. Fitzpatrick and W. J. Thaler, "A barium titanate coaxial cable for the production of a short duration spark," *Phys. Rev.*, vol. 79, p. 231; July 1, 1950.
(632) A. Fromageot and M. A. LaLande, "Calculation of band pass filters using piezoelectric crystals in lattice structures," *Elec. Commun.*, vol. 26, pp. 305–318; December, 1949.
(633) I. Gottlieb and I. R. Mednick, "Crystal control for citizens band," *Electronics*, vol. 23, pp. 96–98; August, 1950.
(634) W. Güttner, "Crystal earpieces for portable hearing aids," *Z. angew. Phys.*, vol. 2, pp. 33–39; January, 1950.
(635) V. E. Hollinsworth, "On the use of crystal controlled synchronous motors for the accurate measurement of time," *Canad. Jour. Res.* vol. 27, pp. 470–478; December, 1949.
(636) M. Indjoudjian, "A high-stability quartz oscillator," *Onde élect.*, vol. 29, pp. 76–78; February, 1950.
(637) L. F. Koerner, "A variable frequency oscillator stabilized to high precision," *Bell Lab. Rec.*, vol. 28, pp. 66–71; February, 1950.
(638) F. J. M. Laver, "Crystal resonators as frequency substandards," *Proc. IEE* (London), vol. 97, part III, pp. 93–99; March, 1950.
(639) F. M. Leslie, "The relative output from magnetostriction ultrasonic generators," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 418–422; July, 1950.
(640) G. H. Lister, "Overtone crystal oscillator design," *Electronics*, vol. 23, pp. 88–93; November, 1950.
(641) W. P. Mason, "Piezoelectric crystal apparatus," U. S. Patent 2,486,187.
(642) D. W. R. McKinley, "Measurement of the velocity of light using quartz crystals," *Jour. Roy. Astr. Soc. Canada*, vol. 44, pp. 89–103; May–June, 1950.
(643) H. J. McSkimin, "A method for determining the propagation constants of plastics at ultrasonic frequencies," Presented, Acous. Soc. of Amer. Meeting, Boston, Mass.; November 9–11, 1950.
(644) H. J. McSkimin, "Ultrasonic measurement techniques applicable to small solid specimens," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 413–418; July, 1950.
(645) Monitor Products Co., "Services, facilities and materials, leading to the fabrication of quartz crystal units using AT-cut 0.25" plates," *Technical Information Pilot*, p. 1917; September 8, 1950.
(646) I. Ördoğan, "Determination of the natural frequency of vibration of a piezoelectric quartz prism using the circuit and acoustic interferometer of Pierce," *Istanbul University Fen. Fak. Mec.*, Ser. A, vol. 12, pp. 53–79; April, 1947.
(647) W. G. Perdok and H. van Suchtelen, "An arrangement for indicating piezoelectricity of crystals," *Philips Tech. Rev.*, vol. 11, pp. 151–155; November, 1949.
(648) W. J. Price and H. B. Huntington, "Acoustical properties of anisotropic materials," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 32–37; January, 1950.
(649) E. A. Roberts and others, "Investigation of use of crystals as meteorologic elements for measurements of temperature, pressure and humidity," *Technical Information Pilot*, p. 1646; June 9, 1950.
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Radio Transmitters

Television

In the television broadcasting field applications continue to be filed, with over 360 pending near the close of

1950. The number of licensed stations increased from 98 to 107 at the end of the year.

The progress in the development of television transmitters has been chiefly in the design of ultra-high-frequency transmitters although detailed improvements in very-high-frequency transmitters were also reported. A number of U. S. system transmitters are being scheduled for South American installations.

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Interest has been shown in the establishment of international television standards. The International Consulting Committee on Radio study group recommended television standards for the participating European countries similar to United States standards except for a nominal field frequency of 50 instead of 60 and 625 lines instead of 525. For consistency between horizontal and vertical resolution, a video bandwidth of 5 instead of 4 mc was adopted with a channel width of 7 mc instead of 6 mc. The sound transmitter swing was specified at ± 50 kc, compared to 25 kc for 100-per cent modulation in the United States and with a 50-microsecond pre-emphasis instead of 75 microseconds.

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Amplitude-Modulation Broadcasting

Licensed amplitude-modulation stations increased from 2,056 to 2,178 at the end of the third quarter, at which time there were still before the Commission 256 applications for construction permits. There continued to be an increase in the power of the present stations (64 have applied for additional power) and there were technical improvements in transmitter and antenna facilities.

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Frequency-Modulation Broadcasting

Less activity was noted in frequency-modulation broadcasting than in previous years. The commercial licenses granted increased from 475 to 513, and the special temporary authorizations decreased.

(800) R. Satas, "A method of linearizing the modulation characteristics for comparatively large frequency deviation," *Arch. elekt. Übertragung*, vol. 4, pp. 255–258; July, 1950.
(801) F. R. Dennis, E. P. Felch, "Reactance tube modulation of phase shift oscillators," *Bell Sys. Tech. Jour.*, vol. 28, pp. 601–607; October, 1949.
(802) P. M. Milner, "Wide range frequency-modulation oscillator," *Electronics*, vol. 23, pp. 118, 144–148; May, 1950.
(803) L. Rohde and others, "A frequency-modulation 250-watt transmitter," *Electrotech. Z.*, vol. 70, pp. 338–343; September, 1949.
(804) H. Chang and V. C. Rideout, "Reactance tube oscillator," Proc. I.R.E., vol. 37, pp. 1330–1331; November, 1949.
(805) O. E. DeLange, "Variable phase-shift frequency-modulated oscillator," Proc. I.R.E., vol. 37, pp. 1328–1331; November, 1949.
(806) "Vhf equipment for sound broadcasting," *Electronic Eng.* (London), vol. 22, pp. 309; August, 1950.
(807) T. E. McConnell, "10-watt FM package," *FM and Telev.*, pp. 12–13, 33; September, 1950.

Citizen Band

The use of the citizen band was confined principally to development of equipment and experimentation.

(808) I. Gottlieb and I. Mednick, "Crystal control for citizen band," *Electronics*, vol. 23, pp. 96–98; August, 1950.
(809) L. M. Conner, "Citizen's band regulations," *Electronics*, vol. 23, pp. 100–101; April, 1950.
(810) A. R. Koch, "Citizen band transmitter," *Electronics*, vol. 22, pp. 118, 132; December, 1949.

International Broadcasting and Communication

There was considerable expansion in the international broadcast and communication fields. Despite the trend towards higher frequencies there are still important uses for low-frequency transmitters.

(811) H. P. Miller, Jr., "Low-frequency radiotelegraph transmitters for arctic use," *Elec. Commun.*, vol. 27, pp. 11–20; March, 1950.
(812) I. F. Deise and L. W. Gregory, "Iron-core interstage and output 3-kw mf transmitter design," *Communications*, vol. 29, pp. 12–14, 35, October, 1949; and pp. 12–13, 30–31, December, 1949.
(813) H. Grumel, "10-kw SFR transmitter for shortwave," *Ann. Radioélect.*, vol. 4, pp. 344–357; October, 1949.
(814) H. H. Merriman and R. W. White, "The application of frequency modulation to vhf multi-channel radiotelegraphy," *Proc. IRE* (London), vol. 97, pp. 123–124; March, 1950.
(815) E. A. Brittingham and J. Moore, "Multiplex boadcasting," *Proc. IRE* (Australia), vol. 11, pp. 55–62; March, 1950.
(816) J. L. Hollis, "Continuously-tuned 50-kw transmitter," *Electronics*, vol. 23, pp. 70–73; March, 1950.
(817) G. Pembose, "2-kw and 20-kw single sideband transmitter," *Ann. Radioélect.*, vol. 4, pp. 358, 371; October, 1949.

Microwave Communication

Many pipe lines, utilities, telephone and telegraph companies, and government agencies have found value in microwaves for communication and control services. Most of these systems employ multiplex channels.

(818) L. J. Libois, "Pulse multiplex equipment for 24-channel telephone," *Onde elect.*, vol. 29, pp. 23–29; January, 1950.
(819) J. J. E. Aspin, "A new vhf multi-circuit radio telephone system," *GEC Telecommun.*, vol. 5, pp. 33–40; 1950.
(820) M. M. Levy, "Technique for the design of pulse time multichannel radio systems," *Proc. IRE* (London), vol. 9, pp. 386–411; November, 1949.
(821) E. Dietrich and P. Barkow, "Decemeter wave lengths used in German telephone operation," *Electrotech. Z.*, vol. 3, pp. 145–154; May, 1950.
(822) D. Samuelson, "Mid-valley operation 1,000 mile microwave relay system," *Oil and Gas Jour.*, pp. 302–304, 307–308; September 21, 1950.
(823) M. G. Staton, "Simple microwave relay communication system," *Tele-Tech*, vol. 9, pp. 40–42, 48; April, 1950.
(824) J. Racker, "Microwave transmitters," *Radio and Telev.*, vol. 14, pp. 13–16; June, 1950.
(825) J. D. Munton, "First to utilize multi-channel microwave radio relay system for pipe line communication," *Telegr. Teleph. Age*, pp. 7–9, 19–20; March, 1950.
(826) M. H. Wood and F. P. Gunter, "Microwave communication equipment for power system applications," *Communications*, vol. 29, pp. 14–16; December, 1949.
(827) F. P. Gunter, "Uhf industrial communications system," *Electronics*, pp. 90–93; September, 1950.
(828) E. J. Rudisuhle and P. B. Patton, "Vhf links at Manila airport," *Electronics*, vol. 23, pp. 80–85; June, 1950.
(829) J. D. Munton, "Multi-channel microwave radio relay system for pipe line communication," *Oil and Gas Jour.*, pp. 88–89 and 110–114; February, 1950.
(830) D. E. Noble, "Microwave radio relay as applicable to railroad operation," *Telegr. Teleph. Age*, pp. 7–9, 33–34; November, 1949.

Television relaying was greatly expanded in the United States with the commercial operation of television stations both in the eastern and western part of the country. Television relaying was also extended in England. It is estimated that by the end of the year there will be more than 15,000 channel miles of television channels interconnecting more than 45 cities. More than 50 per cent of the channel miles will use microwaves and the remainder will use coaxial cable.

(831) H. Cook, "Microwave television relay for navy training programs," *Western Union Tech. Rev.*, vol. 4, pp. 87–92; April, 1950.
(832) J. Z. Millar and Sullinger, "A microwave system for television relaying," Proc. I.R.E., vol. 38, pp. 125–129; February, 1950.
(833) A. H. Munford and C. F. Booth, "Television radio-relay links," *P. O. Elec. Eng. Jour.*, vol. 43, pp. 23–25; April, 1950.
(834) V. Learned, "The klystron mixer applied to television relaying," Proc. I.R.E., vol. 38, pp. 1033–1035; September, 1950.
(835) D. C. Espley and R. J. Clayton, "The London-Burmingham television radio relay link," *GEC Jour.*, vol. 17, pp. 3–10; January, 1950.

Current developments relating to the TD-2 Radio Relay System and a number of the equipment components were reported.

(836) C. E. Clutts, "The TD-2 radio relay system," *Bell Lab. Rec.*, vol. 28, pp. 442–447; October, 1950.
(837) R. D. Campbell and Earl Schooley, "Spanning the continent by radio relay," *Bell Tel. Mag.*, vol. 29, pp. 215–227; Winter, 1950–1951.
(838) M. E. Hines, "A wide range microwave sweeping oscillator," *Bell Sys. Tech. Jour.*, vol. 29, pp. 553–559; October, 1950.
(839) A. E. Bowen and W. W. Munford, "A new microwave triode: its performance as a modulator and as an amplifier," *Bell Sys. Tech. Jour.*, vol. 29, pp. 531–552; October, 1950.
(840) J. A. Morton and R. M. Ryder, "Design factors of the Bell Telephone Laboratories 1553 triode," *Bell Sys. Tech. Jour.*, vol 29, pp. 496–530; October, 1950.

Receivers

Television Receivers

Front-end design was improved to reduce oscillator radiation greatly and to improve signal-to-noise ratio. A 40-mc intermediate frequency received further attention due to interest in ultra-high-frequencies and because of reduced image and interference problems at very-high frequencies. Design is toward improving reception in fringe areas.

(841) "Meeting of R6 committee on FM receivers and R15 committee on radio interference," Receiver Section, RTMA Engineering Department; September 12, 1950.
(842) I. J. Melman, "Noise generators and measuring technics," *Tele-Tech*, vol. 9, pp. 28–29, 58, 60, May, 1950; pp. 26–28, June 1950; and pp. 36–38, 61–62, 64, July, 1950.
(843) A. Newton, "Broad-band television tuners," *Electronics*, vol. 23, pp. 102–106; May, 1950.
(844) K. Schlesinger, "Built-in antenna for television receivers," *Electronics*, vol. 23, pp. 72–77; January, 1950.
(845) I. Kamen, "Trends in TV receiver antenna design," *TV Eng.*, vol. 1, pp. 8–11; January, 1950.
(846) T. Murakami, "An experimental ultra-high-frequency television tuner," *RCA Rev.*, vol. 11, pp. 68–79; March, 1950.
(847) D. W. Pugsley, "Production experience with a 40-mc. if receiver," *Electronics*, vol. 23, pp. 98–100; November, 1950.

Further improvement has been made in noise immunity of synchronizing circuits. Practically all receivers on the market use surge second-anode voltage supplies. Part of an increase in efficiency of sweep circuits is due to the use of ferromagnetic spinels (ferrites) in horizontal-output transformers and in deflection yokes.

(848) M. S. Kiver, "Modern television receivers," *Radio and Telev.*, vol. 43, pp. 50–52, 110; March, 1950.
(849) M. J. Obert and W. A. Needs, "Ferrite-core yoke for wide deflection angle kinescopes," *Tele-Tech*, vol. 9, pp. 42–44, 66–70; October, 1950.
(850) C. E. Torsch, "A universal ceramic iron core sweep transformer," *Tele-Tech*, vol. 9, pp. 34–35; January, 1950.
(851) O. H. Schade, "Characteristics of high-efficiency deflection and high-voltage supply systems for kinescopes," *RCA Rev.*, vol. 11, pp. 5–37; March, 1950.
(852) W. Heiser, "Sync separator circuit analysis," *Electronics*, vol. 23, pp. 108–111; July, 1950.

The trend toward larger kinescopes continues with at least two manufacturers supplying tubes two feet or more in diameter. Rectangular kinescopes are widely used. All-permanent-magnet focusing, both with and without centering plates, became popular. Glare-reducing devices, such as grey glass, frosted glass, and cylindrical face contours in kinescopes, are widely used.

(853) A. E. Martin and R. M. Bowie, "Picture-tube contrast improvement," *Electronics*, vol. 23, pp. 110–112; August, 1950.
(854) K. James and R. T. Capodanno, "A study of permanent magnet focussing devices for television picture tubes," RTMA-IRE Fall Meeting.

Work on several systems of color television has continued, especially on high definition systems and on improved methods of color-picture display.

(855) D. Phillips, "The direct-view single tube color receiving systems," *TV Eng.*, vol. 1, pp. 12–13; May, 1950.
(856) F. Shunaman, "Television in color," *Radio and Electronics*, vol. 21, pp. 28–30; January, 1950.
(857) R. B. Dome, "Frequency interlace color television," *Electronics*, vol. 23, pp. 70–75; September, 1950.
(858) A. V. Loughren, "An analysis of color television," RTMA-IRE, Fall Meeting.

Radio Receivers

Inexpensive AM receivers are again popular in alarm-clock models and portables.

The use of ferrospinel rods instead of loop antennas on small receivers has been proposed. An increasing number of intermediate-frequency transformers are housed in 3/4-inch square cans.

(859) R. L. Harvey, I. J. Hegyi, and Her. Leverenz, "Ferromagnetic spinels for radio frequencies," *RCA Rev.*, vol. 11, pp. 321–363; September, 1950.

Frequency-modulation reception is still provided by most of the higher-price consoles. However, the additional cost of providing a separate FM unit in intercarrier television receivers is reducing the number of television-frequency modulation combinations. The problem of interference with other services caused by oscillator radiation from FM receivers has been given increased attention by the industry. Signal-to-noise ratio has been improved.

(860) "Meeting of R6 committee on FM receivers and R15 committee on radio interference," Receiver Section, RTMA Engineering Department; September 12, 1950.

Standards on Symbols

The following standards on symbols were published during 1950:

(861) "Designations for Electrical, Electronic, and Mechanical Parts and Their Symbols, 1949," PROC. I.R.E., vol. 38, pp. 118–124, February, 1950.

(862) "Graphical Symbols for Heat-Power Apparatus, Z32.2.6—1950," American Standards Association, New York, N. Y.; 1950.

(863) "Graphical Symbols for Railroad Use, "Z32.2.5—1950," American Standards Association, New York, N. Y.; 1950.

(864) "Letter Symbols for Aeronautical Sciences, Z10.7—1950," American Standards Association, New York, N. Y.;—1950.

Television System

General.

Television broadcasting continued to expand at a phenomenal rate during 1950 although hampered by the continued nonissuance of constructional permits for new stations by the Federal Communication Commission since the fall of 1949. An important growth factor was the extension of video cables and microwave relays, which more than doubled the circuit mileage, thus permitting wider distribution of programs material. One of the outstanding events of the year was the coverage of the United Nations Security Council meetings.

The use of horizontal (dot) interlace for color television gave impetus to its consideration for monochrome television as a means for improving resolution without increasing frequency bandwidth.

(865) P. M. G. Toulon, "Discontinuous interlaced scanning system," U.S. Patent No. 2,479,880; August 23, 1949.

(866) W. P. Boothroyd, "Dot systems of color television," part 1, *Electronics*, vol. 22, pp. 88–92; December, 1949.

(867) F. Loomis, "High definition monochrome TV," *Tele-Tech*, vol. 9, pp. 52, 71; December, 1950.

Color Television.

Many important developments occurred in the field of color television and included: first demonstration of a tricolor kinescope, transmission over a 2.7-mc cable of a compatible dot-interlace signal, and the proposal of two additional compatible color systems—the "frequency-interlace" and "dash-sequential" systems. The Federal Communications Commission hearing, which started in September 1949, continued through the first half of 1950 and greatly accelerated the development of color systems.

The first report by the Commission in September favored a field-sequential system of color and requested receiver manufacturers to incorporate circuits for "bracket standards" in all future receivers so that final standardization could be deferred for additional study without further aggravation of the problem of incompatibility. When a majority of manufacturers responded that they could not comply with this request, the Commission adopted the field-sequential color system, introducing different scanning standards for monochrome and color television.

(868) F. Loomis, "Interim report on color-TV hearings," *Tele-Tech*, vol. 9, pp. 36, 50; January, 1950.

(869) W. P. Boothroyd, "Dot systems of color television," *Electronics*, part 1, vol. 22, pp. 88–92, December, 1949; part 2, vol. 23, pp. 96–99, January, 1950.

(870) F. Loomis, "Color investigation reopened by new demonstrations," *Tele-Tech*, vol. 9, pp. 38–39; March, 1950.

(871) "RCA color kinescope demonstrated," *Tele-Tech*, vol. 9, pp. 20–21, 61–63; May, 1950.

(872) "Last rounds of color fight," *Tele-Tech*, vol. 9, pp. 19–20; June, 1950.

(873) "Electronic colour television," *Electronic Eng.* (London), vol. 22, p. 226; June, 1950.

(874) "RCA tri-color picture tubes," *FM and Telev.*, vol. 10, pp. 15, 36, 38; June, 1950

(875) C. S. Szegho, "Experimental tri-color cathode ray tube," *Tele-Tech*, vol. 9, pp. 34–35; July, 1950.

(876) "Condon committee urges single color-TV standard," *Tele-Tech*, vol. 9, p. 22; August, 1950.

(877) W. R. Fraser and G. F. Badgley, "Video recording in color," *Tele-Tech*, vol. 9, pp. 38–39, 57–58; August, 1950.

(878) "First report on color television issues," FCC Public Notice No. 50-1064; September 1, 1950.

(879) R. B. Dome, "Frequency-interlace color television," *Electronics*, vol. 23, pp. 70–75; September, 1950.

(880) "The FCC color-TV decision—calamity or opportunity?" *Tele-Tech*, vol. 9, pp. 26–27, 56–57; October, 1950.

(881) "Second report on color-television issues," FCC Public Notice No. 50-1224; October 10, 1950.

(882) F. H. McIntosh and A. F. Ingils, "Color television," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 55, pp. 343–366; October, 1950.

(883) Senate Advisory Committee on Color Television, "The present status of color television," PROC. I.R.E., vol. 38, pp. 980–1002; September, 1950.

Industrial Television.

Television for industrial applications continued to increase, among which were observations of high-speed tools, safety conditions at dangerous work sites, and work flow at expected bottlenecks, windtunnel operations, and in hospitals. Industrial television has already proven to be successful in such places as power plants, coal mines, steel mills, chemical plants, nuclear energy plants, and in manufacturing.

(884) R. W. Sanders, "Industrial television system," *Elec. Commun.*, vol. 27, pp. 101–111; June, 1950.

(885) R. C. Webb and J. M. Morgan, "Simplified television for industry," *Electronics*, vol. 23, pp. 70–73; June, 1950.

(886) V. K. Zworykin, "Industrial television and the vidicon," *Elec. Eng.*, vol. 69, pp. 624–627; July, 1950.

(887) R. W. Sanders, "Closed-circuit industrial television," *Electronics*, vol. 23, pp. 88–92; July, 1950.

(888) V. K. Zworykin, "New television camera tubes and some applications outside the broadcasting world," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 55, pp. 227–242; September, 1950.

(889) F. A. Friswold, "Television as a research tool," *Electronics*, vol. 23, pp. 122, 162, 166, 170, 174; November, 1950.

Theater Television.

Developments continued on both the instantaneous systems (direct kinescope projection) and the intermediate-film system of theater television, and considerable progress in increasing the brightness range and tonal quality of the reproduced picture was reported. Several theaters equipped with television large-screen projectors operated for paying audiences at special shows.

(890) "Large screen television demonstration to the CCIR," *Electronic Eng.* (London), vol. 22, p. 214; June, 1950.
(891) E. Labin, "The Eidophor method for theater TV," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 54, pp. 393–406; April, 1950.
(892) "Theater television projection on full-size screens," *Electronics*, vol. 23, pp. 198, 200–201; September, 1950.
(893) R. L. Garman and R. W. Lee, "Comprehensive proposal for a closed loop theater TV system," Presented, Soc. Mot. Pic. Telev. Eng. 68th Convention.
(894) R. V. Little, Jr., "RCA PT-100 theater TV equipment," Presented, Soc. Mot. Pic. Telev. Eng. 68th Convention.
(895) E. Stanko and C. Y. Keen, "Installation of theater TV equipment," Presented, Soc. Mot. Pic. Telev. Eng. 68th Convention.
(896) R. Hodgson and J. Hammer, "The high temperature film processing—its effect on quality," Presented, Soc. Mot. Pic. Telev. Eng. 68th Convention.

Subscriber Television.

The Federal Communications Commission approved the Zenith Radio Corporation's request for a ninety-day "Phonevision" test, as well as the test of "Subscriber-vision" by WOR-TV and the Skiatron Corporation.

(897) E. Roschke, "Phonevision: How it works," Part I, *FM-TV.*, vol. 10, pp. 13–14, 48–50; June, 1950. Part II. Hubbard, vol. 10, pp. 26–28, November, 1950.
(898) "Circuits of Phonevision system," *Electronics*, vol. 23, pp. 156–170; June, 1950.
(899) "Box office TV—Skiatron proposal filed, rivals Phonevision," *Broadcasting*, vol. 38, p. 52; June 19, 1950.

Video Techniques

Two standards on video techniques were published during the year.

(900) "Standards on Television: Methods of Measurement of Television Signal Levels, Resolution, and Timing of Video Switching Systems, 1950," Proc. I.R.E., vol. 38, pp. 551–561; May, 1950.
(901) "Standards on Television: Methods of Measurement of Time of Rise, Pulse Width, and Pulse Timing of Video Pulses in Television, 1950," Proc. I.R.E., vol. 38, pp. 1258–1263; November, 1950.

A special film was made available incorporating a number of especially prepared test patterns for checking resolution, transfer characteristic, dc insertion, pickup-tube storage characteristics as well as general quality and performance of television film equipment.

(902) "Television test film," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 54, pp. 209–218; February, 1950.

The technical literature in the television field reflected the growth of television broadcasting and constant pressure for improving over-all systems performance. Several factors influencing television picture quality were investigated and methods for evaluating picture degradation on a subjective basis were evolved. Of particular interest is a comparison method where pictures obtained by direct projection are compared to the same pictures reproduced by means of a television system. The effects of noise and tone rendition have also been treated from the standpoint of their relation to over-all picture quality.

(903) P. Mertz, A. D. Fowler, and H. N. Christopher, "Quality rating of television images," Proc. I.R.E., vol. 38, pp. 1269–1283; November, 1950.
(904) B. M. Oliver, "Tone rendition in television," Proc. I.R.E, vol. 38, pp. 1288–1300; November, 1950.
(905) P. Mertz, "Perception of television random noise," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 54, pp. 8–34; January, 1950.

Considerable emphasis was also placed on development of more efficient arrangements of studio and control-room equipment and in methods of co-ordinating programs originating at both local and remote points. Consideration was also given to methods for improving the production of television programs by utilizing special switching techniques and back-projection equipment.

(906) N. F. Smith, "New ideas in television studio design," *Electronics*, vol. 23, pp. 66–70; October, 1950.
(907) K. E. Mullinger and A. H. Jones, "Multiplexing film cameras to minimize tv program failures," *Tele-Tech*, vol. 8, pp. 34–35; December, 1949.
(908) J. H. Battison, "Unique engineering design featured in WOR-TV studios," *Tele-Tech*, vol. 8, pp. 20–22; December, 1949.
(909) W. E. Wells and J. M. Weaver, "Mixing local and remote TV signals," *Tele-Tech*, vol. 2, pp. 16–18; January, 1950.
(910) R. A. Lynn and E. P. Bertero, "Process screen projection," *Tele-Tech*, vol. 9, pp. 39–41; July, 1950.
(911) R. Bretz, "Television cutting techniques," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 54, pp. 247–267; March, 1950.

Several new types of equipment units, appeared which are primarily auxiliary devices to improve performance of existing equipment or to provide additional flexibility and program possibilities not at present available with standard equipment items. Especially noteworthy is new equipment for producing special effects and wipes in conjunction with switching between two video signals.

(912) W. I. McCord, "Television engineering," *Communications*, vol. 29, pp. 10–11; December, 1949.
(913) C. J. Auditore, "Versatile phase-shift control for studio sync generator," *Communications*, vol. 1, pp. 8–10; August, 1950.
(914) G. L. Fredendall and R. C. Kennedy, "Linear phase shift video filters," *RCA Rev.*, vol. 11, pp. 418–430; September, 1950.
(915) E. D. Goodale and C. L. Townsend, "The Orthogam amplifier," *RCA Rev.*, vol. 11, pp. 399–410; September, 1950.
(916) E. D. Goodale, "The Orthogam amplifier," *Communications*, vol. 1, pp. 12–13; September, 1950.
(917) C. R. Munro, "Flying-spot scanners," *Communications*, vol. 1, pp. 16–18; September, 1950.
(918) E. M. Gore, "Video special-effects system," *Communications*, vol. 1, pp. 14–16; October, 1950.
(919) G. Zaharis, "Television synchronizing generator," *Electronics*, vol. 23, pp. 92–95; May, 1950.
(920) R. Clurman, "Inexpensive picture generator," *Electronics*, vol. 23, pp. 102–106; August, 1950.
(921) J. T. Wilner, "Design for horizontal wipe amplifier," *Tele-Tech*, vol. 9, pp. 28–31; July, 1950.
(922) C. J. Auditore, "A simultaneous video and audio master switcher," *Tele-Tech*, vol. 9, pp. 28–30; October, 1950.
(923) C. J. Auditore, "Modified TV field switcher," *Tele-Tech*, vol. 9, pp. 43–44; November, 1950.
(924) R. Bretz, "Standard television switching equipment," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 54, pp. 407–434; April, 1950.
(925) A. H. Turner, "Artificial lines for video distribution and delay," *RCA Rev.*, vol. 10, pp. 477–489; December, 1949.
(926) B. M. Oliver, "A rooter for video signals," Proc. I.R.E., vol. 38, pp. 1301–1305; November, 1950.
(927) R. A. Erickson and H. Sommer, "The compensation of delay distortion in video delay lines," Proc. I.R.E., vol. 38, pp. 1036–1040; September, 1950.

Several developments including an electronic shutter to replace the usual mechanical shutter in film recording and a method for eliminating line structure provided substantial advances.

(928) F. Gillette, G. King, and R. White, "Video program recording," *Electronics*, vol. 23, pp. 90–95; October, 1950.
(929) W. D. Kemp, "Video recordings improved by the use of continuously moving film," *Tele-Tech*, vol. 9, pp. 32–35; November, 1950.
(930) C. L. Townsend, "Specifications for motion picture films intended for television transmission," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 55, pp. 147–157; August, 1950.

Considerable attention was also devoted to the studio lighting problem and several investigators reported on specific techniques for obtaining various effects in television pictures by means of proper manipulation of lighting fixtures.

(931) A. H. Brolly, "Television studio lighting," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 53, pp. 611–624; December, 1949.
(932) R. Blount, "Lighting distortion in television," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 53, pp. 625–634; December, 1949.
(933) R. S. O'Brien, "CBS television staging and lighting practices," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 55, pp. 243–264; September, 1950.
(934) H. M. Gurin, "Lighting methods for television studios," *Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 54; December, 1950.

Improvements in the picture quality of monitoring units were also made possible by improved methods for obtaining electrical focus on picture-reproducing tubes. This was done primarily by changes in the deflection windings.

(935) C. V. Bocciarelli, "Improved deflection and focus," *Electronics*, vol. 23, pp. 94–95; August, 1950.
(936) B. B. Bycer, "Design considerations for scanning yokes," *Tele-Tech*, vol. 9, pp. 32–35; August, 1950.
(937) O. H. Schade, "Characteristics of high-efficiency deflection and high-voltage supply systems for kinescopes," *RCA Rev.*, vol. 11, pp. 5–37; March, 1950.
(938) R. T. Thalner, "An asymmetrical horizontal scanning system," *Tele-Tech*, vol. 9, pp. 34–36; February, 1950.

Improvements were made in the evaluation and testing of elements of a television system. There were particular contributions in the field of aligning video amplifiers, checking deflection linearity, and evaluating random noise.

(939) R. H. Baer, "Cathode follower video response," *Electronics*, vol. 23, pp. 114; October, 1950.
(940) E. M. Noll, "Use of dc level controls," *FM and Telev.*, vol. 10, pp. 20–23; February, 1950.
(941) D. Martin, "Built-in grating generator," *Tele-Tech*, vol. 9, p. 25; April, 1950.
(942) F. E. Cone and N. P. Kellaway, "Testing and aligning video amplifiers," *Tele-Tech*, vol. 9, pp. 24–25; November, 1950.

Development of smaller and simpler video pickup tubes promoted the production of simplified television equipment designed for industrial or other closed-system services.

(943) R. C. Webb and J. M. Morgan, "Simplified television for industry," *Electronics*, vol. 23, pp. 70–73; June, 1950.
(944) R. W. Sanders, "Closed-circuit industrial tv," *Electronics*, vol. 7, pp. 88–92; July, 1950.

Wave Propagation

Tropospheric Propagation

Radio Scattering. Measurements on high-power vhf broadcast transmissions in recent years have made it increasingly apparent that field strengths well below the horizon are in excess of the values calculated for a smooth earth and a standard refracting atmosphere by many tens of decibels. Because these high nonoptical fields are sometimes observed under atmospheric conditions such that superrefraction is not present, Booker and Gordon have introduced into tropospheric radio propagation theory the hypothesis that scattering of radio waves takes place from inhomogeneities connected with turbulence in the troposphere. The turbulent atmosphere may be pictured as containing "blobs" of air in which the index of refraction differs by a few millionths from the average of the surrounding air because of temperature and humidity differences. The scattering of radio waves by such "blobs" above the horizon of both transmitting and receiving antennas may cause high nonoptical fields, heretofore attributed entirely to surface ducts and elevated refracting layers.

An alternative suggestion was made by Bullington that the large excess of measured fields of high-power transmitters from the smooth-earth values over non-optical paths overland may be an effect of ground roughness. He argues that the exponential decay of field strength with distance beyond the horizon predicted by smooth-earth theory should be expected to occur in practice only if the precise phase cancellation takes place of all the wavelets scattered from the hypothetically smooth surface of the earth. Over actual land profiles at vhf and microwave frequencies, it may be that actual fields are, in practice, more reliably estimated by replacing the profile by a single equivalent knife edge, rather than with the ideally smooth earth of conventional theory. The hypotheses of scattering from omnipresent atmospheric turbulence, from ground roughnesses, or from both seems certain to play an important role during the next few years in interpretation of long-distance tropospheric propagation measurements. The interesting possibility is opened up by these ideas that beyond-the-horizon signals from high-power transmitters may be more practically useful than has been believed heretofore, when rather unreliable superrefracting conditions were thought to be the only cause of high nonoptical fields. During the year, microwave refractometers were described for the accurate direct measurement of fluctuations of the index of refraction of the atmosphere.

(945) H. G. Booker and W. E. Gordon, "A theory of radio scattering in the troposphere," Proc. I.R.E., vol. 38, pp. 401–412; April, 1950.
(946) Kenneth Bullington, "Propagation of uhf and shf waves beyond the horizon," Proc. I.R.E., vol. 38, pp. 1221–1222; October, 1950.
(947) G. Birnbaum, "A recording microwave refractometer," *Rev. Sci. Instr.*, vol. 21, pp. 169–178; February, 1950.
(948) C. M. Crain, "Apparatus for recording fluctuations in the refractive index of the atmosphere at 3.2 centimeters wavelength," *Rev. Sci. Instr.*, vol. 21, pp. 456–457; May, 1950.

Mathematical Theory. The use of an effective earth's radius different from the geometrical radius to allow for the effects of normal refraction in field-strength calculation has hitherto rested on deductions about ray curvature appropriate to the region above the horizon. The validity of the use of the concept for the field diffracted below the horizon, where wave concepts must be employed, has been investigated by Miller. During the year, an alternative treatment of this problem by

Fock in Russia became available in translation. Bremmer published an illuminating interpretation of the physical meaning of the W. K. B. approximation to the wave equation for oblique incidence of radio waves in a stratified medium. Kahan and Eckart presented a convenient summary of their papers of recent years on their solution of the famous problem of Sommerfeld's surface wave. Bouwkamp interprets differentialy some of the recent work by these authors, and Goubau regards the matter as still unsettled after forty years of discussion. Goubau made application and extension of Sommerfeld's ideas to the efficient propagation of cylindrical surface waves along conducting wires threaded or coated with a dielectric layer. Millington published a detailed mathematical treatment, complete with computed curves, of the reflection coefficient of a linearly graded layer, for a plane wave at any angle of incidence. The dielectric constant is assumed to vary linearly with position in the layer.

(949) W. Miller, "Effective earth's radius for radio wave propagation beyond the horizon," *Jour. Appl. Phys.*, vol. 22, pp. 55–62; December, 1950.
(950) V. A. Fock, "Propagation of the ground wave around the earth with due account for diffraction and refraction," *Compt. Rend. Acadl. Sci.* (*USSR*), Physics Series, vol. 12, pp. 82–97; 1948 (in Russian). (English translation available at Central Radio Propagation Laboratory, National Bureau of Standards, Washington, D. C.)
(951) H. Bremmer, "Propagation of electromagnetic waves through a stratified medium and its WKB approximation for oblique incidence," *Physica, 's Grav.*, vol. 15, pp. 593–608; August, 1949.
(952) G. Eckart, "The radiation from a magnetic dipole in a spherically symmetrical stratified medium," *Ann. Telecommun.*, vol. 5, pp. 173–178; May, 1950.
(953) T. Kahan and G. Eckart, "On the existence of a surface wave in dipole radiation over a plane earth," Proc. I.R.E., vol. 38, pp. 807–812; July, 1950.
(954) C. J. Bouwkamp, "On Sommerfeld's surface wave," *Phys. Rev.*, vol. 80, p. 294; Oct. 15, 1950.
(955) G. Goubau, "Surface waves and their application to transmission lines," *Jour. Appl. Phys.*, vol. 21, pp. 1119–1128; November, 1950.
(956) G. Millington, "The reflection coefficient of a linearly graded layer," *Marconi Rev.*, vol. 12, pp. 140–151; October–December, 1949.

Propagation Experiments. Milnes and Unwin published the first results of a very estensive radio meteorological investigation carried out in New Zealand. By airplane flights, simultaneous measurements were made of the field strength, temperature, and humidity profiles 200 kilometers out to sea from a coast from which warm dry air was blowing over a cooler sea to form a surface duct. On a variety of frequencies from 100 to 10,000 mc, the general predictions of duct theory seemed to be borne out. An even wider frequency range, 25 to 24,000 mc, was covered in the overland measurements reported from the U. S. Navy Electronics Laboratory over a 46-mile path of comparatively smooth Arizona desert. Among the many conclusions of this extensive experimental effort were: (a) the importance of surface ducts formed by nocturnal cooling of the land was demonstrated on the propagation of the higher frequencies, especially between low antennas beyond the horizon; (b) microwave fields on nonoptical paths, even in the daytime when the refractive index profile is standard, do not drop to the calculated smooth-earth standard-atmosphere value, and apparently may be plausibly attributed to scattering from inhomogeneous air parcels; (c) even on relatively smooth desert terrain, local surface irregularities can produce striking effects on the field-strength profiles at microwave frequencies. Statistics of a year's observations on four microwave frequencies propagated over a 42-mile optical overland path have been published by Millar and Byam, primarily from the point of view of estimating the continuity of service of a typical microwave relay link.

Two papers were published concerning Macfarlane's suggestion that measured curves of field strength versus height can be used to deduce the average index of refraction profile over paths where a single propagation mode is dominant, without the necessity of meteorological measurements. Green, using Navy Electronics Laboratory data, came to the conclusion that measured radio data in practice could not be accurate enough to yield reliable index-of-refraction profiles. Straiton and LaGrone, using University of Texas data, concluded that index curves could perhaps be more easily obtained than from meteorological measurements, partly because of the badly fluctuating character of the temperature and humidity profiles that were being measured along the coast of the Gulf of Mexico. There was disagreement, however, between the observed attenuation rates and that deduced from the shape of the radio field strength profiles.

Several methods for determining the vertical angle of arrival of microwaves near grazing incidence in the presence of surface reflection over a 2.5-mile overwater path, were reported by Straiton and LaGrone. These experiments involved phase as well as amplitude measurements between two or three vertically spaced antennas.

For overland propagation well within optical range, an interesting method was published by Gough in England, wherein the proposed sites were surveyed radiowise by simple portable microwave equipment for making field-strength-versus-height measurements. The curve thus obtained can sometimes be analyzed to give the path difference between the direct wave and the most important surface reflections produced by the path profile. This microwave measurement permits prediction of the site behavior for other vhf and uhf frequencies.

The reflection coefficients of water, snow, and ice over wide frequency ranges were succintly reviewed in two papers by Saxton, who performed many of the fundamental measurements of the physical properties on which the reflection depends.

A review article by Lehfeldt summarized the theory and experimental results of a large program vhf and uhf measurements carried out in Germany during the war. A paper by Grün and Kleinstuber on the interference facing of decimeter waves over optical paths is noteworthy.

(957) B. Milnes and R. S. Unwin, "A radio meteorological investigation in the South Island of New Zealand," *Proc. Phys. Soc. B* (London), vol. 63, pp. 595–616; August, 1950.

(958) J. P. Day and L. G. Trolese, "Propagation of short radio waves over desert terrain," Proc. I.R.E., vol. 38, pp. 165–175; February, 1950.
(959) J. Z. Millar, "A microwave propagation test, Proc. I.R.E., vol. 38, pp. 619–626; June, 1950.
(960) A. W. Straiton and A. H. LaGrone, "Determination of the modified index of refraction over the Gulf of Mexico from radio data," *Jour. Appl. Phys.*, vol. 21, pp. 661–666; July, 1950.
(961) J. W. Green, "On the deduction of the refractive index profiles of a stratified atmosphere from radio field strength measurements," Proc. I.R.E., vol. 38, pp. 81–88; January, 1950.
(962) A. W. Straiton and A. H. LaGrone, "Microwave angle separation on a two and one-half mile overwater path," *Jour. Appl. Phys.*, vol. 21, pp. 188–193; March, 1950.
(963) M. W. Gough, "VHF and UHF propagation within the optical range," *Marconi Rev.*, vol. 12, pp. 121–139; October–December, 1949.
(964) J. A. Saxton, "Electrical properties of water: reflection characteristics of water surfaces at VHF," *Wireless Eng.*, vol. 26, pp. 288–292; September, 1949.
(965) J. A. Saxton, "Reflection coefficient of snow and ice at VHF," *Wireless Eng.*, vol. 27, pp. 17–25; January, 1950.
(966) W. Lehfeldt, "The propagation of ultra-short (quasi-optical) waves," *Arch. Elek.* (*Uebertratung*), vol. 3, pp. 137–142, 183–186, 221–228, 265–269, 305–312, 339–346; July–December, 1949.
(967) A. Grün and W. Kleinsteuber, "Interference fading in the decimeter-wave band caused by humidity and temperature changes in the lower layers of the atmosphere," *Arch. Elek.* (*Uebertragung*), vol. 3, pp. 209–219; September, 1949.

Broadcasting. Bullington gave a method for estimating the effects of gross terrain obstructions on service field strengths, as well as rough estimates of the tropospheric interfering fields that may be expected from distant stations, and a simple method for estimating the effect of these phenomena on the required separation of co-channel stations. Several field-strength surveys of vhf and uhf television stations were published during the year. For broadcasting, there is always especial concern for the magnitude of the local fluctuations of the field strength about the average values, and how such fluctuations will be expected to vary as frequency is increased. One solution is to use higher transmitted powers. This aggravates the frequency-allocation problem and there have been suggestions both in England and now in the United States that several low-power transmitters may be preferable to a single high power station in overcoming space fluctuations.

(968) K. Bullington, "Radio propagation variations at vhf and uhf," Proc. I.R.E., vol. 38, pp. 27–32; January, 1950.
(969) R. H. Harmon, "UHF coverage in Pittsburgh," *FM and Telev.*, vol. 10, pp. 14–17; May, 1950.
(970) R. P. Wakeman, "WTTG field strength survey," *Tele-Tech*, vol. 9, pp. 27–29; March, 1950.
(971) W. P. Cole and E. G. Hamer, "Multi station vhf communication systems using frequency modulation," *Jour. Brit. IRE*, vol. 10, pp. 244–258; July, 1950.
(972) J. R. Brinkley, "Multi station vhf schemes," *Electronic Eng.* (London), vol. 22, pp. 323–325; August, 1950.
(973) R. M. Wilmotte, "Polycasting," *Tele-Tech*, vol. 10, p. 33; January, 1951.

Atmospheric Attenuation. Of the permanent gases in the atmosphere, oxygen determines the maximum frequency useful for communication in the neighborhood of 60 kmc. The precise frequencies of the oxygen radio-frequency absorption lines have been observed at reduced pressure. Heretofore only the integrated effect of broadened overlapping lines had been observed at atmospheric pressure. Bussey has estimated the number of hours per year that any given microwave path attenuation will be exceeded due to rainfall and water vapor, based on rainfall statistics and calculated rainfall attenuation values. The effect of rainfall in masking echoes from 3-cm marine radar equipment was calculated by Barden. For temperatures below freezing, Yerg pointed out that humidity gradients frequently annul the effect of large temperature inversions near the surface of the ground, so standard propagation is approached.

(974) J. H. Burkhalter, R. S. Anderson, W. V. Smith, and W. Gordy, "The fine structure of the microwave absorption spectrum of oxygen," *Phys. Rev.*, vol. 79, pp. 651–655; August 15, 1950.
(975) H. E. Bussey, "Microwave attenuation statistics estimated from rainfall and water vapor statistics," Proc. I.R.E., vol. 38, pp. 781–785; July, 1950.
(976) D. G. Yerg, "The importance of water vapor in microwave propagation at temperatures below freezing," *Bull. Amer. Met. Soc.*, vol. 31, pp. 175–177; May, 1950.
(977) S. E. Barden, "The effect of rain on marine radar echoes," *Marconi Rev.*, vol. 13, pp. 102–109; (1950).

Velocity of Propagation. Smith-Rose summarized present-day views about the speed of radio and light waves in a vacuum and of radio waves in the troposphere. Essen reviewed the discrepancy of 16 kilometers per second between present-day radio measurements reduced to a vacuum and the average of the thousands of previous optical measurements. The latest optical measurement seems to agree with the prewar accepted optical value rather than with the postwar radio and optical values. Near the end of the year, another provisional microwave radio value was reported by Bol and supports the modern radio figure.

(978) R. L. Smith-Rose, "The speed of radio waves and its importance in some applications," Proc. I.R.E., vol. 38, pp. 16–20; January, 1950.
(979) L. Essen, "Velocity of light and of radio waves," *Nature*, vol. 165, pp. 582–583; April 15, 1950. Also, p. 821; May 21, 1950.
(908) Kees Bol, "A determination of the speed of light by the resonant cavity method," *Phys. Rev.*, vol. 80, p. 298; October 15, 1950.

Ionosphere Studies

Major progress was made in theoretical and experimental work on the physics of ionosphere regions.

(981) S. Chapman, "Upper atmosphere nomenclature," *Jour. Atmo. Terr. Phys.*, vol. 1, pp. 121–124; 1950.
(982) R. Penndorf, "Distribution of atomic and molecular oxygen in the upper atmosphere," *Phys. Rev.*, vol. 77, pp. 561–562; February, 1950.
(983) M. Nazarek, "The temperature distribution of the upper atmosphere," *Bull. Amer. Met. Soc.*, vol. 31, pp. 44–50; February, 1950.
(984) K. C. Westfold, "Refractive index and classical radiative processes in an ionized gas," *Phil. Mag.*, vol. 41, pp. 509–516; June, 1950.
(985) H. E. Newell, "A review of upper atmosphere research from rockets," *Trans. Amer. Geo. Union*, vol. 31, pp. 25–34; 1950.
(986) T. Yonezwa, "On some relations between the night sky light and the ionosphere," *Rep. Ions. Res. Japan*, vol. 4, p. 55; 1950.
(987) G. M. B. Dobson, "Physics and the atmosphere," *Proc. Phys. Soc.*, vol. 63, pp. 252–266; April, 1950.

Further advances were noted in the application of magneto-ionic theory of ionosphere problems.

(988) T. L. Eckersley, "Coupling of the ordinary and extraordinary rays in the ionosphere," *Proc. Phys. Soc.*, vol. 63, pp. 49–58; January, 1950.
(989) V. A. Bailey, "On the relativistic electromagneto-ionic theory of wave propagation," *Phys. Rev.*, vol. 77, pp. 418–419; February, 1950.
(990) J. C. W. Scott, "Longitudinal and transverse propagation in Canada," *Jour. Geo. Res.*, vol. 55, pp. 65–84; March, 1950.
(991) H. G. Booker, "Studies on propagation in the ionosphere," Cornell University, Ithaca, N. Y., Studies on Propagation in the Ionosphere, Tech. Report No. 1; March, 1950.

(992) J. Feinstein, "Higher-order approximations in ionospheric wave propagation," *Jour. Geo. Res.*, vol. 55, pp. 161–170; June, 1950.
(993) J. C. W. Scott, "The Poynting vector in the ionosphere," PROC. I.R.E, vol. 38, pp. 1057–1068; September, 1950.
(994) J. C. W. Scott, "Computation of propagation in the ionosphere," *Jour. Geo. Res.*, vol. 55, pp. 267–269; September, 1950.

Advances were made in the study of ionosphere region characteristics.

(995) K. Weekes, "The formation of the ionized regions," *Proc. Phys. Soc.*, vol. 63, pp. 147–148; February, 1950.
(996) W. Becker and W. Dieminger, "On the incidence and structure of the E_2 layer of the ionosphere," *Naturwissenschaften*, vol. 37, pp. 90–91; February, 1950.
(997) B. Friedman, "Numerical methods for evaluation of the integrals for virtual height," New York University, N. Y., Mathematics Research Group, Report EM-17; February, 1950.
(998) R. Eyfrig, "The problem of the diurnal variation of the electron density of the at layer of equatorial stations," *Naturwiss.* vol. 37, pp. 67–68; February, 1950.
(999) D. R. Bates and M. J. Seaton, "Theoretical considerations regarding the formation of the ionized layers," *Proc. Phys. Soc.*, vol. 63, pp. 129–140; February, 1950.
(1000) R. Rivault, "Diffusion of echoes in the neighborhood of F_2 critical frequencies," *Proc. Phys. Soc.*, vol. 63, pp. 126–128; February, 1950.
(1001) J. A. Gledhill and M. E. Szendrei, "Theory of the production of an ionized layer in a non-isothermal atmosphere, neglecting the earth's curvature, and its application to experimental results," *Proc. Phys. Soc.*, vol. 63, pp. 427–445; June, 1950.
(1002) M. H. Johnson and E. O. Hulbert, "Diffusion in the ionosphere," *Phys. Rev.*, vol. 79, p. 222; July, 1950.
(1003) J. Bartels, "27-day variations in F_2 layer critical frequencies at Huancayo," *Jour. Atmo. Terr. Phys.*, vol. 1, pp. 2–12; 1950.
(1004) R. Eyfrig, E. Harnischmacher, and K. Rawer, "World-wide F_2 ionization," *Jour. Geo. Res.*, vol. 55, pp. 261–266; September, 1950.

Oblique incidence propagation via the ionosphere was studied from several viewpoints.

(1005) P. LeJay and D. Lepechinsky, "Field intensity at the receiver as a function of distance," *Nature* (London), vol. 165, pp. 306–307; February, 1950.
(1006) W. Ross, "The variations in direction of arrival of high-frequency radio waves," *Proc. Phys. Soc.*, vol. 63, pp. 149–150; February, 1950.
(1007) W. J. G. Beynon, "The application of ionospheric data to shortwave transmission problems," *Proc. Phys. Soc.*, vol. 63, p. 145; February, 1950.
(1008) J. M. Kelso, "Radio wave propagation in a curved ionosphere," PROC. I.R.E., vol. 38, pp. 533–539; May, 1950.
(1009) T. T. DeBettencourt and H. Klemperer, "The beacon technique as applied to oblique incidence ionosphere propagation," PROC. I.R.E, vol. 38, pp. 791–792; July, 1950.
(1010) W. Ross, "Lateral deviation of radio waves reflected at the ionosphere," Department of Scientific and Industrial Research, London, England, Radio Research Report No. 19; November, 1949.

Interest continued in the topics of ionosphere absorption and wave interaction.

(1011) E. Argence and K. Rawer, "Calculation of the absorption decrement for a parabolic layer in the case of oblique incidence," *Compt. Rend. Acad. Sci.*, vol. 230, pp. 69–70; January, 1950.
(1012) J. H. Meek, "Attenuation of radio waves in the auroral zone," Defence Research Board, Ottawa, Canada, Radio Physics Lab., Report No. 5; April, 1950.
(1013) L. G. H. Huxley, "Ionospheric cross-modulation at oblique incidence," *Proc. Roy. Soc.*, vol. 200, pp. 486–511; February, 1950.
(1014) M. Cutolo, "Effects of radio gyro interaction and their interpretation," *Nature* (London), vol. 166, pp. 98–100; July, 1950.

Considerable work was reported on the subjects of long waves and polarization.

(1015) R. N. Bracewell and T. W. Straker, "The study of solar flares by means of very long radio waves," *Mon. Not. R. Astro. Soc.*, vol. 109, pp. 28–45; January, 1950.
(1016) J. A. Ratcliffe, "The regular behavior of long and very long waves returned from the ionosphere," *Proc. Phys. Soc.*, vol. 63, p. 142; February, 1950.
(1017) C. Williams, "The characteristics of low frequency radio waves reflected from the ionosphere with particular reference to radio aids to navigation," *Proc. Phys. Soc.*, vol. 63, pp. 143–144; February, 1950.
(1018) W. T. Sanderson, "The effects of sky-wave on the planning of navigational aids using frequencies in the 70–130 kc/s band," *Proc. Phys. Soc.*, vol. 63, p. 143; February, 1950.
(1019) S. B. Smith and K. W. Tremellen, "Very-low-frequency propagation," *Proc. Phys. Soc.*, vol. 63, p. 143; February, 1950.
(1020) R. N. Bracewell, "Measurements on long and very long waves," *Proc. Phys. Soc.*, vol. 63, p. 144; February, 1950.
(1021) R. Bureau, "Sudden strengthening of very long waves," *Proc. Phys. Soc.*, vol. 63, pp. 122–126; February, 1950.
(1022) K. Weekes, "The ground interference pattern of very-low-frequency radio waves," *Proc. IEE* (London), vol. 97, pp. 100–107; March, 1950
(1023) J. N. Brown and J. M. Watts, "Ionosphere observations at 50 kc/s," *Jour. Geo. Res.*, vol. 55, pp. 179–181; June, 1950.
(1024) A. H. Benner, "The diurnal variation of the vertical ionospheric absorption at 150 kcs," PROC. I.R.E., vol. 38, p. 685; June, 1950.
(1025) K. Weekes, "Effects of an SID on very long radio waves reflected obliquely from the ionosphere," *Nature* (London), vol. 165, p. 935; June, 1950.
(1026) A. L. Aden, J. T. deBettencourt, and A. T. Waterman, "A note on ionospheric radio wave polarization," *Jour. Geo. Res.*, vol. 55, pp. 53–56; March, 1950.
(1027) A. H. Benner, C. H. Grace, and J. M. Kelso, "Polarization of low-frequency radio waves reflected from the ionosphere," PROC. I.R.E., vol. 38, pp. 951–952; August, 1950.
(1028) W. Pfister, "Effect of the *D*-ionospheric layer on very low frequency radio waves," *Jour. Geo. Res.*, vol. 54, pp. 315–337; December, 1949.

Increasing interest in the dynamic characteristics of the upper atmosphere, involving work on winds and tides, was noted.

(1029) J. G. Jones and M. W. Jones, "Tidal effects in the ionospheric *F* layer," *Jour. Meteor.*, vol. 7, pp. 14–20; February, 1950.
(1030) D. F. Martyn, "Cellular atmospheric waves in the ionosphere and tropopause," *Proc. Roy. Soc.*, A, vol. 201, pp. 216–234; March, 1950.
(1031) M. W. Jones and J. G. Jones, "A correlation between ionospheric phenomena and surface pressure," *Phys. Rev.*, vol. 77, p. 845; March, 1950.
(1032) G. H. Munro, "Travelling disturbances in the ionosphere," *Proc. Roy. Soc.*, vol. 202, pp. 208–223; July, 1950.
(1033) M. V. Wilkes, "Atmospheric oscillation," *Nature* (London), vol. 164, p. 281; August, 1949.
(1034) L. A. Manning, O. G. Villard, Jr., and A. M. Peterson, "Meteoric study of upper atmosphere winds," PROC. I.R.E., vol. 38, pp. 877–883; August, 1950.
(1035) S. Matsushita, "Circulatory motion in the ionosphere and terrestrial magnetism," *Rep. Ion. Res. Japan*, vol. 4; 1950.
(1036) M. V. Wilkes, "Oscillations of the Earth's Atmosphere," Cambridge University Press, Cambridge, England, 1949.

Important work concerning scattering and fading of ionosphere reflected signals was reported.

(1037) R. L. Smith-Rose, "Solar noise and ionospheric fading," *Nature* (London), vol. 165, pp. 37–38; January, 1950.
(1038) B. H. Briggs, G. J. Phillips, and D. H. Shinn, "The analysis of observations on spaced receivers of the fading of radio signals," *Proc. Phys. Soc.*, vol. 63, pp. 106–121; February, 1950.
(1039) W. L. Hartsfield, S. M. Ostrow, and R. Silberstein, "Back-scatter observations by the Central Radio Propagation Laboratory—August 1947 to March 1948," *Jour. Res. Nat. Bur. Stand.*, vol. 44, pp. 199–214; February, 1950.
(1040) J. W. Findlay, "Irregularities in the horizontal plane in region *E* of the ionosphere," *Proc. Phys. Soc.*, vol. 63, p. 148; February, 1950.
(1041) R. Rivault, "Scattered echoes near the critical frequencies of F_1 region," *Proc. Phys. Soc.*, vol. 63, pp. 126–128; February, 1950.
(1042) G. Millington, "Scattering of radio waves from region *E*," *Proc. Phys. Soc.*, vol. 63, p. 149; February, 1950.
(1043) H. G. Booker, J. A. Ratcliffe, and D. H. Shinn, "Diffraction from an irregular screen with applications to ionospheric problems," *Phil. Trans. Roy. Soc.*, A, vol. 242, pp. 579–609; September, 1950.

(1044) W. E. McNicholl, "The fading of radio waves of medium and high frequencies," *Proc. IEE* (London), vol. 97, p. 366; September, 1950.

Solar relationships and sudden ionospheric disturbances (SID), were subjected to further study.

(1045) W. R. Piggott, "Irregular behavior of the ionosphere associated with solar events," *Proc. Phys. Soc.*, vol. 63, p. 146; February, 1950.
(1046) E. Harnischmacher, "The effect of the sun on the normal *E* layer of the ionosphere," *Compt. Rend. Acad. Sci.*, vol. 230, pp. 1301–1302; March, 1950.
(1047) R. Lindquist, "Ionospheric effects of solar flares," Transactions Chalmers University, Gothenburg, Sweden, Technical Report No. 95; 1950.
(1048) K. Miya, "On the effect of a southward movement of ionospheric disturbance in wireless communication during a geomagnetic storm," *Rep. Ion. Res. Japan*, vol. 4; 1950.
(1049) N. Fukushima, "Propagation of ionospheric disturbances in F_2 layer," *Rep. Ion. Res. Japan*, vol. 4; 1950.
(1050) W. Dieminger, et al., "Solar und terrestriche beobachtungen wahrend des Mogel-Dellinger effektes (SID)," *Jour. Atmo. Terr. Phys.*, vol. 1, pp. 37–48; 1950.

The study of meteors and their effects on ionospheric measurements became of increasing interest.

(1051) A. C. B. Lovell, "Meteor ionization in the upper atmosphere," *Proc. Phys. Soc.*, vol. 63, p. 149; February, 1950.
(1052) D. D. Cherry and C. S. Skyman, "On meteor speed measurements by the radio doppler method at low frequencies," *Phys. Rev.*, vol. 75, pp. 1441–1442; May, 1949.
(1053) J. S. Greenhow, "Fluctuations and fading of radio echoes from meteor trails," *Phil. Mag.*, vol. 41, pp. 682–693; July, 1950.
(1054) C. D. Ellyett, "Influence of high altitude winds on meteor trail ionization," *Phil. Mag.*, vol. 41, pp. 694–700; July, 1950.

An interesting new field of study concerning radio noise of ionospheric origin was reported.

(1055) H. V. Cottony, "Radio noise of ionospheric origin," *Science*, vol. 3, p. 41; January, 1950.

Further work on aurora, ionospheric storms, and sporadic *E* appeared in the literature.

(1056) J. H. Meek, "Occurrence of *E* region sporadic ionization through the auroral zone," Defence Research Board, Radio Physics Lab., Ottawa, Canada, Report No. 3; January, 1950.
(1057) E. V. Appleton and W. R. Piggott, "World morphology of ionospheric storms," *Nature* (London), vol. 165, pp. 130–131; January, 1950.
(1058) M. Nicolet and R. Doganioux, "Nouvelles suggestion au sujet de l'interpretation du spectra des aurores," *Jour. Geo. Res.*, vol. 55, pp. 21–32; March, 1950.
(1059) J. S. Kojan and G. A. Isted, "The first ionospheric-storm warning service," *Marconi Rev.*, vol. 13, pp. 53–71; 1950.

Several bibliographies and reports of meetings concerning ionosphere topics became available.

(1060) "Bibliography of ionosphere propagation," Raytheon Manufacturing Co., Watertown, Mass.; November, 1949.
(1061) "Physical Society conference on the ionosphere at Cambridge University, July 14–16, 1949," *Proc. Phys. Soc.*, vol. 63, pp. 141–150; February, 1950.
(1062) "Summary of proceedings of Australian national committee of radio science, URSI, Sydney, Jan. 16–20, 1950," *Jour. Geo. Res.*, vol. 55, pp. 191–210; June, 1950.
(1063) "Abstracts of published papers in radio research in Australia," Australian National Committee on Radio Science, Canberra, Australia; July, 1950.
(1064) "Proceedings of the conference on ionospheric physics at the Pennsylvania State College, July 24–27, 1950," Pennsylvania State College, State College, Pa., vol. 2; November, 1950.
(1065) "IRE Standards on Wave Propagation: Definitions of Terms, 1950," Proc. I.R.E., vol. 38, pp. 1264–1268; November, 1950.

Solar Radio Waves

The quiescent sun was studied further and serious doubt cast on the sun's having limb brightening. Experimental verification was produced for the assumption that solar radio waves are a continuum sensibly indistinguishable from a thermal continuum.

Radiotransients in the solar atmosphere were studied theoretically and experimentally. There are two types. The first have a narrow spectral width, gradual rise and decline, are circularly polarized, have a duration of seconds, and are probably associated with sunspots. The second have a wide spectral width, a sharp rise and slow decline, are randomly polarized, have a duration of minutes, and are observed to move to successively lower frequencies. This was interpreted as the effect of motion in the solar atmosphere. Some of these transients are believed to be associated with solar flares. The Australians have observed the sources of such energy at distances of over one solar diameter from the limb of the sun.

An expedition organized by the U. S. Naval Research Laboratory observed the total solar eclipse of the sun by the moon on September 12, 1950, on the island of Attu, Aleutian chain. Excellent results were secured at wavelengths of 3, 10 and 65 centimeters. This was probably the first total eclipse of the sun that was observed successfully during a torrential downpour of rain in a hurricane.

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Galactic Radio Waves

The most important discovery of the year was the accurate measurement of radio-frequency energy arriving from the Andromeda Nebula at a frequency of 158 mc. This nebula is at a distance of about 860,000 light years and is the farthest distant object from which radio waves have been detected.

(1076) R. Hanbury Brown and C. Hazard, "Radio frequency radiation from the great andromeda nebula M31," *Nature*, vol. 166, no. 4230, pp. 902–903; November 25, 1950.

A survey of the distribution of radio energy from the milky way at 100 mc was made by the Australians. This is the first survey completed in the southern hemisphere. No minor maxima in the southern constellation of Carina similar to the one in the northern constellation of Cygnus were found. Thus, the distribution of material in the galaxy appears to be assymmetrical with an arm extending in the direction of Cygnus. Using visual astronomical evidence on the direction of rotation of the galaxy, it is thereby deduced that our milky way is an unwinding spiral. This important conclusion allows a selection to be made in various cosmological theories of the origin and history of our galactic system.

At Manchester, England, a mirror 220 feet in diameter was constructed pointing toward the zenith. By making off-center measurements, a region of the sky from +35 to +65 degrees declination could be scanned. Measurements at 39, 78, and 160 mc showed the width of the milky way to be independent of frequency. This is in direct contradiction to theories of the origin of galactic radio waves, which involve free-free transitions in the electron gas of space. The finding is in agreement with the theoretical predictions of Williamson.

Kiepenheuer proposed a new theory that involves cosmic rays traveling through clouds of dust in space. This operation is quite similar to that of a betatron, where the magnetic field is supplied by the turbulence of the dust clouds and the charged particles are supplied by the electron component of the cosmic rays. Since the fields are so small, the energy is emitted as meter waves instead of light waves. Estimates of the intensity of the energy available by this mechanism, and its spectral distribution, indicate it to be a very probable source of these galactic meter waves. Perhaps the term cosmic static has more real significance than was originally guessed.

Further progress was made in the study of the fluctuations in intensity of the meter waves from celestial point sources. The results confirm the belief that these variations are introduced by the atmosphere of the earth, mainly the ionosphere. They are a type of selective fading caused by variations in the refractive index of the ionosphere with frequency. Reduction in bandwidth will substantially mitigate the effects of the phenomenon. They are least at low geomagnetic latitude when the ionosphere is quiescent, as in the early hours of the morning. They are increasingly severe as the observing frequency is reduced toward the critical frequency of entry and on days of ionospheric disturbance. Further study may show these variations to be an index of ionospheric condition.

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(1083) Smith, Little, and Lovell, "Fluctuations of galactic radio waves," *Nature*, vol. 165, pp. 422–424; March 18, 1950.
(1084) M. Nicolet and L. Bosey, "The absorption of short waves in the ionosphere," *Ann. de Geophysique*, vol. 5, pp. 275–292; October–November–December, 1949.

Acknowledgment

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Standards on Abbreviations of Radio-Electronic Terms, 1951*

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1. DEFINITIONS AND SCOPE

1.1. For the purpose of this Standard, an abbreviation is a shortened form of a technical term. This Standard does not include abbreviations for all possible technical terms, nor does it encompass designations, graphical symbols, or letter symbols.

2. PRINCIPLES UNDERLYING THE ABBREVIATIONS

2.1. The same abbreviation serves for either the singular or plural form of a term.

2.2. Periods and hyphens are omitted.

2.3. Either small or capital letters may be used for any abbreviation. A multiletter abbreviation must not be a mixture of small and capital letters, with the exception of the use of μ and Ω for *micro* and *ohm*, respectively. In a given text, some abbreviations may be in small and others in capital letters.

3. RECOMMENDED USAGE

3.1. The use of abbreviations is not mandatory. Abbreviations are employed in technical writing as a matter of convenience to save time or space. Their acceptability depends in large measure on the training of the reader. It is recommended that the term be spelled out and followed by the abbreviation in parentheses when it is first used in text. Abbreviations should not be employed if their inclusion could possibly result in a lack of comprehension or in misunderstanding on the part of the reader. In case of doubt, spell out. In drawings, graphs, and in tabular matter, abbreviations may be necessary if all required information is to be encompassed within reasonable space limitations.

3.2. Where an abbreviation appears in an illustration, panel, or nameplate, specific direct reference in the text to that feature of that illustration, panel, or nameplate must be in the same abbreviated form. However, abbreviations need not be used elsewhere in the text in the general discussion of that component.

4. ABBREVIATIONS

4.1 Metric System Prefixes

Two tables of abbreviations have been prepared. Table I lists the standard metric system prefixes that are used as multipliers for their associated base units. Some examples of the application of these prefixes are: UUF, uuf, $\mu\mu$F, or $\mu\mu$f for micromicrofarad; UH, uh, μH, or μh for microhenry; CM or cm for centimeter; DB or db for decibel; KV or kv for kilovolt; and MEGW or megw for megawatt.

4.2 Complete List of Abbreviations

Table II is a complete list of all abbreviations included in this Standard. Many of the terms in Table II have specialized applications and, in general, will be used only when it may be assumed that the reader is thoroughly familiar with the particular field under discussion. All combinations of metric prefixes and units are not given specifically in Table II but are inherent to the system outlined in Table I.

TABLE I

Metric System Prefixes For Units

(See Section 4.1)

Abbreviation: Use Either Capital or Small Letters		*Prefix*	*Multiplier*
UU or $\mu\mu$	uu or $\mu\mu$	micromicro	10^{-12}
MU or Mμ	mu or mμ	millimicro	10^{-9}
U or μ	u or μ	micro	10^{-6}
M	m	milli	10^{-3}
C	c	centi	10^{-2}
D	d	deci	10^{-1}
K	k	kilo	10^{3}
MEG[1]	meg[1]	mega	10^{6}
KM	km	kilomega	10^{9}
MM	mm	megamega	10^{12}

TABLE II

Complete List of Abbreviations

(See Section 4.2)

Abbreviation: Use Either Capital or Small Letters		*Term*
API	api	air-position indicator
AC	ac	alternating current
AMB	amb	ambient
AWG	awg	American wire gauge
A	a	ampere
AH	ah	ampere-hour
AM	am	amplitude modulation
A	a	angstrom
ANT	ant	antenna
ATR	atr	anti-transmit-receive
AF	af	audio frequency
ABC	abc	automatic brightness control
ADF	adf	automatic direction finder
AFC	afc	automatic frequency control
AGC	agc	automatic gain control
ANL	anl	automatic noise limiter
APC	apc	automatic phase control
ASC	asc	automatic sensitivity control
AVC	avc	automatic volume control
BE	be	band elimination
BP	bp	band pass
BFO	bfo	beat-frequency oscillator, beating oscillator
BO	bo	beat-frequency oscillator, beating oscillator
—	—	bel (spell out)

[1] Usage has established MC and mc as abbreviations for megacycle per second. All other units will use MEG or meg for the prefix mega.

TABLE II (Continued)

Abbreviation: Use Either Capital or Small Letters		*Term*
B	b	bel (combining form)
BC	bc	broadcast, broadcasting
C	c	candle
CP	cp	candle power
CRO	cro	cathode-ray oscilloscope or oscillograph
CRT	crt	cathode-ray tube
C	c	centi (10^{-2})
CM	cm	circular mil
CW	cw	clockwise
CCS	ccs	continuous commercial service
CW	cw	continuous wave
CCW	ccw	counterclockwise
XTAL	xtal	crystal
CO	co	crystal oscillator
CU	cu	crystal unit, piezoelectric
CO	co	cutoff
CY	cy	cycle
C	c	cycle (combining form)
CPS	cps	cycle per second
C	c	cycle per second (combining form)
D	d	deci (10^{-1})
DBM	dbm	decibel referred to 1 milliwatt
DBV	dbv	decibel referred to 1 volt
DBW	dbw	decibel referred to 1 watt
DEG[2]	deg[2]	degree
DET	det	detector
DC	dc	direct current
DF	df	direction finder
DME	dme	distance-measuring equipment
DSB	dsb	double sideband
ECO	eco	electron-coupled oscillator
ENSI	ensi	equivalent noise-sideband input
EHF	ehf	extremely-high frequency
FAX	fax	facsimile
F	f	farad
FT	ft	foot
FC	fc	foot-candle
FL	fl	foot-lambert
FPM	fpm	foot per minute
FM	fm	frequency modulation
FSK	fsk	frequency-shift keying
GND	gnd	ground
GCA	gca	ground-controlled approach
GCI	gci	ground-controlled interception
GPI	gpi	ground position indicator
H	h	henry
HF	hf	high frequency
HP	hp	high pass

[2] This abbreviation is not used in combination with the abbreviations for temperature scales.

TABLE II (Continued)

Abbreviation: Use Either Capital or Small Letters		*Term*
HP	hp	horse power
HR	hr	hour
H	h	hour (combining form)
IFF	iff	identification friend or foe
IN	in	inch
LC	lc	inductance-capacitance
ID	id	inside diameter or dimension
ILS	ils	instrument landing system
IF	if	intermediate frequency
ICAS	icas	intermittent commercial and amateur service
IR	ir	interrogator-respondor
ICW	icw	interrupted continuous wave
K	k	kilo (10^3)
KM	km	kilomega (10^9)
L	l	lambert
LC	lc	inductance-capacitance
LUHF	luhf	lowest usable high frequency
LF	lf	low frequency
LP	lp	low pass
LM	lm	lumen
MVC	mvc	manual volume control
MO	mo	master oscillator
MAX	max	maximum
MUF	muf	maximum usable frequency
MF	mf	medium frequency
MEG	meg	mega (10^6)
MC or MEGC[1]	mc or megc[1]	megacycle per second
MM	mm	megamega (10^{12})
M	m	meter
—	—	mho (spell out)
U or μ	u or μ	micro (10^{-6})
UU or $\mu\mu$	uu or $\mu\mu$	micromicro (10^{-12})
M	m	milli (10^{-3})
MU or Mμ	mu or mμ	millimicro (10^{-9})
MIN	min	minimum
MCW[3]	mcw[3]	modulated continuous wave
MOD	mod	modulator
MTI	mti	moving-target indicator
MX	mx	multiplex
MV	mv	multivibrator
—	—	ohm (spell out in text; Ω elsewhere; see also next entry)
O or Ω	o or Ω	ohm (combining form for use with Table I)
OWF	owf	optimum working frequency
OSC	osc	oscillator
OD	od	outside diameter or dimension
PPM	ppm	part per million
PP	pp	peak to peak

[3] Usually designates tone modulation.

TABLE II (Continued)

Abbreviation: Use Either Capital or Small Letters		*Term*
PM	pm	permanent magnet
PM	pm	phase modulation
PHONO	phono	phonograph
PES	pes	photoelectric scanner
PU	pu	pickup
CU	cu	piezoelectric crystal unit
PPI	ppi	plan-position indicator
POT	pot	potentiometer
PSI	psi	pound per square inch
PWR	pwr	power
PA	pa	power amplifier
PF	pf	power factor
PLC	plc	power-line carrier
PO	po	power oscillator
PREAMP	preamp	preamplifier
PAR	par	precision approach radar
PRI	pri	primary
PBX	pbx	private branch exchange
PA	pa	public address
PAM	pam	pulse-amplitude modulation
PCM	pcm	pulse-code modulation
PCM	pcm	pulse-count modulation
PDM	pdm	pulse-duration modulation
—	—	pulsed frequency modulation (spell out)
—	—	pulse-frequency modulation (spell out)
PF	pf	pulse frequency
PPS	pps	pulse per second
PPM	ppm	pulse-position modulation
PRF	prf	pulse-repetition frequency
PRR	prr	pulse-repetition rate
PTM	ptm	pulse-time modulation
PWM	pwm	pulse-width modulation
PP	pp	push-pull
—	—	radian (spell out)
RDF	rdf	radio direction finder
RF	rf	radio frequency
RCVR	rcvr	receiver
RC	rc	resistance-capacitance
RPM	rpm	revolution per minute
RMS	rms	root-mean-square
RSS	rss	root-sum-square
SR	sr	saturable reactor
SEC	sec	second
S	s	second (combining form)
SEC	sec	secondary

TABLE II (Continued)

Abbreviation: Use Either Capital or Small Letters		*Term*
SW	sw	short wave
SNR	snr	signal-to-noise ratio
SSB	ssb	single sideband
SS	ss	single signal
SWR	swr	standing-wave ratio (same as current or voltage standing-wave ratio)
SHF	shf	super-high frequency
SW	sw	switch
SWBD	swbd	switchboard
SWGR	swgr	switchgear
SYNC	sync	synchronous, synchronizing
TPR	tpr	teleprinter
TTY	tty	teletypewriter
TWX	twx	teletypwriter exchange
TV	tv	television
TCI	tci	terrain-clearance indicator
TR	tr	transmit-receive
TE	te	transverse electric
TEM	tem	transverse electromagnetic
TM	tm	transverse magnetic
TW	tw	traveling wave
TRF	trf	tuned radio frequency
U or μ	u or μ	micro (10^{-6})
UHF	uhf	ultra-high frequency
UU or $\mu\mu$	uu or $\mu\mu$	micromicro (10^{-12})
VT	vt	vacuum tube
VTVM	vtvm	vacuum-tube voltmeter
VFO	vfo	variable-frequency oscillator
VHF	vhf	very-high frequency
VOR	vor	very-high-frequency omnidirectional radio range
VLF	vlf	very-low frequency
VSB	vsb	vestigial sideband
VID	vid	video
VAR	var	visual-aural radio range
VF	vf	voice frequency
V	v	volt
VR	vr	voltage regulator
VA	va	volt-ampere
VAR	var	volt-ampere, reactive
VPM	vpm	volt per meter
VU	vu	volume unit
W	w	watt
WH	wh	watt-hour
XTAL	xtal	crystal

Magnetic Delay-Line Storage*

AN WANG†, ASSOCIATE, IRE

Summary—Recent developments established that binary information could be stored and read out in a magnetic medium statically by electrical pulses only. A number of these magnetic cores are connected together to form a static magnetic delay line in which a series of binary digits can be stored and read out. The operation of this form of delay line is briefly described and carefully analyzed. The optimum operating conditions are derived. The effect of eddy current loss and leakage inductance is considered. The criteria of stability of the system are discussed.

I. Introduction

THE POSSIBILITY of storing information in magnetic materials is well known in the form of magnetic recording. The recording process as such is done by applying magnetizing forces representing the information to a continuous medium of magnetic material. To reproduce the recorded information, mechanical motion is necessary to induce voltages across the pickup coil. Obviously, the necessity of mechanical motion restricts greatly its usefulness.

A static magnetic storage system was recently developed.[1-3] In such a system, binary digits are stored in a magnetic core in the form of its residual magnetism. A series of cores are connected such that binary digits can be fed in at one end. Advancing pulses are applied to advance the digits stored from one core to the next along the series of cores. Eventually, the digits will be sent out at the end of the line. We called such a combination of cores a magnetic delay line.

The purpose of this paper is to analyze how it functions, to find the optimum operating conditions, and, from the results obtained therein, to guide the proper engineering design to insure reliable operation.

As always true to the problem involving magnetic properties, nonlinearity is unavoidable. Especially in the present application, the highly nonlinear property of the magnetic material, namely, the hysteresis loop, is desirable and is utilized to create two distinct states to represent the binary digit. Naturally, the exact mathematical solution of such a problem is presently unavailable. Proper approximations and idealizations are made with due regard to the practical conditions.

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1 An Wang, "Static magnetic recording, storage and delay lines," chap. IV, no. 2, November, 1948; chap. V, no. 3, February, 1949; chap. V, no. 4, May, 1949; chap. IV, no. 6, November, 1949; Computation Laboratory, Harvard University, Reports submitted to the U. S. Air Force under Contract W 19-122-AC-24.

2 An Wang and Way Dong Woo, "Static magnetic storage and delay line," *Jour. Appl. Phys.*, vol. 21, pp. 49–54; January, 1950.

3 An Wang, "Magnetic triggers," Proc. I.R.E., vol. 38, pp. 626–629; June, 1950.

II. Brief Review of the Operation

The magnetic material used for storage has a hysteresis loop as shown in Fig. 1. By the nature of the hysteresis, a large positive magnetizing pulse will leave the magnetic core with a positive residual magnetism as represented by the state "1" in Fig. 1. A large negative magnetizing pulse leaves the core in the state "0." The presence of these two distinct magnetic states in the core makes it a valuable medium to store a binary digit. In the discussion following, we will use the binary digit 1 or 0 to indicate the respective positive or negative residual magnetism stored.

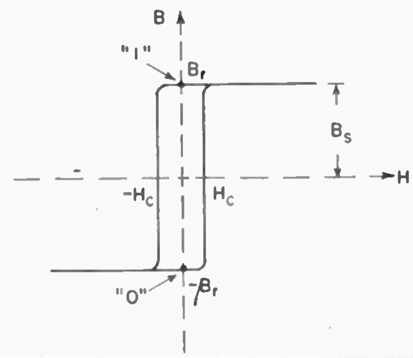


Fig. 1—Hysteresis characteristic.

A series of identical cores with windings are connected as shown in Fig. 2. Two rectifiers are used in each linking circuit between cores. One rectifier unit is in series with the circuit and another shunt across it. Assume first that all cores are in the "0" state, i.e., they are all with negative residual magnetism. Advancing current pulse i_1 is first applied to core #1. This current produces negative magnetizing force to the cores connected. Since the cores are already negatively saturated, very little flux will be changed. Nothing happens to the rest of the system. Cores #1 and #2 remain at 0. If now

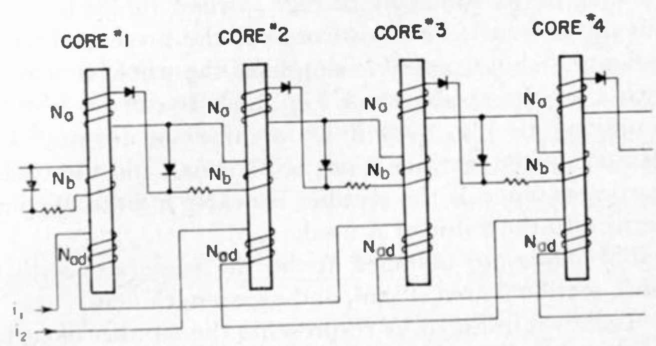


Fig. 2—Circuit of magnetic delay line.

core #1 is in the state 1 while the rest of the cores are all in the state 0, the application of the current pulse i_1 will cause a large change of flux in core #1 from its positive saturation value to its negative saturation value. This large change of flux induces across N_a of core #1 a large positive voltage to force current through the series rectifier to magnetize the core #2 to its positive saturation. That this is possible will be seen in the discussion which follows. After this current pulse, core #2 changes to state 1 and core #1 is reset to state 0. Summarizing, the application of i_1 has, in effect, transferred whatever digit stored in core #1 to core #2 and reset the core #1 to the 0 position. This transferring is isolated within cores #1 and #2 by the use of the rectifiers. During the transfer, the flux of core #2 can only be changed from negative to positive. This induces a negative voltage across N_a of core #2. The series rectifier between cores #2 and #3 blocks any effect that this voltage might have on core #3. As the flux of core #1 changes, the voltage induced across N_b of core #1 tends to affect the previous core, but this effect is eliminated by the use of the shunt rectifier which short-circuits the winding of the previous core. The transfer of the digit from core #1 to core #2 is isolated to these two cores only. Therefore, at the same time, digits can be transferred from core #3 to core #4, core #5 to core #6, and so forth, by the same advancing pulse i_1, as shown in Fig. 2. After this, all the digits have been transferred to the even-numbered cores. The odd-numbered cores have been all reset to 0. Then a current i_2 is applied. This transfers all the digits to the next odd-numbered cores again. In this way, the digit can be advanced along a series of cores by the pair of advancing pulses. Transfer occurs only when an advancing pulse is applied. During the absence of the advancing pulse, the digits are stored in the magnetic medium of the cores, as their residual magnetism. It is clear from its fundamental operation that this form of storage provides a permanent magnetic storage. Yet the stored digit can be read out at will at any speed desired below a certain maximum rate by electrical pulses only. No mechanical motion is involved.

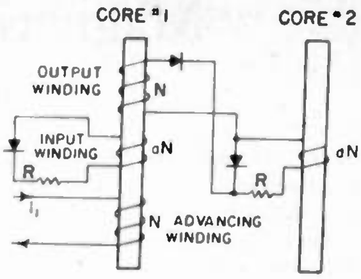
III. Flux Transfer

Let us now analyze in more detail the transfer of flux from one core to the next by the application of the advancing pulse. Referring to Fig. 2, when a digit is being advanced from core #1 to core #2, the presence of the series and shunt rectifiers simplifies the whole structure into a circuit as shown in Fig. 3(a). It can be further simplified to Fig. 3(b) if we assume the forward resistance of the rectifier is negligibly small and the backward resistance of the rectifier is nearly infinite in comparison to the value of R used.

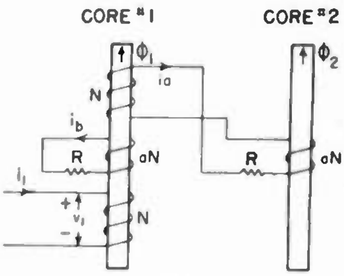
The cores are assumed to be the same size with a cross-sectional area A cm², and core length l cm.

As shown in Fig. 3, N respresents the number of turns on the advancing winding as well as the number of turns on the output winding. The number of turns on the input winding is given as aN where a is a constant to be discussed later.

The hysteresis characteristic of the magnetic material is assumed here to be an ideal one as shown in Fig. 1.



(a)



(b)

Fig. 3—Equivalent circuit of one unit of a magnetic delay line during transfer.

Actual hysteresis loops of the material used are a good approximation to it as seen in Fig. 4. For ease of analysis the ideal hysteresis loop is assumed. The ideal hysteresis characteristic has a rectangular loop with its residual magnetism equal to its saturation value.

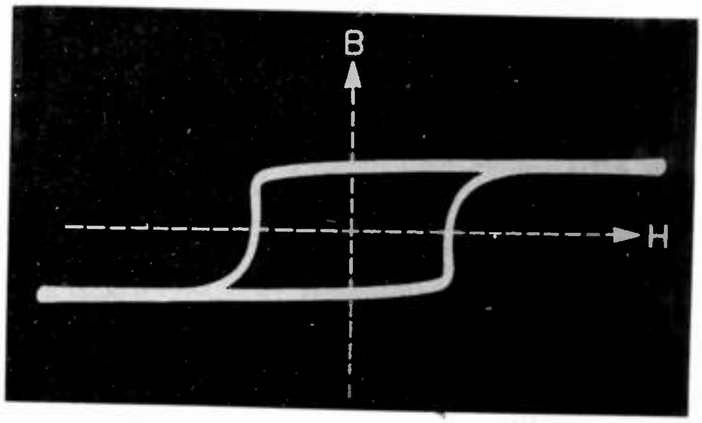


Fig. 4—Hysteresis loop of a typical core.

In Fig. 3(b), core #2 is ready to receive a digit and its magnetic state is in the point 0. If the digit stored in core #1 is a 0, which means that core #1 has a negative residual magnetic flux density, the application of the advancing pulse i_1, which gives a negative magnetizing pulse, does not change appreciably the amount of flux in core #1 since it is already very near its negative saturation. Nothing happens to the rest of the circuit. A digit 0 remains in core #2. This represents the transfer of a digit 0 from core #1 to core #2 by advancing pulse i_1.

Consider the case that a digit 1 is originally stored in core #1. Assume the advancing current i_1 is in the form as shown in Fig. 5. Before i_1 reaches a value i_1' where

$$i_1' = \frac{10 H_c l}{4\pi N} \tag{1}$$

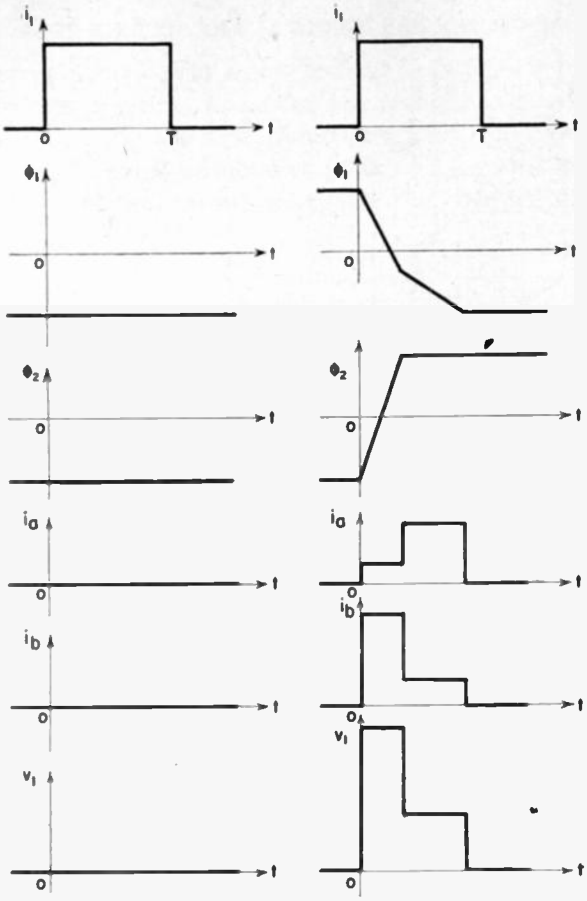


Fig. 5—Flux transfer curves. (a) Case 1: θ at state 0 before transfer. (b) Case 2: θ at state 1 before transfer.

the flux of the core changes very little.

After this, the flux of the core starts to change and secondary load current flows. During the changing of flux of core #1, due to its infinite incremental permeability, the total magnetizing force acting on the core #1 remains constant at its coercive force value.

$$\frac{4\pi N}{10l}\{i_1 - ai_b - i_a\} = H_c. \qquad (2)$$

As i_a starts to increase from zero, the winding aN on core #2 offers very little impedance until i_a reaches a value i_a'

$$i_a' = \frac{10H_c l}{4\pi aN}. \qquad (3)$$

Before this value is reached

$$ai_a = i_b. \qquad (4)$$

As i_1 increases, i_a and i_b increase accordingly until i_a reaches i_a'. Then i_a remains constant and equal to i_a'.

Let $i_1' = mI$, where I_1 is the maximum value of i_1 and solve

$$\begin{cases} N\dot{\phi}_1 \times 10^{-8} = -\dfrac{I_1 R}{a^2}\left[1 - m - \dfrac{m}{a}\right] \\ N\dot{\phi}_2 \times 10^{-8} = \dfrac{I_1 R}{a^3}\left[1 - m - \dfrac{m}{a}(1 + a^2)\right]. \end{cases} \qquad (6)$$

i_1 is assumed to jump from zero to I_1 in a short time during which ϕ_1 and ϕ_2 do not change appreciably. The above equations specify the change of flux ϕ_1 and ϕ_2 completely from the very beginning.

In order to transfer the digit completely from the first core to the second core without any loss, the following relation must hold true,

$$|\Delta\phi_2| \geqq |\Delta\phi_1| \qquad (7)$$

i.e.,

$$a - a^2 \geqq m \qquad (8)$$

but

$$a - a^2 \text{ is a maximum when } a = 0.5.$$

It is thus seen that the optimum-turns ratio a is one half. This agrees with the experimental results. By using a value $a = \frac{1}{2}$ and $m \leqq 0.25$, it is possible to cause ϕ_2 to change faster than ϕ_1. Before ϕ_1 reaches its saturation value, ϕ_2 completely reverses. After ϕ_2 saturates in this direction, the (4) again holds true as the winding on core #2 offers no more inductance, until ϕ_1 is saturated too. In this way, the binary digit 1 represented in the first core by its residual magnetism is able to be transferred to the second core with no attenuation. Summarizing the results, plots of the variations of the currents and fluxes of the core are shown in Fig. 5. Fig. 5 shows clearly how ϕ_2 is changed by the advancing current i_1 under control of ϕ_1, while ϕ_1 itself is changed to the negative state by i_1.

IV. Effect of Eddy Current Loss and Load Coupled to the Cores

As the flux of the magnetic core is changing, unavoidable eddy current loss results. This eddy current loss appears as a resistive load coupled to the core when its flux is changing. The magnetic core has a rectangular hysteresis characteristic. The incremental permeability is infinite. As shown earlier,[4] the flux penetrates from the external layer inward somewhat similar to the skin effect. This makes the effective load resistance cor-

[4] A. G. Ganz, "Applications of thin permalloy tape in wide band telephone and pulse transformers," *Trans. AIEE*, vol. 65, p. 177; 1946.

$$\begin{Vmatrix} 1 & -1 & -a & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -N \times 10^{-8} & 0 \\ 0 & R & 0 & 0 & aN \times 10^{-8} \\ 0 & 0 & 0 & -aN \times 10^{-8} & 0 \end{Vmatrix} \cdot \begin{Vmatrix} i_1 \\ i_a \\ i_b \\ \dot{\phi}_1 \\ \dot{\phi}_2 \end{Vmatrix} = \begin{Vmatrix} i_1' \\ i_a' \\ V_1 \\ V_1 \\ i_b R \end{Vmatrix}. \qquad (5)$$

responding to the eddy current loss vary as the flux penetration. It has been shown that this resistance is inversely proportional to the depth of penetration of the flux.

In the present discussion, a constant resistance equivalent to the variable eddy current loss is assumed. The analysis will then show how this eddy current loss affects the general operation of the delay line. As this constant resistance can also represent an extra load coupled to the cores, the same analysis will show the effect of loading which may be necessary in certain applications.

Let this equivalent resistance be Rb^{-1} across a single-turn winding around the core. This is also equivalent to a resistance load N^2Rb^{-1} across the winding with N turns. So the equivalent circuit for the unit described in

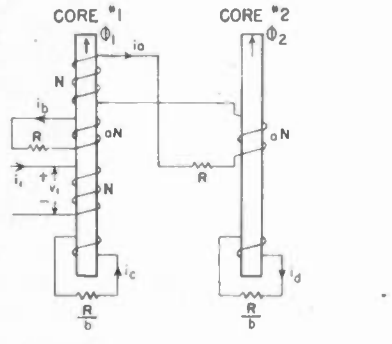


Fig. 6—Equivalent circuit of one unit of a magnetic delay line including eddy current effect.

the previous section becomes as shown in Fig. 6. When both ϕ_1 and ϕ_2 are changing, the following equations hold true:

$$\begin{Vmatrix} 1 & a & 1/N & 0 & 0 & 0 \\ a & 0 & 0 & -1/N & 0 & 0 \\ R & 0 & 0 & 0 & N\times 10^{-8} & aN\times 10^{-8} \\ 0 & R & 0 & 0 & aN\times 10^{-8} & 0 \\ 0 & 0 & R/b & 0 & 10^{-8} & 0 \\ 0 & 0 & 0 & R/b & 0 & -10^{-8} \end{Vmatrix} \begin{Vmatrix} i_a \\ i_b \\ i_c \\ i_d \\ \dot{\phi}_1 \\ \dot{\phi}_2 \end{Vmatrix} = \begin{Vmatrix} I_1 - i_1' \\ i_1' \\ 0 \\ 0 \\ 0 \\ 0 \end{Vmatrix} \quad (9)$$

Solving,

$$\begin{cases} \dot{\phi}_1 \times 10^{-8} = -\dfrac{mNba^{-1} + N(1-m-ma^{-1})(a^2N+b)}{(a^2N^2+b)^2+N^2b} I_1R \\ \dot{\phi}_2 \times 10^{-8} = \dfrac{aN^3(1-m-ma^{-1}) - mN(a^2N^2+b)}{(a^2N^2+b)^2+N^2b} I_1R \end{cases} \quad (10)$$

ϕ_2 increases as ϕ_1 decreases.

Again, we demand $|\dot{\phi}_2| \leqq |\dot{\phi}_1|$ or

$$a - a^2 - m - bN^{-2} \geqq 0. \quad (11)$$

In comparison with (8), the addition of the term bN^{-2} represents the effect of this eddy current loss. If everything else is the same, (11) can be satisfied if the value m be made less than its value in (8). This means a larger advancing current I_1 is needed. The optimum-turns ratio a can be seen to be still a value 0.5.

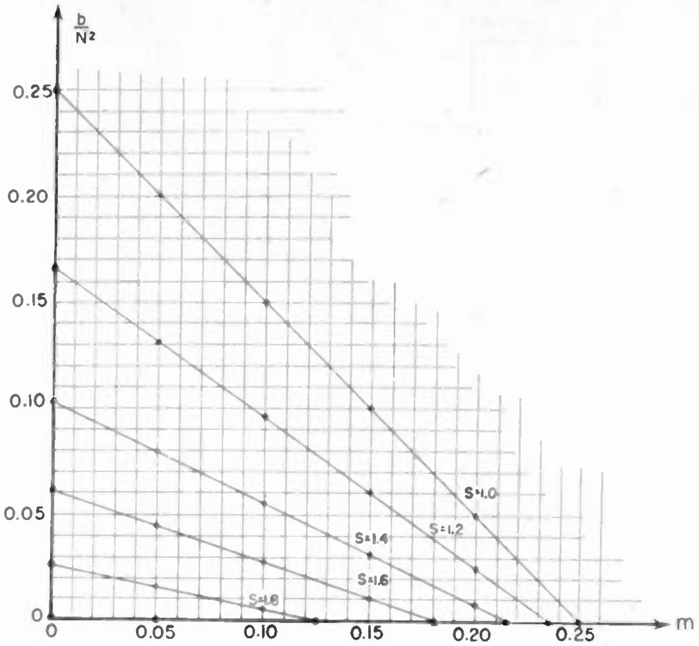


Fig. 7—Criteria of maximum allowable eddy current load.

Sometimes ϕ_2 should be made greater than ϕ_1, in order that stable operation be maintained. This is explained in the next session.

Let

$$\frac{d\phi_2}{d\phi_1} \geqq S. \quad (12)$$

S is a value greater than unity. Assume $a = \frac{1}{2}$ and substitute (10) into (12)

$$2 - 7m - 4mbN^{-2} \geqq S\{1 - 3m + 4bN^{-2} - 4mbN^{-2}\}. \quad (13)$$

This inequality can be plotted in co-ordinates of m and bN^{-2} with S as a parameter as shown in Fig. 7. The area included between the co-ordinate axes and the curve for a particular value of S satisfy the inequality (13).

From the curves obtained, we can see that the effect of eddy current loss is more pronounced when the change of ϕ_2 is faster than the change of ϕ_1.

It is interesting to point out here that the value m is related to the coercive force. For a rectangular hysteresis loop material the coercive force represents the hysteresis loss. The value of bN^{-2} represents the eddy current loss. It is quite natural that the operation of this form of magnetic storage should be controlled by these two fundamental characteristics of the magnetic material.

V. Effect of the Leakage Inductance

There always exists some leakage inductance for a transformer winding. Let L be the leakage inductance as shown in Fig. 8. The immediate result of the introduction of some inductance in the circuit will be to prevent an instantaneous change in the current. As ϕ_1

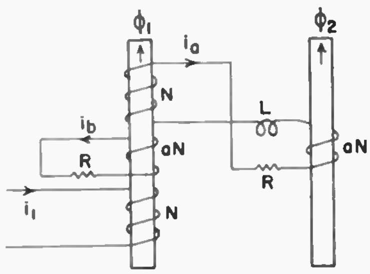


Fig. 8—Equivalent circuit of one unit of a magnetic delay line including leakage inductance effect.

changes, i_a increases exponentially until ϕ_2 starts to change. When ϕ_2 starts to change, i_a remains constant and the introduction of the inductance L is immaterial. Therefore, the previous analysis holds good. The only difference is that when ϕ_1 starts changing,

$$-N\dot{\phi}_1 \times 10^{-8} = Ri_a + Li_a + aN\dot{\phi}_2 \times 10^{-8}. \quad (14)$$

Before i_a reaches i_a'

$$-N\Delta\phi_1 \times 10^{-8} = \int Ri_a dt + \tfrac{1}{2}Li_a'^{2} - 0. \quad (15)$$

Part of the change of the flux linkage $N\Delta\phi_1$ is accounted for in the leakage inductance L and part in the resistance R. ϕ_1 can be changed only by a value of twice its saturation value. In order to cause ϕ_2 to reverse its flux polarity completely by the change of ϕ_1, the ratio of

$$\left|\frac{\Delta\phi_2}{\Delta\phi_1}\right|$$

must be greater than unity. This situation is shown in Fig. 9. Point A represents the starting point with ϕ_1 at its positive residual magnetism and ϕ_2 at its negative residual value. When ϕ_1 starts to decrease, ϕ_2 is not changed due to the presence of the leakage inductance. It is only after i_a reaches i_a' that ϕ_2 starts to increase. In order to saturate ϕ_2 before ϕ_1 is saturated

$$\left|\frac{d\phi_2}{d\phi_1}\right| > 1.$$

A $\phi_1\phi_2$ path of the type shown in Fig. 9 is necessary to insure stable and reliable operation of the delay line. Due to the irregularity of the size and characteristic of the magnetic cores, the position A may be varied somewhat within the cross-hatched zone around A. The saturation phenomena keeps the end of the $\phi_1\phi_2$ path in the zone C.

Point B represents the starting point when ϕ_1 remains at its negative residual magnetism. ϕ_1 has to change a certain amount before ϕ_2 will be changed. Even when ϕ_2 is changed, if the change of ϕ_1 is not too large, the change of ϕ_2 will be smaller compared with the change of ϕ_1. There will be no chance of buildup of this flux change and therĕfore no possibllity that a digit 0 will become a digit 1 after many transfers. The presence of these two stable zones A and B insures the reliable operation of the device as a binary digit-storing device.

In effect, the leakage inductance absorbs small flux variations of ϕ_1 to prevent it from growing during transferring. But this leakage inductance must not be too large so as not to absorb a large first fraction of the change of ϕ_1 requiring a larger $d\phi_2/d\phi_1$ for the remaining change of ϕ_1 to insure the complete flux change of ϕ_2.

A practical $\phi_1\phi_2$ curve of the delay line is shown in Fig. 10. Notice that ϕ_1 changes faster than ϕ_2 at the beginning and slower at the end of the change.

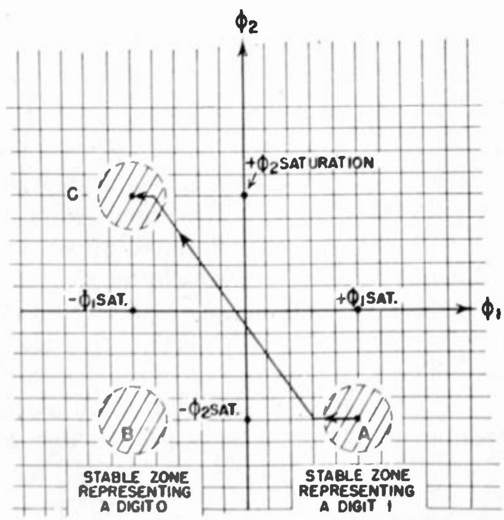


Fig. 9—Flux transfer path.

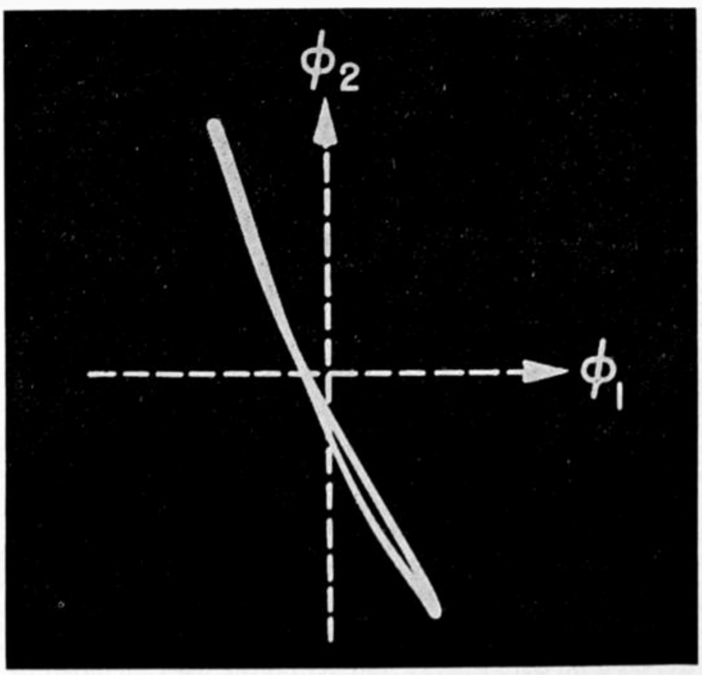


Fig. 10—Oscillogram of a flux transfer path.

VI. Backward Flow of Information

As seen in Fig. 2, the only possible backward effect when transferring a digit is caused by the stray coupling through the shunted rectifier. An ideal rectifier should have a very small forward resistance compared with R. In view of the small value of R used in practice, this ideal rectifier cannot be obtained easily. But small stray coupling backward is harmless due to the existence of a fairly large stable zone of operation. In the selenium rectifiers used in the experiments, the backward effect is in the order of a few per cent. Fig. 11 shows an oscillogram picture of the flux pattern of a particular core in a magnetic delay line of ten digits. A digit 1 is represented when the flux is in the high position and a digit 0 is represented when the flux is the low position.

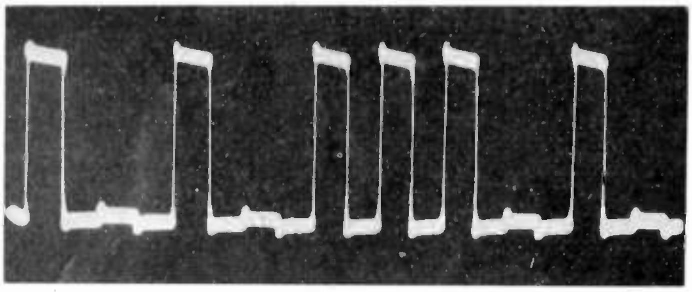


Fig. 11—Oscillogram showing the flux change in one core of a 20-core line.

A little bump occurs following every digit 1. This is the backward leakage of information through the shunting rectifier. This can be reduced by using a rectifier of lower forward resistance. However, the amplitude of the bump is negligibly small compared to the amplitude of the digit 1 pulse.

Selenium rectifiers are used simply for easier manipulation. There is no reason why other types of rectifiers cannot be used. The series rectifier is used to block the current flow for negative voltage. It is therefore to be kept in mind that the inverse peak voltage of the rectifier be not exceeded.

VII. Power Requirements

There is no power necessary to retain the residual magnetism which represents the stored digit. The only power required is the power to step the digit along the delay line by the advancing pulses. In advancing a digit from one core to the next, a magnetizing pulse is applied. If the digit to be advanced is a 0, very little power is necessary as not much flux of the core is to be changed. When the digit 1 is to be advanced, the power required is P per core.

$$P = -NI_1\dot{\phi}_1 \times 10^{-8} \tag{16}$$

If the flux ϕ_1 is to be completely changed in a time T, T must be the minimum pulse width of the advancing pulse. Substitute the relations of (1). Let the volume of the core be equal to V_c. Let A_h be the area included in the hysteresis loop of the magnetic material. Then,

$$P = \frac{A_h V_c}{8\pi m T} \times 10^{-7}. \tag{17}$$

The total energy of the pulse

$$W = PT = \frac{A_h V_c}{8\pi m} \times 10^{-7}. \tag{18}$$

The power requirement of the advancing pulse is proportional directly to the volume of the material, its hysteresis loop area, and inversely to the value m. Naturally, to reduce the driving power we want the value of m as large as possible. The maximum value of m is limited by the relation (8), (11) or (13). The relation (8) does not consider the effect of the eddy current loss. The maximum value of m can be as high as 0.25. If eddy current losses are considered, m should be even smaller.

Let us examine what happens if we increase the value of R. As R is increased, the relative eddy current loss bN^{-2} is increased. This forces the maximum value of m to be reduced. Therefore, the total energy of the advancing pulse has to be increased. By so doing, the speed of transfer is increased too. If R is reduced, bN^{-2} is reduced, and the maximum value of m can be increased. The value I_1 can be reduced, but the speed of transfer is reduced. The pulse width T should be greater. For a pulse of maximum value I_1 and width T, a range of R is fixed within which the operation is satisfactory. Since the advancing pulse is usually supplied by a vacuum tube, the peak current is limited by its emission and the voltage is limited by the dc plate supply voltage. The faster the operation, the less the number of cores that can be driven by a single tube. The volume of the material should be kept at a minimum to reduce the power requirement. There is a limit to the smallest cross-sectional area of the magnetic material used. As the cross section gets smaller, more leakage inductance will be present. As shown above, too large a leakage inductance will prevent the delay line from functioning properly.

VIII. Experimental Facts

A fairly large number of delay-line units have been constructed. Their operations have been proved satisfactory and reliable. A single unit consists of one magnetic core with its three windings, one resistor, and two selenium rectifiers. The core is made up of 0.125-inch strip Deltamax[5] of 0.001-inch thickness wound for two complete turns of 0.5-inch diameter plus about 0.25-inch overlap. Fig. 4 shows the hysteretic characteristic of such a core. The windings are: N 150 turns, N 75 turns, N 200 turns. The cores are placed in small plastic cases for protection against mishandling. The two selenium

[5] Manufactured by Allegheny Ludlum Steel Corporation, Pittsburgh, Pa.

cells have an active area of 0.2 square inch each and are combined into a single plate. A resistor of 18 ohms is used for R. The advancing pulses are of 15 microseconds in duration and 150 ma in amplitude. A voltage drop of 12 volts across the advancing winding is needed when the flux of the core is changing. With the minimum pulse width of 15 microseconds, the maximum speed of the delay line is about 60 kc. A pair of 6V6 tubes is capable of driving a delay line of 64 such units at this frequency, holding 32 binary digits. This form of delay line is being used at the Computation Laboratory of Harvard University as the principal memory device for the new computer under construction.

The speed of operation is now limited by the eddy current loss and the leakage inductance. When a selenium rectifier is used, the high capacity of the rectifier is also a limiting factor. By using germanium rectifiers and suitably dissipating the heat generated by the eddy current and hysteresis losses, the speed of operation can easily be pushed up to 120 kc. Thinner magnetic-tape materials are being currently developed. With sufficiently thin materials and germanium rectifiers, megacycle operation might be attainable before other ferromagnetic phenomena set in. Ferritic cores may be useful for high-frequency operation; but, so far, we have been unable to find any such material, with desirable hysteretic characteristic, to make this form of delay line operative.

A Receiver for Measuring Angle-of-Arrival in a Complex Wave*

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Summary—**Since November, 1945, the Electrical Engineering Research Laboratory of the University of Texas has been engaged in making propagation measurements of 3.2-cm waves. Results of some of these tests have been published, but a description of the equipment used has not been generally available.[1-10] This paper describes the latest arrangement of the phase-difference receivers, modifications of which were used in the tests previously described.**

This receiver provides data for separating two waves received simultaneously by means of signal-strength and phase-difference data received at three points. It is possible to measure phase difference between two 3.2-cm signals to an accuracy of 5° over a signal-strength range of 70 db and a signal-strength ratio between channels as high as 20 db. Absolute signal strength is measured to within 1 db, while relative signal strength is measured to 0.5 db.

I. Introduction

DURING the past four years, the Electrical Engineering Research Laboratory of The University of Texas has been working on a project for the Office of Naval Research of measuring the angle of arrival of microwaves. Preliminary considerations indicated a desired accuracy of measurement of ±0.01°. To obtain this accuracy in measuring angle of arrival, a receiver based upon the interferometer principle was designed and built. The principle of operation is shown in Fig. 1. The approaching wave is received by two antennas and amplified by two identical receiver channels. The outputs of the two receivers are compared in phase and the angle of arrival computed from the phase difference. At a frequency of 9,300 mc with a separation (h) of 10 feet, a measured phase difference of 6° is equivalent to an angle of arrival of about 0.01°. The method is ambiguous in intervals of about 0.6°, but this is resolved by coarser methods. The equipment as it was built and used would measure angle of arrival to about 0.01°, and absolute signal strength to 2 db.

While this receiver was quite useful in that it measured phase difference as well as signal strength, it did

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† The University of Texas, Austin, Texas.

[1] "Electrical properties of soil and water at centimeter wave length," *Nature*, vol. 161, p. 73; January 10, 1948.

[2] A. W. Straiton, W. E. Gordon, and A. H. LaGrone, "A method of determining the angle of arrival," *Jour. Appl. Phys.*, vol. 19, pp. 524–533; June, 1948.

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[8] A. W. Straiton, "An extension of MacFarlane's method of deducing refractive index from radio observations," *Jour. Appl. Phys.*, vol. 20, p. 228; February, 1949.

[9] A. W. Straiton, A. H. LaGrone, and H. W. Smith, "Comparison of measured and calculated microwave signal strength, phase, and index of refraction," to be published in Proc. I.R.E.

[10] A. H. LaGrone and A. W. Straiton, "The effect of antenna size and height above ground on pointing for maximum signal," Proc. I.R.E., vol. 37, p. 1438; December, 1949.

not completely solve the original problem for tropospheric propagation. The difficulty is found in the fact that a single plane wave could not be obtained for measurement. In the usual case, the received signal consisted of the direct wave between the transmitter and receiver plus one or more waves reflected from the earth, water, or atmospheric layers. To solve this difficulty it was necessary to obtain more information than can be obtained at two points, as from a third receiver placed between the original two as shown in Fig. 2. If the received signal is composed of two plane waves, as indicated, and the combined signals at the three receiving points are E_R, E_S, and E_T respectively, and the receiver indicates the phase-difference and signal-strength ratio between the signals as received, the angles of arrival of the two waves may be computed from the equations shown. These equations are developed in the literature.[7] With this in mind, a new receiver was built which would obtain the information necessary to make these computations. The purpose of this paper is to describe this receiver in a general manner as a source of information to those interested in other publications of this Laboratory, as well as to present the several novel features of this equipment.

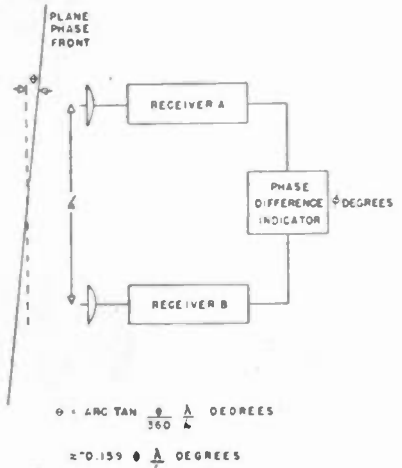

Fig. 1—Measurement of angle of arrival of a plane phase front.

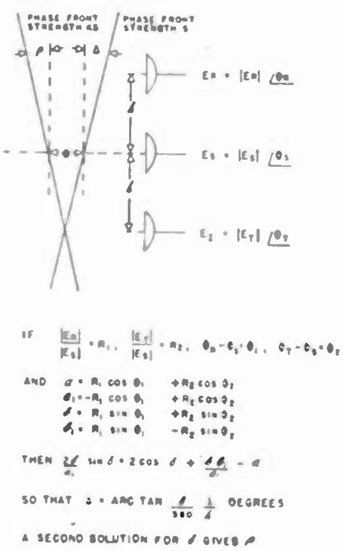

Fig. 2—Measurement of angles of arrival of two plane waves.

II. Circuit Arrangement

The basic block diagram of the receiver is shown in Fig. 3. The signal received in the center, or S, channel is the reference, and the signals received in the outside, or R and T channels, are compared to it in magnitude and phase.

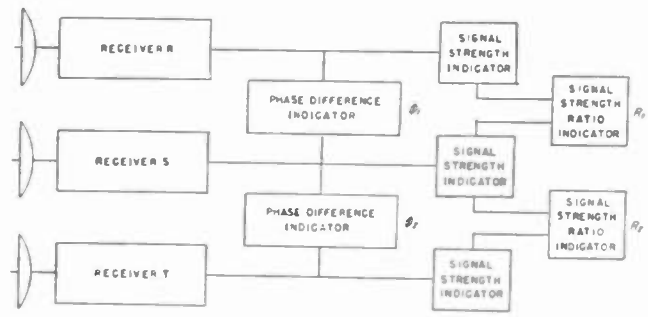

Fig. 3—Block diagram of a receiver for measuring angle of arrival of two plane waves.

A more detailed block diagram of part of the receiver is shown in Fig. 4. Because the signals are very weak as received, and no satisfactory amplifiers are available at 9,300 mc, it is necessary to convert the received signal to a more convenient frequency. A common local oscillator is provided with signals of constant relative phase to the three converters, so that the phase difference at 9,300 mc is maintained as the phase difference at the intermediate frequency of 30.5 mc. It is necessary to prevent interaction between the three receiving

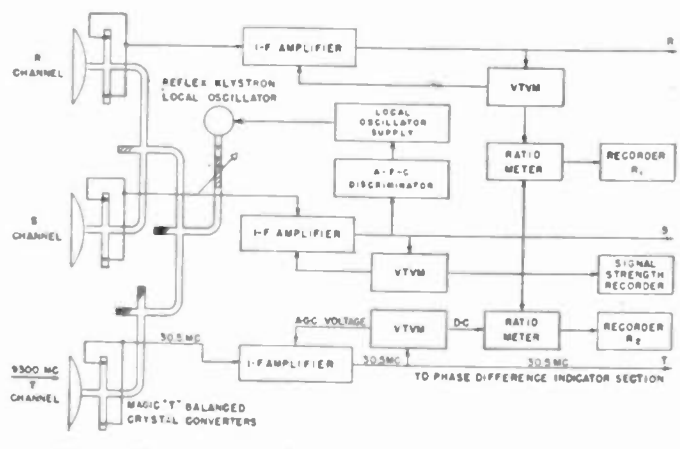

Fig. 4—Detailed block diagram of receiver; rf, IF, signal strength indicator sections.

channels through the common radio-frequency feed from the local oscillator to the converters. For this reason, balanced converters with magic-T feed are used. The isolation between the signal input to separate channels in the microwave portion of the receiver is of the order of 70 db, which is entirely sufficient.

The intermediate-frequency amplifiers employ five stages of 6AK5 tuned amplification with an over-all maximum gain of 110 db. It is necessary that all amplifiers produce the same phase shift at the same frequency, regardless of signal strength and gain. This is accomplished by making each stage individually tuned and adjusting all three amplifiers to have identically the same frequency response characteristics. This is done by using a frequency-modulated sweep-generator, cathode-ray oscillograph, and electronic switch so that frequency response of the three IF amplifiers can be compared simultaneously on the oscillograph screen. By properly adjusting the degeneration through the unbypassed portion of the cathode-bias resistors of the second and third stages, the variation in grid bias to control the gain of the IF amplifier produces no change in the phase shift of the IF amplifier.

While the bandwidth between half-power frequencies is 3 mc for the IF amplifiers, it is necessary to hold the intermediate frequency much closer than this if accurate signal-strength measurements are to be made. This is accomplished by holding the transmitter frequency to within ±100 kc and employing automatic-frequency control of the local oscillator of the receiver. This requires a discriminator circuit at 30.5 mc operating on the output of the *S*-channel IF amplifier. The output of the discriminator is amplified and used to control the repeller voltage of the 2K25 reflex klystron local oscillator. This circuit holds the intermediate frequency to within ±20 kc.

Part of the output of the IF amplifiers is rectified by three separate vacuum-tube voltmeters which give an indication of the signal strength in each channel. These circuits also provide the automatic gain control voltage for the IF amplifiers. The output of the *S* channel is recorded by an Esterline-Angus recording meter to indicate absolute signal strength. The action of the automatic gain control system is such that the output of the IF amplifiers is approximately proportional to the log of the received signal strength. The signal-strength meters thus are approximately linear in decibels. Vacuum-tube voltmeters, indicated as ratio meters, measure the voltage difference between the outputs of the *R*-to-*S* and *T*-to-*S* channels. These ratio meters thus measure the decibel differences in signal level between channels, with a scale approximately linear in decibels. The outputs of the two ratio meters are also recorded on two recording meters.

The phase-difference indicating equipment is particularly sensitive to frequency change. Therefore, the signals used to operate it are kept constant in frequency by a special converter circuit. This is shown in Fig. 5. The output of a 12-mc crystal oscillator is mixed with the signal at 30.5 mc from the *S* channel and the output at 42.5 mc taken. This is used as the mixing signal in each of three identical converters, one for each channel. The output frequency from these converters is 12

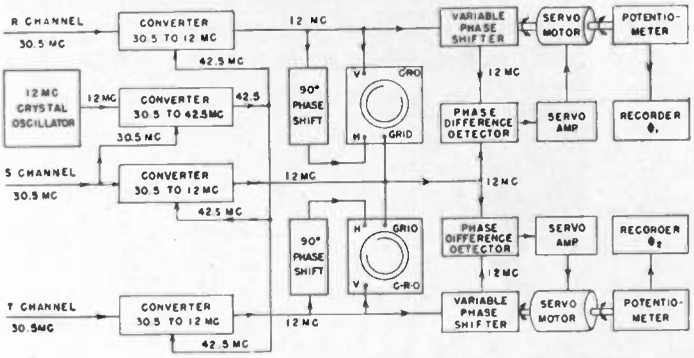

Fig. 5—Detailed block diagram of receiver—phase difference indicator section.

mc. If the 30.5-mc frequency changes, a corresponding frequency change occurs in the 42.5-mc signal, thus maintaining the output of the three channels at 12 mc. Since the same mixing signal is used in all three channels, the phase relation at 30.5 mc is maintained in the 12-mc signals.

The phase differences between the *R*-to-*S* and *T*-to-*S* channels are indicated visually by means of cathode-ray oscilloscopes. The 12-mc *R* and *T* signals are applied, respectively, to the vertical deflection plates of two cathode-ray tubes. The same signals are applied to the horizontal deflection plates through 90° phase-shifting circuits. As a result, circles are traced on the screens of the cathode-ray tubes. The signal in the *S* channel, after suitable peaking, is applied to the grids of both cathode-ray tubes, producing a blanked arc in each circle. The angular position of the blanked arc then indicates the phase difference between the two signals.

To record the phase difference, additional equipment is required. This includes a continuously variable, 360-degree, electrostatic phase shifter[11] and a phase detector. The phase detector gives zero output for two signals in phase. This serves as the error signal in a sermomechanism system, in that it causes a servo motor to operate, turning the phase shifter until the phase detector reaches a null. The position of the phase shifter then indicates the phase difference between the two signals. A 360-degree potentiometer on the phase shifter shaft provides a voltage proportional to the angular position which operates a recording meter to record the phase difference.

[11] This phase shifter is illustrated in F. E. Terman "Radio Engineers' Handbook," McGraw-Hill Book Co., Inc., New York, N. Y., p. 949, Fig. 56(e); 1943.

To obtain the desired accuracy, frequent calibration of the receiver is necessary. The calibration signal is provided by means of a conventional circuit consisting of a 2K25 reflex-klystron oscillator, a cavity wave meter, a bolometer and bridge, and a calibrated attenuator as shown in Fig. 6. This signal is then divided into two equal parts, each branch with a 10-db attenuator. One branch feeds the S channel through a 20-db directional coupler in the antenna feed. The other branch through a wave guide switch feeds either the R or T channel

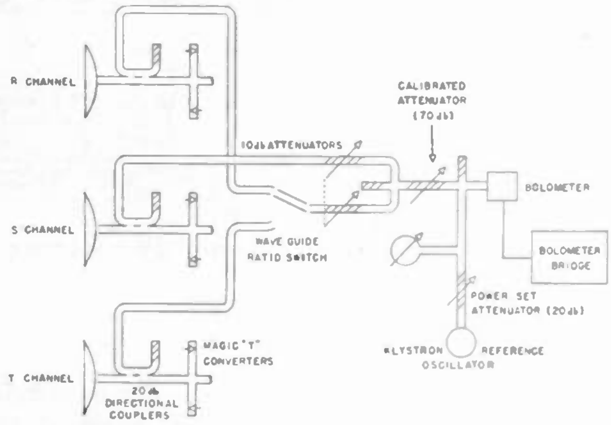

Fig. 6—Reference calibration equipment.

through a directional coupler. This provides means of calibrating the signal strength and ratio meters. In addition, a change in phase difference through the equipment would also be indicated. By using antennas of known gain, absolute signal strength may be measured.

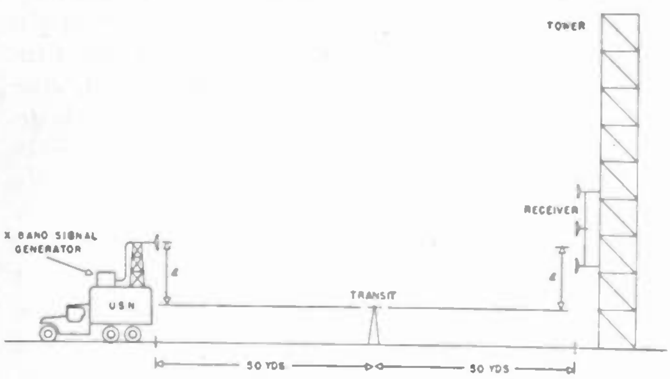

Fig. 7—Absolute angle calibration method.

Additional equipment is required for absolute calibration of phase differences. The method used is illustrated in Fig. 7. A test signal is provided on a portable mount, high enough above the ground to eliminate the effect of ground reflection. By means of a transit, the test signal antenna is placed at the same elevation as a point halfway between the antennas of two channels. Then the two channels are receiving signals of identical phase or zero phase difference and a phase calibration point is obtained. Additional calibration points are obtained by tilting the receiving antenna assembly about a horizontal axis perpendicular to the direction to the test signal. The tilt angle is accurately determined, and from this the phase-difference change introduced is computed and compared with the phase difference change indicated by the phase recorder.

III. Physical Arrangement

The physical arrangement of the equipment is shown in three photographs. All of the microwave circuits and the IF amplifiers are housed in a weather-proofed box,

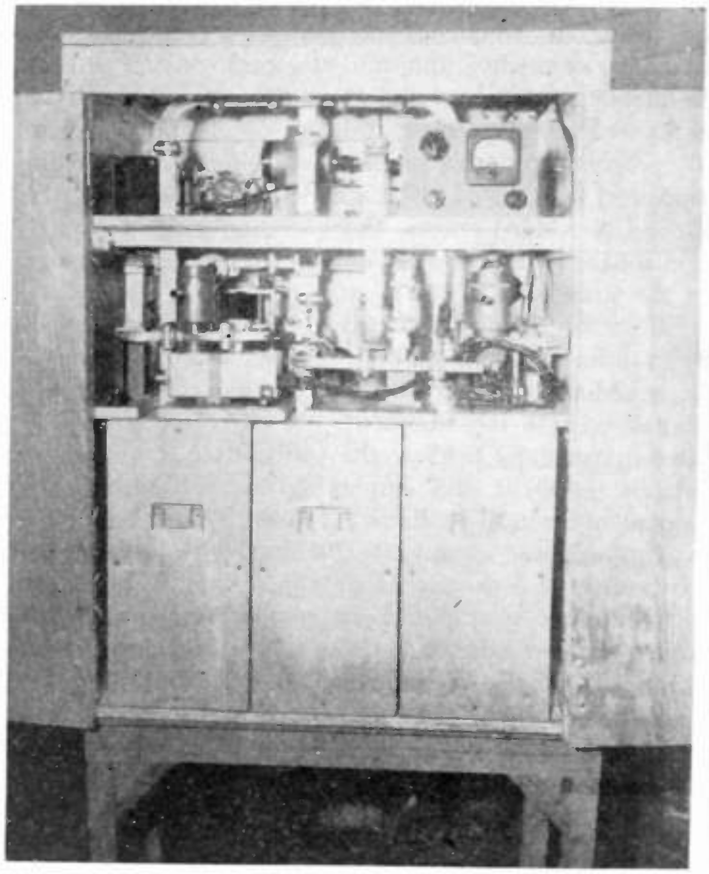

Fig. 8—Inside front view of the pantry.

called the "pantry" which is mounted between the lower two antennas in Fig. 9. Adjustment of oscillator cavities and crystal current in the mixers is made through the doors on the front of the pantry, shown in Fig. 8. The converters and IF amplifiers for each of the three channels are located in individually shielded boxes at the bottom.

The remaining portion of the receiver is located in relay racks, shown in Fig. 10. From the bottom to the top in the left rack are three power supplies; master power control panel; automatic-frequency-control and local oscillator supply unit; automatic-gain-control and signal-strength unit; and at the top, the 30.5- to 12-mc converter. From bottom to top of the right-hand rack are the line voltage regulator; power supply; calibration oscillator and bolometer bridge unit; calibration attenuator control unit; cathode-ray oscilloscope unit; and at the top, the phase-angle recorder unit. Not shown are the Esterline-Angus recording meters.

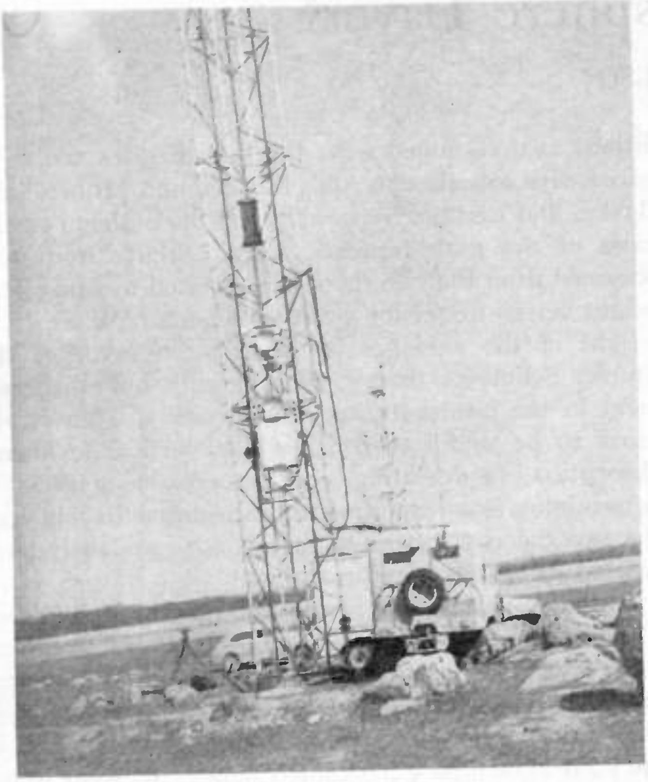

Fig. 9—The 60-foot tower and receiving truck.

In operation, the microwave equipment and three 18-inch parabolic antennas are mounted on an elevator frame which rides on the face of a 60-foot portable tower. The racks are mounted in a truck parked near the tower, shown in Fig. 9. A leveling servomechanism is employed to maintain constant the geometrical angle of the equipment to within 0.002°. The sensing element uses a level bubble and is located on the side of the elevator. The servodrive is just below the top antenna. The shorter tower is the absolute angle calibration tower mounted on top of a truck only partially visible.

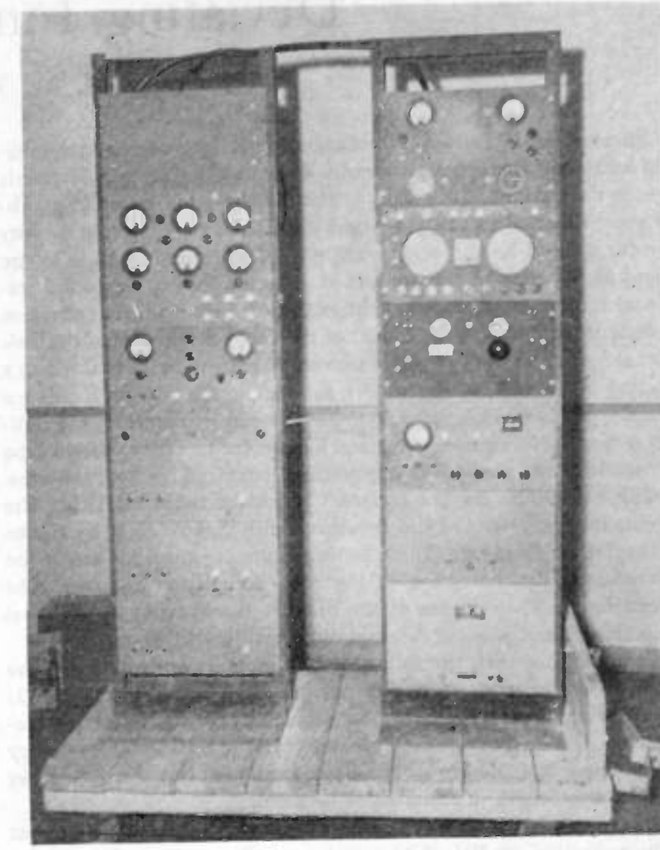

Fig. 10—Front view of the racks.

IV. Conclusion

With the equipment as described, phase difference may be measured to an accuracy of 5° over a signal-strength range of 70 db and a signal-strength ratio between channels as high as 20 db. Absolute signal strength is measured to within 1 db, while signal-strength ratio is measured to 0.5 db.

The Effect of the Lorentz Polarization Term on the Vertical Incidence Absorption in a Deviating Ionosphere Layer*

J. M. KELSO†

Summary—The effect of the Lorentz polarization term on the vertical incidence absorption of a radio wave in a deviating ionospheric layer is determined. This result is obtained by using a double parabola approximation to the Chapman distribution of electron density as a function of height, and a single parabola approximation to the height distribution of the product of electron density times the collisional frequency. A constant times the logarithm of the reflection coefficient divided by the product of the scale height times the collisional frequency at the level of maximum ionization is obtained as a function of the ratio of the wave frequency to the vertical incidence critical frequency. This is compared with a similar result for the Sellmeyer theory of dispersion as given by Hacke. The results for a type of "nondeviating region" absorption are compared for both theories.

The expression for the apparent height of reflection using the Lorentz theory is derived and compared with that obtained by Hacke for the Sellmeyer theory. These latter results are given for use in the experimental determination of the scale height in the layer. The determination of the value of the collisional frequency at the level of maximum ionization is discussed for both theories.

In all of this work the following assumptions are made: (1) the region is of Chapman form, with all the attendant restrictions; (2) the earth's magnetic field may be neglected; (3) the operating frequency is assumed to be much greater than the collisional frequency wherever appreciable absorption occurs; and (4) the absorption per vacuum wavelength is assumed to be small.

It is concluded that, with sufficient sensitivity in the measurement of the reflection coefficient, it may be possible to use this material in deciding whether the Lorentz or Sellmeyer theory of dispersion should be used in ionospheric calculations.

I. Introduction

A NUMBER of workers have considered the question of whether the electric polarization of the ionosphere should be included in ionospheric calculations. In the Lorentz theory of dispersion, the polarization is included, while in the more easily applied Sellmeyer theory, it is not. Darwin[1,2] has studied this matter from a purely theoretical viewpoint, while theoretical-experimental studies have been made by Ratcliffe,[3] Smith,[4] and Beynon,[5] considering the group paths and maximum usable frequencies for various conditions as determined from the two theories and compared with experiment. Also, Martyn and Munro,[6] and Booker and Berkner[7] have attacked the problem on the basis of the gyro frequency and Lorentz frequency obtained from the two theories as related to equivalent height-versus-frequency measurements. While the weight of the evidence is, perhaps, in favor of the simpler Sellmeyer theory, there is still some disagreement in the interpretation of the results. Thus it appears to be useful to consider the vertical incidence absorption in a deviating layer as a possible method for determining from experimental measurements which of the two theories applies. This has not previously been treated using the Lorentz theory.

A double parabola approximation to the well-known Chapman distribution[8] was used by Hacke[9] to compute the vertical incidence absorption of a radio wave reflected by a deviating ionosphere layer, using the Sellmeyer theory. For frequencies greater than one-half of the vertical incidence critical frequency, the value of the absorption obtained in this way agrees quite well with that obtained by Jaeger[10] using numerical integration of the exact Chapman relation. A similar treatment using the customary single parabola distribution differed greatly from Jaeger's results, indicating that this approximation would be invalid as far as absorption is concerned. The purpose of the present work is to apply the treatment used by Hacke to the vertical incidence absorption including the Lorentz term.

A number of restrictions must be considered in the application of the material given here. Since the approximations are based on the Chapman distribution, all of the limitations on the use of that distribution apply. In addition, the following assumptions are made: (1) the angular operating frequency is very much greater than the collisional frequency where appreciable absorption takes place; (2) the earth's magnetic field is neglected; and (3) the absorption per vacuum wavelength is assumed to be small.

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[9] J. E. Hacke, Jr., "An approach to the approximate solution of the ionospheric absorption problem," Proc. I.R.E., vol. 36, pp. 724–728; June, 1948.

[10] J. C. Jaeger, "Equivalent path and absorption in an ionospheric region," *Proc. Phys. Soc.*, vol. 59, pp. 87–96; January, 1947.

II. Summary of Introductory Work

Chapman showed that the electron density as a function of height in a Chapman region is given by

$$N = N_m Ch(x) \tag{1}$$

where

$$Ch(x) = \exp \tfrac{1}{2}(1 - x - \exp(-x))$$
$$x = (h - h_m)/H - \ln \sec \chi; \tag{2}$$

in which

N = the electron density

N_m = the maximum value of the electron density in the layer

H = the scale-height of the atmosphere in the region where the ionization is produced

h_m = the height at which N is a maximum when $\chi = 0$

h = the height at which the ionization is being considered

χ = the sun's angular distance from the zenith.

Equation (2) was approximated by Hacke by two parabolas: $P_1(x)$, used for the region contained between the level of maximum ionization and the height of the lower inflection point of (2); and $P_2(x)$, used for the region between this latter level and the level $x_2 = -2.7811$. The quantity x_2 is the value of x for which the second parabola, $P_2(x)$, becomes zero. Thus, $x_2 = -2.7811$ defines the term "bottom of the layer" as used in the remaining parts of this work.

$$P_1(x) = 1 - \frac{x^2}{T^2}; \qquad x_1 < x < 0; \tag{3}$$

$$P_2(x) = A^2(x - x_2)^2; \quad x_2 < x < x_1; \tag{4}$$

where $T = 1.848$, and $A = 0.4792$, are parameters adjusted to fit (2); and $x_1 = -1.317$ is the negative point of inflection of (2).

The product, $Ch(x)e^{-x}$, which appears in the absorption coefficient below, was approximated by the parabola

$$P_3(x) = a_0 + a_1 x + a_2 x^2, \quad x_3 < x < 0; \tag{5}$$

where $a_0 = 0.7055$, $a_1 = -2.382$, and $a_2 = -1.1696$ are parameters used in the curve fitting, and $x_3 = -2.299$ is the negative root of $P_3(x) = 0$. For values of $x < x_3$, the parabola $P_3(x)$ is negative, and thus the product of electron density times collisional frequency is meaningless in our approximation for such values of x. Consequently, integrations of quantities containing $P_3(x)$ will have as a lower limit the value $x = x_3$ rather than $x = x_2$, which latter value represents the bottom of the layer. As a result of this, the theory will show some possible reflections for which the absorption is given as zero. This anomaly occurs, however, only for values of the frequency such that the angular frequency is no longer greater than the E-region collisional frequency, and hence, for which the present theory is not valid.

The ratios $N/N_m = Ch(x)$, and $N\nu/(N_m \nu_m) = Ch(x)e^{-x}$, where ν_m is the value of ν at the level $x = 0$, are plotted as functions of x in Fig. 1. The parabolic approximations $P_1(x)$, $P_2(x)$, and $P_3(x)$ are indicated on the same figure as dashed curves.

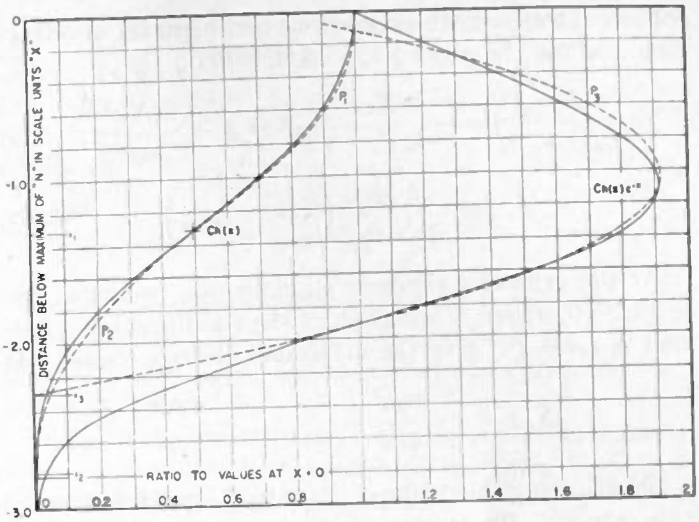

Fig. 1—Electron density and its product with collisional frequency as functions of height in scale units below point of maximum electron density. Solid curves, Chapman distributions; dashed curves, parabolic approximations.

The complex index of refraction M, neglecting the earth's magnetic field, is given by Mitra[11] as

$$M^2 = \left(\mu - \frac{ick}{p}\right)^2 = 1 + \frac{1}{\alpha + i\beta}, \tag{6}$$

where

$$\alpha = -\left(\frac{mp^2}{4\pi Ne^2} + \frac{1}{3}\right), \tag{7}$$

and

$$\beta = \frac{pm\nu}{4\pi Ne^2}. \tag{8}$$

The notation adopted by Mitra is as follows:

μ = the index of refraction

k = the absorption coefficient

i = the square root of minus one

c = the velocity of light in a vacuum

p = the angular frequency of the incident radio wave

m = the mass of an electron

e = the charge of an electron

N = the electron density

ν = the collisional frequency.

The term $\frac{1}{3}$ in (7) is the Lorentz polarization term; its inclusion marks the Lorentz theory of dispersion, its omission, the Sellmeyer theory.

III. Index of Refraction, Absorption Coefficient, and Reflection Height

The following derivation will be carried out in a parallel fashion, using the subscripts L and S to denote the Lorentz and the Sellmeyer theories, respectively.

Equating real and imaginary parts of the two sides of (6) and assuming $\mu^2 \gg c^2k^2/p^2$, and $p^2 \gg \nu^2$, we obtain the

[11] S. K. Mitra, "The Upper Atmosphere," The Royal Asiatic Society of Bengal, Calcutta, India; 1947.

following well-known expressions for the index of refraction and for the absorption coefficient:

$$3\left(\frac{\mu_L^2 - 1}{\mu_L^2 + 2}\right) = \frac{-4\pi N_L e^2}{mp^2}, \quad \mu_s^2 = 1 - \frac{4\pi N_s e^2}{mp^2}; \tag{9}$$

$$k_{L,s} = \frac{-p}{2c}\frac{\beta_{L,s}}{\alpha_{L,s}}\left(\frac{1}{\mu_{L,s}} - \mu_{L,s}\right). \tag{10}$$

At the critical frequency p_c, reflection occurs at the level $x=0$, where $N=N_m$. Since the condition for reflection is $\mu=0$, (9) give the maximum electron density as

$$N_{mL} = \frac{3}{2}\frac{mp_c^2}{4\pi e^2}, \qquad {}_{ms} = \frac{mp_c^2}{4\pi e^2}.$$

Substituting this value of N_m into (1) and introducing this into (9), the square of the index of refraction becomes

$$\mu_L^2 = \frac{1 - Ch(x)/R^2}{1 + \frac{1}{2}Ch(x)/R^2}, \qquad \mu_s^2 = 1 - \frac{Ch(x)}{R^2}; \tag{11}$$

where $R = p/p_o = f/f_o$ is the ratio of the operating frequency to the vertical incidence critical frequency.

Introducing the values of α, β, and μ into (10), the absorption coefficient may be written

$$k_L = \frac{\frac{3}{2}K_m Ch(x)e^{-x}}{\mu_L R^2[1 + \frac{1}{2}Ch(x)/R^2]^2}, \qquad k_s = \frac{K_m Ch(x)e^{-x}}{\mu_s R^2}; \tag{12}$$

where $K_m = \nu_m/2c$.

From (11) it can be seen that the condition for reflection $\mu=0$ leads to the same result $Ch(x)=R^2$, for both the Lorentz and Sellmeyer theories. Using the parabolic approximations $P_1(x)$ and $P_2(x)$ in place of $Ch(x)$, the height of reflection x_0 is given as

$$x_0 = -T\sqrt{1-R^2}, \quad x_1 < x_0 < 0;$$

$$x_0 = x_2 + R/A, \quad x_2 < x_0 < x_1$$

for both theories.

IV. Nondeviating Region Absorption ($\mu = 1$)

When this problem was first attacked, it did not seem likely that the integration of the absorption coefficient given by (12) could be carried out for the Lorentz case, even using the approximations to the Chapman distribution. Thus, the following device was used as a means of obtaining a lower limit to the possible values of the deviating-region absorption. Since the results may be of value, despite the fact that the deviating-region absorption is later determined, the derivation and numerical results for the nondeviating case are given.

A. Sellmeyer Theory

If we put $\mu=1$ in the expression for the Sellmeyer absorption coefficient in (12), we obtain

$$k = \frac{K_m}{R^2}Ch(x)e^{-x}.$$

Using the parabola $P_3(x)$ as an approximation to $Ch(x)e^{-x}$; $\ln \rho = -\int k\,ds$ where ρ is the reflection coefficient and ds is an element of wave path length, is given by

$$\ln \rho = \frac{-2HK_m}{R^2}\int_{x_3}^{x_0}(a_0 + a_1x + a_2x^2)dx$$

which may readily be integrated to give

$$\ln \rho = \frac{-2HK_m}{R^2}\left[a_0(x_0 - x_3) + \frac{a_1}{2}(x_0^2 - x_3^2) + \frac{a_2}{3}(x_0^3 - x_3^3)\right]. \tag{13}$$

The quantity $\ln \rho/HK_m$ is plotted as a function of R in Fig. 2 as "nondeviating region" absorption.

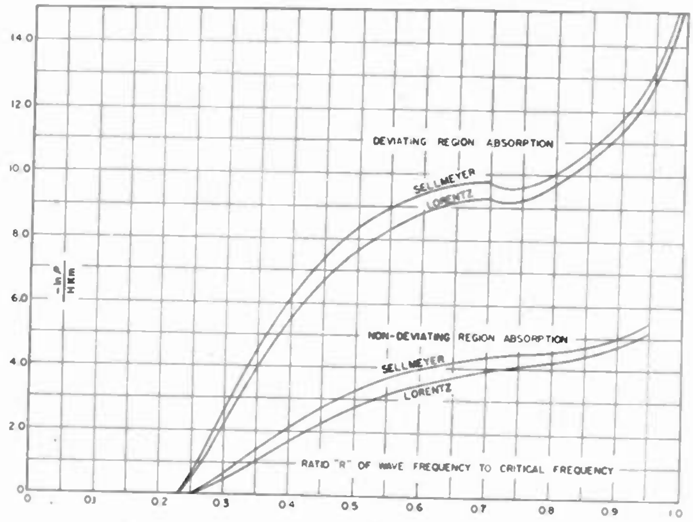

Fig. 2—ln ρ/HK_m as a function of R for the Lorentz and Sellmeyer theories and for both deviating region and "nondeviating region" absorption.

B. Lorentz Theory

Similarly, we set $\mu=1$ in the Lorentz form of (12), and replace $Ch(x)e^{-x}$ by $P_3(x)$. Then

$$\ln \rho = -12HK_mR^2\int_{x_3}^{x_0}\frac{(a_0 + a_1x + a_2x^2)dx}{[2R^2 + Ch(x)]^2}. \tag{14}$$

The introduction of the approximations $P_1(x)$ and $P_2(x)$ in place of $Ch(x)$ requires the separate treatment of three different cases: (1) the absorption in the upper region; (2) the absorption in the lower region when reflection occurs in the upper region; and (3) the absorption in the lower region when reflection takes place in that region. Obviously, if reflection occurs in the upper region, the absorption is given by the sum of parts (1) and (2) above. In the following, the symbol ρ will carry with it a numerical subscript indicating to which of these three cases it belongs. The integrations are to be taken over an interval extending from the bottom of the region being considered up to the point of reflection, or in case (2), up to the level x_1, which is the upper limit of the lower region. Because the $N\nu$ product, which is approximated by $P_3(x)$, is not defined in the present theory for the interval $x_2 < x < x_3$, the integration in the lower region has the lower limit x_3 instead of x_2, the actual level of the bottom of the region. For case (1), the parabola $P_1(x)$ is used in place of $Ch(x)$, and in cases (2) and (3), the parabola $P_2(x)$ is used. Making these substitutions in (14), we have,

$$\ln \rho_1 = -12HK_mR^2T^4 \int_{x_1}^{x_0} \frac{(a_0+a_1x+a_2x^2)dx}{[(2R^2+1)T^2-x^2]^2} \quad (15)$$

$$\ln \rho_{2,3} = \frac{-12HK_mR^2}{A^4} \int_{x_2}^{x_1,x_0} \frac{(a_0+a_1x+a_2x^2)dx}{[2R^2+A^2(x-x^2)^2]^2}. \quad (16)$$

After making the transformation $y=2.7811+x$ in (16), each of these integrals may be written as the sum of three integrals, whose values have been tabulated by Peirce.[12]

Because of the substitution of the variable y in place of x, it is useful to transform $P_3(x)$ to $P_3(y)$:

$$P_3(x) = a_0 + a_1x + a_2x^2$$
$$= b_0 + b_1y + b_2y^2,$$

where

$$b_0 = -1.71617, \quad b_1 = 4.1236, \quad \text{and} \quad b_2 = -1.1696.$$

Then,

$$\ln \rho_1 = -12HK_mR^2T^4\left\{\frac{1}{2(\phi-x_0^2)}\left(\frac{a_0x_0}{\phi}+a_1+a_2x_0\right) - \frac{1}{2(\phi-x_1^2)}\left(\frac{a_0x_1}{\phi}+a_1+a_2x_1\right) + \frac{1}{4\sqrt{\phi}}\left(\frac{a_0}{\phi}-a_2\right)\ln\left[\frac{(\sqrt{\phi}+x_0)}{(\sqrt{\phi}-x_0)}\frac{(\sqrt{\phi}-x_1)}{(\sqrt{\phi}+x_1)}\right]\right\},$$
$$x_1<x_0<0; \quad (17)$$

where

$$\phi = T^2(2R^2+1)$$

$$\ln \rho_2 = \frac{-12HK_mR^2}{A^4}\left\{\frac{1}{2(\psi+y_1^2)}\left(\frac{b_0y_1}{\psi}-b_1-b_2y_1\right) - \frac{1}{2(\psi+y_3^2)}\left(\frac{b_0y_3}{\psi}-b_1-b_2y_3\right) + \frac{1}{2\sqrt{\psi}}\left(\frac{b_0}{\psi}+b_2\right)\tan^{-1}\frac{y_1}{\sqrt{\psi}} - \frac{1}{2\sqrt{\psi}}\left(\frac{b_0}{\psi}+b_2\right)\tan^{-1}\frac{y_3}{\sqrt{\psi}}\right\},$$
$$x_3<x_0<x_1; \quad (18)$$

$$\ln \rho_3 = -\frac{-12HK_mR^2}{A^4}\left\{\frac{1}{2(\psi+y_0^2)}\left(\frac{b_0y_0}{\psi}-b_1-b_2y_0\right) - \frac{1}{2(\psi+y_3^2)}\left(\frac{b_0y_3}{\psi}-b_1-b_2y_3\right) + \frac{1}{2\sqrt{\psi}}\left(\frac{b_0}{\psi}+b_2\right)\tan^{-1}\frac{y_0}{\sqrt{\psi}} - \frac{1}{2\sqrt{\psi}}\left(\frac{b_0}{\psi}+b_2\right)\tan^{-1}\frac{y_3}{\sqrt{\psi}}\right\},$$
$$x_3 < x_0 < x_1 \quad (19)$$

[12] B. O. Peirce, "A Short Table of Integrals," Third Rev. Ed., Ginn and Company, Boston, Mass.; 1929.

where

$$\psi = \frac{2R^2}{A^2}, \quad \text{and} \quad y_i = 2.7811 + x_i, \qquad (i = 0, 1, 3).$$

As mentioned above, (19) gives the value of $\ln \rho$ when reflection takes place in the lower region. If the wave is reflected in the upper region, then $\ln \rho$ is given by the sum of (17) and (18).

In Fig. 2 the quantity $\ln \rho/HK_m$ is plotted as a function of R for both the Lorentz and the Sellmeyer cases as nondeviating region absorption.

V. Deviating Region Absorption ($\mu=\mu$)

In this case we introduce our approximations directly into the absorption coefficient as given in (12) without any further simplifications. Judging on the basis of the numerical work of Jaeger,[10] the Sellmeyer case is, and the Lorentz case should be, a close approximation to the exact solution of the absorption problem when the frequency is greater than one-half of the vertical incidence critical frequency.

A. Sellmeyer Theory

This is the case solved by Hacke,[9] and for which he obtained,

$$\ln \rho_1 + \ln \rho_2 = -2HK_m\left\{\frac{(\theta_1-\theta_3)}{A}\left[\frac{(a_0+a_1x_2+a_2x_2^2)}{R}+\frac{a_2R}{2A^2}\right] - \frac{(\mu_1-\mu_3)}{2A^2}[2a_1+3a_2x_2] - \frac{a_2}{2A^2}(\mu_1x_1-\mu_3x_3) + \frac{T}{R}\left[a_0+\frac{a_2x_0^2}{2}\right]\ln\frac{x_0}{x_1+TR\mu_1} - T^2\mu_1\left[a_1+\frac{a_2x_1}{2}\right]\right\},$$
$$x_1<x_0<0; \quad (20)$$

$$\ln \rho_3 = -2HK_m\left\{[(\pi/2-\theta_3)/A][(a_0+a_1x_2+a_2x_2^2)/R + \frac{a_2R}{2A^2}] + \left[\frac{\mu_3}{2A^2}(2a_1+a_2\{x_3+3x_2\})\right]\right\}$$
$$x_3<x_0<x_1; \quad (21)$$

where

$$\mu_1 = \sqrt{1-(1-x_1^2/T^2)/R^2},$$

$$\mu_3 = \sqrt{1-A^2(x_3-x_2)^2/R^2},$$

$$\theta_1 = \cos^{-1}\mu_1, \qquad \theta_3 = \cos^{-1}\mu_3,$$

and where the subscripts on ρ have the same meanings as in the previous section.

B. Lorentz Theory

When we introduce the three parabolic approximations into the Lorentz form of the absorption coefficient as given by (12), with μ_{2L} given by (11), and integrate over the appropriate ranges, we obtain for the three cases previously defined:

$$\ln \rho_1 = -3\sqrt{8}\, HK_m R^2 T^4 \int_{x_1}^{x_0} \frac{(a_0 + a_1 x + a_2 x^2)dx}{\sqrt{(T^2(R^2-1)+x^2)(T^2(2R^2+1)-x^2)^3}}, \quad (22)$$

$$\ln \rho_{2,3} = -3\sqrt{8}\, HK_m R^2 \int_{x_2}^{x_1,x_0} \frac{(a_0 + a_1 x + a_2 x^2)dx}{\sqrt{\{R^2 - A^2(x_2-x)^2\}\{2R^2 + A^2(x_2-x)^2\}^3}}. \quad (23)$$

Each of these integrals may be written as the sum of three separate integrals. When this is done, the integral of (22), after considerable algebraic manipulation, may be reduced to recognizable elliptic integral combinations by making the following change of variable:

$$x^2 = T^2(2R^2+1)\cos^2\phi + T^2(1-R^2)\sin^2\phi.$$

Using the relations given by Jahnke and Emde,[13] this expression may be written in terms of incomplete elliptic integrals of the first and second kind, $E(\phi, k)$, and $F(\phi, k)$, respectively;

$$\ln \rho_1 = -\sqrt{8}\, HK_m T^2 \Bigg\{\left[\frac{a_0}{\sqrt{T^2(2R^2+1)}} + \frac{a_2 T(1-R^2)}{\sqrt{2R^2+1}}\right][F(\phi_0, k) - F(\phi_1, k)]$$
$$+\left[\frac{a_0}{\sqrt{T^2(2R^2+1)}} + a_2 T\sqrt{2R^2+1}\right]\Bigg[E(\phi_1, k) - E(\phi_0, k) + \frac{\sqrt{1-k^2\sin^2\phi_1}}{\tan\phi_1} - \frac{\sqrt{1-k^2\sin^2\phi_0}}{\tan\phi_0}\Bigg] + a_1\left[\frac{1}{\tan\phi_1} - \frac{1}{\tan\phi_0}\right]\Bigg\};$$
$$x_1 < x_0 < 0; \quad (24)$$

where

$$k^2 = \frac{3R^2}{2R^2+1};$$

$$\phi_i = \sin^{-1}\sqrt{\frac{T^2(2R^2+1) - x_i^2}{3T^2R^2}}, \qquad (i = 0, 1).$$

Similarly, the integrals in (23) may be reduced by the sequence of changes of variables;

$$y = 2.7811 + x = x - x_2;$$

$$\theta = \tan^{-1}\frac{Ay}{\sqrt{2}\,R};$$

$$\phi = \sin^{-1}(\sqrt{3}\sin\theta);$$

to a usable form. Thus, we obtain

$$\ln \rho_2 = -\frac{HK_m}{A}\Bigg[\left(\frac{\sqrt{6}\,b_0}{R} - \frac{\sqrt{24}\,b_2 R}{A^2}\right)(E(\phi_1, \sqrt{1/3}) - E(\phi_3, \sqrt{1/3})) + \frac{2b_1}{A}(\cos\phi_3 - \cos\phi_1)$$
$$+\frac{\sqrt{24}\,b_2 R}{A^2}(F(\phi_1, \sqrt{1/3}) - F(\phi_3, \sqrt{1/3})\Bigg],$$
$$x_1 < x_0 < 0; \quad (25)$$

and

$$\ln \rho_3 = -\frac{HK_m}{A}\Bigg[\left(\frac{\sqrt{6}\,b_0}{R} - \frac{\sqrt{24}\,b_2 R}{A^2}\right)(E(\phi_0, \sqrt{1/3}) - E(\phi_3, \sqrt{1/3})) + \frac{2b_1}{A}(\cos\phi_3 - \cos\phi_0)$$
$$+\frac{\sqrt{24}\,b_2 R}{A^2}((F(\phi_0, \sqrt{1/3}) - F(\phi_3, \sqrt{1/3})\Bigg],$$
$$x_2 < x_0 < x_1; \quad (26)$$

where

$$\phi_i = \sin^{-1}\left\{\sqrt{3}\sin\left[\tan^{-1}\frac{A(x_i - x_2)}{\sqrt{2}\,R}\right]\right\}, \quad i = 0, 1, 3;$$

$b_0 = -1.71617$, $b_1 = 4.1236$, and $b_2 = -1.1696$.

The reflection coefficient for waves reflected in the lower region is then given by (26), and when reflection takes place in the upper region, the value of $\ln \rho$ is given by the sum of (24) and (25).

The quantity $\ln \rho/HK_m$ is plotted in Fig. 2 as a function of R for both the Lorentz and Sellmeyer theories as deviating region absorption.

VI. Scale Height and Collisional Frequency

Whether the Lorentz or the Sellmeyer theory is used, in order to assign a numerical value to $\ln \rho$, it would be necessary to evaluate both the scale height and the collisional frequency at the level of maximum ionization. In the case of each of these quantities, it is necessary that the required evaluation be made according to the particular dispersion theory being used for the absorption calculation, or be made in a manner independent of either dispersion theory.

[13] E. Jahnke and F. Emde, "Tables of Functions With Formulae and Curves," Fourth Edition, Dover Publications, New York, N. Y.; 1945.

Appleton and Beynon[14] have given a method whereby the scale height may be calculated from measurements of the apparent height of reflection as a function of frequency. This method may be applied using either the Lorentz or the Sellmeyer theory, as shown below.

The situation is different with regard to the collisional frequency. Appleton[15] has given a method for determining the average collisional frequency using the Sellmeyer theory. This method depends upon the following expression:

$$\ln \rho = -\frac{\bar{\nu}}{2c}(P' - P),$$

where P' is the group path and P is the phase path which Appleton was able to use to estimate the average value $\bar{\nu}$ of ν in the layer. This author has not been able to find a similar method for the experimental determination of $\bar{\nu}$ for the Lorentz case. However, from the absorption results given in previous sections, if one measures $\ln \rho$ at one frequency, and determines the scale height from experimental data as discussed below, then the collisional frequency at the level of maximum ionization can be calculated. From this information one should be able to predict the reflection coefficient at any other frequency for which the theory is valid.

A. Determination of the Scale Height

The method given by Appleton and Beynon[11] for the experimental determination of the scale height is as follows. The apparent height of reflection in kilometers can be expressed as

$$h' = h_0 + Hx_0', \tag{27}$$

where h_0 is the height in kilometers of the bottom of the ionosphere layer, as measured from the earth's surface; H is the scale height in kilometers; and the factor x_0' is the group height of reflection in scale units of the wave in the ionosphere itself, and is a function of R alone. If x_0' is calculated as a function of R, and h' is measured as a function of R, then the straight line plotted for h' as a function of x_0' will have h_0 as its intercept for x_0' equal to zero, and its slope will be equal to the scale height. It thus remains to compute the quantity x_0' for both the Sellmeyer and Lorentz theories.

(*a*) *Sellmeyer Theory.* Hacke[9] has already given the value of x_0' for the Sellmeyer theory. His result is

$$x_0' = \frac{\pi}{2}\frac{R}{A}, \qquad x_2 < x_0 < x_1; \tag{28}$$

$$x_0' = R\cos^{-1}\left\{\frac{\sqrt{x_1^2 - x_0^2}}{RT}\right\} + TR\ln\left\{\frac{x_0}{x_1 + \sqrt{x_1^2 - x_0^2}}\right\}, \quad x_1 < x_0 < 0; \tag{29}$$

where it was necessary to express x_0' in two parts, depending upon whether the wave was reflected in the upper or lower region. The numerical result of these two equations is plotted as a function of R in Fig. 3, Sellmeyer theory.

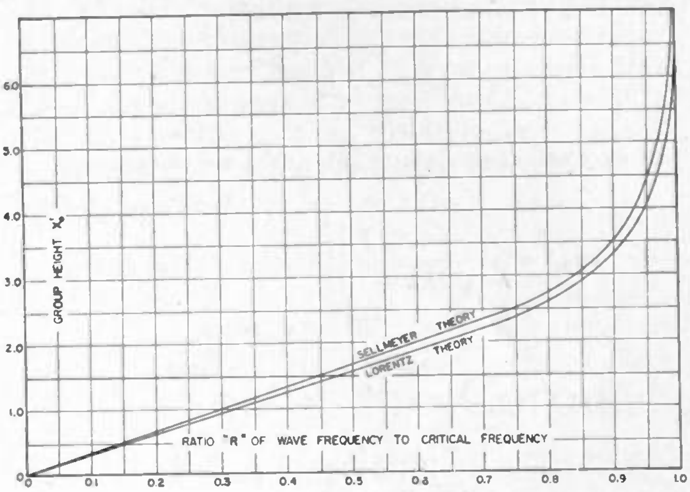

Fig. 3—x_0' as a function of R for the Lorentz and Sellmeyer theories.

(*b*) *Lorentz Theory.* Ratcliffe[3] has calculated the Lorentz value for the apparent height of reflection in the ionosphere, using the ordinary single parabola approximation. The method used here is the same as that of Ratcliffe, but the double parabola approximation is used. We note that the phase height of reflection, which will be denoted by x_p, is given by

$$x_p = \int_{\mu=1}^{\mu=0} \mu_L dx, \tag{30}$$

where μ_L is the index of refraction for the Lorentz theory, and is given by (11).

When the approximations $P_1(x)$ and $P_2(x)$ are substituted for $Ch(x)$, we have, as in the absorption calculations, three cases to consider. Making the appropriate substitutions, using the proper limits, and integrating, we have,

$$x_{p1} = \frac{3\sqrt{2}\,R^2T}{\sqrt{2R^2+1}}\Big[F(\phi, k) - D(\phi, k)\Big]_{\phi=\phi_1}^{\phi=\pi/2}, \quad x_1 < x_0 < 0;$$

where

$$k = \sqrt{\frac{3R^2}{2R^2+1}} \quad \text{and}$$

$$\phi_1 = \sin^{-1}\sqrt{\frac{T^2(2R^2+1) - x_1^2}{3T^2R^2}}$$

$$x_{p2} = \sqrt{\frac{2}{3}}\,\frac{R}{A}\left[D(\psi, \sqrt{1/3}) - \frac{\sin\psi\cos\psi}{\sqrt{1 - 1/3\sin^2\psi}}\right]_{\psi=0}^{\psi=\psi_1} \quad x_1 < x_0 < 0;$$

$$x_{p3} = \sqrt{\frac{2}{3}}\,\frac{R}{A}\left[D(\psi, \sqrt{1/3}) - \frac{\sin\psi\cos\psi}{\sqrt{1 - 1/3\sin^2\psi}}\right]_{\psi=0}^{\psi=\psi_0} \quad x_2 < x_0 < x_1;$$

[14] E. V. Appleton and W. J. G. Beynon, "The application of ionospheric data to radio communication problems; Part I," *Proc. Phys. Soc.*, vol. 52, pp. 518–533; July, 1940.

[15] E. V. Appleton, "A method of measuring the collisional frequency of electrons in the ionosphere," *Nature*, vol. 135, p. 618; April, 1935.

where

$$\psi_{0,1} = \sin^{-1}\left\{\sqrt{3}\sin\left[\tan^{-1}\frac{A(x_{0,1}-x_2)}{\sqrt{2}\,R}\right]\right\}.$$

Now the apparent height of reflection is related to the phase height of reflection as follows:

$$x_0' = x_p + R\frac{dx_p}{dR}. \tag{31}$$

If we evaluate x_0' using (31), then we obtain exact straight line function of x_0' for both the Lorentz and the Sellmeyer theories. This is true because it is not possible to express the ratio of x_0' obtained from the two theories as a constant which holds for all frequencies. However, a comparison of the ratios of the values of x_0' for the two theories at a number of frequencies shows that H obtained by the Lorentz theory is not less than 1.06 times the value of H obtained for the Sellmeyer theory.

If we now use this value of 1.06 for the ratio of the values of H as determined by the Lorentz and Sellmeyer

$$x_{0_1}' = \frac{-\sqrt{2}\,T}{-\sqrt{2R^2+1}}\left\{\Big[(4R^2+1)E(\phi,k) - (1-2R^2)F(\phi,k)\Big]_{\phi=\phi_1}^{\phi=\pi/2} - \frac{3R^2\sin\phi_1\cos\phi_1}{(2R^2+1)\sqrt{1-k^2\sin^2\phi_1}} + \frac{3R^2\cos^2\phi_1(T^2-x_1^2)}{\sqrt{1-k^2\sin^2\phi_1}\sqrt{T^2(2R^2+1)-x_1^2}\sqrt{x_1^2-T^2(1-R^2)}}\right\},$$

$$x_1 < x_0 < 0; \tag{32}$$

$$x_{0_2}' = \sqrt{\frac{2}{3}}\frac{R}{A}\left\{6\left[F(\psi,\sqrt{1/3}) - E(\psi,\sqrt{1/3}) + \frac{2\sin\psi\cos\psi}{\sqrt{1-1/3\sin^2\psi}}\right]_{\psi=0}^{\psi=\psi_1} - \frac{\sqrt{3}\,\dfrac{A(x_1-x_2)}{\sqrt{2}\,R}\cos\left[\tan^{-1}\dfrac{A(x_1-x_2)}{\sqrt{2}\,R}\right]}{\sqrt{1-3\sin^2\left(\tan^{-1}\dfrac{A(x_1-x_2)}{\sqrt{2}\,R}\right)}\left[1+\dfrac{A(x_1-x_2)}{\sqrt{2}\,R}\right]^2}\;\frac{\cos^2\psi_1}{(1-1/3\sin^2\psi_1)^{3/2}}\right.$$

$$x_1 < x_0 < 0; \tag{33}$$

$$x_{0_3}' = 6\sqrt{\frac{2}{3}}\frac{R}{A}\left[(F(\psi,\sqrt{1/3}) - E(\psi,\sqrt{1/3})) + \frac{2\sin\psi\cos\psi}{\sqrt{1-1/3\sin^2\psi}}\right]_{\psi=0}^{\psi=\psi_0}, \qquad x_2 < x_0 < x_1; \tag{34}$$

where k, ϕ_1, ψ_0, ψ_1, have the values given above.

When the wave is reflected in the upper region, the total apparent height in the layer itself is given by the sum of (32) and (33). From this result and (34), a curve is plotted in Fig. 3 showing the quantity x_0' as a function of R for the Lorentz theory. Using this curve, or the one for the Sellmeyer theory on the same figure, and a set of experimental data giving the apparent height of reflection as a function of frequency, one may determine the scale height of the layer and the height of the bottom of the layer, as discussed above.

VII. Conclusions

A glance at Fig. 2 shows that the use of a "nondeviating region" absorption, of the type discussed above, gives results for both theories for ln ρ/HK_m which are less than one-half of the actual values. Thus it appears that the assumption of this type of absorption would be useless for most purposes.

In considering the deviating region results, it appears that it would be profitable first to include the values of H from the two theories. Unfortunately, if we attempt to apply the method given in Section VI for the determination of H, we find that a given set of group-height-versus-frequency data cannot simultaneously be an theories, and take the ratio of log ρ/HK_m for the Lorentz theory at a particular value of R, to the corresponding result for the Sellmeyer theory, and plot these ratios as a function of R, we obtain the curves shown in Fig. 4. Thus it is seen that, for $R = 0.95$, the

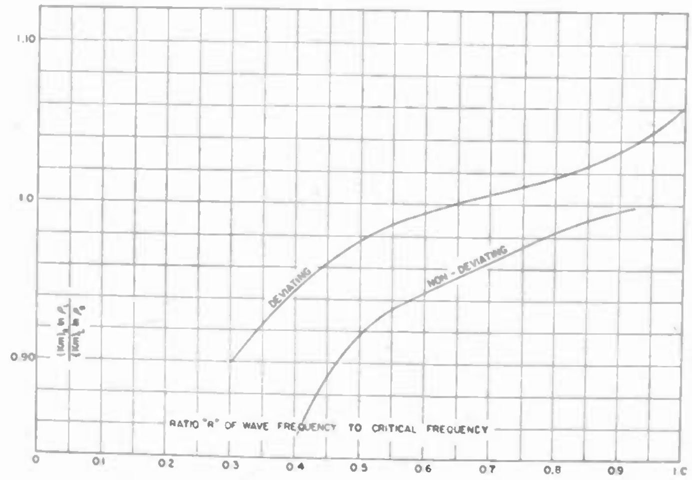

Fig. 4—The ratio of the Lorentz theory value of ln ρ/K_m to that of Sellmeyer theory shown as a function of R for both deviating region and "nondeviating region" absorption.

.orentz theory would predict a value of $\ln \rho/K_m$ which 3 more than 4 per cent greater than that predicted by he Sellmeyer theory. This 4 per cent is a minimum alue, since the choice of the scale height was the smallest possible ratio of the values for the two theories. (One measurement made at this laboratory gave the ratio of he scale heights as 1.14, which would increase the difference in $\ln \rho/K_m$.

In conclusion, then, it can be said that, with sufficient precision of measurement, and an independent determination of K_m, the above theory could be used as a possible method for determining whether the Lorentz or Sellmeyer theory should be applied to ionospheric problems.

VIII. Acknowledgments

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High-Voltage Stabilization by Means of the Corona Discharge Between Coaxial Cylinders*

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Summary—**The corona discharge between coaxial cylinders affords a practical means for stabilizing high voltages in a manner analogous to the stabilization of low voltages by the familiar glow-tube regulator. The corona regulator is particularly suitable for stabilizing voltages above several hundred volts at currents below one milliampere. It is accordingly well adapted for controlling the beam-focusing and accelerating potentials of cathode-ray beam devices such as oscilloscope, iconoscope, and kinescope tubes, of electron diffraction cameras, and for stabilizing Geiger tube voltage sources.**

Some of the theoretical aspects of the corona-discharge region as related to voltage stabilization are reviewed. Circuit design relationships are considered in detail and are developed to an extent sufficient for adapting particular corona regulator tube characteristics to specific performance requirements. Examples of constructional features and performance characteristics of typical high-voltage regulating tubes are presented.

Introduction

THE CORONA DISCHARGE between coaxial cylinders affords a practical basis for stabilizing voltages at currents below one milliampere, above the voltage limits of conventional glow-tube regulators. A degree of stabilization comparable to that obtainable from electronic regulating circuits may be realized in a simple and straightforward manner.

The design of voltage regulator tubes, based on the corona-discharge characteristic between coaxial cylinders, has been the subject of investigation at the Naval Research Laboratory for the past few years. Some early results were described in a previous NRL report.[1] The theory and performance of corona-discharge tubes are discussed more completely in a later NRL report,[2] which contained the basis for the specifications established for the Navy type BS-101 tubes now being manufactured by several sources. Some of the more general aspects of this report have appeared in a recent issue of *Electronics.*[3] Although the emphasis thus far has been on the manufacture of tubes for Radiac devices such as Geiger counter and scintillation counter survey instruments, the tubes are equally useful for a much wider field of application in connection with the control of high-voltage focusing and accelerating potentials of cathode-ray beam devices such as television tubes, oscilloscope tubes, electron microscopes, and X-ray tubes.

A simple theory describing the corona discharge between coaxial cylinders has been treated in several papers by various investigators. The relationships most pertinent to the present problem were covered in the works of Werner[4] and Loeb,[5] and an early description of the application of the self-sustained corona discharge to voltage regulation appeared in a brief note published by Medicus in 1933.[6] Although the earlier NRL reports described most of the general features of corona regulator tubes, little attention was given toward deriving rigorous circuit design relationships for a variety of applications. It is the purpose of this paper to present

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† Naval Research Laboratory, Washington, D. C.

[1] H. Friedman and H. F. Kaiser, "Geiger Counter Technique," NLR Report M-1800, Naval Research Laboratory, Washington, D. C., January, 1942.

[2] I. H. Blifford, R. G. Arnold, and H. Friedman, "Voltage Stabilization by Means of Corona Discharge Between Coaxial Cylinders," NLR Report N-3140, Naval Research Laboratory, Washington, D. C., June, 1947.

[3] I. H. Blifford, R. G. Arnold, and H. Friedman, "Corona-tube regulators for high voltages," *Electronics*, vol. 22, pp. 110–111; December, 1949.

[4] S. Werner, "Types of discharge in cylindrical tube counters," *Zeit. für Phys.*, vol. 90, p. 384; August, 1934.

[5] L. B. Loeb, "Fundamental Processes of Electrical Discharge in Gases," John Wiley and Sons, Inc., New York, N. Y., 1939.

[6] G. Medicus, "Maintenance of a constant potential of about 1000 volts by means of a positive corona discharge portable apparatus for the operation of tube and point counters," *Zeit. für Tech. Phys.*, vol. 14, p. 304; August, 1933.

circuit design relationships which permit the fitting of particular corona regulator tube characteristics to specific load-current and other performance requirements. As background for this paper, a brief review of previous work is presented, together with examples of constructional features and performance characteristics of some typical high-voltage regulating tubes.

Corona Discharge Between Coaxial Cylinders

When voltage from a low impedance source is impressed upon a pair of coaxial cylinders in a gas filling, consisting of a wire anode of small diameter and a comparatively large-diameter cathode, the field will be most intense about the wire. In the absence of external ionizing radiation, the current flow through the gas will at first be small. As the voltage is raised, a critical value will be reached V_{min}, at which a self-sustained corona is established. This is characterized by the formation of a luminous sheath about the anode and a discharge current measured in microamperes. As the impressed voltage is further raised above V_{min}, the discharge current increases continuously until the gap breaks into a complete glow.

The starting voltage in this type of tube structure filled with a monatomic or a diatomic gas is sharply defined. If the voltage supply is connected directly across the tube electrodes, a corona characteristic similar to Fig. 1 is observed. Below V_{min} the discharge is unstable. If ionizing radiation is supplied from an external source, the unstable corona can be stabilized

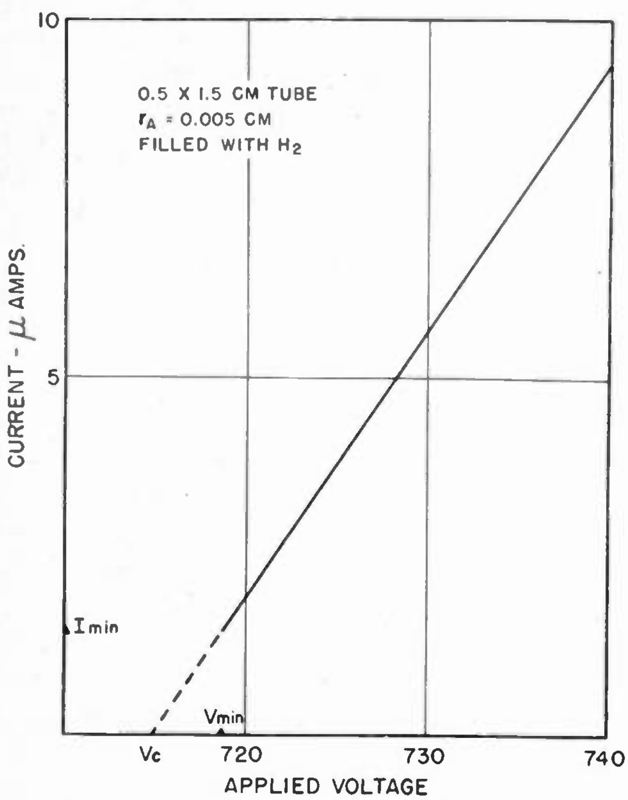

Fig. 1—Corona discharge characteristic.

down to V_C. Below this value no corona discharge is possible.

The slope of the corona characteristic has the dimensions of a resistance R_C and in the idealized case it can be written as

$$V_R = IR_C + V_C, \tag{1}$$

where V_C and R_C are constants and V_R is the voltage across the tube while passing a current I.

If a resistance is included in series with the tube and voltage supply (Fig. 2), the corona discharge tube be-

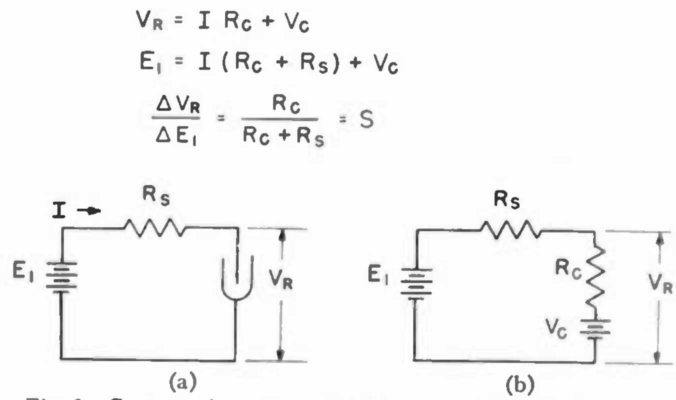

Fig. 2—Corona-tube voltage regulator circuit. (a) Basic circuit. (b) Equivalent circuit.

haves like a voltage stabilizer. The ratio of the change in voltage across the corona discharge to the change in applied voltage is given by

$$S = \frac{\Delta V_{\text{stabilized}}}{\Delta V_{\text{applied}}} = \frac{R_C}{R_C + R_S}, \tag{2}$$

where S defines a very simple form of stabilization constant. As far as input voltage fluctuations are concerned, this equation shows that the output voltage changes become smaller as R_S is increased. As R_S is increased, however, the applied voltage must be increased proportionately for the discharge to strike. The overvoltage necessary for firing the tube becomes large as R_S becomes greater than the load resistance R_L. By a proper choice of tube dimensions R_C can be reduced to 100,000 ohms, or less, which is sufficient for many practical applications.

Striking Voltage and Slope Resistance

The influence of tube dimensions and gas filling upon V_C and R_C was worked out by Werner[4] in connection with the discharge mechanism of counter tubes. This work was later extended by Loeb.[5]

Werner obtained the following expression for the corona starting voltage:

$$V_C = U \log \left[\left(r_c - \frac{nk}{P} \right) \frac{1}{r_a} - 1 \right], \tag{3}$$

where r_c and r_a are the cathode and anode radii, respectively, k is the electron mean free path at unit pressure, P is the actual pressure, and U is a critical potential diference that an electron must fall through during the last n free paths on its way to the anode.

Assuming r_a to be small compared to r_c, the corona resistance per unit length, according to Loeb, is given approximately by

$$R_C = \frac{Pr_c^2}{2KV_R} \log \frac{(r_c)}{r_a} \quad (4)$$

where K is the positive ion mobility at unity pressure and V_R is the voltage across the tube terminals (equation (1)).

It follows from this equation that R_C may be kept small by choosing a gas which produces the required corona voltage at a relatively low pressure and has a high positive ion mobility. Hydrogen offers the best combination of mobility and starting voltage-versus-pressure relationship. It is also evident from this equation that R_C may be reduced by increasing the ratio r_a/r_c. As this ratio is increased, however, the length of the corona region decreases. Finally, when the ratio of the coaxial cylinder radii reaches 0.37, or greater values, the corona region disappears completely and the discharge goes directly into the glow region.[7]

The slope resistance R_C may be further reduced by increasing the length of the tube and by combining within a single envelope a number of short discharge tubes with the electrode elements in parallel.

For a further discussion of the preceding equations, reference is made to the NRL report[2] which has been the principal source for the material thus far presented. It also contains additional curves that disclose effects produced by the gas filling and tube geometry upon the corona tube performance.[6] The following discussion will be confined to new experimental material and to recently completed circuit analysis.

Stability Requirements

To obtain stable performance from a corona voltage regulating tube, the total circuit capacitance in shunt with the tube must lie within well-defined limits. This is due to the influence of the tube discharge current upon the striking voltage as developed in the circuit. When the tube fires, the initial value of striking voltage is lowered by an amount which is dependent upon the ratio of the discharge pulse charge to the capacitance of the circuit in shunt with the tube. This may be expressed as

$$V_2 = E_S - \frac{q_0}{C} \quad (5)$$

where

q_0 = discharge pulse charge
C = capacitance in shunt with the tube
E_S = striking voltage
V_2 = voltage at termination of discharge pulse.

[7] F. W. Peek, "Dielectric Phenomena in High Voltage Engineering," McGraw-Hill Book Co., New York, N. Y., 1929.

When the total effective circuit capacitance C in shunt with a corona discharge tube is too small, the tube voltage during discharge will drop below the value necessary for maintaining the Townsend avalanche. The discharge will thereby become interrupted and will result in pulsing of the circuit current. Such pulsed operation may be avoided by adding sufficient capacitance in shunt with the tube to prevent V_2 from falling below the corona threshold value.

If the shunt circuit capacitance is excessive, the discharge pulse will be incapable of reducing the voltage in the circuit from the initial striking value E_S to an ultimate value within the corona region. The discharge will then be confined to the heavy current region of the firing characteristic and will result in IR drop quenching of the discharge by the series stabilizing resistance. In consequence, the discharge will again be interrupted.

In Fig. 3 are illustrated two distinct modes of operation obtained with a typical corona tube voltage-stabilizing circuit. For no externally added capacitance in shunt with the regulating tube, the discharge current

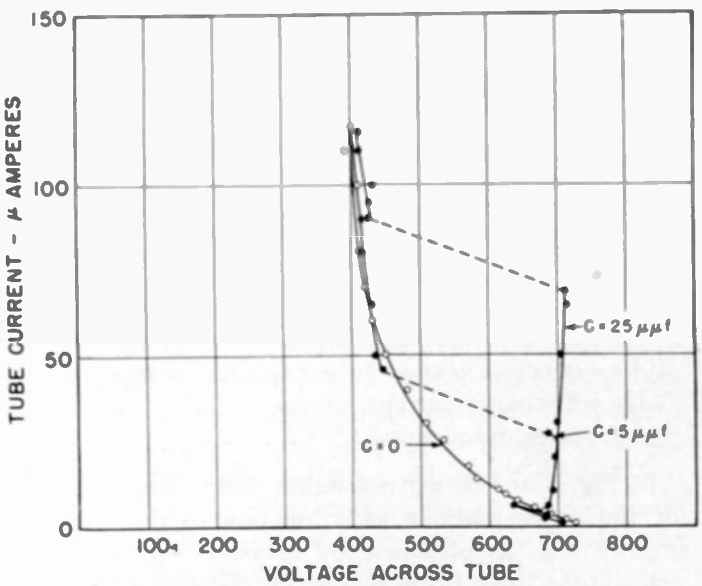

Fig. 3—Continuous and pulsed operation of corona regulator tube

has negative slope and is pulsed. This mode of operation is obviously unsuitable for voltage-stabilization purposes. The addition of sufficient capacitance, however, causes the discharge characteristic to revert to the positive slope, corona-discharge mode of operation, associated with a continuous flow of discharge current.

During pulsed operation, as a result of insufficient stabilizing capacitance, the charge per pulse remains constant and the repetition rate varies directly with the circuit current. This is illustrated in Fig. 4.

The limiting conditions necessary for stable corona operation may be conveniently expressed in terms of the ratio of charge per discharge pulse to the shunt circuit charge. Rearranging (5), there is obtained

$$\eta = \frac{q_0}{Q} = \frac{C_C}{C} = \frac{E_S - V_R}{V_R} \quad (6)$$

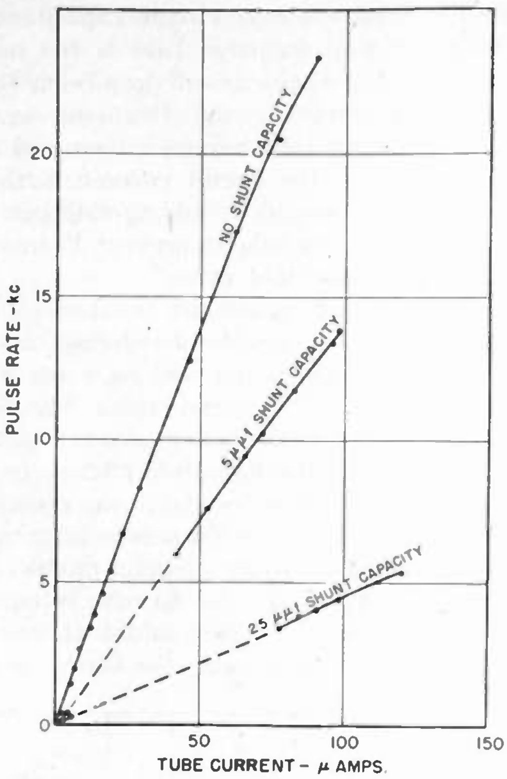

Fig. 4—Pulse rate versus corona-tube discharge current.

where

V_R = regulated voltage ($V_2 = V_R$, for stable operation)
E_S = striking voltage
q_0 = charge per pulse = I_{ave}/f
$Q = CV_R$
C = shunt circuit capacitance
C_C = effective corona tube capacitance = q_0/V_R
I_{ave} = discharge current, average
f = pulse frequency.

In Fig. 5 are shown maximum and minimum values for the charge ratio η as a function of the discharge current I_{ave}, as obtained by measurement of a particular tube type. From this figure, values for the shunt circuit capacitance limits may be computed with the aid of (6).

Upon satisfying the above requirements, a corona voltage stabilizer will be found to perform reliably, whether involving a single tube or various possible series tube combinations for obtaining higher voltages.

Circuit Design Criteria

The stabilization figure S thus far referred to is a convenient factor, but it is an oversimplified parameter inasmuch as it does not take into account the influence of load current upon the operation of a corona regulator.

Over-all circuit relationships may be derived as follows, starting with initial conditions as described by Hoyle and others:[8–10]

k = fractional change in supply voltage
R_C = corona tube slope resistance
R_S = series resistance
E_1 = applied voltage
$I_{C_{max}}$ = maximum corona tube current
$I_{C_{min}}$ = minimum corona tube current
$I_{L_{max}}$ = maximum load current
V_R = regulated voltage
V_C = corona threshold voltage.

For minimum corona tube current

$$E_1(1 - k) = V_{R_1} + R_S(I_{L_{max}} + I_{C_{min}}). \quad (7)$$

And for maximum tube current

$$E_1(1 + k) = V_{R_2} + R_S I_{C_{max}}. \quad (8)$$

Let

$$\Delta V_R = V_{R_2} - V_{R_1}.$$

From these relations the output-voltage stability coefficient β may be computed

$$\beta = \frac{\Delta V_R}{\Delta V_{R_1}} = \frac{R_c(I_{C_{max}} - I_{C_{min}})}{I_{C_{min}} R_C + V_C}. \quad (9)$$

From (1), (7), and (8) there also follows:

$$E_1 = \frac{V_C + I_{C_{min}} R_C + R_S(I_{L_{max}} + I_{C_{min}})}{1 - k}, \quad (10)$$

$$R_S = \frac{[\beta(1 - k) - 2k][V_C + I_{C_{min}} R_C]}{(1 + k)(I_{L_{max}} + I_{C_{min}}) - (1 - k)I_{C_{max}}}. \quad (11)$$

Equations (9), (10), and (11) may be reduced to normalized form through use of the defining identities,

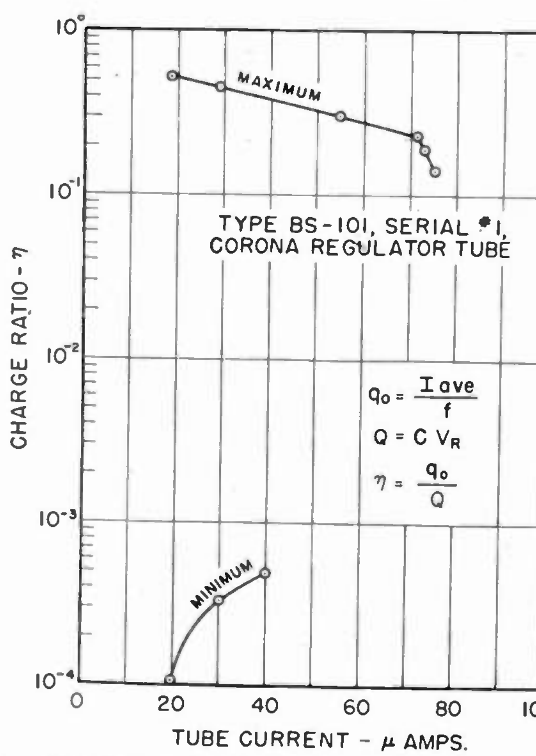

Fig. 5—Maximum and minimum charge ratio limits for stable operation versus corona-tube current.

[8] W. G. Hoyle, "Voltage regulators of the shunt type," *Rev. Sci. Instr.*, vol. 19, pp. 244–246; April, 1948.

[9] E. W. Titterton, "Some characteristics of glow-discharge voltage regulator tubes," *Jour. Sci. Instr.*, vol. 26, pp. 33–36; February, 1949.

[10] W. C. Elmore, "Electronics for the nuclear physicist," *Nucleonics*, vol. 2, p. 55; May, 1948.

$$\psi \equiv \frac{I_{C_{\min}}}{I_{C_{\max}}}, \qquad \alpha \equiv \frac{I_0}{I_{C_{\max}}},$$

$$I_0 \equiv \frac{V_C}{R_C}, \qquad h \equiv \frac{I_{L_{\max}}}{I_{C_{\max}}},$$

$$d \equiv \frac{R_C}{R_S}, \qquad \nu \equiv \frac{V_C}{E_1},$$

esulting in

$$\psi = \frac{1 - \beta\alpha}{1 + \beta}, \tag{12}$$

$$d = \frac{2 - (h + \psi + 1)(1 + k)}{(\alpha + \psi)[k(\beta + 2) - \beta]}, \tag{13}$$

$$\nu = \frac{1 - k}{1 + \left(\frac{1}{\alpha d}\right)[\psi(1 + d) + h]}. \tag{14}$$

Equations (12), (13), and (14) furnish a practical neans for computing E_1 and R_1 in terms of particular ube characteristics, load current, and stability requirenents.

Minimum Input Voltage Solution

In the preceding formulas, $I_{C_{\max}}$ has been used as an ndependent variable. A solution is accordingly provided which operates downwards from $I_{C_{\max}}$ on the orona slope-resistance characteristic. By rearranging erms and introducing one more defining identity,

$$\omega \equiv \frac{I_0}{I_{C_{\min}}},$$

a solution may be obtained working upwards from $I_{C_{\min}}$ on the slope-resistance characteristic. Such a solution will require the smallest value of input voltage to conform with the initial performance requirements.

Rewriting the previous expressions in terms of $I_{C_{\min}}$, here is obtained

$$h = \psi\left(\frac{I_{L_{\max}}}{I_{C_{\min}}}\right)$$

$$\alpha = \psi\omega,$$

whereby (12) becomes

$$\psi = \frac{1}{1 + \beta(1 + \omega)}. \tag{12a}$$

The use of this equation in combination with (13) and (14) furnishes the required solution.

Minimum Input Power Solution

A solution for E_1 and R_1 may be obtained for particular tube characteristics and regulation requirements, corresponding to greatest economy of input power, by determining the value of h which satisfies maximum efficiency conditions:

$$\text{Eff} = \frac{\text{maximum load power}}{\text{maximum input power}} = \frac{V_R I_{L_{\max}}}{E_1(1 + k)I_{C_{\max}}}. \tag{15}$$

$$\text{Eff} = \frac{hA - h^2B}{hC + D}; \frac{d\,\text{Eff}}{dh} = 0$$

$$A = \frac{2 - (1 - k)(1 + \psi)}{(\alpha + \psi)[k(\beta + 2) - \beta]} \tag{16}$$

$$B = \frac{1 + k}{(\alpha + \psi)[k(\beta + 2) - \beta]}$$

$$C = \frac{1 - (\alpha + \psi)B}{S\alpha}$$

$$D = \frac{\psi + \alpha L}{S\alpha}$$

$$L = \frac{2 - (1 + k)(1 + \psi)}{(\alpha + \psi)[k(\beta + 2) - \beta]}$$

$$S = \frac{(V_C + R_C\psi I_{C_{\max}})(1 - k)}{V_C(1 + k)}$$

which reduces to

$$h = -x \pm \sqrt{x(x + z)} \tag{17}$$

where

$$x = \psi\left[1 + \frac{\psi(1 + k)}{(k - 1)(1 + \alpha)}\right] - \frac{\alpha}{1 + \alpha}, \quad \text{and}$$

$$z = \left(\frac{1 - k}{1 + k}\right) - \psi.$$

The use of h from (17) in (13) and (14) leads to a solution for the initial conditions which requires minimum input power.

The preceding relationships are in a form suitable for design applications and may be readily expressed graphically. By means of either the design equations or graphs, it has been found possible to predict performance of corona-tube voltage-stabilizing circuits consistently to within 2 per cent of the physically measured values. This order of agreement also denotes the justification involved in replacing the discharge characteristic with equivalent fixed circuit elements for design purposes.

Tube Construction and Performance

Laboratory models of corona regulating tubes have been made in a wide variety of sizes, utilizing various electrode materials, gas fillings, and types of construction. Satisfactory tubes have been used employing brass cathode cylinders measuring 3 feet in length and ½ foot in diameter, for operation of 40,000-volt X-ray equipment. More recently, efforts have been directed towards the development of tubes of small physical dimensions. From this work, excellent tubes have been constructed in subminiature sizes, suitable for operation up to 2,000 volts.[11] One of these, constructed of chrome iron and a soft glass envelope, used a cathode $\frac{3}{16}$-inch long and ⅛-

[11] H. P. Gauvin and H. Friedman, "Subminiature Corona Regulator Tubes," NLR Interim Report 3700-286/49 Naval Research Laboratory, Washington, D. C., May 12, 1949.

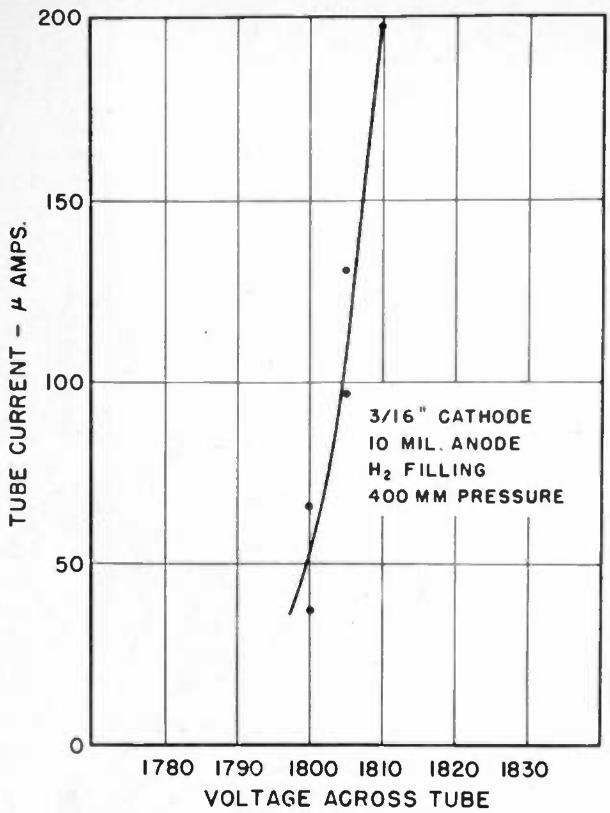

Fig. 6—Discharge characteristic of subminiature tube.

inch inner diameter. The maximum diameter of this tube was $\frac{3}{16}$ inch and its over-all length, when sealed off, was less than one inch. Fig. 6 shows the performance obtained for this tube. It regulates in the vicinity of 1,800 volts at tube currents up to 200 microamperes.

In Fig. 7 is shown a photograph of a production-type, 700-volt, corona regulator tube of miniature-type construction. Adjacent to it is shown a standard miniature type OB-2 tube. The anode connection in the corona tube is made to a cap located on top of the glass envelope and the cathode connection is made through pins in the 7-pin miniature base. This tube has a useful life well upwards of 1,000 hours at a regulating current of 50 microamperes. The filling consists of a mixture of hydrogen plus helium, and the tube is suitable for use over a nominal ambient temperature range of $-50°C$ to $+75°C$. The influence of temperature upon the operation of a tube of this type is shown in Fig. 8. The temperature coefficient, from this figure, is approximately 0.2 volt per degree centigrade and is equivalent to a voltage stability of 0.03 of 1 per cent per degree centigrade.

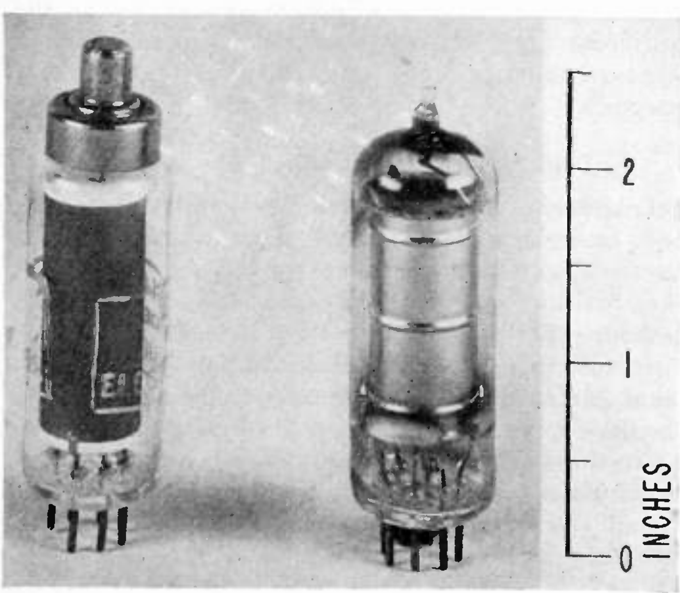

Fig. 7—Miniature-type voltage regulators BS-101 corona tube and OB-2 glow tube.

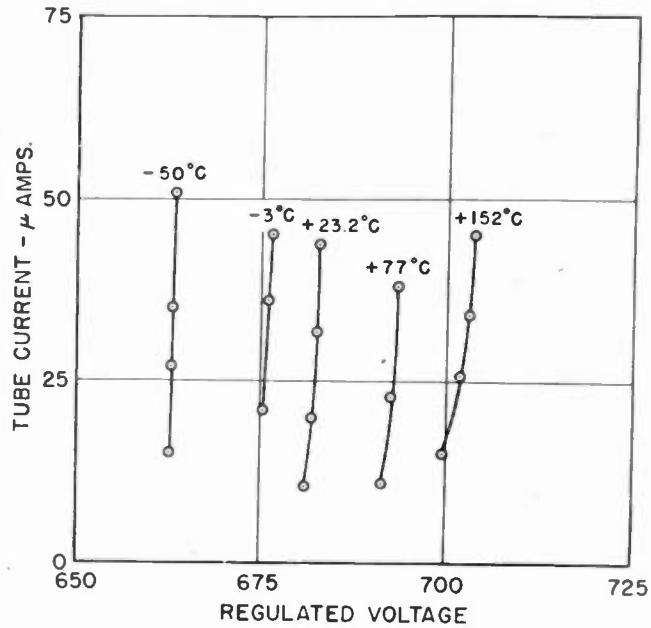

Fig. 8—Temperature influence upon discharge characteristic of miniature-type BS101 corona voltage regulator tube.

To obtain good performance from a corona regulator tube, regardless of the size or type of construction employed, the elements must be in coaxial alignment. Either an eccentricity in centering of the anode or nonparallelism of the cylinder axes will prevent the discharge from being uniformly distributed over the length and surface of the anode. Such a condition raises the slope resistance R_C and may result in abrupt discontinuities in the discharge characteristic. Coaxial cylinder alignment is therefore essential for efficient performance. When properly constructed with electrodes outgassed and suitably cleaned before filling, the coaxial-cylinder corona voltage stabilizer is capable of good dependability, long life, and a high degree of permanence.

Acknowledgments

Acknowledgment is due W. A. Nichols, of the Naval Research Laboratory, for his able assistance in obtaining most of the experimental data contained in this manuscript and for checking through the various mathematical derivations involved. The author is indebted also to H. Friedman, of the Naval Research Laboratory, for his valuable advice and stimulating discussions concerning many phases of the topics treated.

Correlation Functions and Spectra of Phase- and Delay-Modulated Signals*

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Summary—A delay-modulated signal may be regarded as the reponse of a delay modulator to the carrier of the signal. By using this oint of view a general expression for the correlation function of a elay-modulated signal is obtained. This expression is given in an operational form in which the operand is the correlation function of the arrier, and the operator is the correlation function of the delay nodulator. The general result is applied to the determination of the orrelation function of a delay-modulated signal having a periodic arrier, and, more particularly, to the determination of the correlaion function of a phase-modulated signal.

I. Introduction

DURING the past two decades, considerable attention[1–7] has been given to the subject of frequency spectra of phase-modulated signals. In early investigations it was generally assumed that the signal is of the form

$$v(t) = \cos(\omega_c t + \alpha_1 \cos \omega_1 t) \tag{1}$$

where ω_c represents the carrier frequency, ω_1 is an audio frequency, and α_1 is the amplitude of phase deviation. As is well known, the spectrum of such a signal consists of an infinite number of "spectral lines" separated from each other by ω_1 radians per second; the spectrum is symmetrical with respect to the carrier frequency $\omega = \omega_c$, and the amplitude of nth spectral line (from $\omega = \omega_c$) is a Bessel function of nth order of α_1.

In the more advanced analyses of the problem it is usually assumed that the modulating signal is made up of a finite number of sinusoidal components or tones. In other words, in the general expression for a phase-modulated signal

$$v(t) = \cos(\omega_c t - \theta(t)), \tag{2}$$

the modulating signal $\theta(t)$ is assumed to be of the form

$$\theta(t) = \sum_{n=1}^{N} \alpha_n \cos(\omega_n t + \beta_n), \tag{3}$$

where the α_n, β_n, and ω_n are specified constants. This type of modulation is commonly referred to as *multitone* phase modulation.

The assumption that the modulating signal is of the form represented by (3) is unsatisfactory in two respects. First, the expression for the spectrum of a multitone phase-modulated signal is far from being simple—particularly for intermediate values of N. Second, the assumption that $\theta(t)$ is a periodic or almost periodic function of time—as is implied by (3)—would not be justified in many practical cases. In most such cases the modulating signal is of a random nature and is describable only in statistical terms.

Since, in general, the modulating signal is of a random nature, it is appropriate to use a statistical approach to the problem of determining the spectrum of a phase-modulated signal. The purpose of this paper is to present a statistical approach which can be used not only for the solution of the problem stated above, but, more generally, for determining the correlation function or the spectrum of any *delay-modulated* signal. This type of signal is of the general form

$$v(t) = u(t - \mu(t)) \tag{4}$$

where $u(t)$, the carrier, is a random-periodic function[8] of time, and $\mu(t)$, the modulating signal, plays the role of a variable time delay.

It is evident that many of the commonly used forms of modulation may be regarded as special cases of delay modulation. For example, a phase-modulated signal is a special case of (4) wherein $u(t)$ is a sine wave

$$u(t) = \cos \omega_c t. \tag{5}$$

Similarly, a pulse-position-modulated signal may be regarded as a delay-modulated train of regularly spaced pulses. Furthermore, some types of modulation such as pulse-time modulation, may be regarded as a combination of delay modulation and amplitude modulation. In short, the class of signals represented by (4) is quite broad and includes as special cases many important types of modulated signals. The simplest of these is the phase-modulated signal.

The main reason for bringing into the picture the notion of the correlation function is that for the class of signals represented by (4) the expression for the correlation function is quite simple, whereas the corresponding expression for the power spectrum is relatively complicated. Since the latter is the Fourier trans-

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1 B. van der Pol, "Frequency modulation," Proc. I.R.E., vol. 18, pp. 1194–1206; July, 1930.

2 J. R. Carson and T. C. Fry, "Variable frequency electric circuit theory," *Bell Sys. Tech. Jour.*, vol. 16, pp. 513–540; October, 1937.

3 M. Kulp, "Spectra und klirrfactoren frequenz- und amplitudenmodulierter Schwingungen," *Elek. Nach. Tech.*, vol. 19, pp. 72–84 and pp. 96–109; 1942.

4 A. Bloch. "Modulation theory," *Jour. IEE* (London), part III, vol. 91, pp. 31–42; March, 1944.

5 A. S. Gladwin, "Energy distribution in the spectrum of a frequency-modulated wave," *Phil. Mag.*, vol. 35, pp. 787–802, December, 1944; and vol. 38, pp. 229–251, April, 1947.

6 L. J. Giacoletto, "Generalized theory of multitone amplitude and frequency modulation," Proc. I.R.E., vol. 35, pp. 680–693; July, 1947.

7 M. S. Corrington, "Variation of bandwidth with modulation index in frequency modulation," Proc. I.R.E., vol. 35, pp. 1013–1020; October, 1947.

8 A random-periodic signal is one whose amplitude probability distribution is a periodic function of time. This type of signal includes both stationary and periodic signals as special cases.

form of the correlation function[9] (Wiener-Khintchine relation), it will be sufficient in most cases to determine the correlation function of a delay-modulated signal. Then, if necessary, the power spectrum of the signal may be obtained from the correlation function by using the Wiener-Khintchine relation.

II. General Theory

The correlation function of a signal $v(t)$ is defined as the time-average value of the product $v(t)v(t+\tau)$. Thus, denoting the correlation function of $v(t)$ by the symbol $\psi_v(\tau)$, the definition of $\psi_v(\tau)$, reads

$$\psi_v(\tau) = \lim_{T\to\infty} \frac{1}{T}\int_0^T v(t)v(t+\tau)dt. \tag{6}$$

For stationary signals (6) may be replaced by an equivalent relation

$$\psi_v(\tau) = \overline{v(t)v(t+\tau)}, \tag{7}$$

where the bar indicates the ensemble average. More explicitly, the ensemble average of $v(t)v(t+\tau)$—and hence $\psi_v(\tau)$—is given by

$$\psi_v(\tau) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} vv'p(v, v')dvdv' \tag{8}$$

where $v=v(t)$, $v'=v(t+\tau)$, and $p(v, v')$ is the joint probability density of v and v'.

The standard approach to the determination of the correlation function of a stationary signal $v(t)$ consists in finding the joint probability density $p(v, v')$ and evaluating the double integral (8). The difficult part lies in the determination of $p(v, v')$. For instance, in the case of a delay-modulated signal

$$v(t) = u(t - \mu(t)), \tag{9}$$

one is usually given the requisite statistical information about $u(t)$ and $\mu(t)$, but not about $v(t)$. Deriving $p(v, v')$ from this information is generally a difficult problem.

In the case of delay-modulated signals, as well as in many other cases, the necessity for finding $p(v, v')$ may be avoided by using an approach based on a result given in the literature.[10] It will be seen that through this approach the correlation function of a delay-modulated signal can be expressed directly in terms of the available statistical information, specifically, the correlation function of $u(t)$ and the joint probability density of $\mu(t)$ and $\mu(t+\tau)$. In particular, for the case where $\mu(t)$ is a Gaussian variable it is found that the correlation function of $v(t)$ may be expressed in terms of only the correlation function of $u(t)$ and that of $\mu(t)$. In all cases, it is assumed that $u(t)$ and $\mu(t)$ are uncorrelated with each other.

The essence of the approach used in this paper is as follows. The given delay-modulated signal $v(t)$ is regarded as the ouput of a variable delay network Δ whose delay is controlled by and is equal[11] to the modulating signal $\mu(t)$ (Fig. 1(a)). The input to Δ is the carrier $u(t)$. In short, $v(t)$ is regarded as the response of Δ to $u(t)$.

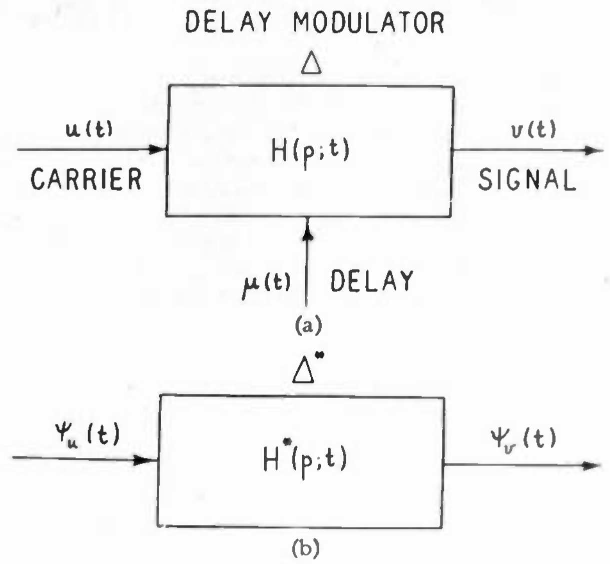

Fig. 1—(a) Process of delay modulation. (b) Relation between the correlation functions of the input and output of a delay modulator.

The above point of view makes possible an effective use of a simple relation between the correlation functions of the input and output of a variable network. Briefly, let $\psi_u(\tau)$ and $\psi_v(\tau)$ denote, respectively, the correlation functions of $u(t)$ and $v(t)$. Then, it can be shown[10] that $\psi_v(t)$ may be regarded as the response of a variable network Δ^*—which is related in a specified manner to Δ—to an input consisting of $\psi_u(t)$ (Fig. 1(b)).

As a preliminary to describing the relationship of Δ^* to Δ, it will be necessary to discuss briefly the so-called *system function*[12] of a variable network. The system function is defined as a function $H(j\omega;\, t)$ such that $H(j\omega;\, t)e^{j\omega t}$ represents the response of the network to $e^{j\omega t}$. In terms of $H(j\omega;\, t)$, the response $e_2(t)$ to an arbitrary input $e_1(t)$ may be written as

$$e_2(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} H(jw;\, t)E_1(j\omega)e^{j\omega t}d\omega \tag{10}$$

where $E_1(j\omega)$ is the Fourier transform of $e_1(t)$. This relation can be expressed compactly in an operational form

$$e_2(t) = H(p;\, t)e_1(t) \tag{11}$$

where the time-dependent operator $H(p;\, t)$ should be treated as an ordinary Heaviside operator; i.e., the variable t in $H(p;\, t)$ should be regarded as a constant

[9] S. O. Rice, "Mathematical analysis of random noise," *Bell Sys. Tech. Jour.*, vol. 23, pp. 282–332; July, 1944.

[10] L. A. Zadeh, "Correlation functions and power spectra in variable networks," Proc. I.R.E., vol. 38, pp. 1342–1345; November, 1950.

[11] More generally, the modulating signal and the time-delay may be related to each other by a linear operator. For example, in the case of frequency modulation the time delay is equal to the integral of the modulating signal. However, the assumption that the modulating signal and the time delay are equal to each other does not entail any loss in generality. All it means is that the analysis is conducted essentially in terms of the variable time delay, rather than in terms of the modulating signal.

[12] L. A. Zadeh, "Frequency analysis of variable networks," Proc. I.R.E., vol. 38, pp. 291–299; March, 1950.

arameter. For example, the system function of Δ (variable delay network) is

$$H(j\omega;\, t) = e^{-j\omega\mu(t)}. \qquad (12)$$

Thus, a delay-modulated signal (9) may be written as

$$v(t) = e^{-p\mu(t)}u(t). \qquad (13)$$

Now let $H^*(j\omega;\, t)$ denote the system function of Δ^*. Since $\psi_v(t)$ is the response of Δ^* to $\psi_u(t)$, it follows that

$$\psi_v(t) = H^*(p;\, t)\psi_u(t) \qquad (14)$$

or more explicitly,

$$\psi_v(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} H^*(j\omega;\, t)S_u(\omega)e^{j\omega t}d\omega \qquad (15)$$

where $S_u(\omega)$ is the Fourier transform of $\psi_u(t)$; that is, $S_u(\omega)$ is the power spectrum of $u(t)$.

The above relation involves a system function $H^*(j\omega;\, t)$ which is as yet unknown. The general expression for $H^*(j\omega;\, t)$ is given in the literature;[10] it is

$$H^*(j\omega;\, \tau) = \lim_{T\to\infty} \frac{1}{T}\int_0^T H(j\omega;\, t)H(-j\omega;\, t+\tau)dt, \qquad (16)$$

which means that $H^*(j\omega;\, \tau)$ is the time-average value of the product $H(j\omega;\, t)H(-j\omega;\, t+\tau)$. In view of the form of this relation, $H^*(j\omega;\, \tau)$ is termed the correlation function of $H(j\omega;\, t)$ or, simply, the correlation function of the network. The relation (16) may then be expressed as a statement to the effect that *the system function of* Δ^* *is the correlation function of* Δ. In the case of delay modulation, $H(j\omega;\, t)$ is given by (12) and hence the expression for $H^*(j\omega;\, \tau)$, (16), reduces to

$$H^*(j\omega;\, \tau) = \lim_{T\to\infty} \frac{1}{T}\int_0^T \exp\{j\omega[\mu(t+\tau) - \mu(t)]\}dt. \qquad (17)$$

The above relations may be summarized in the form of a general result: *The correlation function of a delay-modulated signal*

$$v(t) = u(t - \mu(t)) \qquad (18)$$

in which the carrier $u(t)$ and the modulating signal $\mu(t)$ are uncorrelated with each other, is given by the operational relation

$$\psi_v(\tau) = H^*(p;\, \tau)\psi_u(\tau) \qquad (19)$$

where τ plays the role of t, the operand $\psi_u(\tau)$ is the correlation function of $u(t)$, and the operator $H^*(p;\, \tau)$ is the time-average value of the quantity exp $\{p[\mu(t+\tau) - \mu(t)]\}$.

Of particular interest in practice is the case where $\mu(t)$ is stationary. For this case (17) may be replaced by the ensemble average of exp $\{j\omega[\mu(t+\tau)-\mu(t)]\}$. For convenience, let $\mu=\mu(t)$ and $\mu'=\mu(t+\tau)$. With this notation, the ensemble average of exp $\{j\omega[\mu(t+\tau) - \mu(t)]\}$—and hence the expression for $H^*(j\omega;\, \tau)$—becomes

$$H^*(j\omega;\, \tau) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{j\omega(\mu'-\mu)}p(\mu',\, \mu)d\mu d\mu' \qquad (20)$$

where $p(\mu,\, \mu')$ represents the joint probability density of μ and μ'.

Comparing this relation with the expression for the so-called *characteristic function*[9] of $p(\mu,\, \mu')$, which is

$$Q(j\omega;\, j\omega') = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{j\omega\mu+j\omega'\mu'}p(\mu,\, \mu')d\mu d\mu', \qquad (21)$$

it follows that

$$H^*(j\omega;\, \tau) = Q(-j\omega,\, j\omega). \qquad (22)$$

In other words, *for the case of stationary $\mu(t)$ the correlation function of the delay modulator $H^*(j\omega;\, \tau)$ is given by* (22), *where $Q(j\omega,\, j\omega')$ is the characteristic function of the joint probability density of $\mu(t)$ and $\mu(t+\tau)$.*

An explicit expression for $Q(j\omega,\, j\omega')$ is available for the case most frequently encountered in practice, namely, the case of Gaussian $\mu(t)$. For this case it can readily be shown[9] that

$$Q(j\omega,\, j\omega') = \exp\left\{-\psi_\mu(0)\frac{(\omega^2+\omega'^2)}{2} - \psi_\mu(\tau)\omega\omega'\right\} \qquad (23)$$

where $\psi_\mu(\tau)$ is the correlation function of $\mu(t)$; i.e.,

$$\psi_\mu(\tau) = \overline{\mu(t)\mu(t+\tau)}, \qquad (24)$$

and $\psi_\mu(0)$ is the mean-square value of $\mu(t)$.

By using (22), the expression for $H^*(j\omega;\, \tau)$ for this case is easily found to be

$$H^*(j\omega;\, \tau) = \exp\,\{\omega^2[\psi_\mu(\tau) - \psi_\mu(0)]\}. \qquad (25)$$

Substituting this expression in (19), one obtains a general operational relation

$$\psi_v(\tau) = \exp\,\{p^2[\psi_\mu(0) - \psi_\mu(\tau)]\}\psi_u(\tau), \qquad (26)$$

which gives $\psi_v(\tau)$ in terms of the correlation functions of $u(t)$ and $\mu(t)$. To summarize, *the correlation function of a delay-modulated signal* (9), *in which the modulating signal $\mu(t)$ is stationary and Gaussian, is given by the operational relation* (26), *where $\psi_u(\tau)$ is the correlation function of the carrier $u(t)$, and $\psi_\mu(\tau)$ is the correlation function of $\mu(t)$.*

In what follows, the expression for the correlation function (26) obtained above will be applied to some special cases of practical interest.

III. Special Cases

Phase Modulation

A phase-modulated signal

$$v(t) = \cos\,(\omega_c t - \theta(t)) \qquad (27)$$

is essentially a delay-modulated signal in which $u(t) = \cos\,\omega_c t$ and $\mu(t) = \theta(t)/\omega_c$. The correlation function of $u(t)$ is

$$\psi_u(\tau) = \tfrac{1}{2}\cos\,\omega_c\tau \qquad (28)$$

and hence (26) reduces to

$$\psi_v(\tau) = \tfrac{1}{2} \exp \{p^2[\psi_\mu(0) - \psi_\mu(\tau)]\} \cos \omega_c\tau. \tag{29}$$

Now it can readily be verified[13] that the result of operation with a time-dependent operator $H^*(p; t)$ on $\cos \omega_c t$ is simply the real part of $H^*(j\omega_c; t) \exp(j\omega_c t)$. Thus, (29) yields

$$\psi_v(\tau) = \tfrac{1}{2} \text{ Re } \{\exp\{\omega_e^2[\psi_\mu(\tau) - \psi_\mu(0)]\} \cos \omega_c\tau\} \tag{30}$$

or equivalently,

$$\psi_v(\tau) = \tfrac{1}{2} \cos \omega_c\tau \exp \{\psi_\theta(\tau) - \psi_\theta(0)\} \tag{31}$$

where $\psi_\theta(\tau)$ is the correlation function of $\theta(t)$. This result[14] provides an explicit expression for the correlation function of a phase-modulated signal in which the phase deviation $\theta(t)$ is stationary and Gaussian.

The spectrum of (27) may be obtained from (31) through use of the Wiener-Khintchine relation. Thus,

$$S_v(\omega) = \int_{-\infty}^{\infty} \psi_v(\tau)e^{-j\omega t}d\tau \tag{32}$$

or more explicitly,

$$S_v(\omega) = \int_0^{\infty} \exp \{\psi_\theta(\tau) - \psi_\theta(0)\} \cos \omega_c\tau \cos \omega\tau d\tau. \tag{33}$$

The exact evaluation of this integral is, in general, a difficult problem. In most practical cases the evaluation of (33) would require the use of numerical integration or machine computation. It is thus seen that, in general, it is much easier to determine the correlation function of a phase-modulated signal than it is to determine the spectrum of the signal. The same can be said for other types of delay-modulated signals.

Periodic Carrier

In the more general case to be examined now, the carrier is assumed to be a periodic function of time representing, say, a train of regularly spaced pulses. For this case $u(t)$ may be expressed in the form of a Fourier series such as

$$u(t) = \sum_{n=1}^{\infty} a_n \cos (\omega_n t + \gamma_n). \tag{34}$$

The corresponding expression for the correlation function of $u(t)$ is

$$\psi_u(\tau) = \sum_{n=1}^{\infty} \frac{a_n^2}{2} \cos \omega_n\tau. \tag{35}$$

Substituting this expression in (26) and proceeding in exactly the same manner as in the case of a phase-modulated signal, one obtains

$$\psi_v(\tau) = \sum_{n=1}^{\infty} \frac{a_n^2}{2} \exp \{\omega_n^2[\psi_\mu(\tau) - \psi_\mu(0)]\} \cos \omega_n\tau, \tag{36}$$

which thus constitutes a general expression for the correlation function of a delay-modulated period carrier.

In some practical cases it would be desirable to have a closed expression for $\psi_v(\tau)$. Since $\psi_v(t)$ is the response of Δ^* to $\psi_u(t)$, the problem is essentially that of expressing in a closed form the response of a variable network to a periodic input. Such an expression may be obtained by using an extension of Waidelich's steady-state operational calculus to variable networks.

[13] By definition of $H^*(j\omega; t)$, $H^*(j\omega; t)e^{j\omega t}$ is the response to $e^{j\omega t}$. Hence the response to $\cos w_c t$—which is the real part of $e^{j\omega_c t}$—is the real part of $H^*(j\omega_c; t)e^{j\omega_c t}$.

[14] One of the reviewers of this paper has commented that a similar and more general result for phase-modulated signals is given in a report by D. Middleton, "On the distribution of energy in noise and signal modulated waves," Tech. Report No. 99, Harvard University; March, 1950.

The Synthesis of *RC* Networks to Have Prescribed Transfer Functions*

H. J. ORCHARD†

Summary—**A synthesis procedure is described as an alternative to, and more general than, that due to Guillemin. The resulting network is in the form of a lattice and is capable of providing any arbitrary transfer function which is physically realizable by an *RC* network. Design work is simple and straightforward, and a numerical example is included.**

I. Introduction

IN A RECENT ARTICLE[1] Guillemin has shown how passive linear quadripoles containing only resistors and capacitors may be synthesized so as to produce a specified transfer characteristic when inserted between a given nonreactive generator and load. Such networks are becoming of increasing importance as circuit techniques are extended to very low frequencies, where inductors of adequate quality become difficult to manufacture and yet where transmission characteristics, normally associated with *RLC* circuits, are now being called for.

The restriction which is imposed upon the circuit transfer function by excluding inductors is rather severe. In spite of this restriction, however, such circuits are still reasonably flexible, as Guillemin elegantly demonstrates by his ingenious proof that any specified attenuation frequency characteristic can be approximated arbitrarily closely by the attenuation of an *RC* network.

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[1] E. A. Guillemin, "Synthesis of *RC* networks," *Jour. Math. Phys.*, vol. 28, p. 22; April, 1949.

particular, this implies that filter-like character-i-ics can be produced with a network containing no in-ıctors. Another possibility, not mentioned by Guille-ıin, is that certain all-pass functions can be produced by C networks: these will be mentioned again later.

Assuming that a suitably restricted transfer function s been designed to meet some given requirement, e problem remains of finding an RC network which ls this transfer function when operated between a ecified generator and load. Guillemin gave a solution this problem and derived a network having the rm of a set of separate ladder structures connected in ırallel. In order to do this, he was compelled to place vo further restrictions on the problem: the first was ıat the transfer function should be a minimum-phase ınction (i.e., all poles in the left half of the $p=i\omega$ ane); the second was that the generator should have ro internal resistance. The load resistance was given, r convenience, the value unity.

When the attenuation of the circuit is the only quan-ty of any importance, as in many filters and equalizers, ıe restriction to the minimum-phase conditions is of o consequence. However, the ability to depart from ıis condition is, on occasions, an asset, and its inclusion the standard design process would naturally render ıe theory more general. Furthermore, a requirement pon the operation of the network that it should be riven from a generator having zero internal resistance an ideal which, in any practical case, may or may not e easy to attain. At all events, it will normally involve me degree of approximation.

It was the need to overcome these two restrictions in ıe design process that initiated the work described in ıis paper. As a result it has been found possible to de-ign, by a simple and straightforward process, a general C network to have any prescribed transfer function hich is at all possible by such a network. Moreover, he network is symmetrical and requires a generator nd load having equal resistive impedances. The form aken by the network is that of the well-known lattice tructure.

One possible disadvantage of the lattice is that it is structure balanced with respect to earth; but if *one* ransformer can be produced to operate successfully over he frequency range of interest, it is possible to replace he lattice by one of its many equivalents which are ınbalanced with respect to earth. The other much dis-iked property of the lattice, namely, the need for ritical adjustment to maintain the necessary balance of the bridge circuit at the poles of attenuation, is na-urally present; but it must be pointed out that this lisadvantage also exists in the structure proposed by Guillemin. Such a state of affairs seems almost inevi-able as, with an RC network, poles of attenuation other than those at real negative values of $p=i\omega$ can be produced only by some balance of voltages or currents.

In his paper, Guillemin takes the transfer function ıs the ratio of output signal (voltage or current in the load resistor) to input signal (electromotive force in the input circuit). This is the function normally considered by radio engineers because, when applied to an amplifier, it represents the gain. However, designers of filters and other passive networks are usually more interested in insertion loss than gain and the conventional quantity with which they deal is the insertion transfer function, i.e., the ratio of the voltages (or currents) at the load before and after inserting the network. But, when a resistive generator and load are assumed, the insertion transfer function differs from the transfer impedance in the *complete* circuit only by a constant multiplier (as pointed out by Bode[2]); and this transfer impedance is merely the reciprocal of the quantity considered by Guillemin. In this paper, for convenience, we shall consider the transfer impedance.

II. General Properties of RC Networks

The essential analytical properties of dipoles and quadripoles containing only resistors and capacitors have been given by Cauer.[3] It is proposed here merely to summarize such of these results as are of immediate interest.

All driving-point impedances and admittances of RC networks are rational functions of the complex frequency variable $p=i\omega$, with poles and zeros which are simple, real, negative, and interlaced. If the impedances and admittance are expanded into partial fractions thus:

$$Z(p) = a^{(\infty)} + \frac{a^{(0)}}{p} + \sum_{1}^{n} \frac{a^{(r)}}{p + p_r} \tag{1a}$$

$$Y(p) = b^{(\infty)} \cdot p + b^{(0)} + p \cdot \sum_{1}^{n} \frac{b^{(r)}}{p + q_r}, \tag{1b}$$

then all the $a^{(r)}$ and the $b^{(r)}$ are positive. From these two expressions may be found the element values for the two corresponding canonical structures shown in Figs. 1(a) and 1(b), respectively.

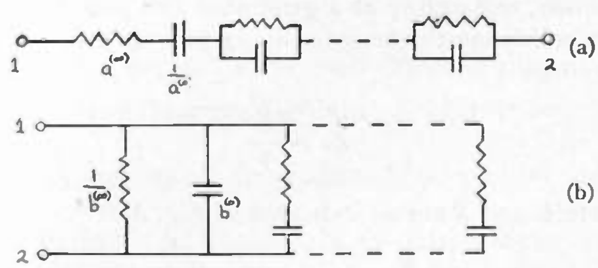

Fig. 1—Canonical RC dipoles.

Quadripoles may be specified conveniently in terms of the z or y coefficients occurring in the two equivalent pairs of linear equations

[2] H. W. Bode, "Network Analysis and Feedback Amplifier Design," D. Van Nostrand Co., Inc., New York, N. Y., pp. 227–230; 1945.

[3] W. Cauer, "Die Verwirklichung von Wechselstromwiderständen vorgeschriebener Frequenzabhängigkeit," *Arch. für Elektrotech.*, vol. 17, p. 355; 1927.

$$\left.\begin{aligned} E_1 &= I_1 z_{11} + I_2 z_{12} \\ E_2 &= I_1 z_{21} + I_2 z_{22} \end{aligned}\right\} \quad (2a)$$

$$\left.\begin{aligned} I_1 &= E_1 y_{11} + E_2 y_{12} \\ I_2 &= E_1 y_{21} + E_2 y_{22} \end{aligned}\right\} \quad (2b)$$

where E_1, E_2, I_1 and I_2 are as shown in Fig. 2.

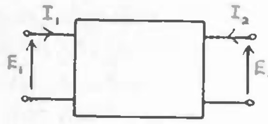

Fig. 2—*RC* quadripole.

As the networks are passive, $z_{12}=z_{21}$ and $y_{12}=y_{21}$. If the z and the y functions are expanded into partial fractions

$$\left.\begin{aligned} z_{11} &= a_{11}^{(\infty)} + \frac{a_{11}^{(0)}}{p} + \sum_1^n \frac{a_{11}^{(r)}}{p+p_r} \\ z_{12} &= a_{12}^{(\infty)} + \frac{a_{12}^{(0)}}{p} + \sum_1^n \frac{a_{12}^{(r)}}{p+p_r} \\ z_{22} &= a_{22}^{(\infty)} + \frac{a_{22}^{(0)}}{p} + \sum_1^n \frac{a_{22}^{(r)}}{p+p_r} \end{aligned}\right\} \quad (3a)$$

$$\left.\begin{aligned} y_{11} &= b_{11}^{(\infty)}\cdot p + b_{11}^{(0)} + p\cdot\sum_1^n \frac{b_{11}^{(r)}}{p+q_r} \\ y_{12} &= b_{12}^{(\infty)}\cdot p + b_{12}^{(0)} + p\cdot\sum_1^n \frac{b_{12}^{(r)}}{p+q_r} \\ y_{22} &= b_{22}^{(\infty)}\cdot p + b_{22}^{(0)} + p\cdot\sum_1^n \frac{b_{22}^{(r)}}{p+q_r} \end{aligned}\right\} \quad (3b)$$

then Cauer's residue theorem states that

$$a_{11}^{(r)} \geqq 0 \qquad a_{22}^{(r)} \geqq 0 \qquad a_{11}^{(r)}\cdot a_{22}^{(r)} - (a_{12}^{(r)})^2 \geqq 0$$
$$b_{11}^{(r)} \geqq 0 \qquad b_{22}^{(r)} \geqq 0 \qquad b_{11}^{(r)}\cdot b_{22}^{(r)} - (b_{12}^{(r)})^2 \geqq 0$$

for all r.

If such a quadripole is inserted between a pair of resistors, one acting as a generator and one as a load, then we define the transfer impedance in the complete circuit as

$$Z_T = \frac{E}{I} \quad (3)$$

where E and I are as indicated in Fig. 3.

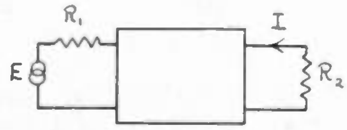

Fig. 3—Circuit defining Z_T.

The transfer impedance is a rational function of p with real coefficients—its zeros are the same as those of any driving point impedance seen into any mesh of the complete circuit and, as the latter contains only resistors and capacitors, these zeros will be simple and occur at real negative values of p. Furthermore, as the circuit contains the resistors R_1 and R_2 in series with meshes numbers 1 and 2 it is impossible for the transfer impedance to have a zero at $p=\infty$.

From (2) it may be seen that the poles of the transfer impedance are produced either by zeros of z_{12} or else by poles of z_{11} or z_{22} which are not contained in z_{12}. As there are no restrictions upon the zeros of z_{12}, there are consequently no restrictions upon the poles of Z_T other than that they should occur in conjugate pairs when complex.

All the typical possible positions for the poles and zeros in the complex p plane are indicated by Figs. 4(a) and 4(b). Poles are denoted by crosses, zeros by circles.

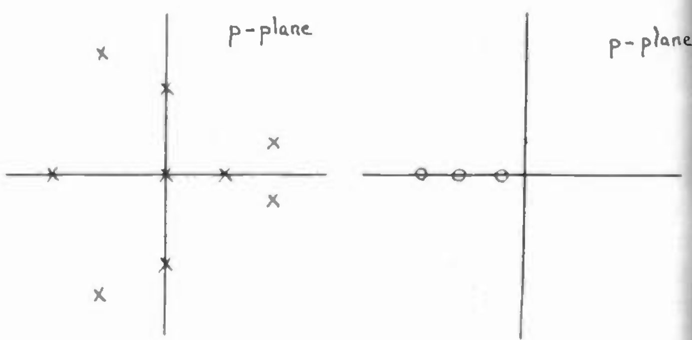

Fig. 4—Typical pole and zero patterns.

Poles at infinity may also occur, with any multiplicity, by virtue of an excess of the number of finite zeros over the number of finite poles.

III. Synthesis of the *RC* Network

Assume now that we are given the problem of producing an arbitrary transfer impedance, subject to the above restrictions, by means of an *RC* network inserted between a resistive generator and load, as in Fig. 3.

The first step is to find an *RC* network which gives the required transfer impedance when it has short circuit terminations as in Fig. 5.

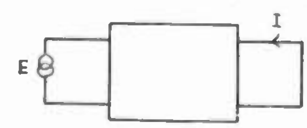

Fig. 5—Preliminary *RC* quadripole.

Putting in (2b) $E_1=E$, $I_2=I$, and $E_2=0$, we see that

$$Z_T = \frac{E}{I} = \frac{1}{y_{12}}. \quad (4)$$

Thus the specification of the transfer impedance alone is not sufficient to define the network, for it gives only one of the three functions which are necessary. The remaining functions y_{11} and y_{22} can be given any values we desire, so long as the three functions obey the residue theorem.

For the time being, we shall assume that the network is to be symmetrical, i.e., $y_{11}=y_{22}$, and that in the resiue theorem, as applied to this network, the equality gn shall hold at each pole.

From (4) the poles of y_{12} are seen to be the zeros of Z_T nd hence are real, negative, and simple. Around these oints, $Z(_T)^{-1}$ may be expanded into partial fractions f the form (2b) and the quantities $b_{12}^{(r)}$ which arise om the expansion may, in general, be of any sign, alnough always real. The assumptions just made regardg y_{11} and y_{22} mean that when these functions are exanded similarly into partial fractions we must have $_{11}^{(r)}=b_{22}^{(r)}=|b_{12}^{(r)}|$ for all r. Hence, from the expansion or $y_{12}=Z_T^{-1}$, it is possible to derive the expansion for $_{11}=y_{22}$ simply by making all the residues positive.

This network, whose admittance matrix is now comletely specified, may be realized physically in any form hich happens to be suitable; in particular, it can *always* e realized by means of a lattice, the arms of which ill have admittances given by $Y_A=y_{11}+y_{12}$ and $Y_B=y_{11}-y_{12}$.

Consider next the impedance matrix of this network. By solving (2b) it can easily be seen that

$$z_{11} = \frac{y_{22}}{y_{11}\cdot y_{22} - y_{12}^2}; \qquad z_{12} = \frac{-y_{12}}{y_{11}\cdot y_{22} - y_{12}^2};$$

$$z_{22} = \frac{y_{11}}{y_{11}\cdot y_{22} - y_{12}^2}. \tag{5}$$

Now the quantities $a_{11}^{(\infty)}$, $a_{12}^{(\infty)}$, and $a_{22}^{(\infty)}$ which arise n the partial fraction expansions of these functions are iven respectively by the following limits:

$$a_{11}^{(\infty)} = \lim_{p\to\infty} z_{11}; \qquad a_{12}^{(\infty)} = \lim_{p\to\infty} z_{12}; \qquad a_{22}^{(\infty)} = \lim_{p\to\infty} z_{22}.$$

As the network is physically realizable, we know, by he residue theorem, that $a_{11}^{(\infty)}\cdot a_{22}^{(\infty)}-(a_{12}^{(\infty)})^2\geqq 0$, but ve cannot say without a little further examination vhether it is the equality or the inequality sign which nolds in this particular case. This further examination s effected most readily by applying the limits just indiated to the function $z_{11}\cdot z_{22}-z_{12}^2$, with the z's replaced by the y's according to the identities of (5). Thus

$$a_{11}^{(\infty)}\cdot a_{22}^{(\infty)} - (a_{12}^{(\infty)})^2 = \lim_{p\to\infty} (z_{11}\cdot z_{22} - z_{12}^2)$$

$$= \lim_{p\to\infty} \frac{(y_{11}\cdot y_{22} - y_{12}^2)}{(y_{11}\cdot y_{22} - y_{12}^2)^2}$$

$$= \lim_{p\to\infty} \frac{1}{(y_{11}\cdot y_{22} - y_{12}^2)}.$$

Now this limit cannot be zero for it would imply that $\lim_{p\to\infty}(y_{11}\cdot y_{22}-y_{12}^2)=\infty$, a condition which is not possible because none of the y's possesses a pole at $p=\infty$. This is easily seen to be so if it is recalled that Z_T is not permitted to have a zero at $p=\infty$ and thus that y_{12} cannot have a pole, i.e., $b_{12}^{(\infty)}=0$. Furthermore, it was prescribed that $b_{11}^{(\infty)}=b_{22}^{(\infty)}$ and $b_{11}^{(\infty)}\cdot b_{22}^{(\infty)} -(b_{12}^{(\infty)})^2=0$. These considerations guarantee that the limit is not infinite and hence that $a_{11}^{(\infty)}\cdot a_{22}^{(\infty)}-(a_{12}^{(\infty)})^2 >0$.

The term $a^{(\infty)}$ in the expansion of the z functions is the constant term which corresponds, as indicated in Fig. 1(a), to the constant series-resistance part of the circuit representing the impedance. By virtue of the inequality just proved, it is possible to extract from each end of the network a series resistor of magnitude $a_{11}^{(\infty)}-|a_{12}^{(\infty)}|=a_{22}^{(\infty)}-|a_{12}^{(\infty)}|$ as shown in Fig. 6. The network which is left is still physically realizable because the only effect of extracting these resistors will be to make the *equality* rather than the *inequality* sign hold

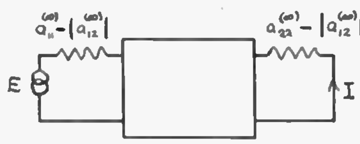

Fig. 6—Extraction of terminating resistors.

for the terms $a^{(\infty)}$ in the z functions. This remaining network, still symmetrical, may now be realized physically as a lattice, the arms of which will have impedances given by

$$Z_A = z_{11}^* + z_{12} \quad \text{and} \quad Z_B = z_{11}^* - z_{12}, \quad \text{where}$$

$$z_{11}^* = z_{11} - (a_{11}^{(\infty)} - |a_{12}^{(\infty)}|).$$

At this stage, the synthesis of the network is complete for we have provided the specified transfer impedance with a symmetrical network which is terminated at each end by the same value of resistor, namely, $a_{11}^{(\infty)}-|a_{12}^{(\infty)}|$.

Although the above derivation is the most convenient theoretically, it is possible, in practice, to arrive at the final network slightly more quickly. A little examination will show that the resistors which are extracted from each end of the network (for use as terminating resistors) have a magnitude which is, precisely, the smaller of the constant series resistors of $z_{11}+z_{12}$ and $z_{11}-z_{12}$. But these latter quantities $z_{11}+z_{12}$ and $z_{11}-z_{12}$ are the arm impedances of the lattice representing the network prior to the extraction of the resistors, and as such must be equal to $(y_{11}+y_{12})^{-1}$ and $(y_{11}-y_{12})^{-1}$, respectively.

Thus the practical procedure becomes as follows:

A. Expand the given Z_T^{-1} into partial fractions giving y_{12}.

B. By making all the residues in y_{12} positive, derive $y_{11}=y_{22}$.

C. Form the admittances of the lattice arms $y_{11}+y_{12}$ and $y_{11}-y_{12}$.

D. Take the reciprocals of these to obtain the corresponding impedances $z_{11}+z_{12}$ and $z_{11}-z_{12}$.

E. Reduce these impedances by the smaller of the two constant series-resistance parts.

F. Use the amount of resistance just reduced as generator and load, and the impedances which are left as the arm impedances of the final network.

G. Scale all the impedances up or down so that the terminating resistances assume some suitable value for use or manufacture.

IV. Dissymmetrical Networks

The assumptions made in the preceding section in order to fix the value of the functions y_{11} and y_{22} are sufficient to allow a network giving the specified transfer impedance to be derived. Nevertheless, these assumptions are not necessary; any positive values could have been allocated to the $b_{11}^{(r)}$ and $b_{22}^{(r)}$ as long as the conditions of the residue theorem were met.

The allocation of values which would cause the inequality sign to hold at any of the poles is without practical significance, for it would imply the existence of dipoles, separable from the network at each end, shunting the short-circuit terminations. These would be redundant elements from the point of view of the transfer impedance.

Unequal values for $b_{11}^{(r)}$ and $b_{22}^{(r)}$ make the network dissymmetrical and hence impossible to be realized as a lattice either before or after extracting the terminating resistors (it should be noted that the proof of the possibility of extracting such resistors did not require $b_{11}^{(r)}=b_{22}^{(r)}$ other than that $b_{11}^{(\infty)}=b_{22}^{(\infty)}=b_{12}^{(\infty)}=0$). The "partial fraction" networks which Cauer developed for *LC* networks could, in principle, be applied to the *RC* networks; but as they require ideal transformers the solution is not attractive.

V. Numerical Example

To illustrate the theory of Section III, and also to give a further example of the use of *RC* networks quite distinct from the filters described by Guillemin, we shall conclude with a numerical example of the design of an all-pass phase-shifting network.

Suppose that the transfer impedance of the all-pass network is required to be

$$Z_T = \frac{(p+1)(p+2)(p+3)}{(p-1)(p-2)(p-3)}.$$

Expanding Z_T^{-1} into partial fractions gives

$$Z_T^{-1} = y_{12} = -1 + \frac{12p}{p+1} - \frac{30p}{p+2} + \frac{20p}{p+3}$$

$$\therefore \quad y_{11} = y_{22} = 1 + \frac{12p}{p+1} + \frac{30p}{p+2} + \frac{20p}{p+3}.$$

The arms of the lattice representing this network have admittances given by

$$Y_A = y_{11} + y_{12} = 2\left(\frac{12p}{p+1} + \frac{20p}{p+3}\right) = \frac{64p^2+112p}{p^2+4p+3}$$

$$Y_B = y_{11} - y_{12} = 2\left(1 + \frac{30p}{p+2}\right) = \frac{62p+4}{p+2}$$

and hence impedances given by

$$Z_A = Y_A^{-1} = \frac{p^2+4p+3}{64p^2+112p} = \frac{1}{64} + \frac{3}{112p} + \frac{15}{28(64p+112)}$$

$$Z_B = Y_B^{-1} = \frac{p+2}{62p+4} = \frac{1}{62} + \frac{30}{31(31p+2)}.$$

The smaller of the two constant series-resistance parts is 1/64 and so this becomes the value of the terminating resistors. The remaining arm impedances are then

$$Z_A^* = \frac{3}{112p} + \frac{15}{28(64p+112)}$$

$$Z_B^* = \frac{1}{1984} + \frac{30}{31(31p+2)}.$$

Multiplying all impedances by 64 so that the network is referred to unit terminating resistors gives arm impedances

$$Z_A^* = \frac{12}{7p} + \frac{15}{7(4p+7)}$$

$$Z_B^* = \frac{1}{31} + \frac{30 \times 64}{31(31p+2)}.$$

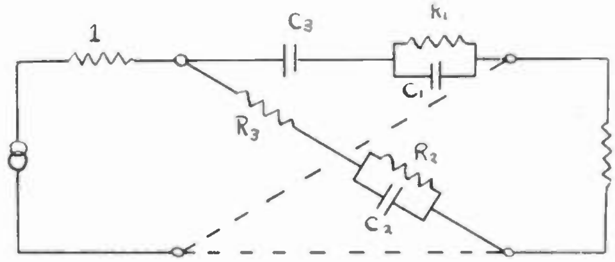

Fig. 7—Circuit of numerical example.

The complete circuit is given in Fig. 7 and the element values are[4]

$$R_1 = \frac{15}{7\times 7}\,\Omega \qquad C_1 = \frac{7\times 4}{15}\,F$$

$$R_2 = \frac{30\times 64}{31\times 2}\,\Omega \qquad C_2 = \frac{31\times 31}{30\times 64}\,F$$

$$R_3 = \frac{1}{31}\,\Omega \qquad C_3 = \frac{7}{12}\,F.$$

Acknowledgment

Acknowledgment is made to the Engineer-in-Chief of the General Post Office, London, England, for permission to make use of the information contained in this paper.

[4] It will be appreciated that these values, together with the prescribed transfer impedance, are normalized with regard to both impedance and frequency. In practice, a subsequent scaling of these two quantities would be necessary to suit the particular problem in hand.

Maximum Output from a Resistance-Coupled Triode Voltage Amplifier*

JOSEPH M. DIAMOND†, ASSOCIATE, IRE

Summary—**The optimum load resistance with respect to output ltage and the maximum voltage swing obtainable are investigated r a resistance-coupled triode voltage amplifier.**

IF IN THE design of a resistance-coupled triode voltage amplifier the following factors are given, then there is a combination of plate load resistance

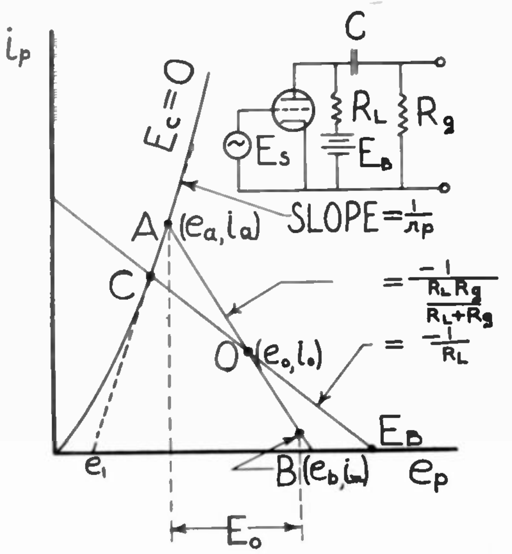

Fig. 1—Triode voltage amplifier and plate family.

R_L (see Fig. 1) and operating point which results in naximum output voltage:

1. R_g (usually determined by the following tube).
2. The zero bias curve of the tube, here idealized as a traight line, yielding the parameters r_p and e_1.
3. E_B.
4. The desired minimum current i_m, determined by considerations of distortion. If considerable feedback is ised, an i_m of zero may be allowable.
5. The desired division of the output voltage E_0 into positive and negative swings, here represented by the parameter γ = *positive swing*/E_0. It is clear that some listortion cancellation scheme (a push-pull circuit, feedback, distortion cancelling between voltage and power amplifiers, or a combination of these) is required if any considerable fraction of the possible voltage amplifier swing is to be used: γ is determined by the scheme employed. For example, if the (push-pull) power amplifier operates in class AB_1 and each output tube is cut off for a considerable part of the negative half cycle, then γ can be made almost unity, thus utilizing most of the available output swing for the positive half cycle. A feedback loop connected around the entire voltage-power amplifier in this case will not require a change in γ. On the other hand, if for any reason feedback is applied from the output of the voltage amplifier to a preceding point, then γ should be made equal to $\frac{1}{2}$, since the feedback will adjust the grid wave form to keep the plate swings symmetrical. In general, a large feedback factor will keep the signal symmetrical at the point from which the feedback voltage is derived, and the wave form at any preceding point in the feedback loop will adjust itself to whatever is required to satisfy this condition. All the above assumes that equally large positive and negative swings occur in the original signal, as is the case in audio applications. If this is not true, then a value of γ appropriate to the wave form can be chosen, with a resultant conservation of available output swing.

Referring to Fig. 1, we see that the maximum obtainable output voltage E_0 equals $e_b - e_a$, where $\overline{CE_B}$ is the dc load line, O is the operating point, and $\overline{AOB}$ is the ac load line. The equations of lines $\overline{Ae_1}$ and $\overline{AOB}$ can be written, since a point on each and the slope of each are known. The intersection of these lines then determines point A. Point B is located by setting the plate current equal to i_m in the equation of $\overline{AOB}$. Thus $e_b - e_a$ can be found; however the equation will contain the operating point (e_0, i_0). The relation $i_0 = (E_B - e_0)/R_L$ eliminates i_0, while the definition of γ given above will eliminate e_0 as well; that is, the operating point is completely determined by the circuit parameters and γ. These calculations are best performed in terms of conductances. It is assumed that the coupling condenser C has negligible reactance. The resulting equation for E_0 is

$$E_0 = (E_B - e_1)\frac{\left(\frac{r_p}{R_L}\right)(1-\delta) - \delta}{\left(\frac{r_p}{R_L}\right)^2 + \left(\frac{r_p}{R_L}\right)\left(1 + \frac{1}{x}\right) + \frac{\gamma}{x}} \quad (1)$$

where

$$\delta = \frac{i_m r_p}{E_B - e_1} \quad (2)$$

$$x = \frac{R_g}{r_p}. \quad (3)$$

* Decimal classification: R363.21. Original manuscript received by the Institute, March 6, 1950; revised manuscript received, July 5, 1950.

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The parameters x, γ, and δ are known. The form of equation (1) indicates that E_0 has a broad maximum as R_L varies. Setting $dE_0/d(r_p/R_L)=0$ we find

$$R_{L\text{ optimum}} = \frac{r_p}{\frac{\delta}{1-\delta}+\sqrt{\left(\frac{\delta}{1-\delta}\right)^2+\left(\frac{\delta}{1-\delta}\right)\left(1+\frac{1}{x}\right)+\frac{\gamma}{x}}}. \quad (4)$$

Inserting this value of R_L into (1), we find the following equation for E_0 under optimum conditions:

$$E_{0\text{ optimum}} = (E_B - e_1)\frac{1-\delta}{1+\frac{1}{x}+2\left(\frac{\delta}{1-\delta}+\sqrt{\left(\frac{\delta}{1-\delta}\right)^2+\left(\frac{\delta}{1-\delta}\right)\left(1+\frac{1}{x}\right)+\frac{\gamma}{x}}\right)}. \quad (5)$$

Ordinarily $\delta \ll 1$ and $x \gg 1$, so that the following approximations are useful:

$$R_{L\text{ optimum}} \doteq \frac{r_p}{\delta+\sqrt{\delta+\frac{\gamma}{x}}} \quad (6)$$

$$E_{0\text{ optimum}} \doteq (E_B - e_1)\frac{1-\delta}{1+\frac{1}{x}+2\left(\delta+\sqrt{\delta+\frac{\gamma}{x}}\right)}. \quad (7)$$

Since the optimum value of R_L is very broad, (7) can be used to compute E_0 even though a standard resistor size, differing somewhat from the optimum value, is used for R_L. Once R_L is known, the required operating point is best determined graphically on the plate family of the tube, although, as mentioned in connection with the derivation, it can be calculated from the circuit parameters and γ. Occasionally the dissipation rating of the tube will be exceeded when optimum parameters are used. In that case, this rating rather than the factors indicated above will limit E_0.

Example: 6J5 tube, $r_p=10{,}000$ ohms, $e_1=5$ volts, $E_B=250$ volts, $R_g=500{,}000$ ohms, $i_m=0.2$ ma, $\gamma=\frac{1}{2}$. Then we find $x=50$, $\delta=0.00816$, $\gamma/x=0.01$, R_L optimum $=70{,}000$ ohms, E_0 optimum $=186$ volts, using equations (6) and (7).

CORRECTIONS AND ADDITIONS

L. J. Chu, co-author of the paper, "Biconical electromagnetic horns," by W. L. Barrow, L. J. Chu, and J. J. Jansen, which appeared on pages 769–779 of the December, 1939, issue of the PROCEEDINGS OF THE I.R.E., has brought the following error and additions to the attention of the editors.

The formulas and curves for the gains are in error by a constant factor. The correct results for the directivity gains[1] in the equatorial plane for a symmetrical biconical horn are given below. The directivity gains are relative to an isotropic radiator.

TEM WAVE

$$\text{Directivity gain} = \frac{2\,|F(v_0)|^2}{\ln\cot\frac{\pi-\theta_0}{4}}$$

[1] IRE Standards on Antennas, Definitions of Terms, 1948.

where

$$F(v_0) = \frac{1}{2}\int_0^{v_0}[J_{-1/2}(v) - jJ_{1/2}(v)]dv$$

$$v_0 = \frac{\pi r_0\theta_0^2}{4\lambda}$$

r_0 = slant length of the horn

θ_0 = flare angle in radiation.

The directivity gain of *TEM* wave in the equatorial plane is shown in Fig. 1. The optimum gain for a given ratio of r_0/λ and the corresponding value of the flare angle are shown in Fig. 2. The curves in Fig. 2 satisfy the following relationships:

$$G = 2.3\sqrt{r_0/\lambda},$$

$$\theta_0 = 82.5\sqrt{\lambda/r_0}\text{ degrees},$$

$$G = 1.6r_0\theta_0/\lambda.$$

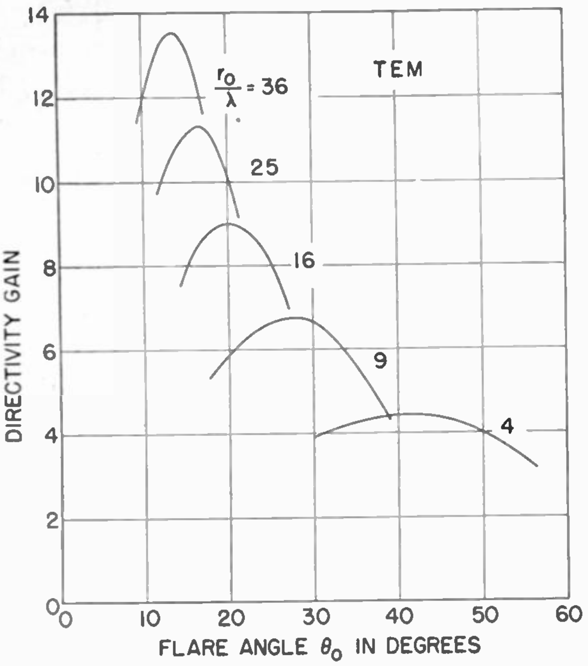


Fig. 1

'or the optimum gain, the constant phase surface over he aperture deviates from the corresponding cylindrical urface by

$$r_0 = \left(1 - \cos\frac{\theta_0}{2}\right) = 0.26\lambda.$$

$TE_{0,1}$ WAVE

$$\text{Directivity gain} = \frac{2}{\theta_0}\left| F(v) \Big|_{v_1}^{v_2} \right|^2, \qquad \text{for } \theta_0\sqrt{r_0/\lambda} < 1;$$

$$= \frac{2}{\theta_0}\left| F(v_1) + F(v_2) \right|^2, \text{ for } \theta_0\sqrt{r_0/\lambda} > 1;$$

where

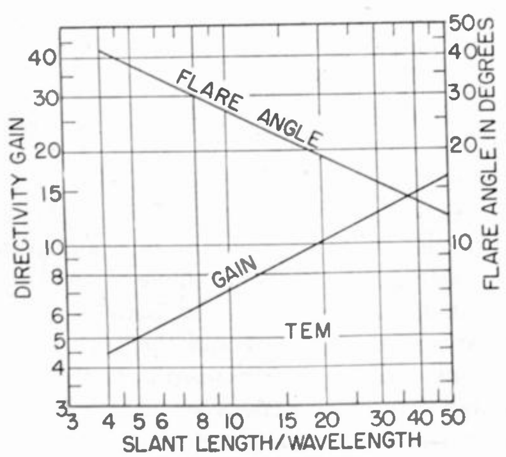


Fig. 2

$$v_1 = \frac{\pi}{4}\left(\frac{1}{\theta_0}\sqrt{\frac{\lambda}{r_0}} + \theta_0\sqrt{\frac{r_0}{\lambda}}\right)^2$$

$$v_2 = \frac{\pi}{4}\left(\frac{1}{\theta_0}\sqrt{\frac{\lambda}{r_0}} - \theta_0\sqrt{\frac{r_0}{\lambda}}\right)^2.$$

The directivity gain of $TE_{0,1}$ wave in the equatorial plane is shown in Fig. 3. The optimum gain for a given ratio of r_0/λ and the corresponding value of the flare

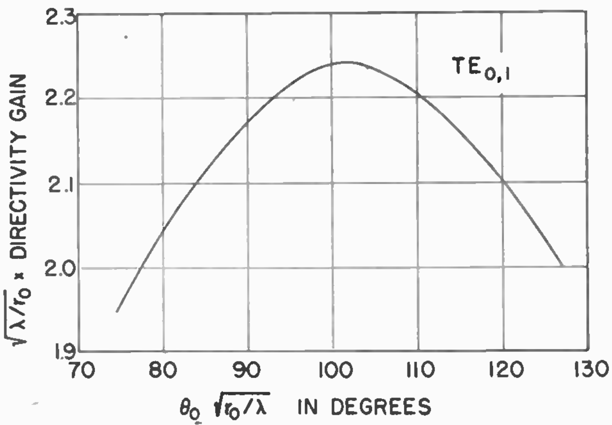


Fig. 3

angle are given in Fig. 4. The curves in Fig. 4 satisfy the following equations:

$$G = 2.24\sqrt{r_0/\lambda},$$
$$\theta_0 = 101\sqrt{\lambda/r_0} \text{ in degrees},$$
$$G = 1.27 r_0\theta_0/\lambda.$$

For the optimum gain, the constant phase surface over the aperture deviates from the corresponding cylindrical surface by

$$r_0\left(1 - \cos\frac{\theta_0}{2}\right) = 0.388\lambda.$$

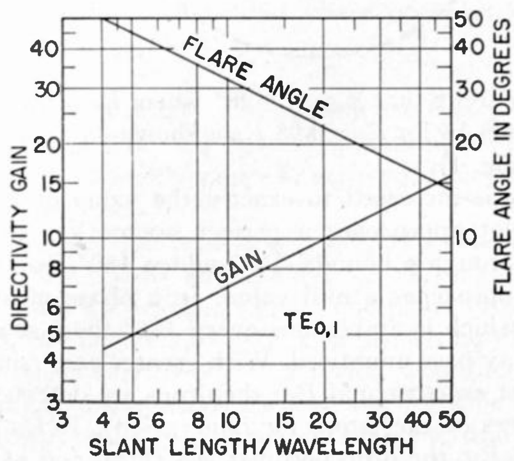


Fig. 4

Discussion on

"A Source of Error in Radio Phase Measuring Systems"*

R. BATEMAN, E. F. FLORMAN, AND A. TAIT

Eberhardt Rechtin[1]: The above-named paper* attempts to show that phase in an electromagnetic field is multi-valued, both from experiment and theory. This is not the case.

1. Equation (3) of the paper referring to the driving antenna may be written as

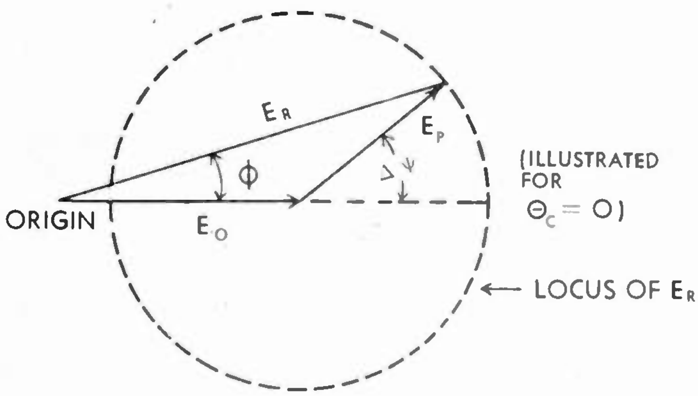
$$\phi = \tan^{-1}\left[\frac{E_P \sin(\theta_c + \Delta\psi)}{E_D + E_P \cos(\theta_c + \Delta\psi)}\right],$$

where

θ_c = a constant phase composed of the authors' $\theta_{DP}+180° - \tau$. For the sake of discussion the driving and parasite antennas are assumed fixed, the receiving antenna mobile.

$\Delta\psi$ = a variable phase angle depending upon the phase relationship of the two received electric vectors E_D and E_P (driven and parasite sources, respectively).

ϕ = the resultant phase angle defined by the figure below.



It is apparent that $\phi_{max} = \pm 90°$ when $E_P = E_D$. A plot of ϕ versus $\Delta\psi$ for $E_P = 0.98\ E_D$ is shown on the enclosed graph (Fig. 1).

As E_P is increased to exactly the value of E_D, the above plot approaches a perfect sawtooth with 180°-peak to trough ϕ bounds. The sudden 180°-drop occurs as E_R approaches a null value. In a phase measuring system which is ambiguous every 180° these sawtooth drops may pass unnoticed. With greater care (since E_P can never *exactly* equal E_D) the drops are detected (see the figures of the paper for illustration). If E_P is not equal to E_D, the drop becomes less sharp and of lesser magnitude. In the limit the plot is that of a sine wave of low ϕ amplitude. The sudden drop phenomenon has been observed in tests made in the course of research here; our system was ambiguous every 360° (not 180°), so that observation was simplified.

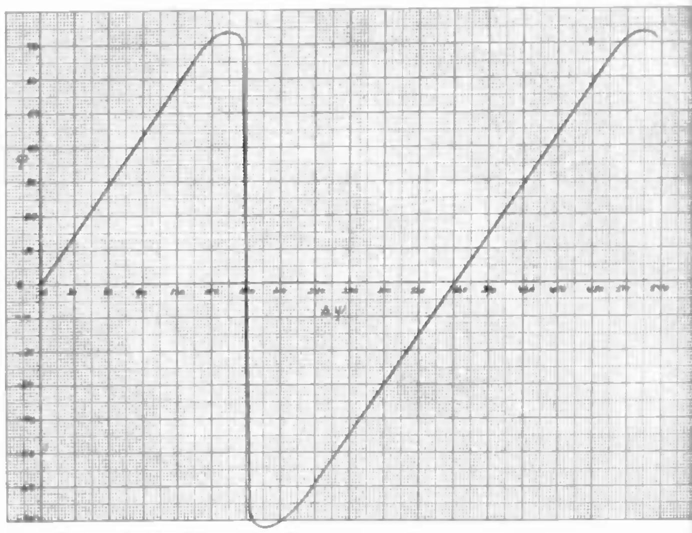


Fig. 1

2. From the principle of conservation of energy, E_P may never exceed E_D in a region free of shielding. If E_P comes from another *driven* antenna, of course, the results are different, but so is the problem. Two driven antennas obviously set up a field different from one antenna alone. The result is much used (normal operation) and certainly does not constitute an error field. Hufford[2] in a succeeding paper, for example, calculates the contours of a lop-sided radio phase measuring system, not of a system composed of a driving antenna with (unsuspected) parasite.

3. Notice that if the 180° drop is ignored, 360° in ϕ may be accumulated every time $\Delta\psi$ is cyclic. The authors give an example where $\Delta\psi$ repeats once for every (equivalent) rotation of the receiver about the driver-parasite system. A related problem was solved at this laboratory: the problem of lobing errors in phase generated by an antenna elevated above a land or sea surface. The image antenna was the parasite. Depending upon the spacing of the antennas (i.e., the antenna elevation in our problem), enormous phase errors might be accumulated *if the 180° phase drops were ignored.* If the drops were taken into account the maximum error was ±90°. In other words, it is not the field that is multi-valued; it is the mistaken plot the observer makes in interpreting data.

* R. Bateman, E. F. Florman, and A. Tait, "A source of error in radio phase measuring systems," Proc. I.R.E., vol. 38, pp. 612–614; June, 1950.

[1] Jet Propulsion Laboratories, Pasadena, Calif.

[2] George A. Hufford, "An analysis of some anomalous properties of equiphase contours," Proc. I.R.E., vol. 38, pp. 614–618; June, 1950.

4. If E_P is reasonably smaller than E_D, only an easily apparent oscillating error is observed as one moves around the system. Such will normally be the case. Unfavorable conditions (when the error takes sharp drops) occur in diffraction regions (E_D shielded, E_P generated on the diffracting ridge), near metal parasites (such as the telephone line the authors used), very near mountains or forest boundaries, when the antennas are elevated above a sea surface, and when a directive receiving antenna is improperly oriented. Results here confirm this statement. Further work here along these lines unfortunately is classified.

R. Bateman, E. F. Florman, and A. Tait[3]: Mr. Rechtin raises some questions concerning the validity of the results presented in our paper.*

His discussion is based on the premise that the field produced by a parasite is always less than the field produced by an associated driven antenna. In theory, as well as in practice, however, situations frequently arise in which the field produced by a parasite is greater than the field produced by a driven antenna.

The current in a parasitic antenna in terms of the current in a driven antenna is given by Brown[4] for a simple system consisting of a single driven antenna and a single parasite as

$$\bar{I}_1 = -\frac{\bar{I}_0\bar{Z}_{01}}{\bar{Z}_{11}},$$

where $\bar{I}_0$ and $\bar{I}_1$ are the currents in the driven antenna and parasitic antenna, respectively, $\bar{Z}_{01}$ is the mutual impedance coupling the two antennas, and $\bar{Z}_{11}$ is the self-impedance of the parasite including any lumped reactance at its base.

In order for the current in the parasite and its distant field to be greater than the current in the driven antenna and its distant field, respectively, it is only necessary for the ratio $|\bar{Z}_{01}/\bar{Z}_{11}|$ to exceed unity. This occurs at all spacings less than approximately 0.065λ in our example employing a quarter-wave driven antenna and a quarter-wave parasite with its reactance tuned out at the base. However, at spacings greater than approximately 0.065λ, $\bar{I}_0$ is greater than $\bar{I}_1$. Both of these conditions are shown in the literature.[5] It is essential to note here that if the driven antenna is carried around a closed path encircling either P_A or P_B in Fig. 4 of our paper, $\bar{I}_1$ will be greater than $\bar{I}_0$ when the distance between the parasite and driven antennas is less than 0.065 λ, and will be smaller than $\bar{I}_0$ at spacings larger than 0.065 λ. It is not always necessary for the current in a parasite to be greater than the current in a driven antenna in order for E_P to be greater than E_D. Propagation effects or directive effects in the antennas can also produce this condition. Probably the most familiar example occurs in the reception of standard broadcast signals. Here, the night field from the parasite (the image antenna caused by ionospheric reflections) is usually greater than the ground wave field produced by the driven antenna at distances larger than about twenty or thirty miles.

In Mr. Rechtin's discussion of our equation (3) he has defined θ_c as being constant and equivalent to our $\theta_{DP}+180°-\tau$. Actually, however, θ_{DP} is a variable and his θ_c does not correspond to the case we considered in which variable mutual impedance effects take place between a fixed parasite and a mobile driven antenna. For an equivalent receiving case it would be necessary to consider a quarter-wave mobile receiving antenna in the vicinity of the parasite with the transmitter at a large fixed distance from the parasite, and to allow for the variable mutual impedance effects between the receiving and parasitic antennas. Results equivalent to the transmitting case would be expected. Paragraph (3) of Mr. Rechtin's comments indicates that our example involving a driven antenna and parasite may have been misinterpreted. In our case the driven antenna is mobile and not the receiver, as Mr. Rechtin's discussion indicates. Furthermore, no net change in phase would result if the transmitter were carried around the fixed parasite and fixed receiver, provided that the points P_A and P_B of Fig. 4 of our paper were both enclosed by the path taken by the transmitter. However, if only one of the points were included, a net change of 360° in indicated phase would take place.

Mr. Rechtin has suggested that our experimental results were in error because of a failure to observe the "180° drop" which occurs under certain conditions. Our measurements were made using a method which was unambiguous within 360°, and the readings were continuously monitored to insure that all changes in indicated phase would be observed and recorded. The driven antenna was moved very slowly in critical regions where large changes in indicated phase occurred over relatively short distances.

Eberhardt Rechtin[1]: The authors are correct in that I did not consider the case of induction fields close to tuned parasites; the case of nearly equal fields is one on which we agree.

The tuned parasite case is one of a general type in which the driven antenna (surveying) signal is overridden by a distorting signal. The phase of each signal alone is single-valued. If a transmitting-to-receiving antenna is carried out of a region where E_D predominates into one in which E_P is greater (or which results in greater E_P than E_D at a measuring point) and then back into the original area at a different point, ambiguity of phase usually results. Sky-wave, diffraction, or reflection-illuminated areas are illustrations. A special case is one in which temporary failure of the receiver during motion occurs: the absolute phase from the transmitter is lost. Another illustration is that of the spiral phase

[3] Central Radio Propagation Laboratory, National Bureau of Standards, Washington, D. C.

[4] G. H. Brown, "Directional antennas," Proc. I.R.E., vol. 25, pp. 78–145; January, 1937.

[5] See Fig. 29 of footnote reference 4.

field: E_D and E_P alternately predominate as a receiver encircles transmitter and parasite.

The fields E_D and E_P are single-valued in phase; the resultant field is also single-valued, although equipment may make observed results ambiguous. The ambiguity at any point may be resolved by use of modulation frequencies in any of the cases mentioned.

I appreciate the opportunity to participate in this discussion, which I hope clarifies the distinction between "ambiguous" and "multivalued."

R. Bateman, E. F. Florman, and A. Tait[3]: In his latest comments, Mr. Rechtin states "the case of nearly equal fields is one on which we agree." We presume from this statement that Mr. Rechtin now concurs with the results of our original paper.

It should be understood that our paper and the companion paper by Hufford[2] were concerned with phase differentials as integrated over different paths, and not with the absolute value of phase at a point. The equipment does not make the results ambiguous; in some cases they are ambiguous.[6]

The use of a system employing modulation frequencies has very definite advantages, as indicated by Mr. Rechtin, in resolving the ambiguity in certain cases. For example, modulation frequencies will provide lane identification in some types of hyperbolic systems. However, the distance errors caused by E_P will in some cases be greater with a system employing modulation frequencies, as compared to a system involving phase measurements at the carrier frequency, particularly when the phase angle between E_P and E_D is substantially greater than 2π radians at the carrier frequency. Therefore it appears desirable to consider each problem separately with regard to the question as to whether or not the use of modulation frequencies would be advantageous.

[6] Fig. 1 of footnote reference 2 shows an example in which ambiguous results are obtained on theoretical grounds.

Contributors to Proceedings of the I.R.E.

Frederick E. Brooks, Jr., (S'42–A'44–M'48) was born at Mineola, L. I., N. Y., on October 14, 1916. He received the B.S. degree in electrical engineering from the University of Kansas in 1940, and the D.Eng. degree from Yale University in 1944.

F. E. Brooks, Jr.

Dr. Brooks has taught at the University of Texas since 1943 and is now associate professor of electrical engineering. He is also assistant director of the Electrical Engineering Research Laboratory of the University of Texas, engaged in research on radio propagation.

Dr. Brooks is a member of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and the American Institute of Electrical Engineers. He is also Chairman of the San Antonio Section of The Institute of Radio Engineers.

❖

Joseph M. Diamond (S'44–A'47) was born in New York, N.Y., on December 26, 1924. He received the B.E.E. degree from Cooper Union in 1944, served in the Navy from 1944 to 1946, and worked on television development at the Bendix Radio Corporation from 1946 to 1947. From 1947 to the present he has been engaged in teaching and research in engineering, and also in graduate work in engineering and mathematics at the University of Pennsylvania. Mr. Diamond received the M.S. degree in electrical engineering in 1949 and the M.A. degree in mathematics in 1950, both from the University of Pennsylvania.

J M. Diamond

❖

John V. L. Hogan (M'12–F'15) was born in Philadelphia, Pa., on February 14, 1890. Following a period as laboratory assistant to Lee de Forest during 1906–1907, he studied electrical engineering at the Sheffield Scientific School. In 1910 he became an electrical engineer on the staff of the National Electric Signaling Company, where he was associated with Professor R. A. Fessenden. Mr. Hogan supervised the erection of the Bush Terminal Station in New York, N. Y., in 1912, and in 1913 was placed in charge of the test operations between the Navy's first high-power station at Arlington, Va., and the U.S.S. *Salem*.

John V. L. Hogan

Mr. Hogan was appointed chief research engineer of the National Electric Signaling Company in 1914. In 1917 this company's name was changed to the International Signaling Company, and he was made commercial manager. He was named manager of the company then known as the International Radio Telegraph Company in 1918, leaving in 1921 to act as a consulting radio engineer in New York, N. Y. He is now president of Hogan Laboratories, Inc., formerly Radio Inventions, Inc., and is responsible for many inventions in the television and facsimile fields. In 1934 he founded radio station WQXR (then W2XR), which the New York *Times* acquired in 1944. As consultant to the Interstate Broadcasting Company, he still is closely associated with the operation of stations WQXR and WQXR-FM.

The author of "The Outline of Radio," Mr. Hogan has been a prolific contributor to radio literature. One of the three original founders of the Institute, he helped to combine the Society of Wireless Telegraph Engineers and the Wireless Institute to form the IRE. Since 1913 he has frequently served as a member of the Board of Directors; from 1916–1919 he was Vice-President, and was elected President in 1920. He has also been Chairman of a number of Institute Committees, including Facsimile, Publicity, and Standardization.

Mr. Hogan is a member of the Patent Compensation Board of the Atomic Energy Commission, of the Electronic Countermeasures Panel of the Research and Development Board, and of the Special Technical Advisory Group working under the Joint Chiefs of Staff and the Research and Development Board. He is chairman of the Joint Technical Advisory Committee and of the Panel on Allocations of the National Television System Committee.

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For a biography and photograph of J. M. Kelso, see page 565 of the May, 1950, issue of the Proceedings of the I.R.E.

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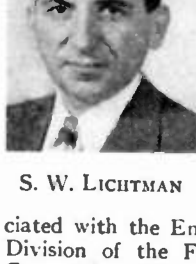
S. W. Lichtman (A'42–SM'48) was born on July 16, 1910, in Chicago, Ill. He received the B.S.E.E. degree from the University of Illinois in 1934.



S. W. Lichtman

From 1934 to 1937, he was engaged in the design and development of radio receivers and electronic apparatus for several eastern and midwestern radio manufacturers. During the period from 1937 to 1941, Mr. Lichtman was associated with the Engineering Field Services Division of the Federal Communications Commission. Since 1941 he has been employed by the Navy Department. During the war years, 1941 to 1945, Mr. Lichtman was with the Aeronautical Radio and Radar Laboratory of the Philadelphia Navy Yard where he supervised the evaluation of aeronautical radio equipment and the design of guided-missile electronic apparatus.

Mr. Lichtman has been affiliated with the Naval Research Laboratory in Washington, D. C., since 1945. Here he directed design and research of microwave, pulse-type radio-control systems for guided missiles until the end of the war. This followed with an investigation of pulse-type multiplexing systems which culminated in his directing the design and development of the NRL matrix-type pulse-time-modulation telemetering system, now in use at the White Sands Proving Grounds, N. Mex., for conducting upper-atmosphere research with the V-2 and other high-altitude rockets. Since 1948 Mr. Lichtman has directed research work in the field of radiological instrumentation.

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H. J. Orchard was born near Birmingham, England, on May 7, 1922. He received the B.Sc. degree in mathematics from London University in 1946.

H. J. ORCHARD

In 1939 he joined the British Post Office at Birmingham and was employed on the maintenance of carrier telephone equipment. He transferred to the staff of the Post Office Engineering Training School, then evacuated to Cambridge in 1942, where he was employed in the line transmission department. Since 1947, Mr. Orchard has been with the Post Office Research Branch in London where he has been primarily concerned with research into linear network problems.

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Frank R. Stansel (A'26–M'33–SM'43) was born in Raleigh, N. C., on August 7, 1904. He received the degree of B.S. in electrical engineering from Union College in 1926, and the M.E.E. and D.E.E. degrees from the Polytechnic Institute of Brooklyn in 1934 and 1941, respectively.

FRANK R. STANSEL

Since 1926 he has been employed as a member of the technical staff of the Bell Telephone Laboratories. From 1926 to 1936 he was located at this organization's Whippany Radio Laboratory and was engaged in development of high-power radio transmitters for broadcast and transoceanic service. Following this, his work was concerned with the development and design of special types of testing apparatus. During the recent war he was a member of a group engaged in the design of radar equipment.

During recent years Dr. Stansel has been located at the Murray Hill Laboratories of the Bell Telephone Laboratories, where he is concerned with the development of new types of carrier telephone systems, particularly the application of germanium varistors to these systems.

Dr. Stansel is a member of the American Institute of Electrical Engineers, Eta Kappa Nu, and Sigma Xi.

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For a photograph and biography of AN WANG, see page 688 of the June, 1950, issue of the PROCEEDINGS OF THE I.R.E.

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Lotfi A. Zadeh (S'45–A'47–M'50) was born on February 4, 1921, at Baku, Russia. He attended Alborz College of Teheran, which is an American missionary school, and received the B.S. degree in electrical engineering from the University of Teheran in 1942. He worked for a year as a technical contractor with the U. S. Army Forces in Iran, and came to the United States in 1944. After a brief association with International Electronics Laboratories in New York, N. Y., he resumed his studies, receiving the M.S. degree from the Massachusetts Institute of Technology in 1946, and the Ph.D. degree from Columbia University in 1949. In 1946 he joined the staff of Columbia University, where he is now assistant professor of electrical engineering.

LOTFI A. ZADEH

Dr. Zadeh is an associate member of the American Institute of Electrical Engineers, and a member of the American Physical Society, the American Mathematical Society, and Sigma Xi.

Correspondence

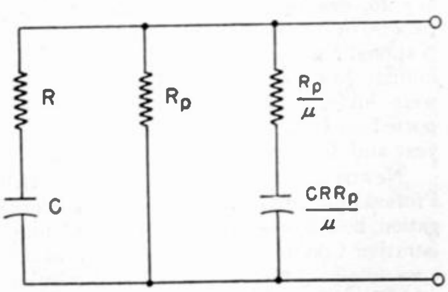
A Note on "Network Representation of Input and Output Admittances of Amplifiers"*

In a letter entitled "Network Representation of Input and Output Admittances of Amplifiers," Vallese[1] has presented a valuable compilation of electron-tube-amplifier equivalent networks.

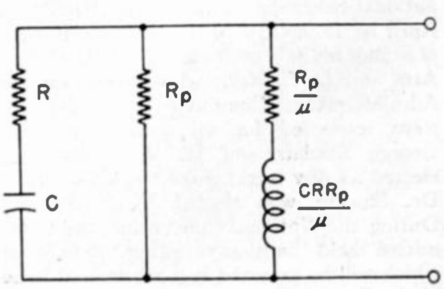
However, I wish to call to your attention an error which appears in one of the illustrative examples which was included therein. In the analysis of the reactance-tube network, the additional impedance which appears in parallel with the reactance-tube terminals because of amplifier action was given as

$$\frac{1}{Y''} = \frac{R_p}{\mu} + j\omega C \frac{RR_p}{\mu}.$$

The output admittance of the reactance tube was then represented by the network shown in Fig. 1(a) and referred to originally as Fig. 2(c).



(a)



(b)

Fig. 1—(a) Incorrect; (b) correct.

It will be noted that in the branch which represents $1/Y''$, the reactance $j\omega C(RRp)/\mu$ is represented as a capacitor. However, by dimensional analysis, using V, Q, and T as basic dimensions (i.e., voltage, charge, and time)

$$C = \frac{Q}{V} = V^{-1}Q^{+1}T^{0}$$

$$R = R_p = \frac{V}{I} = \frac{VT}{Q} = V^{+1}Q^{-1}T^{+1}$$

$$\mu = \text{dimensionless}$$

and

$$C\frac{RR_p}{\mu} = (V^{-1}Q^{+1}T^{0})(V^{+1}Q^{-1}T^{+1})$$

$$= V^{+1}Q^{-1}T^{+2} = \text{inductance}.$$

Thus the quantity $j\omega C(RRp/\mu)$ is an inductive reactance and should be represented as shown in Fig. 1(b).

FREDERICK W. SMITH
National Broadcasting Company
New York 20, N. Y.

* Received by the Institute, December 6, 1950.

[1] L. M. Vallese, "Network representation of input and output admittances of amplifiers," PROC. I.R.E., vol. 37, pp. 407–408; April, 1949.

Institute News and Radio Notes

Technical Committee Notes

The Institute has appointed Chairmen and Vice-Chairmen of the **IRE Technical Committees** for the ensuing year, May 1, 1951–April 30, 1952.

Carl Neitzert of Stevens Institute, W. A. Lynch of the Polytechnic Institute of Brooklyn, J. R. Ragazzini of Columbia University, and Henri Lauer of RCA Victor Division will represent the IRE on the **ASA Sectional Subcommittee Z10.14, Nomenclature for Feedback Control Systems.** E. S. Seeley has been appointed IRE Representative on the **ASA Sectional Committee Z24, Acoustical Measurements and Terminology.** H. E. Roys will represent the IRE on **ASA Sectional Committee Z57, Sound Recording.**

The Institute approved the **Standards on Abbreviations of Radio-Electronic Terms, 1951,** which is contained in this issue of the PROCEEDINGS. Reprints are also available from Headquarters for a nominal charge.

A meeting of the **Circuits Committee** was held on January 19, under the Chairmanship of W. N. Tuttle. This Committee is concerned with the revision of definitions of linear varying-parameter and nonlinear circuits, as prepared by the Subcommittee.

The **Second Conference on High-Frequency Measurements,** sponsored jointly by The Institute of Radio Engineers, the American Institute of Electrical Engineers, and the National Bureau of Standards, was held in Washington, D. C., on January 10, 11, and 12, 1951. The attendance was approximately 590. Patterned after the successful 1949 Conference, it offered an opportunity to those interested to learn of new developments and exchange information on recent advances in the art. The technical program consisted of four sessions on various categories of measurements, and an evening of demonstration lectures. In addition, inspection trips were arranged to the National Bureau of Standards, the Naval Observatory, the Naval Ordnance Laboratory, and the Naval Research Laboratory. This Conference was a part of the celebration of the National Bureau of Standards semicentennial. The **Joint IRE/AIEE Committee on High-Frequency Measurements,** and the **IRE Professional Group on Instrumentation** co-operated in organizing this Conference.

The IRE participated for the first time in the program of the **National Convention of the Institute of Aeronautical Sciences,** which was held at the Hotel Astor, New York, N. Y. The IRE, in co-operation with the Institute of Aeronautical Sciences and the Institute of Navigation, sponsored technical sessions devoted to electronics in aviation. These sessions were particularly interesting and well attended.

Axel G. Jensen, Chairman of the **Definitions Co-ordinating Subcommittee,** reported that three proposed lists of definitions have been circulated for comment. Copies of the revised Master Index, which has been prepared under the supervision of this Committee, will be available within a short time from Headquarters.

The **Antennas and Waveguides Committee** held a meeting on January 23, under the Chairmanship of Gardner Fox. This Committee is working on the preparation of definitions relating to waveguide and transmission lines.

J. W. McRae of Bell Telephone Laboratories has succeeded W. R. G Baker, vice-president of the General Electric Co., as the **IRE Standards Co-ordinator** for the ensuing year. The officers and personnel of the IRE Technical Committees are most grateful to Dr. Baker for his leadership and guidance during the past three years.

The **Committee on Wave Propagation** held a meeting on January 18, H. G. Booker Chairman, presiding. The Chairmen of the various Subcommittees gave detailed reports as to the progress of work going on in each of their groups.

Professional Group Notes

Professional Group activities at the **1951 National Convention** were a great success: Seven Groups sponsored technical sessions, seven held business meetings of the entire membership, and two Groups held small meetings of their Administrative Committees. Tables were arranged at the President's Luncheon to accommodate members of the Professional Groups, and to allow each member to sit at a table with other members of his Group.

The **Committee on Professional Groups** held a meeting on March 5 to consider recommendations made at a joint meeting of the Policy Development Committee and the Committee on Professional Groups on January 26, dealing with publication of Group papers. A meeting also took place at the National Convention. Members of the Administrative Committees of all the Groups were invited to attend. Each Group reported on its activities during the previous year and discussed plans for the future.

Newbern Smith, Chairman of the **IRE Professional Group on Antennas and Propagation,** held a meeting of his Group's Administrative Committee on February 7 to discuss details of the spring technical meeting, which will be held jointly with the United States National Committee of the International Scientific Radio Union (URSI) on April 16, 17, and 18, at the National Bureau of Standards in Washington, D. C. L. C. Van Atta and D. E. Kerr, whose terms on the Administrative Committee had expired, were re-elected for an additional term; George Sinclair and H. W. Wells were elected as new members of the Committee. Dr. Sinclair was elected Vice-Chairman. During the National Convention, the Committee held another meeting, details of which will be reported in a subsequent issue of the PROCEEDINGS.

Newsletter No. 5 was mailed to the members of the **Professional Group on Audio** in February. This outlined the two technical sessions sponsored by the Group at National Convention, and called attention to the special audio exhibit booths at Grand Central Palace. The Group's Chairman, Leo L. Beranek, called a business meeting of the entire membership at the Convention. Headquarters has been informed that Vincent A. Y. Konig is serving as Chairman, and Joseph R. Maklary as Vice-Chairman of the Milwaukee Section Group. A local Group is currently being organized in the Seattle Section.

In February, Lewis Winner, Chairman of the **IRE Professional Group on Broadcast Transmission Systems,** sent a memorandum to its members welcoming them into the Group and outlining the program for Broadcast Day at the National Convention. The Group also held a business meeting during the Convention.

A memorandum was distributed to the **Professional Group on Circuit Theory** during February by the Group's Chairman, J. G. Brainerd. The memorandum welcomed members and listed papers sponsored by the Group at the National Convention. The Group's Administrative Committee held a meeting during the Convention.

Bulletin No. 2 was distributed to members of the **IRE Professional Group on Instrumentation** on February 16, calling members to the annual meeting of the entire Group membership at the National Convention. It also drew attention to one half-day and one full-day symposium sponsored by the Group. This Group, currently under the Chairmanship of Ernst Weber, was responsible for securing the paper, "Progress in the Development of Test Oscillators for Crystal Units," by L. F. Koerner, which was published in the January, 1951, issue of the PROCEEDINGS. S. C. Lawrence, Chairman of the Group's Paper Committee, has organized efforts to secure additional papers which might find the endorsement of the Group. Mr. Lawrence was appointed to the Board of Editors of the IRE to serve as Group Representative.

The **Professional Group on Nuclear Science** issued Newsletter No. 7 on February 9. It announced the national business meeting of the Group at the National Convention, and dealt with the two technical sessions sponsored by the Group, one on instrumentation, and the other on nuclear reactors. The letter also contained summaries of books recently published in this field, and much additional material of particular interest to members. M. M. Hubbard is currently serving as the Group's Chairman.

On February 14, Group Chairman R. F. Rollman issued a memorandum to members of the **Professional Group on Quality Control,** calling attention to the panel discussion on quality control for electron tubes for reliability, sponsored by the Group at the Convention. The Group also held a national business meeting during the Convention.

'he paper, "The Control Chart as a Tool for ›nalyzing Experimental Data," by Enoch 3. Ferrell, which was published in the Februry, 1951, issue of the PROCEEDINGS, was ponsored by this Professional Group.

The Administrative Committee of the **RE Professional Group on Radio Telemetry nd Remote Control** held its first meeting ast November. J. W. Mayo-Wells was lected Chairman; C. H. Hoeppner and . Kauke were elected Secretaries. Planning vas started for the two symposia sponsored y the Group at the Convention. One symosium dealt with telemetering systems, and he other with simulation as an aid to design of remote control systems. The Group held a business meeting of its entire membership during the Convention.

IRE SOUTHWEST CONFERENCE PLANS TENTATIVE PROGRAM

The IRE Southwest Conference, to be eld on the campus of Southwest Methodist University in Dallas, Tex., on April 20 and 21, 1951, has announced the following tentative program:

Keynoter—Donald G. Fink, Editor, *Electronics*—"New Frontier in Electronics."

Banquet Speaker—George E. Sterling, Commissioner, FCC.

Technical Program:

1. Cornelius Lonczos, National Bureau of Standards, Institute of Numerical Analysis, University of California—"The Radiation of a Cylindrical Antenna."
2. C. Crain, University of Texas—"Microwave Refractometer and its Application to the Studies of the Structure of the Lower Atmosphere."
3. F. E. Brooks and H. W. Smith, University of Texas—"A Correlation Computer and Applications to Radio Propagation."
4. J. T. Woods, Atlantic Refining Co.—"Seismodic Design."
5. F. McDonald, Magnolia Petroleum Co.—"An Electronic Fourier Analyzer."
6. Allen Reed, Southwestern Medical School of the University of Texas—"The Instrumentation of Radiation Effects."
7. H. E. Kantor, Southwestern Medical School of the University of Texas—"Contribution which Engineering Must Make for Medicine to Progress."
8. H. L. Jones, Oklahoma Institute of Technology—"Tornado Tracking and Identification."
9. N. Marchand and M. Leifer, Sylvania Electric Products Inc.—"Modern Trends in the Design of Navigation Systems."
10. C. R. Borrows, Cornell University—"Radio Astronomy."
11. H. G. Lindner, Coles Signal Laboratories—"Time Domain Concept of Communication."
12. Robert Scal, National Bureau of Standards—"Electronic Miniaturization Technique in Airborne Equipment."

In addition to the technical papers listed above, a large industrial engineering exposition is being planned, which is to display some of the outstanding new features in radio and electronics.

Calendar of COMING EVENTS

NAB Convention, Hotel Stevens, Chicago, Ill., April 15–19

URSI Spring Meeting, Washington, D. C., April 16–18

AFCA National Convention, Drake Hotel, Chicago, Ill., April 19–21

IRE Southwestern Conference, Dallas, Texas, April 20–21

1951 New England Radio Engineering Meeting, Sponsored by North Atlantic IRE Region, Copley Plaza Hotel, Boston, Mass., April 21

1951 Convention of SMPTE, Hotel Statler, New York, N. Y., April 30–May 4

1951 Annual Meeting of the Engineering Institute of Canada, Mount Royal Hotel, Montreal, May 9–11

IRE Conference on Industrial Electronics, Cleveland, Ohio, May 22 (Details next month)

1951 IRE Technical Conference on Airborne Electronics, Biltmore Hotel, Dayton, Ohio, May 23–25

IRE 7th Regional Conference, Seattle, Wash., June 20–22

1951 Summer General Meeting of AIEE, Royal York Hotel, Toronto, June 25–29

Institute of Navigation National Meeting, Hotel New Yorker, New York, N. Y., June 28–30

1951 IRE West Coast Convention, San Francisco, Calif., August 22–24

1951 National Electronics Conference, Edgewater Beach Hotel, Chicago, Ill., October 22–24

IRE Members, Eligible for Draft—Attention!

The Signal Corps has recently established the following procedures which will assist in the proper assignment of technically skilled IRE members upon entry into the Army:

The Institute of Radio Engineers will provide, upon request, to members who are about to be called into military service in enlisted grades, a Statement of Experience indicating the most applicable military specialties in the radio-electronic field for which a member's experience and background qualify him. This Statement of Experience should be presented by the member upon reporting for military service for reference in assignment to duty.

Interested members write to Mr. George W. Bailey, Chairman, Liaison Committee, 1 East 79 St., New York 21, N. Y., giving full particulars as to education and experience in the radio-electronic field.

JETT, PRATT, RADIO CONFERENCE POLICY GROUP CONSULTANTS

A special ad hoc policy group of three top-level government officials has been formed so that the most constructive basic policy positions can be formulated by the United States on world frequency matters for the Extraordinary Administrative Radio Conference scheduled for August, 1951, at Geneva, to implement the 1947 Atlantic City Radio Frequency Allocation Table.

Two leading radio engineers, former FCC Commissioner E. K. Jett (Fellow, IRE), now vice-president and television director of the Baltimore Sun-papers and former director of the IRE, and Haraden Pratt (Fellow, IRE), vice-president and chief engineer of the American Cable and Radio Corporation, Secretary of the IRE, and former IRE President and Treasurer, have been designated as consultants to review the situation and assist in the determination of the policies.

The special ad hoc policy group consists of Under Secretary of State James E. Webb, Deputy Secretary of Defense Robert A. Lovett, and FCC Chairman Wayne Coy; this group will make recommendations on the United States basic policy positions to the Department of State. Under the guidance of the State Department, considerable government-industry preparatory work for the Geneva Conference, which is to be staged under the aegis of the International Telecommunications Union, has been underway, but it was determined that there still remained certain policy questions to be decided by higher government policy-level authorities.

TORONTO SECTION TO HOLD SILVER ANNIVERSARY DINNER

The Toronto section of the IRE, in commemoration of the silver anniversary of its formation, is holding a dinner on May 7 at the King Edward Hotel in Toronto. The principal speaker will be Donald G. Fink (Fellow, IRE) whose subject will be "Electronics in the Future." Donald McNicol (Fellow, IRE), who was President of the Institute in 1925 when the Toronto Section was formed, will speak on IRE activities during the last quarter of the century.

A cocktail party at 6:00 P.M. will precede the dinner. Tickets are available at $4 from H. G. Byers (telephone: Mayfair 8611), or any member of the Section Membership Committee.

NEW IRE SECTION AND SUBSECTION FORMED

At its January meeting, the IRE Board of Directors approved the formation of the new Phoenix Section, which includes all counties in Arizona, and the new Palo Alto Subsection of the San Francisco Section, which includes the territory of San Mateo County from Belmont south, and of Santa Clara County from San Jose north. Including these additions, IRE Sections now number 58, and Subsections 13.

IRE Conference on Airborne Electronics*

BILTMORE HOTEL, DAYTON, OHIO—MAY 23–25, 1951

PROGRAM

Wednesday Morning, May 23, 1951

Communication and Navigation

"Long-Range Navigation," B. Alexander
"Design Trends in Military Airborne Communication Equipment," G. H. Scheer, Jr.
"Some Problems of Selective Communication with Aircraft," D. G. C. Luck
"Audio Problems in Aircraft Communication," I. H. Bowker

Electronic Components and Techniques

"Electro-Mechanical Filters," J. F. Beckerich
"Etching—A General Fabrication Technique for Miniaturized Components," W. H. Hannahs and J. A. Caffiaus
"Application of Printed Circuit Techniques to IF Amplifiers," R. Bahr, Jr., and W. H. Hannahs
"Semi-Automatic Assembly with Miniaturization Techniques," W. H. Hannahs and W. Serniuk

Theory of Communication

"Cross-Correlation in Periodic Radio Systems," N. Marchand and M. Leifer
"The Infomax Concept for Improving Radio Communication," M. A. Antman
"Multiplexing by Orthogonal Functions," N. Marchand and H. R. Holloway

Wednesday Afternoon, May 23, 1951

General Session

"The Electronic Systems Engineer," R. I. Cole
"Instrumentation of High-Speed Research Airplanes," C. A. Taylor
"The Compensation of Magnetic Fields of Aircraft," W. E. Tolles
"Some Recent Advances in Color Television," A. V. Loughren and C. J. Hirsch

Computers

"Computers for Air Traffic Co-ordination by the Control of Individual Releases at Terminals," D. E. Olshevsky
"A Computer for Correlation Functions," F. E. Brooks and H. W. Smith
"Wind Measurement by Radar," L. A. Matson

Antennas I

"A Glide Path Cavity Antenna for Jet Fighter Aircraft," L. E. Raburn
"Vertical Stabilizer Antenna System for Multiple Operation," R. DeLiban, J. T. Bolljohn, A. R. Ellis, and D. R. Scheuch
"Fin Cap Zero-Drag Loran Antenna," G. Weinstein
"Metal-Clad, Progressive-Phase, Dielectric Antennas," W. Rotman
"A Small Unidirectional Antenna," R. T. Leitner
"An Aural Homing Antenna Pattern Range," W. R. Fried

Thursday Morning, May 24, 1951

Propagation

"Air-to-Air Electromagnetic Wave Propagation," G. B. Fanning and F. P. Miller
"The Effect on Propagation of an Elevated Atmospheric Layer of Nonstandard Refractive Index," L. H. Doherty
"Electromagnetic Scattering from Wedges and Cones," C. J. Sletten

Electronic Instrumentation I

"Simulators for Radar Servomechanisms," L. Goldman, Jr.
"A Rocket-Borne Alphatron Atmospheric Pressure Measurement System," N. W. Spencer and H. F. Schulte
"Aerograph Equipment for Weather Reconnaissance," L. E. Evenson
"An Electronic Regulator for Low Voltage DC Applications," H. J. Galbraith

Microwaves

"The Design and Construction of a Microwave Resonant Cavity for a Linear Electron Accelerator," H. C. Hyams
"Coated-Conductor Waveguides and Antennas," R. E. Beam and E. Bedrosian
"Microwave Printed Circuits," R. M. Barrett and M. H. Barnes

Thursday Afternoon, May 24, 1951

Antennas II

"Systems Consideration in Aircraft Antenna Design," J. V. N. Granger
"A Versatile GCA Antenna," H. Schutz
"Theory and Applications of the Power Equalizer," R. W. Masters
"Multizone Extra Wide-Band Radiating System," E. L. Bock and J. F. Byrne
"A Wing Tip Omnidirectional Range Antenna for Jet Fighter Aircraft," J. D. Martin

Vacuum Tubes I

"Crystal-Controlled Klystrons for Airborne Application," V. R. Learned
"The Application of the Theory of Oscillators to Microwave Generators," J. S. Schaffner
"Recent Developments in Dark Trace Tubes," E. R. Jervis
"An RF Amplifier for UHF," B. F. Tyson and J. G. Weissman
"Development of Cold-Cathode Gas Tubes and Application to Airborne Equipment," M. A. Babb

Measurements I

"Measurements to 2,000 MC with the UHF Admittance Meter," R. A. Soderman
"An Automatic Phase-Plotting Machine," R. M. Barrett and M. H. Barnes
"An Improved Standing-Wave Amplifier," J. G. Rubenson and F. H. Blecher
"Compact VSWR Indicator for Field Use," F. Klawsnik
"A 20-Cycle to 50-Megacycle Signal Generator," J. Van Beuren

Friday Morning, May 25, 1951

Vacuum Tubes II

"On the Characteristics of Microwave Oscillations in Gaseous Discharges," L. Brennan, J. Saloom, and R. Wellinger
"Practical Developments in the Traveling-Wave Tube," S. F. Kaisel, R. W. Peters, and W. J. Dodds
"Consideration of New Experimental and Theoretical Analysis of Germanium Diodes," N. Salz, W. B. Whalley, and C. Masucci
"Rating of Electron Tubes at Very High Altitudes," R. J. Bibbero

Measurements II

"Precision Measurements of Air Stream Velocity Vector," W. M. Kaushagen
"An Audio Spectrum Recording System," N. L. Laschener and A. B. Todd
"Application of High-Speed Electronic Counters," G. J. Giel

Shock and Vibration

"Shock Testing of Airborne Electronic Equipment," Charles E. Crede
"The Electrical Characteristics of Shaker Systems Used for Vibration Testing of Equipment," R. C. Lewis

Friday Afternoon, May 25, 1951

Systems Analysis and Reliability Measurements

"Reliability Testing of Airborne Electronic Systems and Components," W. T. Sumerlin
"Marginal Checking for Airborne Electronic Equipments," G. C. Sumner
"Optimum Systems for the Detection of Pulse Signals in Noise," Harold V. Hance
"A New Concept of Measurement of System Performance," A. L. Witten and R. E. Henning
"Tolerance Measurement in Complex Systems," E. W. Pike and T. R. Silverberg

Electronic Instrumentation II

"Instrumentation for Cannonball I," J. L. Murphy and H. W. Pavela
"The Automatic Flight Schedule Contoller," K. C. Cummings and K. J. Bulleyment
"Flare-Out Unit AN/APN-71, An Aid to Aircraft Instrument Landing," D. M. Pasek and W. J. Shanahan
"Radiosonde Telemetering and Recording System," J. A. Siderman

Circuits

"Method of Generation of Fractional Microsecond Positive Pulses at High Repetition Rates," F. M. Pelton

* See page 1A of this issue for further information.

"The Reluctance Amplifier," F. G. Willey and F. S. Macklem
"A Simplified Servomechanism Approach to the Automatic-Gain-Control Problem," E. E. Lewis and W. A. Adkisson
"Application of Single-Sideband Suppressed-Carrier Modulators in Narrow Band Techniques," H. R. Holloway and H. C. Harris
"Design Considerations in DC and AC Electronic Voltage Regulated Power Supplies," J. E. Zimmerle

Industrial Engineering Notes[1]

Mobilization

Munitions Board Chairman John D. Small appointed Harry K. Clark, president of The Carborundum Co., Niagara Falls, N. Y., as vice-chairman of the Board in charge of production management. Mr. Clark will be responsible for all production activities of the Munitions Board. These include military production programs, facilities and construction, manpower and industrial security, and the aircraft, petroleum, and electronic divisions. He will serve without compensation. . . . William S. Paley, chairman of the board of the Columbia Broadcasting System, was sworn in as chairman of the President's Materials Policy Commission recently. The purpose of this new Commission will be to measure the country's long-range needs and availability of raw materials. The Commission will work on the problems of preventing future shortages of needed raw materials. It will not concern itself with current needs and allocations of raw materials. . . . Creation of an Office of Aviation Defense Requirements within the CAA to administer priorities and allocations for civil aviation was announced recently by Donald W. Nyrop, Administrator of Civil Aeronautics. The office will be headed by G. R. Gaillard, who has been CAA Standardization Coordinator since World War II. The immediate responsibility of the Office of Aviation Defense Requirements will be to handle "DO" defense-rated orders for new air carrier aircraft and for necessary spare parts and equipment to keep United States, and allied foreign carriers, in operation.

NAB Estimate Shows More Radio Families

A tremendous expansion in radio listening in America during the past year was indicated by a National Association of Broadcasters' estimate that there were 41,902,700 radio families as of January 1, 1951. This figure represents an increase of 1,201,000 families over the January 1, 1950, figure. NAB's estimate is based on preliminary figures made available by *Sales Management* Magazine, whose total-families count is 44,108,100.

[1] The data on which these NOTES are based were selected by permission from *Industry Reports*, issues of November 17, November 24, December 1, December 8, January 19, January 26, February 9, and February 19, published by the Radio-Television Manufacturers Association, whose helpful attitude is gladly acknowledged.

FCC Actions

The FCC adopted a report and order amending its Rules Governing Amateur Radio Service. The changes are effective immediately. The finalized rules contain a statement of the basis and purposes of the amateur rules, provide for six grades of amateur licenses, including those comparable to the present classes A, B, and C, specify the requirements for these new operator classes, change the manner of reporting operation required for renewal of operator licenses, and make other changes. Copies of the Report and Order (mimeograph No. 58345) may be obtained from the Secretary of the Federal Communications Commission. . . . The first authorization on a regular basis for remote-control operation of noncommercial educational FM broadcast stations of ten watts or less power was issued recently. The grant was made to the Long Beach Board of Education's station KLON, Long Beach, Calif. The authorization was made under new FCC rules which remove the previous requirement that low-power educational FM stations keep a licensed operator on duty at the transmitter at all times while the station is in operation. . . . In a recent statement, the FCC said that licensed radio amateurs may be requested by the appropriate local Civil Defense authorities to provide civil defense communications to supplement other existing communications systems for civil defense purposes. The frequency bands which will remain available for civil defense use by amateurs are tabulated herewith: 1,800–2,000 kc, 3,500–3,510 kc, 3,090–4,000 kc, 28.55–28.75 mc, 29.45–29.65 mc, 50.35–50.75 mc, 53.35–53.75 mc, 145.17–145.71 mc, 146.79–147.33 mc, and 220–225 mc. In addition to the bands listed above, the band of frequencies 1,750–1,800 kc will continue to be available for use by properly qualified amateurs and others to provide a Disaster Communications Service; but it should be noted that such a service is intended as a permanent one for use in a disaster occurring at any time, to assist in handling communications within or with a disaster area, whereas the frequencies listed above are designated for amateur use for the handling of such communications as may be required in the interest of civil defense

New "Thermal Shunt" Described by OTS

The Office of Technical Services announces a report which describes a unique "thermal shunt" to prevent overheating of miniature electronic components during soldering.

The shunt, which is simply a crocodile-type clip to which heavy copper jaws have been added, was developed after research revealed that the brief overheating resulting from soldering operations during the assembly of miniature electronic equipment permanently changed the value of carbon composition resistors as much as twenty per cent.

By attaching the thermal shunt to the component lead wire during soldering, and leaving it in place for about fifteen seconds after the soldering is completed, the change in value was reportedly held within one per cent, the OTS stated.

RTMA Activities

RTMA has established eleven new categories of electronic component parts in the recently completed reclassification of all electronic parts made at the request of the Munitions Board. The new classifications are: transducers, transducer accessories, antennas, circuit interrupters, resistors, capacitors, transformers, housings, piezo-electric frequency-control devices, plugs and connectors, and hardware. The new categorical breakdown will enable the military and the electronics industry to identify readily component parts by listing them in groups requiring common production facilities, manpower, material, and "know-how." Thus, it is now possible for the Department of Defense to ascertain readily the electronic industry's ability to produce any type of electronic component part. This important information had not been available to the military or to the electronic industry before. . . . At the request of the panel on electron tubes of the Research Defense Board, a JETEC task committee has been appointed to make recommendations on technical policies and procedures for a reliable tube program of RDB, according to Virgil M. Graham, chairman of JETEC. This group, under the chairmanship of A. K. Wright, of Tung-Sol Lamp Works, Inc., held its first meeting on February 5, in New York, N. Y. The following representatives of receiving tube manufacturers were asked to serve on the committee: C. F. Stromeyer, Hytron Radio and Electronics Corp.; A. M. Skellett, National Union Radio Corp.; K. Ishler, Lansdale Tube Co.; R. E. Moe, General Electric Co.; J. R. Steen, Sylvania Electric Products Inc.; G. R. Shaw, Radio Corporation of America; and N. B. Krim, Raytheon Manufacturing Co. . . . Robert C. Tait, president of the Stromberg-Carlson Co., Rochester, N. Y., has been elected co-chairman of the Joint Electronics Industry Committee, which is sponsored jointly by RTMA and the National Security Industrial Association. Fred R. Lack, vice-president of the Western Electric Co., who has served as head of the committee since its inception last August, will serve as the other co-chairman. The JEIC was established by RTMA and NSIA to co-ordinate all industry mobilization activities, and to serve in an advisory capacity to top government policy-making officials. The committee consists of more than a score of industry leaders.

General Elder Chief, Supply Activities, Signal Corps

Brigadier General Eugene V. Elder has been selected to succeed Brigadier General Alfred M. Shearer as chief of the U. S. Army Signal Corps supply activities, the Signal Corps announced recently. The change was effective on Thursday, January 31, 1951. General Elder, who is well known in the radio-television industry, has served as assistant to General Shearer since August 1, 1949.

Television News

Chairman Wayne Coy of the Federal Communications Commission recently made a qualified prediction that the freeze on new television stations will be ended before the third anniversary (September) of the FCC imposed halt on television construction. . . . The annual report of the Senate Select Committee on small business revealed that the group was conducting an investigation into the FCC's decision on color television. The report filed with Congress stated that "many complaints were received by the committee after the Commission's decision in October, 1950." As a result of requests from individual Senators, the committee staff was "directed to undertake a full study and investigation, particularly with respect to the effect of the decision on small business." No recommendations were made, as the committee inquiry "is now in progress," the report stated. In a 7-page review on the subject prepared for the Senate, the Committee followed closely the FCC's two color television reports. It felt that "one year after the adoption of an incompatible system, approximately 40 per cent of the receivers in the hands of the public should be capable of receiving these signals without any change." Adoption of the CBS system does not make present sets obsolete, the Committee stated, because adapters and converters can be built into sets at the point of manufacture. The report is to be printed and will soon be available through the Senate Document Office. . . . The FCC recently announced that it is scheduling a "public conference" for the discussion of television broadcasting problems from the viewpoint of the "public, the Commission, and industry." The FCC said it had not set a date for the conference. "A detailed agenda for that conference will be announced later, and will relate generally to the role of television in serving the needs and interests of the public," the FCC stated.

British Inventor Describes Radio Receiver Attachment

An attachment for radio receivers to provide air raid warnings is described in a letter from a British inventor to the American Embassy in London. The following excerpts were taken from a letter received from James V. Eurich of 100–102 The Broadway, Leigh-on-Sea, Essex, England:

"I have designed a small electrical unit, costing under mass production methods approximately 2/-each, which, when fitted to a radio set of any standard make, will enable the set to be switched on and off whenever necessary by the local authority. The set would remain under the control of the owner, but if he sets it in a given way the automatic method would come into operation. By this method it would be possible to communicate with: 1) the whole country, 2) a specified district, or specified districts as required only, 3) certain sections of the population only, such as wardens, police, and so forth, and 4) the general public in certain sections only.

"It would enable the government to broadcast warnings with detailed instructions, and so forth. In view of possible serious disruptions, I am of the opinion that this idea might prove invaluable. If, upon consideration of these limited details you should require further particulars, I shall be delighted to furnish them. A demonstration is also possible, but any electrical engineer will realize the soundness of the principle the moment it is explained."

Noise Figure Standards

The National Bureau of Standards, in order to assist laboratories and industry in the evaluation of noise figure of a linear electrical network, is offering a calibration service for the noise figure in the frequency range of 500 kc to 300 mc. Standards for this purpose have been developed by the Bureau's Central Radio Propagation Laboratory.

Television Tube Sales 7.4 Million in 1950

Sales of television picture tubes to receiver manufacturers in 1950 amounted to 7,473,614 units valued at $198,737,428, according to RTMA reports. This compares with 3,305,673 tubes valued at $92,402,520 in 1949.

Indicating the pronounced trend to larger television screens, 72 per cent of the television-type cathode-ray tubes sold to manufacturers in 1950 were 16 inches and larger in size. In 1949, only 16 per cent of manufacturers' purchases represented tubes of 14 inches and larger in size.

Total sales to manufacturers of cathode-ray tubes, including oscillographs, camera pickup tubes, and so forth, amounted to 7,530,849 units valued at $200,016,051.

Sales to manufacturers in December totaled 686,815 units valued at $20,639,246. Of these, 95 per cent represented tubes 16 inches and larger in size.

Radio Tube Sales Rise 93 Per Cent

Sales of radio receiving tubes in 1950 increased 93 per cent over sales in 1949, according to a recent report. Sales in 1950 totaled 383,960,599 tubes, compared with 198,753,296 in 1949.

Signal Corps Procurement Office Opened in New York

The U. S. Army Signal Corps. in order to expedite defense communication and electronic equipment procurement, recently opened a New York office of the Signal Corps Procurement Agency. The main office of the agency is in Philadelphia. The new branch is located at 80 Lafayette St., New York 13, N. Y. It has three divisions of which the first, the inspection division, opened on January 15, and the administration and industrial mobilization divisions opened on January 29. The telephone number for all three divisions is WOrth 4-7300.

National Bureau of Standards Marks 50th Year

In recognition of its fiftieth anniversary the National Bureau of Standards was presented with scrolls by the IRE and the AIEE during the High-Frequency Measurements Conference, held in Washington, D.C., January 10–12. From left to right are: T. G. Le Clair, AIEE president; E. U. Condon, director of the National Bureau of Standards; I. S. Coggeshall, IRE President; and Ernst Weber, chairman of the Conference.

RE People

Sydney E. Warner (A'30-SM'47) has ›en appointed director of engineering and search at the La Pointe-Plascomode Corporation, manufacturers of television antennas and accessories. To assume this position, he is giving up his association as partner and chief engineer with the Aircraft Electronic Association.

›YDNEY E. WARNER

Born at Spring Lake, N. J., in 1907, Mr. Warner received the Master's degree ·om the Rensselaer Polytechnic Institute in 934, and served there until 1939 as a mem-'er of the faculty. Subsequently he worked s radio engineer for station WTIC, and as hief engineer for station WBRY in Water-ury, Conn. He served also as radio super-isor for the Connecticut State Police; in onnection with this work he perfected the ngineering for the first FM mobile commu-ications network in the United States, vhich has since served as a model for all olice and many military FM communi-ations networks. He has been a consulting ngineer for the State of New Jersey, and onsultant for the FM Link Company, nanufacturers of police communications quipment. At the beginning of World Nar II he was associated with the Airborne nstrument Laboratory at Columbia Uni-ersity, and participated in a project on sub-narine detection from aircraft. Shortly hereafter he served as chief radio engineer it the Crystal Research Laboratories in Hartford, Conn.

A registered professional engineer in the State of Connecticut, and a member of Sig-na Xi, Mr. Warner served on the IRE Piezoelectric Crystals Committee during 1946, and has been both Chairman (1949) and Vice-Chairman of the IRE Connecticut Valley Section.

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David C. Prince (A'45-SM'45), vice-president of the General Electric Company, has been appointed to the GE president's staff, with special duties as assigned, it was announced recently.

DAVID C. PRINCE

A native of Springfield, Ill., Mr. Prince joined the GE test course after graduating from the University of Illinois, where he obtained the B.S. degree in electrical engineering in 1912, and the M.S. degree the following year.

In 1914, he was assigned to work for E. F. W. Alexanderson (A'13-M'13-F'15), radio and television pioneer, then in the railway engineering department. Afterward he served for three years with the Illinois Public Utilities Commission, and in 1917 was commissioned an Army first lieutenant. He was subsequently cited for his "especially meritorious service" in applying guns to aircraft.

Mr. Prince returned to GE as an assistant to Dr. Alexanderson, and then joined the research laboratory, where he conducted research on vacuum-tube applications. In 1929 he joined the switchgear department at Philadelphia, whereupon he became chief engineer. He was appointed commercial engineer for the entire company in 1940, on the staff of C. E. Wilson, then president. The following year he was elected a vice-president and placed in charge of application engineering for the apparatus department. In 1945 Mr. Prince was named head of the General Engineering Laboratory, the activities of which had been broadened to cover the entire company.

He has been responsible for many important design developments in the fields of switchgear, electric locomotives, ship control, and electronic tubes. An active member of the American Institute of Electrical Engineers, he was its president for the 1941-1942 term, and received the AIEE Lamme Medal in 1946. He belongs also to the American Society of Mechanical Engineers.

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Edward Bennett (M'17-F'18), professor emeritus of electrical engineering at the University of Wisconsin, died on January 11 at a Madison hospital after a prolonged illness.

Born in Pittsburgh, Pa., in 1876, he received the electrical engineering degree from the Western University of Pennsylvania in 1897.

He was appointed to the faculty of the University of Wisconsin in 1909, where he served as chairman of his department from 1918 to 1940, and was awarded the title of professor emeritus in 1943. After his retirement that year, he remained active in his field as a consulting engineer.

Prior to his affiliation with the university, he had been associated with the Westinghouse Electric Corporation, the National Electric Signaling Company, and with a prominent power company in Utah. He will be remembered for his work on many important research projects, and particularly for the invention of a multipath lightning arrester, and the development of the Nerst lamp.

He served as Manager of the Institute from 1923 to 1925, and was a member of the Standardization Committee from 1925 to 1928.

Robert McNeil Bowie (A'34-M'37-SM'43-F'48), formerly manager of the Physics Laboratories of Sylvania Electric Products Inc., Bayside, L. I., N. Y., has been appointed director of engineering on the staff of the vice-president of engineering, E. Finley Carter (A'26-F'36).

ROBERT M. BOWIE

Dr. Bowie joined the staff of Sylvania Electric at Emporium, Pa., as a physicist in 1933. In 1935 he was appointed head of the cathode-ray tube research and development department.

He invented the ion trap which prevents the formation of a darkened "ion spot" on the screen of cathode-ray tubes, using magnetically deflected electron beams. The invention is covered by patents under which a majority of television picture tubes are now being manufactured.

Having been head of the Sylvania research laboratory as well as manager of research, he has directed many outstanding wartime and postwar electronic developments, including the construction of the famous moon radar equipment used by the Signal Corps in 1946, and many developments in television picture tube and circuit improvements.

Born in Tablerock, Neb., Dr. Bowie attended Iowa State College from which he received the B.S. degree in chemical technology in 1929, and the M.S. and Ph.D. degrees in physics in 1931 and 1933, respectively.

His Institute activities have included work on the following committees: Admissions, Board of Editors, Papers Review, Nuclear Studies, Papers Procurement, 1950 Convention Technical Program, and Research. He is also a Fellow of the American Physical Society.

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Edward S. White (A'44-M'49) has been appointed assistant chief of advanced development at Air King Products Co., Inc., New York manufacturer of television receivers, radios, and wire recorders. He will act in a development capacity on new product designs.

Prior to joining Air King, Mr. White was senior engineer with the RCA Industry Service Laboratory from 1947 to 1951, where he performed communications development work and acted as consultant to the licensee companies of RCA. He has filed several patent disclosures and has had papers published on sync-separator circuits and neutralization of bifilar coils. Mr. White holds three degrees, including the M.S. in communications engineering (1947) from Harvard University.

He is a member of the Harvard Engineering Society and the American Institute of Electrical Engineers.

Robert F. Field (A'18–M'30–SM'43–F'47) has retired from the General Radio Company engineering department after 21 years of service.

ROBERT F. FIELD

Born in Center Tuftonboro, N. H., in 1885, Mr. Field received the degrees of A.B. and A.M. from Brown University, and continued his graduate work at Harvard University, whose faculty he joined in 1917. Prior to his association with the General Radio Company, he was employed as an engineer at the Hammond Radio Research Laboratory in Gloucester, Mass. He is well known for his work in impedance standardization, electrical measurements, particularly with bridge circuits, and the study of dielectric materials.

Mr. Field is a Fellow of the American Association for the Advancement of Science, and a member of the American Institute of Electrical Engineers, the American Society for Testing Materials, the American Physical Society, Phi Beta Kappa, and Sigma Xi. His IRE activities have included membership on the Meetings and Papers Committee in 1930, and Chairmanship of the Boston Section from 1942 to 1944.

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Lloyd V. Berkner (A'26–M'34–SM'43–F'47) was recently elected president of Associated Universities, Inc., a nonprofit corporation formed to administer Brookhaven National Laboratory at Upton, L.I., N. Y., under contract with the U. S. Atomic Energy Commission. The trustees also announced the election of **George B. Pegram** (A'12–VA'39) as chairman of the board of AUI.

LLOYD V. BERKNER

Mr. Berkner, born in Milwaukee, Wis., in 1905, took the B.S. degree at the University of Minnesota, and did graduate work at George Washington University. After serving as an engineer, first with the U. S. Bureau of Lighthouses, then with the Airways Division, U. S. Department of Commerce, he joined the first Byrd Antarctic expedition. Later he became a research engineer at the National Bureau of Standards. He served in this capacity also for the Department of Terrestrial Magnetism, Carnegie Institution, from 1933 to 1941. From 1941 to 1946 he organized and headed the Electronics Materiel Branch, Bureau of Aeronautics, U. S. Navy Department, and then served as executive secretary of the Research and Development Board, National Military Establishment. In 1949 he became special assistant to the Secretary of State in directing work relating to the Military Assistance Program.

For his many distinguished contributions, both as a scientist and an administrator, Mr. Berkner has been the recipient of numerous honors. Among these are a special Congressional Gold Medal for his work in the Byrd expedition, the Award of Achievement in Scientific Research given by the Washington Academy, a commendation from the Secretary of the Navy for his radar research, the Order of the British Empire from the British Government, and the Legion of Merit from the President of the United States.

His Institute activities have included work on the Board of Editors, the Papers Committee, and the Wave Propagation Committee. He is a Fellow, also, of the American Physical Society, of the American Institute of Electrical Engineers, and a member of the National Academy of Sciences, the National Research Council, and the American Association for the Advancement of Science. As Chairman of the United States National Committee of the International Scientific Radio Union, he headed the United States delegation to the meeting of the Union at Zurich in 1950.

George B. Pegram, pioneer government advisor on atomic energy and vice-president emeritus of Columbia University, was born in Trinity, N. C., in 1876, and was graduated from Trinity College (now Duke University) in 1895. After doing graduate work at the University of Berlin and in Cambridge, England, he joined the Columbia staff in 1910. His teaching career has included the following positions: dean of Columbia's school of mines, engineering and chemistry, dean of the graduate faculties, of the faculties of political science, philosophy and pure science, and dean of the graduate school. Finally, in 1949, he became vice-president of the University. Head of the University Committee on War Research during World War II, Dean Pegram is still connected with the U. S. Atomic Energy Commission; he has been a member of the board of directors of the Oak Ridge Institute of Nuclear Studies, and is now serving as one of their consultants.

Dr. Pegram has been closely associated with, and has held important positions in the following organizations: the American Physical Society, the American Association for the Advancement of Science, the Society for the Promotion of Engineering Education, the Association of University Professors, the American Association of Physics Teachers, Sigma Xi, the American Institute of Physics, the New York Academy of Sciences, The Optical Society of America, the Acoustical Society of America, the American Society of Mechanical Engineers, the Institute of the Aeronautical Sciences, the Federation of American Scientists, the American Philosophical Society, and the National Academy of Sciences.

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A. V. Astin (SM'50), formerly chief of the electronics and ordnance division of the National Bureau of Standards, has been appointed associate director of the NBS. In this capacity he is responsible for the activities of the divisions of electronics, ordnance development, missile development, and the office of basic instrumentation, and for co-ordination of NBS operations with other government agencies.

Born in Salt Lake City, Utah, he received the B.S. degree from the University of Utah in 1925. The following year he received the M.S., and in 1928 the Ph.D. degrees, both from New York University.

Dr. Astin was one of the original group of scientists assembled at the Bureau in December, 1940, to develop proximity fuzes for bombs and rockets. He played a major part in the development and evaluation of these fuzes and in their introduction to service use during the war. For this work he was awarded the President's Certificate of Merit, the War Department Certificate of Appreciation for Outstanding Services, and from Great Britain, His Majesty's Medal for Service in the Cause of Freedom. From September, 1944, to March, 1945, Dr. Astin was in the European Theater of Operations as representative of the National Bureau of Standards and of Division 4, National Defense Research Committee, working in liaison with the British Armed Forces in the London Liaison Office, Office of Scientific Research and Development. At the end of the war he edited the three-volume "Summary Technical Report of Division 4" (Ordnance Accessories) of the National Defense Research Committee.

Prior to the war, Dr. Astin was active in research and development in dielectrics and in electronic instrumentation. In these fields he made a number of important contributions, including improved methods of measuring the dielectric constants and power factors of dielectric materials, a better understanding of the nature of energy losses in air capacitors, and pioneering work in the development of radio telemetering techniques for exploring the earth's upper atmosphere.

He is a Fellow of the American Physical Society, and belongs also to the Washington Philosophical Society and to the American Ordnance Association.

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Alois W. Graf (A'26–M'44–SM'45) has been elected president of the Illinois Engineering Council. This organization sponsored the enactment of the Illinois professional engineer registration law, and is active in the Chicago Technical Societies Council, and the National Electronics Conference.

His numerous Institute activities have included membership on the Board of Editors, and on the following Committees: Education, Membership, Convention, and Policy Development. He served also, for a number of years, as Chairman of the Sections Committee and of the Chicago Section.

William H. Crew (SM'46), formerly ssistant Secretary of the Institute, has en appointed assistant director for scien-ic personnel at the Los Alamos Scientific boratory.

Born in Evanston, Ill., in 1899, he is an umnus of the United States Naval ademy. His graduate work was done at hns Hopkins University, where he re-ived the degrees of M.A. and Ph.D. in 24 and 1926, respectively.

He began his career as assistant physicist the Naval Research Laboratory in 1925. ree years later, he joined the faculty of e United States Naval Academy. From 29 to 1941 he was engaged in teaching ysics at New York University, becoming airman of his department in 1938. During e war he served as a technical aide in the ffice of Scientific Research and Develop-ent, attached to the National Defense esearch Council. From 1946 to 1948 he eld the position of assistant dean of stu-ents at Rensselaer Polytechnic Institute; ereafter he became dean of the College of ngineering Sciences, Air Force Institute of echnology, at Dayton, Ohio.

Dr. Crew is a Fellow of the American hysical Society and of the American As-ociation for the Advancement of Science. e is a member also of Sigma Xi, and of the merican Association of University Profes-ors, and an associate member of the United tates Naval Institute.

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Everett S. Lee (M'40–SM'43) has been ppointed editor of the *General Electric Review*, a monthly engineering magazine published by the General Electric Company, it was an-nounced recently.

Everett S. Lee

A native of Chicago, Mr. Lee was graduated from the University of Illinois in 1913 with the B.S. degree in electrical engineering, and received the Master's degree in that subject from Union Col-ege in 1915.

Following his graduation from the Uni-ersity of Illinois, Mr. Lee joined General Electric in Schenectady as a student en-gineer on the test course. Shortly thereafter e became an instructor at Union College, Schenectady, and was in charge of the elec-trical engineering laboratory there.

During World War I, as a first lieutentnt, e was officer in charge of machine gunnery of the U. S. Army School of Military Aero-nautics, University of Illinois.

In 1919, Mr. Lee returned to General Electric as division engineer on instruments and measurements in the General Engineer-ing Laboratory. After several promotions, he became its executive engineer in 1945.

A recognized expert on electrical meas-urements, Mr. Lee is the author of numerous papers which have been published in the technical journals, or presented at the meetings of professional societies.

A Fellow of the American Institute of Electrical Engineers, of which he was president from 1948 to 1949, Mr. Lee has served on nineteen national committees for that organization, and has been chairman of six of these for one or more years. In addition, he has been a member of two co-ordinating committees and ten special committees. As AIEE representative, he served on the National Research Council, the Engineers Council for Professional Development, the United Engineering Trustees, Inc., and the American Participating Committee for the Sixth International Congress for Applied Mechanics held in Paris in 1946.

Mr. Lee is a member also of various other technical societies, among these the American Society for Engineering Education, the New York State Society of Professional Engineers, the National Society of Professional Engineers, the Instrument Society of America, the Newcomen Society of England, North American Branch, the American Society for Testing Materials, the American Standards Association, and the Engineers Club of New York. He is a fellow of the American Society of Professional Engineers.

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Stuart L. Seaton (A'41–M'43–SM'43), former director of the Geophysical Institute of the University of Alaska, has joined the staff of the Naval Ordnance Laboratory, White Oak, Md.

Born at Kirkwood, Mo., in 1906, Dr. Seaton is a graduate of the University of Alaska, where he received the B.S. degree in 1942 and the honorary D.Sc. in 1949. He also attended the University of Maryland and George Washington University, doing some of his graduate work at the latter.

Well known for his work in arctic geophysics and ionospheric research, and the author of numerous studies in these fields, Dr. Seaton was attached to the Carnegie Institution from July, 1929, until January, 1947. During this period he devoted considerable time to the study of upper atmospheric phenomena, and also to fundamental development work on the proximity fuze and on degaussing from the standpoint of the earth's magnetic field.

Dr. Seaton is a member, also, of the American Physical Society, the American Association for the Advancement of Science, the American Geophysical Union, and is an associate of the Institute of Physics in London.

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Correction

On page 22 of the Index for the 1950 volume of the Proceedings, which appeared in the December, 1950, issue, the following entry was listed erroneously under **Obituaries:** "Zworykin, Vladimir K., April, p. 447." This item should have appeared under **IRE People** on page 21 of the Index.

Theodore A. Smith (J'25–A'26–SM'45), who for the past five years has headed the sales activities of the RCA engineering products department, has been appointed assistant general manager of the department, it was announced recently.

Theodore A. Smith

At the same time the appointments of **A. R. Hopkins** (A'27–M'32–SM'43) as general sales manager of the department, and that of **Barton Kreuzer** (A'29–M'48) as general product manager were announced.

Born in Brooklyn, N. Y., in 1905, Mr. Smith received the mechanical engineering degree from Stevens Institute of Technology in 1925, and immediately joined RCA's technical and test laboratories in New York, N. Y. In 1928 he built RCA's pioneer television station, W2XBS; now known as WNBT, this station is the oldest television transmitting station in the country. Mr. Smith entered commercial engineering work in 1930 as RCA eastern district sales manager for broadcast equipment. In 1938 he was assigned to Camden headquarters, where he has since held key sales engineering posts.

He is a member of the executive committee of the transmitter division of the Radio-Television Manufacturers Association, and a former Chairman of the Philadelphia Section of the IRE.

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James L. Cox (A'46) has been appointed vice-president of the Duro-Test Corporation. He will be responsible for manufacturing and engineering of its reactivated electronics division.

James L. Cox

Duro-Test Corporation has augmented its defense production. Shortly after the end of World War II the electronics subsidiary was curtailed, but now it has been reorganized to aid the government's electronics defense program.

Until recently, Mr. Cox was chief engineer of the company's lamp division. He is considered an industry authority on gaseous discharge and electronic devices. He is the inventor of the mercury bomb, the double cathode, porous coating for fluorescent lamps, and various other electronic devices. Mr. Cox received the Modern Pioneer Award as one of America's outstanding inventors in the electronic field in 1940.

During World War II, Duro-Test made radar transmitter tubes for the Navy. The current production work is not disclosed.

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Books

Alternating Current Circuits, Third Edition by R. M. Kerchner and G. F. Corcoran

Published (1950) by John Wiley and Sons, Inc., 440 Fourth Ave., New York 16, N. Y. 586 pages+11-page index+ix pages. 471 figures. 6×9¼. $5.50.

The first edition of this textbook by Kerchner and Corcoran found well-deserved acclaim when it appeared in 1938. The revised second edition of 1943 represented a further improvement, and made the text one of the very best summaries of the elementary background of ac circuit analysis; further improvement appeared hardly possible. Indeed, the third edition which has just appeared, does not differ very markedly from the second. A serious gap was filled by the inclusion of the nodal method of analysis, and the inclusion of the dot notation for transformer polarities is distinctly helpful. The three-origin vector diagram is also introduced, but does not represent an important improvement. Probably every instructor would cover this aspect of three-phase vectors, whether or not the textbook discusses it. Indeed, there are no new concepts involved in this representation of three-phase vectors that a moderately alert student could not develop himself, and the advertisement might place less stress on this particular addition.

The third edition follows essentially the same excellent pattern as the first edition. Designed for a one-year junior level course, it starts with a review of concepts probably familiar to the student from his freshman physics course. Complex and vector notation is introduced early in the book, and even the most elementary systems are analyzed by the use of ac vectors (phasors). The discussion of series, parallel, and series-parallel circuits is followed by a brief summary of some important network theorems, and the node method is introduced here. It might have been well to discuss the mesh method in the same connection, and to show the use of determinants in the general solution of the node or mesh equations, respectively, which would aid the student in seeing the similarity of the two methods. However, Chapter VII, "Coupled Circuits," might have offered a better home for both the node and the mesh solution.

Chapter VI covers the resolution of nonsinusoidal waves by the Fourier method, and the analysis of linear networks subjected to nonsinusoidal voltages.

The section on coupled circuits (Chapter VIII) is primarily concerned with magnetic coupling. Completion of this section provides a logical division between the first and second term. In fact, some schools may prefer to divide the group into power and communications majors at this juncture.

Chapters VIII and IX include a rather thorough discussion of balanced and unbalanced polyphase systems, with a first introduction to the double-subscript notation. Because of the clarity of this notation, an earlier mentioning would have been desirable; probably this ought to have been introduced as early as Chapter V.

Chapters X and XI cover ac measurements, and the determination of circuit parameters, respectively. Chapter XII discusses transmission lines, and Chapter XIII, electric wave filters. The material is adequate at this level, but needs more thorough treatment for communications majors.

The material on symmetrical components (Chapter XIV) is very well presented, with a few short application examples. However, this section needs considerable expansion by the instructor if it is to be applied even to simple networks. The per cent and per unit methods are introduced in this chapter.

The text concludes with a discussion of transient conditions (Chapter XVI) in various one-loop circuit, supplied from direct and alternating voltages. In a future revision, this material might be expanded to cover the general approach for multimesh systems. The applicability of the law of superposition might also be underlined, for the transient case, by inclusion of appropriate problems.

In summary, I recommend this text very highly, as one of the most outstanding books at the junior level.

CHARLES F. SPITZER
Yale University
New Haven, Conn.

Encyclopedia on Cathode-Ray Oscilloscopes and Their Uses by John F. Rider and Seymour D. Uslan

Published (1950) by John F. Rider Publisher, Inc., 480 Canal St., New York 13, N. Y. 992 pages+8-page index+vii pages. 3,000 figures. 8½×11. $9.00.

This new book represents an earnest and successful attempt to collect together all practical knowledge concerning oscilloscopes and their uses. The presentation is largely descriptive with only occasional recourse to mathematics.

The body of the book consists of 25 pages of introduction, 171 pages of material concerning cathode-ray tubes, 331 pages covering oscilloscopes and related equipment, 219 pages dealing with applications and uses of oscilloscopes, a chapter of 93 pages on complex wave-form patterns, followed by a chapter of 18 pages on special purpose cathode-ray tubes, and a final chapter of 107 pages giving complete circuit diagrams and operating specifications of commercial oscilloscopes and related equipment. The body is followed by three appendixes on characteristics of cathode-ray tubes, RTMA cathode-ray-tube biasing, and photography, a 338-item bibliography arranged by chapters, and an 8-page index. Only the last chapter is arranged alphabetically by subject, so the word "Encyclopedia" in the title may be somewhat misleading.

There is a wealth of useful information contained in this volume. Those who use oscilloscopes infrequently and those who are planning to use an oscilloscope for the first time will find it of considerable value. To others who have used oscilloscopes for some time, the details concerning cathode-ray tubes and oscilloscope construction and operation may not be important, but the remainder of the book concerning uses and applications will doubtlessly be useful. In view of the greater importance of Chapter 19, "Electrical Measurements, Scientific and Engineering Applications," more space might have been devoted to this subject, possibly at the sacrifice of less material on electromagnetic theory.

Chapter 20, "Complex Waveform Patterns," consists of 1,580 well-organized and annotated oscilloscope photographs of complex wave forms composed of different amplitude and phase combinations of fundamental and one harmonic (up to the eighth), fundamental and two harmonics, and two harmonics without the fundamental. Although this may seem like an ambitious undertaking, the authors indicate in the Foreword that this material may be expanded into a separate book of 25,000 to 50,000 similar photographs, if the material contained in this book proves to be valuable.

Since oscilloscopes at times get out of order, some material on servicing and trouble shooting would have been useful. Another minor, but important omission is the absence of material concerning the use of a "chopper" to adapt ac oscilloscopes to dc signals. However, these and similar omissions can hardly be considered serious, in view of the extensive subject coverage.

L. J. GIACOLETTO
RCA Laboratories Division
Princeton, N. J.

Transmission Lines and Networks by Walter C. Johnson

Published (1950) by McGraw-Hill Book Co., 330 W. 42 St., New York, N. Y. 354 pages+6-page index+x pages. 230 figures. 6×9¼. $5.00.

This book does a fine job of presenting the basic principles, and introducing the use of lines and passive four-terminal networks. It is designed for those with an elementary knowledge of the calculus and steady-state ac circuit theory, presumably senior engineering students.

Part I starts with the most elementary discussion of frequency, velocity of propagation, and wavelength, together with the distributed nature of line constants. The differential equations governing waves on wires are developed from scratch, and expounded. There is an excellent correlation throughout this section between the mathematical equation and its physical meaning.

The next step in the reasoning, the development of concepts such as characteristic impedance, line loading, and so forth, is the one weak point in the book. Phrases like "Network theory shows" (with no reference) crop up; the statement about loaded lines, that "From physical reasoning it can be seen that there must be at least several coils per half wavelength at the highest desired frequency if the line is to behave with a reasonable approximation to smoothness" (p. 52) must have made Pupin stir slightly.

However, after this one halting step, the development really moves. Line constants, with an excellent discussion of skin effect, the ac steady state with reflections, the much-feared hyperbolic functions, transmission line charts, both theory and use, radio-frequency (low loss) lines, with particular reference to resonance and antiresonance, and the subject of measurements by means of lines, with all the associated stubs, couplers, and tuners, follow each other in a well-ordered and carefully developed sequence.

Two short chapters on telephone and

lower lines give a sop to those who insist that the engineer must have some "practical" training, and could be omitted without destroying the continuity of the book.

Waveguides are not included, since electro-magnetic field theory is the essential basis for analysis," and the book limits itself to conventional circuit theory.

Part II covers the usual elementary theory of four-terminal networks from the mesh-current viewpoint, with particular regard to constant-k and m- derived filters, in the same well-organized fashion.

Examples are worked out in the text wherever necessary. A set of practice problems is given at the end of each chapter. Errors are remarkably few for a first edition.

All in all, this is a very good book.

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Receiving Substitution Guide Book by H. A. Middleton

Published (1950) by John F. Rider Publisher, Inc., 480 Canal St., New York 13, N. Y. 215 pages+iv pages. 18 figures. 8½×11. $2.40.

This book is a greatly enlarged and revised edition of the "Wartime Radio Service," published in 1944. It is written for the use of radio and television servicemen in times of tube shortages. The main section is a 111-page table of receiving tube types, ranging from the O1A to 54 types in the 5,500-up series. For each tube type listed, there may be shown up to a dozen or more suggested substitutes with estimates of performance from "excellent" to "poor," together with details of any necessary circuit changes.

This table is preceded by about 25 pages of text giving general information and instructions for making tube substitutions. The largest portion of this first section is devoted to heater circuits and the use of Ohm's law in calculating series and shunt resistors.

The last 72 pages include numerous useful tables and charts of information on receiving tubes, cathode-ray tubes, television heater circuits, and so forth.

The serviceman who uses this book must study the text carefully, since he will be required, in many cases, to do more than follow blindly the instructions in the table. He is expected to compare the electrode voltages and currents of the original and substitute tube, and correct the circuit constants when necessary.

The radio engineer will find the associated collection of tables and charts much more useful and accurate than the substitution guide itself. The guide is sometimes optimistic concerning the performance obtainable from substitutions, such as filamentary type 6A4/LA to replace cathode types such as 6V6, 6F6, 42, and so forth, since both the hum and biasing problems will be very difficult. Also, replacing a 6AC7 by 6SS7 is listed as "good" in performance, although the transconductances are 9,000 and 1,850 micromhos, respectively, and the tubes are sharp and remote cutoff, respectively.

It is suggested that the errors and omissions inevitable in a compilation of this size be weeded out. In addition to this, several other suggestions might be made: When a radio or television set has been altered to take a substitute tube, the equipment should be clearly marked as to what changes have been made, since replacing the substitute tube by a tube of the original type might have undesirable consequences. It would be helpful if tubes that are substantially identical in electrical and mechanical characteristics such as 5654 and 6AK5, and tubes that are in fact identical, but have had two or more type numbers such as OD3 and VR150, be identified as "interchangeable."

If the present shortage of receiving tubes continues and becomes worse, servicemen will have frequent occasion to use this book to keep their customers' sets in working order.

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Ocean Electronic Navigational Aids

Published (1950) by United States Coast Guard Treasury Department. 73 pages+41 figures. 50 cents.

"Ocean Electronic Navigational Aids" is a publication by the United States Coast Guard. Its purpose, as stated in the foreword signed by Admiral J. F. Farley, Commandant of the United States Coast Guard, "is for the information of United States maritime industry, commercial airlines, and others interested in the application of electonic navigational aids." The foreword further states that "it is intended to be of benefit to the industries concerned in improving the safety, economy, and efficiency of transportation over the areas of the world.

A reading of the booklet makes it evident that its purpose is to acquaint navigators, pilots, mariners, and other users of the Coast Guard navigational service with the generalized technical principles of the devices furnishing this service, so that they may be better understood, and thus be more intelligently used in the normal day-to-day transport operations.

The book has four sections. The first of these covers standard loran, the second, the marine radio beacon systems, the third, microwave beacons and radar aids, and the fourth, marine radar. In addition, the book contains a series of appendixes.

The section entitled "Standard Loran, a Long Range Aid to Navigation," is the most complete. It carefully describes the principles of loran, although it does not show circuit diagrams, or assume a knowledge of electronic principles. This section occupies 26 pages.

The section on radio beacons involves 17 pages and describes the various types of radio beacons, as well as the principles of the manual direction finder. The section on microwave beacons and other radar aids consists of six pages, and describes radar reflectors and microwave beacons. The section on marine radar describes the principle of this device, its advantages and limitations. The booklet contains three charts approximately 11×9 inches, showing "Radio Beacon System on the Great Lakes" (including Canadian radio beacons); "Loran and Radio Beacon Systems, Atlantic and Gulf Coast"; and "Loran and Radio Beacon System, Pacific Coast and Islands." These charts are insufficiently detailed for navigational use; however, they serve to give an excellent understanding of the extent of the marine navigational systems maintained by the United States Coast Guard.

The appendixes include a historical outline, and a suggested minimum specification for marine radar equipment and for direction finding equipment. The booklet concludes with a glossary of electronic navigational terms.

In relation to the total electronic navigational field, the booklet has a very narrow coverage; however, it fulfills the purpose for which it was written in an excellent manner.

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Electrons and Holes in Semi-Conductors by William Shockley

Published (1950) by D. Van Nostrand Co., Inc., 250 Fourth Ave., New York, N. Y. 543 pages+6-page index+xxiii pages. 142 figures. 6×9. $9.75.

This excellent book might almost be said to consist of a set of three monographs of increasingly rigorous treatment. Part I, "Introduction to Transistor Electronics," is entirely descriptive and requires no knowledge of solid-state theory for complete understanding. The diamond lattice, into which germanium and silicon crystallize, is first explained so that the energy scheme, the role of impurity atoms, and the occurrence of conduction electrons and holes can easily be visualized. Hole and electron injection and current flow are then explained in simple terms.

The final chapter of Part I is entitled, "On the Physical Theory of Transistors." The filamentary transistor is explained in such a way that the effect of injecting holes into the semiconductor in producing transistor action is easily understood. This is followed by a discussion of the action taking place at a p-n junction and of the p-n-p transistor. Thus, when the type of A transistor using two closely spaced point contacts is discussed, the only new topic that requires explanation is the intrinsic current gain.

Certain of the earlier papers concerning transistor action presented hypotheses which have been found invalid. For example, hole flow was formerly thought to take place in a surface layer, and the nature of current gain as originally visualized would have precluded the possibility of high values subsequently measured. Although the more acceptable theories have already been published, they could easily be overlooked in any but a complete survey of the literature. Dr. Shockley's book provides an adequate background for reading the older as well as the future papers.

The title of Part II, which comprises about half the book, is "Descriptive Theory of Semiconductors." This title, while appropriate, could easily be misconstrued. As the author points out, it would hardly be practicable to present in the beginning the final picture of the properties of holes and electrons in a semiconductor as they emerge from the theory. On the other hand, by discussing first the basic concepts of quantum mechanics, and leading quickly to the Bloch wave functions and the Brillouin zone concepts of electron motion, the behavior of an electron in an ideally perfect crystal can more easily be described. The stuffiness ordinarily encountered in the treatment of the Schroedinger equation is considerably reduced by the use of analogies which allow the reader to attach meaning to the symbol ψ. The second and third chapters are concerned with the flow of electric currents in crystals and the effects of electric and magnetic fields upon the motions of holes and electrons. This provides the picture necessary for an understanding of conductivity, mobility, and the Hall effect explicated in the last chapters of Part II.

In Part III, "Quantum Mechanical Foundations," many of the concepts presented in earlier portions of the book are subjected to rigorous examination. While many aspects of quantum mechanical theory not directly related to semiconductors are not discussed, the foundations for topics introduced in Part II are treated in considerable detail, and the derivations are given for most of the more important relations. On these bases, the theory of electron and hole velocities are treated quantitatively. Statistical treatment of the theory of transition probabilities for holes and electrons in the Brillouin zones, discussed in descriptive fashion in Parts I and II, is the last topic covered in the book.

Despite the theoretical approach which characterized this comprehensive treatment of a rather difficult but intriguing subject, the author remains extremely realistic and never permits the reader to lose sight of the objectives. "The important contribution which theory makes is to provide a *conceptual framework on which to hang the experimental facts* . . . ." Dr. Shockley is to be congratulated for his achievement in producing an exceptionally fine book; it is a pleasure also to recognize the important contribution of the Bell Telephone Laboratories in supporting this publication.

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Electromagnetic Fields, Theory and Application, Volume I, Mapping of Fields by Ernst Weber

Published (1950) by John Wiley and Sons, Inc., 440 Fourth Ave., New York 16, N. Y. 530 pages+13-page index+xiv pages. 166 figures. 5½×8½. $10.00.

This book is the first part of a two-volume treatment of electromagnetic theory on the graduate level by Professor Weber. Volume I treats the mapping of fields, and is concerned with the various methods of solving static field problems.

The basic physical relationships for electric, magnetic, and other stationary fields are developed in the first part of the book. An interesting feature is the discussion of the correspondence of the scalar potential fields in the various branches of physics and the manner in which they satisfy Poisson's or Laplace's equation.

The superposition principle is used to solve for the fields of simple geometries, and many of the common cases are discussed. In practical applications, the engineer is frequently faced with a geometry that is irregular, or so complicated as to make computation overly laborious. Unlike many writers of texts on electromagnetic theory, the author shows an awareness of this by including a discussion of experimental mapping methods, in addition to an excellent treatment of graphical and numerical methods.

Analytic solutions in two and three dimensions are the subject of the latter half of the book. All of the powerful tools of function theory are available for the two-dimensional case, and the author makes use of them to give a treatment of conjugate functions and conformal mapping that is not approached by most mathematical texts on the subject. There is sufficient material here to be used in a short course on applications of functions of a complex variable. The treatment of three-dimensional solutions is based on the general orthogonal co-ordinate system. Solutions are given for most of the co-ordinate systems in which the Laplacian separates, and there is a brief discussion of the various special functions that satisfy the Sturm-Liouville type of ordinary differential equations that result after separation.

The clear style of the author and the large number of well-chosen problems will make this book useful as a text for graduate courses. The extensive references in the text, the nine-page bibliography, and an adequate index greatly enhance its value as a reference work. This book belongs in the library of all who have fields problems to solve.

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Ordinary Non-Linear Differential Equations in Engineering and Physical Sciences by N. W. McLachlan

Published (1950) by Oxford University Press, 114 Fifth Ave., New York 11, N. Y. 179 pages+2-page index+9-page references+10-page appendix+vi pages. 89 figures. 6¼×9¼. $4.25.

Professor McLachlan's new contribution to the literature of nonlinear equations is an extremely practical one, up-to-date, and very useful to the engineer and physicist. In covering a great many of the methods used in the solution of nonlinear problems, the author has written with the desirable cognizance of the fact that many engineers and physicists lack the theoretical background possessed by the professional mathematician.

Some of the standard nonlinear equations that are readily integrable are discussed, and from there the author proceeds to the solutions of nonlinear equations, making use of the elliptic integrals and functions, as well as some well-known transcendental functions. Both general equations that have periodic solutions, and the very popular and useful method of slowly varying amplitude and phase are discussed extremely competently.

Graphical and numerical solutions, as well as a host of approximation schemes are covered in the last three chapters. These chapters make the text an excellent reference book for anyone engaged in the study of solutions of nonlinear equations. Some of the specific applications discussed are: exact solution of single pendulum, thermionic tube oscillators, nonlinear damping, electric circuits with nonlinear elements, stability of synchronous electrical motors, stability problems in general, methods of finite differences, and so forth.

In the appendix, the author deals with the application of Mathieu's equation as a stability criterion. A specific type of nonlinearity is considered, that of including a term involving the cube of the dependent function, and by a perturbation scheme, the nonlinear equation is reduced to the standard Mathieu type.

In another appendix, the problem of sound waves of finite amplitude in an exponential loudspeaker horn is discussed and solved completely, to the extent of including numerical examples.

The information, organization, and subject matter are clearly presented, and all other phases of the text match the author's high reputation as a leader in the field of mathematical physics.

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Piezo-Electric Crystals and Their Applications to Ultrasonics by Warren P. Mason

Published (1950) by D. Van Nostrand Co., Inc., 250 Fourth Ave., New York, N. Y. 437 pages+6-page index+62-page appendix+ix pages. 78 figures. 9¼×6¼. $7.50.

In this book, a leader in his field has combined a series of his original publications with much new material from his laboratories. Two compact chapters introduce the crystallographic and physical relations of piezoelectricity. The formal mathematical character of this introduction should not deter the reader from penetrating to the following very readable chapters. The author describes clearly his methods for the systematic determination of piezoelectric and elastic coefficients of crystals by resonance. Properties and uses of quartz are treated in an excellent short chapter; details may be found in a companion volume.[1] Next come the classical studies made about 1938 by Hans Mueller and Dr. Mason on Rochelle salt, then as now the most widely used piezoelectric material. In the meantime, however, the engineer's repertory has acquired a series of new useful synthetic piezo crystals: ammonium dihydrogen phosphate (ADP), lithium sulphate, neutral potassium tartrate (DKT), and ethylene diamine tartrate (EDT). The last-named is entirely a development of the Bell Laboratories and has found important application in channel filters; it is the final selection from a list of 75 crystal substances ably chosen and prepared by A. N. Holden. Comprehensive measurements are given for about 20 crystals, and their applications, present or potential, are outlined. The monumental scope of his experimental program has not kept Dr. Mason from developing a molecular theory of Rochelle salt and other "ferroelectric" crystals, which is stimulating if not always convincing. Polarized polycrystalline barium titanate, the newest electromechanical transducer material, is treated as an electrostrictive substance. The reviewer agrees with the author's concept, but feels that the presentation could be much simplified.

More than 100 pages are devoted to the interaction of vibrating piezoelectric crystals with gaseous, liquid, or solid matter. The emphasis here is not so much on large-scale applications as on a study of physical properties of matter.

Dr. Mason's book is thoroughly up to date. Most experimental data are conveniently presented in graphs. Typography is excellent. No one concerned with piezoelectricity should be without it.

Hans Jaffe
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[1] R. Heising, Editor, "Quartz Crystals for Electrical Circuits," D. Van Nostrand Co., Inc., New York, N. Y.; 1946.

Abstracts and References

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

NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

The Annual Index to these Abstracts and References, covering those published in the PROC. I.R.E. from February, 1950, through January, 1951, may be obtained for 2s.8d. postage included from the *Wireless Engineer*, Dorset House, Stamford St., London S.E., England. This index includes a list of the journals abstracted together with the addresses of their publishers.

The number in heavy type at the upper ft of each Abstract is its Universal Decimal lassification number and is not to be confused dth the Decimal Classification used by the fnited States National Bureau of Standards. he number in heavy type at the top right is e serial number of the Abstract. DC numbers arked with a dagger (†) must be regarded as rovisional.

ACOUSTICS AND AUDIO FREQUENCIES

34.17:534.874.1 **513**
Maximum Directivity Index and Efficiency f Linear Arrays—R. L. Pritchard. (*Jour. cous. Soc. Amer.*, vol. 22, pp. 676–677; eptember, 1950.) Summary of Acoustical ociety of America paper. The index is calulated as a function of the number and spacing f the elements in the array, and the efficiency s dependent on the manner of excitation and ype of transducers used.

34.22 **514**
The Velocity of Sound in Sea Water—A. Veissler and V. A. Del Grosso. (*Jour. Acous. oc. Amer.*, vol. 22, p. 684; September, 1950.) ummary of Acoustical Society of America aper. Measurements with a 3-mc ultraonic interferometer were made on samples f Caribbean Sea water collected at various epths. The velocities found at 20° and 30°C ere about 4 m/s higher than the values in Kuwahara's tables, for which an accuracy ithin 3 m/s is claimed. The sound velocity, he density and the adiabatic compressibility ere also determined over a wide range of oncentrations for pure solutions of each of the even salts which are the major constituents of he dissolved matter in sea water. The comressibility and sound velocity for sea water gree to within 0.1 per cent with the values etermined by summation of the effects of the idividual salts, each at its proper concentraon.

34.22-13 **515**
The Velocity of Sound in Helium at Temperatures −78°C to 200°C and Pressures up to 70 Atmospheres—W. G. Schneider and G. J. Thiessen. (*Canad. Jour. Res.*, vol. 28, Sec. A, pp. 509–519; September, 1950.) An account of measurements made using an ultrasonic interferometer of the double-crystal type.

534.22-16 **516**
New Methods for Measuring Ultrasonic Velocity in Solids—G. W. Willard. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 684–685; September, 1950.) Summary of Acoustical Society of America paper. Description of methods based on optical interference effects. Accuracy to within 1 per cent can easily be obtained with either transparent or opaque materials.

534.23 **517**
Experimental Determination of Acoustic Wave Fronts—P. Tamarkin, G. L. Boyer and R. T. Beyer. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 686; September, 1950.) Summary of Acoustical Society of America paper. Description of a method making use of a phase discriminator to locate successive points in the wave front.

534.231 **518**
Sonic Wind and Static Pressure in Intense Sound Fields—J. P. Walker and C. H. Allen. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 680–681; September, 1950.) Summary of Acoustical Society of America paper. In the free field above a piston source 12 cm in diameter vibrating sinusoidally at 14.6 kc a sonic wind has been observed, similar to the effect obtained in water with a quartz disk. The wind is directed away from the source along the axis and its velocity is proportional to the square of the source amplitude. Positive static excess pressures were also found on the axis, directly proportional to the sound intensity at the point of measurement. At an acoustic level of 156 db this pressure was 10 dynes per cm^2.

534.231 **519**
An Automatic Sound-Field Mapper—J. J. Baruch. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 686; September, 1950.) Summary of Acoustical Society of America paper. Mechanism is provided for moving a microphone over a plane in the sound field, the microphone output being plotted automatically and giving contours of either constant sound-pressure level or constant phase. Five contours can be plotted simultaneously.

534.231.1 **520**
Finite Amplitude Distortion in a Spherically Diverging Sound Wave in Air—C. H Allen. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 680; September, 1950.) Summary of Acoustical Society of America paper. Measurements were made of the pressure amplitudes of each of the first six harmonics of a free progressive sound wave in air, using a piston source, of diameter about 5λ, vibrating sinusoidally at a frequency of 14.6 kc. The results are discussed.

534.232 **521**
A New Expansion for the Velocity Potential of a Piston Source—A. H. Carter and A. O. Williams, Jr. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 676; September, 1950.) Summary of Acoustical Society of America paper.

534.24 **522**
Scattering of Sound by Cylinders and Spheres—J. J. Faran, Jr. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 677; September, 1950.) Summary of Acoustical Society of America paper.

534.321.7:621.396.615 **523**
A Bridge-Stabilized Generator for Tuning Musical Instruments—R. Gauger and J. Sommer. (*Funk u. Ton*, vol. 4, pp. 554–558; November, 1950.)

534.321.9 **524**
Transmission and Reflection of Ultrasonic Waves from a Solid Plate in Water—M. S. Weinstein and W. C. Wineland. (*Phys. Rev.*, vol. 79, p. 416; July 15, 1950.) Summary of American Physical Society paper. Results of measurements at 1 mc on six Al plates of thickness from 1/32 inch to ½ inch are in good agreement with the theory of Smyth and Lindsay (97 of 1945).

534.321.9 **525**
Variable Resonant Frequency Crystal Systems—W. J. Fry, R. B. Fry and W. Hall. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 676; September, 1950.) Summary of Acoustical Society of America paper. Discussion of the theory and design of low-loss variable-frequency crystal units, with experimental results for a generator covering the range 40–80 kc.

534.321.9:534.22:546.74:538.69 **526**
Some Magneto-Acoustic Effects in Nickel—Rogers and Johnson. (See 642.)

534.321.9:612.7 **527**
An Experimental Study of Temperatures Produced by Ultrasonic Radiations in Bone Marrow, Bone, and Adjacent Tissues—E. J. Baldes, P. A. Nelson and J. F. Herrick. (*Jour.

Acous. Soc. Amer., vol. 22, p. 682; September, 1950.) Summary of Acoustical Society of America paper. Experiments with a 15-w 800-kc generator showed that dangerously high temperatures can be produced in bone and bone marrow within a few minutes, using relatively low outputs of energy. The heating of the adjacent tissues is only moderate.

534.321.9:612.8 528
Ultrasonic Irradiation of Nerve Tissue—W. J. Fry and V. J. Wulff. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 682; September, 1950.) Summary of Acoustical Society of America paper. A preliminary report of investigations in progress.

534.373-14 529
Mechanisms of Sound Absorption in Fluids—J. J. Markham. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 684; September, 1950.) Summary of Acoustical Society of America paper. A survey of suggested mechanisms, which are considered under the headings: (a) viscosity absorption; (b) relaxation absorption.

534.373-14:534.321.9 530
Absorption Measurements in Electrolytic Solutions—M. C. Smith, R. Barrett, and R. T. Beyer. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 684; September, 1950.) Summary of Acoustical Society of America paper. Absorption measurements for solutions of $MgSO_4$ were made at 3 mc by an electrical-detection method, and in the range 12–40 mc by the radiation-pressure method. At the higher frequencies there is an additional absorption process not accounted for by the compressional relaxation in the Liebermann theory.

534.373-14:534.321.9 531
Ultrasonic Absorption in Liquids—C. J. Moen. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 684; September, 1950.) Summary of Acoustical Society of America paper. Results obtained at frequencies down to 140 kc by a reverberation method for various liquids with widely different properties are discussed. For water, benzene, glycerol, and CS_2, the absorption is proportional to the square of the frequency.

534.442.2:621.317.335 532
The Analysis of Oscillations by the Search-Tone Method—W. Meyer-Eppler. (*Arch. elekt. Übertragung*, vol. 4, pp. 331–338; August, 1950.) A mathematical explanation is given of the method in which a heterodyne search-oscillator is used to shift the components of the unknown oscillation within the range of an analyzing band-pass filter. The influence of searching speed is examined; if the analysis is sufficiently slow, components of a steady oscillation, however close, can be separated. Details are given of the frequency ranges usable for analysis, these ranges being restricted by the formation of "zones of confusion" in the course of the heterodyning. A highly simplified arrangement for audio frequencies is described in which the only equipment needed is an interrupter and a galvanometer.

534.6:681.85 533
Methods of Calibrating Frequency Records—R. C. Moyer, D. R. Andrews and H. E. Roys. (PROC. I.R.E., vol. 38, pp. 1306–1313; November, 1950.) 1948 IRE National Convention paper noted in 2430 of 1948. A record having a known amplitude at several frequencies was calibrated by four methods whose relative advantages are discussed. The optical method, which uses light reflected from the walls of the groove, is considered the best.

534.64 534
A Null-Balance Apparatus for Measuring Acoustic Impedance—J. R. Cox, W. M. Ihde, and A. P. G. Peterson. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 679; September, 1950.) Summary of Acoustical Society of America paper. A bridge-like device composed of two adjustable electrical networks and two acoustical networks is used. The latter consist of short cavities, each with a sound source at one end, the other ends being terminated respectively by the unknown impedance and a hard plug. The input currents to the electrical networks are proportional to the pressures in the cavities. When the electrical networks are balanced, the unknown impedance can be read directly from that of one of the adjustable networks.

534.75 535
Short-Duration Effects in Auditory Fatigue—J. D. Harris. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 674; September, 1950.) Summary of Acoustical Society of America paper. An investigation of fatigue as a function of (a) duration, frequency, and intensity of the tone causing fatigue, and (b) the duration of the recovery interval.

534.75 536
A Consideration of the Intensity Loudness Function and its Bearing upon the Judgment of "Tonal Range" and "Volume Level"—S. E. Stuntz. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 674; September, 1950.) Summary of Acoustical Society of America paper.

534.75 537
Observations on the Effect of High Intensity Sounds in the Ear—H. G. Kobrak. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 674; September, 1950.) Summary of Acoustical Society of America paper.

534.78 538
Intelligibility of Amplitude—and Time-Quantized Speech Waves—J. C. R. Licklider. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 677–678; September, 1950.) Summary of Acoustical Society of America paper.

534.78 539
A Speech Analyzer and Synthesizer—W. A. Munson and H. C. Montgomery. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 678; September, 1950.) Summary of Acoustical Society of America paper. Description of the principles of operation of a resonance type of Vocoder.

534.78 540
Measurement, Portrayal, and Interpretation of some Statistical Properties of Speech Sounds—Sze-Hou Chang, G. E. Pihl and M. W. Essigmann. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 677; September, 1950.) Summary of Acoustical Society of America paper. See also 1319 of 1950 (No. 14).

534.78 541
Autocorrelation Analysis of Speech Sounds—K. N. Stevens. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 677; September, 1950.) Summary of Acoustical Society of America paper. Discussion of a method of speech analysis using the short-time autocorrelation function, which is defined. Apparatus for determining correlation functions is described and results for various speech sounds are analyzed.

534.79 542
Calculation and Measurement of the Loudness of Sounds—J. L. Marshall, L. L. Beranek, A. L. Cudworth and A. P. G. Peterson. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 671; September, 1950.) Summary of Acoustical Society of America paper.

534.79 543
The Threshold and Loudness of Repeated Bursts of Noise—I. Pollack. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 671; September, 1950.) Summary of Acoustical Society of America paper.

534.79 544
Masking of a Pure Tone at a Gap in a Thermal-Noise Spectrum—T. H. Schafer, P. O. Thompson and J. C. Webster. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 671; September, 1950.) Summary of Acoustical Society of America paper.

534.833.4 545
The Measurement of the Acoustic Properties of Sound-Absorbent Panels at High Hydrostatic Pressures—W. J. Trott and C. L. Darner. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 681; September, 1950.) Summary of Acoustical Society of America paper. An account of the method used, with results for the underwater reflection and transmission properties of several materials in the frequency range 10–150 kc and at hydrostatic pressures up to 350 lb per inch².

534.844 546
A Tentative Criterion for the Short-Term Transient Response of Auditoriums—R. H. Bolt and P. E. Doak. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 678–679; September, 1950.) Summary of Acoustical Society of America paper.

534.844:519.272.119 547
Correlation Coefficients as Criteria for Randomness of Reverberant Sound Fields—R. K. Cook and S. Edelman. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 678; September, 1950.) Summary of Acoustical Society of America paper.

534.845 548
A Long-Tube Method for Field Determinations of Sound-Absorption Coefficients—E. Jones, S. Edelman and A. London. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 679; September, 1950.) Summary of Acoustical Society of America paper. A modification of the laboratory impedance tube was adapted for field measurements of absorption coefficients at a frequency of 512 cps. The coefficient for reverberant sound is calculated on the basis of a semiempirical development described by London (1846 of 1950).

534.846.6 549
Techniques for Determining Acoustics of Amphitheaters by Scale-Model Studies with High-Frequency Sounds—H. C. Hardy and F. G. Tyzzer. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 679; September, 1950.) Summary of Acoustical Society of America paper. Measurements on small-scale models of two large outdoor amphitheatres are described. Frequencies between 2 kc and 30 kc were used to determine sound levels in the stage area and distribution of sound in the audience area, absorbent materials being used to simulate the effect of an audience. The results obtained simplified the design of the sound amplifying and distributing equipment required in practice.

534.85 550
Stylus/Groove Relations in the Phonograph Playback Processes—F. G. Miller. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 673; September, 1950.) Summary of Acoustical Society of America paper. Mathematical analysis of the motion of a reproducer stylus, taking account of tracing distortion and elastic deformation of the groove wall.

534.85 551
Some Applications of Square-Wave Testing Techniques to the Evaluation of Disk Recording Systems—S. R. Bradshaw and W.

...ithen-Dunn. (*Jour. Acous. Soc. Amer.*, vol. 2, p. 673; September, 1950.) Summary of Acoustical Society of America paper.

...395.61 552
Reciprocal-Resistance Relation between Piezoelectric and Electrodynamic Transducers—F. A. Fischer. (*Arch. elekt. Übertragung*, vol. 4, pp. 321–324; August, 1950.) Completion of previous work (3320 of 1949) on the classification of transducers. Only four classes are now distinguished; these consist of two reciprocal-resistance pairs.

...1.395.61:534.612.4 553
Reciprocity Calibration of Microphones, using a Pulse Technique—R. L. Terry and R. B. Watson. (*Jour. Acous. Soc. Amer.*, vol. ..., p. 672; September, 1950.) Summary of Acoustical Society of America paper. The microphone output is sampled before the sound pulses from the test transmitter can reach the microphone after reflection from the nearest wall. An effective free-field calibration is thus obtained.

...1.395.61.001.11 554
Symmetry in the Equations for Electromechanical Coupling—F. V. Hunt. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 672; September, 1950.) Summary of Acoustical Society of America paper.

...1.395.623.7:534.874.1 555
A Unidirectional Loudspeaker System—... Kalusche. (*Z. angew. Phys.*, vol. 2, pp. 411–...5; October, 1950.) Acoustic delay lines have been previously used with gradient microphones to obtain directional characteristics; their use in combination with loudspeakers for similar purposes is now studied, and similar considerations are found to apply. To suppress backward radiation, the delay member must have frequency-independent delay time and frequency-dependent attenuation; cotton-wool packing, damped resonators, etc., may be used. By using a linear array of loudspeakers, greatly improved directional effects can be obtained. Directional characteristics in both the horizontal and the vertical plane are shown for an array of six loudspeakers, for various frequencies from 100 cps to 10 kc. Less than 10 per cent of the sound energy is radiated backwards.

...1.395.623.7:621.3.018.78† 556
Nonlinear Distortion in Loudspeakers—... Roessler. (*Funk u. Ton.*, vol. 4, pp. 549–...3; November, 1950.) Discussion of a particular form of nonlinear distortion which arises in large halls or in the open air when tones of high and low pitch and of unequal intensity are emitted simultaneously.

...1.395.625.3:534.852 557
Tests on Magnetic Tapes Designed for a Running Speed of 15 in./sec.—P. H. Werner. (*Tech. Mitt. schweiz. Telegr.-Teleph. verw.*, vol. 28, pp. 382–388; October 1, 1950.) In French.) Comparison of the characteristics of the following tapes: Audio; LGH; Genotron ...NA; Pyral; Scotch 111A. The frequency characteristic and the percentage distortion as a function of output level are shown graphically; they are similar for the different tapes. Some difference occurs in their background noise, analyses of which are shown for different operating conditions.

...1.396.611.21 558
Surface Vibration Patterns of Piezoelectric Radiators—J. D. Nixon and A. O. Williams, Jr. (*Jour. Acous. Soc. Amer.*, vol. 22, ... 676; September, 1950.) Summary of Acoustical Society of America paper. A quartz X-cut crystal with one face optically polished is used as one mirror of a Michelson interferometer, the unpolished face radiating into a liquid of acoustic impedance different from that of the crystal. The interference fringes produced allow the direct observation of the vibration of the entire crystal face. Measurements at frequencies of 0.5 and 1.0 mc are described.

621.396.611.21 559
Cylindrical Barium Titanate Transducers—T. F. Johnston and F. D. Wertz. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 676; September, 1950.) Summary of Acoustical Society of America paper. Performance data, including radiation diagrams, frequency-response curves and impedance values, are given for transducers constructed from $BaTiO_3$ ceramic cylinders. To make the units waterproof and to provide additional mechanical strength, they were cast in a thermosetting resin. In general, the performance is comparable with that of crystal or magnetostrictive transducers, but the construction is much simpler.

621.396.611.21.001.8 560
Use of Barium Titanate Transducers for Producing Large Amplitudes of Motion and High Forces at Ultrasonic Frequencies—W. P. Mason and R. F. Wick. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 676; September, 1950.) Summary of Acoustical Society of America paper. Longitudinal oscillations are produced in a $BaTiO_3$ cylinder excited by means of poles arranged radially, the resonance frequency being determined by the length of the cylinder. For a cylinder 12 cm long, resonant at 18 kc, the displacement at the ends can be 3.9×10^{-4} cm. This can be increased tenfold by soldering to the end of the cylinder a brass horn, flared exponentially and with mouth diameter ten times that of the throat. This acts as a transformer to increase the amplitude. Instruments based on such a structure have been produced for various purposes.

621.396.611.21.012.8 561
X-Cut Quartz Crystals—H. Grayson. (*Wireless Eng.*, vol. 27, pp. 270–271; October-November, 1950.) An exact equivalent circuit for a quartz transducer is devised and discussed for different conditions of acoustic loading on the two crystal faces. An approximate equivalent circuit was described in 2162 of 1950 (Leslie).

ANTENNAS AND TRANSMISSION LINES

621.39.09:517.512.2 562
Fourier Transforms in the Theory of Inhomogeneous Transmission Lines—F. Bolinder. (PROC. I.R.E., vol. 38, p. 1354; November, 1950.) The Fourier integral theorem is applied to derive an expression for the reflection coefficient at the sending end of an inhomogeneous transmission line when the receiving end is matched. The method can be applied to acoustic waves.

621.392.09 563
Surface-Wave Transmission Line—N. M. Rust: G.W.O.H. (*Wireless Eng.*, vol. 27, p. 270; October-November, 1950.) Experiments on surface-wave transmission have been described by Goubau (281 of March). It is here pointed out that the only advantage to be gained by covering the wire with dielectric is to reduce launching and collecting loss at the horns. To obtain minimum total loss, bare wire should be used between the horns; tapered dielectric loading may be used on the parts of the wire within and near the horns. This has been verified experimentally.

621.392.26†:621.3.09 564
The Effect of a Diaphragm on the Field of an Electromagnetic Wave in a Tube—E. Ruch. (*Ann. Phys.* (Lpz.), vol. 7, pp. 248–272; May 15, 1950.) Theoretical study of refraction and reflection at a plane diaphragm, of any shape, perpendicular to the tube wall. The solution of a system of equations with an infinite number of unknowns is involved, and this problem is discussed generally. An approximate numerical calculation is performed for the case of a tube with rectangular cross-section and slit-type diaphragm, for an incident H wave.

621.392.26†:621.3.09 565
Electromagnetic Waves in Wave Guides—K. S. Knol and G. Diemer. (*Commun. News*, vol. 11, pp. 33–48; July, 1950.) See 1851 of 1950.

621.392.26†:621.318.572 566
Fabrication of a High-Power Resonant Waveguide Window—E. V. Edwards and K. Garoff. (*Rev. Sci. Instr.*, vol. 21, pp. 787–789; September, 1950.) Higher values of the loaded Q for pre-TR and TR tube windows are recommended to withstand high transmitter powers at 3 kmc. The processing of a glass window, having a loaded Q of 4 and fitting a standard rectangular 1.5-inch $\times$ 3-inch waveguide, is described in detail. Tests show that such windows can withstand a working temperature of 160°C in pre-TR tubes, a temperature at which present conventional windows crack or are sucked in.

621.396.67 567
Effect of a Circular Groundplane on Antenna Radiation—A. Leitner and R. D. Spence. (*Jour. Appl. Phys.*, vol. 21, pp. 1001–1006; October, 1950.) The field of a vertical $\lambda/4$ antenna above a circular conducting disk of zero thickness is calculated theoretically by use of the wave functions for the oblate spheroid. Assuming a sinusoidal current distribution in the antenna, calculations are made of the currents in the ground plane, the radiation resistance and the radiation pattern of the system for various values of the ground plane radius. These results are applied to a study of the field distortion due to finite ground planes.

621.396.67 568
Circularly Grouped Aerials as Omnidirectional and Directive Radiators—W. Burkhardtsmaier and Y. Finkbein. (*Elektrotechnik Berlin*, vol. 4, pp. 239–244 and 284–290; July and August, 1950.) From fundamental theory expressions are derived for the radiation characteristics, impedance, gain, etc., of an antenna system comprising a number of similar vertical elements at the vertices of a regular polygon, with or without a central radiator. Application of such systems for reduction of fading, optimum design for directional operation, and the multiple-feed system are discussed.

621.396.67:621.396.932 569
Antenna Systems for Multichannel Mobile Telephony—W. C. Babcock and H. W. Nylund. (PROC. IRE, vol. 38, pp. 1324–1329; November, 1950.) 1949 IRE National Convention paper noted in 1578 of 1949. Full-scale and model tests were made to determine the best method of mounting several vertical antennas on a single mast so as to minimize mast shielding and mutual coupling at 153 mc. A staggered arrangement was found preferable to one in which the antennas were collinear.

621.396.67.018.424† 570
Wide-Band Folded-Slot Aerials—G. D. Monteath. (*Proc. IEE* (London), Part III, vol. 97, pp. 414–418; November, 1950.) Modified forms of folded-slot antenna are described

in which reactance compensation is achieved by the incorporation of open- or short-circuited transmission-line stubs. Calculation of input impedance is facilitated by considering an equivalent circuit which applies to 3-terminal networks of the folded-dipole or folded-slot type. Results obtained with an experimental folded-slot antenna for use in the 90-mc band show a bandwidth of 7.5 mc with an SWR$\lessapprox$1.1 over the whole band. A method of feeding this antenna is described.

621.396.67.018.424† 571
Omnidirectional Wide-Band Aerials for Decametre and Metre Waves—O. Zinke. (*Fernmeldetech. Z.*, vol. 3, pp. 385–390; October, 1950.) German version of 817 of 1950.

621.396.67.018.424†:621.3.029.62/.63 572
Fundamentals of Wide-Band Aerials for Metre and Decimetre Waves—O. Zinke. (*Funk u. Ton*, vol. 4, pp. 437–450; September, 1950.) The effect of wave change on the radiation field of different types of antenna is first summarized. Requirements for matching are discussed and examples are given of the maximum voltage SWR permissible for wide-band working. Matching arrangements are then considered: the application of $\lambda/2$ and $\lambda/4$ stubs for compensation purposes in the case of thick dipoles is analyzed; methods of balancing asymmetric feeders are indicated; the compensation of narrow-band $\lambda/4$ transformers to obtain wide-band characteristics is described. See also 817 and 818 of 1950.

621.396.671 573
The Effect of a Periodic Variation in the Field Intensity across a Radiating Aperture—J. Brown. (*Proc. IEE* (London), Part III, vol. 97, pp. 419–424; November, 1950.) Such variations may alter the radiation pattern and reduce the power gain of the aperture. The way in which variations arise in the field distribution across the outer surface of a microwave lens is discussed.

621.396.671 574
Impedance/Frequency Characteristics of some Slot Aerials—J. W. Crompton. (*Proc. IEE* (London), Part III, vol. 97, p. 459; November, 1950.) Discussion on 1087 of 1950.

621.396.671 575
The Predetermination of Antenna Characteristics by means of Models—R. D. Boadle. (*AWA Tech. Rev.*, vol. 8, pp. 185–193; December, 1949.) Reprint. See 558 of 1950.

621.396.671.4 576
The Effect of Input Configuration on Antenna Impedance—J. R. Whinnery. (*Jour. Appl. Phys.*, vol. 21, pp. 945–956; October, 1950.) A region in the vicinity of the input is considered as a transducer between the *TEM* mode on the feeder transmission line and the spherical nearly *TEM* mode on the antenna system; the constants of this transducer are found both by calculation and by measurement for a particular case. The approximate configuration of the field was determined by means of measurements in an electrolyte tank. The analysis for the main portion of the antenna is essentially that of Schelkunoff, the *TM* modes in space and near the antenna being expressed as a shunt admittance at the end of the antenna in the *TEM*-mode equivalent circuit. This admittance is transformed to the desired reference on the antenna by a perturbation calculation, and thence to a reference on the feeder line by means of the input-network constants. Values thus calculated are compared with measured values for various monopole antennas at frequencies in the range 200–1,000 mc. Agreement appears considerably better than without consideration of the input configuration.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.015.7:621.387.4† 577
Differential Method of Counting in Pulse-Amplitude Selectors—G. Valladas and J. Thenard. (*Jour. Phys. Radium*, vol. 11, pp. 501–506; August-September, 1950.) Principles of pulse-counting systems are reviewed and the circuit of a single-channel selector is described, the operation of which is independent of pulse shape and of pulse duration down to 1 μs. Dead time is of the order of 10–20 μs.

621.3.015.7:621.387.4† 578
A Simple Differential Pulse-Height Analyzer—K. I. Roulston. (*Nucleonics*, vol. 7, pp. 27–29; October, 1950.) Description of an analyzer circuit suitable for use with scintillation counters. Only three tubes are required for each amplitude level. The discriminators use a conventional two-tube trigger circuit and the anticoincidence circuit for each channel consists of a phase inverter and two resistors. A cathode follower is made available by using one half of the phase-inverter double-triode. Thus, for a 10-channel differential discriminator only 33 tubes are necessary, exclusive of power supply unit and scalers. Each trigger circuit responds to pulses of voltage greater than its own bias voltage. A positive pulse from the nth discriminator and a negative pulse from the $(n+1)$th level are fed differentially to the nth level counter.

621.3.016.352 579
Contribution to the Study of Stability—M. Parodi. (*Jour. Phys. Radium*, vol. 10, pp. 348–352; November, 1949.) Equations encountered respectively in problems of mechanics and of passive electrical networks are studied in which the first elements have the form of determinants. A theorem of Ostrowski is used to determine an upper limit to the real parts of the solutions, the conditions for stability being assumed satisfied. A simpler method can be used in certain cases for networks.

621.3.016.352 580
Nyquist Diagrams and the Routh-Hurwitz Stability Criterion—F. E. Bothwell. (Proc. I.R.E., vol. 38, pp. 1345–1348; November, 1950.) The Nyquist and the Routh-Hurwitz stability criteria as methods of locating regions of stability of dynamical and electrical systems are described and compared. The superiority of the Routh-Hurwitz method in some applications is demonstrated by two examples, the first a Llewellyn 2-loop 3-stage feedback amplifier, and the second a multiloop servo system.

621.314.2:629.135 581
Small Power Transformers for Aircraft Electrical Equipments—A. L. Morris. (*Proc. IEE* (London), Part III, vol. 97, pp. 458–459; November, 1950.) Discussion on 3349 of 1949.

621.314.3† 582
A New Theory of the Magnetic Amplifier—A. G. Milnes. (*Proc. IEE* (London), Part III, vol. 97, pp. 462–464; November, 1950.) Summary only. See 48 of February.

621.316.86 583
Borocarbon Resistors—(*Bell Lab. Rec.*, vol. 28, pp. 447; October, 1950.) The resistive element comprises a film of boron and carbon formed by pyrolytic deposition from suitable gaseous compounds. Stable and inexpensive resistors with temperature coefficients in the range 20–100$\times10^{-6}$ per °C are thus produced. Resistors of high values can be made by the process; films with a resistance of 0.5 MΩ between opposite edges of a square portion are readily obtained and corresponding resistance values$>$1,000 MΩ have been investigated.

621.318.4.042.15.029.4/.5 584
High-*Q* Coils with Iron-Dust Cores for the Frequency Range 100 c/s—100 kc/s—J. Sommer. (*Funk u. Ton*, vol. 4, pp. 458–468; September, 1950.) Analysis of the losses as a function of frequency and of winding space in coils with trolitul dust-filled cores. In the audio-frequency range the highest Q value is obtained when the available winding space is fully used. Ribs in the winding should therefore be excluded. Above 3 kc, higher Q values are obtainable. When the ratio $f^2/N\geq 0.3$, where f is the frequency in kc and N is the number of turns, in order to minimize capacitive loss, the winding space should not be fully used and sectional winding on ribbed formers is preferable.

621.392 585
The Nonlinear Method of Circuit Analysis—Rais Ahmed. (*Proc. Nat. Inst. Sci., India*, vol. 16, pp. 255–262; July-August, 1950.) An appraisal of the usefulness of recently developed methods for solving nonlinear differential equations in their application to the analysis of tube circuits.

621.392.5:519.241.1 586
Correlation Functions and Power Spectra in Variable Networks—L. A. Zadeh. (Proc. I.R.E., vol. 38, pp. 1342–1345; November, 1950.) "The problem considered is that of establishing a relation between the correlation functions and also the power spectra of the input and output of a linear varying-parameter network (variable network) whose transmission characteristics are random-periodic functions of time. The notion of the correlation function of such a network is introduced and the following theorem is established:

"The correlation functions of the input and output of a variable network N may formally be regarded as the input and output of a variable network N^* whose system function is the correlation function of the system function of N.

"This theorem has many practical applications, particularly in connection with the determination of the correlation functions and power spectra of various random-periodic wave forms."

621.392.5:621.385.029.64.65 587
Delay Lines of Comb or Interdigital Type and their Equivalent Circuit—Warnecke, Doehler and Guénard. (See 772.)

621.392.5.001.11 588
On the Approach to Steady State of a Linear Variable Network containing One Reactance—A. A. Grometstein. (Proc. I.R.E., vol. 38, pp. 1349–1351; November, 1950.) The network must be linear and must be capable of reduction to one containing a single reactance. The input voltage and variable circuit components are periodic in value but must have the same period; all variables must possess Laplace transforms. The number of input cycles required by such a network to approach steady-state operation can be found by the method described.

621.392.52:539.2 589
Physical Basis of the Wave Filter—J. L. Salpeter. (*Commun. News*, vol. 11, pp. 48–55; July, 1950.) See 2197 of 1950.

621.392.52:621.396.645 590
Video-Frequency Amplifier Couplings—G. G. Gouriet. (*Wireless Eng.*, vol. 27, pp. 257–265; October–November, 1950.) By a suitable

...ice of the parameters which define the ...gn of unsymmetrical π-section filters, simple ...ressions for the performance are obtained, ...n which the steady-state or the transient ...ponse may be calculated. Curves of the ...plitude characteristic and the group-delay ...racteristic are given for various values of ... variable parameters, and cases of particular ...rest are discussed. Finally, the require-...nts of phase-equalizing networks are given.

...392.52.012.8 591
Band-Pass Low-Pass Transformation in ...iable Networks—L. A. Zadeh. (Proc. ...E., vol. 38, pp. 1339–1341; November, ...0.) "An extension of the band-pass low-pass ...nsformation to linear varying-parameter ...tems is developed . . . This transformation ...conjunction with the use of frequency-...lysis techniques can be applied with ad-...tage to the analysis of a superregenerator ...rating in the linear mode."

...392.6 592
Definition and Characteristics of 'Super-...ed' Circuits—L. Collet. (*Ann. Télécommun.*, ... 4, pp. 42–56; February, 1949.) Splitting ... a Kirchhoff network into closed meshes ...ords two systems of analysis, one with ...erence to currents, the other to potential ...ferences. The matrix of one system may be ...ived from that of the other. This applies ...o to open meshes. The algebraic transforma-...ns corresponding to these operations must ...isfy certain conditions which may them-...ves be expressed by a correlation of matrices. ... analogous method applied to linear net-...rks brings out the most important circuit ...perties. Comparison of an open network to ... equivalent group of "superposed" meshes ...ds to generalizations of theorems such as ...se of Thévenin and Breisig for quadripoles. ...amples are given illustrating the application ...the method in line and circuit problems, and ...nparison is made with the method of sym-...trical co-ordinates for the study of poly-...ase systems.

...1.392.6 593
Solution of the Problem of Synthesis of ...rchhoff Networks by Determination of ...rely Reactive Networks—M. Bayard. (...bles & Trans. (Paris), vol. 4, pp. 281–296; ...tober, 1950.) The methods of network ...nthesis described are based on the determina-...n of the impedance matrix of a purely reac-...e network which, when completed with cer-...n resistances, gives the required matrix. ... the first method, which gives the general ...lution, the chain matrix of the auxiliary ...twork is found by considering it as a gen-...alized quadripole in the sense of Collet's ...finition (592 above). A second and easier ...thod, of more restricted application, makes ...e of a generalization of Leroy's method ...4 of February) for completely reduced mat-...es.

...1.396.6:681.85 594
Pickup Input Circuits—R. L. West and S. ...elly. (*Wireless World*, vol. 56, pp. 386–391; ...ovember, 1950.) Discussion of the design and ...lection of input arrangements suitable for ...andard-speed (78 rpm) and long-playing ...3½ rpm) records.

...1.396.611.1:534.014.1 595
An Electrical Network with Varying ...rameters—C. P. Gadsden. (*Quart. Appl. ...ath.*, vol. 8, pp. 199–205; July, 1950.) ...nalysis of the time variation of voltage and ...rrent (or of charge q and flux Φ) in a series ...CR circuit in which the elements are con-...nuous functions of t with continuous deriva-...ves. The vibrations can be oscillatory or nonoscillatory and transient. Theorems are deduced concerning the criteria of oscillation and stability.

621.396.611.21.012.8 596
X-Cut Quartz Crystals—Grayson. (See 561.)

621.396.615 597
The Wien Bridge as Phase-Shift Element of the RC Oscillator—W. Taeger. (*Funk u. Ton*, vol. 4, pp. 569–575; November, 1950.) Generators having an even number of stages require in-phase feedback, and this is provided by the Wien bridge, but only at one particular frequency. The effect of detuning on circuit performance is investigated mathematically.

621.396.615 598
Phase-Shift Oscillators—W. G. Raistrick. (*Wireless World*, vol. 56, pp. 409–411; November, 1950.) A variable-frequency oscillator giving an output of nearly constant amplitude can be obtained from two phase-shift stages each consisting of a phase-splitting tube circuit and an *RC* network. Suitable circuit values are given for a complete oscillator with two phase-shift stages and an amplifier stage, and with resistive or capacitive single- or double-element tuning control.

621.396.645 599
Amplifier with a Negative-Resistance Load—R. Adler. (*Wireless Eng.*, vol. 27, p. 270; October–November, 1950.) Comment on 2170 of 1950 (Tombs and McKenna).

621.396.645.37 600
A Tunable Audio-Frequency Amplifier of Variable Selectivity—E. A. G. Shaw. (*Jour. Sci. Instr.*, vol. 27, pp. 295–298; November, 1950.) Design theory and practical details of an amplifier with feedback via a Wien-bridge network. Frequency range is 30 cps—20 kc, and operation with values of $Q > 1{,}000$ is possible for short periods.

621.396.662:621.396.615.14 601
Combined Search and Automatic Frequency Control of Mechanically Tuned Oscillators—J. G. Stephenson. (Proc. I.R.E., vol. 38, pp. 1314–1317; November, 1950.) 1949 IRE National Convention paper noted in 1612 of 1949. A receiver-oscillator sweeps continuously over its tuning range until a signal appears. It then locks automatically so as to produce a constant difference frequency. The system was applied to the control of an oscillator covering 100 mc at 1300 mc, whose frequency was thus held automatically to within 15 parts in 10^6. The intermediate-frequency bandwidth was 2.5 mc at 30 mc.

621.3.013.78† 602
Die Elektromagnetische Schirmung in der Fernmelde- und Hochfrequenztechnik (Electromagnetic Screening in Telecommunication and H.F. Technology) [Book Review]—H. Kaden. Publishers: Springer Verlag, Vienna, 274 pp. (*Wireless Eng.*, vol. 27, pp. 273–274; October–November, 1950.) "The treatment throughout is very thorough, and necessarily of a mathematical character, as many of the problems involve Bessel and Hankel functions."

621.318.42 603
The Theory and Design of Inductance Coils [Book Review]—V. G. Welsby. Publishers: Macdonald & Co., 43 Ludgate Hill, London, 180 pp., 18s. (*Wireless Eng.*, vol. 27, p. 272; October–November, 1950.) Largely concerned with problems of coil losses and of iron-cored coils at high frequencies. "This is a book that every communication engineer ought to study."

GENERAL PHYSICS

530.145 604
Research on the Bases of the Quantum Calculus of Probabilities in Pure Cases (Hilbert Space Wave Principle)—G. Bodiou. (*Ann. Phys.*, vol. 5, pp. 451–536; July–August, 1950.)

534.01 605
Magneto-Hydrodynamic Shocks—F. de Hoffmann and E. Teller. (*Phys. Rev.*, vol. 80, pp. 692–703; November 15, 1950.) A mathematical treatment of the coupled motion of hydrodynamic flow and em fields is given, assuming that the motion can be described by a plane shock wave and that the medium is a perfect conductor. Special consideration is given to weak shocks, i.e., sound waves. The waves degenerate into common sound waves in the case of very weak magnetic fields and into common em waves for very strong fields.

534.521.9:534.11 606
Surface Vibration Patterns of Piezoelectric Radiators.—Nixon and Williams. (See 558.)

535.215.2+535.215.6 607
The Surface Photoelectric Effect—M. J. Buckingham. (*Phys. Rev.*, vol. 80, pp. 704–708; November 15, 1950.) "Theoretical expressions describing the photoelectric emission from a metal surface are derived, taking account of the dependence, established by Bardeen, of the effective surface barrier on the momentum of the impinging electron, due to exchange and correlation forces in the interior. This generalization reduces by a significant factor the magnitude of the theoretical expression for the absolute photoelectric yield."

537.224 608
On Certain Matters pertaining to Electrets—W. F. G. Swann. (*Jour. Frank. Inst.*, vol. 250, pp. 219–248; September, 1950.) Mathematical development based on the assumptions made in an earlier paper (2187 of 1950).

537.226.2 609
Dielectric Constants of Non-Polar Fluids. Part 1: Theory—W. F. Brown, Jr. (*Jour. Chem. Phys.*, vol. 18, pp. 1193–1200; September, 1950.) "The dielectric constant of a classical fluid, composed of spherically symmetric molecules with dipole-dipole interactions, is calculated by a method that leads to formulas previously derived by Yvon but is more direct and yields additional results. The relations of the formulas of Lorentz, Yvon, Kirkwood, and Böttcher to one another are clarified." Part 2: 669 below.

537.228.1:548.0 610
Matrices of Piezoelectric, Elastic, and Dielectric Constants—K. S. Van Dyke. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 681; September, 1950.) Summary of Acoustical Society of America paper. The systematic arrangement of the complex array of piezoelectric and associated data simplifies computation, particularly when solutions of higher order than the first are required. The Manual of Piezoelectric Data, by K. S. Van Dyke and G. D. Gordon, is a collection of constants arranged in matrix form and includes complete data for twelve piezoelectric crystals of present-day interest, and in addition the computed matrices for several of these crystals referred to axes other than the crystallographic axes. The use of such matrices in combination with the recent IRE Standard on Piezoelectric Crystals (655 of 1950) greatly simplifies instruction in this subject.

537.291 611
Note on Stability of Electron Flow in the Presence of Positive Ions—J. R. Pierce.

(*Jour. Appl. Phys.*, vol. 21, pp. 1063; October, 1950.) Amplification and clarification of earlier work (689 of 1949). Experiments seem generally to indicate that electron flow becomes unstable for currents nearer to those calculated assuming no positive ions, than to the larger currents calculated under the assumption that positive ions are present.

537.311.33:621.315.592† 612
Note on the Theory of Resistance of a Cubic Semiconductor in a Magnetic Field—F. Seitz. (*Phys. Rev.*, vol. 79, pp. 372–375; July 15, 1950.) Theory applicable to a classical electron gas in combined electric and magnetic fields, developed by Gans and extended by Sommerfeld and Davis, is applied to a system possessing cubic symmetry. Simplifying assumptions are made and the treatment is limited to the case in which terms involving powers of the magnetic field higher than the second can be neglected.

537.523/.525 613
The Initiation of Breakdown in Gases subject to High-Frequency Electric Fields—W. A. Prowse. (*Jour. Brit. I.R.E.*, vol. 10, pp. 333–347; November, 1950.) A discussion of the literature dealing with the experimental aspect. Frequencies up to 9 kmc are considered. 46 references are included.

537.525:621.396.822 614
The Occurrence of Random Electron Oscillations (Noise) in an Electrodeless High-Frequency Discharge subjected to a Steady Magnetic Field—B. Koch and H. Neuert. (*Ann. Phys.* (Lpz.), vol. 7, pp. 97–102; February 10, 1951.) During experiments on resonance phenomena in a high-frequency discharge subjected to a steady magnetic field, intense random oscillations (noise) were observed over a range of pressures (around 10^{-3} Torr) depending on the dimensions of the vessel. This noise was studied as a function of the steady magnetic field and in relation to the power absorbed by the discharge at resonance. A close relation is demonstrated between intensity and frequency range of the noise with unusually high alternating magnetic field strength inside the discharge.

537.525.5:538.561.029.6 615
Resonance Phenomena in Controlled Low-Pressure Mercury Arcs at Ultra-Short Wavelengths—A. Haug. (*Z. angew. Phys.*, vol. 2, pp. 323–329; August 15, 1950.) An equivalent circuit is derived for the arc. In this the grid layer is represented as a capacitance and the plasma as a parallel resonant circuit comprising grid-anode capacitance, plasma inductance and plasma resistance, which are involved in the expression for the complex conductivity of the arc. Two resonances occur: (a) a parallel resonance in agreement with the Langmuir frequency and due to the plasma properties alone, and (b) a series resonance between the plasma and the grid-layer capacitance. Resonance curves obtained experimentally at wavelengths between 70 cm and 270 cm are in qualitative agreement with theory.

537.533+535.317]:535.23 616
On the Energy-Flow Distribution in Certain Types of Paraxial Beams—R. Dorrestein (*Philips Res. Rep.*, vol. 5, pp. 116–127; April, 1950.) "In a paraxial beam proceeding along the axis of a rotationally symmetric (light-optical or electrostatic) refractive medium, special pairs of cross sections may exist in which the corresponding distributions of energy current density (or intensity) are mutually independent. They are called 'independent' cross sections. From the intensity distributions in two such independent cross-sections, one can calculate the intensity distributions in any other cross-section by means of a suitable composition-product integral. The 'Gaussian beam' is defined by a Gaussian intensity distribution and a Gaussian angular energy-flow distribution in one cross-section. This class of beams possesses an infinite number of pairs of independent cross-sections. The equation for the effective radius s, as a function of the distance z along the axis, is identical with the paraxial-ray equation for $r(z)$ in cylindrical coordinates z, r, Φ."

538.114 617
Ferromagnetism and Antiferromagnetism—(*Nature* (London), vol. 166, pp. 777–779; November 4, 1950.) A report summarizing some of the papers presented at a conference held at Grenoble, July, 1950, under the auspices of the Centre National de la Recherche Scientifique, with assistance from the Rockefeller Foundation. The proceedings are to be published in a single volume towards the end of 1950.

538.3 618
Tentative Nonlinear Theory of Electrodynamics—K. Bechert. (*Ann. Phys.* (Lpz.), vol. 7, pp. 369–409; July 20, 1950.)

538.569.4.029.64:539.13 619
Centimetre Waves and Molecular Structure—R. Freymann. (*Onde élect.*, vol. 30, pp. 416–424; October, 1950.) Measurement techniques used to determine the microwave absorption spectra of solids, liquids and gases are described. Theoretical interpretations of the occurrence of different types of absorption band are reviewed. The structure and properties of various molecules, including simple chlorides, CH_3Cl, H_2O, NH_3 and O_2, and the application of microwave absorption technique in chemical analysis are discussed.

538.632:538.221 620
On the Hall Effect in Ferromagnetics—E. M. Pugh, N. Rostoker and A. Schindler. (*Phys. Rev.*, vol. 80, pp. 688–692; November 15, 1950.) Measurements with magnetic fields well above those required for saturation show that the Hall electric field per unit current-density consists of two distinct parts, the "ordinary" effect caused by a uniform field (the magnetizing force) and the "extraordinary" effect due to magnetization.

539.2:621.392.52 621
Physical Basis of the Wave Filter—J. L. Salpeter. (*Commun. News*, vol. 11, pp. 48–55; July, 1950.) See 2197 of 1950.

538.1 622
Electromagnetic Theory, Vols 1, 2 & 3. [Book Review]—O. Heaviside. Publishers: Dover, New York, reprint 1950, 386 pp., $7.50. (*Science*, vol. 112, p. 566; November 10, 1950.) Four pages of the original are reproduced photographically on one page of the new edition, with little reduction, the page size being 12 inches × 9 inches. "Dealing with fields in which great changes have taken place in the past 50 years, some major sections of E.M.T. could easily be used as textbooks for graduate courses today."

538.3 623
The Principles of Electromagnetism. [Book Review]—E. B. Moullin. Publishers: Oxford University Press, London, 2nd ed., 20s. (*Engineer* (London), vol. 190, p. 269; September 15, 1950.) The first edition of this book was published in 1932. A new appendix to the chapter on Skin Effect deals also with the effect on self inductance of the internal field, and with dielectric loss. Mainly for advanced students of electrical engineering.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.72:621.396.822 624
On Bailey's Theory of Growing Circularly Polarized Waves in a Sunspot—R. Q. Twiss. (*Phys. Rev.*, vol. 80, pp. 767–768; November 15, 1950.) Bailey's theory (1909 of 1950) is criticized briefly. The author hopes to publish a detailed criticism later, with particular attention to the physical aspects, together with an alternative explanation for the excess noise from sunspots.

523.72:621.396.822 625
A Radio-Frequency Representation of the Solar Atmosphere—S. F. Smerd. (*Proc. IEE* (London), Part III, vol. 97, pp. 447–452; November, 1950.) A collection of solar data derived from optical observations and originally compiled for use in studies of solar radio frequency noise.

523.72:621.396.822 626
Detection of Solar R.F. Radiation Reflected by the Moon—J. L. Steinberg and S. Zisler. (*Compt. Rend. Acad. Sci.* (Paris), vol. 229, pp. 811–812; October 24, 1949.) From observations made with the radiotelescope at Marcoussis operating at 158 mc with a modulation (interruption) frequency of 530 cps, a reflection coefficient of the order of 10 per cent is deduced.

523.72:621.396.822 627
Comparison of R.F. Radiation received from the Sun on Two Neighbouring Frequencies—E. J. Blum and J. F. Denisse. (*Compt. Rend. Acad. Sci.* (Paris), vol. 231, pp. 1214–1216; November 27, 1950.) Simultaneous observations were made on 156 and 164 mc. Carefully stabilized receivers, each having a bandwidth of 2 mc, use a common antenna passing the frequencies 155–175 mc and located at the focus of the CNRS paraboloid mirror at Marcoussis. Observations show that (a) calm periods lasting for several days are common to the two frequencies, with mean received intensities of 4 to 5×10^{-22} w/m² per cycle and infrequent disturbances generally coinciding; (b) low-intensity radio storms probably confined to a band of a few mc, do not appear simultaneously on the two frequencies; (c) during the storms, occasional selective-extinction phenomena last some tens of minutes, corresponding to obscuration of the source of disturbance by an absorber of the lower-frequency radiation.

523.746"1950.4/.6" 62[illegible]
Provisional Sunspot-Numbers for April to June 1950—M. Waldmeier. (*Jour. Geophys. Res.*, vol. 55, p. 340; September, 1950.)

523.852.32:621.396.822 62[illegible]
Radio-Frequency Radiation from the Great Nebula in Andromeda (M.31)—R. H. Brown and C. Hazard. (*Nature* (London), vol. 166, pp. 901–902; November 25, 1950.) Experiments at a frequency of 158.5 mc, using a paraboloid antenna (aperture 218 feet and focal length 126 feet) with a beam width of about 2°, indicate that radiation comparable with that from the galaxy is received from the Andromeda nebula, the noise source having apparent dimensions of ¾° and ½° along the right-ascension and declination axes respectively.

550.38"1950.1/.3" 63[illegible]
International Data on Magnetic Disturbances, First Quarter 1950—J. Bartels and

Veldkamp. (*Jour. Geophys. Res.*, vol. 55, .337–339; September, 1950.)

.38"1950.4/.6" 631

Cheltenham Three-Hour-Range Indices for April to June 1950—R. R. Bodle. (*Jour. phys. Res.*, vol. 55, p. 340; September, 0.)

0.385"1950.4/.6" 632

Principal Magnetic Storms [Jan.-June 1950] *Jour. Geophys. Res.*, vol. 55, pp. 341–343; tember, 1950.

.510.535:538.566 633

Computation of Propagation in the Ionosphere—Scott. (See 720.)

1.510.535:550.38 634

World-Wide F_2 Ionization—R. Eyfrig, E. rnischmacher & K. Rawer. (*Jour. Geophys. s.*, vol. 55, pp. 261–266; September, 1950.) e distributions of f_0F_2 and (M3000) F_2 with itude are examined month by month for r Eastern stations. In all months the trough the magnetic equator is evident, but no rked seasonal change can be seen in the ily maximum values of f_0F_2 considered; the ily minimum values show a strong seasonal fluence but no trough. Contrary to the servations of Lung (3427 of 1949), the midght values show a trough in most months, it there is also a seasonal effect.

1.510.535:621.396.11 635

Note on the *D*-Layer at Very Low Frequencies—R. E. Burgess. (*Jour. Geophys. s.*, vol. 55, p. 350; September, 1950.) Discuson on 723 of 1950 (Pfister).

1.594.5 636

Evidence for the Entry into the Upper mosphere of High-Speed Protons during roral Activity—A. B. Meinel. (*Science*, vol. 2, p. 590; November 17, 1950.) Spectroaph observations made on the night of igust 19–20, 1950, establish for the first ne that protons of probably solar origin e streaming into the upper atmosphere at locities of the order of 2,500–3,000 km.

1.594.6 637

Radiogoniometer Measurements of Atmospherics on board the *Commandant Charcot*: lentification of a Centre in West Africa—. Bureau and M. Barre. (*Compt. Rend. Acad. ci.* (Paris), vol. 231, pp. 975–977; November 1950.) During the second voyage of the *ommandant Charcot* to Adélie Land, the udy of atmospherics undertaken the previous ear (97 of 1950) was continued. A new direcon finder was used, operating on 27.5 kc and aking a photographic record every two hours r oftener, with 2-minute exposures, using the ethod of Rivault and Haubert. Observations onfirm the existence, at least in autumn, of enter A3 detected in 1934. Goniograms for eptember 29 and October 8, 1949 are reprouced; these indicate location of the center in a gion around Bamako and covering Guinea nd part of Liberia and the Ivory Coast; the eriod of activity is about 1400 to 1800 local me.

21.396.821+551.594.221 638

'Sferics' and the Lightning Discharge—. H. Golde. (*Met. Mag.*, vol. 79, pp. 277–286; ctober, 1950.) Discussion of the characteritics of lightning flashes which are directly ncerned in the development of atmospherics. he oscillatory wave pattern giving rise to atospherics is found to be the result of the inense return stroke of a lightning discharge to arth, and all thunderstorms within about 4,000 iles of an observation station are potential ources of the atmospherics recorded there.

LOCATION AND AIDS TO NAVIGATION

621.396.9 639

The Radio Background of Radar—H. Guerlac. (*Jour. Frank. Inst.*, vol. 250, pp. 285–308; October, 1950.) Historical account of the scientific developments and military requirements that led to the birth of radar.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.787.9 640

The Pirani Effect in a Thermionic Filament as a means of Measuring Low Pressures—J. Blears: W. P. Jolly. (*Brit. Jour. Appl. Phys.*, Vol. 1, pp. 301–302; November, 1950.) Comment on 1922 of 1950 and author's reply.

533.5:061.3 641

Conference on Vacuum Physics—Birmingham, 1950—L. Riddiford. (*Brit. Jour. Appl. Phys.*, vol. 1, pp. 273–274; November, 1950.) Brief account of papers given and apparatus exhibited at the conference arranged by the Midland Branch of the Institute of Physics. It is intended to publish the papers and the discussion on them in a special issue of the *Jour. Sci. Instr.* during 1951.

534.321.9:534.22:546.74:538.69 642

Some Magneto-Acoustic Effects in Nickel—T. F. Rogers and S. J. Johnson. (*Jour. Appl. Phys.*, vol. 21, pp. 1067–1068; October, 1950.) Initial results of an investigation of the effects produced by a magnetic field on the ultrasonic propagation properties of ferromagnetic substances. A large decrease of attenuation was observed on applying a longitudinal field to a rod of commercially pure Ni, the amplitude of the pulses received after transmission through the rod increasing to about 100 times the normal value. The velocity of propagation in the rod increased very considerably on applying a field of about 500 oersted.

535.215.1:539.234 643

Photoelectric Properties and Emission Mechanism of Caesium-Antimony Films—W. Veith. (*Jour. Phys. Radium*, vol. 11, pp. 507–513; August–September, 1950.) Photoelectric Cs/Sb layers are produced by an evaporation process. Sensitivity and conductivity are measured at each stage of the production. At maximum sensitivity the layers may be considered as semiconductors. The effect of added oxygen is discussed.

535.37 644

Effect of Temperature Rise on Electrophotoluminescence Phenomena—G. Destriau and J. Mattler. (*Jour. Phys. Radium*, vol. 11, pp. 529–541; October, 1950.) In general, the degree of permanent quenching of sulphides increases with temperature; for certain mixed sulphides of Zn and Cd the quenching is almost complete at a temperature of the order of 70°C and an electric field of the order of 20–40 kv per cm rms. As the temperature rises, the phenomenon of momentary illumination is at first intensified, then passes through a maximum and becomes weaker. The dose of exciting radiation corresponding to the maximum of momentary illumination decreases steadily as the temperature rises. See also 110 of 1949 (Destriau).

535.37 645

Influence of the State of Oxidation of Luminescence Centres on the Luminescence Colour of Copper-Activated Zinc Sulphide—E. Grillot and M. Bancie-Grillot (*Compt. Rend. Acad. Sci.* (Paris), vol. 231, pp. 966–968; November 6, 1950.)

535.37:546.221 646

Theory of the Luminescence of Sulfide Phosphors—S. Roberts and F. E. Williams. (*Jour. Opt. Soc. Amer.*, vol. 40, pp. 516–520; August, 1950.)

535.37:546.47.284 647

On the Existence of 'Sub-Bands' in the Luminescence Emission Spectrum of Manganese-Activated Zinc Silicate—C. C. Klick and J. H. Schulman. (*Jour. Opt. Soc. Amer.*, vol. 40, pp. 509–516; August, 1950.)

535.37:546.472.21 648

Effect of Infra-Red on Emission and Trapping in ZnS:Cu Phosphors—R. H. Bube. (*Phys. Rev.*, vol. 80, pp. 764–765; November 15, 1950.)

535.37:546.472.21 649

Luminescence and Trapping in Zinc Sulfide Phosphors with and without Copper Activator—R. H. Bube. (*Phys. Rev.*, vol. 80, pp. 655–666; November 15, 1950.)

537.311.31:539.23 651

Experiments on the Electrical Conductivity at Ordinary Temperature of Very Thin Films of Silver subjected to Strong Electric Fields—A. Blanc-Lapierre and M. Perrot. (*Jour. Phys. Radium*, vol. 11, No. 10, pp. 563–569; October, 1950.) The equivalent thickness of the films investigated was < 10 mμ; the method of preparation is described. Field strengths ranged up to nearly 20 kv/cm; a decrease of resistance was observed with increase of applied field strength. The detector properties corresponding to the curved current-voltage characteristic are nearly independent of frequency between 50 cps and 10 kc. See also 2242 of 1950.

537.228.1:549.514.51 650

Piezoelectric Constants of Alpha- and Beta-Quartz at Various Temperatures—R. K. Cook and P. G. Weissler. (*Phys. Rev.*, vol. 80, pp. 712–716; November 15, 1950.) The adiabatic piezoelectric constants d_{11} and d_{14} of α-quartz were measured at temperatures from room temperature up to 571.5°C, where d_{11} has a value about half that at room temperature, while d_{14} is nearly three times greater. At 573°C, where the transition to β-quartz occurs, d_{11} vanishes. The value of d_{14} for β-quartz is practically constant in the temperature range 584–626°C and differs by only a few per cent from the value at 570°C. The values of the constants were deduced from measurements by a *Q*-meter technique of the equivalent circuits of long thin bars driven at frequencies near resonance.

538.221 652

Gyromagnetic Phenomena Occurring with Ferrites—H. G. Beljers and J. L. Snoek. (*Philips Tech. Rev.*, vol. 11, pp. 313–322; May, 1950.) The material ferroxcube is characterized by very low eddy-current and hysteresis losses. In the range 0–10^5 cps some after-effect is observed. Above a certain critical frequency, differing from one material to another, additional losses occur due to gyromagnetic resonances, the theory of which is explained by means of a mechanical model. Measurements are described which have been carried out with a material placed in a constant strong magnetic field polarizing the material in a direction perpendicular to the direction of observation. The gyromagnetic effect can be used to realize a 4-terminal network with new properties, a gyrator. See also 980 and 2745 of 1949 (Tellegen).

538.221 653

Thermomagnetic Investigation of Boroferrites—R. Benoit. (*Compt. Rend. Acad. Sci.* (Paris), vol. 231, pp. 1216–1218; November 27, 1950.)

538.221 654

Coercive Field of Granular and Aggregated Ferromagnetic Materials—L. Weil (*Compt. Rend. Acad. Sci.*, (Paris), vol. 231, pp. 829–831; October 23, 1950.)

538.221 655

Magnetic Properties of Copper in Solid Solution in Cobalt and in Fe/Ni Alloy—A. J. P. Meyer and P. Taglang. (*Compt. Rend. Acad. Sci.*, (Paris), vol. 231, pp. 956–958; November 6, 1950.)

538.221:537.311.33 656

Electrical Conductivity of Ferromagnetic Compounds of Manganese with Perovskite Structure—J. H. van Santen and G. H. Jonker. (*Physica, 's Grav.*, Vol. 16, pp. 599–600; July–August, 1950. In English.) A preliminary account of conductivity measurements at 3 kc on polycrystalline ceramics prepared from mixed crystals of lanthanum hypomanganite and various manganites. Results for different compositions are shown as functions of temperature and are discussed briefly.

621.318.22:538.221.001.11 657

Theory of Magnetic Properties and Nucleation in Alnico V—C. Kittel, E. A. Nesbitt and W. Shockley. (*Phys. Rev.*, vol. 77, pp. 839–840; March 15, 1950.) A possible explanation of the mechanism of nucleation in alnico V is suggested which could account for the observed magnetic properties of the material.

621.318.22:538.221.001.11 658

Theory of Magnetic Properties of Anisotropic Permanent-Magnet Alloys—K. Hoselitz and M. McCaig. (*Phys. Rev.*, vol. 80, pp. 757–758; November 15, 1950.) Criticism of an explanation of the magnetic properties of alnico V proposed by Kittel, Nesbitt and Shockley (657 above). See also 2241 of 1950 (McCaig).

539.23 659

Continuous Observations with the Electron Microscope on the Formation of Evaporated Films of Silver, Gold, and Tin—T. A. McLauchlan, R. S. Sennett, and G. D. Scott. (*Canad. Jour. Res.*, vol. 28, Sec. A, pp. 530–534; September, 1950.) Micrographs are reproduced which illustrate the formation of the films. The results confirm the usually accepted assumptions regarding the formation of nuclei and the growth of aggregates.

546.289 660

Some Properties of High-Resistivity P-Type Germanium—W. C. Dunlap. (*Phys. Rev.*, vol. 79, pp. 286–292; July 15, 1950.) Hall coefficient R, resistivity ρ, mobility figure $\mu(10^8R/\rho)$ and rectification characteristics were measured as functions of temperature T and magnetic field H for homogeneous single crystals of high purity. Average values at $H=3{,}600$ gauss and $T=298°$k were: $-\rho=18.8$ Ω cm; $R=5.14\times10^{-4}$ v cm/a gauss; $\mu=2730$ cm²/vs. Resistance change was about 22 per cent between $H=3{,}600$ and 13,750 gauss. Band separation was 0.82 ev from Hall-effect measurements and 0.75 ev from resistivity measurements. Mobility obeyed a T^{-20} law in the temperature range 78°–400°K. The best rectification ratio obtained was about 6 at 5 v, using an Al whisker.

546.289 661

Magnetoresistance of Germanium Samples between 20° and 300° K—I. Estermann and A. Foner. (*Phys. Rev.*, vol. 79, pp. 365–372. July 15, 1950.) The resistivity of pure samples and of samples with added impurities was measured at various temperatures with various magnetic field strengths H and orientations. The results were compared with those following from the theoretical investigation of a classical electron gas in combined electric and magnetic fields in an isotropic medium and in an anisotropic medium possessing cubic symmetry. For transverse orientation, the relative change in electrical conductivity Q was found proportional to H^2 for small values of H, but nearly proportional to H for larger values of H. Q was found to increase with the purity of the sample. For longitudinal orientation, Q was of the expected order of magnitude for p-type samples but much larger than the theoretical prediction for n-type samples. The angular dependence of Q was as predicted. Carrier mobilities calculated from magnetoresistance measurements agreed reasonably well with those calculated from Hall-effect and conductivity measurements.

546.289 662

Electronic Mobility in Germanium—V. A. Johnson and K. Lark-Horovitz. (*Phys. Rev.*, vol. 79, pp. 409–410; July 15, 1950.) The resistivity ρ is made up of resistivities ρ_e due to lattice scattering and ρ_i due to impurity scattering. The mobility $|R|/r\rho_e$ (R is the Hall coefficient) is dependent on ρ_i/ρ through r. Using calculated values for r, the mobility is found to be 3270 ± 700 cm²/vs and is the same for single-crystal and polycrystalline samples, and also for high- and low-resistivity samples.

549.514.51:621.396.611.21.002.2 663

The Manufacture of Quartz Oscillator-Plates: Part 1—W. Parrish. (*Philips Tech. Rev.*, vol. 11, No. 11, pp. 323–332; May, 1950.) In cutting an oscillator plate out of a quartz crystal according to a low-temperature-coefficient cut, the angle tolerances for the orientation of the crystal are only about 10 minutes. For a rough adjustment of the angle of cut, double-refraction methods are used. The crystallographic orientation of a test cut is then determined very accurately by an X-ray diffraction measurement and the correction for the position of the saw-table is deduced. Twinning is also briefly discussed and the practical problems arising from its occurrence are considered.

549.514.51:621.396.611.21.002.2 664

The Manufacture of Quartz Oscillator-Plates: Part 2—Control of the Cutting Angles by X-Ray Diffraction—W. Parrish. (*Philips Tech. Rev.*, vol. 11, pp. 351–360; June, 1950.) An X-ray diffraction apparatus which uses a GM counter tube for detection of the reflected beam is described. The angle between the reflecting lattice plane and the reference surface of the test crystal may be readily and quickly determined to within a few minutes of arc by relatively unskilled personnel. Examples of the use of the apparatus in checking AT, BT and YZ cuts are given. Part 1: 663 above.

621.315.592†:546.289:621.385.3 665

The Transistor—Bibliographical Survey—Gaulé. (See 778.)

621.315.61 666

Dielectric Properties of Liquid Insulating Substances with Polar Components—P. Henninger. (*Frequenz*, vol. 4, pp. 233–245; September, 1950.) Debye's theory gives the frequency variation of permittivity and loss angle for a very dilute solution of a polar substance. Experiments on mixtures of paraffin oil and Clophen A50 (a mixture of various chlorinated diphenylenes) are described, and discrepancies between calculated and measured results are traced to neglect of the dispersion of relaxation times. A characteristic quantity Z is introduced which is a measure of the departure of a medium from nonpolarity; Z can be determined as the integral of the imaginary component of the permittivity over the logarithmic fre quency band. To illustrate the theory, the per mittivity of a class of purely polar liquids i calculated.

621.315.61 66

The Dielectric Properties of Polyethylen Terephthalate (Terylene)—W. Reddish (*Trans. Faraday Soc.*, vol. 46, pp. 459–47 June, 1950.)

621.315.61 66

The Rheological Properties of Dielectri Polymers—W. Lethersich. (*Brit. Jour. App Phys.*, vol. 1, pp. 294–301; November, 1950

621.315.61:537.226.2 66

Dielectric Constants of Non-Polar Fluid Part 2: Analysis of Experimental Data—W. F Brown, Jr. (*Jour. Chem. Phys.*, vol. 18, p 1200–1206; September, 1950.) Part 1: 60 above.

621.317.335.3.029.64† 67

Microwave Techniques for the Measur ment of the Dielectric Constant of Fibers an Films of High Polymers—Shaw and Windl (See 686.)

621.357.7:546.23 67

The Electroplating of Metallic Selenium— A. von Hippel and M. C. Bloom. (*Jour. Chem Phys.*, vol. 18, pp. 1243–1251; Septembe 1950.) The fact that selenium is a nonmetal peculiar properties has delayed accomplis ment of a satisfactory method of electroplatin it; such a method is described.

621.357.7:621.385.032.21 67

Making Small Metal Tubes by Electr deposition on Nylon Fibers—R. J. E. G zelius. (*Rev. Sci. Instr.*, vol. 21, p. 886; O tober, 1950.) A brief account of a method f producing metal tubes with diameters fro 1 mm down to 0.1 mm or less, as require e.g., for indirectly heated cathodes.

621.396.622.5.029.64:621.385.2/.3 67

Crystal Detectors and Their Use at Ultr High Frequencies—Engel; Welker; Matar (See 775.)

661.1.037.5 67

A Nickel-Chromium-Iron Alloy for Sealin to Glass—J. E. Stanworth. (*Jour. Sci. Inst* vol. 27, pp. 282–284; October, 1950.) The d velopment is described of an alloy containing 4 per cent Ni and 5 per cent Cr, and matchin ordinary lead glass as used for lamps ar valves. Stresses in seals made with these m terials are low at all temperatures, even thoug there is a 60° difference between the all Curie temperature (about 340°C) and the gla transformation temperature (about 400°C).

778.3:621.317.755.087.5 67

Techniques of Photo-Recording—H. Mansberg. (*Oscillographer*, vol. 12, pp. 3–1 April–June, 1950.) Suitable methods for r cording a wide range of stationary patter and transients are outlined. The determinati of the optimum exposure, and the selection filters, type of cathode-ray-tube screen and fil are considered. Processing techniques, t avoidance of various forms of fog, and metho of trace calibration are also described.

MATHEMATICS

517.5:517.942.4 6

Eigenfunction Problems with Period Potentials—E. C. Titchmarsh. (*Proc. Ro Soc. A*, vol. 203, pp. 501–514; October 2 1950.) The expansion of an arbitrary functi in terms of the solutions of the different equation $d^2\phi/dx^2+\{\lambda-q(x)\}\phi=0$ is obtain in the case where $q(x)$ is a periodic function of

1941.4:517.522.5 677

The Remainder Theorem and its Applica-i to Operational-Calculus Techniques—. Richardson, Jr. (Proc. I.R.E., vol. 38, pp. 5–1339; November, 1950.) "The necessary cedure involved in the transition from the lace transformation to the solution of linear ferential equations is summarized, and a icular form of partial-fraction expansion ch may be advantageous in special cases is ed. The remainder theorem with regard to braic polynomials is restated, and it is wn how this theorem may be applied to the luation of high-degree polynomials for real complex numbers. A numerical example is ited to illustrate application to a typical isfer function. Finally, the method is shown e useful in the evaluation of the frequency ponse of such a transfer function."

.21:621.396.812 678

Probability Distributions of the Resultants Two or More Vibrations—C. F. Kent and . Boyd. (*Phys. Rev.*, vol. 79, p. 417; July 15, 0.) Summary of American Physical Society per. The method of "random flights" outed by Chandrasekhar (2866 of 1943) is used derive probability distributions for the retants of 2, 3, 4 or more vibrations of equal plitude and random phase. The calculation extended to cases involving functionally ied amplitudes as well as random phases. hen normalized relative to their mean intenes, the probability distribution curves for resultants of relatively small numbers of rations (10 or more) of equal amplitude are sely similar to the Rayleigh distribution for immense number of vibrations. Two ran-n-phased components with a Gaussian disbution of amplitude give a probability curve ich is almost identical with the Rayleigh ve. Experimental frequency distributions of crowave radio signal strength, obtained m measurements of propagation over land der changing atmospheric conditions, are nd to be similar to the theoretical problity distributions for many vibrations.

).283:621.39.001.11 679

Correlation Functions and their Application to Communication Problems—Y. W. e and J. B. Wiesner. (*Acous. Soc. Amer.*, vol. p. 677; September, 1950.) Title only of oustical Society of America paper. See also 2 of 1950.

1.142:621.385.832 680

A Storage System for Use with Binary-gital Computing Machines—F. C. Williams d T. Kilburn. (*Proc. IEE* (London) Part III, l. 97, pp. 453–454; November, 1950.) Dission on 2258 of 1949.

MEASUREMENTS AND TEST GEAR

1.317:538.56.029.6:538.65 681

Ponderomotive Effects of Centimetre aves and the Possibility of their Application Measurement Purposes—H. A. Bomke and Schmidt. (*Arch. elekt. Übertragung*, vol. 4; nuary, March, June and September, 1950.)

1.317.088.4:621.314.12 682

The Fundamental Limitations of the Second-Harmonic Type of Magnetic Modulator as plied to the Amplification of Small D.C. Signals—F. C. Williams and S. W. Noble. (*Proc. EE* (London) Part III, vol. 97, pp. 461–462; ovember, 1950.) Summary only. See 152 of uary.

1.317.3.001.4:621.396.615.142.2 683

Test Methods and Apparatus for the Development of 3-cm Low-Voltage Klystrons— Musson-Genon, J. Chantereau and R. tivier. (*Onde élect.*, vol. 30, pp. 425–432; October, 1950.) Illustrated description of manufacturers' tests on reflex klystrons for the frequency range 8.5–9.6 kmc. Measurement of the Q factor of the cavity alone is based on Slater's method: to facilitate measurement of the voltage SWR a waveguide transmission line is used to lengthen the coaxial output line from the valve; two series of measurements are made at frequencies close to the resonance frequency of the cavity; Q at resonance may be calculated without a knowledge of the impedance characteristics of the coupling line. The Q value on load is measured similarly. A study is made of the output line regarded as a transformer and the conditions for optimum Q value are discussed. See also 1680 of 1948 (Musson-Genon) and 1720 of 1950 (Musson-Genon & Brissonneau).

621.317.333.029.6 684

A Resonance Method of Impedance Measurement at Ultra-Short Wavelengths—A. Haug. (*Z. angew. Phys.*, vol. 2, pp. 330–331; August 15, 1950.) The imepdance to be measured is connected across one end of a Lecher-wire system, which is loosely coupled to a constant-voltage source and is short-circuited at the other end. A capacitively coupled instrument at a constant distance from the short-circuiting link measures the voltage V. The position of the link is adjusted first to obtain resonance at a voltage Vo and then to obtain a voltage of $Vo/\sqrt{2}$. The real and imaginary components of the unknown impedance are derived from the lengths of the line in the two cases.

621.317.335:534.442.2 685

The Analysis of Oscillations by the Search-Tone Method—Meyer-Eppler. (See 532.)

621.317.335.3.029.64† 686

Microwave Techniques for the Measurement of the Dielectric Constant of Fibers and Films of High Polymers—T. M. Shaw and J. J. Windle. (*Jour. Appl. Phys.*, vol. 21, pp. 956–961; October, 1950.) A resonant-cavity method is described and results obtained for wool, nylon, and cellophane at 3 kmc are given.

621.317.7 687

A Novel R.M.S.-Value Rectifier [meter] with Reduced Wave-Form Error—H. Boucke. (*Arch. elekt. Übertragung*, vol. 4, pp. 267–270; July, 1950.) Description of circuit and operation of an ac moving-coil rectifier-type meter in which the time constants for the charge and discharge of a capacitor in the rectifier circuit are so related that the rms indication is largely free from wave-form error. A square wave is investigated as a particular example. Results indicating the accuracy in practice are given.

621.317.725:621.3.018.78† 688

A New Distortion Meter—H. Boucke. (*Funk u. Ton*, vol. 4, pp. 451–457; September, 1950.) Circuit and description of an instrument based on the Küpfmüller bridge. Range is 0.5 to 4.5 v for frequencies from 30 cps to 10 kcs.

621.317.725.083.6 689

An Electronic A.C. Differential Voltmeter—L. A. Rosenthal and H. S. Zablocki. (*Rev. Sci. Instr.*, vol. 21, pp. 799–801; September, 1950.) An instrument giving a direct reading of percentage changes of voltage in the range ± 10 per cent, for voltages from 1.5 to 150 v and frequencies from 20 cps to 200 kc.

621.317.73:621.385 690

Impedance-Testing Set for Valves at High Frequencies—(*Engineering* (London), vol. 170, No. 4408, p. 56; July 21, 1950.) A short description of equipment intended primarily for research or development purposes in connection with tubes operating in the range 10–150 mc. The basic principles are similar to those of Q meters. Measurements of input impedance are made by connecting the tube cathode and control grid to the terminals of a parallel resonant circuit and noting the change in tuning capacitance and dynamic resistance of the circuit. A calibrated piston attenuator, together with tuning capacitors with micrometer adjustment, enable high accuracy of measurement to be obtained.

621.317.733.089.6+621.3.011.2(083.74) 691

H. F. Resistance Standards and their Use in the Calibration of an Admittance Bridge up to 60 Mc/s—W. H. Ward, M. H. Oliver and S. J. Fray. (*Proc. IEE* (London), Part III, vol. 97, pp. 438–446; November, 1950.) Transfer standards are described for the calibration of an admittance bridge covering the ranges 0–100 millimhos and -150 pF to $+150$ pF.

621.385.012:621.317.79 692

Apparatus for the Determination of [valve] Characteristics—W. Graffunder and H. Schultes. (*Frequenz*, 1950. vol. 4, pp. 229–233; September, 1950.) An arrangement is described which enables an accurate quantitative assessment to be made by simultaneously displaying the characteristic and a pair of coordinate axes on the screen of a cro. The method is applicable when the tube is to be tested under positive-grid or overload conditions, when pulse methods have to be used.

621.396.615:534.321.7 693

A Bridge-Stabilized Generator for Tuning Musical Instruments—R. Gauger and J. Sommer. (*Funk u. Ton*, vol. 4, pp. 554–558; November, 1950.)

621.396.615.015.7† 694

Narrow-Pulse Generator—C. S. Fowler. (*Wireless Eng.*, vol. 27, pp. 265–269; October–November, 1950.) The generator produces pulses of known amplitude either singly or at repetition rates between 5 and 5,000 per second. The shape of the pulses is such as to give an energy spectrum which is substantially flat up to 40 mc. The pulse amplitude is expressed in terms of the equivalent sine-wave voltage per unit bandwidth of the circuit in which the voltage is developed.

621.397.335.001.4(083.74) 695

Standards on Television: Methods of Measurement of Time of Rise, Pulse Width, and Pulse Timing of Video Pulses in Television, 1950—(See 750.)

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.717.1 696

A Thickness Gauge for Ceramic Coatings—C. C. Gordon and J. C. Richmond. (*Jour. Amer. Ceram. Soc.*, vol. 33, pp. 295–300; October, 1, 1950.) The gauge is designed to measure coatings with a maximum thickness of about 0.09 inch, and operates by an electromagnetic method based on the dependence of the inductance of a coil on the proximity of the nonmagnetic metal surface carrying the coating.

551.508.11:621.396.9 697

International Radiosonde Trials—H. E. Painter. (*Weather* (London), vol. 5, pp. 307–310; September, 1950.) Short account of the trials held at Payerne, Switzerland, in May, 1950, with descriptions of the different types of equipment used.

621.314.634:621.384.6.027.85 698

A 500-Kilovolt Linear Accelerator using Selenium Rectifiers—Arnold. (See 745.)

621.384.611.1/.2† 699
Field Measurements on Model Betatron and Synchrotron Magnets—E. A. Finlay, J. F. Fowler, and J. F. Smee. (*Jour. Sci. Instr.*, vol. 27, pp. 264–270; October, 1950.)

621.384.611.2† 700
The Birmingham Proton Synchrotron—L. U. Hibbard. (*Nucleonics*, vol. 7, pp. 30–43; October, 1950.) Details of design and construction. Maximum proton energy is 1,300 mev.

621.385.833 701
A Method for the Detection and Measurement of Elliptical Astigmatism—R. Castaing. (*Compt. Rend. Acad. Sci.* (Paris), vol. 231, pp. 835–837; October 23, 1950.) A study is made of a particular form of image distortion which constitutes a sensitive test for astigmatism in electron lenses. See also 702 below.

621.385.833 702
Detection and Direct Measurement of the Elliptical Astigmatism of an Electron Lens—R. Castaing. (*Compt. Rend. Acad. Sci.* (Paris) vol. 231, pp. 894–896; October 30, 1950.) Description of a method based on observation of the distortion suffered by the image of a wire in the shadow microscope. See also 701 above.

621.385.833 703
Calculation of the Optical Constants of Powerful Magnetic Electron Lenses—W. Glaser. (*Ann. Phys.*, (Lpz.), vol. 7, pp. 213–227; May 20, 1950.) Formulas are derived for the focal length, the positions of foci, the projection magnification, the chromatic aberration, and the aperture error of the powerful magnetic lenses of the ultramicroscope, as functions of lens strength (coil excitation), accelerating voltage, and pole-shoe parameter.

621.385.833 704
Velocity and Two-Directional Focusing of Charged Particles in Crossed Electric and Magnetic Fields: Part 1—N. Svartholm. (*Ark. Fys.*, vol. 2, pp. 195–207; October 11, 1950. In English.) A mathematical analysis of the aberrations of cylindrically symmetrical magnetic and electric fields with particular application to mass-spectrometer problems. The radial, axial, astigmatic, double-directional, and velocity-focusing field functions are given and a system of fields is found which possesses both first-order velocity focusing and second-order two-directional focusing.

621.385.833 705
Calculation of Optical Parameters of Magnetic Electron Lenses with Extended Bell-Shaped Field—F. Lenz. (*Z. angew. Phys.*, vol. 2, pp. 337–340; August 15, 1950.)

621.385.833 706
Determination of the Resolving Power of the Electron Microscope by means of Fresnel Diffraction—L. Wegmann. (*Helv. Phys. Acta*, vol. 23, pp. 437–452; June 20, 1950. In German.)

621.385.833:621.316.721 707
A Mains Unit for Generating Highly Constant Magnetization Currents for Electron Lenses—Kinder and Schleich. (See 746.)

621.386.1.027.89:621.396.611.4 708
A Million-Volt Resonant-Cavity X-Ray Tube—B. Y. Mills. (*Proc. IEE* (London), Part III, vol. 97, pp. 425–434. Discussion, pp. 434–437; November, 1950.) Description of a very compact X-ray tube in which the accelerating voltage is developed in a resonant cavity excited by a high-power magnetron operating on a wavelength of 25 cm. A mean beam current of 70 μa has been obtained at a peak voltage of 1.1 megv.

621.387† 709
The Properties of Proportional Tubes and Ion Chambers with Glass Envelopes and External Graphite Electrodes—A. L. Cockroft and J. M. Valentine. (*Jour. Sci. Instr.*, vol. 27, pp. 262–263; October, 1950.)

621.387.4† 710
The Propagation of the Discharge in Geiger-Müller Counters with External Cathode—M. Schérer and E. Vieille. (*Compt. Rend. Acad. Sci.* (Paris), vol. 231, pp. 964–966; November 6, 1950.)

621.387.4†:621.3.015.7 711
Differential Method of Counting in Pulse-Amplitude Selectors—Valladas and Thénard. (See 577.)

621.387.4†:621.3.015.7 712
A Simple Differential Pulse-Height Analyzer—Roulston. (See 578.)

621.387.422† 713
Calibration of Proportional Counters by the Excitation of Fluorescence Radiation with Radioactive Sources—G. M. Insch. (*Phil. Mag.*, vol. 41, pp. 857–862; September, 1950.)

621.387.424† 714
Temperature Effect in Geiger-Müller Counters—M. Kimura. (*Phys. Rev.*, vol. 80, pp. 761–762; November 15, 1950.) Measurements of the variation of the rate of spurious discharges in GM counters when heated and cooled at constant rates are described and discussed.

621.387.424† 715
An Improved Resolving-Time Measuring Device—B. W. Roberts, Jr., K. E. Perry, and R. G. Fluharty. (*Rev. Sci. Instr.*, vol. 21, pp. 790–796; September, 1950.) A circuit for measuring the resolving time of counters is described; this is based on Curran and Rae's scheme (1708 of 1948), but uses a delayed pulse of variable width. Any random event initiates a delayed pulse which is fed in coincidence with subsequent pulses, causing a sharp increase in the coincidence rate at a delay time close to the resolving time. Theory is given which accounts for observed curve shapes, and data for several counters illustrate the operation for different counting rates and overvoltages.

621.365.54/.55† 716
Industrial High-Frequency Electric Power [Book Review]—E. May. Publishers: John Wiley & Sons, Inc., New York, N. Y. 355 pp., $5.00. (*Elec. World*, vol. 134, p. 196; October 9, 1950.) Deals with circuits and design details for induction furnaces and dielectric-heating apparatus.

PROPAGATION OF WAVES

538.56:537.525.6 717
Electrical Waves in Moving Plasma—W. O. Schumann. (*Z. angew. Phys.*, vol. 2, pp. 393–399; October, 1950.) Previous work by Hahn, Bailey, the author, and others is reviewed; em waves can be built up in plasma if an electron stream is present together with either (a) another stream of moving particles, or (b) a static magnetic field, or (c) a sufficiently large thermal motion of the electrons. Propagation along moving plasma layers is investigated, making use of relativistic transformations and neglecting oscillations of the positive ions; the plasma boundaries may be conducting or insulating (e.g., atmosphere), and the theory is worked out for both absence and presence of magnetic field. The frequency ranges and phase velocities of the wave modes possible in the various sets of conditions are determined.

538.566
"Internal" Reflection in a Stratif Medium: Particular Application to the Tro sphere—G. Eckart and T. Kahan. (*Jour. Ph Radium*, vol. 11, pp. 569–576; October, 195 "External" reflection in a stratified medium caused by discontinuity in the values of electric constant ϵ, or permeability μ, or tl differentials, while "internal" reflection caused by continuous gradation of ϵ and μ. T problem is analogous to that of a line w graded inductance and capacitance per u length. To eliminate the internal reflection i necessary and sufficient that the ratio of μ a ϵ shall be constant. Two methods are p sented for calculating the internal reflecti one based on classical cable theory and other more general. Vertical propagation in troposphere is considered and the practical possibility of observing internal reflection demonstrated. See also 977 of 1950.

538.566:517.544.2
Green's Function for Electromagn Waves in a Half-Space with a Plane Disc tinuity—T. Kahan and G. Eckart. (*Jo Phys. Radium*, vol. 10, pp. 333–341; Novem 1949.) Mathematical treatment of the probl of propagation in an atmospheric duct boun below by a plane perfectly conducting ea and above by the plane of a discontinuity in dielectric constant. See also 1446 and 1467 1949 and 1480 of 1950.

538.566:551.510.535
Computation of Propagation in the Io sphere—J. C. W. Scott. (*Jour. Geophys. R* vol. 55, pp. 267–269; September, 1950.) using hyperbolic functions of a comp variable, the Appleton-Hartree equations radio-wave propagation in the ionosphere given a simple form suitable for computati The indices of refraction and absorption a the polarization may be easily computed wi out using approximations.

538.566:551.510.535
The Origin of Harmonics in the Ionosph at Points of Zero Dielectric Constant— Försterling and H. O. Wuster. (*Compt. Re Acad. Sci.* (Paris), vol. 231, pp. 831–832; tober 23, 1950.) Further consideration of propagation of a plane wave in a stratif ionosphere [see 3518 of 1949 (Försterlin Where the dielectric constant ϵ is zero, ther strong local variation of the field. Hence whe is calculated from the fundamental equation motion of the electrons, the value of the fi obtained from Maxwell's equations is in plicable, and the actual value as a function the instantaneous position of the electron m be substituted; harmonics of the radiated w are thus introduced. The energy in the h monics is drawn from the fundamental, whi thus undergoes absorption.

621.396.11+621.397.8
Long-Range Television—T. W. Benni ton and R. Morris (*Wireless World*, vol. 56, 407–408; November, 1950.) Analysis of resu obtained between March 13, 1949, and July 1950. The 41.5-mc sound-channel signals fr the Alexandra Palace transmitter were ceived frequently at the SABC station, Joh nesburg, during the late-winter/early-spr and late-autumn/early-winter periods, casionally during mid-winter, and not at al the summer. Peak reception during the l winter/early-spring period of 1950 was less quent than during both peak-reception peri of 1949. These seasonal and annual variati of signal strength agree with those of predic muf values, although the actual frequencies the path tend to be higher than predicted.

1.396.11 723
Circle Diagrams for the Reflection Coefficient of Electromagnetic Waves Reflected at a ro- or First-Order Discontinuity of the Dielectric Constant—G. Eckart. (*Z. angew. ys.*, vol. 2, pp. 334–337; August 15, 1950.) e dependence of reflection coefficient r on frequency, angle of incidence, and polarization is idied in the two cases of discontinuity of (a) e permittivity ϵ, (b) the permittivity gradit. In case (b) r is frequency-dependent; iger waves are favored. The Brewster angle is °, the limiting value for case (a) as the values ϵ on either side of the discontinuity approach uality. For grazing incidence $r=-1$; the ange from this value with increasing angle of idence is greater the shorter the wavelength. e also 3135 of 1950.

1.396.11:551.510.535 724
Note on the *D*-Layer at Very Low Freiencies—R. E. Burgess. (*Jour. Geophys. es.*, vol. 55, p. 350; September, 1950.) Disission on 723 of 1950 (Pfister).

21.396.11(083.72) 725
Standards on Wave Propagation: Definions of Terms, 1950—(Proc. I.R.E., vol. 38, p. 1264–1268; November, 1950.) Copies of iis Standard, 50IRE24.S1, may be obtained hile available from the Institute of Radio ngineers at $.60 per copy.

21.396.11.029.55 726
Round-the-World Radio Signals—A. H. e Voogt. (*Onde élect.*, vol. 30, pp. 433–437; ctober, 1950.) Transit time T and details of ajectory are calculated using hypothetical nization curves and assuming maximum elecon density to be between 5×10^5 and 6×10^5 ectrons per cm³ and at a height of 200–300 km. abulated values of T for frequencies of 10 and 0 mc are between 136 and 145.5 ms, according the ionization curve and radiation angle condered. Measurements of T made during the inter of 1949–1950 at Kootwijk and Horsteieer, Holland, using frequencies of 10–22 mc nd square pulses of duration 100–1,000 μs, ave values between 137 and 139 ms. Reception f the first signal is usually preceded by "scater"; sometimes even the third round-theorld signal is received with little distortion. urther experimental results are to be pubshed.

21.396.11.029.64 727
Outline of a Theory of Radio Scattering in he Troposphere—H. G. Booker and W. E. Gordon. (*Jour. Geophys. Res.*, vol. 55, pp. 241–46; September, 1950.) See 1757 of 1950.

21.396.812 728
Variability of Sky-Wave Radio Signals under Conditions of Ionospheric Absorption—G. M. Allcock. (*Nature* (London), vol. 166, pp. 902–903; November 25, 1950.) The instantaneous value of signal strength of a 9.15-mc adio wave was recorded once a minute at a disance of 788 km from the transmitter. The Rayleigh distribution of amplitudes was found o give a poor fit to the observed distribution at imes around local noon, when ionospheric aborption is considerable. A good fit was, however, obtained with a lognormal curve, an example of which is given covering the period une 14–30, 1949. The lognormal curve also ffords a more accurate means of predicting the alue of signal strength which is exceeded for 0 per cent and 95 per cent of the time. The 95-er cent value calculated from the Rayleigh listribution would lead to a transmitter power nore than twice that actually required to mainain good communication.

621.396.812:519.21 729
Probability Distributions of the Resultants of Two or More Vibrations—Kent and Boyd. (See 678.)

RECEPTION

519.272.15:621.39.001.11 730
Application of Correlation Analysis to the Detection of Periodic Signals in Noise—Y. W. Lee, T. P. Cheatham, Jr., and J. B. Wiesner. (Proc. I.R.E., vol. 38, pp. 1165–1171; October, 1950.) The theory of correlation analysis is briefly reviewed and then applied to the detection of periodic signals in random noise. An electronic correlator, capable of performing the mathematical processes necessary to obtain the required correlation functions, is described and experimental results obtained with it are presented in support of the theoretical conclusions.

621.396.621 731
A Frequency-Modulation Receiver for Use on the 88-108-Mc/s Band—P. M. Miller. (*AWA Tech. Rev.*, vol. 8, pp. 203–215; December, 1949.) The broadcast receiver described is a 13-tube superheterodyne with controls for tuning and volume only and visual tuning indication. Critically coupled transformers are used. The discriminator is of Foster-Seeley type, linear over a band of ±200 kc. The push-pull output stage is capable of delivering 3 w with <3 per cent distortion over the range 30 cps-15 kc. Test results are reported.

621.396.621 732
Signal-to-Noise Improvement Through Integration in a Storage Tube—J. V. Harrington and T. F. Rogers. (Proc. I.R.E., vol. 38, pp. 1197–1203; October, 1950.) The theory of the ideal (linear) and the nonideal integrator is developed, relating improvement in signal-to-noise ratio to certain tube parameters and the number of integration cycles. The expected improvements have been verified experimentally, using a storage tube as the integrating device. Where the number of integrations is small and the output signal-to-noise ratio need not exceed 10 to 15, the Type STE-A barrier-grid storage tube has practical value as an integrator for repetitive signals.

621.396.621:621.396.662 733
Variable-Filter Tuning—A. B. Shone. (*Wireless World*, vol. 56, pp. 355–358 and 393–398; October and November, 1950.) General design data are given of variable-frequency filters for radio-frequency and intermediate-frequency stages. Details are included of typical filters constructed from commercially available components to give stipulated frequency-response characteristics. Photographs and diagrams show the practical layout of a filter-tuned receiver and its over-all audio-frequency response for different settings of its variable intermediate-frequency filter.

621.396.81:621.396.932 734
A Test of 450-Megacycle Urban Area Transmission to a Mobile Receiver—A. J. Aikens and L. Y. Lacy (Proc. I.R.E., vol. 38, pp. 1317–1319; November, 1950.) 1949 IRE National Convention paper noted in 1757 of 1949. Transmissions at 456 mc and at 152 mc were compared, using identical speech modulation. Average speech-noise ratio is plotted against received-signal amplitude. Ignition noise is the limiting factor for both frequencies. For equal speech-noise ratios, the required radio-frequency signal voltage input to the receiver was about 10 db lower at 450 mc than at 150 mc.

621.396.621.5 735
Super-regenerative Receivers. [Book Review]—J. R. Whitehead. Publishers: Cambridge University Press, London, England, 169 pp., 21s. (*Wireless World*, vol. 56, p. 392; November, 1950.) "The treatment is perfectly general, and the influence of particular conditions and modes of operation are only brought in when the more general results have been fully established. . . . the author has arranged his work admirably and has expressed the results clearly in words and in formulae that can be directly applied in design."

STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 736
The Design of Periodic Radio Systems—M. Leifer and N. Marchand. (*Sylvania Technologist*, vol. 3, pp. 18–21; October, 1950.) "The design of radio systems which utilize a periodic signal for the transmission is examined in the light of the modern theory of communication. Conventional practice requires signal detection and a human observer at the receiver to accomplish recognition of the signal. Such design has persisted despite the decrease in signal-to-noise ratio caused by detection and the fluctuations of signal threshold and inefficiencies of an observer. The statistical approach utilizing the auto- and cross-correlation functions is developed. It is noted that signal recognition may be achieved by the latter without requiring an observer. The method requires a correlation of the received signal with a replica of the transmitted signal, suitably phased and noise-free. Inasmuch as all of the characteristics of the signal are utilized, the efficiency of the recognition process may be considerably increased. The theory provides a basis for the choice of the fundamental parameters of transmitted power, signal bandwidth, and receiver bandwidth, and shows the fundamental distinction between the last two."

621.39.001.11 737
The Information-Theory Point of View in Speech Communication—R. M. Fano. (*Jour. Acoust. Soc. Amer.*, vol. 22, p. 677; September, 1950.) Title only of Acoustical Society of America paper.

621.39.001.11:519.283 738
Correlation Functions and their Application to Communication Problems—Y. W. Lee and J. B. Wiesner. (*Jour. Acoust. Soc. Amer.*, vol. 22, p. 677; September, 1950.) Title only of Acoustical Society of America paper. See also 2262 of 1950.

621.395.44 739
A 48-Channel Carrier Telephone System. Part 1: the Method of Modulation—G. H. Bast, D. Goedhart, and J. F. Schouten. (*Commun. News*, vol. 11, pp. 22–32; May, 1950.) Reprint. See 2356 of 1948.

621.396.619.16 740
Crosstalk Considerations in Time-Division Multiplex Systems—S. Moskowitz, L. Diven, and L. Feit. (Proc. I.R.E., vol. 38, pp. 1330–1336; November, 1950.) 1949 IRE National Convention paper noted in 1785 of 1949. "An experimental study was made of the effects on interchannel cross talk of the bandwidth characteristics of the transmission medium in pulse-time multiplex systems. Pulse-amplitude modulation and pulse-position modulation systems are considered. The effects of various types of high- and low-frequency response are discussed from both experimental and theoretical points of view."

621.396.932 741
A Six-System Urban Mobile Telephone Installation with 60-kc Spacing—R. C. Shaw,

P. V. Dimock, W. Strack, Jr., and W. C. Hunter. (PROC. I.R.E., vol. 38, pp. 1320–1323; November, 1950.) 1949 IRE National Convention paper noted in 1785 of 1949. The commercial operation of six channels in the 160-mc band in Chicago with half the normal channel spacing, and the measures necessary to prevent mutual interference, are described. No major equipment changes are necessary.

621.396.93.029.6 742
Radio Communication at Ultra-High Frequency [Book Review]—J. Thomson. Publishers: Methuen, London, England, 203 pp., 21s (*Jour. Sci. Instr.*, vol. 27, p. 318; November, 1950.) Seven chapters cover ultra-high-frequency circuit elements, tubes, transmitters, receivers, modulation techniques, methods of frequency control, and the communication system as a whole.

SUBSIDIARY APPARATUS

621–526 743
Theory of Relay Servomechanisms—J. R. Dutilh. (*Onde Élect.*, vol. 30, pp. 438–445; October, 1950.)

621.314.634 744
Capacitance Measurements on Selenium Rectifiers: Evidence of Anomalous Dispersion—R. Cooper. (*Proc. Phys. Soc.*, vol. 63, pp. 176–179; March 1, 1950.) Contrary to the generally accepted view, the audio-frequency capacitance of a Se rectifier may vary with frequency. The magnitude of the variation depends on the metal used as counter-electrode; little variation occurs with Sb or Bi, but with Cd there is considerable decrease over the frequency range 300–2,000 cps. Related work by Breckenridge indicates that the effect may be due to relative motion in the Se lattice of the negatively charged impurity centers and positive ions which diffuse into the Se from the counter-electrode.

621.314.634:621.384.6.027.85† 745
A 500-Kilovolt Linear Accelerator using Selenium Rectifiers—W. R. Arnold. (*Rev. Sci. Instr.*, vol. 21, pp. 796–799; September, 1950.) Description of equipment designed for use in a linear accelerator. A cascade arrangement of Se rectifiers and 1-μf capacitors in 22 voltage-doubler stages is used, fed from a 750-cycle 10-kva alternator.

621.385.833:621.316.721 746
A Mains Unit for Generating Highly Constant Magnetization Currents for Electron Lenses—E. Kinder and F. Schleich. (*Z. angew, Phys.*, vol. 2, pp. 332–334; August 15, 1950.) In the electron microscope, separate rectifiers supply the capacitor, objective and projection lenses. The control circuit for the two latter is described. This uses two pentodes, V_1 and V_2. The lens coil is in the cathode circuit of V_2 and the voltage drop across a cathode resistor is applied to the grid of V_1, which is battery biased. The anode of V_1 is connected to the control grid of V_2. Refinements and the operation of the circuit are discussed.

778.36 747
A 100,000,000 Frame-per-Second Camera—M. Sultanoff. (*Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 55, pp. 158–166; August, 1950.) See 3178 of 1950.

621.352 748
Primary Batteries [Book Review]—G. W. Vinal. Publishers: John Wiley & Sons, Inc., New York, N. Y., 336 pp., $5.00. (*Elec. World*, vol. 134, p. 196; October 9, 1950.) Historical résumé with survey of properties and performance of present-day types.

TELEVISION AND PHOTOTELEGRAPHY

621.397.335 749
A Television Synchronizing-Signal Generator—J. E. Benson, H. J. Oyston, and B. R. Johnson. (*Jour. Brit. I.R.E.*, vol. 10, pp. 348–361; November, 1950. *Tech. Rev.*, vol. 8, pp. 231–261; December, 1949.) Reprint. See 760 of 1950.

621.397.335.001.4(083.74) 750
Standards on Television: Methods of Measurement of Time of Rise, Pulse Width, and Pulse Timing of Video Pulses in Television, 1950—(PROC. I.R.E., vol. 38, pp. 1258–1263; November, 1950.) Copies of this Standard, 50IRE23.S2, may be obtained while available from the Institute of Radio Engineers at $.75 per copy.

621.397.5 751
Quality Rating of Television Images—P. Mertz, A. D. Fowler, and H. N. Christopher. (PROC. I.R.E., vol. 38, pp. 1269–1283; November, 1950.) 1950 IRE National Convention paper noted in 1534 of 1950 (No. 104). The impairment of the image is measured by two subjective methods: (a) an extension of Baldwin's method (1425 of 1941) in which observers state their preference for a television image or an optically projected one; (b) the impairment is rated by observers in terms of a list of comments to which values are assigned. Results thus obtained for the impairment caused by several types of interference are discussed.

621.397.5 752
Television Outside Broadcasts—T. H. Bridgewater. (*BBC Quart.*, vol. 5, pp. 179–192; Autumn, 1950.) Supplements Birkinshaw's paper on BBC television studio technique (3284 of 1949). In television outside broadcasts, extreme values of illumination and of ratio of highest to lowest light intensity are encountered. Problems of gamma, color response, focusing, and perspective are discussed.

621.397.5:621.396.712.3 753
The Lime Grove Television Studios—M. J. L. Pulling. (*BBC Quart.*, vol. 5, pp. 173–178; Autumn, 1950.) Illustrated description of the converted film studios at Shepherds Bush, London, England, serving as temporary television studio headquarters for the BBC.

621.397.61 754
A Rooter for Video Signals—B. M. Oliver. (PROC. I.R.E., vol. 38, pp. 1301–1305; November, 1950.) A nonlinear impedance (triode) is used to give an output whose amplitude varies as the nth root of the input. The device is inserted after the linear camera of a television system and linearizes the over-all transfer characteristic of such a system using normal viewing tubes.

621.397.61 755
The Design of a Television Camera Channel for Use with the C.P.S. Emitron—E. L. C. White and M. G. Harker. (*Proc. IEE* (London), Part III, vol. 97, pp. 393–408. Discussion, pp. 408–413. November, 1950.) The characteristics of the pickup tube and mechanical considerations affect the design of equipment suitable for use in a van fitted up as a mobile control room. A general description is given of the camera group and rack group of units and of their electrical features, with additional details of circuits of particular interest, including the signal-amplifier chain, head amplifier, contrast-law control in the main amplifier, camera control unit, line-scan generator, and camera-cable circuits. Methods of testing the over-all performance as regards sensitivity, resolution, hum pickup, geometrical distortions, and radio-frequency interference are described.

621.397.611.2 756
A Review of Some Television Pick-Up Tubes—J. D. McGee. (*Proc. IEE* (London), Part III, vol. 97, pp. 377–392. Discussion, pp. 408–413; November, 1950.) The performance characteristics of the emitron, superemitron and orthicon tubes are compared and an attempt is made to draw up a specification for an ideal pickup tube. The cathode-potential-stabilized emitron is described. The advantages of the methods of focusing and em deflection used are explained and the method of eliminating spurious signals (caused by gas ions) by the use of a mesh trap is outlined. Processes in the manufacture of the tube and the technique of forming the target mosaic by means of a stencil mesh are described. Performance characteristics for sensitivity, image movement and stability are discussed with reference to the specification of the ideal tube.

621.397.62 75[illegible]
Tone Rendition in Television—B. M. Oliver. (PROC. I.R.E., vol. 38, pp. 1288–130[illegible]; November, 1950.) The relations between scene and image brightness and signal strength (brightness characteristics) are studied. Families of curves corresponding to various transmitter and receiver brightness characteristics are given.

621.397.62:77 75[illegible]
Tone Rendition in Photography—W. T. Wintringham. (PROC. I.R.E., vol. 38, pp. 1284–1287; November, 1950.) General discussion. Possible application to television is considered briefly.

621.397.645:621.392.53 75[illegible]
The Orthogam Amplifier—C. L. Townsen[illegible] and E. D. Goodale. (*RCA Rev.*, vol. 11, p[illegible] 399–410; September, 1950.) Gradient correc[illegible]tion for a television film transmission system [illegible] discussed and correction amplifiers giving ad[illegible]justable nonlinear compensation for the ligh[illegible] grey and the white components of the pictur[illegible] signal are described, full circuit details bein[illegible] given for Model "B."

621.397.8+621.396.11 76[illegible]
Long-Range Television—Bennington an[illegible] Morris (See 722.)

621.397.823:621.396.619.16 7[illegible]
Interference Effects in Pulse-Width Modu[illegible]lation—W. E. Ingham. (*Wireless Eng.*, vol. 2[illegible] pp. 241–256; October and November, 195[illegible]) The effects of ignition interference on a widt[illegible] modulated synchronizing-pulse method [illegible] transmitting television sound is described. T[illegible] tests simulated the practical conditions [illegible] closely as possible in so far as the source [illegible] interference and the subjective method [illegible] measurement were concerned. The investig[illegible]tion showed how the noise output for a giv[illegible] interference level is affected by changes in t[illegible] synchronizing-pulse demodulator, and provid[illegible] data for a comparison with AM and FM sy[illegible]tems.

621.397 7[illegible]
Practical Television Servicing and Troubl[illegible] Shooting Manual [Book Review]—Coyne El[illegible]trical and Radio-Television School. Publishe[illegible] Greenberg Publishers, New York, N. Y., 19[illegible] 392 pp., $4.25. (PROC. I.R.E., vol. 38, p. 13[illegible] November, 1950.) Fairly complete and clea[illegible] written. No mathematics is used.

TRANSMISSION

621.396.61/.62:629.13 7[illegible]
A V.H.F. Transceiver for Small Aircraf[illegible]

B. Rudd. (*AWA Tech. Rev.*, vol. 8, pp. 195–)1; December, 1949.) The transceiver provides AM transmission with a 200-mw carrier ı two crystal-controlled frequencies, reception with manual tuning of signals >10μv ithin the range 112–122 mc, means for establishing a common send-receive frequency, and tercommunication within the aircraft. It is ntained in a case about 4 inches×4 inches :4 inches, and weighs 3½ lb. A separate power iit, 4 inches×4 inches×7 inches, weighs ‡ lb.

21.396.61:621.396.619.13 764
High-Power F.M. Broadcasting Transmitters—L. Rohde, H. Nitsche, and A. fefferl. (*Frequenz*, vol. 4, pp. 217–228; September, 1950.) Problems of efficiency and cost re discussed generally; apart from special conderations, the economically optimum transmitter power is about 1 kw. Limitations imosed by 100-mc operation on choices of tubes re explained; tetrodes are useful for outputs p to 2–3 kw, but triodes are more suitable for ride-band applications (television and radioelephony); air cooling is almost universal. nductance rather than capacitance is varied or tuning; tuning-circuit Q must be limited to eep down distortion factor. Power stages use rounded-grid circuits up to about 10 kw and rounded-anode circuits for higher outputs. A rief description is given of a complete 10-kw ransmitter. Antenna feed arrangements are onsidered and a coaxial-line filter device is deribed which enables a common antenna to be sed for two transmitters.

21.396.61:621.396.662 765
Automatic Tuning of Large Transmitters by neans of an Electrically Controlled Tuning Mechanism—A. G. Robeer and W. L. Vervest. (*Commun. News*, vol. 11, pp. 56–64; July, 950.) The mechanism described is capable of uning the final stage, or any other large tuning lement, of a high-power transmitter to one of ix preset frequencies within a few seconds, in esponse to a resetting of the frequency-selector witch. In special cases, e.g., when ice forms n feeders and antenna, the tuning can be orrected continuously.

21.396.61:621.396.97 766
Co-ordinated Design of A.M. Broadcast Transmitters for a Range of Power Output—P. R. Hellyar. (*AWA Tech. Rev.*, vol. 8, pp. 17–229; December, 1949.) Reprint. See 775 f 1950.

21.396.61.029.55:629.13 767
The Application of Impulse-Governed Oscillators (I.G.O.) in Aircraft Transmitters—I. H. Hugenholtz. (*Commun. News*, vol. 11, pp. 3–21; May, 1950.) An account of the SVZ 01 transmitter, which covers the frequency ange 2.8–24 mc with great setting accuracy nd stability, using a single piezoelectric rystal of resonance frequency 100 kc and a ighly stable oscillator tunable from 200 to 00 kc. The circuit is based on one described y Boosman and Hugenholtz (2070 of 1949). Antenna power is about 100 w. The click gear escribed by Vervest (2941 of 1949) is used for electing one of 12 frequencies.

TUBES AND THERMIONICS

35.215.2+535.215.6 768
The Surface Photoelectric Effect—Buckngham. (See 607.)

21.383.42 769
Investigation of the Spectral Sensitivity of Selenium Photo cells—H. G. Sanner. (*Ann. Phys.* (Lpz.), vol. 7, pp. 416–419; July 20, 950.)

621.385:537.291 770
Graphical Representation of Particle Trajectories in a Moving Reference System—M. Garbuny. (*Jour. Appl. Phys.*, vol. 21, pp. 1054–1056; October, 1950.) "A graphical method is derived for the analysis of microwave electron tubes, ion accelerators etc., which refers particle positions and velocities to a moving reference system. If the forces are dependent on time only, the trajectories are transformed into straight lines. For inhomogeneous fields an approximation procedure applies. To demonstrate the capabilities of this method a brief treatment of the transit-time phenomena in cavity triodes is outlined."

621.385.012:621.317.79 771
Apparatus for the Determination of [Valve] Characteristics—Graffunder and Schultes. (See 692.)

621.385.029.64./65:621.392.5 772
Delay Lines of Comb or Interdigital Type and Their Equivalent Circuit—R. Warnecke, O. Doehler, and P. Guenard. (*Compt. Rend. Acad. Sci.* (Paris), vol. 231, pp. 1220–1221; November 27, 1950.) Substitution of such lines for the more commonly used types in traveling-wave tubes reduces the energy stored per unit length and hence increases interaction between beam and wave. The nature of the couplings is examined for both types of line, and curves are presented giving the variation of wave retardation with wavelength for two modified forms of the comb-type line and for the interdigital type. Using the latter, traveling-wave tubes may be designed having a wide pass band and outputs of the order of a kilowatt for continuous operation and of a megawatt for pulsed operation at $\lambda=10$–20 cm. See also 2064 of 1950 (Warnecke et al.).

621.385.032.216 773
A New Thermionic Cathode for Heavy Loads—H. J. Lemmens, M. J. Jansen, and R. Loosjes. (*Philips Tech. Rev.*, vol. 11, pp. 341–350; June, 1950.) The "L" cathode consists of a mixture of barium and strontium oxides contained behind a wall of porous tungsten. When heated, the oxides are reduced and Ba, Sr and BaO escape through the pores of the wall to form on the surface a monatomic layer of Ba and Sr with some oxygen between. This layer reduces the work function to 1.6–2 v. The maximum useful emission amounts to some hundreds of amperes per cm². Other properties claimed for the cathode are great mechanical strength, ability to withstand electron bombardment, and rapid recovery after gas poisoning.

621.385.032.216 774
Thermionic Processes in Thoria Cathodes—G. Mesnard. (*Compt. Rend. Acad. Sci.* (Paris), vol. 231, pp. 833–835; October 23, 1950.) Continuation of study noted in 504 of February. The observed results suggest that for every operating temperature there is a corresponding emission value giving dynamic equilibrium. This emission value is reached the more rapidly the higher the temperature and the thinner the thoria layer. With increase of temperature in the range 1,450–2,800° K, A and ϕ both decrease up to about 2,150°, increase from 2,150° to about 2,600°, and then decrease again slightly, as does also the emission. An interpretation is given involving the availability of free thorium and the layer thickness.

621.385.2/.3]:621.396.622.029.64 775
Crystal Detectors and Their Use at Ultra-High Frequencies—A. Engel; H. Welker; and H. F. Mataré. (*Bull. Soc. franç. Élect.*, vol. 10, pp. 379–396; August, 1950.) After an introduction (Engel), the atomic structure and mechanism of semiconductors are discussed, barrier layer conditions are considered quantitatively and transistor action is analyzed (Welker). The characteristics and operation of crystal diodes and transistors are then dealt with (Mataré). Values of conductivity, conversion loss, sensitivity, and so forth, for different crystal diodes are compared and equivalent circuits, based on observed behavior at different frequencies, are derived. Formulas for amplification, slope of power characteristic, and the like, of a transistor, based on quadripole theory, are given, and conflicting theories on interaction current and surface states are discussed. See also 2976 of 1949; 855 and 1505 of 1950 (Mataré).

621.385.2:621.3.011.2.029.5 776
High Frequency Impedance of Low-Pressure Gaseous Diodes—Chai Yeh and E. L. Chaffee. (*Jour. Appl. Phys.*, vol. 21, pp. 981–986; October, 1950.) A simple theory of the lagging effect of the positive ions in neutralizing the space charge near the cathode of a gaseous diode is developed. The theory is confirmed by measurements of the high-frequency impedance of diodes. Constants such as the transit time and the lifetime of a positive ion can be deduced from the theoretical and experimental results.

621.385.2.011 777
Theory of the Parallel Plane Diode—A. H. Taub and N. Wax. (*Jour. Appl. Phys.*, vol. 21, pp. 974–980; October, 1950.) General solutions of the fundamental equations for transient and steady-state conditions are applied to analysis of the space-charge-limited diode. Power consumption is discussed; the notion of complex impedance is insufficient alone to account for all the power consumed by the diode.

621.385.3:621.315.592†:546.289 778
The Transistor—Bibliographical Survey—G. Gaule. (*Fernmeldtech. Z.*, vol. 3, pp. 390–400; October, 1950.) Review of transistor theory and applications, in the form of abstracts and summaries of over 40 published papers, to which references are given.

621.385.3:621.315.592†:621.396.822 779
Background Noise in Transistors—H. C. Montgomery. (*Bell Lab. Rec.*, vol. 28, pp. 400–403; September, 1950.) A brief nonmathematical account. Illustrations show the variation of transistor noise power per cycle with frequency, an oscillogram of transistor noise over the band 30–1,500 cps compared with one of thermal noise, and variation of noise output with collector bias for a fixed emitter bias. A definition of "noise figure" is given. Causes of transistor noise are still under investigation.

621.385.3.029.64 780
Low-Level Triode Amplifier for Microwaves—G. Diemer and K. S. Knol. (*Philips Res. Rep.*, vol. 5, pp. 153–154; April, 1950.) Advantages and performance obtainable using an "L-type" cathode (see 773 above) are summarized. Over-all noise level in a receiver circuit was found to be 7 db at 3 kmc.

621.385.38 781
Pulse Measuring of Deionization Time—H. H. Wittenberg. (*Elec. Eng.*, vol. 69, pp. 823–827; September, 1950.) Description of a flexible method, using repeated probing pulses, for measuring deionization time of thyratrons.

621.385.38 782
Hot-Cathode Thyratrons: Practical Studies of Characteristics—H. de B. Knight. (*Proc.*

IEE (London), Part III, vol. 97, pp. 455–458; November, 1950.) Discussion on 504 of 1950.

621.385.5:621.318.572 783

Construction of Cold-Cathode Counting or Stepping Tubes—M. A. Townsend. (*Elec. Eng.*, vol. 69, pp. 810–813; September, 1950.) AIEE Winter General Meeting paper, 1950. An electronic digital counter capable of operating at high speed is described in which the position of a glow discharge is made to step along a row of cathodes, under the control of input pulses. A large number of elements may be accommodated in one envelope and with a small driving power sufficient output is obtained to operate electromechanical devices.

621.385.5:621.318.572 784

Multicathode Gas-Tube Counters—G. H. Hough and D. S. Ridler. (*Elec. Commun.* (London), vol. 27, pp. 214–226; September, 1950.) A new principle of priming is described which makes possible the transfer, from one cathode to another in a multicathode gas-filled tube, of the discharge to a common anode. Various types of counter tube resulting from different electrode combinations are discussed. A more detailed account is given of a practical decade unidirectional counter which is triggered by a pulse of width 16 μs and amplitude 120 v; the maximum operating frequency at present is about 25 kc. Other operational details are given, together with typical circuits, including a 27-point distributor using three of the tubes in series. See also 266 (Lamb and Brustman) and 2066 (Bacon and Pollard) of 1950.

621.385.83:537.291 785

Some Crossover Properties in the Electron Immersion Objective—L. Jacob. (*Jour. Appl. Phys.*, vol. 21, pp. 966–970; October, 1950.) Analysis of electron motion in electrostatic fields. Correct solution of the trajectory equation shows that the simple theory [183 of 1949 (Einstein and Jacob)] gives an adequate approximation for cathode-ray-tube design purposes.

621.85.832 786

Charge-Storage Picture Tubes with Storage Grids—M. Knoll and J. Randmer. (*Arch. elekt. Übertragung*, vol. 4, pp. 238–246; July, 1950.) Various ways of operating charge-storage picture tubes are discussed; the potential levels corresponding to the different steps of the "writing" and "reading" processes are illustrated graphically and tabulated. The use as storage electrode of a separate grid, exercising point-to-point control over the "reading" beam, has the advantage over the capacitive signal-plate assembly that the signal can be read without removal of charge; hence more repetitions of the same signal can be obtained without loss of detail. An experimental demountable tube is described.

621.385.832 787

Storage of Small Signals on a Dielectric Surface—J. V. Harrington. (*Jour. Appl. Phys.*, vol. 21, pp. 1048–1053; October, 1950.) "A mathematical analysis is presented which is believed to be applicable to a general class of storage tubes where signal storage is accomplished by depositing through secondary emission a charge pattern on a dielectric surface. The assumptions made to linearize and simplify the problem are outlined and plots are given of the predicted output signals for writing, reading, and cancellation operations when the input signal is a step function. Experimental evidence is presented to substantiate the analytical results."

621.385.832:621.3.087 788

The Recording Storage Tube—R. C. Hergenrother and B. C. Gardner. (Proc. I.R.E., vol. 38, p. 1287; November, 1950.) Correction to paper abstracted in 2942 of 1950.

621.396.615.141.2 789

Some Observations on the Back Heating of Magnetron Cathodes—R. T. Young, Jr., L. W. Holmboe, and W. E. Waters, Jr. (*Jour. Appl. Phys.*, vol. 21, pp. 1066–1067; October, 1950.) Discussion of effects observed in various types of magnetron. It appears that a state of oscillation is involved which is primarily a function of the space-charge conditions in the interaction space. No satisfactory explanation is available at present.

621.396.615.142 790

Pendular Secondary-Electron Multiplication in High-Frequency Fields—K. Krebs. (*Z. angew Phys.*, vol. 2, pp. 400–411; October, 1950.) The operation of velocity-modulation tubes is discussed generally, and a method of calculating the high-frequency power from the field dimensions is developed. From discrepancies between theoretical and measured results it is established that within certain voltage-amplitude ranges a pendular secondary-electron multiplication system is set up, of the type first described by Farnsworth; the energy abstracted from the high-frequency system by the rapidly increasing secondary-electron current is the cause of the power loss. The pendular multiplication process is studied, taking into account electron emission velocities corresponding to 5–10 ev; calculated values of critical voltage-amplitude range agree well with observed values. Methods of eliminating the effect by choice of materials and dimensions are indicated.

621.396.615.142.2:621.317.3.001.4 791

Test Methods and Apparatus for the Development of 3-cm Low-Voltage Klystrons—Musson-Genon, Chantereau, and Métivier (See 683.)

621.383 79

Photoelectric Cells in Industry [Bool Review]—R. C. Walker. Publishers: Pitmai Publishing Corp., New York, N. Y., 510 pp. 1948, $8.50. (*Electronics*, vol. 23, pp. 134, 138 October, 1950.) "The object of this Britis book is . . . to present a representative selec tion of the industrial uses of light-sensitiv cells of the emission and rectifier types . . . ade quate information is supplied for design an construction of even the most elaborate in stallations."

MISCELLANEOUS

5+6]:621.317.2 79

The Bell Telephone Laboratories—A Example of an Institute of Creative Tech nology—M. J. Kelly. (*Proc. Roy. Soc. A* vol. 203, pp. 287–301; October 10, 1950 Text of a lecture describing the structure an scope of the organization.

621.396 79

The Radio Manual [Book Review]—G. I Sterling and R. B. Monroe. Publishers: I Van Nostrand Co., New York, N. Y., 4t ed., 890 pp., 1950, $12.00. (*Electronics*, vo 23, pp. 142, 146; October, 1950.) " . . . a com prehensive study of the entire field of rad communication . . . a completely rewritten an reworked version . . . a ready reference for th engineer and/or operator who needs a quic answer to routine or special questions ar problems."

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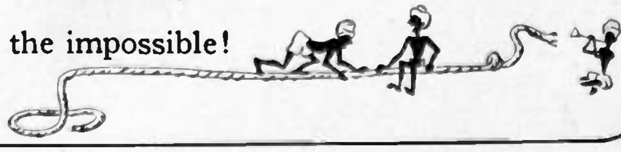

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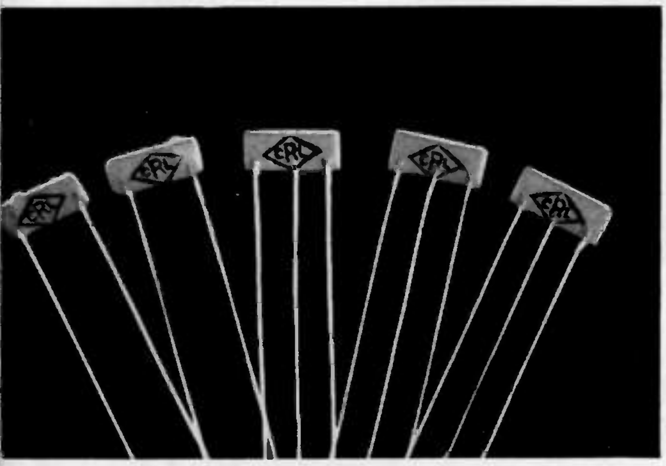

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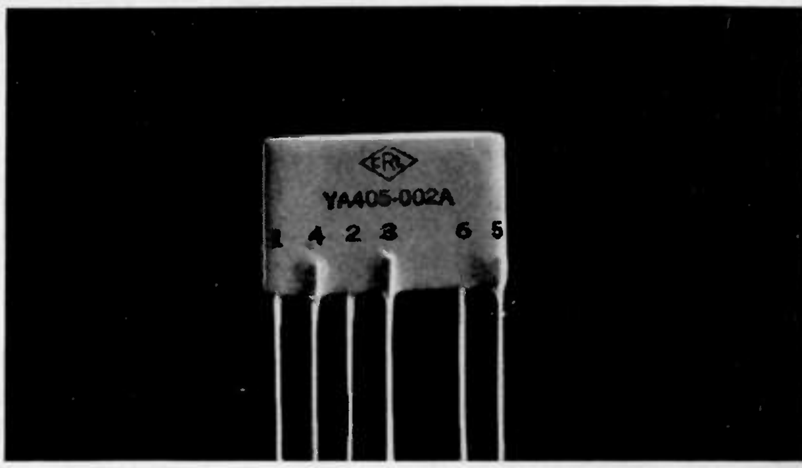

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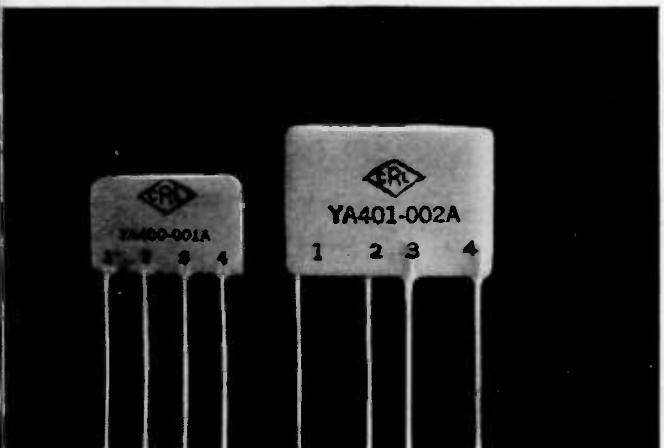

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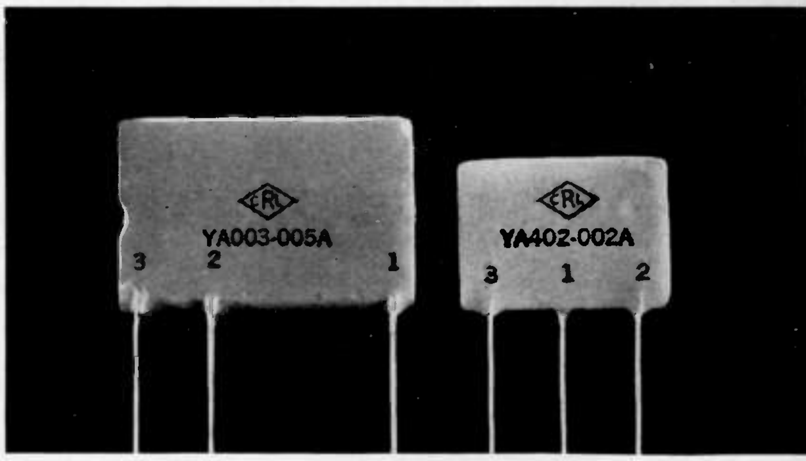

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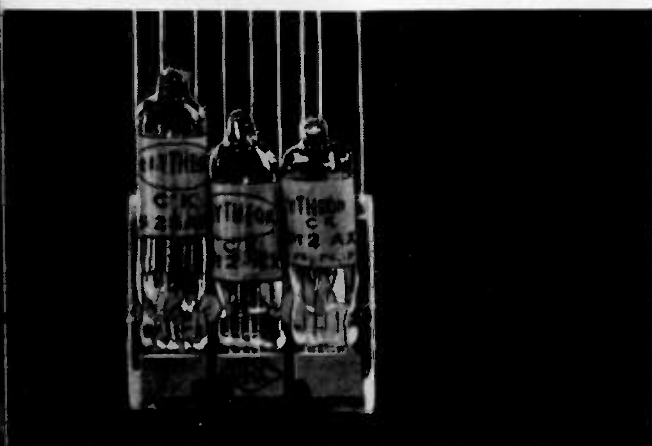

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SECTION MEETINGS

ATLANTA

"Neutrons, Protons and Atomic Fusion," by Dr. J. E. Boyd, Physicist, Department of Physics and The State Engineering Experiment Station; January 19, 1951.

BALTIMORE

"More Waves, More Words, Less Wires," by J. O. Perrine, American Telegraph and Telephone Company; January 18, 1951.

"Traveling-Wave Tubes," by H. D. Arnett, Naval Research Laboratories; February 14, 1951.

BEAUMONT—PORT ARTHUR

Productive Power Show presented by the Engineers of the Westinghouse Electric Corporation; January 19, 1951.

BOSTON

"Transcontinental Radio Relay—1951," by G. W. Gilman, Bell Telephone Laboratories; January 18, 1951.

"Molecular Beams as Frequency Standards," by Luther Davis, Raytheon Manufacturing Company; February 15, 1951.

BUFFALO-NIAGARA

"Television Facilities of the Bell System," by G. L. Johnson, New York Telephone Company; January 17, 1951.

CEDAR RAPIDS

"Religion and Science," by W. Argow, Pastor, Peoples Church, Cedar Rapids, Iowa; January 10, 1951.

"Coaxial and Microwave Television Relay Systems," by J. W. McRae, Bell Telephone Laboratories; January 17, 1951.

CLEVELAND

"Relationship Between Our Progress in Science and Technology and Our Democracy," by F. I Schramm; January 11, 1951.

COLUMBUS

"The Behavior of a Human Being as a Servomechanism," by Major R. C. Gibson, Wright Field, Dayton, Ohio; January 26, 1951.

"Nondestructive Testing," by R. C. McMasters, Battelle Memorial Institute; February 1951.

CONNECTICUT VALLEY

"Nuclear Physics—Background for the Operating Engineer," by Professor E. C. Pollard, Yale University; January 9, 1951.

DALLAS-FORT WORTH

Election of Officers; January 26, 1951.

DES MOINES-AMES

"Research Development and Engineering Involved in Radio-Relay Systems," by Dr. J. W. McRae, Bell Telephone Laboratories; January 1951.

DETROIT

"Electronic Carillons," by O. L. Angevin, Stromberg-Carlson Company; February 16, 1951.

EVANSVILLE-OWENSBORO

"Electronic Music," by Dr. Martin, Baldwin Company; January 10, 1951.

"Color Television," by R. B. Dome, General Electric Company; February 7, 1951.

INDIANAPOLIS

"Consideration in the Design of Television Preamplifiers," by R. C. Koch, Industrial Development Engineering Associates; November 17, 19

(*Continued on page 38A*)

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ERIE CERAMICONS®

Erie Ceramicons fulfil all the requisites for efficient by-passing—low inductance, compact design, and conservative 500 volt D. C. rating. Erie Resistor offers the most complete line of ceramic by-pass units available. Each design has been thoroughly proven in domestic and military equipment.

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For use where space is at a premium and radial leads are desired. Capacity range 10 to 15,000 MMF. Smallest size .240" x .460" max. with dipped insulation; .200" x .400" max. non-insulated.

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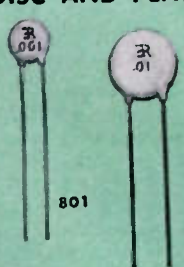

801

811

Compact, high capacitance units with extremely low inductance. Available in single and multiple capacitors up to .01 mfd per section.

INSULATED STAND-OFF *Ceramicons*

Rugged, molded insulated construction. Mounts with 6-32 nut. Style 323 mounts 19/32" high above chassis. Capacity range 0.5 to 700 MMF. Style 324 mounts 27/32" high. Capacity range 710 to 1,500 MMF. Available with 20 gauge wire lead or post type top terminal.

NON-INSULATED STAND-OFF *Ceramicons*

Style 318 (left) mounts ½" high above chassis, has .032" diameter wire top terminal. Capacity range 1 to 560 MMF. Style 319 (right) mounts .520" high has .067" diameter top terminal. Capacity range 2 to 1,000 MMF. Both styles have 3-48 thread.

SIDE-LEAD STAND-OFF *Ceramicons*

Wire leads are correct height from chassis for shortest possible connection to tube sockets. Style 2322 (left) 45/64" high. Capacity range 5 to 2,500 MMF. Style 2336 (right) 15/16" high. Capacity range 6 to 5,000 MMF.

FEED-THRU *Ceramicons*

By-pass R. F. to ground when feeding through chassis or metal can. Styles 357 (with rigid hooked wire lead) and 362 (with # 20 straight pig-tail wire lead) mount with 12-28 nut, Styles 2404 (with rigid wire lead) and 2405 (no lead) have eyelet for soldering to chassis. Max. capacitance 1,000 MMF for Style 357; 1,500 MMF for Styles 362, 2404, and 2405.

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Style 325 has most efficient design for UHF. Compact and rugged. Easily installed with standard push-on clip or soldered to chassis. Available 10 to 1,500 MMF.

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These extremely compact silver mica condensers have 360° current path from short, heavy terminals to ground, providing very low inductance. Made in Stand-off and Feed-thru styles.

Capacity range 15 to 1,000 MMF in .447" diameter, 1,000 to 6,000 MMF in .651" diameter.

Electronics Division

ERIE RESISTOR CORP., ERIE, PA.

LONDON, ENGLAND . . . TORONTO, CANADA

SECTION MEETINGS

(*Continued from page 36A*)

"Survey of Latest Color Television Developments," by A. G. Jensen, Bell Telephone Laboratories; December 18, 1950.

"Brains for Guided Missiles," by G. J. Fiedler, Sverdrup and Parcel; January 23, 1951.

Kansas City

"Television—Why The Deep Freeze?" by S. L. Bailey, Jansky & Bailey; December 13, 1949.

"Bandwidth Reduction in Communication Systems," by W. G. Tuller, Melpar, Incorporated; March 14, 1950.

"Instrumentation Engineering," by R. J. Jefferies, Michigan State College; November 21, 1950.

"Brains for Guided Missiles," by G. J. Fiedler, Sverdrup and Parcel; December 13, 1950.

"Magnetic Amplifier Circuits and Applications," by W. J. Dornhoefer, Vickers Electric Division; January 16, 1951.

"Quality Control in the Electronic Field," by C. Gartner, Allen B. DuMont Laboratories, Inc.; February 13, 1951.

London

"The New CBC Master Control Equipment, Montreal, Quebec," by Robert Tanner, Northern Electric Company; January 22, 1951.

Los Angeles

"Determination of Optimum Communication Frequency by Back Scatter Observation," by J. L. Heritage, Naval Electronics Laboratory; January 16, 1951.

"Stellar Oscillators," by Horace Babcock, Mount Wilson Observatories; February 6, 1951.

Louisville

"Characteristics of Simple Antennas Over The Earth," by N. B. Fowler, American Telephone and Telegraph Company; February 13, 1951.

Miami

"Discussion of the Scope of the IRE," by Ben Ackerman, IRE Regional Director; November 17, 1950.

"Electronic Mathematics," by C. N. Hoyler, RCA Laboratories; December 8, 1950.

Montreal

"Some Aspects of Circuit Analysis," by H. G. I. Watson, McGill University; January 24, 1951.

New York

"Microwave Spectroscopy," by C. H. Townes, Columbia University; January 3, 1951.

Omaha-Lincoln

Annual Meeting; January 15, 1951.

Ottawa

"Working Concepts in Colorvision Shots," by O. Kendall, National Film Board; January 16, 1951.

"Resistor Noise Measurements," by K. A. Chepman, McGill University; February 8, 1951.

Philadelphia

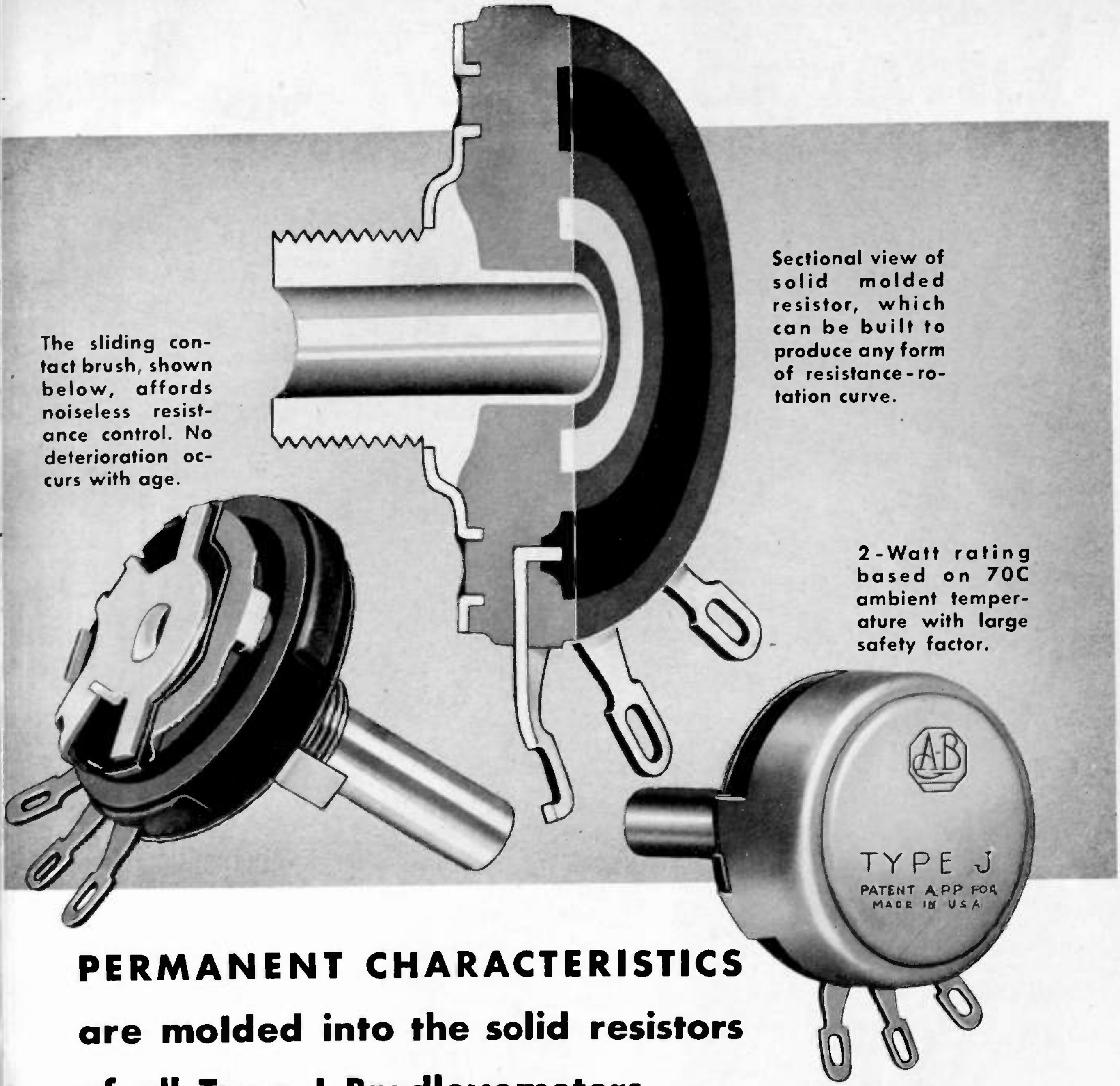
"The Future of Color in Television," by D. G. Fink, *Electronics* Magazine; February 7, 1951.

Portland

Business Meeting; December 7, 1951.

"Bass Response of Direct Radiator Loudspeakers," by W. R. Hill, University of Washington; January 18, 1951.

(*Continued on page 40A*)



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SECTION MEETINGS

(Continued from page 38A)

Sacramento

"Analysis of a Modern Wired Music System," by F. C. McPeak, McClatchy Broadcasting Company; January 23, 1951.

Salt Lake

"The 'Why and How' of Servomechanisms and Automatic Regulators," by L. D. Harris, University of Utah; February 5, 1951.

San Antonio

Annual Meeting for Election of Officers; January 15, 1951.

San Diego

"Dielectric and Magnetic Studies at Microwave Frequencies," by W. D. Hershberger, Professor of Engineering, University of California at Los Angeles; January 9, 1951.

"An Analysis of Color Television," by D. E. Foster, Hazeltine Research of California; February 6, 1951.

Syracuse

"Tracer Technology in Medicine and Industry," by W. Dunlap, General Electric Company Laboratories; January 8, 1951.

Toronto

"Super High-Frequency Broad-Band Relay System," by J. W. McRae, Bell Telephone Laboratories; January 15, 1951.

"Recent Circuitry Developments at Canadian Signals Research and Development Establishment," by Major J. A. Loutit and Captain R. M. Bennett, Canadian Signals Research and Development Establishment; January 29, 1951.

Twin Cities

"Musical Electronics," by A. F. Knoblaugh, The Baldwin Company; January 11, 1951.

Washington

"An Analysis of Color Television Processes," by A. V. Loughren, Hazeltine Corporation; February 12, 1951.

SUBSECTIONS

Hamilton

Tour of Canadian Westinghouse Corporation Laboratories; January 15, 1951.

"Some Ideas in Communication," by G. Sinclair, University of Toronto; February 8, 1951.

Lancaster

"Color Television," by A. G. Jensen, Bell Telephone Laboratories; January 10, 1951.

Long Island

"Applications of a New Cathode Structure," by G. A. Espersen, Philips Laboratories, Incorporated; January 16, 1951.

Mid-Hudson

"Electricity in Metals and Semi-Conductors," by K. K. Darrow, Bell Telephone Laboratories; January 9, 1951.

Monmouth

"Some Recent Advances in Color Television," by C. J. Hirsch, Hazeltine Electronics; January 17 1951.

Northern New Jersey

"A Practical Explanation and Demonstration of Saturable Reactor Characteristics," by F. H Shepard, Jr., Shepard Laboratories; January 10 1951.

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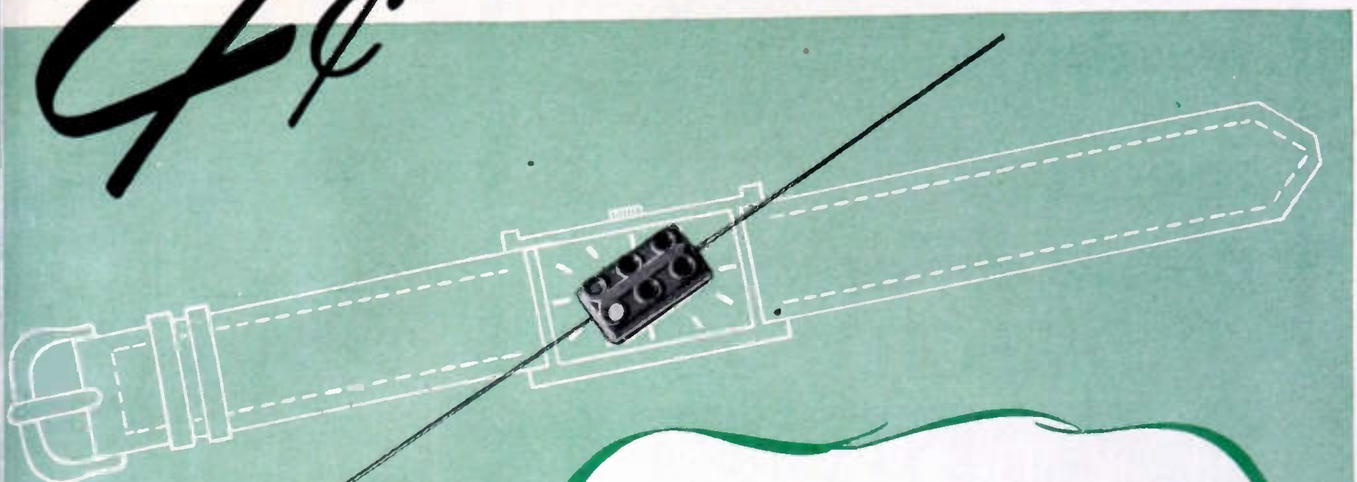

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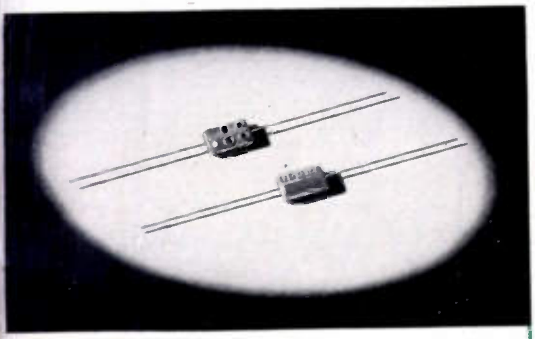

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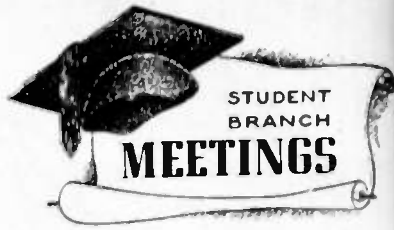

UNIVERSITY OF ARKANSAS, IRE BRANCH

Election of Officers; February 7, 1951.
"Electronic Computers," by Bernard Gundlach, University of Arkansas; February 21, 1951.

POLYTECHNIC INSTITUTE OF BROOKLYN, IRE BRANCH (EVENING)

Films: "Action Pictures of Sound" and "Mobile Telephones"; January 11, 1951.

CALIFORNIA STATE POLYTECHNIC COLLEGE, IRE BRANCH

"Problems in Vacuum-Tube Design and Application," by Bernard Walley, RCA Application Engineer; January 24, 1951.

CARNEGIE INSTITUTE OF TECHNOLOGY, IRE-AIEE BRANCH

"Problems in Everyday Electrical Engineering," by F. N. McClure, Westinghouse Electric Corporation; January 16, 1951.

CLARKSON COLLEGE OF TECHNOLOGY, IRE BRANCH

Business Meeting; February 15, 1951.

UNIVERSITY OF COLORADO, IRE-AIEE BRANCH

"The Local Workshop, and Facilities," by E. L. Amonette and J. A. Garvin, Students, University of Colorado; January 24, 1951.
Annual Student Competition; February 14, 1951.

COLUMBIA UNIVERSITY, IRE-AIEE BRANCH

"Orientation of the Young Engineer in Industry," by Professors J. A. Balmford, W. La Pierre and J. B. Russell, Columbia School of Engineering; January 5, 1951.

UNIVERSITY OF DENVER, IRE-AIEE BRANCH

Business Meeting; January 18, 1951.
Business Meeting and Film, "Stepping Along With Television"; February 1, 1951.
Business Meeting; February 16, 1951.

DREXEL INSTITUTE OF TECHNOLOGY, IRE-AIEE BRANCH

"A Novel Electrical Instrument—The Franklin Institute's 10-Channel Airborne Spectrograph," by C. W. Hargens, Franklin Institute; January 18, 1951.

UNIVERSITY OF FLORIDA, IRE-AIEE BRANCH

Business Meeting and Film, "Plan for Disaster"; February 20, 1951.

GEORGIA INSTITUTE OF TECHNOLOGY, IRE BRANCH

Business Meeting; January 23, 1951.
"Basic Television," by C. F. Daugherty, Chief Engineer Radio Station WSB; January 24, 1951.
"Electronic Instrumentation in Nuclear Applications," by W. T. Clary, Professor, Georgia Institute of Technology; February 6, 1951.

STATE UNIVERSITY OF IOWA, IRE BRANCH

Election of Officers; January 24, 1951.

KANSAS STATE COLLEGE, IRE BRANCH

Business Meeting; October 5, 1950.
"The New Student Constitution at Kansas State College," by G. Hanson, Student, Kansas State College; December 7, 1950.

UNIVERSITY OF KENTUCKY, IRE BRANCH

"Four-Tower Antenna Array of Radio Station WLAP," by H. C. Locklar, Radio Station WLAP; December 14, 1950.

(*Continued on page 44A*)

STUDENT BRANCH

MEETINGS

(Continued from page 42A)

"Brother Man," by Dr. C. E. Snow, University of Kentucky; January 11, 1951.
"Headline Humor," by Dr. N. Plummer, University of Kentucky; February 14, 1951.

LAFAYETTE COLLEGE, IRE-AIEE BRANCH

"Mechanics of Short Span Cables," by Henry Lee, and "The TVA," by Chris Sherrerd, Students, Lafayette College; February 13, 1951.

LOUISIANA STATE UNIVERSITY, IRE-AIEE BRANCH

Business Meeting; February 13, 1951.

MARQUETTE UNIVERSITY, IRE-AIEE BRANCH

Election of Officers; January 18, 1951.
"Television," by A. F. Petrie, Student, Marquette University; February 1, 1951.

MICHIGAN COLLEGE OF MINING AND TECHNOLOGY, IRE-AIEE BRANCH

"Capacitors," by W. A. Buck, Michigan College of Mining and Technology; January 9, 1951.
"Interviews," by Professor P. Holub, Michigan College of Mining and Technology; January 23, 1951.

UNIVERSITY OF MINNESOTA, IRE-AIEE BRANCH

Trip to Television Studios of Station WTCN; January 23, 1951.
"The Engineer's Civic Responsibility," by J. D. Cunningham, Republic Flowmeter Company; February 7, 1951.

UNIVERSITY OF MISSOURI, IRE-AIEE BRANCH

Business Meeting; December 19, 1950.
Business Meeting; January 9, 1951.

NEW YORK UNIVERSITY, IRE BRANCH (DAY DIVISION)

Business Meeting and Films: "High-Powered Laboratory Research" and "Voice Sentinels"; February 8, 1951.

NORTHEASTERN UNIVERSITY, IRE-AIEE BRANCH

Films: "AC Welding" and "Motor Lubrication"; January 18, 1951.
"Electronics and the Human Brain," by Dr. W. A. Rosenblith, Harvard University; January 20, 1951.

NORTHWESTERN UNIVERSITY, IRE-AIEE BRANCH

Business Meeting; January 10, 1951.
Business Meeting and Film, "Inductive and Capacitive Heating Applications in Industry"; January 23, 1951.
Business Meeting and Film, "Electrical Proving Ground"; February 6, 1951.
"Color Television," by Professor A. B. Bronwell, Northwestern University; February 13, 1951.

UNIVERSITY OF NOTRE DAME, IRE-AIEE BRANCH

"Development of Cathode-Ray Tube and Television," by Mr. Fogg, Sylvania Electric Company; December 13, 1950.

OHIO STATE UNIVERSITY, IRE-AIEE BRANCH

"Rube Goldberg Inventions of the Past, Present, and Future, or Servomechanisms," by F. W. Weimer, Professor, Ohio State University; January 25, 1951.

OREGON STATE COLLEGE, IRE BRANCH

Film: "Birds and Animals of Mount McKinley National Park in Alaska"; January 18, 1951.

(Continued on page 46A)

STUDENT BRANCH
MEETINGS

(*Continued from page 44A*)

"Custom Production of Communication Equipment," by Ray Morrow, Morrow Radio Company; February 1, 1951.

"Atomic Radiation Precautions in Engineering," by J. H. Black, Hanford Atomic Energy Plant; February 15, 1951.

PENNSYLVANIA STATE COLLEGE, IRE-AIEE BRANCH

Final Student Prize Paper Competition; January 9, 1951.

"Distribution and Transmission Problems," by H. McVaugh, Pennsylvania Electric Company; January 11, 1951.

PRINCETON UNIVERSITY, IRE-AIEE BRANCH

"Ultra-Violet Rays—A Most Useful Tool," by W. H. Garrett, Westinghouse Lamp Division; February 1, 1951.

RENSSELAER POLYTECHNIC INSTITUTE, IRE-AIEE BRANCH

"High-Frequency Transmitting Tubes, Yesterday and Today," by T. A. Elder, General Electric Company; February 13, 1951.

SAN JOSE STATE COLLEGE, IRE BRANCH

"Aspects of Defense in the Event of Atomic Attack," by Dr. A. Guthrie, U. S. Naval Radiological Defense Laboratory; January 22, 1951.

Business Meeting; February 2, 1951.

SOUTHERN METHODIST UNIVERSITY, IRE-AIEE BRANCH

"Electronics in the Aviation Industry," by Robert Sawyer, Braniff Airways; January 25, 1951.

"Silicones for the Electrical and Electronic Industries," by T. B. Goldman, Dow Corning; February 8, 1951.

STANFORD UNIVERSITY, IRE-AIEE BRANCH

"High-Voltage Testing With 60-Cycle and Impulse Voltage," by J. S. Carroll and W. G. Hoover, Professors, Stanford University; January 17, 1951.

SYRACUSE UNIVERSITY, IRE-AIEE BRANCH

"Professional Engineering and the Society of Professional Engineers," by D. Stearns, B. Dawson and K. Larson, Society of Professional Engineers; February 13, 1951.

VIRGINIA POLYTECHNIC INSTITUTE, IRE BRANCH

Films: "On the Air" and "Banshee"; January 23, 1951.

UNIVERSITY OF VIRGINIA, IRE BRANCH

"More Waves, More Words, Less Wires," by J. O. Perrine, American Telegraph and Telephone Company; January 22, 1951.

UNIVERSITY OF WISCONSIN, IRE BRANCH

Business Meeting; October 5, 1950.

Demonstration of latest electronic instruments manufactured by Hewlett-Packard, DuMont, and Technology Instrument Corporation; November 9, 1950.

"Capitalizing on Creative Engineering," by A. W. Graf, Patent Attorney, Chicago, December 7, 1950.

WORCESTER POLYTECHNIC INSTITUTE, IRE-AIEE BRANCH

Annual Student-Faculty Forum; February 20, 1951.

UNIVERSITY OF WYOMING, IRE-AIEE BRANCH

"Tape Recorders," by Robert Libbey; January 16, 1951.

"Electric Alarm Devices," by Jim Green; February 13, 1951.

AIRCRAFT RADIO CORPORATION

Type H-14 Signal Generator

108-132 mc

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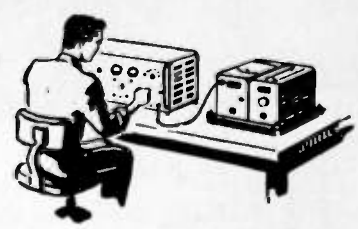

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The H-14 Signal Generator provides simulated omni, phase localizer, and tone localizer signals for testing of VHF navigational equipment in one aircraft, or in a squadron of aircraft simultaneously. The instrument will check:

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

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H. M., Franklin and Marshall College, Lancaster, Pa.
mith, J., 824 Brunswick Rd., Essex 21, Md.
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hart, R. W., 6015 S. Massasoit Ave., Chicago 38, Ill.
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ein, K., 29 Bobrich Dr., Rochester 10, N. Y.
s, C. L., 1007 E. Citrus Way, Phoenix, Ariz.
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dell, W. A., 339 Kentucky Ave., Lorain, Ohio
dad, S. G., 14 Bobolink St., W. Roxbury 32, Mass.
m, W. J., St. Mary's University, San Antooio 1, Tex.
er, C. A., 17221 Mapleboro Rd., Maple Heights, Ohio
b, J. W., 2004 Princeton Dr., Dayton 6, Ohio
n, S. H., 210 Chamberlain St., Raleigh, N. C.
, H. J., 100 Franklin St., Bldg. 1, Apt. A-3, Morristown, N. J.
rling, H. W., 365 LaVilla Dr., Miami Springs, Fla.
er, E. S., 314 Ferndale Ave., Highland Park, Ill.
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(Continued on page 64A)

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(Continued on page 52A)

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POSITIONS OPEN

(Continued from page 50A)

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Electrical engineers and physicists in university connected research institute outside continental United States. Minimum B.S. degree. Security clearance necessary. Send Airmail resume of training and professional experience, photograph, references, salary desired to Box 938.

TECHNICAL WRITERS

Electronics section of leading technical publisher offers permanent positions to experienced writers with engineering background; must be familiar with Government instruction book specs. Send resume and salary desired, P.O. Box 311, Yonkers, New York.

ENGINEERS AND PHYSICISTS

Several outstanding opportunities open for engineers and physicists with B.S. or advanced degrees and up to 10 years' experience in fields of electronics and physical measurements. Permanent positions in research and instrument development with independent laboratory. Send resume including type of work desired to: Physics Department, Southwest Research Institute, San Antonio 6, Texas.

(Continued on page 54A)

SCIENTISTS AND ENGINEERS

for

challenging research and advanced development in fields of

RADAR
GYROSCOPES
SERVOMECHANISMS
MECHANICAL SYSTEMS
ELECTRONICS CIRCUITS
APPLIED PHYSICS AND MATH
PRECISION MECHANICAL DEVICES
ELECTRICAL SYSTEM DESIGN
GENERAL ELECTRONICS
INSTRUMENTATION
MICROWAVES
COMPUTERS
AUTOPILOTS

Scientific or engineering degree and extensive technical experience required.

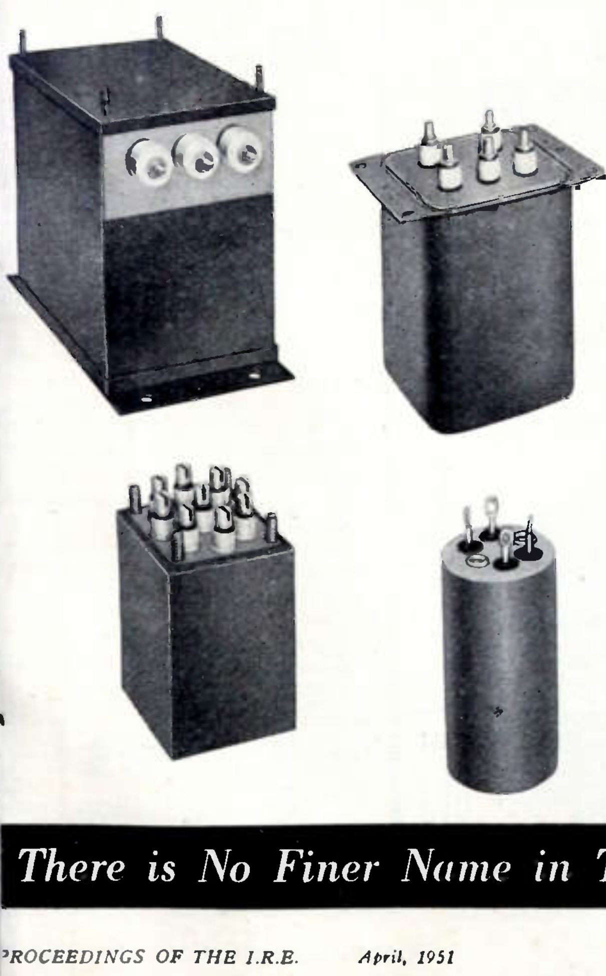
WRITE:
Manager, ENGINEERING PERSONNEL

BELL AIRCRAFT CORPORATION
P.O. Box 1, Buffalo 5, N.Y.

Precision Built

for the Finest Equipment

FERRANTI Transformers



Our long experience in building all types of transformers, including hermetically sealed units, qualifies us as a dependable supply source for transformers used in military applications. We offer sound engineering and faultless craftsmanship . . . custom design with the economy and speed of modern mass production methods.

Hermetically Sealed Types for MIL-T-27 applications . . . Special Cores . . . High Temperature Insulation . . . as well as all normal types for every purpose.

FERRANTI ELECTRIC, INC.
30 Rockefeller Plaza, New York 20, New York

There is No Finer Name in Transformers than **FERRANTI**

POSITIONS OPEN

(Continued from page 52A)

ENGINEER OR PHYSICIST

For development and production. Experience: semi-conductor devices employing germanium and silicon. Very good opportunity with growing organization. Jensen Industries, Inc., 329 South Wood Street, Chicago 12, Illinois.

ELECTRONICS ENGINEER

Young electronics engineer (M.S. or Ph.D.) having initiative and imagination and an outstanding academic record wanted by a small but well-known and growing manufacturer of precision electronic measuring apparatus located in northern New Jersey about 30 miles from New York City for research and development work. Should have thorough knowledge of network theory and familiarity with electronic circuitry and VHF measurement techniques together with several years of laboratory experience. Ideal working conditions and adequate housing facilities. Salary $5,000 plus bonus. Box 648.

ENGINEERS

DESIGNER of radio receiving equipment for automobiles. Salary: $8,000 to $10,000. Age: under 40. B.S. in E.E.

ENGINEER to design and develop small antennae for radar equipment. Salary $8,000 to $10,000. B.S. in E.E.

(Continued on page 55A)

POSITIONS OPEN

(Continued from page 54A)

'ANUFACTURING EXECUTIVE

:o plant manufacturing cathode ray and :eiving tubes. E.E. degree, with experi-:: at Superintendent level. Salary: about ;1000. Age: under 45.

ROJECT ENGINEERS with E.E. :rees and experience in electronics man-:turing. Salary: $10,000 to $12,000. A:: under 40. Reply Box 649.

CHIEF ENGINEER

hief engineer for manufacturer of :nd recording equipment and electro-:hanical devices. Experience in electro-:gnetic and audio-circuit design. Com-p:e responsibility for engineering, from :ign and through production. Salary: $,000. Reply Box 650.

TEST FACILITIES ENGINEER

'est Facilities Engineer experienced in :ign of test equipment for ultra-pre-:on mechanical or electrical assemblies. :ary: $8,000 to $12,000. Reply Box 651.

LECTRONIC ENGINEERS—PHYSICISTS

:lectronic engineers and physicists; at :st one year experience in circuit work; :lo design and development of electronic :c equipment and geophysical instru-:nts. Southwestern Industrial Electron-: Co., P.O. Box 13058, Houston, Texas.

(Continued on page 56A)

PHYSICISTS AND SENIOR RESEARCH ENGINEERS

POSITIONS NOW OPEN

:nior Engineers and Physicists having out-:anding academic background and experience : the fields of:

- Microwave Techniques
- Moving Target Indication
- Servomechanisms
- Applied Physics
- Gyroscopic Equipment
- Optical Equipment
- Computers
- Pulse Techniques
- Radar
- Fire Control
- Circuit Analysis
- Autopilot Design
- Applied Mathematics
- Electronic Subminiaturization
- Instrument Design
- Automatic Production Equipment
- Test Equipment
- Electronic Design
- Flight Test Instrumentation

:e offered excellent working conditions and :pportunities for advancement in our Aero-:hysics Laboratory. Salaries are commensurate :ith ability, experience and background. Send :nformation as to age, education, experience :nd work preference to:

NORTH AMERICAN AVIATION, INC.
Aerophysics Laboratory
Box No. N-4, 12214 South Lakewood Blvd.
Downey, California

PROJECT ENGINEERS!
JUNIOR ENGINEERS!
COME WITH
MOTOROLA!

Now is your opportunity to work with an organization of top electronic engineers. You can engage in the *long-term development program* that continues through war or peace—constantly improving radio communications for Civil Defense, Public Safety, Transportation, and Industry.

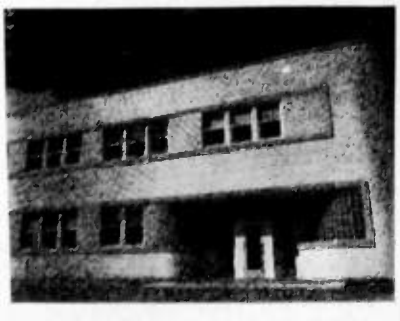
AT MOTOROLA, YOU'LL SHARE IN MANY BENEFITS!

Motorola, often used as the "model" for industry, offers you ideal working conditions, the most liberal profit-sharing plan in existence, free insurance, free training courses, plus entertainment and recreational programs.

You may apply at once by letter to Mr. John F. Byrne, Associate Director of Research, and be sure of prompt, courteous consideration. Please state your qualifications, references, and salary requirements in your first letter.

MOTOROLA INC.

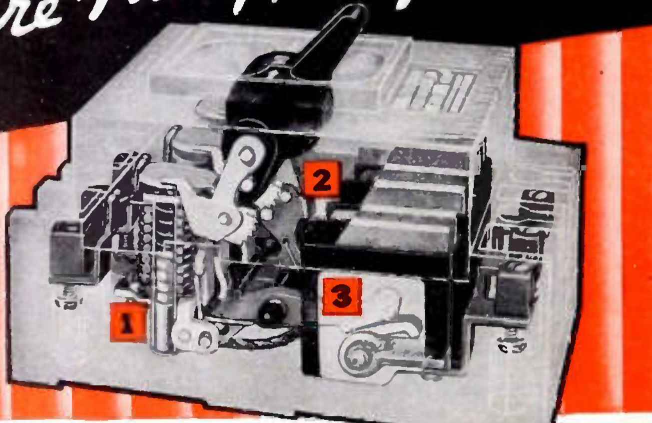
COMMUNICATIONS AND ELECTRONICS DIVISION
4545 Augusta Blvd., Chicago 51, Illinois



2-WAY RADIO
MICROWAVE
CARRIER & CONTROL
TELEMETERING
SUPERVISORY CONTROL

WORLD LEADERS IN FM 2-WAY MOBILE RADIO

HEINEMANN CIRCUIT BREAKERS *Are Fully Magnetic!*



1. BECAUSE the MAGNETIC-HYDRAULIC TIME DELAY retards the trip unit in time inverse to the magnitude of the current, allowing passage of inrush current, but causing instantaneous breaking of the circuit on excessive overload or short circuit.
2. BECAUSE the HIGH SPEED LATCH operates with minimum friction and maximum speed. It functions only under overload or short circuit, but it does that even if handle is held in "ON" position during overload. Rotation of latch releases contacts which are under heavy spring pressure.
3. BECAUSE the HIGH SPEED BLOWOUT, through magnetic action, gives instant arc interruption. The blowout contacts are separated from each other by means of individual arcing chambers. The higher the current, the greater is the quenching effect, due to the intensification of the magnetic field.

Send for Bulletin SW

HEINEMANN ELECTRIC CO.

154 PLUM STREET — EST. HECO 1888 — TRENTON, N.J.

RESEARCH OPPORTUNITIES IN THE LOS ANGELES AREA

Unusual Opportunity for Senior men with degrees and at least five years of outstanding proven accomplishment to achieve further growth by working with some of the nation's outstanding scientists on commercial and military projects in large modern electronics laboratories.

ELECTRONIC ENGINEERS
PHYSICISTS—CIRCUITRY
PHYSICISTS—ANALYSIS
PHYSICISTS—OPTICS
PHYSICISTS—ELECTRON TUBES
SERVOMECHANISMS ENGINEERS
ELECTRO MECHANICAL ENGINEERS
MECHANICAL DESIGNERS

Long term program of research and development in the fields of Radar, Guided Missiles, Computers, Electron Tubes, and related equipment.

Please do not answer unless you meet the above requirements.

RESEARCH AND DEVELOPMENT LABORATORIES
Hughes Aircraft Company — CULVER CITY, CALIFORNIA

POSITIONS OPEN

(Continued from page 55A)

ELECTRONIC ENGINEERS

Research and development engineers and physicists wanted with educational background in mechanical, electrical or electronic engineering, physics or engineering physics for openings in plant and laboratory instrumentation, physical measurements, geophysics, and industrial electronics. Prefer two to four years' experience in experimental research design and development of instruments, servo-mechanisms, electronic apparatus, optical equipment, intricate mechanisms or allied fields. Positions are of immediate and permanent importance to our operations. Write Personnel Director, Research and Development Department, Phillips Petroleum Company, Bartlesville, Oklahoma.

ELECTRICAL ENGINEERS

Leading manufacturer of X-ray equipment requires 3 men to train for position of sales engineers in east and middlewest. Excellent opportunity, depression proof business, stimulating field. If you can sell, like to work on your own, tangle with troublesome field service problems, don't mind occasional dirty hands or lack of a swivel chair and secretary, this is a worthwhile opportunity. Our men do well financially but work hard. If you want a soft berth, please don't reply. Previous sales helpful but not essential. State edu

(Continued on page 57A)

POSITIONS
IN THE WEST FOR
ELECTRONICS ENGINEERS

For Work in Fields of

Radar
Servomechanisims
Telemetering
Microwaves
Communicatior

NOW

Direct Inquiry To
FIELD TEST DIRECTOR

BELL Aircraft CORPORATION

Box 391
Holloman Air Force Base, New Mexico

In this panel are illustrated standard models of HELIPOT multi-turn and single-turn precision potentiometers—available in a wide range of resistances and accuracies to fulfill the needs of nearly any potentiometer application. The Beckman DUODIAL is furnished in two designs and four turns-ratios, to add to the usefulness of the HELIPOT by permitting easy and rapid reading or adjustment.

A B C

MODELS A, B, & C HELIPOTS
A—10 turns, 46" coil, 1-13/16" dia., 5 watts—resistances from 10 to 300,000 ohms.
B—15 turns, 140" coil, 3-5/16" dia., 10 watts—resistances from 50 to 500,000 ohms.
C—3 turns, 13-1/2" coil, 1-13/16" dia., 3 watts—resistances from 5 to 50,000 ohms.

D E

MODELS D AND E HELIPOTS
Provide extreme accuracy of control and adjustment, with 9,000 and 14,400 degrees of shaft rotation.
D—25 turns, 234" coil, 3-5/16" dia., 15 watts—resistances from 100 to 750,000 ohms.
E—40 turns, 373" coil, 3-5/16" dia., 20 watts—resistances from 200 ohms to one megohm.

F G

MODELS F AND G PRECISION SINGLE-TURN POTENTIOMETERS
Feature both continuous and limited mechanical rotation, with maximum effective electrical rotation. Versatility of designs permit a wide variety of special features.
F—3-5/16" dia., 5 watts, electrical rotation 359°—resistances 10 to 100,000 ohms.
G—1-5/16" dia., 2 watts, electrical rotation 356°—resistances 5 to 20,000 ohms.

LABORATORY MODEL HELIPOT
The ideal resistance unit for use in laboratory and experimental applications. Also helpful in calibrating and checking test equipment. Combines high accuracy and wide range of 10-turn HELIPOT with precision adjustability of DUODIAL. Available in eight stock resistance values from 100 to 100,000 ohms, and other values on special order.

R W

MODELS R AND W DUODIALS
Each model available in standard turns ratios of 10, 15, 25 and 40 to 1. Inner scale indicates angular position of HELIPOT sliding contact, and outer scale the helical turn on which it is located. Can be driven from knob or shaft end.
R—2" diameter, exclusive of index.
W—4-3/4" diameter, exclusive of index. Features finger hole in knob to speed rotation.

FOR PRECISION POTENTIOMETERS come to Helipot

For many years The HELIPOT Corporation has been a leader in the development of advanced types of potentiometers. It pioneered the *helical* potentiometer—the potentiometer now so widely used in computer circuits, radar equipment, aviation devices and other military and industrial applications. It pioneered the DUODIAL*—the turns-indicating dial that greatly simplifies the control of multiple-turn potentiometers and other similar devices. And it has also pioneered in the development of many other unique potentiometric advancements where highest skill coupled with ability to mass-produce to close tolerances have been imperative.

In order to meet rigid government specifications on these developments—and at the same time produce them economically—HELIPOT* has perfected unique manufacturing facilities, including high speed machines capable of winding extreme lengths of resistance elements employing wire even less than .001" diameter. These winding machines are further supplemented by special testing facilities and potentiometer "know-how" unsurpassed in the industry.

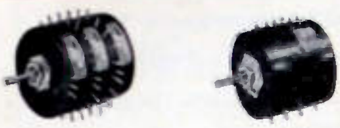
So if you have a problem requiring *precision potentiometers* your best bet is to bring it to The HELIPOT Corporation. A call or letter outlining your problem will receive immediate attention!

**Trade Marks Registered*

The versatility of the potentiometer designs illustrated above permit a wide variety of modifications and features, including double shaft extensions, ganged assemblies, the addition of a multiplicity of taps, variation of both electrical and mechanical rotation, special shafts and mounting bushings, high and low temperature operation, and close tolerances on both resistance and linearity. Examples of potentiometers modified for unusual applications are pictured at right.

A C

3-GANGED MODEL A HELIPOT AND DOUBLE SHAFT MODEL C HELIPOT
All HELIPOTS, and the Model F Potentiometer, can be furnished with shaft extensions and mounting bushings at each end to facilitate coupling to other equipment.
The Model F, and the A, B, and C HELIPOTS are available in multiple assemblies, ganged at the factory on common shafts, for the control of associated circuits.



B F

MULTITAPPED MODEL B HELIPOT AND 6-GANGED TAPPED MODEL F
This Model B Helipot contains 40 taps, placed as required at specified points on coil. The Six-Gang Model F Potentiometer contains 19 additional taps on the middle two sections. Such taps permit use of padding resistors to create desired non-linear potentiometer functions, with advantage of flexibility, in that curves can be altered as required.

THE Helipot CORPORATION, SOUTH PASADENA 6, CALIFORNIA

POSITIONS OPEN IN RESEARCH AND ADVANCED DEVELOPMENT PROGRAMS

TO

Research Physicists

Senior Electronic Engineers

Senior Mechanical Engineers

Engineering Physicists

Circuit Engineers

Microwave Engineers

Vacuum Tube Research Engineers

Technical Report Writers

Electronic Technicians

Experienced or Holding Advanced Degrees For Research, Design, or Development In

Radar, Servomechanisms, Computers, Receivers, Photo Emission, Secondary Emission, Converters, Pulse and Timing Techniques, Special Test Equipment, Special Purpose Tubes, Circuit Design, Solid State Physics, Light and Electron Optics, etc.

We invite interested personnel with experience in the above fields to submit a complete and detailed resume of education and experience, together with salary requirements and availability date, to:

The Employment Department
CAPEHART-FARNSWORTH CORPORATION
Fort Wayne 1, Indiana

Positions Open

(Continued from page 56A)

cation, experience, reason for making change and past earnings. All replies held strictly confidential. Arrangements will be made to interview qualified applicants. Mr. Ed. Smith, Personnel Mgr. The Kelley-Koett Manufacturing Company, 212 West Fourth Street, Covington, Kentucky.

ENGINEERS

Precision instrument plant has positions available for highest caliber personnel in the field of airborne automatic electromechnical control equipment. Mechanical design, electronic, servo, and junior engineers. Write or apply. AC Spark Plug Division, General Motors Corporation, 1925 E. Kenilworth Place, Milwaukee 2, Wisconsin.

ELECTRICAL ENGINEERS—PHYSICISTS

Men to train in oil exploration for the operation of seismograph instruments and the computing and interpreting of seismic data. Beginning salary $250 to $325 depending upon background. Excellent opportunity for advancement determined by integrity and ability. Nature of work requires several changes of address each year; work indoors and out; general location in oil producing states. To apply write, giving scholastic and employment background; age, nationality, marital status; and include recent snapshot to: National Geophysical Company, Inc., 8800 Lemmon Avenue, Dallas 9, Texas.

(Continued on page 59A)

COLLINS RADIO COMPANY

Western Division

Announces

Establishment of a research and development laboratory in the Los Angeles area.

Immediate openings are available for a few

SENIOR ENGINEERS
PHYSICISTS
JUNIOR ENGINEERS

Direct inquiries or resumes to

2700 West Olive Avenue
Burbank, California

ATOMIC ENERGY INSTALLATION

NEEDS

ELECTRONICS ENGINEERS

Two to ten years' experience in research, design, development or test. Patent history desirable but not necessary. A variety of positions open for men with Bachelor's or advanced degree qualified in one or more of the following fields:

- RELAYS
- TELEMETERING
- PULSE CIRCUITS
- UHF TECHNIQUES
- SERVO-MECHANISMS
- INSTRUMENTATION
- QUALITY CONTROL
- LOW POWER APPLICATION
- TEST EQUIPMENT RELATING TO ABOVE FIELDS

TECHNICAL WRITERS

College graduate. Technical background preferred. Several years' professional writing experience.

These are PERMANENT POSITIONS with Sandia Corporation in Albuquerque, New Mexico. Sandia Laboratory is operated by Sandia Corporation, a subsidiary of Western Electric Company, under contract with the ATOMIC ENERGY COMMISSION. This laboratory offers good working conditions and liberal employee benefits, including paid vacations, sick leave, and a retirement plan.

Albuquerque, center of a metropolitan area of 150,000, is located in the Rio Grande Valley, one mile above sea level. The "Heart of the Land of Enchantment." Albuquerque lies at the foot of the Sandia Mountains, which rise to 11,000 feet. Climate is sunny, mild and dry the year 'round.

MAKE APPLICATION TO

Professional Employment

SANDIA CORP.

SANDIA BASE
ALBUQUERQUE, N.M.

Positions Open

(Continued from page 58A)

ELECTRICAL ENGINEERS

Electrical engineers to design sound equipment, audio amplifiers and electric carillons, requirements: B.S. degree, one to five years' experience in audio, electronic and acoustical systems. Location: Upstate New York. Box 653 IRE.

ELECTRICAL ENGINEER

New Florida research company requires engineer preferably with Nuclear instrumentation experience in tubes or circuits. Part or full time with age no objective. Write qualifications in full to: Box 951, West Palm Beach, Florida.

ENGINEERS—TECHNICIANS

Large mid-west manufacturer has positions open for electrical and electronics engineers and technicians. Applicants are requested to submit data concerning their education and experience together with photograph. Box 656 IRE.

ENGINEERS—PHYSICISTS

Several senior and junior engineers are required immediately for the direction of important research and design work by an organization specializing in all types of advanced armament development. This is an opportunity to participate in the growth of an exceptionally active group in a highly technical field. Positions open include: Electronics engineers, Electromechanical engineers, engineering physicists: Write, phone, or wire to R. W. Sanford, Ch.

(Continued on page 60A)

Positions Open

(*Continued from page 59A*)

Engr., Aircraft Armaments, Inc., 4415 Reisterstown Road, Baltimore 15, Maryland.

ELECTRONICS ENGINEER

Naval Ordnance Laboratory, outside Washington, D.C., has opening for electronics engineer with degree in electrical engineering and several years of experience in the design of electronic circuits; to supervise the design and development of advanced electronic equipment and control systems employed in hyperballistics investigations. Starting salary $5,400. per year. Address: Personnel Department, Atten: AO, Naval Ordnance Laboratory, White Oak, Silver Spring 19, Maryland.

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.

(*Continued on page 61A*)

Positions Wanted

(Continued from page 60A)

members who are now in the Service or have received an honorable discharge. 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.

COMMUNICATIONS TECHNICIAN

Age 34, married. Extensive experience installation maintenance D.S.B., S.S.B. Diversity communications receivers; radio-telephone terminal units, etc., radio-facsimile specialist. Six years' war-time experience line communications and mobile radio. Five years' British communications company. Consider suggestions for mid 1951. Canada preferred. Box 505 W.

ENGINEER

Three years' experience as Production Supervisor and test B.S.T.E. A.T.I.T. some experience at circuit design, seven years' analyzing and repair TV and radio receivers. Age 27, married, one child. Desires either production or design, Midwest. Box 506 W.

ELECTRONICS ENGINEER

Electronics engineer—Physicist. Physics degree from Brooklyn College. Two years' Army electronics officer, Harvard, M.I.T. radar school. Continuing graduate work. Three years' design and development work

(Continued on page 62A)

Positions Wanted

(Continued from page 61A)

in radar with emphasis on microwave circuitry. Box 516 W.

ELECTRICAL ENGINEER

M.S. in E.E., University of Illinois. One year as industrial development electrical engineer. Two years' full time university teaching. Single, age 28, desire a position as development engineer involving automatic control work. Box 517 W.

ELECTRICAL ENGINEER

B.S. and M.S. Caltech, three years' Signal Corps, one year own business, three years' teaching. Southern California area. Possibly invest in business. Box 518 W.

ENGINEER

B.E.E. electronic option, Unniversity of Kentucky, June 1950. Age 31, married; U. S. Civil Service training, field radio and frequency modulation; three years' Army Signal Corps, installation and repair. Desire position in design and development. Resume on request. Box 519 W.

ENGINEER

M.S. in E.E. University of Michigan, June 1951. Communications field major. 1½ years' teaching Navy electronics, research in upper atmosphere rocket program. Married, age 24. California area. Box 520 W.

MEMBERSHIP

(Continued from page 49A)

Norton, H. N., 86-04 Elmhurst Ave., Elmhurst, L. I., N. Y.
Pavlasek, T. J. F., 506 Prince Albert Ave., Westmount, Montreal 6, Que., Canada
Santangelo, J., 194 Barbara Rd., Waltham 54, Mass.
Schneider, C. A., 432 Riddle Rd., Apt. 4-B, Cincinnati, Ohio
Stasz, C. E., 179 Edgewood Ave., Audubon 6, N. J.
Swearingen, T. J., 90-23 171 St., Jamaica 3, N. Y.
Wiegert, P. G., 539 Forrer Blvd., Dayton 9, Ohio

Admission to Member

Anderson, C. F. W., 2001 South Rd., Baltimore 9, Md.
Atcheson, S. E., Box 2158, Greensboro, N. C.
Burnham, J., 11 School St., Williamstown, Mass.
Carlton, M. D., Edge Rd., R.F.D., Syosset, N. Y.
Collins, J., 307 Adams St., N.E., Washington 2, D. C.
Dandelake, J., 1304 Morvenwood Rd., Jacksonville, Fla.
Debski, J. M., 14 Victoria Rd., Farnborough, Hampshire, England
Erwin, V. R., 600 Bond Bldg., Washington 5, D. C.
Fernekees, J. E., 9 Park Ave., Wappingers Falls, N. Y.
Gadler, S. J., 1524 Gummer St., Dayton, Ohio
Hekster, S., Groenestraat 18, Bennekom (Gld), Netherlands
Lang, G. J., 33 Hauptgasse, Olten (Solothurn), Switzerland

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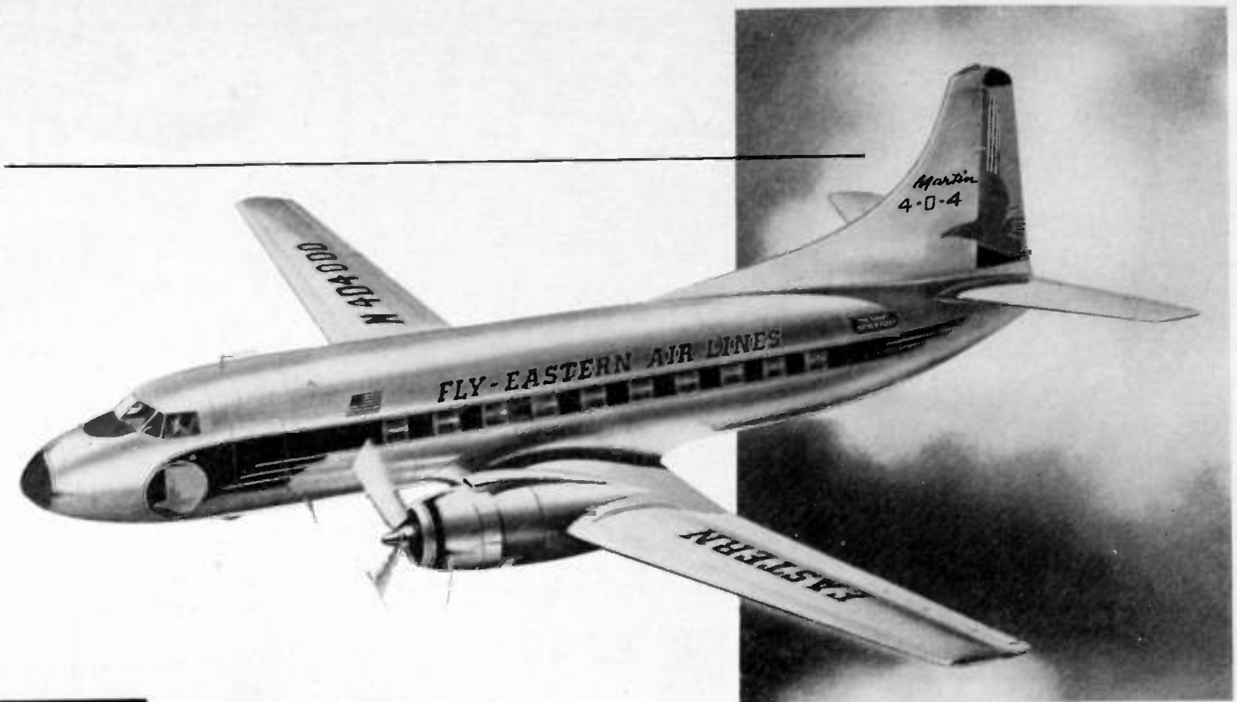
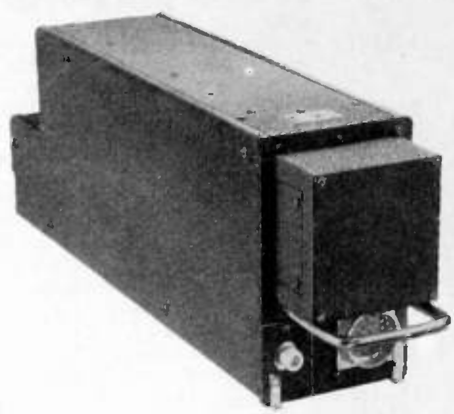


WILCOX ***...Choice of***

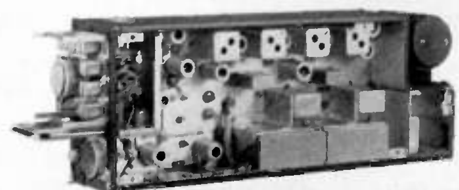
ASTERN Air Lines

ilcox Type 429A Glideslope Receiver
iosen for EASTERN'S Entire New Fleet of
artin 4-0-4's and Super Constellations



T: safety and performance record of Eastern Air Lines' magnificent nv fleet will depend upon the flawless operation of their I.L.S. nvigation system. In selecting the Wilcox Type 429A Glideslope R:eiver as an important part of this system, Eastern paid a great cnpliment to the dependability and performance of Wilcox e ipment.

T: Wilcox Type 429A Glideslope Receiver provides 90/150 CPS e modulated glideslope signals in the 329-335 Mc. range.



Right side

ISTANT ACCESSIBILITY FOR EASY MAINTENANCE

R:tine inspection and service is made easy by the careful arrange-nnt and instant accessibility of all tubes, components, and wiring.

Left side

AILABLE FOR D.C. OR A.C. POWER

T: Type 429A is supplied for operation on either 28-volt D.C. or 1)-volt A.C. 400-cycle current. D.C. or A.C. power supply occupies t same physical space interchangeably. The right-side illustration ws the Glideslope Receiver equipped for D.C. operation with namotor, and the left-hand photo as supplied for A.C. input. T is it fits the requirements for all commercial, military, and private .

Write Today **FOR COMPLETE INFORMATION ON THE WILCOX 429A GLIDESLOPE RECEIVER**

WILCOX
ELECTRIC COMPANY
KANSAS CITY 1, MISSOURI, U. S. A.

MEMBERSHIP

(Continued from page 64A)

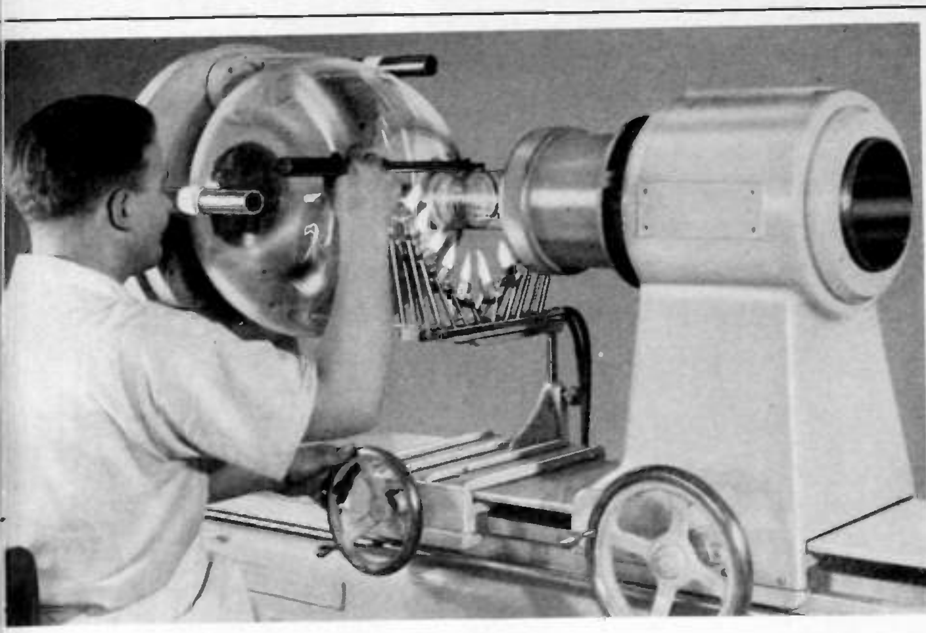
Lindeman, B., 2845 Ocean Ave., Brooklyn 35, N.Y.
McElwee, E. M., Sylvania Electric Products, Inc., 83-30 Kew Gardens Rd., Kew Gardens 15, L. I., N. Y.
Naidu, C. R. V., Superintendent, U.M.S. Radio Factory, "Gopal Bagh," Coimbatore, S. India
Poch, S., Driver-Harris Co., 201 Middlesex St., Harrison, N. J.
Rafi, M. A., Deputy Director, Civil Aviation Department, Govt. of Pakistan, Karachi Pakistan
Raman, K. V., Senior Lecturer, College of Engineering, Trivandrum, S. India
Riska, G. G., 8 Suffolk St., Lynn, Mass.
Wehner, G. K., 4038 Cleveland Ave., Dayton 10 Ohio
Weiss, G., 1546 J. J. Diaz, Beccar (F.C.N.G.B.M.) Argentina

The following elections to Associate were approved and are effective as of March 1, 1951:

Annett, M. E., Liberty Bell Trailer Village, R.D. 3, Langhorne, Pa.
Antrim, G. H., R.D. 3, Cedar Rapids, Iowa
Applegate, C. E., 4901 Stenton Ave., Philadelphia 44, Pa.
Atkinson, B. A., 3992 W. 224 St., Fairview Park 26 Ohio
Bailey, B. H., 107 Campania, Rayne, La.
Ballard, D. C., 536 W. James, Lancaster, Pa.
Blau, W., 1157½ 23 St., N. W., Washington 7, D. C.

(Continued on page 68A)

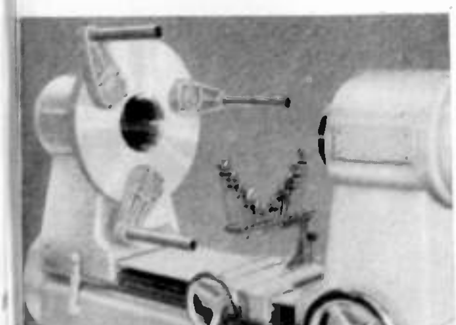
LITTON INDUSTRIES NEWS



ITTON GLASSWORKING LATHES PEED PRECISION ASSEMBLY OF V KINESCOPE, VACUUM TUBES

:odern vacuum tubes have extremely ose alignment tolerances. Often, sub-.semblies must be separately aligned be-re junction. During sealing, both assem-ies must be rotated in perfect phase to aintain this alignment.

Versatile, adaptable Litton Glasswork-g Lathes meet these requirements. They e built on a normalized cast iron bed, ith precision ground ways and axial align-ents of highest accuracy and positive nase. The lathes will chuck and hold units ıch as copper anodes to runouts of .001".



se-up of spindle head, Litton Model K lathe, showing ceptionally large diameter opening of universal chuck

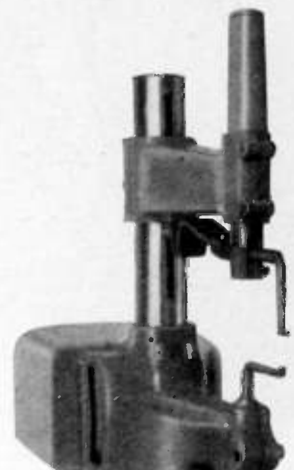
Air passages are arranged to avoid contamination, yet permit use of neutral gasses when sealing glass to metal. Burners provide the narrowest possible heating area commensurate with ample total heat. Continuously variable spindle speed, which makes possible much glassworking without blowing, is optional on all models. Foot pedals control the air or neutral gas supply, and the oxygen and gas volume. Convenient hand controls govern carburetion and air intake to the spindles.

Leading TV tube makers use Litton Glassworking Lathes to speed production of kinescope tubes 10" to 27" in diameter. Manufacturers find that the speed and handling ease of Litton lathes enable glassworkers to seal tube funnels to domes in minimum time—with complete control of glass distribution. Since most manufacturers align sub-assemblies on the lathe, the accurate phasing of Litton spindle heads is also an important factor.

Reliable Litton Glassworking Lathes are adaptable to the widest possible variety of glassworking jobs. Five models offer a choice of radial clearance ranging from 4" to 17½", and axial working lengths from 20¾" to 75½".

LITTON SPOTWELDERS OFFER HIGH POWER, EXTREME FLEXIBILITY FOR PRECISION JOBS

Litton Model A Precision Spotwelder offers broad applicability of use in the manufacture of vacuum tubes. It makes possible the quick altering of production setups. Rated 2 kva continuous duty, it efficiently handles average sized



or very precise jobs. Accurate alignment and absence of side play permit butt welding or parallel welding of small wires without rolling. Foot pedals and switches control top mandrel and power supply. Model A spotwelder has 6½" throat depth and extension jaws can be added.

SPOTWELDER TIMER

A new timer for the Litton Model A Spotwelder has been developed by Litton Industries and will be available for delivery soon. The timer employs two simple controls. One adjusts weld time in steps of 1, 2, 3, 5, 7, 10, 15, 25 and 60 cps. The other adjusts heat control in 6 steps. Proper adjustment of these controls makes possible precision welds up to the 2 kva rating of the welder.

LITTON INDUSTRIES

SAN CARLOS, CALIFORNIA, U.S.A.

DESIGNERS AND MANUFACTURERS of: Glassworking Lathes and Accessories, Vertical Sealing Machines, Burner Equipment, Precision Spotwelders, Oil Vapor Vacuum Pumps, Glass Baking Ovens, Vacuum Tubes and Tube Components, Magnetrons, High Vacuum Molube Oil, Microwave Equipment.

(Continued from page 66A)

MEMBERSHIP

Blowers, R. C., 156 Roycroft Ave., Long Beach, Calif.
Brady, J. A., Sr., Box 139, Golden Meadow, La.
Bravo, M. V., Box 503, Tularosa, N. Mex.
Bright, R., Jr., 195 Broadway, New York, N. Y.
Brown, E. L., Mile 201, Alaska Highway, Trutch, B. C., Canada
Burn, C. A., 2017 S. 20, E., Salt Lake City, Utah
Busch, M. A., 6651 Kingsbury, University City, Mo.
Butler, R. I., 21160 La Salle Blvd., East Detroit, Mich.
Campbell, T. E., 509 Sherman St., Johnstown, Pa.
Chandler, J. A., 171 N. Ditman Ave., Los Angeles 33, Calif.
Chartier, E. G., 309 13 St., Cloquet, Minn.
Christie, C. B., 1020 N. Broadway, Milwaukee 2, Wis.
Clark, J. G., Radio Station KERB, Kermit, Tex.
Clark, M. R., 8316 Grandville, Detroit 28, Mich.
Classon, H. T., 133 Cleveland St., Orange, N. J.
Cotcher, A. L., 3410 Highview Ct., Wheaton, Md.
Darlington, H. T., Jr., 8771 Dumbarton, Detroit 4, Mich.
DaRoza, F. G., Barlum Hotel, Rm. 2023, Cadillac Sq., Detroit, Mich.
DeLorenzo, V. H., 3610 Wabash Ave., Cincinnati 7, Ohio
Denzler, E. W., Det. 1, 657th AC&W Sqdn., DOW A.F.B., Bangor, Maine
Dore, A. J., 1707 N. 20 Ave., Melrose Park, Ill.
Drankhan, O. W., 215 St. Joseph St., Long Beach, Calif.

(Continued on page 70A)

MEMBERSHIP

(Continued from page 68A)

Dudeck, M. P., 50 Chestnut Lane, Levittown, L. I., N. Y.
Duffy, A. F., 137 Moore St., New Hyde Park, L. I. N. Y.
Engelhart, C. F., 1851 Plaza Blvd., R.D. 1, Dallas, Tex.
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Fay, A. H., 1784 Fulton St., E. Hempstead, L. I., N. Y.
Fetzner, R. W., 35 Armitage Ave., Northlake, Melrose Park, Ill.
Fleming, H. D., 35 Forrester St., S.W., Washington, D. C.
Foster, J. H., 515 N. 50 St., Seattle, Wash.
Fudaley, S. L., 1733 W. 75 Pl., Chicago 20, Ill.
Gage, D. D., 58 Grant St., Needham 92, Mass.
Gamson, E. R., Stanford Research Institute, Stanford, Calif.
George, N., Jr., 2703 Upshur St., Mt. Rainer, Md.
Gerber, S., 2958 W. 35 St., Brooklyn 24, N. Y.
Ghose, S. C., 16C Bethune Row, Calcutta, India
Glantz, R. H., 1841 S. 20, E., Salt Lake City, Utah
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Gudmandsen, P. E., Junggreensvej 11, Kobenhavn, Denmark
Guild, E. G., 5250 Knollwood Dr., Cleveland 29, Ohio
Gumbs, J., 231 Grant St., Perth Amboy, N. J.
Hackett, F. J., Box 399, Kenora, Ont., Canada
Hafer, A. C., 318 W. Newton Ave., York, Pa.
Hammond, J. R., 5615 E. Lafayette Blvd., Phoenix, Ariz.
Henry, W. E., 518 46 St., Sandusky, Ohio

(Continued on page 71A)

MEMBERSHIP

(Continued from page 70A)

Hobson, R. J., 5826 Darlington Rd., Pittsburgh, Pa.
Hoffman, H. J., 366 Cantubury Rd., Bay Village, Ohio
Holder, C. R., Jr., 3291 Hull Ave., New York 67, N. Y.
Holman, W. S., 227 Basswood Ave., Dayton 5, Ohio
Holmes, R. L., 23 Harris Ave., Salt Lake City 15, Utah
Hotchkin, E. E., 2121 N. Cambridge St., Milwaukee, Wis.
Huber, R. H., 5015 N. California Ave., Chicago 23, Ill.
Hughes, J. M., 1251 Masonic Ave., San Francisco, Calif.
Hyams, I., 1131 N. 41 St., Philadelphia 4, Pa.
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Kessler, W. B., 339 Forest Ave., Woodmere, L. I., N. Y.
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King, C. W., 5412 Pine St., Philadelphia 43, Pa.
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Perna, F. J., 111 S. 22 St., Philadelphia 3, Pa.
Petersen, J. H., 535 Margaret Ct., Orlando, Fla.

(Continued on page 73A)

Membership

(Continued from page 71A)

Podlusky, M. V., 2635 N. Central Ave., Chicago 39, Ill.
Pomeroy, I. D., 937 Campus Dr., Phoenix, Ariz.
Ponticello, J. A., Box 115, Turner St., Austin, Pa.
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Rafajko, M., 355 N. Limestone, Lexington 16, Ky.
Rath, H. B., 8234 Manor Rd., Elkins Park 17, Pa.
Reesor, G. E., 169 Gillard Ave., Toronto, Ont., Canada
Ricciardelli, G., 151 Robinson St., Binghamton, N. Y.
Robinson, W. H., 420 S. San Pedro St., Los Angeles, Calif.
Rogers, H. F., Jr., 561 N. Second W., Salt Lake City, Utah
Rosier, E. S., 1824 Castle Pl., Dallas, Tex.
Ruderfer, M., 1588 Sterling Pl., Brooklyn 13, N. Y.
Russell, H. J., 4106 Farnham Ave., Dayton 10, Ohio
Sacco, V., 1937 Fulton St., Brooklyn 33, N. Y.
Saini, B. R., National Eko Radio, Mahalakashmi, Bombay, India
Sainton, J. B., 5118 Hass Rd., Dallas, Tex.
Sayre, M. B., Box 277, Waterford, Calif.
Scheftelowitz, H., 6 St. Mollevey, Copenhagen S, Denmark
Scordato, M., 17 Maple Pl., Clifton, N. J.
Slusny, M. D., 1348 Ashland Ave., Dayton 10, Ohio
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Stratton, C. H., 2601 N. Broad St., Philadelphia 32, Pa.
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Strauss, K. J., 173-12 47 Ave., Flushing, L. I., N. Y.
Stretanski, P. A., 6395 Belfast St., Detroit 10, Mich.
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Tiffany, G. B., 46 Newell Ave., Needham 92, Mass.
Uiga, E., 85 E. High St., Ballston Spa, N. Y.
Van Ormer, D. D., 38½ W. Orange St., Lancaster, Pa.
Vaughn, T. J., 9 Rose St., Somerville 43, Mass.
Vieira, A., 200 Haven Ave., New York, N. Y.
Virtue, G. L., 3335 Sandwich St., W. 1, Windsor, Ont., Canada
Vrbik, J., 2114 Mt. Vernon Ave., Cedar Rapids, Iowa
Waller, H. H., 210-01 43 Ave., Bayside, L. I., N. Y.
Ward, D. O., 1756 Allendale Ave., E. Cleveland 12, Ohio
Weinberger, E. F., 2690 University Ave., New York 63, N. Y.
Weiss, H., 6635 W. 19 St., Berwyn, Ill.
Welter, N. E., 4135 Prospect Ave., Kansas City 4, Mo.
Williamson, A. P., Hughes Aircraft Company, Holloman A.F.B., N. Mex.
Winters, W. D., 242 S. Loop Rd., Dayton 4, Ohio
Yanagihara, F. T., 1050 N. LaSalle St., Chicago 10, Ill.

A Survey of Advertising Preferences of Members of The Institute of Radio Engineers

In December, 1950, the Advertising Department of the Institute initiated a survey to determine what advertisements were most acceptable and helpful to the membership—and why.

To obtain the information a Post Card (see illustration) was mailed to a portion of

(Continued on page 75A)

HICKOK new model 640 OSCILLOGRAPH

STABLE • VERSATILE
OUTSTANDING RANGE

Model 640

For Industrial and Electronic *Laboratories*

The new HICKOK Model 640 Oscillograph with its exceptional design features and characteristics provides an outstanding versatile instrument for the engineer in observing regular recurring or transient phenomena.

Wide Band Amplifier: Frequency response DC, 0 to 4.5 mc, (down 3 db.).

Vertical DC and AC Amplifier: 10 MV per inch with sensitivity switch in high position. 25 MV per inch in low position.

Frequency Response: 0 to 1,000,000 cycles, (3 db point), in high position. 0 to 4,500,000 cycles, (3 db point), in low.
Maximum Input Potential; 1000 volts peak. Input Impedance; 2 megohms, 50 mmf.

Horizontal Amplifier: Deflection Factor—Direct: 20 volts RMS per inch.
Full Gain Setting; 50 millivolts RMS per inch. Frequency Response; 0 to 200,000 cycles, (3 db down).

Test Signals: Line Frequency, 3 volts RMS per inch.
Sawtooth available from front panel. Direct connection to both horizontal and vertical deflection plates.

Linear Time Base: Recurrent and Driven Sweep; 2 cycles to 30,000 cycles.
Provision for external capacities for slower frequency sweeps of 10 seconds and slower. Sweep Speeds; Faster than 0.75 inch per microsecond.
Television Fixed Frequencies; 30 and 7,875 for observing blanking and sync waveforms in the horizontal and vertical circuits of TV receivers.
Synchronization at line or 2-times line frequency.

"Z" Axis Modulation: Capacitively coupled to the grid of the cathode ray tube. 15 volts will blank trace fully at normal intensity.

Shielded, Shock Mounted, Built-in Calibrating Voltages, Excellent Stability and Expandable Sweep (6 times expansion) are several additional features of this highest quality instrument. Write for further information today. Price $355; Subject to change without notice.

Model 539

Dynamic Mutual Conductance
TUBE TESTER
HIGHLY ACCURATE
Laboratory Model

- Dynamic Mutual Conductance circuits . . . Readings in micromhos.
- Permits choice of 3 AC signals, .25, .5 and 2.5 volts.
- Vernier adjustment permits accurate setting of grid voltage.
- Separate AC meter measures line voltage at all times.
- Provision for insertion of plate millimeter for measuring plate current.
- Optional self-bias arrangement.
- Tube life and tube gas

Write for additional information today!

THE HICKOK ELECTRICAL INSTRUMENT CO.
10551 DUPONT AVENUE • CLEVELAND 8, OHIO

THE STANDARD OF QUALITY FOR OVER 40 YEARS

THE TWIN TUBE POCKETSCOPE®
BY WATERMAN

MODEL S-15-A

Wt. 16¼ lbs.
12" x 6" x 7"

A new concept in multiple trace oscilloscopy made possible by Waterman developed RAYONIC rectangular cathode ray tube, providing for the first time, optional screen characteristics in each channel. S-15-A is a portable twin tube, high sensitivity oscilloscope, with two independent vertical as well as horizontal channels. A "must" for investigation of electronic circuits in industry, school or laboratory.

Vertical channels: 10mv rms/inch, with response within —2DB from DC to 200kc, with pulse rise of 1.8μs. Horizontal channels: 1v rms/inch within —2DB from DC to 150kc, with pulse rise of 3μs. Non-frequency discriminating attenuators and gain controls, with internal calibration of traces. Repetitive or trigger time base, with linearization, from ½cps to 50kc, with ± sync. or trigger. Mu metal shield. Filter graph screen. And a host of other features.

WATERMAN PRODUCTS CO., INC.
PHILADELPHIA 25, PA.
CABLE ADDRESS: POKETSCOPE

WATERMAN PRODUCTS INCLUDE:

S-10-B GENERAL	POCKETSCOPE
S-11-A INDUSTRIAL	POCKETSCOPE
S-14-A HI-GAIN	POCKETSCOPE
S-14-B WIDE BAND	POCKETSCOPE
S-21-A LINEAR TIME BASE	

Also RAKSCOPES, LINEAR AMPLIFIERS, RAYONIC® TUBES and other equipment

WATERMAN PRODUCTS

(Continued from page 73A)

the membership representing a good cross-section of the country. This will be done each month, until the entire roster has been polled. Replies were received from 27 states, Washington, D. C., Alaska, Canada, and the Army overseas.

The reason why a member liked an advertisement fell into the following "pattern" (not necessarily in order of preference).

1. Specifications or Data.
2. Prices Quoted.
3. Application Data.
4. Engineering Drawing, Charts, Graphs, or Wiring Plan.
5. Good Visual Display—Attracts Attention.
6. Brief Yet Complete.
7. Dignified Presentation.
8. Generally Informative or Instructive.
9. Performance Characteristics.
10. No Ballyhoo or Advertising Blurbs.
11. No Answer.
12. Definitely Negative.

Other Reasons Infrequently Given—

A. New Techniques.
B. Order Blank in Ad.
C. Physical Dimensions.
D. New Product.
E. Cut Away Drawing or Exploded View.
F. Invites Correspondence.

The recipient of the card is requested to make a choice for the specific month, and then to state the reason for selection. Next, to choose an advertisement from the IRE Directory. Thirdly to state his type of business; and last to tell us if (A) he makes purchases, (B) sets specifications, (C) can influence buying, (D) has no interest in buying. Each of the last group is given a numerical value which is totaled to obtain a "point evaluation" of the men who prefer the ad.

This is the result of the January study. (2nd report)

Firm & Page	Vote	Ans.	Value
Hewlett-Packard Co. Page 3	31	1	83
General Elec. Co., Electr. Dept. Page 29	11	5	20
General Radio Co. Back Cover	11	1	28
Genral. Elec. Co., Appar. Dept. Pages 10 & 11	10	8	31
Centralab, Div. of Globe Un. Pages 33, 34, 35	13	5	31
Erie Resistor Corp. Page 19	7	1	18
Electrical Reactance Corp. Page 7	7	1	17
Bell Telephone Labs Page 6	5	8	8
Radio Corp. of America Page 16	4	5	11

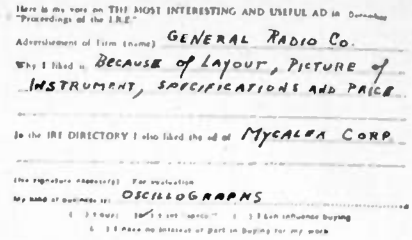
Only the top group of votes are being reported in this study.

General Radio Co. Pages 234 & 235	9	Directory
Mycalex Corp. of America Insert	8	Directory
Raytheon Mfg. Co., Rec. Tube Div. Insert	5	Directory
Hewlett-Packard Co. Pages 232 & 233	4	Directory
Approved Electr. Instru. Corp. Insert	4	Directory

NOTE: *Vote* indicates total votes.
Ans. indicates the answer most frequently given, or in a tie, both.
Value indicates point evaluation total of voters.
Directory refers to the IRE Directory.

(Continued on page 76A)

(Continued from page 75A)


Here is my vote on THE MOST INTERESTING AND USEFUL AD in "Proceedings of the I.R.E."

Advertisement of firm (name) GENERAL RADIO CO.

Why I liked it BECAUSE OF LAYOUT, PICTURE OF INSTRUMENT, SPECIFICATIONS AND PRICE

In the IRE DIRECTORY I also liked the ad of MYCALEX CORP

OSCILLOGRAPHS

More than one reason was given by most men as the basis for selecting an ad. To avoid making a prejudiced selection, the researcher took the first reason in 90 per cent of the answers, on the basis that the most important factor would be stated first. This may be a fallacy, however, interpretation was avoided, in an attempt to be factual

News—New Products

(Continued from page 28A)

New Ultrasonic Generator

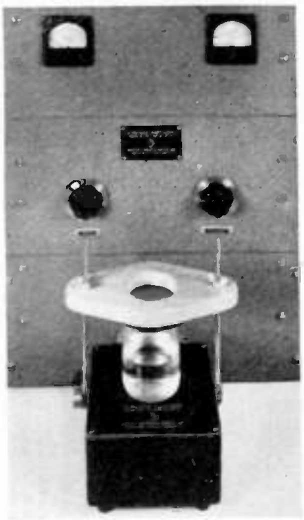
The new Massa Model GA-1010 ultrasonic equipment has been made available, by **Massa Laboratories, Inc.**, 5 Fottler Rd., Hingham, Mass., for use where the higher frequency quartz crystals were not found satisfactory. This new equipment includes a 1-kw magnetostriction transducer, operating at approximately 24 kc and having an exposed flat vibrating surface of 20 square centimeters. The structure is oil-filled and is provided with a water-cooled radiator.

(Continued on page 77A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 76A)

The transducer is designed to permit the activation of glass or metallic con-



tainers having a diameter of about four inches.

Melting Furnace

Development of a new, improved electric melting furnace has been announced by the **Santa Anita Engineering Co.**, 2435 E. Colorado St., Pasadena 1, Calif.

This new unit has a built-in thermostatic heat control which automatically maintains a temperature within ±20° F of any given setting from 450° to 850° F. It is designed primarily for use with lead, lead alloys or other metals and materials with fusing point or melting point within its thermostatic limits of operation.

Materials are discharged into a mould or other receptacle through a spout located in the base of the pot. The spout valve is operated by a top handle lever, which remains cool during operation. By drawing the molten alloy off the bottom, each mould cavity is filled under the head of pressure, thus eliminating air pockets, resulting in full castings. Slag problems are also overcome by drawing off the bottom.

An ingot mould, which casts four ingots, is furnished with each furnace. The furnace is large enough to accept standard 5-pound (lead) ingots without cutting or prior melting.

(Continued on page 78A)

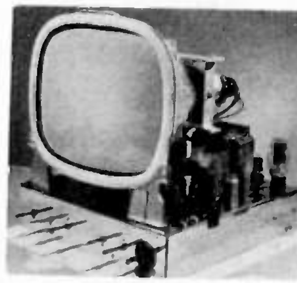
News New—Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 77A)

Plastic Insulation For Mounting TV Tubes

Development of a new type mounting and insulating *Ring and Sleeve* for 17-inch rectangular metal tubes has been announced by **Anchor Industrial Co.**, 533 Canal St., New York 13, N. Y.



The *Ring and Sleeve* which incorporate several major improvements in their design are, however, of the same general type as those at present supplied to television manufacturers. Full production schedules have been initiated, according to Richard A. Fisch, owner of the company.

Shown in the picture is a tube assembled with the standard *Ring and Sleeve*. Specially engineered models are available for round and rectangular metal picture tubes.

(Continued on page 79A)

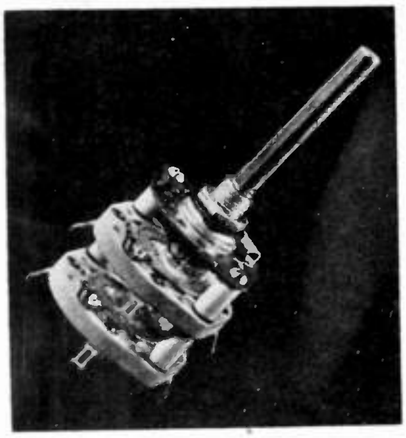
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 78A)

New "Ham-Type" Switch

Rapid band switching in medium power transmitter and exciter units with voltages up to 1,000, and inputs up to 150 watts, may be accomplished with a new "ham-type" switch developed by **Centralab, Div. Globe-Union, Inc.**, 900 E. Keefe Ave., Milwaukee 1, Wis.



Constructed of heavier than normal steatite insulation (0.203 inch thick), the

(Continued on page 80A)

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 79A)

switch itself will handle 15 watts, and its steatite spacers afford a higher than usual breakdown-to-ground rating.

The switch is nonshorting, has a 90-degree positive action index and is adjustable from two to four positions. It is available in one of five sections. The switches are packaged singly, including mounting nut, lockwasher, knob and dial plate.

Miniature Slip Ring Assemblies

Electro Tec Corp., South Hackensack, N. J., is currently supplying precision

miniature slip ring assemblies, constructed by an electro-deposition method.

(Continued on page 81A)

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 80A)

In this method a plastic (Selectron 5003), a product of **Pittsburgh Plate Glass Co.** or an equivalent, is molded around the wire leads. Machining reduces this core to the proper shape with grooves; this procedure makes conducting rings an integral part of the unit. Hard silver is then electro deposited into the grooves to form the rings. Subsequent machining insures concentricity and dimensional accuracy.

A flash electro deposit of palladium plus an 0.00001-inch rhodium deposit prevents tarnish, and insures wear resistance.

The wide range of sizes possible with this method of manufacture includes diameters from 0.050 inch to several inches. Cross sections of the silver may vary from 0.005 inch to 0.007 inch on small diameter assemblies and from 0.050 inch to 0.060 inch on large power carrying assemblies. The silver rings are polished to 4 microinch, or better, on miniature rings.

High Power Mercury Plunger Type Relay

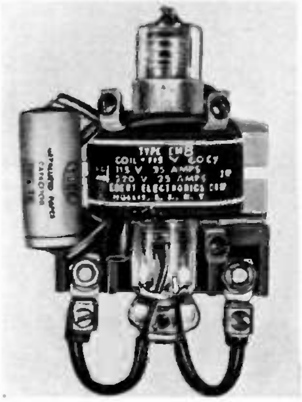
A new sensitive high-power relay (power amplification, 10,000) has just been released by **Ebert Electronics Corp.**, 185-09 Jamaica Ave., Hollis 7, L. I., N. Y.

(Continued on page 83A)

News—New Products

These manufacturers have invited PROCEEDINGS
information. Please mention your I.R.E. affiliation.
readers to write for literature and further technical

(Continued from page 81A)



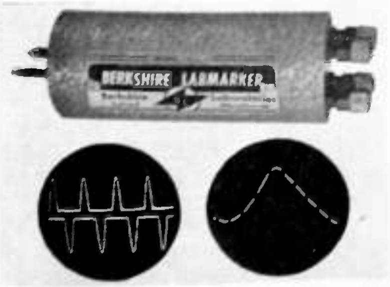
This new relay is of the the mercury plunger type, similar to the company's standard line of 1-, 2-, and 3-pole relays, has load ratings to 35 amperes and 440 volts with life tests of 100 million operations, and requiring no maintenance because of the hermetically sealed mercury-to-mercury design.

The new model EM-8 employs an energizing coil in a resonant circuit so that the external contact (mercury thermometer, instrument contact, etc.) need only carry sufficient power to detune the circuit. This external contact power is the equivalent of 100 volts, 8 ma ac. The relay load rating is 35 amperes, 115 volts, 30 amperes, 220 volts, 20 amperes, 440 volts with virtually unlimited inrush current.

Also available from the firm is a 4-page catalog which lists the complete line of heavy-duty 1-, 2-, and 3-pole mercury plunger and sensitive relays.

Wave-Shaping Device For C-R Oscillography

The *Labmarker*, a wave-shaping device for producing timing marks in cathode-ray oscillography, has been developed by **Berkshire Laboratories**, P.O. Box 70P, Concord, Mass.



The device converts a sinusoidal input of up to 30 volts rms into a series of sharp unidirectional pulses. The new Model 1-U Labmarker permits the use of either positive or negative pulses, or both at once.

(Continued on page 85A)

Another PRECISION PRODUCT

Burlington

RUNNING TIME METER

- 9999.9 hour range
- 10,000 hour automatic reset
- —55 to +55° C. operating temperature.

• Designed for use on AC lines where successful servicing of electronic or electrical equipment depends upon the regular servicing of such equipment based on actual operating (or idle) time. Unit has a range of 9999.9 hours and resets automatically at 10,000 hours. Can be supplied for either 120 or 240 volts. 60 cycle operation and has operating temperature of —55 to +55° C.

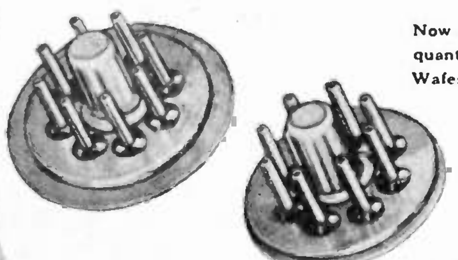
• The Running Time Meter is housed in Burlington's attractive, black bakelite 3" square or 3½" round case.

Write Dept. I-41 for further details.

BURLINGTON INSTRUMENT COMPANY
BURLINGTON, IOWA

E-I HERMETIC SEALING COMPONENTS

NEW! OCTAL PLUG-IN WAFERS



Now available in production quantities, E-I Series OBS Plug-in Wafers feature several important new developments. Hollow keys are form fitting and a new hermetic sealing technique makes the seal practically indestructible, even when the pins are bent. The entire assembly is extremely rigid. For complete data, call or write for the E-I illustrated brochure.

STANDARD SIZES	
MODEL	OUTSIDE DIA.
OBS 146	1.460
OBS 125	1.250
OBS 106	1.060

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840 Barry St. New York 59, N.Y.

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(Continued from page 83A)

Approximate characteristics are: pulse duration, 0.33 cps; pulse amplitude, one-half of the rms input voltage; frequency range, 25 cps to 1 Mc. The oscillograms show the output wave forms of the Model 1-U and a record timed with the instrument. The Labmarker was connected to the *Z* axis terminals of the oscilloscope to produce the short breaks in the cathode-ray trace.

The Labmarker is a self-contained unit which may be plugged into the terminals of a suitable oscillator. No other power source is required. The output binding posts may be used with leads having single or double banana plugs, spade tips, phone tips, or plain wire ends.

The Berkshire Labmarker, Model 1-U, is available immediately from stock, and is priced at $18.50, delivered in the U.S.A.

Resonant Paper Tubulars For Improved IF Filtering

To meet critical **IF** bypass functions in modern receivers, new resonant capacitors are made available by **Aerovox Corp.**, 740 Belleville Ave., New Bedford, Mass.

Such resonant capacitors act as series resonant circuits effectively bypassing undesirable **IF** signals; improve the filtering of **IF** systems without resorting to larger

(Continued on page 87A)

NEW! FREQUENCY AND TIME MEASUREMENTS ACCURATELY . . . CONVENIENTLY!

-using $f=\frac{n}{t}$

ANY FACTOR MAY BE MEASURED FOR FIXED VALUE OF THE OTHER

Universal 6-in-One MEGACYCLE FREQUENCY-TIME COUNTER

Model 801 by **Potter**

Now, the Potter Instrument Company offers all in one equipment, the features heretofore available only in separate counting systems. Two complete counting channels, a 100 kc crystal oscillator time base and unique gating circuits are combined to provide the new FREQUENCY-TIME COUNTER.

FREQUENCY MEASUREMENTS	0 to 1 mc range by counting cycles per pre-selected time or by measuring time per pre-selected count. Accuracy 0.001% minimum.
TIME INTERVAL MEASUREMENTS	0 to 10 seconds ± 10 microseconds.
FREQUENCY RATIO MEASUREMENTS	Ratio of two external frequencies can be measured.
SECONDARY FREQUENCY	100 kc crystal oscillator with divided frequencies available at 10, 1 kc and 100, 10, 1 cps.
TOTALIZING COUNTER	Six decades, pulses 0 to 1 mc, sine wave 10 cps to 1 mc.
DIRECT RPM READING TACHOMETER	Through the use of an external 60 count per revolution photoelectric disc generator an accuracy of ± 1 rpm is obtained.

Please address inquiries to Dept. 5-H

POTTER INSTRUMENT COMPANY
INCORPORATED
115 CUTTER MILL RD., GREAT NECK, NEW YORK

FOR BETTER PERFORMANCE

Output characteristics of television transformers must match the circuit exactly.

Acme Electric transformers are custom engineered to your specifications.

(illustrated) Television Power Transformer with copper shorting band.

BETTER BUY Acme Electric TRANSFORMERS

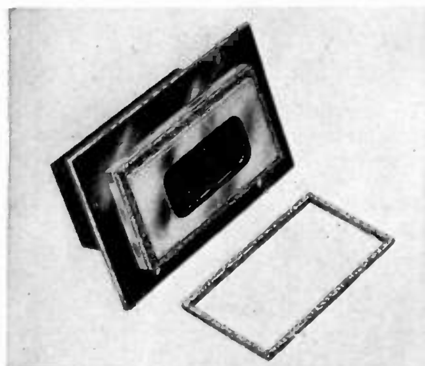
ACME ELECTRIC CORPORATION • 444 Water St., Cuba, N.Y., U.S.A.

Acme Electric TRANSFORMERS

"We have found Metex Electronic Gaskets excellent for HF currents inexpensive to assemble."
Sylvania Electric Products Inc.

Sylvania has been using Metex gaskets for over a year as conductive shields for their TR tubes used in radar and micro-wave ranging equipment.

To quote their experience: "We have found Metal Textile knitted wire gaskets excellent for conducting high frequency currents without boundary arcing. The gaskets are resilient, and yet do not deform too readily. Best of all, the material is inexpensive to assemble through soft soldering techniques."



A Sylvania Electric TR tube showing Metex gasket loose and in position

The properties—electrical and physical—which make Metex Electronic Gaskets effective in this, and other demanding HF and UHF applications are due to their being made from *knitted* (not woven) wire mesh. The hinge-like action of the knitted mesh permits controlled resiliency of the finished gaskets. These can be die-formed to close dimensional tolerances, when required. There is practically no limit to the metal or alloy which can be used.

If the equipment you are manufacturing or designing requires a resilient conductive or shielding material, our engineers will welcome the opportunity of working with you. A letter, addressed to Mr. R. L. Hartwell, Executive Vice President and outlining your requirements, will receive immediate attention.

METAL TEXTILE CORPORATION
637 EAST FIRST AVE., ROSELLE, N. J.

News—New Products

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(Continued from page 85A)

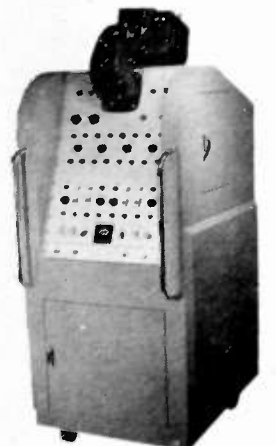
capacitor size and reduce cost as well as bulk. Such capacitors are applied where it is necessary to bypass the **IF** circuit in order to prevent any **IF** frequency currents or voltages (between 425 and 485 kc) from circulating in the system.

Adequate elimination can be accomplished with resonant capacitors acting as series resonant circuit in the given frequency range. Such capacitors will have much lower impedance across the terminals than that of a regular type. A resonant capacitor acts as a very low resistance short-circuit at the **IF** frequency, and therefore smothers any unwanted voltages in the frequency range for which it is designed.

Type *RC* capacitors are available in these standard ratings: 0.05, 0.1 and 0.2 uf, 400 v dc working.

Vibration, Strain, And Stress Analyzer

A completely self-contained electronic instrument for the study of vibration, strain and dynamic stresses has been introduced by the **Electronic Tube Corp.**, 1200 E. Mermaid Lane, Philadelphia 18, Pa.



Known as the H-42A Strainalyzer, the unit records phenomena up to 50 kc, and amplifies these weak signals up to 35,000 times. It makes possible the simultaneous observation and recording of four separate

(Continued on page 88A)

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(Continued from page 87A)

traces on a single 5-inch oscilloscope tube, each appearing in correct time relationship without the necessity of optical alignment.

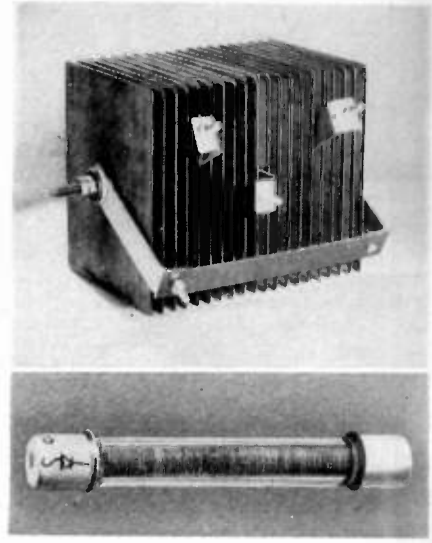
As a typical application, the Strainalyzer can be used to check relative pressures at 4 different points of a gun barrel. In rocket and jet engine testing or research, firing cycle, the chamber pressure, thrust, and temperature may all be recorded simultaneously. All four traces appear simultaneously on the screen for correct time and phase relationship. Recording is accomplished with a Fairchild Oscillo-Record camera.

Model H-42A Strainalyzer is designed for dc bridge excitation from self-contained batteries and has the necessary high-gain dc amplifiers, balance controls, and voltage and calibration controls for each strain gage bridge channel. It is used in conjunction with standard strain gages.

Sweep durations of the linear sweep generator have been extended to 10 seconds for accurate study of extremely low-frequency phenomena. A double-ended input gives flexibility and improved attenuators allow the amplifiers to handle larger signals. Drift of the dc amplifiers is practically negligible. The instrument is not acoustically sensitive. The cathode-ray tube is a four-gun type designed especially for the Strainalyzer.

Two New Rectifiers

The **Rectifier Div., Sarkes Tarzian, Inc.**, 415 N. College Ave., Bloomington, Ind., has announced the availability of their ***"Centre-Kooled"*** power rectifier and enclosed high-voltage selenium rectifiers.



The power rectifiers are available in 10 basic cell sizes and by employing series-

(Continued on page 91A)

News—New Products

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(Continued from page 88A)

parallel connections and combinations, any practical current and voltage range is attainable. The wide range of applications includes battery charging, electro-plating, railway signaling, aviation, elevator control and power supply, cathodic protection and wherever direct current is either required or desirable.

The high-voltage selenium rectifiers are available in two cell sizes and inverse voltage ratings to 5,000 volts and dc current ratings of 5 and 25 ma in half-wave circuits and 10 and 50 ma in full-wave circuits.

Complete information and literature are available from the manufacturer.

HF Low-Power Loss Transmission Line

Communication Products Co., Inc., Broadway & Clark St., Keyport, N. J., announces production of a new Seal-O-Flange transmission line for TV, FM, and other services, using increasingly high frequencies.

Incorporating new Dupont Teflon for insulation, the new transmission line permits operation at frequencies previously impossible because of excessive power loss in lines utilizing insulators of high dielectric loss.

(Continued on page 93A)

SOLVE YOUR **RADAR** CALL PAUL J. PLISHNER **SONAR** SUPPLY PROBLEMS

MAGNETRONS

Tube
2J27
2J31
2J21 A
2J22
2J26
2J32
2J37
2J38
2J39
2J40
2J49
2J34
2J61
2J62
3J31
5J30
714AY
718DY
720BY
720CY
725-A
730-A
728
700
706

KLYSTRONS

723A
707B
417A
2K41

TEST SETS

TS 12
TS 33
TS 35
TS 36
TS 45/APM3
TS 62 3CM
TS 108

SCR 584 PARTS AVAILABLE

BC1056A
BC1058A
BC1086B
RA71A
BC1090A
BC1090B
BC1096A
BC188B
BC1058B
BC1094A
BC1088A

SONAR SYSTEMS

QBF
QBG
QC
QCJ
QCL
QCO
QCS
QCU
WEA

3000 Mc BENCH TEST PLUMBING

SIGNAL GENERATOR, using 417A klystron, 2700-3300 mc. Output approx. 50 mw. 115 vac power supply. With tubes, new $425
10 CM RF PACKAGE, using 2J22 magnetron, freq. range 3267-3333 mc, complete with power supply and pulser giving apx. 20 kv @ 30 A. 1 usec, 1000 PPS. Power output 265 kw. ⅞" rigid coax plumbing thruout. Uses 417A klystron mixer, 6Ac7 preamp. Pulser is 715 B hard tube. Complete RF unit, pulser unit, receiver front end, new, with tubes. Requires 115v. 400 cy ac primary source $385.00
RECEIVER POWER SUPPLY for GL 446 type lighthouse tubes (2C40, etc.) 115 vac, 60 cycles. Panel mounting. Less tubes $32.50
10 CM DISH AND DIPOLE ASSY; apx. 30" parabola, with 360 deg rotating mechanism, and approx. 10 deg. tilt mechanism. Operating from 24 vdc. With selsyn $85
10 CM LOW POWER tunable load with circ. cover $225
CDAX. CRYSTAL MOUNT, type N connectors $17.50
RT-39/APG-5 10 cm. lighthouse RF head c/o Xmtr.-Recvr-TR cavity, compl. recvr & 30 MC IF strip using 6AK5. (2C40, 2C43, 1B27 lineup) w/Tubes.
721A TR BOX complete with tube and tuning plungers ..$12.50
McNALLY KLYSTRON CAVITIES for 707B or 2K28. Three types available $4.00
F 29/SPR-2 FILTERS, Type "N" input and output $12.50
WAVEGUIDE TO ⅞" RIGID COAX "DOORKNOB" ADAPTER CHOKE FLANGE, SILVER PLATED BROAD BAND $32.50
WAVEGUIDE DIRECTIONAL COUPLER, 27 db. Navy type CABY 47 AAN, with 4 in. slotted section $32.50
SQ FLANGE to rd choke adapter. 18 in. long OA 1½ in. x 3 in. guide, type "N" output and sampling probe $27.50
AN/APR5A 10 cm antenna equipment consisting of two 10 cm waveguide sections, each polarized. 45 degrees $75.00 per set.
POWER SPLITTER: 726 Klystron input dual "N" output $5.00
MAGNETRON COUPLING FOR TYPE 720 MAG. to 1½" x 3" Waveguide $35.00
10 CM WAVEMETER WE type B43540 Transmission type. Type N Fittings Veeder Root Micrometer dial. Gold Plated W/Calib. Chart P/o Freq. Meter X66404-A. New $99.50
AS14A/AP-10 CM Pick up Dipole with "N" Cables $4.50
LHTR. LIGHTHOUSE ASSEMBLY Part of RT39 APG 5 & APG 15. Receiver and Trans Cavities w/assoc. Tr Cavity and Type N CPLG. To Recvr. Uses 2C40, 2C43, 1B27. Tunable APX 2400-2700 MCS. Silver Plated $49.50
BEACON LIGHTHOUSE cavity 10 cm with miniature 28 volt DC FM motor. Mfg. Bernard Rice ....$47.50 ea.
MAGNETRON TO WAVEGUIDE Coupler with 721A Duplexer Cavity, gold plated $45.00

⅞" RIGID COAX—⅜" I.C.

⅞" RIGID COAXIAL TUNING STUBS with vernier stub adjustment. Gold Plated $17.50
⅞ RIGID COAX. ROTARY JOINT. Pressurized. Sperry 2810613. Gold Plated $27.50
DIPOLE ASSEMBLY. Part of SCR-584 ....$25.00 ea.
ROTARY JOINT. Part of SCR-584 ....$35.00 ea.
RIGHT ANGLE BEND, with flexible coax, output pickup loop $8.00
SHORT RIGHT ANGLE BEND, with pressurizing nipple $3.00
RIGID COAX, to flex coax, connector $3.50
STUB-SUPPORTED RIGID CDAX. gold plated 5' lengths. Per length $5.00
RT. ANGLES for above $2.50
RT. ANGLE BEND 15" L OA $3.50
FLEXIBLE SECTION. 15" L. Male to female $4.25
MAGNETRON COUPLINGS to ⅞" rigid coax. with TR pickup loop, gold plated $7.50
FLEX. COAX. SECT. Approx. 30 ft. $16.50
CG 54/U—4 foot flexible section ¼" IC pressurized $15.00
⅞ RIGID COAX. Bead Supported $1.20
SHORT RIGHT ANGLE BEND $2.50

23,000 to 27,000 Mc BENCH TEST PLUMBING

½" to ¼" Waveguide

LOW POWER LOAD $20.00
SHUNT TEE $35.00
WAVEGUIDE LENGTHS, 2" to 6" long, gold plated with circular flanges and coupling nuts ....$2.25 per inch
APS-34 ROTATING JOINT $49.50
RIGHT ANGLE BEND E or H Plane, specify combination of couplings desired $12.00
45° BEND E or H Plane, Choke to cover $12.00
MITERED ELBOW, cover to cover $4.00
TR-ATR-SECTION, Choke to cover $4.00
FLEXIBLE SECTION 1" choke to choke $5.00
"S" CURVE CHOKE to cover $4.50
ADAPTER, round to square cover $5.00
FEEDBACK TO PARABOLA Horn with pressurized window $27.50
WAVEGUIDE ½" to ¼" $1.00 per ft. 90° Twist $10.00
"K" BAND DIRECTIONAL COUPLER ....$49.50 ea.

6000 Mc to 8500 Mc BENCH TEST PLUMBING

1½" x ¾" Waveguide

KLYSTRON MOUNT. DB356 complete with shield and tunable termination $125.00
FLAP ATTENUATOR. DB 361 ....$45.00
VARIABLE STUB TUNER $90.00
WVGD. TO TYPE "N" ADAPTER $18.50
WAVEMETER TEE. DB352 ....$32.50
MAGIC TEE $80.00
DIRECTIONAL COUPLER, two hole 25DB coupling, type "N" output $25.00
PRECISION CRYSTAL MOUNT. Equipped with tuning slugs and tunable termination $125.00
TUNABLE TERMINATION. Precision adjust $70.00
LOW POWER LOAD $35.00

4000 to 6000 Mcs BENCH TEST PLUMBING

2" x 1" Waveguide

FLAP ATTENUATOR $48.00
VARIABLE STUB TUNER and Low Power Termination $48.00
WAVEMETER TEE $48.00
ADAPTERS: Choke to choke $18.00
Cover to cover $14.00
Choke to cover $16.00
WAVEGUIDE TO TYPE "N" Adapter $45.00
DIRECTIONAL COUPLER. Two hole type "N" output ..$48.00
KLYSTRON MOUNT. Equipped with tunable termination and micrometer adjust. Klystron antenna tuning $110.00
CRYSTAL MOUNT. Equipped with tunable termination and micrometer adjust crystal tuning $125.00
TUNABLE TERMINATION. Precision adjust $90.00

8500 Mc to 9600 Mc BENCH TEST PLUMBING

1" x ½" Waveguide

3 CM SIGNAL GENERATOR and thermistor bridge, using 723AB oscillator, calibrated variable attenuator, direct reading power meter; reg. 115 vac. 60 cy. power supply. Complete with tubes $125
3 CM SLOTTED LINE, with probe, and including accessories. i.e. low power load, adaptors, etc. TS 12/Unit 2 ....$385
AN/APS-15A "X" Band compl. RF head and modulator, incl. 725 A magnetron and magnet, two 723A/B klystrons (local osc. & beacon), 1B24, TR, recvr-ampl. duplexer, HV supply, blower, pulse xtmr. Peak-Pwr Out: 45 KW apx. Input: 115, 400 cy. Modulator pulse duration .5 to 2 micro-sec. apx. 13 KV Pk Pulse. Compl. with all tubes incl. 715-B, 829B, RKR 73, two 72's. Compl. pkg., new $375

COMPLETE 3 CM RADAR SYSTEM EQUIPMENT

40 KW PEAK TRANSMITTER, pulse modulator, receiver, using 723AB, power supply operating from 115V 800 Cycle, antenna system. Complete radar set neatly packaged in less than 16 cubic feet, less revg type tubes, but incl. all others, in used but excellent condition—This price for laboratories, schools, and experimental purposes only $350

AN/APQ-13 RADAR MANY PLUMBING COMPONENTS AVAILABLE

2J42 PULSE MODULATOR, 14 Kw max. rating, 7 kw min. Plate voltage pulsed 5.5 kv, 6.5 amp. .001 duty cycle. 2.5 usec pulse length max, filament 6.3 v. .5 amp. Includes magnetron mtg. and blower. Requires 3C45 and 2-3B24 ....$75.00
3 CM SECTOR SCANNING ANTENNA, 18" dish, cutler feed dipole, 24 vdc drive motor $75.00
APS-3 RADAR, new and complete, using 725A magnetron $950.00
TS 36 X band power meter 1¼" x ⅝" waveguide; thermistor bridge with indicating meter, complete $175.00
TS 33 X band coax. freq. meter/with resonance indicating meter crystal mount, type N fitting $225.00
WAVEMETER, 8500 to 9400 Mcs., with calibration. Micrometer adjust head. Reaction type $85.00
90 DEGREES ELBOWS, E or H plane, 2½" radius $12.50
90 DEGREE TWIST, 6" long $8.00
BULKHEAD FEED-THRU Assembly $15.00
PRESSURE GAUGE SECTION 15 lb. gauge and press nipple $10.00
PRESSURE GAUGE, 15 lbs. $2.50
DUAL OSCILLATOR-BEACON Mount. P/O APS10 Radar for mounting two 723A/B klystron with crystal mts. matching slugs, shields $42.50
DUAL OSCILLATOR, MOUNT, (Back to back) with crystal mount, tunable termination attenuating slugs $18.50
DIRECTIONAL COUPLER, UG-40/U Take off 20 DB ..$17.50
ROTARY JOINT Choke to Choke $10.00
2K25/723 AB RECEIVER local oscillator Klystron Mount, complete with crystal mount, Iris coupling and choke coupling to TR $22.50
TR-ATR DUPLEXER section for above $8.50
CU 105/APS 31 Directional Coupler 25 DB $25.00
723AB MIXER—Beacon dual Osc. Mnt. w/xtal holder ..$12.00
TR-ATR SECT. APS 15 for 1B24 w/724 ATR cavity w/1B24 & 724 Tubes, Complete $21.00
STABILIZER CAVITY with bellows $21.50
3 CM. 180° BEND, with pressurizing nipple ....ea. $6.00
3 CM. 90° BEND, 14" long. 90° twist with pressurizing nipple ....ea. $6.00
3 CM. "S" CURVE 18" long ....ea. $5.50
3 CM. "S" CURVE 6" long ....ea. $3.50
3 CM. RIGHT ANGLE BENDS, "E" plane 18" long cover to cover ....ea. $6.50
3 CM. CUTLER FEED DIPOLE, 11" from parabola mount to feed back ....ea. $8.50
3 CM. DIRECTIONAL COUPLER. One way waveguide output ....ea. $15.00
CIRCULAR CHOKE FLANGES, solid brass ....55¢
SQ. FLANGES, Flat Brass ....ea. 55¢
APS-10 TR/ATR Duplexer section with additional iris flange $10.00
"X" BAND PREAMPLIFIER, consisting of 2-723 A/B local oscillator-beacon feeding waveguide and TR-ATR Duplex sect. incl. 60 mc. IF amp. $47.50
15 DEG. BEND 10" choke to cover $4.50
5 FT. SECTIONS choke to cover. Silver plated $14.50
18" FLEXIBLE SECTION $17.50
BULKHEAD FEED THRU $15.00
WAVEGUIDE 1" x ½" I.D. per foot $1.50
TR CAVITY for 724 ATR Tube $3.50
724 TR TUBE (41 TR 1) $2.50
SWR MEAS. Section, & L with 2 type "N" output probes MTD full wave apart. Bell size guide. Silver plated $10.00
ROTARY JOINT with slotted section and type "N" output pickup $17.50
WAVEGUIDE SECTION 12" long choke to cover 45 deg. twist & 2½" radius, 90 deg. bend $4.50
TWIST 90 DEG. 5" choke to cover w/press nipple $6.50
WAVEGUIDE SECTIONS 2½ ft. long, silver plated with choke flange $5.75
ROTARY JOINT choke to choke with deck mounting $17.50
3 CM MITRED ELBOW "E" plane unplated $12.00

1¼" x ⅝" WAVEGUIDE

TUNABLE TERMINATION. Precision adjust $65.00
LOW POWER TERMINATION $25.00
MAGIC TEE $45.00
90 DEGREE ELBOWS, E or H plane $12.50
WAVEGUIDE LENGTHS. Cut to size and supplied with 1 choke, 1 cover, per length ....per ft. $2.00
BI DIR-COUPLER Wg output calibrated—25 db nominal $17.50
FLEX SECTIONS, 12" Rubber Coated $14.50
MITRED ELBOW H Plane UG51-UG52 ....$12.00
6" ST. SECT. choke to choke $3.50
APQ 13 CONSTANT Z Rotat. Jnt. $22.50
CG 98B/APQ 13 12" Flex. Sect. 1¼" x ⅝" OD $10.00
WAVE GD RUN 1¼" x ⅝" Gd. consists of 4 ft. sect. w/RT angle bend on one end, 2" 45 deg. bend on other end ..$8.00
X BAND WAVE GD. 1¼" x ⅝" O.D. 1/16" wall aluminum ....Per ft. 75¢
SLUG. TUNER ATTENUATOR W.E. guide, Gold Plated $6.50

APS-2
APS-3
APS-4
APS-6
APS-6A
APS-10
APQ-13
APS-15
APS-31
CPN-8
CEXH
FD MK 4
MARK 10
SA
SC
SD
SE
SF
SG
SJ
SK
SL
SM
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SO
SQ
SW
SCR 518
SCR 520
SCR 533
SCR 545
SCR 663

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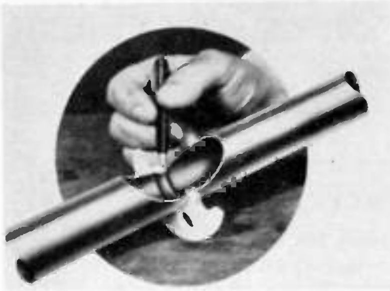
(Continued from page 91A)



This transmission line with Teflon insulators is available in three standard sizes, 7/8 inch, 1 5/8 inches, and 3 1/8 inches. With the exception of gas stops and elbows, the new Seal-O-Flange Super Transmission Line is interchangeable with all other CP fittings including end seals, tower hardware, flanges, "O" rings, inner conductor connectors, and miscellaneous accessories.

Construction features include one-piece inner connector made of a single piece of copper tubing. Teflon disks are locked in place in the inner conductor in order to provide positive, permanent positioning. The cutaway view shows the copper inner conductor of a section of the new transmission line. The one piece insulating disk fits into a depression formed into the tube wall to prevent movement.

Readers may secure complete details, by requesting CP Catalog No. 114.

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The G-R Type 1023-A Amplitude Modulator is designed to produce an a-m signal, with no significant FM, from standard-signal generators.

It is particularly useful for checking the performance of such apparatus as voice ground-to-air communication equipment; air navigation Omnirange and ILS; telemetering and remote control equipment using AM.

It provides a means of adding AM, without incidental FM, to F-M signal generators, so that simultaneous measurements of a-m rejection and f-m response can be made on equipment used in such services as FM, TV, telemetering and remote control.

It also makes an unmodulated test oscillator into a modulated signal source, free from FM.

With most A-M signal generators incidental FM may be as high as 20 kc at 50 Mc and 80 to 100% modulation. Use of the Type 1023-A Amplitude Modulator will result in an improvement of as much as 1000 to 1.

One of its features is a second range of 10.1 to 11.3 Mc. At 10.7 (the RMA standard F-M receiver intermediate frequency) this range provides a gain of 10 with a band-width to the half-points of ±0.6 Mc, gain and modulation percentage being substantially independent of input voltage at levels up to 0.1 volt. Output voltages up to 3 volts can be obtained without serious increase in envelope distortion, with some change in gain.

Modulation up to 80% is provided, either internal at power-line frequency or external from 20 to15,000 cycles. Envelope distortion is less than 5% at 80% modulation. From 1 microvolt to 1.5 volts gain and modulation percentage are practically independent of r-f input voltage.

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