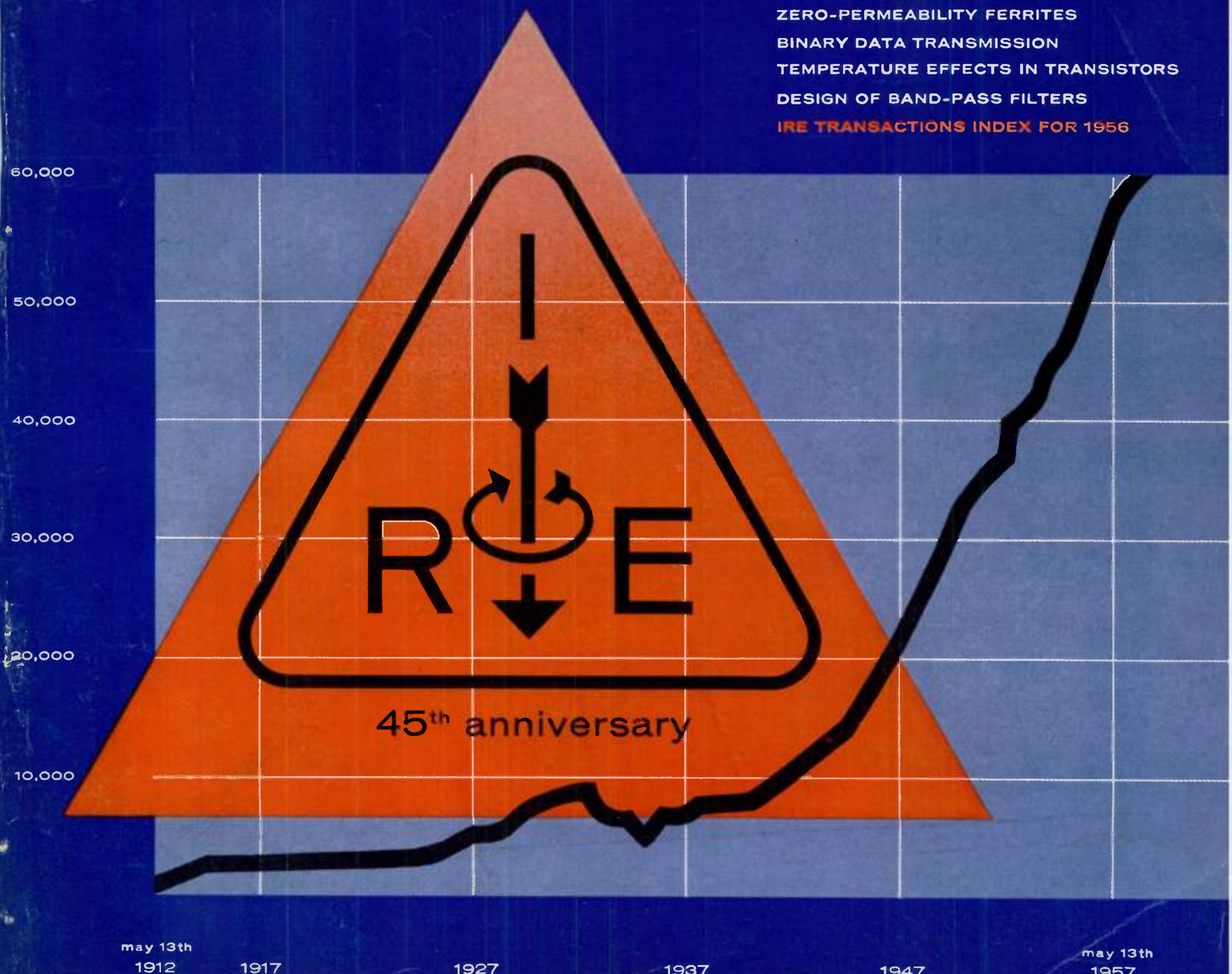
may 1957

the institute of radio engineers

Proceedings of the IRE

in this issue



surface barrier transistors from SPRAGUE

high speed transistors for computer switching circuits

Sprague 2N240 Transistors with their fast response time—in the millimicrosecond range—give reliable operation in switching circuits up to 20 megacycles. The ideal electrical characteristics of these surface barrier transistors permit direct coupling for faster operation than any alloy junction type.

And the 2N240 gives you:

- low saturation resistance
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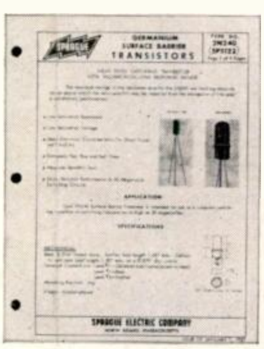
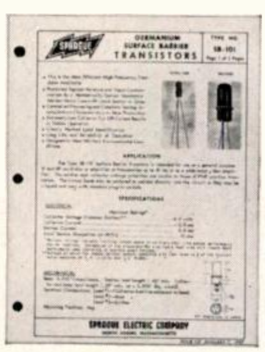
Among these features, the most important to you may well be availability. Sprague is manufacturing 2N240 Transistors NOW in production volumes. You can answer today's transistor needs *today* by specifying Sprague Surface Barrier Transistors!

Write for complete data sheets on Sprague 2N240 Germanium Surface Barrier Transistors and on Sprague General Purpose High-Frequency Surface Barrier Types 2N344/SB101, 2N345/SB102, 2N346/SB103. All are available on letterhead request to the Technical Literature Section, Sprague Electric Co., 235 Marshall Street, North Adams, Massachusetts.





SPRAGUE®

the trademark of reliability

CAPACITORS • RESISTORS • MAGNETIC COMPONENTS
TRANSISTORS • INTERFERENCE FILTERS • PULSE NETWORKS
HIGH TEMPERATURE • MAGNET WIRE • PRINTED CIRCUITS

PROCEEDINGS OF THE IRE May, 1957, Vol. 45, No. 5. 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, one additional copy, $1.25; non-members $3.00. Yearly subscription price: to members, one additional subscription, $13.50; to non-members in 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 96A

This is the eleventh report in a series on various subjects of interest to us at AIL. We bring them to you with the thought that you will find them of interest to you.

Casting A Mote

by Warren Offutt

A few years ago, while reading Wiener's "Cybernetics," we were fascinated by the passages describing the close correlation between the malfunctions that appear in automatic computing machinery, and in men. We have also been interested to find a somewhat similar (but less sophisticated) correlation of environmental problems in St. Luke 6:46, and in our own radar work. The common problem is temporary blindness produced by contamination of the operating environment. It is a popular concept that radar sees through clouds and darkness. This is not always true, however: Figure 1 shows the scope of an S-Band radar (a CAA ASR-3 at LaGuardia Field) during a period of moderately heavy rain. Rain-produced clutter has made the radar virtually useless. We know of four methods that aid the radar in displaying aircraft targets in the presence of such clutter. MTI (Moving Target Indication) of course comes to mind; however, Figure 1 was taken with a MTI equipped radar. The improvement offered by MTI techniques is not insignificant, but is frequently inadequate. The British have used a technique of logarithmic I-F amplifiers in conjunction with fast time-constant presentation to display aircraft targets in the presence of clutter, even though the clutter is 30-40 db or more above the usual dynamic range of the radar receiver. This system however, requires the aircraft signal to be stronger than the clutter signal. It offers no hope for the frequently-encountered case of aircraft signals 10-20 db *below* the clutter level. The third and fourth methods are based on the decided radar symmetry of rain particles contrasted to the decided lack of radar symmetry of aircraft. In both of these methods, the discrimination in favor —of the aircraft target is accomplished in the radar antenna assembly. We call these two methods "crossed-linear polarization" and "circular polarization." In the crossed-linear case the radar antenna is equipped with two pairs of terminals, one pair for transmitting a vertically polarized signal

Figure 1

Figure 2

(for example), and one pair for receiving horizontally polarized signals. The signal reflected from a spherical raindrop is unaltered in polarization and hence does not appear at the receiver terminals. The signal reflected from an aircraft target has its polarization scrambled and hence some signal does reach the receiver terminals. Circular polarization functions in precisely the same fashion except that it is unique in that an orthogonal conversion (i.e., right-to-left hand sense) occurs with reflection from a symmetrical target and consequently only one feed structure (one pair of terminals) is necessary.

At A.I.L. we have designed (or are now designing) circular polarization feeds for many radars working at frequencies between 1000 and 26,000 Mc.

We are particularly gratified by the reports that have come to us from the CAA Air Traffic Controllers' of the effectiveness of the ASR-3 circular polarization modification kits we have installed at LaGuardia, Idlewild, Newark, Washington, Chicago and Boston. Figure 2 illustrates an example of the improved performance they have observed. This photograph was taken about 5 seconds after Figure 1, under similar conditions except that the circular polarization feature was in operation.

What are our circular polarization plans for the future equipments? We are convinced that serious consideration should be given to equipping all new radars operating at frequencies about 1000 Mc and we of course expect to see lighter, smaller, higher power, more broadband and more effective circular polarizers.

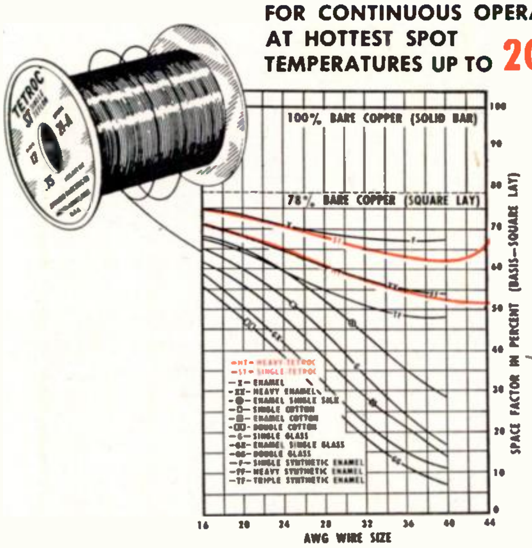
Finally, we expect to follow with much interest the continued use of circularly-polarized (and crossed-linearly polarized) radars in the field against various civil and military aircraft under differing rain and snow conditions. We confidently expect future results to be even more significant that those achieved to date.

(This material was prepared by Warren Offutt who has handled many of these projects).

THESE ARE SPRAGUE'S TWO OUTSTANDING

HIGH-TEMPERATURE MAGNET WIRES

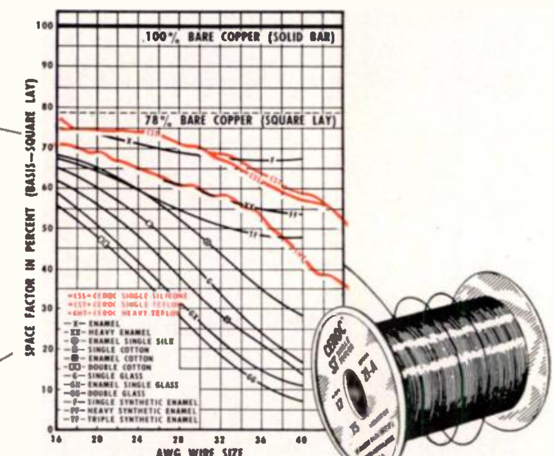
FOR CONTINUOUS OPERATION AT HOTTEST SPOT TEMPERATURES UP TO 200°C



COMPARATIVE SPACE FACTOR OF MAGNET WIRES

Tetroc®

FOR CONTINUOUS OPERATION AT HOTTEST SPOT TEMPERATURES UP TO 250°C



COMPARATIVE SPACE FACTOR OF MAGNET WIRES

Ceroc®

SPRAGUE offers you a choice of 2 *truly* high-temperature magnet wires:

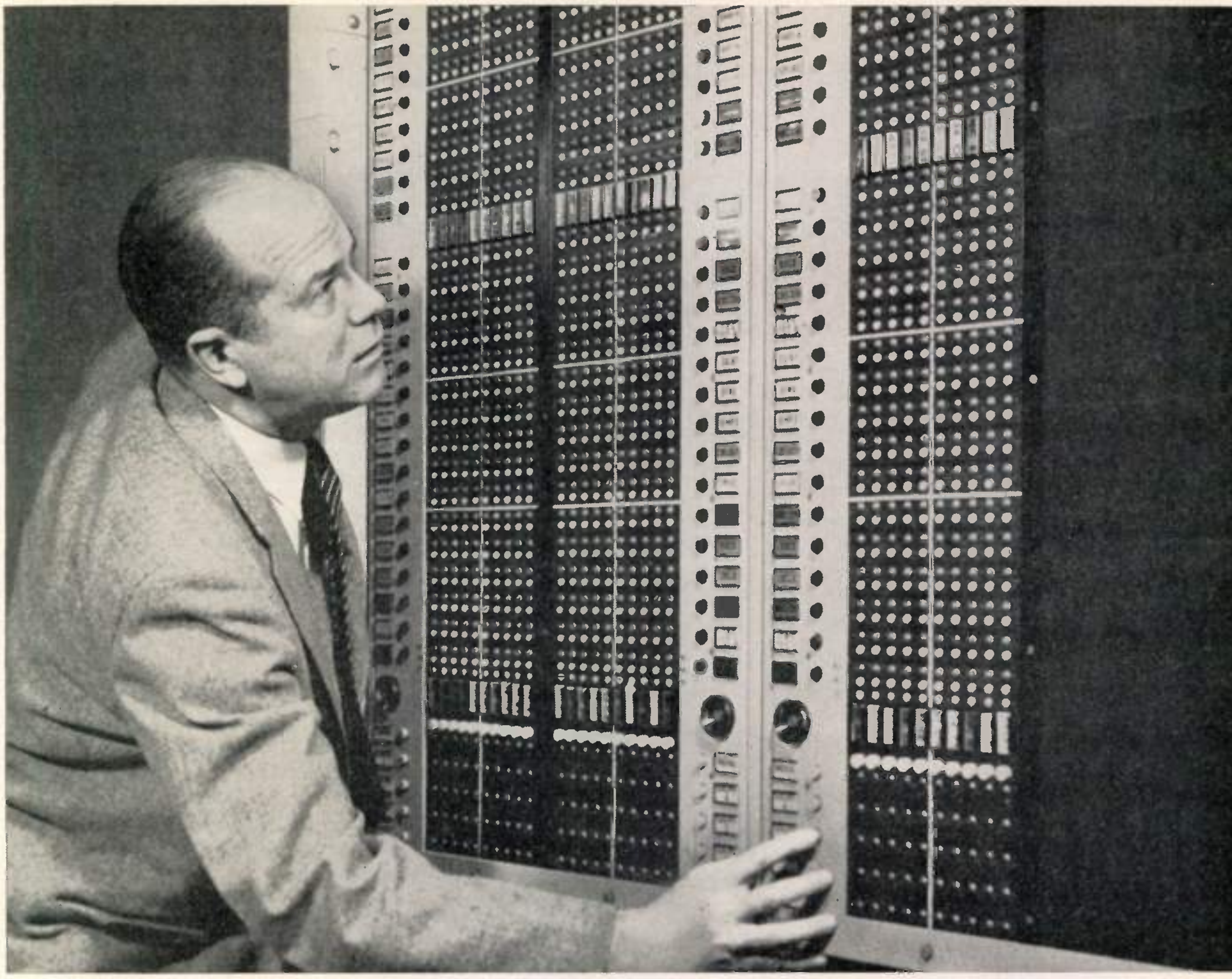
TETROC is recommended for continuous operation at hottest spot temperatures up to 200°C (392°F) and up to 250°C (482°F) for short periods of time. Tetroc, a teflon-insulated wire is available in both single and heavy coatings.

CEROC is recommended for continuous operation at hottest spot temperatures up to 250°C (482°F) and up to 300°C (572°F) for short periods of time. Ceroc wire insulation consists of a ceramic base with either single or heavy Teflon overlays—combining the best properties of both materials.

Both Tetroc and Ceroc Magnet Wires provide extremely high space factors.

FOR COMPLETE DATA WRITE FOR ENGINEERING BULLETIN 405 (TETROC WIRES) 400A (CEROC WIRES).

SPRAGUE ELECTRIC COMPANY • 235 MARSHALL ST. • NORTH ADAMS, MASS.



Bell Laboratories engineer Cyril A. Collins, B.S. in E.E., University of Washington, demonstrates new TV switching control panel for black and white or color. Complex switching connections are set up in advance; in a split-second a master button speeds dozens of programs to their destinations all over the nation. Special constant-impedance technique permits interconnection of any number of broadband circuits without picture impairment.

Telephone science speeds TV enjoyment

Telephone science plays a crucial part in your TV entertainment. An interesting example—one of many—is the latest TV switching center developed at Bell Telephone Laboratories.

Switching centers control the transmission of programs which come to your local TV station over Bell System facilities. To be available exactly on cue, programs must be switched at high speed and with very great accuracy.

To create the new switching center Bell Laboratories engineers borrowed from the switching control art which handles your dial telephone calls. They developed a special control panel which puts complex switching patterns within the easy grasp of one man. By pushing buttons, he sets up—and double-checks—forthcoming network changes far ahead of time. On cue he presses a master button which sends the programs racing to their respective destinations around the nation.

To connect the broadband circuits, the Laboratories engineers developed a new video switch which operates on a constant-impedance principle. The new switch permits the interconnection of any number of circuits, without the slightest impairment of transmission quality.

Thus the technology which serves your telephone also works for your TV enjoyment.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

having your ups and downs?

... if they involve Deposited Carbon Resistors

DALOHM has the answer!

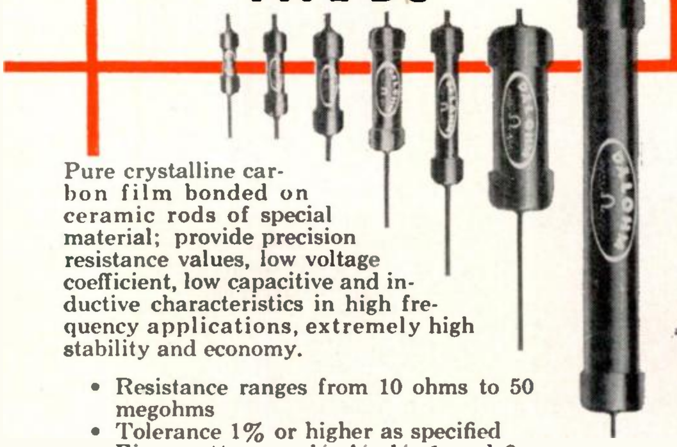
All Dalohm products are carefully designed and skillfully made to assure you of supreme quality and dependability, plus the widest versatility of application.

Outstanding examples of the Dalohm line are these deposited carbon resistors, made for accurate performance where carbon composition resistors are not suited or wire wound resistors too expensive.

You Can Depend On

DALOHM Ω ®

TYPE DC



Pure crystalline carbon film bonded on ceramic rods of special material; provide precision resistance values, low voltage coefficient, low capacitive and inductive characteristics in high frequency applications, extremely high stability and economy.

- Resistance ranges from 10 ohms to 50 megohms
- Tolerance 1% or higher as specified
- Five wattages—1/8, 1/4, 1/2, 1 and 2; seven physical sizes

Write for Bulletin R-24A

TYPE DCH

Essentially the same as type DC except hermetically sealed in a non-hydroscopic ceramic envelope to provide absolute protection against thermal shock, salt water immersion and humidity.

Write for Bulletin R-27A

TYPE DC-5

For extremely high resistance where maximum stability is a prime factor in high voltage applications. Powered at 5 watts; high voltage up to 20,000 VDC; resistance range 1 megohm to 200 megohms; tolerance 1% or up to 10% on request.

Write for Bulletin R-28

JUST ASK US

You are invited to write for the complete catalog of Dalohm precision resistors, potentiometers and collet-fitting knobs.

If none of our standard line fills your need, our staff of able engineers and skilled craftsmen, equipped with the most modern equipment, is ready to help solve your problem in the realm of development, engineering, design and production.

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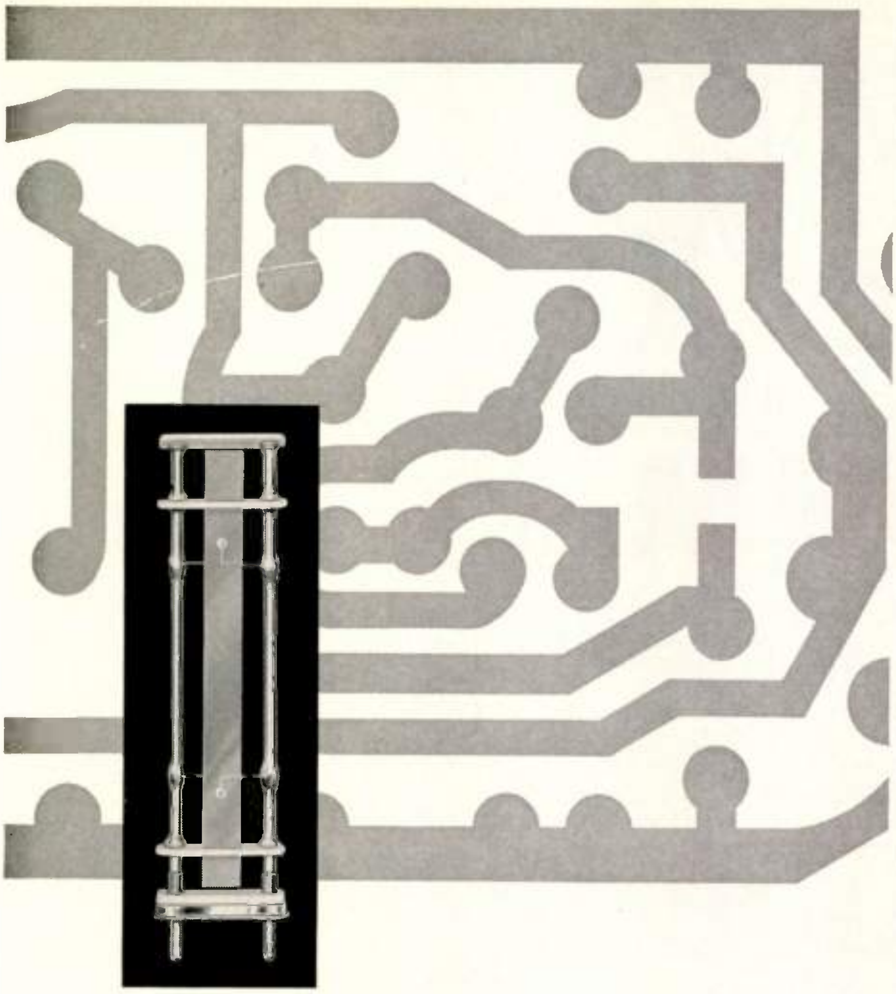


Meetings with Exhibits

● **As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups which include exhibits.**

Δ

May 13-15, 1957
National Aeronautical & Navigational Conference, Dayton-Biltmore Hotel, Dayton, Ohio
Exhibits: Mr. Donald V. Meyers, 6962 Miami Road, Cincinnati 27, Ohio

May 20-22, 1957
Armed Forces Communication & Electronics Association, Convention & Exhibits, Sheraton Park Hotel, Washington 8, D.C.
Exhibits: Mr. William C. Copp, 1475 Broadway, New York 36, N.Y.

June 6-7, 1957
First Annual Conference on Production Techniques, Willard Hotel, Washington, D.C.
Exhibits: Mr. James P. Nigro, 9510 Milstead Dr., Bethesda, Md.

June 17-19, 1957
National Meeting, Professional Group on Military Electronics, Sheraton Park Hotel, Washington, D.C.
Exhibits: Mr. L. L. Whitelock, 5614 Greentree Rd., Bethesda, Md.

August 20-23, 1957
Western Electronic Show and Convention, Fairmount Hotel & Cow Palace, San Francisco, Calif.
Exhibits: Mr. Don Larson, WESCON, 342 No. La Brea Ave., Los Angeles 36, Calif.

September 4-6, 1957
Special Technical Conference on Magnetic Amplifiers, Penn Sheraton Hotel, Pittsburgh, Pa.
Exhibits: Ira Mosher Assoc., 10 Rockefeller Plaza, New York 20, N.Y.

October 7-9, 1957
National Electronics Conference, Sherman Hotel, Chicago, Ill.
Exhibits: Mr. J. S. Powers, National Electronics Conference, 84 East Randolph St., Chicago 1, Ill.

October 16-18, 1957
IRE Canadian Convention, Exhibition Park, Toronto, Ont., Canada.
Exhibits: Mr. E. O. Swan, 512 Bayview Ave., Toronto 17, Ont., Canada.

October 28-30, 1957
East Coast Aeronautical and Navigational Conference, Lord Baltimore Hotel & Seventh Region Armory, Baltimore, Md.
Exhibits: Mr. C. R. Maynard, Westinghouse Electric Corp., Box 746, Baltimore, Md.

November 6-8, 1957
Third Annual Symposium on Aeronautical Communications, Hotel Utica, Utica, N.Y.
Exhibits: Mr. E. E. Mitchell, French Road, Utica, N.Y.

November 11-13, 1957
Third Instrument Conference & Exhibit, Biltmore Hotel, Atlanta, Ga.
Exhibits: Mr. W. B. Wrigley, Eng. Exp. Sta., Georgia Tech., Atlanta 13, Ga.

"We find BUSS Fuses provide the dependable electrical protection we must have for our equipment" . . .

George Thole, CHIEF CONTROL DESIGN ENGINEER
D. W. ONAN & SONS INC., MINNEAPOLIS, MINNESOTA

"Our automatic line transfer units are used to transfer the electrical load from the normal commercial service to the Onan Standby Generating Set should a power failure occur.

"It is essential that our units operate properly in this emergency otherwise there would be a plant shut-down and the possibility of damaged equipment and property. In some cases human lives would be in danger.

"You can see why all the components used in our equipment must meet the very highest standards for dependability.

"Fuses are an integral part of the battery charging circuit which is incorporated into our line transfer controls.

"In fuses, we have found by experience that BUSS Fuses can be depended upon to meet the standards of reliability that are required by our stand-by power units."

You, too, can profit by standardizing on BUSS fuses.

The unfailing dependability of BUSS fuses helps keep equipment operating properly. Whereas, faulty fuses might cause needless burnouts or useless shutdowns,—BUSS fuses can be relied on to operate properly under all service conditions.

To meet your needs, there is a complete line of BUSS and Fusetron fuses, . . . plus a companion line of fuse clips, blocks and holders.

For more information on BUSS and FUSETRON Small Dimension fuses and fuseholders . . . Write for bulletin SFB. Bussmann Mfg. Co. (Division of McGraw-Edison Co.) University at Jefferson, St. Louis 7, Mo.

BUSS fuses are made to protect—not to blow, needlessly

FUSETRON
TRUSTWORTHY NAMES IN ELECTRICAL PROTECTION
BUSS

Makers of a complete line of fuses for home, farm, commercial, electronic, automotive and industrial use.

557

When railroad traffic gets too heavy or complex, a train will be switched onto a siding until the tracks are clear. However, high-speed aircraft in busy traffic patterns over metropolitan areas cannot wait . . .

THERE ARE NO RAILROAD SIDINGS IN THE SKY

Hughes, a leader in the development of highly advanced data processing techniques, is doing research on air traffic control systems which can continuously monitor a high volume of air traffic and precisely control each individual airplane. With this system the time delays, inefficiency and inaccuracies present in manual control are practically eliminated.

Air traffic control represents only one of many projects underway. Confidential new projects . . . many infinitely more complex . . . promise an unlimited future to scientists and engineers in the Hughes Ground Systems Division.

If your experience is in electronic circuit design, logical design, electronic packaging, and radar systems, we invite you to investigate these outstanding opportunities.

the West's leader in advanced electronics

HUGHES

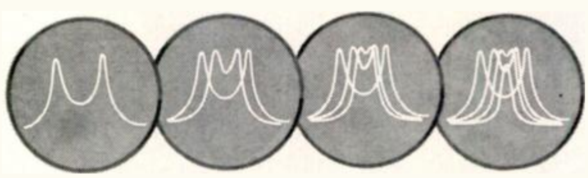
SCIENTIFIC STAFF RELATIONS

RESEARCH AND DEVELOPMENT LABORATORIES

Hughes Aircraft Co., Culver City, California

The oscilloscope that holds traces indefinitely

HUGHES 104 MEMO-SCOPE* OSCILLOSCOPE



SINGLE OR SUCCESSIVE writings can be retained as permanent transients by the 104 MEMO-SCOPE Oscilloscope until intentionally erased. Stored traces may be almost instantaneously erased by front panel push button or external switch.

TYPICAL APPLICATIONS

Study of transient electrical phenomena.
Presentation of tube or transistor characteristics without necessity of repetition.
Display of frequency response curves without the need of a repetitive sweep generator.
Spectrum analysis.
Shock testing.
Detection and measurement of relay bounce or contact noise.
High-speed or low-speed X-Y plotting.
Investigation of transient behavior of power supply regulation.
Study of camera shutter curves.

THE 104 MEMO-SCOPE Oscilloscope is available in the portable model (illustrated in shock test application), 13″ wide, 14″ high, 20″ deep, or in rack-mounted model with standard 14″ × 19″ relay panel. Optional plug-in preamplifiers are available for increased flexibility.

Now you can leisurely view, analyze and compare electrical phenomena lasting no longer than microseconds or minutes...without resorting to photography!

The new Hughes-developed MEMO-SCOPE instrument is a self-contained storage-type oscilloscope which combines the distinct advantage of information retention with the features of a superior quality laboratory oscilloscope.

Because of the high visibility of its brilliant displays, the MEMO-SCOPE Oscilloscope can be used in a well-lighted room without the aid of a viewing hood...where single transients or any number of successive waveforms may be studied at will and photographed as desired.

A hinged camera mount swings photographic apparatus aside for direct-display views.

For additional information or demonstration of the new Model 104, write to HUGHES PRODUCTS • MEMO-SCOPE OSCILLOSCOPE
International Airport Station, Los Angeles 45, California

HUGHES PRODUCTS

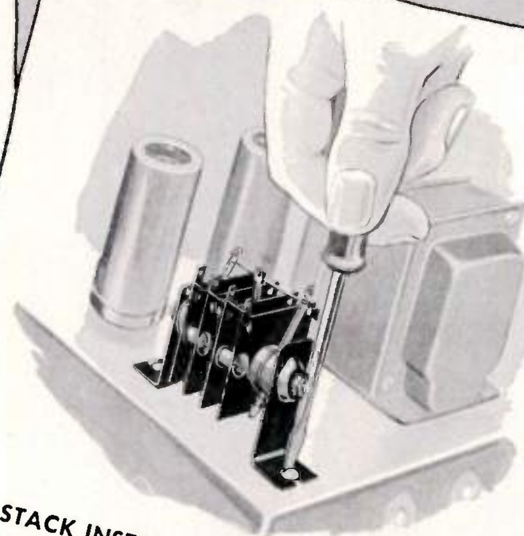
**Trademark of Hughes Aircraft Company*

"G-E SILICON Low Current RECTIFIERS cover the field from ¼ amp up to 18 amps† ... really stay on the job ... and *the price doesn't hurt*"

Every engineer who works with d-c power supplies for assemblies or components of moderate current demand finds a valuable source in the General Electric rectifier line. G-E Silicon Rectifiers–whether the Axial Lead or the Stud Mounting models in single cells, or in Stack assemblies with their remarkable range of current and voltage ratings – are part of our extensive range of rectifier or other semiconductor devices.

The table on output and performance figures only suggests the range of specifications available. For further data, or exact information on rectifiers for your specific needs, call your General Electric Semiconductor representative. Or write *General Electric Company, Semiconductor Products, Section S5457, Electronics Park, Syracuse, N. Y.*

STUD RECTIFIERS. Fit them in wherever you need maximum current and temperature in minimum space with rigid chassis mounting.



STACK INSTALLATION. A typical way of mounting General Electric Silicon Rectifier Stacks. Just two screws fasten the entire assembly in place.

REPRESENTATIVE G-E SILICON RECTIFIER RATINGS

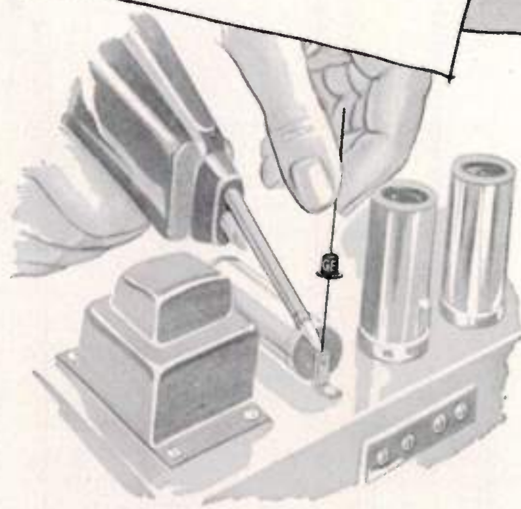
PIV	STUD*	LEAD**	STACKS***
50		1N536	4JA411F Series
100	1N1115	1N537	4JA411A Series
200	1N1116	1N538	4JA411B Series
300	1N1117	1N539	4JA411C Series
400	1N1118	1N540	4JA411D Series
NEW . . . Following is now in production			
500		1N1095	

***Maximum Current**— 600 ma @ 150°C Case Temperature; 1500 ma @ 85°C Case Temperature

****Maximum Current**— 250 ma @ 150°C Ambient Temperature; 750 ma @ 50°C Ambient Temperature

*****Maximum Current**— ½ amp per fin @ 150°C Ambient Temp.; 1½ amp per fin @ 85°C Ambient Temp.

†For higher currents, G-E High Current Rectifiers may be used, or Stacks may be used in parallel.



AXIAL LEAD MOUNTED. See the versatility of G-E Axial Lead models. They're easy to mount anywhere you need low current silicon rectifiers.

CUSTOMER CONFIDENCE 10th SEMICONDUCTOR PROGRESS

Progress Is Our Most Important Product

GENERAL ELECTRIC

Microwave Frequency Meters

by

FREQUENCY STANDARDS

In offering these frequency meters we have endeavored to bring to the electronics industry instruments for frequency measurement which are fairly priced yet without sacrificing a high degree of accuracy resulting from precision manufacture. The frequency determining element of these instruments is a cylindrical resonator with a tuneable choke plunger that provides a smooth and accurate interpolation of frequency. Four models are offered, each model covering a wide frequency range and employing standard waveguide and flanges. Three types, described below, are offered in each frequency range. All models have been designed to use the standard FS Model M-1000 Micrometer Head which has been widely accepted by the electronics industry. Construction is of Invar and accuracy is .01% under laboratory conditions.

Three Types Available

WAVEGUIDE ABSORPTION TYPE I cavity is mounted on the broad face of waveguide. The transmission indication is secured by a crystal loop monitor located opposite the iris input coupling hole. (Type illustrated)

WAVEGUIDE FEED TYPE II cavity is mounted as the termination of a short section of waveguide. The cavity body and output coupling loop are the same as Type I.

WAVEGUIDE TRANSMISSION TYPE III cavity is the same as Types I and II but waveguide is used for input and output coupling.

DESCRIPTIVE LITERATURE AVAILABLE ON REQUEST

TYPE	FREQUENCY RANGE	WAVEGUIDE
Models 8211— 3	8200 to 11500 MC	RG-52/U
Models 7010— 3	7000 to 10000 MC	RG-51/U
Models 5882—1, 2, 3	5800 to 8200 MC	RG-50/U
Models 4458—1, 2, 3	4400 to 5800 MC	RG-49/U

Frequency Standards

General Offices: ASBURY PARK, NEW JERSEY

Address inquiries to
BOX 504

Electron Tube News
—from SYLVANIA

Meeting industry's basic needs—everywhere in electronics

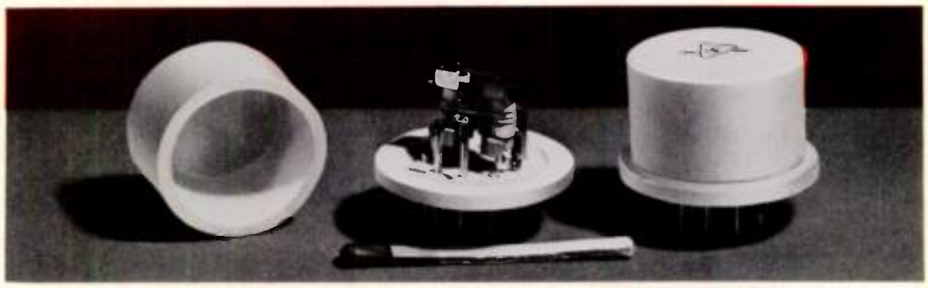
—IN STACKED TUBES

Sylvania and Industry team up to evaluate "Tubes of the Future"

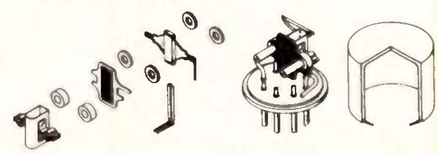
Handmade samples of Sylvania stacked tubes are being made available to interested military equipment manufacturers. These potential users are conducting experiments which provide them with basic experience in the application of these radically new vacuum "tubes of the future."

In turn they are supplying Sylvania with analyses of their findings on the potential advantages of stacked tubes, their resistance to heat, shock, vibration, altitude and humidity. This teamwork, the interchange of data and ideas, will benefit the entire electronics industry. It will speed the full-scale availability of stacked tubes and make possible refinements in design which will take full advantage of the inherent potentials of the stacked tube.

Presently, experimental sampling includes single cathode double triodes and an audio power pentode. Development is underway to include double cathode dual section tubes and RF and audio pentodes in the basic complements planned for military application.



Internal view and completely assembled ceramic stacked tube.



Exploded view of stacked tube demonstrates its rugged planar mount construction utilizing ceramic element spacers assembled on a ceramic stem. Note that element spacings are independent of the tube envelope.

—IN TELEVISION

Type 6CZ5
for 110° vertical deflection

The Sylvania Type 6CZ5 is a beam pentode intended primarily for use as a vertical amplifier or audio amplifier and has controlled heater warm-up for series string operation.

Vertical Deflection Ratings (pentode connection)

Plate V.	315 V max.
Peak Positive Plate V.	2200 V absolute max.
Plate Dissipation	10 Watts max.
Grid No. 2 V.	285 V max.
Grid No. 2 Dissipation	2 Watts max.

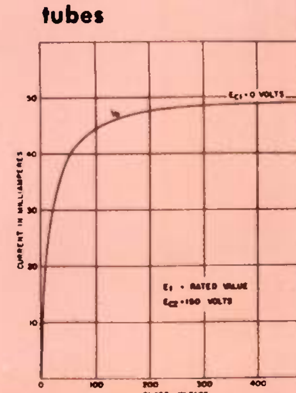
Type 6DQ6A
for 110° horizontal deflection

The type 6DQ6A has been upgraded for higher screen dissipation to meet the need for a horizontal deflection tube in 110° circuits. For series string circuits the type 12DQ6A features controlled heater warm-up time and 600 ma heater current.

Design Center Ratings

Peak Positive Plate V.	6000 volts abs. max.
Plate Dissipation	15 W max.
Grid No. 2 Dissipation	3 W max.
Zero bias plate current	300 ma

New improved video amplifier tubes



ZERO BIAS PLATE CHARACTERISTIC CURVE

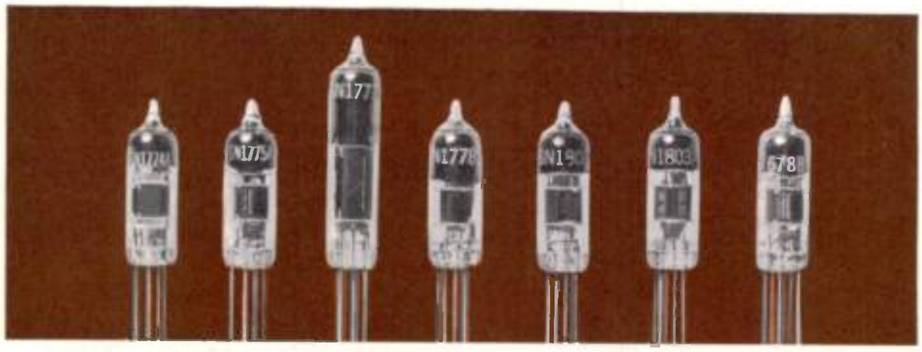
The sharp-cutoff pentode sections of the types 6AW8A and 6BA8A have been redesigned to exhibit a lower knee characteristic as shown in the graph. This permits a wider range of B+ supply voltages. In addition, pentode plates have been redesigned to increase dissipation from 3.0 to 3.25 watts.

Meeting industry's basic needs

—IN GUIDED MISSILES

New Guided Missile Line "giant step" in the evolution of tube reliability

Sylvania offers the first line of tubes specifically designed and tested for guided missile application to meet the industry's need for greater reliability where severe conditions of environmental temperature and vibration exist.



Visual inspection—visual inspection criteria as outlined in MIL-E-1C is applied to Guided Missile Tube production. This highly stringent and definitive spec helps to insure optimum reliability.

This line of tubes and the new levels of reliability it achieves represent the newest step in Sylvania's continuing program of tube reliability.

The Guided Missile Tube Line, developed under a Buship contract, is the result of thorough investigation of the missile field and emphasis in design has been placed on those tube parameters most critical to missile requirements.

Features of the line include new reliability tests such as "white noise," more severe flicker short tests, and more stringent fatigue test.

Of equal significance is the manufacturability of the Guided Missile Tube Line. It is capable of being mass produced on present facilities to meet military requirements in time of need.

7 types meet the basic requirements for Guided Missile applications

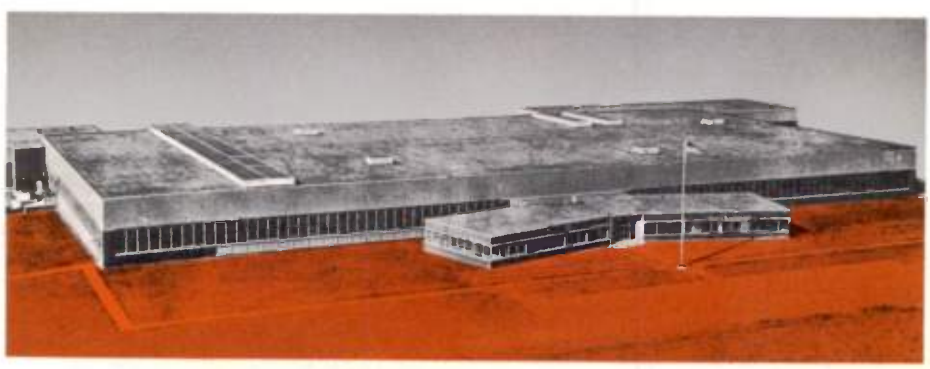
Sylvania exp. type	Description	Nearest Prototype
SN1774A	Sharp cutoff RF pentode	6205
SN1775A	Semi-remote cutoff RF pentode	6206
SN1776A (6788)	Pentode audio voltage amplifier	—
SN1777A	Audio beam power pentode	5902
SN1778A	Medium mu single triode	5977
SN1802A	Double, medium mu triode	6021
SN1803A	Double, high mu triode	6112

—IN FACILITIES

Subminiature plant combines "area cleaning" with "point cleaning" to help achieve greater tube reliability.

Sylvania's plant at Burlington, Iowa, is the most modern plant ever designed, built, and equipped for the exclusive production of "Gold Brand" premium subminiature tubes.

The recent installation of complete air conditioning and air purification adds a new measure of control in the manufacture of the world's most reliable tubes.



"area cleaning"—new installation of complete air conditioning and air filtering keeps areas, such as mounting department, relatively free from dirt and dust.

"point cleaning"—immediate work areas are kept spotlessly clean as in mount assembly. Air currents under hooded tables isolate the mounting area from outside air.

temperature control—plays an important factor in manufacturing processes, such as heater preparation. Makes it possible to control the manufacture of small diameter 26.5 volt heaters for maximum uniformity and dependability.

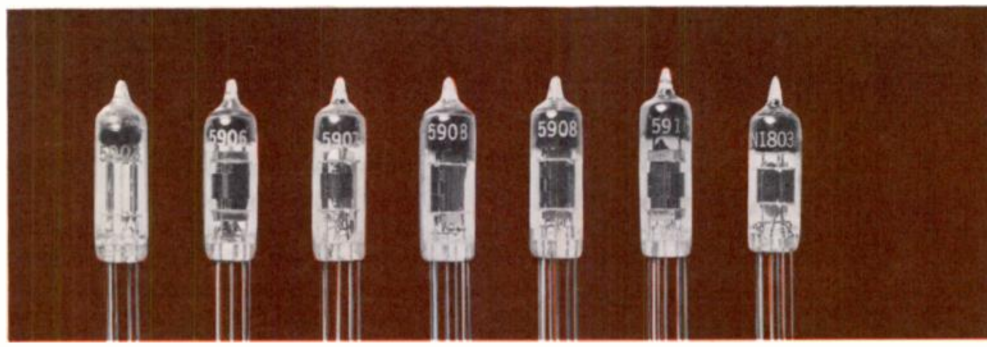
everywhere in electronics

—IN COMMUNICATIONS

New Subminiature Types for 26.5 Volt Systems

Sylvania now offers the designer a line of subminiature tubes designed with 26.5 volt heaters for systems operating from 26.5 volt power supplies. Mechanical and electrical design are combined with a proved quality control program to assure a high degree of reliability. "Burn-in" period before test improves the life expectancy rated at 5000 hours under life test conditions.

In addition to types rated for 26.5 volts on all elements, other types are provided for higher plate voltage operation. Thus the designer will find greater circuit design flexibility through appropriate selection of types to meet his equipment needs.



Type	Description	Heater Voltage	Plate Voltage
5903	Double diode with separate cathodes	26.5 V	Detector
5904	Medium Mu Triode	26.5 V	26.5 V
5905	Sharp cutoff RF pentode	26.5 V	26.5 V
5906	Sharp cutoff RF pentode	26.5 V	100 V
5907	Remote cutoff RF pentode	26.5 V	26.5 V
5908	Pentode mixer	26.5 V	26.5 V
5916	Pentode mixer	26.5 V	100 V

—IN CATHODE-RAY TUBES

Lightweight 17", 90° tube is TV's newest picture tube development

Following closely on the heels of the 110° picture tube, Sylvania announces a 17" tube with 90° deflection and standard neck diameter for portable TV application. The new 17" tube is three pounds lighter than the currently popular 17", 90° types.

Types are offered with either a 450 ma or 600 ma heater, for use with or without ion-trap. This new development makes it possible to design lighter portables while using readily available deflection yokes and existing circuitry.

see next page →

New Flying Spot Scanner Tube

The new Sylvania Type 5BNP16 flying spot scanner tube is a typical development in Sylvania's rapidly expanding special purpose cathode-ray tube program.

It is an inexpensive tube with shorter overall length (10⅝"). It employs low voltage electrostatic focus, an aluminized screen, and operates without ion-trap for simplified installation.

SYLVANIA

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No Postage Stamp Necessary if Mailed in the United States

BUSINESS REPLY CARD
(First Class Permit No. 46687, New York 19, N. Y.)

SYLVANIA ELECTRIC PRODUCTS INC.
1740 Broadway
New York 19, N. Y.

Meeting industry's basic needs everywhere in electronics

—IN TUNER AND IF TYPES

6BN4

Medium mu triode designed for amplifier use in VHF tuners. Characteristics are similar to one section of the 6BZ7. 3BN4 and 2BN4 are series string versions with controlled heater warm-up.

6CY5

Sharp cutoff tetrode designed particularly for amplifier service in VHF tuners. Types 4CY5, 3CY5, and 2CY5 offer controlled heater warm-up for series string circuits.

6DK6

7-pin miniature sharp cutoff pentode. High transconductance at low plate and screen potentials make them especially useful as TV IF-amplifiers. Types 3DK6 and 4DK6 are series string versions.

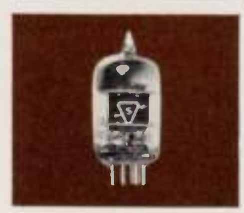
—IN RECTIFIERS

Type 12DF5

The 12DF5 is a T6½ full wave rectifier with separate cathode connections and center tapped heater. Its ratings are comparable to the type 12BW4. Unique construction adds flexibility in rectifier or doubler use and permits operation from 6- or 12-volt heater supply.

—IN COMMUNICATIONS

Type 407A
Type 408A



Type 407A is a T6½ double triode with separate cathodes and a center-tapped heater for 20- or 40-volt operation. Its useful range extends to VHF for use as an amplifier, oscillator, multi-vibrator, or clamper.

Type 408A is a 7-pin, T5½ pentode for 20-volt heater operation. High Gm makes it desirable for amplifier service from audio through VHF ranges.

New Series String reference chart

Here is a chart designed to fit your notebook or hang conveniently on the wall. It is a complete listing of all 600 ma and 450 ma tube types designed for series string operation.

SYLVANIA

SYLVANIA ELECTRIC PRODUCTS INC.
1740 Broadway, New York 19, N. Y.
In Canada: Sylvania Electric (Canada) Ltd.
Shell Tower Bldg., Montreal

LIGHTING • RADIO • TELEVISION • ELECTRONICS • ATOMIC ENERGY

Please send additional information on the items checked below.

- [ ] 110° Deflection
- [ ] 6AW8A—6BA8A
- [ ] Guided Missile Line
- [ ] 26.5 volt line
- [ ] 90° Lightweight 17" Picture Tube
- [ ] 5BNP16
- [ ] 6DK6
- [ ] Series String Chart
- [ ] Tuner Types
- [ ] 12DF5
- [ ] 407A—408A

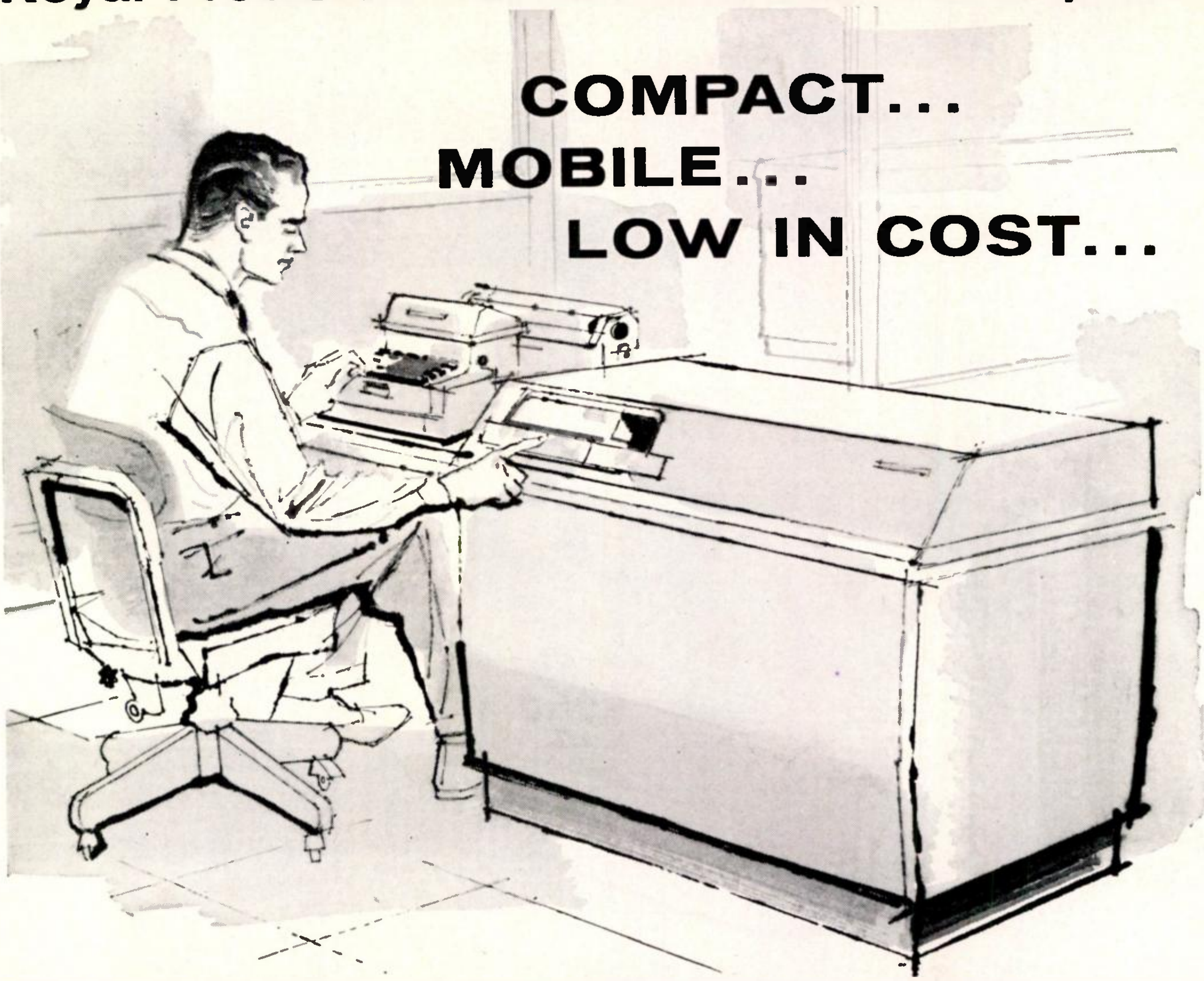
Name __________

Address __________

Company __________

Use this handy business reply card to request additional information on these important new Sylvania developments

Royal Precision LGP-30 Electronic Computer



high-speed computation right at your desk

The result of 20 years' experience in the design of electronic computers, LGP-30 puts you in complete control of your own engineering problems. Used right at your desk, LGP-30 allows you to program your own material without planning in detail. You modify equations on the spot, follow your work to completion. Thus, you eliminate much detailed calculation . . . uncover added time for creative engineering.

Ease of operation. LGP-30's simple command structure offers the same complete internal programming found in computers many times its size and cost. Internally binary, serial, single address . . . LGP-30 enters and reports alpha-numeric information by punched paper tape or keyboard.

Greatest capacity in price range. The most powerful stored program computer of its size yet developed, LGP-30 has a magnetic drum "memory" of 4096 words. Fully automatic, it performs sub-routines . . . executes self-modifying programs.

Exceptional flexibility. LGP-30's wide range of applications includes double precision abstractions; compiling and diagnostic routines; 3-address interpretive routine with floating point abstractions; matrix operations including inverting and Eigen value problems; basic trigonometry and log functions; square root and roots of polynomials.

Nation-wide sales and service. Detailed analysis of your requirements is available through Royal McBee's nation-wide staff of trained applications engineers.

Outstanding features of LGP-30

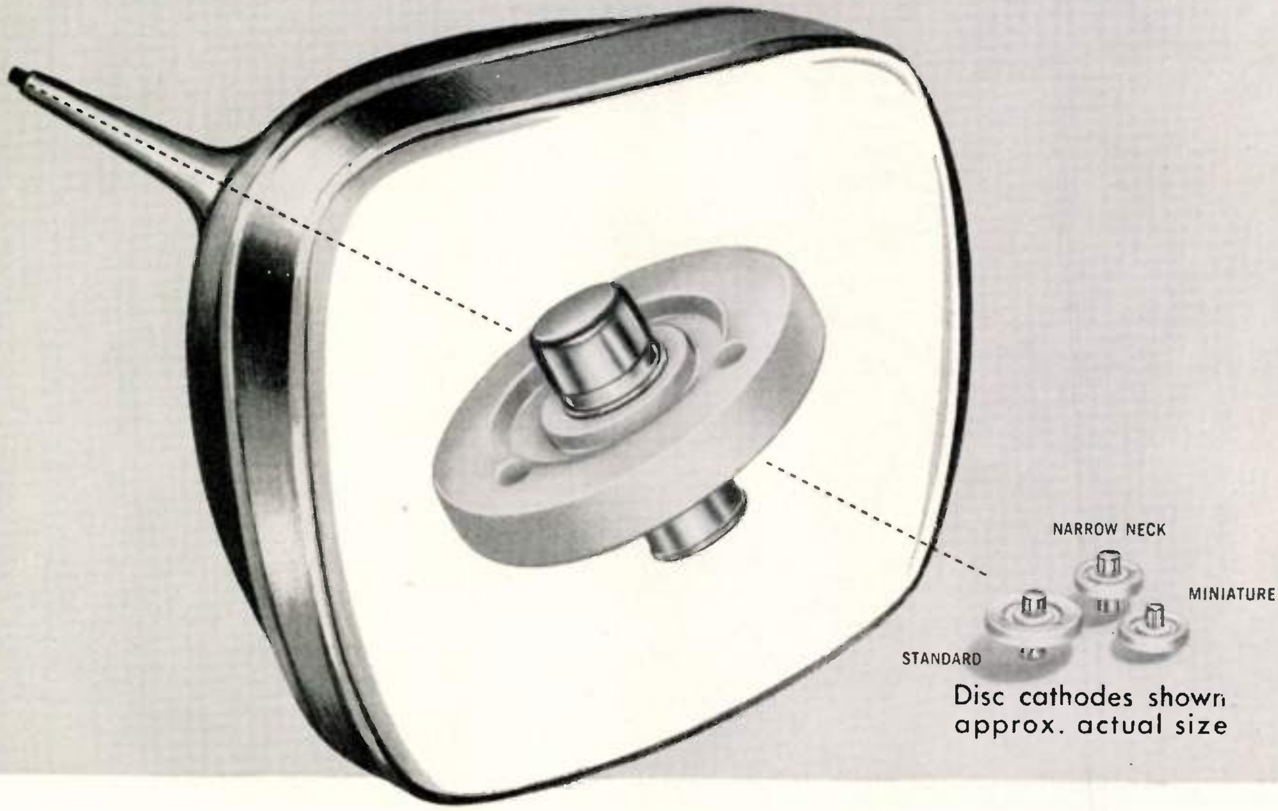
- Operates from regular wall outlet (110 volts AC).
- No expensive installation . . . no external air conditioning.
- Unusually large "memory"— 4096 words.
- Word length: 32 bits, including sign and spacer bit.
- Average access time: 8.5 ms.
- Optimum access time: 2 ms.
- Lowest cost ever for a "complete" computer.
- Nation-wide sales and service.

For further information, write Royal McBee Corporation, Data Processing Equipment Division, Port Chester, N. Y.

ROYAL McBEE
CORPORATION
ROYAL TYPEWRITERS • McBEE BUSINESS SYSTEMS

HERE'S NEW

PRECISION in CERAMICS



High quality of SUPERIOR'S disc cathodes made possible with G-C precision steatites

Superior Tube Company's miniature disc cathodes save space and heater power, reduce cost to users of cathode ray tubes by utilizing slender tube necks. The application required Steatite discs with a heretofore unobtained degree of dimensional accuracy. General Ceramics' progressive manufacturing techniques have made it possible to achieve these critical tolerances and maintain absolute uniformity in volume production runs. Since the inception of Superior's disc cathodes in 1950, engineers at General Ceramics have helped produce more compact, precision components by refining tolerances over 50% on steatite discs. New design criteria on *precision* steatites for your products is available now — write to General Ceramics Corporation, Keasbey, New Jersey, Dept. P.

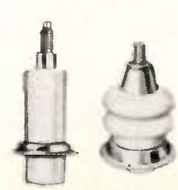
GENERAL CERAMICS

Industrial Ceramics for Industrial Progress Since 1906

FERRAMIC CORES

FERRAMIC MAGNETIC CORES

MAGNETIC MEMORY PLANES



"ADVAC" HIGH TEMPERATURE SEALS

SOLDERSEAL TERMINALS

Dial indicator gage measures the critical "E" dimension.

Precision disc cathodes simplify assembly of TV picture tubes

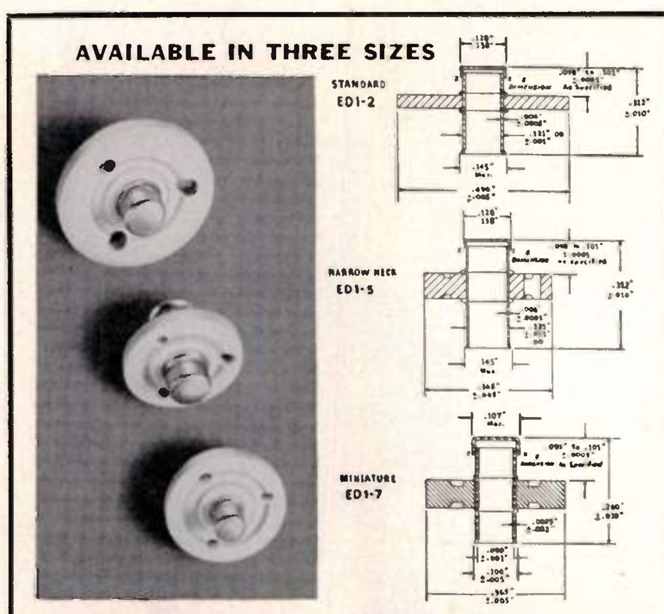
Because Superior Tube guarantees such close tolerance in disc cathode "E" dimension, makers of TV picture tubes can save the time and cost of compensating for variations.

Cathodes can be used universally in different tubes, and are interchangeable with each other during electron gun assembly. This means both manufacturing efficiency and quality control can be significantly improved.

In addition, Superior Tube precision disc cathodes offer these four important advantages:

1. **Separate cap alloy.** *Permits use of best alloys for both cap and shank in varying applications.*
2. **Slight flare of shank opening.** *Easier insertion of heater. Less abrasion of heater coating during normal expansion and contraction.*
3. **Shadow groove in ceramic.** *Inhibits electrical leakage between cathode and No. 1 grid.*
4. **Chemically clean shank interior.** *Minimizes heater-cathode leakage.*

Superior Tube disc cathodes are available in three sizes: standard, narrow neck making possible shorter tubes, and miniature for 3-gun color TV picture tubes. Write for complete information to Superior Tube Co., 2506 Germantown Ave., Norristown, Pa.



HOW SUPERIOR DOES IT—GENERAL CERAMICS CORPORATION, Keasbey, N.J., working for many years with Superior Tube's engineers, has developed mass-production methods resulting in the supply of millions of close-tolerance insulators which have greatly assisted in achieving this uniform "E" dimension. These insulators are produced under rigid quality controls. The cathode shank is double-beaded to the ceramic to insure tight fit. The cap is electrically spot-welded to the shank while held in a precision jig.

Superior Tube
The big name in small tubing
NORRISTOWN, PA.

Johnson & Hoffman Mfg. Corp., Mineola, N.Y.—an affiliated company making precision metal stampings and deep-drawn parts such as those used in the electron guns that go with this new cathode.

Announcing the Raytheon

—a new type of broadband, high power.........

QK520
AMPLITRON
TYPICAL OPERATION (PULSED)

ANODE VOLTAGE	40 kV
ANODE CURRENT	35 amps
PEAK POWER OUTPUT	800 kw
AVERAGE POWER OUTPUT	1200 watts
EFFICIENCY	55%
OPERATING BAND (± 1 db)	1225–1350 Mc
PEAK POWER INPUT	80 kw
PHASE STABILITY WITH ANODE CURRENT	1°/amp

The Amplitron is a new type of tube developed by Raytheon, capable of power amplification at microwave frequencies. Amplification is obtained over a broad range of frequencies with no mechanical or electrical adjustments required. This device is a derivative of the magnetron and retains many of its advantages—such as high operating efficiency, construction simplicity, small size, light weight, low operating voltage. Where efficiency counts in high-power systems, the broadband Amplitron has applications of major significance.

The Amplitron uses crossed electric and magnetic fields, a reentrant beam produced by a magnetron-type cathode, and a non-reentrant broadband circuit matched at either end to external circuits.

Proposed Standard Cores

Magnetics, Inc., Butler, Pa., displayed the complete line of standard sizes of tape wound cores proposed by an AIEE-Sub-Committee at the Winter General Meeting in New York in February and at the IRE Show in March.

This was the first opportunity for users of toroidal tape wound cores to see in one place the size standards which are expected to improve dependability as well as ease of purchasing. All of these Magnetics' "Performance Guaranteed" Tape Wound Cores are in stock in both aluminum and phenolic core boxes, and are available for immediate delivery.

In addition to tape wound cores, the display featured bobbin cores, permalloy powder cores, magnetic shield, and magnetic laminations. All of these products are Performance Guaranteed.

DC Supply

A new dc power supply with a specially designed front panel for rack mounting has been announced by **Electro Products Laboratories,** 4500 N. Ravenswood Ave., Chicago 40, Ill.

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

Designated model "NFAR," the new unit features a new steel panel, 19 inches wide, $10\frac{1}{2}$ inches high and $\frac{1}{8}$ inch thick which permits it to be portable or mounted in racks for permanent and semi-permanent installation.

The power supply operates on 115 volt 50/60 cps input, and is said to produce filtered power with less than $\frac{3}{4}$ per cent ripple at top load. It provides a continuously variable source for voltage from 0 to 32 volts for all current loads from 1 to 15 amperes, according to the manufacturer.

A single control offers continuous voltage adjustments for different load conditions over its specified range. Other features include a circuit breaker, full view meters, pilot light and carrying handles.

Broadband Sweep Generator

A new high-power, completely electronic, broadband sweep oscillator has been announced by **Polarad Electronics Corp.** The Model ESG, provides complete coverage from 1,000 to 15,000 mc at 60 cps with a power output of from 10 milliwatts to one watt, with 7 interchangeable microwave oscillator units.

The new instrument is designed for rapid, dynamic testing of broad and narrowband microwave systems and components such as receivers, amplifiers, preselectors, hybrid junction jammers, intercept equipment, beacons, antennas, T/R tubes, crystal mounts, fixed and tunable filters and complete radar and microwave systems.

Used in conjunction with the Polarad Rapid Scan Ratio-Scope, the instrument can make direct and instantaneous measurements of reflection or transmission coefficients, directly viewable on an oscilloscope as a go-no go device, eliminating the need for point-by-point measurements or for maintaining a constant power input to the device under test.

Pressure Switches

A differential pressure switch designed to make or break electrical circuits when the difference between two pressures is equal to or greater than a predetermined value is one of a new line of Glennite pressure switches announced by **Gulton Industries, Inc.** 212 Durham Ave., N. J. The new instruments were presented for the first time at the Radio Engineering Show.

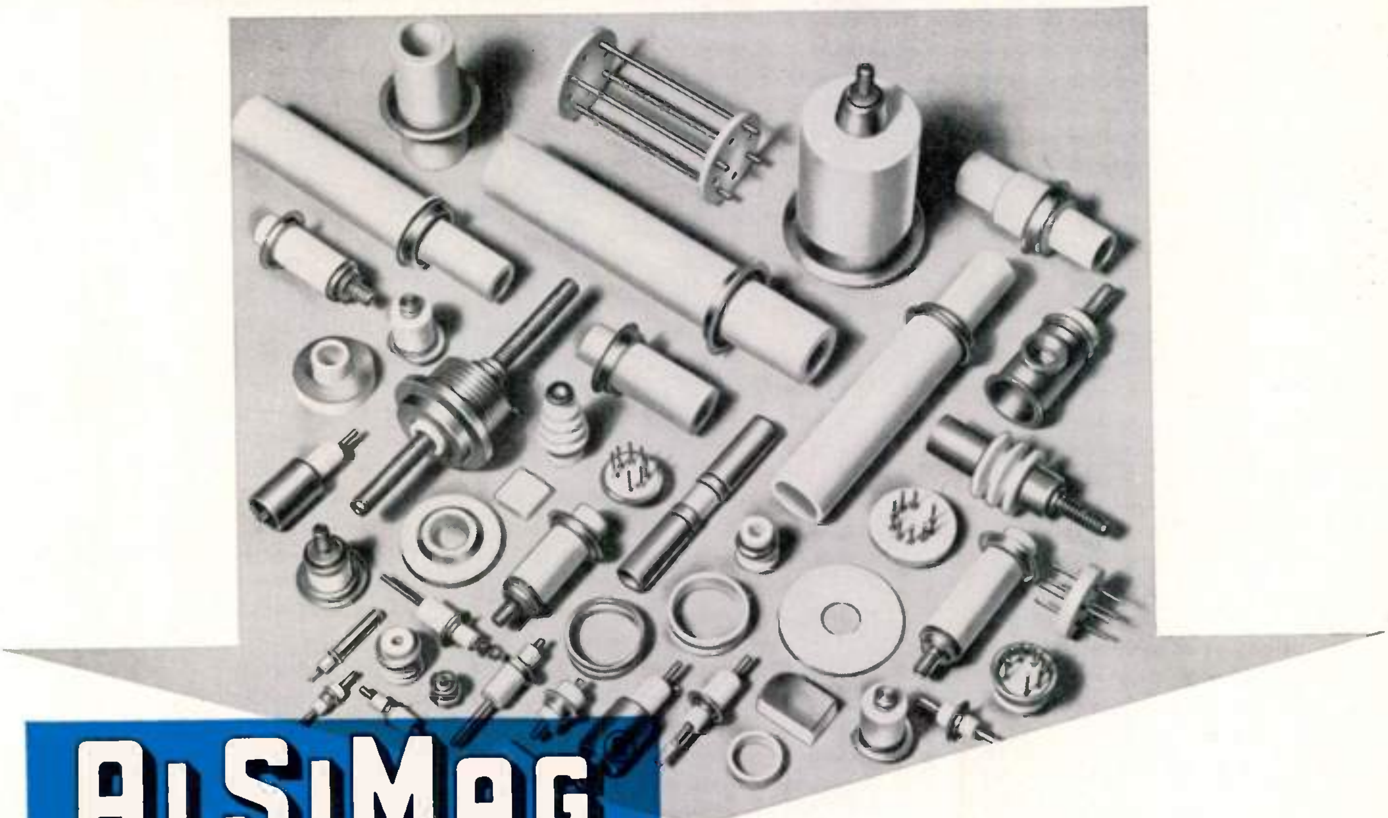
The differential pressure switch, Model 501-A, features low and high operating pressures of 250 psig and 500 psig respectively and weighs 0.75 pound. The pressure differential is sensed by a diaphragm type capsule designed to withstand high overpressure without sacrificing sensitivity.

Other new units in the Glennite line include a gauge pressure switch, Model 301-A, and an altitude switch, Model 101-A. All instruments in this line are designed to pass MIL-E-5272A, Environmental Test.

For further information write: L. C. Oakley, Engineering Sales Manager.

(Continued on page 100A)

dependable



AlSiMag

Hi-Temp Hermetic Seals

Rugged, low-loss AlSiMag Alumina ceramics permanently bonded to appropriate metals to produce superior high temperature seals.

Outstanding electrical and mechanical characteristics over wider temperature and frequency ranges.

Excellent heat shock resistance. High softening temperatures. Vacuum tight. Improved glaze with superior surface resistivity. Greater impact and tensile strengths. Resistant to chipping and spalling. Precision tolerances.

Complete facilities for volume production. Uniform . . . piece to piece. Standard or custom designs. To assure optimum performance of the latter, our engineers cooperate in establishing proper specifications and configurations. Low temperature metal-ceramic combinations available.

For complete information on AlSiMag Metal-Ceramic Seals for either low or high temperature applications, send blueprint with planned installation and operating temperatures, electrical requirements or other relevant data.

AMERICAN LAVA CORPORATION
CHATTANOOGA 5, TENN.
56TH YEAR OF CERAMIC LEADERSHIP

A Subsidiary of Minnesota Mining and Manufacturing Company

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I R E People

Varo Mfg. Co. recently announced the appointment of **W. D. Fuller** (M'47–SM'54) as Director of Research. His first association with Varo was in 1953 when he was employed as a project engineer on airborne power conversion equipment. In 1954 he moved to Tulsa to further his education toward his doctorate degree, and also to open his own consulting firm of SAER Labs. He was appointed Chief Engineer for Varo in June, 1956, and held this post until transferred to this new position due to the expansion of Varo's Research Division.

W. D. Fuller

Mr. Fuller holds a B.S. degree in electrical engineering from Michigan College of Mining and Technology, and a Master of Science degree in electrical engineering from Iowa State. In addition, he has completed the majority of his work on a Doctorate Degree at Oklahoma A&M which he expects to complete this year.

He started his professional career in 1943 with General Electric in their Transmitter Engineering Department as development engineer working on radar components and communication systems.

In 1947, he accepted an instructorship in the electrical engineering department at Iowa State College to gain experience in teaching and to further his education. In 1949, Mr. Fuller became associated with Engineering Laboratories, Inc. in Tulsa, Okla., as a research Engineer and was promoted to chief engineer in 1950. During this time, he gained considerable experience in the fields of sonar and general instrumentation along with control systems for servo-mechanisms.

He is a member of the American Society for Engineering Education and Pi Mu Epsilon.

❖

The appointment of **E. L. Ginzton** (S'39–A'40–SM'46–F'51) to a new position as Assistant to the Chairman of the Board of Directors was announced by Dr. Russell H. Varian, board chairman of Varian Associates, Palo Alto, Calif.

Dr. Ginzton will carry out his assignment on a part time basis. His principal duties as Professor of Applied Physics and Electrical Engineering and as the Director of the Microwave Laboratory of Stanford University will not be affected by the appointment.

A board member of Varian Associates since the Company's inception in 1948, Dr. Ginzton is also a member of Varian's Technical Policy Committee and its President's Advisory Committee.

❖

The appointment of **Nathan Marcuvitz** (S'36–A'37–VA'39–M'55) as Director of the Microwave Research Institute of the Polytechnic Institute of Brooklyn has been announced by H. S. Rogers, president. He succeeds **Ernst Weber** (M'41–SM'43–F'51) who has been named vice-president for research.

Appointed as associate director with Dr. Marcuvitz is **H. J. Carlin** (M'47–SM'50–F'56).

Dr. Marcuvitz was educated at Polytechnic, receiving a bachelor's degree in electrical engineering in 1935, an M.E.E. in 1941, and a D.E.E. in 1946.

He served with the Radio Corporation of America from 1935 to 1940 as a development engineer. From 1940 to 1946 he was a research associate at the Radiation Laboratory of the Massachusetts Institute of Technology. He returned to Polytechnic in 1946 as assistant professor of electrical engineering, and became associate professor in 1949 and professor in 1952. Dr. Marcuvitz is the author of *Waveguide Handbook*, and a contributor to numerous journals and technical publications.

The new associate director, Dr. Carlin, received his bachelor's and master's degrees from Columbia University and his D.E.E. from Polytechnic. He joined the staff of the Microwave Research Institute in 1945. At the time of his appointment as associate director of MRI he held the rank of research professor.

❖

F. M. Viles, Jr. (A'56) has been appointed Vice-President in charge of manufacture of semiconductors of Federal Telephone and Radio Company, Clifton, N. J., a division of International Telephone and Telegraph Corporation.

F. M. Viles, Jr.

Mr. Viles joined Federal in April, 1956, as Technical Director of the Components Division. In July, 1956, he assumed the additional duties of Aircraft Program Director.

Prior to joining Federal Telephone and Radio Company, Mr. Viles had been ad-

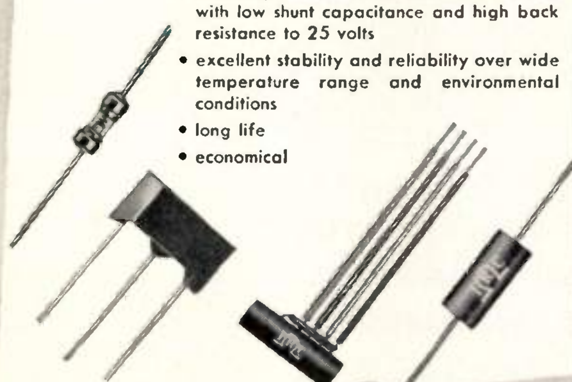
(*Continued on page 24A*)

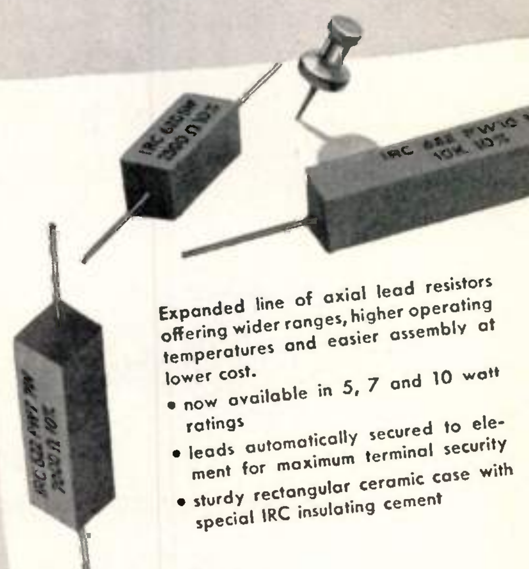
6 NEW ANSWERS TO TODAY'S

New IRC Dual Diodes

New answer to the bulk, higher cost, and assembly problems of vacuum tube diodes in low current applications.

- featuring balanced miniature selenium cells with low shunt capacitance and high back resistance to 25 volts
- excellent stability and reliability over wide temperature range and environmental conditions
- long life
- economical





Expanded line of axial lead resistors offering wider ranges, higher operating temperatures and easier assembly at lower cost.

- now available in 5, 7 and 10 watt ratings
- leads automatically secured to element for maximum terminal security
- sturdy rectangular ceramic case with special IRC insulating cement

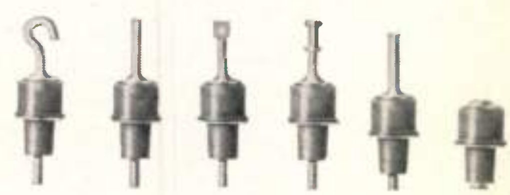
Power Resistor Line

New IRC Distributed Parameter Delay Lines

A compact, more uniform product for time delays of less than 1.0 microsecond at impedance levels of 4000 ohms or less.

- designed for mass production in a continuous process
- featuring high stability and uniform characteristics
- economical

New IRC Hermetic Sealing Terminals



Superior hermetic sealing and insulating performance in miniature units meeting a wide variety of space, electrical, and termination requirements.

- four body designs and six lead types
- excellent resistance to thermal shock, zero water absorption, physically tough, will not crack or craze.
- special fluorocarbon plastic body with superior electrical and mechanical characteristics

Insulated Composition Resistors • Deposited and Boron Carbon Precistors • Power Resistors • Voltmeter Multipliers • Ultra HF and Hi-Voltage Resistors

Wherever the Circuit Says

IRC

Low Wattage Wire Wounds • Resistance Strips and Discs • Selenium Rectifiers and Diodes • Hermetic Sealing Terminals • Insulated Chokes • Precision Wire Wounds • Potentiometers

IRC PLANTS—Asheville, N.C. • Boone, N.C.
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Hycor Division, Sylmar, California
Circuit Instruments Inc., St. Petersburg, Fla. (subsidiary)
Hycor Company, Inc., Vega Baja, P.R. (subsidiary)

INTERNATIONAL RESISTANCE COMPANY

Dept. 371, 401 N. Broad St., Philadelphia 8, Pa.
In Canada: International Resistance Co., Ltd., Toronto, Licensee

Send complete information on ☐ Selenium Dual Diodes, ☐ Delay Lines, ☐ Hermetic Sealing Terminals, ☐ Power Resistors, ☐ Molded Deposited Carbon Resistors, ☐ BW Wire Wound Resistors

Name __________

Company __________

Address __________

City __________ *State* __________

IRE People

(Continued from page 20A)

ministrative assistant to the general manager of Litton Industries, Beverly Hills, California. He is also a former general manager of International Telemeter Corporation, Los Angeles.

Previously, Mr. Viles was associated with the Philco Corporation for eight years, serving in various capacities, including the presidency of the affiliated Philco Service, Inc., New York; and manager of the corporation's industrial field engineering department in Philadelphia. Before World War II, Mr. Viles worked extensively throughout the northwest area in the electric power field and public utilities.

A veteran of Navy service from 1941 to 1945, Mr. Viles was a communications officer in the Mediterranean theatre during World War II.

He had received a degree in electrical engineering from Utah State College. During the war he did advanced work in communication engineering at the Massachusetts Institute of Technology.

Mr. Viles is a member of the American Institute of Management and the Armed Forces Communications & Electronics Association.

❖

Power systems for electronic equipment is a new type of consulting service being offered by J. J. Gano and Associates of Cambridge, Mass. **J. J. Gano** (SM'57) recently formed the organization for this particular service which bridges the field between the industrial power engineer and the electronic circuit designer. It covers power generation, conversion, distribution and control, and marginal-checking and equipment-cooling systems. For the past nine years Mr. Gano was a staff member at the Digital Computer and Lincoln Laboratories of M.I.T. where he was responsible for the development of power systems for large electronic computers including those in Whirlwind and the Sage (semi-automatic ground environment) air-defense system.

J. J. Gano

Mr. Gano received a Bachelor of Science degree in Mechanical Engineering from Harvard University in 1935 and a Master of Science in Electrical Engineering from M.I.T. in 1952. He has authored several technical articles for the American Institute of Electrical Engineers.

❖

Granger Associates has filled two executive posts with the appointment of **W. E. Ayer** (S'42–A'47–M'50–SM'53) as vice-president and director of engineering and

H. D. Kennedy (S'47–A'50–M'55) as production manager. Both men assumed their duties upon the company's occupancy of its new production facilities at 966 Commercial St., Palo Alto, Calif.

Dr. Ayer, a native of Phoenix, Ariz., has been a research associate with Stanford University's Electronics Laboratories for the past six years. There he conducted applied research in military electronic systems, principally in the countermeasures field and covering the vhf, uhf and microwave frequency ranges. In 1955 he was made supervisor of the Stanford group's program in systems development.

After attending the University of Redlands, Dr. Ayer entered Stanford University in 1941. He holds A.B., M.A., E.E. and Ph.D. degrees from Stanford, the latter awarded in 1951.

During 1944–46 he served as an officer with the U. S. Navy and took part in radar maintenance on developmental long-range search systems.

Immediately following his service career he was an engineer with Mackay Radio & Telegraph Co., Palo Alto, Calif., where until 1951 he was responsible for the development and design of antennas and associated distribution systems for the company's point-to-point and ship-to-shore communications systems.

Dr. Ayer is a member of Tau Beta Pi and Sigma XI. He holds call letters W6UXE as a licensed radio amateur.

Mr. Kennedy has joined Granger Associates from Sierra Electronic Corp., San Carlos, where he was production engineer from 1953 through 1956.

Previously he was a production control engineer for the Hewlett-Packard Co. and a production foreman for the AC Spark Plug division of General Motors Corp. at Milwaukee, Wis., where he dealt with the manufacture of airborne bombing and navigational computers.

Mr. Kennedy received a B.S. degree in electrical engineering from the University of Wisconsin in 1949 and served as a Navy aircraft radio technician during World War II. He is a member of Eta Kappa Nu.

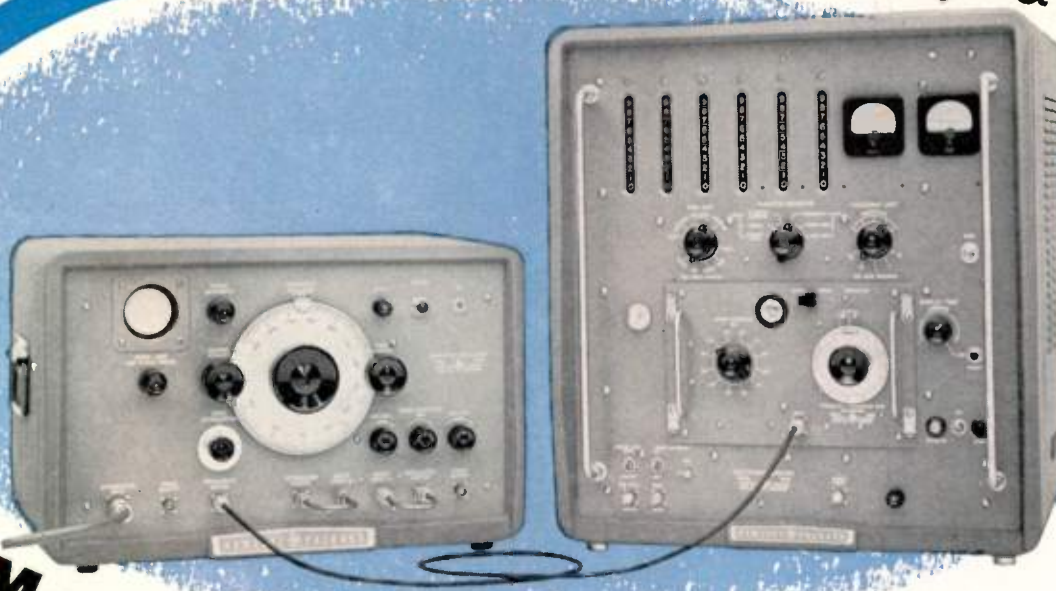
❖

J. E. Scott (SM'53) has been appointed Chief, Reconnaissance Subsystems Branch, Aerial Reconnaissance Laboratory of the Wright Air Development Center. He was formerly Chief of the Reconnaissance Section in the same laboratory.

In this new position, Mr. Scott will be responsible for the development of aerial reconnaissance sub-systems, non-communications types of antennas and for studies required in guiding the Laboratory's effort in these areas.

Mr. Scott has been connected with the development and testing of military airborne electronics systems since 1926.

with new simplicity and



Measure frequency to 12 KMC on pulsed AM, FM, CW and noisy circuits!

Fast, simple, extremely accurate

Eliminates guess-work, "trial-and-error"

Eliminates expensive, complex setups

Includes self-contained oscilloscope

Two compact, portable *-hp-* instruments permit you to measure unknown frequency from zero to 12 KMC with revolutionary convenience and *electronic counter accuracy!*

Hewlett-Packard 540A Transfer Oscillator and 524B Electronic Counter (524B plus proper plug-ins, oscillosynchroscope or detectors) are the only instruments required. Complex instrument arrangements and tedious trial-and-error "guesstimates" are eliminated.

Model 540A contains a highly stable, 100 to 220 MC oscillator generating harmonics to 12 KMC. These harmonics are provided for comparison with the unknown. The comparison device is a diode mixer, amplifier and built-in oscilloscope. In conjunction with *-hp-* 524B, the 540A extends the 524B's range to 12 KMC with no loss of accuracy or convenience.

Simple Measuring Procedure

To measure, with approximate signal frequency known, *-hp-* 540A is tuned until one of its harmonics zero beats with the unknown. The multiplying factor is noted, and the 540A's frequency measured directly on the 524B. This 524B reading, times the multiplying factor, is the frequency of the unknown.

When the signal frequency is totally unknown, a simple calculation employing two or more harmonics determines the proper multiplying factor. Frequency of the unknown is then determined as before.

Pulsed Carrier Frequency

In measuring carrier frequency of pulsed signals, an external oscillosynchroscope is used to display the detected pulse. Zero beat appears as horizontal lines across pulses when the oscillator is tuned to an exact submultiple. Video amplifier frequency response controls can be used to simplify this procedure.*

In working with noisy or AM signals, the *-hp-* 540A response can be narrowed to obtain more accurate indication of zero beat.*

In signals with appreciable FM, the 540A's oscilloscope presents a characteristic pattern pin-pointing upper and lower frequency deviation limits. If FM deviation is present, center frequency may also be determined.*

1/1,000,000 Accuracy

The 540A-524B system's accuracy approaches one part per million for stable CW signals. On pulsed signals,

Precision accuracy, utmost value;

electronic counter accuracy

accuracy is governed by carrier frequency and pulse lengths. On noisy or intense AM signals, the transfer oscillator system with *–hp–* 540A often provides the only means of accurate measurement. Over-all system accuracy is better than 10 times that of the best microwave wavemeters.

Quality Features

Each of the circuit elements of *–hp–* 540A may be used separately by shifting front panel patch cords. Controls are provided for coarse and fine tuning; there is also an electrical vernier with range approximating ± 125 parts per million. The video amplifier has both gain and bandwidth controls. Horizontal input to the internal oscilloscope is power line frequency with phase control. Input attenuation is variable from approximately 20 to 80 db to adjust signal level for optimum mixing level.

**For complete details see your –hp– representative and write –hp– for Vol. 6, No. 12, Hewlett-Packard Journal*

SPECIFICATIONS

–hp– 540A Transfer Oscillator

GENERAL:

Frequency Range: 10 MC to 5,000 MC. (10 MC to 12,000 MC or higher with external detector such as *-hp-* 440A)
Input Signal: CW, FM, AM or pulse
Input Signal Level: Varies with frequency and individual crystals. Minimum input signal approximately 0 dbm to attenuator. Maximum input 0.5 watt average (5 volts into 50 ohms)

OSCILLATOR:

Fundamental Frequency Range: 100 MC to 220 MC
Harmonic Frequency Range: Above 12,000 MC
Stability: Less than 0.002% change per minute after 30-minute warmup
Dial: Six inch diameter, calibrated in 1 MC increments. Accuracy: ± 0.5%
Output: Approximately 2 v into 50 ohms

ATTENUATOR:

Range: Approximately 20 db to 80 db
Input Impedance: 50 ohms, SWR: 1.5 max. at 1 KMC; 3 max. at 5 KMC

AMPLIFIER:

Gain: Variable. Maximum 40 db or more
Bandwidth: Variable. High Frequency: 3 db point adjustable approximately 1 KC to 2 MC. Low Frequency: 3 db point switched from 100 cycles to below 10 KC. Adjustable to above 400 KC
Output: 1 volt rms maximum into 1,000 ohms

OSCILLOSCOPE (Self-Contained):

Frequency Range: 100 cps to 200 KC
Vertical Deflection Sensitivity: 5 mv rms per inch at mixer output
Horizontal Sweep: Internal, power supply frequency with phase control, or external (connection at rear) with 1 v per inch. Sensitivity, 20 cps to 5 KC

MISCELLANEOUS:

Size: Cabinet Mount: 20½" wide, 12½" high, 15¼" deep
Power Supply: 115/230 v ± 10%, 50/1,000 cps, approximately 110 watts
Price: *-hp-* $615.00

–hp– 524B Electronic Counter

FREQUENCY MEASUREMENT: (without plug-in units)

Range: 10 cps to 10 MC
Gate Time: 0.001, 0.01, 0.1, 1, 10 seconds or manual control
Accuracy: ± 1 count ± stability
Reads In: Kilocycles. Automatic decimal.

PERIOD MEASUREMENT: (without plug-in units)

Range: 0 cps to 10 KC
Gate Time: 1 or 10 cycles of unknown
Accuracy: ± 0.3% (1 period) ± 0.03% (10 period average)
Standard Frequency Counted: 10 cps; 1 or 100 KC, 10 MC, or external
Reads In: Seconds, msec, μsec; automatic decimal

GENERAL:

Registration: 8 places, maximum count 99,999,999
Stability: 1/1,000,000 short term; 2/1,000,000 per week. May be standardized against WWV or external 100 KC primary standard
Display Time: Variable 0.1 to 10 seconds, or held indefinitely
Price: $2,150.00

PLUG-IN UNITS:

-hp- 525A, converts for frequency measurement, 10 cps to 100 MC. Price $250.00

-hp- 525B, converts for frequency measurement, 100 MC to 220 MC. Price $250.00

-hp- 526A, converts for high sensitivity frequency measurement, 10 cps to 10 MC. Price $150.00

-hp- 526B, converts for time interval measurement, 1 μsec to 10^7 seconds. Price $175.00

-hp- 526C, improves period measurement accuracy, 0 to 10 KC. Price $225.00

Data subject to change without notice.

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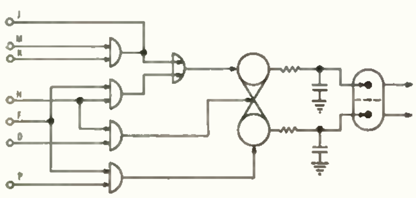
EECO Data Sheet

- Gray-to-binary code conversion with new EECO Computer-Series plug-in (Y-103).
- Small Engineering Company Organization—a philosophy and method for tailoring operating procedures.

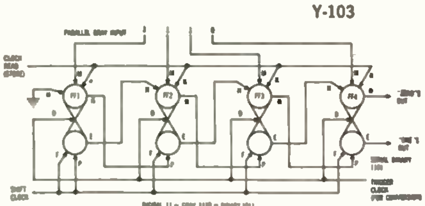
Y-103

Gray-to-binary Code Converter

Included among the many functional circuits available in EECO's new Computer-Series plug-ins is a Flip-Flop—Shift Register Element (Y-103) that is



Y-103



adaptable for use as a composite Gray-to-binary code converter and shift register. For this use, the Gray number is read into the shift register in parallel form (for example, from a code wheel or flip-flop register), converted internally to a binary number, and then shifted out in serial form.

In the schematic illustration, the input Gray number is 1110, corresponding to decimal 11 and binary 1011. The Gray-to-binary conversion is based on the rules that:

1. The most significant digit is identical in each code system.
2. Each succeeding Gray digit is complemented if the preceding *binary* digit is a 1, or repeated if the *binary* digit is a 0.

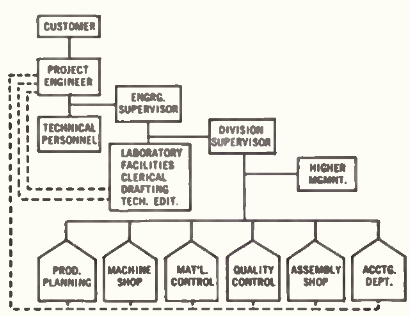
Trigger clock (conversion) pulses cause the Gray-to-binary conversion and must be one less in number than the number of digits in the Gray code. After conversion, the binary number is shifted out serially by shift clock pulses

More detailed information on this and other applications of EECO Standard-Series and new Computer-Series plug-ins is available in Catalog No. 856-A. Write for your copy.

Tailor-Making a Company Organization

Each of the two classical types of company organization — "Project" and "Departmental" — has weak as well as strong points. By combining the strong and eliminating the weak points of the two (insofar as practicable within the limits imposed by the type of company activities and objectives involved) it is possible to evolve a third system superior to either of the original two.

This complete analysis and integration process is described in detail in the reprint of a talk delivered by T. W. Jarmie, president of Engineered Electronics Co. and a director of Electronic Engineering Co. of California, before the Professional Group on Engineering Management of the IRE. The final operation chart developed by this process (illustrated below) reflects the operating procedure that has proven so successful at EECO.



Although this talk was first delivered in 1955, so much recent interest has been shown in the subject that reprints of the paper have again been made available. Ask for Reprint J-2.

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Professional Group Meetings

Aeronautical & Navigational Electronics

Dayton—January 10

"Current Engineering Aspects of Space Flight," Darrell Romick, Goodyear Aircraft Co.

Audio

Boston—February 7

"Audio Transmission by Pulse Techniques," F. M. Young, EPSCO, Inc.

Milwaukee—January 14

"New Adventures in Electronics," C. N. Hoyler, RCA Laboratories.

Broadcast Transmission Systems

Boston—February 14

"Care of Transmitter Tubes," Jesse Sadler, Westinghouse Electric Company.

Boston—January 3

"New Monitor for TV Transmitters," Charles Cady, General Radio Company.

Circuit Theory

Philadelphia—January 22

"Design and Application of Crystal Filters," D. I. Kosowsky, Hycon Eastern, Inc.

Communications Systems

Washington, D. C.—January 28

"Multiple Signal Correlators," B. S. Melton, U. S. Air Force, Office of Atomic Energy.

Washington, D. C.—December 11

"Impressions of Poland from the CCIR Warsaw Conference," E. W. Allen, Federal Communications Commission; and "Impressions of Poland from the CCIR Warsaw Conference," H. E. Dinger, Naval Research Laboratory.

Washington, D. C.—November 28

"Reliability of Communications Systems," J. A. Scanga, Aeronautical Radio, Inc.; and "Reliability of Communications Systems," S. R. Scott, Aeronautical Radio, Inc.

Washington, D. C.—October 15

"Operations Research of Communications Systems," R. V. Higdon, Haller, Raymond & Brown, Inc.; and "Operations Research of Communications Systems," George Jacobs, United States Information Agency (VOA).

(Continued on page 42A)

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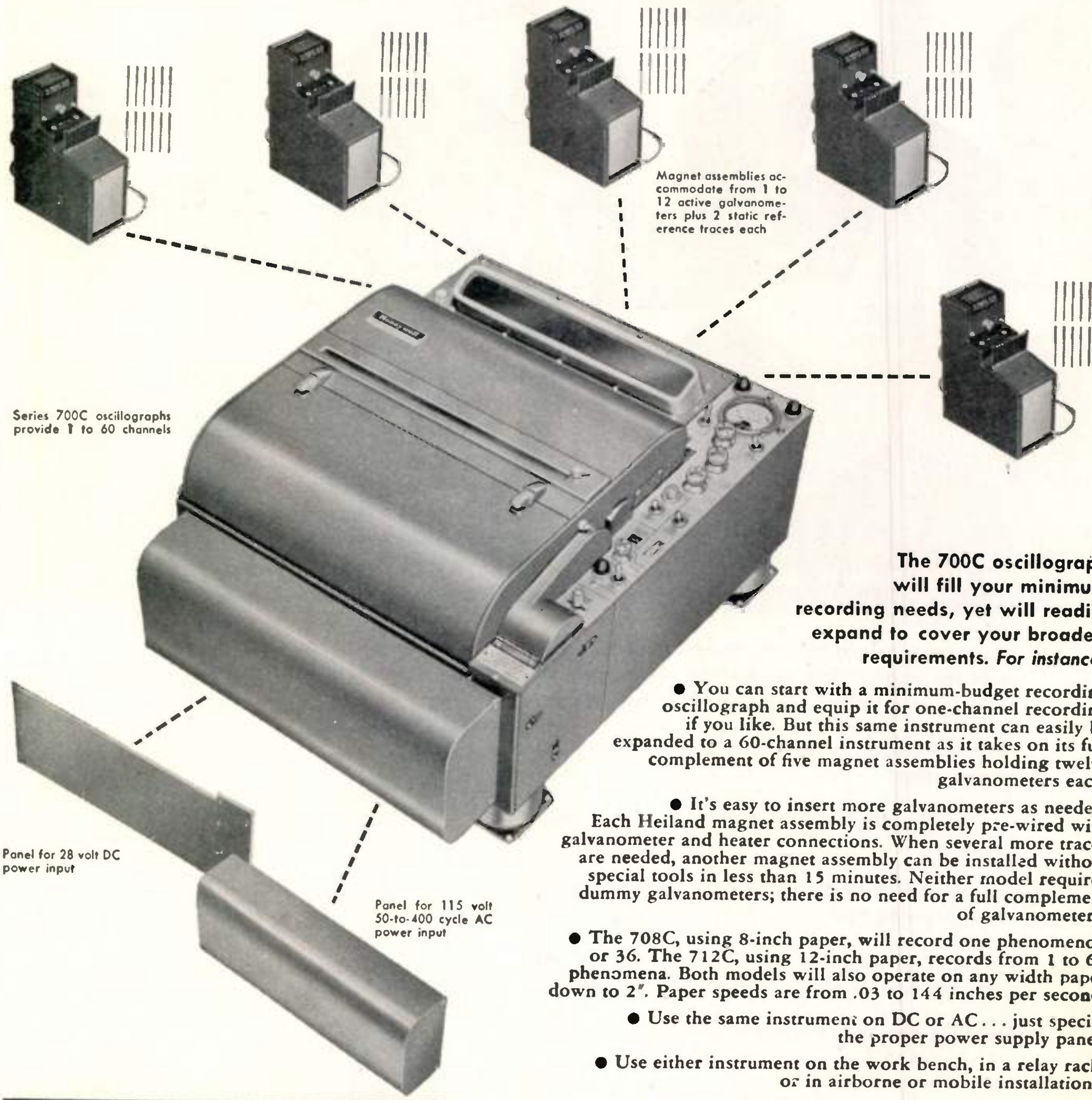

The 700C oscillograph will fill your minimum recording needs, yet will readily expand to cover your broadest requirements. *For instance*:

- You can start with a minimum-budget recording oscillograph and equip it for one-channel recording if you like. But this same instrument can easily be expanded to a 60-channel instrument as it takes on its full complement of five magnet assemblies holding twelve galvanometers each.
- It's easy to insert more galvanometers as needed. Each Heiland magnet assembly is completely pre-wired with galvanometer and heater connections. When several more traces are needed, another magnet assembly can be installed without special tools in less than 15 minutes. Neither model requires dummy galvanometers; there is no need for a full complement of galvanometers.
- The 708C, using 8-inch paper, will record one phenomenon or 36. The 712C, using 12-inch paper, records from 1 to 60 phenomena. Both models will also operate on any width paper down to 2". Paper speeds are from .03 to 144 inches per second.
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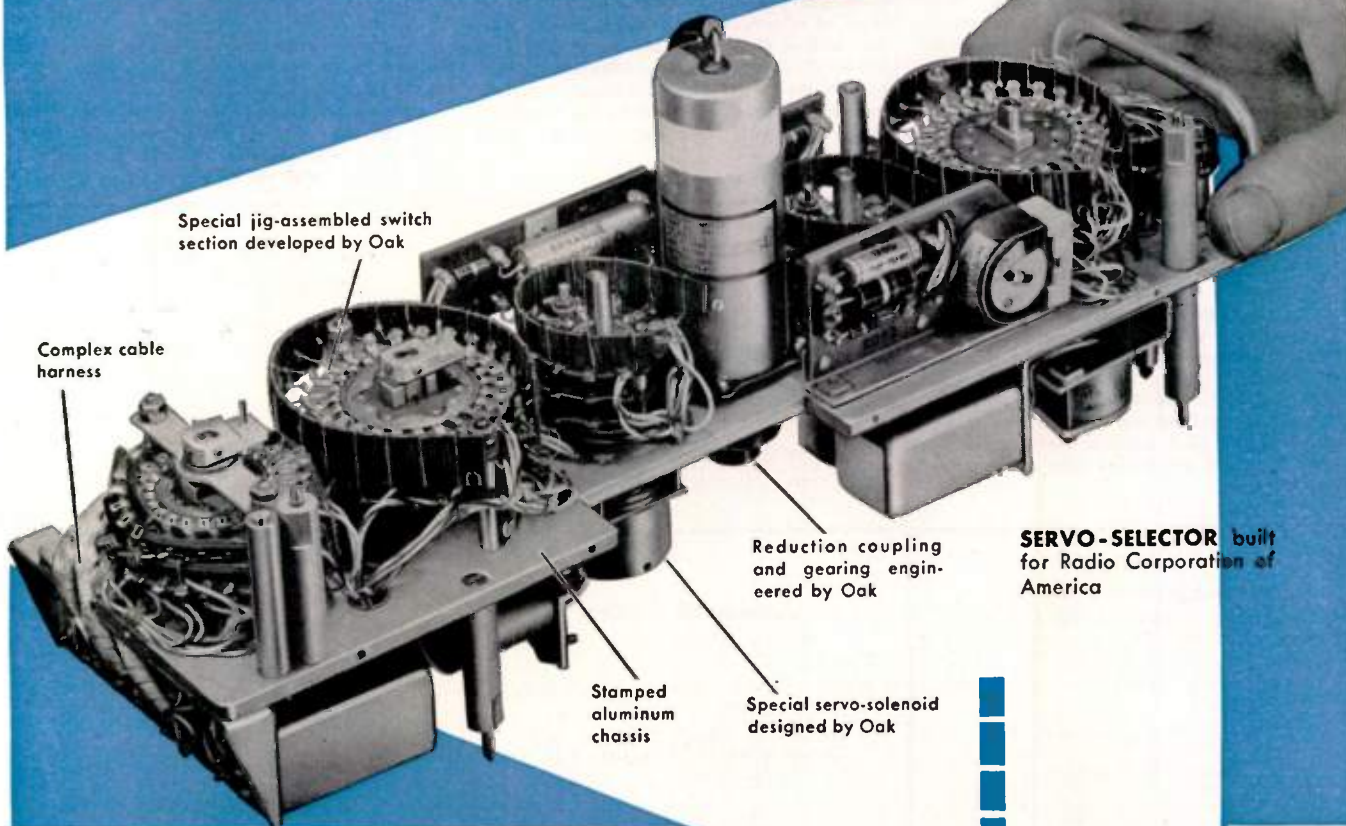

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In the servo-selector, shown above, Oak engineers solved three different design problems. They developed (1) an ingenious jig-assembly for fastening the clips to the switch sections, giving exceptional accuracy in placement and retention; (2) lower speed operation through special reduction coupling and gears; and (3) special solenoids for positive clutching.

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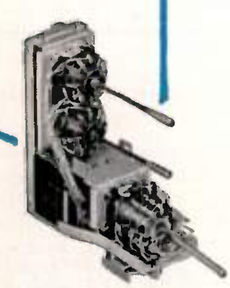
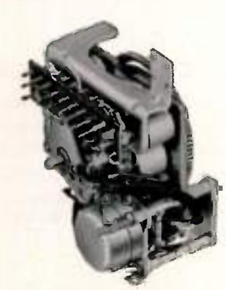


CHANNEL SELECTOR switch built for Sylvania Electric Products Inc.



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PUBLICATIONS

Every Group publishes a magazine which is called TRANSACTIONS of the Professional Group, generally on a regular quarterly schedule. The TRANSACTIONS serve to preserve and disseminate the body of knowledge that constitutes the fields of interest of the Groups. All editions are distributed without additional cost to members who have paid the annual assessment.

The CONVENTION RECORD covering the sessions presented at the IRE National Convention is furnished without further charge to the members of Groups who have paid assessments.

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The IRE Professional Group is established under a constitution within the framework of the IRE. The constitution defines the technical field of interest of the Group, establishes committee structures, describes broadly its functions and procedures, and fixes a minimum level of activity. The management of an IRE Professional Group is in the hands of its Administrative Committee, the officers and members of which are elected annually. The IRE provides financial assistance to the Groups in accordance with their activity and current needs.

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Mr. Joseph General, 6019 Highgate Drive, Baltimore 15, Md.

21 Transactions, 5 Newsletters, *5, *6, *8, & *9, and *Vol. ANE-1, Nos. 1, 2, 3 and 4. Vol. 2, No. 1-4; Vol. 3, No. 1-2-3-4.

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Technical advances in antennas and wave propagation theory and the utilization of techniques or products of this field.

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THE INSTITUTE OF RADIO

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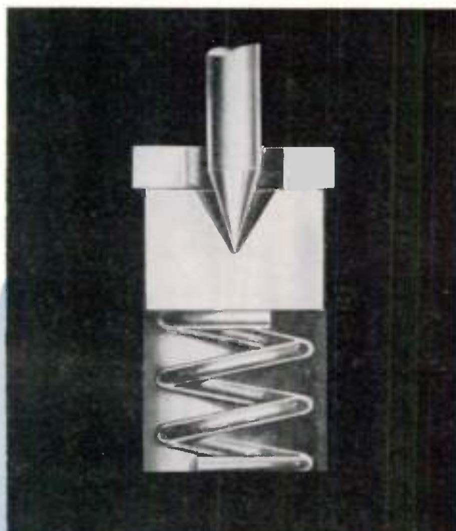

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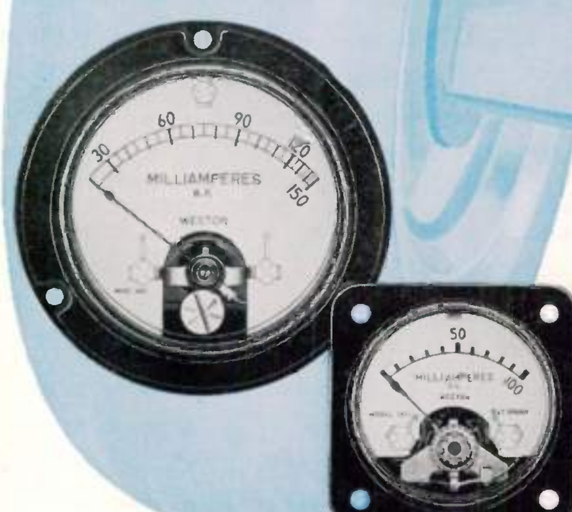

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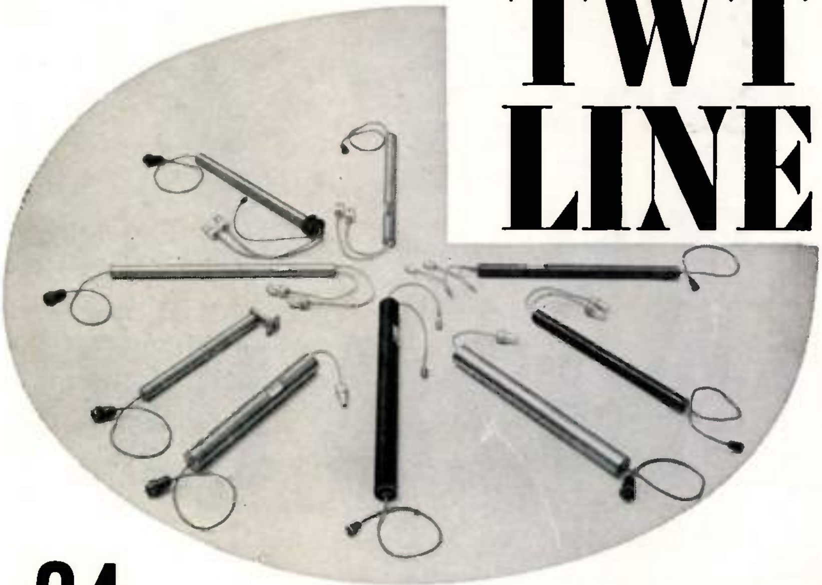


24 types in production by the pioneer and leader in design and manufacture

(delivery: normally 4 to 6 weeks)

AMPLIFIERS

	Frequency, kmc					
	0.5-1	1-2	2-4	4-8	8-12	12-18
Broadband						
10 mw standard	x	x	x	x	x	
10 mw medium noise		x	x		x	
10 mw low noise		x			x	
1 watt standard			x	x	x	
Dispersive						
standard	x	x	x	x		
Backward Wave						
standard			x		x	

OSCILLATORS

	0.5-1	1-2	2-4	4-8	8-12	12-18
>10 mw standard			x	x	x	x

Many special modifications of these tubes have been made to customer specifications. Inquire about your particular problems.

Besides the industry's broadest line of traveling-wave tubes shown above, there are other types under development including different *frequency bands* as well as *p-m periodic focusing*. A technical staff is available for special research and development.

A comprehensive engineering handbook and catalog is waiting for your request. Write for your copy today.

MANUFACTURE
DEVELOPMENT
ENGINEERING
DESIGN
RESEARCH

ENGINEERS: If you are interested in electron devices and microwave techniques, why not consider sharing in our exponential growth? Submit resume to Dick Huggins.

HUGGINS LABORATORIES

MENLO PARK 2 CALIFORNIA

Doing it Yourself?

It's Easier to Standardize on

Jeffers R.F.

Choke Coils

You can eliminate tedious, expensive hand assembly from miscellaneous forms and wires by using completely assembled standard Jeffers R. F. choke coils. You will save time, labor and money by stocking the broad range of Jeffers coils just as you do resistors, capacitors and other similar electrical components.

Jeffers coils are made of highest quality materials ... using insulated copper wire windings encased in husky molded jackets. All windings are soldered to leads ... no chance of shorted end turns.

Enjoy the benefits of superior, standardized components in your circuits. Jeffers Electronics offers you a full line of R. F. choke coils with a complete range of inductance values ... ready for immediate delivery. Write today for our specification sheets.

Other Jeffers Products
fixed composition capacitors

Other Speer Products for the Electronics Industry
anodes • contacts • resistors
discs • brushes • molded notched* coil forms
battery carbon • graphite plates and rods

*Patented

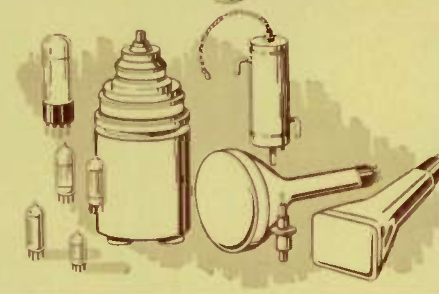
JEFFERS ELECTRONICS

JEFFERS ELECTRONICS DIVISION
SPEER CARBON COMPANY
Du Bois, Pennsylvania

Other Speer Divisions:
Speer Resistor, Speer Carbon Products, International Graphite & Electrode

TUBE DESIGN NEWS

GENERAL ELECTRIC



RECEIVING • POWER • CATHODE RAY

7329 G-E 5-Star 6414's in IBM SAGE Computer Still Show No Opens, Shorts or Mechanical Defects after 3000 Hours Service

This huge computer, only a small part of which is illustrated, was engineered and built by IBM to serve as heart of the Semi-Automatic Ground Environment (SAGE) air defense system. G-E 5-Star 6414's in the computer had a perfect record of NO opens, shorts or mechanical defects.

No shorts, no opens, no mechanical defects . . . this is the history of 7329 5-Star 6414's that have performed in excess of 3000 hours in IBM's first XD-1 computer, engineered and manufactured for the experimental sub-sector of the USAF SAGE system.

"Out of electrical tolerance" has been the sole removal cause. In contrast: 17% of removals of another twin triode of earlier design tested in this giant computer, have been for one of the three reasons above—shorts, opens, mechanical defects—any one of which can render a tube inoperative.

General Electric's 5-Star 6414 was one of the first high-reliability tubes developed expressly for computers . . . just as G.E. previously had pioneered special tubes for commercial computers.

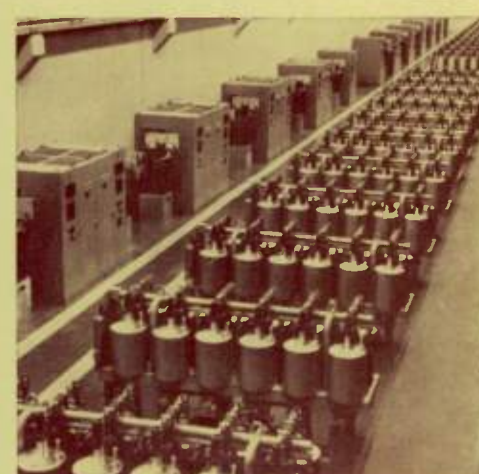
Experience not found elsewhere enters into the design, manufacture, and testing of the three General Electric 5-Star, and seven commercial computer types now available. Ask any office on the next page for further information!

Special G-E Welding Technique Makes Possible Pumpless Ignitrons with Sealed-for-Life Vacuum

General Electric pumpless ignitrons are helping industry convert a-c to d-c more economically than ever before. A continuous welding process developed by G.E. seals off the vacuum inside the tubes permanently. No pumps are needed once the tubes are installed. Doing away with vacuum pumping equipment gives cleaner installations, and leads to important savings.

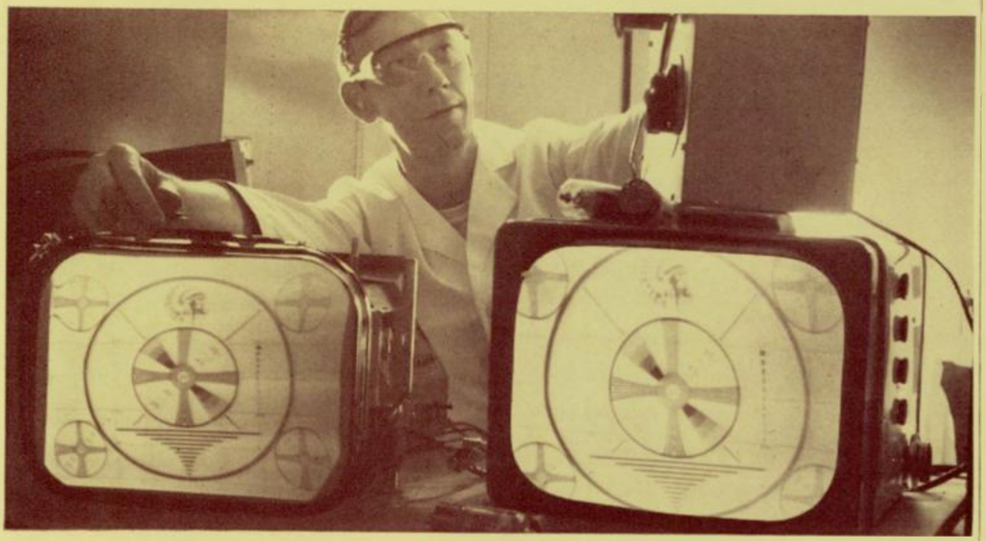
One of a long series of G-E ignitron advancements, pumpless ignitrons are a General Electric "first". Today G.E. builds and offers types with the highest ratings in the field—fully able, in multiple groupings, to meet the power requirements of aluminum producers and others who are massive users of d-c.

(Continued on Page 2, Column 1)



LEFT: a continuous air-tight weld of ignitron covers to tanks is formed by rotating the big tubes in motorized jigs. RIGHT: showing a large rectifier installation of G-E pumpless ignitrons. Note the clean layout, free from vacuum pumping equipment, headers, gages, and connections. Eliminating these components saves substantially in equipment, power, and maintenance costs.

Improvements in G-E Horizontal-Amplifier Tubes Assure Full Picture Sweep, Lengthen Tube Life



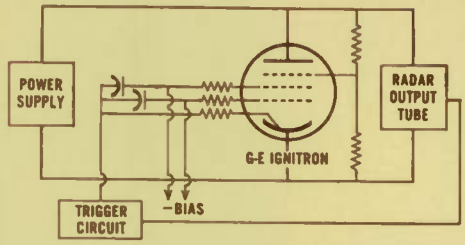
Superior sweep of G-E horizontal-amplifier tubes under low-line-voltage conditions, is demonstrated on screen at right. Large plate size and special finned or dimpled construction; advanced cathode processing; these and other features give improved performance. Tubes, moreover, are tested at factory for zero-bias plate current and plate-to-screen current ratio.

By continuously upgrading tube performance, General Electric contributes to the acceptance of today's TV sets in a market which is ever more exacting as to picture quality.

No group of G-E tubes has been improved more extensively than horizontal-amplifier types. Plate areas have been enlarged to cut plate and screen emission, causes of shrinking raster and distorted image . . . finned or dimpled plate design lessens danger of "snivets" . . . new, advanced cathode-processing techniques make for better low-line-voltage operation.

Design improvements that increase tube service life and stabilize performance include specially-processed screen grids to dissipate more heat . . . new beam plates which prevent glass deterioration from bulb bombardment . . . mica slots and mica spraying that combat inter-element leakage and arcing.

Rigid General Electric performance tests and life tests promote uniform quality for all horizontal-amplifier tubes that are built and shipped.



Trigger circuit goes into action whenever radar output tube receives an overload—actuates the ignitron, which instantly becomes a current bypass ("crowbar") in order to short out the threatened tube.

"Crowbar" Circuit Featuring G-E Ignitron Protects Radar Output Tubes From Overload Damage

Valuable use is being made of General Electric ignitrons to shield costly radar output tubes from overload damage. The ignitron is triggered to short out the tube in the event of a dangerous power surge. Such action, of course, must be virtually instantaneous—and an ignitron operates with split-second rapidity, far faster than any conventional switch.

Moreover, an ignitron will conduct current in the large amounts called for by overload protection. Type GL-6228/-506, used increasingly for this work, conducts up to 60,000 amp—yet will not fire until triggered at 65,000 v. This high hold-off voltage assures that normal variations in power will not cause circuit interruptions.

For low-power radar and broadcast stations, General Electric's GL-5630 Ignitron is a more economical, and equally popular, "crowbar-tube" investment.

Pumpless General Electric Rectifier Ignitrons

(*Continued from Page 1*)

A typical grouping of twelve General Electric 20-inch pumpless ignitrons, for example, will furnish up to 5000 kw of d-c power at 850 v. See the listing of 20-inch and 16-inch sizes under "New Tube-Product Briefs" at right. Consult further with any General Electric office below.

NEW TUBE-PRODUCT BRIEFS

Receiving Tubes

25EC6. New G-E beam power pentode for TV. Horizontal sweep type for 110-degree-deflection picture tubes. High performance at low line voltages. Physically shorter than 25CD6-GB, and has controlled heater warm-up for 600-ma series-string circuits.

Power Tubes

GL-6963, GL-6964. New General Electric 16-inch pumpless ignitrons for power rectification. Single-grid and double-grid respectively. Sealed-for-life vacuum.

GL-6965, GL-6966. New G-E 20-inch pumpless ignitrons, for power-rectification service. Single-grid and double-grid, with sealed-for-life vacuum.

Cathode-Ray Tubes

3ACP1, 3ACP7, 3ACP11. New G-E 3-inch flat-face C-R types for radar and oscilloscope applications. Electrostatic deflection and focus. Post-acceleration gives maximum deflection sensitivity with a high degree of brightness. Deflection structure is electrostatically shielded—this improves beam accuracy and minimizes interaction.

EASTERN REGION
General Electric Company, Tube Sales
200 Main Avenue, Clifton, N. J.
Phones: (Clifton) GRegory 3-6387
(N.Y.C.) WIsconsin 7-4065, 6, 7, 8

CENTRAL REGION
General Electric Company, Tube Sales
3800 North Milwaukee Avenue
Chicago 41, Ill.
Phone: SPring 7-1600

WESTERN REGION
General Electric Company, Tube Sales
11840 West Olympic Boulevard
Los Angeles 64, Calif.
Phones: GRanite 9-7765; BRadshaw 2-8566

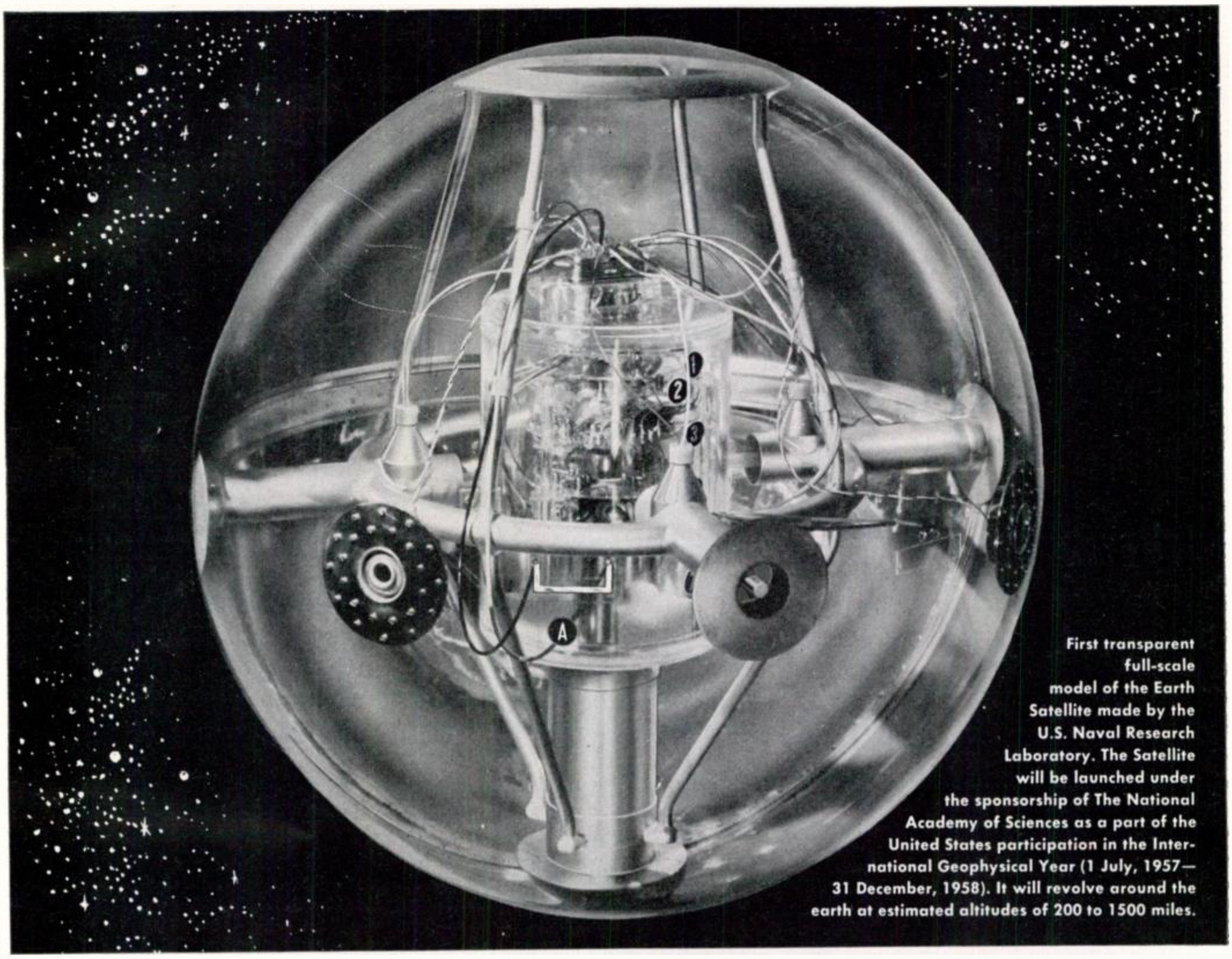
Progress Is Our Most Important Product

GENERAL ELECTRIC

182-1C5

ELECTRONIC COMPONENTS DIVISION, GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y.

DRIVER-HARRIS ALLOYS AT WORK IN PRODUCT ADVANCEMENT



First transparent full-scale model of the Earth Satellite made by the U.S. Naval Research Laboratory. The Satellite will be launched under the sponsorship of The National Academy of Sciences as a part of the United States participation in the International Geophysical Year (1 July, 1957—31 December, 1958). It will revolve around the earth at estimated altitudes of 200 to 1500 miles.

How measure the impact of micro-meteorites on the first "Earth Satellite"?

When physicists at the U.S. Naval Research Laboratory consider an instrument or a material to record accurately the secrets of outer space—it's not size alone that counts, but dependable, reliable precision.

The strip of "Nichrome"* evaporated on glass ("A" in the photo above) which may be fitted to the outer skin of the Satellite, measures only ¼" wide x 1½" long. Its thickness: 100 Angstrom units (1/10,000 mm). Its function: to measure the surface erosion caused by the impact of micro-meteorites. The resistance of the Nichrome ribbon increases as the film becomes pitted by meteor particles.

"Nichrome is being considered for making this gage," states the Naval Research Laboratory, "because it supplies electrical resistance in a desirable range; adheres satisfactorily to glass in thin film form; and has a very low thermal coefficient of resistance."

There'll be no one on hand, 300 miles out in space, to check on or supervise the performance of the Nichrome strip. Nichrome needs no one. It will do its job dependably there—just as it will in *your* electronic or electrical equipment, after it is in your customers' hands.

And remember, Nichrome is only one of the 132 special purpose alloys developed by Driver-Harris since 1899 for electrical heating, resistance, and electronic applications. Do you need a special alloy? Send us your specifications.

*T. M. Reg. U. S. Pat. Off.

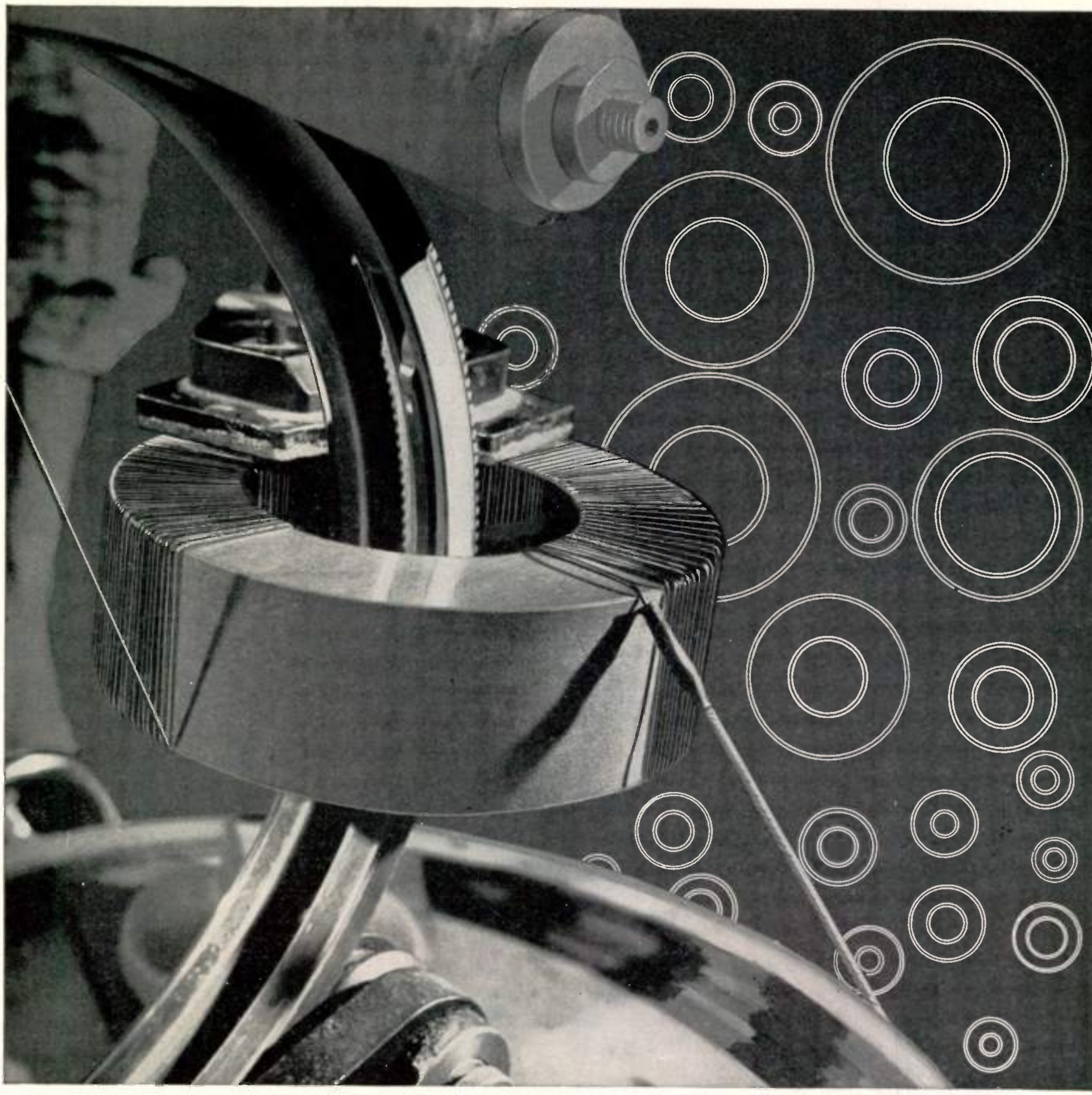
SPECIAL PURPOSE ALLOYS SINCE 1899 — D H — TRADE MARK REG. U. S. PAT. OFF.

Driver-Harris COMPANY HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Louisville, Los Angeles, San Francisco In Canada: The B. GREENING WIRE COMPANY, Ltd., Hamilton, Ontario

MAKERS OF THE MOST COMPLETE LINE OF ELECTRIC HEATING, RESISTANCE, AND ELECTRONIC ALLOYS IN THE WORLD

KEEP UP-TO-DATE ON MAGNETICS



How will tape wound core users be affected by new size standards?

If toroidal core winding is a familiar sight in your plant, you'll welcome news that standard sizes for tape wound cores have been proposed by the A.I.E.E.* You are going to benefit from a high in consistency of core performance, brought about by our being able to concentrate on your most important sizes.

Magnetics, Inc. is now stocking all of the proposed standard core sizes in both aluminum and phenolic core boxes for immediate delivery. Consistency of core performance is increased because each size is made in large lots taken from the same alloy batch and dry hydrogen anneal. They all bear our exclusive Performance-Guarantee.

You can find all specifications for these AIEE-standardized tape wound cores in Catalog TWC-102, a new publication which, incidentally, is the most comprehensive tape wound core text published anywhere by anybody. Your copy of this Catalog-Design Manual may be obtained by writing on your letterhead to *Magnetics, Inc., Dept. I-34, Butler, Pa.*

MAGNETICS inc.

**Paper 57-206, Proposed Size Standards for Toroidal Magnetic Tape Wound Cores. Report of the Magnetic Amplifiers Material Sub-Committee, at the 1957 Winter General Meeting, A.I.E.E.*

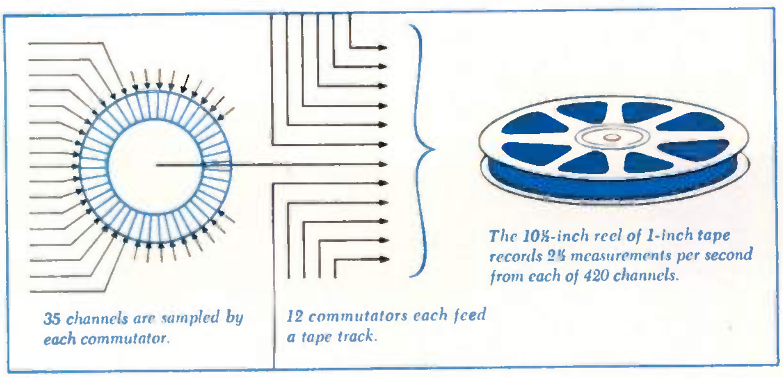
MAGNETIC TAPE APPLICATIONS BY AMPEX

ONE OF A SERIES 2

How to record 420 channels of simultaneous data

Boeing Airplane Company's flight tests demonstrate an easy way

Have you ever seen an oscillograph record that was eight and a half feet wide? At fifty channels per foot this is what it would take . . . which shows the decided advantages in the way the Boeing Airplane Company solves the problem. They put 420 channels of data onto a one-inch magnetic tape. Two hours of flight test can be recorded on one 10½-inch reel.



In a published article, Mr. Arthur T. Snyder of Boeing describes their system as a low level, low-speed, pulse-width-modulation technique. It time-multiplexes 35 channels of data onto each of 12 tracks (of 14) on an Ampex 814 Airborne Magnetic Recorder; (35 × 12 = 420). The system inputs are variable resistances, thermocouples, strain-gage bridges and other bridge-type transducers. Each is fed to a segment on one of twelve rotating commutators that sample every channel 2½ times per second. The Ampex 814 recorder running at 3¾ in/sec. records over 8-million measurements in two hours.

This recording system used by Boeing is limited *by choice* to data that changes at a slow rate. This is by no means a fixed limitation. Certain Ampex recorders (Series 800, FR-100 and FR-1100) have interchangeable amplifiers. Each track can thus be used with any one of three types of recording according to frequency requirements:

With PWM recording (like the Boeing example) as many as 88 channels of low-frequency data can be put onto one track.

With direct recording up to 18 channels of RDB subcarrier data of varying frequency requirements can go onto one track – or very high-frequency data uses one track per channel.

With FM carrier recording one channel of data occupies one track and provides high instantaneous amplitude accuracy. FM is particularly suitable for shock and vibration records.

When a recording containing a large number of channels of data is reproduced, another of magnetic tape's advantages becomes apparent. The data can be reproduced in electrical form. Consequently it is a relatively simple matter to unscramble the channels by automatic or semi-automatic means. Any combination of channels can be scanned, correlated and fed to computing devices. These fortunate faculties of magnetic tape help reduce the handling of vast amounts of data down to a task of wieldy size. For example in the Boeing flight tests already mentioned, all data is published within two or three days after the test instead of from several weeks to several months later as by previous methods.

Boeing KC-135 tanker in flight.

If you have a specific problem involving large amounts of data or unusual combinations, Ampex's application engineers will be pleased to furnish further information. More of the capabilities of magnetic tape will be discussed in this continuing series of bulletins. Would you like to have copies mailed direct? If so, write Dept. G-3103

Series FR-100

Series 800 Mobile and Airborne

Model FR-200 Digital

Tape Loop Recorder

Series FR-1100

INSTRUMENTATION DIVISION AMPEX CORPORATION

FIRST IN MAGNETIC TAPE INSTRUMENTATION

934 Charter Street • Redwood City, California

District offices serving all areas of the United States and Canada; Foreign Representatives in countries around the world.

Leadership: Avionics Design and Packaging

COLLINS in GROUND COMMUNICATION

Collins engineers, designs and supplies the equipment, installs, and puts into operation integrated point-to-point communication systems of any scope. The Collins system engineering staff is backed by the finest equipment in the world, whether standard MF, HF or VHF, Transhorizon "scatter," microwave relay and multiplex or single sideband HF. Typical of Collins communication progress is "Kineplex" — a high speed data transmission system doubling communication capacity.

COLLINS in AMATEUR RADIO

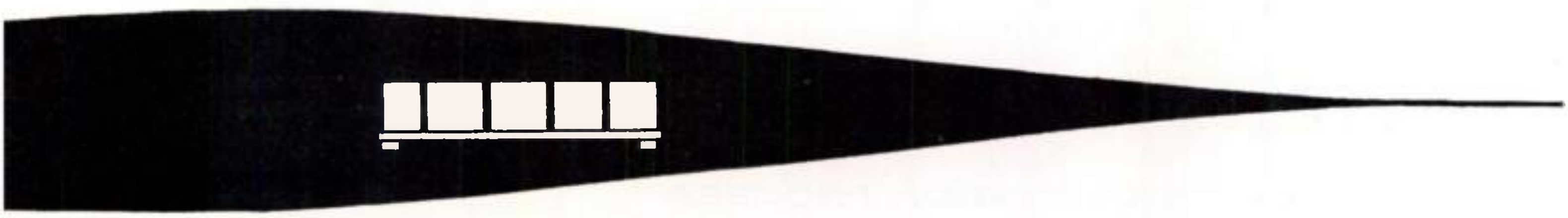
In the early 1930's Collins set the standard in Amateur radio and, through continuous design and development, has raised this standard to its present single sideband station — the most honored and prized in the Amateur fraternity. This station is the top performing rig on the air with its kilowatt KWS-1 transmitter and highly selective 75A-4 receiver. Many of the leaders in the electronics industry became acquainted with Collins through the Company's superior Amateur equipment.

Collins CREATIVE LEADER IN AVIATION ELECTRONICS

CNI

Collins CNI is an efficient electronics package designed to each aircraft type and provides a common logistics base by utilizing identical modules for all aircraft.

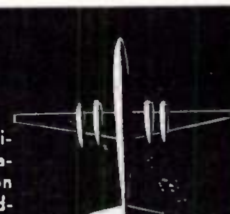
Communication
Navigation
Identification



Advanced packaging techniques plus increased attention to problems regarding vibration, heat transfer and mutual interference have led to development of the Collins-designed AN/ASQ-19 Integrated Electronics System.

McDonnell Aircraft Corporation, first to use this design, has been instrumental in proving and refining the system.

COLLINS in AVIATION



Collins completely oufits airline, military and business aircraft with the most advanced communication, navigation, flight control and instrumentation systems in aviation. Many new lightweight, reduced-size versions are now being delivered. Collins designed the original Integrated Flight System, leads in combining comm/nav/ident units into a single compact "CNI" package for new military aircraft, and continues to pace the industry in developments in airborne radar, ADF, ILS, VOR, HF and VHF communication.

COLLINS in COMPONENTS AND TEST EQUIPMENT

The degree of precision and reliability of Collins products requires development by Collins engineering of components such as Autotunes and Autopositioners, Mechanical Filters, oscillators, heat reducing tube shields and ferrites. These developments and other high quality components are sold by a Collins subsidiary, Communication Accessories Company of Hickman Mills, Missouri. The same principles of accuracy and reliability apply to Collins test equipment, built especially for Collins but adaptable to testing other equipment types.

COLLINS

COLLINS RADIO COMPANY, CEDAR RAPIDS, IOWA • DALLAS • BURBANK • NEW YORK
WASHINGTON, D. C. • MIAMI • SEATTLE • COLLINS RADIO COMPANY OF CANADA, LTD., TORONTO • COLLINS RADIO COMPANY OF ENGLAND, LTD., LONDON

Professional Group Meetings

(Continued from page 28A)

Syracuse—February 13

"VHF Radio Coordinated Traffic Light Control System," E. W. Hassel, General Electric.

Component Parts

Dayton—January 3

"Transistor Power Supplies," R. F. Morey, Clevite Transistor Products.

Los Angeles—January 7

"Radio Interference Filters," A. J. Devot, Filtron Co., Inc.

Los Angeles—November 12

"Comparison of Lumped Parameter and Distributed Constant Delay Lines," Hirschel Schwartz, RCA Electronics; and "Some Applications of Network Synthesis to the Design of Electric Wave Filters," P. R. Geffe, Hycon Division of I.R.C.

Electron Devices

Boston—February 12

"An Improved High-Frequency Silicon Transistor," C. G. Thornton, Philco Corp., Lansdale Tube Company.

Electronic Computers

Akron—January 15

"Large Scale Computing Systems for Operational Flight Tactics Trainers," Bradley Peters, Goodyear Aircraft Corporation.

Akron—November 27

"GEDA Economic Power Dispatch Computer," S. B. Yochelson, Goodyear Aircraft Corporation.

Los Angeles—February 21

"LARC Drum System," Robert Douthitt, Remington Rand Univac; and "Electro Data Multiple Magnetic Tape Storage Unit," Arthur Dowling, Electro Data.

Los Angeles—January 17

"Nationalization of Research and Development in the United States," J. C. DeHaven, Rand Corporation.

Los Angeles—December 20

"Static Design of Transistor Flip-Flops and Related Circuits," R. G. Clark; and "A Technique for Using Memory Cores as Logical Elements," L. J. Andrews.

Los Angeles—November 15

"LGP-40," James Cass, Librascope; and "LGP-40 Circuit Design," W. H. Reinholtz, Librascope.

(Continued on page 46A)

VISIT THE AFCEA NATIONAL CONVENTION

May 20, 21, 22, 1957.
Monday, Tuesday, Wednesday.

- **103 Exhibitors**
- **155 Exhibit Units**
- **Daily Technical Sessions**

Washington, D.C.
Sheraton-Park Hotel—All under one roof.

- **6 Important Social Events**
- **Trip to Naval Research Lab.**
- **Special Program for Ladies**

This Program means business:

Monday, May 20th

8:30 AM—Sheraton Hall
Opening Breakfast
9:30 AM— **Official Opening of Exhibits**
10:00 AM—Caribar Room
Chapter Presidents Conference
10:00 AM-12:00 M—Sheraton Hall
Engineering Papers on Research and Application
12:30 PM—Sheraton Hall
Keynote Luncheon
1:00 PM-5:00 PM—Adams Hamilton Room
Industrial Movies
2:30 PM-4:30 PM—Sheraton Hall
Monitored Panel on Scatter Propagation
7:00 PM—Sheraton Hall
Buffet Supper

Exhibits: 9:30 AM—9:00 PM

Tuesday, May 21st

9:00 AM—Caribar Room
Council & Directors Meeting
10:00 AM-12:00 M—Sheraton Hall
Engineering Papers on Research and Application
12:00 M—Box Lunch
Tour—Naval Research Laboratory
1:00 PM-5:00 PM—Adams Hamilton Room
Industrial Movies
6:00 PM—Continental Room
Reception
7:30 PM—Sheraton Hall
Banquet

Exhibits: 9 AM—9 PM

Wednesday, May 22nd

8:00 AM—Caribar Room
Officers & Directors Breakfast
10:00 AM-12:00 M—Sheraton Hall
Engineering Papers on Research and Application
12:30 PM—Sheraton Hall
Industrial Luncheon
1:00 PM-5:00 PM—Adams Hamilton Room
Industrial Movies
2:30 PM-4:30 PM—Sheraton Hall
Procurement Management Forum

Exhibits: 9 AM—5 PM

These Technical Papers:

1. "Rapid Fault Elimination in Complex Electronic Systems," by John F. Scully of Monroe Calculating Machine Company
2. "Single Sideband Receivers," by H. F. Comfort of Radio Corporation of America
3. "Single Sideband Applied to Air-Ground Communications," by E. W. Pappenfus of Collins Radio Company
4. "A Single-Sideband Radio Central to Replace Military Wire Lines," by A. M. Creighton and D. B. Reeves of Motorola, Inc.
5. "The Trend of Facsimile in Military Communications," by A. G. Cooley of Times Facsimile Corporation
6. "Processing, Narrow-Band Transmission, and Remote Display of Radar Data," by Sheldon P. Detwiler of Lewyt Manufacturing Corporation
7. "Multiplexing Circuits in the National Air Defense Communications Networks," by J. B. Naugle of Lenkurt Electric Company
8. "The Air Route Surveillance Radar for U.S.A. Air Traffic Control," by Bruce I. McCaffrey of Raytheon Manufacturing Company
9. "The Vanguard Launching Vehicle Instrumentation System," by Vernon J. Crouse, Jr., of The Martin Company
10. "Results of a Simple Technique for Handling Complex Microwave Circuits," by Alexander Horvath of Sylvania Electric Products Company
11. "A Fully Automatic Teletypewriter Distribution System," by R. C. Stiles and L. Johnston of Automatic Electric Company
12. "Some Aspects of Telegraphic Data Preparation and Transmission," by W. B. Blanton of Western Union Telegraph Company

For Information write or wire: **SIGNAL**

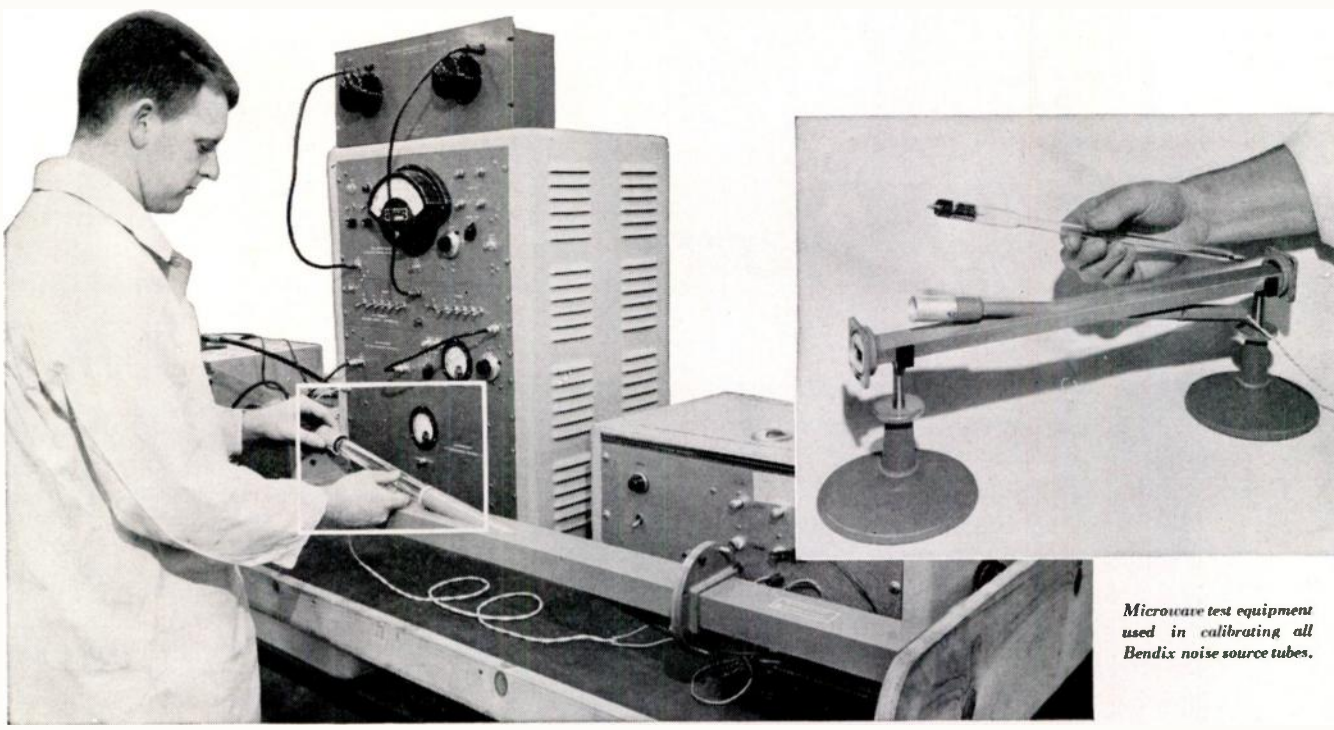
WILLIAM C. COPP & ASSOCIATES
1475 Broadway • New York 36, N. Y. • BRyant 9-7550

AFCEA at Boston 1956

Bendix Red Bank

NOISE SOURCE TUBES

Offer unusual stability plus freedom from ambient temperature corrections



Microwave test equipment used in calibrating all Bendix noise source tubes.

As measured sources of noise power in microwave equipment, Bendix Red Bank noise source tubes offer several distinct advantages.

First, temperature changes and fluctuations in noise output present no problems with these tubes, because we make them so that no correction in noise figures is necessary over the range from −55°C. to +85°C. Next, our precise quality control works to close tolerances that produce unusual stability and long life—far beyond that usually found in noise source measuring equipment.

Finally, as can be seen in the table at right, Bendix Red Bank noise source tubes cover an extremely wide range of frequencies, so that there is no difficulty in finding a type to meet any specific need.

If you have any sort of application in measuring noise and sensitivity in microwave receiving equipment, check with us for the most efficient answer. Write RED BANK DIVISION, BENDIX AVIATION CORPORATION, EATONTOWN, NEW JERSEY.

West Coast Sales & Service: 117 E. Providencia Ave., Burbank, Calif.
Export Sales & Service: Bendix International Division, 205 E. 42nd St., New York 17, N. Y.
Canadian Distributor: Aviation Electric Ltd., P.O. Box 6102, Montreal, Quebec

Bendix Type	RETMA No.	Wave-guide No.	Frequency KMC	Anode Cur-rent MA	Nom. Tube Drop Volts	Nom. Noise Rating db	Mount Type
TD-10	6356	RG49/U	3.95-5.85	250	70	15.2	10°E
		RG50/U	5.85-8.20				
TD-11	6357	RG25/U	8.20-12.40	200	75	15.2	10°E
TD-12	6358	RG48/U	2.60-3.95	250	80	15.2	10°E
TD-13	6359	RG53/U	18.00-26.50	200	65	15.2	10°E
TD-18	6684	RG91/U	12.40-18.00	200	70	15.2	10°E
TD-21	—	RG69/U	1.12-1.70	250	65	15.2	90°H
TD-22	—	RG48/U	2.60-3.95	250	45	15.2	90°H
TD-23	—	RG52/U	8.20-12.40	200	115	18.0	10°E
TD-24	—	WR 229	3.30-4.90	250	65	15.2	10°E

Red Bank DIVISION

Bendix AVIATION CORPORATION

Professional Group Meetings

(*Continued from page 42A*)

Los Angeles—October 18

"Large-Signal Application of Junction Transistor Digital Circuitry," Ralph Rodriquez; and "1092-BU-7 Storage Unit," B. T. Goda, Telemeter Magnetics & Electrons Corporation.

New York—February 14

"Thinking Machines," Elliot Gruenberg, W. L. Maxson Corporation.

San Francisco—February 5

"Magnetic Character Reading Techniques," Kenneth Eldrege, Stanford Research Institute.

Engineering Management

Boston—January 31

"Listening as a Management Technique in Human Relations," L. C. Mead, Tufts College.

Dayton—January 15

"Views on Decentralization in Large Corporations," E. U. DaParma, Sperry Gyroscope Co.

Los Angeles—February 19

"The Dilemma of Engineers in Management," A. N. Curtiss, RCA; and "The Legal Pitfalls of Engineers in Management," C. R. Simpson, Southern California Edison Company.

Metropolitan New York—February 6

"Psychological Test Procedures for the Selection & Development of Personnel in Industry," M. E. Feinberg, Research Institute of America.

Industrial Electronics

Chicago—December 7

"Magnetic Amplifier for Industrial Control," J. W. Grant, Tammen & Denison, Inc.

Information Theory

Washington—November 20

"Some Current Ideas in Information Theory," David Middleton, Melpar, Inc.

Medical Electronics

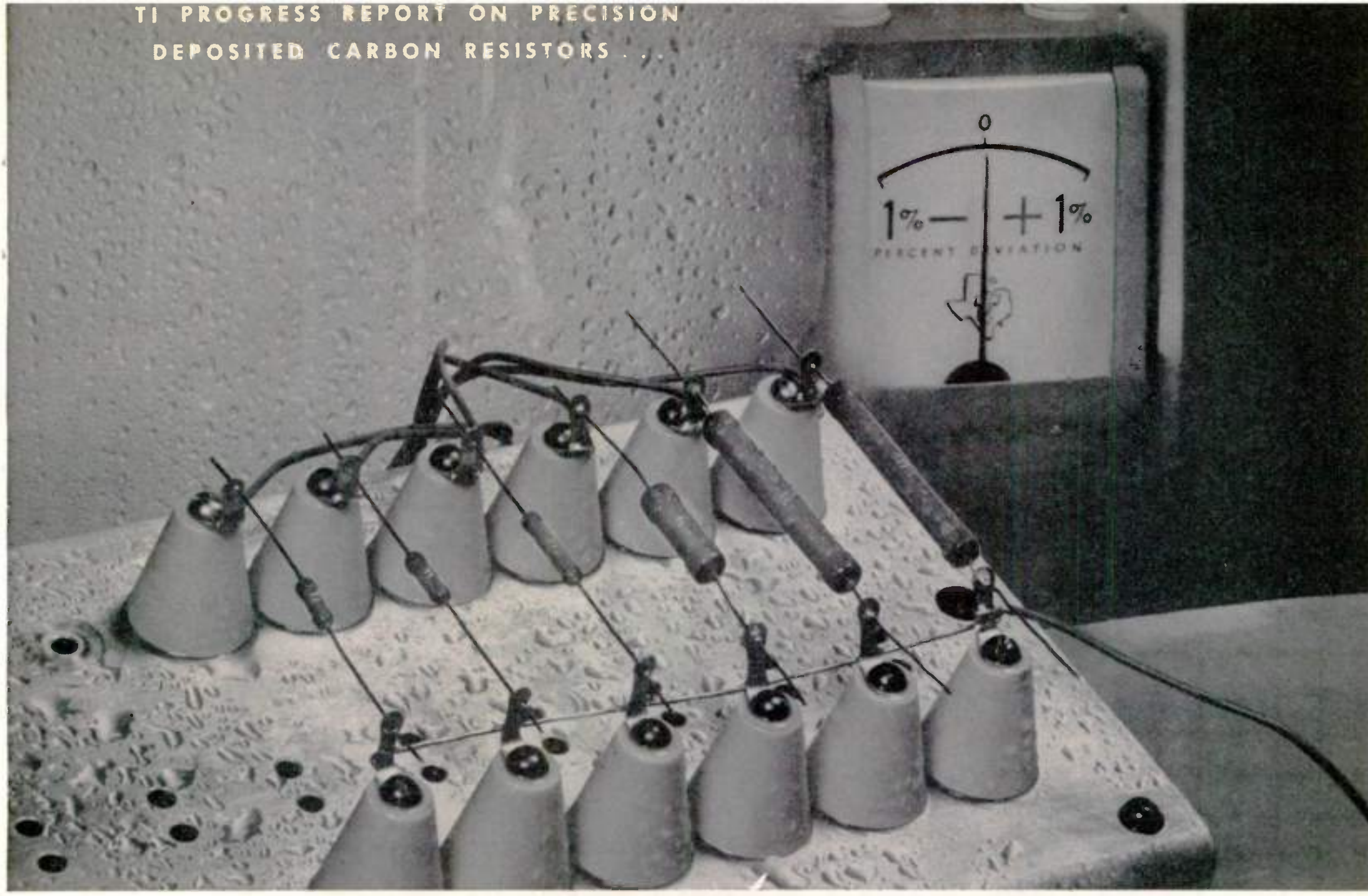
Buffalo-Niagara—February 14

"Panel Discussion on Heart Sound Production and Recording," speakers of the PGME Heart Sound Symposium.

San Francisco—February 7

"Ocular Electromyography," A. J. Jampolsky, Stanford University School of Medicine.

(*Continued on page 48A*)



TI MIL-Line Precision Resistors

HOLD TOLERANCE...EVEN WHEN DRIPPING WET!

Soaking wet, dried out, or 'shook up' – TI MIL-Line deposited carbon resistors still far exceed MIL-R 10509B . . . emerge from one acceptance test after another – by major electronics manufacturers – with performance records that have not been equalled. *It's the seal that makes the difference* . . . an exclusive Texas Instruments process that snugly wraps these precision resistors in tough jackets of a special coating with high dielectric strength.

For ease in design, production, and maintenance . . . for improving the reliability and saleability of your products, the moisture resistance of TI deposited carbon MIL-Line resistors is just *one* field-proven factor. You also get a choice of 1, 2, or 5% tolerances . . . high stability over wide temperature ranges and under full load . . . low negative temperature coefficients . . . negligible voltage coefficient and noise levels . . . long shelf-life . . . wide selection of sizes and resistance values . . . reasonable prices . . . and, if desired, reel-type packaging for automation.

Here is a typical TI reel pack designed to speed production. TI precision deposited carbon resistors are mass produced and packaged in five sizes from 1/2 watt to 2 watts with resistance values from 25 ohms to 30 megohms.

For complete data, write for Bulletin DL-C 539.

TEXAS INSTRUMENTS
INCORPORATED
6000 LEMMON AVENUE DALLAS 9, TEXAS

Convair F-102A flight-test data now digital at the source...

Simplified ground monitoring of Convair F-102A flight-tests is now obtained with airborne remote-sensing Vibrotron Digital Transducers. Rapid response and exceptional accuracy under difficult environmental conditions are characteristic of two Vibrotron Absolute Pressure Transducers mounted immediately aft of the F-102A nose boom. Frequency changes indicating changes in total pressures and static pressure (altitude) are FM/FM telemetered to ground monitors where total pressure minus static pressure is *digitally read-out* as airspeed. Otherwise unavoidable analog-to-digital converter inaccuracies are eliminated when Vibrotron Transducers are incorporated into your aircraft or missile flight telemetering system. Full details concerning Vibrotron Transducers and related BJ Digital Data Systems upon request.

The Vibrotron Transducer basically consists of a fine wire stretched in a magnetic field between a diaphragm and anchor point. Tension changes upon the wire are sensed as extremely precise frequency changes which are directly readable as numerical indications. Mated amplifiers are supplied.

Model 101 Vibrotron Absolute Pressure Transducer and amplifier Model 215.

Qualified engineers are assured interesting, rewarding positions at this new Borg-Warner electronic center. Inquire today!

BJ Reliability You Can Count Upon

ELECTRONICS

BORG-WARNER CORPORATION

3300 NEWPORT BLVD., P. O. BOX 1679, SANTA ANA, CALIF.

Professional Group Meetings

(Continued from page 46A)

Washington, D. C.—February 7

"Measurement of Body Functions in the Stratosphere," N. L. Barr, U. S. Navy, Naval Medical Center.

Microwave Theory & Techniques

Boston—January 24

"The Statistical Prediction of Voltage Standing Wave Ratio," W. L. Pritchard and J. A. Mullen, Raytheon Manufacturing Company.

New York—January 17

"Simple Theory of the Backward Wave Oscillator," H. A. Wheeler, Wheeler Labs., Inc.

Military Electronics

Dayton—January 10

"Current Engineering Aspects of Space Flight," D. C. Romick, Goodyear Aircraft Co.

Nuclear Science

Dayton—January 3

"Radiation Effects on Semiconductors," W. L. Lehman, Air Force Institute of Technology, Wright-Patterson AFB.

Pittsburgh—January 15

"High Energy Sources for Radiation Studies," R. H. Schuler, Mellon Institute.

Reliability & Quality Control

Los Angeles—February 18

"Some Mathematical Considerations of Redundancy," J. R. Duffet, Radioplane Co.

Telemetry & Remote Control

Dayton—January 3

"Instrumentation and Control of Spacecraft," M. V. Kiebert, Applied Research Inc.

Section Meetings

Atlanta

"The New Building, 'White Columns' of WSB & WSB-TV," by C. F. Daugherty, WSB & WSB-TV; "Radio and TV Equipment and Installation at WSB and WSB-TV," by Robert A. Holbrook, WSB & WSB-TV; March 1, 1957.

(Continued on page 50A)

sierra

Peak-reading and average-reading

WATTMETERS—POWER MONITORS

Sierra 195A-Z Termination Wattmeter

TERMINATE RF COAX SYSTEMS

MEASURE RF POWERS

MEASURE INCIDENT, REFLECTED POWERS

MATCH ANTENNAS, LOADS

SIERRA TERMINATION WATTMETERS

Sierra 195A series Peak-Reading Termination Wattmeters are rugged, conservatively rated instruments specifically designed for measuring peak powers and terminating rf coaxial systems in testing and adjusting pulse transmitters and oscillators. They are designed for maximum reliability and minimum rf leakage. Three basic models cover 250 MC to 1000 MC and have characteristics given alongside. All require a 110 v 60 cps power source.

Sierra 185A series Average-Reading Termination Wattmeters are also offered for average-power measurement or termination on rf coaxial systems. The table at right gives models, frequency coverage, etc. No auxiliary power is required.

BI-DIRECTIONAL POWER MONITORS

Sierra Power Monitors are convenient, versatile instruments for measuring incident or reflected power, or precise matching of loads to lines. A twist of the wrist selects incident or reflected power, or any power range. Compact, rugged construction makes these instruments ideal for portable field applications or laboratory use.

Peak-Reading Sierra 194A-A Bi-Directional Peak Power Monitor reads 0-1/3/10/30 Kw from 200 MC to 1215 MC. Minimum pulse width 1.0 μsec, minimum repetition rate 400 pps, accuracy ±10% full scale. Insertion VSWR 1.10 maximum. Requires 110 v 60 cps power source.

Average-Reading Sierra 164 series Bi-Directional Power Monitors cover 25 MC to 1000 MC with as few as two plug-in elements. Each plug-in covers broad frequency range and has full scale power ranges of 1, 5, 10 and 50 watts or 10, 50, 100 and 500 watts. Power is read direct on linear scale within ± 5% full scale. Insertion VSWR less than 1.08 (Type N connectors) except on 1 watt ranges. 50 ohm impedance available with Type N or UHF connectors. No auxiliary power required.

Sierra 194A-A

MODEL 195A PEAK-READING WATTMETERS

Model	Frequency	Peak Power, Kw	Max. Average Power	Connector
195A-Z	250-1000 MC	0-1/3/10	15 watts	N
195A-X	250-1000 MC	0-10/30/100	100 watts	LC
195A-Y	250-1000 MC	0-100/300/1000	500 watts	LC

MODEL 185A AVERAGE READING WATTMETERS

Model	Frequency	Power Range, Watts	Max. Power Dissipation	Connector
185A-15FN	20-1000 MC	0-5/15	15 watts	N
185A-100FN	20-1000 MC	0-30/100	100 watts	N
185A-500FN	20-1000 MC	0-150/500	500 watts	N

Note: 185A series accuracy ± 5% full scale maximum VSWR 1.2. 195A series accuracy ± 10% full scale, pulse width 1.0 μsec minimum, repetition rate 400 pps minimum. Female connectors standard.
Sierra also manufactures calorimeter wattmeters; details on request. Data subject to change without notice.

Sierra Electronic Corporation

A Subsidiary of Philco Corporation

3885 Bohannon Drive DAvenport 6-2060 Menlo Park, California, U.S.A.

Sales Representatives in Major Cities

Canada: Atlas Radio Corporation, Ltd., Toronto, Montreal, Vancouver, Winnipeg

Export: Frazar & Hansen, Ltd., San Francisco, New York, Los Angeles

sierra

4088

Section Meetings

(*Continued from page 48A*)

BALTIMORE

"Highlights of Antenna Lore," by Edmund A. Laport, Radio Corporation of America; February 13, 1957.

"Lecture-Demonstration of the Fluxvalve Pickup and the Isophase Electrostatic Speaker," by Walter O. Stanton, Pickering & Company; March 13, 1957.

BAY OF QUINTE

"U.H.F. Long Range Point to Point Communications," by Dr. Hans J. Von Baeyer, Systems Engineering Group, R.C.A.F.; February 12, 1957.

BEAUMONT-PT. ARTHUR

Tapescript: "The Bell Solar Battery," by Dr. Gordon Raisbeck, Bell Telephone Laboratories, Inc.; February 19, 1957.

BOSTON

"Electronics Research in Canada," by Dr. John T. Henderson, IRE President; February 26, 1957.

CEDAR RAPIDS

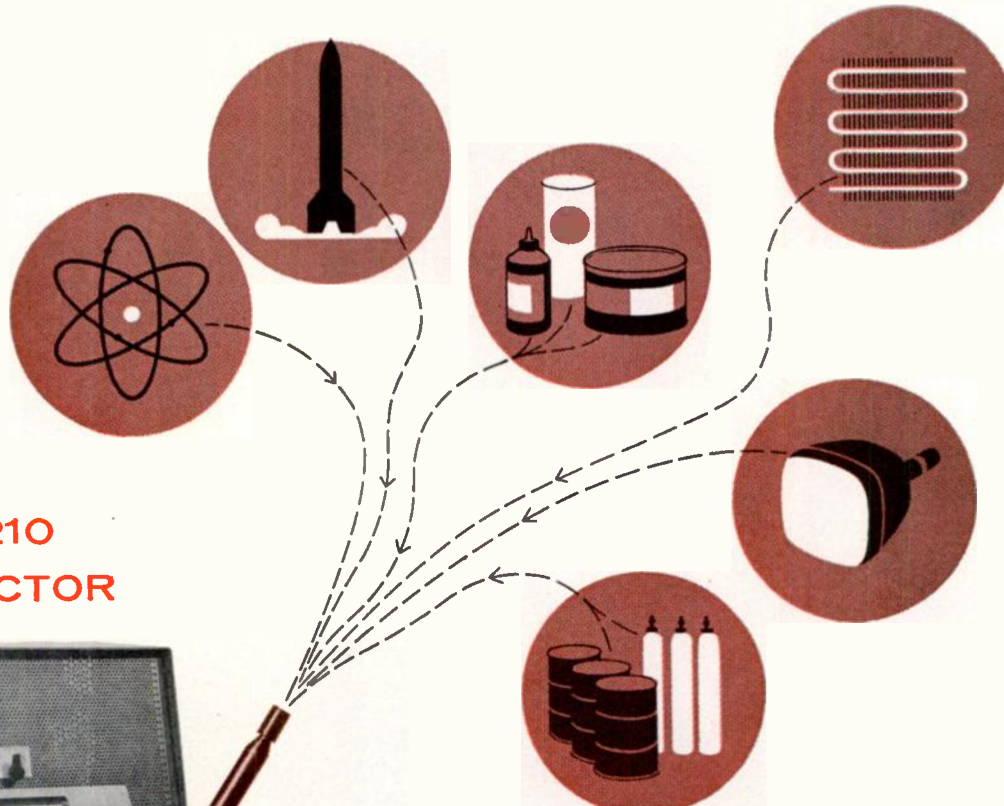
"The Transistor—Present and Future," by Art Evans, Texas Instrument; Talk on Belgium by William Windus; February 20, 1957.

CHINA LAKE

"Cine-Radiography, A New Testing Technique for Improving the Reliability of Airborne Components," by W. H. Grumet and Dr. I. Rehman, Roto-Test Laboratory; February 12, 1957.

(*Continued on page 54A*)

Easiest, most economical way to leak-test your product



CEC'S 24-210
LEAK DETECTOR

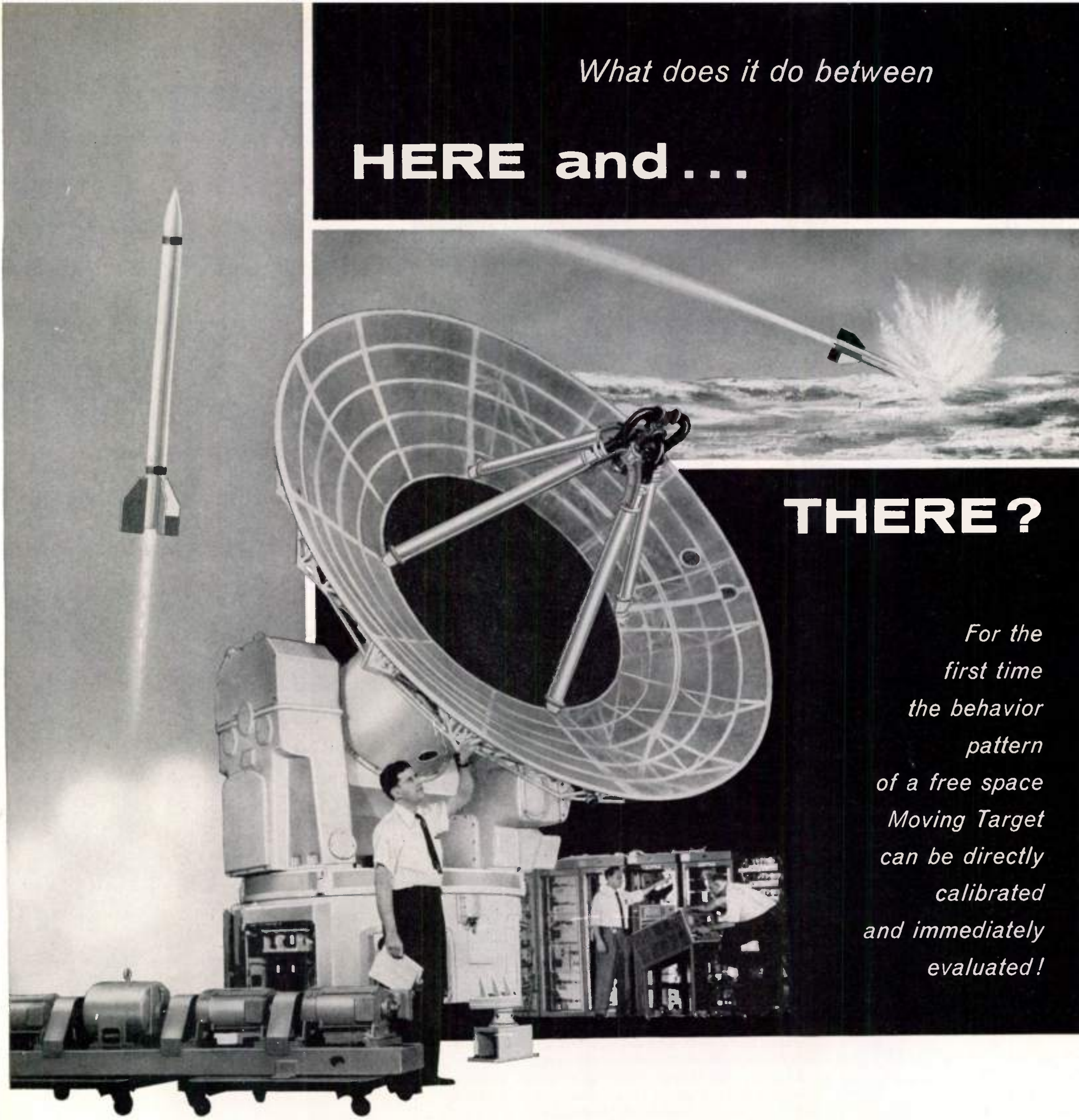
Unlimited applications in leak detection

Now you can test your product for vacuum seal, or locate leaks in any pressurized system with pinpoint precision and practical economy. CEC's 24-210 gives you highly sensitive leak detection and long, trouble-free service. Compact and highly simplified, this low-cost, mass-spectrometer-type instrument detects leaks so minute that 50 years would be required for 1 cc to escape. Easy, convenient operation requires no special training or experience. Just plug into a 115-volt, 60-cycle line. Find out how fast the CEC 24-210 Leak Detector pays for itself. For detailed information contact your nearby CEC field office or write for Bulletin CEC 1830-X19.

Consolidated Electrodynamics

300 North Sierra Madre Villa, Pasadena, California

OFFICES IN PRINCIPAL CITIES THROUGHOUT THE WORLD



The proof of any guided missile is its performance. Not only is it necessary to provide accurate trajectory data in order to determine its effectiveness, but this must be made immediately available.

To meet both requirements is the purpose of the AN/FPS-16 instrumentation radar. This is the first radar developed specifically for Range Instrumentation. It has demonstrated its ability to track with accuracy in darkness, through clouds—under any atmospheric conditions—over extended ranges, and to yield data that can be reduced almost instantaneously to final form. This unit can also be assigned to plot performance of missile, satellite, drone and other free space moving targets.

In the past, this data has depended upon optical devices, triangulation systems with long base lines and precision limitations, modified radar equipment and data reduction methods often requiring months for computation. The immediate availability of data evaluation provided by the AN/FPS-16, now being built by RCA under cognizance of the Navy Bureau of Aeronautics for all services, is a great forward step in Range Instrumentation.

Defense Electronic Products

RADIO CORPORATION of AMERICA

Camden, N.J.

Tmk(s) ®

Section Meetings

(Continued from page 50A)

COLUMBUS

"Transistors," by Dr. Smith, Bell Labs.; January 8, 1957.

"Military Applications of Infra Red," by Dr. Neil Beardsley; February 12, 1957.

"Communications and Lightning in the New 250 KV Distribution System," by C. J. Miller, C & SOE; March 4, 1957.

DALLAS SECTION

"ERMA," by Dr. Byron J. Bennett, Stanford Research Institute; March 5, 1957.

DAYTON

"25 mc and UP—A New Look at Frequency Allocations," by Stuart L. Bailey, Jansky and Bailey, Inc.; February 7, 1957.

DENVER

"The Sun and the Upper Atmosphere," by Dr. Walter Orr Roberts, High Altitude Observatory of University of Colorado; February 25, 1957.

ELMIRA-CORNING

"Neutron Detection Systems," by H. Gleason, Westinghouse; February 18, 1957.

"Brain Storming," by T. Riggen, Consultant in Electronics; March 11, 1957.

FORT HUACHUCA

"Obstacle Gain," by Sam Bradshaw, Motorola, Inc.; February 26, 1957.

FORT WAYNE

"Guided Missiles—How We Got Where We Are, and Where We Are Going," by Capt. U. S. Brady, Farnsworth Electronics; March 7, 1957.

HAMILTON

"Electronic Digital Computors," by Dr. A. G. Ratz, Cdn. Westinghouse; February 11, 1957.

"The Measurement of the Energies of Radio-Active Disintegrations by Pulse Amplitude Analysis," by G. Cowper, Atomic Energy of Canada; March 11, 1957.

HUNTSVILLE

"Electronic Computers," by Mrs. Dan Loposer, International Business Machines; January 29, 1957.

"Radio Interference Measurements," by M. T. Harges, Empire Devices Products Corp.; February 21, 1957.

ITHACA

"The Wamoscope, Operation," by Dr. Rudolph G. E. Hutter, Sylvania Electric Products, Inc.; "The Wamoscope, Application," by Mr. Herbert Briskin, Sylvania Electric Products, Inc.; March 7, 1957.

LOS ANGELES

Technical talks from Seven Los Angeles Section Professional Groups and Panel Discussions on Military-Industria Relations, Major J. B. Medaris, Rear Admiral J. E. Clark and Brigadier General O. J. Ritland for the military, with Mr. H. L. Hoffman, Mr. W. F. Joyce and Mr. T. A. Smith for Industry; March 5, 1957.

LONDON

Annual Students Night; March 11, 1957.

LITTLE ROCK

"Analog Computers," by Prof. Walter W. Cannon, Arkansas State University; March 12, 1957.

LUBBOCK

"CYPAK Magnetic Control System," by J. K. Howell, Westinghouse; March 11, 1957.

MILWAUKEE

"Atomic Power Development," by Henry C. Anderson, General Electric Co.; February 20, 1957.

(Continued on page 56A)

Section Meetings

(Continued from page 54A)

New Orleans

"The Nike and Other Missile Systems," by Charles H. Boyd, Western Electric Co.; Feb. 28, 1957.

New York

"Industry-Wide Panel Discussion on Component-Considerations for Printed Circuitry and Automatic Assembly Techniques," by F. C. Collings, RCA, A. H. Postle, Sprague Electric Co., H. L. Shortt, Technograph Printed Electronics; March 6, 1957.

North Carolina-Virginia

"Scientific Training," by Robin D. Compton, George C. Davis Radio & TV Consulting Engrs.; January 25, 1957.

"Digital Computing Techniques Applied to Air Traffic Control," by Dan C. Ross, International Business Machines; March 8, 1957.

Northern Alberta

"New Pacific Coast Submarine Repeated Cable," by Max Edgar, Northwest Communication System; March 12, 1957.

Northwest Florida

"Pulse-Width Telemetry," by Mr. Roesby, Applied Science Corp.; February 29, 1957.

Oklahoma City

"The New Environment of Nuclear Radiation and Its Effects on Electronic Components," by Dr. E. L. Secrest, Convair; February 21, 1957.

Omaha-Lincoln

"The Common Emitter Jct. Transistor as a Low Freq. Amplifier," by Glen W. Ashley, Jr., General Dynamics Corp.; February 22, 1957.

Ottawa

"The Transistor as an Intermediate Frequency Amplifier," by M. A. Gullen, Canadian Army Signals; December 13, 1956.

"The New Ampex Television Tape Recorder," by L. F. Bennett, Canadian Military Electronics Standards Agency; January 10, 1957.

Student Papers by: P. C. Clatt and E. J. Woods, Queens University; W. C. Woodbury & J. A. McPherson, Royal Military College; R. P. Brown & E. N. Almery, Carleton College; B. L. Chan, University of Ottawa; February 7, 1957.

Philadelphia

"Electronic Weather Prediction," by Paul H. Kutchenreuter, U. S. Weather Bureau and Henry Adams, Philadelphia Weather Bureau; February 6, 1957.

Phoenix

"Univac," by Malcolm Keene, Arizona Public Service Co.; March 1, 1957.

Pittsburgh

"The Sage System," by Brig. Gen. S. T. Wray; Elec. Defense Systems; E. W. Baker, Western Electric Co.; February 18, 1957.

"Nucleonics in Medicine," by Dr. Sergi Feitelberg, Mt. Sinai Hospital; March 11, 1957.

Princeton

"The Cryotron—A Superconductive Computer Element," by Dr. Dudley A. Buck, M.I.T. Lincoln Laboratory; February 18, 1957.

(Continued on page 58A)

FREQUENCY STANDARDS

AVIONIC

FREQUENCIES

PRECISION FORK

TYPE 50

FREQUENCIES
240–400–500–1,000 cy.

ACCURACIES
Type 50 ±.02% (—65° to 85°C)
Type R50 ±.002% (15° to 35°C)

Requires double triode and 5 pigtail components

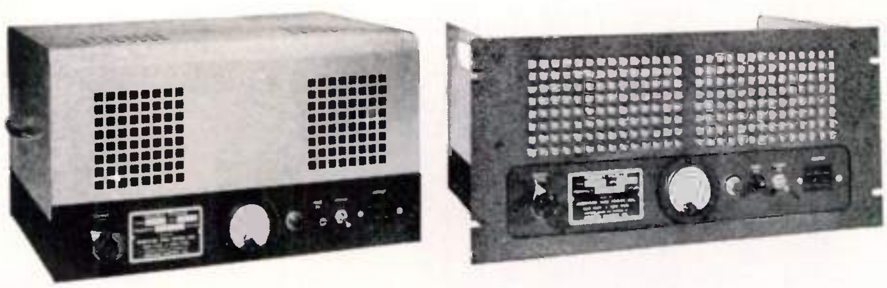
Size, 1" diameter x 3¾" high
Weight, 3.5 ounces

POWER

75 Watt

FREQUENCY STANDARD

TYPE 2111C



FREQUENCIES: ....50 to 1,000 cycles
ACCURACY: ..±.002% (+15° to +35°C)
OUTPUT: ....115V, 75 Watts
INPUT: ....110V, 50 to 75 cycles
SIZE: with cover....10"x17"x9" high
PANEL model,..10"x19"x8¾" high
WEIGHT: ....25 pounds

INDUSTRIAL

FREQUENCY STANDARD

TYPE 50L

FREQUENCIES
50–60–75 or 100 cy.

ACCURACIES
TYPE 50L
±.02% (—65° to 85°C)
TYPE R50L
±.002% (15° to 35°C)

INPUT: 150 to 300V, B (6 V at .6 amps.)
OUTPUT: ....2V into 200,000 ohms.
SIZE: ..3¾"x4½"x5½" high. Wgt., 2 lbs.

This organization makes frequency standards within a range of 30 to 30,000 cycles. They are used extensively by aviation, industry, government, (armed forces) where maximum accuracy and durability are required.

American Time Products Inc.
580 Fifth Avenue, New York 36, N. Y.

American Time Products, Inc.
580 Fifth Ave., New York 36, N. Y.
Gentlemen: Please send details on your Type______
Name______
Company______
Address______
City______

Section Meetings

(Continued from page 56A)

REGINA

"When Worlds Collide" and "Birth of an Oilfield," Films; February 15, 1957.

"New Tube Developments and the Manufacture of Cathode Ray Tubes," by D. Simkins, Rogers Majestic Electronics, Ltd.; February 25, 1957.

ROCHESTER

"The Stromberg-Carlson Experimental Microwave Link," by John E. Troutman, Stromberg-Carlson Company; February 21, 1957.

ROME-UTICA

"Vanguard Tracking," by Clarence A. Shroeder, U. S. Naval Research Laboratory; March 5 1957.

SAN ANTONIO

"VHF and UHF Propagation Modes," by J. H. Dunlavy and C. R. Graf, Kelley Air Force Base; February 27, 1957.

SAN FRANCISCO

"Linear Transistor Amplifiers," by Dr. Donald O. Pederson, University of California; February 13, 1957.

"Patent Law with Respect to Electronics," by Ben J. Chromy, Allan & Chromy; February 20, 1957.

"Transistor Switching Circuits in Computer Applications," by John O. Paivinen, General Electric Computer Laboratory; February 21, 1957.

"Future Trends, New Devices, and Applications," by William Shockley, Shockley Semiconductor Laboratories; February 27, 1957.

SOUTH BEND-MISHAWAKA

"Scatter Propagation Communication Systems," by Dr. R. L. McCreary, Collins Radio Co.; February 28, 1957.

TORONTO

"Color Television Using an Apple Display," by W. P. Boothroyd, Philco Corporation; February 25, 1957.

"An Integrated Radio Relay and Railway Communications System," by John E. Raftis, Rogers Majestic Electronics, Ltd.; March 18, 1957.

TUCSON

"Flying Platforms," by Dr. Hu, University of Arizona; February 27, 1957.

TULSA

"The Electrograph (An Electrophotographic Oscillograph)," by John C. Westervelt, Century Electronics and Instruments, Inc.; February 21, 1957.

TWIN CITIES

"Acoustical Research at RCA Laboratories," by Cyril N. Hoyler, RCA Laboratories; January 17, 1957.

Tour and Explanation of KSTP-TV Facilities, conducted by W. Sadler, KSTP-TV Station; February 14, 1957.

"Measurements in Medicine," by Robert A. Floyd, Waters Corp.; March 7, 1957.

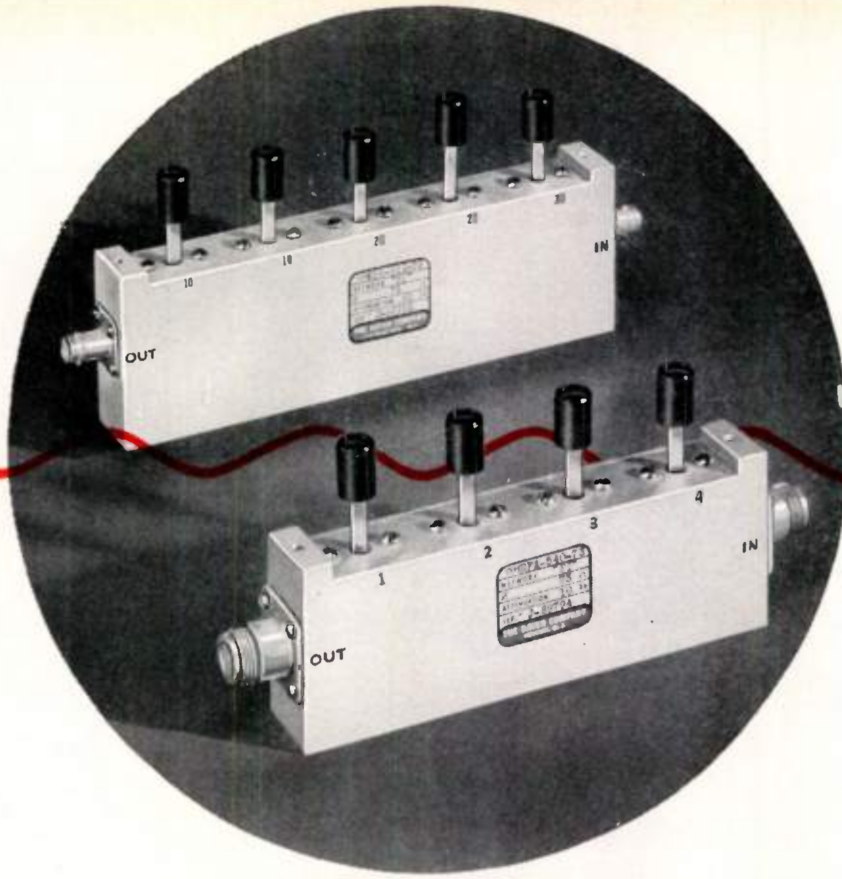
WASHINGTON

"The Central Problem of Information Theory and its Practical Implications," by Dr. Robert Fano, Massachusetts Institute of Technology; March 11, 1957.

WICHITA

"Telecommunication Services in a Power Network," by John Dill, Kansas Gas and Electric Co.; February 27, 1957.

(Continued on page 62A)



FOR ACCURATE ATTENUATION OVER A WIDE FREQUENCY RANGE...

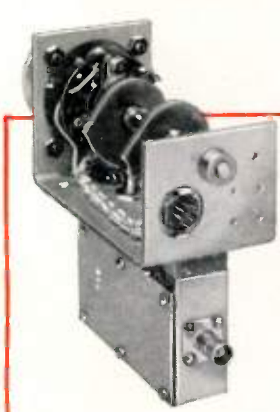
RF Attenuators by DAVEN

These units are used in signal generators, wide-band amplifiers, pulse generators, field intensity meters, micro-wave relay systems, and repeater stations. They find application as laboratory standards, test equipment, and for checking out all types of instruments.

Daven RF Attenuators are available, in combination, with losses up to 120 Db in two Db steps; or 100 Db in one Db steps. Due to their internal circuitry and construction, they have a **zero insertion loss** over the **frequency range from DC to 225 megacycles.**

Standard impedances are 50 and 73 ohms, with special impedances available on request. Resistor accuracy is within $\pm 2\%$ at DC. An unbalanced circuit is used which provides constant input and output impedance. The units are supplied with either UG-58/U or UG-185/U receptacles or Coaxial lead terminations. Individual units with single-section cavities can be obtained.

Many of these types are available for delivery from stock.



Solenoid actuated RF Attenuators are also available in various decibel combinations and any number of steps up to 5.

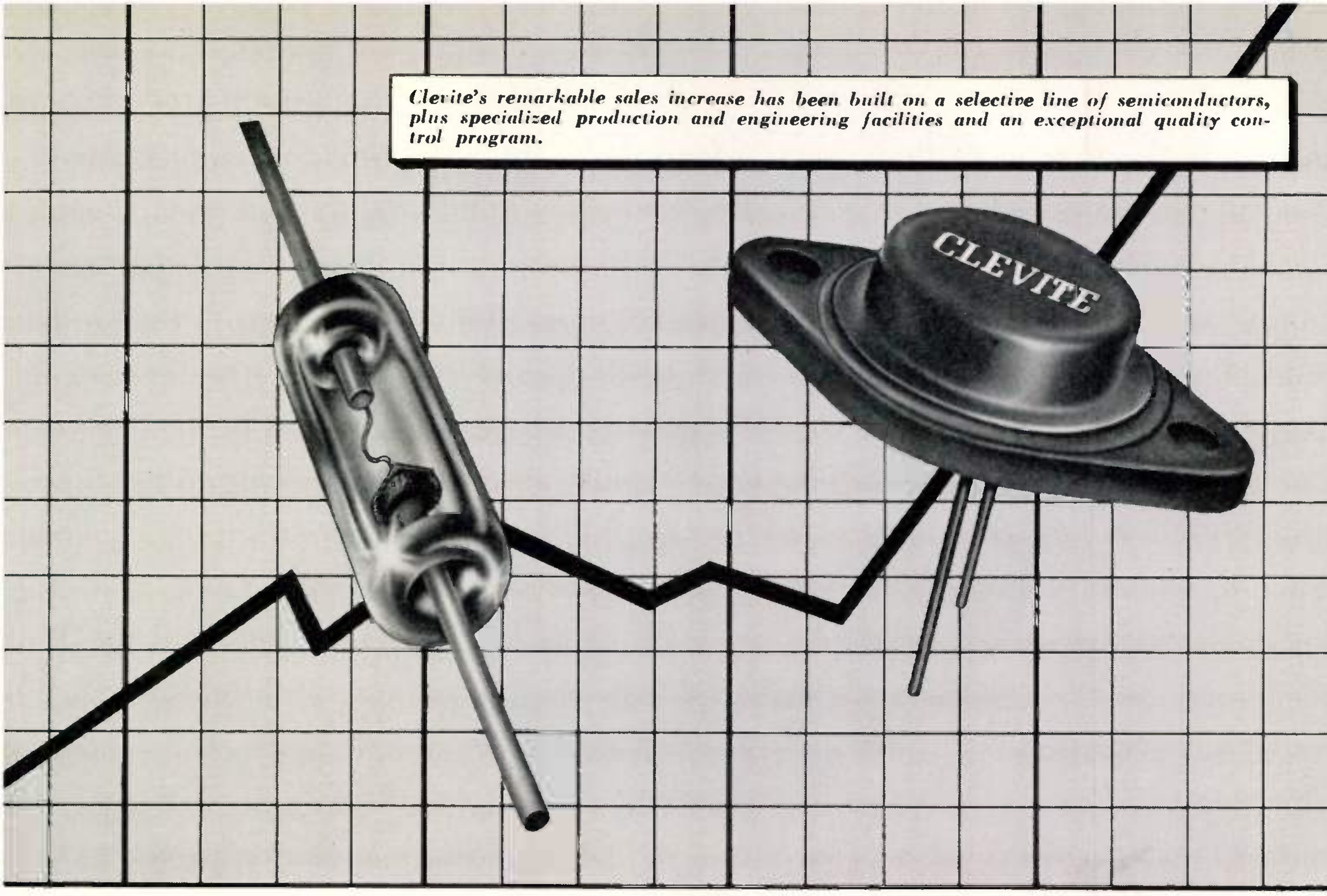
TYPE	LOSS	TOTAL Db	STANDARD IMPEDANCES
RFA & RFB 540	1, 2, 3, 4 Db	10	50/50Ω and 73/73Ω
RFA & RFB 541	10, 20, 20, 20 Db	70	50/50Ω and 73/73Ω
RFA & RFB 542	2, 4, 6, 8 Db	20	50/50Ω and 73/73Ω
RFA & RFB 543	20, 20, 20, 20 Db	80	50/50Ω and 73/73Ω
RFA & RFB 550	1, 2, 3, 4, 10 Db	20	50/50Ω and 73/73Ω
RFA & RFB 551	10, 10, 20, 20, 20 Db	80	50/50Ω and 73/73Ω
RFA & RFB 552	2, 4, 6, 8, 20 Db	40	50/50Ω and 73/73Ω

Other Db loss combinations are available.

Write for complete information

THE DAVEN CO.
528 West Mt. Pleasant Ave.
Route 10, Livingston, N. J.

WORLD'S LARGEST MANUFACTURER OF ATTENUATORS



Clevite's remarkable sales increase has been built on a selective line of semiconductors, plus specialized production and engineering facilities and an exceptional quality control program.

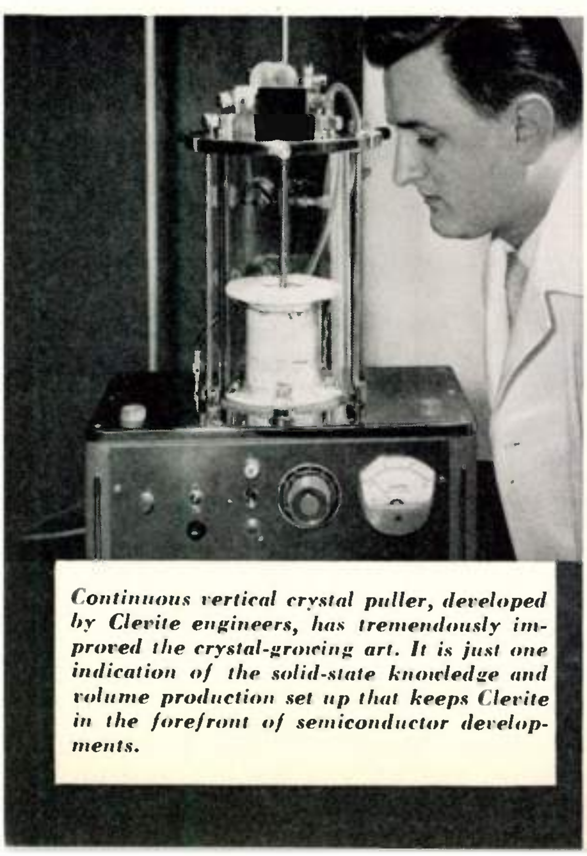
Reliability *in volume* accelerates Clevite Transistor Product's steady growth

New gains won by focusing unusual production, engineering and quality control facilities on selected semiconductors

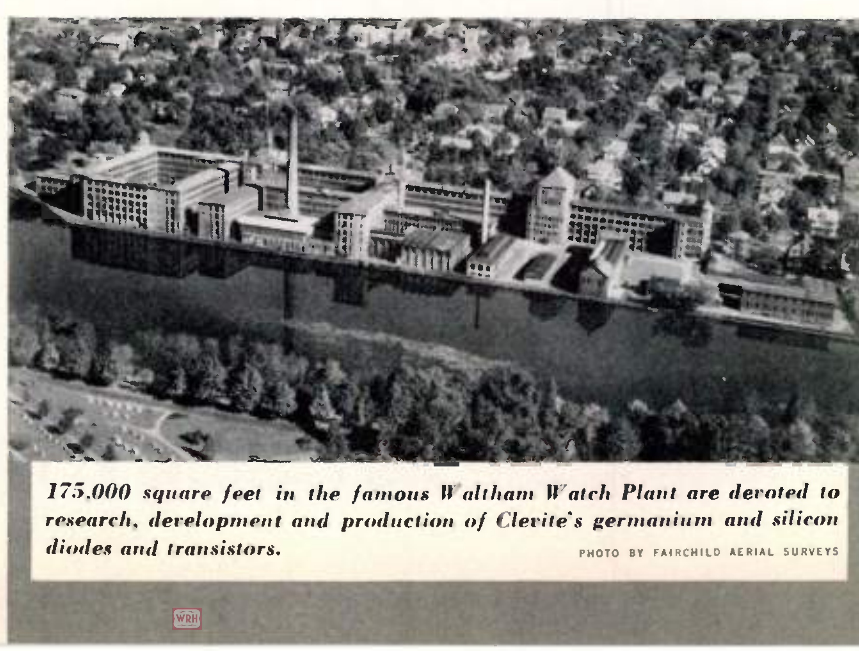
WALTHAM, MASSACHUSETTS—Improved facilities for large volume production have brought about a rapidly growing demand for Clevite's high-reliability semiconductors.

Long a leader in the transistor-diode field, Clevite Transistor Products has stepped up its production capacity and concentrated its research, development and manufacturing on a carefully selected product line.

Located in 175,000 square feet of the famous Waltham Watch building in the heart of one of the nation's most active electronics areas, this division of Cleveland's Clevite Corporation is credited with an impressive number of industry "firsts".



Continuous vertical crystal puller, developed by Clevite engineers, has tremendously improved the crystal-growing art. It is just one indication of the solid-state knowledge and volume production set up that keeps Clevite in the forefront of semiconductor developments.



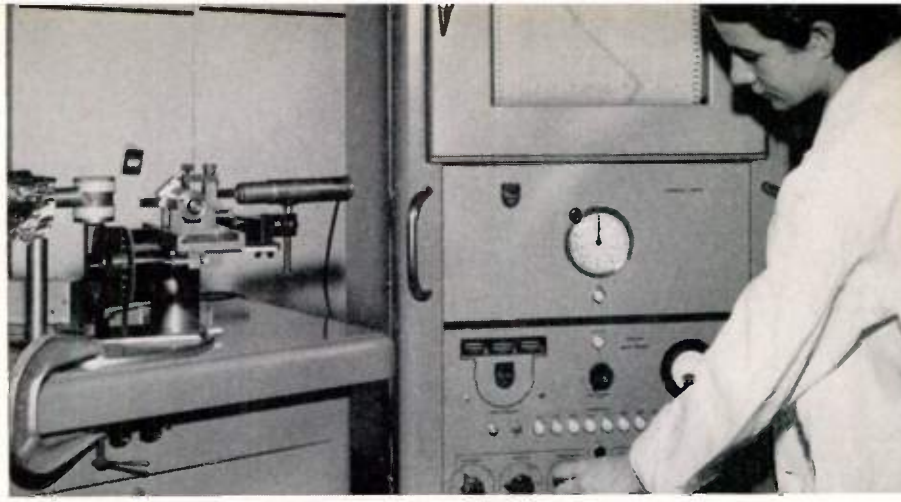
175,000 square feet in the famous Waltham Watch Plant are devoted to research, development and production of Clevite's germanium and silicon diodes and transistors.

PHOTO BY FAIRCHILD AERIAL SURVEYS

Winner of the first power transistor IPS contract awarded by the Signal Corps, Clevite Transistor Products developed the only military-approved power transistor. In the commercial field, its power transistors are approved for the new radios used in nine out of ten makes of 1957 automobiles. Clevite's high-back resistance and fast recovery time glass diodes have won great favor in the computer industry. A new Remington-Rand Univac Computer, for example, utilizes approximately 60,000. Clevite is also the largest single supplier of germanium diodes to the television industry.

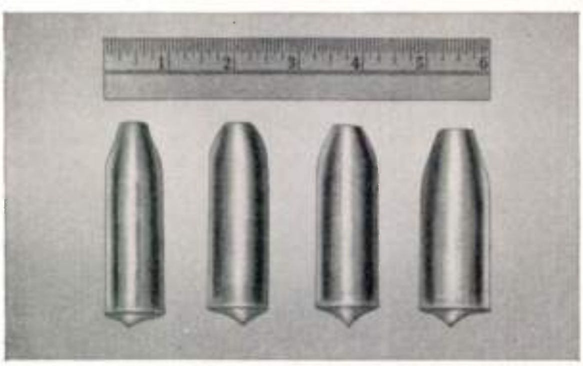
Originally a producer of varied types of semiconductors, Clevite Transistor Products now concentrates research and development on a select line of transistors and diodes. The 50 members of the engineering staff — part of an employee group of almost 500 — are concentrating their efforts on the product improvement and quality control of power transistors and high-quality diodes for the more critical applications. Their work is supported by the scientists and engineers of both Clevite Research Center in Cleveland and the German subsidiary Intermetall G.m.b.H. of Dusseldorf, Europe's second largest manufacturer of semiconductors.

Extreme crystal uniformity — the key to high quality semiconductors — has been achieved by the development of a continuous vertical crystal puller in Clevite's Waltham metallurgical laboratories. Quality control is further advanced by a device that simplifies the measurement of thermal resistance in power transistors.



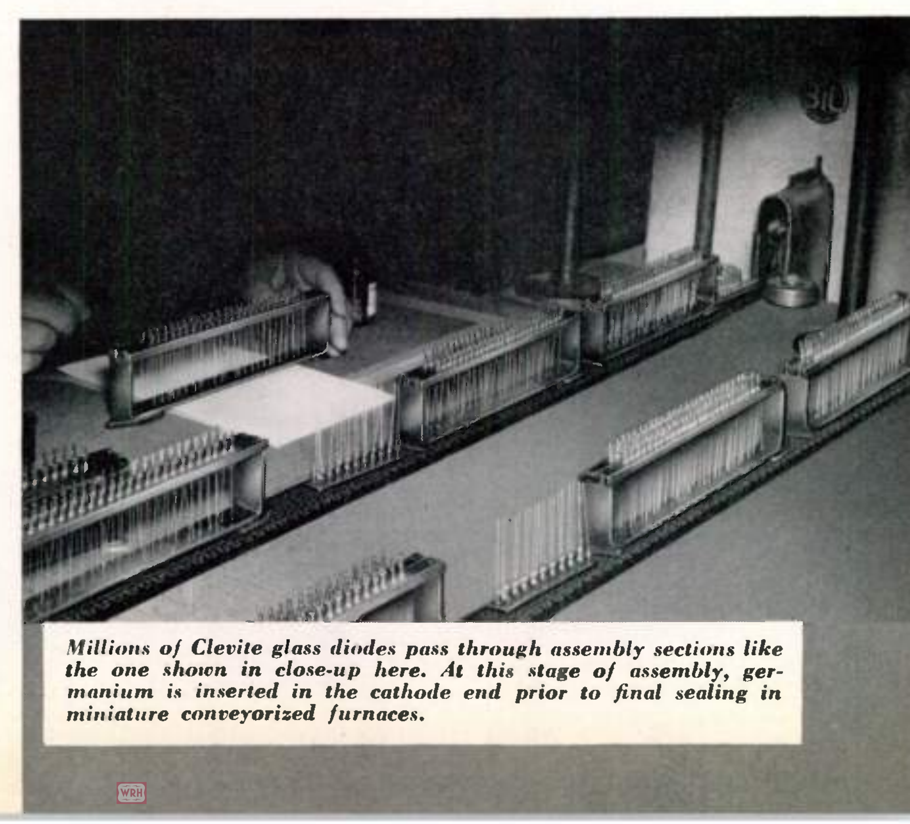
Crystal structures are double-checked in Clevite's Materials and Metallurgy Laboratory by X-Ray and Double Crystal Spectrometer to match crystal quality to specific application requirements.

Thermal resistance measurement equipment, another Clevite development, is used to check temperature drop between the junction and mounting base of power transistors under actual operating conditions. It's one of many specialized testing procedures to control quality and improve performance.



Single crystals of silicon, grown at Clevite Transistor Products Metallurgical Laboratory, demonstrate the unusual uniformity made possible by Clevite's crystal pulling technique.

Automated production of diodes now underway is another indication of Clevite's ability to control quality level and achieve high volume rates. Clevite is itself a large producer of silicon and germanium crystals — a basic advantage in meeting exceptional volume requirements.



Millions of Clevite glass diodes pass through assembly sections like the one shown in close-up here. At this stage of assembly, germanium is inserted in the cathode end prior to final sealing in miniature conveyorized furnaces.

FOR DETAILS on specifications, prices and deliveries, write or phone . . .

CLEVITE

TRANSISTOR PRODUCTS

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A Division of Clevite Corporation

Section Meetings

(Continued from page 58A)

WINNIPEG

"Forward Scatter in Communications," by E. H. Edge, Collins Radio Company; February 25, 1957.

"High Frequency Design Problems in Radio Tubes," by D. S. Simkins, Canadian Radio Corp.; March 4, 1957.

SUBSECTIONS

BERKSHIRE

"Bistable Solid State Light Cells," by Dr. Howard P. Stabler, Williams College; February 12, 1957.

CHARLESTON

"Technical Discussion of Station Facilities," by Walter Nelson, WUSN Television; March 18, 1957.

EAST BAY

"Patent Law With Respect to Electronics," by Ben J. Chromy, Allen & Chromy; February 20, 1957.

LANCASTER

"Principles of Microwave Tubes," by B. B. Brown, RCA; February 20, 1957.

MID-HUDSON

"An outline of 'Logic'," by Dr. B. Dunham, IBM Corporation; February 19, 1957.

"Digital Computing Techniques Applied to Air Traffic Control," by Dan C. Ross, IBM Corporation; March 12, 1957.

NEW HAMPSHIRE

"The Sage System," by R. G. Enticknap, M.I.T. Lincoln Lab.; January 30, 1957.

PIEDMONT

"Missile Instrumentation," by Gordon Thorpe, Bell Telephone Lab.; February 22, 1957.

RICHLAND

"Theoretical Aspects of Transistors," by G. E. Driver, General Electric; February 25, 1957.

SHREVEPORT

"Computers and Their Application," by Edward Gordon, United Gas Research Laboratory; March 5, 1957.

WESTCHESTER

"Doppler Radar Navigation Systems," by F. B. Berger, General Precision Laboratory, Inc.; February 20, 1957.

Membership

The following transfers and admissions were approved and are now effective:

Transfer to Senior Member

Achenbach, J. C., Haddonfield, N. J.
Bagnall, J. J., Jr., Watertown, Mass.
Baldwin, G. F., Clinton, N. Y.
Barale, J. J., Oakland, Calif.
Beattie, H. S., Poughkeepsie, N. Y.
Beyer, C. M., Washington, D. C.
Bradshaw, S. R., Arlington, Calif.
Brown, L. W., Rochester, N. Y.
Buchbinder, M. M., Whitestone, L. I., N. Y.
Burns, M. C., Medford Lakes, N. J.
Child, T. M., Avon-by-the-Sea, N. J.
Cook, H. B., Washington, D. C.
Crowley, J. J., Washington, D. C.

(Continued on page 66A)

Systems engineering—38th parallel style

Here's the challenge we received from the Korean Civil Assistance Command and the U. S. Army Signal Corps:

Build a telephone communications system to their specifications that will function over mountainous terrain. Cost to be within reasonable limits . . . upkeep minimum . . . equipments compatible with the experience and background of the population.

The answer is the system now being installed in South Korea.

Manually operated telephones, central offices and PBX switchboards, suited to a civilian population unfamiliar with dial methods.

Wire lines for basic country-wide linkage, augmented with many channels of *Carrier*, wherever estimated traffic warrants it.

And—delivery on schedule.

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Volts—
Microfarads and
Miniaturization

......*for Transistor Circuitry*

The daily progress of transistor usage is calling for smaller, yet better components. Mallory is proud of their continuous contribution to miniaturization—smaller components without sacrifice of reliability.

In the power supply field, Mallory is a pioneer in the development and production of mercury cells. Their techniques have made possible mass production at highest quality levels. The constant voltage discharge characteristic is ideally suited for transistor operation.

Mallory subminiature capacitors, in four types, offer wide choice of ratings and characteristics.

- **TAW**—an ultra-miniature tantalum capacitor—from 1 mfd/24 V to 6 mfd/4 V.
- **TAP**—a tantalum capacitor with −55° to +80° C ratings, from 2 mfd/90 V to 30 mfd/6 V.
- **TNT**—the smallest tantalum ever for its ratings—from 8 mfd/50 V to 80 mfd/3 V.
- **TT**—a commercially priced miniature aluminum electrolytic—from 1 to 110 mfd at from 1 to 50 V.

Mallory will be glad to consult with you on specific problems of miniaturization and transistor application components, or supply full technical data on battery, capacitor and other Mallory products. Write us, or contact the Mallory representative—today.

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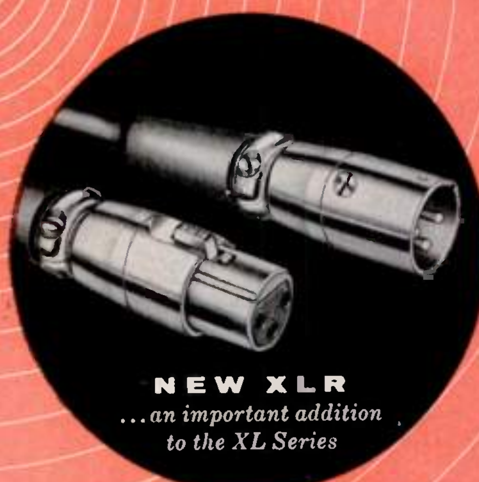
Parts distributors in all major cities stock Mallory standard components for your convenience.

STANDARDIZE WITH CANNON



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You'll find exactly the type you need in 14 extensive series expressly designed for radio, sound, TV and related fields . . . in cord, rack or panel chassis, audio and low-level, portable, hermetic sealed, miniature and subminiature, and power-supply types. Standard equipment with leading manufacturers of electronic equipment. The old reliable "Latchlock" feature on Cannon microphone connectors . . . standard on top-ranking microphones.

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Distributors everywhere.

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(Continued from page 62A)

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Faulkner, W. H., Jr., Boston, Mass.
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Huang, C., Watertown, Mass.
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Kendall, R., Lexington, Mass.
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Kingsley, B., Princeton, N. J.
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Lee, F. F., Norristown, Pa.
Liguori, A., Huntington Station, L. I., N. Y.
Linden, A. E., Plainview, L. I., N. Y.
Linhardt, R. J., Haddonfield, N. J.
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Loras, J., Dallas, Tex.
Lovell, R. E., Alamogordo, N. Mex.
Lovick, E., Jr., Van Nuys, Calif.
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Lutz, I. C., Berkeley, Calif.
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Redhead, P. A., Ottawa, Ont., Canada
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Swanson, E. H., Glen Head, L. I., N. Y.
Tasker, R. B., Van Nuys, Calif.
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Tomlinson, C. C., Glen Burnie, Md.
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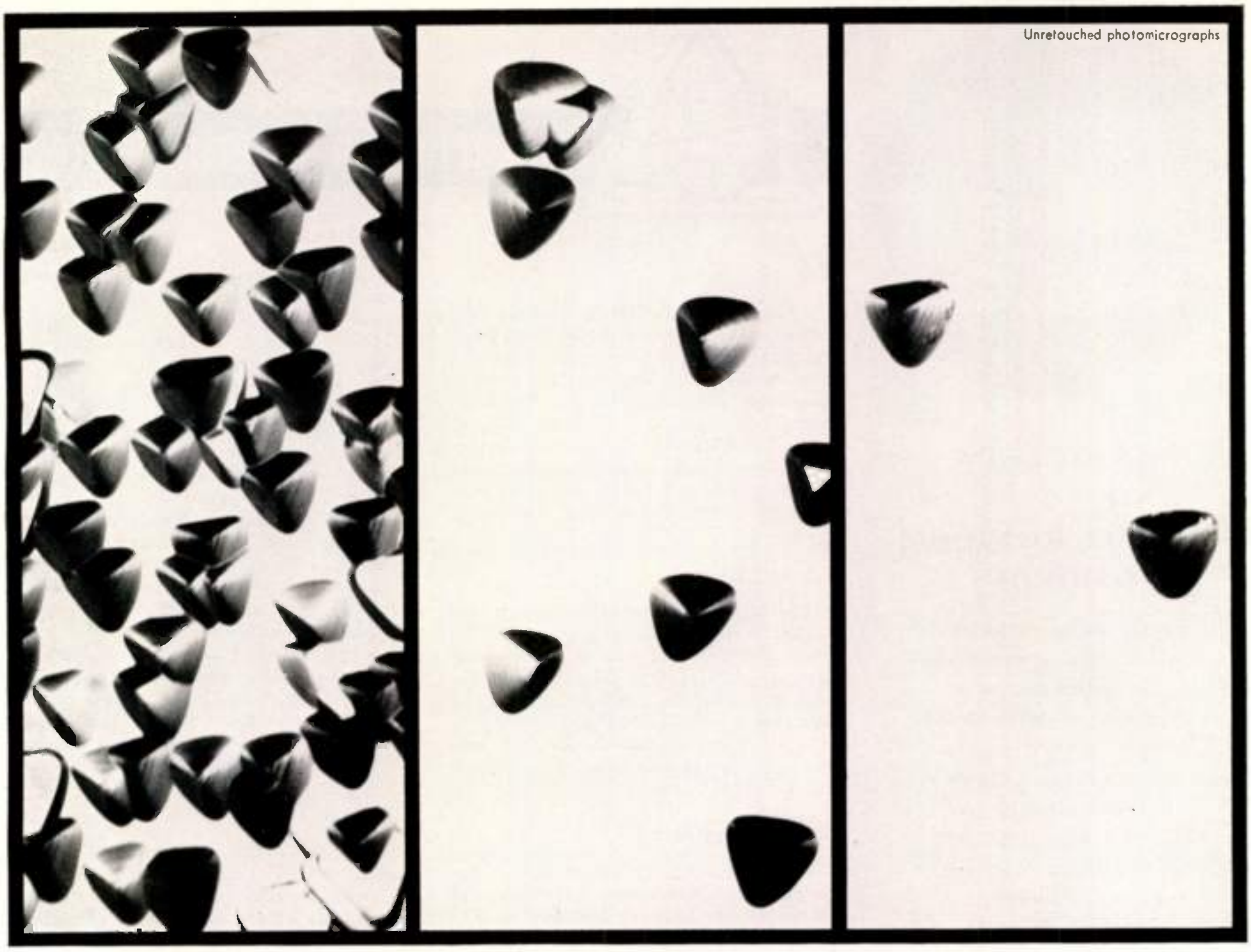
Trego, D. G., Phoenix, Ariz.
Underwood, J. F., Collingswood, N. J.
Valenta, M. F., Millersville, Md.

(Continued on page 68A)

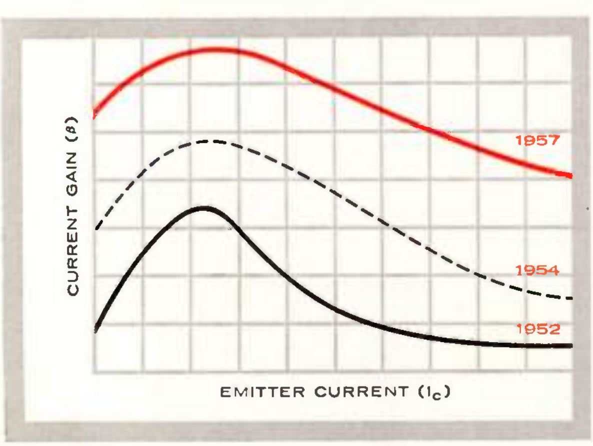


1952 Germanium crystals average many of these triangular "dislocations" or imperfections, here magnified 200 diameters.

1954 Processing improvements are bringing dislocations under better control, but density can be further reduced.

1957 Mechanized growing of CBS single crystals has uniformly minimized dislocations. Density is that of purest diamonds.

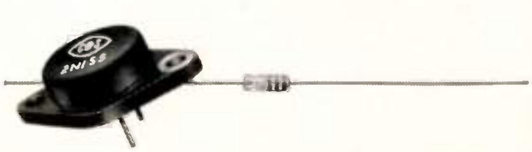
How more-perfect crystals improve transistor performance



BETA Note the higher Beta or current gain (other factors being equal) derived from today's perfected CBS germanium crystals. Beta is used as just one concrete example of many important performance factors improved by CBS-Hytron's better crystal processing methods.

How does CBS grow uniformly dislocation-free crystals with uniform resistivity? By precise checking of the "seed" for orientation and dislocation density. By growing the single crystal in smoothly operating, shock-proof mechanized furnaces. By automatic temperature control and a uniform temperature gradient throughout the growing period. Research and development advances like these are constantly at work to make CBS transistors better.

And you can *see* the difference in quality that is built not tested into CBS transistors: In crystal photomicrographs. In Beta and other figures of merit. And in actual performance. Try CBS transistors and see for yourself.



CBS **semiconductors**

Reliable products through Advanced-Engineering

CBS-HYTRON
Semiconductor Operations, Lowell, Mass.
A Division of Columbia Broadcasting System, Inc.

Industrial Engineering Notes*

Engineering

The Systems Reliability Analysis Task Group of the Electronic Applications Committee (Reliability) has recently issued "A General Guide for Technical Reporting of Electronic Systems Reliability Measurement." Copies may be obtained upon request to the RETMA Engineering Department at no charge to member companies. Copies will be sold for $1 each to all nonmember companies or their representatives.

Marketing

Sales of transistors at the factory continued to rise sharply in January. A total of 1,436,000 were sold for $4,119,000 compared with 572,000 at $1,893,000 a year ago. Employment in communications equipment industry declined slightly to 585,100 from November's 598,500. Production workers also dropped to 407,800 from 422,800.

Mobilization

Defense Secretary Wilson recently announced the combination of the Offices of Assistant Secretary of Defense for Research and Development and Assistant Secretary of Defense for Engineering into a new office designated as Assistant Secretary of Defense for Research and Engineering. F. D. Newbury was designated to be Assistant Defense Secretary in charge of the new office and W. M. Holaday was named Deputy.

Procurement

A contract awarded the General Electric Co. was announced by the Air Materiel Command, Dayton, Ohio. The letter contract totals $20 million for production of airborne electronic countermeasures equipment (radar jammers). No estimate was made by the AMC of the anticipated final value of the contract. The first Universal Digital Operational Flight Trainer (UDOFT) is being developed by Sylvania Electric Products Inc., Waltham, Mass., under a contract of more than a million dollars awarded by the Naval Training Device Center, Port Washington, N. Y., a field activity of the Office of Naval Research, the Navy announced. Benrus Watch Co., Waterbury, Conn., recently has been awarded a $1.9 million contract to supply the Navy with launchers for its newest air-to-air missile, "Sidewinder." The contract covers 4,080 Aero 3A launchers and pylons. The Office of Defense Mobilization also announced that the Crosley Division of AVCO Manufacturing Corp., Evendale, Ohio, received a certificate of necessity for accelerated tax amortization in the amount of $98,887, allowing 65 per cent depreciation, for the manufacture of radar sets for military use.

Technical

The Navy has announced that the Bell Automatic Carrier Landing System, a highly mobile combination of radio and radar, will be installed on a carrier soon for tests under actual carrier flight operations at sea. The system was developed under Bureau of Ships contract and built by Bell Aircraft Corp., at Buffalo, N. Y. Radar locates the airplane and determines its altitude and position in relation to the carrier deck. An electronic computer does the rest, sending the necessary course corrections to a device which directs the airplane into the desired flight pattern, the Navy said.

* The data on which these Notes are based were selected by permission from *Industry Reports*, issues of February 25, and March 4 and 11, published by the Radio-Electronics-Television Manufacturers Association, whose helpfulness is gratefully acknowledged.

Membership

(Continued from page 66A)

Van Tilbury, J. D., Marion, Iowa
Voelker, F., Pleasant Hill, Calif.
Vought, N. F., Glendale, L. I., N. Y.
Ward, A. E., Waban, Mass.
Waterman, A. T., Jr., Stanford, Calif.
Westbom, A. C., Jr., Westwood, Mass.
Westcot, J. L., Cedar Rapids, Iowa
Widerquist, V. R., Melbourne, Fla.
Widmann, F. W., Haddonfield, N. J.
Williams, E. M., Silver Spring, Md.
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Parker, J. D., London, England
Morgan Voyce, A. M., Watford, Herts., England
Taylor, L. A., Jackson, Mich.
Tylor, H. L., Baltimore, Md.
Vanous, J. A., Cedar Rapids, Iowa
Vaughn, C., Jr., Atlanta, Ga.
Woods, R. B., Dalas, Tex.
Wurdemann, W. H., Jr., New York, N. Y.

Transfer to Member

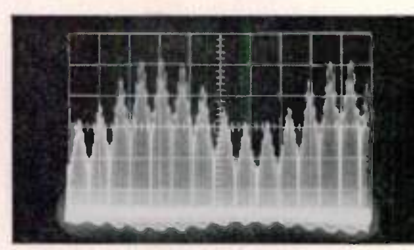
Aaron, M. R., Murray Hill, N. J.
Abeyta, I., West Long Branch, N. J.
Acker, W. W., Anaheim, Calif.
Adkins, F. L., Jr., Winston-Salem, N. C.

(Continued on page 70A)

Hoffman Beacon Simulator bench tests TACAN-VORTAC for all-weather flying safety

The Hoffman-developed HLI-103 Beacon Simulator provides a sure, safe way to ground test airborne TACAN—and the TACAN portion of VORTAC. It duplicates the functions of a TACAN Land Beacon (AN/URN-3) and tests airborne units (AN/ARN-21) for azimuth from 0 to 360° with a ±0.2° accuracy or better, and range from 0 to 200 nautical miles with a ±0.1 mile accuracy or better. The Hoffman Beacon Simulator also tests the AN/ARN-21 at instrument airspeed from 0 to 1500 knots, land beacon identity tone and decoding functions—even simulates adverse weather conditions to assure complete operational reliability.

Hoffman TACAN-VORTAC test instruments, now used by the military services, are also available to aircraft manufacturers, commercial airlines and service operators to provide a vital, extra measure of flying safety for air navigation equipment *from the ground up*. Additional information will be promptly sent upon request.



Hoffman HLI-103 simulates the functions of TACAN Land Beacons. Photo shows 135 cps and 15 cps pulse burst detail. Phase relationships indicate surface beacon is due east of aircraft. Comparison of input settings with TACAN dial readings determines operational accuracy.

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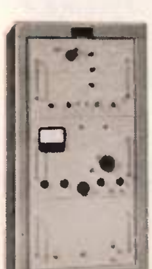
Significant developments at Hoffman in the fields of TACAN, VORTAC, advanced navigation techniques, VLF, HF, VHF, UHF, forward scatter and tropospheric communications and advanced ECM have created important positions for physicists and engineers of high calibre. Please address inquiries to Vice-President of Engineering.



HOFFMAN HLI-103
BEACON SIMULATOR

Hoffman

LABORATORIES, INC.

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FOR IMMEDIATE DELIVERY FROM STOCK

POWER TRANSFORMERS-STANDARD
All primaries 105/115/125 v., 60 c.p.s.

Cat. No.	Hi Volt Sec.	ct	DC Volts	DC Amps	Filament #1 Volt	Filament #1 Amp.	Filament #2 Volt	Filament #2 Amp.	MIL Case Size
MGP1	400/200	√	185	.070	6.3/5	2	6.3	3	HA
MGP2	650	√	260	.070	6.3/5	2	6.3	4	JB
MGP3	650	√	245	.150	6.3	5	5.0	3	KB
MGP4	800	√	318	.175	5.0	3	6.3	8	LB
MGP5	900	√	345	.250	5.0	3	6.3	8	MB
MGP6	700	√	255	.250					KB
MGP7	1100	√	419	.250					LB
MGP8	1600	√	640	.250					NB

FILAMENT TRANSFORMERS-STANDARD
All primaries 105/115/125 v., 60 c.p.s.

Cat. No.	Secondary Volt	Secondary Amp	Test VRMS	MIL Case
MGF1	2.5	3.0	2,500	EB
MGF2	2.5	10.0	2,500	GB
MGF3	5.0	3.0	2,500	FB
MGF4	5.0	10.0	2,500	HB
MGF5	6.3	2.0	2,500	FB
MGF6	6.3	5.0	2,500	GB
MGF7	6.3	10.0	2,500	JB
MGF8	6.3	20.0	2,500	KB
MGF9	2.5	10.0	10,000	JB
MGF10	5.0	10.0	10,000	KB

PULSE TRANSFORMERS

Cat. No.	Block'g. Osc.	Int. Coupl'g	Low. Pow. Out.	Pulse Voltage Kilovolts	Pulse Duration Microseconds	Duty Rate	No. of Wdgs.	Test Volt. KVRMS	Char. Imp. Ohms
MPT1	√	√		0.25 0.25 0.25	0.2-1.0	.004	3	0.7	250
MPT2	√	√		0.25 0.25	0.2-1.0	.004	2	0.7	250
MPT3	√	√		0.5/0.5/0.5	0.2-1.5	.002	3	1.0	250
MPT4	√	√		0.5 0.5	0.2-1.5	.002	2	1.0	250
MPT5	√	√		0.5 0.5 0.5	0.5-2.0	.002	3	1.0	500
MPT6	√	√		0.5 0.5	0.5-2.0	.002	2	1.0	500
MPT7	√	√	√	0.7/0.7 0.7	0.5-1.5	.002	3	1.5	200
MPT8	√	√	√	0.7 0.7	0.5-1.5	.002	2	1.5	200
MPT9	√	√	√	1.0 1.0 1.0	0.7-3.5	.002	3	2.0	200
MPT10	√	√	√	1.0 1.0	0.7-3.5	.002	2	2.0	200
MPT11	√	√	√	1.0 1.0 1.0	1.0-5.0	.002	3	2.0	500
MPT12	√	√	√	0.15 0.15 0.3 0.3	0.2-1.0	.004	4	0.7	700

AUDIO TRANSFORMERS

Frequ. resp. 300 to 10000 cps ± 2 DB. All Case Sizes AJ

Catalog No.	Application	Impedance Prim. Ohms	Ct.	Sec. Ohms	Ct.	DC Current Prim. P. Side MA	Max. Unbal. MA	Max Level DBM
MGA1	Single or P.P. Plates — to Single or P.P. Grids	10K	√	90K Split	√	10	10	+15
MGA2	Line to Voice Coil	600 Split		4, 8, 16		0	0	+33
MGA3	Line to Single or P.P. Grids	600 Split		135K	√	0	0	+15
MGA4	Line to Line	600 Split		600 Split		0	0	+15
MGA5	Single Plate to Line	7.6K 4.0T		600 Split		40	40	+33
MGA6	Single Plate to Voice Coil	7.0K 4.0T		4, 8, 16		40	40	+33
MGA7	Single or P.P. Plates to Line	15K	√	600 Split		10	10	+33
MGA8	P.P. Plates to Line	24K	√	600 Split		10	1	+30
MGA9	P.P. Plates to Line	60K	√	600 Split		10	1	+27

Send for further information on these units, or special designs. Also ask for complete laboratory test instrument catalog.

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1720 Weirfield Street
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(Continued from page 68A)

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Brandt, W. E., Poughkeepsie, N. Y.
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Butler, J. G., Jr., University City, Mo.
Calabrese, J. F., New York, N. Y.
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Christensen, A. A., Cedar Rapids, Iowa
Chu, H., Hawthorne, Calif.
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Clark, J. E., Jr., Fort Worth, Tex.
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Corr, J. J., Riverton, N. J.
Crosby, R. W., Great Neck, L. I., N. Y.
De Clue, J. L., Medfield, Mass.
de la Parra, A. F., Long Island City, L. I., N. Y.
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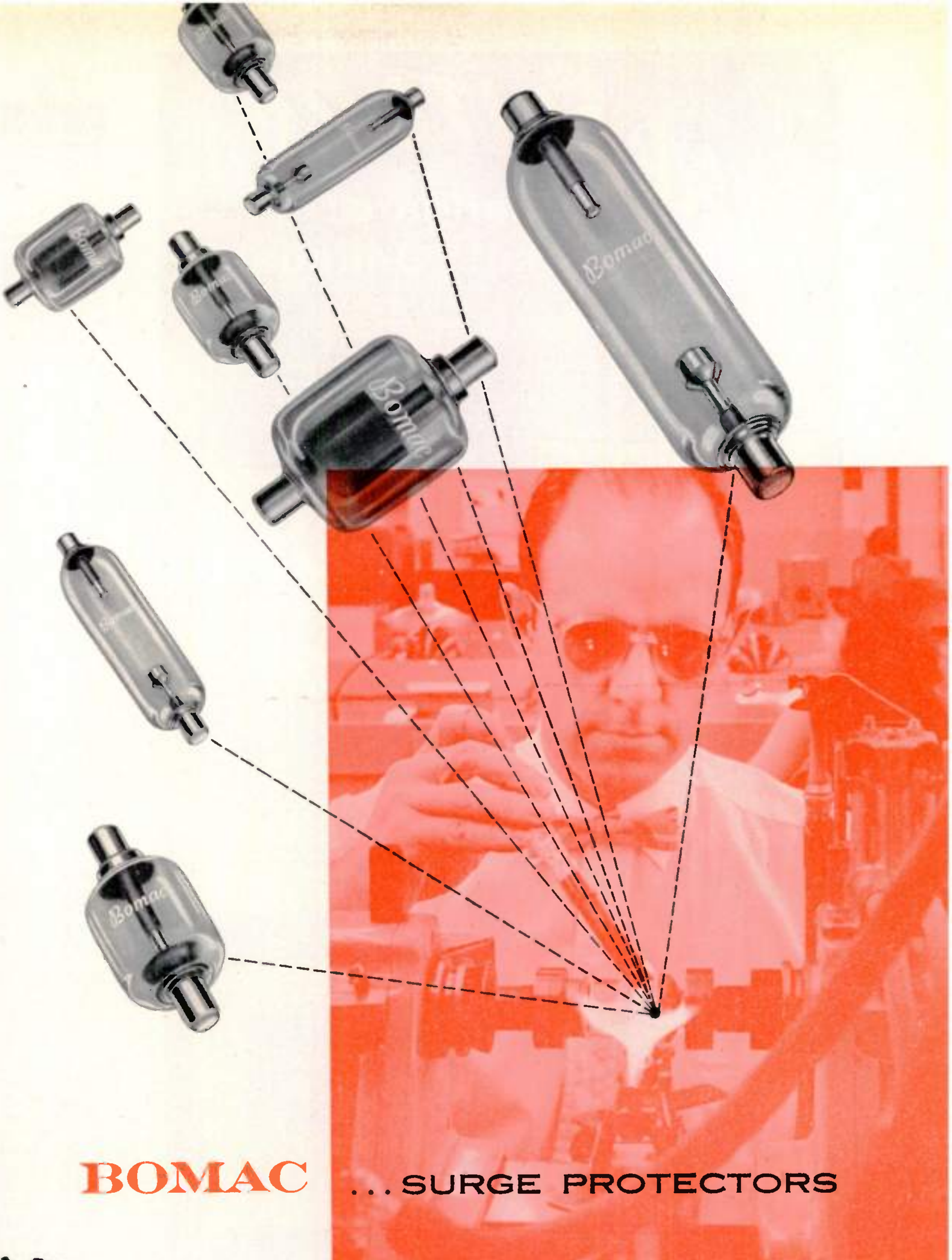

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(*Continued on page 82A*)

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	Max. DC Inverse Operating Voltage (volts)	Maximum Average Forward Current (mA) @25°C	@150°C	Maximum Forward Voltage @200mA @25°C (volts)	Inverse Current At Specified DC Test Voltage (μa) 25°C	150°C	Test Voltages (volts)
HD-6764	70	200	50	1.0	0.025	5	60
HD-6766	130	200	50	1.0	0.025	5	125
HD-6768	180	200	50	1.0	0.025	5	175
HD-6771	225	200	50	1.0	0.05	25	225
HD-6773	300	200	50	1.0	0.1	25	300
HD-6775	380	200	50	1.0	0.1	25	380

Second, a related high conductance series in the Hughes glass package with somewhat different characteristics.

	Comparable Competitive Types *	Max. DC Inverse Operating Voltage (volts)	Maximum Average Forward Current (mA) @25°C	@150°C	Maximum Forward Voltage @100mA @25°C (volts)	Inverse Current At Specified DC Test Voltage (μa.) 25°C	150°C	Test Voltages (Volts)
HD-6132	1N482B	36	200	50	1.0	0.025	5	30
HD-6133	1N483B	70	200	50	1.0	0.025	5	60
HD-6134	1N484B	130	200	50	1.0	0.025	5	125
HD-6135	1N485B	180	200	50	1.0	0.025	5	175
HD-6136	1N486A	225	200	50	1.0	0.05	25	225

*Currently these competitive types are not registered with RETMA; hence their specifications are subject to change. When they are registered, diodes now designated as HD types will be supplied as 1N types according to the registered specifications.

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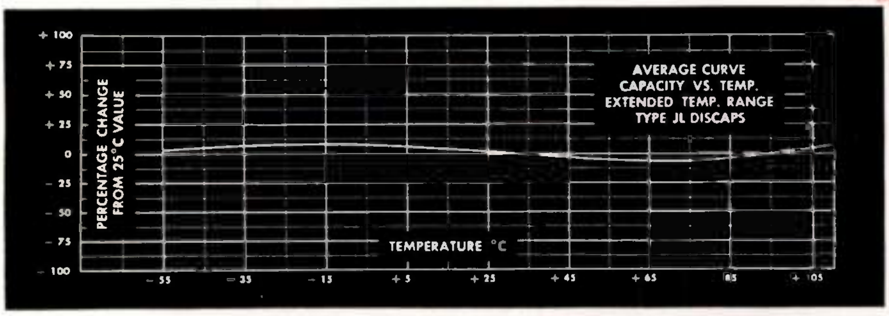
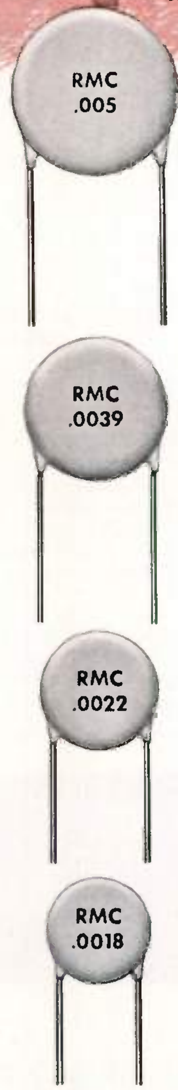
(*Continued on page 86A*)

"Temperature Stable"





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(Continued on page 90A)

"re: *Your shipment on the 5th...*"

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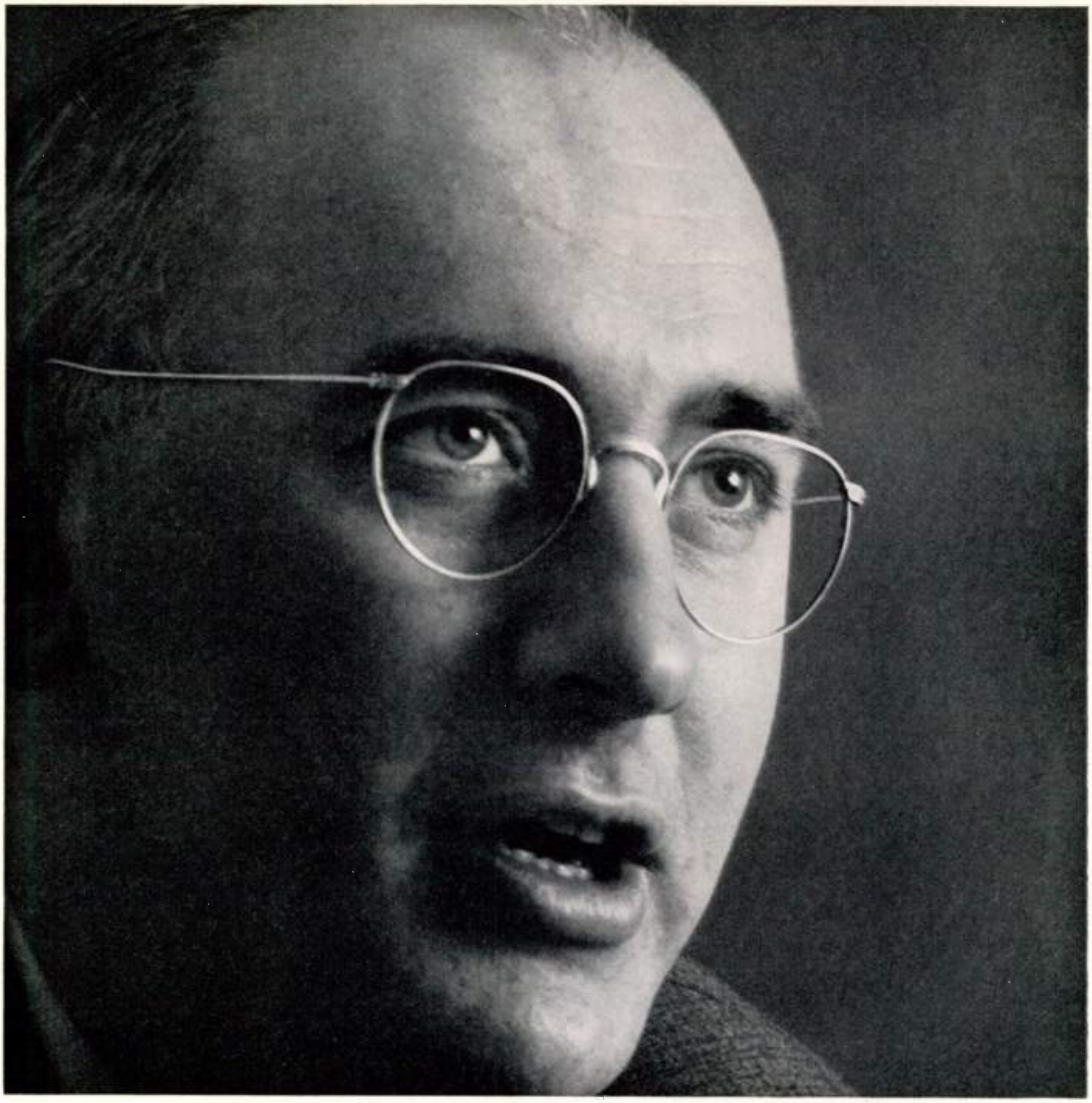

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...on the engineer and national security

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— E. J. Barlow, Head of the Engineering Division

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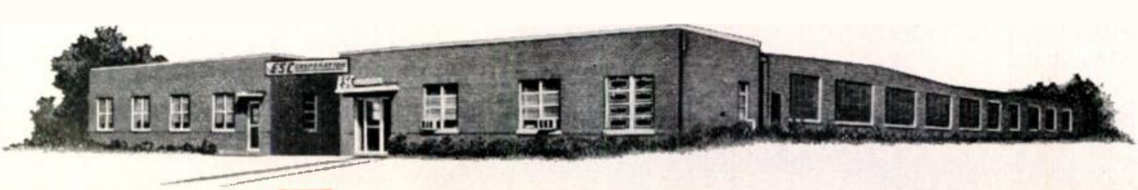

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(Continued on page 100A)

TECHNIQUES and DEVELOPMENTS in oscillographic recording

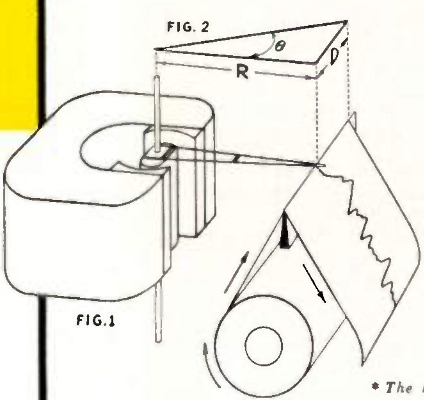
FROM

SANBORN

RECORDING METHOD USED IN SANBORN DIRECT WRITERS, AND A REVIEW OF THEORETICAL AND ACTUAL ERROR FACTORS

Figure 1 shows the basic scheme by which Sanborn oscillographic recording galvanometers produce graphic records of electrical signal values. If the rapid deflection action of the heated ribbon tip stylus is visualized when current flows in the coil, it can be seen that a straight line at right angles to the chart length is recorded on the chart, at the point where the chart is drawn over a knife edge. The trace, therefore, is a true rectangular co-ordinate graph.

Since this is essentially a process of expressing coil (or stylus) deflection *angles* in terms of *distances* on a chart, the trigonometry of the situation (Fig. 2) must be examined to ascertain the accuracy of the method. Initially, and when θ is small, the tangent and the angle are almost equal numerically. The expression $D = R \tan \theta$ can, therefore, be rewritten $D = R\theta$ (approx.). To the extent this latter expression is true, deflection distances (rather than deflection angles) are an accurate measure of signal values. But to determine the extent of error resulting from using this approximation, the following data have been calculated*, using a chart width of 25 mm either side of zero ("D" in Fig. 2) and effective stylus length of 100 mm ("R" in Fig. 2) in the series expansion for the tangent function. Error as a function of deflection then becomes:



D mms	Radians	Theoretical Error ϵ	Corrected Error δ	Corrected Error in mms
10	.10	.0033	0	0
15	.15	.0075	.004	.06
20	.20	.0133	.010	.20
25	.25	.0209	.018	.45

When the recording system is calibrated, that calibration is often made on the basis of a one centimeter deflection from the chart center, or by means of a two centimeter deflection starting one centimeter below chart center and finishing one centimeter above chart center. In either case the deflection at one centimeter from chart center is accepted as the standard, and, therefore, is without error. The foregoing table can therefore be corrected by subtracting .0033 from each of the error terms to show the error, δ, to be expected in actual use. The final column in the table shows this error in mms.

Since the active length of the stylus increases as θ increases, deflection D increases more rapidly than θ. All positive error terms in the series expansion bear this out, but the error terms would occur as predicted only if the galvanometer produced deflections exactly proportional to coil currents (that is, ideal spring properties in the torsion rods and uniformity of magnetic field). Pole tips in Sanborn galvanometers are proportioned so that in maximum deflections, galvanometer sensitivity *decreases* slightly, the compensation resulting in *actual* linearity better than that predicted in the table.

** The mathematics involved here, as well as a discussion of fixed length stylii, design parameters affecting over-all galvanometer performance, etc., are contained in an article by Dr. Arthur Miller "Sanborn Recording Galvanometers", published in the May 1956 Sanborn RIGHT ANGLE. Copies are available on request.*

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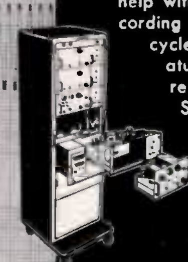

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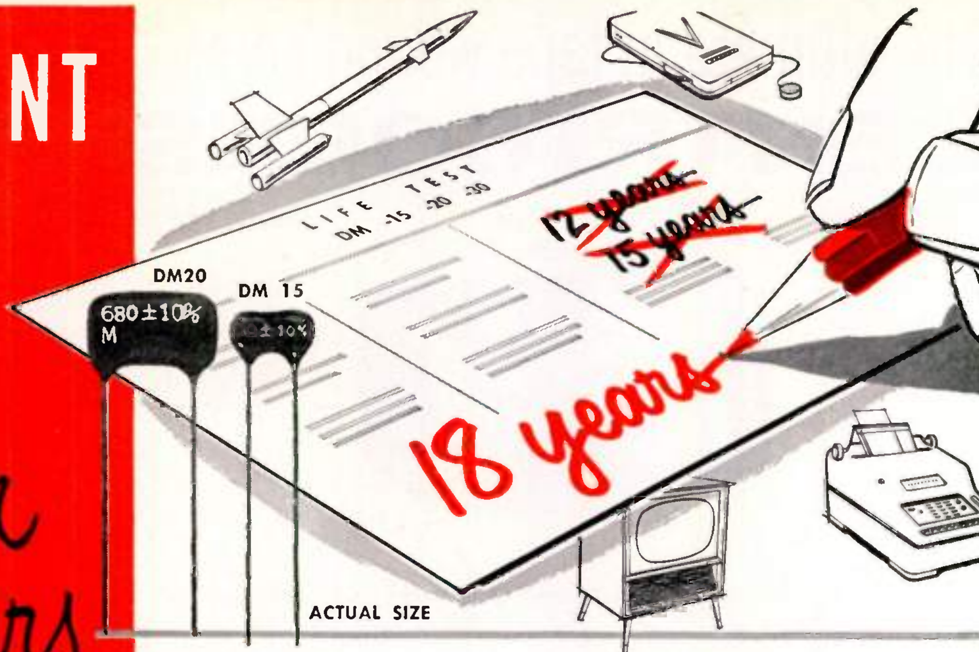

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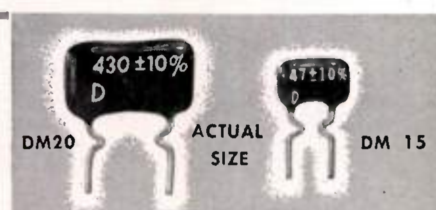

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	I.D.	O.D.	Strip Width	I.D.	O.D.	H		I.D.	O.D.	Strip Width	I.D.	O.D.	H
47	.500	.625	.125	.440	.685	.195	75	1.250	2.000	.375	1.170	2.110	.445
2	.500	.750	.125	.440	.820	.195	15	1.500	2.500	.500	1.400	2.600	.600
37	.625	1.000	.188	.570	1.085	.262	16	1.625	2.000	.250	1.525	2.110	.330
3	.625	1.000	.250	.570	1.085	.340	17	2.000	2.500	.500	1.860	2.652	.610
5	.650	.900	.125	.585	.975	.195	58	2.000	3.000	1.000	1.860	3.152	1.188
79	.750	1.000	.250	.665	1.085	.340	76	2.000	3.000	.500	1.900	3.100	.610
7	.750	1.125	.188	.665	1.215	.262	18	2.500	3.000	.500	2.360	3.152	.610
9	1.000	1.250	.125	.915	1.340	.195	19	2.500	3.500	.500	2.313	3.688	.688
30	1.000	1.250	.250	.915	1.340	.320	20	2.500	3.500	1.000	2.313	3.688	1.188
10	1.000	1.375	.250	.925	1.455	.320	21	2.500	3.750	1.250	2.313	3.938	1.438
39	1.000	1.500	.250	.925	1.570	.320	22	2.500	3.750	1.500	2.313	3.938	1.688
62	1.000	1.500	.500	.925	1.570	.610	23	3.250	4.500	1.500	3.062	4.688	1.688
11	1.000	1.500	.375	.925	1.570	.445	77	3.250	5.000	1.500	3.062	5.188	1.688
13	1.250	1.750	.250	1.170	1.820	.330	25	4.000	5.250	2.000	3.813	5.438	2.188
29	1.250	1.750	.500	1.170	1.820	.610	78	4.000	6.000	2.000	3.813	6.188	2.188

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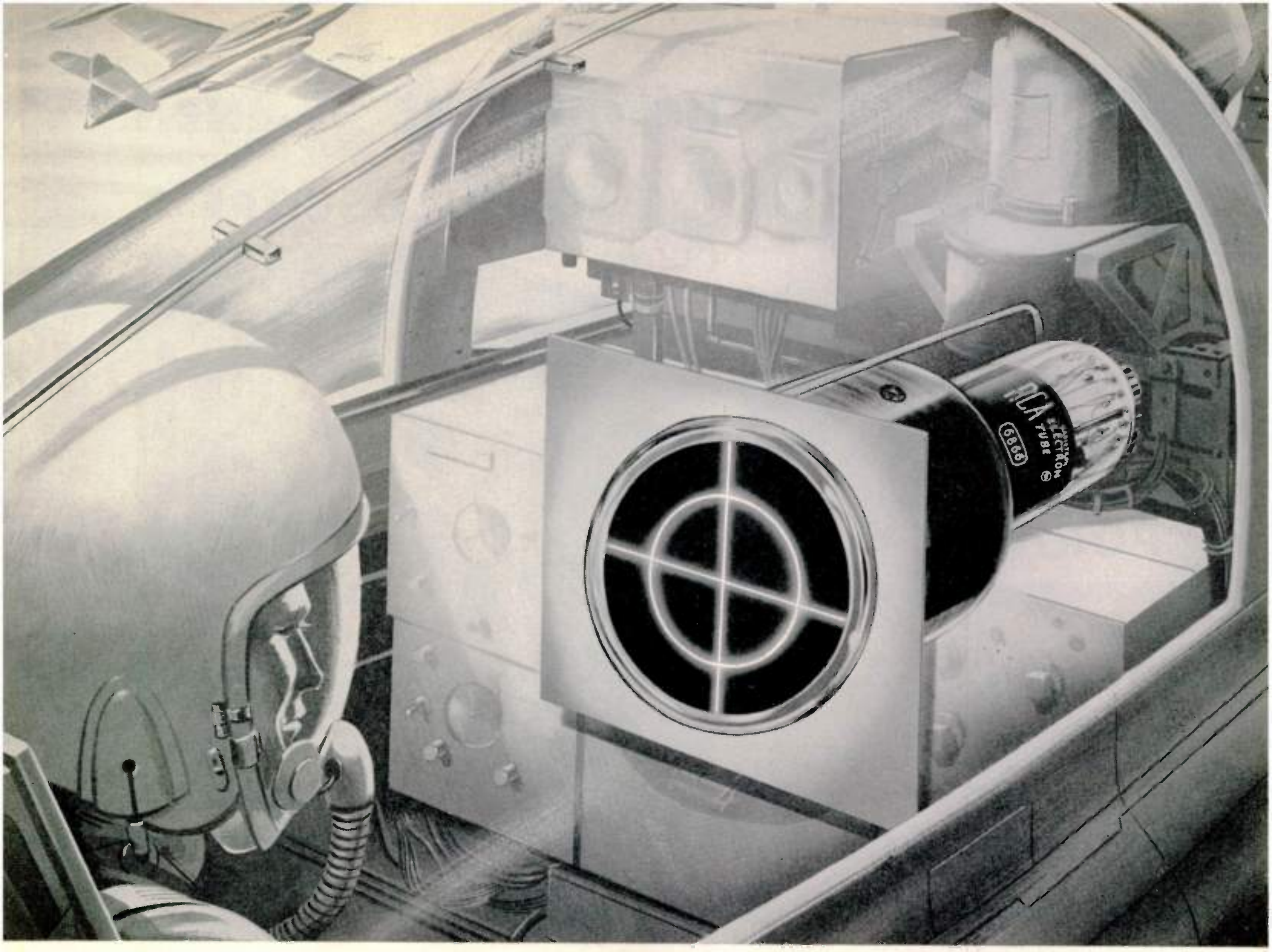

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PROCEEDINGS OF THE IRE®

Published Monthly by

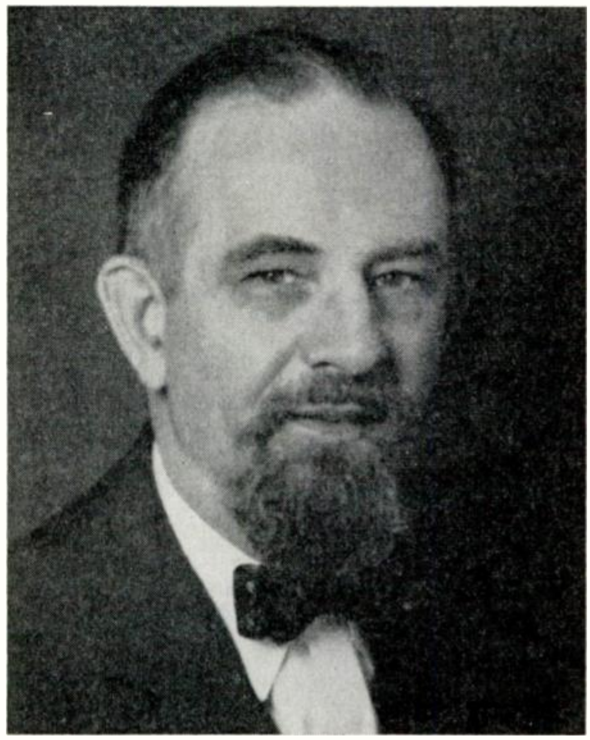
The Institute of Radio Engineers, Inc.

VOLUME 45 — *May, 1957* — NUMBER 5, PART I

CONTENTS

ADVERTISING SECTION

THE COVER—May 13, 1957 marks the 45th anniversary of the formation of the IRE. Starting with 46 members in 1912, the IRE membership grew slowly but steadily during the first decade, accelerated as radio broadcasting came into its own in the late 20's declined during the depression years, and then rocketed upwards as wartime research opened up vast new fields for technical developments. Sometime this month the membership will pass the 59,000 mark, and by the end of this year will be well beyond 60,000. The interesting history of IRE's development over this period is described in the article starting on page 597.



Alois W. Graf

DIRECTOR, 1957

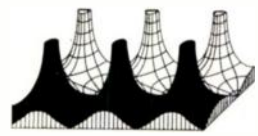
Alois W. Graf was born March 20, 1901, at Mankato, Minn. He obtained a bachelor's degree in electrical engineering from the University of Minnesota in 1926, and a bachelor of law degree from the National Law University in 1931.

Mr. Graf was first employed as an examiner in the U. S. Patent Office. He subsequently was employed by a patent lawyer to work on validity and infringement searches and resulting prosecutions. The next eight years, from 1930 to 1938, saw him associated with the patent department of the General Electric Company for which he standardized patent procedures and formulated manufacturing policies for vacuum tube devices. He became a patent lawyer for Productive Inventions, Inc., Gary, Ind. In 1940 he began his own private patent law practice, and subsequently became associated with a number of patent law firms, among which were Sheridan, Davis and Cargill; Davis, Lindsey, Smith and Shonts; and Loftus, Moore, Olson and Trexler. He again opened his own law practice in 1949, and in May, 1956, announced the formation of a new patent law firm with L. G. Nierman and M. A. Burmeister. This firm specializes in patent, trade-mark, and copyright law in the radio communications and electronics field.

Mr. Graf is a member of the bar in the District of Columbia, Indiana, and Illinois. He also holds membership in the American Bar Association, Illinois Society of Professional Engineers, and the National Society of Professional Engineers.

He became an IRE Associate in 1926, a Member in 1944, and a Senior Member in 1945. He was elevated to Fellow status in 1955. His IRE activities include membership on the Board of Editors from 1945–1953, Editorial Review Committee from 1954–1956, Education Committee from 1945–1955, and Policy Advisory Committee from 1954–1955 and 1956–1957. He was Chairman of the Sections Committee from 1948–1950, Vice-President of the Professional Groups Committee in 1954, and Chairman of the Constitution and Laws Committee from 1954–1955, 1956, and 1957. He held the office of Secretary from 1944–1945 in the Chicago Section; from 1946–1947 he was its Chairman. In addition, Mr. Graf served as IRE representative to the National Electronics Conference Board of Directors in 1952 and 1954.

Poles and Zeros



45 Years. In this issue we commemorate the 45th anniversary of the founding of the Institute of Radio Engineers by presenting a paper, "The IRE—45 Years of Service," prepared by Laurens E. Whittemore at the suggestion of the Committee on History. Mr. Whittemore, a member of the Institute since 1916, has spent months of painstaking research assembling the organizational record of IRE from 1912 to the present.

Anniversaries are times for reflection, occasions to discern the trends of the past and to plot a reasonable extrapolation to the future. We hope that this paper will inspire such reflection and we take the liberty of quoting some thoughts which occurred to G. C. Southworth (a comparative newcomer who joined IRE in 1926) when he read the paper in manuscript.

Wrote Dr. Southworth: "This is the 45-year life story of a remarkable organization, the IRE. Born within a few years of Marconi's early work, when considerable mystery surrounded the new field, it fell to this young organization to provide a healthy atmosphere in which young engineers might exchange ideas and a publication medium in which their conclusions could be recorded. That it has succeeded in its objectives is attested by the fact that during its 45-year life its membership on the average has more than doubled every five years and its publications have expanded at an even faster rate.

"The purpose of this paper is to record the more important organizational changes and events that led to the present status of the Institute; no attempt has been made to trace the corresponding development of radio itself. It is quite evident, however, that the two have been quite closely related. Without the phenomenal growth of radio technology, the Institute could not have reached its present proportions and without the Institute, radio technology could hardly have made its rapid progress.

"In reading this paper, it may appear that the Institute may have far outgrown the industry it has served, but reflection shows that this is not the case. One dimension by which the growth of an industry may be scaled is the dollars invested in it; the growth here need not be documented—it is enormous. Another dimension is the roster of services rendered by the industry. Starting with safety of life at sea at the turn of the century this has been expanded to so many services that "the electronic age" properly describes our epoch. A third dimension is the band of frequencies occupied by radio, analogous to the right-of-way of railway systems. In this dimension the expansion has been so rapid that the spectrum has doubled no less than twenty times during a period when the membership of the Institute has doubled only twice."

Little further need be said by way of introduction to Mr. Whittemore's thorough-going account of IRE's first 45 years. We express the thanks of all members to him for the hours of effort in collecting the material and for his skill in assembling it.

Dust. Dr. Southworth's reference to the spectrum reminds us of the great stretch of perspective needed in relating the frequency ranges occupied by various radio systems. Take the spectrum used in transmitting a video signal, extending uniformly from 30 cycles to about 4 megacycles. This range represents a mere modulating signal to the television engineer, not to be classed as "radio-frequency." But this signal covers a wide swath in the radio spectrum, from below the very low frequencies well into the high frequency range. This contrast is vividly illustrated in an experiment recently conducted by Ampex engineers with a tape recorder capable of recording television signals. It seems the boys hooked up an antenna to the recorder input and let her run. Then they played back the tape, feeding the output to a radio receiver. Sure enough, there were *all* the broadcast stations and their programs, among many others, frozen in magnetic dust.

Quarterly. Radio engineers don't have to be students in college to read, and enjoy thoroughly, the *IRE Student Quarterly*. Ted Hunter, who edits this remarkable journal, proceeds on the assumption that students are mature people (new graduates are paid on that basis, certainly) and he fills the *Quarterly* with papers that make excellent reading for many a forty-year-old "student." One such paper, explaining color television techniques in simple terms was reprinted in the PROCEEDINGS some months ago, and many other *Quarterly* articles deserve a wide audience. While it is not practical to reprint from every issue of the *Quarterly*, it is practical and rewarding to subscribe to it. The price to IRE members is $3.00.

Score. The total registered attendance at the March 1957 IRE National Convention was 54,074. This is an all-time record for our "annual classic" and represents by a large margin the largest gathering of engineers and technicians ever assembled anywhere.—D. G. F.

Scanning the Issue

The Institute of Radio Engineers, Forty-Five Years of Service (Whittemore, p. 597)—May 13 marks the forty-fifth anniversary of an historic meeting. On that date 46 members of the Society of Wireless Telegraph Engineers and The Wireless Institute, led by Alfred N. Goldsmith, John V. L. Hogan, and Robert H. Marriott, met at Fayerweather Hall, Columbia University, to form The Institute of Radio Engineers. From these humble beginnings has arisen one of the world's major professional societies which, by this May 13th, will be able to count 59,000 members in some 80 countries all over the globe. This article is far more than a statistical tracing of the growth of the IRE over the years. It is a penetrating and absorbing study of the management, administration and policy-making which has led the IRE to its present position of eminence. The preparation of this material, done at the request of the IRE History Committee, represents nearly a year's effort on the part of a Fellow and former Vice-President of the IRE, who himself has actively served the Institute for nearly four decades. He has brought to this monumental task not only his own intimate knowledge of IRE history but also the fruits of searching voluminous records and interviewing a score or more IRE leaders, past and present, resulting in an historical record of remarkable scope and authenticity.

The Effect of Fading on Communication Circuits Subject to Inteference (Bond and Meyer, p. 636)—Many types of communication systems are subject to fading, due to the signal arriving at the receiver via two or more paths of different lengths. In this paper the author analyzes what effects this has on the performance of communication circuits that operate in the presence of interference. He studies the fading of the signal alone, of the interference alone, and of both together and derives curves which indicate how much the signal-to-interference power ratio must be increased to maintain satisfactory operation a high percentage of the time. For example, the curves show that to obtain 99.9 per cent satisfactory operation will require 30 db more signal power in the presence of signal fading, regardless of whether the interference is also fading. The study also discloses the improvements offered by various diversity reception techniques. The formulas and curves presented will be especially useful to persons concerned with systems engineering and frequency allocation problems.

Microwave Frequency Doubling from 9 to 18 KMC in Ferrites (Melchor, *et al*, p. 643)—Although previous work has been reported on using ferrites as frequency doublers, the conversion efficiency obtained was very low, about −60 db. This paper reports results that are very much better. Using an input frequency of 9 kmc at a peak power level of 32 kw, the authors obtained an output of 8 kw at 18 kmc. This represents a doubling conversion efficiency of −6 db. These results demonstrate that ferrites are superior to crystal doublers, both as to efficiency and power-handling ability. Moreover, this work will serve notice on ferrite users that in addition to the more well-known applications (isolators, phase shifters, etc.), ferrites promise to become equally important as frequency doublers and mixers.

Effects of Zero Ferrite Permeability on Circularly Polarized Waves (Duncan and Swern, p. 647)—Theoretical predictions and experimental data are presented that describe the propagation characteristics of ferrites in circular and rectangular waveguides. It is shown that ferrites magnetized near zero permeability behave, under certain conditions, like a metal; *i.e.*, practically all the microwave energy is expelled from the interior and the ferrite exhibits skin effect and skin loss. This behavior is utilized to obtain large nonreciprocal attenuation at low applied magnetic fields over large bandwidths, that is, waves are passed in one direction with very little loss, and drastically attenuated in the other direction. The paper, while specialized, makes a contribution of fundamental significance to the development of ferrite isolators.

Binary Data Transmission Techniques for Linear Systems (Doelz, *et al*, p. 656)—A novel coding scheme has been combined with multiplexing and single-sideband techniques to maximize the amount of binary information that can be transmitted over a narrow-band communication link. The coding method is based on the idea of transmitting a "mark" and a "space" as signals of opposite phase and of comparing the phases of successive pulses as they are received to encode the message. The novelty of the method presented here is that the pulse is transmitted with not two, but four possible phases (0°, 90°, 180° or 270°), and thus can uniquely describe the "mark" and "space" information of two messages simultaneously. This method requires a transmission link of high linearity with precisely synchronized oscillators at either end—a situation ready-made for single-sideband equipment. By using frequency division multiplexing, it is possible to transmit 20 channels (40 messages) over a single SSB voice channel at a total rate of 3000 bits per second. This work will be particularly interesting to those engaged in information theory, radio teletype systems, and high frequency multipath transmission problems.

Temperature Dependence of Junction Transistor Parameters (Gärtner, p. 662)—This study provides a great deal of useful information, in the form of design equations, tables and graphs, on the effects of temperature variations on the electrical characteristics of four representative types of transistors. The extensive calculations made by the author represent a very considerable effort and will be a valuable reference for transistor designers and practicing circuit engineers, to whom the problems of temperature variations and compensation are important ones.

Design of Three-Resonator Dissipative Band-Pass Filters Having Minimum Insertion Loss (Taub and Bogner, p. 681)—Present-day design of narrow-band band-pass filters stems essentially from some general design equations developed eight years ago for various numbers of synchronously-tuned resonant circuits. As it turned out, each set of equations contained one more unknown than there were equations and, hence, their solution yielded many sets of circuit constants that would produce the desired amplitude-frequency response. In this paper the authors add one additional requirement, which permits them to find a single set of circuit constants. They specify that the insertion loss, that is, the ratio of generator power to load power, be a minimum, a stipulation that is frequently of practical interest. The calculations are carried through to produce universal design curves for three-resonator filters that will be especially useful to radio receiver, microwave, and filter engineers in general.

1956 Index to IRE Transactions (follows p. 734)—The tables of contents, a combined author index, and a combined subject index are presented covering the 69 issues of Transactions issued by all IRE Professional Groups during the year 1956.

The Institute of Radio Engineers—Forty-Five Years of Service*

LAURENS E. WHITTEMORE†, FELLOW, IRE

Foreword

On October 6, 1955, the Executive Committee of the Institute approved a suggestion by Haraden Pratt, Chairman of the History Committee and Secretary of the Institute, that the May, 1957 issue of the PROCEEDINGS be planned as a special anniversary number in commemoration of the 45th anniversary of the founding of the Institute of Radio Engineers. It was proposed that a subcommittee of the History Committee be asked to prepare an historical article on IRE management, administration, and policy making. Pursuant to that action, this paper has been prepared.

Formation of the Institute of Radio Engineers

Background

MEETINGS and publications have been the twin activities of the Institute of Radio Engineers from the beginning. The desire of members to improve communication among themselves, both through oral presentations and discussions and through writing and reading papers, was the basic reason for the formation of the Institute and this has continued to be the principal impelling force behind the growth of the Institute during its 45 years of existence. This same twofold reason for existence applied also to the two earlier associations—one in Boston and one in New York—that were merged in 1912 to form a new and stronger organization, which was named The Institute of Radio Engineers.

Some inkling of the limited field of activity of radio engineers in 1912 may be had from the fact that the principal, and almost the only, commercial use of radio was for marine radiotelegraph message transmission. In 1910 the Government had established a legal requirement that certain classes of ships leaving United States ports be equipped with radio transmitting and receiving apparatus. In that year also, a system of ship radio inspection was established by the Government.

This was an era of jealously guarded secrets and ruthless competition. The barriers of supersecrecy which existed between competing wireless companies were so great that men were dismissed for associating with engineers of rival firms. Competition was often devoid of ethics as we know them today. There was, however, a growing realization among a number of engineers that many of the technical problems encountered by one company were common to all and that these problems might be solved more readily if engineers from all companies could get together to discuss them.

Society of Wireless Telegraph Engineers

The Society of Wireless Telegraph Engineers (SWTE) had been formed in Boston, Mass., on February 25, 1907, by John Stone Stone as an outgrowth of seminars held by engineers on the staff of the Stone Wireless Telegraph Company. Membership was eventually opened to men from Fessenden's National Electric Signaling Company and some other organizations. Members of this society were familiarly known as "swatties." John Stone Stone was the first President of this society.

The Wireless Institute

Robert H. Marriott made what appears to have been the first specific attempt to form a radio engineering society composed of members from any and all companies. On May 14, 1908, he sent a circular letter to some two hundred persons interested in wireless asking their opinions regarding the formation of such a society. It is rather remarkable that after nearly 50 years the embryo of the IRE can still be clearly distinguished in Marriott's letter, the text of which was published in the PROCEEDINGS OF THE IRE for May, 1952, on page 516.

Marriott's letter bore fruit. He received about 60 replies, and with one or two exceptions they were favorable to forming an institute on the lines he indicated. On January 23, 1909, a temporary organization was formed to draw up a constitution, and on March 10 of that year the first meeting was held at the United Engineers Building (now the Engineering Societies Building) in New York City at which a constitution was adopted and officers were elected. The name of the new society was "The Wireless Institute."

Robert Marriott was elected first President of The Wireless Institute, and served in that capacity during the three years of its existence.

* Original manuscript received by the IRE, February 1, 1957; revised manuscript received, March 4, 1957.

† American Telephone and Telegraph Co., New York, N. Y.

The Wireless Institute (TWI) was somewhat more active than its fellow society in Boston (SWTE), possibly because of the greater number of wireless operators and engineers in the New York area. It started with only 14 members, but by 1911 had grown to a more impressive total of 99. TWI held meetings every month except July and August, and during the year 1909 printed six issues of a magazine containing the papers presented at these meetings. Alfred N. Goldsmith took on the task of Editor of *The Wireless Institute Proceedings*, little realizing that more than four decades later he would still be serving in the same capacity for its successor, the PROCEEDINGS OF THE IRE.

By 1911 the Stone Wireless Telegraph Company had gone out of existence and the National Electric Signaling Company had moved to Brooklyn so there was very little left of the SWTE. The Wireless Institute was also struggling to hold its membership and to keep out of debt.

PRESIDENTS OF IRE'S PARENT SOCIETIES

Society of Wireless Telegraph Engineers

1907	John Stone Stone
1908	John Stone Stone
1909	Lee DeForest
1910	Lee DeForest
1911	Fritz Lowenstein
1912	Fritz Lowenstein

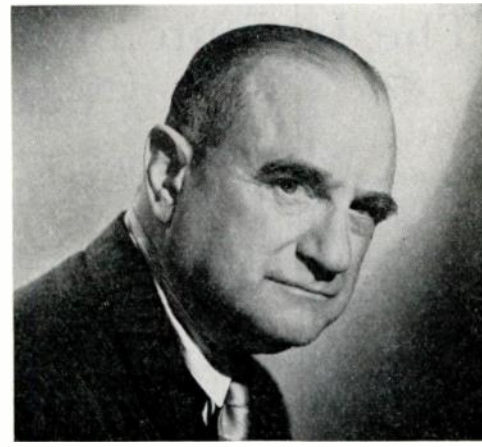
The Wireless Institute

1909	Robert H. Marriott
1910	Robert H. Marriott
1911	Robert H. Marriott
1912	Robert H. Marriott

Institute of Radio Engineers

It was early in 1912 that Robert H. Marriott and Alfred N. Goldsmith, representing The Wireless Institute, with John V. L. Hogan, who was very active in the Society of Wireless Telegraph Engineers, held an informal meeting to discuss the plights of both societies. Out of their discussions there developed a meeting on the night of May 13, 1912, at which members of TWI and SWTE gathered in Room 304 of Fayerweather Hall at Columbia University in New York City. A constitution was approved and an election of officers was held at which the following were chosen: Robert H. Marriott, President; Fritz Lowenstein, Vice-President; E. D. Forbes, Treasurer; E. J. Simon, Secretary; Alfred N. Goldsmith, Editor; and Lloyd Espenschied, Frank Fay, J. H. Hammond, Jr., John V. L. Hogan, and John Stone Stone, Managers.

As a name for the organization "The Institute of Radio Engineers" was chosen. The original membership roster of the IRE consisted of 46 members, 22 from SWTE and 25 from TWI. One member, Greenleaf W. Pickard, was the only charter member of IRE who had been affiliated with both of the preceding organizations; he therefore bore the informal title of "IRE's double-jointed" member.



Alfred N. Goldsmith, co-founder of the IRE, has served one term as President, 10 terms as Secretary, 44 years as Editor and Editor Emeritus, and all 45 years as a Director. A former Vice-President of RCA and for many years a consultant, he has made numerous inventions in the radio, TV, color TV, and motion picture fields. At present he is a consulting engineer in New York City.

Robert H. Marriott, founder of the Wireless Institute in 1909 and co-founder of the IRE, served as its first President in 1912 and as Vice-President in 1913. He was an early experimenter in radio and became a well-known pioneer in this field. He was a radio aide of the U.S. Navy and consultant to the Federal Radio Commission. He retired from private practice in 1943 and passed away on October 31, 1951.

John V. L. Hogan, co-founder of the IRE, has served one term as President, four terms as Vice-President, and 28 years as a Director. He is responsible for many inventions in the radio, television, and facsimile fields, and was founder and owner of WQXR until it was acquired by the New York *Times*. He is president of Hogan Laboratories in New York City.

Original Members of the Institute of Radio Engineers and their Affiliation with Parent Societies

Society of Wireless Telegraph Engineers

J. C. Armor	W. S. Hogg
Sewall Cabot	Guy Hill
W. E. Chadbourne	F. A. Knowlton
G. H. Clark	W. S. Kroger
T. E. Clark	Fritz Lowenstein
E. R. Cram	Walter W. Massie
G. S. Davis	G. W. Pickard
*Lee DeForest	Samuel Reber
E. D. Forbes	Oscar C. Roos
V. F. Greaves	J. S. Stone
*J. V. L. Hogan, Jr.	*A. F. VanDyck

The Wireless Institute

William F. Bissing	*Frank Hinners
A. B. Cole	James M. Hoffman
*P. B. Collison	Robert H. Marriott
James N. Dages	A. F. Parkhurst
*Lloyd Espenschied	G. W. Pickard
Philip Farnsworth	H. S. Price
Frank Fay	A. Rau
Edward G. Gage	Harry Shoemaker
*Alfred N. Goldsmith	*Emil J. Simon
Francis A. Hart	A. Kellogg Sloan
Robert L. Hatfield	C. H. Sphar
Arthur A. Hebert	Floyd Vanderpoel

R. A. Weagent

* Member of the IRE as of January, 1957.

After about a year, it was decided to incorporate the society. A meeting to decide details of this move was held at Sweet's Restaurant on Fulton Street in downtown New York, on June 23, 1913. Those members with a more legal mind in the make-up of the Institute, drew up Articles of Incorporation and on August 23, 1913, the organization was incorporated under the laws of the State of New York.

In brief, the expressed aims of the new association were:

> "To advance the art and science of radio transmission, to publish works of literature, science and art for such purpose, to do all and every act necessary, suitable and proper for the accomplishment of any of the purposes or the attainment of any of the powers herein set forth, either alone or in association with other corporations, firms or individuals to do every act or acts, thing or things, incidental or appurtenant to or growing out of or connected with the aforesaid science or art, or power or any parts thereof, provided the same be not inconsistent with the laws under which this corporation is organized, or prohibited by the State of New York."

One of the most important functions of the Institute was to preserve its technical papers, and the remarks made regarding them, in published form. One of the early decisions of the Institute, therefore, was to publish a technical magazine which was named The Proceedings of the Institute of Radio Engineers. The first issue was dated January, 1913.

In his inaugural address as President of the IRE for 1928, Dr. Alfred N. Goldsmith made some remarks about the beginnings of the Institute which, he said, originated "among a little group of serious thinkers in the radio field who felt the urgent need for some means for self-expression and mutual cooperation among radio engineers. . . . It is composed of televisionaries—men who see far into the future and are yet realists."

By the end of 1912, the Institute's membership had risen to 109 and during the succeeding year more than doubled. The rapid increase in membership after consolidation, compared with the slow rate of growth of SWTE and TWI, bore out the wisdom of the founders who suggested the merger.

Growth of Membership of the Institute of Radio Engineers and its Predecessors, 1907–1914

	SWTE	TWI	IRE
February 25, 1907	11		
January 1, 1908	17		
January 1, 1909	27		
March 10, 1909		14	
January 1, 1910	36	81	
January 1, 1911	36	99	
January 1, 1912	43	27	
May 13, 1912	(22)	(25)	46
January 1, 1913			109
January 1, 1914			231

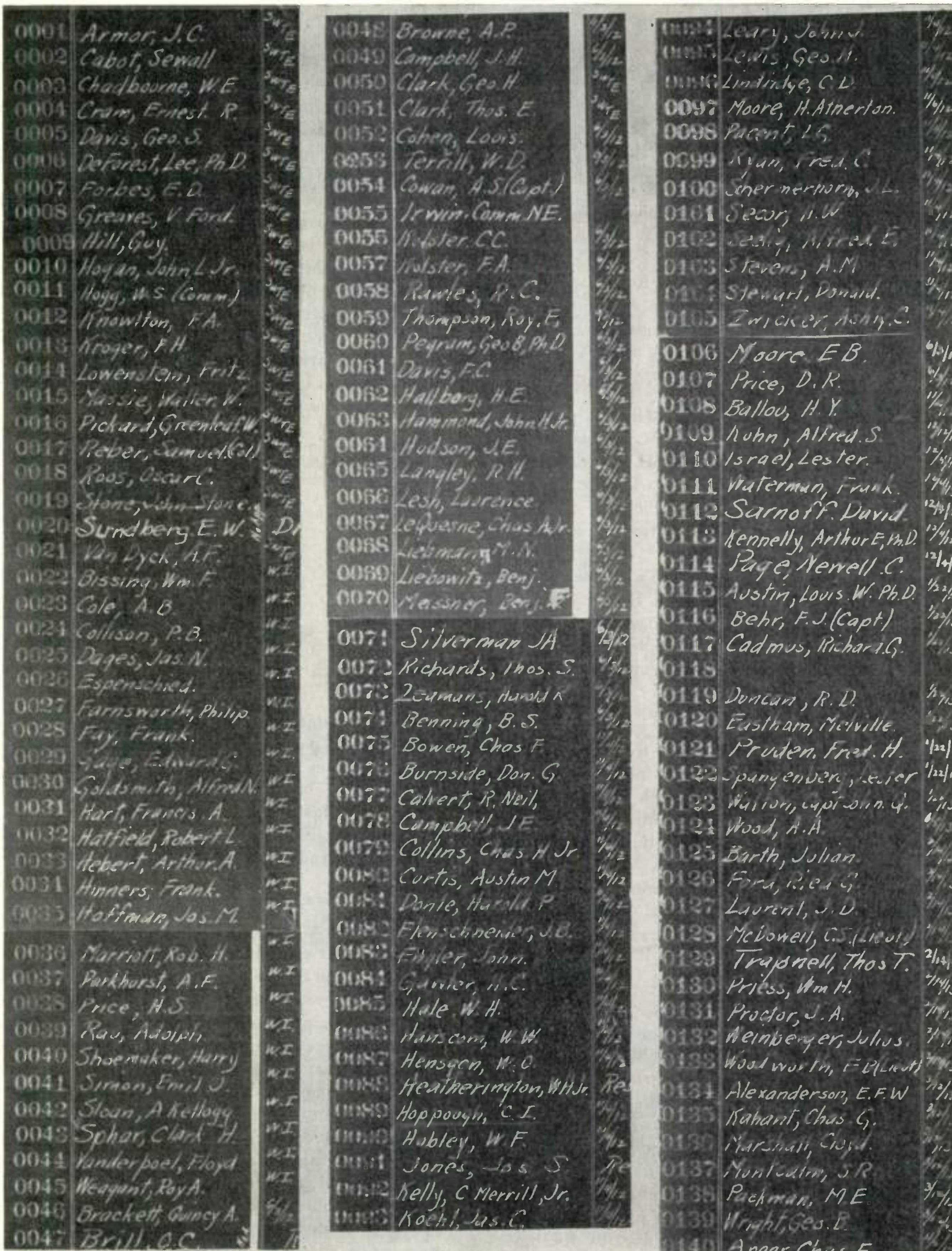
The original ledger book of the Institute, in which the names and dues payments of early members were recorded, constitutes a veritable *Who's Who* in the early history of radio. The names of many radio pioneers can be seen in the illustration on the next page of the first few pages of the list of those members who joined the Institute during the first year.

Name of the Institute

In considering a name for the new organization the founders felt that something should be preserved from the names of both of the two component societies. The word "Institute" was borrowed from The Wireless Institute, and "Engineers" from the Society of Wireless Telegraph Engineers. Because the word "radio" was gradually supplanting "wireless," the title "The Institute of Radio Engineers" suggested itself. There was considerable temptation to add "American," particularly since TWI and IRE were modeled after the American Institute of Electrical Engineers in certain other respects. However, the temptation was resisted because it was expected that the IRE, as the only radio engineering society in existence, would be international in scope, an expectation that was promptly realized.

Why a Separate Organization?

The question arises from time to time: "Why did it happen that the radio engineers started an organization



0001 Armor, J.C.
0002 Cabot, Sewall
0003 Chadbourne, W.E.
0004 Cram, Ernest R.
0005 Davis, Geo. S.
0006 DeForest, Lee, Ph.D.
0007 Forbes, E.D.
0008 Greaves, V. Ford.
0009 Hill, Guy.
0010 Hogan, John L. Jr.
0011 Hogg, W.S. (Comm.)
0012 Knowlton, F.A.
0013 Kroger, F.H.
0014 Lowenstein, Fritz
0015 Massie, Walter W.
0016 Pickard, Greenleaf W.
0017 Reber, Samuel (Col.)
0018 Roos, Oscar C.
0019 Stone, John Stone
0020 Sundberg E.W.
0021 Van Dyck, A.F.
0022 Bissing, Wm. F.
0023 Cole, A.B.
0024 Collison, P.B.
0025 Dages, Jas. N.
0026 Espenschied.
0027 Farnsworth, Philip
0028 Fay, Frank.
0029 Gage, Edward C.
0030 Goldsmith, Alfred N.
0031 Hart, Francis A.
0032 Hatfield, Robert L.
0033 Hebert, Arthur A.
0034 Hinners, Frank.
0035 Hoffman, Jos. M.
0036 Marriott, Rob. H.
0037 Parkhurst, A.F.
0038 Price, H.S.
0039 Rau, Adolph
0040 Shoemaker, Harry
0041 Simon, Emil J.
0042 Sloan, A. Kellogg
0043 Sphar, Clark H.
0044 Vanderpoel, Floyd
0045 Weagant, Roy A.
0046 Brackett, Quincy A.
0047 Brill, O.C.
0048 Browne, A.P.
0049 Campbell, J.H.
0050 Clark, Geo. H.
0051 Clark, Thos. E.
0052 Cohen, Louis.
0053 Terrill, W.D.
0054 Cowan, A.S. (Capt.)
0055 Irwin, Comm. N.E.
0056 Hofstetter, C.C.
0057 Holster, F.A.
0058 Rawles, R.C.
0059 Thompson, Roy. E.
0060 Pegram, Geo. B. Ph.D.
0061 Davis, F.C.
0062 Hallborg, H.E.
0063 Hammond, John H. Jr.
0064 Hodson, J.E.
0065 Langley, R.H.
0066 Lesh, Laurence
0067 LeQuesne, Chas. A. Jr.
0068 Liebmann, M.N.
0069 Liebowitz, Benj.
0070 Meissner, Benj. F.
0071 Silverman J.A.
0072 Richards, Thos. S.
0073 Zeamans, Harold K.
0074 Benning, B.S.
0075 Bowen, Chas. F.
0076 Burnside, Don. G.
0077 Calvert, R. Neil,
0078 Campbell, J.E.
0079 Collins, Chas. H. Jr.
0080 Curtis, Austin M.
0081 Donle, Harold P.
0082 Flenschneider, J.B.
0083 Fowler, John.
0084 Garner, H.C.
0085 Hale W.H.
0086 Hanscom, W.W.
0087 Hensgen, W.C.
0088 Heatherington, W.H. Jr.
0089 Hoppough, C.I.
0090 Hubley, W.F.
0091 Jones, Jos. S.
0092 Kelly, C. Merrill, Jr.
0093 Koehl, Jas. C.
0094 Leary, John J.
0095 Lewis, Geo. H.
0096 Lindridge, C.D.
0097 Moore, H. Atherton.
0098 Pacent, L.G.
0099 Ryan, Fred. C.
0100 Schermerhorn, J.L.
0101 Secor, H.W.
0102 Seelig, Alfred E.
0103 Stevens, A.M.
0104 Stewart, Donald.
0105 Zwicker, Ashly C.
0106 Moore E.B.
0107 Price, D.R.
0108 Ballou, H.Y.
0109 Kohn, Alfred S.
0110 Israel, Lester.
0111 Waterman, Frank.
0112 Sarnoff David.
0113 Kennelly, Arthur E. Ph.D.
0114 Page, Newell C.
0115 Austin, Louis W. Ph.D.
0116 Behr, F.J. (Capt.)
0117 Cadmus, Richard G.
0118
0119 Duncan, R.D.
0120 Eastham, Melville.
0121 Pruden, Fred. H.
0122 Spangenberg, Lester
0123 Watson, Capt. John G.
0124 Wood, A.A.
0125 Barth, Julian.
0126 Ford, Fred G.
0127 Laurent, J.D.
0128 McDowell, C.S. (Lieut.)
0129 Trapnell, Thos T.
0130 Priess, Wm H.
0131 Proctor, J.A.
0132 Weinberger, Julius.
0133 Woodworth, F.B. (Lieut.)
0134 Alexanderson, E.F.W.
0135 Kahant, Chas. G.
0136 Marshall, Cloyd.
0137 Montcalm, S.R.
0138 Packman, M.E.
0139 Wright, Geo. B.
0140 Apgar, Chas. E.

Pages from the first IRE record book listing the earliest members.

of their own instead of joining with the American Institute of Electrical Engineers as a subdivision of some kind?" The answer is that 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 meetings per year, sandwiched in between meetings devoted to what was sometimes called "heavy-current" electrical engineering. The matter was discussed with representatives of the American Institute of Electrical Engineers, but the original members of the IRE felt that they needed and that they could develop a society of their own. Events have confirmed their judgment.

The Emblem or Symbol of the IRE

Neither of the emblems of the predecessor societies seemed readily adaptable to the new IRE. The SWTE emblem pictured a simple form of spark oscillator. The membership badge of TWI showed a spark gap functioning in the center of a dipole surrounded by a circular resonator provided with a micrometer gap for reception.

The founders of IRE decided not to use a representation of any specific form of equipment or physical structure but to devise a more general and perhaps perpetual symbol. It was realized that the Institute would always deal with electromagnetic energy, guided by conductors or passing through space, and that the distinguishing character of the transmission process was the existence of electrical forces and of their correlative magnetic forces. A representation of these forces was adopted as part of the symbol; the electrical force being represented by a vertical arrow and the magnetic force by a circular arrow surrounding the electrical line and in the conventional relationship to it. The shape of the resulting drawing lent itself to a triangular placement of the letters I, R, and E. This, in turn, led to the selection of a triangular emblem. Incidentally, the letters I, R, and E also symbolize the fundamental quantities, current, resistance and electromotive force, as well as the name, Institute of Radio Engineers.

Officers

The officers of the IRE have from the beginning been President, Vice-President, Secretary, Treasurer, Editor, and Directors with the infrequent addition of an Assistant Secretary or an Assistant Treasurer. The President and Vice-President have always been elected by the IRE membership as have part or all of the members of the Board of Directors except the Editor. Beginning in 1915 the elected members of the Board were authorized by the Constitution to choose several additional persons to complete the Board membership. The Secretary and Treasurer have always been elected by the Board.

Prior to the 1931 revision of the Constitution the elected Board was known as the "Board of Direction," and its members—other than the Officers—were called "Managers." For the sake of simplicity, however, the term "Directors" will be used throughout this review.

An accompanying table shows, for each year since the formation of the IRE, the names of the Officers who served during that year.

G. W. Pierce had been elected President of the IRE for 1918, but served two years, since it was impossible, in view of the then-existing conditions during World War I, to get together enough members to hold an election.

Beginning in 1930, it became the custom for the Vice-President of the IRE to be a member who resides in a country other than the United States. In 1957, neither the President nor the Vice-President is a resident of the United States.

Prior to the year 1939 members of the IRE of all grades other than Junior Member and Honorary Member were voting members. Beginning with that year there has been a distinction between voting Associate members and nonvoting Associate members. Those who have been elected as Associate members subsequent to 1939 are not eligible to vote until they have transferred to a higher grade of membership for which they have become eligible.

A proposal was made to the Board in 1930 that membership on the Board should be limited to one person from any one company or government department, the purpose presumably being to insure diversification of representation. After very thorough and careful consideration by the Board it was agreed that members of the Board of Directors should represent no particular organization or group of organizations but should represent only the membership of the Institute in a broad sense. It was decided, therefore, not to include any such limiting requirements among the constitutional amendments which were then being formulated for consideration by the Institute members.

In order to facilitate action on various matters relating to the business of the IRE, an Executive Committee was formally established by the Board of Directors at its meeting in April, 1941. Subsequently, for several years, certain members of the Executive Committee were assigned responsibility for certain aspects of the Institute's activities. These assignments during the year 1944, for example, were such that one member of the Executive Committee took special cognizance of the activities of the Committees on Admissions, Membership, and Public Relations. Another member of the Executive Committee gave special attention to the work of the technical committees of the Institute. A third member of the Executive Committee concerned himself with activities covering sections, conventions, meetings, and advertising.

As the IRE membership increased in numbers and geographical distribution there developed an apprecia-

IRE Officers, 1912–1957

Year	President	Vice President	Secretary	Treasurer	Editor	Hdqs. Manager
1912	R. H. Marriott	Fritz Lowenstein	E. J. Simon	E. D. Forbes	A. N. Goldsmith	
1913	G. W. Pickard	R. H. Marriott	"	J. H. Hammond, Jr.	"	
1914	L. W. Austin	J. S. Stone	"	"	"	
1915	J. S. Stone	G. W. Pierce	David Sarnoff	W. F. Hubley	"	
1916	A. E. Kennelly	J. V. L. Hogan	"	"	"	
1917	M. I. Pupin	"	"	L. R. Krumm	"	
1918	G. W. Pierce	"	A. N. Goldsmith	Warren F. Hubley	"	
1919	"	"	"	"	"	
1920	J. V. L. Hogan	E. F. W. Alexanderson	"	"	"	
1921	E. F. W. Alexanderson	Fulton Cutting	"	"	"	
1922	Fulton Cutting	E. L. Chaffee	"	"	"	
1923	Irving Langmuir	J. H. Morecroft	"	"	"	
1924	J. H. Morecroft	J. H. Dellinger	"	"	"	
1925	J. H. Dellinger	Donald McNicol	"	"	"	
1926	Donald McNicol	Ralph Bown	"	"	"	
1927	Ralph Bown	Frank Conrad	"	"	"	J. M. Clayton
1928	A. N. Goldsmith	L. E. Whittemore	J. M. Clayton	Melville Eastham	"	"
1929	A. H. Taylor	Alexander Meissner	"	"	W. G. Cady	"
1930	Lee de Forest	A. G. Lee	H. P. Westman	"	A. N. Goldsmith	H. P. Westman
1931	R. H. Manson	C. P. Edwards	"	"	"	"
1932	W. G. Cady	E. V. Appleton	"	"	"	"
1933	L. M. Hull	Jonathan Zenneck	"	"	"	"
1934	C. M. Jansky, Jr.	B. van der Pol, Jr.	"	"	"	"
1935	Stuart Ballantine	G. H. Barkhausen	"	"	"	"
1936	L. A. Hazeltine	Valdemar Poulsen	"	"	"	"
1937	H. H. Beverage	P. P. Eckersley	"	"	"	"
1938	Haraden Pratt	E. T. Fisk	"	"	"	"
1939	R. A. Heising	P. O. Pederson	"	"	"	"
1940	L. C. F. Horle	F. E. Terman	"	"	"	"
1941	F. E. Terman	A. T. Cosentino	"	Haraden Pratt	"	" (Jan.–Oct.) J. D. Crawford (Nov.–Dec.)
1942	A. F. Van Dyck	W. A. Rush	"	"	"	J. D. Crawford (Jan.–Mar.) L. B. Keim (Apr.–May) W. B. Cowilich (Oct.–Dec.)
1943	L. P. Wheeler	F. S. Barton	Haraden Pratt	R. A. Heising	"	W. B. Cowilich
1944	H. M. Turner	R. A. Hackbusch	"	"	"	"
1945	W. L. Everitt	H. F. van der Bijl	"	"	"	G. W. Bailey
1946	F. B. Llewellyn	E. M. Deloraine	"	W. C. White	"	"
1947	W. R. G. Baker	Noel Ashbridge	"	R. F. Guy	"	"
1948	B. E. Shackelford	R. L. Smith-Rose	"	S. L. Bailey	"	"
1949	S. L. Bailey	A. S. McDonald	"	D. B. Sinclair	"	"
1950	R. F. Guy	R. A. Watson-Watt	"	"	"	"
1951	I. S. Coggeshall	Jorgen Rybner	"	W. R. G. Baker	"	"
1952	D. B. Sinclair	H. L. Kirke	"	"	"	"
1953	J. W. McRae	S. R. Kantebet	"	"	"	"
1954	W. R. Hewlett	M. J. H. Ponte	"	"	J. R. Pierce	"
1955	J. D. Ryder	Franz Tank	"	"	"	"
1956	A. V. Loughren	Herre Rinia	"	"	D. G. Fink	"
1957	J. T. Henderson	Yasujiro Niwa	"	"	"	"

tion by the members of the Board that some specific measures should be adopted, possibly of an organizational nature, to make it more certain that the contacts between the Board and the IRE membership would always be close and continuous and that the Board would comprise a truly democratic representation of the IRE membership. After several years of consideration of this problem the Board of Directors recommended an amendment to the Constitution which was adopted by the Institute membership in 1947, establishing Regional Directors, selected specifically to represent designated regions of the United States and Canada from which they came and whose memberships had elected them. Effective in January, 1955, a new regional boundary plan provided for a more even distribution of membership and Sections among the eight regions.

Membership

Growth in Numbers

It is fitting to consider as the "Charter Members" of the IRE those members of the two parent societies who became the first members of the IRE when it was organized on May 13, 1912. The formal charter of the Institute of Radio Engineers, however, was granted on October 24, 1913. The list of members of the IRE which appears in the 1914 Year Book does not identify "charter members" as such. That Year Book gives an analysis of the geographical distribution of the 271 Members and Associate Members of the IRE as of March 1, 1914 as follows:

Geographical Distribution of IRE Membership, March 1, 1914

	Members	Associates	Total
United States	52	197	249
Canada	3	2	5
Porto Rico	—	1	1
Philippine Islands	1	—	1
Honduras	—	1	1
British Guiana	1	1	2
Japan	1	1	2
Great Britain	3	4	7
Germany	3	—	3
Total	64	207	271

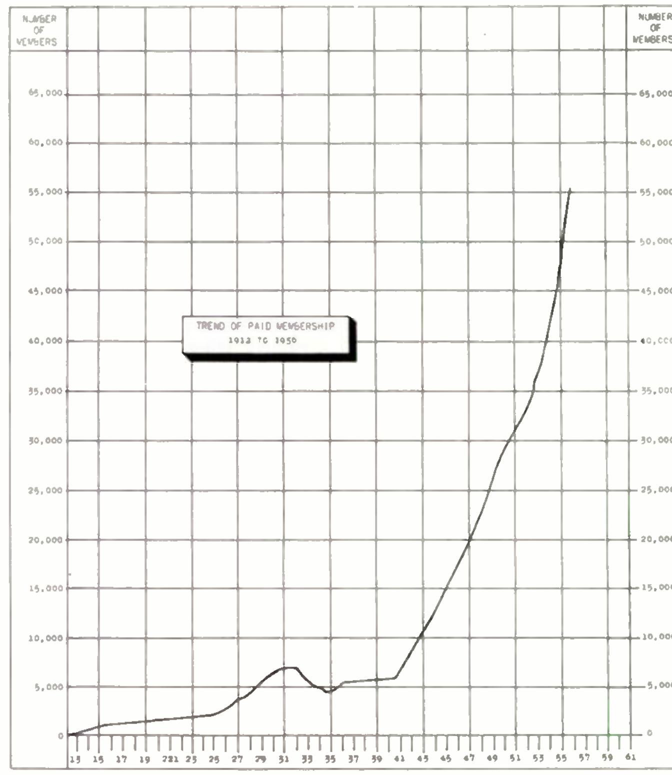
In 1914 a "Special Committee on Increase of Membership" was appointed, under the chairmanship of John Hays Hammond, Jr., Treasurer of the Institute.

The 1916 Year Book shows that the membership of the Institute immediately began to increase and by January 1, 1916, was only slightly under 1000. The membership figures shown are:

	Membership
January 1, 1914	231
January 1, 1915	633
January 1, 1916	984

The Constitution, as adopted in May, 1912, provided that the names of applicants for membership in the IRE should be sent out to each member of the Institute, prior to their acceptance as members. The members who were elected were required to subscribe personally to the Constitution of the IRE.

From the beginning, membership was open not only to radio engineers (Member grade) but also to those who had a real interest in radio engineering even though they were not professionally engaged in this field (Associate Member grade). Recognition of "Honorary Members" was provided for.



In 1916 the grade of Junior Member was established for persons under 21 years of age. The scale of annual dues for the several grades of membership was also slightly increased and transfer fees were established.

The entry of the United States into the World War in 1917 began a difficult period for the IRE. Many, if not most, of its members were engaged in some type of communication work directly or indirectly connected with wartime activities. The membership which had been about 1300 in 1917 fell to something like 800 the following year. Except for that period the membership, stimulated by the development of radio broadcasting during the 1920's, grew steadily until 1931 when a peak of 6700 was reached.

During the depression of the early 1930's, there was again a drop in membership to 4250 in 1934. In order to hold its members and to attract additional members the Board of Directors considered ways of publicizing the IRE. It was recognized that a closer insight into the activities of the IRE might give the existing membership a greater appreciation of the value to them of the various services of the Institute. This led to the expansion of "Institute Notes" section of the Proceedings.

In contrast to the experience during World War I, the IRE suffered very little diminution in membership during World War II. There was a drop in the number of members in European countries and in Japan in 1940 and 1941. Compensating for this, however, was the fact that the field of activities associated with radio engineering was becoming much broader and the applications of radio and allied engineering techniques related to wartime activities became much greater. Technicians were trained to handle radio equipment in the field and found that their interest became a continuing one calling for participation in IRE activities and resulting in their desire to obtain the benefit of IRE publications.

One of the outstanding aspects of IRE membership is the substantial number and generally increasing proportion of its membership living in countries outside of the United States. The IRE has taken special steps from time to time to recognize outstanding members living in other countries and to stimulate membership in such areas. In 1931 the IRE appointed a special committee to investigate the possibility of increasing its membership outside of the United States and establishing sections of the Institute in other countries. On a number of occasions, special dinners or meetings have been held in honor of Fellows from other countries who visited the United States.

Membership Growth in U.S.A., Canada and Abroad

Year	U.S. and Possessions	Canada	Abroad	Total
May 13, 1912	46			46
1927	3,550	184	476	4,210
1936	3,975	178	1,042	5,195
1946	15,898	978	1,278	18,154
1956	51,551	2,085	1,858	55,494

In 1948 the Board of Directors announced the resumption of formal membership in the IRE for German and Japanese nationals following the interruption of relations during World War II, even though dues could not then be paid by such members because of restrictions on foreign exchange. Meanwhile, however, the Board ordered that technical magazines published by the Institute be sent to the members residing in those countries.

During the year 1956, the increase in members living in the United States and its territories was 17 per cent and the increase in membership in other countries was 15.5 per cent. As of December 31, 1956 the dues-paying membership of the IRE was 55,494. Their geographical distribution included 80 countries outside of the United States.

Significance of Membership Grades

In the IRE, as is customary in professional societies, the several grades of membership are intended as a basis for giving recognition to the experience and achievements of the members in radio engineering and the related technical fields.

From the beginning the Fellow grade has been intended to represent high attainment. In 1914 Professor Jonathan Zenneck became the first person to be elected to this grade. In January, 1915, the Board elected A. N. Goldsmith, J. V. L. Hogan, Jr., R. H. Marriott, and E. J. Simon to the grade of Fellow. During the first 25 years of the Institute's existence, the attainment of Fellow grade was possible upon application subject to approval by the Board of Directors, or upon the initiative of the Board. Elections to Fellow grade were not numerous in any one year. Usually there were fewer than 10.

Beginning with the year 1940, all entries to the Fellow grade have been by invitation rather than upon application. The custom has been established of presenting the Fellow awards at meetings of the local Sections of which the recipients are members, and 75 persons were being honored in this way in the early part of 1957.

The Senior Member grade was established in 1943 as a means of providing a higher grade than the Member grade into which members of the IRE might advance on the basis of their experience and training. This enabled the Institute to keep the Fellow grade as a special recognition.

In 1955 there was an increase of 118 per cent in those of the Member grade resulting largely from the upgrading of qualified Associate members.

The Board felt that such upgrading was called for in order to give appropriate recognition to the professional attainments of many Associates, and it brought the per cent of professional grade members up to 42.1 per cent as compared with 29.1 per cent at the beginning of the year 1955.

Recognizing the desirability of encouraging engineering students to become affiliated with the Institute of Radio Engineers, a Student Grade of membership in the IRE was established by constitutional amendment effective in 1932. The previously existing grade of Junior member was dropped in 1943.

It was a natural development for the Student Members at a given college to meet together to discuss radio engineering questions among themselves or to hear ad-

Membership Growth by Grades

Year	Junior	Student	Associate Non-Voting	Associate Voting	Member	Senior Member	Fellow	Total
May 13, 1912				46				46
1936	34	299		4,092	637		133	5,195
1946		2,252	9,890	1,701	2,330	1,763	218	18,154
1956		10,384	18,491	388	19,110	6,486	635	55,494

dresses by visiting engineers, and a number of informal Student groups or "chapters" came into existence.

The Board consequently authorized the establishment of Student Branches in schools of recognized standing in order that the important segment of Student Members might be given official and direct support of the IRE. The first Student Branches which were formally recognized by the IRE were those at the College of the City of New York and at New York University, which were formed in February, 1947.

In order to promote affiliation of engineering students with the IRE Student Branches recognition was given to "100 Per Cent Clubs" in colleges where 100 per cent of the membership of the senior electrical engineering class had become affiliated with the IRE or the IRE-AIEE Student Branches through membership in one or the other of these engineering societies. In May, 1956, it was announced that 11 Student Branches were "100 Per Cent Clubs."

Interest in Student membership was stimulated during 1956 through visits made by the President of the IRE who traveled several thousand miles on his visits to Student Branches in the middle west and elsewhere. By the latter part of that year there were 135 Student Branches in as many colleges. Of these 107 operated as joint IRE-AIEE branches. In each of these schools a faculty representative who is a member of the Institute has been designated as IRE representative for that school. In addition there were 47 colleges having IRE faculty representatives where there was no organized Student Branch. Thus the IRE has a designated representative in each of 182 colleges in the United States and Canada.

The IRE Bylaws provide that every member who has attained the age of 65 years and who has been a member of the IRE for 35 years or more, is eligible for Life Membership with waiver of payment of further dues. As of December 31, 1956, there were 101 Life Members of the IRE.

Problems of the Depression

In November, 1931, in recognition of the difficult financial situation into which many members of the IRE had been forced because of the business depression, the Board of Directors voted to allow members who had paid their dues for the years 1929 and 1930 to have until December 31, 1932, in which to pay dues for 1931 and 1932, while still retaining full active membership in the IRE.

In January, 1932, the Board of Directors considered what steps the IRE might take to assist unemployed radio engineers and established a committee to survey the situation. This committee was to take appropriate steps to circularize IRE members for contributions, ascertain those radio engineers in need, determine what activities of interest to IRE members were not normally being carried out and employ needy engineers in such activities in so far as circumstances and finances would permit. The complete story of the relationships of the IRE to its membership during this trying time has never been fully disclosed publicly, but the relationships were of such a nature as to be thoroughly beneficial to its loyal and substantial members.

The offer by the IRE to extend the time for the payment of dues during the depression was accepted with great appreciation by several hundred members, the maximum number being about 730 at the end of 1933. The date for the acceptance of deferred payments without break in membership was extended but this practice was brought to a close at the end of 1935.

Early in 1932 an Emergency Employment Committee was established by the Board of Directors under the chairmanship of the first President of the Institute. Later in the year the membership of this committee was expanded to include the chairmen of all Sections of the Institute. Job surveys were conducted in 34 states by 105 IRE members. As a result of the committee's activities jobs were found for about 120 IRE members. Most of the expenses of the Emergency Employment Committee other than the maintenance of its office were paid by means of voluntary contributions rather than from IRE funds.

In May, 1933, the work of the Emergency Employment Committee was superseded by the "Emergency Employment Service" operated under the Secretary of the IRE. 185 registrants were placed in jobs during 1933 and 212 additional persons received jobs partly through the Institute's effort. It was estimated that the cost of this activity to the Institute was not more than $1000 per year.

Standardization

From the beginning of its existence, the officers of the IRE have recognized that standardization is necessary for the orderly exchange of information and for effective progress in a technological field. A Committee on Standardization was one of the committees of the Institute during its first calendar year, 1913. In his inaugural address in April, 1913, the President of the Institute, Greenleaf W. Pickard, said "the work of our Committee on Standardization is admittedly of first importance. Our art has grown so rapidly that so many of us have, perforce, made our own and sadly variant technical vocabularies. To progress, we must standardize; we must all speak and understand the same language. . . . Standardization in such a branch of the electrical art as ours, may never be complete. Rather, it must be a living, growing structure, added to and revised to keep pace with the changes and development of the art."

The Standardization Committee in 1913 published a report dealing with definitions of terms, letter and mathematical symbols, and methods of testing and rating equipment. The Committee held fifty meetings before the completion of its report, which was then submitted to the membership of the Institute as a whole for adoption. This Standardization Committee was the forerunner of more than a score of technical committees and many more subcommittees whose activities have contributed appreciably to the advancement of the electronic and communication art bringing conformity and clarity to all fields of this endeavor.

The Standards publication program of the IRE has been modified from time to time to meet the needs of a rapidly growing field. The initial Standards report of 1913 was succeeded by revised reports by the Standardization Committee appearing in 1915, 1922, 1926, 1928, 1931 and 1933. Each of these reports contained, in a single document, data on many branches of the art. Due to the rapid strides made in certain fields, the Committee on Standardization, during 1924 and 1925 was supplemented by a number of subcommittees, each one concerning itself with one specialized branch. As a result of this change in committee structure, the 1926 Standards report and subsequent reports were separated into several sections. Eventually it was found desirable to give these subcommittees full standing-committee status. Accordingly there was initiated in 1938 a new series of Standards in which each Standard dealt with a separate field. More recently, this subdivision has been carried further by the publication of separate Standards within each field, on definition of terms, on symbols, and on measuring and testing methods.

With the advent of radio broadcasting and the rapid growth of the radio manufacturing industry during the 1920–1930 decade, the IRE undertook to coordinate its Standardization activities with those of the trade associations of radio manufacturers—The National Electrical Manufacturers' Association and The Radio Manufacturers' Association. Reciprocal committee memberships were arranged and steps were taken to avoid duplication or possible conflict of proposed standards. Copies of preliminary editions of several of the reports of the Standardization Committee of the IRE were distributed to members of NEMA and RMA as well as AIEE for comment prior to final adoption.

In connection with the publication, in the 1929 YEAR BOOK, of the Standardization report for 1928 this statement was made:

"The following plan has been evolved under which the field of radio standardization has been divided between the Institute of Radio Engineers on the one hand and the manufacturers' organization on the other. It is recognized, of course, that in this new field, it is impossible at the present time to determine upon any hard and fast dividing line.

"*Institute of Radio Engineers.* 1) Terms, definitions and symbols, and 2) methods of testing materials and apparatus in order to determine their important characteristics. This work may consist of purely advisory discussion as to convenient forms of tests, precautions to be taken, etc., or it may include standardization of definite test procedures to serve as a common basis of comparison of the properties or performance of material or apparatus.

"*Manufacturers' Groups.* 1) Standardization of size and characteristics of apparatus, to promote interchangeability of parts, either mechanical or electrical, and 2) setting of standard ratings for the properties or performance of material or apparatus."

In the YEAR BOOK published in 1929, and distributed to all IRE members, there was included for the first time the text of the report of the Standardization Committee. This 1928 Standardization report contained nine sections of definitions classified as follows: 1) General, 2) Waves and wave propagation, 3) Transmission, 4) Reception, 5) Vacuum tubes, 6) Circuit Elements and Properties, 7) Antennas, 8) Direction Finding and 9) Electroacoustic Devices. Additional sections of this Standardization report dealt with the Transmission Unit, graphical symbols, abbreviations, letter symbols (vacuum-tube notation), and standard tests of radio broadcast receivers.

During the period of the development of radio broadcasting which involved the formulation of a nationwide pattern for the assignment of frequencies to broadcast transmitting stations, it came to be recognized by radio engineers both in the government and in industry that the intervals between assigned channels should be measured in terms of differences between the frequencies of the carrier waves rather than in terms of differences between wavelengths. The "wavelength" concept had been predominant in radio terminology but it became clear that the "frequency" concept would in the long run be much more significant and convenient if it could be brought into the current discussions of this problem and into the literature. This recognition and a consequent change in terminology were slow in developing. In 1929 the Board of Directors of the Institute appointed a committee to consider publicizing the desirability of using the term "kilocycles" in place of "meters" in radio terminology wherever practicable. Largely as a result of the activities of Institute members and of the cooperation given by government officials a substantially complete conversion from the wavelength to the frequency concept was accomplished.

Recognizing that the promotion of standardization in the engineering field required continuing cooperation among the various agencies which are active in industry and in government, the Board of Directors of IRE in 1927 undertook the joint sponsorship with the American Institute of Electrical Engineers of the Sectional Committee on Radio of the American Standards Association. The field of radio standardization undertaken at that time on a broad cooperative basis with other related engineering groups consisted of the following: 1) nomenclature, symbols, definitions; 2) methods of testing; 3) acceptable limits for performance, ratings, capacities, operation, etc.; 4) sizes and dimensions, to provide interchangeability and economy; 5) quality of materials, and 6) safety.

This cooperative effort with other engineering groups, with the radio manufacturing industry, and with government has continued to be active and many standards adopted as a result of this procedure have been published and given wide distribution. In October, 1930, the IRE became a formal Member of the American Standards Association. The YEAR BOOK which was published in 1930 included a number of standards closely related to radio engineering, which had been prepared by other organizations, in order to encourage the use of these standards by IRE members and others. These standards were: mathematical symbols, letters symbols, preferred numbers, electrical measuring instruments, definitions—telephony and telegraphy, definitions—storage batteries and provisions that were particularly applicable to radio installations, selected from the National Electrical Code and the National Electrical Safety Code.

The standards report issued early in 1931 reflected the increasing interest in a new field of communication by including material prepared by a Technical Committee on Electro-Visual Devices. Later in that year the Board of Directors created a technical committee of the IRE on Television to operate under the Standardization Committee and to work jointly so far as possible, with the Television Committee of the Radio Manufacturers' Association.

In 1939 the American Standards Association listed four standards as having been sponsored by the IRE. They related to vacuum tubes, loudspeakers, radio receivers, and audio volume measurements. As of the end of 1956, thirteen current IRE standards have been adopted by the ASA as American Standards.

With the broadening of the field of activity of the Standards Committee it became increasingly important to provide close coordination between the recommendations of various technical committees in order to avoid unnecessary duplication in their activities as well as to avoid inconsistencies between their recommendations. To this end in 1947, one of the members of the Executive Committee of the Board of Directors was designated to serve as Standards Coordinator for the Institute. In 1948 a Definitions Coordinating Committee for the Standards Committee was established and at IRE Headquarters during the years 1948 and 1949 there was prepared a master index of all terms covered by standard definitions of the IRE and of other organizations in the electronics field.

A major innovation in IRE policy regarding the publication of standards was the appearance of four such standards in the PROCEEDINGS OF THE IRE for December, 1949. It was felt by the Board that this form of publication of each standard upon its adoption would serve to emphasize with all members of the IRE the existence and importance of the standards. It was believed also that availability in this form and also in separate reprints would make reference to this material more convenient and practicable. The standards that were published in the December, 1949 PROCEEDINGS were: standards of radio aids to navigation, definitions of terms; standards on railroad and vehicular communications, methods of testing; standards on piezoelectric crystals; and standards on radio receivers—tests for effects of mistuning and for downward modulation. There was recognized, here, the increasing use of radio in the mobile field.

The IRE technical committees (sometimes in collaboration with technical committees of other engineering societies) publish standards of definitions of terms and methods of measurement of physical quantities used in radio engineering practice that are widely accepted throughout the technical world.

The current IRE standards are 63 in number. Of these 37 standards deal with terminology, symbols, and definitions of terms, and 26 standards deal with testing or measurement methods. Most of these standards have appeared in the PROCEEDINGS and all of them are available in reprint form. A list of the current standards is published from time to time in the PROCEEDINGS.

SECTIONS

Formation

The activities of the IRE, originally confined to the New York area, quickly spread to other cities as the membership increased. Small groups of members in various localities began to hold their own local meetings and elected their own officers for organizing and running these meetings. These groups of members were called Sections.

The first local Section of the IRE was organized at Washington, D. C. in January, 1914. Section meetings were held each month for the benefit of the group of perhaps a score of engineers, then described as "a large number of members residing in the vicinity of the capitol." At that time it was expected that other Sections would be formed, as appropriate, with the increase in membership of the IRE in various cities. This did not take long, for a Section was established in Boston, Mass. in November, 1914, another in Seattle, Wash. in February, 1915, and one in San Francisco in 1917.

It is interesting to note how the development of IRE Sections reflected the growth of the radio field. The first four IRE Sections were formed in large coastal cities due to the predominance of maritime radio just prior to World War I. In 1925 other Sections were formed in Philadelphia, Chicago, and Toronto as the broader aspects of radio engineering began to materialize and as the influence of IRE was felt in other areas.

The Chairman of the Sections Committee of the IRE in 1925 (Donald McNicol, who became President of the Institute in 1926), realizing that the membership of the Institute had grown to the point where there were a number of additional localities which were potential centers of Section activity, made trips to a number of such cities to stimulate interest in the establishment of Sections and to help in their organization.

An approved form of a Constitution for Sections was made mandatory in 1930, by action of the Board of Directors. In 1940 a Manual for Sections was prepared to facilitate passing on to new Section officers the experience of earlier officers and to put in one place all rules and regulations relating to the management and operation of Sections. This manual was the forerunner of other manuals for other activities of the IRE.

The IRE headquarters staff has made special efforts, from time to time, to arrange tours by speakers of national reputation who would present papers on technical subjects to meetings of members of IRE Sections. In 1935, Harold P. Westman, the Secretary of the Institute, visited the Sections in Buffalo, Cleveland, Detroit, Emporium, Rochester, and Washington for the purpose of assisting the officers of these Sections in the further development of their local IRE activities.

In 1939 the President of the Institute, Raymond A. Heising, visited nineteen of the twenty-three IRE Sections. At their meetings he spoke of Institute affairs, outlining the significance of changes recently made in the Constitution, discussing the desirability of membership of the highest grade for which an individual is qualified, emphasizing the advantages of active participation in Institute affairs, and ascertaining first-hand their problems and their desires. Before several of these Sections he also presented technical papers of timely interest. Upon his return from these visits the President presented to the Board a number of questions to be resolved, if the Institute was to be of greatest value to the Sections and continue their active relationship with the IRE. These included the importance of emphasizing the identity of the local group as an IRE Section and the problem of making financial grants or allowances to a Section organization in order to enable it to strengthen its local program.

These early presidential trips were the forerunners of many visits by succeeding Presidents to Sections of the IRE in various parts of the country. In the course of these trips it was apparent that there was a desire to add greater significance to the Member grade and to find ways in which the management people in the companies whose engineers held Institute membership could be given a fuller appreciation of the values both to the men and to the companies resulting from such membership. At the same time there was developing, especially in some localities, a desire to have the requirements for eligibility for IRE membership broadened to include people in the various allied fields. This was a consequence of the fact that high-frequency techniques were being developed for use in nonradio industries.

It was felt that the primary problem with which the Institute would be confronted if membership requirements were to be broadened would involve the scope of the Institute's publication field. It was thought that if the Institute were to publish more varied types of technical material, it might find itself publishing many papers in which radio engineers—the backbone of the Institute membership—might be not interested. The solution of this problem was not clear at the outset but later became crystallized in terms of the wider scope of membership, the recognition of Professional Groups and the publication of Professional Group TRANSACTIONS.

The increase in Section activity continued during the late 1930's and it was reported that in 1941 a new record was established for the number of Section meetings held in a year, the total in that year being 235.

From the time of the formation of the IRE until 1941 the meetings in New York were considered meetings of the Institute as a whole. In that year, however, consideration was given to the formal establishment of a New York Section. This action was completed in 1942. Since that time several other Sections and Subsections have been established in the New York-New Jersey metropolitan area.

Effective January 1, 1946, the Board made a change in the method of assigning territory to Sections. Instead of assigning a small territory around a city as the area of each Section it was decided that the entire area of the United States should be assigned to one Section or another. This meant that every member of the IRE in the United States would automatically be on the membership list of a Section and would receive notices of Section meetings. This was a prelude to the establishment of territorial Regions as a basis for the election of Regional Directors. The Section boundaries and the Regional boundaries were established by the Board in such a way as to recognize such factors as community of interest and travel habits of members as well as to equalize, to the extent practicable, the membership in the several regions.

Following the establishment of Professional Groups, referred to below, there have been organized many Professional Group Chapters which meet jointly with other members of IRE Sections in various cities.

Assistance given to Section activities by the headquarters organization in 1945 included a traveling lecture series on television and frequency modulation. In 1954 a program of "tapescripts" or tape recordings, accompanied by lantern slides, was prepared for shipment to IRE Sections, Subsections, Student Branches, and Professional Group chapters which are so located that speakers for their sessions are not always readily obtainable. These tapescripts are useful as short supplements or additions to other programs.

In March, 1955, the administrative work of the Boston Section (with about 3000 members) had grown to such magnitude that an IRE office, with a paid employee, was established by the Executive Committee. At this time the Boston Section had a larger membership than did the IRE as a whole when it established its first regular office with paid personnel. The first Boston Office was at 12 Norfolk Street, Central Square, Cambridge, Mass. On September 1, 1955, the office was moved to 73 Tremont Street, Boston, Mass.

IRE Sections by Regions and Foreign Countries

Region 1 Binghamton Boston Buffalo-Niagara Conn. Valley Elmira-Corning Ithaca Rochester Rome-Utica Schenectady Syracuse *Region 2* Long Island New York Northern New Jersey Princeton *Region 3* Atlanta Baltimore Central Florida Florida West Coast Huntsville Miami North Carolina-Va. Northwest Florida	Philadelphia Washington *Region 4* Akron Central Pennsylvania Cincinnati Cleveland Columbus Dayton Detroit Emporium Pittsburgh Toledo Williamsport *Region 5* Cedar Rapids Chicago Evansville-Owensboro Fort Wayne Indianapolis Louisville Milwaukee Omaha-Lincoln South Bend-Mishawaka Twin Cities	*Region 6* Alamogordo-Holloman Beaumont-Pt. Arthur Dallas Denver El Paso Fort Worth Houston Kansas City Little Rock Lubbock New Orleans Oklahoma City St. Louis San Antonio Tulsa Wichita *Region 7* Albuquerque-Los Alamos China Lake Fort Huachuca Hawaii Los Angeles Phoenix Portland Sacramento Salt Lake	San Diego San Francisco Seattle Tucson *Region 8 (Canada)* Bay of Quinte Hamilton London Montreal Newfoundland Northern Alberta Ottawa Regina Southern Alberta Toronto Vancouver Winnipeg *Argentina* Buenos Aires *Brazil* Rio de Janeiro *Egypt* *Israel* *Japan* Tokyo

Section Finances

In 1926 the Board of Directors decided to send "rebate checks" to five Sections in addition to two Sections which had previously received them, in order to assist the Sections in obtaining suitable meeting quarters or more helpful technical programs. A total of slightly more than $12,000 of Headquarters funds was devoted to Section operation during 1927.

In 1931 a more uniform system of Section rebates was put into operation. As then ordered, each Section was to be allotted $10 for each meeting during the year and, in addition, fifty cents for each paid member residing in the Section territory.

Increases in Section membership rebates were made at various times over the years and are now $1.10 per member up to 700 members and $1.25 per member for those Sections in excess of 700.

Sections in Other Countries

On October 2, 1925, the first Canadian Section was formed in Toronto at a meeting attended by fifty-three IRE members and guests. Now, twenty-six years later the IRE has a membership in Canada of over 2000 members of all grades. Meanwhile in 1945 the Canadian Council of the IRE had been formed to coordinate the activities of various Canadian Sections on a national basis. This plan formed the basis of the organization that later became effective in the eight IRE Regions of North America.

Consideration was given in 1927 and again in 1932 to the possibility of forming Sections of the IRE in countries outside of North America but on both occasions it was decided that such action would be inadvisable because of their remoteness and the problems of coordination of their activities with those of the Institute as a whole. The first Section of the IRE formally established outside of the United States and Canada was the Buenos Aires, Argentina Section established in 1939. In January, 1956 the IRE Executive Committee approved the establishment of an IRE Section in Tokyo, Japan. This was the sixth Section to be formed outside of North America and the sixteenth outside of the continental United States. These sixteen Sections are Egypt, Israel, Buenos Aires, Hawaii, Rio de Janiero, Tokyo, and ten cities in Canada. Although there are no IRE Sections in Europe, there are members of the IRE in most of the European countries. The total IRE membership in 80 countries other than the United States is about 4000.

Growth Under Regional Plan

The Sections were tied in more closely with the administration of the IRE in 1946 when the Sections were grouped into eight Regions and each Region was given representation on the IRE Board of Directors, each Regional Director being elected on a biennial basis by the membership of the respective Region. Since then the Regional Plan has provided an effective channel of communication between the Board and the membership of the local Sections. The growth of this important "grass roots" activity has continued unabated so that there were at the end of the year 1956, 85 Sections and 26 Subsections in the United States, Canada, and Hawaii. As noted previously, there were then five Sections in other countries. A list of Sections and their officers appears bimonthly in the Proceedings of the IRE.

Professional Group System

The most basic change in the structure of the IRE which occurred during its more than forty years of growth was the establishment in 1948 of the Professional Group System, providing for Groups within IRE along lines of technical specialization of the members. The successful development of the Professional Group System is proving to be an effective means of counteracting the centrifugal tendencies that otherwise might have accompanied the rapid expansion of the Institute.

For several years prior to 1948 a study was made of various means for developing ways within the IRE whereby members having interests in a given specialized field could give expression to those special interests and develop appropriate activities related thereto. In May of that year plans were announced for the inauguration of a Professional Group System within the broad structure of the IRE. Within less than a year the System had become substantially an accomplished fact. Necessary amendments to the Bylaws had been adopted, a permanent Professional Groups Committee had been established, a model Constitution and Bylaws for Professional Groups had been prepared, and a detailed manual for the guidance of would-be Professional Group organizers had been published.

Under these provisions, those members of the IRE who are interested in a specific technical field can organize and elect their Chairman, Vice-Chairman, and Administrative Committee and, after approval by the IRE Board of Directors, hold meetings either of a national scope or as Chapter meetings associated with an IRE Section. A petition for the establishment of a Professional Group must bear 25 signatures. A petition for a Group Chapter must bear 10 signatures. When approved, any number of members of any Section, however small, may hold local Group Chapter meetings. All meetings of all Groups must be open to all members of IRE.

A Professional Group may establish its own publication which becomes known as TRANSACTIONS of that Group, as discussed below, under "Publications." The members of a Group may establish special honors to promote local and general recognition of their leaders.

It was recognized at the outset that the success of the Professional Group movement would depend upon the interest and spontaneous activities of the groups of IRE members. The multiplication of the applications of radio and electronics led to a greater divergence of the fields of interest of the individual specialists. They were linked together by the use of the same phenomena—electronics or radiation or both. The underlying organizational tie is The Institute of Radio Engineers. The means of expression of individual technical interests is the Professional Group System.

The first two Professional Groups were authorized by the Board on September 9, 1948. These were Groups known as "Audio," and "Broadcast Engineers." In 1948, also, steps had been taken to form Professional Groups on "Nuclear Science" and "Antennas and Wave Propagation." The subsequent establishment of these and other Groups has brought the list to 24 at the end of 1956. A list of the Professional Groups appears bimonthly in PROCEEDINGS OF THE IRE.

Total Paid Membership of IRE Professional Groups

	No. of Groups	Total Paid Members
1948	2	
1949	8	
1950	10	8,500*
1951	16	13,000*
1952	17	12,482
1953	20	21,797
1954	21	28,158
1955	23	36,562
1956	24	53,015

* Estimated; includes both paid and unpaid members.

Accounts of Professional Group activities are published in PROCEEDINGS OF THE IRE and the various Sections are kept informed of Group activities by notices which appear in the Section news letters.

Practically all of the Professional Groups have appointed Sectional Activities Committees to stimulate interest in the establishment of Group Chapters in the various Sections.

The IRE has followed the course of limiting the extent to which the headquarters staff undertakes to stimulate and guide the Professional Groups in their development. The IRE has established general policy and procedure but has left the formation and activities of individual Groups to the initiative of interested IRE members.

The Groups have not been uniformly active nor are their problems identical. Financial assistance has been provided by the headquarters including provision for reimbursing the Sections for Chapter meetings which have been held.

The procurement of papers and management of national symposia are now entirely in the hands of the Professional Groups. Each of the Groups had sponsored one or more technical meetings in the past year in addition to technical sessions at the IRE National Convention, the Western Electronics Show and Convention (WESCON), the National Electronics Conference, and other joint meetings, for a total of 91 meetings of national import in 1955.

Professional Group Chapters

There were 191 Professional Group Chapters, organized by Group members in 44 IRE Sections, as of March, 1957. Chapter growth is continuing at a healthy rate. The Chapters are meeting regularly and sponsoring meetings in the fields of interest of their associated Groups.

PROFESSIONAL GROUP CHAPTERS

Name of Group	No. of Chapters	Section Location
Aero. and Navig. Electronics	10	Akron; Baltimore; Boston; Dallas-Ft. Worth; Dayton; Kansas City; Los Angeles; N. Y.; Phila.; St. Louis
Antennas and Propagation	11	Albuquerque; Chicago; Denver; Los Angeles; Orange Belt (L. A.); Phila.; San Diego; Wash. D. C.; Akron; Boston; Syracuse
Audio	18	Albuquerque; Baltimore; Boston; Chicago; Cincinnati; Cleveland; Dayton; Hawaii; Houston; Milwaukee; Phila.; Phoenix; San Antonio; San Diego; San Francisco; Seattle; Syracuse; Wash. D. C.
Automatic Control	6	Akron; Baltimore; Boston; Dallas-Ft. Worth; Los Angeles; Twin Cities
Broadcast and TV Receivers	2	Chicago; Los Angeles
Broadcast Transmission Systems	8	Boston; Chicago; Cleveland; Houston; Los Angeles; Pittsburgh; San Francisco; Twin Cities
Circuit Theory	11	Albuquerque; Chicago; Urbana; China Lake; Dallas-San Antonio-Ft. Worth; Los Angeles; Montreal; Phila.; Seattle; Syracuse
Communications Systems	5	Chicago; Phila.; Rome-Utica; Syracuse; Wash., D. C.
Component Parts	6	Buffalo-Niagara; Dayton; Los Angeles; Joint, N. Y., No. N. J. & L. I.; Phila.; Wash., D. C.
Electron Devices	9	Boston; Elmira-Corning; Emporium, Pa.; Los Angeles; Jt., N. Y., No. N. J. & L. I.; Phila.; San Francisco; Schenectady; Wash., D. C.
Electronic Computers	15	Akron; Baltimore; Boston; Chicago; Dallas-Ft. Worth; Dayton; Detroit; Houston; Los Angeles; Montreal; N. Y.; Phila.; Pittsburgh; San Francisco; Wash., D. C.
Engineering Management	10	Boston; Chicago; Dayton; Los Angeles; Jt. N. Y., No. N. J. & L. I.; Phila.; Rome-Utica; San Francisco; Syracuse; Wash., D. C.
Industrial Electronics	3	Chicago; Cleveland; Schenectady
Information Theory	4	Albuquerque; Los Angeles; Wash., D. C.; White Sands Proving Grounds, (El Paso)
Instrumentation	6	Atlanta; Chicago; Houston; L. I.; Los Angeles; Wash., D. C.
Medical Electronics	10	Boston; Buffalo; Chicago; Conn. Valley; Los Angeles; Montreal; Jt. N. Y., No. N. J., L. I. & Princeton; Phila.; San Francisco; Wash., D. C.
Microwave Theory and Techniques	14	Albuquerque; Baltimore; Boston; Buffalo; Chicago; L. I.; Los Angeles; No. N. J.; N. Y.; Phila.; San Diego; San Francisco; Schenectady; Syracuse
Military Electronics	10	Boston; Buffalo-Niagara; Chicago; Dayton; Ft. Wayne; L. I.; Los Angeles; Phila.; Syracuse; Wash., D. C.
Nuclear Science	9	Albuquerque; Boston; Chicago; Conn. Valley; Dayton; Los Alamos; Oak Ridge, Tenn. (Atlanta Sec.); Pittsburgh; Wash., D. C.
Production Techniques	4	Los Angeles; Jt. N. Y. No. N. J. & L. I.; San Francisco; Wash., D. C.
Reliability and Quality Control	3	Chicago; Los Angeles; Wash., D. C.
Telemetry and Remote Control	6	Albuquerque; Chicago; Dayton; Central Florida; Los Angeles; Phila.
Vehicular Communications	11	Baltimore; Boston; Chicago; Detroit; Houston; Los Angeles; Jt. N. Y., No. N. J. & L. I.; Phila.; Portland; Wash., D. C.; Dallas
23	191	44

As of the end of 1956, about half of the IRE members had, on the average, joined two Professional Groups, for a total Professional Group membership of 53,015. About one-third of the Student Members of the IRE, numbering nearly 3619, had by the end of 1956, joined one of the Groups covering their particular field of interest at the Student Member rate of $1.00 for each year.

A copy of the portion of the IRE NATIONAL CONVENTION RECORD which pertains to the field of interest of his Group is sent without charge to all paid members of Professional Groups.

The comment has been made by John V. L. Hogan, one of the Founders and past Presidents of IRE that "the Institute of Radio Engineers can well be considered to be the federal body which unites an increasing number of autonomous professional groups."

This decentralized activity, with centralized service and coordination, seems to explain the extraordinary vitality of the Professional Group System. There has been growth, not only in number of Groups, but in the size and professional attainment of each Group. More and more first-rate papers are finding their way into the Group TRANSACTIONS, papers which in an earlier day would certainly have been published in the PROCEEDINGS.

"Affiliate" Plan

In January, 1957, the Board took a step which may prove to be a notable one in IRE history. Based on a need which had developed especially in the case of the Professional Group on Medical Electronics, it adopted on an experimental basis a plan which enables non-IRE members whose main professional interests lie outside the sphere of IRE activities to become affiliated with certain of the IRE Professional Groups in whose activities they wish to share without having to join the IRE. To be such an "Affiliate" of a Group a person must belong to an accredited organization approved by that Group and by the IRE Executive Committee. Participation in the Affiliate Plan is at the option of each Professional Group. On payment of the regular assessment fee of his Group, plus $4.50, the Affiliate is entitled to receive the TRANSACTIONS of the Group and the part of the IRE NATIONAL CONVENTION RECORD which pertains to that Group. The Affiliate Plan is intended to recognize and provide for the rapidly spreading influence of electronics in every walk of scientific and technological life, and to enable the IRE to further fulfill its aim—that of advancing radio engineering and related fields of engineering and science.

PUBLICATIONS

PROCEEDINGS OF THE IRE

As an essential element in meeting its objective of promoting the exchange of radio engineering knowledge the IRE at the outset undertook the publication of a periodical, and its publication program is perhaps the most important single activity of the Institute.

The PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS was established originally as a quarterly publication, in 1913. An amendment to the IRE Constitution, effective in 1916, authorized the publication of six issues of the PROCEEDINGS per year instead of four. For the last thirty years, beginning in 1927, the PROCEEDINGS has been published monthly. In 1939, the name of the journal was shortened to PROCEEDINGS OF THE IRE.

The first Editor was Alfred N. Goldsmith, one of the three Founders of the IRE. It is under his inspired leadership that the IRE has, through the ensuing years, turned out a publication which has been generally recognized as the leading technical magazine in the radio field.

Prior to the inauguration of the PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS there had been the *Proceedings of the Wireless Institute*, mentioned above. The only other radio engineering periodical of significance was *Jahrbuch der Drahtlosen Telegraphie* edited by Dr. Jonathan Zenneck in Berlin.

As to the early years of the IRE, it has been said that "the Secretary got members and the Editor got papers;" there was always an editorial office of the IRE wherever Dr. Goldsmith, a blue pencil, and a submitted manuscript got together. Editorial facilities other than those that were provided by the Editor were meager for a number of years. The correspondence, proofreading, typographical, and related editorial matters that had to be taken care of must have made a pretty strenuous task for one man. The recognition that the PROCEEDINGS has received throughout the world is in no small measure due to the determination and ability which Dr. Goldsmith exhibited throughout a period of four decades.

The PROCEEDINGS for the years 1913 to 1927 inclusive were printed at various printing plants in New York. Beginning with the October, 1927 issue the printing of the PROCEEDINGS was transferred to the Banta Publishing Company of Menasha, Wisconsin, by which firm it has been printed throughout the ensuing years. The Institute is fortunate in having a printing house with which such a close and cooperative relationship has developed as to make it seem like a member of the IRE family.

At the outset, the contents of the PROCEEDINGS consisted of certain papers and discussions as presented at meetings in New York and other cities. During the year 1913, thirteen technical papers were published and a total of 268 pages were occupied, an average of 67 pages per issue, size $6\frac{1}{2}$ by 9 inches. The scope of the PROCEEDINGS was soon broadened to include other technical papers, and also lists of newly elected members, personal notes, reports of meetings and committees, and other information pertaining to the Institute. In addition, from April, 1921 to January, 1928, inclusive, there was published a monthly Digest of U. S. Patents Relating to Radio Telegraphy and Telephony.

In order to relieve the Editor of the PROCEEDINGS of some of the burden of the technical editorial work that must be done on papers submitted for publication, a Board of Editors was established in 1928 to assist in this work. This Board consisted of the Editor and 5 other members of the Institute who were experienced in the editorial or publication field.

Throughout the years the IRE has followed in its publishing activities a policy which spreads ideas throughout the world hoping that somewhere they may fall on fertile ground. Thus, the Institute has been instrumental in disseminating scientific and technical information that forms the foundation of radio enterprises as they are developing. It has been effective in providing a world-wide avenue of discussion and publication that has promoted the rapid development of radio for nearly half a century.

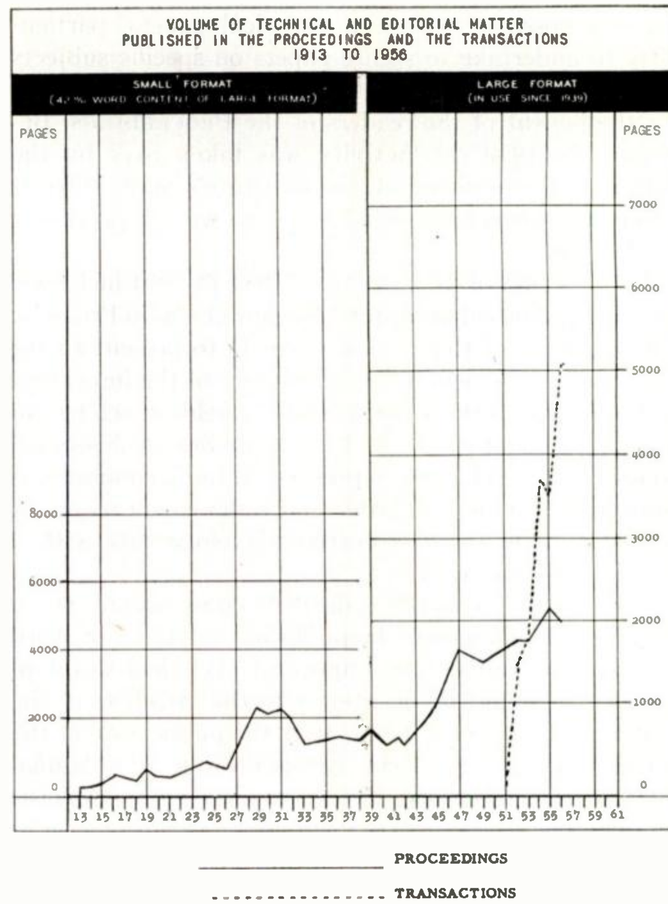
There was recognition, also, of the interest of European members of the IRE in the Final Protocol of the European Radio Conference signed at Prague, April 13, 1929, of which an English translation was published in the PROCEEDINGS in July of that year. That document related to radio broadcasting in Europe and dealt with frequency assignments, power limits, etc.

Beginning in January, 1939, each issue of the PROCEEDINGS has contained photographs of the authors of technical papers published in that issue, in addition to the biographical notes which had been printed previously.

In 1941 the practice of publishing an editorial in each issue of the PROCEEDINGS was begun. These started chiefly as "Guest Editorials" but have included from time to time editorial writings by the Editor of the PROCEEDINGS and by the President of the IRE or a Committee Chairman.

During World War II the volume of technical material published in the PROCEEDINGS was materially smaller than had been the case during the several prior years. While technical advances during that period were very extensive, censorship limitations applied to certain subjects. Furthermore, the preoccupation of IRE members with urgent military tasks precluded their devoting the necessary time to the writing of papers in form that would be most useful to PROCEEDINGS readers. The shortage of paper for printing necessitated the use of a minimum of paper and such paper as was available was of inferior quality. It was through the personal effort of the Editor that the supply of paper for the IRE PROCEEDINGS was not curtailed even further.

In 1946 the supply of paper suitable for magazine production was even shorter than during war time. On the other hand the number of meritorious technical papers submitted for publication increased substantially upon the termination of the war. It became necessary, therefore, to request authors to submit manuscripts in the briefest possible form, to materially shorten some papers which had already been accepted for publication, and to be patient with substantial delays in the publication schedule. The cooperation received from authors was gratifying and within a very few years the publication process was able substantially to keep pace with the supply of available papers.



During the years 1946 to 1949, inclusive, there was published along with the PROCEEDINGS and bound within the same covers a section known as "Waves and Electrons." This portion of the magazine was intended to meet the interest of readers of the PROCEEDINGS who wished to see more material published outside of the field of advanced research and technical developments. The "Waves and Electrons" section contained news, notes, book reviews, biographical notes, information regarding other technical organizations, and current information regarding radio apparatus developments, as well as some historical and tutorial papers. It was found, however, that this formal separation of material did not lend itself to the integrated arrangement of technical and editorial material which was desirable and the "Waves and Electrons" section, as such, was discontinued at the end of 1949.

Prior to 1949 there had existed from time to time a committee of the IRE known as the Papers Procurement Committee. The purpose of the committee was to canvass possible sources of technical papers, particularly to undertake to secure papers on specific subjects on which it was felt desirable to round out the material for the benefit of the readers of the PROCEEDINGS. Beginning in 1949 this activity was taken over by the Editorial Department of the Institute's staff, since it was in a position to know what papers were in process of publication.

For a period of 21 years from 1934 to 1954 inclusive, the IRE published an Annual Review of Radio Progress. The purposes of this review were: 1) to present to the specialist in one field a general picture of the important forward steps in the other specialist's fields which he can not follow day by day, and 2) to provide an historical record of the evolutionary progress in radio communication and allied fields in order that radio engineers might be better able to view current developments with a proper prospective.

It became increasingly difficult to cover adequately in a summary which could be published in March or April of each year all of the important technical developments that might be of interest to the members of the Institute. It was concluded, after the publication of the survey for the year 1954, to discontinue this Annual Review. Instead, it was decided to place more emphasis on the preparation by experts in various fields of a series of review papers, each of which would cover the developments in a given field during a recent period of years.

With the broadening of Professional Group activity and with the presentation of an increasing number of technical papers at Professional Group meetings and at the annual National Conventions of the IRE, it became desirable to crystallize on the terminology that would be useful in describing the growing variety of IRE publications. By 1951 it appeared that these publications might be primarily of the following four categories:

1) PROCEEDINGS OF THE IRE—the official monthly publication of the Institute,
2) TRANSACTIONS of each of the Professional Groups—publications sponsored by the groups, containing papers and discussions of a more specialized nature,
3) CONVENTION JOURNAL (hereafter to be known as the IRE NATIONAL CONVENTION RECORD)—a publication containing all papers presented at an IRE National Convention,
4) IRE YEAR BOOK AND DIRECTORY—an annual publication summarizing the categories of activities of the Institute and containing a list of IRE members together with listings of manufacturers and their products which might be found of interest to the members. The last three of these publications are discussed more fully below.

To accomplish a balanced publication program the IRE must supplement the contributed papers by invited papers, either to fill gaps in the coverage of new technical developments or to present a general review of a given field in a way which is helpful to a reader who is not a specialist in that field.

Beginning in 1951 there have been published, from time to time, nine unusually large issues of the PROCEEDINGS, each devoted exclusively to a single subject. The first of these was the October, 1951 issue devoted to color television. This issue consisted of 400 pages and was the largest single issue of the PROCEEDINGS ever published up to that time.

The Board of Editors, by 1949, had found that its work could be facilitated by the establishment of an Editorial Administrative Committee. This Committee made final decisions on papers under review for publication in the PROCEEDINGS, in addition to concerning itself with general editorial matters. In 1954, the Board of Editors and the Editorial Administrative Committee were replaced by the Editorial Board which concentrated its attention largely on policy questions and has left operational and papers review matters chiefly to the staff of the Institute.

The IRE has had the unique good fortune to benefit from the continuous service of the original Editor of the PROCEEDINGS who served in that capacity for all but one of the first 42 years of the existence of the Institute. As of January 1, 1954, Dr. Goldsmith was relieved of active editorial responsibilities and "in recognition of the invaluable service he has rendered the Institute and his monumental contributions to the growth and high standards of its publications" was appointed Editor Emeritus. Since that date two other persons, John R. Pierce and Donald G. Fink, have served as Editor. Previously, however, the Institute had established the position of Managing Editor which is filled by a full-time employee of the Institute.

Beginning in January, 1956, the section of the PROCEEDINGS known as "IRE News and Radio Notes" was expanded to include several pages of pictures as part of a new program of reporting more fully the activities of the Professional Groups and Sections. The news of IRE officers' visits, conferences, banquets, award ceremonies, and publications serve to keep the general IRE membership informed of current activities.

Beginning in February, 1956, there appeared in the PROCEEDINGS, under the caption "Poles and Zeros," a page of comment by the Editor on matters of concern to the IRE membership.

A regular editorial feature of the PROCEEDINGS written by the Managing Editor and which has also appeared since February, 1956, carries the caption, "Scanning the Issue." These "program notes" are intended to indicate to the general reader not only what is in the papers but what is behind them—what their significance is, to whom they will be of interest and, by implication, why they are being published.

A portion of the PROCEEDINGS is frequently devoted to correspondence with the Editor. During the past few years this feature has grown in significance. For example, in the August, 1956 issue 23 items appeared, including brief technical contributions or comments and discussion on previously published papers.

Apropos of the current revival of interest in the subject of long-distance transmission of microwaves there was published in the PROCEEDINGS for August, 1956, an English translation of Marconi's last paper, only 13 sentences long, entitled, "On the Propagation of Microwaves Over Considerable Distance." This paper had been presented by Marconi at a meeting of the Royal Academy of Italy on October 14, 1933.

One reason for the continued recognition of the PROCEEDINGS as an outstanding technical journal is that so large a part of the technology of radio engineering is the common property of everyone in the field, regardless of his specialization. Papers qualify for the PROCEEDINGS when the subject matter is of common interest to several types of specialists.

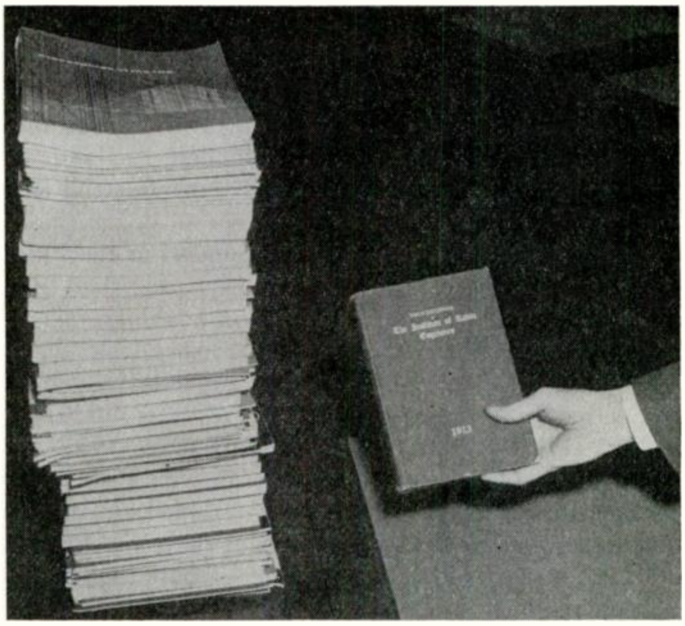
To date, in total, about 5900 technical papers, letters to the Editor and book reviews have been published in PROCEEDINGS.

In order to reduce the number of pages in each issue while still accommodating the increasing volume of technical material and advertising which was available for publication, it was decided, effective in January, 1939, to increase the size of the PROCEEDINGS page to 8½ by 11 inches. The issue of the PROCEEDINGS for December, 1956 contained 34 technical papers, 15 items of technical correspondence, five book reviews, and other technical material, all occupying a total of 250 pages of this large size. The total technical contents of the twelve issues of the year 1956 took more than 1900 pages.

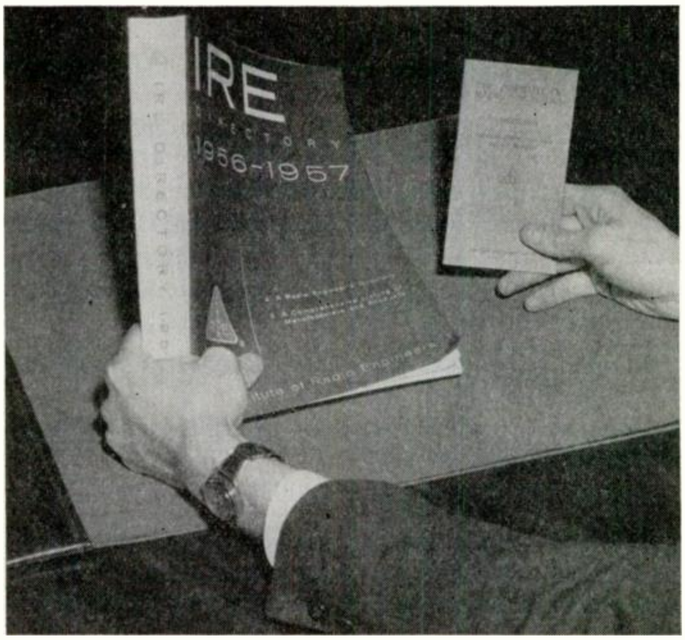
The growth in the total publication output of the IRE, as indicated in the two photographs opposite, is shown in a striking way by the contrast between the total size of the PROCEEDINGS and the YEAR BOOK published in 1914 and the size of the total of IRE publications in 1956. The PROCEEDINGS in 1914 had a volume that if printed on pages of the size now utilized would be 124 pages; the 1914 YEAR BOOK, if measured in pages the same size as those of recent YEAR BOOKS would be a total of 12 pages, making a total publication volume of 136 pages. The 1956 editorial output of the IRE consisted of 97 issues of publications, amounting to a total of 12,908 pages, made up as follows:

Publication	Pages
PROCEEDINGS OF THE IRE	4,796
CONVENTION RECORD (in 9 parts)	1,696
TRANSACTIONS of Professional Groups	5,044
1956–1957 DIRECTORY	1,004
STUDENT QUARTERLY	228
Miscellaneous Technical Publications	140
Total	12,908

The IRE publications are in substantial demand by persons who are not members of the Institute. Paid subscriptions to the PROCEEDINGS by libraries and nonmembers amounted, at the end of 1956, to 4254. About 2500 nonmember subscriptions are in effect from 63 countries other than the United States and Canada.



The 268 pages published by the IRE in 1913 are compared with the total output for 1956 of 12,908 pages.



Contrasting sizes of last year's 1000-page IRE Directory and the original 24-page membership pamphlet issued January 1, 1913.

Abstracts and References to Radio Literature

Beginning in 1928 there were published in each issue of the PROCEEDINGS several pages of "References to Radio Literature" furnished by the National Bureau of Standards of the United States. These references were classified in accordance with an extension to radio of the Dewey Decimal Classification. At the same time the practice was begun of classifying each of the technical papers published in the PROCEEDINGS under this same classification, and this was continued through 1954.

Beginning in June, 1946, in place of these reference lists the Institute began the publication in the PROCEEDINGS of "Abstracts and References" which were made available by a special arrangement with Iliffe and Sons and the *Wireless Engineer* of London, England, as well as the Department of Scientific and Industrial Research of the British Government.

The Abstracts and References published in the PROCEEDINGS for December, 1956, number more than 300 references classified under 19 technical headings.

In 1955 it was felt that an index to these references would be useful to IRE members. An index covering the period June, 1946 to January, 1954 was published as Part II of the PROCEEDINGS for November, 1955. An index to references published from February, 1954 to January, 1955 inclusive had been published as Part II of the PROCEEDINGS for April, 1955. A third installment of this index covering the references published from February, 1955 to January, 1956 inclusive was published as Part II of the PROCEEDINGS for June, 1956. Accompanying the index is a selected list of journals scanned for abstracting together with publisher's addresses.

Indexes to IRE Publications

With the increasing quantity of material published by the Institute, and in view of the widening areas of subject matter dealt with, it became apparent that a general cumulative index should be prepared and made available to all subscribers to the PROCEEDINGS. Several such indexes have been compiled from time to time. The three indexes which now cover this material are:

Cumulative Index, 1913–1942 (Part II of PROCEEDINGS, June, 1943)
Cumulative Index, 1943–1947 (Part II of PROCEEDINGS, June, 1948)
Cumulative Index of IRE Publications, 1948–1953

This latter index, printed as a separate pamphlet, includes references to the PROCEEDINGS OF THE IRE, the IRE TRANSACTIONS, and the IRE CONVENTION RECORD.

Transactions of Professional Groups

The first major broadening of the IRE publication program was the appearance of the TRANSACTIONS issued by the Professional Groups. They immediately proved to serve a very useful purpose as a quick, practical method of providing Professional Group members with technical papers in their particular fields of interest. As early as in 1951, six issues of such TRANSACTIONS were issued by the Audio Group and two issues of TRANSACTIONS by the Airborne Electronics Group.

The material published in these IRE TRANSACTIONS consists in part of contributed papers, and in part of papers presented at meetings of the Professional Groups or at Symposia of which they undertake joint sponsorship. The growth of the Professional Group TRANSACTIONS is indicated by the fact that in 1951 eight issues of TRANSACTIONS appeared, each consisting of a single paper, whereas, in 1956 some 69 issues of TRANSACTIONS were published by 23 Professional Groups containing a total of over 500 papers. The total annual TRANSACTIONS output now exceeds that published in the PROCEEDINGS.

The principal Symposium publications that have not been included in TRANSACTIONS of Professional Groups, but of which copies are obtainable from the office of the IRE, are the following:

8 Electronic Computer Conferences (joint AIEE-IRE-AGM) 1951–1956 inclusive
3 National Telemetering Conferences, 1953–1955 inclusive
2 Electronic Components Symposia 1954–1955
2 National Symposia on Quality Control and Reliability in Electronics 1954 and 1956

Beginning with the issue for June, 1954, there were published in the PROCEEDINGS abstracts of all technical papers appearing in the TRANSACTIONS of the various Professional Groups. Further steps taken to avoid overlap of the PROCEEDINGS and the TRANSACTIONS were the establishment of restrictions on the reprinting of TRANSACTIONS papers in the PROCEEDINGS and the participation of Professional Group representatives in the review of papers submitted for publication in the PROCEEDINGS. The Professional Group TRANSACTIONS are proving to be such a substantial source of technical information that, by the end of 1956, 450 technical libraries, including those of many colleges and industrial organizations, had subscribed for all issues of all TRANSACTIONS of all Professional Groups.

CONVENTION RECORD

The papers that were presented at the National Conventions of the IRE in New York from 1953 to 1956, inclusive, have been published as Volumes I, II, III, and IV, respectively, of the IRE CONVENTION RECORD. This has grown to be a very sizable RECORD. An important feature of the publication is that each paid Professional Group member receives, free, a copy of the part pertaining to his Group.

About 6000 copies of each of the nine parts of the CONVENTION RECORD for 1956 were printed of which a total of 40,000 copies were sent free to Professional Group members. This publication is now known as the IRE NATIONAL CONVENTION RECORD.

Late in 1956 the Board decided that thereafter the papers presented at the Western Electronics Show and Convention should be published as the IRE WESCON CONVENTION RECORD

STUDENT QUARTERLY

In September, 1954, a new publication of the IRE was successfully launched. It was the IRE STUDENT QUARTERLY which is sent free to all Student Members of the

IRE as part of a program of increased service to students. It contains news of Student Branches, articles of technical value, and papers of significance to students who are interested in considering carefully whether to devote themselves to an engineering career.

Year Book and Directory

The first published list of IRE members, dated January 1, 1913, was a 24-page pamphlet, size $3\frac{1}{2}$ by 6 inches, listing 100 persons. The names of 15 of these persons still appear in the current list of IRE members—the 1956–1957 Directory.

The first Year Book was published in 1914, the second in 1916, and then they were published annually from 1926 to 1932, inclusive. The Year Book was published in 1937, 1942, and 1946. With the 1948 Year Book, annual publication was resumed. In 1950 its name was changed to Directory. The Year Book has customarily included the current list of members and basic information about the organization of the Institute. In some of the earlier issues, the report of the Committee on Standardization was included.

The 1946 Year Book was the first one that included as a separate feature the biographies of all who hold the Fellow grade of membership in the IRE.

The 1956 Year Book bearing the title IRE Directory—1956–57, contains a total of 1004 pages. Almost half of it consists of a list of members of the Institute (other than Student members) along with basic information regarding the Institute's organization, Officers, and Constitution. The second half of the Year Book is a section consisting of a directory of manufacturing firms and a product index. This latest Year Book weighs 5 lbs. The entire shipment of nearly 47,000 copies (copies are not sent to Student members) from the printing office at Menasha, Wisconsin in September, 1956, weighed more than 100 tons.

Awards

The Institute of Radio Engineers has, from the beginning, gone to some lengths to show honors to those among its membership who have made accomplishments of outstanding value to the development of the radio engineering field. Evidence of this attitude was the reference to "Honorary Membership" in the Constitution as originally adopted. In place of this membership grade, other honors of a formal nature were subsequently provided for, to be awarded by action of the Board of Directors. In addition, the granting of special honors for individual accomplishments, by the action of Sections, Professional Groups, and Student Branches has been authorized by the Board from time to time.

From the beginning the IRE has had a strong core of men who have given unstintingly of their time and effort for the promotion of the Institute's service to its members. The various IRE awards are the tangible expression of appreciation by the Institute and of encouragement to continue these individual professional contributions with renewed and greater effort, in order to serve better the IRE and the profession.

The IRE now bestows seven formal awards, of which six are awarded annually in recognition of outstanding technical and administrative achievements in the field of radio communication. The recipients of these awards are named by the Board of Directors upon the recommendation of the Awards Committee. The names of all of those who have received these formal awards are given in the 1956–1957 IRE Directory.

Medal of Honor

The Medal of Honor is given annually in recognition of outstanding scientific or engineering achievements in the field of activity of the IRE. This medal was first given in 1917 and has been given annually since that year, with the exception of the years 1918, 1925, and 1947 in which no award was made.

Medal of Honor.

Founders' Award.

Founders' Award

The Founders' Award is bestowed only on special occasions for outstanding leadership in planning and administration of important technical developments. The award commemorates the three radio pioneers who founded the Institute of Radio Engineers in 1912—Alfred N. Goldsmith, John V. L. Hogan, and Robert H. Marriott. This award has so far been made to three persons—David Sarnoff in 1953, Alfred N. Goldsmith in 1954, and Raymond A. Heising in 1957.

Vladimir K. Zworykin Television Prize

The Vladimir K. Zworykin Television Prize was first awarded in 1952 and is to be awarded annually for 20 times to the member of the IRE who makes the most important technical contribution to electronic television during the preceding three calendar years or the importance of whose contribution to electronic television shall have been realized during this period. The award consists of a citation and a check for $500 drawn from a fund of $10,000 donated to the Institute by Vladimir K. Zworykin to encourage outstanding technical developments in fully electronic television.

Morris N. Liebmann Memorial Prize

The Morris N. Liebmann Memorial Prize has been given annually beginning in 1919. This award was originally based on a fund made available to the Institute for this purpose by E. J. Simon to preserve the memory of Colonel Morris N. Liebmann, a member of the Institute who gave his life in the first World War. The award now consists of a certificate and a check for $1000 given to a member of the Institute who has made an important contribution to the radio art.

Browder J. Thompson Memorial Prize

The Browder J. Thompson Memorial Prize, established in 1945, is given annually to the author or joint authors under 30 years of age for a paper of sound merit recently published in one of the technical publications of the IRE, which has been selected as constituting the best combination of technical contribution to radio and electronics and presentation of the subject.

The award comprises the income from a fund established by voluntary contributions to preserve the memory of Browder J. Thompson, a Director of the Institute who was killed in action in World War II while on a special mission for the Secretary of War.

Harry Diamond Memorial Award

The Harry Diamond Memorial Award, established in 1949, is given annually to a person or persons in Government service for outstanding contributions in the field of radio or electronics, as evidenced by publication in professional society journals such as the PROCEEDINGS OF THE IRE or journals of similar standing. The award consists of a certificate provided for from proceeds of a fund established by friends who felt that the professional life of Harry Diamond, a Fellow of the Institute, exemplified the highest type of scientific effort in United States Government service.

W. R. G. Baker Award

The W. R. G. Baker Award, instituted in 1957, is to be given annually to the author of the best paper published in the TRANSACTIONS of the IRE Professional Groups. The award consists of a certificate together with a cash award comprising the income from a fund donated to the IRE by Dr. W. R. G. Baker, Chairman of the IRE Professional Groups Committee.

Other Awards

The Editor of the PROCEEDINGS, Alfred N. Goldsmith, was awarded in 1926 an embossed and framed "Memorial to the Secretary of the Institute" in recognition of his service to science and engineering in the upbuilding of the Institute of Radio Engineers. In expressing their appreciation to this Founder, who had been serving as Editor since the beginning of the IRE, the Board of Directors stated: "He has given unstintingly of his time, his substance, his ability and gracious good will to the Institute, has personally built into its structure much of the strength it now has, and has continuously borne the burden of its problems." He was also the recipient of the Medal of Honor in 1941 and the Founders' Award in 1954.

The other living Founder of the Institute, John V. L. Hogan, who had served as President of the IRE in 1920, was awarded the IRE Medal of Honor in 1956 "for his contributions to the electronic field as a founder and builder of the Institute of Radio Engineers, for the long sequence of his inventions, and for his continuing activity in the development of devices and systems useful in the communication art."

In 1950 the Board of Directors established a plan whereby students in the different Student Branches might be given awards by the local Sections. Seventy-eight Student Branch awards were announced for 1956.

A few of the local Sections of the IRE have taken steps to recognize and honor outstanding members of their Sections. One purpose of such an award is to give early recognition to accomplishments that have not previously received national attention. One such instance was the "Electronic Achievement Award of Pacific Region IRE" established in 1951 by the Pacific Region Committee. The recipient is to have made important contributions to the electronic arts and industry in one or more of the general categories of education, research and invention, system engineering, or contributions to the literature or to IRE activities.

Several of the Professional Groups have established the custom of making awards for outstanding papers or engineering accomplishments in their fields.

MEETINGS AND CONVENTIONS

National IRE Meetings

One of the principal purposes of the founders of the IRE and of the charter members was to hold meetings at which radio engineers could exchange information on questions of general interest. The first YEAR BOOK of the IRE, published in 1914, stated that "Institute meetings are held in New York monthly excepting in July and August of each year for the presentation and discussion of engineering papers. These papers are presented by members who have specialized in some division of the subject and who desire to lay their results before the profession." This same YEAR BOOK stated that the Annual Meeting, held during the first week in January, had up until then been held in New York City. It was stated that the Board of Directors intended to have it held in different sections of the country from year to year, according to the distribution of the membership, with special regard to conventions or congresses of the radio or allied professions which may from time to time convene.

It was not until 1925, however, that the Board made specific plans for an Annual Meeting outside of New York City. The January, 1926 Annual Meeting was held in Washington, D. C. with the active cooperation of members of the Washington Section of the IRE.

By 1928 the monthly meetings in New York were drawing an attendance sufficiently large to call for consideration of a regular meeting place of larger proportions than the college classrooms, members' private offices, committee rooms, etc., in which meetings had been held. Accordingly, it was decided to rent Room No. 1 on the fifth floor of the Engineering Societies Building, 29 West 39th Street, New York, for monthly meetings of the IRE, even though this meant an expenditure of $75 for each such meeting.

The interest of IRE members in holding meetings for technical discussions has never abated. It has, in fact, increased in an astounding manner. If one takes into account the annual meetings, the joint symposia, the meetings of Sections and Subsections, Professional Groups and their Chapters, IRE Student Branches, and not forgetting the many meetings of technical committees and subcommittees and of groups of IRE members who are planning and arranging for all of these meetings, it may be nearly literally the case that there is not a day on which there is not an IRE meeting somewhere.

What was apparently the first joint Convention of the IRE and the AIEE was the one held on the grounds of the Panama-Pacific Exposition at San Francisco in 1915. In recognition of this event, the IRE was awarded a bronze medal by the Exposition management. On this occasion two technical radio papers were presented. One of these entitled, "Radio Development in the United States," was given by R. H. Marriott, the first President of the IRE.

The annual IRE meetings in New York through the year 1925 were considered to be the meetings required by the provisions of the IRE Constitution. After that date the procedures for the election of officers were conducted by mailing ballots to the members as specified or permitted by successive amendments of the Constitution without the necessity of holding meetings for election purposes. Beginning in 1926, therefore, the annual meetings were much more in the nature of National Conventions and had emphasis on technical papers rather than on the conduct of the business affairs of the Institute.

The first Convention in 1926 had a banquet as one of its features, and appropriately enough, dinner music was received by radio. In 1928 in response to the appeal of the Convention Committee to the Board of Directors for funds to enable the Institute to have a more extended technical meeting of three days as well as the banquet on this occasion, the Board decided to appropriate "an undesirable maximum" of $900 for Convention expenses. In contrast, the expenses of the Convention held in New York in March, 1956, amounted to over $300,000.

In further appreciation of the desire of IRE members to hold more technical meetings and in recognition of the geographical distribution of members in areas somewhat distant from New York, the Institute has held or cooperated with other societies in holding many regional technical meetings, some of which have been carried out as symposia in specific technical fields.

Perhaps the first of these regional meetings was the one approved by the Board of Directors early in 1929. This was planned initially as a district convention of the Rochester, Buffalo-Niagara, Toronto, and Cleveland Sections. It was held in Rochester on November 18 and 19, 1929, and was later referred to as the Eastern Great Lakes District Convention. This Convention was a great success and was followed by a series of annual meetings, extending through 1948, known as the Rochester Fall Meeting of the IRE.

The first three Annual Conventions, however, were held in New York City (1926, 1927, 1928). The next eight Annual Conventions (1929–1936 inclusive) were held in other cities. Beginning in 1937 the Conventions were again held in New York, this having been necessitated by the large attendance and the availability of facilities for accommodating the many technical sessions. The only subsequent exception to this practice was the Convention held in Boston in 1940.

The interests of IRE members in the Pacific region who have found it inconvenient to attend the national meetings held annually in New York have been met by a series of Pacific Coast Conventions which have been held since 1937 at substantially annual intervals at principal cities on the West Coast.

Another regional conference is the New England Radio Engineering Meeting which has been held at Cambridge, Mass. each year beginning in 1947. The technical meetings have been supplemented by exhibits.

A series of regional Conferences in recognition of the interest of a substantial number of IRE members located at some distance from New York was the succession of Southwestern IRE Conferences held for several years beginning in 1948 at various cities in Texas.

History of IRE National Conventions

Date	City	Papers	Exhibits	Attendance
Jan. 18–19, 1926	N. Y. C.	6	0	**
Jan. 10–12, 1927	N. Y. C.	5	0	425*
Jan. 9–11, 1928	N. Y. C.	9	0	800
May 13–15, 1929	Washington	37	0	555
Aug. 18–21, 1930	Toronto	23	20*	575
June 4–6, 1931	Chicago	19	50	400
Apr. 7–9, 1932	Pittsburgh	23	25*	460
June 26–28, 1933	Chicago	24	35	487
May 28–30, 1934	Philadelphia	32	56	940
July 1–3, 1935	Detroit	21	34	586
May 11–13, 1936	Cleveland	19	40	360
May 10–12, 1937	N. Y. C.	30	37	1,189
May 15–17, 1938	N. Y. C.	49	29	1,866
Sept. 20–23, 1939	N. Y. C.	26	34	1,668
June 27–29, 1940	Boston	44	35*	1,071
Jan. 9–11, 1941	N. Y. C.	28	30*	1,310
Jan. 12–14, 1942	N. Y. C.	25	30*	1,790
Jan. 28, 1943	N. Y. C.	11	0	1,750
Jan. 28–29, 1944	N. Y. C.	22	0	1,704
Jan. 24–27, 1945	N. Y. C.	43	39	3,000
Jan. 23–26, 1946	N. Y. C.	88	135	7,200
Mar. 3–6, 1947	N. Y. C.	118	177	12,013
Mar. 22–25, 1948	N. Y. C.	130	180	14,459
Mar. 7–10, 1949	N. Y. C.	144	225	15,710
Mar. 6–9, 1950	N. Y. C.	163	253	17,689
Mar. 19–22, 1951	N. Y. C.	198	277	22,919
Mar. 3–6, 1952	N. Y. C.	211	365	28,673
Mar. 23–26, 1953	N. Y. C.	214	412	35,642
Mar. 22–25, 1954	N. Y. C.	242	605	39,302
Mar. 21–24, 1955	N. Y. C.	248	704	42,133
Mar. 19–22, 1956	N. Y. C.	277	716	41,017
Mar. 18–21, 1957	N. Y. C.	284	756	54,074

* Estimated.
** Information not available.

The Canadian IRE Convention held in October, 1956, gave special recognition to the 30th Anniversary of the IRE in Canada. The program at this Convention included more than 125 technical papers and more than 120 exhibits. Other features were a banquet and a program for ladies. Special arrangements were made to encourage attendance by university students.

An important feature of the recent National Conventions, and of some of the Regional Conventions, is the manufacturers' exhibit of equipment that is of interest to radio engineers. It is believed that through these exhibits of the products of radio engineering and electronic development, mutual benefits accrue to both engineer and manufacturer through first-hand acquaintance with the activities of one another. An accompanying table shows the date and meeting place of each of the IRE Annual Conventions as well as some additional information as to their size and, during the last ten years, of the extent of the Radio Engineering Show, held as a feature of the Convention.

Attendance at the 1956 National Convention in New York included persons from 36 countries outside of the United States.

Engineering Conferences and Symposia

For many years the IRE has cooperated with other scientific and engineering organizations, as a joint sponsor or in a similar capacity, in the conduct of engineering meetings or of extensive technical symposia.

In November, 1919, several technical papers were presented by IRE members at a joint meeting with the American Physical Society in Chicago.

Beginning in 1933 the American Section of the International Scientific Radio Union (URSI) enlisted the cooperation of The Institute of Radio Engineers in the conduct of a series of joint meetings usually held annually at Washington, D. C. The papers presented at these meetings have dealt largely with radio transmission questions, including studies of the propagation of radio waves and the characteristics of the electronic circuit elements employed in the transmission and reception of radio signals.

During the period 1937–1947 several Broadcast Engineering Conferences were held at which papers were presented and discussions took place with regard to technical aspects of radio broadcasting. This series of meetings was in some respects the forerunner of meetings of the Professional Group on Broadcasting and the organization of that Group made the continuation of separate Broadcast Engineering Conferences unnecessary.

During the Annual Convention in 1939, the presentation speech, awarding the IRE Medal of Honor to a British member of the Institute, was transmitted over the transatlantic radiotelephone service and the reply was heard by the group assembled at the Awards Luncheon in New York.

A special feature of the Annual IRE Convention held in January, 1946, was the conduct of a session which was in effect a joint meeting of the IRE and of the British Institution of Electrical Engineers. On this occasion, meetings that were held simultaneously in New York and London were joined by a radiotelephone circuit across the ocean, so that the participants at both locations could hear the addresses given by all of the speakers at both sessions.

The participation of the IRE in the newly developing field of nuclear physics is illustrated by a series of four Nuclear Conferences held during the years 1949–1952 inclusive. Papers presented at these conferences cover a field ranging from fundamental nuclear physics to nuclear-medical instrumentation.

A National Electronics Conference, in Chicago, in 1944 was attended by more than 2200 persons—more than had attended any IRE National Convention up to that time. This was the forerunner of an annual series of such Conferences sponsored jointly with other Societies and Universities.

The largest meeting under IRE joint auspices is the annual Western Electronics Show and Convention (WESCON), now held on alternate years in Los Angeles and in San Francisco. It is sponsored by the West Coast Electronic Manufacturers' Association and the Los Angeles and San Francisco IRE Sections. At the 1956 meeting in Los Angeles over 200 technical papers were presented in 48 technical sessions. There were 706 exhibits and five field trips. About thirty thousand engineers, scientists and business representatives of the electronics industry attended the convention.

The engineering conference or symposium has come to be one of the major activities of the IRE during the past few years and the "Calendar of Coming Events" has come to be a regular feature of the PROCEEDINGS. This Calendar referred to a total of 46 such meetings during the year 1956.

Radio Pioneers' Dinners

New York members of the IRE, numbering about 125, held an Old Timers' Meeting on May 6, 1942, to "call the roll of the past, and to view ancient scenes and personages of radio by means of lantern slides"—the television of 1912.

Another dinner meeting sponsored by the New York Section of the IRE—a much more elaborate event—was held on November 8, 1945, and was known as the Fourth Radio Pioneers' Dinner. This occasion was notable because of the large attendance—over 800 persons—and because of the enthusiastic and effective work of a number of pioneer radio engineers in the preparation of a souvenir booklet of 64 pages, edited by Harold P. Westman, a former Secretary of the IRE, presenting the history of "wireless" from its early beginnings through 1925, together with pictures of equipment and personalities associated with "the good old days." Attending this dinner as guests of the IRE were the presidents of the American Radio Relay League, Radio Club of America, and Veteran Wireless Operators Association.

COMMITTEES

One of the most effective means for collaboration among members of the IRE has been through the activities of the various IRE committees. In the YEAR BOOK for 1914, it was stated that a considerable portion of the important work of the Institute was accomplished by committees. The three Standing Committees of the IRE and their functions, as stated at that time, were:

Papers Committee—to secure papers of merit and interest

Standardization Committee—to prepare standard terms, symbols, units and methods of testing and rating radio apparatus

Publicity Committee—to keep the public and the technical press informed as to the work done by the Institute and its recommendations, thus ensuring that the public and the art shall benefit by the labors of the Institute

By 1915 another Standing Committee was added—the Finance Committee—and there were three special committees, one to consider possible representation of the IRE at the Panama-Pacific Exposition in San Francisco, one to consider the formation of a Seattle Section of the IRE, and a third to consider what amendments to the IRE Constitution should be recommended to the membership in order to make the Institute's work more effective.

The broadening scope of IRE interests over the years was accompanied by the establishment of additional committees dealing both with technical subjects and with operational matters. There has been repeated emphasis in the summaries of IRE activities published in the YEAR BOOK and in the PROCEEDINGS of the fact that the major activities of the Institute have been sponsored by and accomplished through the voluntary work of the many Institute committees.

The evolutionary development of IRE activities is indicated by some of the committees that have been established from time to time to deal with new problems or those which have assumed special significance.

In 1926 a Committee on Broadcast Engineering was established. In 1927 there was submitted to the IRE by the Federal Radio Commission of a series of questions on which it sought opinions. It was recognized by the Board of Directors that the field of activity of this committee could not be limited strictly to its technical aspects but that the very nature of radio broadcasting was such that the engineering conclusions would, if adopted, have an effect on some of the relationships between the public and the broadcasting industry. It was decided, therefore, that any publicity regarding the recommendations of this committee should be subject to approval by the Board of Directors.

The IRE Year Book—Directory for 1956–1957 lists as Standing Committee of the Institute 25 Technical Committees with a hundred Subcommittees, along with 13 other Committees dealing largely with management and operational aspects of the Institute. A complete list of all Committees of the Institute and of their members is published semiannually in the issues of the Proceedings for June and October.

The effectiveness of the IRE throughout these forty-five years of its existence has been due in no small measure to the enthusiastic collaboration of the many hundreds of Committee members and to their recognition that there could be no satisfactory substitute for the contributions which this activity could make to the more rapid and effective development of the field of radio engineering.

Cooperation with Governmental Bodies

Technical Aspects of Radio Regulation

The problems of radio regulation are such as to require, for their solution, a thorough consideration of the physical facts as to the behavior of radio waves, as to the external performance of radio transmitting equipment, and as to many of the operating characteristics of radio receiving apparatus.

At first, broadcasting, like Topsy, "just grew." Everyone wanted to operate on 360 meters, and it wasn't long before the interference was so great that almost all broadcast programs were meaningless, regardless of the care which had been put into their preparation. Herbert Hoover, Secretary of Commerce of the United States held a series of four National Radio Conferences in 1922, 1923, 1924, and 1925 in which representatives of the IRE took an active part. Government officials, senators, and congressmen began talking meters and kilocycles. A new radio law was passed in 1927, and the uses of radio began to be regulated by the Federal Radio Commission.

When the Federal Radio Commission was first organized it had no engineering staff, so it naturally looked to the engineers of industry for assistance on technical matters. This led to renewed activities of the IRE, those of studying and preparing reports on a series of problems put to it by the Commission and its Acting Chief Engineer.

At a special meeting of the Board of Directors the President of the IRE was authorized to appoint a Broadcasting Committee to assist the Federal Radio Commission and the general public in obtaining information on such subjects as service areas, interference areas, cross-talk interference between channels, harmonic and parasitic interference, the areas covered by network operation, frequency stability, and modulation as affecting service and interference areas.

The plan for the allocation of broadcast channels to zones and states which was put into effect by the Federal Radio Commission on November 11, 1928, was closely related in its main engineering aspects to that recommended by the IRE.

The IRE Committee on Broadcasting prepared a series of reports which, after approval by the Board, were forwarded to the Federal Radio Commission and published in the Proceedings during the years 1928–1930.

In order to make clear its position with respect to cooperation with the Government, the Board of Directors in February, 1931 adopted a resolution "that the records of the Institute be made available to all Governmental departments for their use in enforcing the laws and regulations of the United States and any other country."

The 1926 President of the IRE, Donald McNicol, in an editorial published in the Proceedings in February, 1948, sounded a renewed appeal to radio engineers to play their proper part in meeting the problems of the Government. He quoted the following from an address previously given by the President of the American Chemical Society: "Today scientists recognize that they have greater responsibilities than mere discovery and are determined to see that what they develop for the betterment of mankind shall not be used for its destruction."

Government agencies concerned with the regulation and use of radio facilities are faced with technical problems of ever increasing complexity; *e.g.*, propagation data are required over a spectrum spanning more than 25 octaves. Performance data on hundreds of different types of transmitters and receivers and antennas are required. As a supplement to the staffs of Government groups, impartial, skilled advisors are needed and are available through such groups as the Joint Technical Advisory Committee, the National Television System Committee, and the Radio Technical Planning Board which are referred to below.

An outstanding case of a call by the Government for wise technical-administrative assistance in the radio field was the designation by the President of the United States in 1951 of Haraden Pratt, the Secretary of the IRE, to serve as Telecommunications Advisor to the President.

Increasing reliance by Government agencies over the years on recommendations and reports of the Institute of Radio Engineers is exemplified by the reference to certain IRE Standards in rules promulgated by the Federal Communications Commission early in 1956. The IRE standard methods for measuring radiation and for measuring power line interference are relied upon for determining whether such incidental radiation exceeds the permissible limits specified by the Commission.

In a guest editorial in the Proceedings of the IRE for December, 1956 the Chairman of the Federal Communications Commission commended the IRE for its outstanding contributions toward advancement of the art of radio communication and for the whole-hearted cooperation it has always given all agencies of the government concerned with utilization and administration of the radio spectrum.

Joint Technical Advisory Committee (JTAC)

In response to a request from the Federal Communications Commission in 1948 for advice on a number of technical radio problems with which the Commission was concerned, a group of eight distinguished radio engineers was asked to form themselves into the Joint Technical Advisory Committee (JTAC). This joint action was taken in June, 1948, by the Boards of Directors of the IRE and the Radio and Television Manufacturers Association (RTMA). The purpose of JTAC was to consult with Government agencies and other professional and industrial groups, to determine what technical information was required to ensure the wise use and regulation of radio facilities, and to collect and disseminate such information.

JTAC has issued a series of technical reports on questions of public interest on which the FCC has sought information. JTAC has also presented technical testimony at meetings held under FCC auspices. The first request for advice from JTAC was for information on the utilization of ultra-high frequencies for television. A JTAC report entitled, "Utilization of Ultra-High Frequencies for Television" was issued September 20, 1948.

Subsequent reports issued by JTAC over the period of eight years since its formation have dealt with such subjects as fm broadcasting, interference problems in tv, standards of good engineering practice, principles for the allocation of frequencies in the land mobile and other radio communication services, interference from arc welders, etc.

Normally the reports of the Committee were issued in mimeographed form and distributed to several hundred interested individuals and agencies, including, of course, the Federal Communications Commission.

The eighth report in this series was believed to be of such general interest as to warrant the widest possible distribution and accordingly, the sponsoring organizations, IRE and RTMA, decided to underwrite its publication in book form. This report was a comprehensive analysis of the problems involved in the efficient use of the radio spectrum for the great and increasing variety of services for which radio waves are employed and was entitled, "Radio Spectrum Conservation—A Program of Conservation Based on Present Uses and Future Needs." Its purpose was to review the principles of radio transmission in language as simple as the subject allows, and to discern the course to be pursued in order to bring the benefits of radio in maximum measure to the largest number of the world's people. More than 2000 copies were mailed throughout the world as a public service to professional societies, industry groups, government officials, educational institutions, libraries, technical publications, research laboratories, etc.

Another outstanding report to the Federal Communications Commission by JTAC was on the subject of television. The IRE office staff also cooperated with RMA in the preparation of a report, which was made by that organization to the FCC in September, 1949, dealing with the technical aspects of manufacturing problems related to color television, which was included in part in the JTAC report.

Cooperation with other Technical Organizations

Early Activities

From the beginning the Board of Directors of the IRE has recognized the close relationships between the field of activity of the Institute and the activities of other scientific and engineering organizations. The IRE has, therefore, endeavored to keep closely in touch with such organizations and has appointed representatives to serve on many joint committees.

The development of radio broadcasting during the 1920's resulted in rapid expansion of the radio manufacturing field and in the organization of trade associations in that field. The IRE has contributed to the development of radio engineering and manufacturing through the expansion of its standardization activities and by the publication of technical and educational papers useful in training engineers for future employment by radio manufacturers.

The IRE Year Book for 1926 lists the following organizations on which the IRE had representation or with which it was engaged in active participation in joint projects:

- Council of the American Association for the Advancement of Science
- National Fire Protection Association
- Fourth National Radio Conference called by the Secretary of Commerce
- Radio Advisory Committee of the Bureau of Standards, Department of Commerce
- Executive Committee of the Sectional Committee on Radio of the American Engineering Standards Committee.

In 1927 the IRE and AIEE undertook joint sponsorship of the Sectional Committee on Radio under the procedure of the American Engineering Standards Committee (later called the American Standards Association). The IRE at that time was also cooperating in the formulation of standards on five other subjects. Several years later the IRE accepted sole sponsorship of the Sectional Committee on Radio.

In 1928 the American Engineering Standards Committee invited the IRE to become formally affiliated as a member body of that organization.

Radio Technical Planning Board (RTPB)

In 1943, before the termination of World War II, a joint industry technical committee was formed to coordinate the advice and suggestions of various parts of the radio engineering, manufacturing, and operating agencies on questions which were believed to be helpful to the Government, particularly the Federal Communications Commission, in revising the regulations applicable to the operation of radio stations in such a way as to meet more adequately the needs of a rapidly developing postwar radio industry. The Chairman of the Radio Technical Planning Board (RTPB) was W. R. G. Baker, a Fellow of the IRE. The IRE sustained its status as a contributing sponsor by appropriating $500 toward the support of the RTPB in 1945.

The Radio Technical Planning Board went out of existence in 1948 when it appeared that its form of organization no longer served to meet the problems which had developed in the continuing postwar period. At about that time the IRE, in conjunction with the Radio Manufacturers Association and with the encouragement of the Federal Communications Commission, created in June, 1948, the Joint Technical Advisory Committee (JTAC), referred to above.

National Television System Committee (NTSC)

A notable example of the effectiveness of the IRE in its cooperation with other technical organizations has been in connection with the work of the National Television System Committee (NTSC). The first NTSC had been formed in 1940 by several industrial organizations which had a major interest in the sound development of television field and particularly in presenting to the Federal Communications Commission, in response to its request, a coordinated recommendation as to the technical standards that should be recognized as the basis for the licensing of television broadcasting stations for both monochrome and color television service. A report on this work was made in 1941. The monochrome standards then proposed were reviewed by the RTPB referred to above and became the basis for commercial monochrome television service authorized by the Commission in the United States.

The second NTSC became active in January, 1950, and was reorganized in June, 1951, in a renewed endeavor by representatives of various industrial organizations to obtain industry agreement on recommendations to the Federal Communications Commission on frequency allocation problems involved in television and on standards for color television. As an evidence of its desire to contribute actively to the attainment of a sound technical basis for the Committee's recommendations, the IRE put the facilities of its Headquarters Office at the disposal of the Committee. During the years 1952 and 1953, meetings of the NTSC or of its various panels were held at the IRE headquarters, there being on the average more than one meeting per week. In addition, the Technical Secretary of the IRE served as Secretary for the coordinating panel of the NTSC. The final report of the NTSC was filed with the FCC in the latter part of 1953.

In recognition of its distinguished contribution to the television industry and to the development of color television, the NTSC received the "Emmy" Award of the Academy of Television Arts and Sciences in 1954.

Other Activities

By 1956, in contrast to the situation in 1926 when the IRE was listed as cooperating with five societies, the IRE was carrying out formal active cooperative endeavors with 38 organizations. This included 30 Sectional Committees, boards, or other bodies organized under the procedures of the American Standards Association. Similar activities were also carried on jointly with the following organizations:

American Association for the Advancement of Science
Atomic Energy Commission
International Radio Consultative Committee (CCIR)
International Scientific Radio Union (URSI)
Joint IRE-AIEE Committee on High Frequency Measurements
Joint IRE-RETMA-SMPTE-NARTB Committee for Intersociety Coordination—Television (JCIC)
National Electronics Conference
National Research Council—Division of Engineering and Industrial Research
U. S. National Committee of the International Electro-technical Commission (IEC)

International Cooperation

Radio engineers and scientists have unique opportunities to know and understand their fellow human beings in other countries. The very conduct of international radio transmission, both commercial and amateur, requires continual contacts. The problems of frequency allocation and the reduction of radio interference are continually compelling bases for collaboration and discussion of matters of mutual concern. International Communication Conferences—many of them under Governmental auspices—provide occasions not only for formal negotiation and agreement but furnish opportunities, sometimes even more valuable, for informal discussions, thus helping to avoid misinterpretation of the appellation "foreigner."

The founders of the IRE recognized that the nature of radio transmission is such that radio waves recognize no national boundaries. They realized, too, that the problems in the radio field and the accomplishments of radio engineers are bound to be of interest to technical radio men throughout the world. It has thus been traditional with the IRE to foster international cooperation in radio, to encourage interest in the IRE, and to promote its services and the spread of its publications as widely as possible in all countries of the world. As early as at the end of 1915 there were 83 members of the IRE living in eleven countries other than the United States; of these 20 were Canadian members.

In 1927, the International Radiotelegraph Conference, which was held in Washington, D. C., for the purpose of revising the International Radiotelegraph Convention and Regulations, brought to the United States several hundred representatives of other countries. This was the first world conference to deal with the allocation of radio frequencies to radio services which had expanded so rapidly since World War I. Accordingly, there were many radio engineers included in the delegations to this International Conference.

As a result of action taken at this International Conference there came into being the International Radio Consultative Committee (CCIR), an organization which, through the participation of representatives from all interested countries, has as its continuing task the preparation of advisory recommendations on technical questions that are involved in the allocation of frequencies to various radio services.

The first meeting of the CCIR was held at The Hague in 1929. One of the delegates to this meeting was designated by the Board of Directors to serve as the Institute's representative and to offer the facilities of the IRE and its committees to the CCIR in any manner in which it was thought that the Institute could be of assistance. Many members of the IRE and its technical committees have cooperated in the work of the CCIR and its Study Groups throughout the period of its existence.

As a contribution to the proceedings of the World Engineering Congress in Tokyo in October, 1929, the IRE Board of Directors asked a group of IRE members to prepare a symposium paper on "The Trend of Radio Broadcasting and Its Relation to National Solidarity."

In 1931 the United States National Committee, operating under the International Electrotechnical Commission, asked the IRE to cooperate with it in meeting some of the problems of international standardization of terminology. The IRE was very ready to lend its cooperation in this direction by contributing results of its own work on the standardization of terms and definitions.

Cooperation between the IRE and the International Union of Scientific Radio (URSI) has been active since 1926. By IRE representation on the USA National Committee of URSI there is a formal link. On repeated occasions, at International Assemblies and at meetings of the USA National Committee, members of the Institute have presented papers on radio transmission and other technical subjects. The IRE or one of its Professional Groups has also been joint sponsor of most of the meetings of the USA National Committee. Several members of the IRE participated in the Eleventh General Assembly of the URSI held at The Hague in 1954.

In 1946 the Board created an International Liaison Committee which continued until 1956. Its activities during the early part of this period formed the basis for the working arrangements for cooperation between the IRE and the Institution of Electrical Engineers in London.

Notices have been published in the PROCEEDINGS from time to time of radio developments of special interest in various countries. Notice was published in April, 1947, for example, of the Popov Gold Medal awarded annually by the Presidium of the Academy of Sciences of the U.S.S.R. to a scientist of any nationality for outstanding scientific research or invention in the field of radio on the basis of submission of manuscripts and other information.

By 1950 the variety of international contacts in the broadening field of interest of the Institute had become such that the Board of Directors appointed a member of the Institute to serve as chairman of an IRE Coordination Committee with international technical organizations. This involved cooperation with the CCIR, URSI, IEC, and other international bodies, as well as coordination with the interests of the United States Department of State in such matters. The chairman of this Coordinating Committee was to report directly to the Executive Committee of the IRE Board.

By the very nature of its worldwide effects, radio lends itself ideally to international collaboration and radio engineers feel that they are privileged to work in a field which promotes international understanding. It is the fact that radio services simply could not operate without world collaboration in the control of interference. The very fact that radio communications systems do operate smoothly on a worldwide basis proves that men of all nations can work out together the most complicated and difficult problems. This activity is in itself a real contribution to the development of good will and international friendliness.

CONSTITUTION

The Constitution adopted by the original members of the Institute at a meeting on May 13, 1912 was a fairly simple document. It stated the objectives of the Institute and recognized three grades of membership—Honorary Members, Members, and Associates. The dues for Members and Associates were set at $5 and $3, respectively. There was no entrance fee and Honorary Members were to pay no dues. The business affairs of the Institute were to be handled by a Board of Direction of nine persons, consisting of four Managers, President, Vice-President, Secretary, and Treasurer all of whom were to be elected by the Institute membership, and an Editor of Publications who was to be elected by the other members of the Board.

A few clarifying amendments of the Constitution became effective November 2, 1914, and December 5, 1915. Two new grades of membership were established—Fellow and Junior—and 5 additional members were added to the Board of Direction. Entrance fees ranging from $1 to $10, depending on the grade of membership, were established and dues for the several grades of membership were increased slightly. Honorary members and Junior members did not have voting privileges. The Board, comprising a total of fourteen persons, was to include six elected Managers and three Managers appointed by the elected members of the Board.

In January, 1921, the membership by letter vote approved a change in the Constitution to provide that the list of nominees should comprise at least one name and not more than three names, proposed by the Board or by petition, for each of the following offices: President, Vice-President, Secretary, Treasurer, and two Managers. The elected Managers held office for three years, and three Managers were elected by the Board, thus forming a total Board membership of fourteen.

The Constitution stood without further change until October 7, 1931. At this time the grade of Honorary Member was deleted. The name of the Board of Direction was changed to Board of Directors and all reference to Managers was deleted. The Board was again enlarged, this time to a total of 20 persons, consisting of the President, Vice-President, Secretary, Treasurer, nine elected Directors, five Directors appointed by the elected members of the Board, and the two most recent past Presidents. This revision of the Constitution brought in the first reference to Bylaws and gave the Board authority to adopt or amend Bylaws as might be appropriate within the terms of the Constitution itself. Specific recognition of local Sections of the Institute was included.

This revision also provided for nomination by the Board of Directors of only a single name for President so as to make the presidency more of an honor and less of a contest than had been previously the case.

A general revision of the Constitution was effective on March 1, 1939. The Chairman of the Board of Editors was added to the Board as an appointed member, making a total of 21 persons. At this time it was provided that Associates who joined after this date would have no voting privileges and that election to the Fellow grade would thereafter be by invitation by the Board of Directors. It was also provided that the ballots submitted to the membership should contain at least one candidate for each office.

In 1941 a proposed amendment to establish Regional Directors failed of adoption. Several amendments adopted in 1943, 1944, 1945, and 1946, made certain changes in the membership structure, in the entrance fees, transfer fees, and dues, and dealt with certain other details of committee appointments and other management matters.

The Executive Committee was established in 1941 to take over the administrative matters that had been handled by the Board of Directors since its early days so as to enable the Board to function more as a policy-making organization. The functioning of the Executive Committee has been discussed earlier in this paper.

Effective July 30, 1946, an amendment was adopted putting into effect a Regional Representation plan under which the Board having a total membership of 24, included six Directors elected-at-large (two elected each year for a three-year term), three appointed Directors, one Regional Director elected (for a two-year term in alternate years) by the members in each of eight Regions, and the two most recent past Presidents.

By 1946 the offices of Executive Secretary, Technical Secretary, and Technical Editor as full-time headquarters staff positions had been created by the Board and it was clear that some of the details of Institute procedures which had previously been dealt with in the Constitution should more properly be handled by the Board of Directors itself or by members of the staff to whom the Board would give authorization. Constitutional amendments in 1946 and 1947, recognized these principles and thus added other powers to the Board and to the administrative officers of the Institute, effective August 15, 1947. Regional Directors continued to be selected specifically to represent the Regions from which they come and whose memberships elect them. All details of membership requirements, dues, and fees were transferred from the Constitution to the Bylaws.

Office Locations

The first meeting of members of the Institute of Radio Engineers was held in Fayerweather Hall at Columbia University, New York. For several years most of the meetings for the presentation of papers were held at that location. As has been already noted, some of the early meetings of the IRE or of the Board of Directors were also held at Sweet's Restaurant in the Fish Market area on Fulton Street in downtown New York. Sometimes meetings were held at Whyte's Restaurant, also on Fulton Street.

The initial arrangements for handling the Institute's office work were entirely dependent upon the personal cooperation of the various officers. The information pamphlet issued by the Institute under date of January 1, 1913, stated that correspondence relating to Institute matters in general should be sent to the Secretary and gave the address of his residence in Brooklyn, New York. It asked that all papers submitted to the Institute and all correspondence relating to such papers be addressed to the Editor of Publications at his office at the College of the City of New York.

The IRE had no headquarters staff office for a number of years. Some business was conducted at an office used by the 1913–1914 Treasurer, John Hays Hammond, Jr., located at 71 Broadway, New York. A year or two later the IRE moved "uptown" to 111 Broadway in the shadow of Trinity Church. Subsequently, for about six years beginning in 1918, the business affairs of the IRE were conducted from the office of Alfred N. Goldsmith, who served both as Secretary and Editor, located at the College of the City of New York.

In the spring of 1924 the Board of Directors felt that the IRE could afford to rent an office and employ a full-time clerk. A small suite of rooms was leased at 37 West 39th Street, closely adjacent to the Engineering Societies Building in which the monthly meetings for the presentation of technical papers were then being held.

Late in 1928, in order to obtain larger quarters, space was rented in the Engineering Societies Building at 33 West 39th Street. Committee rooms as well as larger rooms for the New York monthly meetings were available in this building.

The staff again was enlarged and included a full-time Secretary, Assistant Secretary, Assistant Editor, Circulation Manager, Advertising Manager, and Head Bookkeeper. The space in the Engineering Societies Building was adequate for a few years but in the spring of 1934 it was necessary to move again, this time to the McGraw-Hill Building at 330 West 42nd Street. In the winter of 1942, that suite proved to be too small and the Institute was moved, in the same building, to larger but soon inadequate quarters.

In order to relieve congestion at the IRE Headquarters in the McGraw-Hill Building and to permit expansion of the editorial staff of the PROCEEDINGS, the Editorial Department in April, 1945, was moved to the fourth floor of a loft building at 26 West 58th Street, New York. In July, 1946, the Editorial Department needed additional space and took occupancy of one half of the second floor in the same building.

The continued need for more space, which could be satisfied only by making frequent moves and by locating different parts of the Headquarters organization in separate buildings, was obviously not to be taken as a satisfactory answer to the Headquarters housing problem. Accordingly, in 1944 the Board of Directors appointed an Office Quarters Committee under the Chairmanship of Raymond A. Heising, the 1939 President of the Institute. As a result of a thorough study by this Committee and following a careful consideration of its report by the Board, it was decided to inaugurate a Building Fund Campaign with a goal of $500,000 for the purpose of providing the Institute with a permanent home which would permit the expansion of its facilities and service to its members and which would enable the IRE to create a closer union between engineers and their industries.

The $500,000 goal was arrived at on the basis that somewhat more than one half would be available for purchasing, altering, finishing, and equipping the land and building, and the remainder would be invested to give a return which would be applied to maintenance and carrying charges. The IRE had been paying $4000 annually for rental and it was estimated that the higher annual maintenance costs for a building could be met through the receipt of interest on the money invested without requiring any increase in the membership fees.

The Institute's Building Fund Campaign was publicly inaugurated under the chairmanship of B. E. Shackelford during the midwinter Technical Meeting in New York in January, 1945. The IRE asked for support from its members and from its friends in industry.

The members of the IRE and executives high in industry rallied with enthusiasm and vigor. Contributions to the fund were made by those in every grade of membership not excluding the Student grade. The bonds of common interest between the IRE Sections and the Headquarters organization were made evident through contributions received through Sections and from individual members amounting to well over $100,000.

By the end of 1945 the total subscriptions to the Building Fund were very close to $625,000 and this amount was exceeded within the first month or two of the following year. The overwhelming success of this campaign was recognized as an indication of the strength of the IRE membership and of the recognition by industry of its indebtedness to the engineering profession. The Board of Directors were in a position to move on to new tasks and plans for service to the membership with confidence and assurance.

With the money in hand the Board of Directors was in a position to proceed with the acquisition, for $200,000, of a building which had been sought out by the Office Headquarters Committee. The building so acquired was the former Brokaw Mansion located at 1 East 79th Street (corner of Fifth Avenue) in New York City. The Board felt that this building might serve the IRE for a period of 25–40 years, recognizing that their successors, alert to changing conditions, would in their time probably initiate more ambitious plans.

The building has four stories, attic, basement, and cellar. It is of chateau design and its facade is patterned on that of the Chateau de Chenonceaux in the Loire Valley in France. The building has rooms which are suitable for committee meetings, Board meetings, and activities of the Headquarters staff. No attempt was made to find a building that could serve as a meeting place for a large number of members. The cost of such a building would not be justified for meeting rooms which would be used by the IRE only once or twice a month. It was felt that meetings of the New York Section could continue to be held either in the Engineering Societies Building on 39th Street or in other auditoriums in the city. It was felt that the new Headquarters Building, with its exceptionally attractive appearance and efficient facilities for carrying out the work of the Institute's staff, would have a homelike and welcoming atmosphere and thus serve to encourage IRE members to plan and hold frequent conferences with the IRE staff and with their fellow members engaged in committee activities.

In November, 1946, the IRE staff moved into the new Headquarters Building. All departments except that concerned with advertising then came under one roof with over-all administration being directed by the Executive Secretary.

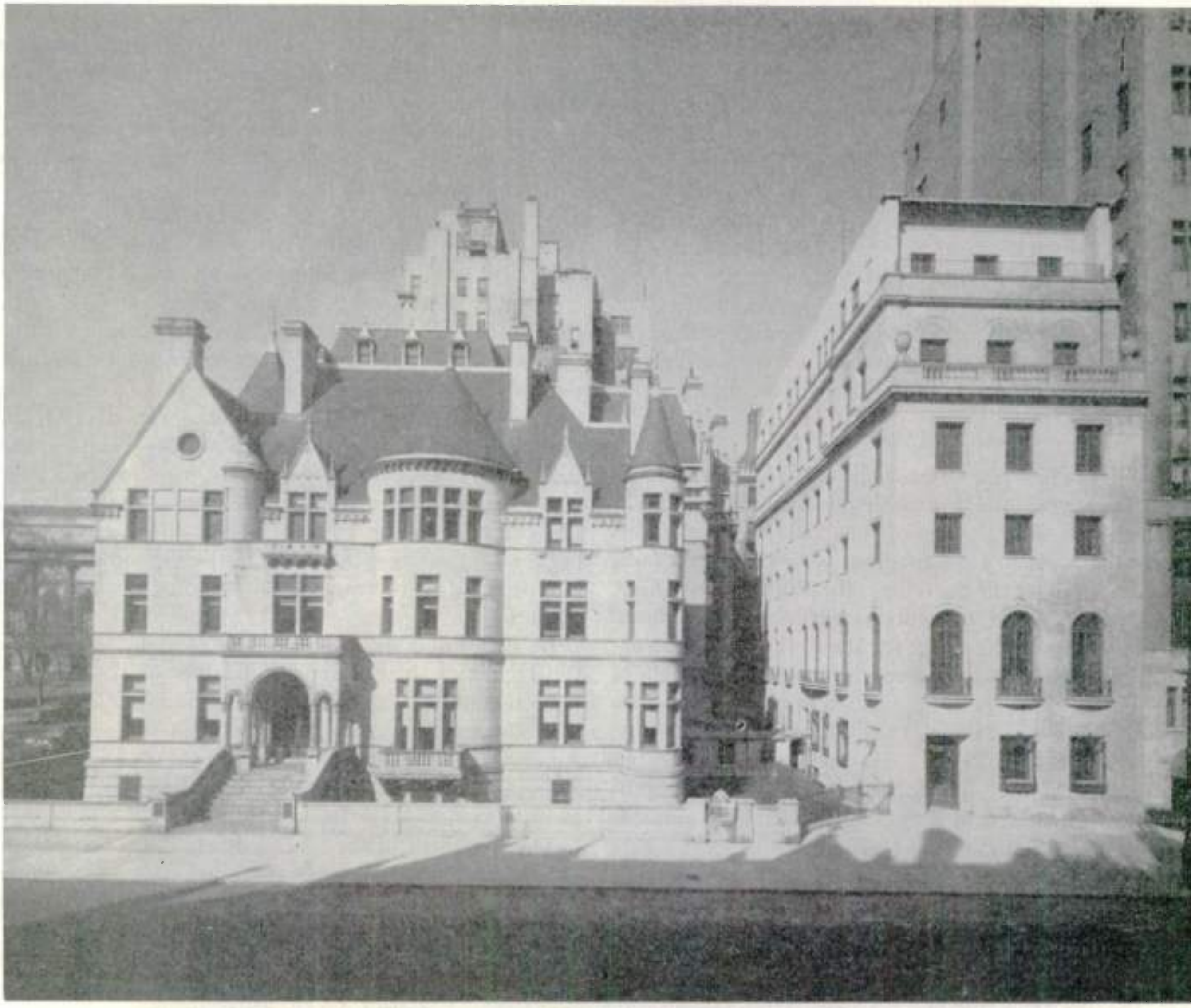
The tremendous growth in membership and related activities following World War II again made it clear

39 Newbury St., Boston, where the Society of Wireless Telegraph Engineers was formed in 1907.

42 Broadway, New York City, where Robert H. Marriott called a meeting on January 23, 1909, to form the Wireless Institute.

Sweet's Restaurant on Fulton St., New York City, where, in 1911–1912, informal meetings were held leading to the formation of the IRE. The Articles of Incorporation were outlined here in 1913.

The office of John Hays Hammond, Jr., at 71 Broadway, New York City, gave the IRE its first "office" in 1914.



The IRE now owns and fully occupies these two mansions at 1 and 5 East 79th St.

A view of the 1928 IRE office in the Engineering Societies Building and the lobby of the present headquarters at 1 East 79th St.

that additional office space and meeting space were required. During 1953 the number of committee meetings of the IRE reached the unprecedented number of 369. Fortunately, there was available a six story building at 5 East 79th Street, New York, immediately adjoining the Headquarters Building. This annex building was purchased early in 1954 and has become the office quarters of the Editorial Department, Bookkeeping Department, and the Technical Secretary and their staffs. It thus serves as a base for the production of the publications of the IRE and for the cooperation of the IRE staff with Sections, Professional Groups, Student Branches, and other technical bodies with which so many joint meetings and symposia are arranged.

Office Management

During the first few years of the existence of the IRE, the Secretary or the Editor made available for IRE work the part-time services of one of the members of his regular office staff. This, together with the use of individual services by the Secretary, the Editor, and others, kept the drain on the Institute's treasury at a minimum. The report of the Treasurer for the year 1915 shows expenditures for stenographic services and clerical help of $984. During that year, also, $200 was spent for office rent for a period of 8 months and $67.50 for typewriters.

By 1924 the volume of correspondence necessitated by the large increase in the membership and the additional work involved in preparing material for publication in the Proceedings had reached a point where the Board of Directors was beginning to realize that more adequate provisions needed to be made for office space, clerical assistance, and supervisory attention. In 1926 at a meeting of the Board authorization was given for the purchase of a "stencil making machine" for use in addressing publications. The purchase of two typewriters was also approved in order to replace machines which had been rented. Additional office equipment such as desks, chairs and filing cabinets were also purchased properly to furnish "the new and enlarged headquarters offices." During this period individual attention was given by various members of the Board to many details of the Institute's office management with a view to affecting savings wherever possible.

The President of the Institute, Donald McNicol, in 1926 undertook the preparation of a "Blue Book" as a guide to Board members and to Committee Chairmen in carrying on the routine duties of the Institute. The Board appreciated, however, that a more comprehensive look should be taken at the problems of organization of the Institute's management and upon recommendation of a special committee of the Board authorized the employment of John M. Clayton as a full-time Assistant Secretary of the Institute and its first headquarters manager, beginning January 1, 1927. The Board was fortunate in finding a person for this position who had experience in the radio field through his employment by the American Radio Relay League. A small clerical staff was provided to handle the increasing volume of correspondence.

Among the improvements in office management which were effected in 1927 was the adoption of a new system of bookkeeping that involved the expenditure of $400. Since 1918, the Treasurer's books, which had previously been kept at the Treasurer's own office, have been kept at the headquarters office of the Institute.

In 1928 the move of the Headquarters office to the Engineering Societies Building made available a 50 per cent increase in space. This was needed to provide facilities for the 9 new members added to the office force during a period of 2 years. By the end of 1929 the Headquarters staff numbered 15 persons. The increase from 5 to 15 staff members during a period of 3 years was necessitated by an increase during that period of 100 per cent in the membership of the Institute, 200 per cent in the pages published in the Proceedings, and 200 per cent in the number of standing committees in operation.

In 1927 John M. Clayton was elected Secretary of the IRE and thus became a member of the Board of Directors until 1930. His successor, Harold P. Westman, who also came to the Institute from the staff of the American Radio Relay League, held the position of Secretary and was a member of the Board of Directors from 1930 to 1942, inclusive.

The President of the IRE in 1941, F. E. Terman, devoted a great deal of personal attention to the operation of the Institute's office, even flying repeatedly across the country to attend the Board meetings. He spent many weeks examining the records of the IRE, observing the functioning of its processes, and considering the effectiveness of its facilities. Late in that year, on the recommendation of an outside management consultant, the Board of Directors employed an Office Manager to give more direct supervision to the Institute's clerical staff.

Late in the year 1944 in order to broaden the activities of the IRE, including the expansion of the publication program, the Board of Directors decided to establish three new staff positions—Executive Secretary, Technical Editor, and Technical Secretary. This was a major step in recognizing the fact that the supervision and operation of the administration of the activities of the IRE could no longer be a part-time job for individual members of the Board of Directors. The Executive Secretary, whose services the Institute was fortunate enough to obtain, was George W. Bailey, who had had some years of administrative experience as an officer of the American Radio Relay League and whose ability in administrative service with the Government during World War II had been well demonstrated.

The administrative activities of the IRE, by the end of 1956, required the services of about 130 people whose work was being directed by the Executive Secretary, Managing Editor, Technical Secretary, Chief Accountant, Assistant to the Executive Secretary, and the Office Manager. The Advertising Department, with its Advertising Manager and Assistant Advertising Manager is situated in another location in New York City.

Advertising

The first volume of the Proceedings, published in 1913, did not contain any advertisements since in those days there was not much in the radio field to be advertised and there were not many people interested in buying radio apparatus. The principal interest in radio apparatus was in the radio amateur field and this field was being covered by one or two other publications of a somewhat less formal nature.

The first advertising appeared in the Proceedings in 1915. At that time the solicitation of advertising was in the hands of L. G. Pacent, a member of the IRE, who was mentioned in the 1916 Year Book as Advertising Manager. The 1916 Year Book noted that "the revenue derived from this source has been most helpful to the Institute." During the year 1917 there were 48 pages of advertising published in the Proceedings—an average of eight pages (size 6×9 inches) per month. Among the consistent advertisers were several who have continued to be well-known in the radio manufacturing field to the present day.

One of the Institute's regular office staff under the direction of the Assistant Secretary undertook to handle all advertising solicitation for the Institute beginning in 1928. The Board was apparently somewhat reluctant to include advertising in the 1928 Year Book but concluded that this should be done in an effort to obtain sufficient revenue from this source to cover the actual cost of printing. This Year Book contained 28 pages of advertising.

The arrangement whereby the Institute's office handled the advertising activities continued until 1941 when the Board of Directors felt that substantially increased revenue might be obtained if an experienced advertising manager were to handle this part of the Institute's business. Accordingly, a contract was entered into with an advertising manager who provided his own office assistance at an outside location for this task.

In order that the advertising rates of the IRE might be on a firm basis, the Proceedings of the Institute of Radio Engineers became a member of the Audit Bureau of Circulations in 1942.

The Institute's policy with respect to the textual content of advertising carried in its publications was once stated as follows: "Advertisements should present useful facts; engineers will thrive on them."

Today there are some 700 advertisers, representing over 80 per cent of the manufacturing volume of the radio-electronic industry, who use the Institute's publications to bring information about their products and services before the members of the IRE. This serves to stimulate a wide interest in the IRE on the part of industry management. It also makes it possible for the IRE to publish a far greater volume of editorial matter of scientific and technical value to its readers than would be possible without this recognition of the financial value of such readership on the part of the industry.

Finances

Throughout the life of the IRE the Board of Directors has planned and provided services to the membership with meticulous attention to the extent of the available funds. Accordingly, the publication program of the Institute at the outset was very modest—a small magazine published four times a year. The Year Book was small and was not published every year. Expenditures for meeting rooms and for Headquarters staff purposes were kept at a minimum.

The total receipts of the IRE for the year 1913 (including $150.97 carried over from the previous year) amounted to $850.93. This included $50.00 from the former Society of Wireless Telegraph Engineers and also $150.00 which was provided by or through the good offices of the Editor. The amount received in dues was $476.75. After payment of $647.25 for printing the Proceedings, $16.00 for janitor service in connection with meetings held at Fayerweather Hall at Columbia University, and other miscellaneous expenses, the balance at the end of the year 1913 was $24.43.

The report of the Treasurer contained in the 1916 Year Book referred to the fact that the Institute had "good friends and loyal members . . . who have donated money and fixtures more than enough to start the new year with a clean slate." These donations which included cash, a cancelled note, and furniture given to the IRE by the Editor out of his personal generosity, amounted in the year 1915 to over $1300.00 and this was specifically recognized in the Institute's Annual Report for that year which expressed deep gratitude to Professor Alfred N. Goldsmith "who has been so generous in providing the Institute home with complete furnishings which have added materially to the comfort and appearance of the Institute office."

By the year 1926, to meet the needs resulting from the growth in membership and the corresponding expansion of activities, the Institute's auditors recommended that a new system of bookkeeping be installed.

As the Institute's cash balance gradually increased, the Board of Directors gave repeated attention to the safe investment of its funds so as to insure to the utmost possible extent the continuing ability of the IRE to serve its members and especially to preserve the integrity of the specific funds which had been made available to the Institute for the granting of prizes and awards.

The importance of maintaining a financial reserve was emphasized by the experience of the IRE during the depression in the 1930's. The predepression peak of the Institute's balance in 1930 was $59,166. Even with a curtailment of the Institute's expenses there was so sharp a drop in membership dues collected during the next few years that the year-end unexpended balance dropped to a low of $31,141, in 1934. The process of recovery, however, was soon under way and by the end of 1940 the balance reached $60,905, which was the highest year-end balance in the history of the IRE up to that time. This amount was approximately the same as the operating expenses of the IRE during the year 1940.

The drain on the reserves of the IRE during the depression years in which there were annual deficits would have been serious if there had not been previously an accumulation of adequate surplus.

The upturn which enabled the IRE to operate in the black during 1935 after experiencing a deficit during the preceding 3 years enabled the Board of Directors to take steps immediately to relieve the back-log of papers awaiting publication and to materially enlarge the size of the PROCEEDINGS.

These early fiscal experiences of the IRE and the amounts of money involved in the financial storms which were major problems of the time stand in striking contrast to the amounts now involved in the Institute's operations.

During the year 1956 the total income of the IRE was slightly over $2,400,000, which exceeded expenses by a margin of only about 5 per cent. The total accumulated cash reserve at the end of the year, however, was somewhat less than the current operating expenses for one year.

IRE INCOME AND EXPENSES

	Income	Expenses
1913	$ 850.93	$ 826.50
1926	40,729.77	30,696.54
1936	62,591.44	57,096.65
1946	382,002.98	377,802.82
1956	2,451,237.67*	2,327,469.05*

* Subject to closing audit.

GENERAL CHARACTER OF ACTIVITIES AND POLICIES

Vigor and Enthusiasm

More important than the quantitative expansion of the IRE during the past 45 years is the aspect of its qualitative growth. The true measure of the success of the IRE is in the significance of its labors in serving humanity through the technology of the communications and electronics industry.

In taking stock, therefore, of the progress made by the IRE in fulfilling the vision of its founders, one should ask whether the quality, the aims, and the significance of the Institute's activities are always improving. From a look at the curves that portray the growth of the IRE from 1912 to the present and whether one considers membership, meetings, publications, or the many intangibles of engineering contribution to social welfare, one can only conclude that the IRE is still young and vigorous.

From the beginning of the IRE, its existence has been characterized by the enthusiasm that seems to be an attribute of individual radio engineers generally. The 1930 President, Lee De Forest, gave testimony to this, and also reflected his own personality when he said that "A never tiring enthusiasm seems to distinguish the ever young in this game to a far more marked degree than in any other profession."

Cooperation and Good Citizenship

The new awareness of the indispensability of the technical man featuring the postwar era creates a serious challenge to the engineering profession to become acquainted with the reservoir of scientific knowledge, appraise it in the light of the needs of the life of the people, and then by judicious interpretation, develop useful applications. Engineers must themselves take the lead in enlarging the engineer's scope and educate themselves to fit it, thereby not only contributing to their own success, but also ensuring the better fulfillment of their proper function in the society of today and tomorrow.

Quality and Integrity

A clarion call for integrity among radio engineers was sounded by the first President, Robert H. Marriott, in an address delivered before the Institute of Radio Engineers on January 8, 1913, at Fayerweather Hall, Columbia University, in which he said:

"Misrepresentation concerning radio apparatus and radio companies has been, and unfortunately still is, a damper on the advancement of the radio science and art. One of the most commonly prevalent methods has been to provide an able press agent with a company owned or controlled publication, and with the privilege of inserting such statements as may suit his fancy in acquiescent newspapers. Many mysterious and hero-worshipping exaggerations have thus found their way into the press. Thus the public has been at times woefully misinformed. Such a misleading policy is directly opposed to the spirit of the Institute. What is wanted about radio apparatus and engineers is the simple truth."

An appeal for conformity with high standards in engineering relationships was made by the second president of the IRE, G. W. Pickard, in his inaugural address in 1913 on the subject "Engineering Ethics." The incoming President in 1927, Ralph Bown, emphasized further that the growing prestige and professional standing of the IRE must flow from recognized high standards and from the utility of the Institute's output. To command respect the IRE must maintain dignity.

Accepting the Challenge

The postwar expansion of the communication and electronics field resulted, on the one hand in a greater need for service to IRE members and the radio industry, and on the other hand, in the development of IRE activities and facilities for meeting this need. The 1947 Annual Convention, for example, included technical papers in larger numbers and variety as well as an engineering exhibit which was more comprehensive than any that had previously been held.

The IRE Constitution has been revised from time to time in ways which has made it possible for the Board of Directors to take various steps considered necessary for continued successful service to members. These new activities have included the provision of increased financial assistance to Sections, the enlargement of the PROCEEDINGS, the provision of a more adequate centralized staff in the new Headquarters Building in New York, and the payment of travel expenses to the Board meetings of the Board members elected to represent the several Regions of the country.

At a meeting of the Board of Directors early in 1947 the Institute's policy was confirmed as follows: "The Institute welcomes to its membership, in each case in an appropriate member grade, all persons professionally active in the communications and electronic engineering field or interested in that field. The meetings and publications of the Institute are exclusively of a professional engineering nature and will remain of that character. The Institute offers all its members the opportunity to mingle with its professional engineering members, to participate in the technical meetings of the Institute, and to study the scientific and engineering publications of the Institute."

The Executive Secretary of the IRE in 1947 called attention to the ways in which the IRE contributes directly to the opportunities and successes of its members and of the organizations with which they work. Through its Standards Reports and Technical Committee operations the IRE gathers and distributes to its members the most advanced and valuable engineering information, enabling the engineer to avoid "technical blind alleys and to create better products, and thus to provide larger quantities of communications and electronic equipment. The industry is developed, new jobs created, existing jobs become more important and have, it is hoped, greater recognition."

Even though the IRE had seemingly achieved significant stability as a technical society that uniquely served the field of radio communication, electronics, and allied activities throughout the world, the Board of Directors in 1947 established a Committee of the Board under the chairmanship of Raymond A. Heising to survey the Institute's activities in the light of greater possible service to its members and to plan a suitable course in future action.

In 1948 the Planning Committee reported to the Board that it had been developing the idea of Professional Groups in the Institute. The tremendous subsequent development of the Professional Group System described above is striking evidence of the soundness of that proposal.

Keeping Pace With an Expanding Field

The President of IRE for 1925, J. H. Dellinger, in his retiring address at the First National Convention in January, 1926 emphasized the rapidly broadening field of radio engineering by stating that, "A well-known radio engineer, in one of his moments of tribulation said that these days a radio engineer must be all of the following things: an electrician, a physicist, an expert in acoustics, a mechanical engineer, a musician and a diplomat." He stated his belief that the foundations of the services of radio to humanity had been laid, largely by empiricism. Now the task of the radio engineer was to apply the principles of science and technology to advance beyond these foundations and obtain, by both logical and laborious procedure, all of its possibilities for public good.

In considering applications for membership in the IRE, the Board of Directors in 1929 found that the broadening scope of activities in which radio engineers were becoming active was leading to a desire by people in associated fields to become affiliated with the IRE. After careful consideration of the question, the Board concluded that the words "closely allied work" contained in the Constitution of the IRE, as it then stood, should be held to include telephone, telegraph, and cable engineering. While it was planned to publish an increasing number of papers on those subjects, this was not to alter the fundamental interest of the IRE in radio and no change was to be made in the Institute's name.

The Board of Directors has endeavored to keep itself alert to every opportunity for meeting these widening interests of the IRE membership in the radio and electronic field. There was one proposal, however, considered in 1931, which the Board felt that it must reject. This was a proposal that a meeting of the Institute be held at which Dr. Charles P. Steinmetz , a notable radio and electrical engineer, then deceased, might address the audience through a suitably entranced medium. The Board felt that this would be beyond the scope of the Institute's proper function.

At the end of World War I, there had come radio broadcasting and a radio spectrum extending up to 3 megacycles. During the next two decades radio operations extended rapidly using frequencies up to 30 megacycles. At the end of World War II there existed many of the conditions necessary for an "explosive mixture." The spark of public demand for new forms of radio communication services and the allocation to various services of frequencies in the radio spectrum extending as high as 30,000 megacycles constituted one of the important milestones in radio history.

It seems significant that the scope of the field of the radio engineer has widened to the entire universe—as illustrated by the work on radio astronomy as well as other activities of the Professional Group on Antennas and Propagation; and has narrowed to the tiniest fragment of matter—as exemplified by the development of electron microscopy and by the activities of the Professional Group on Nuclear Sciences. Thus, the physicist, the geographer, even the astronomer, the medical investigator, the general scientist, and the industrialist find, in the issues of the PROCEEDINGS OF THE IRE, papers of substantial information and value.

One cannot help wondering what it is that 50,000 technical specialists in the field of radio, communication, and electronics have in common that would cause them to swarm in such numbers. It cannot be entirely the prestige of the membership or the practical utility of publications and meetings. While these are important, there appears to be real significance in the fact that the IRE has developed and put at the disposal of all of the members a technical language of unique value and significance—possibly to a degree unmatched among other professional people.

It may be that the work of the Technical Committees, particularly their Standardization Reports dealing with terms, definitions, and methods of measurement, have had a greater significance than has been appreciated at the time by the many hundreds of engineers who have been participating in this part of the Institute's activity.

One of the original members of the IRE gave an interesting description of the state of the art when the IRE was formed. In his presidential address in January, 1930, Lee De Forest, referring to the formation of the IRE in 1912, said that it was "at a time when our only source of wave energy was the open sparkgap, the only detectors the coherer and anti-coherer, when ten miles of sea were considered wide-open spaces, when all antennas were vertical and a wave-meter was unknown, it required more than a prophet to foresee just what radio communication was destined to become." He then referred by way of contrast to the "vivid example of the wonder which modern radio has achieved in the progress of communication . . . the reporting to the breathlessly awaiting world of the recent flight over the South Pole by Commander (now Admiral) Byrd." This brought a reality to the event and accomplishment which had not been possible twenty years earlier when Peary came out of the North to file his first dispatches five months after he had reached the Pole.

Radio was becoming an essential strand in the life line of communications on land, on the sea, and in the air.

Postscript

In Washington, D. C. there is a large and imposing building erected to house the Government Archives. On its facade there appear in bold letters the words, "What is Past is Prologue." It is said that a Washington taxi driver told a visiting sight-seer that this really means, "You Ain't Seen Nothing Yet!" If radio engineers will continue to follow Marriott's injunction to cooperation, there appears to be every reason to believe that, for The Institute of Radio Engineers, also, as expressed in another inscription on the National Archives building, "The Heritage of the Past is the Seed that Brings Forth the Harvest of the Future."

Acknowledgment

In the preparation of this review of the activities of the Institute of Radio Engineers over the past 45 years, the author has consulted various records which are available in the IRE office. Material which has appeared in past issues of the PROCEEDINGS OF THE IRE has been drawn upon freely. This includes news items about IRE organization and Section activities, editorials by Institute officials and others, addresses which have been given at Annual Conventions and on other occasions, and several articles of a historical nature which have appeared from time to time. A list of the principal categories of IRE publications and records which are at the Office of the Institute is given in Appendix I. A list of outstanding historical summaries, including a few other papers that relate to special situations in the Institute's history, is given in Appendix II.

Acknowledgement is due also to a number of people, Founders, persons who have served as Secretary of the IRE, some of the past Presidents, and several others who were familiar with early activities of the IRE as well as the members of the IRE History Committee and members of the IRE staff, from whom helpful information and suggestions have been received. The author gives special thanks for the advice received from E. K. Gannett, Managing Editor, and for his cooperation in the endeavor to make this review as accurate as possible and in preparing the charts, tables and illustrations.

Appendix I

Previous Publications of Significance Relating to IRE History

"Silver Anniversary—The Institute of Radio Engineers," Beverly Dudley, *Electronics*, pp. 15–21; May, 1937.

"Institute of Radio Engineers to Act to Secure a Permanent Home," PROC. IRE, vol. 32, pp. 768–769; December, 1944.

"Symposium on the Occasion of the Completion of the

Building-Fund Campaign, PROC. IRE, vol. 33, pp. 620–630; September, 1945.
"Radio Pioneers, 1945." Pamphlet Commemorating the Radio Pioneers Dinner on November 8, 1945, under the auspices of the New York Section of the Institute of Radio Engineers. H. P. Westman, Editor-in-Chief.
"1 East 79 Street—A Pictorial Tour of the Home of the Institute of Radio Engineers," PROC. IRE, vol. 36, pp. 89–100; January, 1948.
"What's Behind IRE?" PROC. IRE, vol. 39, pp. 340–341; April, 1951.
Series of Papers on the occasion of the 40th Anniversary of the Institute of Radio Engineers, PROC. IRE, vol. 40, pp. 514–524; May, 1952
"The Founders of the IRE"
"Life Begins at Forty," The Editor
"The Genesis of the IRE"
"The IRE in Cohesion or Depression?" Donald B. Sinclair
"A Look at the Past Helps to Guess at the Future in Electronics," William C. White
"The Institute of Radio Engineers," E. K. Gannett, *General Electric Rev.*, pp. 53–55; March, 1953.

APPENDIX II

PRINCIPAL CATEGORIES OF IRE RECORDS AT OFFICE OF INSTITUTE OF RADIO ENGINEERS

PROCEEDINGS OF THE IRE, 1912 to 1956 inclusive, Bound Volumes
Annual Reports, 1927–1955, inclusive, Bound Volumes
Annual Reports of the Secretary, 1936–1955, inclusive, Bound Volumes

YEAR BOOKS and Directories:

1914	1937
1916	1946
1926 to 1932, inclusive	1948 to 1956, inclusive
	1956–1957

Minutes of Meetings of Board of Directors (originally called "Board of Direction"):

1926–1930 Bound Volume
1931 Bound Volume—includes Reports of Secretary and Auditor
1932–1955, inclusive—Bound Volumes, several years in each volume

Cumulative Indexes

1913–1942, inclusive
1943–1947, inclusive
1948–1953, inclusive

Standardization Reports

Master Index of IRE Definitions
Index to Testing Methods
Index to Abstracts and References
Professional Group TRANSACTIONS
IRE STUDENT QUARTERLY

1955 Proceedings of:

National Symposium on Quality Control and Reliability in Electronics
Western Joint Computer Conference
WESCON Computer Sessions

CONVENTION RECORD

JTAC Proceedings. Volumes, I to XIII, inclusive.
NTSC Final Report
Section Manual
Professional Group Manual (including PG Chapter Manual)

Note: There are in existence a number of complete sets of the PROCEEDINGS OF THE IRE, Volumes 1 to 44, inclusive, not only at the Office of the Institute and in the possession of several individual members of the Institute, but available for public reference at several libraries. Among such library reference sets are those at the Library of Congress, the New York City Public Library, and the Engineering Societies Library in New York City.

CORRECTION

The editors wish to correct an error which appeared in the frontispiece article on page 2 of the January, 1957 issue of PROCEEDINGS. Following World War II, Presient John T. Henderson was the Canadian delegation's scientific advisor to the Atomic Energy Commission of the United Nations, not the United States.

The Effect of Fading on Communication Circuits Subject to Interference*

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Summary—The statistical performance of radio communication circuits in the presence of interference is analyzed for the cases where either the desired or undesired signal or both are subject to Rayleigh fading over the propagation path. The significant parameter considered is the ratio of mean signal power to mean interference power needed at the receiver for satisfactory performance. When satisfactory performance is required a high percentage of the time the signal power must be greatly increased over the nonfading case, *e.g.*, 99.9 per cent satisfactory operation requires 30 db more signal power in the presence of signal fading whether or not the interference is fading.

The improvement which dual diversity reception offers is discussed for each case. For 99.9 per cent satisfactory operation a practical dual diversity system offers a 14 db improvement over nondiversity for fading signal and fading interference.

Introduction

ADVANCES in both the theory and the art of communications during the last decade have resulted in systems capable of giving satisfactory performance under many kinds of heavy interference. For every system, however, there will always be a definite amount of a given type of interference that can be tolerated when both signal intelligence and interference contain overlapping spectral components. It is the purpose of this paper to consider how fading modifies the amount of interference that can be tolerated.

For every type of communication system and every type of interference, a definite ratio of mean signal power to mean interference power, $\overline{S}^2/\overline{I}^2=K^2$, may be established which provides the minimum acceptable standard of performance. For example, tests of a particular start-stop frequency shift radio teletype system have shown that an average error rate of 1 error in 20 lines will not be exceeded when the signal to interference power ratio is 8 db, if the interference is caused by another radio teletype transmission with similar characteristics. Therefore, if an error rate not exceeding 1 in 20 lines is an *acceptable* standard for *satisfactory* operation, this standard can be met by establishing 10 log K^2 at 8 db and, provided this value of K^2 is maintained or exceeded, the acceptable standard or better will result. K^2, then, represents the minimum ratio needed for acceptable performance. Most communication systems can be designed to handle a large dynamic range of inputs; thus the absolute magnitudes of signal and interference are of little importance, but their ratio is the primary factor. The quality or standard of performance of the communication system will be some function of mean signal power $\overline{S}^2$ to mean interference power $\overline{I}^2$,[1] *i.e.*, K^2. The exact function depends upon the statistics of signal and interference and the characteristics of the communication system.

At the input to the receiver let the mean received signal power to mean received interference power be represented by R^2. If there were no other considerations, R^2 could be made equal to K^2. In the presence of fading, however, R^2 must be made greater than K^2 to obtain satisfactory performance for a large percentage of time. The larger R^2 is made, compared to K^2, the greater the percentage of time the standard of acceptable performance determined by K^2 will be achieved in the presence of fading. Returning to the previous example, under Rayleigh fading conditions, it may be found that by increasing the power ratio from 6.31 (8 db) to 100 (20 db), an error rate not exceeding 1 in 20 lines will be realized 99 per cent of the time. The ratio R^2/K^2 necessary to give the desired performance in the presence of fading will be designated as Q^2. In the example $Q^2=100/6.31$ (12 db). It should be noted that R^2, K^2, and hence Q^2 are determined from long-term averages.

Fading Phenomena

The most common type of fading is caused by propagation of the signal over more than one path followed by recombination of the components from the various paths by vector addition at the receiving antenna. The path lengths vary due to variations in the propagation medium and hence the phases of the individual paths at the receiver tend to vary at random with respect to one another. If the path length differences are small, an appreciable band of frequencies will tend to fade up and down in unison. The greater the path length differences, the narrower the band of frequencies that may be considered as fading together. In the extreme case the differences may be so great that frequencies within the channel carrying the intelligence will fade noncoherently giving rise to the effect known as selective fading. For the purpose of this paper the band of interest will be considered small with respect to the bandwidth of coherent fading, in other words, the nonselective or flat fading case.

From both theoretical considerations and experiment it has been determined that the amplitude of the envelope of this type of fading signal is generally Rayleigh distributed. The Rayleigh function may be de-

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[1] The effect of local receiver noise is discussed later under "The Meaning of I^2."

rived by considering the distribution of the vector sum of a significant number of waves with independent, uniformly distributed varying phases. This well-known function may be expressed by the probability density

$$P(B) = \frac{2B}{b^2} e^{-B^2/b^2} \quad (1)$$

where $p(B)dB$ is the probability that the instantaneous length of the resultant vector lies between B and $B+dB$ when the constant b^2 represents the mean power of the sum of the waves. The instantaneous length of the resultant vector is equivalent to the instantaneous amplitude of the envelope. By integration and substitution of appropriate limits it may be shown that the probability that the instantaneous envelope amplitude will exceed B is given by

$$P(B) = e^{-B^2/b^2}. \quad (2)$$

The Rayleigh distribution will be used here for all fading phenomena.

Fading rates are ordinarily much slower than signal intelligence rates. Therefore, during a number of successive Nyquist intervals corresponding to the intelligence bandwidth the mean powers of signal and interference are quite constant. Under these conditions, fading varies the short-term mean power at the receiver but does not otherwise modify the short-term statistics of signal or interference.

Case I—Fading Signal in the Presence of Nonfading Interference

A fading signal received in the presence of nonfading interference is commonly encountered in practice when an ionosphere propagated signal is being received in the presence of ground-wave interference. The reception of scatter propagated signals under conditions of line-of-sight interference offers another example of this case of fading.

In the notation used here it is desired to find the probability that a signal subjected to Rayleigh fading in the presence of nonfading interference will exceed the desired K^2 as a function of Q^2. It is shown in Appendix I that this probability is given by

$$P(S^2/I^2 > K^2) = e^{-1/Q^2}. \quad (3)$$

The function is plotted as curve 3, Fig.1. It may be seen that at a value $Q^2=1$ (0 db), *i.e.*, with the same signal to interference power $\overline{S}^2/\overline{I}^2$ that would give acceptable operation 100 per cent of the time if there were no fading, acceptable operation can be expected only 37 per cent of the time. To obtain satisfactory operation 99.9 per cent of the time it is necessary to increase the received $\overline{S}^2/\overline{I}^2$ 1000 times (10 log $Q^2=30$ db).

Case II—Nonfading Signal in the Presence of Fading Interference

This is the opposite of Case I. The effect is found in practice when a ground-wave signal is being received in the presence of ionosphere propagated interference. In the case of scatter propagation this is the effect of interference from the scatter signal on reception of a line-of-sight signal.

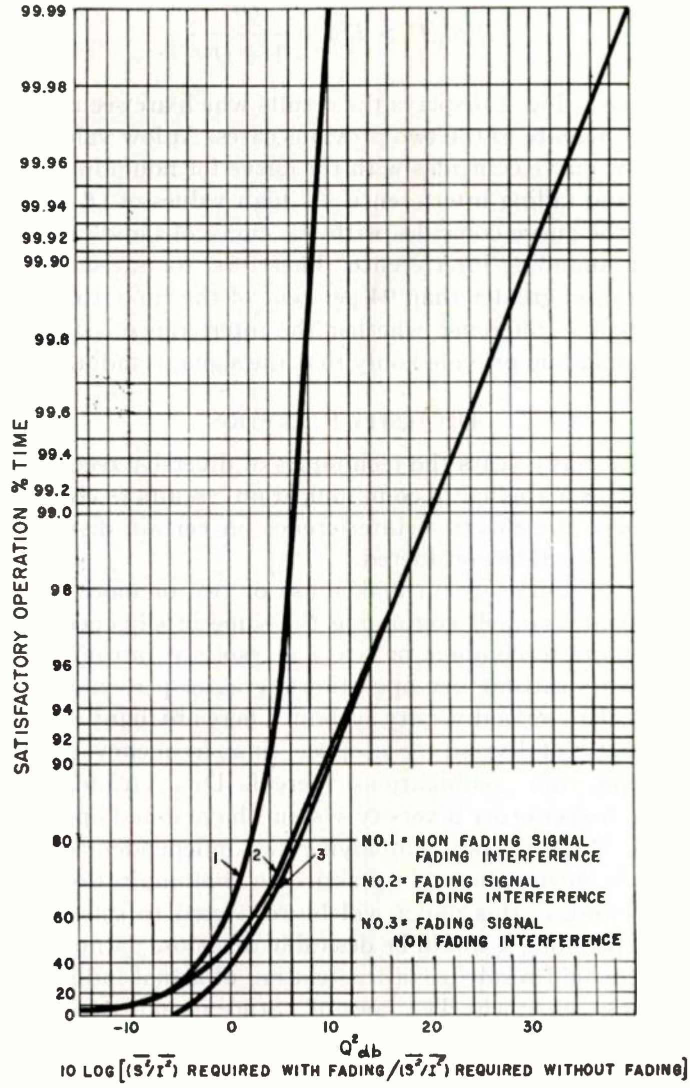

Fig. 1—Nondiversity.

The problem here is to determine the probability that a nonfading signal in the presence of fading interference will exceed the desired K^2 as a function of Q^2. Appendix II shows this probability is given by

$$P(S^2/I^2 > K^2) = 1 - e^{-Q^2}. \quad (4)$$

Curve 1, Fig. 1 is a plot of this case. It may be seen that the results are much more favorable to the desired signal compared to Case I. At a value of $Q^2=0$ db satisfactory operation can be expected 63 per cent of the time and to obtain satisfactory operation 99.9 per cent of the time it is only necessary to increase $\overline{S}^2/\overline{I}^2$ 8 db.

Case III—Fading Signal and Fading Interference

When both signal and interference are subject to Rayleigh fading it is shown by Appendix III that the probability of satisfactory operation is given by

$$P(S^2/I^2 > K^2) = \frac{Q^2}{1 + Q^2}. \quad (5)$$

Curve 2, Fig. 1 displays the results which are seen to be intermediate to the two previous cases. At low values of Q^2 the curve coincides with the curve for nonfading signal and fading interference. At high values of Q^2 (>12 db) the curve coincides with the curve of fading signal and nonfading interference. Therefore, for satisfactory operation greater than 94 per cent of the time it makes negligible difference whether the interference is fading or nonfading provided only that the signal is fading.

Diversity Reception

For many years the techniques of diversity reception have been applied to communication circuits to combat fading. The effects of interference on certain diversity systems will be considered.

A diversity system makes use of two or more independent channels containing the same intelligence and attempts to combine or select a resultant output that provides satisfactory operation a greater percentage of time than a nondiversity system. There are many different types of diversity, *e.g.*, space, time, frequency, polarization, and combinations thereof. Dual, triple, and even higher order diversity systems have found application. Dual diversity employing two independent channels is most common in practice on communication circuits today; this paper will be restricted to this type.

If possible, it would be desirable to choose parameters that would result in anticorrelation of signal fading on the two channels. The laws of nature do not generally allow this condition and an efficient diversity system depends upon independent fading in the two channels.

The method used to combine the outputs from the diversity channels has an effect on the performance of the system. Simple addition will not effect an improvement over nondiversity. One of the oldest types of combining and one that is in wide use today detects the output of each channel and makes a selection in favor of the channel with the highest output. Certain techniques, *e.g.*, common limiting, only partially suppresses the weaker output, while others act as a switch to select the stronger and eliminate the weaker. If interference was not a factor such a system would select the strongest signal. When interference is present the system selects the output with the strongest signal plus interference. The system is, therefore, designated herein as S^2+I^2 diversity. Since signal and interference are uncorrelated and are delivered to the same impedance they may be considered to add as the sum of the average powers. The success of S^2+I^2 diversity depends upon the premise that the channel having the highest signal plus interference has the best probability of simultaneously having the best signal to interference ratio, S^2/I^2. It is self-evident that this will be true when the mean signal power is greater than the mean interference power provided the signal is fading.

More recently, a technique has been devised to combine the outputs of the channels in order to obtain an instantaneous resultant signal to interference ratio greater than that of either channel by itself. Called ratio squared combining,[2] this system can give up to 3 db improvement compared to S^2+I^2 diversity when the outputs of the two channels approach equality and the interference is noncoherent in the two channels. When one output is much lower than the other there is no gain over S^2+I^2 diversity. This technique is not analyzed here, but experimental work on actual circuits has shown a long-term gain over S^2+I^2 diversity of the order of one to one and one-half db.

An idealized diversity system will be postulated here in which the output of the channel having the best S^2/I^2 is selected. Such a system is approached by existing techniques which are suitable for specific types of interference and signals. As will be shown later, under certain circumstances S^2+I^2 diversity becomes equivalent to S^2/I^2 diversity. As an example of a diversity combining system that approaches the S^2/I^2 criterion consider an FSK radio teletype system wherein the train of mark and space pulses can be passed through a diversity detector. In the absence of interference the output will be a slowly varying dc, corresponding to the varying amplitude of the signal as it fades. If the interference is nonperiodic such as noise or speech, the output will contain ac information with possible frequency components up to the bandwidth of the system. An S^2/I^2 measure may then be obtained by comparing the power of the higher frequency ac components to the power of the dc and low-frequency components. Such a system will obviously not work when the interference is periodic as, for example, a sine wave carrier interference close in frequency to the desired signal. The S^2/I^2 diversity system is considered further because heuristically it seems to offer optimum results for diversity when considered under all conditions of interference.

For S^2/I^2 diversity it is assumed that a selection giving satisfactory operation can be obtained when the S^2/I^2 output ratio in one or both channels exceeds K^2. If P is the probability of satisfactory operation for nondiversity, then

$$P_d = 2P - P^2 \quad (6)$$

is the probability of satisfactory operation for S^2/I^2 diversity.

For S^2+I^2 diversity it is assumed that a selection giving satisfactory operation can be made when the S^2/I^2 output ratio in one or both channels exceeds K^2. It is necessary then to find the probability that $S_1^2/I_1^2 > K^2$ when $S_1^2+I_1^2 > S_2^2+I_2^2$ where the subscripts refer to channels 1 and 2 respectively. Since on the average $S_1^2+I_1^2$ will exceed $S_2^2+I_2^2$ as often as $S_2^2+I_2^2$ exceeds $S_1^2+I_1^2$, the total probability of satisfactory operation

[2] L. R. Kahn, "Ratio squarer," Proc. IRE, vol. 42, p. 1704; November, 1954.

will be the same as the probability calculated for $S_1^2/I_1^2 > K^2$.

Effects of S^2/I^2 Diversity

Case I with diversity of the S^2/I^2 type, *i.e.*, a fading signal and nonfading interference, may be calculated by substituting (3) in (6) which gives the probability of satisfactory operation with diversity as

$$P_d = e^{-1/Q^2}(2 - e^{-1/Q^2}). \tag{7}$$

The curve of this function is plotted as No. 3, Fig. 2.

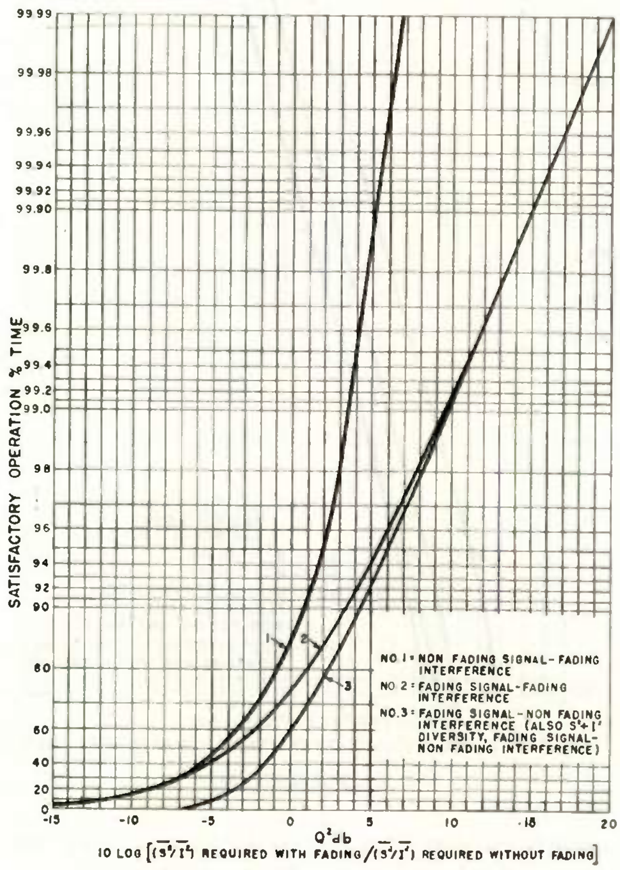

Fig. 2—S^2/I^2 diversity.

Comparing with curve 3, Fig. 1 it may be seen that the improvement due to diversity increases with increasing probability of satisfactory operation and reaches a value of 20 db at 99.99 per cent. This case has been reported previously in the literature with a somewhat different presentation of the results.[3]

Similarly substituting (4) in (6) gives

$$P_d = 1 - e^{-2Q^2} \tag{8}$$

for S^2/I^2 diversity and Case II, a nonfading signal and a fading interference. This function is plotted as curve 1, Fig. 2 and here the diversity gain is much smaller, reaching 2.75 db at 99.99 per cent.

[3] Z. Jelonek, E. Fitch, and J. H. Chalk; *Wireless Eng.*, vol. 24, pp. 54–62; February, 1947.

To find the performance for S^2/I^2 diversity in Case III, a fading signal and fading interference, (5) is substituted into (6), giving

$$P_d = \frac{Q^2}{1 + Q^2}\left(2 - \frac{Q^2}{1 + Q^2}\right). \tag{9}$$

Plotted as curve 2, Fig. 2, it is apparent that the results are intermediate to the other two curves as was found for the nondiversity situation. Again for the condition of high probability of satisfactory operation a fading signal suffers to the same degree whether or not the interference is fading.

Effects of $S^2 + I^2$ Diversity

In the case of a fading signal and nonfading interference, the interference is an equal constant in both channels. Hence the selection of the channel with the highest S^2+I^2 is equivalent to selecting the channel with the best S^2/I^2. Therefore, S^2+I^2 diversity becomes S^2/I^2 diversity and the results are as given in (7) and curve 3, Fig. 2.[4]

For the case of a nonfading signal and fading interference S^2+I^2 diversity would obviously result in a diversity loss because the channel with the highest S^2+I^2 would have a lower probability of the best S^2/I^2 compared to the channel with the lowest S^2+I^2. The only time that satisfactory operation will be obtained occurs when both channels have an $S^2/I^2 > K^2$. This is the square of (8), or

$$P_d = (1 - e^{-2Q^2})^2. \tag{10}$$

Eq. 10 is not plotted but it should be apparent that better results can be obtained without diversity when this condition exists. It would be possible to arrange the diversity system to select the channel with the lowest S^2+I^2 in which case the results would be the same as S^2/I^2 diversity for a nonfading signal and fading interference and a diversity gain would result.

S^2+I^2 diversity with a fading signal and fading interference is a more complex mechanism. Appendix IV shows that the probability of satisfactory operation is

$$P_d = 2\left[\frac{Q^2}{1 + Q^2} - \left(\frac{Q^2}{(1 - Q^4K^4)(Q^2(K^2 + 2) + 1)} - \frac{Q^4K^4}{2(K^2(Q^2 + 2) + 1)(1 - Q^2K^2)}\right)\right]. \tag{11}$$

[4] Subsequent to the preparation of this paper, a Russian publication on a closely related subject has been brought to the attention of the authors, *i.e.*, V. I. Zhitomirskii, "Determination of the probability of communication interference caused by interfering signals," *Radiotekhnika*, vol. 10, pp. 15–22; 1955.

Zhitomirskii studied the fading signal/fading interference case for for a theoretical dual diversity system. In this system the 4 components S_1, I_1, S_2, I_2 are assumed to be independently available to permit a selection of the diversity channel. Based upon which of the 4 components has the greatest amplitude at a given instant, the diversity channel associated with that component is selected and the probability that S^2/N^2 in the channel will exceed K^2 is computed. The results show that this theoretical diversity system produces a lower percentage of satisfactory operation in the presence of interference than nondiversity operation when $K^2 > 1$.

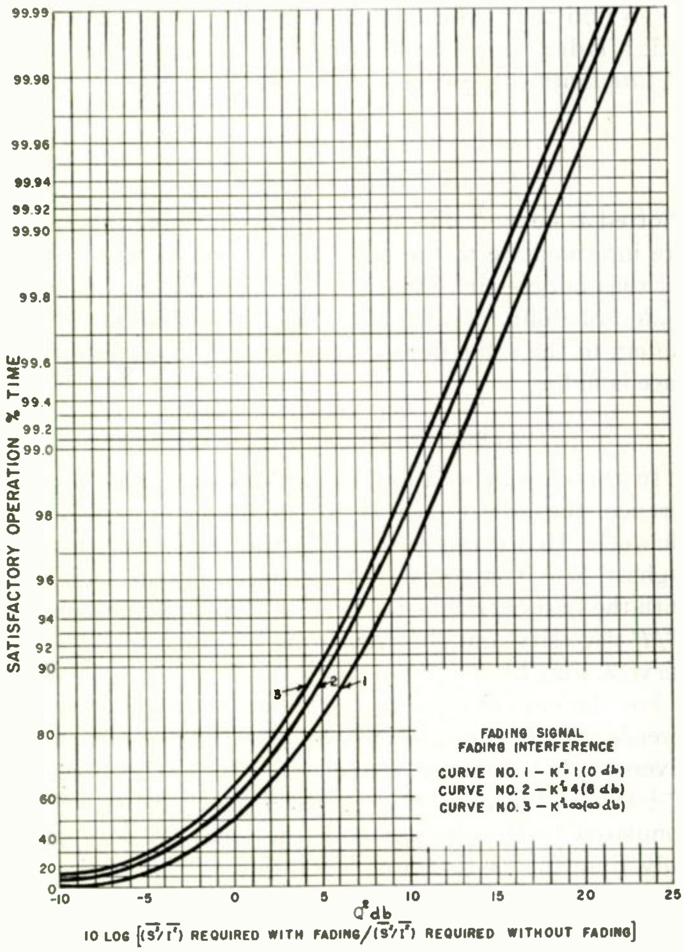

Fig. 3—S^2+I^2 diversity.

The probability is a function of both Q^2 and K^2. Fig. 3 shows a plot of this function vs Q^2 for values of K^2 equal to 0, 6, and ∞ db. For values of $K^2>10$ db the curve approaches the condition $K^2=\infty$ quite closely. Most communication systems require a value of $K^2>10$ db for satisfactory operation and, therefore, the $K^2=\infty$ curve may be used to a good approximation.

Diversity Gain

Fig. 4 is a plot of the diversity gain vs probability of satisfactory operation from 90 to 99.99 per cent for various diversity systems. Diversity gain is defined as the signal power required with diversity to the signal power required without diversity to give a desired probability of satisfactory operation. For the higher probabilities the diversity gains of the systems maintain essentially a fixed db difference from one another. For the fading signal-fading interference case S^2/I^2 diversity gives 1.5 db more gain than the best S^2+I^2 diversity.

The Meaning of I^2

A tacit assumption was made that I^2 originated completely outside the receiver. In effect this assumes a noiseless receiver. Such an assumption can only be approximated when the mean value of S^2 and I^2 are both

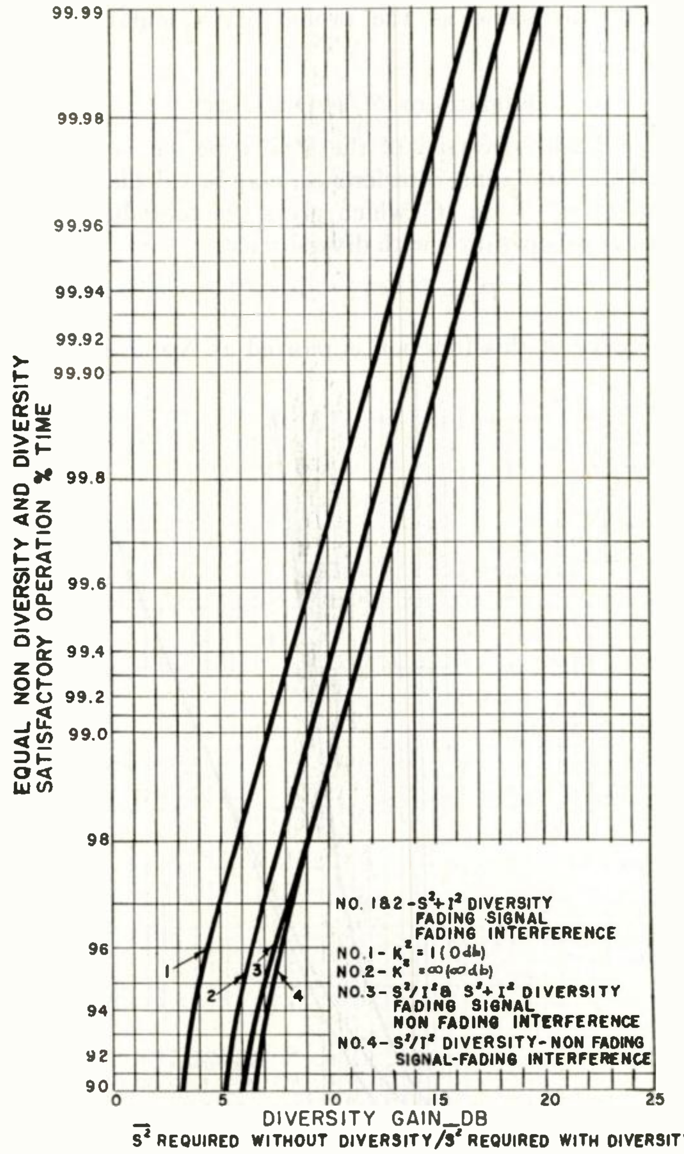

Fig. 4—Diversity gain.

very much greater than the equivalent receiver mean noise power N^2. In practice, if K^2 is determined by measurement it will, in general, include the effects of both N^2 and true interference, I_t^2.

In the event of nondiversity, S^2/I^2 diversity, or S^2+I^2 diversity it is apparent that I^2 may be taken as $N^2+I_t^2$ provided I_t^2 is nonfading. For nondiversity or S^2/I^2 diversity with a fading signal and fading interference it has been shown that at the higher probabilities, which are of greatest interest, fading interference acts in the same manner as nonfading interference of the same mean power. Therefore, for this latter situation I^2 may again be taken as $N^2+I_t^2$.

The situation for local noise, fading interference, fading signal, and S^2+I^2 diversity combined is more complex. If I^2 is predominantly N^2 the results will approach closely curve 3, Fig. 2. If I^2 is predominantly I_t^2 the results will tend to follow the appropriate curve of Fig. 3. Remembering that most practical systems will follow the curve $K^2=\infty$ approximately for fading interference, the question arises as to the difference between this curve and curve 3, Fig. 2. This may be answered by comparing the diversity gain curves Fig. 4, curves 2 and 3. It may be seen that in the region above 90 per cent the two curves are within 1 to 1½ db of each other. Given I^2 then, the results will fall between these limits depending upon the relative contributions of I_i^2 and N^2.

A general observation may be drawn that under all conditions considered there is little difference in performance whether the interference is fading or not fading when the signal is fading and the desired probability of satisfactory operation is greater than 90 per cent. I^2 may be taken for practical purposes as the sum of I_i^2 and N^2. For S^2+I^2 diversity and I_i^2 fading, the use of curve $K^2=\infty$, Fig. 3 will represent conservative practice.

Appendix I

Derivation of (3)

The desired distribution is:

$$P\left(\frac{S^2}{I^2} > K^2\right) = P(S > Kb)$$

where:

$$p(S) = \frac{2S}{a^2}\exp\left(-\frac{S^2}{a^2}\right), \qquad a^2 = \bar{S}^2$$

and $I^2=b^2$ (constant envelope power)

$$P(S > Kb) = \int_{Kb}^{\infty} p(S)dS = \exp\left(-\frac{K^2b^2}{a^2}\right).$$

Now if $R^2=a^2/b^2$ and $Q^2=R^2/K^2$ then

$$P\left(\frac{S^2}{I^2} > K^2\right) = \exp\left(-\frac{1}{Q^2}\right)$$

for I^2 constant.

Appendix II

Derivation of (4)

The desired distribution is:

$$P\left(\frac{S^2}{I^2} > K^2\right) = P\left(I < \frac{a}{K}\right)$$

where:

$$p(I) = \frac{2I}{b^2}\exp\left(-\frac{I^2}{b^2}\right), \qquad b^2 = \bar{I}^2$$

and $S^2=a^2$ (constant envelope power)

$$P\left(I < \frac{a}{K}\right) = \int_0^{a/K} p(I)dI = 1 - \exp\left(-\frac{a^2}{K^2b^2}\right)$$

$$P\left(\frac{S^2}{I^2} > K^2\right) = 1 - \exp\left(-Q^2\right)$$

for S^2 constant.

Appendix III

Derivation of (5)

The desired distribution is

$$P\left(\frac{S^2}{I^2} > K^2\right) = P(S > KI)$$

where

$$p(S) = \frac{2S}{a^2}\exp\left(-\frac{S^2}{a^2}\right)$$

and

$$p(I) = \frac{2I}{b^2}\exp\left(-\frac{I^2}{b^2}\right).$$

Now

$$P(S > KI)$$

$$= \int_{I=0}^{\infty}\int_{S=KI}^{\infty} p(S, I)dSdI = \int_0^{\infty}\int_{KI}^{\infty} p(S)p(I)dSdI$$

$$= \int_0^{\infty}\left[\frac{2I}{b^2}\exp\left(-\frac{I^2}{b^2}\right)\right]\left[\exp\left(-\frac{K^2I^2}{a^2}\right)\right]dI$$

$$= \left|\frac{\exp - I^2\left[\frac{1}{b^2}+\frac{K^2}{a^2}\right]}{1+\frac{K^2b^2}{a^2}}\right|_0^{\infty}$$

$$= \frac{1}{1+\frac{K^2}{R^2}}$$

$$\therefore P\left(\frac{S^2}{I^2} > K^2\right) = \frac{Q^2}{1+Q^2}.$$

Appendix IV

Derivation of (11)

Given:

$$p(S_i) = \frac{2S_i}{a^2}\exp\left(-\frac{S_i^2}{a^2}\right)\text{ for } i = 1, 2 \tag{12}$$

$$p(I_i) = \frac{2I_i}{b^2}\exp\left(-\frac{I_i^2}{b^2}\right)\text{ for } i = 1, 2 \tag{13}$$

and all four variables independently distributed.

The conditional distribution sought is:

$$P\left(\frac{S_1^2}{I_1^2} > K^2 \,\middle|\, S_1^2 + I_1^2 > S_2^2 + I_2^2\right)$$

$$= \frac{P\left(\frac{S_1^2}{I_1^2} > K,^2 S_1^2 + I_1^2 > S_2^2 + I_2^2\right)}{P(S_1^2 + I_1^2 > S_2^2 + I_2^2)}. \tag{14}$$

But the marginal distribution in the denominator is obviously ½. Thus the desired expression reduces to the joint distribution.

$$2P\left(\frac{S_1}{I_1} > K, S_1^2 + I_1^2 > S_2^2 + I_2^2\right)$$

$$= 2\int_0^\infty P\left(\frac{S_1}{I_1} > K, S_1^2 + I_1^2 = v, S_2^2 + I_2^2 < v\right) dv$$

$$= 2\int_0^\infty P\left(\frac{S_1}{I_1} > K, S_1^2 + I_1^2 = v\right) P(S_2^2 + I_2^2 < v) dv$$

$$= 2\int_{u=K}^\infty \int_{v=0}^\infty p\left(\frac{S_1}{I_1} = u, S_1^2 + I_1^2 = v\right) \cdot P(S_2^2 + I_2^2 < v) dv du. \quad (15)$$

The first factor in the integrand is a joint density function $p(u, v)$ which may be evaluated from the densities of S_1 and I_1 with the transformation

$$p(u, v) = p(S_1[u, v])p(I_1[u, v]) \left| \frac{\partial S_1}{\partial u} \frac{\partial I_1}{\partial v} - \frac{\partial S_1}{\partial v} \frac{\partial I_1}{\partial u} \right|. \quad (16)$$

Now note that

$$v^2 = S_1^2 + I_1^2 \quad \text{and} \quad u = \frac{S_1}{I_1}$$

hence

$$S_1 = u\sqrt{\frac{v}{u^2+1}} \quad \text{and} \quad I_1 = \sqrt{\frac{v}{u^2+1}}.$$

Substituting in (16), using the distributions in (12) and (13),

$$p(u, v) = \frac{2uv}{a^2b^2(u^2+1)^2} \cdot \exp\left[-\left(\frac{v}{u^2+1}\right)\left(\frac{u^2}{a^2} + \frac{1}{b^2}\right)\right]. \quad (17)$$

The second factor in the integrand of (15) may be determined by a similar transformation process.

Let

$$W = S_2^2 + I_2^2.$$

Hence

$$I_2 = \sqrt{W - X^2}$$

and $X = S_2$.

Then

$$p(W, X) = p(S_2[W, X])p(I_2[W, X]) \cdot \left| \frac{\partial S_2}{\partial W} \frac{\partial I_2}{\partial X} - \frac{\partial S_2}{\partial X} \frac{\partial I_2}{\partial W} \right| = \frac{2X}{a^2b^2} \exp\left(-\frac{W}{b^2}\right) \exp\left(-X^2\left[\frac{1}{a^2} - \frac{1}{b^2}\right]\right).$$

Then

$$p(W) = \int_{X=0}^{\sqrt{W}} p(W, X)dX = \frac{\exp\left(-\frac{W}{b^2}\right) - \exp\left(-\frac{W}{a^2}\right)}{b^2 - a^2}$$

and

$$P(W < v) = \int_0^v p(W)dW$$

$$\therefore P(S_2^2 + I_2^2 < v) = 1 - \left[\frac{b^2 \exp\left(-\frac{v}{b^2}\right) - a^2 \exp\left(-\frac{v}{a^2}\right)}{b^2 - a^2}\right]. \quad (18)$$

Substituting (17) and (18) in (15) integrating with respect to v and using $R^2 = a^2/b^2$ yields

$$2\int_{u=K}^\infty 2\mu R^2\left[\frac{1}{(u^2+R^2)^2} - \frac{1}{(1-R^2)(1+R^2)^2\left(u^2 + \frac{2R^2}{R^2+1}\right)^2} + \frac{R^2}{4(1-R^2)\left(u^2 + \frac{(R^2+1)}{2}\right)^2}\right]du$$

$$= 2R^2\left[\frac{1}{K^2+R^2} - \frac{1}{(1-R^2)}\left\{\frac{1}{(1+R^2)^2\left(K^2 + \frac{2R^2}{R^2+1}\right)} - \frac{R^2}{4\left(K^2 + \frac{R^2+1}{2}\right)}\right\}\right].$$

Then, substituting $R^2 = K^2Q^2$,

$$= 2\left[\frac{Q^2}{1+Q^2} - \left\{\frac{Q^2}{(1-K^4Q^4)(Q^2[K^2+2]+1)} - \frac{Q^4K^4}{2(K^2[Q^2+2]+1)(1-Q^2K^2)}\right\}\right] \quad (19)$$

which is the desired result.

An alternate method of solution was suggested by R. Griel Miller, Jr., of Stanford University in a letter to the authors. It is based on the evaluation of the quadruple integral

$$P\left(\frac{S_1}{I_1} > K, S_1^2 + I_1^2 > S_2^2 + I_2^2\right)$$

$$= \int_0^\infty \int_0^\infty \int_0^\infty \int_{S_1 = \max\{KI_1, \sqrt{S_2^2+I_2^2-I_1^2}\}}^\infty \cdot p(I_2)p(S_2)p(I_1)p(S_1)dS_1dI_1dS_2dI_2.$$

Microwave Frequency Doubling from 9 to 18 KMC in Ferrites*

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Summary—**Frequency doubling in ferrites is theoretically predicted from the equation of motion of the component of magnetization that is along the dc magnetic field direction. The low conversion efficiency previously reported by the authors has been significantly improved. Efficiencies as high as −6 db have now been observed as a result of a lengthy study of geometry effects. For an input power of 32-kw peak at 9 kmc, outputs have been measured as high as 8 kw at 18 kmc. The conversion efficiency is found to depend markedly on the geometry of the ferrite.**

Introduction

In an earlier paper,[1] experiments were described which verified predictions that a ferrite excited at high-power level will act as a frequency doubler and generate power at harmonic frequencies. These initial experiments were performed between 3175 and 6350 mc using ferrite disks mounted in cavities and excited with peak-power levels of up to several hundred watts. For this geometry and power level, conversion efficiencies were found to be very low, approximately −60 db.

Since then, measurements have been continued at higher frequencies and higher power levels and significantly improved conversion efficiencies have been observed. Using a fundamental frequency of 9 kmc and a fundamental peak-power level of 32 kw, outputs at 18 kmc were measured to be 8 kw. This represents a doubling conversion efficiency of −6 db. The ability of the ferrite to generate high peak powers constitutes a significant advantage over crystal doublers. This results from the fact that the ferrite effect is a volume one while the crystal depends upon a surface effect.

Theory

Frequency doubling in ferrites results from the generation of a double frequency component of magnetization along the direction of the dc magnetizing field. The equation of motion for this component of magnetization for the lossless case is written as

$$\dot{m}_z = \gamma(m_x h_y - m_y h_x) \tag{1}$$

where h_x and h_y are the rf magnetic fields inside the ferrite; m_x, m_y, and m_z are the rf magnetizations of the ferrite; γ is 2.8 mc/oersted; and the dc field is applied in the z direction. A solution of the magnetic torque equation for the two components of magnetization normal to the dc magnetizing field yields

$$\begin{aligned} 4\pi m_x &= \chi h_x - j\kappa h_y \\ 4\pi m_y &= j\kappa h_x + \chi h_y \end{aligned} \tag{2}$$

where χ and κ are the usual elements of the tensor susceptibility of ferrites[2] and third-order terms were neglected. No second-order terms exist for these components. In arriving at (2), a time dependence of $e^{j\omega t}$ was assumed for the rf quantities involved. Due to this complex time factor, care must be taken when (2) is substituted into (1). When this is done properly, it is found[1] that the double frequency terms in the magnetization are

$$4\pi\dot{m}_z = -\frac{j\kappa\gamma}{2}(h_x^2 + h_y^2). \tag{3}$$

This equation shows that the rate of change of the z component of magnetization is proportional to the square of the internal magnetic fields. Thus if h_x and h_y vary at a frequency ω and if $h_x \neq jh_y$ (*i.e.*, the magnetic fields are not circularly polarized), then m_z varies at a frequency of 2ω. Since the z component of magnetization has a component oscillating a frequency of 2ω, the ferrite will radiate an electromagnetic wave of frequency 2ω. Also, the output peak power level at the double frequency should vary as the square of the input peak power level at the fundamental frequency. This square law dependence has been found to be essentially correct for input power levels approaching 32 kw. This indicates that the "small signal" theory presented here is substantially correct for these power levels.

The foregoing theory must be extended considerably to take into account the ferrite geometry and the loss in the ferrite. In the experiments it has been found that the conversion efficiency depends markedly upon the ferrite geometry, and the dependence is not one that is amenable to an intuitive analysis. In addition, a number of high-power nonlinear effects[3-5] have been observed

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[1] W. P. Ayres, P. H. Vartanian, and J. L. Melchor, "Frequency doubling in ferrites," *J. Appl. Phys.*, vol. 27, pp. 188–189; February, 1956.

[2] C. L. Hogan, "The ferromagnetic Faraday effect at microwave frequencies and its applications," *Bell Sys. Tech. J.*, vol. 31, pp. 1–31; January, 1952.

[3] N. Bloembergen and S. Wang, "Relaxation effects in para- and ferromagnetic resonance," *Phys. Rev.*, vol. 93, pp. 77–83; January, 1954.

[4] H. Suhl, "The nonlinear behavior of ferrites at high microwave signal levels," Proc. IRE, vol. 43, pp. 1270–1284; October, 1956.

[5] N. G. Sakiotis, H. N. Chait, and M. L. Kales, "Nonlinearity of propagation in ferrite media," Proc. IRE, vol. 43, p. 1011; August, 1955.

which are not described by this theory and which affect the conversion efficiency in an unknown manner.

Physically, the reason for the generation of the double frequency magnetization is easily seen. The magnetization of the body is precessing about the direction of the dc field. It can be thought of as a constant length vector whose projection on the appropriate plane determines m_x, m_y, and m_z. Since, in general, m_x and m_y are not equal, the magnetization must be precessing in an elliptical orbit as viewed along the dc field direction as shown in Fig. 1(a). But since the magnetization vector must be constant in length, it is easily seen that the projection along the z axis must have a component of rf magnetization at double the frequency of the excitation fields. If m_x and m_y should have the same magnitude (which can occur if the excitation is circularly polarized) then no double frequency output would be expected as shown in Fig. 1(b). This agrees with the results of (3).

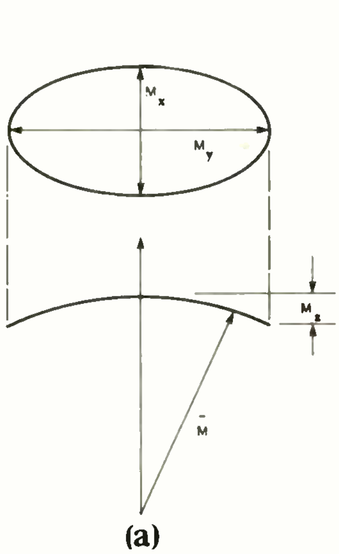

Fig. 1—Precession of the magnetization about the dc magnetic field direction. (a) is for the case $|m_x| \neq |m_y|$ and (b) is for $|m_x| = |m_y|$.

The simplified theory presented here is easily extended to indicate that frequency mixing can also be accomplished using a ferrite. This is seen in (3) if the magnetic field h_z should have two components at different frequencies, then sum and difference frequency terms will be generated. Pippin[6] has elaborated on the implications of this frequency mixing.

Experimental Apparatus

As has been shown, the requirements for frequency doubling are a magnetized ferrite excited with an rf magnetic field linearly polarized in a plane perpendicular to the dc field. A coupling structure is required which will couple to the harmonic frequency and reject the fundamental frequency. The first structure used in the study of frequency doubling[1] consisted of an S-band cavity to generate high fields in a ferrite disk magnetized perpendicular to its plane, and fastened to one end wall. A wire loop encircled the ferrite, coupling the double frequency energy into a coaxial line. A high-pass waveguide filter eliminated any fundamental frequency energy which was picked up by the coupling loop. Using this setup, double frequency outputs of fractions of a milliwatt were generated from a peak fundamental power of several hundreds of watts. The output power was measured to be very closely a square-law function of the input power over a wide range of power levels. This cavity technique was abandoned because of the added complexity introduced by the requirement that the cavity be matched and tuned to resonance. The ferrite affected both these parameters, making adjustments very difficult.

A very successful configuration for doubling from 9 to 18 kmc is shown in Fig. 2. It consists of a ferrite rod, disk, or slab in an X-band section of waveguide magnetized along the direction of the rf E field. The ferrite generates K-band energy with an electric field polarization in the H plane of the X-band waveguide. A constriction in the E plane of the X-band guide on the generator side of the ferrite prevents the K-band energy from propagating towards the generator. On the load side of the ferrite the X-band waveguide is then narrowed in the H plane through a three-step transition to K-band waveguide, which is parallel but rotated 90° relative to X-band waveguide. All the generated K-band energy must propagate out the K-band waveguide which also filters out any X-band energy. A polystyrene slab in the H plane of the X-band waveguide and located on the generator side of the ferrite acts as a phase shifter for the K-band energy. It is tuned for maximum output from the ferrite.

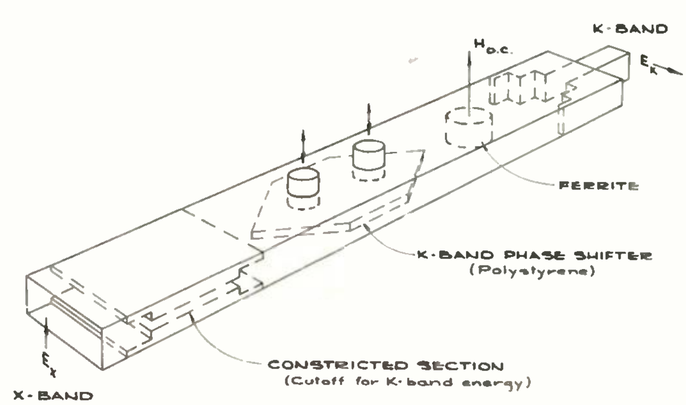

Fig. 2—Microwave plumbing required for the operation of the frequency doubler from X-band to K-band frequencies.

A block diagram of the apparatus is shown in Fig. 3. An isolator is required in the X-band setup to isolate the high vswr presented by the doubler when it is not properly tuned. In taking the measurements three parameters must be adjusted; the 9-kmc tuner, the 18-kmc tuner and the magnetic field.

[6] J. E. Pippin, "Frequency doubling and mixing in ferrites," Proc. IRE, vol. 44, pp. 1054–1055; August, 1956.

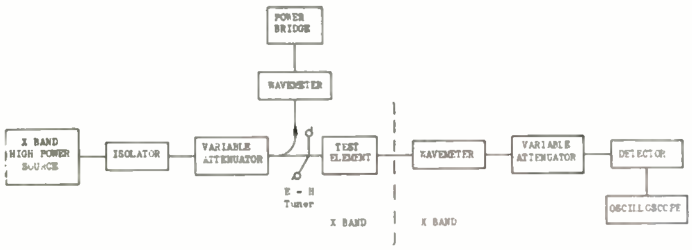

Fig. 3—Block diagram of apparatus for frequency doubling from 9 kmc to 18 kmc.

Measurements

Data were taken for each of the ferrite loading configurations indicated in Fig. 4. The thickness, lengths, and heights were varied in each case to maximize conversion efficiency. Also the ferrite material was varied using Ferramic R-1, Ferroxcube 106, and an experimental magnesium aluminate ferrite with a saturation magnetization of approximately 600. Of these, the Ferramic R-1 gave the best conversion efficiency. Using any geometry indicated in Fig. 4 a conversion efficiency of approximately −20 db or better was obtained.

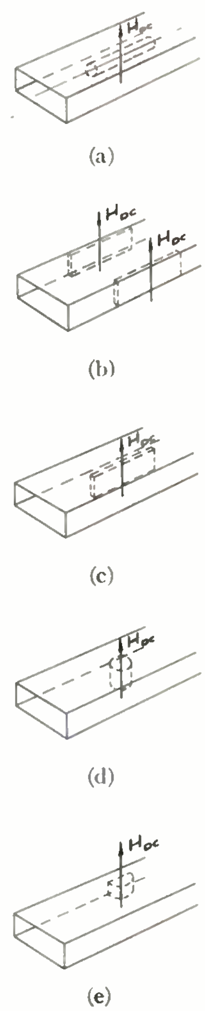

Fig. 4—Ferrite loading configurations used in the experiment. (a) Rod along axis of guide; (b) vertical slabs against sidewalls of guide; (c) vertical slab centered in guide; (d) vertical post centered in guide; and (e) half disk against sidewall of guide.

Data are shown in Fig. 5 for centered posts of Ferramic R-1 as a function of post height for $\frac{1}{4}$- and $\frac{1}{2}$-inch diameters. The data shows that conversion efficiency improves as post height increases and as post diameter increases. For large post heights there does not seem to be an appreciable difference in output when the diameter of the post is changed.

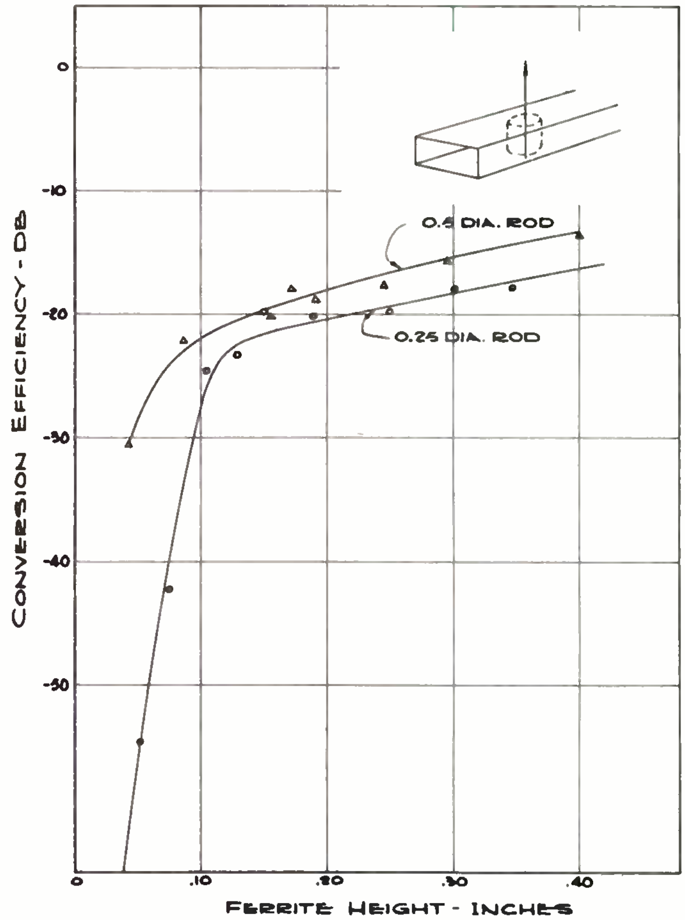

Fig. 5—Frequency doubling conversion efficiency as a function of post height for two post diameters. The input is 32-kw peak, prf—20 cps, and pulse width 0.8 microsecond.

Fig. 6 shows the data for the best geometry of those tried. It is an approximately semicircular segment of a $\frac{1}{2}$-inch diameter 0.20-inch thick Ferramic R-1 disk which is mounted against the side of the waveguide wall. Conversion efficiencies of −6 db were measured repeatedly for a 32-kw peak input. The curve of output power vs average imput power was measured by maintaining a constant peak power level while increasing the pulse repetition frequency. When this is done, it is seen that the peak power output increases slightly and then falls off considerably as the average power is raised. This is a result of heat altering the intrinsic properties of the material.

Doubling in Ferroxcube 106, which has a higher saturation magnetization than Ferramic R-1, was also investigated as a function of increasing average power. The peak output power increased slightly but never approached that obtained using Ferramic R-1. This

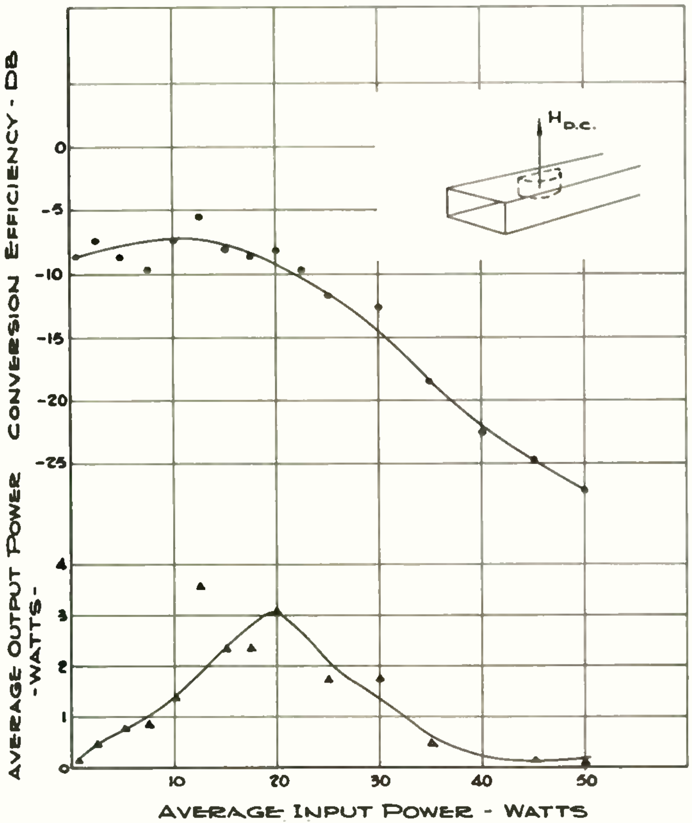

Fig. 6—Frequency doubling conversion efficiency and average power output as a function of average input power. Peak input power is constant at 32 kw. Pulse width is 0.8 microsecond and prf is varied. The geometry is a half disk of ferrite against the sidewall of the waveguide.

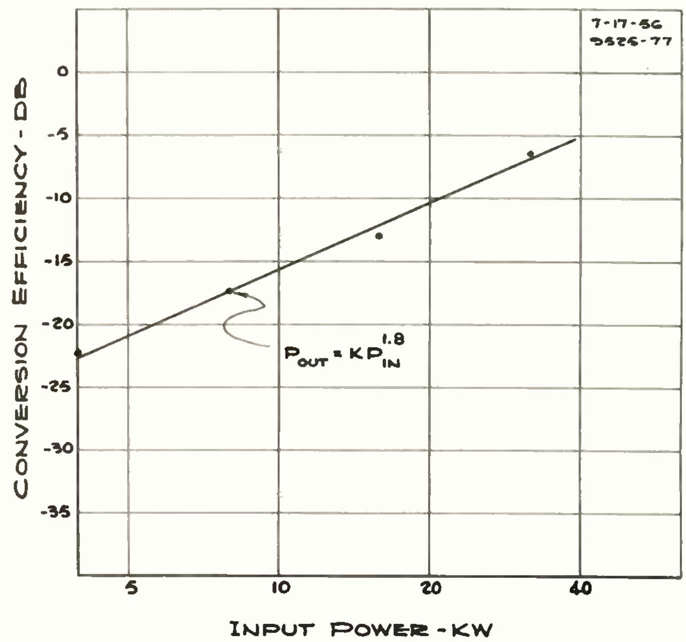

Fig. 7—Conversion efficiency as a function of peak input power. The straight line indicates a 1.8 law for the relation of the output to input peak power. At lower input powers the response is square law. The geometry is a half disk of ferrite against the sidewall of the waveguide.

may be due to the narrower linewidth of the R-1 material.

The average output power level is also shown in Fig. 6. It is seen that the average power output increases to a maximum of 3 watts at 18 kmc for an average input power of 20 watts at 9 kmc. For greater input power, the output decreases because of heating in the ferrite. In all these measurements, the magnetic field and tuning were optimized at each new average power level. This is necessary since the saturation magnetization of the material is dependent on the temperature and consequently on the average fundamental frequency power.

Fig. 7 shows a curve of the peak power output vs the peak power input, and indicates that the ferrite is operating according to a 1.8 law. At low power levels the doubler acts as a square-law device. This deviation from the square law suggests that a large percentage of energy is being converted to higher order harmonics. Preliminary measurements have verified the presence of these higher harmonics.

Conclusion

1) At high peak powers, frequency doubling in ferrites can be made more efficient than low-power doubling in crystals. The ferrite will stand higher average power and it is not irreparably damaged if overloaded.

2) The choice of ferrite geometry is extremely important for frequency doubling. The frequency conversion efficiency depends on sample shape and dimensions, as well as on its position in the waveguide.

3) For the geometries studied frequency doubling follows closely a square law response at low power levels and deviates to a 1.8 law response at a conversion efficiency of −7 db.

4) Frequency doubling in ferrites can be a practical means of generating high frequency microwave power.

5) Measurable power can also be generated in higher order harmonics than the second.

Acknowledgment

The authors are indebted to Marlowe Medina and A. B. Howard for making many of the microwave measurements.

Effects of Zero Ferrite Permeability on Circularly Polarized Waves*

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Summary—**Experimental data is presented describing the propagation characteristics of ferrites in the vicinity of zero permeability as seen by a wave which exhibits a positive sense of circular polarization of its microwave *H* vector. Detailed results derived in the 9000-mc region are given for a ferrite rod axially located in circular waveguide in which the TE_{11} circularly polarized mode is propagating. A theoretical treatment is also presented which predicts that the behavior of a ferrite rod so located in circular waveguide and biased to the zero permeability region can be made to expel practically all microwave energy from its interior. Experimental results verifying these predictions and an experimental setup used in obtaining a portion of these results are presented in detail. It is shown that similar behavior near zero permeability can be obtained from ferrite rods located in rectangular waveguide. The utilization of ferrites near zero permeability to obtain large nonreciprocal attenuations is discussed for the cases of low, moderate, and high loss ferrites.**

Introduction

IT HAS BEEN demonstrated by Polder[1] and Hogan[2] that if the imaginary part of the effective wave permeability of a ferrite is negligible at the proper value of magnetic biasing field, the ferrite can be made to exhibit a zero permeability to a wave which has a positive sense of circular polarization[3] (henceforth referred to as a positive wave), and a corresponding nonzero permeability to a wave of a negative sense of circular polarization (henceforth referred to as a negative wave). This would tend to indicate that differential interaction of positive and negative waves with a ferrite can be obtained under certain conditions in the low-field region.

A significant amount of information on field displacement effects of ferrite slabs located in rectangular waveguide near—or adjacent to—the narrow waveguide walls has appeared in the literature.[4–9] No discussion of this particular configuration will be found in this article. Also, some information on the behavior of ferrite rods in circular waveguide operating in the zero permeability region has appeared in the literature[10–13] but has concentrated mainly on the behavior of the negative wave with only limited attention devoted to the propagation of the positive wave. It is this latter wave which principally gives rise to interesting and valuable low-field effects.

A thorough study of the low-field behavior of ferrites on a variety of transmission lines propagating circularly polarized waves has been in progress in the Sperry laboratory.

It is the purpose of this paper to present the more pertinent results derived from this work on ferrites located in circular and rectangular waveguide in the region of microwave *H*-vector circular polarization.

In particular, the present paper will concentrate on describing the behavior of the positive wave and will also present some of the experimental results on negative wave behavior.

Experimental

The three measurement setups used in this investigation permitted the measurement of ferrite element absorption loss, ferrite reflection and depolarization loss, and waveguide wavelength in ferrite loaded circular waveguide propagating the TE_{11} circularly polarized mode.

Two of these systems are similar to those previously reported[2,14] and will not be described here. It suffices to state that these two systems were designed to permit measurements of losses introduced by the presence of the ferrites, and of ferrite phase shift. Each of the quantities could be measured using these systems, both as a function of externally applied magnetic field H_a and frequency.

The method of measuring the wavelength of circularly polarized waves propagating in a ferrite loaded circular waveguide immersed in a uniform magnetic

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1 D. Polder, "On the theory of ferromagnetic resonance," *Phil. Mag.*, vol. 40, pp. 99–114; January, 1949.

2 C. L. Hogan, "The ferromagnetic Faraday effect at microwave frequencies and its applications," *Rev. Mod. Phys.*, vol. 25, pp. 253–263, January, 1953.

3 The notation used here is the one where the positive component is the component which is rotating in the direction of the positive electric current which generates the dc magnetic biasing field.

4 B. Lax, K. J. Button, and L. M. Roth, "Ferrite phase shifters in rectangular waveguide," *J. Appl. Phys.*, vol. 25, pp. 1413–1421; November, 1954.

5 S. Weisbaum and H. Boyet, "A double-slab ferrite field displacement isolator at 11 kmc," Proc. IRE, vol. 44, pp. 554–555; April, 1956.

6 A. G. Fox, S. E. Miller, and M. T. Weiss, "Behavior and applications of ferrites in the microwave region," *Bell Syst. Tech. J.*, vol. 34, pp. 5–103; January, 1955.

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8 M. L. Kales, "Topics in guided-wave propagation in magnetized ferrites," Proc. IRE, vol. 44, pp. 1403–1409; October, 1956.

9 B. Lax, "Frequency and loss characteristics of microwave ferrite devices," Proc. IRE, vol. 44, pp. 1368–1386; October, 1956.

10 A. G. Fox and M. T. Weiss, "Discussion of the ferromagnetic Faraday effect at microwave frequencies and its applications," *Rev. Mod. Phys.*, vol. 25, pp. 262–263; January, 1953.

11 J. L. Melchor, W. P. Ayres, and P. H. Vartanian, "Energy concentration effects in ferrite loaded waveguides," *J. Appl. Phys.*, vol. 27, pp. 72–77; January, 1956.

12 P. H. Vartanian, J. L. Melchor, and W. P. Ayres, "Broadband ferrite microwave isolator," IRE Trans., vol. MTT-4, pp. 8–13; January, 1956.

13 N. Karayianis, and J. C. Cacheris, "Birefringence of ferrites in circular waveguide," Proc. IRE, vol. 44, pp. 1414–1421; October, 1956.

14 B. J. Duncan and L. Swern, "Temperature behavior of ferrimagnetic resonance in ferrites located in waveguide," *J. Appl. Phys.*, vol. 27, pp. 209–215; March, 1956.

field will be described in this article. The method to be described applies to a longitudinally magnetized ferrite rod axially located in circular waveguide propagating a TE_{11} circularly polarized mode.

Consider an unmagnetized ferrite located in a section of slotted circular waveguide. If the output end of the slotted line is terminated in a short circuit then, in the presence of an input linearly polarized TE_{11} mode, a large standing wave ratio will be set up in the region of the ferrite. Assuming negligible mode conversion the presence of the slot will not appreciably affect the waves in the vicinity of the ferrite. With the ferrite in the unmagnetized state the wavelength in the ferrite loaded waveguide can be determined by measuring the distance between two adjacent nulls. The wavelength thus obtained will be identical to that for a circularly polarized TE_{11} wave.

However, if the same ferrite is located in circular waveguide propagating the TE_{11} circularly polarized mode and longitudinally magnetized, the wavelength of both positive and negative waves in the section of ferrite loaded waveguide will change with magnetic field. Furthermore, the change will be different for each wave. This change in wavelength will be accompanied by a change in the phase shift of each wave. A measure of the phase shift, correlated with the wavelength at zero magnetic field, permits the determination of the wavelength at any value of H_a.

This can be seen very simply from the following analysis. Let λ_0 represent the ferrite loaded waveguide wavelength for the unmagnetized state. Similarly, let $\lambda_\pm$ be the waveguide wavelength and $\phi_\pm$ the phase shift of a positive and negative wave respectively. Now for H_a equal to zero

$$\lambda_0 = L\frac{360}{\delta}, \tag{1}$$

where L is the physical length of the ferrite in centimeters and δ is the electrical length in degrees of the section of unmagnetized ferrite loaded waveguide.

For H_a greater than zero, and with positive wave propagation, the electrical length δ_+ of the magnetized ferrite, is given as

$$\delta_+ = \delta - \phi_+ \text{ (degrees)}. \tag{2}$$

Hence, λ_+ is given by:

$$\lambda_+ = L\frac{360}{\delta_+} = L\frac{360}{\delta - \phi_+}. \tag{3}$$

From (1) and (3)

$$\lambda_+ = \frac{\lambda_0\delta}{\delta - \phi_+}. \tag{4}$$

Similarly, it can be shown for the negative wave that:

$$\lambda_- = \frac{\lambda_0\delta}{\delta - \phi_-}. \tag{5}$$

The quantities λ_0, δ, and $\phi_\pm$ are easily measurable quantities which can, in general, be obtained with a fair degree of accuracy. It should be noted, however, that ferrite end effects introduce a small error since the wavelength in the waveguide does not change suddenly from its value in the empty waveguide to its value in the ferrite filled region.

THEORETICAL

General

The differential interactions obtainable in the ferrite zero permeability region are directly attributable to the differential permeabilities exhibited by the ferrite to circularly polarized waves.[10,11] However, the magnitude of the interaction of either a positive or negative wave depends not only on the complex permeability of the ferrite but also on its complex dielectric constant. A brief analysis of microwave propagation in a saturated infinite ferromagnetic medium characterized by both a complex microwave permeability and a complex dielectric constant is presented in the following section. This theory is then applied in a general sense to ferrites of finite dimensions in waveguide.

Saturated Infinite Medium

Hogan[2] has shown that for propagation of circularly polarized waves of opposite senses of polarization in an infinite saturated ferromagnetic medium each wave is characterized by a different propagation constant. The equation relating the propagation constant for each of these waves $\Gamma_\pm$ to angular frequency ω, velocity of light c, ferrite dielectric constant ϵ and the effective wave permeabilities $\mu_\pm$ is given as:

$$\Gamma_\pm = \frac{j\omega}{c}(\epsilon\mu_\pm)^{1/2}. \tag{6}$$

Now $\mu_\pm$ and ϵ are both complex. Hence, (6) can be written as

$$\Gamma_\pm = \frac{j\omega}{c}\left[(\epsilon' - j\epsilon'')(\mu_\pm' - j\mu_\pm'')\right]^{1/2}. \tag{7}$$

The quantity $\Gamma_\pm$ can also be expressed in terms of an attenuation constant $A_\pm$ and a phase constant $B_\pm$ as follows:[15]

$$\Gamma_\pm = A_\pm + jB_\pm. \tag{8}$$

By squaring both (7) and (8), and then solving these equations for $A_\pm$ and $B_\pm$, equations relating $A_\pm$ and $B_\pm$ to quantities associated with microwave ferrite behavior are obtained in the following convenient forms:

[15] C. L. Hogan, "The ferromagnetic Faraday effect at microwave frequencies and its applications: the microwave gyrator," *Bell Sys. Tech. J.*, vol. 31, p. 1; January, 1952.

$$A_{\pm} = \frac{\omega}{c}\left\{\frac{[(\mu_{\pm}'\epsilon' - \mu_{\pm}''\epsilon'')^2 + (\mu_{\pm}'\epsilon'' + \mu_{\pm}''\epsilon')^2]^{1/2} - (\mu_{\pm}'\epsilon' - \mu_{\pm}''\epsilon'')}{2}\right\}^{1/2} \quad (9)$$

and

$$B_{\pm} = \frac{\omega}{c}\left\{\frac{[(\mu_{\pm}'\epsilon' - \mu_{\pm}''\epsilon'')^2 + (\mu_{\pm}'\epsilon'' + \mu_{\pm}''\epsilon')^2]^{1/2} + (\mu_{\pm}'\epsilon' - \mu_{\pm}''\epsilon'')}{2}\right\}^{1/2}. \quad (10)$$

Eqs. (9) and (10) can be used to describe the microwave propagation in any saturated infinite ferromagnetic medium.

Examination of these equations reveals the factors which determine the interaction of microwave energy with the ferrite. It can easily be seen that if $\mu_+'' \cong 0$, A_+ and B_+ will be zero near that value of magnetic field which renders $\mu_+' = 0$. Since at this same value of field μ_-' is large, B_- will be quite large under these circumstances. On the other hand, if $\mu_+'' \neq 0$, B_+ will never reduce to zero even though $\mu_+' = 0$. From the point of view of differential interaction effects ferrites fall into two main classes: those with $\mu_+'' \cong 0$ when $\mu_+' = 0$ (Class I), and those with $\mu_+'' \neq 0$ when $\mu_+' = 0$ (Class II). The placement of a ferrite in one class or another depends upon the saturation magnetization of the ferrite, its shape and direction of H_a, frequency, and the width of the absorption line. It should be noted that the existence of a dielectric loss does not prevent a ferrite from falling into Class I. As long as $\mu_+' = \mu_+'' = 0$, $A_+ = B_+ = 0$ regardless of the size of ϵ''. It is also significant to note that extremely small values of A_+ and B_+ are obtained in the negative permeability region between $\mu_+' = 0$ and gyromagnetic resonance.

Using (9) and (10) values of $A_{\pm}$ and $B_{\pm}$ were calculated for ferrites closely resembling Ferramics R-1 and H 419; at X band these ferrites fall into Class I. In each case $\mu_{\pm}'$ and $\mu_{\pm}''$ were calculated from equations given by Hogan;[2] in these equations the damping perameter was arbitrarily chosen to be 1.9×10^7 c/sec since in a polycrystalline ferrite no good theoretical method of accounting for effective damping has yet been proposed. While this is probably not the correct value for these ferrites it is sufficiently accurate for its intended use in this paper. The plots of $A_{\pm}$ and $B_{\pm}$ as a function of ferrite internal field H_s for the two mediums are shown in Figs. 1 and 2.

An analysis of these curves shows that practically no propagation of energy associated with a positive wave can occur inside either of the ferrites over a significant range in H_s. However, it is also shown that propagation of a negative wave inside a ferrite can occur. Since A_- is finite, it is expected that the negative wave will be attenuated; the magnitude of the attenuation encountered by this wave will be dependent upon μ_-', ϵ'', μ_-'', and ϵ''.

At frequencies below approximately 4000 mc the above and similar ferrites may no longer fall into Class I. This stems from the fact that magnetic losses associated with gyromagnetic resonance may be quite large at these frequencies in ferrites characterized by either an appreciable $4\pi M_s$ or a broad resonance linewidth, or both. In addition, when ferrites are operated at low frequencies, resonance may occur before the medium is completely saturated. If this is the case then no true zero or negative permeability effects can take place, and the ferrite may be placed essentially in Class II.

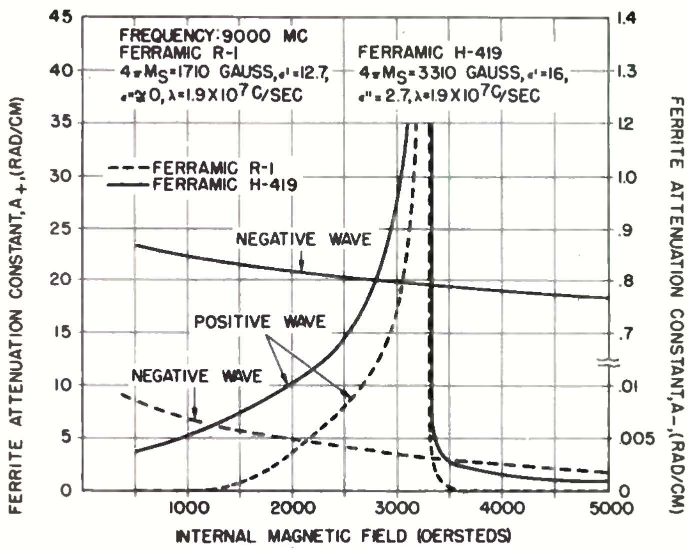

Fig. 1—Dependence of ferrite attenuation constant ($A_{\pm}$) on internal magnetic field (H_s) in ferramics R-1 and H-419.

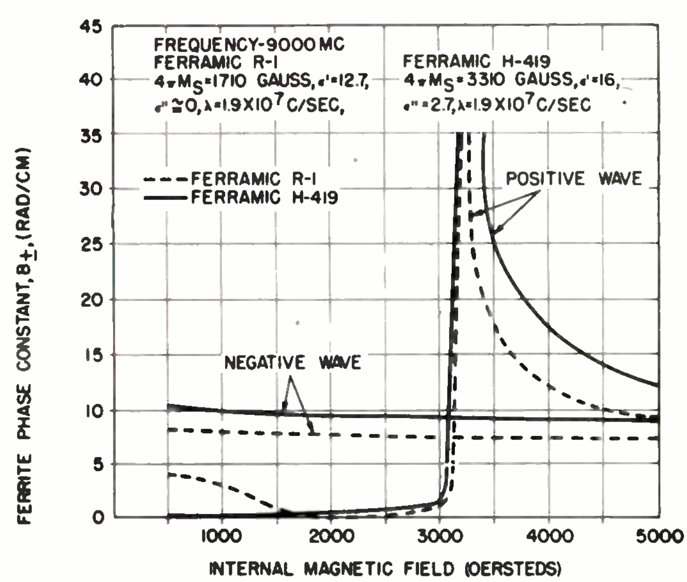

Fig. 2—Dependence of ferrite phase constant ($B_{\pm}$) on internal magnetic field (H_s) in ferramic R-1 and H-419.

Thus, as pointed out by Hogan[16] the phenomenon of zero permeability is not, in itself, a solution to the low frequency problem in ferrites, since at low frequencies both the positive and negative waves will interact with the ferrite. Only by making both the ferrite $4\pi M_s$ and resonance linewidth extremely small can a ferrite at low frequencies be classified as a Class I material. Of course, at very low frequencies a practical limit is reached beyond which a reduction in $4\pi M_s$ to maintain a low μ_+'' is no longer feasible. This represents the minimum frequency at which operation in the zero permeability region can be affected. No experimental data on Class II ferrites will be included in this article.

Finite Medium—Ferrites in Waveguide

The discussion thus far has dealt exclusively with propagation of circularly polarized waves in a saturated infinite medium. Also, the effects of damping were neglected in all calculations of $\mu_\pm'$. In practice, however, the infinite medium does not exist and, also, damping occurs. Despite these modifications, the above theory can be used in many cases, as those considered herein, to predict qualitative microwave effects which occur in practical applications. In addition, it can be used in many cases to obtain a general rather than a precise description of ferrite behavior under the particular conditions considered.

If infinite medium theory is to be applied as suggested above to the cases treated in this paper then the ferrite must represent only a small perturbation, and it must be located in a region where a sense of circular polarization of the microwave H vector exists. Also, it is required that H_i be replaced by its equivalent in terms of H_a and $4\pi M_s$. Equations relating H_i to these two quantities can be obtained from the literature.[17]

Experimental Results and Discussion

It is of particular importance to present detailed experimental data on the propagation characteristics of extremely low μ_+'' ferrites in waveguide operating near zero permeability. Even though theory shows that owing to the Poynting vector being extremely small, negligible propagation occurs in the ferrite itself, propagation of microwave energy through ferrite loaded waveguide can readily be made to take place. The behavior of microwave propagation in the ferrite loaded waveguide depends upon the waveguide and ferrite structures. Two cases which are of particular interest will be treated in this article, with the main emphasis on the first of these cases.

The first of these is the case of a ferrite rod axially located in circular waveguide in which propagation occurs in the TE_{11} circularly polarized mode (Fig. 3). An axial magnetic field of sufficient magnitude to

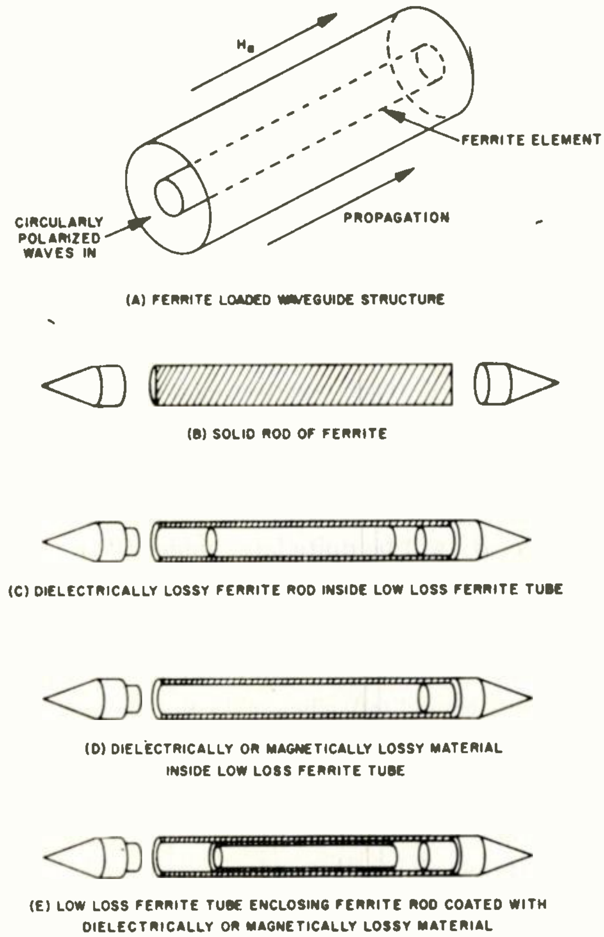

Fig. 3—Waveguide and ferrite element configurations used for zero ferrite permeability studies.

render $\mu_+'=0$ is utilized. Under these conditions it is shown experimentally that almost lossless energy transfer can be accomplished provided a thin ferrite rod is used. It is only required that the ferrite rod diameter be sufficiently small so that, if it were replaced by a metal rod of similar dimensions, propagation in the coaxial line TE_{11} circularly polarized mode could be affected.

The prediction that a large portion of the positive wave microwave energy is excluded from the ferrite under these circumstances and propagates almost exclusively in the space around it suggests that this configuration may exhibit certain characteristics similar to those exhibited by a section of coaxial line. To test the validity of this conclusion, a series of experiments was conducted including wavelength measurements in the ferrite loaded guide as previously described. The results obtained on wavelength in waveguide loaded with Ferramics H-419 and R-1, as a function of H_a are shown in Fig. 4. Similar results have been obtained on many additional ferrite samples of various types and diameters.

As suggested in the previous paragraph, for each ferrite λ_+ in the ferrite loaded waveguide passes through that value which characterizes a coaxial line with a metal center conductor whose diameter is equal to that of each ferrite. This is approximately the field at which

[16] Private communication between Dr. C. L. Hogan, of Harvard University, and the authors.
[17] C. Kittel, "On the theory of ferromagnetic resonance absorption," *Phys. Rev.*, vol. 73, pp. 155–161; January 15, 1948.

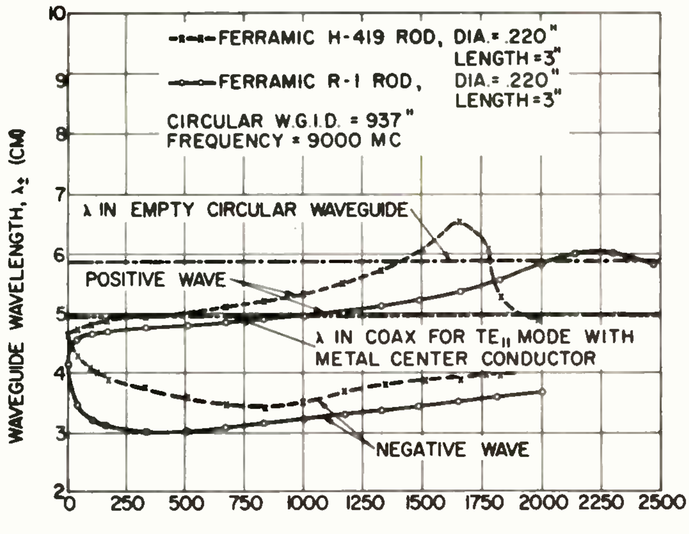

Fig. 4—Dependence on external magnetic biasing field of waveguide wavelength in circular waveguide loaded with ferramic H-419 and R-1.

minimum energy density exists in the ferrite for positive wave propagation. Besides, as H_a is further increased λ_+ eventually reaches and slightly exceeds λ for empty waveguide. This latter condition occurs at fields just below those required to produce gyromagnetic resonance.

The data of Fig. 4 indicates that the positive wave in the zero permeability region is largely excluded from the ferrite and travels in a modified TE_{11} coaxial mode. This is as might be anticipated from infinite medium theory. However, it will be shown later that the wave is not completely excluded since, if it were, it would not be circularly polarized in the vicinity of the ferrite. Thus there can probably only be an incomplete exclusion of this wave; *i.e.*, the tendency of the ferrite to expel the positive wave is not as large as one might anticipate from infinite medium theory, and there is a partial penetration at all fields. Since there is a finite interaction of the positive wave with the ferrite it is possible that perturbation theory might be used to gain a better insight into ferrite behavior in the zero permeability region than can be achieved from infinite medium theory. This is a subject of further investigations being conducted at Sperry. Also, the effects of λ_+ exceeding λ for empty waveguide, and λ_0 for Ferramic H-419 being greater than for Ferramic R-1, shown in Fig. 4 are under investigation.

In spite of the considerations of the previous paragraph it is useful in interpreting the observed ferrite experimental characteristics to regard the ferrite behavior in the zero permeability region as being of a semicoaxial line nature. Data to be presented later will demonstrate the extent to which this picture is valid.

The effect of the ferrite on the negative wave is appreciably different from that of the positive wave. For an H_a of the same value as that required for μ_+' equals zero, μ_-' has some value greater than unity. Also, the complex ϵ of the ferrite may be quite large. Thus it appears reasonable that the negative wave will strongly interact with the ferrite. Such a strong interaction is also clearly indicated by the data in Fig. 4, where it is shown that for negative wave propagation the ferrite loaded waveguide wavelength is much less than for positive wave propagation. One might reasonably expect the differential wavelength $\Delta\lambda$ to be greater in Ferramic H-419 than in Ferramic R-1. The smaller value of $\Delta\lambda$ recorded here for the former is probably owing to the larger mode distortion that might be expected to occur for Ferramic H-419. The anticipated larger mode distortion in this ferrite arise from the larger $\mu_+\epsilon$ product which characterizes it.

Under the most ideal conditions of ferrite diameter and operating frequency it is feasible that the negative wave is almost entirely concentrated inside the ferrite. This can be seen from an analysis of the equation relating effective ferrite rod diameter to its electrical and physical characteristics. It can be shown that a ferrite rod will have an effective propagating diameter a' given by

$$a' = (\epsilon\mu_\pm)^{1/2}a \tag{11}$$

where a is the ferrite diameter and ϵ and $\mu_\pm$ are the quantities previously defined. For a typical ferrite of a diameter approximately one-fourth that of the i. d. of the waveguide in which it is located the effective ferrite propagating diameter and waveguide i. d. will be about the same. Thus, it is to be expected that the ferrite will behave as a waveguide with almost total transmission of microwave energy for the negative wave inside the ferrite in a dielectric mode.

A ferrite will, in general, be characterized by a finite loss. Thus, for propagation of the negative wave in a dielectric mode inside the ferrite, it is anticipated that the wave will be attenuated, the degree of attenuation being dependent upon the dielectric and magnetic lossiness of the medium and the magnitude of the interaction of the negative wave with the ferrite. The attenuation characteristics of a Ferramic H-419 rod (Fig. 3) near zero permeability to positive and negative waves are shown in Fig. 5. The measured differential attenuation $\Delta\alpha$ of the two waves is in excess of 50 db, with only 0.7 db attenuation of the positive wave. The positive wave attenuation (α_+) near zero permeability is small owing to the small energy density of this wave in the ferrite. As in the case of λ_+ in this same region, perturbation theory can possibly be used to calculate α_+ to a reasonable degree of accuracy. Also, some information on α_+ can be obtained from infinite medium theory. However, it should be noted that a true representation of ferrite attenuation in the zero permeability region for the cases considered herein probably cannot be obtained from either perturbation theory or infinite medium theory. Once again, it is convenient to rely on the coaxial line picture to describe the observed results. Using this picture it can be shown that a small microwave energy density exists in the ferrite particularly in the surface region and can, in essence, be considered to

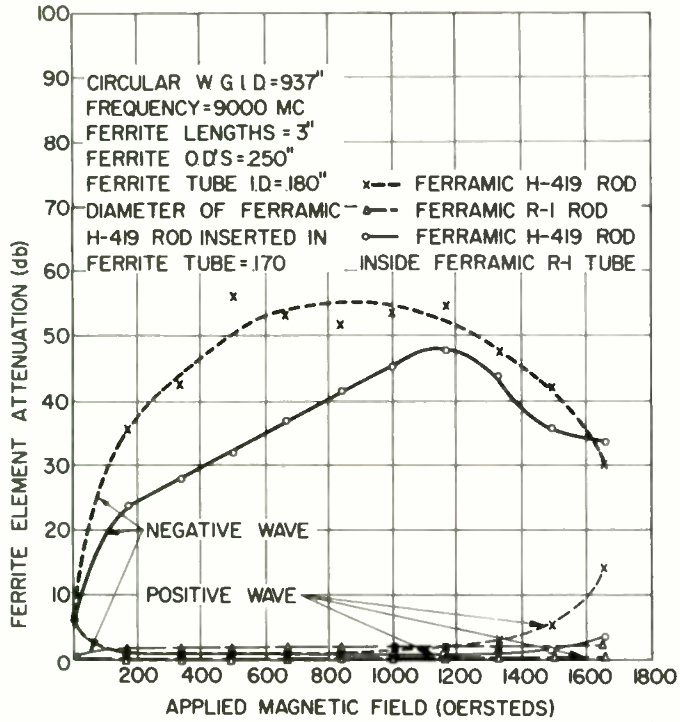

Fig. 5—Dependence of attenuation characteristics of ferrite in circular waveguide on external magnetic biasing field for (a) a solid rod of ferramic H-419, (b) a solid rod of ferramic R-1, and (c) a rod of ferramic H-419 inside a ferramic R-1 tube.

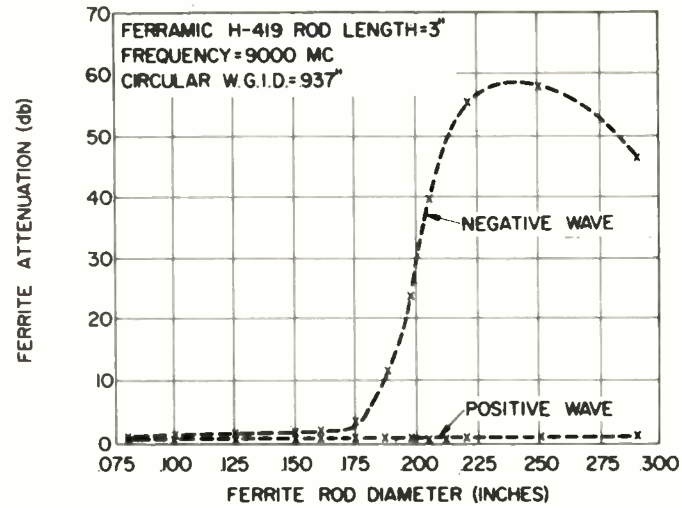

Fig. 6—Dependence on ferrite rod diameter of differential attenuation characteristics of ferramic H-419 in circular waveguide biased near zero permeability.

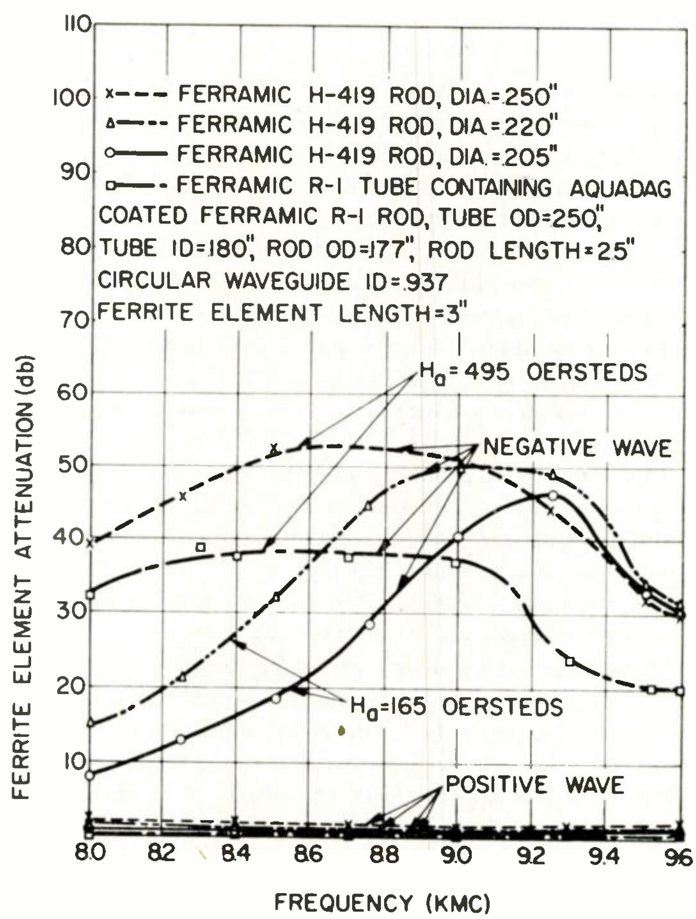

Fig. 7—Dependence on frequency of the differential attenuation characteristics of (a) solid rods of ferramic H-419 of various diameters and (b) a ferramic R-1 tube filled with an aquadag coated rod of ferramic R-1.

correspond to a "skin effect." Correspondingly, the finite α_+ can be considered to be in part a "skin loss" and the depth of interaction a "skin depth." The large negative wave attenuation (α_-) can be attributed to the moderately lossy nature of Ferramic H-419 (*i.e.*, $\epsilon'' > 0$) and the concentration of a propagating wave inside the ferrite.

The dependence of α_+ and α_- on ferrite rod diameter is clearly demonstrated in Fig. 6. It is significant to note the sharp decrease in α_- as the diameter of the ferrite rod is decreased from 0.225 inch to 0.175 inch. This is due to the decrease in microwave energy concentration inside the ferrite. For ferrite rod diameters below 0.175 inch propagation no longer occurs in a dielectric mode and, as a result, $\Delta\alpha$ is drastically reduced for smaller diameter rods.

The frequency dependence of the nonreciprocal attenuation characteristics obtainable in the zero permeability region is demonstrated in Fig. 7. As anticipated from (9) and (10) a rather broad-band effect is obtained provided (11) is satisfied at all frequencies over the band. However, as noted in Fig. 7, the use of an undersized ferrite rod will cause a sharp decrease in α_-. Also, the use of an oversized rod will cause an increase in α_+. Hence, for optimum performance (11) should just be satisfied at a frequency just below the lowest frequency in the desired operating band.

It has been reported previously that the differential attenuation characteristics obtainable in Ferramic H-419 at zero permeability are temperature dependent.[14] Furthermore, it was indicated that this temperature dependence stems chiefly from the dependence of ferrite $4\pi M_s$ and ϵ on temperature. The decrease in $4\pi M_s$ with temperature causes a large decrease in negative wave interaction with the ferrite and hence a decrease in α_-. The increase in ϵ'' causes α_+ to increase. This is chiefly an increase in ferrite skin loss.

Measurements of α_+ and α_- in a Ferramic R-1 rod (Fig. 3) revealed very little attenuation of either wave (Fig. 5). This is due to the practically lossless nature of this ferrite. Thus, even though the negative wave energy density in the ferrite is large it encounters only a very small attenuation; of course, the positive wave is attenuated even less because of its lower energy density.

In order to obtain a more detailed picture of the field distribution inside a ferrite rod in the zero permeability region, a series of experiments were performed with tubes of ferrite filled with various materials. The results of these experiments are described below.

In the first experiment a tube of Ferramic R-1 was filled with a rod of Ferramic H-419 [Fig. 3 (c)]. In this case a large differential loss was obtained, as anticipated, with an extremely low α_+ (Fig. 5). Similar results were obtained when the Ferramic H-419 was replaced by other high ϵ'' ferrites such as Ferramic C-159. The plotted results arise from the fact that Ferramic R-1 is a low-loss ferrite while Ferramic H-419 is characterized only by high dielectric losses. As such, both ferrites are in Class I and tend to exclude a positive wave and enhance the interaction of a negative wave. In addition, the low-loss Ferramic R-1 exhibits an almost undetectable α_+, owing to its practically lossless nature. The data in Fig. 5 verifies the anticipated condition of only a small penetration of the positive wave through the low-loss Ferramic R-1 shell and, therefore, little interaction of this wave with the moderately lossy Ferramic H-419 rod. Conversely, the negative wave penetrates the ferrite shell and interacts strongly with the ferramic H-419 rods. Consequently, it undergoes a large attenuation.

In the second experiment data was obtained on the following four ferrite configurations: a) a tube of Ferramic R-1 coated internally with aquadag, b) a tube of Ferramic R-1 filled with polyiron, c) a tube of Ferramic R-1 filled with an aquadag coated rod of R-1, and d) a tube of Ferramic R-1 filled with a polyiron coated rod of R-1. This experiment was devised to investigate the relative sizes of microwave electric and magnetic fields inside a ferrite rod and to determine the roles played by the ferrite tube and rod in excluding the positive wave energy. The results of this experiment are given in Fig. 8 and will be discussed in the following paragraphs.

Data on α_+ and α_-, each as a function of H_a, for the Ferramic R-1 tube internally coated with aquadag [Fig. 3(a) and (d)] shows some differential attenuation (Fig. 8). However, α_+ for this configuration is quite large. When the aquadag was removed and the tube was filled with powdered polyiron $\Delta\alpha$ was observed to be extremely small and α_+ again was very large. The large α_+ in both cases indicates that the ferrite skin depth exceeds the ferrite wall thickness and, hence, a finite energy exists inside the ferrite tube for the positive wave. The small $\Delta\alpha$ obtained in each case is owing to the small value of the ferrite element $\Delta\mu\epsilon$ product.

The removal of the internal coat of aquadag and the subsequent insertion of an aquadag coated Ferramic R-1 rod inside the ferrite tube [Fig. 3(a) and (c)] results in an appreciable smaller α_+ and an enhanced α_- (Fig. 8). The reduction of α_+ occurs as a result of the rod aiding in the exclusion of the positive wave and, consequently, in the reduction in the ferrite element skin depth. This reduces the interaction of the positive wave with the aquadag and hence reduces the loss. The increase in α_- is due to the ferrite rod enhancing the penetration of the negative wave into the aquadag.

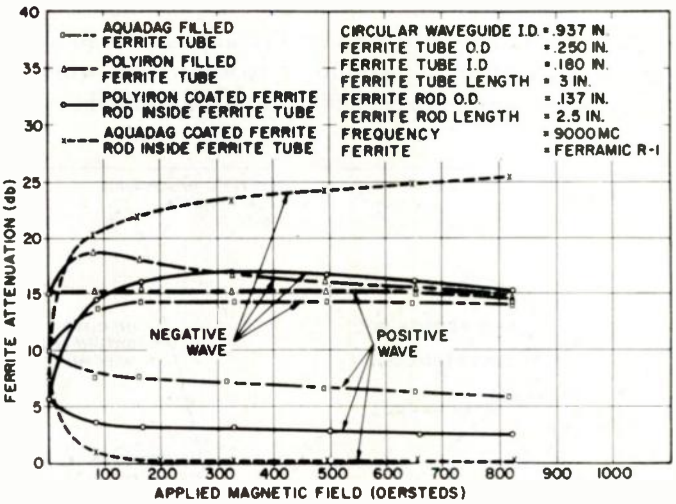

Fig. 8—Attenuation characteristics of (a) a tube of ferramic R-1 filled with aquadag, (b) a tube of ferramic R-1 enclosing an aquadag coated rod of ferramic R-1, (c) a tube of ferramic R-1 filled with polyiron, and (d) a tube of ferramic R-1 enclosing a rod of ferramic R-1 surrounded by polyiron.

Similar tests performed using this same ferrite structure, but with the aquadag coating replaced with powdered polyiron inserted in the region between the ferrite rod and tube [Fig. 3(a) and (e)] revealed a much larger interaction of the positive wave with the ferrite element. This is reflected in the smaller $\Delta\alpha$ and larger α_+ obtained for this case (Fig. 8).

Using the experimental results derived from both the aquadag and the polyiron experiments, coupled with the previously derived theory of ferrite behavior near zero permeability several important conclusions can be derived. It is well known that aquadag is electrically lossy only while polyiron is both electrically and magnetically lossy. Hence, the data in Fig. 8 using aquadag indicates that the microwave electric field is almost totally excluded from a ferrite rod in the zero permeability region. This data alone reveals little or no information on the effects of the ferrite on the positive wave magnetic field. However, the use of the magnetically lossy polyiron indicates a high degree of interaction of the positive wave magnetic field with a ferrite rod even at zero permeability. That this is indeed the case has also been shown theoretically.[18] The magnetic field

[18] C. L. Hogan, Progress Rept. No. 2, from Harvard University to AFCRC on Contract No. AF19(604)–1084; August–October, 1955.

quantities inside the ferrite rod associated with positive wave propagation have been calculated and are plotted in Fig. 9. As shown, the microwave magnetic flux B inside the ferrite rod actually passes through zero whereas both the internal microwave magnetic field H and the microwave magnetization M have nonzero values from zero field to resonance. That B actually passes through zero is owing to the 180° phase relationship between M and H. It is also significant to note that B equals zero in a thin ferrite rod at approximately the same applied field as required for μ_+' equals zero in the infinite saturated medium case. Similar results were indicated in Fig. 2 where μ_+' equals zero for Ferramic R-1 is shown to occur in the infinite medium at 1650 oersteds while B_+ approaches zero between 2000 and 2200 oersteds.

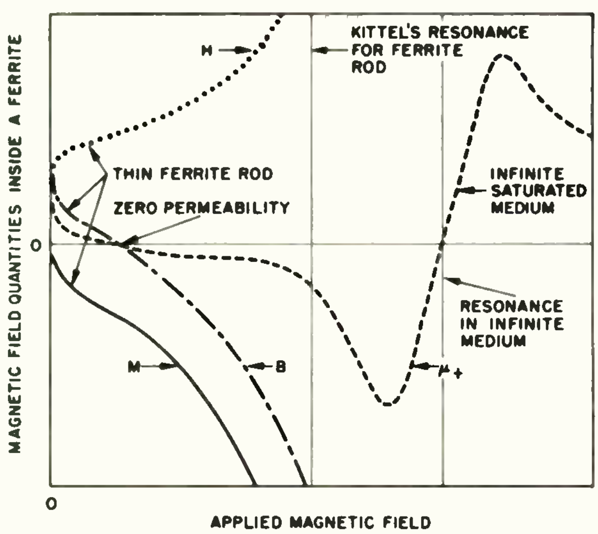

Fig. 9—Typical plot of the dependence of the microwave internal magnetic field (H), flux density (B), magnetization (M), and permeability (μ_+) on H_{dc}.

It is significant to note in Fig. 7 the inherent broadband attenuation characteristics of the ferrite element configuration of Fig. 3(e) when using aquadag. As indicated in the figure α_- remains greater than 20 db and α_+ is less than 0.5 db over the entire frequency range of 8.0 to 9.5 kmc. The magnetic biasing field in this case is approximately 495 oersteds.

By use of the theoretical information and experimental data reported herein an approximate mode configuration in the ferrite loaded waveguide near zero permeability can be derived. Of particular significance in this respect is the data on waveguide wavelength (Fig. 4) and ferrite attenuation (Fig. 8). Since the microwave electric field is excluded from the ferrite and the microwave magnetic field interacts with the ferrite, it is reasonable to expect that these mode configurations will be shown in Fig. 10(a). As shown the microwave magnetic field will be everywhere parallel inside the ferrite rod and everywhere perpendicular to the microwave electric field outside the ferrite except for fringing at the ferrite surface.

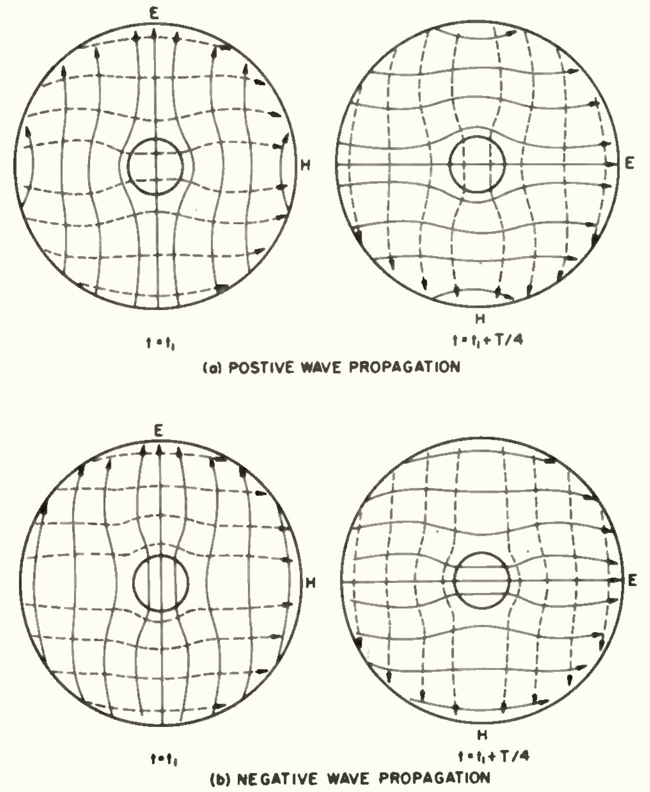

Fig. 10—Probable microwave field configuration in a section of ferrite loaded circular waveguide in which microwave energy is incident in the circularly polarized TE_{11} mode.

The strong negative wave interaction with the ferrite suggests the mode configuration shown in Fig. 10(b). This mode configuration assumes propagation in the TE_{11} circularly polarized mode with negligible higher order mode generation. This mode picture is derived on the basis that the ferrite ϵ is sufficiently large compared with the ferrite μ so as to be the controlling factor in determining the mode configuration. As shown, with $\epsilon \gg \mu$, the microwave H field may actually tend not to concentrate in the ferrite owing to the overriding effect of a large ferrite ϵ.

It is also very significant to examine the above results as related to the manner in which the ferrite near zero permeability affects the microwave H-vector ellipticity across the waveguide. In the absence of the ferrite the axial ratio of the microwave H vector is practically unity over a large cross sectional area near the center of the waveguide (Fig. 11). However, the presence of the ferrite near zero permeability will alter the axial ratio of the microwave H vector, the predicted manner being as also shown in Fig. 11. The increase in wave ellipticity at the ferrite surface can be seen by analyzing the H-vector amplitudes [Fig. 10(a)] at quarter period intervals for any point on the surface. It is immediately evident that the H-vector amplitudes will be different and, hence, the wave will be elliptically polarized.

This predicted field pattern, with an appreciable wave ellipticity at the ferrite surface suggests that there is also some penetration of the positive wave electric field

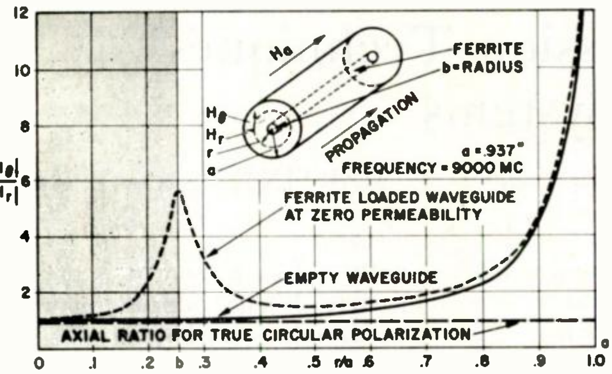

Fig. 11—Axial ratio across a cross section of circular waveguide of the microwave H-vector components giving rise to a sense of circular polarization along the direction of propagation of the circularly polarized TE_{11} mode.

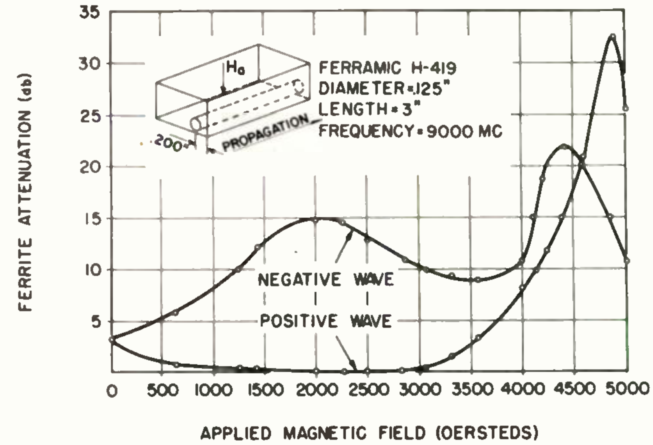

Fig. 12—Attenuation characteristics near zero permeability of ferramic H-419 in rectangular waveguide.

into the ferrite surface even in the $\mu_+'=0$ region. This suggestion is confirmed by the data shown in Fig. 8. Using the coaxial line picture, this finite penetration can, in essence, be considered as a "skin effect." It is the presence of this skin effect, and a finite ϵ'', in Ferramic H-419 that in part gives rise to a finite α_+ (Fig. 5). Similarly, if the Ferramic R-1 tube wall thickness is very thin (Figs. 5 and 8) this "skin effect" will serve to enhance α_+. This is due, in this case, to the presence of aquadag near the ferrite surface.

It should also be noted that, in most cases reported herein, brass metal tapers were used on the ends of each ferrite element (Fig. 3). In each case the tapers aided in the reduction of forward wave loss by helping launch the modified coaxial line TE_{11} circularly polarized mode. This served to reduce reflection loss and TM_{01} mode generation. These tapers can likewise be constructed of soft iron plated with a metallic conductor, or of permanent magnet material likewise metallic plated. When so constructed, they tend to reduce the applied field required for $B_+ \cong 0$.

Differential attenuation characteristics similar to those obtained in circular waveguide likewise can be made to exist in rectangular waveguide. It is only necessary that a low μ_+'' and a moderate to high ϵ'' ferrite be located in one of the planes of circular polarization of the microwave H vector, and subsequently magnetized to zero positive wave permeability by a magnetic field oriented parallel to the microwave E vector.

The results obtained for a pencil rod of Ferramic H-419 in rectangular waveguide are shown in Fig. 12. The data, for a 0.125 inch diameter rod, selected from a large group of ferrites to obtain the largest $\Delta\alpha$, adequately demonstrates the zero permeability effect. As indicated, optimum attenuation characteristics are obtained for an H_a of approximately 2000 oersteds. The difference in the values of H_a for the circular and rectangular waveguide cases are due to the different demagnetizing factors which characterize the two situations. Even more significant differential attenuation characteristics than those shown in Fig. 12 have been obtained without ferrite selection with a low loss—large ϵ—dielectric material located in the vicinity of the ferrite in a manner similar to that suggested by Weiss.[19]

Conclusion

A ferrite located in a region of microwave H-vector circular polarization, and magnetized near zero permeability, can, subject to the conditions previously described, be regarded as behaving similar in certain respects to that of a metal; *i.e.*, it can be made to exclude a microwave electric field and to exhibit a skin effect and skin loss. This is especially true for the case of a ferrite rod when used as a center conductor in coaxial line propagating a TE_{11} circularly polarized mode. A ferrite so located can be made to almost completely expel a positive wave, *i.e.*, reduce the Poynting vector inside the ferrite to a very small value, whereas a negative wave can be made to interact very strongly with the ferrite. In fact, the negative wave can be made to propagate in a dielectric mode inside the material.

The above ferrite behavior can be used in conjunction with microwave dielectrically lossy materials to obtain large nonreciprocal attenuations at low applied fields with very low forward (positive) wave loss. This behavior can be obtained over large bandwidths due to inherent broad-band behavior of the ferrite element. These effects can be obtained in both circular and rectangular waveguide. In actuality, they can probably be obtained in any structure exhibiting positive and negative senses of circular polarization in the ferrite region.

Acknowledgment

The authors wish to express their indebtedness to Dr. K. Tomiyasu and Dr. R. E. Henning for their generous contributions, and to Professor C. L. Hogan for his very enlightening contribution in discussions on this subject. Gratitude is also expressed to R. Mangiaracina and P. Iassogna for significant contributions in obtaining much of the experimental data reported herein.

[19] M. T. Weiss, "Improved rectangular waveguide resonance isolators," IRE Trans., vol. MTT-4, pp. 240–243; October, 1956.

Binary Data Transmission Techniques for Linear Systems*

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Summary—**The linearity and highly stable frequency characteristics of modern single-sideband equipment make possible improvements in the frequency spectrum utilization and performance of binary data transmission systems.**

Problems associated with fully utilizing the binary data transmission potential of an SSB voice channel are discussed. These problems include consideration of frequency and phase stability of the SSB equipment and the propagation media, multipath reception of signals, delay distortion within the voice channel, maximum performance in the presence of noise, and maximum spectrum utilization.

Equipment designed to transmit 3000 bits per second over a SSB voice channel is described. Comparative performance data with standard systems are included.

RECENT DEVELOPMENTS in radio communication systems permit a change in data transmission philosophy, allowing the system design to be primarily concerned with the propagation media without the many compromises previously required to accommodate the deficiencies of the associated radio equipment.

In particular, recent advances in single-sideband transmission techniques provide practical radio circuits of greatly improved linearity and frequency precision. Oscillators with stabilities of approximately 1 part in 10^8 per day are in use, linear amplifiers providing high power with low distortion have been designed, special filters have been developed for sideband separation, and methods have been devised to stabilize the heterodyne frequencies by locking them to precision oscillators.

Single-sideband systems can now provide a linear communication link between two points, and the precision oscillators make it possible to establish time and frequency synchronization at both terminals, permitting the use of improved methods of binary data transmission.

Of the many factors governing the choice of modulation methods for long range high frequency (hf) communications the following are among the most important:

1) Performance in noise and interference.
2) Ability to work through multipath.
3) Spectrum conservation.

All three of these are improved by narrowing the received band to a minimum consistent with the information content and coding of the transmitted information.

The nature of binary transmission is such that the only information which needs to be transmitted is that of MARK or SPACE for each element, since the length of time, shape, or nature of each element is pre-established for a given system. Binary information may be encoded in the plus or minus variations of a single parameter of the signal. The object of the receiving terminal therefore need be only to determine whether a MARK or SPACE has been transmitted.

Optimum filtering of a pulse in the presence of white noise is obtained by multiplying the pulse by a stored weighting function identical in form to the transmitted pulse and coincident with it in received time. Integration of this product over the period of the weighting function yields a result proportional to and having the sign of the transmitted pulse.

Weighting functions most commonly used are those of LC or mechanical filters and necessarily only approximate the desired form. W. H. Wirkler has suggested[1] kinematic and hybrid kinematic and dynamic methods for construction of the receiving weighting function.

The use of kinematic filtering methods provides the designer with complete control of the weighting function. This control has been used to provide matching of the incoming signal for performance in noise and to provide nominally zero crosstalk between properly placed keyed tones in a frequency division system. This allows the construction of practical equipment capable of approaching closely both the theoretical transmission limit of $2B$ measurements per second in band B and the theoretical limit for performance in white noise.[2]

In the system to be described, information is encoded in the transmitted signal in the form of phase reversals or lack of reversals between subsequent elements of a pulse train.[3] A gated resonator is used to accumulate and properly weight plus and minus contributions of the received signal within each pulse. The relative phase of adjacent pulses is obtained by comparing the after-rings of a pair of resonators storing these pulses.[4]

High frequency SSB signals suffer distortion resulting from multipath and from unequal delays across the pass band of the sideband separation filters. To cope with this distortion it is necessary to transmit pulses which are long compared with the distortion expected. Typical hf

* Original manuscript received by the IRE, September 4, 1956; revised manuscript received February 1, 1957.

† Collins Radio Co., Burbank, Calif.

[1] An unpublished paper of W. H. Wirkler (April 12, 1949) discussed detection methods applied to telegraph signaling.

[2] B. M. Oliver, J. R. Pierce, and C. E. Shannon, "The philosophy of pcm," PROC. IRE, vol. 36, pp. 1324–1331; November, 1948.

[3] M. L. Doelz, "Special Techniques for Detection in Noise," Collins Eng. Rep. (CER-W272), Burbank, Calif., presented at IRE Subsection, Monmouth County, N. J.; January 21, 1953.

[4] A. A. Collins, "Predicted Wave Signalling-Kineplex," presented at IRE Section, Dallas, Texas; December 16, 1954.

multipath distortions of 1 to 3 milliseconds make pulse lengths of 10 to 20 milliseconds desirable.

Where the radio frequency channels are restricted to a relatively narrow bandwidth, as is the case in hf and wire line systems, frequency division multiplexing offers the greatest data carrying capacity by minimizing the required guard bands at the channel edges, while synchronous detection within the band permits close spacing and independent separation of the multiplexed tones.

A binary communication system has been designed based on these ideas, capable of providing 3000 bits per second of data in an SSB voice channel. The name Kineplex has been adopted for the system because of the kinematic aspect of the filtering and detecting process. The receiving equipment has stored in it detailed information as to the form of the expected signal. This information is used in the detection process to an extent consistent with the characteristics of hf propagation. Data is transmitted by means of multiple tones in the voice band, each tone carrying two independent subchannels. A separate tone is transmitted to provide synchronizing information.

Information is contained in the relative phase of two adjacent pulses (Fig. 1). Subchannel 1 is carried as a phase reversal between adjacent pulses (0° for a MARK and 180° for a SPACE). The second subchannel is carried in a 90°, or quadrature, relation to the first (+90° for a MARK and −90° for a SPACE). The resultant signal has an amplitude of $\sqrt{2}$ times either subchannel and one of the four possible values of phase shown. The output signal for one or for two channels is a tone of constant center frequency with phase discontinuities occurring between pulses. Twenty tones, at different frequencies, are multiplexed to provide the 3000 bit per second capacity. The frequency spacing between tones is determined by the detector characteristics. The tones are at audio frequency and the composite output may be fed directly to the voice channel input of an SSB exciter.

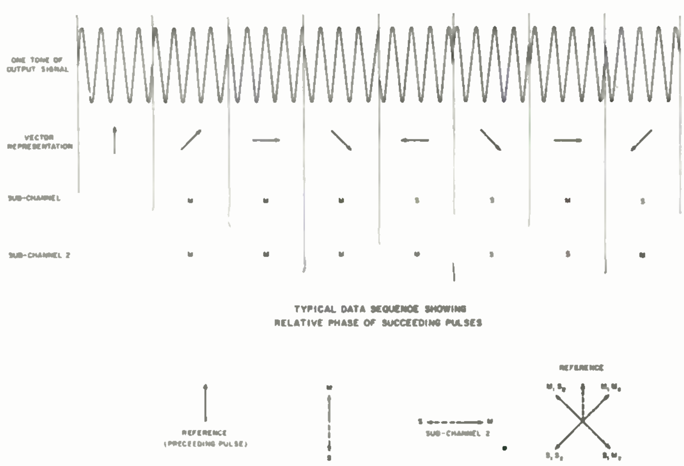


Fig. 1—Phase coding scheme.

At the receiver the SSB equipment translates the received signal back to audio frequency. Detection circuitry at each tone frequency measures the relative phase of successive pulses and reforms the MARK-SPACE code as it appeared at the transmit terminal input.

The method used to make this phase comparison is shown in Fig. 2. Starting at rest, with no previous information in storage, the first received pulse is gated into the high Q resonant circuit, resonator 1. The circuit responds to the signal energy at the resonator frequency and at the end of the received pulse period has an amplitude proportional to the input pulse amplitude and a phase corresponding to the phase of the input signal. The input gate is then closed and the resonator used to store this amplitude and phase information.

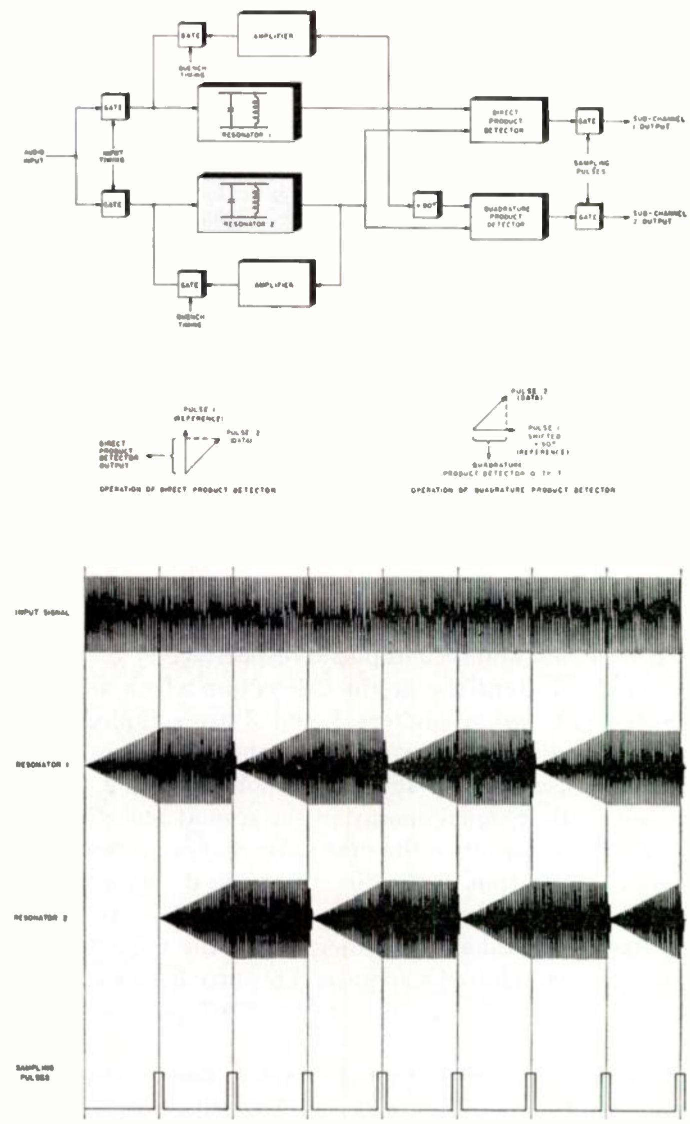


Fig. 2—Detection system.

The second pulse is admitted to resonator 2 which accumulates the amplitude and phase information associated with the second pulse. At the end of this pulse the

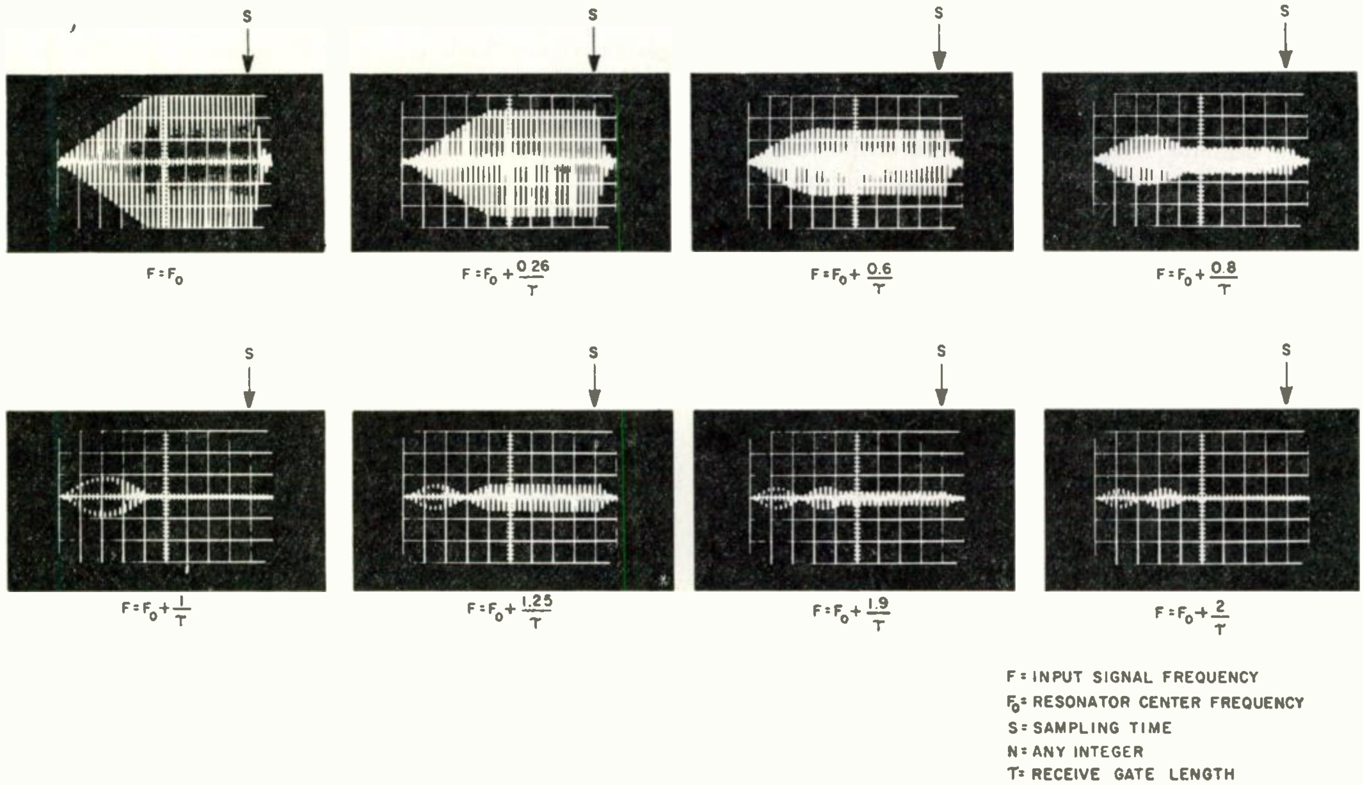


Fig. 3—Effect of variation of input frequency on resonator amplitude at sampling—orthogonal points at f_0+N/γ.

input gate is closed. The two resonators now store the integrated amplitude and phase information associated with the first and second pulses respectively.

At this instant the product detectors which are connected between resonators 1 and 2 are sampled. The direct product detector output is the projection of the second pulse on the first pulse as shown in Fig. 2. It can be noted that signal energy in the second pulse shifted $\pm 90°$ with respect to the first pulse makes no contribution to the output of the direct product detector.

The quadrature product detector, with the first pulse shifted $+90°$ takes the projection of the second pulse on this $+90°$ shifted reference. This product detector is insensitive to signal energy at 0° or 180° with respect to the first pulse.

Immediately following the sampling pulse the quench gate is opened around resonator 1 causing strong negative feedback to drive the stored energy to essentially zero in a time quite short compared with the transmitted pulse length. The quench gate is then closed and the input gate opened to admit the third pulse to the resonator. The comparisons between the second and third pulses are then made and resonator 2 quenched prior to admitting the fourth pulse. This procedure is continued on down the incoming pulse chain. An auxiliary circuit is used to permit the reference and data pulses alternately to be shifted 90° in the quadrature channel rather than to provide gating to switch reference pulses to one input. It should be noted that each pulse affects only two successive measurements, thus requiring phase continuity over only this period of time.

In determining the frequency spacing to be used between the multiple tones it is necessary to observe an additional characteristic of the detector. As the input frequency is varied from the center frequency of the resonator the phase change during the pulse period causes interference between the instantaneous driving signal and the signal stored in the resonator by earlier contributions. This is shown in Fig. 3. At a frequency separated from the resonator center frequency by the reciprocal of the receive gate length, τ, this interference causes the stored energy to be zero at the time the gate closes. This phenomena is repeated at frequency differences of $2/\tau$, $3/\tau$, $\cdots$, etc. If additional tones are placed at frequencies corresponding to these zeros, or orthogonal points, no crosstalk results between channels. The system could then use tones spaced at frequency intervals corresponding to $1/\tau$ cycles per second (cps) with each tone carrying $2/\tau$ bits per second. Thus in a bandwidth B, $B\tau$ tones could be placed, neglecting guard bands. In time t the potential data rate of the system is then $2Bt$ bits. This corresponds to the maximum number of independent measurements in band B and time t given by Oliver, Pierce, and Shannon.[2]

A part of the potential data rate is used to provide tolerance for reception of signals distorted by multipath and by the unequal delays across the pass band of sideband separation filters. This is accomplished by making the receive gate-open period shorter than the length of the transmitted pulse by approximately 3 ms. This time is used for sampling and quenching the resonators as well as being available for distortion tolerance. As the tone spacing is dependent on the length of the receive gate, the tones become separated more widely than the minimum required by the transmitted data rate.

For the 3000 bit per second system twenty tones are used, each carrying two subchannels operating at 75 bits per second per subchannel. The transmitted pulse length is 13.3 ms and the receive gate length is 10 ms. This requires a tone spacing of 100 cps, or a total bandwidth of 2000 cps. Comparing this with $2Bt$ gives an efficiency of transmission of 3000/4000 or 75 per cent.

Fig. 4 shows a comparison of error rates as a function of input signal to noise ratios for several systems. The ideal curve is computed on the basis of a perfect phase reference. The remaining curves were obtained in the laboratory using random noise sources. Various synchronous systems providing performances between those of the Kineplex and the reference fsk system could be shown; however each of these would require a detailed explanation to add useful information. As the purpose of these curves is to provide a frame of reference and show relative performance, only well known systems are used.

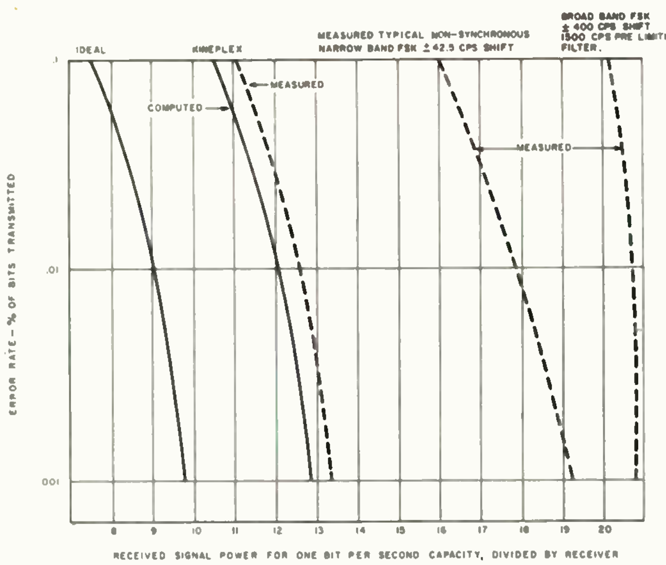
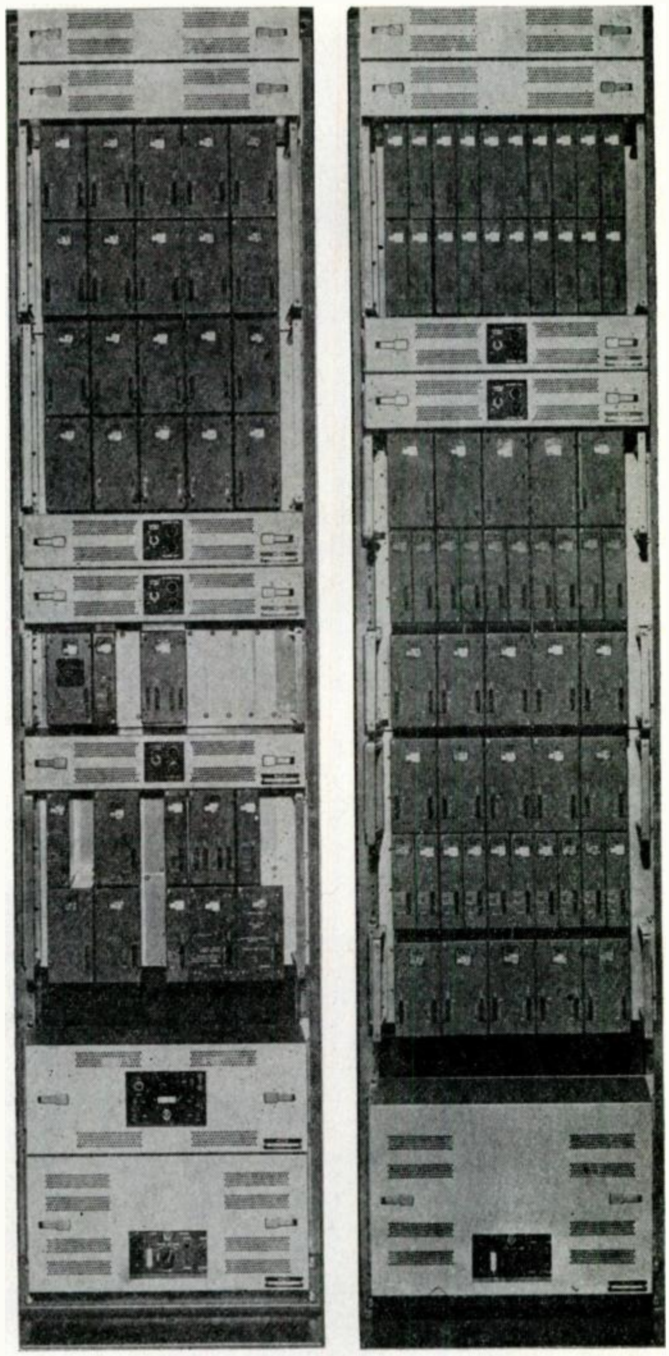


Fig. 4—Error rate vs signal-to-noise ratio for white noise.

A duplex terminal of the 3000 bit per second data system is shown in Fig. 5. Diversity operation, either frequency or space, is obtained by duplicating the detection equipment (36 inches of rack space, one side, plus power supply). The measurements of the incoming signals are made independently on the two diversity channels, which are maintained at equal gains, and the outputs of the product detectors added. Thus the diversity decision is based on the decision obtained with the stronger of the two signals.

The transmit equipment accepts synchronous data on 40 parallel inputs, each operating at 75 (or optionally 45 or 56) bits per second and provides a multitone output which may be fed directly into the voice frequency input of an SSB exciter or into a telephone channel for remote operation. The receive terminal equipment accepts the audio outputs of two diversity receivers, independently detects and diversity combines these signals, and provides 40 parallel regenerated outputs corresponding to the transmitted information.



(a) (b)

Fig. 5—3000-bit data system. (a) Front. (b) Rear.

Converters to equip the data system for use in teleprinter service occupy one side of an additional rack. These provide for 40 channels operating at 100 wpm (or optionally 60 or 75 wpm), accepting nonsynchronous start-stop inputs from keyboards or tape and providing 60-ma neutral outputs for operation of page printers. Other converters may be used to provide for a variety of services. Shift registers to convert between high speed time sequential data at speeds to 3000 bits per second and the data link are shown in Fig. 6.

All units are of modular design and are completely transistorized. Light components are mounted on printed circuit boards with heavy components sup-

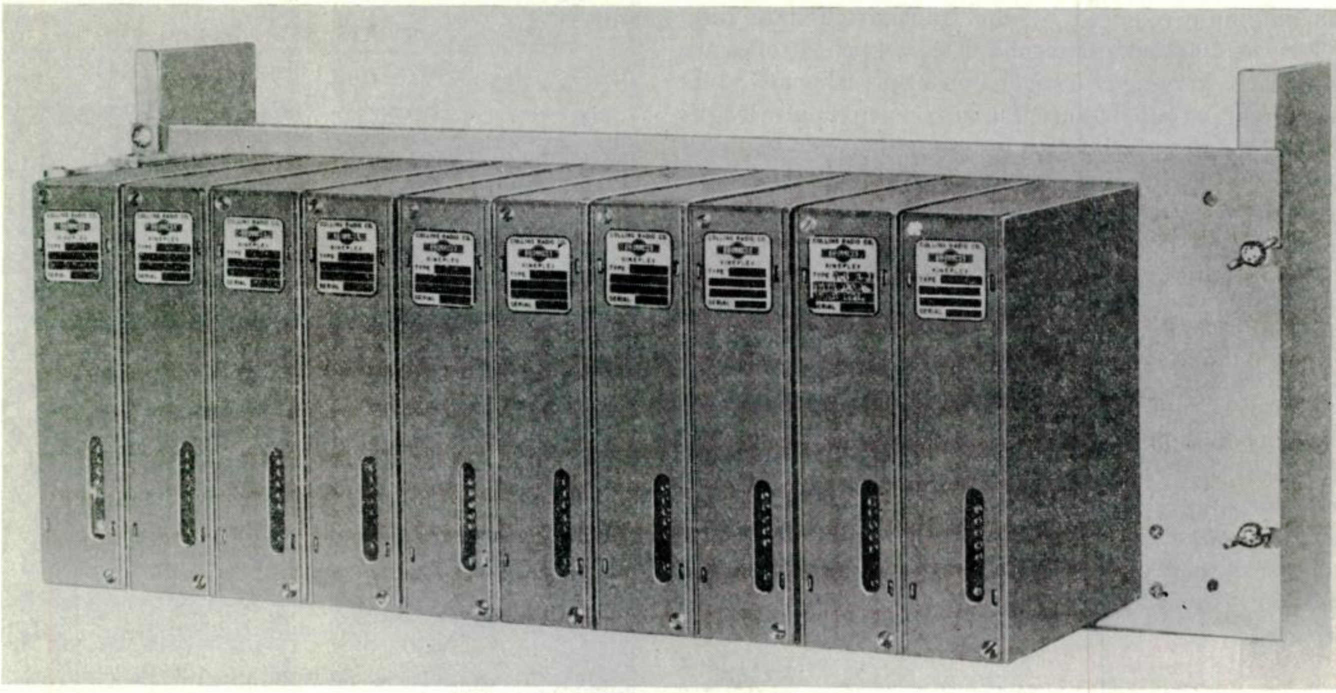


Fig. 6—Series/parallel converter.

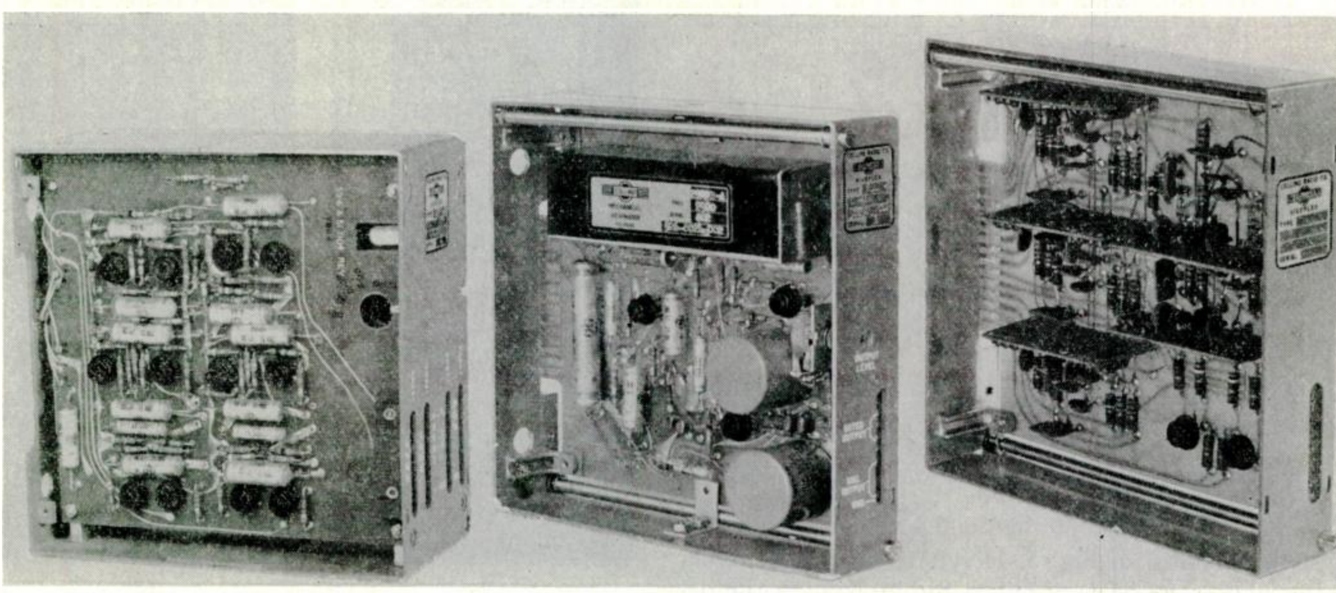


Fig. 7—Typical modules.

ported on shelves in the module. The equipment is designed for operation from dc power at 21 to 31 volts and is shown with power supplies which derive this power from 115-volt 60-cps service. Typical modules are shown in Fig. 7.

A high frequency SSB circuit has been set up between Cedar Rapids, Iowa and Canoga Park, California, to make propagation measurements and to test the operation of the system. Additional propagation measurements of the phase stability of signals received from WWV have been made. Fixed frequency SSB receivers are used for both series of measurements. All injection voltages are derived from a stabilized master oscillator which is locked to a frequency standard. The receiving installation is shown in Fig. 8.

Some of the results of the WWV phase stability measurements, over the Washington, D. C., to Canoga Park, California, path, are shown in Fig. 9.[5] These photographs show the relative phase and amplitude of successive pairs of pulses 22 milliseconds in length. Detectors of the type described above were used to receive WWV.

[5] A report describing these tests in detail is being prepared by G. Barry, Collins Radio Company.

Fig. 8—HF receive terminal.

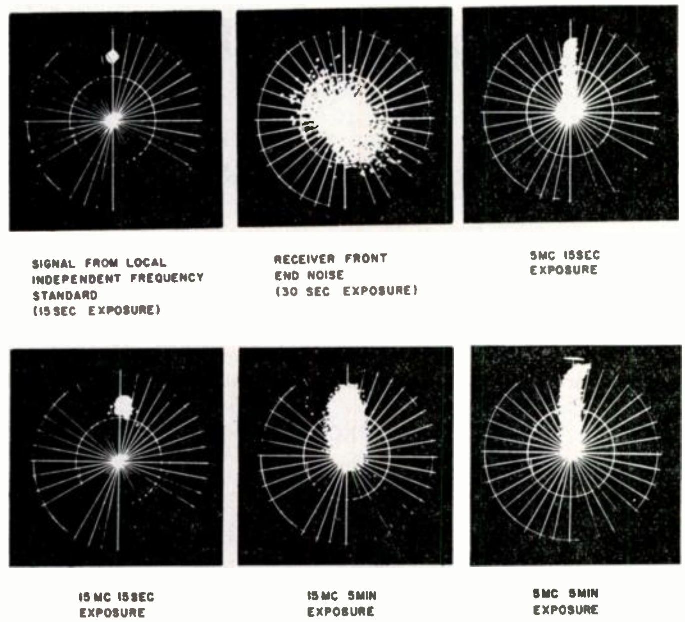


Fig. 9—Polar display of incremental phase shift.

The WWV carrier transmission may be thought of as a long series of 22 millisecond pulses with successive pulses in phase, providing a maximum output on the direct product detector (Fig. 2) and a zero output on the quadrature product detector. The direct product detector output was connected to the vertical plates of an oscilloscope, and the quadrature product detector output was connected to the horizontal plates. Equal gains were used on the two axes. Z-axis (intensity) modulation was used to turn on the beam only at the sampling time. The number of samples per photograph was then varied by changing exposure time.

The first photograph shows the response of the detector to a signal derived from a local frequency standard. This is of constant amplitude and shows no phase difference between pulses. The second photograph shows the response to amplified receiver noise indicating an essentially random distribution of amplitude and phase. Typical samples of received data are shown in the remaining photographs.

Especially important is the shape of the pattern of samples. Additive noise would cause the X-axis deflection to be independent of signal amplitude on the Y axis and result in an essentially rectangular pattern. Phase shift in the propagation path due to rapid path length changes, etc., would result in phase shifts which would tend to be independent of signal amplitude. This would cause the pattern to lie along lines of constant phase shift in a pie-shaped segment.

As may be seen, the test patterns are narrow and nearly rectangular, indicating good relative phase stability between adjacent pulses.

Test transmissions of the data system have been carried out over the path between Cedar Rapids, Iowa, and Canoga Park, California. The received audio frequency signals are transmitted over approximately 30 miles of class C telephone circuit to the Burbank laboratory before detection. Tests to date have used teleprinter data to provide input and output signals. Twelve channels operating on six adjacent tones have been used for test and evaluation purposes. Forty channel circuit loading has been tested using four data channels plus 18 additional unkeyed tones. Preliminary results have been favorable and confirm conclusions based on system characteristics and propagation measurements.

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Temperature Dependence of Junction Transistor Parameters*

WOLFGANG W. GÄRTNER†, MEMBER, IRE

Summary—**Based on existing design theories and the known temperature behavior of the semiconductor properties, the temperature variations of transistor characteristics are calculated for four representative types. The results, expressed in terms of four-pole parameters and equivalent circuits, may serve as a guide line in transistor design and temperature compensation of transistor circuits.**

I. Introduction[1]

THE TEMPERATURE variation of the electrical characteristics of transistors has always been a major problem. Guide lines are needed for proper temperature compensation in transistor circuits and for the proper design of types which will operate at substantially higher temperatures than present day units. The question has been given some consideration.[2–7] It is the purpose of this paper to point out additional phases of the general problem and provide some of the needed theoretical background.

In view of the complexity of the problem, a theoretical approach was developed as a first step. Such an approach shows what temperature dependence should be expected of the semiconductor itself, and helps to separate it from any influence which may be due to the construction of the particular type under investigation.

A theoretical attack carries with it the danger of too great generality. We tried to avoid this by calculating in detail four representative types instead of permuting all possible structures and material properties. Graphical presentation of the results has been used for all quantities.

The temperature T which appears throughout the paper is the junction temperature, or better, the temperature of the whole semiconductor. It depends on the ambient temperature and the heat dissipation of the unit which is a function of internal and external mounting, structure and material of the encapsulation, and cooling measures.

* Original manuscript received by the IRE, March 15, 1956; revised manuscript received, December 27, 1956.

† Signal Corps Eng. Labs., Fort Monmouth, N. J.

[1] A considerably more detailed discussion of the problem is contained in SCEL Tech. Memo. No. 1849.

[2] A. Coblenz and H. L. Owens, "Variation of transistor parameters with temperature," Proc. IRE, vol. 40, pp. 1472–1481; October, 1952.

[3] R. F. Shea, "Principles of Transistor Circuits," John Wiley and Sons, New York, N. Y.; 1953.

[4] E. Groschwitz, "Zum theoretischen Temperaturkoeffizient von Halbleitern," *Z. Angew. Phys.*, vol. 7, pp. 245–249; May, 1955.

[5] E. Groschwitz, "Zum theoretischen Temperaturkoeffizienten eines Flächentransistors," *Z. Angew. Phys.*, vol. 7, pp. 280–282; June, 1955.

[6] A. W. Lo, *et al.*, "Transistor Electronics," Prentice-Hall, Englewood, N. J.; 1955.

[7] R. J. Kircher, "Properties of junction transistors," IRE Trans., vol. AU-3, pp. 107–124; July–August, 1955.

Several sets of parameters have been used to characterize the transistor. This has become necessary because the final h parameters are too complicated for their temperature behavior to be understood directly. With the help of the intermediate steps of the y and h' parameters, however, the picture becomes much clearer.

II. Design Data

The theoretical expressions for the transistor characteristics are generally too complicated for their temperature behavior to be obvious. Four types of transistors, which are believed to be representative of many audio transistors, have been chosen, therefore, as examples and will be discussed in detail. On the basis of their analysis, conclusions may be drawn as to the temperature behavior of transistors in general. The four types mentioned are: *a germanium p-n-p alloy junction transistor, germanium n-p-n junction transistors of the regular grown and the rate grown types, and a silicon n-p-n grown junction transistor*. Their assumed structures and the room temperature values of their material properties and electrical characteristics are given in Figs. 1 and 2, opposite, and in Table I on pp. 664–665. The electrical characteristics refer to the semiconductor structure itself. Parasitic influences have been neglected.

III. Design Theory and Equivalent Circuits

Design theory provides the connection between the physical properties of the transistor and its electrical behavior. Electrical characterization of the device may be achieved through four-pole parameters or equivalent circuits together with some additional quantities like collector reverse current or alpha cut-off frequency. To provide a good understanding, we shall calculate the temperature dependence for several representations.

The design theory[8–11] yields directly the y' parameters of a transistor model which accounts for diffusion effects and depletion layer capacitances and neglects the base spreading resistance r_b'. These parameters are defined by (see Fig. 3)

$$i_e = y_{11}'v_e + y_{12}'v_c$$
$$i_c = y_{21}'v_e + y_{22}'v_c. \qquad (1)$$

[8] W. Shockley, "The theory of *p-n* junctions in semiconductors and *p-n* junction transistors," *Bell Sys. Tech. J.*, vol. 28, pp. 435–489; July, 1949.

[9] W. Shockley, M. Sparks, and G. K. Teal, "*P-N* junction transistors," *Phys. Rev.*, vol. 83, pp. 151–162; July, 1951.

[10] J. Early, "Design theory of junction transistors," *Bell Sys. Tech. J.*, vol. 32, pp. 1271–1312; November, 1953.

[11] R. J. Pritchard, "Frequency variations of junction-transistor parameters," Proc. IRE, vol. 42, pp. 786–799; May, 1954.

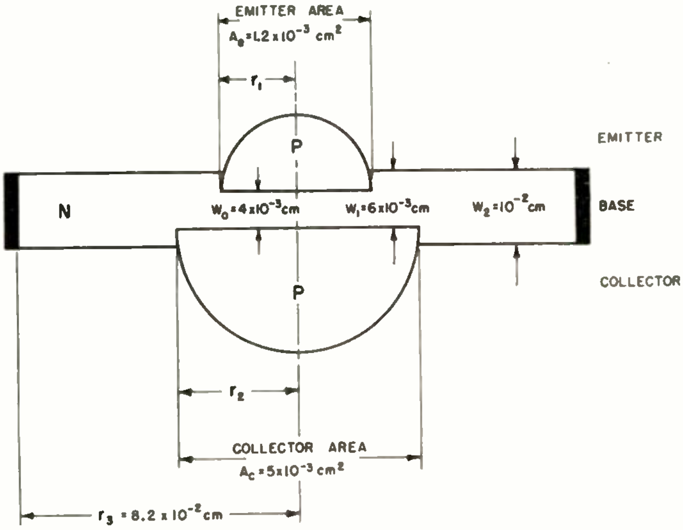


Fig. 1—Geometry for model of *p-n-p* alloy junction transistor (cross section of structure with cylindrical symmetry; not drawn to scale).

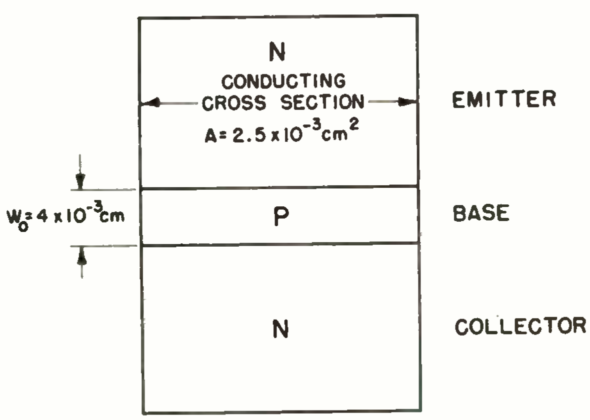


Fig. 2—Geometry for models of *n-p-n* grown junction transistors (not drawn to scale).

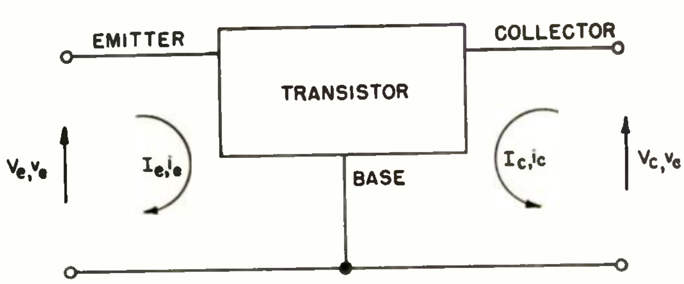


Fig. 3—Sign convention for the four-pole representations.

The "hybrid" h' parameters are defined by

$$v_e = h_{11}'i_e + h_{12}'v_c$$
$$i_c = h_{21}'i_e + h_{22}'v_c \qquad (2)$$

and are related to the y''s by

$$h_{11}' = 1/y_{11}' \qquad (3a)$$
$$h_{12}' = -y_{12}'/y_{11}' \qquad (3b)$$
$$h_{21}' = y_{21}'/y_{11}' \qquad (3c)$$
$$h_{22}' = y_{22}' - y_{12}'y_{21}'/y_{11}'. \qquad (3d)$$

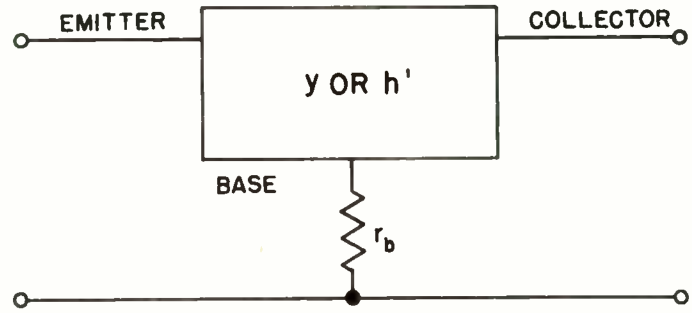


Fig. 4—Inclusion of the base resistance. The over-all four-pole is then characterized by the *h* parameters.

If the base spreading resistance is included (see Fig. 4), one arrives at realistic h parameters given by

$$h_{11} = h_{11}' + r_b'(1 + h_{21}')(1 - h_{12}')/(1 + r_b'h_{22}')$$
$$h_{12} = (h_{12}' + r_b'h_{22}')/(1 + r_b'h_{22}')$$
$$h_{21} = (h_{21}' - r_b'h_{22}')/(1 + r_b'h_{22}')$$
$$h_{22} = h_{22}'/(1 + r_b'h_{22}'). \qquad (4)$$

DC Relationships

The dc currents and voltages in a *p-n-p* transistor having $r_b' = 0$ are related by

$$I_e = Aq(e^{qV_e/kT} - 1)[(D_{pb}p_{ob}/L_{pb}) \coth (w_o/L_{pb}) + (D_{ne}n_{oe}/L_{ne})] - Aq(e^{qV_c/kT} - 1) \cdot [(D_{pb}p_{ob}/L_{pb}) \operatorname{csch} (w_o/L_{pb})] \qquad (5a)$$

$$I_c = Aq(e^{qV_c/kT} - 1)[(D_{pb}p_{ob}/L_{pb}) \coth (w_o/L_{pb}) + (D_{nc}n_{oc}/L_{nc})] - Aq(e^{qV_e/kT} - 1)[(D_{pb}p_{ob}/L_{pb}) \operatorname{csch} (w_o/L_{pb})]. \qquad (5b)$$

The equations apply to *n-p-n* transistors by providing q with a minus sign and substituting p to n and vice versa. Setting $I_e = 0$ and using the resulting V_e in the expression for I_c, one obtains the collector reverse current for zero emitter current, I_{co}.

AC Parameters

The y' parameters defined by (1) are for the *p-n-p* transistor

$$y_{11}' = Aq\frac{D_{pb}p_{ob}}{L_{pb}}\frac{q}{kT}e^{qV_e/kT}(1 + j\omega\tau_{pb})^{1/2} \times \coth\left(\frac{w_0}{L_{pb}}\sqrt{1 + j\omega\tau_{pb}}\right) + Aq\frac{D_{ne}n_{oe}}{L_{ne}}\frac{q}{kT}e^{qV_e/kT}(1 + j\omega\tau_{ne})^{1/2} + j\omega C_e \qquad (6a)$$

$$y_{12}' = -Aq\frac{D_{pb}p_{ob}}{L_{pb}^2}\left[(e^{qV_c/kT} - 1)\operatorname{csch}\frac{w_o}{L_{pb}} + \coth\frac{w_o}{L_{pb}}\right] \times \left(\frac{\partial w}{\partial V_c}\right)(1 + j\omega\tau_{pb})^{1/2}\operatorname{csch}\left(\frac{w_o}{L_{pb}}\sqrt{1 + j\omega\tau_{pb}}\right) \qquad (6b)$$

$$y_{21}' = -Aq\frac{D_{pb}p_{ob}}{L_{pb}}\frac{q}{kT}e^{qV_e/kT}(1 + j\omega\tau_{pb})^{1/2}$$

TABLE I

DESIGN DATA AND PROPERTIES OF MODELS FOR JUNCTION TRANSISTORS AT ROOM TEMPERATURE

Geometry

	Ge *p-n-p* Alloy	Ge *n-p-n* Grown	Ge *n-p-n* Rate Grown	Si *n-p-n* Grown
Base width, w_0/cm	4×10^{-3}	4×10^{-3}	4×10^{-3}	4×10^{-3}
Emitter area, A_e/cm^2	1.2×10^{-3}	—	—	—
Collector area, A_c/cm^2	5×10^{-3}	—	—	—
Conducting cross section, A/cm^2	—	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}

Junctions

	Ge *p-n-p* Alloy		Ge *n-p-n* Grown		Ge *n-p-n* Rate Grown		Si *n-p-n* Grown	
	Emitter	Collector	Emitter	Collector	Emitter	Collector	Emitter	Collector
Graded Junction			X	X		X	X	X
Step Junction	X	X			X			

Material Properties

Properties	Ge *n-p-n* Alloy	Ge *n-p-n* Grown	Ge *n-p-n* Rate Grown	Si *n-p-n* Grown
Impurity content				
emitter				
N_a/cm^{-3}	1.55×10^{19}		1.2×10^{16}	
N_d/cm^{-3}		1.25×10^{18}	3.5×10^{16}	6.25×10^{18}
(N_d-N_a)/cm^{-3}			2.3×10^{16}	
base				
N_d/cm^{-3}	8.7×10^{14}		8.1×10^{15}	
N_a/cm^{-3}		4.57×10^{15}	1.2×10^{16}	1.87×10^{16}
(N_a-N_d)/cm^{-3}		3.7×10^{15}	3.9×10^{15}	1.5×10^{16}
collector				
N_a/cm^{-3}	1.55×10^{19}		1.2×10^{16}	
N_d/cm^{-3}		8.7×10^{14}	3.5×10^{16}	3.7×10^{15}
$(N_d-N_a$/cm$^{-3})$			2.3×10^{16}	
Equilibrium carrier densities				
emitter				
electrons, n_{oe}/cm^{-3}	3.3×10^{7}	1.25×10^{18}	2.3×10^{16}	6.25×10^{18}
holes, p_{oe}/cm^{-3}	1.55×10^{19}	4.12×10^{8}	2.24×10^{10}	5.23×10^{2}
base				
electrons, n_{ob}/cm^{-3}	8.7×10^{14}	1.4×10^{11}	1.32×10^{11}	2.18×10^{6}
holes, p_{ob}/cm^{-3}	5.9×10^{11}	3.7×10^{15}	3.9×10^{15}	1.5×10^{16}
collector				
electrons, n_{oc}/cm^{-3}	3.3×10^{7}	8.7×10^{14}	2.3×10^{16}	3.7×10^{15}
holes, p_{oc}/cm^{-3}	1.55×10^{19}	5.9×10^{11}	2.24×10^{10}	8.4×10^{6}
Mobilities μ and Diffusion Constants D				
emitter				
electrons				
μ_{ne}/cm^2 V^{-1} sec^{-1}	123	866	2660	112
D_{ne}/cm^2 sec^{-1}	3.2	—	—	—
holes				
μ_{pe}/cm^2 V^{-1} sec^{-1}	61.4	200	975	62
D_{pe}/cm^2 sec^{-1}	—	5.15	25	1.59
base				
electrons				
μ_{nb}/cm^2 V^{-1} sec^{-1}	3700	3350	2822	782
D_{nb}/cm^2 sec^{-1}	—	84	72	20
holes				
μ_{pb}/cm^2 V^{-1} sec^{-1}	1700	1570	1340	426
D_{pb}/cm^2 sec^{-1}	43	—	—	—
collector				
electrons				
μ_{nc}/cm^2 V^{-1} sec^{-1}	123	3700	2660	971
D_{nc}/cm^2 sec^{-1}	3.2	—	—	—
holes				
μ_{pc}/cm^2 V^{-1} sec^{-1}	61.4	1700	975	450
D_{pc}/cm^2 sec^{-1}	—	43.7	25	11.5

TABLE I—(*continued*)

Material Properties				
Properties	Ge *p-n-p* Alloy	Ge *n-p-n* Grown	Ge *n-p-n* Rate Grown	Si *n-p-n* Grown
Resistivities				
emitter, ρ_e/ohm-cm	0.0066	0.0058	0.1	0.009
base, ρ_b/ohm-cm	1.9	1.1	1.2	0.978
collector, ρ_c/ohm-cm	0.0066	1.95	0.1	1.75
Lifetimes				
electrons in emitter, τ_{ne}/μ sec	0.06	—	—	—
holes in base, τ_{pb}/μ sec	60	—	—	—
electrons in collector, τ_{nc}/μ sec	0.06	—	—	—
holes in emitter, τ_{pe}/μ sec	—	0.1	1.9	0.56
electrons in base, τ_{nb}/μ sec	—	14	11	20.8
holes in collector, τ_{pc}/μ sec	—	59	1.9	50
Diffusion Lengths				
electrons in emitter, L_{ne}/cm	4.5×10^{-4}			
holes in base, L_{pb}/cm	5.1×10^{-2}			
electrons in collector, L_{nc}/cm	4.5×10^{-4}			
holes in emitter, L_{pe}/cm		7.2×10^{-4}	6.9×10^{-3}	9.4×10^{-4}
electrons in base, L_{nb}/cm		3.4×10^{-2}	2.8×10^{-2}	6.47×10^{-2}
holes in collector, L_{pc}/cm		5.2×20^{-2}	6.9×10^{-3}	2.4×10^{-2}
Electrical Properties				
DC Biases				
emitter current, I_e/ma	1	−1	−1	−1
collector voltage, V_c/volts	−5	5	5	5
Small Signal Four-Pole Parameters at 1 kc				
h_{11}/ohms	25.9	28	38	30
h_{12}	2×10^{-4}	8.6×10^{-5}	1.2×10^{-4}	9×10^{-5}
h_{21}	−0.99	−0.99	−0.96	−0.98
h_{22}/mhos	5×10^{-8}	4.2×10^{-8}	1.5×10^{-7}	10^{-7}
Alpha Cut-Off Frequency, $f_{\alpha co}$/cycles/sec	10^{6}	2×10^{6}	1.75×10^{6}	4.9×10^{5}
Collector Capacitance, $C_c/\mu\mu$f	22	6.3	6	5.2

$$\times \operatorname{csch}\left(\frac{w_0}{L_{pb}}\sqrt{1+j\omega\tau_{pb}}\right)\left(1+\frac{n_{oc}\mu_{nc}}{p_{oc}\mu_{pc}}\right) \tag{6c}$$

$$y_{22}' = \left\{Aq\frac{D_{pb}p_{ob}}{L_{pb}^2}\left[(e^{qV_e/kT}-1)\operatorname{csch}\frac{w_0}{L_{pb}} + \coth\frac{w_o}{L_{pb}}\right]\right.$$
$$\times\left(\frac{\partial w}{\partial V_c}\right)(1+j\omega\tau_{pb})^{1/2}\coth\left(\frac{w_o}{L_{pb}}\sqrt{1+j\omega\tau_{pb}}\right)$$
$$\left.+\,j\omega C_c\right\}\left(1+\frac{n_{oc}\mu_{nc}}{p_{oc}\mu_{pc}}\right). \tag{6d}$$

For step junctions

$$\frac{\partial w}{\partial V_c} = -\frac{1}{2V_c}\left(\frac{2\kappa\epsilon_o V_c}{qn_{ob}}\right)^{1/2} \tag{6e}$$

(for our geometry

$$\partial w/\partial V_c = 9.38\times10^2 n_{ob}^{-1/2} cmV^{-1}).$$

If, in (6a) to (6d) q is provided with a minus sign and p is substituted to n and vice versa, these expressions apply to *n-p-n* transistors. However, since the *n-p-n* transistors are of the grown type, we have

$$\left|\frac{\partial w}{\partial V_c}\right| = \left|\frac{1}{6V_c}\left(\frac{3\kappa\epsilon_o V_c}{qa}\right)^{1/3}\right| \tag{7}$$

(for our geometry

$$|\partial w/\partial V_c| = 1.18\times10^{-5} cmV^{-1}).$$

The barrier capacitances C_e and C_c are given by

$$C = A\kappa\epsilon_o[q\,|\,N_d - N_a\,|\,/(2\kappa\epsilon_o V')]^{1/2} \tag{8}$$

for step junctions, and by

$$C = \frac{A\kappa\epsilon_o}{2}\left(\frac{2q\,|\,a\,|}{3\kappa\epsilon_o V'}\right)^{1/3} \tag{9}$$

for graded junctions. V' stands for the electrostatic potential across the depletion layer.[10]

The base spreading resistance[10] r_b' for the structure in Fig. 1 is

$$r_b' \simeq \rho_b[1/(8\pi w_o) + 1/(2\pi w_1)\times\ln(r_2/r_1) + 1/(2\pi w_2)\times\ln(r_3/r_2)] \tag{10}$$

and for the structure of Fig. 2

$$r_b' \simeq \rho_b/w_o. \tag{11}$$

The h' and h for both types may now be calculated using (3), (4), and (6)–(11).

Important for the characterization of the frequency behavior of a transistor is the alpha cut-off frequency given by

$$f_{\alpha co} = 2.43 D_b/(2\pi w_o^2). \tag{12}$$

In addition to this four-pole representation, we want to describe the temperature behavior in terms of a simplified[10] equivalent circuit (see Fig. 5).

$$g_{ee} = Aq \frac{D_{pb}p_{ob}}{L_{pb}} \frac{q}{kT} e^{qV_e/kT} \frac{L_{pb}}{w_o} \tag{13}$$

$$g_{cc} = Aq \frac{D_{pb}p_{ob}}{L_{pb}^2} \left[(e^{qV_e/kT} - 1) \operatorname{csch} \frac{w_o}{L_{pb}} + \coth \frac{w_o}{L_{pb}} \right] \left(\frac{\partial w}{\partial V_c} \right) \frac{L_{pb}}{w_o} \tag{14}$$

$$\omega_a = 2D_{pb}/w_o^2 \tag{15}$$

for the *p-n-p*, and corresponding equations for the *n-p-n* transistor.

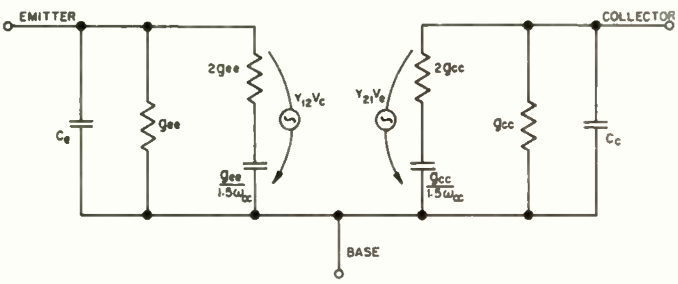


Fig. 5—Simplified equivalent circuit for junction transistor.

IV. Temperature Dependence of Semiconductor Properties

The design equations of the previous section contain the properties of the semiconducting material, and the temperature behavior of the electrical device characteristics is completely determined by the temperature dependence of these material properties which will be discussed individually in this section. These properties are the carrier densities, mobilities and diffusion constants, resistivities, lifetimes, diffusion lengths, and dielectric constants.

Carrier Densities

The majority and minority carrier densities in a region with a density N_a of ionized acceptors and a density N_d of ionized donors are calculated from the condition for electrical neutrality which is satisfied in any homogeneous semiconductor

$$p_o - n_o + N_d - N_a = 0 \tag{16}$$

and the relationship

$$n_o \cdot p_o = n_i^2 \tag{17}$$

between the equilibrium carrier densities in the extrinsic semiconductor, n_o, p_o and the equilibrium carrier densities n_i in the intrinsic semiconductor at the same temperature.

The values for n_i are given by[12]

[12] E. S. Rittner, "Extension of the theory of the junction transistor," *Phys. Rev.*, vol. 94, pp. 1161–1171; June, 1954.

$$n_i^2 = 9.3 \times 10^{31} \times T^3 \times e^{-8700/T} \text{ cm}^{-6} \tag{18}$$

for germanium, and

$$n_i^2 = 7.8 \times 10^{32} \times T^3 \times e^{-12900/T} \text{ cm}^{-6} \tag{19}$$

for silicon, corresponding to energy gaps of 0.75 ev and 1.12 ev respectively. The expressions are empirical and the temperature dependence of the energy gaps themselves, which has been found to be linear,[13] is absorbed in the constants multiplying the exponentials. Plots of n_o, p_o in the emitter, base, and collector regions of the various models are shown in Fig. 6.

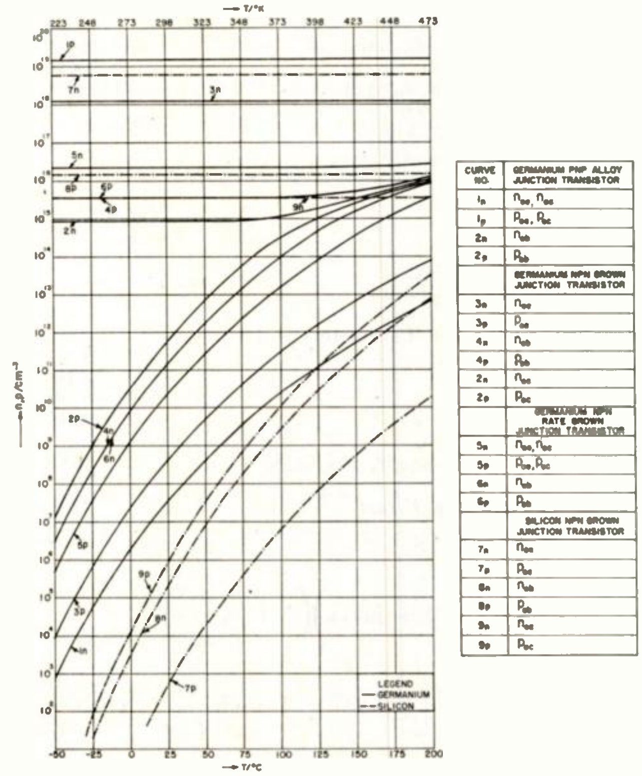


Fig. 6—Carrier densities in germanium and silicon as a function of temperature.

The basic picture is the same in germanium and silicon, but due to the wider energy gap, the increase of the minority carrier density in the extrinsic region is faster in silicon than in germanium. However, the minority carrier densities start as much lower values so that the transition to intrinsic behavior occurs at higher temperatures in silicon.

Mobilities

In transistors only scattering by thermal lattice vibrations, charged impurities, and free carriers must be considered in the calculation of drift mobilities. Prince[14,15] has determined the temperature dependence

[13] E. M. Conwell, "Properties of silicon and germanium," Proc. IRE, vol. 40, pp. 1327–1337; November, 1952.

[14] M. B. Prince, "Drift mobilities in semiconductors, I. Germanium," *Phys. Rev.*, vol. 92, pp. 681–687; November, 1953.

[15] M. B. Prince, "Drift mobilities in semiconductors, II. Silicon," *Phys. Rev.*, vol. 93, pp. 1204–1206; March, 1954.

of the lattice mobilities μ_L for electrons and holes in germanium and silicon using samples with resistivities higher than a few ohm-cm. The information on silicon is not as complete and accurate as for germanium, but probably sufficient for the purpose of this paper.[16] Prince found

$$\mu_{nL} = 9.1 \times 10^8 \times T^{-2.3} \text{ cm}^2 V^{-1} \text{sec}^{-1} \qquad (20)$$

for electrons in germanium,[14]

$$\mu_{pL} = 3.5 \times 10^7 \times T^{-1.6} \text{ cm}^2 V^{-1} \text{sec}^{-1} \qquad (21)$$

for holes in germanium,[14]

$$\mu_{nL} = 5.5 \times 10^6 \times T^{-1.5} \text{ cm}^2 V^{-1} \text{sec}^{-1} \qquad (22)$$

for electrons in silicon,[15] and

$$\mu_{pL} = 2.4 \times 10^8 \times T^{-2.3} \text{ cm}^2 V^{-1} \text{sec}^{-1} \qquad (23)$$

for holes in silicon.[15] These findings deviate from the results of a simplified theory[17] of lattice scattering, and have to be interpreted on the basis of more complicated considerations.[18,19]

Coulomb scattering by charged impurities and free carriers of the opposite sign is theoretically described by the Conwell-Weisskopf formula[20]

$$\mu_I = \frac{8\sqrt{2}k^{3/2}}{m^{1/2}\pi^{3/2}q^3} \frac{\kappa^2 m^{1/2} T^{3/2}}{m_{eff}^{1/2} N_I} \cdot \left\{ \ln\left[1 + \left(\frac{3k}{q^2}\right)^2 \frac{\kappa^2 T^2}{N_I^{2/3}}\right]\right\}^{-1} \qquad (24)$$

to which quantum mechanical corrections have been added.[21,22] The experimental curves, however, are usually well approximated by (24). (For a discussion see Prince[14] and Debye.[23])

The mass ratios in (24) have been chosen to be[14,24] $m/m_{eff} = 4$ for electrons in germanium, $m/m_{eff} = 1/3$ for holes in germanium, $m/m_{eff} = 1$ for both electrons and holes in silicon.

The combination of the effects of lattice and coulomb scattering is achieved by the relationship[23,25,26]

$$\mu = \mu_L[1 + M^2\{C_iM \cos M + S_iM \sin M - \tfrac{1}{2}\pi \sin M\}] \qquad (25)$$

where $M^2 = 6\mu_L/\mu_I$ which is a better approximation than the customary way of summing the reciprocals of the individual mobilities. A plot of relation (25) for graphical addition is found by Conwell.[18]

On the basis of these considerations, the mobilities in the various regions of the transistor models are calculated and shown in Fig. 7.

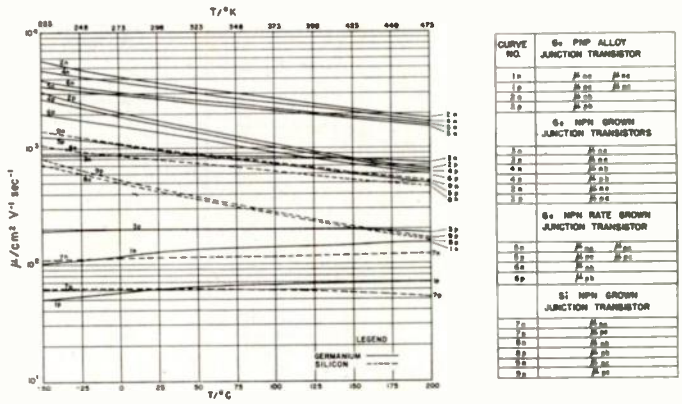


Fig. 7—Carrier drift mobilities in germanium and silicon as a function of temperature.

Diffusion Constants

The diffusion constants D of mobile carriers are connected with their mobilities μ by the Einstein relationship[27,28]

$$D = (kT/q)\mu \qquad (26)$$

which is assumed to be valid in all the regions of the models considered. The diffusion constants of the minority carriers in each region which alone enter the design equations are shown in Fig. 8. The numbering of the curves corresponds to the numbering of the mobility curves in Fig. 7.

Resistivities

The electrical resistivity ρ of a piece of semiconductor with the carrier densities n_o, p_o and the mobilities μ_n, μ_p is given by

$$\rho = (qn_o\mu_n + qp_o\mu_p)^{-1}. \qquad (27)$$

It enters explicitly only the expressions for the base spreading resistance, and it has, therefore, been calcu-

[16] After this paper had been prepared it was brought to the author's attention that recently the following values have been measured (G. W. Ludwig and R. L. Watters, "Drift and conductivity mobility in silicon," to be published)

$$\mu_{nL} = (2.1 \pm 0.2) \times 10^9 \times T^{-2.5 \pm 0.1} \text{ cm}^2 V^{-1} \text{sec}^{-1}$$
$$\mu_{pL} = (2.3 \pm 0.1) \times 10^9 \times T^{-2.7 \pm 0.1} \text{ cm}^2 V^{-1} \text{sec}^{-1}.$$

Compare also F. J. Morin and J. P. Maita, "Electrical properties of silicon containing arsenic and boron," *Phys. Rev.*, vol. 96, pp. 28–35; October, 1954.

[17] J. Bardeen and W. Shockley, "Deformation potentials and mobilities in nonpolar crystals," *Phys. Rev.*, vol. 80, pp. 72–80; October, 1950.

[18] F. Herman and J. Callaway, "Electronic structure of the germanium crystal," *Phys. Rev.*, vol. 89, pp. 518–519; March, 1953.

[19] F. Herman, "Calculation of the energy band structures of the diamond and germanium crystals by the method of orthogonalized plane waves," *Phys. Rev.*, vol. 93, pp. 1214–1225; March, 1954.

[20] E. Conwell and V. F. Weisskopf, "Theory of impurity scattering in semiconductors," *Phys. Rev.*, vol. 77, pp. 388–390; February, 1950.

[21] H. Brooks, "Scattering by ionized impurities in semiconductors," *Phys. Rev.*, vol. 83, p. 879; August, 1951.

[22] C. Herring (personal communication).

[23] P. P. Debye and E. M. Conwell, "Electrical properties of n-type germanium," *Phys. Rev.*, vol. 93, pp. 695–706; February, 1954.

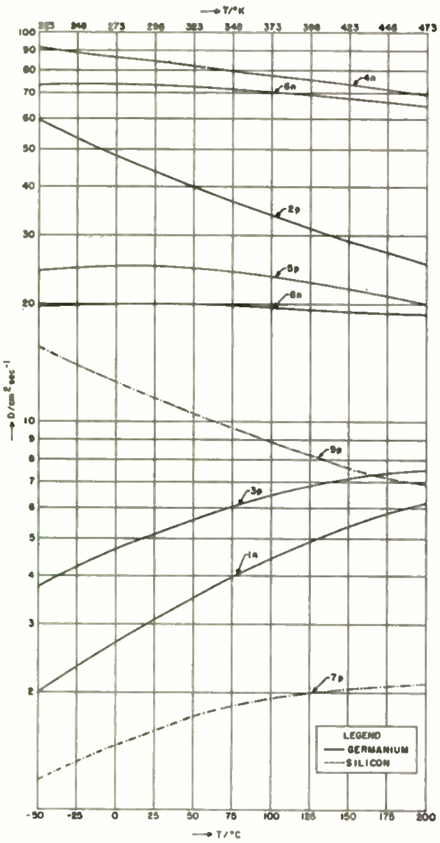
[24] P. P. Debye and T. Kohane, "Hall mobility of electrons and holes in silicon," *Phys. Rev.*, vol. 94, pp. 724–725; May, 1954.

[25] H. Jones, "The hall coefficient of semiconductors," *Phys. Rev.*, vol. 81, p. 149; June, 1951.

[26] V. A. Johnson and K. Lark-Horovitz, "The combination of resistivities in semiconductors," *Phys. Rev.*, vol. 82, pp. 977–978; June, 1951.

[27] A. Einstein, "Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegg. von in ruhenden Flüssigkeiten suspendierten Teilchen," *Ann. der. Phys.*, vol. 17, p. 549; 1905.

[28] W. Shockley, "Electrons and holes in semiconductors," D. van Nostrand, New York, N. Y., p. 299, 1950.



CURVE NO.	GERMANIUM PNP ALLOY JUNCTION TRANSISTOR
1n	D_{ne}, D_{nc}
2p	D_{pb}
	GERMANIUM NPN GROWN JUNCTION TRANSISTOR
3p	D_{pe}
4n	D_{nb}
2p	D_{pc}
	GERMANIUM NPN RATE GROWN JUNCTION TRANSISTOR
5p	D_{pe}, D_{pc}
6n	D_{nb}
	SILICON NPN GROWN JUNCTION TRANSISTOR
7p	D_{pe}
8n	D_{nb}
9p	D_{pc}

Fig. 8—Diffusion constants in germanium and silicon as a function of temperature.

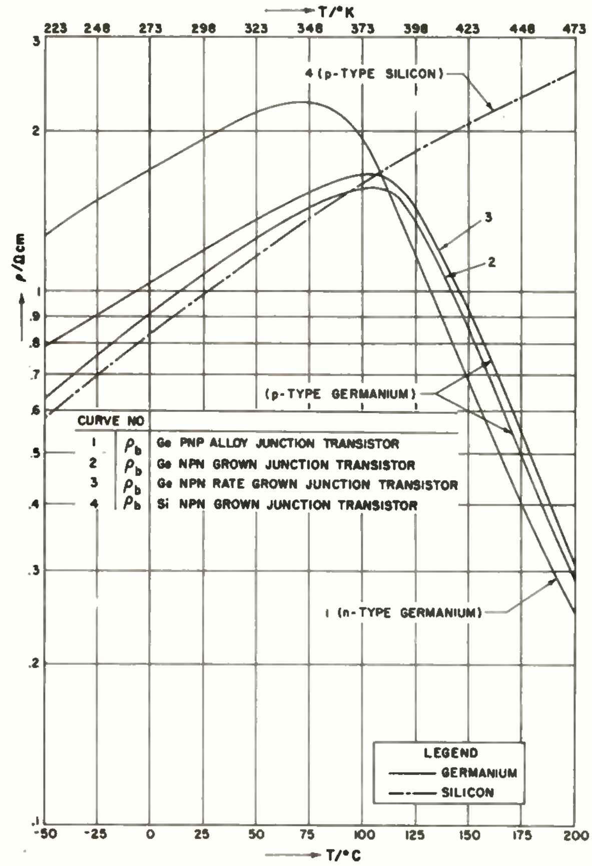


Fig. 9—Resistivities in germanium and silicon as a function of temperature.

lated for the base regions of the four models using the carrier densities and mobilities of Figs. 6 and 7. The results are shown in Fig. 9. The crossing of curve 1 for the n-type base of the p-n-p transistor with curves 2 and 3 for the p-type bases of the n-p-n transistors portrays the fact, noticed earlier,[29,30] that n- and p-type samples approach the intrinsic curve from different sides.

Lifetimes

The temperature variation of lifetime, the theoretical description of which follows the Hall[31] and Shockley-Read[32] theories of lifetime, depends on the carrier densities in the sample and on the density and nature of the recombination centers, in particular, on the position of the recombination level as is seen from the equation.

$$\tau = \tau_{po}(n_o + n_i)/(n_o + p_o) + \tau_{no}(p_o + p_i)/(n_o + p_o) \quad (28)$$

on which the following analysis is based. It is well known that the lifetime picture in semiconductors may be much more complicated,[33] but for transistor grade material, (28) seems to describe the recombination phenomenon very well. In (28) n_o and p_o are the equilibrium carrier densities given by[34]

$$n_o = N_c e^{(E_F - E_c)/kT} \quad (29a)$$

$$p_o = N_v e^{(E_v - E_F)/kT} = n_i^2/n_o; \quad (29b)$$

n_1 and p_1 are the equilibrium carrier densities that would prevail if the Fermi level fell at the recombination level E_t and are given by

$$n_1 = N_c e^{(E_t - E_c)kT} \quad (30a)$$

$$p_1 = N_v e^{(E_v - E_t)/kT} = n_i^2/n_i; \quad (30b)$$

τ_{no} and τ_{po} are the lifetimes of electrons injected into highly p-type material and of holes injected into highly n-type material, respectively. Based on reported measurements[35,36] the recombination level was chosen to lie

[29] At very high frequencies which are not considered in this paper, the resistances of the other regions are also of importance (personal communication by J. M. Early).

[30] P. G. Herkart and J. Kurshan, "Theoretical resistivity and Hall coefficient of impure germanium near room temperature," *RCA Rev.*, vol. 14, pp. 427–440; September, 1953.

[31] R. N. Hall, "Electron-hole recombination in germanium," *Phys. Rev.*, vol. 87, p. 387; July, 1952.

[32] W. Shockley and W. T. Read, Jr., "Statistics of the recombinations of holes and electrons," *Phys. Rev.*, vol. 87, pp. 835–842; September, 1952.

[33] See *e.g.*, H. Y. Fan, "Effect of traps on carrier injection in semiconductors," *Phys. Rev.*, vol. 92, pp. 1424–1428; December, 1953.
H. Y. Fan, D. Navon and H. Gebbie, "Recombination and trapping of carriers in germanium," *Physica*, vol. 20, pp. 885–872; 1954.
A. Rose, "Recombination processes in insulators and semiconductors," *Phys. Rev.*, vol. 97, pp. 322–333; January, 1955.

[34] Shockley, *op. cit.*, p. 240.

[35] R. Wiesner and E. Groschwitz, "Zur Temperaturabhängigkeit des Photostromes in P-N Ubergängen," *Z. ang. Phys.*, vol. 7, p. 496; 1955. The author is indebted to Drs. Wiesner and Groschwitz for making their work available to him prior to publication.

[36] G. Bemski, "Lifetime of electrons in p-type silicon," *Phys. Rev.*, vol. 100, pp. 523–524; October, 1955. The author is indebted to Dr. Bemski for making his work available to him prior to publication.

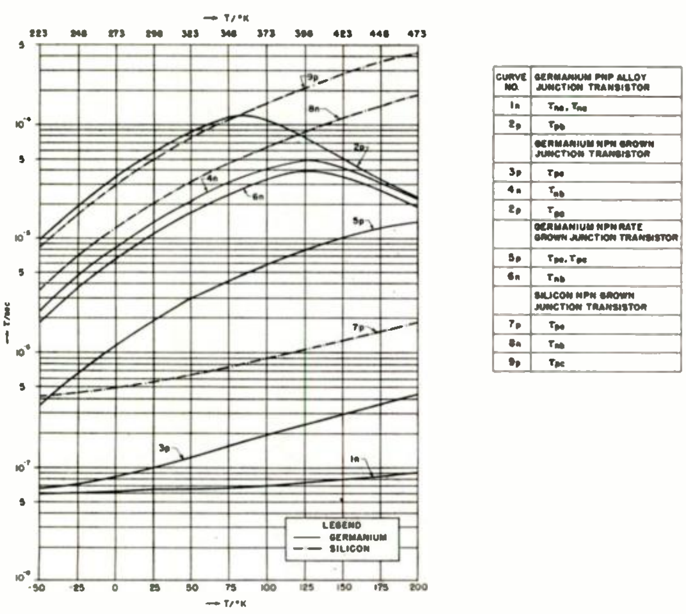


Fig. 10—Lifetimes in germanium and silicon as a function of temperature.

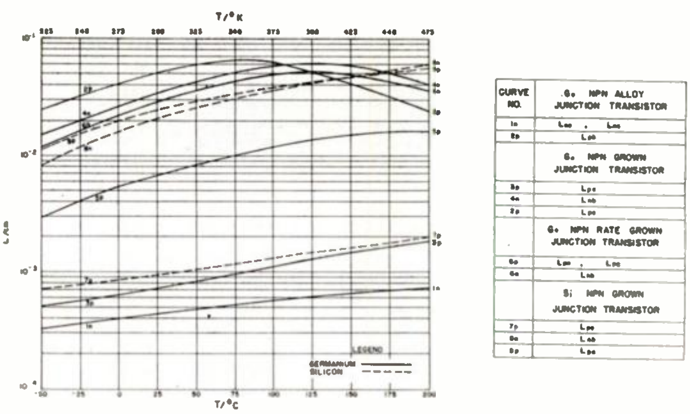


Fig. 11—Diffusion lengths in germanium and silicon as a function of temperature.

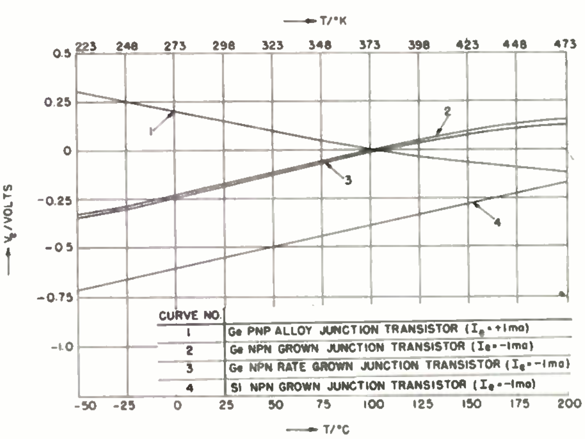


Fig. 12—Emitter voltage V_e for $I_e = (\pm)1$ ma as a function of temperature.

0.2 ev above the valence band in both materials. For the ratio τ_{po}/τ_{no}, widely differing values have been reported,[35–37] but as it fortunately does not enter the calculations in a critical way, the ratio was chosen equal to 1. τ_{po} and τ_{no} are then determined by the room temperature lifetimes for which typical values have been assumed (see Table I). Calculations carried out on this basis yield the curves of Fig. 10.

Diffusion Lengths

The quantities L entering the design equations are the so-called diffusion lengths of the minority carriers defined as $L = (D\tau)^{1/2}$. Their temperature dependence results from a combination of the previously described behavior of diffusion constants and lifetimes (Fig. 11).

Dielectric Constants

The dielectric constants of the materials enter the design equations (*e.g.*, in the capacitances and through the formulas for the scattering processes). They were measured by various authors[38–42] and the values $\kappa = 16$ for germanium and $\kappa = 12$ for silicon were assumed constant over the whole temperature range considered here.

[37] J. A. Burton, G. W. Hull, F. J. Morin, and J. C. Severiens, "Effect of nickel and copper impurities on the recombination of holes and electrons in germanium," *J. Phys. Chem.*, vol. 57, pp. 853–859; November, 1953.

[38] H. B. Briggs, "Optical effects in bulk silicon and germanium," *Phys. Rev.*, vol. 77, p. 287; January, 1950.

[39] T. S. Benedict and W. Shockley, "Microwave observation of the collision frequency of electrons in germanium," *Phys. Rev.*, vol. 89, pp. 1152–1153; March, 1953.

[40] W. C. Dunlap, Jr. and R. L. Watters, "Direct measurement of the dielectric constants of silicon and germanium," *Phys. Rev.*, vol. 92, pp. 1396–1397; December, 1953.

[41] G. C. Dacey, "Space-charge limited hole current in germanium," *Phys. Rev.*, vol. 90, pp. 759–763; June, 1953.

[42] The author is indebted to Prof. H. Y. Fan for a personal communication regarding measurements of the temperature dependence of the dielectric constants of germanium and silicon at Purdue University

V. Temperature Dependence of the Transistor Characteristics

Prepared with the knowledge of the temperature behavior of the material properties, one can calculate the temperature variation of the electrical characteristics with the help of the design equations of the third section. The analysis is carried out for common base operation from which conclusions about other configurations can be drawn.

DC Currents and Voltages

If the dc bias conditions of $I_e = \pm 1$ ma and $V_c = \mp 5$ volts (upper sign for *p-n-p*, lower sign for *n-p-n* transistors) are maintained throughout the whole temperature range, the voltage V_e across the emitter junction and the collector current I_c will undergo changes with temperature.

The absolute value of the emitter junction voltage, V_e, which is shown in Fig. 12 decreases initially with increasing temperature. As seen from (5a) and Fig. 6, this is necessary to offset the fast increase with temperature of the minority carrier density in the base region, p_{ob} in the *p-n-p*, and n_{ob} in the *n-p-n* transistor (curves 2*p*, 4*n*, 6*n*, 8*n* of Fig. 6). At lower temperatures (and thus higher absolute bias voltages) the first term in the

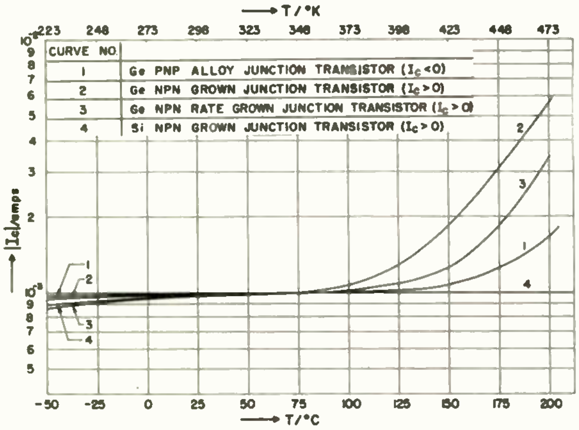


Fig. 13—Collector current I_c under ordinary bias conditions as a function of temperature.

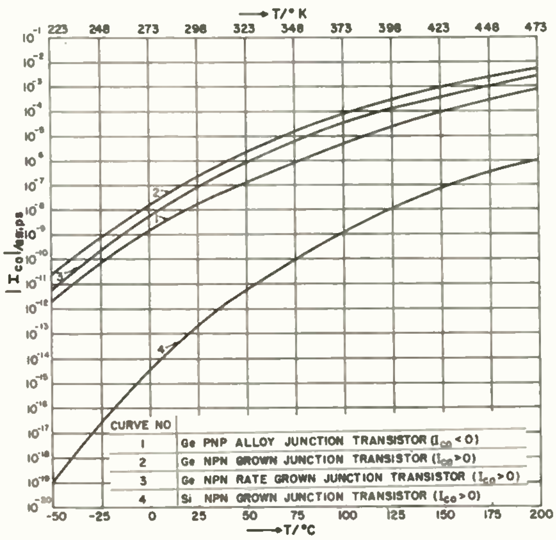


Fig. 14—(Theoretical) collector reverse current I_{co} as a function of temperature.

expression for I_e is dominant, the second term negligible At higher temperatures, however, the second term which is not controlled by the emitter voltage gains in importance until finally the emitter voltage has to change sign. The emitter junction is then biased slightly in reverse and transition from injection to a different kind of operating condition, related to extraction[43–46] has occurred in which the dc bias reduces the minority carrier density in the base region.

The collector current I_c under ordinary bias conditions [Fig. 13, (5b)] is determined in its low temperature range by the dc current amplification factor $\alpha = -h_{21}$, and is usually a few per cent less than the emitter current. This is the region where the term containing V_e (the second term in the expression for I_c) is dominant. At higher temperatures, however, the dc collector current increases to values higher than the emitter current (for the silicon model—curve 4—this transition occurs above 200°C.). This is due to different effects. In the regular grown junction germanium transistor (curve 2) with the high resistivity collector region which shows the largest increase, the major portion of the excess current is carried by (minority) holes, p_{oc}, from the collector into the base but also the (minority) electrons in the base, n_{ob}, contribute more than 1 ma to the collector current at the highest temperature point. For the rate grown n-p-n transistor (curve 3) with the much lower collector resistivity (Table I), a little more than half the collector current is carried by holes from the collector, the rest by electrons from the base. Despite their lower equilibrium density, the minority carriers in the collector region p_{oc} are more effective because equilibrium electron density in the base n_{ob} is multiplied by

$$\coth (w_o/L_{nb}) + (e^{-qV_e/kT} - 1) \operatorname{csch} (w_o/L_{nb}) \quad (31)$$

which has a value of about 0.5 at 200°C. In the p-n-p alloy transistor, the minority carrier current from the collector is negligible ($n_{oc} = 6.5 \times 10^{12}$ cm^{-3} at 200°C.) and I_c is only carried by (minority) holes from the base. In silicon, similar considerations apply but only at temperatures above the 200°C. which was assumed as the upper limit in this paper. To achieve small I_c, low resistivity in the collector region is important. A further reduction in collector current, even for highly doped collector regions, may be obtained by a low base resistivity.

Considerations very similar to those employed for the collector current I_c under ordinary bias conditions apply to the collector current I_{co} for open circuit emitter ($I_e = 0$). Its theoretical value starts at very low values as seen from Fig. 14. For silicon (curve 4) it never attains any appreciable value up to 200°C. In the germanium transistors I_{co} becomes large at the high temperatures. It is composed of minority carriers from both sides of the collector junction, but the collector region is more effective than the base for a reason similar to the case of the regular I_c above. In order that no current flows across the emitter junction, a certain (reverse) voltage V_{eo} is developed across it (Fig. 15) and the multiplication factor (31), or its analog for the p-n-p transistor, may be smaller than 0.1 at the higher temperatures. The temperatures at which I_{co} becomes appreciable correspond to the temperatures at which I_e becomes noticeably larger than 1.

The difference between emitter and collector currents (with the sign convention of Fig. 3, it is actually the sum) flows through the base lead as base current. For ordinary operating conditions, it is plotted in Fig. 16. I_b changes sign wherever the collector current goes from a smaller to a higher value than the emitter current.

[43] P. C. Banbury, "Carrier injection and extraction in lead sulphide," *Proc. Phys. Soc.* (London), vol. B66, pp. 50–53; January, 1953.

[44] A. F. Gibson, "Carrier extraction in germanium," *Physica*, vol. 20, pp. 1058–1059; 1954.

[45] A. F. Gibson, J. W. Granville, and W. Bardsley, "A germanium point-contact transistor to operate at high ambient temperatures," *Brit. J. Appl. Phys.*, vol. 6, pp. 251–254; July, 1955.

[46] J. B. Arthur, W. Bardsley, M. A. C. S. Brown, and A. F. Gibson, "Carrier extraction in germanium," *Proc. Phys. Soc.* (London), vol. B68, pp. 43–50; January, 1955.

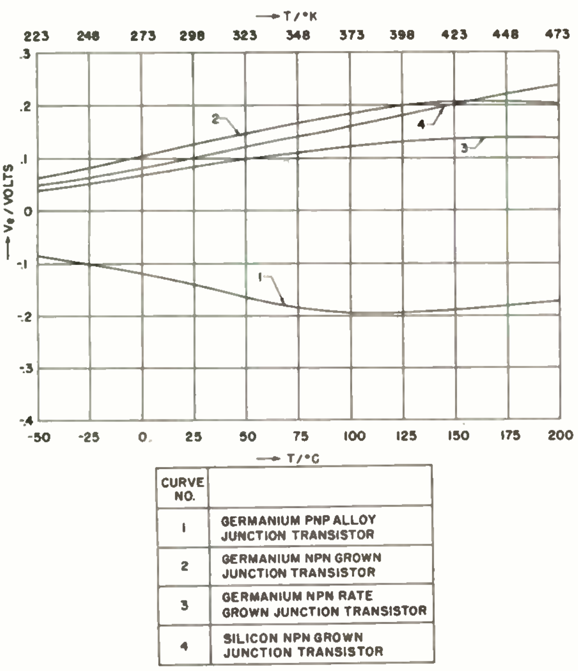


Fig. 15—Emitter voltage V_{eo} for $I_e=0$ as a function of temperature.

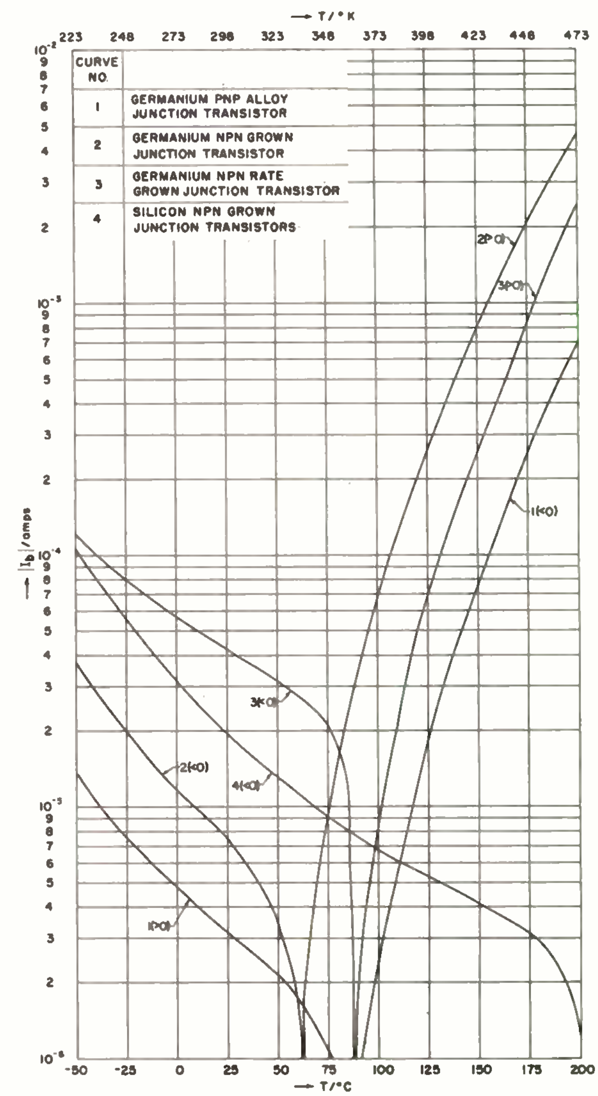


Fig. 16—Base current I_b under ordinary bias conditions as a function of temperature.

This occurs at lower temperatures for higher collector currents, and any reduction in collector current will lead to the same reduction in base current. For the silicon model, the crossover point again lies above 200°C.

Small-Signal Four-Pole Parameters

The small-signal y' parameters as defined by (1) and given by (6) and (7) depend on temperature as shown in Figs. 17 through 20, pp. 672–673.

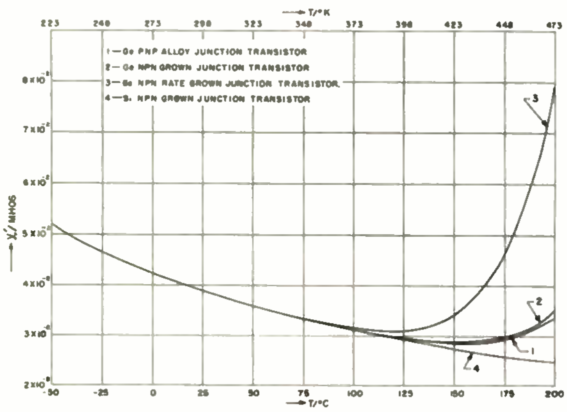
The emitter and collector barrier capacitances which enter the higher frequency expressions of the four-pole parameters (6) are found to be practically constant with temperature.

y_{11}': The temperature behavior of the low frequency y_{11}' [Fig. 17(a)] can be understood by comparing (6a) with (5a). Since all the emitter regions are well doped for injection efficiency considerations the (low frequency) y_{11}' is practically given by

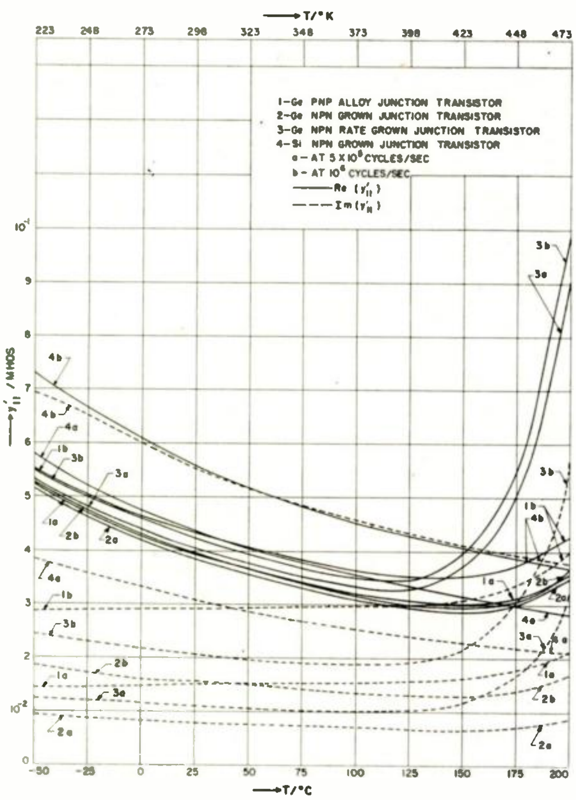
$$y_{11}' \simeq I_e \frac{q}{kT}\left[\frac{e^{qV_e/kT}\cdot\coth\,(w_o/L_{pb})}{e^{qV_e/kT}\coth\,(w_o/L_{pb}) - \coth\,(w_o/L_{pb}) + \operatorname{csch}\,(w_o/L_{pb})}\right]. \tag{32}$$

At lower temperatures and high-forward emitter voltages the bracketed factor which depends on the emitter voltage and the diffusion lengths in the base is practically equal to 1. This gives a $1/T$ dependence for y_{11}'. At the higher temperatures these factors increase, however, leading to the increase of y_{11}' in Fig. 17(a). Only for the rate grown transistor with its relatively high resistivity emitter region does the hole current from base to emitter help to increase y_{11}'. In the case of silicon, the emitter voltage does not become small enough to show any of the above effects below 200°C.

At the higher frequencies [Fig. 17(b)], the real part of y_{11}' is not greatly affected unless the frequency exceeds the alpha cut-off frequency (as curves 4b for the silicon transistor), and the temperature dependence closely resembles the low-frequency curves. The imaginary part of y_{11}' shows a similar behavior as the real part, only modified by a factor which is essentially proportional to $1/D_b$. Thus, where D decreases approximately as $1/T$ (p-n-p alloy junction transistor, curve 2p of Fig. 8) the low temperature portion of the curve is almost constant. Where D, however, shows little tem-

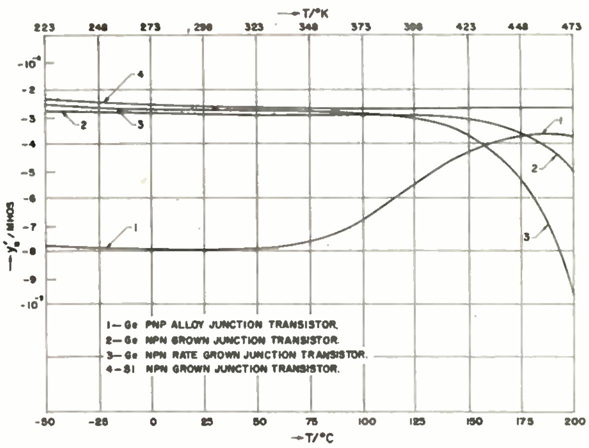


(a)

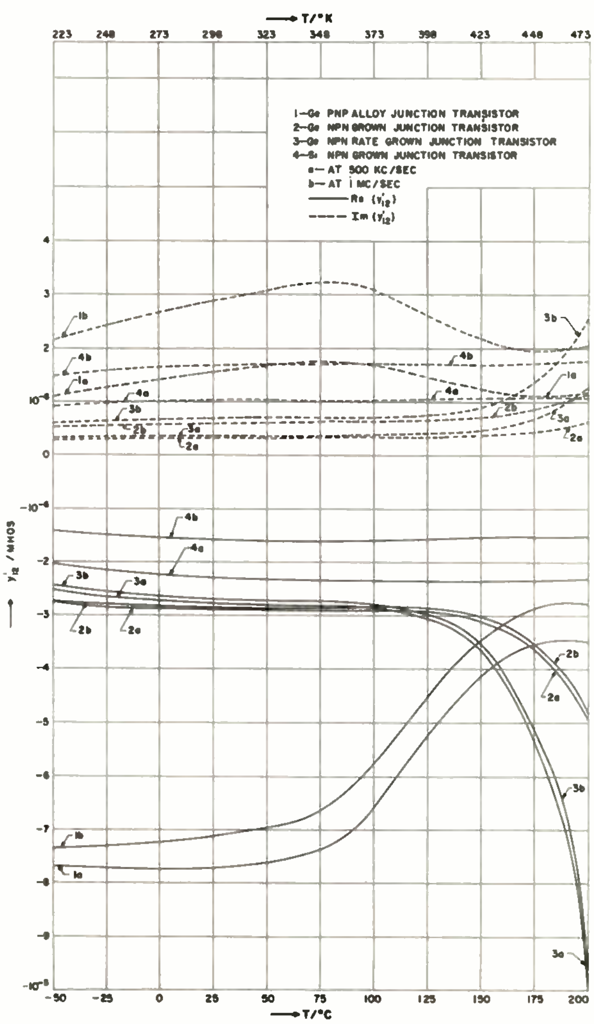


(b)

Fig. 17—(a) Four-pole parameter y_{11}' as a function of temperature (frequency $f=0$ cps); (b) four-pole parameter y_{11}' as a function of temperature.



(a)



(b)

Fig. 18—(a) Four-pole parameter y_{12}' as a function of temperature (frequency $f=0$ cps); (b) four-pole parameter y_{12}' as a function of temperature.

perature variation (silicon transistor, curve 8a of Fig. 8), the low temperature decrease of the imaginary y_{11}' curve is close to the $1/T$ behavior of the real part [curves 4 of Fig. 17(b)]. The other cases are intermediate.

y_{12}': The temperature dependence of the low frequency y_{12}' is shown in Fig. 18(a). The constancy of the lower temperature portions of the curves for the three *n-p-n* transistors is understood on the basis of the almost constant collector hole current to which y_{12}' is proportional. The three grown junction transistors (curves 2, 3, 4) also have the identical space charge widening factor $(\partial w/\partial V_c)$ (for graded junctions) so that they differ only by their low-frequency current amplification factors, and diffusion lengths in the base. At higher temperatures, the values increase (sign!) in keeping with the trend in I_e (see Fig. 13). The *p-n-p*

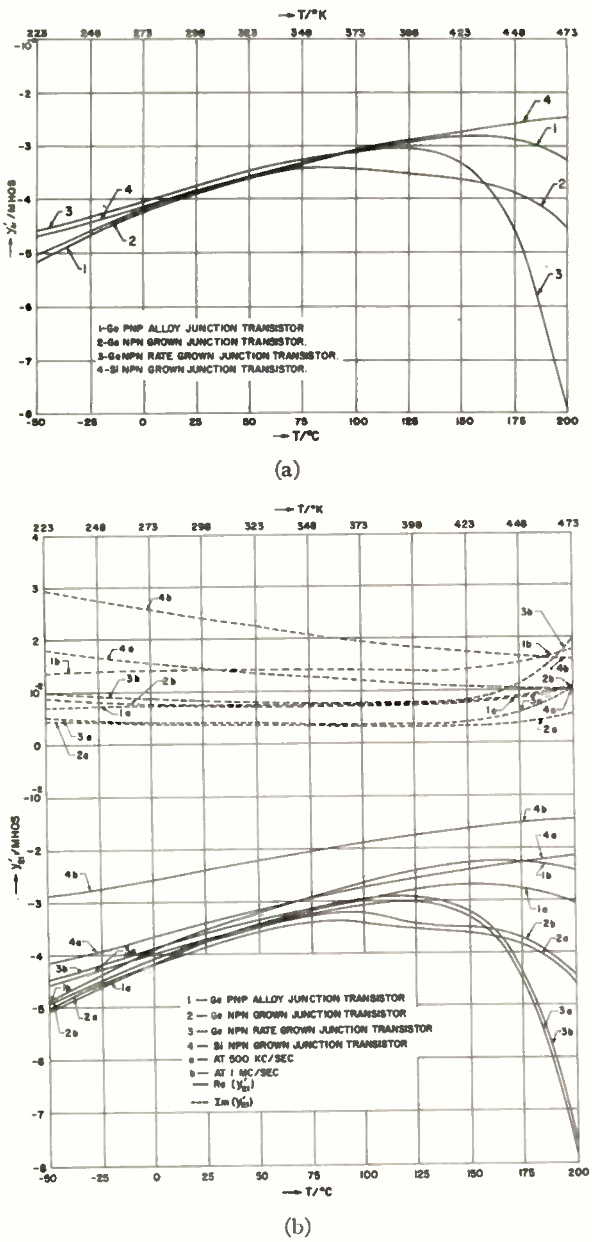


Fig. 19—(a) Four-pole parameter y_{21}' as a function of temperature (frequency $f=0$ cps); (b) four-pole parameter y_{21}' as a function of temperature.

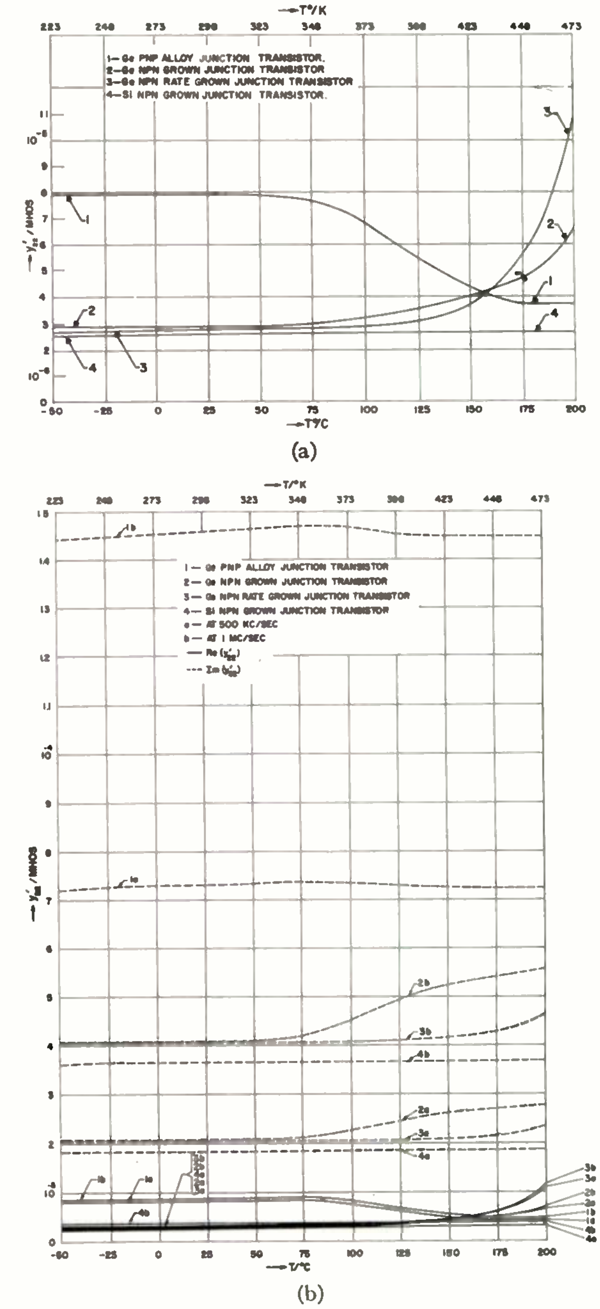


Fig. 20—(a) Four-pole parameter y_{22}' as a function of temperature (frequency $f=0$ cps); (b) four-pole parameter y_{22}' as a function of temperature.

alloy transistor (curve 1) has a different $(\partial w/\partial V_c)$, for step junctions, which changes proportional to $n_{ob}^{-1/2}$ and accounts for most of the differences in the temperature behavior as compared to the graded junction transistors. The low temperature constancy of the y_{12}' is here due to the almost constant collector hole current [compare (6b) and (5b)] and the practically constant majority carrier density, n_o, in the base. As soon as n_o increases (see Fig. 6), y_{12}' starts to decrease, but at the highest temperatures, the increase in I_c finally leads to an increase in y_{12}' also for the *p-n-p* alloy transistor. No changes occur for the silicon model because of its constant collector current (Fig. 13, curve 4).

The temperature behavior of y_{12}' at the higher frequencies is shown in Fig. 18(b). With the operating frequency below the alpha cut-off frequency, the real parts show no great differences as compared to the low-frequency behavior of Fig. 18(a). The imaginary part of y_{12}' shows the same general trend, but modified by a factor essentially proportional to the diffusion constant in the base (Fig. 8). Correspondingly, the *p-n-p* alloy junction transistor is most affected (see curves 2p, 4n, 6n, 8n in Fig. 8) whereas the other curves are only slightly modified.

y_{21}': Very similar considerations apply to the low frequency y_{11}' and y_{12}' as is seen by comparing (6c) with

(5a) and looking at the curves of Fig. 19(a) (note that $y_{21}'<0$). The differences at the low-temperature end stem from the differences in the coth and csch functions. The high-temperature curves, too, are similar to the ones for y_{11}' except for the grown *n-p-n* transistor where the collector multiplication is noticeable due to the high-collector resistivity.

At the higher frequencies [Fig. 19(b)], we find the same picture as previously, namely, slightly changed real parts and the imaginary parts modified by the diffusion constant in the base.

y_{22}': The low frequency y_{22}' [Fig. 20(a)] is very similar to y_{12}' except for the slight differences in the csch and coth functions. The collector multiplication factor which is of influence only in the grown junction germanium transistor raises y_{22}' faster than y_{12}' [curves 2 in Figs. 18(a) and 20(a)].

At the higher frequencies [Fig. 20(b)], the real part is not changed appreciably and the imaginary part is dominated by the essentially constant collector capacitance.

h' parameters: The h' parameters which are calculated from the y's according to (3), are shown in Figs. 21 through 24, pp. 675–677, and can be understood on the basis of these conversion equations.

As we go from the y' to the h' and h parameters, the mathematical expressions become more involved and limitations in space prohibit discussion of all the details. h_{11}' (Fig. 21) is simply the reciprocal of y_{11} (Fig. 17). h_{12}' is equal to $-y_{12}'\cdot h_{11}'$ so that a comparison with Figs. 18 and 21 explains Fig. 22. The temperature dependence of h_{21}', given by $y_{21}'\cdot h_{11}'$ and shown in Fig. 23, may be understood by comparing Fig. 23 with Figs. 19 and 21. h_{22}' is shown in Fig. 24. The low temperature curve is easily understood if (3d) is written in the form of $h_{22}'=y_{22}'-y_{12}'\cdot h_{21}'$ (see Figs. 18, 20, and 23). At the higher frequencies, the imaginary part of h_{22}' is dominated by the collector capacitance.

Base Spreading Resistance, r_b': As mentioned in the third section, the description of the transistor is not complete without considering the base spreading resistance r_b', (Fig. 25, p. 678). As seen from (10) and (11) r_b' is proportional to the resistivity of the base region and Fig. 25 is easily explained by comparison with Fig.9. The values of r_b' are now combined with the h' to yield the actual h parameters.

h parameters: The h parameters are given by (4) and calculations show that at low frequencies only h_{11} (Fig. 26, p. 678) and h_{12} (Fig. 27, p. 679) are noticeably affected by r_b' whereas changes occur in all four parameters at the higher frequencies. h_{11} is shown in Fig. 26(a) and (b). The additional term as compared to h_{11}' [see (4)] raises the low temperature portion of the low frequency h_{11} curves [Fig. 26(a)] with respect to h_{11}' [Fig. 21(a)]. Especially interesting is curve 2 of Fig. 26(a) where h_{11} goes to negative values causing instability in some circuits. This is due to the fact that for the regular grown germanium *n-p-n* transistor h_{21} exceeds 1 (see Fig. 23). With decreasing base spreading resistance, the effect is diminished and h_{11} returns to positive values. Fig. 27(a) and 27(b) shows the temperature behavior of the h_{12} parameter which is most affected by the base spreading resistance. Looking at (4), the curves can be understood by comparing them with Fig. 25 (r_b') and Fig. 24(b) (h_{22}'). Little influence of r_b' on h_{21} and h_{22} [Figs. 23(a)–(d); 24(a)–(c)] is noticed even at the higher frequencies [compare Figs. 23(b), 24(b) with 23(c), 24(c)]. Since it is customary to represent $h_{21}=-\alpha$ by magnitude and phase rather than by real and imaginary parts such a plot has been included [Fig. 23(d)].

The alpha cut-off frequency is an important quantity in the characterization of the frequency behavior of a transistor. It is given by (12) and shown in Fig. 28, p. 679. Since there is direct proportionality with the diffusion constants, curves 1, 2, 3, 4 of Fig. 28 may be understood by comparing them with curves 2p, 4n, 6n, 8n respectively of Fig. 8.

Early[10] has pointed out that there exists a base resistance modulation feedback, μ_{bc}, in the transistor. It is given by

$$\mu_{bc} \simeq I_b\rho_b\left(\frac{1}{8\pi w_1^2}+\frac{1}{2\pi w_2^2}\ln\frac{r_2}{r_1}\right)\frac{\partial w}{\partial V_c} \tag{34}$$

for the *p-n-p* and by

$$\mu_{bc} \simeq I_b(r_b/w)(\partial w/\partial V_c) \tag{35}$$

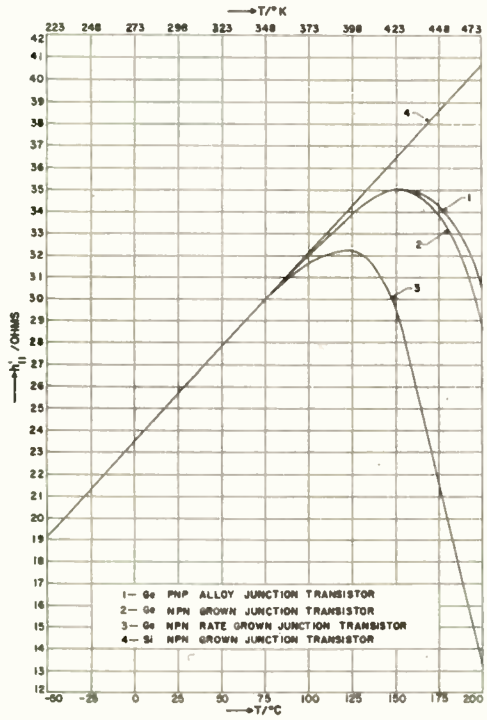
for the *n-p-n* transistor. It is shown in Fig. 29, p. 679. The curves follow the general pattern of the I_b curves (Fig. 16) modified by the temperature behavior of the base resistivity (Fig. 9).

Equivalent Circuits

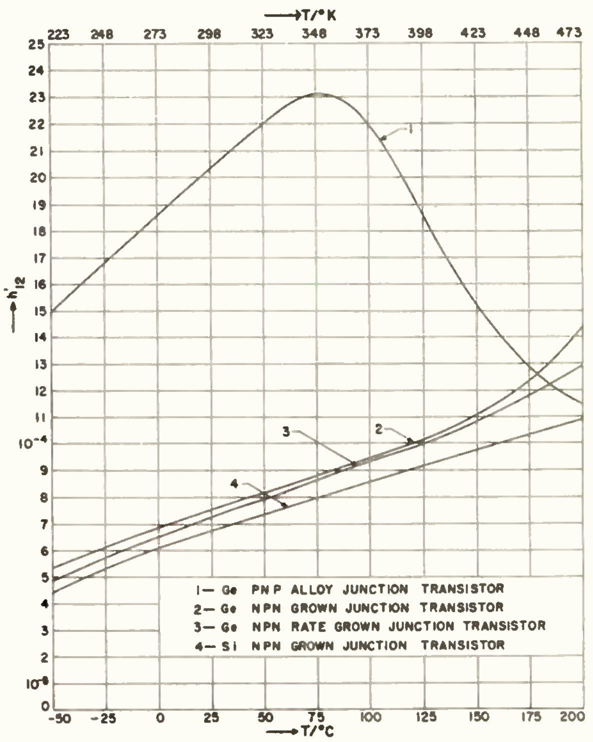
The temperature variations of the parameters for the simplified equivalent circuit [Fig. 5, (13) through (15)] are easy to understand on the basis of the previous discussions because of the mathematical similarities between g_{ee} and y_{11} [Fig. 17(a)], between g_{ce} and y_{22} [Fig. 20(a)], and between ω_α and $f_{\alpha co}$ (Fig. 28).

VI. Conclusion

Some general conclusions as to the construction of high-temperature transistors may be drawn from the above considerations. Particular applications may require special designs, but for general purposes the following guide lines will yield satisfactory results: low collector resistivity reduces I_{co} and prevents alpha from becoming greater than 1. For a further reduction in I_{co} the base should be doped as highly as emitter efficiency and alpha cut-off frequency permit. On the other hand, if the small signal parameters rather than bias problems are the major consideration, base doping for temperature insensitive diffusion constant (different for *p-n-p* or *n-p-n* transistors) seems more desirable. Graded collector junctions appear superior to step junctions.



(a)



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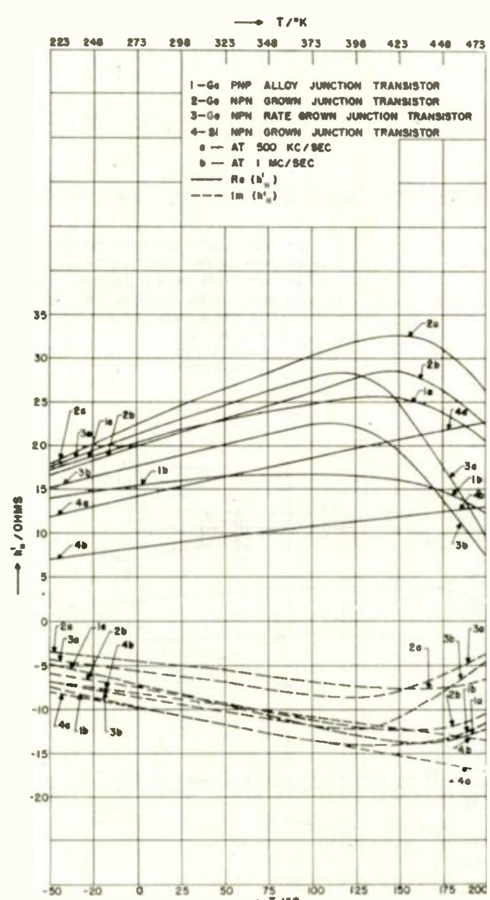

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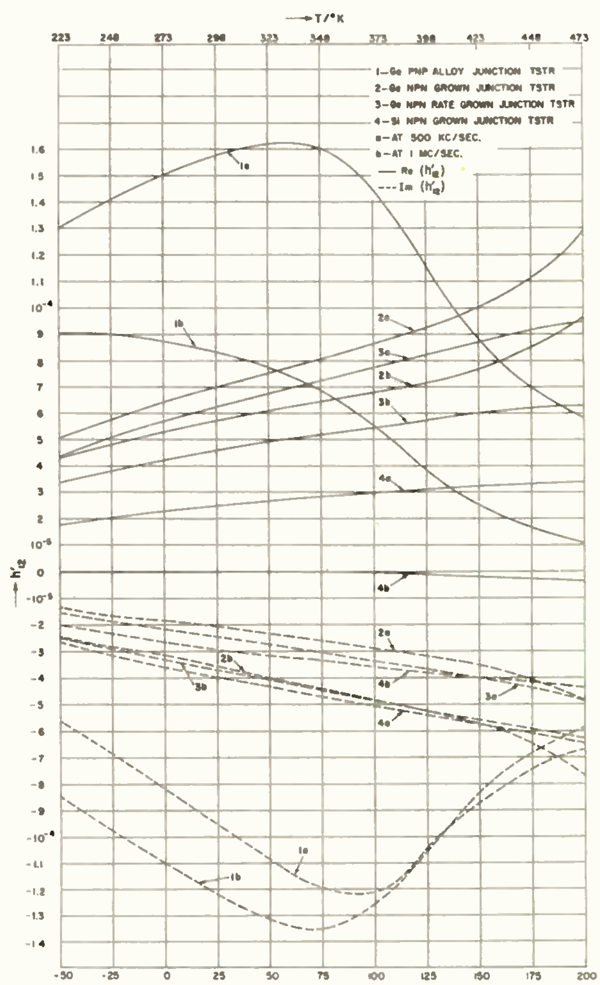


(b)

Fig. 21—(a) Four-pole parameter h_{11}' as a function of temperature (frequency $f=0$ cps); (b) four-pole parameter h_{11}' as a function of temperature.

Fig. 22—(a) Four-pole parameter h_{12}' as a function of temperature (frequency $f=0$ cps); (b) four-pole parameter h_{12}' as a function of temperature.

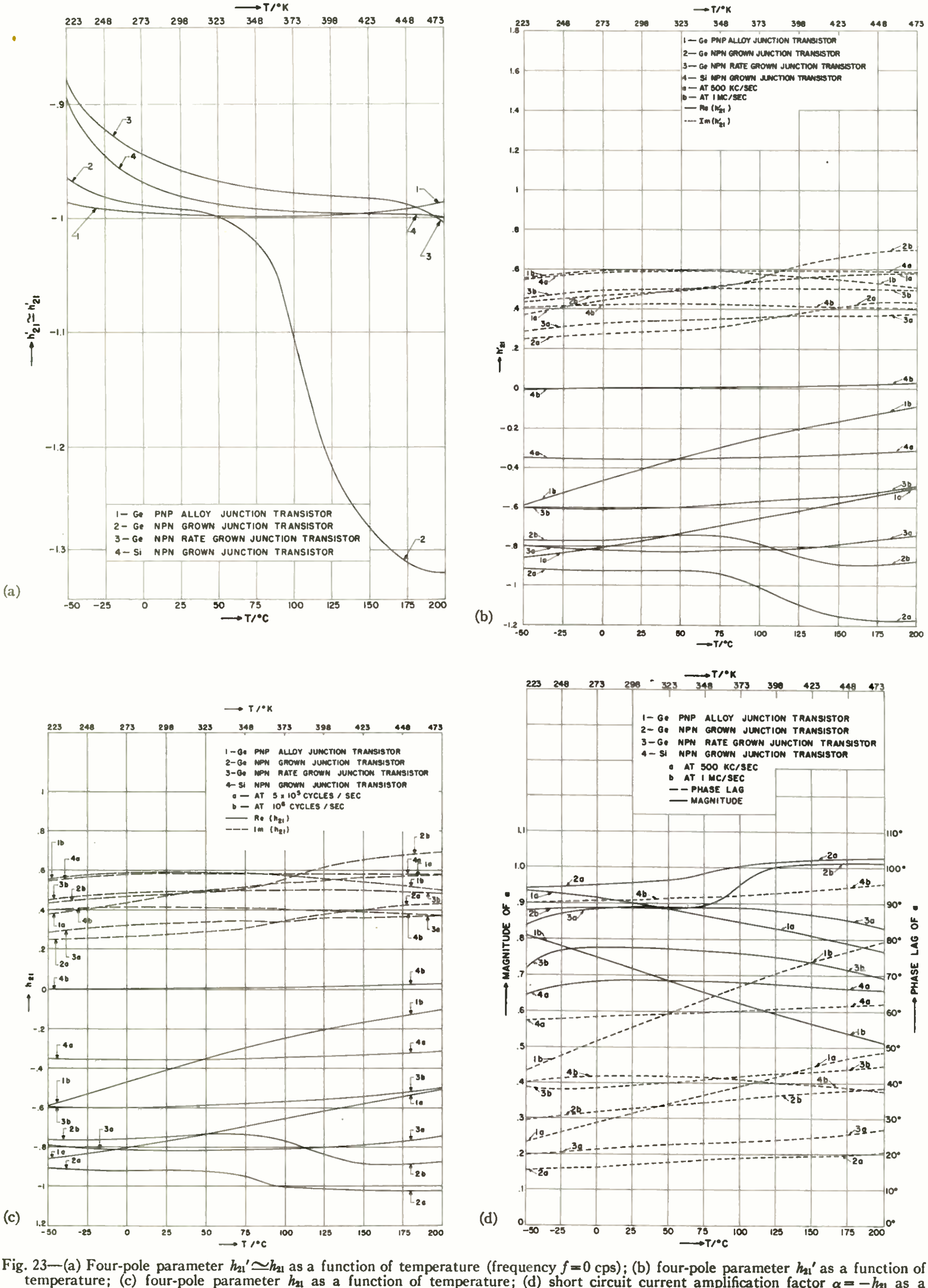


Fig. 23—(a) Four-pole parameter $h_{21}' \simeq h_{21}$ as a function of temperature (frequency $f=0$ cps); (b) four-pole parameter h_{21}' as a function of temperature; (c) four-pole parameter h_{21} as a function of temperature; (d) short circuit current amplification factor $\alpha = -h_{21}$ as a function of temperature.

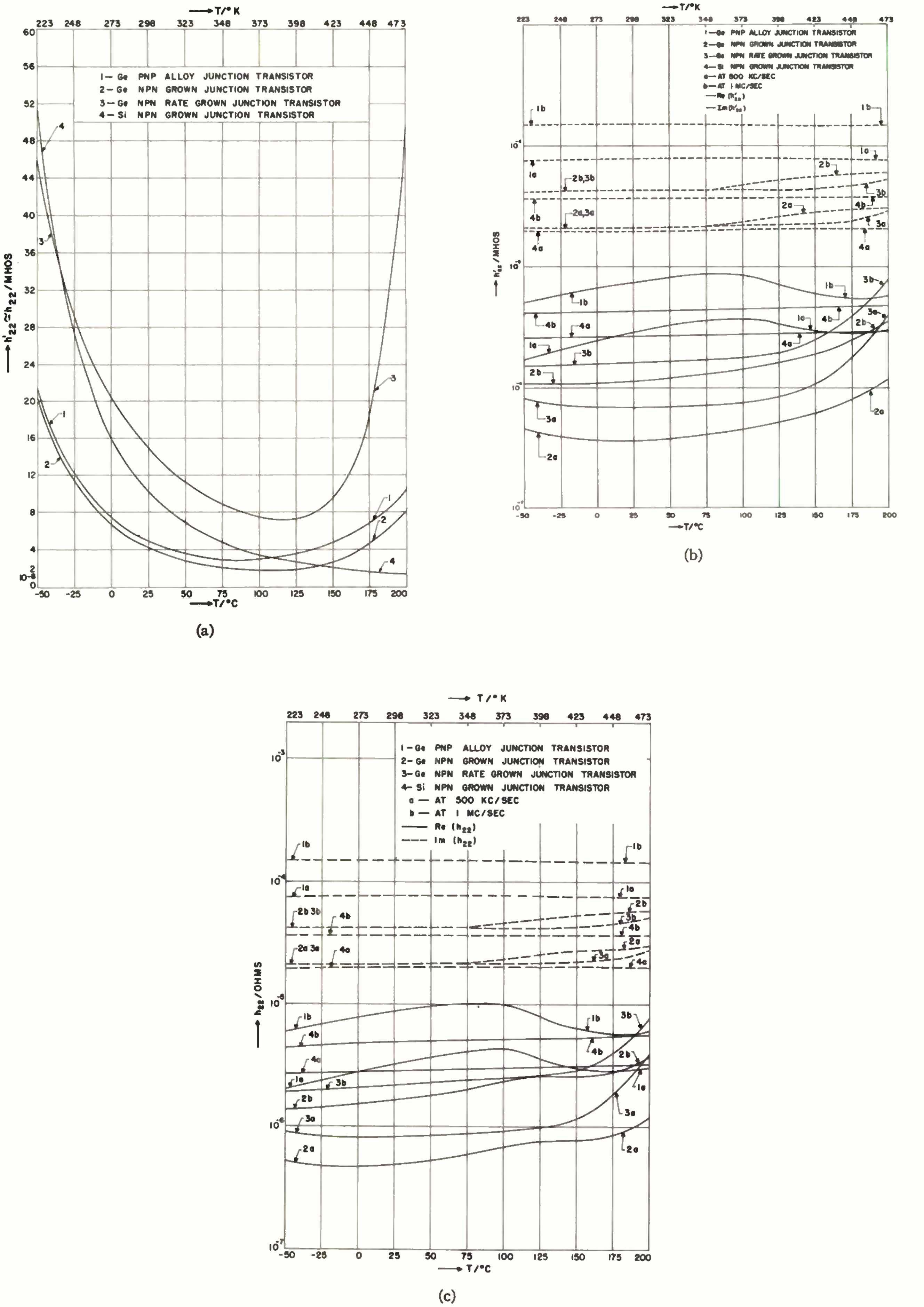


Fig. 24—(a) Four-pole parameter $h_{22}' \simeq h_{22}$ as a function of temperature (frequency $f = 0$ cps); (b) four-pole parameter h_{22}' as a function of temperature; (c) four-pole parameter h_{22} as a function of temperature.

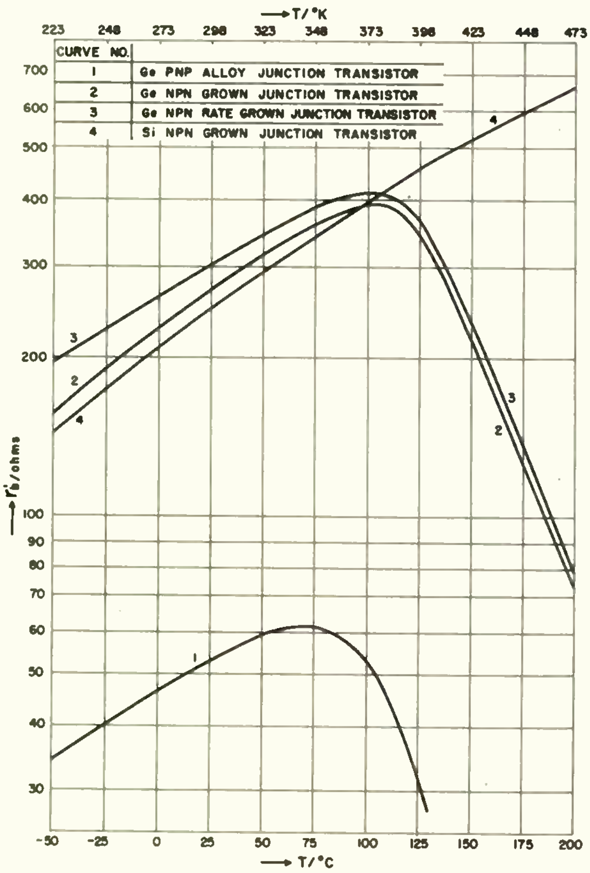


Fig. 25—Base spreading resistance r_b' as a function of temperature.

The question of upper limit of performance of a transistor depends on what deviations from room temperature values one wants to allow and to what extremes of stabilization one wants to go.

Although each case has to be investigated separately, the foregoing analysis seems to show that germanium units incorporating the "high temperature design" features will operate satisfactorily above 100°C, possibly up to 150°C, whereas it should be possible to build silicon transistors which operate well in excess of 200°C, if operation with slightly reverse emitter voltage is excluded because of the radical changes which then occur in the small signal parameters.

The calculations also show that the theoretical collector current does not become large enough to cause runaway by internal heating.

This accentuates an important result of the above considerations: the semiconductor nucleus of the transistor can be designed to operate at high temperatures and the actual performance of a finished unit will depend upon how carefully the junctions have been prepared and to what degree it has been possible to avoid the deleterious effects of solders, fluxes, moisture, gaseous ambients, potting compounds, etc. on the temperature characteristics. Next to proper design these problems have to be given the greatest attention because they are equally essential to the construction of a high temperature transistor.

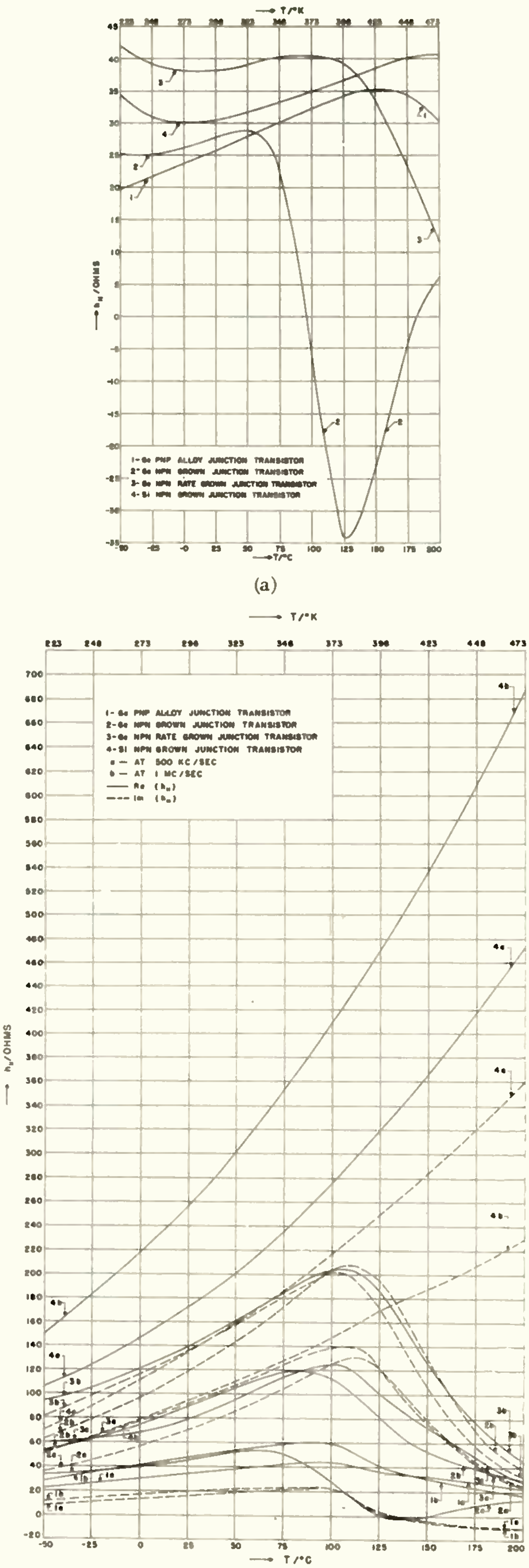
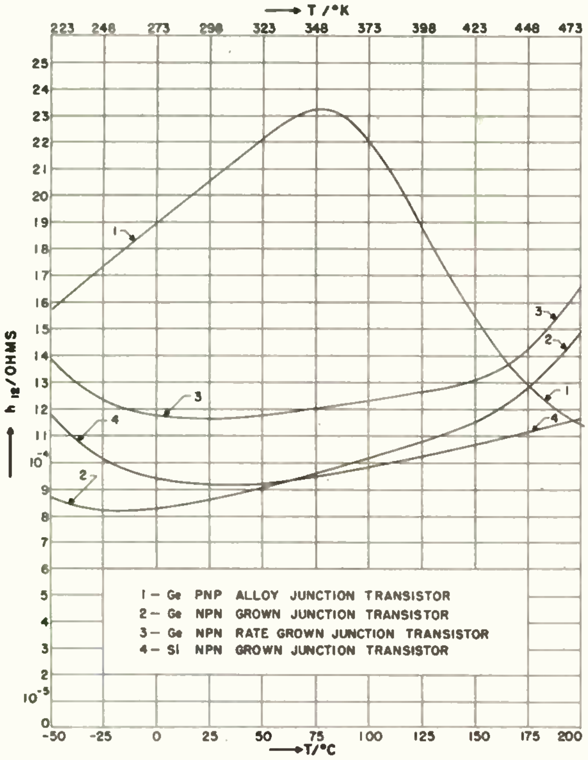
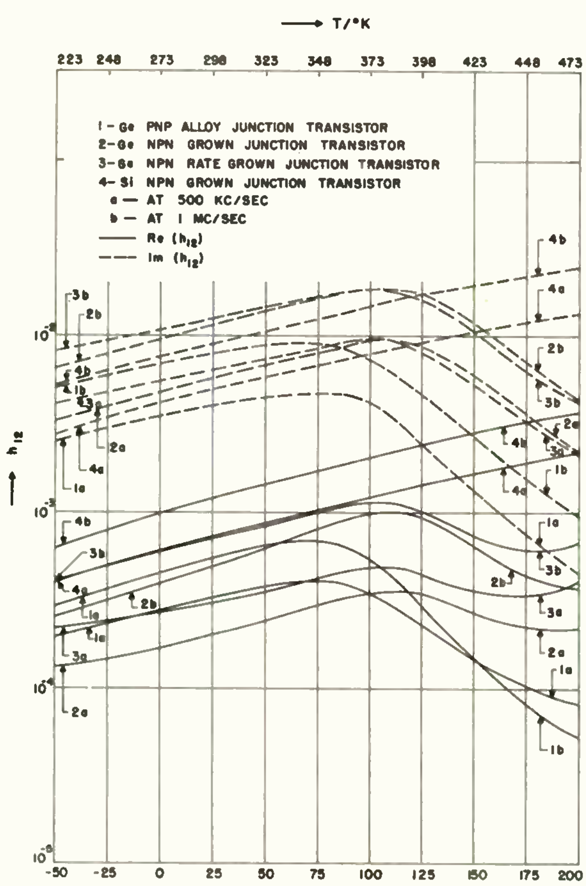


Fig. 26—(a) Four-pole parameter h_{11} as a function of temperature (frequency $f=0$ cps); (b) four-pole parameter h_{11} as a function of temperature.



(a)



(b)

Fig. 27—(a) Four-pole parameter h_{12} as a function of temperature (frequency $f=0$ cps); (b) four-pole parameter h_{12} as a function of temperature.

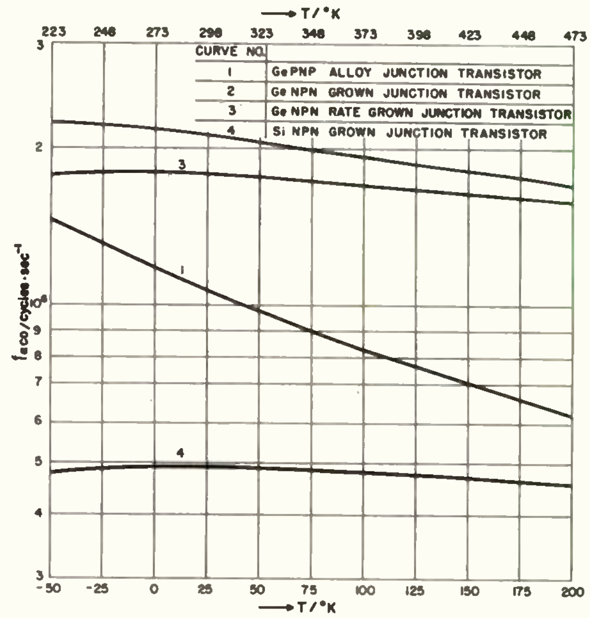


Fig. 28—Alpha cut-off frequency $f_{\alpha co}$ as a function of temperature.

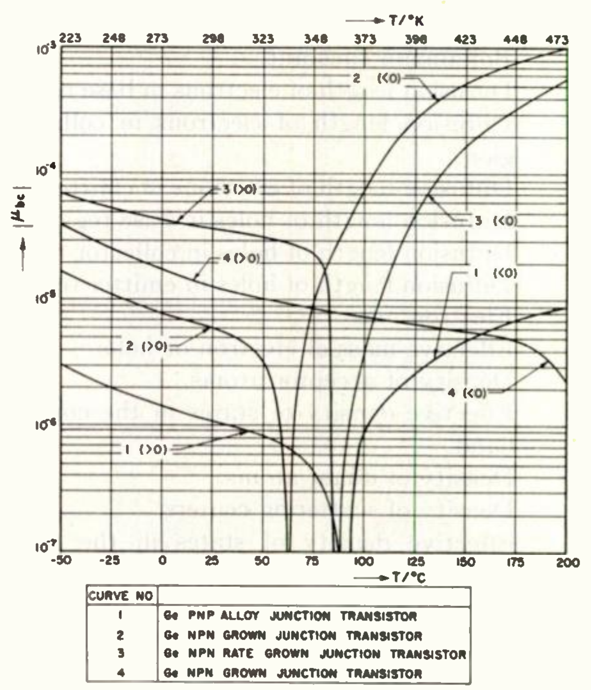


Fig. 29—Base resistance modulation feedback μ_{bc} as a function of temperature.

List of Symbols

A	Conducting cross section of semiconductor bar.
A_c	Collector area of alloy junction transistor.
A_e	Emitter area of alloy junction transistor.
a	Gradient of total impurity density across junction.
C_c	Collector capacitance.
C_e	Emitter capacitance.

D_{nb} Diffusion constant of electrons in base region.
D_{nc} Diffusion constant of electrons in collector region.
D_{ne} Diffusion constant of electrons in emitter region.
D_{pb} Diffusion constant of holes in base region.
D_{pc} Diffusion constant of holes in collector region.
D_{pe} Diffusion constant of holes in emitter region.
E_c Lower edge of conduction band.
E_f Fermi level.
E_t Recombination level.
E_v Upper edge of valence band.
$f_{\alpha co}$ Alpha cut-off frequency
g_{cc} Conductance in equivalent circuit (Fig. 5) given by (14).
g_{ee} Conductance in equivalent circuit (Fig. 5) given by (13).
$h_{11}, h_{12}, h_{21}, h_{22}$ Four-pole parameters defined by (4).
$h_{11}', h_{12}', h_{21}', h_{22}'$ Four-pole parameters defined by (3).
I_c DC Collector current (for $I_e = \pm 1$ ma).
I_{co} DC Collector current for $I_e = 0$.
I_e DC emitter current.
i_c AC collector current.
i_e AC emitter current.
k Boltzmann constant.
L_{nb} Diffusion length of electrons in base region.
L_{nc} Diffusion length of electrons in collector region.
L_{ne} Diffusion length of electrons in emitter region.
L_{pb} Diffusion length of holes in base region.
L_{pc} Diffusion length of holes in collector region.
L_{pe} Diffusion length of holes in emitter region.
m Electron mass.
m_{eff} Effective mass of electron or hole.
N_a Density of acceptor atoms.
N_c Effective density of states in the conduction band.
N_d Density of donor atoms.
N_I Density of scattering centers.
N_v Effective density of states in the valence-band.
n_1 Electron density defined by (30a).
n_i Intrinsic carrier density.
n_o Equilibrium electron density.
n_{ob} Equilibrium electron density in base region.
n_{oc} Equilibrium electron density in collector region.
n_{oe} Equilibrium electron density in emitter region.
p_1 Hole density defined by (30b)
p_o Equilibrium hole density
p_{ob} Equilibrium hole density in base region.
p_{oc} Equilibrium hole density in collector region.
p_{oe} Equilibrium hole density in emitter region.
q Electron charge.
r_b' Base spreading resistance.
T Temperature.
V_c DC collector voltage.
V_e DC emitter voltage (for $I_e = \pm 1$ ma).
V_{eo} DC emitter voltage for $I_e = 0$.
v_c AC collector voltage.
v_e AC emitter voltage.
w_o Base width of transistor.
$\partial w / \partial V_c$ Space charge widening factor.
$y_{11}', y_{12}', y_{21}', y_{22}'$ Four-pole parameters defined by (1).
ϵ_o Permittivity of free space.
κ Dielectric constant.
μ_{bc} Base resistance modulation feedback given by (34) and (35).
μ_I Impurity mobility.
μ_L Lattice mobility.
μ_{nb} Electron mobility in base region.
μ_{nc} Electron mobility in collector region.
μ_{ne} Electron mobility in emitter region.
μ_{nL} Lattice mobility for electrons.
μ_{pb} Hole mobility in base region.
μ_{pc} Hole mobility in collector region.
μ_{pe} Hole mobility in emitter region.
μ_{pL} Lattice mobility for holes.
ω Circular frequency.
ω_α Frequency parameter in equivalent circuit (Fig. 5) given by (15).
ρ_b Resistivity in base region.
ρ_c Resistivity in collector region.
ρ_e Resistivity in emitter region.
τ Carrier lifetime.
τ_{nb} Lifetime of electrons in base region.
τ_{nc} Lifetime of electrons in collector region.
τ_{ne} Lifetime of electrons in emitter region.
τ_{no} Lifetime of electrons injected into highly *p*-type material.
τ_{pb} Lifetime of holes in base region.
τ_{pc} Lifetime of holes in collector region.
τ_{pe} Lifetime of holes in emitter region.
τ_{po} Lifetime of holes injected into highly *n*-type material.

VII. Acknowledgment

I have to thank my former colleagues at Siemens and Halske, A. G. Halbleiterfabrik, Munich, Germany for many interesting discussions as well as Drs. R. L. Pritchard and R. N. Hall of the General Electric Research Laboratory, and F. A. Brand and W. G. Matthei, Evans Signal Laboratory for corrections and helpful suggestions regarding the manuscript. Particular thanks are due to D. E. Amos of Oregon State College and W. Nakamura of Evans Signal Laboratory for carrying out all the numerical calculations.

Design of Three-Resonator Dissipative Band-Pass Filters Having Minimum Insertion Loss*

J. J. TAUB†, MEMBER, IRE AND B. F. BOGNER†, MEMBER, IRE

Summary—**The purpose of this paper is to present universal design curves for three-resonator band-pass filters having minimum insertion loss. This information is obtained by solving Dishal's equations for a band-pass network uniquely for the condition of minimum insertion loss, the network here consisting of three synchronously tuned resonant circuits (coupled to a resistive generator and a resistive load) having the same finite value of unloaded Q. The general solution for the maximally flat response is presented in detail in the second half of this paper.**

The exact values of the circuit constants for a minimum-insertion-loss response are given both analytically and graphically in terms of the unloaded Q and the fractional bandwidth. Also, the deviation from the exact response shape of a maximally flat filter is discussed for varying values of circuit constants.

Introduction

PRESENT-DAY design of narrow-band (less than 10 per cent bandwidth) band-pass filters employing synchronously-tuned coupled resonant circuits stems essentially from Dishal's design equations[1] for dissipative band-pass filters. Dishal's equations enable the designer to calculate, for each resonator, the coefficients of coupling and the decrements that will yield the desired amplitude-frequency filter response. These equations were derived by expressing the transfer impedance of an n-coupled synchronously-tuned set of resonant circuits in terms of their coefficients of coupling and decrements. This is equated to the transfer impedance corresponding to the desired relative insertion-loss function (usually a Tchebycheff function[2] with a given pass-band ripple). By equating the n coefficients of each, Dishal obtained sets of design equations for different numbers of resonant circuits. Examination of these relationships reveals n equations containing $n+1$ unknowns ($n-1$ coefficients of coupling and two decrements—the first and the last). For any given problem, the other decrements and the desired bandwidth are known.

The solution of Dishal's equations will yield many sets of circuit constants that would produce the desired response. By imposing the additional condition that the insertion loss—the ratio of the power available from a resistive generator to the power delivered to a resistive load—be minimum, a unique set of circuit constants can be obtained. This principle has been used by the authors to obtain design information for three-resonator filters, with either maximally flat or Tchebycheff-type response. (Only the case of maximally flat response is discussed in detail here.) The only assumption made in this analysis is that the unloaded Q is the same for each of the resonant circuits. In practice, this is usually the case.

The first section presents the curves that give the design information, together with an explanation of their use. An illustrative example is given. The second section describes the derivation and computation of the curves and includes a theoretical evaluation of the criticalness of the design. An expression for midband insertion loss is derived in Appendix I. Appendix II discusses the effect on maximally flat response of small variations in circuit constants.

Symbols are defined below. For clarity, the notation used by Dishal is employed wherever possible, in order to show the logical extension to the optimum design. To obtain universal curves, it was necessary to normalize the circuit constants to the 3-db fractional bandwidth. Fig. 1 shows the relations used in normalizing. (Although Fig. 1 depicts a voltage-fed network, by duality the analysis also holds for a current-fed network.)

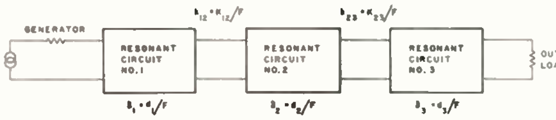


Fig. 1—Block diagram of three-coupled circuit filter.

The subscripts 1, 2, and 3 denote: 1) resonant circuit 1 loaded only by the generator, 2) resonant circuit 2 in its unloaded condition, and 3) resonant circuit 3 loaded only by the output.

C = equivalent capacitance of resonant circuit
$d = 1/Q$ = total resonant circuit decrement
$\delta = d/F$ = normalized decrement
F = total 3-db fractional bandwidth
f_0 = resonant frequency of each resonant circuit
$\omega_0 = 2\pi f_0$ = angular resonant frequency
g = equivalent conductance of resonant circuit
g_g = equivalent conductance of generator
g_L = equivalent conductance of load
I = magnitude of current from equivalent constant-current generator that drives network

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† Airborne Instruments Lab., Mineola, N. Y.
[1] M. Dishal, "Design of dissipative band-pass filters producing desired exact amplitude-frequency characteristics," Proc. IRE, vol. 37, pp. 1050–1069; September, 1949.
[2] W. R. LePage and S. Seely, "General Network Analysis," McGraw-Hill Book Co., Inc., New York, N. Y., pp. 235–256; 1952.

K = resultant coefficient of coupling between resonant circuits
$k = K/F$ = normalized coefficient of coupling
L = midband insertion loss in db
L_r = relative insertion loss in db
n = number of resonant circuits
P_a = available input power
P_{out} = output power
$Q_1 = Q$ of first resonant circuit loaded only by the input
$Q_2 = Q_u$ = unloaded Q of second resonant circuit
$Q_3 = Q$ of third resonant circuit loaded only by the output
V_p = magnitude of voltage output at frequency of peak response
v = relative voltage response
$\phi = 2(f-f_0)/(Ff_0)$ = normalized frequency variable

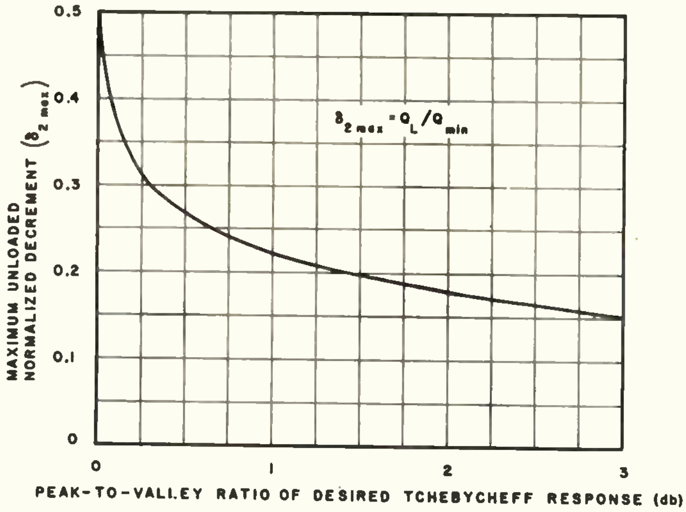

Fig. 2—Ratio of filter loaded Q to minimum unloaded Q required, as a function of peak-to-valley ratio for three resonator-filter.

Design Procedures

Discussion of Design Curves

By definition, $\delta(=d/F=1/FQ)$ is the decrement for the resonant circuit designated by the subscript, normalized with respect to fractional bandwidth F; δ_2 is the value corresponding to unloaded Q_2. (Since it is assumed that the unloaded Q is the same for all three resonant circuits, Q_2 becomes Q_u.) The normalized coefficients of coupling are k_{12} and k_{23}.

For the sake of completeness, Dishal's minimum-Q curve for three-resonator filters[3] is reproduced here as Fig. 2. In Fig. 3 the loss curve for a particular response shape is plotted against δ_2/δ_{2max}, where δ_{2max} is the value of δ corresponding to Q_{min}, and Q_{min} is defined as the smallest value of unloaded Q that will produce a specified exact response shape with resulting infinite insertion loss. The loss curves shown are for maximally flat response and ½-db and 3-db Tchebycheff response. Those for 1-db and 2-db response fall between the ½-db and 3-db curves, and cannot be shown with clarity.

Fig. 3 therefore shows a useful common property of all three-resonator filters—for all response shapes the curves thus plotted are so close to each other that for engineering purposes they can be approximated by a single "universal" curve. This universal curve is especially important because it tells the designer what unloaded Q his resonators must have in order to satisfy a particular requirement on midband insertion loss.

The universal design charts are given in Fig. 4; they show the required values of δ_1, δ_3, k_{12}, and k_{23} as a function of δ_2 for maximally flat response [Fig. 4(a)] and for Tchebycheff-type response for peak-to-valley values of 0.5 db [Fig. 4(b)], 1 db [Fig. 4(c)], 2 db [Fig.

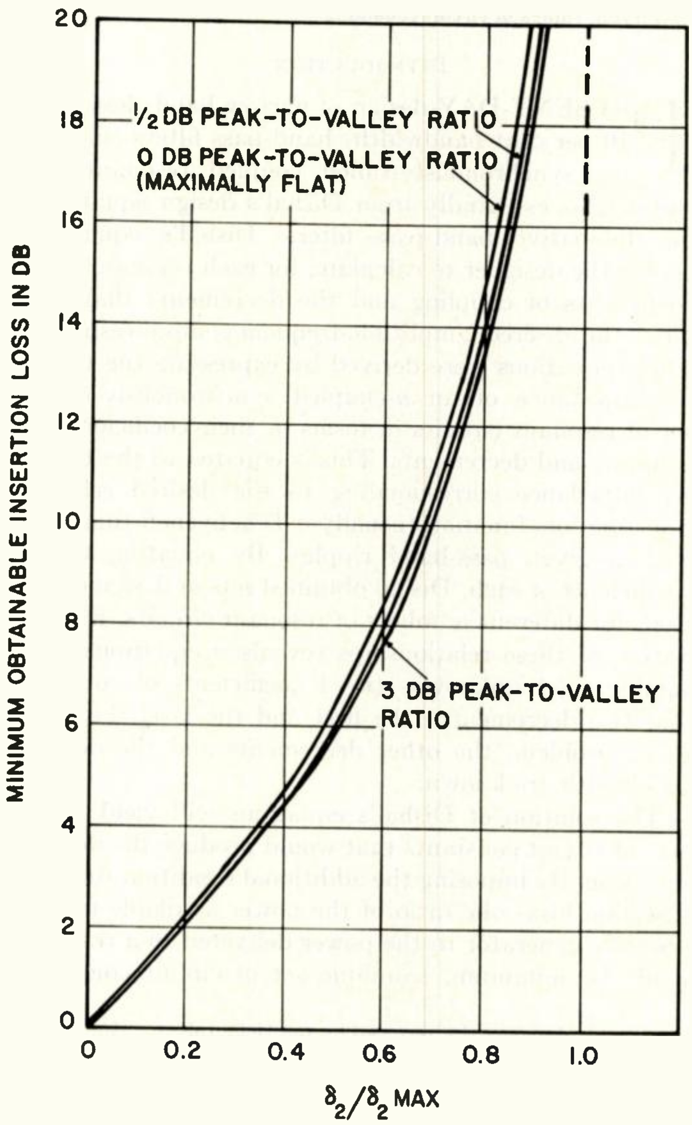

Fig. 3—Minimum insertion loss curves for three-resonator filters. (The curves for 1-db and 2-db response fall between the ½-db and 3-db curves.)

[3] M. Dishal, "Concerning the minimum number of resonators and the minimum unloaded-resonator Q in a filter," *Elec. Comm.*, vol. 32; pp. 257–277; December, 1954.

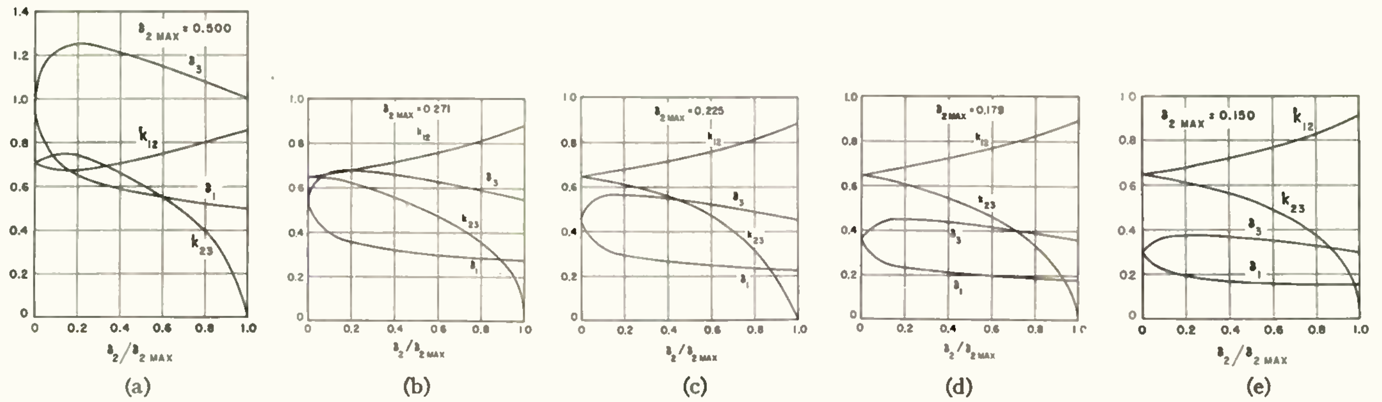

Fig. 4—Design charts for three-resonator Tchebycheff filters: (a) 0-db ripple (Butterworth), (b) ½-db ripple, (c) 1-db ripple, (d) 2-db ripple, and (e) 3-db ripple, where δ_1 = decrement of resonant circuit No. 1, δ_2 = unloaded decrement of each resonant circuit, δ_3 = decrement of resonant circuit No. 3, k_{12} is coefficient of coupling between resonant circuits No. 1 and No. 2, k_{23} = coefficient of coupling between resonant circuits No. 2 and No. 3—all normalized to 3-db fractional bandwidth.

4(d)], and 3 db [Fig. 4(e)]. From these charts the designer can readily obtain the unique values of circuit constants after the unloaded Q has been determined.

To summarize, Fig. 2 shows the designer the minimum unloaded Q he must have to realize a given response; Fig. 3 indicates the minimum insertion loss that can be attained for the prescribed unloaded Q; and the pertinent design chart of Fig. 4 shows directly the design values of circuit constants that will yield the desired filter.

The following example illustrates the use of these charts. Let the specifications for the filter be:

Center frequency (f_0): 10,000 mc

3-db bandwidth: 10 mc (fractional bandwidth $F = 10^{-3}$)

Maximum midband insertion loss (L): 10 db

Skirt response: 25 db down from peak ±15 mc from f_0.

A three-resonator maximally flat filter is chosen because it meets the response requirements—that is, the skirts are down 28.6 db from peak at ±15 mc.[4] From Fig. 2, for maximally flat response (peak-to-valley ratio 0 db), $\delta_{2max} = 0.5$. From Fig. 3, for 10-db insertion loss, $\delta_2/\delta_{2max} = 0.66$; hence $\delta_2 = 0.33$. Then the normalized design values of the circuit constants can be read from Fig. 4a: $\delta_1 = 0.53$, $\delta_3 = 1.13$, $k_{12} = 0.76$, and $k_{23} = 0.52$.

Since F here is 10^{-3}, and by definition $\delta_1 = d_1/F$, etc., the design values are

$$d_1 = 5.3 \times 10^{-4} \qquad K_{12} = 7.6 \times 10^{-4}$$

$$d_3 = 1.13 \times 10^{-3} \qquad K_{23} = 5.2 \times 10^{-4}.$$

These values are then properly set by using the method outlined by Dishal.[5]

[4] S. Butterworth, "On the theory of filter amplifiers," *Experimental Wireless and Wireless Eng.* vol. 7, pp. 536–541; October, 1930.

[5] M. Dishal, "Alignment and adjustment of synchronously tuned multiple-resonant-circuit filters," Proc. IRE, vol. 39, pp. 1448–1455; November, 1951.

Practical Considerations

The design procedure outlined above is based upon the assumption that the required value of Q_u is obtainable, though in many instances this is not the case. It is also conceivable that the Q_u realized in production may be different from that about which the filter was designed. In the second section deviations of response shape for variations in Q_u from an exact design value are considered. Fig. 5 (next page) shows these deviations for a particular value of δ_2. The results indicate that, for Q_u less than that required for a given insertion loss (Fig. 3), the 3-db bandwidth narrows and the skirt response deteriorates. For Q_u greater than the design value, the 3-db bandwidth widens and the skirts become steeper.

Theoretical Considerations

The solution for the unique set of constants yielding the required response with minimum midband insertion loss was first obtained by graphical means. This gave insight into the problems of filter design and enabled the authors to present the design procedures outlined previously. With the aid of this work, the analytical expressions for the design values were then derived by E. G. Fubini of Airborne Instruments Laboratory. His results indicate that exact solutions are obtainable for circuits containing three or more resonant coupled circuits. The work he is doing for four or more sections will be presented at a later date.

Solution of Design Equations

The design equations due to Dishal[1] for three coupled resonant circuits having a maximally flat response are

$$d_1 + d_2 + d_3 = 2F \qquad (1a)$$

$$K_{12}^2 + K_{23}^2 + d_1d_2 + d_1d_3 + d_2d_3 = 2F^2 \qquad (1b)$$

$$K_{12}^2d_3 + K_{23}^2d_1 + d_1d_2d_3 = F^3. \qquad (1c)$$

These equations hold for both voltage-fed and current-

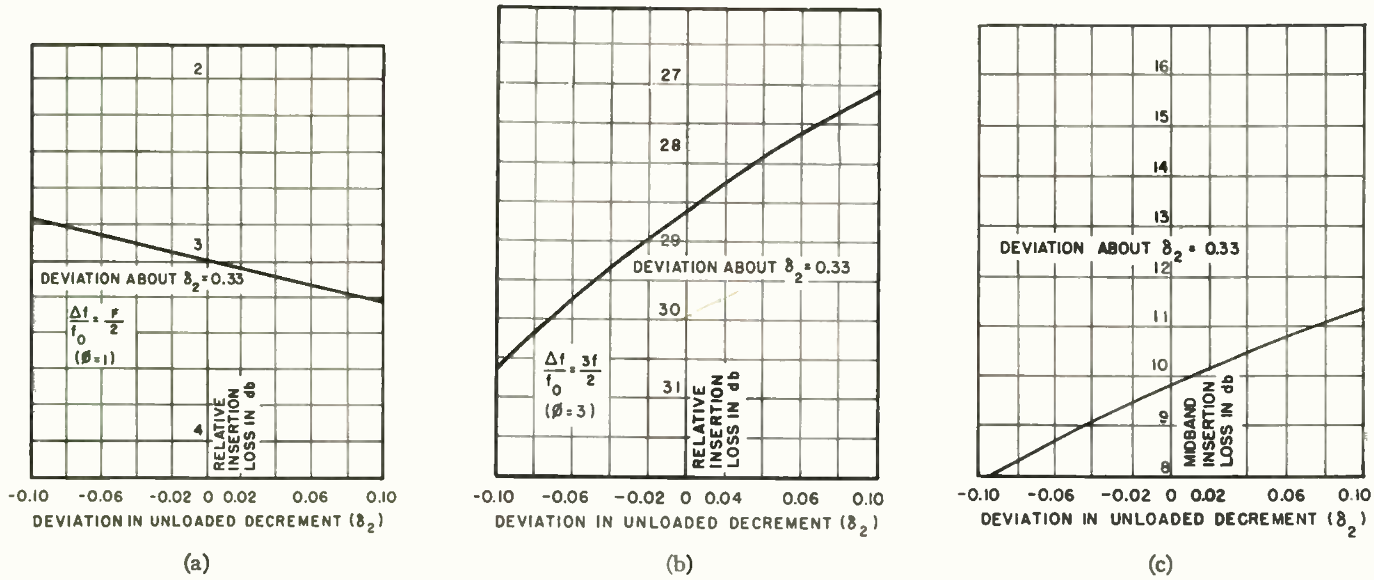

Fig. 5—Effect of change in unloaded decrement on (a) 3-db bandwidth, (b) filter response 1.5 bandwidths from center frequency, and (c) midband insertion loss, for three-resonator maximally flat filter.

fed networks. For convenience, they can be rewritten in terms of variables normalized to the fractional bandwidth F:

$$\delta_1 + \delta_2 + \delta_3 = 2 \tag{2a}$$

$$k_{12}^2 + k_{23}^2 + \delta_1\delta_2 + \delta_1\delta_3 + \delta_2\delta_3 = 2 \tag{2b}$$

$$k_{12}^2\delta_3 + k_{23}^2\delta_1 + \delta_1\delta_2\delta_3 = 1. \tag{2c}$$

An expression for midband insertion loss is derived in Appendix I. For maximally flat response it is

$$L = 10 \log \left[4k_{12}^2k_{23}^2(\delta_1 - \delta_2)(\delta_3 - \delta_2)\right]^{-1}. \tag{3}$$

By expressing L as a function of δ_1 and δ_2 and specifying the value of δ_2, a value of δ_1 that will minimize L can be obtained. To determine $L(\delta_1, \delta_2)$ it is necessary to utilize (2a), (2b), and (2c). The choice of δ_1 as the independent variable is arbitrary, since δ_1 and $\delta_3(\delta_1 \leq \delta_3)$ are interchangeable in (2a), (2b), and (2c). Since δ_2 is known for a given design, the loss function is minimized with respect to δ_1. The factors of (3) expressed in terms of δ_1 and δ_2 are

$$\delta_3 - \delta_2 = 2(1 - \delta_2) - \delta_1 \tag{4a}$$

$$k_{12}^2 = \frac{(1 - \delta_1 + \delta_1^2)(1 - \delta_1)}{2 - 2\delta_1 - \delta_2} \tag{4b}$$

$$k_{23}^2 = \frac{[3 - 3(\delta_1 + \delta_2) + (\delta_1 + \delta_2)^2][1 - (\delta_1 + \delta_2)]}{2 - 2\delta_1 - \delta_2}. \tag{4c}$$

Substitution of (4a), (4b), and (4c) in (3) yields the expression for insertion loss, for which two methods of solution are shown: graphical and analytical.

Graphical Solution: Fig. 6 shows L plotted as a function of δ_1, with δ_2 as a parameter. From this plot the value of δ_1 that, for a given δ_2, produces minimum loss

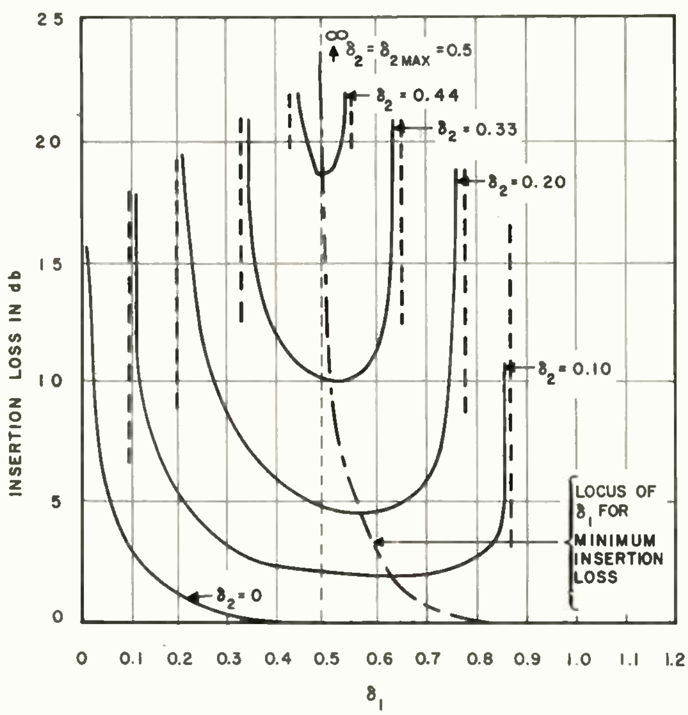

Fig. 6—Insertion loss as a function of δ_1 (input loading) with δ_2 (unloaded decrement) as a parameter, for a three-resonator maximally flat filter.

was then used to obtain the design curves of Fig. 4(a). Fig. 6 also shows that, for high-insertion-loss filters, it is important to be able to obtain the correct values of the constants, because the insertion loss rises rapidly from the minimum value obtainable.

Analytical Solution: Since a complete presentation of the exact solution for a three-section minimum insertion loss Butterworth filter will be made at a later date, only the results are included. They are as follows.

$$\delta_1 = \delta_2 \frac{\alpha + 2 - \sqrt{\alpha^2 - 4\rho}}{2} \tag{5a}$$

$$\delta_3 = \delta_2 \frac{\alpha + 2 + \sqrt{\alpha^2 - 4\rho}}{2} \tag{5b}$$

$$k_{12}^2 = \delta_2^2 \left[\beta - \rho + \frac{\gamma - \alpha(\beta - \rho)}{\sqrt{\alpha^2 - 4\rho}} \right] \tag{5c}$$

$$k_{23}^2 = \delta_2^2 \frac{-\gamma + \alpha(\beta - \rho)}{\sqrt{\alpha^2 - 4\rho}} \tag{5d}$$

where

$$\alpha = \frac{1}{\delta_2} (2 - 3\delta_2) \tag{6a}$$

$$\beta = \frac{1}{\delta_2^2} (2 - 4\delta_2 + 3\delta_2^2) \tag{6b}$$

$$\gamma = \frac{1}{\delta_2^3} (1 - 2\delta_2 + 2\delta_2^2 - \delta_2^3) \tag{6c}$$

$$\rho = \frac{1}{\delta_2^2} \left[1 - \frac{8\delta_2}{3} + 2\delta_2^2 - \frac{\delta_2}{6} \sqrt{\frac{6 - 8\delta_2}{\delta_2}} \right]. \tag{6d}$$

Deviations from Exact Shape

Knowing the circuit constants of a filter that will give the desired response shape and minimum loss, the designer is often interested in the criticalness of the setting of any given K or d in order to meet a set of specifications. To study this problem, the relative shape equation for triple-tuned maximally flat circuits (Appendix II) was used, and the value of each circuit constant was allowed to vary independently. These variations are shown in (12) through (16), for the specific case of $\delta_2 = 0.33$. This value of δ_2 corresponds to a filter having 10-db insertion loss, and represents a region of difficult design (see illustrative example in first section). The investigation was limited to two regions of general interest: $\phi = 1$ (3-db point of desired Butterworth response), and $\phi = 3$ (28.6-db point of desired Butterworth response).

In an actual design, $\phi = 1$ indicates the crossover point between two adjacent filters; $\phi = 3$ shows the actual off-band rejection 1.5 bandwidths away from f_0. In practice, the quantity that is most likely to vary is the unloaded Q of the individual circuits (the value of Q_u is assumed to be the same for all three circuits). Eq. (17) shows the variation for the case where the normalized decrements all change by the same amount for small changes (less than 25 per cent) in Q_u; it is plotted in Figs. 5(a) and 5(b).

The remaining point to consider is the change in midband insertion loss resulting from variations in value of the circuit constants. This variation was plotted from (7) and is shown in Fig. 5(c).

The proper interpretation of Fig. 5 will aid the designer of filters with high insertion loss to analyze experimentally obtained filter response shapes and determine possible sources of error in the fabrication.

Appendix I

Midband Insertion Loss

Fig. 7 shows the equivalent circuit of a capacitively coupled three-resonator filter. In terms of the symbols used there, $P_{out} = V_p^2 g_L$; $P_a = I^2/4g_g$. The insertion loss is defined as $L = 10 \log P_a/P_{out}$. Therefore

$$L = 10 \log \frac{I^2}{4g_g g_L V_p^2} = 10 \log \frac{1}{4g_g g_L (V_p/I)^2}.$$

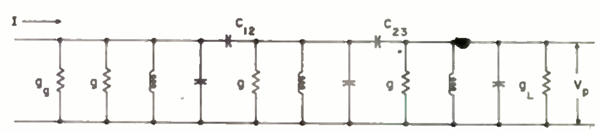

Fig. 7—Equivalent circuit of a capacitively coupled three-resonator filter.

Since the midband insertion loss is of interest, V_p/I is set equal to the filter transfer impedance at midband. For the circuit shown above,

$$\Delta = \begin{vmatrix} Y_{11} & Y_{12} & 0 \\ Y_{21} & Y_{22} & Y_{23} \\ 0 & Y_{32} & Y_{33} \end{vmatrix}$$

$$\frac{V_p}{I} = \frac{\begin{vmatrix} Y_{21} & Y_{22} \\ 0 & Y_{32} \end{vmatrix}}{\Delta}.$$

Since the three resonant circuits are synchronously tuned, the self nodal admittances of the resonant circuits are purely resistive. The admittances are:

$$Y_{11} = g_g + g$$

$$Y_{12} = -j\omega_0 C_{12}$$

$$Y_{22} = g$$

$$Y_{23} = -j\omega_0 C_{23}$$

$$Y_{33} = g_L + g.$$

By definition,

$$d_1 = \frac{g_0 + g}{\omega_0 C}$$

$$d_2 = \frac{g}{\omega_0 C}$$

$$d_3 = \frac{g_L + g}{\omega_0 C}$$

$$K_{12} = \frac{C_{12}}{C}$$

$$K_{23} = \frac{C_{23}}{C}.$$

Therefore

$$Y_{11} = \omega_0 C d_1$$

$$Y_{12} = -j\omega_0 C K_{12}$$

$$Y_{22} = \omega_0 C d_2$$

$$Y_{23} = -j\omega_0 C K_{23}$$

$$Y_{33} = \omega_0 C d_3$$

$$\frac{V_p}{I} = \frac{Y_{12}Y_{23}}{Y_{11}Y_{22}Y_{33} - Y_{11}Y_{23}^2 - Y_{33}Y_{12}^2}$$

$$= \frac{-(\omega_0 C)^2 K_{12}K_{23}}{(\omega_0 C)^3[d_1d_2d_3 + d_1K_{23}^2 + d_3K_{12}^2]}$$

$$\left[\frac{V_p}{I}\right]^2 = \frac{K_{12}^2K_{23}^2}{(\omega_0 C)^2[d_1d_2d_3 + d_1K_{23}^2 + d_3K_{12}^2]^2}.$$

Therefore

$$L = 10 \log \frac{[d_1d_2d_3 + d_1K_{23}^2 + d_3K_{12}^2]^2}{4(d_1 - d_2)(d_3 - d_2)K_{12}^2K_{23}^2}.$$

Normalizing to fractional bandwidth F gives

$$L = 10 \log \frac{[\delta_1\delta_2\delta_3 + \delta_1 k_{23}^2 + \delta_3 k_{12}^2]^2}{4(\delta_1 - \delta_2)(\delta_3 - \delta_2)k_{12}^2k_{23}^2}. \quad (7)$$

This expression also holds for the general network of Fig. 1.

It is interesting that, by using (2c), the mid-band insertion loss for maximally flat response reduces to

$$L = 10 \log [4(\delta_1 - \delta_2)(\delta_3 - \delta_2)k_{12}^2k_{23}^2]^{-1}. \quad (8)$$

Appendix II

Effect of Variations in Circuit Constants on Amplitude-Frequency Response of Three-Resonator Maximally Flat Filter

The relative voltage response for a triple-tuned circuit is[1]

$$v = \frac{1}{C_0'}[(j\phi)^3 + C_2'(j\phi)^2 + C_1'(j\phi) + C_0'] \quad (9)$$

where

$$C_2' = \delta_1 + \delta_2 + \delta_3$$

$$C_1' = k_{12}^2 + k_{23}^2 + \delta_1\delta_2 + \delta_1\delta_3 + \delta_2\delta_3$$

$$C_0' = k_{12}^2\delta_3 + k_{23}^2\delta_1 + \delta_1\delta_2\delta_3.$$

By equating (9) to the transfer function for a three-resonator filter, the shape equations for a triple-tuned filter can be obtained. The result for the relative insertion loss is

$$L_r = 10 \log \left\{1 + \left[\frac{C_1'^2 - 2C_0'C_2'}{C_0'^2}\right]\phi^2 + \left[\frac{C_2'^2 - 2C_1'}{C_0'^2}\right]\phi^4 + \frac{\phi^6}{C_0'^2}\right\}^{-1}. \quad (10)$$

For a Butterworth response it is

$$L_r = 10 \log [1 + \phi^6]^{-1}. \quad (11)$$

To see deviations in the shape as each circuit value varies, let

$$\delta_2' = \delta_2 + q$$

$$\delta_1' = \delta_1 + r$$

$$\delta_3' = \delta_3 + s$$

$$(k_{12}')^2 = (k_{12})^2 + t$$

$$(k_{23}')^2 = (k_{23})^2 + u.$$

The equations for the case of $\delta_2 = 0.33$ are

$$L_r = 10 \log \left[1 + \frac{(2.22q + 1.51q^2)\phi^2 + (0.66q + q^2)\phi^4 + \phi^6}{1 + 1.23q + 0.38q^2}\right]^{-1} \quad (12)$$

$$L_r = 10 \log \left[1 + \frac{(1.28r + 0.84r^2)\phi^2 + (1.1r + r^2)\phi^4 + \phi^6}{1 + 1.26r + 0.40r^2}\right]^{-1} \quad (13)$$

$$L_r = 10 \log \left[1 + \frac{(-1.52s - 0.735s^2)\phi^2 + (2.24s + s^2)\phi^4 + \phi^6}{1 + 1.52s + 0.58s^2}\right]^{-1} \quad (14)$$

$$L_r = 10 \log \left[1 + \frac{(-0.48t + t^2)\phi^2 - 2t\phi^4 + \phi^6}{1 + 2.24t + 1.25t^2}\right]^{-1} \quad (15)$$

$$L_r = 10 \log \left[1 + \frac{(1.8u + u^2)\phi^2 - 2u\phi^4 + \phi^6}{1 + 1.1u - 0.30u^2}\right]^{-1}. \quad (16)$$

In an actual filter, the factor most subject to error in production is the unloaded Q of each resonant circuit. In this case q, r, and s are equal and each can be represented by p. Then, for $\delta_3 = 0.33$,

$$L_r = 10 \log \left[1 + \frac{(0.24p + 5.36p^2)\phi^2 + (4p + 3p^2)\phi^4 + \phi^6}{1 + 4.9p + 10p^2} \right]^{-1} \tag{17}$$

where, since p is less than 0.2, terms containing powers of p higher than the second have been neglected.

There are two general areas of interest: at $\phi = 1$ and at $\phi = 3$. Fig. 5(a) and (b) shows (17) plotted for these areas.

Acknowledgment

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Correspondence

Oneway Circuit by the Use of Hybrid T for the Reflex Klystron Amplifier*

A reflex klystron amplifier of the metallic internal cavity type has been constructed by the author.[1] In this amplifier, the amplifier tube is mounted on the waveguide between the antenna and load as shown in Fig. 1. The amplified signal is divided into two parts, one of them being carried to the load side while the other is carried back to the antenna side. The latter is a cause of poor efficiency.

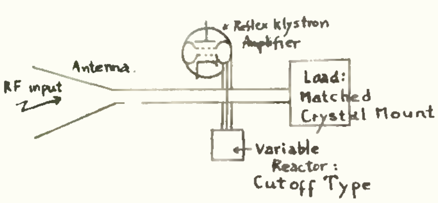

Fig. 1.

To improve the efficiency, a hybrid T was used, and the major part of the amplified backward wave power was sent to the load side.

Figs. 2 and 3 show the construction of the experimental circuit. This circuit consists of the receiving and transmitting horn antennas, hybrid T, twisted waveguide, bends, screw tuners, and reflex klystron amplifier. The amplifier tube is mounted at a position about equal phase distance from the joint of the hybrid tee.

The received signal is divided into three parts, the first part being coupled directly to the colinear arm and reradiated from the transmitting antenna; the second part is coupled to the E-plane arm; and the last part to the H-plane arm of the hybrid T, respectively. If the circuit is adjusted to the equiphase distance from the joint of the hybrid T to the reflex klystron mount, both coupled waves in the H-plane arm and E-plane arm are added together on the antenna of the center conductor of the coaxial cable of the reflex klystron and excite the cavity resonator through the coaxial cable. This signal is amplified by the reflex klystron and comes out from the coaxial cable, being divided into two parts in the waveguide.

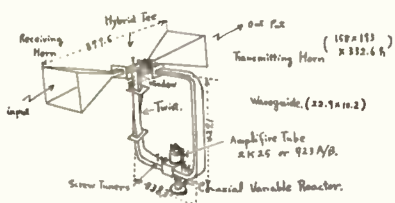

Fig. 2.

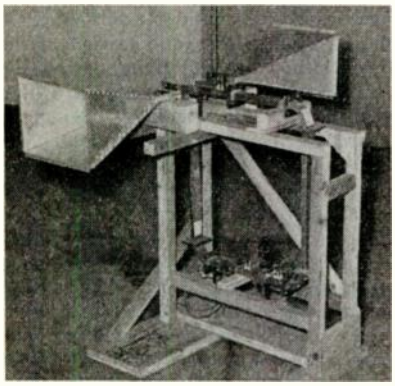

Fig. 3.

The amplified waves go back to the joint of the hybrid T through both E and H arms.

In this case, if the amplitude and phase of the amplified waves are properly adjusted, we may cancel the coupled back wave in the colinear arm of the receiving horn side from both E and H arms and we may add together the coupled wave in the colinear arm of the transmitting horn side by the well-known nature of the hybrid T.

Hence, the efficiency of the reflex klystron amplifier may be improved about 3 db compared with the normally arranged reflex klystron amplifier.

Through the employment of this device, the gain was improved at least 3 db, while the insertion loss and frequency bandwidth were almost equal to the case of the normal arrangement. The apparent gain of this oneway system is 28 db, with 6.8 db of insertion loss at the center frequency of 9370 mc, a 3-db-down frequency bandwidth of 35 mc, and a directivity of 39.82 db.

The author wishes to acknowledge the special assistance of Hiroshi Suzuki, Ikuo Sato, Kaoru Kataishi, and Stanley Repac.

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* Received by the IRE, July 10, 1956; revised manuscript received, November, 1956. This work was carried out at the Laboratory of Microwaves, Nihon University, Tokyo, Japan.

[1] K. Ishii, "X-band receiving amplifier," *Electronics*, vol. 28, pp. 202–210; April, 1955.

On the Cotton-Mouton Effect in Ferrites*

Cacheris[1] has constructed a reflection-type ferrite single-sideband microwave modulator (SSM) by placing a shorting plate at the plane of symmetry that exists at the midpoint of a transmission-type SSM. Fox, Miller, and Weiss[2] have pointed out that a stronger birefringence effect could

* Received by the IRE, February 28, 1957.

[1] J. Cacheris, "Microwave single-sideband modulator using ferrites," Proc. IRE, vol. 42, pp. 1242–1247; August, 1954.

[2] A. G. Fox, S. E. Miller, and M. T. Weiss, "Behavior and applications of ferrites in microwave region," *Bell Sys. Tech. J.*, vol. 34, pp. 5–103; January, 1955.

be obtained by subjecting a piece of ferrite tubing to a four-pole transverse magnetic field rather than a two-pole field used in the microwave modulators built by Cacheris.

It is interesting to note, however, that a reflection-type SSM (which has the considerable practical advantage of requiring a quarter-wave rather than a half-wave differential phase shift section), using a four-pole applied field, cannot be obtained because a ferrite tubing followed by a shorting plate will show no birefringence when subjected to an applied magnetic field as shown in Fig. 1.

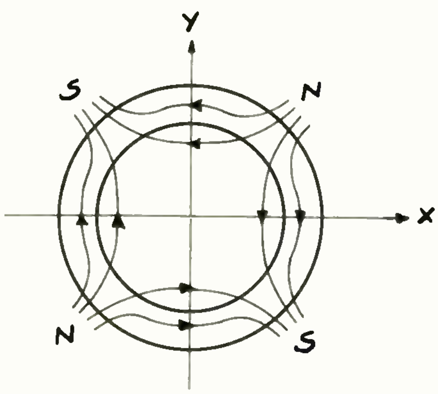

Fig. 1.

A TE_{11} mode, linearly polarized along the x axis while traveling through the ferrite section in the forward direction will receive a phase shift of, say, ϕ^1 radians. Traveling in the reverse direction, the phase shift imparted to this mode will be different, say, ϕ_2 radians. Simple physical reasoning will show that a TE_{11} mode, linearly polarized in the y direction, will receive a phase shift of ϕ_2 radians while traveling in the forward direction, whereas its passage through the ferrite tubing in the reverse direction will result in a phase shift of ϕ_1 radians. Hence for either polarization the round-trip phase shift is $\phi=\phi_1+\phi_2$. No differential phase shift between these two orthogonal modes is obtained, and consequently under these conditions the ferrite tubing is not birefringent.

The advantage of using a quarter-wave rather than a half-wave differential phase-shift section, however, can also be realized in a transmission-type SSM, which makes use of a four-pole magnetic field. In the following, only the differential phase shifts will be considered, and the time factor $e^{j\omega t}$ will be implied. Assume that a circularly-polarized microwave field, described in an xy-coordinate system by $\vec{e_i}=\vec{a_x}+j\vec{a_y}$ (where $\vec{a_x}$ and $\vec{a_y}$ denote unit vectors), is incident on a quarter-wave differential phase-shift ferrite section. Further assume that a transverse applied magnetic field in an $x'y'$-coordinate system is rotating counterclockwise at a constant angular velocity ω_m. Without any loss of generality assume that the y' component of the microwave field receives a phase shift of $\pi/2$ radians, whereas the x' component receives no phase shift while passing through the ferrite section.

In the $x'y'$-coordinate system, the incident microwave field is described by $\vec{e_i}=(\vec{a_{x'}}+j\vec{a_{y'}})e^{j\omega_m t}$. After passing through the ferrite the microwave field will be linearly polarized in the $x'y'$-coordinate system: $\vec{e_0}=(\vec{a_{x'}}-\vec{a_{y'}})e^{j\omega_m t}$. In the stationary xy-coordinate system, however, e_0 will have the form:

$$\vec{e_0}=\left(\frac{1+j}{2}\right)(\vec{a_x}+j\vec{a_y}) + \left(\frac{1-j}{2}\right)(\vec{a_x}-j\vec{a_y})e^{j2\omega_m t}.$$

The carrier frequency component can be easily rejected because its sense of circulation is opposite to that of the single-sideband component. If we consider that a half-wave differential phase-shift section theoretically completely converts the incident microwave power from the carrier frequency to a single sideband, we see that in the SSM described above we have traded 3 db of microwave power for a 75 per cent reduction in the modulation power (assuming a linear relationship between the differential phase shift and magnet current).

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Grid Current in Regulator Tubes*

The series regulator tube in a regulated dc power supply should be capable of passing the desired load current with a minimum of voltage drop. This consideration has led to the design of large low μ triodes such as the 6AS7, since the voltage amplifier driving the grid of the series tube is invariably a high impedance device, incapable of driving the grid positive. This communication reports the substantial improvement made in the case of the 6550 (triode $\mu=8$) tube by introducing a low impedance driver.

The schematic (Fig. 1) shows a fairly conventional regulated power supply, using a two-stage voltage amplifier. The voltage amplifier can drive the 6550 grid directly, or through a 6AQ5 (triode-connected) cathode follower, or through a 6C4 cathode follower in tandem with the 6AQ5 cathode follower. The plates of these cathode followers are connected to the supply B+, since that is the highest potential available. The plate load resistor of the second voltage amplifier stage is also connected to the supply voltage, since the 6550 grid has to be driven above its cathode.

The curves (Fig. 2) show the minimum series tube drop required to maintain regulation, as a function of output current. One cathode follower reduces the required drop about 47 per cent, and tandem cathode followers about 61 per cent. The disadvantage of the single cathode follower is due to the severely-limited plate voltage available for it when it is driving the series tube grid

* Received by the IRE, July 23, 1956; revised manuscript received, November 9, 1956.

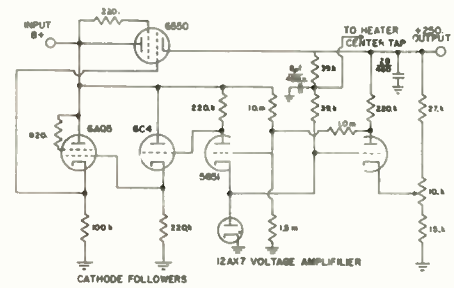

Fig. 1—Regulated power supply. (Shown with both cathode followers connected.)

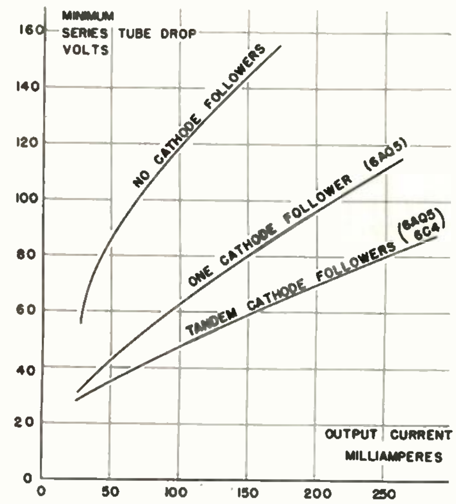

Fig. 2—Minimum series tube drop vs output.

positive. This voltage is simply the series tube drop minus the positive grid swing. The additional (6C4) cathode follower drives the grid of the first positive, which enables it to drive much more grid current into the series tube. This grid current, incidentally, is not wasted, but is part of the output current of the series tube.

Among the details of the circuit are the 10-megohm resistor, which cancels input hum, and the by-pass at the center of the gas tube series resistor, which circumvents the internal ac impedance of the gas tube, as far as the over-all feedback loop is concerned. This point is also a convenient one for fixing the dc potential of the heaters, and the by-pass prevents the introduction of capacitively-coupled hum from the power transformer.

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An Absolute Microwave Wattmeter*

A new microwave high-power wattmeter (hpw) has been developed which appears to be greatly superior to the conventional water

* Received by the IRE, January 25, 1957.

flow power meter in accuracy, sensitivity, and simplicity of construction and operation. It is apparently suitable for standards and other high-precision work.

The problem of measuring a few watts average or more of microwave power in a few minutes or less, can be reduced to a purely calorimetric problem if the rf energy can be converted to heat in a suitable container.

The field of calorimetry is well developed and accuracies of 1 per cent are commonly attained with the crudest of calorimeters, and 0.03 per cent accuracy is possible by the use of advanced techniques.[1] It therefore seemed sensible to design a microwave hpw around a very simple calorimeter.

Three versions of the calorimetric hpw have been constructed and operated: 1) an x-band version which operates in air and employs a Beckman thermometer; 2) a similar k-band version, and 3) a more refined twin x-band calorimeter with an oil bath for ambient temperature stabilization and a four-junction thermopile for measuring the temperature rise. The last named version which is much less convenient than the first two and which is nonportable, provides much better protection against ambient temperature variations and has a thermometric sensitivity of about 3/10,000 of a degree. Since only a few measurements have been made with this third version, most of what follows will concern the first two versions.

Fig. 1 is a schematic of the calorimeters. Fig. 2 is an exploded view of the x-band loads. Windows are cut in commercial guide and sealed with mica. The microwave energy leaks out of the guide through these windows and is dissipated directly in the water.

The measurement technique depends on the accuracy desired and the nominal power level. For an accuracy of about 2 per cent at a nominal level of 50 watts, heat losses and heating of the water due to the stirring may be ignored.

A single calibration is made by exciting the heater coil with a known dc power and measuring the temperature rise. The calibration will hold for several weeks or until a significant amount of evaporation has taken place and reduced the heat capacity. At 50 watts into the x-band version a 0.5°C temperature rise takes about 3 minutes; in the k-band version a 0.5°C rise takes about one minute.

For higher accuracy, the calorimeter can be calibrated so as to take account of thermal losses and stirring power. For highest accuracy, the calibration is carried out just previous to a measurement. Another high-accuracy method which has proved successful but tedious is as follows. The calorimeter is first heated with rf for a time T_r and the temperature rise θ_r is noted. The calorimeter is then cooled to its original temperature by means of dry ice in a glass tube.

The amount of rf is estimated to within a few per cent from the time and the temperature rise. The calorimeter is then

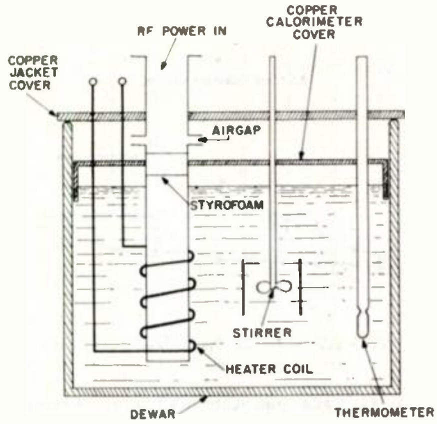

Fig. 1.

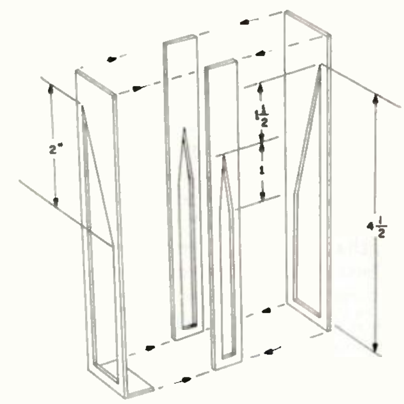

Fig. 2.

heated with a dc power, P_d, equal to the estimated rf power, for a time, T_r, and the temperature rise, θ_d, is noted. Then since the thermal losses, stirring power and even the range in which the thermometer was used are nearly identical for the rf and dc heating, $P_r = P_d\theta_r/\theta_d$.

The standing-wave ratios looking into the calorimeters were measured only over a limited frequency range. For the x-band version, the swr was less than 1.2 between 8500 and 9400 mc, and for the k-band version the swr was less than 1.1 between 21.7 and 24.8 kmc.

The rf design of the loads can almost certainly be improved. The upper limit of peak power is probably about the same as that for the waveguide itself since there are no projections into the guide. There is no apparent reason why pressurizing could not be employed to increase the upper peak-power limit.

The highest peak powers employed in this work were 40 kw for the x-band version and 60 kw for the k-band version. There was no arcing at these powers. Higher average powers can be handled by faster stirring, larger calorimeters, or possibly by the addition of a known amount of ice.

The least detectable power is probably limited by the erratic leakage of heat into and out of the calorimeter. This will depend on the details of construction of the calorimeter, *i.e.*, whether or not the calorimeter is immersed in an oil bath, the treatment of heat leaks through the top of the calorimeter, etc. In the k-band calorimeter, the estimated least detectable power is about 0.1 watt in the x-band twin calorimeter it is about 0.01 watt. These figures can almost certainly be lowered by equipment improvement and by a statistical treatment of the drift. The simple construction of the loads and the high sensitivity of the hpw would seem to be ideal for millimeter-band work.

A more thorough discussion of the hpw's including a first-order heat-loss theory, a discussion of accuracy, of constructional details, of experimental results, and a comparison with the water-flow powermeter will appear in an NBS report.

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[1] W. P. White, "The Modern Calorimeter," The Chemical Catalog Co., Inc., New York, N. Y., pp. 17–19; 1928.

Note on the Analog Computation of Small Quotients*

To the above paper by Bailey[1] may I add this observation. The method given by Bailey is at once a consequence of the relations

$$x \approx \tanh^{-1} x = \frac{1}{2} \log \frac{1+x}{1-x}, \quad |x| < 1.$$

Setting $x = \frac{1}{2} \cdot e_1/e_2$, where e_1/e_2 is the quotient sought, there results

$$\frac{e_1}{e_2} \approx \log\left(e_2 + \frac{e_1}{2}\right) - \log\left(e_2 - \frac{e_1}{2}\right)$$

as deduced by Bailey. That the quotient is obtained directly as a difference of logs with no antilog circuit required is evident from the initial choice of approximating x. Letting 100 ϵ be the per cent error in the computed quotient, then,

$$\epsilon = \frac{\tanh^{-1} x}{x} - 1, \quad x = \frac{1}{2} \cdot \frac{e_1}{e_2}.$$

Clearly, x may be set equal to any $k/2 \cdot e_1/e_2$, of magnitude less than unity, with the result (following Bailey's notation) that

$$\frac{e_1}{e_2} \approx \frac{1}{k} \log \frac{ke_1 + \frac{e_2}{2}}{ke_1 - \frac{e_2}{2}},$$

but with an error, increasing with k, given by

$$\epsilon = \frac{\tanh^{-1} x}{x} - 1, \quad x = \frac{k}{2} \frac{e_1}{e_2}.$$

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* Received by the IRE, December 26, 1956.
[1] A. D. Bailey, PROC. IRE, vol. 44, p. 1874; December, 1956.

Experiments on Noise Reduction in Backward-Wave Amplifiers*

The purpose of this letter is to report some interesting preliminary results of an investigation of noise reduction in backward-wave amplifiers.

Although a generalized one-dimensional noise theory[1] predicts identical ultimate noise figures for both forward and backward-wave amplifiers it does not guarantee that such performance can be realized in practice. The problem of achieving ultimate noise reduction in backward-wave amplifiers differs considerably in character from the corresponding problem in conventional traveling-wave tubes. Beam voltage and plasma wavelength vary rapidly as the pass band is tuned in frequency; the standing wave ratio and phase of the noise convection current in the beam vary in a direction opposite to that which is theoretically required to maintain minimum noise figure. From a fundamental viewpoint, since the parameters encountered in helix-type backward-wave tubes (which we have used in this work) fall in considerably different ranges (hollow beam, large γa, very low impedance) than those used in previous experiments on noise in electron beams, it is expected that, aside from the practical importance of low noise, the experiments will shed further light on the assumptions and validity of the existing one-dimensional noise theory.

The experimental work described here was done at *S* band on tubes which employ single-filar helix circuits operating on the (-1) space-harmonic (skew symmetric). The electron gun structure is unconventional; it features a series of velocity jump electrodes both inside and outside of an annular beam with the internal electrodes supported by a "christmas tree" protruding through the center of the cathode. The high total perveance obtainable with this type of gun furnishes a degree of freedom not obtainable with conventional solid beams; it is an unique feature of this type of gun and permits a high degree of flexibility in transforming the noise waves on the beam.

Some typical data obtained from a single-helix amplifier of this type at a particular midband frequency are shown in Fig. 1. The abscissa is the ratio of operating current I_0 to start-oscillation current *Ist*. These data were obtained by adjusting the noise figure to an optimum value at about 12 db gain and then taking the measurements as a function of current by varying the potential of the first anode and optimizing the helix voltage for maximum gain at each point. The data shown are terminal noise figures with no corrections for input lead loss. The gain curve of Fig. 1 is typical of the single-helix type of backward-wave amplifier; the use of a cascade amplifier[2] would have the general effect of shifting the gain curve further away from the oscillation threshold.

The noise figure did not vary significantly as the tube was tuned through its sharply

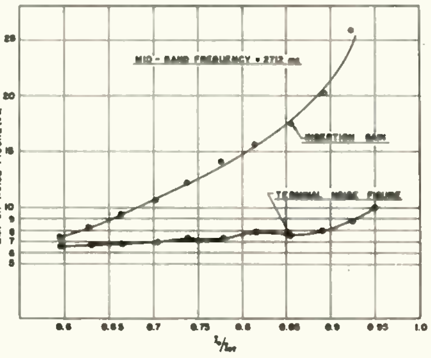

Fig. 1—Gain and noise figure as a function of beam current at a particular midband frequency.

peaked response curve (in agreement with theoretical calculations). The general variation of noise figure with beam current of Fig. 1 is typical of curves measured at other midband frequencies. The data showed an interesting variation of noise figure with cathode temperature, a distinct minimum being attained just above the temperature-limited region. This variation agrees qualitatively with some recent calculations by Siegman and Watkins.[3] It is possible, however, that pronounced temperature-dependent barium migration contributed to this effect since the low noise figures were not always highly reproducible and appeared to fade in and out with a long time constant.

The minimum theoretical noise figure for this tube at 2700 mc and 10 db gain is somewhat greater than 6 db (including factors for circuit loss,[4] shot-noise reduction[5] and finite gain). Thus our best measured results do not differ appreciably from the minimum values predicted by the one-dimensional theory.

In Fig. 2, we have plotted noise figure as a function of midband frequency with the gain held constant at 12 db. The first anode

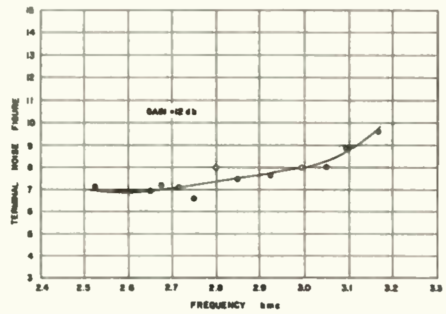

Fig. 2—Noise figure vs midband frequency at a constant level of gain. The potentials of the noise reducing electrodes were not programmed as a function of frequency.

voltage was varied somewhat to maintain constant gain but no other gun potentials were programmed with frequency. It is thus seen that in spite of relatively large variation of tube parameters, tuning ranges of 20 per cent or more with very low noise figures appear to be feasible with backward-wave amplifiers.

In these experiments no effort was made to produce the smooth uniform type of cathode which has proven essential for very low noise performance in conventional traveling-wave tubes. We believe that the use of hollow beams might well offer some inherently significant advantages even in conventional low noise traveling-wave tubes. An obvious application would be in the higher microwave frequency bands.

Furthermore, we tentatively conclude that the backward-wave type of tube is feasible in receiver applications—it may satisfy the increasingly apparent need for rapidly tunable selective preamplification.

A detailed paper on this research and further applications to the cascade type of backward-wave amplifier will appear at a later time.

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* Received by the IRE, January 25, 1957.

[1] H. A. Haus and F. N. H. Robinson, "Minimum noise figure of microwave amplifiers," Proc. IRE, vol. 43, pp. 981–991; August, 1955.

[2] M. R. Currie and J. R. Whinnery, "The cascade backward-wave amplifier: a high-gain voltage-tuned filter for microwaves," Proc. IRE, vol. 43, pp. 1617–1632; November, 1955.

[3] A. E. Siegman and D. A. Watkins, "Potential minimum noise in the microwave diode," presented at 14th Annual Conf. on Electron Tube Research, Boulder, Colo.; June, 1956. (To be published.)

[4] M. R. Currie and D. C. Forster, "Noise in backward wave tubes," presented at 14th Annual Conf. on Electron Tube Research, Boulder, Colo.; June, 1956.

[5] D. A. Watkins, "Noise at the potential minimum in the high-frequency diode," *J. Appl. Phys.*, vol. 28, pp. 622–624; May, 1955.

An Extension of the Noise Figure Definition*

In the course of extending our previous general studies[1,2] of noise performance of linear amplifiers, we have been led to generalize the definitions of *available gain G* and *noise figure F* beyond their original meanings.[3] The need arises from situations involving negative resistance, and stems from difficulties in such cases with the usual notion of *available power*. An extension of this concept is required.

Normally, the available power P_{avl_s} of a source is defined as

P_{avl_s} = *the greatest power which can be drawn from the source by arbitrary variation of its terminal current (or voltage).* (1)

If the Thévenin representation of the source has rms open-circuit voltage E_s and internal impedance Z_s, with $R_s = \text{Re}(Z_s) > 0$, (1) leads to

$$P_{avl_s} = \frac{|E_s|^2}{4R_s} > 0 \text{ for } R_s > 0 \quad (2)$$

which is also a *stationary value* (*extremum*) of the power output regarded as a function of the complex terminal current. Moreover, the available power (2) can actually be delivered to the (passive) load Z_s^*.

* Received by the IRE, November 26, 1956. This work was supported in part by the Army (Signal Corps), the Air Force (Office of Scientific Research, Air Res. and Dev. Command), and the Navy (Office of Naval Research).

[1] H. A. Haus and R. B. Adler, "Invariants of linear noisy networks," 1956 IRE Convention Record, Part 2, pp. 53–67.

[2] H. A. Haus and R. B. Adler, "Limitations on Noise Performance of Linear Amplifiers," presented at the Congrès International "Tubes Hyperfréquences," Paris, France; June, 1956 (to be published).

[3] H. T. Friis, "Noise figures of radio receivers," Proc. IRE, vol. 32, pp. 419–422; July, 1944.

When $R_s<0$, however, definition (1) leads to

$$P_{avl_s} = \infty \text{ for } R_s < 0 \qquad (3)$$

since this is indeed the greatest power obtainable from such a source, and is achievable by loading it with the (passive) impedance, $-Z_s$. Observe that (3) is *not* either a stationary value or extremum of the power output as a function of terminal current.

The singular value and failure of the extremal property in (3) make (1) unsatisfactory in the negative resistance case. The following problem of noise figure for a cascade of two amplifiers (Fig. 1) focuses attention clearly upon some of the details which support this statement.

In the neighborhood Δf of some frequency f, the first stage in Fig. 1 has a noise figure

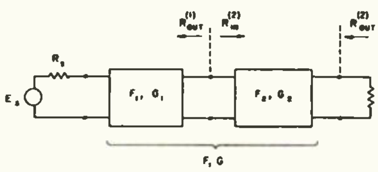

Fig. 1—Two amplifiers in cascade. R_s, R_L, >0.

F_1 and an available gain G_1, while the second stage has a noise figure F_2 and an available gain G_2. The noise figure of the cascade is then presumably given by the well-known cascading formula

$$F = F_1 + \frac{F_2 - 1}{G_1}. \qquad (4)$$

Suppose, however, that the first amplifier has a negative output resistance $R_{out}^{(1)}$, whereas the second amplifier has positive input and output resistances $R_{in}^{(2)}$ and $R_{out}^{(2)}$. The closer the value of $R_{in}^{(2)}$ to $|R_{out}^{(1)}|$, the higher the transducer gain[4] of the first stage. Indeed, the condition $R_{in}^{(2)} = |R_{out}^{(1)}|$ would lead to infinite gain and instability, and we therefore assume $R_{in}^{(2)} \neq |R_{out}^{(1)}|$ in Fig. 1. Thus the available gain G of the *over-all* amplifier is perfectly well defined in terms of the usual definition (1) of available power.

$$G = \frac{P_{avl_{out}}}{P_{avl_s}}. \qquad (5)$$

Similarly the noise figure F of the *over-all* amplifier is equally well defined by the general relation

$$F = 1 + \frac{N_{avl_{out}}}{GkT\Delta f} \qquad (6)$$

where $N_{avl_{out}}$ is the noise power available at the output terminals in the frequency band Δf, when no noise is introduced by the source. It becomes clear, by visualizing the noise voltages (not shown in Fig. 1) which characterize the noise of each amplifier and by noting the condition $R_{in}^{(2)} \neq R_{out}^{(1)}$, that $N_{avl_{out}}$ is finite. So also is $GkT\Delta f$, which is the power available at the output caused only by the noise power $kT\Delta f$ available from the source resistance at temperature T.

Now, if we try to apply the cascading formula (4) we find that we are in trouble. Indeed, the available gain G_1 of the first stage is infinite by (5), (3), and (2); and thus, according to a cursory inspection of (4), the second stage does not seem to contribute to the over-all noise figure. That this conclusion is incorrect physically follows from a direct consideration of the contributions of the noise generators of the individual amplifiers, in the manner which would be used to obtain the *over-all* system noise figure [(6), etc.]. A more careful examination of (4) in this case reveals the following additional difficulties connected with the fact that $R_{out}^{(1)}<0$:

1) Noise figure F_1 is indeterminate when calculated from (6), because $N_{avl_{out}} = \infty$ according to (1) and (3), and $G_1 = \infty$.

2) Noise figure $F_2 = \infty$ by (6). This occurs because $G_2 = 0$, on the basis of (3), (2), and (5). Thus the term $(F_2-1)/G_1$ in (4) is actually *indeterminate* also, which makes F in (4) *entirely indeterminate.*

3) The use of $kT\Delta f$ in (6) for computing F_2 in this case requires some comment, because $R_{out}^{(1)}<0$ does *not* represent a resistance at thermal equilibrium temperature T, and the "available thermal noise power" $kT\Delta f$ has no clear physical meaning under the circumstances.

We shall now propose a new concept called the *exchangeable power*, of a source, in terms of which an *exchangeable power gain* and a *new noise figure* can be defined. These new definitions remove all of the foregoing difficulties, and always reduce to the familiar ones whenever the latter apply.

The *exchangeable power* P_e of a source is defined as

$P_{e|_s}$ = *the stationary value (extremum) of the power output from the source, obtained by arbitrary variation of the terminal current (or voltage).*

In terms of the Thévenin representation of the source (E_s, Z_s),

$$P_{e|_s} = \frac{|E_s|^2}{4R_s} \text{ for } R_s \neq 0. \qquad (7)$$

Observe that $P_{e|_s}$ reduces to the conventional available power when $R_s>0$. When $R_s<0$ the exchangeable power is negative. As can be confirmed easily, the exchangeable power is in this case the maximum power that can be pushed *into* the "source," achievable by connecting the (nonpassive) impedance Z_s^* to the source terminals. The negative sign of the exchangeable power then conveniently underscores the fact that here we are speaking about a power extremum corresponding to a flow of power *into* rather than *from* the source.

The introduction of exchangeable power suggests the definition of a "ratio of exchangeable powers," the *exchangeable power gain* G_e.

$$G_e = \frac{P_{e|_{out}}}{P_{e|_s}}. \qquad (8)$$

The exchangeable power gain is the ratio of the exchangeable power at the output terminals of a network to the exchangeable power of the source connected to the input. It reduces to the conventional available power gain if both the output resistance and the source resistance are positive. If either *one* of these resistances is negative, $G_e<0$. If both source and output resistance are negative, $G_e>0$.

We may now extend the definition of the noise figure on the basis of exchangeable power. Let

$$F_e = 1 + \frac{N_{e|_{out}}}{G_e kT\Delta f} \qquad (9)$$

where $N_{e|_{out}}$ is the exchangeable noise power at the output terminals with no noise from the source, and G_e is the exchangeable power gain of the system. The magnitude of the exchangeable noise power of the source is arbitrarily set equal to the standard $kT\Delta f$, simply for normalization purposes. It should be noted that $(F_e-1)<0$ only when the source resistance is negative; $(F_e-1)>0$ in all other cases.

We may now confirm that the cascading formula (4) has been extended to include all cases, provided F and G are reinterpreted as F_e and G_e. We have

$$N_{e|_{out}} = N_{e|_{out}}^{(1)} G_{e2} + N_{e|_{out}}^{(2)} \qquad (10)$$

$$G_e = G_{e1} G_{e2} \qquad (11)$$

and thus

$$F_e = 1 + \frac{N_{e|_{out}}}{G_e kT\Delta f}$$

$$= 1 + \frac{N_{e|_{out}}^{(1)} G_{e2} + N_{e|_{out}}^{(2)}}{G_{e1} G_{e2} kT\Delta f} \qquad (12)$$

or

$$F_e = F_{e1} + \frac{F_{e2} - 1}{G_{e1}}$$

The result (12) differs from (4) only when negative output resistance occurs somewhere in the cascade. Aside from the use of the generalization in such situations, we find it necessary for a careful treatment of the general noise theory of linear amplifiers.

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[4] The transducer gain is defined as the ratio of the *actual* power delivered at the output to the *available power* from the source.

An Accelerated Aging and Coating Procedure for Lowering Current Noise in Carbon Composition Resistors*

The Navy is more or less resigned to noisy carbon composition resistors though they are specifying acceptable noise levels. Cases occur, though, in certain low-signal level guided missile applications, where use of bulky low-noise, wire-wound resistors is required but, due to lack of space, cannot be employed. Also, since experience shows that these resistors occasionally exhibit undesirably high current noise or microphonic properties, an effort was made by the Naval Ordnance Division of the Eastman Kodak

* Received by the IRE, February 5, 1957.

Company who were under contract with the Bureau of Ordnance, to investigate reports that noise properties of carbon composition resistors could be improved by suitable treatment. Other disadvantages of wire-wound resistors, in addition to bulkiness, are cost, particularly for larger sizes; radial leads only; and nonavailability in larger values of resistance. The results of Eastman Kodak's investigation are reported below.

Allen-Bradley carbon composition resistors, selected for treatment as laboratory tests on a limited quantity of resistors, seemed to indicate they had generally good low-noise properties as compared to some other makes and types. Some low-noise film change in either the noise or resistance of one and two-watt resistors. These resistors were noisier than the equivalent baked ½-watt value before baking, and there was no improvement after baking.

The ½-watt resistors were definitely improved noisewise by the aging process, especially in the lower resistance values, without seriously affecting their resistance. There also was evidence of stabilization of resistance with time and environment.

The following, Table I, summarizes the results of aging these resistors under controlled high temperature. The last two columns refer to the changes brought about by aging process.

TABLE I

Value of resistor in ohms and watts	No. of resistors treated	Average per cent reduction in		Estimated approximate noise microvolts peak-to-peak	
		Resistance	Noise	Before aging	After aging
390, ½w	25	2.5	44	30	16
56k, ½w	24	2.8	49	75	39
120k, ½w	25	3.0	19	52	42
3.3 Meg., ½w	25	3.3	18	75	60
56k, 1w	—	No change	No change	—	—
62k, 2w	—	No change	No change	—	—

type resistors were not found to be as good as wire-wound resistors. The ½-watt size of Allen-Bradley was particularly good for noise.

Allen-Bradley ½-watt carbon composition resistors were baked for 120 hours at 125°C. in an oven. Immediately after being removed from the oven, each resistor was dipped in a thin solution of Tufon No. 58-5 lacquer (made by Brooklyn Varnish Manufacturing Co., Inc.) to prevent absorption of moisture. Resistance and noise measurements were made before and after baking. Resistance was measured on a Shallcross Type 617-F Percent Limit Bridge, except for the highest value resistor, where a General Radio Type 544-B Mehohm Bridge was used. Noise was measured using a component noise tester, a Tekronix Preamplifier Type 122, and a Tekronix Oscilloscope Type 512. (See Fig. 1).

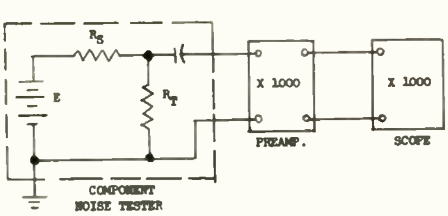

Fig. 1—Noise test circuit.

R_T is the resistor under test. R_S is a low-noise wire-wound resistor of known value. The preamplifier band-pass is 0.2 cps to 40 kc. The voltage source, E, is a well-filtered battery supply with noise output below the 11 microvolts system noise of the measuring equipment. The dc voltage impressed across R_T was equal to that impressed across similar resistors used in a standard production preamplifier application.

After being removed from the oven and dipped in Tufon, the resistors were allowed to cool before any measurements were taken.

The baking process caused no appreciable

Later tests have shown that a similar lacquer, Interchemical Company's Paladin water dip lacquer #3119, is equally as effective as Tufon in sealing the baked resistors; however, the Paladin is much easier to apply than the Tufon. The Paladin lacquer was used subsequently in the production preamplifiers with excellent results.

Satisfactory shelf life of these treated resistors beyond nine months has not yet been fully evaluated though favorable reports of such resistors in use in servo amplifiers since World War II, have been received. These resistors were baked 400 hours. Laboratory tests showed 120 hours to be about as effective however.

The baking and coating process as described has been found effective in reducing current noise and stabilizing resistance value of some carbon composition resistors. These treated resistors compare favorably with some of the more bulky wire-wound resistors. On the basis of the above findings, baked and coated carbon composition resistors have been used in certain production preamplifier bias circuits with very good results. The improvements obtained could have wider application in other electronic equipment and further investigation is warranted.

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Transactors*

A set of dual ideal active elements has recently been proposed.[1] These elements were called the "transactor" elements and a symbolism was introduced. This is shown in Fig. 1(a). The voltage-current transactor (vct) is defined by its admittance matrix.

$$Y = \begin{bmatrix} 0 & 0 \\ g & 0 \end{bmatrix}. \quad (1)$$

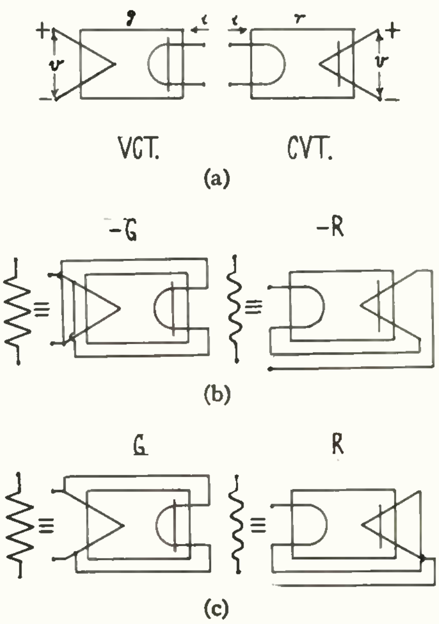

Fig. 1—(a) The ideal transactors. (b) Negative resistance. (c) The ideal dissipators.

The current-voltage transactor (cvt) is defined by its impedance matrix.

$$Z = \begin{bmatrix} 0 & 0 \\ r & 0 \end{bmatrix}. \quad (2)$$

The causal equations for these elements are

$$g \cdot v \to i$$
$$r \cdot i \to v \quad (3)$$

g and r are real and the arrow implies that the process is not reversible. These active elements are physically distinct, and their method of operation is characterized by an irreversible electric to magnetic (or magnetic to electric) transfer action. They have therefore been called the *transactor* elements.

In these elements complete separation of voltage and current branches is obtained. A current branch is therefore denoted by the letter C (or C turned through 180°) and a voltage branch by the letter V laid on its side (or turned through 180°). The bar across a branch indicates that transmission is unilateral from the closed to the open end of the branch.

The above results may be stated as follows.

HYPOTHESIS ON ACTIVITY

When a change from voltage to current (or vice versa) is accompanied by an energy gain to the system it can be considered to have been caused by one of a dual pair of ideal active elements (or by their derivatives).

One dual pair of active derivatives of the transactor elements is represented by the

* Received by the IRE, December 17, 1956.
[1] G. E. Sharpe, "Ideal active elements," *J. IEE*, vol. 3, pp. 33–34; January, 1957.

negative conductor (voltage-transacting) and negative resistor (current-transacting) shown in Fig. 1(b). The terminal pairs are now identified by means of parallel and series connection, but these devices remain, by hypothesis, physically distinct.

For all voltages, except zero voltage, the negative conductor is active but unstable. It is, therefore, short-circuit stable. For all currents, except zero current, the negative resistor is active but unstable. It is, therefore, open-circuit stable. The phenomenon of open and short circuit stability of "negative resistance" can, therefore, be predicted and explained by the introduction of the transactor elements.

A distinct symbolism for these elements is now introduced. The voltage transacting conductor is depicted by a saw-tooth line (Letters V laid on side, end to end). The current transacting resistor is depicted by a wavy line (Letters C end to end).

A slight change in the identification of terminals, leads to the dissipative connection shown in Fig. 1(c). In order to remain consistent, one is led to the general view that dissipators must also be of dual nature and therefore physically distinct.

Hypothesis on Dissipation

When a change from voltage to current (or vice versa) is accompanied by a loss of energy to the system it can be considered to have been caused by one of a dual pair of ideal dissipating elements.

The same distinct symbolism as used for negative resistance has been retained. The ideal dissipators are defined as follows: 1) The "conductor" is voltage-transacting. It dissipates energy while changing voltage to current. 2) The "resistor" is current-transacting. It dissipates energy while changing current to voltage.

Moreover, an ideal dissipator remains an open (or a short) circuit unless brought into conductance (or resistance) by an impressed voltage or current.

This generalization of Ohm's law appears necessary, if activity and dissipation are to be mutually compatible.

Details of these researches will be published elsewhere.

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An Exact Solution for a Cylindrical Cavity Containing a Gyromagnetic Material*

This communication gives exact expressions for the fields and resonant frequencies of a circular cylindrical cavity oscillating in any TM_{nq0}-mode[1] and containing a centered circular rod of gyromagnetic material. The merit of selecting these modes is their great simplicity. The equations are sufficiently simple to be practicable for use with experimental measurements. The general solution for a cavity given by Epstein[2] will yield our results, but it is more convenient to obtain them directly for the modes specified above.

It is assumed that the medium has a magnetic susceptibility (for sinusoidal fields) such that

$$(\mu) = \begin{pmatrix} \mu_1 & i\alpha & 0 \\ -i\alpha & \mu_1 & 0 \\ 0 & 0 & \mu_3 \end{pmatrix}. \quad (1)$$

μ_1, α, and μ_3 may be complex. A ferrite material magnetized by a dc field along the z direction may exhibit the property (1).

We use Maxwell's curl equations for such a medium as given by Epstein, assuming no free charge and exp $(-i\omega t)$ time dependence:

$$(\mu)^{-1}\nabla \times \bar{E} = i\omega\bar{H} \quad (2)$$

$$\nabla \times \bar{H} = -i\omega\epsilon\bar{E}. \quad (3)$$

$(\mu)^{-1}$, the inverse of (μ) is

$$(\mu)^{-1} = \begin{pmatrix} M & iK & 0 \\ -iK & M & 0 \\ 0 & 0 & M_3 \end{pmatrix}, \quad (4)$$

in which

$$M = \frac{\mu_1}{\mu_1^2 - \alpha^2}, \quad K = \frac{-\alpha}{\mu_1^2 - \alpha^2}, \quad M_3 = \frac{1}{\mu_3}. \quad (5)$$

We consider the special case where the fields are independent of the z coordinate, which yields the two independent wave equations (as was first shown by Kales)[3]

$$(M\nabla_p^2 + \epsilon\omega^2)E_z = 0 \quad (6)$$

$$(M_3\nabla_p^2 + \epsilon\omega^2)E_p = 0, \quad (7)$$

where ∇_p^2 is the Laplacian in the transverse (r, ϕ) space and E_p is a certain transverse electric field. Eq. (6) corresponds to a TM-wave and (7) to a TE-wave.

We now consider the solutions of (6) and (7), independent of the coordinate z, fitting the boundary conditions in a closed cylindrical cavity (Fig. 1). In this case a nontrivial solution involving E_p cannot exist because a transverse electric field cannot exist on the end plates of the cavity. Therefore, only (6) has a solution and only a TM-mode can exist under the conditions imposed.

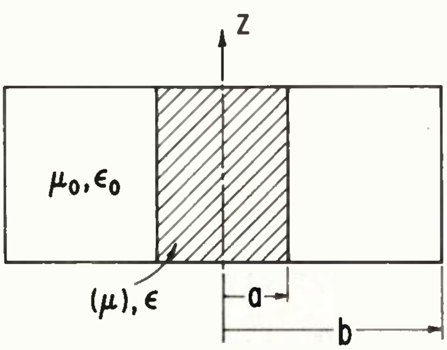

Fig. 1—Circular cylindrical cavity with centered post.

Using a right-handed circular cylindrical coordinate system and the method of separation of variables, one obtains $E_z = AJ_n(\beta' r)e^{\pm in\phi}$ as the solution for the electric field in the rod, where A is the amplitude. The cylinder function $J_n(\beta' r)$ is chosen here because it is appropriate to the region from $r=0$ to $r=a$, β' is $(\omega^2\epsilon/M)^{1/2}$, and n is an integer. Similarly, in the unfilled annulus the solution of (6) with M replaced by $M_0 \equiv 1/\mu_0$ and ϵ by ϵ_0 gives $E_z = C_n(\beta r)e^{\pm in\phi}$ where $\beta = (\omega^2\epsilon_0\mu_0)^{1/2}$, and $C_n(\beta r) = BJ_n(\beta r) + DY_n(\beta r)$. The ratio D/B of the amplitudes must be chosen so that E_z vanishes at the metal wall $(r=b)$. This gives

$$C_n(\beta r) = B[J_n(\beta r) - Y_n(\beta r)(J_n\beta b)/Y_n(\beta b)]. \quad (8)$$

For brevity the indices n and q have been omitted from ω, β', and β. They are, however, implied as subscripts everywhere in this letter.

Eq. (2) is used to obtain H from E. The fields in the post are then $H_z = E_r = E_\phi = 0$, and

$$E_z = AJ_n(\beta' r)e^{\pm in\phi}$$

$$H_r = \frac{A}{\omega}\left[\pm\frac{nM}{r}J_n(\beta' r) - \beta' K J_n'(\beta' r)\right]e^{\pm in\phi}$$

$$H_\phi = \frac{A}{i\omega}\left[\pm\frac{nK}{r}J_n(\beta' r) - \beta' M J_n'(\beta' r)\right]e^{\pm in\phi}. \quad (9)$$

Likewise, in the annular space the fields are $H_z = E_r = E_\phi = 0$, and

$$E_z = C_n(\beta r)e^{\pm in\phi}$$

$$H_r = \pm\frac{nM_0}{\omega r}C_n(\beta r)e^{\pm in\phi}$$

$$H_\phi = \frac{i\beta M_0}{\omega}C_n'(\beta r)e^{\pm in\phi}. \quad (10)$$

M_0 is $1/\mu_0$. $J_n'(x)$ and $C_n'(x)$ are the derivatives with respect to x.

By equating the tangential components E_z and H_ϕ from (9) and (10) at the boundary $r=a$, we obtain two homogeneous equations in the amplitudes A and B [B is the amplitude attached to $C_n(\beta r)$]. Setting the determinant of the coefficients of A and B equal to zero, we obtain the transcendental equations in β'

$$\frac{\beta' a M J_n'(\beta' a)}{J_n(\beta' a)} \mp nK = \frac{\beta a M_0 C_n'(\beta a)}{C_n(\beta a)}. \quad (11)$$

Eq. (11) represents two equations, the upper sign pertaining to $e^{+in\phi}$ and the lower sign to $e^{-in\phi}$. With (11) the unknowns M and K may be obtained from the two resonant frequencies ω_+ and ω_- for the positively and negatively rotating waves, respectively, and vice versa.

After setting $M = 1/\mu$ and $K=0$ (case of a post with scalar permeability) β' becomes $(\omega^2\mu\epsilon)^{1/2}$, and with $n=0$, (11) reduces to

$$\frac{(\epsilon/\epsilon_0)^{1/2}J_0'(\beta' a)}{(\mu/\mu_0)^{1/2}J_0(\beta' a)} = \frac{C_0'(\beta a)}{C_0(\beta a)}. \quad (12)$$

This formula (12) obtained from (11) is identical with one that we have previously obtained directly for a TM_{010}-mode cavity containing a rod with scalar electrical constants μ and ϵ (unpublished notes).

* Received by the IRE, December 20, 1956. This work was partially supported by Order No. Buships /1700R-564.

[1] TM_{nqp} refers to a transverse magnetic mode with ϕ, r, z indices of n, q, and p respectively.

[2] P. S. Epstein, "Theory of wave propagation in a gyromagnetic medium," *Rev. Mod. Phys.*, vol. 28, pp. 3–17; January, 1956.

[3] M. L. Kales, "Modes in waveguides containing ferrites," *J. Appl. Phys.*, vol. 24, pp. 604–608; May, 1953.

With considerable algebra, $C_n'(\beta a)/C_n(\beta a)$ reduces to

$$\frac{J_{n-1}(\beta a)}{J_n(\beta a)} + \frac{2J_n(\beta b)}{\pi\beta a J_n(\beta a)[J_n(\beta b)Y_n(\beta a)-J_n(\beta a)Y_n(\beta b)]} - \frac{n}{\beta a}, \tag{13}$$

which is convenient for computations.

When the sample radius a is very small (11) may be approximated and compared with an available TM_{110}-mode cavity perturbation formula.[4] Using the fact that as $x \to 0$, $xJ_1'(x) \doteq J_1(x)$, the left side of (11) becomes $M \mp K = (\mu_1 \mp \alpha)^{-1}$, for $n=1$. We use one-term expansions of the function on the right-hand side, in the form (13). $J_1(\beta b)$ is nearly zero, since βb is nearly r_{11}, the first root of J_1. Therefore we use for its argument $\beta b = r_{11}(1-\Delta\omega/\omega)$, where $\Delta\omega/\omega = (\omega_0-\omega_1)/\omega_0$ is the fractional change in the resonant frequency of the cavity due to the magnetic perturbation. Elsewhere use $\beta b = r_{11}$. Eq. (11) then becomes

$$\frac{\Delta\omega_\pm}{\omega} = \frac{\mu_1 \mp \alpha - \mu_0}{\mu_1 \mp \alpha + \mu_0}\,\frac{\pi r_{11} Y_1(r_{11})}{4J_0(r_{11})}\,\frac{a^2}{b^2}, \tag{14}$$

which is equivalent to the perturbation formula given in (21) of Le Craw and Spencer,[4] although the signs differ because our off-diagonal signs in (1) are different.

Exact calculations may start with M and K estimated from (14) followed by an iterative procedure in (11). In the usual case ϵ is unknown too, but (11) can also furnish ϵ if M and K are known, so an iterative calculation using two different cavity modes, say the TM_{010} and the TM_{110}, can yield ϵ, M, and K. Complex frequencies may be used to obtain losses.

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[4] R. C. LeCraw and E. G. Spencer, "Tensor permeabilities of ferrites below magnetic saturation," 1956 IRE Convention Record, Part 5, pp. 66–74.

Effects of Evaporated Electrodes on Quartz Resonator Vibrating in a Contour Mode*

It is well-known that evaporated electrodes, deposited on the surface of quartz resonator vibrating in a *thickness mode*, always lower the resonant frequency of the resonator and have little effect on its Q. But this is not the case of a resonator vibrating in a *contour mode*. Both the frequency and the Q are remarkably influenced by the presence of electrodes. In certain cases the frequency increases with the thickness of electrodes.

The metallic deposits on crystal surface, which make up evaporated electrodes, are usually quite different from ordinary metal in their nature. It is found, however, that values of elastic constants can be assumed to be equal to those of ordinary metal, and the internal loss follows the Voight's model[1] after appropriate heat treatments.

From a consideration of the energy relation in a vibrating elastic body, the change of the resonant frequency f due to electrodes, can be expressed by the form:

$$\frac{\Delta f}{f} \doteq \frac{1}{2}\left(\frac{P'}{P} - \frac{K'}{K}\right). \tag{1}$$

While, as shown below, the over-all Q consists of Q_i and Q' which depend on internal loss of the resonator itself and the electrodes, respectively. As the Q' is usually of the order of $10^5 \sim 10^6$, it takes a considerable part of the Q for the recent high-Q quartz resonator whose Q_i is better than 10^6.

$$\frac{1}{Q} = \frac{1}{Q_i} + \frac{1}{Q'} \tag{2}$$

$$Q' \doteq \frac{F'}{P}. \tag{3}$$

The K, P, and F in (1) and (3) are, respectively, the time averages of kinetic energy, potential energy, and internal energy loss in the resonator itself, and the primes indicate the corresponding quantities in the electrodes. They can be expressed by the following tensor forms neglecting a certain numerical coefficient.

$$K = (2\pi f)^2 \iiint \rho u_i u_i dv \tag{4}$$

$$P + jF = \iiint T_{ij} S_{ij} dv \tag{5}$$

where ρ, u, S, and T are density, displacement, strain, and stress, respectively. According to the Voigt's model the stress-strain relationship takes the form:

$$T_{ij} = (c_{ijkl} + j2\pi f b_{ijkl}) S_{kl}. \tag{6}$$

The thickness of electrodes is usually thin enough to assume that the displacement in the electrodes is equal to the displacement at the crystal surface. This makes the evaluation of these integrals fairly easy, if we know the solution of free vibration of the resonator.

It is not always necessary, however, to perform the integrations. If we use *full electrodes* and if one and only one strain component predominates for the mode under consideration, then both integrals in numerator and denominator of (1) and (3) can be canceled out except certain numerical constants. The latter condition is the case of most contour modes for practical use.

For example, for the longitudinal mode (1) and (3) reduce to:

$$\frac{\Delta f}{f} = \frac{1}{2}\left(\frac{E'}{E} - \frac{\rho'}{\rho}\right)\frac{t}{t} \tag{7}$$

$$Q' = \frac{Et}{2\pi f b_l' t'} \tag{8}$$

while for the face shear mode:

$$\frac{\Delta f}{f} = \frac{1}{2}\left(\frac{E'}{2(1-\sigma')s_\theta} - \frac{\rho'}{\rho}\right)\frac{t'}{t} \tag{9}$$

$$Q' = \frac{\quad}{2\pi f b_f' s_\theta t'} \tag{10}$$

where E is Young's modulus, σ Poisson's ratio, t thickness and s_θ elastic (shear) compliance. The first term in the brackets of (7) and (9) is characteristic of contour modes in contrast with thickness modes. In Table I the calculated values of $(\Delta f/f)/(t'/t)$, for several cuts and metals, are compared with experimental values.

TABLE I

Cut	Metal of electrodes	$-(\Delta f/f)/(t'/t)$	
		Calculated	Measured
18.5° X	silver	1.41	1.5_8
CT	silver	1.51	1.4_7
CT	gold	3.14	3.0_3

Details concerned with the loss factors, b_l' and b_f', will appear elsewhere, as they are highly dependent on evaporation procedure and heat treatments. It might be interesting, however, to point out, as a direct conclusion of (10), that the Q' of CT-cut is 2.3 times higher than the Q' of DT-cut, when the frequency, the thickness of resonator, and the thickness of electrodes are equal for both cuts.

For partial electrodes, effects of electrodes on the frequency and the Q' depend not only on its thickness but also on its shape and its location on the crystal surface. This is because P' and F' become large at the portion of high strain, while K' becomes large at the portion of large displacement.

For the longitudinal mode the displacement is maximum and the strain is minimum at the very end of the plate, while the displacement is minimum and the strain is maximum at the center of the plate. Therefore, a small electrode at the end of the plate considerably lowers the frequency, but has little effect on the Q'. An electrode at the center of the plate, however, increases the frequency and considerably lowers the Q'. Quantitative experiments done by Mr. Takahara at Electrical Communication Laboratories, Japan Telephone and Telegram Corporation, using a 18.5° X cut with electrodes divided into 12 segments along its length have shown good agreement with this theory.

The author wishes to acknowledge the advice by Prof. N. Takagi and the information kindly sent by Mr. Takahara.

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* Received by the IRE, January 10, 1957.

[1] W. Voigt, "Lehrbuch der Kristallphysik," B. G. Teubner, Leipzig, 1910, s.792.

Amplification-Bandwidth Exchange in Transistor Video Amplifiers*

Bruun[1] has described several ways of efficiently trading amplification for band-

* Received by the IRE, January 24, 1957.

[1] G. Bruun, "Common-emitter transistor video amplifiers," Proc. IRE, vol. 44, pp. 1561–1572; November, 1956.

width in an RC coupled transistor video amplifier. One technique involves the choice of emitter current bias to provide the desired exchange. The external interstage load is kept a constant optimum value no matter what low frequency stage amplification is used.

As it is not always desirable from a practical point of view to vary emitter current bias over a wide range, it is interesting to inquire what penalty is paid by maintaining the bias constant and varying the interstage load as is done in the vacuum tube video amplifier.

Some specific data on this question are available from work done at our Laboratories on RC coupled common emitter transistor video amplifiers. The performance of representative transistors in amplifiers was calculated by means of the NBS SEAC digital computer. The results of interest here are shown in Fig. 1. The amplification-

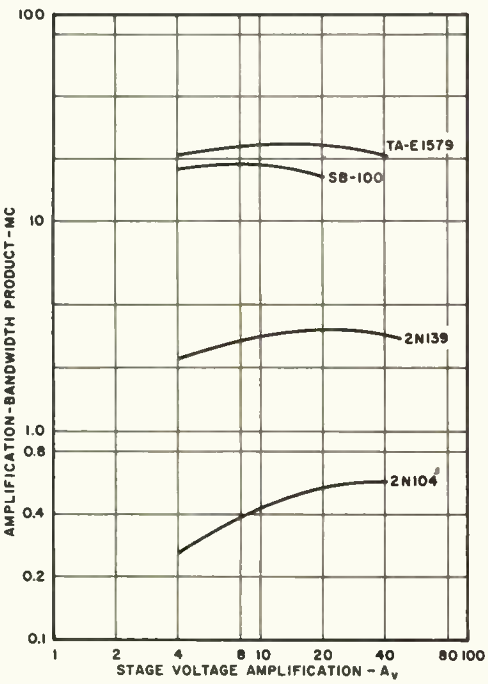

Fig. 1—Video amplification-bandwidth products of various transistors.

bandwidth product as a function of stage voltage amplification (one stage of an iterative amplifier) is shown for four transistor types. The 2N104 (audio) and 2N139 (IF) are alloy germanium transistors. The SB-100 is a surface barrier type; the TA-E 1579 is a drift transistor, the predecessor of the 2N247.

The point of interest to this discussion is the fact that the amplification-bandwidth products of the two high-frequency transistors (SB-100 and TA-E 1579) very only slightly over the useful range of stage voltage amplification.

For most applications the loss from the optimum value of amplification-bandwidth product would be unimportant.

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A Precise New System of FM Radar*

Presumably voicing a question that has arisen in the minds of others working in the radar altimeter field, I would like to ask Mr. Ismail to expand upon his excellent presentation,[1] to describe the effect of direct signal leakage between antennas of his altimeter. The mixing process expressed by (17) of his paper presumes that only the local oscillator signal u_{F1} and the signal u_r received from the ground are present. It would appear that there is also a third signal which I shall call u_i, which is a direct leakage signal between transmitter and receiver. This signal, even though suppressed by isolation, does not seem to be negligible by comparison with the reflected signal u_r, and, since it produces a spectrum also centered at the intermediate frequency F_{s01}, it should be at least accounted for in the analysis.

The leakage signal u_i has the same form as (12) of the paper, except that the time delay T is replaced by T_a, the transit time between antennas, and the Doppler shift w_v is absent. When this signal is applied to the mixer along with signals u_r and u_{F1}, there results sums and differences of the possible argument combinations. The sums, of course, are removed by filtering, as is the component centered at "zero" frequency. The two differences of interest are the ones expressed by (18) of Ismail and another one like it given by, if the approximations of Ismail are applied:

$$u_{Zi} = U_{Zi} \cos \left[\Omega_{s01}t - \Delta\Omega T_a \cos \omega_m t + \phi_i\right], \quad (1)$$

which is of the form

$$B \cos (\alpha + \gamma) \quad (2)$$

where $\alpha = \Omega_{s01}t$, and the nomenclature is seen by comparison. Similarly, (18) of Ismail is of the form

$$A \cos (\alpha + \beta). \quad (3)$$

The sum of (2) and (3) may be expressed as

$$B \cos (\alpha + \gamma) + A \cos (\alpha + \beta) = R \cos (\alpha + \psi) \quad (4)$$

where

$$R = \sqrt{A^2 + B^2 + 2AB \cos (\beta - \gamma)} \quad (5)$$

$$\psi = \mathrm{Tan}^{-1} \frac{A \sin \beta + B \sin \gamma}{A \cos \beta + B \cos \gamma}. \quad (6)$$

Now as long as $A \neq B$, which would cause R to swing through zero at intervals, we may assume that R can be made constant by limiting, so that only the derivative of the argument of (4) is of interest. This can be shown to be

$$\omega_{s1} = (\dot{\alpha} + \dot{\psi}) = \dot{\alpha} + \frac{A^2\dot{\beta} + B^2\dot{\gamma} + AB \cos (\beta - \gamma)(\dot{\beta} + \dot{\gamma})}{A^2 + B^2 + 2AB \cos (\beta - \gamma)} \quad (7)$$

$$= \dot{\alpha} + \dot{\beta} - (\dot{\beta} - \dot{\gamma}) \cdot \frac{B}{A} \frac{\frac{B}{A} + \cos (\beta - \gamma)}{1 + \left(\frac{B}{A}\right)^2 + 2\frac{B}{A} \cos (\beta - \gamma)}, \quad (8)$$

* Received by the IRE, November 26, 1956.
[1] M. A. W. Ismail, PROC. IRE, vol. 44, pp. 1140–1145; September, 1956.

wherein, from (1) above and (18) of Ismail,

$$\dot{\alpha} + \dot{\beta} = \Omega_{s01} + \omega_v + \omega_m \Delta \Omega T \sin \omega_m t$$
$$\dot{\beta} - \dot{\gamma} = \omega_m \Delta\Omega(T - T_a) \sin \omega_m t + \omega_v$$
$$\beta - \gamma = \omega_v t - \Delta\Omega(T - T_a) \cos \omega_m t + \phi' - \phi_i$$
$$\frac{B}{A} = \frac{U_{si}}{U_{s1}}.$$

Since from the mixing process

$$U_{si} \propto U_{F1}U_i,$$

and

$$U_{s1} \propto U_{F1}U_r$$

then

$$\frac{B}{A} = \frac{U_i}{U_r},$$

which might be termed the "spillover ratio" for the system. For the case where $U_i = 0$, (8) reduces to the result of Ismail, since the last term becomes zero. To the extent that the spillover ratio is finite, it would appear that the last term of (8) introduces a time-varying distortion into the frequency measurement, periodic in ω_m, irrespective of the fact that subsequent mixing processes translate the center frequency to a new and lower value. The distortion is similar to that due to multipath propagation in fm communication and distance-measuring systems, which has been studied in considerable detail by Argimbau[2] and others,[3] and, at least in these systems, has been shown to produce serious effects under certain circumstances.

It would be preposterous to imply that an unworkable or inaccurate altimeter results because of this leakage, since Ismail has obviously built one and tried it. However, the effect would not have appeared in his reported bench tests except by accident, since there was but one delay path via a cable, and not two as exist when antennas are present. Therefore, I believe some more data should be supplied by him relating to tests with an actual altimeter, particularly as regards the accuracy thereof, in the interests of a complete discussion. Alternatively, bench tests with two propagation paths of greatly differing lengths might prove informative.

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Author's Comment[4]

The effect of direct signal leakage between the transmitting and the receiving antennas, which Mr. Johnson has brought out in his discussion on my paper, has always been a serious problem that has accompanied all fm radar systems from the beginning of their use in practice. Hence, utmost care has to be taken when designing and locating the antennas to attain a very high degree of isolation between them. In spite of this, there always exist some weak signal that succeeds in reaching the receiving antenna directly from the transmitting one

[2] See quarterly reports of Res. Lab. Electronics, Mass. Inst. Tech., Cambridge, Mass., for the past several years.
[3] T. E. Sollenberger, "Multipath phase errors in cw-fm tracking systems," IRE TRANS., vol. AP-3, pp. 185–192; October, 1955.
[4] Received by the IRE, January 8, 1957.

Direct signal leakage is one of the main causes that confined the use of fm radar systems to the cases where its troublesome results could be kept at an acceptable minimum. One of the cases in which fm radar is used almost exclusively, is as a low range airplane altimeter. For altimeters working at 440 mc, a 70 db or more signal attenuation from one antenna to another could be attained. As the reflecting surface here is unlimited, since it is that of ground or sea water, the reflected signal strength in the 0–400 feet range will, undoubtedly, be so strong that U_i will be negligibly small with respect to U_r. In such a case, the precision of the new system still holds, and very low altitudes can be measured accurately. This is actually the most important advantage of this system, since its main object is to measure accurately and without a fixed error very low altitudes, to help in the blind landing of airplanes. In the higher altitude range from 400–4000 feet, the direct feedthrough becomes more troublesome as the altitude increases, especially when flying over very poor conducting ground, because the reflected signal becomes very weak. However, a proper flight test on the altimeter which I had built should be carried out, to see actually what the effect of direct signal leakage at different altitudes will be. Unfortunately, I did not have the opportunity to carry out the flight test myself in Switzerland. Moreover, as I have been in Egypt since October, 1955, after developing the prototype for Hasler Laboratories in Bern, Switzerland, it is materially impossible to carry out further bench tests.

In the interest of further investigating the effect of direct signal leakage at high altitudes, let us consider the case where

$$U_i = 0.1\, U_r. \tag{1}$$

If we substitute this in Johnson's (8) we get,

$$\omega_{s1} = \dot{\alpha} + \dot{\beta} - (\dot{\beta} - \dot{\gamma}) \cdot \frac{0.01 + 0.1 \cos(\beta - \gamma)}{1 + 0.01 + 0.2 \cos(\beta - \gamma)}. \tag{2}$$

Also, at high altitudes $T \gg T_a$, so that we may substitute T for $T - T_a$ in both $\dot{\beta} - \dot{\gamma}$ and $\beta - \gamma$ which, therefore, will be:

$$\dot{\beta} - \dot{\gamma} \cong \omega_m \Delta\Omega T \sin \omega_m t + \omega_v$$

$$\beta - \gamma \cong \omega_v t - \Delta\Omega T \cos \omega_m t + \phi' - \phi_i.$$

The difference between the two values of ω_{s1} as given by (18)[5] and (2) above, will be, in this case, the error caused by direct signal leakage and is given by

$$\Delta\omega_{s1} \cong -(\omega_m \Delta\Omega T \sin \omega_m t + \omega_v) \cdot \frac{0.01 + 0.1 \cos(\omega_v t - \Delta\Omega T \cos \omega_m t + \mathring{\phi})}{1 + 0.2 \cos(\omega_v t - \Delta\Omega T \cos \omega_m t + \mathring{\phi})} \tag{3}$$

where

$$\mathring{\phi} = \phi' - \phi_i.$$

The magnitude of the denominator here can vary between maximum and minimum values of 1.2 and 0.8, respectively. The numerator of (3) can be expanded as follows:

$$\begin{aligned}
&-(\omega_m \Delta\Omega T \sin \omega_m t + \omega_v) \\
&\cdot [0.01 + 0.1 \cos(\omega_v t - \Delta\Omega T \cos \omega_m t + \mathring{\phi})] \\
&\cong -(\omega_m \Delta\Omega T \sin \omega_m t + \omega_v) \\
&\quad \{0.01 + 0.1 [I_0(\Delta\Omega T) \cos(\omega_v t + \mathring{\phi}) \\
&\quad + I_1(\Delta\Omega T) [\sin(\omega_m t + \omega_v t + \mathring{\phi}) \\
&\quad - \sin(\omega_m t - \omega_v t - \mathring{\phi})] \\
&\quad - I_2(\Delta\Omega T) [\cos(2\omega_m t + \omega_v t + \mathring{\phi}) \\
&\quad + \cos(2\omega_m t - \omega_v t - \mathring{\phi})] \\
&\quad + I_3(\Delta\Omega T)(\cdots\cdots\cdots\cdots) \\
&\quad + \cdots\cdots\cdots\cdots\cdots\cdots \text{etc.}]\}
\end{aligned} \tag{4}$$

where $I_n(\Delta\Omega T)$ is the Bessel function of the first kind with argument $\Delta\Omega T$ and nth order.

Since the lf amplifier that precedes the altitude indicator is selective at frequency f_m, then only components of (4) at a frequency f_m approximately can cause errors in altitude. This can only occur at $f_v \cong 0$, f_m, $2f_m$, $3f_m$, $\cdots$, etc. Considering the case where $f_v = 0$, we get

$$\Delta\omega_{s1(\omega_v=0)} \cong -\frac{\omega_m \Delta\Omega T [0.01 \sin \omega_m t + 0.1 \sin \omega_m t \cos \mathring{\phi} (I_0(\Delta\Omega T) - I_2(\Delta\Omega T))]}{1.2 > \text{denominator} > 0.8}, \tag{5}$$

showing that the relative error $\Delta\omega_{s1(\omega_v=0)} / \omega_m \Delta\Omega T \sin \omega_m +$ changes with range and will only be 1 per cent at such a range where $I_0(\Delta\Omega T) = I_2(\Delta\Omega T)$. Eq. (4) also shows that at $\omega_v \cong 0$, the mean value of (4) = 0; *i.e.*, no false indication of speed of a target of a fixed range exists.

In my book "A Study of the Double Modulated FM Radar," I have already proposed a method to minimize the effect of direct signal leakage at high altitudes. A summary of this method is given below:

Analogous to (22),[6] the output signal from the last IF amplifier, resulting from the direct signal leakage alone is

$$u_{si}''' = U_{si}''' \cos(\Omega_{s03} t - \Delta\Omega T_a \cos \omega_m t + \phi_i''') . \tag{6}$$

The expansion of (6) gives

$$\begin{aligned}
u_{si}''' = U_{si}''' \{ & I_0(\Delta\Omega T_a) \cos(\Omega_{s03} t + \phi_i''') \\
& + I_1(\Delta\Omega T_a) [\sin(\Omega_{s03} t + \omega_m t + \phi_i''') \\
& - \sin(\Omega_{s03} t - \omega_m t + \phi_i''')] \\
& + I_2(\Delta\Omega T_a) [\cos(\Omega_{s03} t + 2\omega_m t + \phi_i''') \\
& + \cos(\Omega_{s03} t - 2\omega_m t + \phi_i''')] \\
& + I_3(\Delta\Omega T_a) \cdot \cdots\cdots\cdots\cdots \text{etc.} \}
\end{aligned} \tag{7}$$

As the transit time between the antennas T_a usually is very small, $\Delta\Omega T_a$ will also be very small, especially when ΔF is made small, which is always true when measuring long ranges. In this case, the only component of significant amplitude in (7) is the first with $I_0(\Delta\Omega T_a) \cong 1$, while all other components are negligibly very small.

For example:

$\Delta F \cong 150$ kc for 0–4000 feet range

direct signal leakage path = 5 meters

$\Delta\Omega T_a \cong 0.0157$

$\therefore I_0(\Delta\Omega T_a) \cong 1, \quad I_1(\Delta\Omega T_a) \cong 0.0075$

and $I_2(\Delta\Omega T_a) \cong 0.$

If, therefore, the first component, namely at frequency F_{s03}, is balanced out, signal u_{si}''' will be almost completely suppressed, giving a remainder of only 1 or 2 per cent of its normal amplitude. This can easily be accomplished in pratice by adding to the output of the last IF amplifier a local signal at frequency F_{s03} that is made equal in amplitude and opposite in phase to the fundamental component of u_{si}'''.

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[5] Ismail, *op. cit.*, p. 1143.

[6] *Ibid.*, p. 1143.

On the Tail in the Transient Behavior of Point-Contact Diodes*

Several recent discussions of the transient behavior of small hemispherical p-n junctions,[1,2] to which point-contact diodes are at least an approximation, agree that the transient is determined largely by the radius of the junction, and little affected by the carrier lifetime. This is in contrast to the behavior of large area junctions where the lifetime is an important factor.

Although the main part of the transient in the point-contact diodes is almost independent of lifetime, it is interesting to notice that there is a "tail" on the transient which is almost exponential, and is determined by the lifetime. This tail may or may not be important, or even noticeable, in a given situation, according to the circumstances.

This is probably most easily shown for the open circuit transient after the diode has passed a pulse of forward current. It has been shown[2] that p_n, the minority carrier concentration at the junction (the discussion here assumes that holes are injected into n-type material; with necessary changes, it would, of course, apply to the opposite case) is given by:

$$p_n = p_{ni} - (p_{ni} - p_{no}) \left(\frac{L}{L - r_o} \right) \cdot \left\{ 1 - \frac{r_0}{L} \operatorname{erf} \left(\frac{t}{\tau} \right)^{1/2} - e^{((L^2/r^2)-1)t/\tau} \operatorname{erfc} \frac{(Dt)^{1/2}}{r_0} \right\}. \tag{1}$$

p_{ni} is the value of p_n at time $t = 0$, p_{no} the equilibrium value, D the diffusion constant, τ the lifetime, $L = (D\tau)^{1/2}$ the diffusion length, and r_o the radius of the junction.

Ordinarily $L \gg r_o$. Then, for not too small values of t the erfc term may be represented by the first term in its asymptotic representation.[3] This, along with some rearranging, makes (1) become

* Received by the IRE, November 21, 1956.

[1] B. R. Gossick, "On the transient behavior of semiconductor rectifiers," *J. Appl. Phys.*, vol. 27, pp. 905–911; August, 1956.

[2] H. L. Armstrong, "On open circuit transient effects in point contact rectifiers," *J. Appl. Phys.*, vol. 27, pp. 420–421; April, 1956.

[3] B. O. Pierce, "A Short Table of Integrals," Ginn and Co., Boston, Mass., 3rd ed., p. 120; 1929.

$$p_n = p_{no} + \frac{r_o(p_{ni} - p_{no})}{L - r_o}\left\{\left(\frac{\tau}{\pi t}\right)^{1/2} e^{-t/\tau} - \operatorname{erfc}\left(\frac{t}{\tau}\right)^{1/2}\right\}. \quad (2)$$

Over a range $t \sim \tau$, the erfc term does not depart too far from exponential behavior; thus under these circumstances the excess charge may decay almost exponentially.

For $t \gg \tau$, the asymptotic representation of the erfc term may again be used; then (2) gives

$$p_n \sim p_{no} + \frac{r_o(p_{ni} - p_{no})}{2(L - r_o)(\pi)^{1/2}}\left(\frac{\tau}{t}\right)^{3/2} e^{-t/\tau} \quad (3)$$

which is the eventual behavior of p_n as $t \to \infty$. Thus it is seen that the lifetime does control a part of the transient, but only that part which follows the initial change due to diffusion effects.

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The Influence of Threshold Action on the RMS Value of Input Gaussian Noise*

Threshold action is often present in many communication systems containing pulse shapers and coding equipment, either as an inherent feature of the system or as a parameter designed into the system for a definite purpose. When noise is present at the input, either in place of or in addition to some desired signal, the threshold action changes the probability distribution of the noise input. In treating both military and commercial problems which involve signal-to-noise statistics, such an alteration can be significant.

This discussion shows how the presence of a threshold reduces the rms value of the input voltage when the input voltage is Gaussian noise. In particular, an expression is derived which relates S, the rms value of noise voltage after threshold action, to σ, the rms value of noise voltage before threshold action.

Before threshold action, if the input noise is Gaussian the probability density $\phi(y)$ is as shown in Fig. 1 and is given by

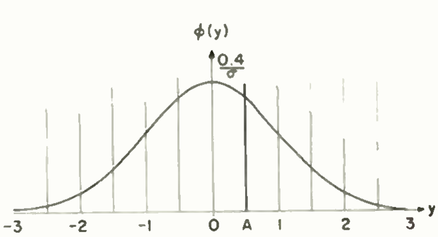

Fig. 1—Probability density before threshold action.

* Received by the IRE, March 11, 1957.

$$\phi(y) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(\frac{-y^2}{2\sigma^2}\right).$$

After threshold action the probability density $p(x)$ will be that shown by Fig. 2.

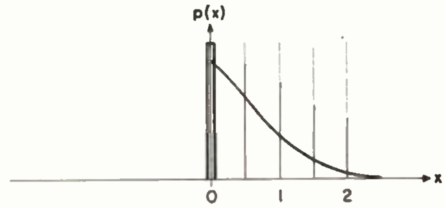

Fig. 2—Probability density following threshold action.

For positive x, $p(x)$ is given by

$$p(x) = B\delta(0) + p'(x)$$

$$p(x) = B\delta(0) + \frac{1}{\sqrt{2\pi\sigma^2}} \exp \frac{-(x + A)^2}{2\sigma^2} \quad (x \geq 0) \quad (1)$$

where B is the probability that a noise amplitude lies between $-\infty$ and A

$\delta(0)$ is the Dirac delta function at $x = 0$
A is the threshold level, and

$x = y - A$.

By definition the mean square value (the variance) S^2 of $p(x)$ is given by

$$S^2 = m_2 - m_1^2 \quad (2)$$

where m_2 is the second moment and m_1 is the first moment (mean) of the distribution after threshold action. These moments are defined by (3) and (7).

By definition

$$m_1 = \frac{1}{N}\int_0^\infty xp(x)dx = \int_0^\infty xp'(x)dx \quad (3)$$

where N, the normalizing factor, is given by

$$N = \int_0^\infty p(x)dx = 1.$$

Substitution of (1) into (3) and integration yield

$$m_1 = \frac{\sigma}{\sqrt{2\pi}} \exp\left(\frac{-g^2}{2}\right) - \frac{A}{2} \operatorname{cerf}\left(\frac{g}{\sqrt{2}}\right) \quad (4)$$

where

$$g = \frac{A}{\sigma}, \text{ a convenient dimensionless ratio,} \quad (5)$$

and cerf denotes the complementary error function defined by

$$\operatorname{cerf} U = \frac{2}{\sqrt{\pi}} \int_u^\infty e^{-z^2} dz. \quad (6)$$

In a similar fashion

$$m_2 = \frac{1}{N}\int_0^\infty x^2 p(x)dx = \int_0^\infty x^2 p'(x)dx. \quad (7)$$

Substitution of (1) into (7) and integration yield

$$m_2 = \frac{-A\sigma}{\sqrt{2\pi}} \exp\left(\frac{-g^2}{2}\right) + \left(\frac{\sigma^2 + A^2}{2}\right) \operatorname{cerf}\left(\frac{g}{\sqrt{2}}\right). \quad (8)$$

Substitution of (4) and (8) into (2) and normalization to σ^2 yield

$$\left(\frac{S}{\sigma}\right)^2 = \frac{-g}{\sqrt{2\pi}} \exp\left(\frac{-g^2}{2}\right) + \left(\frac{1 + g^2}{2}\right) \operatorname{cerf}\left(\frac{g}{\sqrt{2}}\right) - \left\{\frac{\exp\left(\frac{-g^2}{2}\right)}{\sqrt{2\pi}} \frac{-g}{2} \operatorname{cerf}\left(\frac{g}{\sqrt{2}}\right)\right\}. \quad (9)$$

Eq. (9) is the desired expression. It is used to obtain Fig. 3 where S/σ is plotted as a function of $g = A/\sigma$. Fig. 3 shows how S,

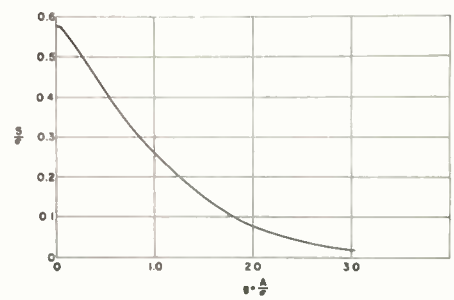

Fig. 3—RMS value S following threshold action.

the rms value after threshold action, depends upon σ, the rms value before threshold action, and upon the threshold level, A. For example, if the threshold level A is set equal to σ, then the rms value of the output voltage is approximately one-quarter of the rms value of the input Gaussian voltage.

By using the curve of Fig. 3, a designer can predict how much a specified threshold level A will decrease the rms value of the input noise voltage. Or, he can determine where the threshold level must be set to reduce the rms value of noise below some specified value which can be tolerated. These features should be of particular interest, for example, when a receiver must operate in the presence of considerable interference due to noise originating outside the receiver.

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Radar Horizon and Propagation Loss*

If a radar is at a height h_1 above the surface of the earth, the distance R_1 to the point of tangency is given by

$$R_1 = \sqrt{2kah_1} \quad (1)$$

* Received by the IRE, February 15, 1956. The research reported here was supported jointly by the U. S. Army, Navy, and Air Force under contract with Massachusetts Institute of Technology.

where a is the radius of the earth (3960 statute miles) and ka is the effective earth's radius, Fig. 1. A smooth earth is assumed. The factor k allows for the effects of atmospheric refraction and under normal conditions in most of the United States, it is taken to be equal to 4/3. This fortunate choice of k allows (1) to be written as

$$R_1 \text{ (statute miles)} = \sqrt{2h_1 \text{ (feet)}} \qquad (2)$$

The point of tangency in Fig. 1 has been called by some the optical horizon,[1] and by others, the radio,[2] or radar horizon.[3]

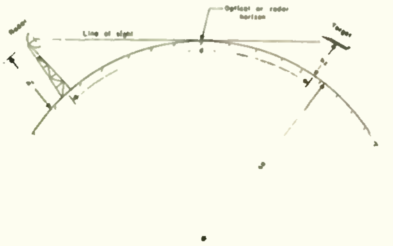

Fig. 1—Geometry for radar propagation over curved earth.

If the target is at a height h_2 above the earth's surface, its distance to the point of tangency is also given by an expression similar to (1). Hence, the length of the "line of sight" joining the radar at height h_1 and the target at height h_2 and which is tangent to the surface of the earth is

$$d = \sqrt{2kah_1} + \sqrt{2kah_2}. \qquad (3)$$

The line of sight as shown in Fig. 1 and given by (3) has sometimes been used to indicate the limits of the low altitude coverage of a radar.[3] That is, a target at distance d from the radar was said to be within the view of a radar at height h_1 if the target were at a height of h_2 or greater. This implies that the simple radar range equation[4] can be used when the target is on the radar line of sight without taking account of propagation losses. It is the purpose of this note to show that neglecting propagation losses along the line of sight can lead to overly optimistic results and that the use of (3) to predict the low altitude coverage of a radar is not justified. The radar signal received from a target located along the line of sight is usually many decibels below the signal which would have been received at the same range in free space. Although this fact is well known to propagation workers, it may not be as familiar to the radar systems engineer.

Some examples of the radar propagation losses experienced when the radar and target are both on the line of sight are shown in Fig. 2. The losses are for two-way (radar) propagation. The losses encountered by the radar system at the line of sight are of sufficient magnitude to rule out simple geometrical considerations for predicting radar coverage.

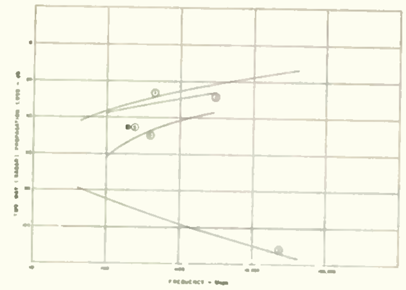

Fig. 2—Radar propagation losses (two-way) when target and radar are both on the optical line of sight.
Curve 1—$h_1 = h_2 = 100$ m, vertical polarization, $k = 1$, dry soil; from Burrows and Attwood.[5]
Curve 2—Same as (1) but with $h_1 = 100$ m, $h_2 = 0$; from Burrows and Attwood.[6]
Curve 3—$h_1 = 110$ feet, $h_2 = 2100$ feet, horizontal polarization, $k = 4/3$, sea water; from Kerr.[7]
Curve 4—$h_1 = 9$ m, $h_2 = 282$ m, horizontal polarization, $k = 4/3$, sea water; from Burrows and Attwood.[8]
Curve 5—$h_1 \approx 0$, $h_2 = 30{,}000$ ft., AFCRC experimental measurements.[9]

The so-called radar coverage obtained with (3) is shown by the dashed curve 1 of Fig. 3 for a radar at a height of 200 feet. A more realistic indication of the low altitude capabilities of a radar would be that contour which corresponded to the minimum detectable radar signal. The calculation of the contours of constant signal strength is tedious and much more complicated than merely taking a square root as in (3), but it can be found by using well-known techniques.[10,11] Examples of such contours are indicated in Fig. 3 by curves 2–5. These were drawn assuming that the radar minimum detectable signal occurred at free space ranges of 32, 64, 128, and 256 miles. Also shown in Fig. 3, curve 6, is the boundary between the diffraction region and free space region. Below this curve, propagation losses must be taken into account. The assumptions used in obtaining curves 2–6 are shown in the figure caption. Figs. 2 and 3 illustrate that targets on the optical or radar line of sight lie within the diffraction zone of the radar and radar signals received from such targets are subject to considerable losses beyond that obtained with normal free space propagation.

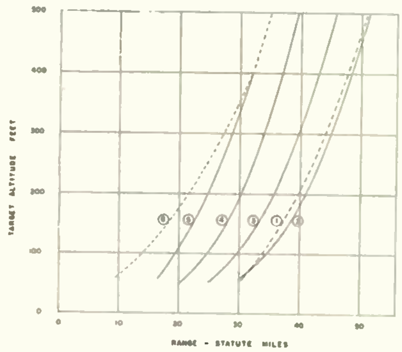

Fig. 3—Contours of "radar coverage" for radar height of 200 feet above curved earth.
Curve 1—Optical or radar line of sight contour from (3) with $k = 4/3$.
Curve 2—Constant radar signal contour in the diffraction zone for a signal strength equal to the free space signal at 256 miles, vertical polarization, sea water, $k = 4/3$, $f = 500$ mc.
Curve 3—Same as 2, but for 128-mile free space signal.
Curve 4—Same as 2, but for 64-mile free space signal.
Curve 5—Same as 2, but for 32-mile free space signal.
Curve 6—Zero transmission loss contour, same conditions as curves 2–5.

Although a radar was used as the example in this note, the same arguments apply to a radio communications system located within the diffraction region except that only one-way propagation losses need be considered. In Fig. 3, the curves apply directly to the communications case if radar height and target are interpreted as transmitter height and receiver height.

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[1] C. R. Burrows and S. S. Attwood, "Radio Wave Propagation," Academic Press, New York, N. Y., p. 379; 1949.
[2] H. R. Reed and C. M. Russell, "Ultra-High Frequency Propagation," John Wiley and Sons, New York, N. Y., p. 3; 1953.
[3] J. F. Reintjes and G. T. Coate, "Principles of Radar," McGraw-Hill Book Co., Inc., New York, N. Y., p. 970; 1952.
[4] L. N. Ridenour, "Radar System Engineering," McGraw-Hill Book Co., Inc., New York, N. Y., p. 21; 1947.
[5] Burrows and Attwood, *op. cit.*, p. 382, Fig. 6.
[6] *Ibid.*, p. 382, Fig. 5.
[7] D. E. Kerr, "Propagation of Short Radio Waves," McGraw-Hill Book Co., Inc., New York, N. Y., p. 408, Fig. 6; 1951.
[8] Burrows and Attwood, *op. cit.*, p. 9, Fig. 13.
[9] P. J. Klass, "Discovery may triple uhf-vhf range," *Aviation Week*, vol. 65, p. 87; November 5, 1956.
[10] Burrows and Attwood, *op. cit.*, pp. 377–453.
[11] K. A. Norton, "The calculation of ground-wave field intensity over a finitely conducting spherical earth," PROC. IRE, vol. 29, pp. 623–639; December, 1941.

Contributors

Wesley P. Ayres (M'56) was born on September 26, 1924, at Los Angeles, Calif. He served as an electronic technician aboard a destroyer during World War II, returned to college in 1948, and received the B.S. degree in physics from Fresno State College in 1951. He then entered Stanford University where he received the M.S. degree in 1953 and the Ph.D. degree in 1954 in physics.

W. P. Ayres

In 1954, he joined the Electronic Defense Laboratory of Sylvania Electric Products, Inc., Mountain View, Calif., where he engaged in ferrite research at microwave frequencies. In 1956, Dr. Ayres joined the staff of the Microwave Engineering Laboratories, Inc., Palo Alto, Calif., where he is presently doing research on microwave components. Dr. Ayres is a member of RESA and the American Physical Society.

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Bruce F. Bogner (M'56) was born in New York, N. Y. on June 22, 1931. He received the B.E.E. degree from City College of New York in 1953 and is currently pursuing studies leading to a degree of Master of electrical engineering at the Polytechnic Institute of Brooklyn.

B. F. Bogner

In June, 1953, he joined Airborne Instruments Laboratory, Mineola, N.Y. and did work on stripline components before entering the armed forces in August, 1953. From 1953 to 1955, he was in the Signal Corps attached to the radar division at Evans Signal corps Laboratory, Fort Monmouth, N. J. While in the army, he did research and development work on antennas and made echo area measurements on missiles. In 1955, he returned to Airborne Instruments Laboratory and has been working on countermeasures systems and the development of strip transmission lines.

Mr. Bogner is a member of Eta Kappa Nu.

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Frederick E. Bond (M'47–SM'55) was born in Philadelphia, Pa, on January 10, 1920. He received the B.S. degree in electrical engineering from Drexel Institute of Technology in 1941. During World War II, he served with the U. S. Army Signal Corps in Europe where his assignments included research and development on British fire control radar for coastal artillery, and staff planning for the use of electronic countermeasures.

F. E. Bond

Since 1946 he has been with the Communications Department of the Signal Corps Engineering Laboratories engaged in research and development of ground radio and wire transmission equipments and communications systems engineering. At present he is Director of the Radio Communication Division.

He received the M.S. E.E. degree from Rutgers University in 1950, and the D.E.E. from Polytechnic Institute of Brooklyn in 1956.

Dr. Bond is a member of Sigma Xi, Tau Beta Pi, and Eta Kappa Nu. He is also a Major in the U. S. Army Reserve.

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Melvin L. Doelz (M'45–SM'54) was born in Minneapolis, Minn., on December 30, 1918. He received the B.S. degree in electrical engineering from the University of Minnesota in 1941 and the M.S. degree in physics from the State University of Iowa in 1946. In 1941 he joined the Collins Radio Company where he has been engaged in the development of binary signaling systems, voice multiplex equipment, mechanical filters, magnetostriction resonators, hf airborne communications equipment, and hf mobile equipment.

M. L. Doelz

In 1951 Mr. Doelz became director of the Burbank Research and Development Division of Collins Radio Company. He was promoted to resident manager of the Burbank plant in 1955 while retaining his capacity of director of engineering.

Mr. Doelz is a member of Eta Kappa Nu and Tau Beta Pi, and an associate member of Sigma Xi.

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For a photograph and biography of Bobby J. Duncan, see page 544 of the April, 1957 issue of Proceedings.

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Wolfgang W. Gärtner (M'54) was born in Vienna, Austria on July 5, 1929. He received the Ph.D. degree in physics from the University of Vienna and the Dipl.-Ing. degree from the Technische Hochschule, Vienna, in 1951 and 1955 respectively. He has been engaged in electron tube and semiconductor research with Siemens and Halske A.G. in Vienna, Austria and Munich, Germany. He became associated with the Signal Corps Engineering Laboratories, Fort Monmouth, N. J. in 1953.

W. W. Gärtner

Dr. Gärtner is the author of papers on semiconductor properties, transistor design, circuit theory, and ultrasonics. He is a member of the American Physical Society.

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Earl T. Heald was born in Tipton, Iowa, on March 29, 1919. He attended William Penn College in 1936, and the University or Iowa (extension study) in 1942. He joined Collins Radio Company in 1941 and served in the United States Navy during World War II.

E. T. Heald

In 1946, he assumed the responsibilities of development engineer with the special products department, Collins Radio Company, Burbank, Calif. In 1950 he became project engineer, Western Division, and was promoted to Head of Development Group B, Department II, Western Division, in 1952. He has developed data systems and predicted wave signaling systems.

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Donald L. Martin (S'50–A'52) was born in Terra Bella, Calif., on September 5, 1925. He received the B.S. degree in electrical engineering from Stanford University in 1950 and the M.S. degree from Stanford in 1951. He joined Collins Radio Company, Burbank, Calif., in 1951 as a research and development engineer in the Western Division. In 1955, he became assistant director of research and development, Western Division. He has since been engaged in the development of AFCRC

D. L. Martin

data system receiver, Signal Corps baud sync signaling system, TE-101 signaling system (Dewline), and Kineplex system.

Mr. Martin is a member of the AIEE.

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Jack L. Melchor (SM'56) was born on July 6, 1925, in Mooresville, N. C. He received the B.S. degree and the M.S. degree in physics from the University of North Carolina. His undergraduate studies were interrupted by military service in the U. S. Navy. In 1949 he worked as a civilian physicist with the U. S. Navy Mine Countermeasures Station.

J. L. Melchor

While attending the University of Notre Dame in 1950, he was a U. S. Rubber Co. Fellow in high polymer physics, In 1952 and 1953, he worked with the Missile Division of Bendix Aviation Corp. and received the Ph.D. degree from Notre Dame in 1953. In 1953, Dr. Melchor joined the Electronic Defense Laboratory of Sylvania Electric Products, Inc., Mountain View, Calif., where he was engaged in ferrite research at microwave frequencies.

In 1956, he left Sylvania to form Microwave Engineering Laboratories, Inc., Palo Alto, Calif. where he is president of the new organization, doing research and development in microwave components and systems. He is a member of Sigma Xi and RESA.

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For a photograph and biography of Harold F. Meyer, see page 1885 of the December, 1956 issue of Proceedings.

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For a photograph and biography of Leonard Swern, see page 546 of the April 1957 issue of Proceedings.

Jesse J. Taub (S'48–A'50–M'55) received the B.E.E. degree from City College of New York in 1948. After obtaining the M.E.E. degree from Polytechnic Institute of Brooklyn in 1949, he joined the microwave tube section of the Naval Material Laboratory as a project engineer. In 1951, he assumed the position of supervisor of the klystron and microwave semiconductor unit at the Naval Material Laboratory. In June, 1955, Mr. Taub joined the special systems and components department of Airborne Instruments Laboratory where he is presently engaged in the development of special microwave receiving and transmitting systems.

J. J. Taub

He is currently pursuing studies leading toward the D.E.E. degree at Polytechnic Institute of Brooklyn.

Mr. Taub is a member of Sigma Xi.

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Perry H. Vartanian (S'52–M'56–SM'56) was born in Rochester, N. Y. on June 14, 1931. He received the B.S. degree in electrical engineering in 1953 from the California Institute of Technology and the M.S. and Ph.D. degrees from Stanford University in 1954 and 1956.

P. H. Vartanian

At Stanford, he was a Tau Beta Pi Fellow and later a research assistant at the Electronics Research Laboratory. In 1951 and 1952, he worked part time at the U. S. Naval Radiological Defense Laboratory on radiation detectors.

In 1954, Dr. Vartanian joined the Electronic Defense Laboratory of Sylvania Electric Products, Inc., Mountain View, Calif., where as a senior project leader he is engaged in research in microwave applications of ferrites. Dr. Vartanian is a member of Tau Beta and RESA.

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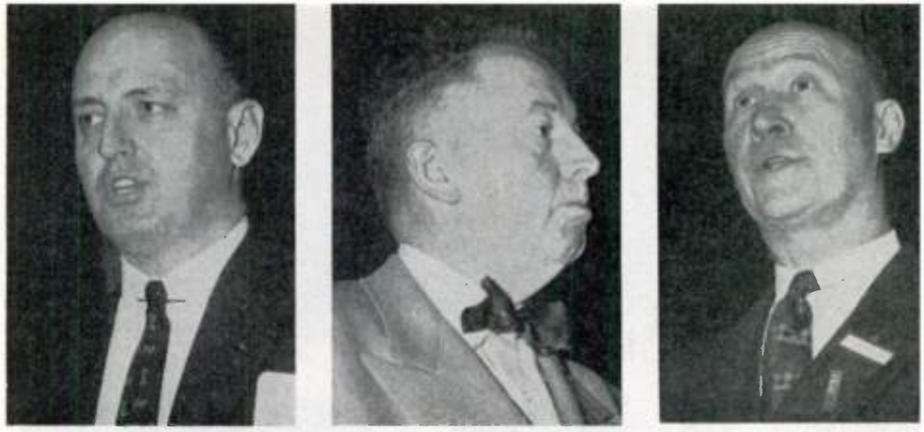
Laurens E. Whittemore (A'16–M'25–F'27) was born in Topeka, Kan. on August 20, 1892. He graduated from Washburn College in Topeka in 1914 and received the M.A. degree from the University of Kansas in 1915 where his major work was in physics. After three years of graduate study and teaching at the University of Kansas he went to Washington, D. C. where he was employed in the Radio Laboratory of the National Bureau of Standards from 1917 to 1923. In 1924 he was a member of the staff of the U. S. Department of Commerce and served as Secretary of the Interdepartment Radio Advisory Committee. He was Assistant Secretary or Secretary of the four annual National Radio Conferences called by the Secretary of Commerce, Herbert Hoover, 1922–1925.

L. E. Whittemore

From 1925 to date Mr. Whittemore has been a member of the headquarters staff of the American Telephone and Telegraph Company in New York where he has been concerned, among other things, with relations with Federal regulatory agencies. He has attended a number of International Radio and Communication Conferences either on behalf of the U. S. Government or the American Telephone and Telegraph Company. He was Secretary of the International Radio Conference at Washington in 1927.

Mr. Whittemore was Vice-President of the IRE in 1928 and was a member of the Board of Directors from 1926 to 1929 and from 1935 to 1937. He has held assignments on a number of IRE Committees, including the Standardization Committee of which he was Chairman from 1926 to 1929, and the Annual Review Committee of which he was Chairman from 1940 to 1949. He served on the Board of Editors from 1929 to 1953. He is also a member of the American Institute of Electrical Engineers and Sigma Xi.

THE 1957 IRE NATIONAL CONVENTION IN PICTURES



The Annual Meeting of IRE on opening day heard Editor D. G. Fink (*left*) speak on "Electronics and the IRE—1967" and saw outgoing President A. V. Loughren turn over the gavel of office to J. T. Henderson (*right*).

HIGHLIGHTS AND EVENTS

54,000 Attendance Shatters All Records

On March 18–21, New York City was the scene of the largest gathering of technical manpower and equipment ever witnessed anywhere, as the IRE held what was unquestionably the most successful national convention in its forty-five year history.

Although numbers do not alone spell success, they do give some idea of the tremendous mass-interchange of technical information that is made possible by the convention. This year 54,074 engineers had the opportunity to hear 284 technical papers and see some 17,000 of the latest products produced by 756 firms.

The record-breaking attendance, larger than any previous professional meeting of any kind, was 32 per cent ahead of last year's snow-laden 41,017. The previous high was 42,133 in 1955. New York's top-coat weather, a marked change from last year's 18-inch blizzard, was an important factor in the large turnout.

An even greater factor was the new and much-improved location of the Radio Engineering Show. The recently-opened Coliseum offered superior facilities, more exhibit space, a location convenient to midtown Manhattan and to the Waldorf-Astoria Hotel, and room for 22 of the 55 technical sessions.

The outstanding program of technical papers (see March issue) drew larger audiences than ever before, with the 5300-seat capacity of the eight session halls filled almost continuously during the four days. One session, on high fidelity, overflowed into another room which, appropriately, was equipped with loudspeakers of lesser, but adequate, fidelity.

Highlighting the program were two special symposiums on "Applications of Electronics to Air Traffic Control" and on "Microminiaturization—The Ultimate Technique," held Tuesday evening at the Waldorf-Astoria and the Coliseum, respectively.

All available papers will be published shortly in the *IRE National Convention Record* (see p. 563, April issue).

A picture record of the annual meeting, banquet and other convention highlights appears on these pages.

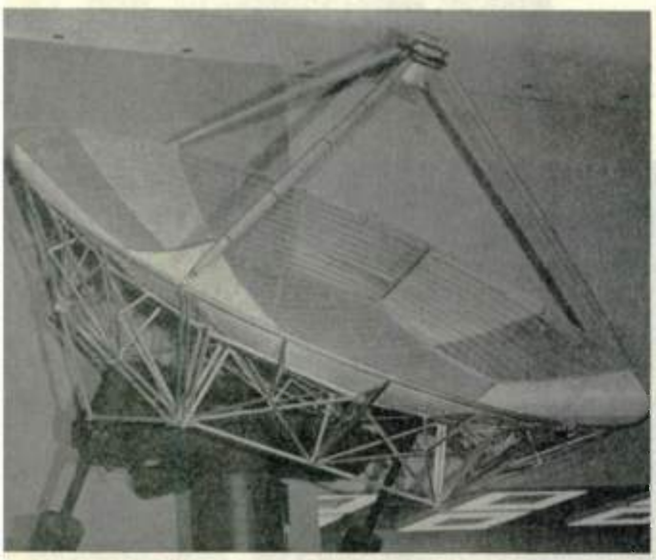
Left to right: R. A. Heising, winner of the Founders Award; J. T. Henderson, 1957 IRE President; and J. A. Stratton, winner of the Medal of Honor. Dr. Heising, a consulting engineer and patent agent, won his award "for his leadership in IRE affairs, for his contributions to the establishment of the permanent IRE Headquarters, and for originating the PG system." Dr. Stratton, Chancellor of M.I.T., won his award "for his inspiring leadership and outstanding contributions to the development of radio engineering as a teacher, physicist, engineer, author and administrator."

Above—1957 award winners were (*left to right*): D. A. Buck, Browder J. Thompson Memorial Prize; O. G. Villard, Jr., Morris Liebmann Memorial Prize; Georg Goubau, Harry Diamond Memorial Award; and Donald Richman, Vladimir K. Zworykin Television Prize. Below—W. R. G. Baker (*right*) congratulates the joint winners of the new W. R. G. Baker Award, R. J. Kircher, D. R. Fewer and R. L. Trent, authors of papers published in TRANSACTIONS on Audio.

A view of the annual banquet in the Grand Ballroom of the Waldorf-Astoria.

Above—Maj. Gen. J. D. O'Connell, Chief Signal Officer for the U. S. Army Signal Corps, was spokesman for the newly-elected Fellows. Below—J. A. Hannah (*left*), president of Michigan State University and principal banquet speaker, with C. F. Horne, banquet toastmaster.

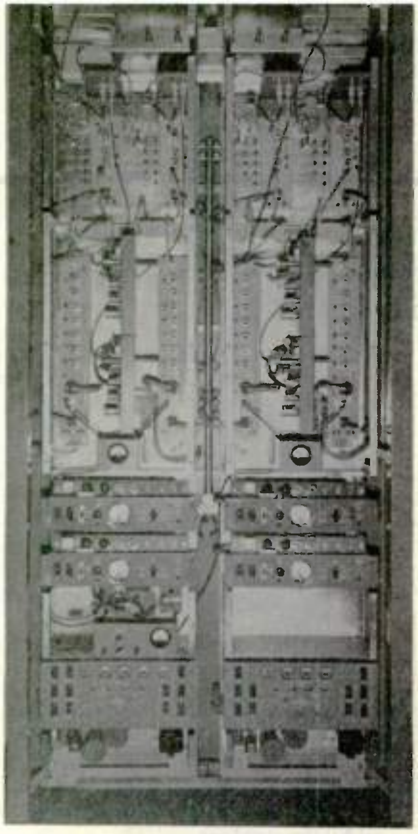
At the rostrum during the Annual Meeting were (*left to right*): past president A. V. Loughren IRE officers D. G. Fink, J. T. Henderson, Haraden Pratt and W. R. G. Baker; and Convention Chairman G. W. Bailey.



The largest item on display at the Coliseum was this 28-foot scatter propagation antenna.

Above—Opening day scene at a press conference at the Coliseum. Below—At the British exhibits during the show were (*left to right*): G. W. Bailey, Convention Chairman; Peter Garran, Minister for Commerce, British Embassy at Washington, D. C.; J. T. Henderson, 1957 IRE President; and J. S. Rooke British Consul-General for Commerce at New York City.

Below—Microminiaturized one- and four-stage transistor amplifiers, discussed at an evening session March 19.



Above—A receiver used in a broadband tropospheric over-the-horizon microwave system. The quadruple-diversity receiver consists of two dual-diversity receivers mounted together with a common air supply and a quadruple combiner. Receiver filters for separating the two incoming frequencies are mounted at the top of the bay.

Above left—The youngest exhibitor, six-year-old Ellen Shunaman, demonstrated a crystal radio set she built herself.
Above right—This machine mechanically inserts a variety of components onto printed wiring boards.

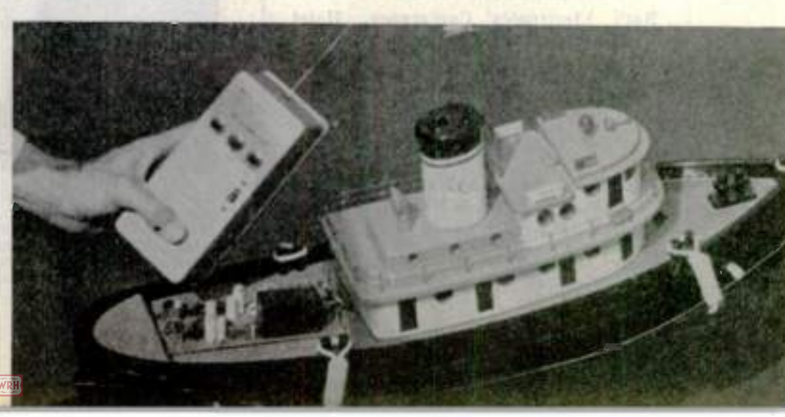
EXHIBITS AND EXHIBITORS

Above—Some of the 54,000 who saw the exhibits.

AT THE RECENT COLISEUM SHOW

Above—A photograph of the latest air-launched guided missile, Sparrow III, mounted under the wing of a U. S. Navy fighter plane, was shown for the first time at the show. Below—This miniature fully-transistorized radio-controlled tugboat was maneuvered from "ashore" by means of the transmitter shown at the left.

Below—In this air-conditioned, pressurized model of an actual factory girls demonstrated the making of receiving tubes.



IRE News and Radio Notes

Calendar of Coming Events

Electronic Components Conference, Morrison Hotel, Chicago, Ill., May 1–3

Symposium on Image Formation and Measurement with Electronic Techniques, Morse Audit, Boston Museum of Science, May 2

Annual Frequency Control Symposium, Hotel Berkeley-Carteret, Asbury Park, N. J., May 7–9

Symposium on Microwave Ferrites and Devices & Applications, Western Union Audit., New York City, May 9–10

Nat'l Aero. and Nav. Electronics Conference, Dayton, Ohio, May 13–15

Annual Semiconductor Symposium of the Electrochemical Society, Statler Hotel, New York City, May 13–16

ACM Annual Meeting, Masonic Temple, Detroit, Mich., May 22–24

IRE-URSI Spring Meeting, Hotel Willard, Wash., D. C., May 22–25

PGPT Annual Conference on Production Techniques, Willard Hotel, Washington, D. C., June 6–7

RETMA Symposium on Applied Reliability, Hotel Syracuse, Syracuse, N. Y., June 10–11

Digital Differential Analyzer Council Meeting, Hotel Statler, New York City, June 11

Nat'l Conf. of Elec. Engineers, Weizman Institute, Rehovot, Israel, June 16–17

PGMIL Nat'l Meeting, Sheraton-Park Hotel, Washington, D. C., June 17–19

ACM Nat'l Meeting, Univ. of Houston, Houston, Tex., June 19–21

Brit. IRE Convention, Univ. of Cambridge, Eng., June 27–July 1

International Symposium on Physical Problems of Color Television, Paris, France, July 2–6

Symp. on Automatic Control, San Francisco, Calif., Aug. 19

WESCON, Fairmont Hotel and Cow Palace, San Francisco, Calif., Aug. 20–23

URSI General Assembly, Boulder, Colo., Aug. 22–Sept. 5

Special Technical Conference on Magnetic Amplifiers, Penn Sheraton Hotel, Pittsburgh, Pa., Sept. 4–6

Industrial Electronics Symposium, Morrison Hotel, Chicago, Ill., Sept. 24–25

PGBTS Fall Symp., Willard Hotel, Wash., D. C., Sept. 27–28

Nat'l Electronics Conference, Hotel Sherman, Chicago, Ill., Oct. 7–9

IRE Canadian Convention, Exhibition Park, Toronto, Can., Oct. 16–18

Convention of The Institution of Radio Engineers, Sydney, Australia, Oct. 21–26

East Coast Aero. & Nav. Conf., Lord Baltimore Hotel & 7th Reg. Armory, Balt., Md., Oct. 28–30

1957 Transistor and Solid State Circuits Conference Held at Philadelphia

The 1957 Transistor and Solid State Circuits Conference was held in Philadelphia, Pennsylvania February 14–15, at the University of Pennsylvania under the sponsorship of the Philadelphia Section of the IRE, the Science and Electronics Technical Division of the AIEE, the IRE Professional Group on Circuit Theory, and the University of Pennsylvania. 1374 persons attended.

The conference program provided a total of 28 technical papers, four of which were of a tutorial nature, aimed at surveying recent advances in the subject and providing the practicing engineer in solid state circuitry with a broader picture of the state of the art.

The opening session of the conference offered an address by A. L. Samuel, this year's National Conference Chairman, followed by G. L. Haller, National Chairman of the 1956 Conference, who presented slide projecting equipment and a selection of books to the Moore School of the University. J. G. Brainerd formally accepted these presents on behalf of the university.

On the evening of the first day of the conference, a series of group discussions was held in conference rooms at the Bellevue-Stratford Hotel. J. A. Rajchman's extension of remarks concerning solid state devices, a subject which he covered in one of the tutorial sessions earlier that day, was especially noteworthy.

Although no conference proceedings will be issued, there are plans to publish many of the papers in the September issue of the TRANSACTIONS of the IRE Professional Group on Circuit Theory. An innovation of this conference was the distribution of a booklet containing reproductions of all slides, including mathematical expressions used by the speakers.

Left to right—G. L. Haller, 1956 Conference Chairman; A. L. Samuel, 1957 Conference Chairman; and J. G. Brainerd, Head of the Moore School of Engineering and IRE Director, at the opening conference session.

The National Committee of the 1957 Transistor and Solid State Circuits Conference included (*left to right, seated*): G. H. Kunstadt, Publicity; M. S. Corrington, IRE Philadelphia Section Chairman; A. L. Samuel, National Committee Chairman; J. C. Logue, National Committee Secretary. *Left to right, standing:* W. J. Popowsky, National Committee Treasurer; G. H. Royer, Program; G. L. Haller, Past National Committee Chairman; N. A. Koss, Chairman of the Science and Electronics Technical Division of the AIEE Philadelphia Section; and J. G. Leisenring, Local Arrangements.

THIRD NATIONAL SYMPOSIUM ON RELIABILITY AND QUALITY CONTROL IN ELECTRONICS

The Third National Symposium on Reliability and Quality Control in Electronics was held at the Hotel Statler, Washington, D. C., January 14–16. Twelve hundred people attended the symposium which featured thirty technical papers, three panel sessions, and six tours. A thousand people listened to D. E. Noble, Vice-President of Engineering Defense Products, Motorola, Inc., who delivered an address at the banquet, and J. M. Bridges (*right*), of the Office of the Assistant Secretary of Defense, who gave the keynote address.

Committee chairmen responsible for the success of the symposium were (*above, left to right*): *Seated*—C. M. Ryerson, Program; M. M. Tall, General Chairman; Mrs. R. Murrell, Registration Co-Chairman; I. Schoeninger, Facilities; J. W. Greer, General Co-Chairman. *Standing*—the late M. E. King, Finance; R. M. Jacobs, Publicity; R. Murrell, Registration; J. Culbertson, Facilities Co-Chairman; and P. K. McElroy, TRANSACTIONS.

Foreign guests at the symposium are shown in the photograph below. From left to right they are: *Front row*—Karl-Otto Omhagen, Arne Almesaker, and Major C. G. Regardh, all of the Royal Swedish Air Force. *Back Row*—V. Turello of Italy; Hans Prussog, IBM, Stuttgart, Germany; Neville Boothroyd, IBM, London, England; and L. Kmigh, British Tabulating Machine Co., London, England. A contingent from Canadian armed forces and commercial companies also attended the symposium.

The Executive Board of the symposium is shown in the photograph at bottom of the page. From l. to r. they are: L. Jacobson, Ch. of the Qualifications Acceptance Com. of RETMA; M. M. Tall, General Ch. of the symposium; R. Harris, Ch. of the Reliability and Quality Control Com. of AIEE; A. Mundel, Ch. of the Electronics Division of the American Society for Quality Control; and V. Wouk, Ch. of the IRE Professional Group on Reliability and Quality Control.

Non-PGRQC members should order copies from IRE Hdqts. at $5.00 per copy.

ACTIVITIES OF IRE SECTIONS AND PROFESSIONAL GROUPS

J. L. Barnes (*left*), chairman of the recent Western Joint Computer Conference, examines a computer component as A. L. Samuel (*center*), research advisor to IBM, and J. M. Bridges, Director of Electronics at the Office of the Assistant Secretary of Defense, look on. Highlight of the conference was a session devoted to discussion of the TX-2 transistorized computer system

Keith Kinsey (*left*), speaker at the February meeting of the San Fernando Valley Subsection, explains target drones to Subsection Chairman J. C. Van Groos.

H. L. Richardson, a Sylvania vice president (*left*), talks over engineering management problems with L. G. Clarke, president of the San Francisco Chapter of PGEM. Mr. Richardson was the speaker before a recent joint PGEM-San Francisco Section dinner meeting. This was only one in a series of meetings in which electronics firms' engineering management problems were discussed.

At the annual banquet of the IRE Washington, D. C. Section, six Fellow awards were presented by J. T. Henderson, 1957 IRE President, and five distinguished service citations were awarded by Section Chairman R. I. Cole to Section members. J. M. Bridges of the Office of the Secretary of Defense made the student awards. Shown left to right are: J. M. Bridges; Donald Carruth, Univ. of Maryland; E. E. Reber, Geo. Washington Univ.; J. T. Henderson; J. R. Manning, Geo. Washington Univ.; J. A. Reyes, Univ. of Maryland; and R. I. Cole. Among the four hundred present were also IRE national officers A. V. Loughren, J. G. Brainerd, and G. W Bailey.

IRE Members Invited to Aid FCC in Interference Program

The IRE has been asked by the Joint Technical Advisory Committee to assist the Federal Communications Commission in organizing local Cooperative Interference Committees (CIC) throughout the United States to help the FCC in the huge task of investigating and eliminating sources of radio communication interference.

Under the CIC Plan, which is already operating with conspicuous success in a few localities, individuals in a given area who have a common interest in radio communication services—manufacturers, engineers, service organizations and users—are encouraged to form a self-governing committee to consider and resolve interference problems with which the members are mutually concerned. Each CIC is an autonomous organization whose sphere of operation is determined entirely by the wishes of the participating members.

The IRE has distributed full details of the CIC Plan to the Chairman of each IRE Section. IRE members who are interested in participating in this important work are urged to contact their Section Chairmen. Their names and addresses appear on page 713 of this issue.

May MARS Schedule Released

The Air Force MARS Eastern Technical Net which broadcasts over the air every Sunday afternoon from 2:00 until 4:00 p.m. (EST) on 7635 or 7540 kc announces the following guest speakers for the month of May:

May 5—Raymond Chapman, Chief Airborne Equipment Engineer, General Precision Laboratories. Topic: Doppler applications for aircraft.

May 12—C. J. Hirsch, Chief Engineer, Research Div., Hazeltine Corp. Topic: color TV.

May 19—J. N. Dyer, Vice-Pres., Airborne Instruments Laboratory. Topic: antenna theory.

May 26—J. V. Bernardo, Aviation Development Advisor, N.E. Regional HQ, C.A.A. Topic: electronics in air traffic control.

News of interest to all members of the IRE residing in states east of the Mississippi River is broadcast on the Eastern Technical Net each Sunday at 3:30 p.m.

IRE Adds Another Subsection

The IRE Executive Committee, at its meeting of March 5, approved the formation of the Kitchener-Waterloo Subsection of the Hamilton Section.

IRE Adds New PG Chapters

The following Professional Group Chapters were approved by the IRE Executive Committee at its meeting March 5: PG on Circuit Theory, San Antonio Section; and PG on Antennas & Propagation, Boston Section.

The following Professional Group Chapters were approved by the Executive Committee on April 10: PG on Microwave Theory & Techniques and PG on Broadcast Transmission Systems, Washington, D. C., Section; PG on Communications Systems, Hawaii Section.

Program and Speakers of First PGPT National Meeting Set for June 6–7 at Capitol

The first National Symposium on Production Techniques, sponsored by the Washington Chapter of the IRE Professional Group on Production Techniques, will be held at the Hotel Willard, Washington, D. C., June 6–7. Registration at the door will start at 8 A.M., June 6. Advance registration is $3.00; registration at the door is $4.00.

The first session, scheduled for 9:30 A.M.–12:00 P.M., will contain talks by D. D. Israel, Emerson Radio & Phonograph Corp.; Mel Parkes, Admiral Corp.; J. A. Cadwallader, G. E. Co.; A. H. Postle, Sprague Electric; Edgar Weinberg, Bureau of Labor Statistics, Dept. of Labor; R. W. Daniels, United Shoe Co.; and Jacob Rabinow, Rabinow Engineering Co., on how management prepares for and implements automation. Mr. Israel will preside.

Annual awards going to IRE-PGPT members for outstanding contributions to the field of production techniques will be a feature of the luncheon on June 6.

E. R. Gamson, North American Aviation, will be chairman of the Thursday afternoon session, which runs from 2:00 to 5:00 P.M. Production design and production engineers will present papers on automation techniques covering experiences, approaches materials handling, bottle-necks, automatic testing and quality control.

The session scheduled from 9:00 A.M. to noontime June 7 will be headed by J. M. Bridges, Director of Electronics, Office of the Assistant Secretary of Defense. Speakers will be J. M. Bridges; Capt. W. I. Bull, Assistant Chief of Bureau of Ships for Electronics, Department of the Navy; A. W. Rogers, Director, Electronic Parts & Materiel Division of Signal Corps; D. E. Noble, Motorola, Inc.; William Schneider, Stavid Engineering; and William Bainbridge, Aerovox Corp. They will discuss military problems in implementing automation.

A. A. Lawson is general chairman of the symposium. Helping him are: J. M. Lee, vice-chairman; S. Levine, technical program; J. P. Nigro, local arrangements, exhibits and finance; H. S. Wolf, publicity and publications; and P. Zukauska. The steering committee consists of R. E. Bauer, J. W. Brush, R. L. Henry, F. Israel, A. A. Lawson, J. H. Lee, S. Levine, J. P. Nigro, G. Shapiro, Mrs. H. S. Wolf and R. I. Cole. The advisory board consists of R. R. Batcher, J. M. Bridges, L. M. Clement, R. I. Cole, A. R. Gray, and R. L. Henry.

It is hoped that papers presented at this symposium will later be made available in Transactions. Specific information can be obtained from each speaker.

Books

Basic Electrical Engineering, 2nd ed. by A. E. Fitzgerald and D. E. Higginbotham

Published (1956) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 523 pages+3 appendix pages+11 index pages+xi pages. Illus. 9¼×6¼. $6.50.

Those who know the first edition of this book will be well pleased with the current edition. The new edition contains revisions, reorganization, and additions which are the result of technical progress and the experience of the authors and others in the use of the earlier edition of the book.

This second edition is an extremely well organized complete modern text and basic reference work recognizing the scientific, analytical, and physical basis of modern electrical engineering. Particular emphasis has been placed on electronics, measurements, and control in addition to adequate coverage of the machinery and power fields.

The introductory chapters cover electrical circuits, magnetic circuits, machinery, and electronics. Feedback control theory is introduced in the chapters on circuit theory, machinery, and electronics so that the student is familiar with this concept when the chapter on feedback control is reached. The revised edition now includes such subjects as magnetic amplifiers, transistors, self-balancing recorders and controllers, phase sensitive modulators and demodulators, control amplifiers, dc and ac control motors, and transfer-function and frequency-control analysis.

This text has been written primarily for the undergraduate and provides a thorough ly up-to-date treatment of the field of basic electrical engineering. However it also is an excellent source of reference and refresher material for the electrical or electronic engineer who by specialization or for some other reason may have lost contact with the subjects covered by the text. Careful selection of examples at the end of each section has contributed to this edition's understandability. A number of well chosen problems are given at the end of each chapter.

The second edition is an outstanding contribution to the material available for training future engineers.

J. L. Heins
Garden City, N. Y.

Statistical Analysis of Stationary Times Series by Ulf Grenander and Murray Rosenblatt

Published (1957) by John Wiley & Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. 287 pages +6 appendix pages +5 pages of bibliography +2 index pages. 9¼ × 6¼. $11.00.

It is encouraging to note the growing trend toward unification of the several approaches to the problems which engineers classify under "noise," the statisticians call "time series," and the mathematicians define as "stochastic processes." Convergence of these various points of view should lead to a greatly improved understanding of many natural phenomena. Communication between investigators in the different schools of thought has been hampered by lack of a common language. Different motivations have also obstructed mutual interchange of ideas and results. The mathematician pursued abstract ideas and was content to prove theorems from hypotheses without regard to physical meaning. The statistician lived in a world of his own constructed of parametric models about which he computed confidence intervals. The engineer relied on his measuring equipment and his mastery of the laboratory environment to make his work meaningful.

Now it is becoming apparent that the three schools are working in a common field and each could benefit from the discoveries and techniques of the others. Unfortunately the engineer is likely to be frustrated in his attempts to understand what the mathematicians and statisticians have to say about his problem because of the unfamiliar concepts upon which their arguments are based. Whether the representatives of the other fields have found the engineering literature equally opaque is not certain, but there is evidence that in spite of semantic difficulties the basic engineering concepts have begun to diffuse through the mathematical and statistical fields.

This preamble introduces a book which should advance the general understanding of what is now known about noise from the three different points of view. It is not a royal road to knowledge and in fact it is tough going most of the way. But the development is honest and there are adequate references given to what is not included. As a reward for effort, many of the now classical formulations of basic noise problems are interspersed in remarkably neat and concise form. The economy of presentation is deceptive for it depends on an essential framework of advanced mathematical thinking. It appears likely that once the principles are mastered, one could go on to solve new and more difficult problems, but this cannot be guaranteed. The best reward would probably come to one willing to go through the material for its own sake.

Specifically the book deals almost entirely with "weakly stationary processes," that is, ensembles in which first and second order statistics, including, for example, first and second moments, spectral density, and covariance, do not change with time. Emphasis is placed on the spectral density as a basic analytical tool and respects are paid to the physical sciences which have been pioneers in the exploitation of the spectral method. To the statisticians, spectral density represents an example of a non-parametric model. There is only one chapter of the book dealing with parametric models. One favorite type would be described by the engineer as consisting of oscillators, tapped delay lines, and feedback connections. With a sufficiently complicated arrangement one should be able to fit almost data. Physical reality of the model is not a necessary adjunct. It is amusing to read that in former times some statisticians ran their data through what the engineer would call transversal filters in order to remove random fluctuations and expose the hidden periodicities. A damper was put on this practice by Slutzky's theorem, which when translated into engineering terms, warns the unwary that transmission of noise through a long chain of identically tuned resonant circuits produces an output with spectral density function approaching that for a sine wave at the resonant frequency. No doubt parallel cases could be found where engineers have been equally obtuse about situations which would be clear to statisticians.

The book includes chapters about what can be done if the spectrum is known, how to estimate the spectrum from a finite number of observations, and how to find distribution functions for spectral estimates. Applications are given to electrical noise, turbulence, optics, and ocean waves. Sundry other topics touched upon include detection of signals in noise, confidence intervals and tests, zeros and maxima, prefiltering, tests of normality, and various species of prediction. In short, the book appears to be a gold mine for the reader who is not afraid to dig below the surface.

W. R. Bennett
Bell Tel. Labs., Inc.
Murray Hill, N. J.

Advances in Electronics and Electron Physics, Vol. VIII, ed. by L. Marton

Published (1956) by Academic Press, Inc., 111 Fifth Ave., N. Y. 3, N. Y. 539 pages +22 index pages +xi pages. Illus. 9¼ × 6¼. $13.00.

This volume contains reviews of the following subjects: new applications and techniques of molecular beams; field emission; mass spectroscopy; amplitude and time measurement in nuclear physics; pulse amplitude analysis; electron guns and focusing in high-density electron beams; the electrical life of an oxide-cathode receiving tube; storage tubes; magnetron mode transitions.

"Some New Applications and Techniques of Molecular Beams," by V. G. King and J. R. Zacharias starts with a brief review of the applications of molecular beams to masers, frequency standards, and the measurement of magnetic fields, acceleration, and length standards. The rest of the article consists of descriptions of more or less conventional molecular-beam components with suggestions for future development, with the purpose of assisting new users of molecular beams. Under a description of sources and associated equipment are considered gas sources, source slits, canals, gas-flow control, ovens, ion sources, and recirculating sources. Types of detectors received are Pirani gauges, deposition and ionizing detectors, mass spectrometers, and equipment for measuring small currents. This is followed by some practical notes on the design of deflecting and uniform magnetic fields, and radio-frequency equipment.

"Field Emission," by W. P. Dyke and W. W. Dolan is an able historical summary of field emission theory and observation, with special attention to the crystal structure of the emitter. The recent work at Linfield College is described, with emphasis on pulsed emission microscopy and the practical applications of field emission as a pulsed source. The description of the effects on cathode stability of helium diffusion through the glass envelope is especially interesting, as is also a critical review of the evidence supporting the view that some of the peculiar dynamic phenomena seen in a field emission microscope in the presence of contaminants are actually due to single molecule adsorbed on the emitting surface.

The work of Dyke and his colleagues has gone a long way towards the achievement of stable practical field emission sources, and the concluding description of their techniques will interest new people in this field.

"Mass Spectroscopy," by L. Kerwin, Laval University, covers the high points of this rapidly developing field since 1947. It includes sources, analyzers, detecting and recording systems, data processing, and descriptions of individual instruments, including first- and second-order, single and double focusing, high-order double focusing, pulsed, time-of-flight, single and double focusing, and radio frequency time-of-flight, single and double focusing. Applications are treated only lightly, since the field is so large. Recent significant work in isotope existence and abundance, atomic masses, nuclear studies, chemical analysis, and ionization and dissociation phenomena is reviewed.

"Amplitude and Time Measurement in Nuclear Physics," by E. Baldinger and W. Franzen, is an exposition of their own circuit design methods in these two fields. The concept of "ballistic deficit" is employed in amplitude measurement, this being defined as the difference between the voltage amplitude resulting from a current pulse of finite duration and the amplitude resulting from an infinitely short current pulse carrying the same total charge. Input, amplifier, and output circuits are then designed to minimize this quantity. The section on time measurement discusses the problem of coincidence, and the effect of time dispersion on the information from the ionizing particle before it reaches the coincidence stage.

"Pulse Amplitude Analysis," by J. L. W. Churchill and S. C. Curran is a review of gas, liquid, and solid counters in which the energy of the primary particle is measured, so that the devices act both as detectors and spectrometers. Subjects discussed are proportional counters, scintillation spectrometers, voltage discrimination, voltage-to-length conversion analysis, voltage-to-time conversion analysis, and alternative methods of data presentation in amplitude-to-time conversion analyzers.

"Electron Guns and Focusing for High-Density Electron Beams," by C. Susskind is a critical review of present gun design, including the Pierce, Heil and Muller guns, with a discussion of focusing methods, such as the immersed gun, the shielded gun, and periodic focusing. New cathode materials are treated briefly.

"On the Electrical Life of an Oxide-Cathode Receiving Tube," by G. H. Metson is a review of the important work done by the thermionics group of the English Post Office, and should be read by every tube engineer. Microchemical actions in the oxide cathode, including those that support emission as well as those that lead to emission failure, are extensively discussed. Other causes of failure, such as growth of conducting films, heater-cathode insulation failure, residual gas, etc., are reviewed.

"Viewing Storage Tubes," by M. Knall and B. Kazan is a competent review of the various types and modes of operation of these complex tubes.

"Magnetron Mode Transitions," by E. C. Okress is the latest addition to the already extensive literature dealing with the shortcomings of magnetrons.

Each of the above reviews includes an extensive bibliography. Altogether, like the preceding volumes of this series, the book should be a valuable addition to the library of any engineer or physicist who has anything to do with electron or particle physics.

C. W. Carnahan
Varian Associates
Palo Alto, Calif.

Circuit Theory and Design by J. L. Stewart

Published (1956) by John Wiley & Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. 467 pages+6 index pages+7 pages of bibliography+xiv pages. Illus. 9¼×6¼. $9.50.

The central theme of this stimulating and imaginative book is the presentation of circuit theory and design from a pictorial point of view. This approach emphasizes the natural modes and infinite loss points of a system. Although the singularities associated with a network have long been recognized as basic properties, the author deserved special credit for being among the first to write an entire book around this important concept.

For purposes of review the fourteen chapters of this text can be divided into four main sections having relative emphasis as follows: 24 per cent elementary circuit theory, 21 per cent modern synthesis, 12 per cent image parameter design, and 43 per cent active circuits.

The section on elementary circuit theory includes steady state circuit analysis, determinants, poles and zeros, and simple transient analysis. The portion devoted to modern synthesis covers single and double energy storage systems, frequency and impedance normalizations, transformations with frequency, the approximation problem, and Darlington realization. The presentation of image parameter design follows the conventional pattern. The largest section of the book is concerned with active circuits and treats vacuum tube equivalent circuits, low pass and band pass amplifiers, feedback amplifiers, oscillators, and servo mechanisms.

The extensive collection of over four hundred problems, which are well distributed throughout the book, should certainly enhance the value of the material for teaching purposes.

The choice of references, which average about three per chapter, seem to be somewhat inadequate and probably reflect the author's disarming statement in the preface that: "Much of the work here is a result of personal effort and as such may show ignorance of what may have been done by others at an earlier date."

The author has "tried to organize the subject matter so that the book can be used at either the graduate or undergraduate level." In view of the rather imprecise and colloquial treatment of an exact subject it is doubtful whether this book could be used at the undergraduate level without danger of introducing considerable confusion. On the other hand, for graduate students or practicing engineers who already have a good foundation, the book should provide better pictorial insight into many important problems.

Certainly one of the strong points of the book is the lively and enthusiastic style in which the author seems to say, "Here's a new and interesting way of looking at this problem."

No doubt many readers will believe that the book attempts to cover too large an area. Others may be disappointed at the omission of some of the following topics: flow graphs, trees, conformal mapping, scattering matrices, etc.

A particularly unfortunate omission in Chapter Five is that no mention is made of the use of Bessel polynomials for the approximation of maximally flat delay functions.

The definition of unstable network as given on Page 32 is subject to criticism, and the use of the term "brick wall" to describe a phase function which is linear with frequency might easily confuse the student.

An example of the lack of care which detracts from the merits of the book is an amusing misprint in the preface. The author states, "I have not *flaunted* standard notation; rather, I have avoided it." Without judging the logic of this statement, it appears that the intended word was *flouted*.

To solve synthesis problems the author frequently used the technique of equating coefficients in equivalent expressions. This should be accompanied by a warning to the student that the method is adequate only for relatively simple cases such as are used for illustration.

In view of the rather broad coverage and novel point of view it is likely that most communication engineers will find certain sections in this book of special interest and value.

J. T. Bangert
Bell Telephone Labs.
Murray Hill, N. J.

Scientific Uses of Earth Satellites, ed. by J. A. Van Allen

Published (1956) by University of Michigan Press, Ann Arbor, Michigan. 316 pages+x pages. Illus. 10¼×7¼. $10.00.

In January, 1956, a group of scientists gathered at the University of Michigan and presented a series of papers which gave the best thinking at that time of the various experiments that might be carried out in the proposed earth satellite. This group, through probing the upper atmosphere with sounding rockets, had for some years been making forward strides in the field of geophysics. Most of the speakers contributed manuscripts, and those have been collected and are here published in one volume.

This book will make informative reading for those who are interested in knowing the objectives of this part of the IGY effort and how it may contribute to our knowledge of geophysics in the broader sense.

The editor does not attempt here to evaluate the many proposed experiments; so the reader must not look for a suggestion as to what will be attempted, but rather as to what might be. He will doubtless become impressed with the immensity of the problem and with the amount of information that already has been gathered, and convinced that to understand better this new world in which we live it is imperative to pursue these investigations.

There are papers on the shape of the orbit of a close earth satellite and what can be learned from observing how such an orbit changes in time. The problem of optically tracking a small, rapidly moving object in the sky is discussed, but a full treatment of the possibilities of radio tracking is not given. The instrumented experiments described cover such fields as solar radiation, both ultraviolet and corpuscular; meteorology and the heat balance of the atmosphere; the atmosphere itself, its density and temperature; magnetic fields high in theat mosphere and the possible associated Störmer "ring" current; the ionosphere and aurorae; the density of hydrogen in space; the changed appearance of the heavens when the full ultraviolet radiation, now largely absorbed by the atmosphere, is seen; and then a group of experiments designed to measure the physical conditions within the satellite in this strange new environment.

There are thirty-three papers in all, and many more experiments are proposed than can possibly be accommodated in the satellite program announced for the IGY. A Technical Panel of the U. S. National Committee for the IGY, charged with the responsibility of choosing the few experiments that can be performed, started with the material found in this book and has now chosen a preferred list of experiments to be prepared for flight.

J. P. Hagen
Naval Research Laboratory
Washington 25, D. C.

Further Comments on Review of "Reliability Factors for Ground Electronic Equipment"

In the book review section of the February Proceedings of the IRE, Keith Henney comments[1] on my review of the book, "Reliability Factors for Ground Electronic Equipment," which he edited. I am sorry that it was not possible to have Mr. Henney's reply published side-by-side with the review; this would have permitted easier comparison of the opposing views. For my part, I shall be satisfied to let the readers study each case—referring, where necessary, to the book itself and to the other sources discussed—and arrive at their own decision.

If it were true that I was seeking to "vaunt my knowledge," as Mr. Henney suggests, then certainly chastisement would be in order. The fact is, however, that, after devoting the last six years of my life to the full-time study of reliability, I am keenly conscious of how little I know about it. Prior to these six years, I spent eleven years in the

[1] "Comment on Review of 'Reliability Factors for Ground Electronic Equipment,'" Keith Henney, Proc. IRE, vol. 45, pp. 251–252; February, 1957.

tube industry and there, also, I became deeply impressed by the need for further knowledge.

I am keenly interested in reliability and its vital implications to our national defense. This concern, rather than any desire to display such knowledge as I may have, was the motivating factor in my remarks. Since the book under discussion bears directly on the reliability problem and national defense, it is not an ordinary book, but one which, in my opinion, can have far-reaching effects on our military establishment. Because of this belief, I felt that I had no choice but to point out what appeared to me erroneous or misleading. In speaking emphatically on the issues, I had no desire or intention of doing injustice to Mr. Henney or his publisher. I regret any words which may have seemed caustic—they were intended only to be forceful.

Of the nine examples given in the review, only two, I believe, require further discussion. These are concerned with the mathematical approach to reliability, and ionic grid currents in vacuum tubes.

(1) *Mathematical Approach to Reliability*
The original review stated:
"The author fails to distinguish between the 'population' and the 'sample,' defining probability relations and concepts only in terms of the sample. This is dangerous, for it infers to the uninitiated that one failure in two observations has precisely the same meaning as ten failures in twenty observations."

This statement, as I read it now, is easily misinterpreted and does not unambiguously convey my original intent. For this, I apologize to Mr. Miles. My objection was that reliability was defined in terms of the sample and not in terms of a true probability. Defining reliability in terms of the sample tends to obscure the necessity for computing the effects of sample size on the result. But defining it in terms of probabilities forces attention to the sample size and encourages recognition of the fact that the *sample results are only an estimate of the probability.* The difference between these viewpoints may seem esoteric, but I sincerely believe that a clear understanding of this distinction is of fundamental importance to sound progress in reliability. Mr. Miles did include statements on the importance of sample size, but the nature of his definition seems to preclude consideration of this important factor in the mathematical approach to reliability.

(2) *Ionic Grid Currents in Vacuum Tubes*
The original review stated:
"Figure 8-20 shows ionic grid current increasing to a maximum and then decreasing as plate current in the electron tube is increased. That ionic grid current is directly proportional to plate current has been an established fact of physical electronics for many decades."

In the interests of brevity, the review did not mention several other points of variance between Figure 8-20 and other published information on grid currents. Those readers interested in resolving this issue in their minds may wish to refer to:

(1) *Fundamentals of Engineering Electronics*, William G. Dow; p. 177, fig. 6.4.
(2) IRE Standards on Electron Tubes; p. 931, fig. 27.

A study of the references and some reflection on the probable voltage scale of the figure should help to clarify my criticisms. Also, since the figure represents "high vacuum" tube characteristics, I believe it is reasonable to disregard plasma effects.

C. R. KNIGHT
Aeronautical Radio, Inc.
Washington, D. C.

CORRECTION

In the February, 1957 issue on page 252 of the PROCEEDINGS OF THE IRE, there was a review of the book, "Handbook of Basic Circuits" by Matthew Mandl, published by The Macmillan Co., 60 Fifth Ave., N. Y. 11, N. Y. It was erroneously stated that the book had 110 pages of text. Actually, there are 309 pages of text.

RECENT BOOKS

Czech, J., *The Cathode Ray Oscilloscope*, Interscience Pub., 250 Fifth Ave., N. Y. 1, N. Y. $8.50.

Electronic Computers, ed. by T. E. Ivall. Philosophical Library, Inc., 15 E. 40 St., N. Y. 16, N. Y. $10.00.

Martin, T. L., Jr., *Physical Basis for Electrical Engineering*. Prentice-Hall, Inc., 70 Fifth Ave., N. Y. 11, N. Y. $10.00.

Most-Often-Needed 1957 Radio Diagrams and Servicing Information, Vol. 17. Compiled by M. N. Beitman. Supreme Publications, 1760 Balsam Road, Highland Park, Ill. $2.50.

Proceedings of the Symposium for Management on the Industrial Applications of Analog Computers. Midwest Research Institute, 425 Volker Blvd., Kansas City 10, Mo. $5.00.

Solid State Physics, Volume Three—Advances in Research and Applications, ed. by Frederick Seitz and David Turnbull. Academic Press, Inc., 111 Fifth Ave., N. Y. 3, N. Y. $12.00.

Stibitz, G. R. and Larrivee, J. A., *Mathematics and Computers*. McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. $5.00.

The Radio Amateur's Handbook, 34th ed., 1957. American Radio Relay League, West Hartford 7, Conn. $3.50 in the United States; $4.00, U. S. Possessions; $4.50, elsewhere.

Tubes for Computers. Elsevier Press Inc., 2330 Holcombe Blvd., Houston 25, Tex. $1.50.

Tube Selection Guide 1956–1957. Compiled by T. J. Kroes. Elsevier Press Inc., 2330 Holcombe Blvd., Houston 25, Tex. $1.50.

Tuska, C. D., *Patent Notes for Engineers*, 7th ed. McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. $4.00.

UHF Tubes for Communication and Measuring Equipment. Elsevier Press Inc., 2330 Holcombe Blvd., Houston 25, Tex. $1.50.

Wayland, Harold, *Differential Equations Applied in Science and Engineering*. D. Van Nostrand Co., Inc., 257 Fourth Ave., N. Y. 10, N. Y. $7.50.

First National Convention on Military Electronics

SHERATON PARK HOTEL, WASHINGTON, D. C., JUNE 17–19, 1957

SPONSORED BY THE IRE PROFESSIONAL GROUP ON MILITARY ELECTRONICS

The theme of the first National Convention on Military Electronics will be "Missiles and Electronics." With a large attendance expected, advance registration fees will be $1.00 for IRE members, $3.00 for non-IRE members; registration at the convention will be $2.00 for IRE members, $4.00 for non-IRE members.

Convention committee chairmen are: L. D. Whitelock, Exhibits; J. W. Klotz, Arrangements and Registration; R. E. Frazier, Technical Program; Henry Randall, Finance and George Rappaport, Public Relations.

MONDAY, JUNE 17
2—5 P.M.

Design goals for future missile system electronics

Invited papers to be announced.

Instrumentation and telemetry

Automatic Tracking Digitherodolite, A. B. White, W. I. Frank and E. Jamgochian, Electronic Corp. of America.

Visual Surveillance System, J. F. Clevenger, Glenn L. Martin Co.

Recovering Experimental Missile Data, M. W. DeMerit, Jr., General Electric Company.

Telemetering Equipments Utilizing Transistor-Magnetic Circuitry and High-Density Packaging, W. D. Murray and R. M. Tillman, Burroughs Corp.

Rugged, Wide-Band Magnetic Tape Recorder, J. D. Rosenberg, Diamond Ordnance Fuze Lab.

Optical and Electromagnetic Range Instrumentation, E. Kullman, Rome Air Development Center.

Mechanical design for reliability

A Working Procedure for Evaluating the Thermal Effects on Airborne Equipment Reliability, T. C. Reeves, RCA.

Approximation of Heat Transfer Within a Closed System, R. J. Spotz, G. E. Co.

Evaporative-Gravity Cooling for Electronic Equipment, M. Mark, Mark Stephenson, Costas Goltsos, Raytheon Mfg. Co.

Investigation of Temperature Distribution and Thermal Stresses in a Supersonic Radome, R. D. Sutherland, Convair.

Electronic Packaging in the Terrier Missile, H. Chrystie, Convair.

Electronics Packaging for a Tactical Guided Missile Weapons System, M. G. Comuntzis and G. F. Ervin, Jet Propulsion Lab.

Circuitry and subsystems I

Keyed Local Oscillator as Microwave Receiver Range Gate, Harry Beazell, Bendix.

The Ultrasonic Light Modulator, Adolph Rosenthal, Fairchild Corp.

High Frequency Transistor Circuit Design, A. E. Hayes, Jr., General Mills, Inc.

Interval Timing with Transistor Switching Elements, J. W. Higginbotham, Glenn L. Martin Co.

Signal Enhanced Delay Line, T. I. Humphreys, Packard-Bell Co.

A Stable and Reliable Direct Current Transistor Amplifier for Missile Applications, A. R. DeRuyck, Bendix.

TUESDAY, JUNE 18

9 A.M.—NOON

Precision ranging and tracking I (Confidential)

The Effect of Automatic Gain Control on Radar Tracking Performance, D. D. Howard, U. S. Naval Research Lab.

Short Pulse Radar, C. D. Hardin and J. Salerno, Diamond Ordnance Fuze Lab.

A High Accuracy Ground to Ground Optical Radar, J. G. Lawton and R. F. Schneeberger, Cornell Aeronautical Lab., Inc.

Delay Stabilized Transponder, G. Rabow and A. Nashman, Fed. Telecommunication Labs.

The AN/APN-81 Doppler Navigation System, F. A. McMahon, General Precision Lab., Inc.

The AN/APN-81 Frequency Tracker, W. B. Lurie and J. W. Gray, General Precision Lab., Inc.

Component parts I

Component Part Reliability Studies for Complex Military Equipments, J. W. Gruol, Signal Corps Engineering Lab.

Precise Frequency Control Devices for Missiles, E. A. Gerber, Signal Corps Engineering Lab.

Reliability of Electron Tubes for Guided Missiles, L. L. Kaplan, Signal Corps Engineering Lab.

Radiation Effects on Semiconductor Diodes, J. W. Clark and H. L. Wiser, Hughes Aircraft Co.

The Application of Transistors to Ordnance Electronics, S. H. Gordon, Diamond Ordnance Fuze Lab.

The Application of Auto-Sembly (Printed Wiring and Automatic Assembly) to the Missile Field, S. G. Bassler, Signal Corps Engineering Lab.

Electrical interference avoidance

RF Interference Design Techniques in Radar Systems, E. R. Radford, G. E. Co.

Radio Interference Testing of Airborne Electronic Equipment, C. F. W. Anderson, C. W. North and F. W. Snow, Glenn L. Martin Co.

Evaluation of Radar and Communications Interference Existing at Air Force Bases, J. W. Worthington, RADC, USAF, and C. L. Frederick, Frederick Research Corp.

Electronically Controllable IF Bandpass Varies Symmetrically Around Center Frequency, G. W. Clevenger, Bendix.

Reduction of Spurious Signal Radiation from Microwave Radars, P. L. Hammann, Bell Tel. Labs.

A Program for Reducing Electronic Interference in a Guided Missile System, G. P. Allison and R. V. Danner, Glenn L. Martin Co.

Test equipment and maintenance

A Precise Electro-Pneumatic Altitude Simulator, H. H. Chanowitz and B. B. Cunningham, Associated Missile Products Corp.

Introduction of Automation in Military Maintenance, Arthur Morrow, Sperry Gyroscope Co.

Guided Missile Test Set AN/DSM-18, speaker from Bendix.

Considerations in the Development of Checkout and Maintenance Equipment to Meet Army Ordnance Requirements, Alvin Steinberg, Redstone Arsenal.

British and American Maintenance Techniques from the Maintainability and Equipment Design Viewpoint, M. V. Ratynski, Rome Air Development Center.

2—5 P.M.

Simulation equipment I (Confidential)

Stacked Beam Radar Signal Simulator, R. J. Hansen, G. E. Co.

Aero 21B Aircraft Tail Turret System Operator's Trainer, Irwin Friedland, U. S. Naval Training Center.

Simulated Air-to-Air Firing Technique, Thomas Mongello, U. S. Naval Training Center.

Altitude Effects on Absorption of Radio Signals by Rocket Exhausts, J. M. Headrick and J. L. Ahearn, Jr., U. S. Naval Research Lab.

A Realistic Radar and Target Simulator, N. V. O'Neal, U. S. Naval Research Lab.

Component parts II

High Rate Batteries for Guided Missile Applications, A. Fischbach, Signal Corps Engineering Lab.

Design Data for Silicon Infrared Optical Systems, Harry Letaw, Jr., Raytheon Mfg. Co.

Radiation Properties of a VHF Ferrite Antenna, O. R. Cruzan, Diamond Ordnance Fuze Lab.

Pencil-Tube, S-Band, Pulsed Oscillator Units for Military Beacon Use, D. W. Power, D. K. Wilde and H. G. Parish, RCA.

Application of Mechanical Filters to Military Electronic Equipment, J. W. Bunce, Collins Radio Co.

A Fast Response, Full Wave Magnetic Amplifier, G. E. Lynn, Westinghouse Electric Co.

Operations analysis

Coordinated Weapon Assignment in Missile Systems with Overlapping Coverage, J. K. Carlyle, RCA.

The Value of Range and Overlapping Coverage in Air Defense Missile Systems, S. N. Mille, D. A. Cole, A. D. Davies, and M. E. Hawley, RCA.

The Application of Game Theory to Tactical Problems, Walter Biernat, Admiral Corp.

Reliability of a Radar System, F. D. Mason, Operations Analysis Group, USAF.

Operational Study of a Ballistic Camera System, Ernest Stern, Ramo-Wooldridge Corp.

An Example of Operations Analysis of the Matador Tactical Missile, R. M. Wood, Jr., Headquarters Tactical Air Command.

Computers and data links

High Speed, High Accuracy Computers for Military Electronic Control Systems, C. T. Leondes, Univ. of Calif.

An Airborne Digital Computer for System Control, R. E. Slack, IBM.

Instrument Thermo-Elements as Nonlinear Elements in Analog Computers, J. R. Boykin, Westinghouse Corp.

A Wideband Data Link Incorporated Video Channelling and Angle Data Equipment, W. L. Wright and R. P. Shipway, Marconi's Wireless Telegraph Co., Ltd.

A Data Transmission System Using Pulse Phase Modulation, R. R. Mosier, Collins Radio Co.

A Magnetized, Digital Data Link, Lyle Thompson and C. A. Taylor, Burroughs Corp.

WEDNESDAY, JUNE 19

9 A.M.—NOON

Miscellaneous (Confidential)

Planning the Instrumentation to Support an Integrated Weapon System Development, J. N. James, Jet Propulsion Lab.

Determination of Velocity and Position, J. R. White, Army Ballistic Missile Agency.

Cooling Infrared Detectors, Ernest Zahn, Perkin-Elmer Corp.

System Human Engineering for Guided Missiles, J. H. Hill, U. S. Naval Research Lab.

A New Approach to Antenna Feeds for Precision Tracking Radars, P. J. Allen, U. S. Naval Research Lab.

Recent Developments in Inertial Instrumentation Bell Aircraft Corporation Accelerometer-Integrator, D. D. Lenhard, Bell Aircraft Corp.

Reliability, performance and methods

Predicting Performance Reliability for Electronic Equipments of High Unit Cost, B. J. Wilson, U. S. Naval Research Lab.

Reliable Operation of Electron Tubes in the SAGE System, N. E. Nitachke, IBM.

A Reliability Test Program, TACAN AN/ARN-21, R. A. Simendinger, U. S. Naval Air Development Center.

Programmed Marginal Checking of the SAGE Computer, R. J. Brennan, IBM.

Weapon Systems Reliability, M. M. Tall, RCA.

Reliability, Methods and Performance,

R. C. Gillis and J. W. Tarzwell, Autonetics of North American.

Simulation equipment II

Resolver Synchros as Ballistic Function Generators, Anthony Bruno, Frankford Arsenal.

Search Radar Track and Noise Simulator, L. Packer and M. Raphael, Gruen Applied Science Labs.

Determination of Loop Performance of Sampled Data Systems with Nonlinear Elements Using Digital Simulation Techniques, J. O. Clark and W. E. Shepard, Westinghouse Electric Corp.

Radar Simulation Techniques, J. I. Leskinen, U. S. Naval Training Device Center.

Standardizing Flight Simulation Circuits, H. L. Ehlers, Autonetics, North American.

Target Simulation for Closed Loop Testing of Fire Control Systems, John Russell and George Barton, Sperry Gyroscope.

Inertial systems

Principles of Inertial Navigation, C. F. O'Donnell, Autonetics, North American.

Use of a "Strapped-Down" Hermetic Integrating Gyroscope System as an Inertial Reference for Guidance and Control of the Vanguard Satellite Launching Vehicle, R. A. Delp, Minneapolis-Honeywell Regulator Co.

Comparison of Acceleration Feedback and Sensitivity Feedback in Missile Guidance Servos, R. B. Schaaf, Bendix.

Effects of Errors in External Damping Reference for Inertial Guidance Systems, J. P. Martino, Wright Air Development Center.

Platform Stabilization, D. P. Chandler and R. H. Cannon, Autonetics, North American.

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Guidance systems (Confidential)

Problems in Infrared Guidance, L. W. Sieck, Air Force.

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Airborne Guidance Employing Television Displays, L. Brotman, J. Minker, and S. W. Spaulding, RCA.

A Transistorized Guidance Equipment for NIKE, J. R. Logie, Jr., Bell Tel. Labs.

Experience with the LACROSSE Precision CW Ranging System, A. R. Tanguay and R. E. Frazier, Cornell Aeronautical Lab.

Circuitry and subsystems II

Comparison of Shunt and Series Feedback in Precision Transistor Amplifiers, R. J. Patch, G. E. Co.

An Automatic Gain Control for an Acceleration Command Autopilot, L. J. Schipper, Bendix.

A Laboratory Standard AC Power Supply, D. A. Rosenfield, Bell Aircraft Corp.

Problems Presented by the Integrating Capacitor in a Missile-Borne DC Analog Integrator, Paul Jones, Jet Propulsion Lab.

Variable Bandwidth Servo to Optimize Slewing and Noise Rejection, V. F. Raque, G. E. Co.

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Component assemblies

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Ranging and tracking

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Center of Gravity Beam Splitting, J. Kirshner, E. Ramos and C. Ravilious, Diamond Ordnance Fuze Lab.

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Antennas & Propagation

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News and Views (p. 1)

Contributions—The Impedance Properties of Narrow Radiating Slots in the Broad Face of Rectangular Waveguide—Part I—Theory— A. A. Oliner (p. 4)

Theoretical results, valid at and away from resonance, for the impedance properties of the rotated series slot, the displaced series slot, and the longitudinal shunt slot have been derived by the use of variational expressions coupled with certain stored power considerations. The additional influence of finite wall thickness, an appreciable factor, is taken into account by a microwave network treatment. The results for the zero-thickness resistive elements become identical with those of Stevenson when the slot length is made equal to a half wavelength.

The theoretical derivations are presented in Part I. In Part II, comparison is made with experimental data both previously available and specially taken in this connection. The effect of wall thickness and the distinction between slots of rounded and rectangular ends are also considered. The agreement between theory and measurement is reasonably good.

The Impedance Properties of Narrow Radiating Slots in the Broad Face of Rectangular Waveguide—Part II—Comparison with Measurement—A. A. Oliner (p. 12)

A Luneberg Lens Scanning System—J. S. Hollis and M. W. Long (p. 21)

A 16,000-mc scanner is described which scans a 40° azimuth sector alternately with each of two beams at a rate of 17 scans per beam per second. The beams have half-power vertical and horizontal beamwidths of 0.76° and 1.06° respectively and are separated vertically by an angle of 1.85°. Horizontal collimation of each beam is achieved by a geodesic analog of the two-dimensional Luneberg lens. The lenses feed a section of a semiparabolic cylinder for effecting vertical collimation. Feeding the lenses is a switching system, consisting of two four-way turnstile waveguide switches and a waveguide chopper switch, which gives a scan-time deadtime ratio of 8:1.

A Design Procedure for Dielectric Microwave Lenses of Large Aperture Ratio and Large Scanning Angle—F. S. Holt and A. Mayer (p. 25)

Methods are given for designing point-source three-dimensional aspheric rotationally-symmetric dielectric lenses and for zoning such lenses. Designs for scan angles and aperture ratios much larger than conventional may be achieved and all computations can be done on a desk calculator. The three-dimensional lens is obtained by first designing an exact two-point corrected cylindrical dielectric lens and then rotating a section of the cylindrical lens about the axis of symmetry of the section. The design procedures for the cylindrical lens are based on ray-tracing techniques. Experimental results indicate that the three-dimensional lenses possess good wide-angle scanning characteristics.

Circularly Polarized Slot Radiators—A. J. Simmons (p. 31)

A pair of narrow slots crossed at right angles and located at the proper point in the broad wall of a rectangular waveguide will radiate a circularly polarized wave. Some of the results of a study of the properties of such slots is presented. The study was undertaken with the aim of obtaining information useful in design of a circularly polarized linear array.

Some of the properties of the slot pairs are as follows:

1) They are inherently matched, independent of the slot length.
2) When the slot arms are made resonant, approximately 75 per cent of the incident power is radiated, with a vswr of 1.12.
3) When fed from one end of the waveguide, the slots radiate right-hand circular polarization; from the other end, left-hand.

In using these slots in linear arrays the power radiated is varied by changing slot length, since position and orientation are fixed by the requirements of circular polarization. The slots must be separated by a guide wavelength, so waveguide loading or other complicated schemes must be used to reduce the slot spacing.

The Effect of Mutual Impedance on the Spacing Error of an Eight-Element Adcock—D. N. Travers (p. 36)

An eight-element Adcock array has the advantage of reduced spacing error as compared to four element arrays of the same size. If this error is calculated when the mutual impedances between elements are neglected, spacing error curves result which are poor approximations and may not be attainable in actual measurement. New relationships are derived for the two-phase eight-element array which include the effect of mutual impedance. Curves are plotted to show that earlier published values for the angular spacing between elements are probably too high to result in the best performance. It is shown that the value of $\rho=27°15'$ which results when the mutual impedances are neglected may result in an appreciable spacing error. It is apparent that the selection of an antenna becomes quite important since the mutual impedance is determined thereby. Evaluation of the error in a particular case will depend on the antenna selected. It is also shown that, if the goniometer impedance is high, the spacing error will be reduced.

Correction (p. 39)

On the Synthesis of Line-Sources and Infinite Strip-Sources—J. L. Yen (p. 40)

In this investigation Woodward's synthesis problem for line-sources and infinite strip-sources with arbitrarily spaced sample points is discussed on the basis of the well-known sampling theorem of bandwidth limited functions. Herein is described a method of synthesis based on the migration of zeros of the integral function $(\sin \pi u)/\pi u$ from which all possible solutions of the problem can be derived. Because of the nonuniqueness of the solution, a criterion is introduced, to derive a unique distribution function so that the integrated value of its squared magnitude is a minimum. It turns out that the solution under this criterion coincides with the one obtained by Woodward and Lawson. Examples are given to illustrate the different solutions obtainable for particular problems, and the significance of the least integrated squared magnitude criterion.

Radiation Characteristics with Power Gain for Slots on a Sphere—Y. Mushiake and R. E. Webster (p. 47)

Radiation patterns, impedances, and power gains of nonsymmetrically excited narrow slots on a sphere are considered. Numerical calculations of higher order ϕ-dependent modes of the radiation and admittance functions are discussed. These functions are applied to obtain the radiation characteristics of an equatorial slot backed by a radial transmission line and excited by feed points along the slot periphery. This geometry is treated directly as a boundary value problem, no assumption of aperture field distribution along the slot being made. Further application is shown for half wave slots on the sphere and for determining gains of uniformly excited zonal slots as a function of their location. Experimental results simulating the asymmetrically excited equatorial slot geometry are given.

Cylindrical Radio Waves—Samuel Sensiper (p. 56)

The formulas required for simple accurate numerical evaluation of the radiation patterns from slots on large circular cylinders are derived. From the usual harmonic series, integral representations are obtained. These lead to either the residue series via the Watson transformation, or to the geometrical-optics representations via a saddle-point evaluation. Considerable attention is given to the calculation of the residue series constants so as to obtain sufficiently accurate numerical values for a wide range of circumference to wave-length ratios. Very good numerical agreement is shown between the representations derived here and results previously obtained from the harmonic series.

The physical significance of the various representations is discussed and compared.

A Study of Radar Elevation-Angle Errors Due to Atmospheric Refraction—B. M. Fannin and K. H. Jehn (p. 71)

Refractive-index variations in the atmosphere cause errors in radar measurements. This paper presents the results of a theoretical study of the elevation-angle error due to the refraction of electromagnetic waves in the troposphere. The study is based upon ray theory, using standard meteorological data reported by the United States Weather Bureau for the surface and the standard pressure levels. Computed errors are tabulated for thirty-four monthly mean refractive-index profiles selected as being representative of various type air masses for different seasons and latitudes. In order to get an indication of the spread in propagation errors to be expected during a particular season for fixed locations, computations have been carried out based on the 0300Z soundings for the odd days of January (1950–1954) and July (1950–1953) for nine U. S. locations. The diurnal influence is investigated by analyzing the variations in surface refractive index for January and July, 1953, and also for nine U. S. locations.

Solar Flares and Atmospheric Noise—E. I. King and A. W. Sullivan (p. 78)

In this paper, the effects of solar flares on low-frequency atmospheric noise are examined. Relations between the rise of noise, and the area of the flare, its intensity, location on the sun, and time of day are studied. Noise levels preceding flares are also examined to determine whether there are any phenomena which may be used for the prediction of high-frequency fade-outs.

On Scattering and Reflection of Electromagnetic Waves by Rough Surfaces—Victor Twersky (p. 81)

Simple approximations for the reflection coefficients and differential scattering cross sections per unit area of a random distribution of arbitrary protuberances on a ground plane are given in terms of the scattering amplitude of an isolated protuberance, their average number in unit area, and the given incident wave. These functions take into account multiple coherent scattering, and are mutually consistent in fulfilling the energy principle. It is shown, in general, that if the horizon angle approaches zero, then the reflection coefficients approach unity linearly, and the horizontal/vertical back scattering vanishes like the fourth/second power of the angle. General results are then specialized to arbitrary hemispheres and circular semicylinders, and applied to limiting cases of perfect conductors with radii very small or very large compared to wavelength.

Radio Communications by Means of Very Short Electric Waves—G. Marconi (p. 90)

Diffraction of Surface Waves by a Semi-Infinite Dielectric Slab—C. M. Angulo (p. 100)

The discontinuity at the end of the slab is regarded as the junction of an open dielectric-filled waveguide and a free-space waveguide.

A variational expression is set up for the terminal impedance representing the effect of the discontinuity on the surface wave. Close upper and lower bounds for the impedance are obtained.

A variational expression is also set up for the transfer impedance between the surface wave and one of the modes of the continuous mode spectrum associated with the free-space waveguide. The transfer impedances yield the modal amplitudes of the fields. The synthesis of all the modal components gives the electromagnetic field scattered by the end of the slab. The synthesis is carried out for the far field by the method of steepest descents.

Terminal impedances and forward radiation patterns are plotted as functions of the thickness for several permittivities $\epsilon_r = 2.49$; 10; 100. The approximation obtained by the variational expression is excellent for small values of ϵ_r and begins to be bad for $\epsilon_r > 10$. For very large values of ϵ_r it is possible to obtain a rough estimate of the impedance, immediately, from the values for $\epsilon_r = 10$.

Alternative Field Representations in Regions Bounded by Spheres, Cones, and Planes—L. B. Felsen (p. 109)

Alternative representations are obtained directly by the method of characteristic Green's functions for the fields radiated by arbitrarily placed scalar and vector (electromagnetic) point sources in regions bounded by surfaces which are describable in terms of single coordinates in a spherical coordinate system. Such surfaces are spheres, cones, and planes, or a combination of these. The representations are distinguished from one another by different convergence properties for various ranges of values of the location of source and observation points and of the boundary surface geometry. Considered in particular are the diffraction by a sphere, a wedge, and a wedge with a spherical dome for both the scalar and vector cases.

Plane-Wave Scattering by Small-Angle Cones—L. B. Felsen (p. 121)

Rigorous expressions alternative to the familiar formulas in terms of spherical harmonic series are developed for the scattering of acoustic (and electromagnetic) waves by the tip of a perfectly rigid (or perfectly conducting) semi-infinite cone. For plane wave incidence the expressions are valid for observation points lying in a region excluding the rays which are reflected from the sides of the cone according to the laws of geometrical optics. Approximate closed-form results are obtained for on-axis or off-axis incidence and observation for cones with small apex angle for the acoustical plane wave scattering, and for electromagnetic scattering of incident waves whose electric vector is directed perpendicular to the cone axis. The results are correct to $0(\phi^2)$, where ϕ is the cone apex angle, and agree, for the special case of plane wave back-scattering along the cone axis with those obtained previously by a different method.

The case of diffraction by a spherically tipped cone is also treated.

Theory of the Scintillation Fading of Microwaves—Osamu Tukizi (p. 130)

A theory is presented indicating that the scintillation fading may be attributed to the incoherent scattering of microwaves by atmospheric irregularities in mass motion at an average velocity.

By use of the perturbation theory, the resultant of scattered fields at the receiver is calculated which, on account of the interference with the direct wave, gives rise to the received field oscillating rapidly with small amplitudes around a mean level. Account is taken of the directivity of transmitting and receiving antennas which facilitates the calculation of received field, and also of the Doppler effect due to the translational mass motion of turbulent eddies.

Agreement with experimental results is satisfactory.

Ray Theory vs Normal Mode Theory in Wave Propagation Problems—L. G. McCracken (p. 137)

The Euler-Maclaurin expansion, as a possible tool for summing mode series in wave propagation problems, is examined for the problem of a dipole radiating monochromatic energy between two parallel plates. When the expansion is applied to this problem, it is found that the expansion formula transforms the mode series into the known ray theory solution.

Universal Curves for the Vertical Polarization Reflection Coefficient—G. P. Ohman (p. 140)

A set of universal curves is presented by which the approximate magnitude and phase of the reflection coefficient for vertical polarization can be determined at any grazing angle with relatively little computation. The approximation, which is almost always sufficiently accurate for engineering purposes, is excellent if the relative impedance of the reflecting medium is high and still quite good even if the impedance ratio is only moderately greater than unity.

Communications—Aircraft Telemetry Antenna—F. E. Butterfield (p. 143)

The Optimum Aperture Function in a Long Array—G. C. McCormick (p. 144)

Variational Principles for Electromagnetic Resonators and Waveguides—V. H. Rumsey (p. 146)

Symposium on Present and Future Uses of Refractive Index Data for Radio Propagation Purposes—L. J. Anderson (p. 147)

Abstracts of Papers From the IRE-URSI Symposium Held April 30, May 1-3, 1956—Washington, D. C. (p. 148)

Abstracts of Papers From the IRE-URSI Symposium Held October 11-12, 1956—Berkeley, Calif. (p. 164)

Contributors (p. 169)

Circuit Theory

VOL. CT-3, NO. 4, DECEMBER, 1956

Abstracts of Papers in This Issue (p. 206)

Signal Theory—W. H. Huggins (p. 210)

It is suggested that much of the subject matter now lumped under the heading of "circuit theory" might better be called "system theory," which in turn may be separated into three subdivisions—that which deals with the representation of the *physical elements;* that which deals with the representation of the *signals*, and that which deals with the representation of the *transformations* and *relations* between the signals and the elements. For the first subdivision, the name "circuit theory" in its original sense is suggested; for the second subdivision, the name "signal theory"; and for the third, the name "operator theory." This paper describes some of the distinctions between the first and second subdivisions.

Signal representations are needed for two purposes: To study the *transmission properties* of a *system*, and to reveal the *information-bearing attributes* of a *signal*. Steady-state (i.e., Fourier) representations are well suited to the first purpose, but representations that explicitly involve temporal parameters are needed for the latter purpose. The expansions of signals in terms of nonsinusoidal components provide one type of representation which has been used extensively in physics but has been little used in the practical analysis of signals. A specific example is given of a filter structure which analyzes the incoming signal in terms of a set of orthogonal functions formed from the exponential components e^{-t}, e^{-2t}, e^{-3t}, etc., and it is shown how an "ideal" filter, in the sense of Zadeh, may be constructed for separating these components. A practical use of this ideal filter is to measure the nonlinear distortion of an arbitrary dynamical system under transient conditions.

System Theory as an Extension of Circuit Theory—W. K. Linvill (p. 217)

The attitudes and techniques of circuit analysis and synthesis can profitably be extended to system analysis and design. The main problems of system analysis are characterization of components and combination of component characteristics into system characteristics. Techniques analogous to familiar circuit theory techniques are applicable to the study of noncircuit problems. As an example, the analysis of a discrete-data system is described. Such familiar network theory terms as transfer function, transform, stability, return difference, and error coefficients are used. Applications of system analysis techniques to the study of convergence of iterative methods for solving equations and to the study of error propagation are described.

The Use of Least Squares in System Design—M. R. Aaron (p. 224)

Approximation, realization, and alignment in the circuit theoretic sense are the essential ingredients in the development of a large class of physical systems. It is shown that the method of least squares is an effective tool for obtaining "optimum" performance in the three facets of system design. Tangent descent and Taylor Series are recommended for use in the application of least squares to system design. The mathematical processes inherent in this procedure have been programmed for solution by a digital computer. The marriage of digital computers to this means of system design has been compatible, and "offsprings" are displayed to attest to this fact. These examples include: 1) alignment of a one port to match a prescribed magnitude characteristic, and 2) synthesis of all-pass networks into a composite delay equalizer.

Signal Theory in Speech Transmission—E. E. David, Jr. (p. 232)

The mechanism of speech production imposes a number of well-defined constraints on the resulting acoustic wave. The nature of these constraints is associated with the anatomy of the human vocal tract and vocal cords. This mechanism can be characterized as a time-varying linear dynamic system excited alternatively by a noise or pulse source which contains only frequencies much higher than the variational rate. Thus, speech can be described by a small number of parameters which change at the slower rate. Such parameters in effect describe the constants of the dynamic system and its excitation. Representations of this kind demonstrate the philosophy underlying the signal theory approach to the design and analysis of transmission circuits.

The Theory of Analytic Band-Limited Signals Applied to Carrier Systems—J. Oswald (p. 244)

The recently-developed concept of the "analytic signal," together with that of bandwidth-limited signals, is used to construct a general theory of amplitude modulation. The basic definition and properties of an "analytic signal" are reviewed with particular reference to band-limited signals. The "analytic signal" is a signal of the form $s(t)=x(t)+jy(t)=\rho(t)e^{j\phi(t)}$ where $x(t)$ and $y(t)$ have the same norms, are orthogonal and related to one another by the Hilbert transform, and where $\rho(t)=\sqrt{x^2+y^2}$ defines an envelope function while $\phi(t)=\tan^{-1} y(t)/x(t)$ defines a phase function whose rate of change determines an instantaneous frequency. The Fourier transform $Z(\omega)$ for $s(t)$ is identically zero for $\omega<0$.

The theory of amplitude modulation based on the band-limited analytic signal is used to define clearly the properties of single-side-band transmission systems. The problem of amplifier overloading in multiplex single-sideband transmission is referred to and some comparisons are drawn between the amplitude probability distributions of the envelopes of double and single-sideband transmission of random signals.

It is suggested that the concept of the analytic bandwidth-limited signal may facilitate the development of a general theory of frequency modulation.

On Nonuniform Sampling of Bandwidth-Limited Signals—J. L. Yen (p. 251)

The purpose of this investigation is to examine four special nonuniform sampling processes in detail, and to deduce some interesting properties of bandwidth-limited signals. The main results are contained in four generalized sampling theorems. These theorems not only contain the nature of determination (unique-specification, over-specification, and under-specification) of signals but also include explicit reconstruction formulas. From the reconstruction formulas, the complexity and accuracy of the nonuniform sampling processes discussed can be estimated. In addition, these theorems lead to observations regarding the allowable shapes, the "prediction," and the "energy" of bandwidth-limited signals in general. A "minimum-energy" signal is introduced which has certain advantages as compared to the ordinary "time-limited" signals when a finite number of sample values are given. Finally, a statement due to Cauchy on the sampling of bandwidth-limited signals is generalized to include a wider class of nonuniform sample point distributions and modified to give more exact information regarding the nature of determination of signals.

Systems Analysis of Discrete Markov Processes—R. W. Sittler (p. 257)

The properties of discrete Markov processes are related to those of analogous linear, time-invariant, sampled-data systems. Methods are given for the systems-analysis solution and interpretation of problems and theorems relating to such Markov processes. Correlation functions of signals generated by Markov processes are determined. Transform procedures, flow graphs, and signal-flow ideas play an important role in these studies.

A Study of Rough Amplitude Quantization by Means of Nyquist Sampling Theory—Bernard Widrow (p. 266)

Quantization is an operation that takes place when a physical quantity is represented numerically. It is the assignment of an integral value to a physical quantity corresponding to the nearest number of units contained in it. Quantization is like "sampling-in-amplitude," which should be distinguished from the usual "sampling-in-time." The probability density distribution of the signal is sampled in this case, rather than the signal itself.

Quantized signals take on only discrete levels and have probability densities consisting of uniformly-spaced impulses. If the quantization is fine enough so that a Nyquist-sampling restriction upon the probability density is satisfied, statistics are recoverable from the grouped statistics in a way similar to the recovery of a signal from its samples.

When statistics are recoverable, the nature of quantization "noise" is understood. As a matter of fact, it is known to be uniformly distributed between plus and minus half a unit, and it is entirely random (first order) even though the signal may be of a higher-order process, provided that a multidimensional Nyquist restriction on the high-order distribution density is satisfied.

This simple picture of quantization noise permits an understanding of round-off error and its propagation in numerical solution, and of the effects of analog-to-digital conversion in closed-loop control systems. Application is possible when the grain size is almost two standard deviations. Here the dynamic range of a variable covers about three quantization boxes.

On the Identification Problem—L. A. Zadeh (p. 277)

The identification problem involves the determination of the identity of a black box from the observation of its responses to a set of input signals. In this paper attention is focused on the identification of zero-memory multipoles and two-poles of class $\mathfrak{N}_1$. The test signals are sine waves of different amplitudes and frequencies, and the measured quantity is the describing function of the device.

In the case of two-poles of class $\mathfrak{N}_1$, it is found that the describing function is related to the characteristic function by an integral equation of second order which can be solved explicitly by the use of the Fourier-Hankel transformation.

Limiting Conditions on the Correlation Properties of Random Signals—G. Kraus and H. Potzl (p. 282)

A system of n signals that has random character is completely characterized by its self-power spectra and cross-power spectra which when normalized, can be combined in a correlation matrix. It is shown that the correlation matrix must fulfill the fundamental condition that none of its principal minors is negative. It is shown that no further restriction exists, that is, that all correlation matrices fulfilling this condition are realizable.

Definitions of "Bandwidth" and "Time Duration" of Signals Which Are Connected by an Identity—D. G. Lampard (p. 286)

In this paper we give definitions of "equivalent time duration" $\Delta\tau$ and "equivalent bandwidth" Δf and show that they are connected by a simple reciprocal identity. An example is given and it is shown that the same concepts can be applied in antenna theory to give useful definitions of "equivalent aperture distribution width" and "equivalent angular spectrum."

Ladder Network Analysis by Signal-Flow Graph—Application to Analog Computer Programming—Omar Wing (p. 289)

S. Mason's signal flow graph technique is applied to the analysis of ladder networks. Briefly, the flow graph of a ladder is developed using Ohm's and the two Kirchhoff's equations. The graph is then reciprocated so that it contains only forward paths. The transfer function, in the case of a simple ladder, is the reciprocal of the sum of all distinct paths from the output to the input node. In the case of ladders containing internal generators, independent or dependent, the transfer function can be found in a similar way with slight modifications. Other relations, such as the input impedance, transfer admittance, etc., can also be found directly from the flow graph. In essence, instead of writing mesh equations or applying recursion formulas of continuants, we construct a flow graph by inspection and analyze the network from the graph.

In the last part of the paper, the striking similarities between the flow graph of a network and its analog computer simulation are pointed out. Indeed, the flow graph is the computer set-up in a schematic form.

Reviews of Current Literature (p. 295)

The Continuous Delay-Line Synthesizer as a System Analogue—J. H. Westcott. (IEE Monograph, no. 176M; May, 1956.) Reviewed by W. E. Thomson.

Analysis of Linear n-Port Networks—I. Cederbaum. IEE Monograph, no. 163R; January, 1956. Reviewed by H. J. Orchard.

Inter-Reciprocity Applied to Electric Networks—J. L. Bordeijwk. *Appl. Sci. Res. (Netherlands)* vol. 6, sec. B, no. 1–2, pp. 1–74; 1956. Reviewed by V. Belevitch.

Abstracts of Foreign Language Articles on Circuit Theory (p. 297)

Comparison of Image Parameter Filters with Insertion Loss Filters and Current Trends in Filter Calculations—V. Fetzer (in German). (*Archiv der Elektrischen Übertragung*, vol. 10, pp. 225–240; June, 1956.)

Canonical Representation for a Class of Dissipative Circuits—B. Gross (in German). (*Archiv der Elektrischen Übertragung*, vol. 10, pp. 299–302; July, 1956.)

Bridged-*T* Filters with One or Two Cut-Off Frequencies—J. E. Colin (in French). (*Cables and Transmission*, vol. 10, pp. 165–206; July, 1956.)

Correspondence (p. 297)

PGCT News (p. 300)

Index to IRE Transactions on Circuit Theory—Volume CT-3, 1956 (following p. 300)

Engineering Management

Vol. EM-4, No. 1, March, 1957

Weapons System Management—G. J. Strickroth

A weapons system provides for, and includes, all elements required to perform a desired mission. The scope of a weapons system begins at the conception of an idea and ends with the successful use of the weapon in the field. A wide variety of weapons systems are concurrently in process at Martin. To manage these projects, a somewhat unique organizational structure has been developed. In fact, it is two organizational structures existing at the same time with much the same personnel. One structure provides the climate necessary for a superior job, the training programs for personnel development, facilities, and technical staff assistance. The other structure establishes project objectives and provides project planning and control.

Operations Research as a Managerial Instrument of Advice and Decision—Z. Prihar

The paper attempts to give a general appraisal of the significance and trend of operations research as a managerial instrument of advice. The paper also indicates how this field has gradually grown in scope and includes an analysis and appraisal of the various methods employed, their scientific importance, suggestions for their assimilation to other fields, and a discussion on the possible application of information theory to operations research.

Operations Research: The Inventory Problem—Z. Prihar

As pointed out in the opening paragraph of the paper, the inventory problem, one of the mathematical tools of operations research, is discussed and its application illustrated by an application to a production and sales problem. A solution of an inventory problem yields quantitative data on which decisions can be taken with a view to minimizing risks and maximizing profits.

Analysis of Engineering Costs—B. E. Blume

The comprehensive analysis of the information supplied by an adequate cost accounting system can reduce the guesswork of managerial decisions to a minimum. Your accounting system should be designed not only as an instrument to determine historical cost, but as a tool of financial information that will project your future operation under varying conditions.

Standard costs and predetermined budgets can offer management an opportunity to study efficiency from automatically prepared reports. Study of variable, semivariable, and fixed costs can predict the future and offer such information as price concessions that may be extended. Use your accounting tools and take the guesswork out of otherwise difficult decisions.

Situations That Affect the Productivity of Engineers—M. C. Batsel

The performance of engineers is closely related to their motivation. Some techniques of administration that encourage individual engineers to identify themselves with their jobs and to feel a responsibility for accomplishing the objectives of management will be discussed.

Improved Management of Military Development Programs Needed to Conserve Our Engineering Manpower—J. M. Bridges

The future security of this nation requires continued technological superiority in weapons and weapons systems. To maintain this technical lead in the face of our already inadequate supply of scientists and engineers is a matter of grave concern. The outlook for increasing the supply of technical graduates to meet these demands over the next decade is not good. It is essential, therefore, that we utilize our valuable engineering resources with maximum efficiency. Certain aspects of military program management are resulting in waste of engineering resources. Among these are the requirement for multiple technical proposals prior to selection of a developmental contractor, requirements for unnecessary engineering records, failure to make continued use of trained engineering teams in specialized design areas, and duplication of engineering effort by a prime weapon-system contractor and his subcontractors. It also appears that existing military procurement policies and procedures are tending to create a philosophy of "mass engineering" which is not only wasteful of technical resources, but is having an adverse effect upon the morale of engineers and the engineering profession.

People, Things, and The Engineer—J. F. Gordon

Is it realistic for engineers to expect the same rigid honesty of performance from people that they do from machines?

The engineer's effectiveness in a business society may be directly proportional to his ability to differentiate between human and machine performance.

Logic does not always play the leading role in dictating human behavior.

The engineer's growing responsibility to society as a whole demands that he recognize these things. By such action he can markedly improve his own effectiveness.

Scientific Manpower—Adequate Resources! Inadequate Development? Inadequate Refinement?—G. D. McCann

It is pretty generally realized that our country faces a serious scientific and engineering manpower shortage. We have at present about half the engineers which we need, and each year we are graduating only about half of our annual needs. The factors effecting this shortage, our abilities to overcome it, and the time required for this, however, are not well understood. First and foremost it must be realized that this is a long-range shortage for which a significant increase cannot be made within the next five to ten-year period. This means that the immediate solution to the problem can come only through a more efficient utilization of existing manpower supply.

This shortage is not due to a lack of raw materials. If only the male youths of the country are considered, the supply of competent young students to our technical colleges could be quadrupled, and if more women could be assimilated properly into our engineering system, the supply might be increased ten-fold.

The small percentage of competent youth that is attracted to scientific education constitutes the most important problem which we face. This is due in part to a general lack of understanding on the part of the general public of science itself, of its increasing importance to society, and to the general nature of the opportunities which it affords as a career.

Our high schools, technical universities, industry, and the government have a grave common responsibility to set up an adequate program of mutual cooperation for solving this problem.

Some Methods of Freeing Engineers for Increased Creative Effort—S. W. Herwald

Some methods of freeing engineers from routine activities so that they have more time for creative engineering are discussed. The use of technicians at a particular plant location is described. Engineering clerical aids are spoken of. The ways in which adequate laboratory tools and facilities can help are discussed. Mechanical computing and design schemes are mentioned in their relationship to better utilization of creative engineering talent

Industrial Electronics

PGIE-4, March, 1957

(Papers Presented at the Conference on Industrial Electronics, Sept. 24–25, 1956, Cleveland, Ohio)

Short Cuts in Printed-Circuit Wiring—Robert Ost (p. 1)

The purpose of this paper is to illustrate the responsibilities of product engineering and design in evolving printed wire products. The short cuts are the results of planning with maximum standardization. The products to be used for illustration are 23 servo-amplifier designs used in military airborne equipment. The quantity of amplifiers to be produced is not large and might be classified as a short-run type production. Printed wiring was decided upon on the basis of reduced unit cost and consistency of amplifier performance. It is important to point out that the products mentioned are part of a large system within a large company. Many of the principles illustrated herein are necessary because of the great coordination a large program requires.

Human Engineering, an Aid to Improving Electronic Equipment—Maurice Rappaport (p. 6)

The applied experimental psychologist, or human engineer, can be of great assistance in the design, production, and maintenance of simple or complex electronic equipment. By his knowledge of human sensory and motor characteristics, by systematic application of fundamental principles of psychology, physiology, and anthropometry, and by application of psychophysiological research techniques to man-machine problems, he can contribute to the development of compatible and more efficient man-machine systems. In many applications, reduction of human factor errors can be as important as the reduction of electromechanical errors.

A Modern Concept of Electronic Packaging—R. P. Noble (p. 12)

This paper points out the relationship between human engineering, design approach, and engineering management. Application of electronic packaging with printed circuit design is discussed and several slides illustrating finished units are shown. A modern design approach is explained, both from management's standpoint and the design engineer's point of view. Design procedure is discussed and the various functions and responsibilities of a design group are outlined.

Packaging of Transistorized Assemblies—A. A. Lawson and R. J. Simms (p. 24)

This paper discusses the basic concept of utilizing functional circuits and packaging them into modular end products. As the modular philosophy has advanced, the size of the modular assembly itself has decreased. Several different modes of encapsulation are discussed. Encapsulation by casting is presented. Trimming operations on the cast module are discussed. Encapsulation by pressure molding is compared to casting methods. It is shown that many of the disadvantages of the individual methods can be eliminated by the combination of these two encapsulation methods.

Automation for Electronics—A 1956 Status Report—A. R. Gray (p. 29)

At the 1955 IRE National Convention, the author delivered a paper entitled "Guided Missile Reliability and Electronic Production Techniques." A general description was given of several contemporary concepts of automation-for-electronics. The present paper is a sequel to the previous report. An attempt is made to view objectively the various improved concepts and their advancing techniques, and to evaluate them in terms of present trends for their use. Three needed basic improvements for automatic electronic assembly machines are outlined, and a prediction is made that the early incorporation of these improvements will rapidly advance the acceptance and application of automation-for-electronics.

Manufacture of Wire Spring Relays for Communication Switching Systems—J. W. Rice (p. 45)

This paper describes the manufacture of the major sub-assemblies for the general purpose wire spring relay. Their mass production to close tolerances and at low cost has required the development of entirely new and different machines and techniques. Several machines of the type discussed are already in operation and more are under construction to satisfy the ever-increasing demand for these excellent relays.

The combination of such widely different kinds of processes into integrated machine units is a great step forward in the march toward the automatic factory so widely acclaimed in these modern times. Knowledge gained during this development has already been used by Western Electric in planning the manufacture of future communication apparatus and in lowering the cost of present Bell System products.

It will doubtless be recognized that automatic facilities of the type described require a major capital investment, the justification for which must depend upon a large and continuing demand as well as a stable product design.

The Status of Standardization in Electronic Production and Machine Tool Control—E. H. Bosman (p. 55)

The techniques of automation have been experiencing a rapid expansion in the past few years. It became apparent that standards should be arrived at to prevent chaos in this relatively new means of production.

In August, 1954, the Radio-Electronics-Television Manufacturers' Association organized a committee to propose standards in this field of automation. The great interest shown, by industry in general, indicated the urgent need for this type of action.

The progress, observations, and results of this standardization activity will be described and outlined in detail.

Production Testing in the Automatic Factory—H. S. Dordick (p. 59)

Progress in the mechanization of production testing of electronic products is reviewed. Several test equipments are described and evaluated. The necessity for considering the quality monitoring function of production as a continuous and integrated system is emphasized. This approach enables the test process planner to utilize the powerful tools of operations research in determining the nature of the test equipment and procedures required for optimum operation. A test system for the automatic factory is described. This system calls for the more efficient use of statistical sampling techniques as well as the more efficient feedback of test data. Within the framework of this system, new requirements on test equipment have been developed. The activities of an industry-wide RETMA Task Group on Standards for Product Testing in Mechanized Production is described.

The Xatron—A Variable Speed Electronic Drive for Process Control—A. J. Humphrey (p. 68)

The trend today is the use of electronic variable speed drives in applications which normally would have been filled by rotating conversion units. Physically, electronic drives have a space and weight advantage over rotating equipment. Electrically, they lend themselves to precise control and rapid response to error signals.

Small drives using thyratrons to supply and control d-c motors are quite common. Large Ignitron and Excitron drives have been in successful use for many years. An electronic drive, the Xatron, using a grid controlled rectifier has been marketed in the 30 to 100 horsepower range. It is believed that this drive will capture the mass market for packaged drives within five to ten years. Chief use will be in the machine tool industry and for process control.

Many varieties of electric variable-speed drives have been built and used in the past seventy-five years. The common feature in most of them has been the prime mover itself, the d-c motor. Compared to the induction motor, the d-c motor is an expensive device to produce, chiefly due to necessity for a commutator and brushes. In spite of this factor the d-c motor today remains the foundation upon which the commercial wide range variable speed drive is based.

Today between 80 and 90% of the electric drives built consist of a motor driven d-c generator providing a variable armature voltage for a d-c motor. Until 10 years ago an additional d-c generator was used to supply excitation for the motor field. This rotating member has been largely replaced either with a hot cathode rectifier or with a dry plate rectifier. The ease with which a thyratron field supply could be regulated pointed the way to completely static conversion for both armature and field. The increasing cost of copper and iron has tended to give the static converter an economic advantage over the older combination.

Several factors which have led to increasing use of electronic drives are listed.

1. *Space and weight:* The electronic drive today is much lighter and is furnished in smaller cabinets than are comparable rotating drives. If progress in electronic drives continues, we may expect a complete drive in a cabinet scarcely larger than that of a reduced voltage starter for an induction motor.
2. *Efficiency:* Rotating drives can be made with high efficiencies but at the expense of using extra material. Electronic drives of today are more efficient than their rotating counterparts. Electronic drives of the future will approach 96 to 98% conversion efficiency, and present drives are as high as 92%.
3. *Starting surges:* An a-c motor when started with a contactor across an a-c line usually causes considerable voltage dip which affects other equipment. Starting transients in an electronic drive are related only to output torque and can be easily controlled.
4. *Swift response:* Electronic drives have opened a new era of control with the speed of response that is available through their use. Both the physical inertia and the electrical time constant of larger d-c generators have made it difficult to control motors for rapid variation in speed or load. Rapid changes in power level are inherently easy to obtain with an electronic drive.
5. *Maintenance:* Electronic drives eliminate a good deal of the bearing and brush maintenance problems. Breakdowns are repaired by part replacement rather than by rewinding. Maintenance is usually no more than keeping the electronic unit clean.

Automatic Process Control with Radiation Gauges—W. H. Faulkner, Jr., G. F. Ziffer, and Gilbert Corwin (p. 76)

The optimum automatic process control system requires a continuous flow of information relating to the process variations. Radiation gauges utilizing absorption or scattering of radiation produced by a radioisotope source as a means of measuring thickness, weight per unit area, or density of a product offer a means for obtaining this information. Process control utilizing these gauges differs from the usual control system in that large delays exist between the measuring point and the control point. The existence of such delays requires the use of specialized control systems, usually utilizing interrupted control. A typical control system of this type is described and the safety precautions required to prevent malfunction or damage are discussed.

Measurement and Control in a Large Steam Turbine-Generator Department—R. G. Goldman (p. 82)

Rapidly rising steam temperatures and pressures in addition to new design techniques have vastly increased both the quantity and quality of x-ray and ultrasonic testing required. Consequently, the development pressure, particularly in ultrasonics, which in its modern form is of postwar birth, has been heavy. Some of the techniques, equipment and circuitry of present day inspection are described and the characteristics and operation of ultrasonic transducers noted.

Sodium iodide, the linear accelerator and industrial television have brought the promise of mechanization to the examination of large castings, while the promulgation of acceptance standards and the use of ABC scan representation and recording gives equal promise of speeding up the inspection and quality control of forgings. Preliminary experiments and electronic design work towards these objectives are described.

An interesting development is the use of ultrasonics in nozzle-area determination, wall-thickness measurements on large castings, and liquid-level indication. Possibilities exist for automatic control of machining operations and liquid-level control. Distances and cross sections can be checked with accuracies of 0.1%. As a control device, the feedback nature of the system will tend to suppress dependence on machine or template accuracies.

Analog Versus Digital Techniques for Engineering Design Problems—D. B. Breedon (p. 86)

Nearly every problem encountered in engineering at some time proceeds from the qualitative to the quantitative phase where the results of mathematical analysis must be applied in actual computation. Most often the computation is short enough that automatic means are not necessary. However, more and more problems are requiring powerful aids to calculation. This increase is due as much to expanded thinking encouraged by the mere availability of computers as to any actual backlog of work. Therefore it is to the engineer's advantage to know what computers can do for him, even though he may take his problem to someone else for final preparation and programming.

The following text presents some examples in which automatic calculation is being used. The logic used in choosing the computing methods is shown based on the characteristics of problem and computer. As background for the examples the most important of these characteristics are presented briefly in the next section.

Computers—The Key to Modern Manufacturing Scheduling—J. J. Gravel and T. F. Kavanagh (p. 90)

Manufacturing operations with poor scheduling plans are headed for trouble. Load capacity analysis is a technique for measuring the feasibility and desirability of proposed scheduling plans. Simply stated mathematically, load capacity analysis consists of a series of multiplications and additions. However, the numerous computations in a typical problem usually take more time than can be allowed. The paper describes a special purpose analog computer specifically designed to solve this problem in a matter of minutes.

A Tank Farm Data Reduction System—D. J. Gimpel (p. 94)

A tank farm data reduction system has been developed for the new Tidewater Oil Company installation in Delaware by the Armour Research Foundation and Panellit, Inc. The function of the unit is to secure the temperature corrected volume of fluid in each of the approximately 100 tanks in the field. The inputs to the system are the fluid height and average tank temperature. Fluid volume is tabulated digitally as a function of the height on magnetic tape. The system automatically searches the tape for the indicated volume and multiplies the number by the temperature correction factor. This paper describes the operation of the multiplier, the tape search elements, and the sensing instruments employed in the field. The factors governing the selection of the specific elements in the storage and computing system are also discussed.

(*Paper Presented at the* 1955 *Industrial Electronics Conference, Detroit, Mich.*)

Automation Re-Examined—J. J. Graham (p. 101)

The author re-examines the subject to re-orient thinking along constructive lines which will utilize the concept as we use the many other valuable tools in our industrial storeroom. The mechanization involved in the production of printed boards is discussed. The requirements for numbers and training of people are increased rather than decreased, as outlined by the author.

Military Electronics

Vol. MIL-1, No. 1, March, 1957

Editorial (p. 1)

PGMIL'S "Place in the Sun"—W. R. G. Baker (p. 2)

A Message From Your National Chairman, PGMIL—C. L. Engelman (p. 3)

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The Great Discovery of Modern Mathematics—L. R. Lieber (p. 10)

Battle Scars of Military Electronics—The *Scharnhorst* Break-Through—Sir Robert Watson-Watt (p. 19)

Will Science Come to an End?—George Gamow (p. 26)

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Abstracts and References

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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 number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number and is not to be confused with the Decimal Classification used by the United States National Bureau of Standards. The number in heavy type at the top right is the serial number of the Abstract. DC numbers marked with a dagger (†) must be regarded as provisional.

The Index to the Abstracts and References published in the PROC. IRE from February, 1956 through January, 1957 is published by the PROC. IRE, May, 1957, Part II. It is also published by *Electronic and Radio Engineer*, incorporating *Wireless Engineer*, and included in the March, 1957 issue of that journal. Included with the Index is a selected list of journals scanned for abstracting with publishers' addresses.

ACOUSTICS AND AUDIO FREQUENCIES

534.121.2 **975**

A Difference Equation for the Approximate Calculation of the Natural Frequencies of a Membrane (Recurrence Method)—J. Hersch. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1475–1478; November 12, 1956.)

534.75 **976**

Auditory Reaction Time as a Function of Frequency of the Signal Tone—M. S. P. Rao and N. A. Nayak. (*Cur. Sci.*, vol. 25, p. 255; August, 1956.) Reaction times of the human ear to tones of frequencies between 600 cps and 15 kc have been studied. For a constant intensity of 30 db there is a minimum reaction time for frequencies in the range 1.5–4 kc; this is also the frequency range over which the sensitivity of the human ear is greatest.

534.75:534.862.3/.4 **977**

An Audio Flutter Weighting Network—F. A. Comerci and E. Oliveros. (*J. Soc. Mot. Pict. Telev. Eng.*, vol. 65, pp. 419–425; August, 1956.) The results of listener tests are compared with flutter-index measurements. The meter used incorporates two automatically switched weighting networks, and is thus able to provide a correct objective assessment of flutter effect under different flutter conditions. See also 2507 of 1955 (Comerci).

621.317.7.029.4:537.54 **978**

Narrow-Band A.F. Noise Generator—Steffen. (See 1197.)

621.395.623.7 **979**

Efficiency and Power Rating of Loudspeakers—R. W. Benson. (IRE TRANS., vol. AU-4, pp. 19–23; January/February, 1956.) For abstract see PROC. IRE, vol. 44, p. 716; May, 1956.

621.395.623.7 **980**

High-Fidelity Loudspeakers: the Performance of Moving-Coil and Electrostatic Transducers—H. J. Leak. (*J. Brit. Inst. Radio Eng.*, vol. 16, pp. 681–693; December, 1956.) The advantages and disadvantages of moving-coil-, ribbon- and electrostatic-type loudspeakers with power-handling capacities of about 10 w are discussed. The advantages of the balanced push-pull e.s. loudspeaker are particularly mentioned.

621.395.623.7+621.395.61]:534.61 **981**

An Automatic Integrator for Determining the Mean Spherical Response of Loudspeakers and Microphones—A. Gee and D. E. L. Shorter. (*B.B.C. Eng. Div. Monographs*, pp. 1956.) Detailed description of apparatus designed for use in conjunction with polar plotting equipment; the necessary integrations are effected simultaneously with the measurement of the polar characteristics. When a loudspeaker is tested it is rotated in front of a stationary microphone; the af output from the microphone is amplified, rectified, and converted by a vibrating interrupter to a fixed frequency of 50 cps, and the resulting signal is applied through separate amplifiers to the voltage and current coils of a specially designed kwh meter, which thus registers a quantity proportional to the rate of energy flow per unit area of wave front.

621.395.625.3 **982**

Magnetic Recording, 1888–1952—C. F. Wilson. (IRE TRANS., vol. AU-4, pp. 53–81; May/June, 1956.) An extensive bibliography including 38 important patents.

ANTENNAS AND TRANSMISSION LINES

621.315.213:621.397.24 **983**

Video-Pair Cable System—S. Aoki, O. Kameda, Y. Yokose, and T. Uchino. (*Rep. Elect. Commun. Lab., Japan*, vol. 4, pp. 20–25; June, 1956.) A cable for a television studio /transmitter link is formed by twisting 1.4-mm foamed-polyethylene-insulated wires and screening the pair with Cu tape. Transfer-constant/frequency and characteristic-impedance/frequency curves are shown. The repeater amplifiers and synchronizing-pulse clamping circuits are discussed briefly.

621.372.2 **984**

Dilemmas in Transmission-Line Theory—R. A. Chipman. (*Electronic Radio Eng.*, vol. 34, pp. 64–67; February, 1957.) Errors due to approximations used in calculations of transmission characteristics of electrically-short lines are calculated and the "optimum" and "proper" line terminations are discussed. Some useful relations between line constants are also given.

621.372.2 **985**

The Wave Impedance Occurring in One Kind of Symmetrical Feed System—K. Bochenek. (*Archiwum Elektrotech*, vol. 5, pp. 135–147. English summary, p. 147; 1956.) The characteristic impedance of a particular symmetrical transmission line is determined by a method involving conformal mapping.

621.372.8+621.372.413 **986**

Ferrite Post in a Rectangular Waveguide—P. S. Epstein and A. D. Berk. (*J. Appl. Phys.*, vol. 27, pp. 1328–1335; November, 1956.) "A thin circular ferrite post magnetized lengthwise is placed in a rectangular waveguide with its axis normal to the direction of propagation of the incident waves. The polarization is such that the electric vector is parallel to the post. The reflected and transmitted waves are calculated both with respect to their intensities and phases. The results are also applied to find the influence of a thin ferrite post upon the resonant frequency of a rectangular cavity."

621.372.8 **987**

On Transient Radiation of a Dipole inside a Waveguide—R. Gajewski. (*Acta Phys. Polon.*, vol. 15, pp. 25–41. In English, 1956.) Exact formulas are given for the em field radiated by a dipole of moment **M** inside a waveguide of arbitrary cross section; the time dependent factor of **M** was taken as $1(t)\,[1-\exp(-pt)]\sin\omega t$, where $1(t)$ is the Heaviside step function.

621.372.8 **988**

Observed 5–6-mm Attenuation for the Circular Electric Wave in Small and Medium-Sized Pipes—A. P. King. (*Bell Sys. Tech. J.*, vol. 35, pp. 1115–1128; September, 1956.) Measurements are reported on two circular-section waveguides, of internal diameter 7/16 inch and 7/8 inch respectively. The attenuation of the TE_{01} mode is considerably less than that of the dominant mode in both cases; transmission losses as low as 0.5 db/100 ft have been attained. For a given line, the frequency variation of attenuation can be reduced by inserting mode filters. Losses due to oxygen absorption are taken into account.

621.372.8:621.384.622.2 **989**

Determination of the Series Impedance and of the Attenuation Length-Constant of a Helical Waveguide for a Linear Proton Accelerator A. Septier. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1748–1750; November 26, 1956.) Continuation of work reported previously (927 and 928 of 1955). Calculated and experimental results are compared. Application of the results to traveling-wave tubes is indicated.

621.396.67 990
Circular-Arc Antennas—S. B. Rao. (*Indian J. Phys.*, vol. 30, pp. 390–406; August, 1956.) General analysis is presented for the radiation from a circular-arc element with current distributed sinusoidally along it. Two symmetrical composite arrangements are studied particularly. Measurements of the radiation patterns of these arrangements are compared with calculated values.

621.396.674.3:550.837 991
The Radiation Resistance of a Dipole Aerial above a Conducting Plane, from the Viewpoint of Geophysical Prospecting—F. Minaw. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1603–1605; November 19, 1956.) Conditions approximating to those for a layer of sand covering a conducting layer of water, *e.g.*, are considered. The periodic variation of the radiation resistance with frequency and with dipole height, due to interference between the direct and reflected fields, is studied. In practical conditions, the atmospheric humidity must be taken into account.

621.396.677.81 992
Effect of Spacing of Vibrators on Resonance and Directional Properties of a System of Vibrators of the "Wave Channel" [Yagi] Type—D. M. Vysokovski. (*Radiotekhnika, Moscow*, vol. 11, pp. 21–25; May, 1956.) Theoretical characteristic curves are given for element spacings of 0.1, 0.2, 0.3 and 0.4λ for Yagi antennas using 1, 2, or 3 director elements.

621.396.677.83 993
The Construction of a Sheet-Reflector Aerial with Conical Radiation Pattern—W. Güth. (*Z. angew. Phys.*, vol. 8, pp. 368–372; August, 1956.) The antenna consists of a flat box with the front partially transparent to em waves and the reflecting back plate carrying a ring of absorption wedges surrounding a small klystron-fed dipole. Useful directivity is obtained; the efficiency is low, but may be improved by making the enclosure a resonator.

621.396.677.833.2 994
A 60-ft-Diameter Parabolic Antenna for Propagation Studies—A. B. Crawford, H. T. Friis, and W. C. Jakes, Jr. (*Bell Sys. Tech. J.*, vol. 35, pp. 1199–1208; September, 1956.) Details are given of a steerable antenna with high gain and narrow beam width, designed for studies of beyond-horizon propagation. The structure comprises 48 aluminium sectors and a central hub 8 feet long, and weighs 5½ tons. Measurements of gain and radiation pattern at 460 mc 3.89 kmc and 9.4 kmc are reported.

621.396.677.85 995
Experimental Investigation of Wavelength Lenses—G. von Trentini. (*Z. angew. Phys.*, vol. 8, pp. 364–368; August, 1956.) Results are given of tests on the beaming of microwaves by means of disks of insulating material arranged transversely along the main path of propagation. Lenses consisting of trolitul or glass disks were tested with three different primary antennas at a wavelength of 3.25 cm. Arrays of loaded wire grids (see also 3483 of 1953) gave similar results, which compare favorably with those obtained from dielectric rod lenses, though side lobes require further reduction.

621.396.677.85 996
A Homogenous Dielectric Sphere as a Microwave Lens—G. Bekefi and G. W. Farnell. (*Canad. J. Phys.*, vol. 34, pp. 790–803; August, 1956.) Analysis based on geometrical optics and on the diffraction theory of optical aberrations indicates that a sphere of not too high refractive index and of diameter not greater than about 30λ has imaging properties suitable for the rapid scanning of a microwave beam through an angle of 360°. Spheres of larger size can be used if the radiation source is designed to eliminate spherical aberration.

AUTOMATIC COMPUTERS

681.142 997
Electronic Computers—(*Onde Élect.*, vol. 36; August/September, 1956.) The main part of this issue is devoted to a group of papers on computers, including the following:

The Principles of Universal Numerical Computers—F. H. Raymond (pp. 709–718).

The Electronic Computer GAMMA, with Magnetic Drum—(pp. 719–726).

The I.B.M. Type-650 Electronic Machine for Scientific Management—J. G. Maisonrouge and J. Montigny (pp. 727–731).

An Automatic Method of Solving Mathematical Problems with an Arithmetic Electronic Computer—L. Gaudfernau (pp. 732–741).

The Problem of Locating the Characteristic Values of Matrices in the Complex Plane and the Criteria of Stability in the Operation of Analog Computers—M. Parodi (pp. 753–761).

Possibilities and Developments of the Method of Rheoelectric Analogs—L. Malavard (pp. 762–769).

A New Computing Method using High-Frequency Currents—H. J. Uffler (pp. 770–779).

The DJINN Analog Computer—J. Girerd and A. Riotte (pp. 780–786).

The "Micro-network": Possible Types of Investigation and Recent Improvements—R. Robert (pp. 787–790).

681.142 998
Industrial Data-Reduction and Analogue-Digital Conversion Equipment—P. Partos. (*J. Brit. Inst. Radio Eng.*, vol. 16, pp. 651–678; December, 1956.)A review of typical system specifications is presented and several existing and proposed installations are described.

681.142 999
Document Processor Reads Coded Dots—R. L. Fortune. (*Electronics*, vol. 29, pp. 164–168; December, 1956.) The equipment described converts information in the form of printed dots into pulse signals for the operation of data-handling equipment.

681.142:512 1000
Solution of Algebraic Equations on an Analogue Computer—C. R. Cahn. (*Rev. Sci. Instr.*, vol. 27, pp. 856–858; October, 1956.) The roots of the equation are found, with an electronic differential analyzer, using a method in which the operator adjusts a gauged potentiometer while observing a transient on a voltmeter or oscilloscope. Factors affecting the accuracy are discussed.

681.142:512.831 1001
Analog Computer Synthesis and Error Matrices—P. M. Honnell and R. E. Horn. (*Commun. and Electronics*, pp. 26–32; March, 1956.) The performance of analog networks is studied by means of matrix analysis; errors and stability are evaluated.

681.142:538.221 1002
High-Speed Coincident-Flux Magnetic Storage Principles—L. P. Hunter and E. W. Bauer. (*J. Appl. Phys.*, vol. 27, pp. 1257–1261; November, 1956.) Random-access magnetic-core storage systems are discussed in which the summation of coincident magnetic fluxes effects switching, the magnitude of the currents inducing the flux not being critical. Flux densities much greater than that corresponding to the coercive field may be used, giving very short switching times.

681.142:621.375.4.018.7:621.314.7 1003
Transistor Pulse Regenerative Amplifiers—Tendick. (See 1034.)

681.142:621.385.832 1004
A Function Multiplier—J. D. N. van Wyk. (*Nature, Lond.*, vol. 178, pp. 1247–1248; December 1, 1956.) A function multiplier for incorporation in an electronic differential analyzer is based on displacing a rectangular area relative to a set of rectangular axes which divide the area, when undeflected, into four equal component rectangles. A cr tube is used, with the operational area formed on the screen by using the deflection plates as a rectangular aperture. Light emitted by the component rectangles passes along perspex lightguides to four separate photomultipliers.

CIRCUITS AND CIRCUIT ELEMENTS

621.316.825 1005
Thermistor Equivalent Circuits and their Application—E. De Castro. (*Piccole Note Ist. super. Poste e Telecommunicazioni*, vol. 5, pp. 481–508; July/August, 1956.) Four basic types of linear network are considered as equivalents to nonlinear temperature-sensitive elements for small changes around a given static condition. The behavior of thermistors used in v.l.f. oscillators and voltage-stabilizing circuits is examined. A systematic study of transients in control circuits containing thermistors is planned.

621.318.3:629.13 1006
Solenoids for Airborne Applications—A. S. Gutman. (*Electronic Radio Eng.*, vol. 34, pp. 42–45; February, 1957.) A formula is derived for the optimum dimensions of a single-turn solenoid, which takes account of weight limitations for the solenoid and associated equipment. The space efficiency of foil-wound coils exceeds that of wire-wound types. Although edge winding results in greater power saving, wafer-type layer windings are preferable because of ease of manufacture.

621.318.4.011.1 1007
Multiple Resonance Frequencies—W. W. Fain. (*Electronic Radio Eng.*, vol. 34, pp. 68–69; February, 1957.) A formula for single-layer coils is derived empirically.

621.318.42:621.385.029.6 1008
The Magnetic Field in Wafer-Type Solenoids—A. S. Gutman. (PROC. IRE, vol. 45, pp. 88–89; January, 1957.) Foil-wound solenoids used for beam focusing in traveling-wave tubes are considered, and an analysis is made of the nonuniformity of the field in the gaps between wafer-type sections.

621.318.57:621.314.7 1009
D.C. Graphical Analysis of Junction-Transistor Flip-Flops—T. R. Bashkow. (*Commun. & Electronics*, no. 23, pp. 1–7; March, 1956.)

621.319.45.002.2 1010
Measurement of the True Surface of a Metal—S. S. Gutin, L. L. Prochakov, and M. G. Serbulenko. (*Zh. Tekh. Fiz.*, vol. 26, pp. 865–869; April, 1956.) A method is proposed for rapid measurement of the surface area of aluminium foil for use in electrolytic capacitors during the electrochemical etching process.

621.37.049.7.002.72:679.5 1011
The Production and Testing of Potted Circuits—T. C. B. Talbot. (*Electronic Eng.*, vol. 28, pp. 512–516; December, 1956.) Method and equipment suitable for small batch production are described and future developments are outlined. Details of special test gear are given.

621.372.012:621.396.822 1012
Influence of Norman Fluctuations on Typical Nonlinear Elements—I. N. Amiantov and V. I. Tikhonov. (*Bull. Acad. Sci. U.R.S.S., Tech. Sci.*, No. 4, pp. 33–41. April, 1956. In Russian.) A method of calculating moments of various orders in the case of normal fluctuations acting on noninertial nonlinear elements is presented. Piecewise linear characteristics are assumed.

621.372.413+621.372.8 1013
Ferrite Post in a Rectangular Waveguide—Epstein and Berk. (See 986.)

621.372.413 1014
Application of the Method of Curvilinear Coordinates to the Design of a Π-Type Resonator—V. L. Patrushev. (*Zh. Tekh. Fiz.*, vol. 26, pp. 821–831; April, 1956.) Extension of analysis presented previously (2385 of 1951) to the general case of a Π-type resonator with a tuning rod of an arbitrary thickness. A numerical example of the design in included.

621.372.413:621.385.029.6 1015
The Excitation of a Cavity Resonator by a Density-Modulated Electron Beam Passing Through the Entire Resonator Cross-Section—P. Szulkin. (*Archiwum Elektrotech.*, vol. 5, pp. 149–208. English summary, pp. 207–208; 1956.) The effect of the modulated beam on the frequency and amplitude of oscillation is analyzed by determining the scalar and vector potentials as functions of the exciting space charges and currents.

621.372.45.011.1 1016
Nonlinear Circuit Equation—J. Irving and N. Mullineux. (*Electronic Radio Eng.*, vol. 34, pp. 53–55; February, 1957.) A perturbation method of solving nonlinear equations is described and checked by numerical integration; it is more generally applicable than the analysis given by Liebetegger (687 of 1956).

621.372.5 1017
Delay Unit with Computing Amplifiers and Capacitors—Ya. I. Grinya and P. N. Kopai-Gora. (*Avtomatika i Telemekhanika*, vol. 17, pp. 524–531; June, 1956.) A delay unit using a capacitor storage system is described. The delay of signals in the frequency range 0.05–0.5 cps is variable between 0.1 and 20 sec.

621.372.5:621.3.018.75 1018
The Design of Pulse Systems based on the Method of Moments—R. Kulikowski. (*Archiwum Elektrotech.*, vol. 5, pp. 69–80. English summary, pp. 79–80; 1956.) A method of analysis is presented based on the relation between the transient and the steady-state response of a network. An expression is derived for the steady-state amplitude characteristic corresponding to minimum rise time for the transient. An amplifier and a differentiating circuit are treated as examples.

621.372.51 1019
Network Matching Problems—J. Deignan. (*Electronic Radio Eng.*, vol. 34, pp. 70–73; February, 1957.) A graphical method for solving problems involving impedances in parallel is described with numerical examples.

621.372.542.2 1020
The Properties and the Problem of Realization of the Fundamental Transfer Functions of a Low-Pass Network—J. Dörr. (*Nachrichtentech. Z.*, vol. 9, pp. 356–364; August, 1956.) Special and general transfer functions for the calculation of transient response are derived mathematically. The conversion into practical circuit elements is achieved by approximation with the aid of fractional rational functions in the lower half of the complex plane. A reasonably close approximation produces a response virtually identical with the transfer function.

621.372.543.2:621.396.6 1021
Survey of Mechanical Filters and their Applications—J. C. Hathaway and D. F. Babcock. (Proc. IRE, vol. 45, pp. 5–16; January, 1957.)

621.372.63:621.317.74 1022
Coupled High-Frequency Transmission Lines as Directional Couplers—H. Wolf. (*Nachrichtentech. Z.*, vol. 9, pp. 375–382; August, 1956.) The 8-terminal network formed by two coupled lines is analyzed using scattering matrices, which leads to a clear expression of the directional properties of the system. Formulas are derived for the application of the network as a reflectometer and performance estimates are compared with experimental results.

621.375+621.375.9]:538.561.029.6 1023
Proposal for a New Type Solid-State Maser—Bloembergen. (See 1062.)

621.373:538.567:621.396.822 1024
Shape of the Spectral Line of an Oscillator with Fluctuating Frequency—A. N. Malakhov. (*Zh. Eksp. teor. Fiz.*, vol. 30, pp. 884–888; May, 1956.) Both "natural" and "technical" fluctuations are considered; the former include thermal and shot noise, the latter microphony in a tube oscillator.

621.373.42:621.396.822 1025
Effect of Slope Fluctuations on the Sensitivity of Oscillators—M. Buyle-Bodin. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1618–1621; November 19, 1956.) Discussion of noise in oscillators operating at frequencies near lower-cutoff, due to variations of tube slope associated with flicker variations of current.

621.373.43:513.83 1026
Topological Analysis Methods for the Solution of Nonlinear Differential Equations. Application to Oscillators used in Radio Equipment—Hontoy and Janssens. (See 1179.)

621.373.5+621.375.4]:621.314.7:621.311 1027
Application of Germanium Triodes in Equipment for the Protection, Telemechanics and Communication Channels of Power Systems—G. K. Martynov and V. V. Pavlov. (*Avtomatika i Telemekhanika*, vol. 17, pp. 570–580; June, 1956.) Characteristics and circuit diagrams are given of a multistage af amplifier, oscillator, and multivibrator. The characteristics of 12 Russian junction-type and nine point-contact transistors are tabulated.

621.374.4:621.373 1028
Even-Order Subharmonic Oscillations—W. J. Cunningham. (*J. Appl. Phys.*, vol. 27, pp. 1374–1375; November, 1956.) "The generation of an even-order subharmonic, or harmonic, oscillation in a driven nonlinear resonant system described by just a cubic nonlinear term requires the simultaneous appearance of a zero-frequency component. This component effectively introduces a squared nonlinear term. A simple experiment with an electrical circuit is described, showing the presence of the zero-frequency component."

621.375.132 1029
Resistance-Capacitance Tuned Amplifiers using Negative Feedback—D. J. O'Connor. (*Electronic Eng.*, vol. 28, pp. 536–539; December, 1956.) A design procedure is outlined for circuits with predicted performance.

621.375.2.029.3 1030
Output Transformerless Amplifiers—(*Wireless World*, vol. 63, pp. 58–62; February, 1957.) A review with 13 references.

621.375.3 1031
Characteristics of Magnetic Amplifiers with Feedback—N. M. Tishchenko. (*Avtomatika i Telemekhanika*, vol. 17, pp. 532–539; June, 1956.) Approximate formulas are derived.

621.375.3 1032
The Operation of the Self-Balancing Magnetic Amplifier—A. D. Krall and E. T. Hooper. (*Commun. and Electronics*, no. 23, pp. 79–84; March, 1956.) Analysis explaining the operation of the circuit is presented.

621.375.4.018.7:621.314.7:621.394:621.376.56 1033
Transistorized Binary Pulse Regenerator—Wrathall. (See 1228.)

621.375.4.018.7:621.314.7:681.142 1034
Transistor Pulse Regenerative Amplifiers—F. H. Tendick, Jr. (*Bell Syst. Tech. J.*, vol. 35, pp. 1085–1114; September, 1956.) Design techniques are presented for synchronized regenerative amplifiers operating at a pulse repetition rate of the order of 1 mc and suitable for use in digital computers.

621.375.422:621.314.7 1035
Temperature Stability of Transistor Amplifiers—G. Stuart-Monteith. (*Electronic Eng.*, vol. 28, pp. 544–547; December, 1956.) An analysis of the general form of dc amplifier leads to the definition of a "figure of merit" for expressing the stability and gain characteristics of the circuit. Multistage dc coupled amplifiers are also considered.

621.375.9:538.569.4.029.6 1036
Quantum-Mechanical Amplifiers—M. W. P. Strandberg. (Proc. IRE, vol. 45, pp. 92–93; January, 1957.) Possible alternatives to the molecular-beam amplifier [see *e.g.*, 403 of 1956 (Gordon *et al.*)] are discussed; systems involving interaction between protons or electron spins and magnetic fields are given as examples. Noise-free amplifiers for any frequencies should be attainable.

GENERAL PHYSICS

53.05:519.24 1037
The Analysis of Experimental Results by the Method of Least Inaccuracy or by the Method of Least Squares—P. Vernotte. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1733–1734; November 26, 1956.)

53.087/.088 1038
Optimum Smoothing of Two-Dimensional Fields—P. D. Thompson. (*Tellus*, vol. 8, pp. 384–393; August, 1956.) "The problem of smoothing out nonsystematic errors in a two-dimensional field of measurements has been studied from the standpoint of finding the type of weighted area average for which the rms difference between the true field and the weighted average of the field of observations is the least. For fields whose space-autocorrelation functions are invariant with rotation and have a simple and rather typical form, the optimum weighting function is a linear combination of Bessel functions, whose rate of decrease away from the origin depends partially on the so-called "signal/noise" ratio, but primarily on the ratio of the scales of the true field and error field. A comparison of optimum averaging with the analyst's subjective process of smoothing indicates that the former is significantly superior in its ability to distinguish between random small-scale fluctuations and minor synoptic features of only slightly greater scale." The discussion is conducted with particular reference to weather prediction.

534.2:537.3 1039
Acoustodynamic Effects in Semiconductors—G. Weinreich. (*Phys. Rev.*, vol. 104, pp. 321–324; October 15, 1956.) Effects resulting from

the interaction between charge carriers and acoustic waves, first discussed by Parmenter (2281 of 1953) are further analyzed.

535.215:537.311.33 1040

Exciton Structure of Spectral Curves of the Internal Photoelectric Effect in Crystals—E. F. Gross, A. A. Kaplyanski, and B. V. Novikov. (*C.R. Acad. Sci. U.R.S.S.*, vol. 110, pp. 761–764; October 11, 1956. In Russian.) MgI_2 and CdS crystals are considered.

537:22 1041

General Problem of the Charge Acquired by a Spherical Particle in an Electric Field associated with Positive and Negative Ions—M. Pauthenier, R. Cochet, and J. Dupuy. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1606–1608; November 19, 1956.) Analysis shows that there is a limiting value to the charge acquired by the particle.

537.221 1042

Electrostatic Charge Separation at Metal/Insulator Contacts—P. E. Wagner. (*J. Appl. Phys.*, vol. 27, pp. 1300–1310; November, 1956.) Experiments continuing those of Peterson (3516 of 1954) were made with the object of clarifying the effective contact potential mechanism. Insulators used were quartz, Al_2O_3, MgO, NaCl, KCl, KBr and KI; metals used were Ni, Cu, and Pt.

537.311.1:061.3 1043

Electron Transport in Metals and Solids—J. M. Ziman. (*Nature, Lond.*, vol. 178, pp. 1216–1217; December 1, 1956.) Brief report of an international conference held in Ottawa in September, 1956. A full account is to be published as a special number of *Canad. J. Phys.*

537.311.62 1044

Matrix Theory of Skin Effect in Laminations—L. A. Pipes. (*J. Franklin Inst.*, vol. 262, pp. 127–138; August, 1956.) A simplified method for calculating the field and current distribution in composite slabs is presented; matrix multiplication is used.

537.312.62:538.569.4 1045

Transmission of Superconducting Films at Millimetre-Microwave and Far-Infrared Frequencies—R. E. Glover, III, and M. Tinkham. (*Phys. Rev.*, vol. 104, pp. 844–845; November 1, 1956.) A note of measurements made on evaporated films of Pb of thickness ~20 Å and Sn~100 Å.

537.523 1046

Temporal Growth of Ionization in Gases—G. G. Morgan. (*Phys. Rev.*, vol. 104, pp. 566–571; November 1, 1956.) Rate of current growth in a uniform electric field E in hydrogen at pressure p was measured over a wide range of E/p between 50 and 400 v/cm per mm Hg. Comparison of experimental with analytical data shows a change in the relative importance of secondary processes as E/p changed. For low values of E/p (~50) the predominant secondary process was photoelectric emission from the cathode; at high values (~300) 50 per cent of the emission was due to the incidence of positive ions.

537.523 1047

Microwave Studies of the Electron Loss Processes in Gaseous Discharges—R. F. Whitmer. (*Phys. Rev.*, vol. 104, pp. 572–575; November 1, 1956.) Electron loss processes in pure hydrogen have been studied by measuring the phase change and attenuation of microwave signals transmitted through a discharge. For electron densities of 5×10^{10} cm^{-3} the electron ion recombination coefficient was $\sim5.9\times10^{-11}$ cm^{-3} sec^{-1}. The dominant loss process was attachment.

537.533/.534 1048

The Desorption of Positive and Negative Ions due to Strong Electric Fields—F. Kirchner and H. A. Ritter. (*Z. Naturf.*, vol. 11a, pp. 35–37; January, 1956.) Continuation of work reported previously [1360 of 1956 (Kirchner and Kirchner)]. Observations of field-type electron emission from evaporated films of KCl on W points indicate that positive K ions can be pulled off by positive fields and negative Cl ions by negative fields when the thickness of the film is greater than that corresponding to minimum work function; the effective work function for electrons is increased in the first case and decreased in the second. With the thinnest possible films, only positive ions could be pulled off at the field strengths used.

537.533 1049

The Emission of Electrons during Crystallization—G. Bathow and H. Gobrecht. (*Z. Phys.*, vol. 146, pp. 1–8; August 16, 1956.) Investigations of some metals failed to reveal an increase in emission associated with the crystallization process. Increases noted under certain conditions may be due to the liberation of gases when the sample solidifies.

537.533 1050

Higher-Order Corrections to the Field Emission Current Formula—P. H. Cutler and R. H. Good, Jr. (*Phys. Rev.*, vol. 104, p. 308; October 15, 1956.) Approximations involved in analysis presented by Murphy and Good (3694 of 1956) are discussed quantitatively.

537.533 1051

Origin of the Characteristic Energy Losses of Electrons in Solids—E. J. Sternglass. (*Nature, Lond.*, vol. 178, pp. 1387–1389; December 22, 1956.) An explanation is outlined in terms of individual atomic ionization and excitation processes according to the Bohr-Bethe theory.

537.533/.534 1052

Auger Ejection of Electrons from Tungsten by Noble Gas Ions—H. D. Hagstrum. (*Phys. Rev.*, vol. 104, pp. 317–318; October 15, 1956.) Results of a previous study (681 and 682 of 1955) were subsequently found to include an effect due to a small proportion of the ions being in metastable states. Data are here presented on the yield and kinetic-energy distribution of electrons ejected by normal singly charged ions only. In a separate paper (*ibid.*, pp. 309–316) it is shown that ions in metastable states can be detected by their greater ability to eject electrons from a metal surface.

537.533:537.534.8 1053

Auger Ejection of Electrons from Molybdenum by Noble Gas Ions—H. D. Hagstrum. (*Phys. Rev.*, vol. 104, pp. 672–683; November 1, 1956.) Basic measurements of electron yield and energy distribution of ejected electrons have been made for ions in the range 10–1000 kev.

537.533.8 1054

The Distortion of Secondary-Emission Voltage/Current Characteristics in the Region of Positive Potential on the Collector—N. B. Gornyi. (*Zh. Tekh. Fiz.*, vol. 26, pp. 723–725; April, 1956.) A discussion of the previously observed effect that secondary-emission current increases as the collector potential is increased from zero to small positive values. The usual explanations (effect of space charges, of electrons with "insufficient" energy) are regarded as unsatisfactory, and it is suggested that this phenomenon is due to emission of tertiary electrons from the collector.

537.56:523.165 1055

Energy Loss of a Charged Particle Traversing Ionized Gas and Injection Energies of Cosmic Rays—S. Hayakawa and K. Kitao. (*Progr. Theor. Phys.*, vol. 16, pp. 139–148; August, 1956.) The energy loss is calculated taking into account direct collisions with free electrons and plasma excitation. The loss increases with the degree of ionization.

537.56:538.56 1056

Theory of Wave Motion of an Electron Plasma—A. I. Akhiezer and R. V. Polovin. (*Zh. Eksp. Teor. Fiz.*, vol. 30, pp. 195–928; May, 1956.) A theoretical investigation of nonlinear wave motion of an electron plasma with arbitrary electron velocities is reported. The plasma temperature is assumed to be zero and the state of the plasma is described by the particle density given as a function of position and time. The frequency characteristics of longitudinal and nonlinear transverse plasma oscillations are calculated and relations are obtained for complex coupled transverse-longitudinal oscillations.

537.56:538.6 1057

Experimental Study of Ionized Matter Projected Across a Magnetic Field—W. H. Bostick. (*Phys. Rev.*, vol. 104, pp. 292–299; October 15, 1956.) A gun has been developed which is capable of emitting pulses of plasma comprising electrons and metallic and deuterium ions at speeds up to 2×10^7 cm. Experimental evidence indicates that the plasma comes away in the form of expanding toroidal entities (termed "plasmoids") which are shaped by their own magnetic field. Characteristic configurations and interactions of such plasmoids in an external magnetic field are discussed; photographs are reproduced showing structures rather like smoke rings at various stages.

538.3 1058

The Concept of the Infinitely Thin Infinitely Conducting Screen—P. Poincelot. (*C. R. Acad. Sci., Paris*, vol. 243, pp. 1616–1618; November 19, 1956.) The importance in em theory of the particular method chosen for proceeding to the limit of the infinitely thin infinitely conducting screen is indicated. A simple formula for Babinet's principle is given which is not based on the concept of magnetic currents; this is developed more fully in a separate paper (*ibid.*, vol. 243, pp. 1743–1745; November 26, 1956.)

538.3 1059

Electromagnetic Field Solutions for Rotational Coordinate Systems—R. C. Hanson. (*Canad. J. Phys.*, vol. 34, pp. 893–895; August, 1956.) The vector-potential approach is used.

538.3:531.19 1060

Statistical Mechanics of Matter in an Electromagnetic Field: Part 2—On Pressure and Ponderomotive Force in a Dielectric.—P. Mazur and S. R. de Groot. (*Physica*, vol. 22, pp. 657–669; August, 1956.) Ambiguity in the definitions of ponderomotive force and pressure is elucidated on the basis of a derivation of these quantities from the known microscopic interactions between the constituent particles of the system. Part 1: 1390 of 1954 (Mazur and Nijboer).

538.521 1061

Shielding of a Transient Electromagnetic Dipole Field by a Conducting Sheet—J. R. Wait. (*Canad. J. Phys.*, vol. 34, pp. 890–893; August, 1956.) Analysis presented previously for the shielding provided in the steady state (119 of 1954) is extended to apply to the case of a transient field.

538.561.029.6:[621.373+621.375.9 1062

Proposal for a New Type Solid-State Maser—N. Bloembergen. (*Phys. Rev.*, vol. 104, pp. 324–327; October 15, 1956.) "The Overhauser effect (*Phys. Rev.*, vol. 92, pp. 411–415;

October 15, 1953.) may be used in the spin multiplet of certain paramagnetic ions to obtain a negative absorption or stimulated emission at microwave frequencies. The use of nickel fluosilicate or gadolinium ethyl sulphate at liquid helium temperature is suggested to obtain a low noise microwave amplifier or frequency converter. The operation of a solid state maser based on this principle is discussed."

538.566 1063
The Estimation of Kottler's Correction Factors—S. Pogorzelski. (*Archiwum Elektrotech.*, vol. 5, pp. 81–106. English summary, pp. 104–106; 1956.) Methods of calculating the em field in a homogeneous dielectric from the field distribution on a surface enclosing the sources is discussed; an evaluation is made of the correction factors representing the difference between values given by Kottler's method and those given by the Kirchhoff and Larmor-Tedone methods. The relevance of the discussion to antenna calculations is indicated.

538.566 1064
Wide-band Resonance Absorber for Centimetre Electromagnetic Waves—H. J. Schmitt. (*Z. Angew. Phys.*, vol. 8, pp. 372–382; August, 1956.) The absorber described consists of a regular grid of lossy dipoles at a distance of $\lambda/4$ in front of a metal surface. By selecting suitable materials and spacings, an effective bandwidth of half an octave is obtained for the waveband around 3 cm. The addition of a second grid rotated by 90° with respect to the first makes the absorption independent of the polarization angle of the incident wave.

538.566:535.43 1065
The Scattering of Electromagnetic Waves by Conducting Spheres and Disks—J. S. Hey, G. S. Stewart, J. T. Pinson, and P. E. V. Prince. (*Proc. Phys. Soc.*, vol. 69, pp. 1038–1049; October 1, 1956.) "A laboratory method is described for measuring the returned signal scattered from an object in an electromagnetic field. Measurements on conducting spheres and discs are compared with theoretical formulas. A new computation of the scattering function for conducting spheres is tabulated."

538.566:537.56:621.385.029.6 1066
Growing Electric Space-Charge Waves—J. R. Pierce and L. R. Walker. (*Phys. Rev.*, vol. 104, pp. 306–307; October 15, 1956.) Discussion of theory developed by Piddington (2258 of 1956), with particular reference to traveling-wave and related types of tubes.

538.569.4 1067
Radiation Damping and Resonance Shapes in High-Resolution Nuclear Magnetic Resonance—C. R. Bruce, R. E. Norberg, and G. E. Pake. (*Phys. Rev.*, vol. 104, pp. 419–420; October 15, 1956.) " An analysis of a nuclear spin-resonant circuit system shows that the electric circuit parameters rather than the nuclear spin relaxation times may determine resonance widths, maximum signal, and integrated intensities in high-resolution continuous-wave nuclear magnetic resonance."

538.569.4:537.312.62 1068
Nuclear Magnetic Resonance in a Superconductor—W. D. Knight, G. M. Androes, and R. H. Hammond. (*Phys. Rev.*, vol. 104, pp. 852–853; November 1, 1956.) Discussion of the nuclear magnetic resonance observed in colloidal Hg above and below the transition temperature, 4.15°K.

539.15.098 1069
Spectral Diffusion in Magnetic Resonance—A. M. Portis. (*Phys. Rev.*, vol. 104, pp. 584–588.) "Electron spin-spin interaction is discussed for the case of strong hyperfine broadening."

539.15.098:538.569.4 1070
Sample Spinning and Field Modulation Effects in Nuclear Magnetic Resonance—G. A. Williams and H. S. Gutowsky. (*Phys. Rev.* vol. 104, pp. 278–283; October 15, 1956.)

539.153:548:538.63 1071
Energy Spectrum of an Electron in a Crystal in a Magnetic Field—G. E. Zil'berman. (*Zh. Eksp. Teor. Fiz.*, vol. 30, pp. 1092–1097; June, 1956.)

530.1 1072
Modern Physics. A Textbook for Engineers. [Book Review]—R. L. Sproull. John Wiley and Sons, New York, and Chapman and Hall, London, 1956, 491 pp., (*Nature, Lond.*, vol. 178, pp. 1420–1421; December 29, 1956.) Aims at supplying the theoretical background for engineers grounded in wave propagation and communication theory. Analogies between macroscopic properties of em waves and the behavior of wave functions are indicated. Numerical exercises are included.

537.533 1073
Elektronik des Einzelektrons. [Book Review]—F. Ollendorff. Springer, Vienna, 643 pp., 1955. (*Acta Phys. Austriaca*, vol. 10, pp. 303–304; August, 1956.) An authoritative work on fundamental electronic theory.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 1074
Radio Emission from the Extragalactic Nebula M87—J. E. Baldwin and F. C. Smith. (*Observatory*, vol. 76, pp. 141–144; August, 1956.) Results of interferometer measurements made at a frequency of 100 mc using antenna spacings between 3λ and 157λ indicate that the source previously observed by Mills (1754 of 1954) is surrounded by a halo.

523.7:538.12 1075
The Sun's General Magnetic Field—H. Alfvén and B. Lehnert. (*Nature, Lond.*, vol. 178, p. 1339; December 15, 1956.) Continuation of discussion noted previously [110 of 1957 (Babcock)].

523.7:538.12.082 1076
A Solar Magnetograph—D. W. Beggs and H. von Klüber. (*Nature, Lond.*, vol. 178, p. 1412; December 22, 1956.) A note on the technique of use and some observations made with the photoelectric magnetometer newly installed at Cambridge, England.

523.75:550.385 1077
The Time Interval between Chromospheric Eruptions and Geomagnetic Perturbations—O. Sipahioglu. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1427–1430; November 5, 1956.) An analysis of records for the period 1939–1954 indicates that the characteristic distribution of time lag is very different for geomagnetic storms from that for isolated impulses; for the latter class of perturbation the most frequently occurring value of time lag is 25–30 h.

55:621.396.934 1078
Electronics in the I.G.Y. Program—D. A. Findlay. (*Electronics*, vol. 29, pp. 138–142; December, 1956.) Details of the satellite tracking transmitter and the measuring and telemetering systems are summarized. See also 2718 of 1956.

550.385 1079
The Diurnal Behaviour of Sudden Commencements of Magnetic Storms at Agincourt [Canada]—J. A. Jacobs and T. Obayashi. (*Canad. J. Phys.*, vol. 34, pp. 876–883; August, 1956.) Analysis of data obtained during the period 1946–1953. The results suggest that the diurnal control of the magnetic variation must be due to some additional field produced in the earth's upper atmosphere at the time of sudden commencement, tending to modify the primary cause.

551.510.535 1080
Horizontal Wind Systems in the Ionospheric E Region Deduced from the Dynamo Theory of the Geomagnetic Sq Variation—(*J. Geomag. Geoelect.*, vol. 7, pp. 121–132; December, 1955, and vol. 8, pp. 24–37; March, 1956.)
Part 1—Nonrotating Earth—H. Maeda.
Part 2—Rotating Earth—S. Kato.
It is shown that the diurnal variation of the wind velocity in the ionosphere dominates the semidiurnal variation in its influence on quiet-day magnetic variations. The semidiurnal component is nearly in phase with that of winds on the ground, and its tidal amplification is estimated as about 50 for the nonrotating earth and 25–30 for the rotating earth. Estimates of the vertical drift velocities in the F region are derived.

551.510.535:621.396.11 1081
Influence of Radio Waves on the Properties of a Plasma (Ionosphere)—A. V. Gurevich. (*Zh. Eksp. Teor. Fiz.*, vol. 40, pp. 1112–1124; June, 1956.) A method is developed of determining the electron velocity distribution function for a plasma in the presence of both an alternating electric and a constant magnetic field, assuming elastic collisions between the electrons and the molecules and ions. Expressions are derived for the mean electron energy, the conductivity and the permittivity of the plasma and the effective number of electron collisions.

551.594.6 1082
Noise Radiation from Tropical Thunderstorms in the Standard Broadcast Band—S. V. C. Aiya. (*Nature, Lond.*, vol. 178, p. 1249; December 1, 1956.) Results of measurements made at Poona of the power radiated by atmospherics at frequencies of 620 and 930 kc indicate values lower than those derived from the formula presented previously (3263 of 1955). Further examination of the data indicates that radiation at frequencies <1 mc is contributed only by the stepped leaders of discharges to the ground; a modified formula is derived consistent with these findings.

551.594.6:621.396.821 1083
Measured Statistical Characteristics of V.L.F. Atmospheric Radio Noise—A. D. Watt and E. L. Maxwell. (Proc. IRE, vol. 45, pp. 55–62; January, 1957.) Equipment for measuring the amplitudes and timing of atmospheric noise pulses is described. The greatest variation in average power level observed in a region of America between latitudes 9° and 71°N during the autumn of 1955 was about 46 db, using a receiver bandwidth of about 1 kc around 22 kc. The dynamic range of the instantaneous noise envelope, defined as the ratio of the field strength exceeded during 0.0001 per cent of the time to that exceeded during 90 per cent of the time, varied from 59 to 102 db for 66 measurement periods of 20–30 min; the average dynamic range in the arctic region was 68 db, and in the tropics 81 db. The change in the dynamic range with reduction in the receiver bandwidth is discussed.

LOCATION AND AIDS TO NAVIGATION

621.396.93 1084
The Effect of Ground Inhomogeneities on the Calibration of Direction Finders—J. Grosskopf and K. Vogt. (*Nachrichtentech. Z.*, vol. 9, pp. 349–355; August, 1956.) Investigations show that the maximum bearing error on

medium and short waves due to local ground conductivity variations of up to 1:10 is unlikely to exceed 2°; this figure may be increased by re-radiation. To forecast the azimuthal error in the df signal from conductivity measurements is only possible where the distribution of ground conductivity values follows a simple pattern.

621.396.96 1085

Marine Radar Equipment—(*Engineer, Lond.*, vol. 202, p. 239; August 17, 1956.) Description of commercially available equipment intended for craft where size and weight must be kept low. The minimum range is 35 yards or less and the maximum range 48 miles. The antenna system is a 60-foot end-fed slotted waveguide in which the slots are set at different angles in order to reduce side lobes. The transmitter operates at a frequency of 9.32–9.5 kmc and uses a 60-kw magnetron with a pulse repetition rate of 1100 per sec. A 9-inch cr tube is used for the ppi display.

621.396.96 1086

Radar Performance Nomograph—E. A. Wolff. (*Electronics*, vol. 29, p. 182; December, 1956.) A nomogram is presented for determining the performance of a pulsed radar system in terms of the percentage of rated range available for a given target area from the pulse parameters and the minimum detectable signal.

621.396.96:621.32 1087

The Illumination of Rooms used for Radar Screen Monitoring—K. Ohlsen. (*Elektronische Rundschau*, vol. 10, p. 200; July, 1956.) The lamp described produces white illumination from a combination of red, green and blue light, to avoid the excitation of afterglow screens by yellow light.

621.396.963.325:621.385.832 1088

Storage Tube projects Radar P.P.I. Display—Gates (See 1288.)

621.396.969:551.57 1089

Radar-Scope Interpretations of Wind, Hail, and Heavy Rain Storms between May 27 and June 8, 1954—G. E. Stout and H. W. Hiser. (*Bull. Amer. Met. Soc.*, vol. 36, pp. 519–527; December, 1955.) From a detailed study of field data and radar observations it appears that in many cases radar can give additional information useful in short-range weather forecasting.

621.396.969.3 1090

On the Mechanisms of Radar Sea Clutter—M. Katzin. (Proc. IRE, vol. 45, pp. 44–45; January, 1957.) Discussion of observations indicates that the scattering elements of the sea surface are illuminated indirectly by reflection from neighboring elements, as well as directly. At small depression angles, destructive interference occurs, giving rise to the so-called critical angle, polarization dependence, "spikiness" in the A-scope display, and steeper frequency dependence. Theory is developed relating the frequency dependence of the scattering to the size and slope distribution of the elementary surface facets.

MATERIALS AND SUBSIDIARY TECHNIQUES

533.5 1091

High-Vacuum Seals Suitable for Baking Out—M. J. Higatsberger. (*Acta Phys. Austriaca*, vol. 10, pp. 181–185; August, 1956.)

533.5 1092

A Simple Vacuum Leak Detector using a Radio-Frequency Mass Spectrometer—P. F. Váradi and L. G. Sebestyén. (*J. Sci. Instr.*, vol. 33, pp. 392–394; October, 1956.)

535.215:537.29 1093

Photoelectric Work Function from Analysis of Emission in an Accelerating Field—P. E. Carroll. (*Phys. Rev.*, vol. 104, pp. 660–661; November 1, 1956.) "A plot of I *vs* $E^{1/2}$ gives a straight line for incident light a few tenths of an Ve from the threshold. The ratio of the zero-field intercept to the slope of this line is directly proportional to $h(\nu-\nu_0)$ and is independent of the intensity of the incident light. The work function can be determined from this ratio for both metallic and semiconducting emitters." The work function of Te determined by this method from data of Apker *et al.* (1908 of 1949) is 4.78 ev.

535.215:546.472.21 1094

Potential Distribution and Localized Photo-effects in Zinc Sulphide Single Crystals—A. Lempicki. (*J. Opt. Soc. Amer.*, vol. 46, pp. 611–614; August, 1956.) Potential distributions have been measured and correlated with photoconductive regions found by light-scanning experiments. Crystals having uniform potential distributions have peak photosensitivity in the middle. An interpretation of the results based on nonuniform absorption of light is proposed.

535.215:546.482.21 1095

The Structure of the Spectral Curve of the Internal Photoeffect in Cadmium Sulphide Crystals—E. F. Gross, A. A. Kaplyanski, and B. V. Novikov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 913–916; April, 1956.) Experimental results indicate that the photoeffect in CdS crystals is due to the optical excitation of excitons.

535.215:546.482.21:621.396.822 1096

Measurements of Noise and Response to Modulated Light of Cadmium Sulphide Single Crystals—K. M. van Vliet, J. Blok, C. Ris, and J. Steketee. (*Physica*, vol. 22, pp. 723–740; August, 1956.) The noise of photoconducting single crystals of Ag-activated and undoped CdS has been investigated in the frequency range 1 cps–2 mc. The observed noise spectra are not of inverse-frequency type; they differ according as the irradiation is in the fundamental absorption band or beyond the absorption limit. The observed response to light modulated at frequencies in the range 7 cps–10 kc indicates that a large part of the noise is photo-induced. The remainder of the noise is ascribed to fluctuations in the rates of recombination and trapping. See also 3796 of 1956 (van Vliet and Blok).

535.37 1097

Some Optical and Electrical Measurements on Blue-Fluorescent ZnS-Cl Single Crystals—F. A. Kröger. (*Physica*, vol. 22, pp. 637–643; August, 1956.)

535.37 1098

The Luminescent Response of Silver-Activated Zinc Sulphide to Lithium Ions of Different Energies—C. F. Eve and H. E. Duckworth. (*Canad. J. Phys.*, vol. 34, pp. 896–897; August, 1956.) The work of Stanle and Rau (734 of 1953) is extended to include Li^+ ions of energy 15–40 kev.

535.37:535.215 1099

The Photoconductivity of Phosphors with Different Luminescence Mechanisms: Part 2—H. Gobrecht, D. Hahn, and H. J. Kösel. (*Z. Phys.*, vol. 146, pp. 87–94; August 16, 1956.) Previous investigations (1437 of 1954) were continued for a further 30 powder phosphors, using improved apparatus. Photocurrents and dark currents are tabulated. The importance of conductivity investigations in relation to electroluminescence is emphasized.

535.37:535.215 1100

The Temperature Dependence of the Dark Current and Photocurrent of Phosphors—H. Gobrecht, D. Hahn, and H. J. Kösel. (*Z. Phys.*, vol. 146, pp. 95–106; August 16, 1956.) In continuation of previous work (1776 of 1954) further powders were investigated at temperatures up to about 270°C. Photocurrent characteristics differed according to the mechanism of luminescence and no saturation was noted in recombination phosphors. Plotted "conductivity-glow" curves show the trap distribution, and the spectral distribution of photocurrent excitation is examined in terms of temperature and field strength.

537.226/.228.1 1101

Ferroelectric Materials—P. Popper. (*J. Inst. Elect. Eng.*, vol. 2, pp. 450–457; August, 1956.) A short review describing the basic physical properties and indicating possible applications of ferroelectric materials, particularly $BaTiO_3$.

537.226/.228.1 1102

A Calculation of Physical Constants of Ceramic Barium Titanate—M. Marutake. (*J. phys. Soc. Japan*, vol. 11, pp. 807–814; August, 1956.) The dielectric, piezoelectric, and elastic constants of polycrystalline material are calculated on the assumption that it is composed of spherical crystallites. The calculated values are in good agreement with experimentally determined values. The "de-stressing factor," expressing the relations between the internal stress of the sphere and the stress in the surrounding medium, is defined and calculated.

537.226 1103

New Non-ferroelectric Dielectrics with High Dielectric Constant and Low Conductivity—G. I. Skanavi and E. N. Matveeva. (*Zh. Eksp. Teor. Fiz.*, vol. 30, pp. 1047–1051; June, 1956.) The combination of an internal field favoring polarization with relaxation ionic polarization results in a high dielectric constant without spontaneous polarization or other ferroelectric properties. This is the case in strontium titanate containing a small amount of bismuth trioxide; experimentally determined ϵ/temperature and tan δ/temperature characteristics at frequencies between 5 kc and 10 mc and log $\rho/(1/T)$ curves are presented, as well as curves showing the relation between the temperatures of two electrodes in a specimen, the current between them and time. At room temperature $\epsilon \simeq 800$ and varies only slightly with frequency. Other materials of this class are (Ca, Bi) titanate and (Ba, Bi) titanate.

537.226.2/.31 1104

Permittivity and Loss Angle of some Solid Dielectrics at a Wavelength of 3 cm and their Dependence on Temperature and Frequency—G. I. Skanavi and G. A. Lipaeva. (*Zh. Eksp. Teor. Fiz.*, vol. 30, pp. 824–832; May, 1956.) Experimental results are reported. The frequency and temperature dependence of ϵ and tan δ are presented graphically and the values of ϵ and tan δ at 3.1 cmλ are tabulated for materials including steatite, barium tetratitanate, the titanates of Mg, Zn, Ca, Bi and Sr and porcelain. The graphs cover a frequency range from l.f. to 10^{10} cps and a temperature range from about 20° to 160°C.

537.227 1105

Ferroelectricity of Glycine Sulphate—B. T. Matthias, C. E. Miller, and J. P. Remeika. (*Phys. Rev.*, vol. 104, pp. 849–850; November 1, 1956.) Glycine sulphate and its isomorphous selenate are ferroelectric, with Curie points 47°C and 22°C respectively. For glycine sulphate at room temperature the spontaneous polarization is 2.2×10^{-6} coul/cm² and the coercive field is 220 V/cm. A formal similarity among ferroelectric sulphates regardless of crystal structure is suggested.

537.311.31+537.311.33 1106

Pictorial Kinetic Methods in the Theory of Metals and Semiconductors—R. B. Dingle.

(*Physica*, vol. 22, pp. 671–680; August, 1956.) The "pictorial kinetic method" of treating electron transport problems is based on calculations of the average drift velocity in the direction of the applied field. The importance of the particular method used for superposing the drift velocity on the distribution function corresponding to the absence of applied field is demonstrated. Relations valid for semiconductors are derived by averaging over the transport distribution function the corresponding relations for metals.

537.311.31:539.234:538.63 1107

Influence of a Magnetic Field on the Electrical Resistance of Thin Films of Nickel—T. Rappeneau. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1403–1406; November 5, 1956.) Measurements have been made on evaporated films at normal temperature. With medium-strength fields (up to 500 oersted) the resistance decreases when the magnetization is perpendicular to the current and increases when the magnetization is parallel to the current; hysteresis effects are exhibited. With high-strength fields (1000–6000 oersted) the resistance decreases slightly with magnetization in either direction.

537.311.31:546.56:537.533 1108

Electron Irradiation of Copper below 10°K—J. W. Corbett, J. M. Denney, M. D. Fiske and R. M. Walker. (*Phys. Rev.*, vol. 104, pp. 851–852; November 1, 1956.) Measurements on high-purity Cu foil bombarded by 1.35-MeV electrons give a value of $(8.25 \pm 1.2) \times 10^{-27} \Omega$ cm for the resistivity change per electron per cm^2.

537.311.33 1109

Semiconducting Intermetallic Compounds—L. Pincherle and J. M. Radcliffe. (*Advances Phys.*, vol. 5, pp. 271–322; July, 1956.) A comprehensive survey of published data on the preparation, properties, theory, and applications of these materials, with an extensive bibliography.

537.311.33 1110

Recombination of Electrons and Holes at Dislocations—S. R. Morrison. (*Phys. Rev.*, vol. 104, pp. 619–623; November 1, 1956.) "The phenomenon of hole-electron recombination at dislocations is examined, and it is demonstrated that the space charge barrier surrounding the dislocation may have a dominant effect in determining the characteristics of recombination. In particular, the inclusion of the space charge effect leads directly to the slow decay phenomena observed in silicon and *n*-type germanium. The characteristics of electrical fluctuations due to trapping at these levels are discussed on the basis of the model."

537.311.33 1111

The Statistics of Charge-Carrier Fluctuations in Semiconductors—R. E. Burgess. (*Proc. Phys. Soc.*, vol. 69, pp. 1020–1027; October 1, 1956.) "The statistical fluctuations in the number of charge carriers (conduction electrons or valence band holes) in a given volume of semiconductor in the steady state is calculated from the transition probabilities of electrons between the conduction and valence bands or between either band and impurity levels. The case in which one independent fluctuating variable (either n or p) specifies the electronic state of the system is considered. Simple general formulas are developed for the mean value n_0 of n and its variance and it is shown that for large numbers n tends to be normally distributed about n_0. The relaxation time for small deviations from equilibrium is evaluated. These results are applied to three cases: 1) the intrinsic semiconductor, 2) the strongly extrinsic semiconductor, and 3) the slightly extrinsic semiconductor with all impurity atoms ionized. The relation between the statistical approach and the thermodynamical treatment [793 of 1956] is indicated."

537.311.33 1112

Defects with Several Trapping Levels in Semiconductors—P. T. Landsberg. (*Proc. Phys. Soc.*, vol. 69, pp. 1056–1059; October 1, 1956.) Analytical discussion is presented.

537.311.33:535.215 1113

Structural Characterization of Caesium Antimonide: Temperature Factors in Cubic Crystals—K. H. Jack and M. M. Wachtel. (*Nature, Lond.*, vol. 178, pp. 1408–1409; December 22, 1956.)

537.311.33:535.215:546.482.21 1114

Changes in Conductivity Resulting from Breakdown in Cadmium Sulphide Single Crystals—J. Woods. (*Proc. Phys. Soc.*, vol. 69, pp. 975–980; October 1, 1956.) Experiments are described, the results of which are in general agreement with those of Diemer (2960 of 1954); CdS crystals can be activated to become good photoconductors simply by passing large currents through them.

537.311.33:535.3 1115

The Influence of Electrons on the Optical Properties of Semiconductors—E. Groschwitz and R. Wiesner. (*Z. angew. Phys.*, vol. 8, pp. 391–398; August, 1956.) The contribution of the conduction electrons to the optical properties is investigated in detail for *n*-type Ge. The principal optical parameters are plotted as functions of light frequency, temperature, and impurity content. Convenient measurements are not yet possible in the mm- and tenth-mm-λ ranges where the electron contribution is greatest, but parameters can be predicted from results of experiments on adjoining frequency ranges.

537.311.33:535.34 1116

The Anomalous Skin Effect and the Optical Absorptivity of Semiconductors: Part 1—R. B. Dingle. (*Physica*, vol. 22, pp. 683–697; August, 1956.) The "pictorial kinetic method" (1106 above) is used to derive tentative expressions for optical absorption by semiconductors. The variations of carrier concentration and collision time with temperature and impurity concentration are discussed and the relative importance of the "Drude-Kronig" and "anomalous" terms in the optical absorption are assessed. The anomalous term may be important at wavelengths from 1 to 300 μ for semiconductors with a fairly high impurity concentration, but is comparatively unimportant for nondegenerate systems unless the effective carrier mass is unusually small.

537.311.33:537.32 1117

Thermoelectric Properties of Cd-Sb Alloys—V. A. Yurkov and N. E. Alekseeva. (*Zh. Tekh. Fis.*, vol. 26, pp. 191–912; April, 1956.) A brief report is presented on an experimental investigation which suggests that the energy structure of CdSb is of the type normal for semiconductors.

537.311.33:539.23 1118

The Use of an Interference Microscope for Measurement of Extremely Thin Surface Layers—W. L. Bond and F. M. Smits. (*Bell Syst. Tech. J.*, vol. 35, pp. 1209–1221; September, 1956.) "A method is given for the thickness measurement of *p*-type or *n*-type surface layers on semiconductors. This method requires the use of samples with optically flat and reflecting surfaces. The surface is lapped at a small angle in order to expose the *p-n* junction. After detecting and marking the *p-n* junction, the thickness is measured by an interference microscope. Another application of the equipment is the measurement of steps in a surface. The thickness range measurable is from 5×10^{-4} cm to 10^{-8} cm."

537.311.33:546.23 1119

Influence of the Physical State and of Infrared Irradiation on the R. F. Dipolar Absorption of Very Pure Specimens of Hexagonal Selenium—J. Meinnel, M. Eveno, and F. Trigolet. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1761–1764; November 26, 1956.) The energy level of acceptors due to crystal imperfections is determined from measurements of the rf absorption. Irradiation at wavelengths >1.4μ is ineffective in displacing the absorption bands; peaks in this effect occur at 0.7 and 1.1μ, probably as a result of trapping levels.

537.311.33:[546.28+546.289 1120

Absorption and Emission Spectra of Silicon and Germanium in the Soft X-Ray Region—D. H. Tomboulian and D. E. Bedo. (*Phys. Rev.*, vol. 104, pp. 590–597; November 1, 1956.)

537.311.33:[546.28+546.289]:538.569.4 1121

Cyclotron Resonance Experiments in Silicon and Germanium—R. N. Dexter, H. J. Zeiger, and B. Lax. (*Phys. Rev.*, vol. 104, pp. 637–644; November 1, 1956.) "Experimental techniques are described for cyclotron resonance in silicon and germanium at 9000 mc, 24,000 mc, and higher frequencies. Results are presented for electrons and holes in both germanium and silicon. The parameters for the heavy holes are evaluated, with corrections from an approximate theory of line shape for warped surfaces. Observations of the harmonics of cyclotron resonance of the heavy holes in germanium and silicon are described."

537.311.33:546.281.26 1122

The Mechanism of the Voltage-Dependent Contact Resistance of Silicon Carbide—W. Heywang. (*Z. angew. Phys.*, vol. 8, pp. 398–405; August, 1956.) Examination of experimental results indicates that the boundary-layer model proposed by Jones *et al.* (3168 of 1949) correctly represents the capacitance of SiC contacts and its pressure dependence for voltages below 10 v per single contact.

537.311.33:546.289 1123

Interferometric Wavelength Measurements of Germanium Lines of a Hollow-Cathode Discharge—R. D. Van Veld and K. W. Meissner. (*J. Opt. Soc. Amer.*, vol. 46, pp. 598–604; August, 1956.) Spectral lines of wavelengths from 4685 to 2019 Å have been investigated experimentally. From the results precise calculations can be made of the wavelengths of 29 lines in the range 1998–1691 Å.

537.311.33:546.289 1124

Effects of Growth Rate on Crystal Perfection and Lifetime in Germanium—A. D. Kurtz, S. A. Kulin, and B. L. Averbach, (*J. Appl. Phys.*, vol. 27, pp. 1287–1290; November, 1956.) "Effects of crystal growth rate and growth direction on the density of random dislocations and on the minority carrier lifetime have been observed. The dislocation density increases rapidly with growth rate above a rate of about 0.15 inch per minute and varies somewhat with growth direction. The capture efficiency per unit length of dislocation decreases at high growth rates and it is suggested that this effect is caused by the failure of impurity atoms to segregate at dislocations or by the clustering of dislocations." See also 2435 of 1956.

537.311.33:546.289 1125

Investigation of Single-Crystal Ge Films Prepared by Evaporation in Vacuum—G. A. Kurov, S. A. Semiletov, and Z. G. Pinsker. (*C. R. Acad. Sci. U.R.S.S.*, vol. 110, pp. 970–

971. October 21, 1956. In Russian.) Results are reported of various electrical measurements and a structural investigation of films produced by evaporation of 2–30 Ω cm *n*- or *p*-type Ge on single crystals of Ge. In one case, deposition (at 550°C) of a film 18.5μ thick on a Ge crystal of thickness 0.7 mm and resistivity 10.5 Ω cm reduced the combined resistivity to 0.83 Ω cm. Measurements also showed that the Hall constant for the film was ~3 cm³/C and the hole mobility ~150 cm²/v, these values being considerably lower than those in the single crystal. The films obtained were all *p*-type, irrespective of the type of the evaporated Ge. Electron-microscope photographs of the surfaces are shown and discussed.

537.311.33:546.289 1126

Galvanomagnetic Effects in a Heavily Doped Germanium Crystal—W. Sasaki. (*J. Phys. Soc. Japan*, vol. 11, pp. 894–895; August, 1956.) Measurements over the temperature range 1.3°–280°K of the variations of resistivity and Hall constant with the strength of an applied magnetic field are reported.

537.311.33:546.289 1127

Some Experiments on a Germanium Surface Layer—M. Kikuchi. (*J. Phys. Soc., Japan*, vol. 11, p. 898; August, 1956.) Resistivity measurements were made, using the four-probe method, on a thin *p*-type layer formed by heat treatment on an *n*-type single crystal. The effects of variations in the ambient conditions are shown.

537.311.33:546.289 1128

Dislocations in Plastically Bent Germanium Crystals—F. L. Vogel, Jr. (*J. Metals, N.Y.*, vol. 8, pp. 946–949; August, 1956.) The densities and distributions of dislocations were studied before and after annealing of the bars. Three significant changes were produced by the annealing process; 1) the average density of dislocations is reduced; 2) dislocations migrate from the high-density outer regions towards the low-density neutral axis; 3) a polygonized structure is formed by movement of the dislocations into walls normal to the slip plane.

537.311.33:546.289 1129

Combined Measurements of Field Effect, Surface Photovoltage and Photoconductivity—W. H. Brattain and C. G. B. Garrett. (*Bell Syst. Tech. J.*, vol. 35, pp. 1019–1940; September, 1956.) An experimental study of the properties of fast surface states on etched Ge surfaces is reported. Both *N*- and *p*-type specimens were investigated, and the surfaces were exposed to a series of gaseous ambients as described previously [1698 of 1953 (Brattain and Bardeen)]. The results indicate that the height of the surface barrier, measured with respect to the Fermi level, varies from −0.13 to +0.13 v, and that the surface recombination velocity varies over about a factor of ten in this range. The dependence of the charge trapped in fast surface states on barrier height and on the steady-state concentration within the semiconductor is determined.

537.311.33:546.289 1130

Distribution and Cross-Sections of Fast States on Germanium Surfaces—C. G. B. Garrett and W. H. Brattain. (*Bell Syst. Tech. J.*, vol. 35, pp. 1041–1058; September, 1956.) A theoretical interpretation is provided for the experimental results reported in 1129 above. It is deduced that the density of fast states is lowest near the center of the energy gap, increasing sharply as the accessible limits of surface potential are approached; the fast states are largely of acceptor type. Estimates are made of the cross sections for transitions between the fast states and the conduction and valence bands.

537.311.33:546.289 1131

Scattering of Holes by Phonons in Germanium—H. Ehrenreich and A. W. Overhauser. (*Phys. Rev.*, vol. 104, pp. 331–342; October 15, 1956.) Expressions are derived for the differential cross sections for scattering of holes in the valence band of Ge by acoustical and optical phonons. The wave functions are calculated for holes in the valence band near $k=0$. The electron-phonon interaction Hamiltonian is developed, and the matrix elements and transition probabilities for lattice scattering are derived.

537.311.33:546.289 1132

Lattice-Scattering Mobility of Holes in Germanium—H. Ehrenreich and A. W. Overhauser. (*Phys. Rev.*, vol. 104, pp. 649–659; November 1, 1956.) Results of preceding analysis (1131 above) are used to calculate the mobility for a temperature range approximately 100°K–300°K where lattice scattering is the predominant scattering mechanism.

537.311.33:546.289 1133

Mechanism of Diffusion of Copper in Germanium—F. C. Frank and D. Turnbull. (*Phys. Rev.*, vol. 104, pp. 617–618; November 1, 1956.) "To explain the rapid diffusivity of copper in germanium and its dependence on structure it is proposed that the copper be dissolved in two states, interstitial and substitutional. It is deduced that in the interstitial state the solubility of copper is about 10^{-2} times less and the diffusivity many orders of magnitude greater than in the substitutional state. Conversion from the interstitial to the substitutional state is effected by lattice vacancies which are generated at free surfaces and dislocations; this accounts for the structure dependence of the diffusivity observed by Tweet and Gallagher [169 of January]."

537.311.33:546.289 1134

Mass Ratio and Magnetoresistance in *N*-Type Germanium—G. C. Della Pergola. (*Phys. Rev.*, vol. 104, pp. 598–599; November 1, 1956.) "An upper limit of 15.7 for the ratio of longitudinal to transverse mass of conduction electrons at room temperature was determined by magnetoresistance measurements on *n*-type germanium single crystals. Experimental values of this ratio range between 7.0 and 11.4."

537.311.33:546.289 1135

Electrical Properties of Germanium at Very Low Temperatures—E. I. Abaulina-Zavaritskaya. (*Zh. Eksp. Teor. Fiz.*, vol. 30, pp. 1158–1160; June, 1956.) Results are reported of an experimental determination of 1) resistance /temperature characteristics of 1-Ω. cm Ge specimens at field strengths of 50–100 mV/cm, and 2) resistance/field-strength characteristics at temperatures between 0.15 and 4.2°K. The critical field strength at which the resistance drops sharply is 11 V/cm. Curves 1) indicate that the activation energy between 0.15 and 1°K is less by one order of magnitude than between 1.6 and 4.2°K.

537.311.33:546.289:538.214 1136

Further Measurements on the Magnetic Susceptibility of Germanium down to Liquid-Helium Temperatures—A. van Itterbeek and W. Duchateau. (*Physica*, vol. 22, pp. 649–656; August, 1956.) Continuation of work reported previously [2022 of 1955 (van Itterbeek *et al.*)]. For pure Ge crystals the diamagnetic susceptibility increases by about 5 per cent between room and liquid-hydrogen temperatures and is nearly constant in the liquid-helium region. For specimens containing Sb over a certain low concentration a minimum is observed in the susceptibility/temperature curve between liquid-H and liquid-He points; a paramagnetic term appears at the lowest temperatures.

537.311.33:546.289:538.63 1137

High-Field Longitudinal Magnetoresistance of Germanium—H. P. Furth and R. W. Waniek. (*Phys. Rev.*, vol. 104, pp. 343–345; October 15, 1956.) "The longitudinal magnetoresistance of germanium N_{100}, N_{111}, P_{100}, P_{111}, and P_{211} single crystals of 2 ohm cm resistivity has been measured to the point of saturation, by means of transient magnetic fields up to 600,000 gauss. An *N*-type effective mass ratio of 17.2 ±0.4 has been determined at 300°K. The magnitude and variation with field of the *P*-type magnetoresistances was found to be anomalous."

537.311.33:546.289:548 1138

Defects in Germanium Crystals Grown from the Melt—E. Billig. (*Brit. J. Appl. Phys.*, vol. 7, pp. 375–376; October, 1956.) "Thermal stresses arising from differential shrinkage as the crystal cools down from the freezing point to room temperature are considered as a major source of structural defects. The distribution of etch pits over various parts of a crystal has been studied and correlation has been obtained with the lifetime of minority carriers and with transistor action."

537.311.33:546.289:621.396.822 1139

Excess Noise in Deformed Germanium—J. J. Brophy. (*J. Appl. Phys.*, vol. 27, pp. 1383–1384; November, 1956.) Brief report of experiments indicating that plastic deformation greatly increases the current noise in Ge single crystals.

537.311.33:546.561–31 1140

Study of Cuprous Oxide Formed at 410°C at Pressures of Air between 0.5 and 75 mm of Hg—K. R. Dixit and V. V. Agashe. (*Z. Naturf.*, vol. 11a, pp. 41–45; January, 1956. In English.) "At these low pressures we get only one oxide, namely Cu_2O. The increase of pressure and the time of oxidation appear mainly to produce a change in the orientation of the Cu_2O crystallites. The films when sufficiently thick peel off, but even at this stage of thickness (1μ to 3μ) they do not show any electrical resistance or rectification."

537.311.33:546.682.86 1141

Carrier Lifetime in Indium Antimonide—G. K. Wertheim. (*Phys. Rev.*, vol. 104, pp. 662–664; November 1, 1956.) "The lifetime in well-compensated, single-crystal indium antimonide samples has been obtained as a function of temperature between 130° and 250°K. The results suggest that the lifetime is limited by radiative recombination at high temperatures and by a recombination center mechanism at low temperatures."

537.311.33:546.682.86:621.396.822 1142

Excess Noise in InSb—G. H. Suits, W. D. Schmitz, and R. W. Terhune. (*J. Appl. Phys.*, vol. 27, p. 1385; November, 1956.) Measurements on several specimens are briefly reported; the frequency used was 20 cps. Very low values of excess noise were observed.

537.311.33:546.817.221 1143

Magnetoresistance Effect of Lead Sulphide Group of Semiconductors: Part 1—Measurements on Natural Specimens of Lead Sulphide—T. Irie. (*J. phys. Soc. Japan*, vol. 11, pp. 840–846; August, 1956.) Measurements were made with various angles between the electric and magnetic field directions. Results are discussed in relation to theory based on spheroidal energy surfaces.

537.311.33:546.817.221:621.383.4 1144

Field-Induced Doping of PbS Layers—D. E. Martz, L. G. LaMarca, and R. S. Witte. (*J. Appl. Phys.*, vol. 27, pp. 1382–1383; November, 1956.) Brief report of measurements of the resistance of a PbS photoconductive cell subjected to an electric field, as a function of time and temperature; the results indicate that the effect of the substrate may be important when interaction occurs between the PbS film and the substrate.

537.311.33:621.317.3 1145
Direct Method of Measuring the Contact Injection Ratio [of a rectifying barrier]—O. L. Curtis, Jr., and B. R. Gossick. (*Rev. Sci. Instr.*, vol. 27, pp. 828–829; October, 1956.) A method requiring no auxiliary contacts is discussed. The injection ratio is determined by comparing the area on an oscilloscope screen corresponding to a current injection pulse with the area of the resulting hole storage pulse.

537.312.9:546.87 1146
Piezoresistance in Bismuth—R. W. Keyes. (*Phys. Rev.*, vol. 104, pp. 665–666; November 1, 1956.) Piezoresistance phenomena in Bi are consistent with multivalley models proposed.

538.22 1147
Magnetic Compounds with Perovskite Structure: Part 4—Conducting and Nonconducting Compounds.—G. H. Jonker. (*Physica*, vol. 22, pp. 707–722; August, 1956.) It is shown that the antiferromagnetic compound $LaMnO_3$ would be ferromagnetic if the cubic perovskite structure present at high temperatures could be preserved at low temperature. Part 3: 2701 of 1953 (Jonker and van Santen).

538.22 1148
Contribution to the Experimental Study of Interactions of Molecular-Field Type. Case of Solid Solutions of a Ferromagnetic or Antiferromagnetic Metal in Palladium—J. Cohen. (*C. R. Acad. Sci., Paris*, vol. 243, pp. 1613–1616; November 19, 1956.)

538.22 1149
Calculation of the Primary Excitations in Magnetic Substances—P. G. de Gennes. (*C. R. Acad. Sci., Paris.*, vol. 243, pp. 1730–1732; November 26, 1956.) The spectrum of the spin waves can be calculated from measurements of elastic diffusion of neutrons.

538.221 1150
On the Minimum of Magnetization Reversal Time—R. Kikuchi. (*J. Appl. Phys.*, vol. 27, pp. 1352–1357; November, 1956.) "A modified Landau-Lifshitz equation is solved for a single-domain sphere and an infinitely-wide thin single-domain sheet of ferromagnetic material neglecting anisotropy. The external magnetic field is switched from one direction to its opposite instantaneously at the initial time and the behavior of the magnetization vector is investigated thereafter. It is shown that there is a critical value of the damping constant corresponding to the minimum value of the (repetitive) magnetization reversal time."

538.221 1151
Spatial Correlations in a Ferromagnetic Material Near the Curie Point—P. G. de Gennes and A. Herpin. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1611–1613; November 19, 1956.) The form of the spin correlations is deduced from the theory of the molecular field.

538.221 1152
Fluctuation Magnetic After-Effect Near the Curie Point—D. Pescetti and J. C. Barbier. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1740–1743; November 26, 1956.) The variation of the effect with temperature is studied; a maximum is observed near the Curie point.

538.221 1153
The Anisotropy Correction in Ferromagnetic Resonance—K. J. Standley and K. W. H. Stevens. (*Proc. Phys. Soc.* vol. 69, pp. 993–996; October 1, 1956.) A method is described for finding the net absorption for a given magnetic field, resulting from the superposition of absorption lines from the randomly distributed crystallites of a polycrystalline material. Owing to magnetocrystalline anisotropy, the maximum in a ferromagnetic resonance curve does not coincide with the center of gravity of the absorption line. The magnitude of the correction required is estimated; it can be important in iron and in some ferrites.

538.221 1154
The Saturation Magnetization of Nickel under High Hydrostatic Pressure—K. H. von Klitzing and J. Gielessen. (*Z. Phys.*, vol. 146, pp. 59–64; August 16, 1956.) Three different methods are described which were used to determine the effect of pure hydrostatic pressure. Results obtained agree more closely with those of Ebert and Kussmann (*Phys. Z.*, vol. 38, pp. 437–445; 1937) than with those of Stacey (3115 of 1956) whose considerably higher values of the pressure coefficient may be due to the combination of unidirectional and hydrostatic pressure.

538.221 1155
The Magnetomechanical Hysteresis Loop of Nickel—M. Kornetzki. (*Z. Phys.*, vol. 146, pp. 107–112; August 16, 1956.) The results of torsion tests on hard and annealed Ni tubes are plotted as eleastic-hysteresis loops and are analyzed. The value of "coercive force" is assessed and compared with that obtained for soft iron.

538.221 1156
Saturation Magnetization in Copper-Nickel Alloys—S. A. Ahern and W. Sucksmith. (*Proc. Phys. Soc.*, vol. 69, pp. 1050–1052; October 1, 1956.) Measurements are reported on six alloys with compositions ranging from 4.7 to 34.4 per cent Cu.

538.221 1157
Spectroscopic Splitting Factors for Iron and Silicon Iron—G. S. Barlow and K. J. Standley. (*Proc. Phys. Soc.*, vol. 69, pp. 1052–1055; October 1, 1956.)

538.221 1158
Neutron Diffraction Study of the Structures and Magnetic Properties of Manganese Bismuthide—B. W. Roberts. (*Phys. Rev.*, vol. 104, pp. 607–616; November 1, 1956.)

538.221 1159
The Temperature Characteristics of the Initial Permeability of Mn_3Sb, Cobalt, Iron and Nickel—M. Kersten. (*Z. Angew. Phys.*, vol. 8, pp. 382–386; August, 1956.) An analysis of experimental results of other workers confirms the correctness of the temperature characteristics derived from the theory outlined previously (501 of 1957).

538.221:534.232:538.652 1160
The Dynamic Magnetostriction of Nickel-Cobalt Alloys—C. A. Clark. (*Brit. J. Appl. Phys.*, vol. 7, pp. 355–360; October, 1596.) Ni-Co alloys for transducers are discussed. Measurements of the electromechanical coupling coefficient, the reversible permeability and Young's modulus are described. Two alloys containing respectively about 4.4 per cent and 18.4 per cent Co give good performance.

538.221:537.311.31 1161
The Effect of Spontaneous, True, and Ferromagnetic Magnetization on Electrical Resistance—E. Böhringer. (*Z. Phys.*, vol. 146, pp. 65–74; August 16, 1956.) Resistance changes were measured in ferromagnetic wires under transverse magnetization up to and above saturation, for temperatures from −185° to +232°C. The magnitude of the changes decreases with decreasing temperature; above saturation the fall in resistance is proportional to the magnetizing field.

538.221:538.6:539.23 1162
Magnetic Domains in Thin Films by the Faraday Effect—G. A. Fowler, Jr., and E. M. Fryer. (*Phys. Rev.*, vol. 104, pp. 552–553; October 11, 1956.) Technique developed previously for investigating magnetic domains by examining the rotation of reflected light (2441 of 1954) is adapted to observations of the transmitted light.

538.221:539.234 1163
The Domain Structure of Thin Films of Iron—B. Elschner and D. Unangst. (*Z. Naturf.*, vol. 11a, pp. 98, 48d; January, 1956.) Observations have been made on oriented films deposited on NaCl bases; photomicrographs are reproduced.

538.221:539.234:538.67 1164
Magnetic Domains in Evaporated Thin Films of Nickel-Iron—C. A. Fowler, Jr., E. M. Fryer, and J. R. Stevens. (*Phys. Rev.*, vol. 104, pp. 645–649; November 1, 1956.) Domain patterns have been observed in Ni-Fi films of thickness 500–5000 Å by the longitudinal Kerr magneto-optical effect [2441 of 1954 (Fowler and Fryer)]. Certain unusual features of domain behavior appear characteristic of the thinnest specimens. Films of thickness 10,000 Å and 20,000 Å showed no domain structure by this technique.

538.221:621.318.12 1165
Preferred Orientations and Magnetic Properties of Rolled and Annealed Permanent-Magnet Alloys—W. R. Hibbard, Jr. (*J. Metals, N.±.*, vol. 8, pp. 962–967; August, 1956.) Pole figures, torque curves, and coercive force have been determined for cunife, cunico, silmanal, vicalloy I, vicalloy II, and Heusler's alloy.

538.221:621.318.134 1166
Properties and Uses of Ferrites—K. J. Standley. (*Nature, Lond.*, vol. 178, pp. 1371–1373; December 22, 1956.) Report of the conference organized by the Institution of Electrical Engineers in the autumn of 1956. Nearly 60 papers were read; these are to be published, with the discussion, in *Proc. Inst. Elect. Eng.* during 1957.

538.221:621.318.134 1167
Method for Forming Large Ferrite Parts for Microwave Applications—L. G. Van Uitert, F. W. Swanekamp, and F. R. Monforte. (*J. Appl. Phys.*, vol. 27, pp. 1385–1386; November, 1956.) Sludge pressing technique is briefly discussed.

538.221:621.318.134 1168
Neutron Diffraction Study of Manganese Ferrite—J. M. Hastings and L. M. Corliss. (*Phys. Rev.*, vol. 104, pp. 328–331; October 15, 1956.)

538.221:621.318.134 1169
Anisotropy Constants and g Value of Nickel Ferrite.—D. W. Healy, Jr. and R. A. Johnson. (*Phys. Rev.*, vol. 104, pp. 634–636; November 1, 1956.) Experimental data are presented for the temperature range 4°–300°K and frequency range 7.9–11.5 kmc. Measured g values show a significant variation with frequency not observed in previous measurements on single crystals.

538.221:621.318.134 1170
Magnetic Properties of Rare-Earth Ferrites $3M_2O_3 \cdot 5\ Fe_2O_3$, with M = Tb, Dy, Ho, Er, Tm, Yb, Lu. Experimental Results—R. Pauthenet. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1499–1502; November 12, 1956.)

538.221:621.318.134 1171
Interpretation of the Magnetic Properties of the Ferrites $3M_2O_3 \cdot 5Fe_2O_3$ where M=Y, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu—R. Pauthenet. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1737–1740; November 26, 1956.)

539.15.098:538.569.4 1172
Antiferromagnetism and Antiferromagnetic Resonance in $CuBr_2 \cdot 2H_2O$ at 9800 mc/s—M. Date. (*Phys. Rev.*, vol. 104, pp. 623–624; November, 1956.)

539.23:537.533.8 1173
Preparation and Properties of Thin-Film MgO Secondary Emitters—P. Wargo, B. V. Haxby, and W. G. Shepherd. (*J. Appl. Phys.*, vol. 27, pp. 1311–1316; November, 1956.) "Some simple methods of preparing MgO thin films on Mg-Ag alloy with high secondary emission ratios are discussed. The oxidation procedure and a discussion of the underlying phenomena are presented. Films with a secondary yield of 12 at 600 V may be produced by oxidation in either oxygen or carbon dioxide. Results of a study of some of the factors influencing the life of a secondary emitter are given. These include the effects on the secondary emitting characteristics of evaporation products from an oxide-coated cathode and the deterioration of the thin film under electron bombardment."

539.234:548.5 1174
The Orientation of Thin Evaporated Metal Films—H. Göttsche. (*Z. Naturf.*, vol. 11a, pp. 55–68; January, 1956.) Report of an electron-diffraction investigation of the growth of layers of metals with face-centered cubic crystal structure (Ag, Au, Al, Pd, and Cu) on alkali halide crystals with the same structure.

546.56:621.385:666.1.037.5 1175
Copper as a Material in High-Vacuum Technology—W. Espe. (*NachrTech.*, vol. 6, pp. 355–364; 401–408; August and September, 1956.) Comprehensive data are presented on the physical and chemical properties of pure Cu; its advantages and disadvantages in the manufacture of vacuum apparatus are tabulated. Particular uses are discussed; Cu/glass seals receive special attention.

549.514.51 1176
Paramagnetic Resonance of Lattice Defects in Irradiated Quartz—R. A. Weeks. (*J. Appl. Phys.*, vol. 27, pp. 1376–1381; November, 1956.)

549.514.51:621.372.412 1177
The Effect of Various Types of Radiation on Piezoelectric Quartz and Crystal Resonators—F. Seidl. (*Acta. Phys. Austriaca*, vol. 10, pp. 169–174; August 1956.) Experimental results obtained by various workers indicate that the piezoelectric properties of quartz are affected by exposure to X rays and particle rays. The increase in the piezoelectric constant induced by X rays decays more rapidly in a loaded than in an unloaded resonator. The relation between discoloration and frequency deviation in resonators is discussed [see also 3309 of 1946 (Frondel)].

621.315.613.1 1178
Surface Adhesion and Elastic Properties of Mica—G. L. Gaines, Jr., and D. Tabor. (*Nature, Lond.*, vol. 178, pp. 1304–1305; December 8, 1956.) The important role of es forces in the adhesion of mica is indicated.

MATHEMATICS

513.83:621.373.43 1179
Topological Analysis Methods for the Solution of Nonlinear Differential Equations. Application to Oscillators used in Radio Equipment—P. Hontoy and P. Janssens. (*Rev. HF, Brussels*, vol. 3, pp. 221–244; 1956.) General theory is presented and the case of the multivibrator with common cathode resistance is analyzed in detail.

517 1180
A Direct Approach to the Problem of Stability in the Numerical Solution of Partial Differential Equations—J. Todd. (*Commun. Pure Appl. Math.*, vol. 9, pp. 597–612; August, 1956.) An arithmetic treatment is presented applicable to the wave equation and some other partial differential equations.

517:[535.3/.4+534.24/.26 1181
On Radiation Conditions—J. J. Stoker. (*Commun. Pure Appl. Math.*, vol. 9, pp. 577–595.) Steady-state solutions of the differential wave-propagation equation are discussed for waves refracted, reflected or diffracted at a boundary. An examination is made of the conditions to be imposed at infinity to ensure the uniqueness of a desired solution.

517:[535.42+534.26 1182
The Scope and Limitations of the Method of Wiener and Hopf—A. E. Heins. (*Commun. Pure Appl. Math.*, vol. 9, pp. 447–466; August, 1956.) Boundary-value problems arising in the solution of certain elliptic partial differential equations are discussed; the method is applicable to diffraction problems.

517:621.384.612 1183
Hill's Nonlinear Equation and the Stroboscopic Method of Minorsky—Blaquiere. (See 1210.)

517.942.9 1184
The Solutions of Laplace's Equation for the Case of Cylindrical Symmetry—S. Colombo. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1471–1473; November 12, 1956.)

519.2:621.396.822 1185
The Statistical Distribution of the Maxima of a Random Function—D. E. Cartwright and M. S. Longuet-Higgins. (*Proc. Roy. Soc. A.*, vol. 237, pp. 212–232; October 9, 1956.) A study is made of a random function which is the sum of an infinite number of sine waves in random phase. The work is related to that of Rice (440 and 2168 of 1945) on electrical noise, but the particular application in this case is to sea waves.

517 1186
Functional Analysis. [Book Review]—F. Riesz and B. Sz.-Nagy. Blackie, London, and Glasgow, 468 pp., 65s. 1956. (*Nature, Lond.*, vol. 178, p. 1368; December 22, 1956.) English translation of second French edition. Fundamental ideas are introduced step by step; numerous illustrative examples are included.

MEASUREMENTS AND TEST GEAR

531.76:621.374.32 1187
The Vernier Time-Measuring Technique—R. G. Baron. (Proc. IRE, vol. 45, pp. 21–30; January, 1957.) A detailed description is given of a system for accurate measurement of the time interval between nonperiodic pulses. The coarse measure is obtained by means of a clock pulse of usual type, while the intervals between the start and end pulses on the one hand and the nearest clock pulse on the other hand are determined by causing the start and end pulses to generate a train of auxiliary pulses with a repetition rate greater than that of the clock pulses. Readings are taken at coincidence between the auxiliary and clock pulses, the operation being thus analogous to that of a mechanical vernier.

538.569.4.029.6:535.33 1188
Further Extension of Microwave Spectroscopy in the Submillimetre-Wave Region—M. Cowan and W. Gordy. (*Phys. Rev.*, vol. 104, pp. 551–552; October 15, 1956.) The wavelength range of the investigations described previously [*e.g.*, 2156 of 1956 (Burrus and Gordy)] has been extended down to 0.587 mm.

621.317.3:537.311.33:537.323 1189
Methods of Measuring the Coefficient of Thermo-e.m.f. of Semiconductors—G. I. Skanavi and A. M. Kashtanova. (*Zh. Tekh. Fiz.*, vol. 26, pp. 895–899; April, 1956.) Two known methods are discussed and their deficiencies pointed out. A modified method is described which gives satisfactory results.

621.317.3:621.315.61 1190
A New Electrode System for Determining the Transverse Revistivity of Insulators—R. Lacoste. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1609–1611; November 19, 1956.) The use of evaporated-film electrodes is outlined.

621.317.3.029.6(43):621.396.65 1191
Microwave Measuring Devices—H. H. Klinger. (*Electronic Eng.*, vol. 28, pp. 524–527; December, 1956.) Brief review of German equipment for measurements in radio-link systems.

621.317.33:621.315.612.6 1192
Determination of Resistivity of Lossy Materials from Dielectric Measurements, making Use of Interfacial Polarization—R. T. Lewis and L. R. Bickford, Jr. (*J. Amer. Ceram. Soc.*, vol. 39, pp. 222–226; June 1, 1956.) A method is described in which the resistivity of glass is determined from measurements of the variation with temperature and frequency of the capacitance and dielectric loss of a sandwich comprising a relatively thick piece of glass and a relatively thin piece of mica.

621.317.361:621.396.822 1193
Some Results on the Analysis of Random Signals by means of a Cut-Counting Process—I. Miller and J. E. Freund. (*J. Appl. Phys.*, vol. 27, pp. 1290–1293; November, 1956.) Extension of work reported by Steinberg *et al.* (2060 of 1955).

621.317.361.029.6 1194
Measurement of Instantaneous Frequency with a Microwave Interferometer—H. P. Raabe. (Proc. IRE, vol. 45, pp. 30–38; January, 1957.) A system is described in which a frequency discriminator comprising a transmission-line circuit is used to convert frequency variations of a microwave signal to amplitude variations; these are applied to a detector followed by an amplifier and oscilloscope indicator. The adjustment of the discriminator to minimize distortion is discussed. The method has been found practical for measuring the frequency stability of a radar pulse.

621.317.4 1195
Magnetic Measurements—C. E. Webb. (*Metallurgia, Manchr*, vol. 54, pp. 57–66; August, 1956.) "The basic principles of the chief methods of determining the properties of ferromagnetic materials—ballistic, slowly varying flux, and alternating current methods—are described. Special consideration is given to the testing of permanent magnets by standard and comparative methods, and to the conditions necessary to ensure that test results give reliable indications of practical performance. Some representative methods of measuring field strength are reviewed."

621.317.42 1196
Measurement of Nonuniform Magnetic Fields in Narrow Gaps—J. Knizak. (*Acta Phys. Austriaca*, vol. 10, pp. 186–189; August, 1956.) A probe suitable for use in very restricted spaces, with volumes down to 1 mm^3, is described; operation is based on the deflec-

tion of current carriers in Hg by the field to be measured.

621.317.7.029.4:537.54 1197

Narrow-Band A. F. Noise Generator—D. Steffen. (*Elektronische Rundschau*, vol. 10, pp. 185–188; July, 1956.) The equipment described, comprising glow-discharge generator followed by a selective amplifier and frequency changer, produces a noise band of width variable from about 10 to 165 cps anywhere in the af range. It facilitates qualitative measurements; *e.g.*, of loudspeaker frequency response and distortion because the effects of standing acoustic waves are avoided.

621.317.7.029.6:621.315.212 1198

Short-Circuiting Plunger for Coaxial Lines—H. K. Ruppersberg. (*Arch. Elekt. Übertragung*, vol. 10, pp. 358–360; August, 1956.) A plunger is described which comprises a brass cylinder with radial slits held by a spiral spring at one end so as to exert pressure on the inner and outer conductors at the other end; the short-circuiting plane does not shift with variations of signal frequency.

621.317.7.029.6:621.373.423:621.385.029.6 1199

The Use of Travelling-Wave Valves for Measurements—A. Lauer. (*Elektronische Rundschau*, vol. 10, pp. 190–192; July, 1956.) Wobbulator, frequency-doubler and oscillator circuits using the Type-TL6 valve (4-kmc range) are briefly described.

621.317.726 1200

A Novel High-Voltage Peak Voltmeter—W. P. Baker. (*Proc. IEE*, Part A, vol. 103, pp. 519–522; October, 1956.) The performance of the instrument is made nearly independent of the characteristics of the rectifiers by including them in a feedback loop.

621.317.755:621.3.014.33 1201

A High-Speed-Oscillograph Cathode-Ray Tube for the Direct Recording of High Current Transients—R. Feinberg. (*Electronic Eng.*, vol. 28, pp. 540–541; December, 1956.) The tube described uses an external single-turn coil for direct signal deflection. An oscillogram of a 1650-A, 15-μs pulse with a gradient of 250 A/μs is shown.

621.317.761 1202

Theory and Practice of a Very-High-Accuracy Arrangement for Frequency Measurement—G. Becker. (*Arch. Elekt. Übertragung*, vol. 10, pp. 315–325; August, 1956.) Details are given of an arrangement using frequency multiplication of the unknown, followed by comparison with a reference frequency and counting of the resulting beats. Typical measurement results are discussed in relation to the theoretical results, and the errors are hence determined. Over the range 15 kc–15 mc the maximum error is 1 part in 10^9 for a measuring time of 100 sec. By using averaging methods, the error can be reduced to a few parts in 10^{11} for a measuring time of about 1 sec.

621.317.761 1203

Direct-Reading High-Sensitivity Frequency Meter—J. Lagasse, R. Lacoste, and J. Prades. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1406–1408; November 5, 1956.) Apparatus for determining frequencies between 47 and 51 cps is based on measurement of the frequency of beats between a multiple of the frequency to be determined and a submultiple of the frequency of a quartz-controlled reference oscillator.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.768:534.86 1204

Calibration of Vibration Pickups by the Reciprocity Method—S. Levy and R. R. Bonche. (*J. Res. Nat. Bur. Stand.*, vol. 57, pp. 227–243; October, 1956.)

550.837:621.396.674.3 1205

The Radiation Resistance of a Dipole Antenna above a Conducting Plane, from the Viewpoint of Geophysical Prospecting—Minaw. (See 991.)

621-526:621.387 1206

Grid Control of Thyratrons with Particular Reference to Servomechanism Applications—K. R. McLachlan. *J. Brit. Inst. Radio Eng.*, vol. 16, pp. 695–699; December, 1956.

621.319.3:621.385.822 1207

Use of Electrostatic High-Voltage Machines with the Electron Microscope—W. Herchenbach and H. Düker. (*Optik, Stuttgart*, vol. 13, pp. 375–376; 1956.) A short note indicating that es generators can be used satisfactorily, even without stabilizing devices, for power supply in es electron microscopes and electron diffraction apparatus.

621.384.611 1208

Modes of Acceleration of Ions in a Three-Dee Cyclotron—M. Jakobson, M. Heusinkveld, and L. Ruby. (*Phys. Rev.*, vol. 104, pp. 362–365; October 15, 1956.)

621.384.612 1209

Elimination of the Critical Energy in a Strong-Focusing Synchro-Phasotron—A. A. Kolomenski. (*Zh. Tekh. Fiz.*, vol. 26, pp. 740–748; April, 1956.

621.384.612:517 1210

Hill's Nonlinear Equation and the Stroboscopic Method of Minorsky—A. Blaquière. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1711–1714; November 26, 1956.) Discussion of stabilization conditions for an equation representing oscillations occurring in a strong-focusing cosmotron.

621.385.833:537.533/.534 1211

The Resolving Power of the Field [-emission] Ion Microscope—E. W. Müller. (*Z. Naturf.*, vol. 11a, pp. 88–94; January, 1956.) Considerations of resolving power indicate that the field-emission microscope should be operated with ion rather than electron emission. Helium is particularly suitable for examining metal surfaces. Cooling to very low temperature enables the atomic structure of the specimen to be made visible. See also 3329 of 1956 (Müller and Bahadur).

621.398 1212

Radio Transmission of an Electrocardiogram—E. Evrard and J. Rens. (*Rev. HF, Brussels*, vol. 3, pp. 193–208; 1956.) Description of a fm telemetry system for recording on the ground the cardiogram of an aircraft pilot in flight.

621.398:621.396.41 1213

Radio System controls Railroad in Venezuela—Sheffield. (See 1232.)

PROPAGATION OF WAVES

621.396.11 1214

Wave Scattering and Meteoric Influences on Short and Near-Ultra-short Waves—H. Wisbar. (*Arch. Elekt. Übertragung*, vol. 10, pp. 343–352; August, 1956.) It is shown that in a frequency band about 30 mc wide above the critical frequency for grazing incidence a certain residual ionization favor scatter propagation even with low-power transmitters; the intensity of this ionization depends on the diurnal and seasonal variations in the E and F layers. At higher frequencies, scattering occurs only as a result of the "background effect," assumed to be directly related to the incidence of sporadic meteors. Turbulence in the ionosphere enhances the reflection effect due to the weak ionization produced by meteoric dust; corpuscular radiation may also make a small contribution at the poles and the magnetic equator. Auroral and other effects on scatter propagation are considered.

621.396.11:551.510.535 1215

The Waveguide Mode Theory of V.L.F. Ionospheric Propagation—J. R. Wait and H. H. Howe. (Proc. IRE, vol. 45, p. 95; January, 1957.) Calculations are made and the results are shown in graphs for the attenuation factor as a function of the reciprocal of the ionospheric conductivity, 1) for different propagation modes, and 2) for different values of ground conductivity.

621.396.11.029.6 1216

Propagation of Ultra-short Waves Far Beyond the Horizon—V. N. Troitski. (*Radiotekhnika, Moscow*, vol. 11, pp. 3–20; May, 1956.) The u.s.w. field strength is calculated taking into account both stratification and turbulence in the troposphere. Fading and distortion of the signal are also discussed and the calculated and published experimental results are compared.

621.396.11.029.6:551.510.535 1217

A Disturbing Factor in Very-High-Frequency Communications via Ionospheric Forward Scatter—D. A. Crow, F. A. Kitchen, G. A. Isted, and G. Millington. (*Nature, Lond.*, vol. 178, pp. 1280–1283; December 8, 1956.) Difficulties experienced with a frequency-shift telegraphy link between Gibraltar and the U.K. on 37.3 mc are discussed. On effectively pulsing the transmitter it was observed that discrete delayed signal components were present. The path of the delayed components is apparently first backward from the transmitter via the E layer and ground, and then forward by normal reflection at the F layer, the critical frequency being near the solar-cycle maximum. In order to achieve a safe signal/interference ratio, the back/front ratio of the array must be greatly increased.

621.396.812.3 1218

The Analysis of U.S.W. Fading—G. Eckart. (*Z. angew. Phys.*, vol. 8, pp. 407–416; August, 1956.) A detailed discussion in physical terms of dielectric-constant variations and turbulence in the troposphere and their effect on propagation at $\lambda > 3$ m, based on mathematical analysis to be published elsewhere.

RECEPTION

621.396.621:621.376.3 1219

Effect of a Discontinuity of the Instantaneous Frequency on an Ideal Frequency-Modulation Receiver—J. Charles and H. Vigneron. (*Rev. HF, Brussels*, vol. 3, pp. 209–219; 1956. The response of a fm receiver with ideal IF band-pass characteristics to a sudden variation of signal frequency, is compared with that of an AM receiver to a sudden variation of amplitude. Differences in the observed overshoot effects are discussed.

621.396.621:621.376.33 1220

Limiters and Discriminators for F.M. Receivers—G. G. Johnstone. (*Wireless World*, vol. 63, pp. 8–14, 70–74; January and February, 1957.) The performance of the Round-Travis, Foster-Seeley, ratio detector, locked oscillator, phase-difference comparator and counter discriminator circuits, and of the grid, anode, dynamic and clipper-type limiters is discussed.

621.396.621.001.11 1221

Interference Immunity of the Correlation Reception Method—A. E. Basharinov. (*Radiotekhnika, Moscow*, vol. 11, pp. 26–34; May, 1956.) The general case of correlation reception when the signal frequency is initially not accurately known is investigated theoretically. The calculations show that the relative interference immunity of the correlation-type receiver with incoherent detection is only $\sqrt{2}$ times that of a receiver with a square-law detector.

621.396.621.54:621.3.018.783 1222
Contribution to the Theory of Nonlinear Distortion—E. Henze. (*Arch. Elekt. Übertragung*, vol. 10, pp. 326–338; August, 1956.) General formulas are derived for the characteristics of nonlinear circuit elements, with particular reference to tubes. The production of harmonics and the mixing process are discussed; IF amplitudes resulting from cross-modulation with an interfering signal are calculated and compared with the normal IF amplitudes. The dependence of these nonlinear effects on the applied bias is investigated.

621.396.621.54.029.6 1223
Wideband V.H.F. Converter—G. P. Anderson. (*Wireless World*, vol. 63, pp. 88–91; February, 1957.) Details are given of the construction of a superheterodyne unit extending the turning range of a s.w. receiver up to 60 mc.

621.396.821:551.594.6 1224
Measured Statistical Characteristics of V.L.F. Atmospheric Radio Noise—Maxwell. (See 1083.)

STATIONS AND COMMUNICATION SYSTEMS

621.39:621.376.5 1225
Pulse Technique with Particular Reference to Line and Radio Communication—E. M. Deloraine. (*J. Inst. Elect. Eng.*, vol. 2 pp. 458–463; August, 1956.) A short review including a discussion of the relative merits of frequency-division AM and time-division PM multichannel systems; a table shows the estimated channel-miles of pulse-multiplex radio links in various countries as at January, 1956.

621.39.001.11 1226
A Theory of Word-Frequency Distribution—A. F. Parker-Rhodes and T. Joyce. (*Nature, Lond.*, vol. 178, p. 1308; December 8, 1956.) A simple experimental relation governing word frequencies in language is explained in terms of a process of scanning the words in the memory.

621.39.001.11:621.372.012 1227
Signal-Flow Graphs and Random Signals—W. H. Huggins. (Proc. IRE, vol. 45, pp. 74–86; January, 1957.) The flow-graph technique discussed previously [*e.g.*, 2985 of 1956 (Mason)] is used to derive formulas for the correlation functions and power spectra of signals; particular cases studied include a random telegraph message, a series of periodic pulses with time jitter, and a series of pulses of alternate polarity with random timing.

621.394:621.376.56:621.375.4.018.7:621.314.7 1228
Transistorized Binary Pulse Regenerator—L. R. Wrathall. (*Bell Syst. Tech. J.*, vol. 35, pp. 1059–1084; September, 1956.) A simple repeater circuit is described which is suitable for use in a 12-channel pcm system over substantial lengths of transmission line. The system is arranged so that distortion due to lf cutoff in the output of one repeater is compensated in the next repeater, special feedback connections being provided for this purpose. Some performance figures and oscillograms are presented. The effect of interference on the production of errors is discussed.

621.396.3 1229
Phase-Shift Radio Teletype—J. P. Costas. (Proc. IRE, vol. 45, pp. 16–20; January, 1957.) A system using suppressed-carrier keyed am with the frequency-shift system and the "predicted-wave" system [see 1954 Convention Record, Part 8, pp. 63–69 (Doelz and Heald), also 861 of 1955 (Doelz)]. Coherent or synchronous detection is used at the receiver.

621.396.3 1230
Radio Teleprinter Systems with Automatic Error Correction—F. Hennig. (*Nachrichtentech. Z.*, vol. 9, pp. 341–348; August, 1956.) Methods for increasing the reliability of teleprinter operation via radio links are outlined. They include the adoption of synchronous systems using codes capable of error detection and correction.

621.396.41:621.396.65:621.396.82 1231
Interference in Radio Links and Radio-Frequency Channelling—B. Peroni. (*Ricerca Sci.*, vol. 26, pp. 2483–2511; August, 1956.) An investigation is made of interference in a multi-channel system from transmitters external to the system; an expression is derived for the ratio between the unwanted and the wanted signals. The design of terminal equipment to minimize interference effects is discussed. C.C.I.R. proposals for frequency channeling are compared with the method adopted in the TD-2 system, and measurements on systems of both types are reported; the latter type is preferred.

621.396.41:621.398 1232
Radio System controls Railroad in Venezuela—B. Sheffield. (*Electronics*, vol. 29, pp. 158–163; December, 1956.) The installation described permits centralized traffic control by means of a multiplex fm carrier system. Safety measures and a number of mobile radio and other communication channels are also provided.

621.396.65:621.317.3.029.6(43) 1233
Microwave Measuring Devices—Klinger. (See 1191.)

SUBSIDIARY APPARATUS

621.311.6:621.314.7 1234
Transistorized Regulated Power Supply—M. Lillienstein. (*Electronics*, vol. 29, pp. 169–171; December, 1956.)

621.311.62:621.316.722.1 1235
Cathode-Follower-Type Power Supplies—B. J. Perry. (*Electronic Eng.*, vol. 28, pp. 517–520; December, 1956.) The use of triodes as rectifiers in variable-voltage power supplies is examined. A power pack combining series-stabilization with a cathode-follower type rectifier circuit is described; it is suitable for electrophoresis applications and performance details are given.

621.314.6 1236
Current-Rectifying Devices—J. D. Cooney. (*Elect. Mfg.*, vol. 56, pp. 139–157; September, 1955.) A review of thermionic and solid-state rectifiers, providing comparative data for selecting appropriate types for particular purposes.

621.314.63 1237
An Investigation into the Rectifying Properties of *n-p* Junctions: Selenium-Sulphides or Selenides of Tin—V. R. Grimm and D. N. Nasledov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 707–715; April, 1956.) The *n-p* junctions at the boundaries between selenium and sulphides or selenides of tin were investigated experimentally: they possess sharply defined rectifying properties. On the basis of these results, Se rectifiers of a new type have been developed and their properties investigated. In comparison with ordinary Se rectifiers the new types have a decreased voltage drop in the forward direction (of the order of 0.2 v) and allow a higher forward current density. The disadvantages of the new rectifiers are the temperature dependence of the reverse current and the adverse effect of heating on their electrical strength.

621.314.63:[546.28+546.289 1238
Germanium and Silicon Power Rectifiers—T. H. Kinman, G. A. Carrick, R. G. Hibberd, and A. J. Blundell. (*Proc. IEE*, Part A, vol. 103, pp. 533–536; October, 1956.) Discussion on 2885 of 1956.

621.316.722:621.314.7 1239
Transistor Voltage Regulator—R. H. Spencer and T. S. Gray. (*Commun. and Electronics*, pp. 15–17 March, 1956.) A circuit which makes use of the high-voltage gain and low-emitter resistance of the junction transistor is described.

621.316.722.1 1240
A Stabilized Mains Rectifier—H. W. Jaskula. (*Elektrotech. Z. Edn B.*, vol. 8, pp. 298–300; August 21, 1956.) The voltage-supply unit described uses saturated transformer stabilization, full-wave tube rectification and gas-filled- as well as hard-tube stabilizing circuits. It can supply 400V, 0–100 ma dc with a variation of less than 0.005 per cent for mains fluctuations of ±10 per cent.

TELEVISION AND PHOTOTELEGRAPHY

621.397.24:621.315.213 1241
Video-Pair Cable System—Aoki, Kameda, Yokose and Uchino. (See 983.)

621.397.5 1242
A Method for Narrowing the Frequency Band of a Television Channel—D. A. Novik. (*Zh. Tekh. Fiz.*, vol. 26, pp. 900–910; April, 1956.) The proposed method is based on the extension in time of the steeper edges of television signals at the expense of the contraction of the more gradual ones. Storage tubes could be used for such a redistribution of the time scale. The restoration of the original signal at the receiving end is considered, and the saving in bandwidth is estimated. Use of the method for transmission on long-distance lines is suggested.

621.397.5:356/359 1243
Television as a Military Intelligence and Communications Medium—N. Gray and J. C. Jangarathis. (*J. Soc. Mot. Pict. Telev. Eng.*, vol. 65, pp. 415–418; August, 1956.) An outline of essential requirements and possible applications. Equipment used in recent maneuvers includes a slow-scan vidicon camera tube.

621.397.5:535.623 1244
N.T.S.C. Colour Information—E. L. C. White. (*Wireless World*, vol. 63, pp. 75–78; February, 1957.) The efficacy of the N.T.S.C. system of transmitting the color information is criticized on the ground that the amplitude of the color subcarrier is dependent not only on the color saturation but also on the brightness; the particular method of gamma correction used also has disadvantages. An outline is presented of a receiver for operation with a single-gun picture tube, using a "symmetrical-ratio" signal.

621.397.5:535.623 1245
The Choice of a Color-Television System Conforming to the "Gerber" Standards and the Effect of the Chrominance Subcarrier on Monochrome Picture Reception—J. Piening. (*Nachrichtentech. Z.*, vol. 9, pp. 365–370; August, 1956.) Possible systems for German color television and modifications required to adapt the N.T.S.C. system to the 625-line standard are outlined. Transmission in bands IV and V is considered as well as in bands I and III. Test results are given showing the interference caused in monochrome reception by the chrominance signal.

621.397.6.001.4:621.317.755 1246
A Television Line Selector Unit—P. L. Mothersole. (*Electronic Eng.*, vol. 28, pp. 520–523; December, 1956.) The unit described enables a triggered oscilloscope to be used as a line waveform monitor.

621.397.611.2:778.5 1247
Flying-Spot and Vidicon Film Scanners. A Comparison on the Basis of the Gerber [C.C.I.R.] Standard—W. Dillenburger. (*Elektronische Rundschau*, vol. 10, pp. 181–184, 216–218; July and August, 1956.) The comparison indicates that the vidicon arrangement has the advantage that picture quality is largely independent of film density.

621.397.62 1248
Improved Sync Separator—M. P. Beddoes. (*Wireless World*, vol. 63, pp. 83–87; February, 1957.) A circuit is described using a pentode-triode tube the pentode portion serving to separate the composite synchronizing signal from the picture signal while the triode portion separates the frame synchronizing signal, its output consisting of single narrow pulses. Though the accuracy of timing is good, the noise immunity is less than that of some other separator circuits.

621.385.832.002.2:621.397.621.2:535.623 1249
Control of Fluorescent-Screen Dot Size for Colour TV—S. H. Kaplan. (*J. Soc. Mot. Pict. Telev. Eng.*, vol. 65, pp. 407–410; August, 1956.) Photographic methods are outlined for producing fluorescent screens for parallax-mask color-television tubes. Dot size control is facilitated by using an annular light source.

621.397.7:621.3.06 1250
Video Switching for TV Broadcast Centres—E. B. Pores. (*Electronics*, vol. 29, pp. 146–149; December, 1956.) Electronic and electromechanical systems are briefly described and their relative advantages and cost are discussed.

621.397.7:621.325 1251
Carbon Arcs for Television-Studio Lighting—R. B. Dull and J. G. Kemp. (*J. Soc. Mot. Pict. Telev. Eng.*, vol. 65, pp. 432–434; August, 1956.) The performance of typical carbons, including color-corrected types, is summarized.

621.397.8 1252
The Influence of Phase Errors on the Picture Quality of Television Transmissions—H. J. Griese and P. Klopf. (*Elektronische Rundschau*, vol. 10, pp. 212–216; August, 1956.) The effect of various forms of phase delay on transient response and the importance of delay characteristics in specifying television circuits is examined. A method is outlined for measuring sideband phase and amplitude in television transmitters.

621.397.8:778.5 1253
Gradation Problems in Television Film Transmissions—G. Uhlenbrok. (*NachrTech.*, vol. 6, pp. 341–346; August, 1956.) Gamma-control systems are discussed based on use of 1) variable external resistance; *e.g.*, diode, 2) variable slope, depending on the sequential cutting-off of parallel-connected tubes, and 3) variable modulation, also with parallel-connected tubes.

TRANSMISSION

621.376.22 1254
Amplitude Modulation with Diodes—A. D. Artym. (*Radiotekhnika, Moscow*, vol. 11, pp. 35–43; May, 1956.) The modulation method described is designed for low distortion modulation depths up to nearly 100 per cent and modulation frequencies approaching carrier frequency. The circuit is based on a pair of opposed diodes.

621.396.61 1255
The B.B.C. Radio Microphone—F. A. Peachey and G. A. Hunt. (*Electronic Radio Eng.*, vol. 34, pp. 46–48; February, 1957.) Description of a pocket fm transmitter for use by radio commentators. It operates in the range 50–70 mc with an output of ½ w.

621.396.61:621.385.029.6 1256
Scatter S.S.B. Technique uses Power Klystron—Badger. (See 1276.)

TUBES AND THERMIONICS

621.3.018.783:621.396.621.54 1257
Contribution to the Theory of Nonlinear Distortion.—Henze. (See 1222.)

621.314.63 1258
Surface Leakage Current in Silicon Fused-Junction Diodes—M. Cutler and H. M. Bath. (Proc. IRE, vol. 45, pp. 39–43; January, 1957.) "The forward and reverse current of fused-junction silicon diodes are compared with the predicted equations arising from a simplified model for surface leakage. It is found that analysis of the forward current in the 'exponential' region leads to resolution of the contributions of the junction and the leakage path. The activation energies of the parameters describing these two contributions were determined; the former agrees with the value of the band gap. The implications and deficiencies of the model are discussed."

621.314.7 1259
Accurate Measurement of Emitter and Collector Series Resistance in Transistors—B. Kulke and S. L. Miller. (Proc. IRE, vol. 45, p. 90; January, 1957.)

621.314.7 1260
Approximating the Alpha of a Junction Transistor—A. B. Macree. (Proc. IRE, vol. 45, p. 91; January, 1957.) A simple method based on a second-order power series is presented.

621.314.7:[621.373.4+621.375.4]:621.311 1261
Application of Germanium Triodes in Equipment for the Protection, Telemechanics and Communication Channels of Power Systems—Martynor and Pavlov. (See 1027.)

621.38+537.533](083.74) 1262
IRE Standards on Electron Tubes: Physical Electronics Definitions, 1957—(Proc. IRE. vol. 45 pp. 63—65; January, 1957.) Standard 57 IRE 7.51.

621.383 1263
Wavelength Dependence of Radiation-Noise Limits on Sensitivity of Infrared Photodetectors—J. R. Platt. (*J. Opt. Soc. Amer.*, vol. 46, pp. 609–610; August, 1956.) A formula is derived for the limiting sensitivity as a function of the area and long-wavelength cutoff of the photocell and of the exposure time.

621.383.2 1264
Electron-Microscope Investigation of the Structure of Photocathodes—A. I. Frimer and A. M. Gerasimova. (*Zh. Tekh. Fiz.*, vol. 26, pp. 726–732; April, 1956.) The object of this investigation was to determine the relation between the structure and the sensitivity of complex (oxygen-caesium and bismuth-caesium) photocathodes. A number of photomicrographs are shown.

621.383.2 1265
The Resistance of Semitransparent Photocathodes—W. J. Harper and W. J. Choyke.—(*J. Appl. Phys.*, vol. 27, pp. 1358–1360; November, 1956.) "The resistance of the semitransparent photoemissive films Sb-Cs, Sb-Rb, Bi-Cs, Bi-Rb, Te-Cs, Te-Rb, and Ag-O-Cs was measured as a function of temperature. A thermal activation energy associated with conductivity was determined for each of the materials."

621.383.42 1266
An Anomaly in the Forward and Backward Conduction of a Selenium Photocell Cooled to Low Temperature and Reactivated by Infrared Radiation—G. Blet. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 1753–1755; November 26, 1956.) Experimental evidence indicates that at temperatures below 125°K, and for low values of applied voltage, current is passed in the reverse direction. The effect did not vary with frequency over the range 50 cps–5 kc. The photoelectric current did not exhibit this reversal.

621.385.029.6 1267
International Congress on Microwave Valves—(*Le Vide*, vol. 11, pp. 210–432; September/October, 1956.) The text is given of the following papers presented at the Congress:

The Principal Results Achieved in the Field of Microwave Valves—R. R. Warnecke (pp. 217–225).

Transmitter Valves with Control Grid—F. Hülster (pp. 226–235).

"Moding" in Magnetrons—C. Azéma (pp. 236–242).

Asymmetries in Strapped Resonator Systems of Magnetrons—B. Vallantin (pp. 243–247).

The Use of Getters in Magnetrons—P. Zijlstra (pp. 248–250, in French and English).

An Experimental Cold-Cathode Magnetron—J. R. M. Vaughan (pp. 251–257, in French and English). See 2580 of 1956.

Practical Millimetre-Magnetron Considerations—L. W. Roberts and R. S. Briggs (pp. 258–263, in French and English).

Reflex Klystrons for Millimetre Waves—B. B. van Iperen (pp. 264–269).

A Low-Noise High-Power Klystron Oscillator of Great Reliability—G. A. Espersen (pp. 270–280, in French and English).

Operation and Application of the Retarding-Field Oscillator at Millimetre Wavelengths—C. J. Carter, W. H. Cornetet, Jr., and M. O. Thurston (pp. 281–285, in French and English).

A Transmitter Klystron for Radio Links—C. Azéma (pp. 286–289).

A Travelling-Wave Valve for 4-cm Wavelength—A. Bobenrieth (pp. 290–295).

Wide-Band Travelling-Wave Valves for Wavelengths of 2–3 cm—D. H. O. Allen (pp. 296–302, in French and English).

A 4000-Mc/s Low-Noise Travelling-Wave Valve—P. F. C. Burke and W. J. Pohl (pp. 303–309, in French and English).

Characteristics of a Strophotron Oscillator of 10-cm Wavelength—T. S. Robinson (pp. 310–320, in French and English).

Preliminary Electron Bunching in the Linear Accelerator—M. Papoular (pp. 321–327).

Electrolytic Tank with Current Input Elements for the Study of Space-Charge Distribution in Valves—V. S. Loukochkov [Lukoshkov] (pp. 328–337, in French and English).

Plasma Electron Oscillations—F. Berz (pp. 338–344)

Breakdown of Air at Microwave Frequencies—W. Roberts (pp. 345–351, in French and English).

A Wide-Band T.R. Valve Incorporating an Interdigital Line—D. Reverdin (pp. 352–356).

The Fully-Coupled T.R. Valve—R. Jean and D. Reverdin (pp. 357–361).

Contribution to the Study of Keep-Alive Electrodes of T.R. Valves—R. Jean (pp. 362–372).

Measurements on Gas-Filled [t.r. and a.t.r.] Valves—R. Belbeoch and M. Bricon (pp. 373–376).

Measurement of the Transmission Characteristic of [t.r.] Switching Valves for Millimetre Radar—A. Regeffe (pp. 377–378).

Investigation of Noise in Travelling-Wave Valves—A. S. Tagher (pp. 379–388, in French and English).

Overlapping the Operating Ranges of Gas-Filled Noise Tubes and Noise Diodes by means of Helical Lines—H. Schnitger (pp. 389–399, in French and German).

Oscillograph for the Observation and Photography of Microwave Signal Patterns—A. M. Tchernouchenko [Chernoushenko] (pp. 400–409, in French and English). (See 885 of 1956.)

High-Power Microwave Test Bench—L. Milosevic and Vautey (pp. 410–416).

Shock Sensitivity of Reflex Klystron—J. Boissière (pp. 417–419).

[Use of] Ceramics in Valves—G. Gallet (pp. 420–423).

Resistance Welding of Microwave Valves—R. Paliès (pp. 424–428).

The Development of Microwave Valves in Electronic Aids to Navigation—N. Schimmel (pp. 429–432, in French and English).

621.385.029.6 1268

Anomalies of Power Output and Modulation Sensitivity in Reflex [-klystron] Oscillators—J. Labus. (*Nachrichtentech Z.*, vol. 9, pp. 371–374; August, 1956.) The deviation from the theoretical output characteristic is shown to be due to a spread in the values of electron transit time, and the anomalies in the sensitivity are attributed to space-charge effects near the reflector.

621.385.029.6 1269

Performance and Design of Low-Noise Guns for Travelling-Wave Tubes—R. C. Knechtli and W. R. Beam. (*RCA Rev.*, vol. 17, pp. 410–424; September, 1956.) Discussion indicates that sharp potential discontinuities should be avoided in a low-noise gun; an exponential type of space-charge-wave transformation is hence desirable. Suitable conditions can be established with "multi-region" guns comprising a triode section followed by a number of appropriately space apertured plane parallel electrodes.

621.385.029.6 1270

The Backward-Travelling Power in High-Power Travelling-Wave Amplifiers—P. K. Tien: J. E. Rowe. (Proc. IRE, vol. 45, pp. 87–88; January, 1957.) The discussion of methods of analyzing the large-signal operation of traveling-wave tubes [3577 of 1956 (Rowe and Hok)] is continued.

621.385.029.6:537.533 1271

Confined Electron Flow in Periodic Electrostatic Fields of Very Short Periods—K. K. N. Chang. (Proc. IRE, vol. 45, pp. 66–73; January 1957.) "By utilizing the centrifugal force of an electron, resulting from a magnetic field in the cathode plane as a restoring force, an electrostatically-confined beam flow can be obtained through the strong focusing of a periodic electric field. Because of the extremely steep nature of the potential valley derived from its particular force field, the focusing scheme is far more stable than any previous ones. A uniform magnetic field threading the cathode is employed when a very thin, hollow beam is to be focused. By using a radially varying magnetic field, the focusing scheme can be applied to thick hollow beams, of low as well as of high perveance. Experimental results indicate that the focusing performance obtained is much less critical than that obtained with a periodic magnetic field which has been recently tested extensively."

621.385.029.6:538.566:537.56 1272

Growing Electric Space-Charge Waves—Pierce and Walker. (See 1066.)

621.385.029.6:621.372.2 1273

Approximate Calculation of the Propagation Constants of Transmission Lines in the Presence of an Electron Beam—L. N. Loshakov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 809–820; April, 1956.) A general method of calculation, based on certain simplying assumptions, is proposed for analyzing conditions in a traveling-wave tube.

621.385.029.6:621.372.413 1274

The Excitation of a Cavity Resonator by a Density-Modulated Electron Beam Passing Through the Entire Resonator Cross-Section—Szulkin. (See 1015.)

621.385.029.6:621.385.2 1275

The Behaviour of the Space Charge in a Diode with an Axial Magnetic Field: Part 2—The Probe Method—M. M. Filippov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 1004–1014; May, 1956.) In part 1 (*Zh. Tekh. Fiz.*, vol. 23, p. 1716; 1953.) A report was given of an experimental investigation into the behavior of the space charge in cylindrical magnetron by the method of equivalent currents. The present report deals with measurements of the current flowing through an auxiliary probe electrode in the cathode-anode space of the magnetron. The probe characteristics so obtained are used for appraising the theoretical conclusions regarding the distribution of the electrons and the shape of electron trajectories in a nonoscillating cylindrical magnetron with a thin cathode.

621.385.029.6:621.396.61 1276

Scatter S.S.B. Technique uses Power Klystron—G. M. W. Badger. (*Electronics*, vol. 29, pp. 176–179; December, 1956.) The performance of high-power klystrons in s.s.b. tropospheric-scatter transmitters is improved by using a segmented collector, with successively lower voltages on the segments, and special mixer and modulator circuits which are described.

621.385.029.6:621.396.822 1277

Factors Affecting the Correlation Conditions in Space-Charge Waves—H. W. König. (*Arch. Elekt. Übertragung*, vol. 10, pp. 339–342; August, 1956.) An investigation is made of the effect on the coherence conditions discussed by Haus (3123 of 1955) of passing an electron beam through a linear quadripole. Analysis is based on the transformation properties of the correlation determinant. It is shown that if the quadripole has a specified determinant the voltage and current fluctuations of the beam will be correlated at its output irrespective of the conditions at its input.

621.385.032.216 1278

The Electron Temperature in Oxide Cathodes—D. G. Bulyginski and D. N. Dobretsov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 977–984; May, 1956.) No definite answer has yet been given to the question whether the temperature of the electron gas can exceed that of the crystal lattice in an oxide cathode. A method is proposed for measuring the electron temperature, and experiments are described in detail. These show that an "overheating" of the electron gas does take place and that it increases with temperature. A theoretical interpretation of the results is given; it is pointed out that the emission from an oxide cathode is not of a purely thermionic nature.

621.385.032.216 1279

The Schottky Effect in Oxide Cathodes—G. Déjardin, G. Mesnard, and R. Uzan. (*Le Vide*, vol. 11, pp. 194–205; July/August, 1956.) Measurements on nearly saturated diodes at normal operating temperatures show that the Schottky effect tends to exceed the theoretical value. Various aspects of cathode surface condition are discussed as possible causes of the anomaly, 25 references.

621.385.032.216 1280

Emission of Oxide Cathodes Supported on a Ceramic—G. E. Moore and H. W. Allison. (*J. Appl. Phys.*, vol. 27, pp. 1316–1321; November, 1956.) Experiments made with a (BaSr)O layer applied to a MgO ceramic support, thus eliminating the metal support and interface, indicated that these two latter features are not of fundamental importance for the cathode emission. From the results of treatments with methane and hydrogen, it is concluded that other factors are much more important than excess Ba content for determining the emission.

621.385.032.216 1281

The Decrease of Thermionic Emission of Alkaline-Earth-Oxide and Thoria Cathodes in a Pulsed Regime—G. Mesnard and R. Uzan. (*C.R. Acad. Sci., Paris*, vol. 243 pp. 1502–1504; November 12, 1956.) A comparison is made of the effect in the two types of cathode. The extent of the emission decrease increases with rising temperature in both types, but the variation with duty factor is more pronounced in the case of the oxide cathodes. In these, at temperatures up to a certain level, the decreased emission is preceded by a significant increase which is never observed with thoria cathodes. The mechanism described by Plumlee (3583 of 1956) is thought to apply in the case of the oxide cathodes.

621.385.032.216 1282

Reactions Occurring during Decomposition of Alkaline Earth Carbonates on Tungsten—M. A. Cayless and B. N. Watts. (*Brit. J. Appl. Phys.*, vol. 7, pp. 351–354; October, 1956.) Report of an investigation made to elucidate reactions occurring during the breakdown and activation of an oxide cathode on a tungsten substrate. Analysis shows that CO_2, CO and H_2 are the principal gases evolved. The CO is produced during the formation of a basic tungstate interface of the type $(Ba, Sr, Ca)_3WO_6$. The chemical reactions involved do not reach equilibrium during normal decomposition schedules. The rate of formation of free Ba in the completed cathode is determined by the amount of interface produced during breakdown.

621.384.032.216:537.226 1283

Dielectric Constant of Barium Orthosilicate—C. P. Hadley, H. W. Kraner, and M. R. Royce. (*J. Appl. Phys.*, vol. 27, pp. 1384–1385; November, 1956.) Measurements are reported on specially prepared specimens, as a function of the apparent density. The results are plotted; they are probably valid for frequencies up to several hundred mc, and may be used in calculations of the thickness of oxide-cathode interface layers.

621.385.032.216:621.396.822 1284

New Mechanism for the Generation of Flicker Noise in Tubes with Oxide-Coated Cathodes—W. W. Lindemann and A. van der Ziel. (*J. Appl. Phys.*, vol. 27, pp. 1179–1183; October, 1956.) "Evidence is presented which seems to indicate that a major part of the flicker noise in tubes with oxide-coated cathodes is generated in a thin surface layer of the coating. The effect is shown to be caused by the fact that a dc voltage drop and a noise voltage fluctuation are generated in the surface layer. In tubes with a porous cathode coating this noise voltage modulates the current coming out of the surface pores, thus leading to a true fluctuation in the current. In tubes with a nonporous cathode coating this noise voltage modulates the emission current, thus leading to a true fluctuation in the emission."

621.385.2/.3:621.396.822 1285
Correlation Conditions for Noise Fluctuations at the Potential Minimum of a Diode (Triode)—H. Kosmahl. (*Arch. Elekt. Übertragung*, vol. 10, pp. 353–357; August, 1956.) A rigorous calculation is made of the correlation between the electron current and velocity fluctuations for a particular case. A value of 0.65–0.75 is found for the correlation coefficient in the ideal case; for practical tubes the value is considerably lower. The use of this coefficient for calculating the induced grid noise current is outlined.

621.385.3:621.365 1286
The New Transmitting Tube FTL 3-1 for Industrial Purposes—R. Hübner. (*Brown Boveri Rev.*, vol. 43, pp. 279–280; July, 1956.) Data are presented for an air-cooled triode with a directly heated thoriated-tungsten cathode, for use as an oscillator at frequencies up to 30 mc; outputs up to 6.4 kw are obtainable.

621.385.832 1287
Electrostatic Cathode-Ray Storage Tubes and their Applications—G. Dufour. (*Ann. Radioélect.*, vol. 11, pp. 200–215; July, 1956.) The various types are classified and the principles of operation and applications are detailed. 11 references.

621.385.832:621.396.963.325 1288
Storage Tube projects Radar P.P.I. Display—H. W. Gates. (*Electronics*, vol. 29, pp. 172–175; December, 1956.) A 50-inch remote ppi display is obtained by means of an "iatron" tube. This is a combined storage and projection device which uses a narrow writing beam of low intensity to create an es image of the signal on a thin insulating target supported by a mesh screen. A high-intensity beam continuously floods the image and is thereby modulated on passing through the mesh and striking he phosphor screen. Ancillary circuitry providing erasure and clutter attenuation is also described.

621.385.832.002.2:621.397.621.2:535.625 1289
Control of Fluorescent-Screen Dot Size for Color TV—Kaplan. (See 1249.)

621.387:621-526 1290
Grid Control of Thyratrons with Particular Reference to Servomechanism Applications—K. R. McLachlan. (*J. Brit. Inst. Radio Eng.*, vol. 16, pp. 695–699; December, 1956.)

621.387.002.2 1291
New Method of Filling [gas-] Discharge Valves—R. Hübner. (*Elektronische Rundschau*, vol. 10, p. 227; August, 1956.) A tablet containing HgO and other materials is enclosed in the tube envelope and, after the extraction of gases, an adequate amount of Hg is freed in a chemical reaction started by induced heat. Tubes thus prepared can be used in any position, no pre-heating of the cathode is necessary and the risk of arcing is reduced.

621.385:533.5 1292
Arbeitsverfahren und Stoffkunde der Hochvakuumtechnik, Technologie der Elektronenröhen [Book Review]—H. Steyskal. Mosbach /Baden, Physik Verlag, 185 pp., 1955. (*Acta Phys. Austriaca*, vol. 10, pp. 309–310; August, 1956.) A useful work for tube development engineers.

621.385.029.6 1293
Studien über Travelling-Wave Tubes. Mitteilungen aus dem Institut für Hochfrequenztechnik der E. T. H. Zürich, No. 23. [Book Review]—G. E. Weibel. Zurich, Leemann, 95 pp., 1956. (*Arch. Elekt. Übertragung*, vol. 10, p. 360; August, 1956.) Detailed theory is presented, including a new method of investigating the behavior of the beam on entering a monotonically increasing magnetic field. The construction of a demountable tube is described.

MISCELLANEOUS

621.3.002.2 1294
Automatic Component Assembly [for Printed Circuits]—K. M. McKee. (*Wireless World*, vol. 63, pp. 63–69; February, 1957. *J. Inst. Elect. Eng.*, vol. 2, pp. 515–519; September, 1956.) Description of a multistation in-line conveyor system of a general type in use in the U.S.A. and being introduced in G.B. for the mass production of electronic equipment. Printed wiring boards are transported along the conveyor and the various components are introduced by separate machines. Adjustments for production changeover can be effected rapidly, and individual machines can be mounted as bench units for short production runs.

621.3.002.2:68 1295
The Flowsolder Method of Soldering Printed Circuits—R. Strauss and A. F. C. Barnes. (*Electronics Eng.*, vol. 28, pp. 494–496; November, 1956.) A method is described in which a stationary wave of molten solder is created by pumping the metal upwards through a rectangular nozzle, and the pre-fluxed circuit panels are passed through the crest of the wave.

001.891:621.396 1296
Report of the Radio Research Board for 1955. [Book Review]—London, H. M. Stationery Office, 56 pp., 1956. (*Nature, Lond.*, vol. 178, pp. 1446–1447; December 29, 1956.) Includes the report of the Director of Radio Research, reviewing the work of the Radio Research Station of the Department of Scientific and Industrial Research, and giving a description of the new building.

413=00:[537:621.3 1297
International Electrotechnical Vocabulary (Electronics). [Book Review]—British Standards Institution, London, 2nd edn, 157 pp., 24s. 1956. (*Brit. J. Appl. Phys.*, vol. 7, p. 343; September, 1956.) Gives definitions in French and English and the terms themselves also in German, Spanish, Italian, Dutch, Polish, and Swedish.

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Vol. TRC-3, No. 1, March, 1956 (Cont'd)

Ultrasonics Engineering

PGUE-4, August, 1956

PGUE-4, August, 1956 (Cont'd)

Vehicular Communications

PGVC-6, July, 1956

PGVC-6, July, 1956 (Cont'd)

PGVC-7, December, 1956

COMBINED INDEX TO AUTHORS

Code numbers refer to papers as given in the contents list for each Professional Group. The letters in the code number designate the particular Professional Group, as follows:

ANE: Aeronautical and Navigational Electronics
AP: Antennas and Propagation
AU: Audio
AC: Automatic Control
BTR: Broadcast and Television Receivers
BTS: Broadcast Transmission Systems
CT: Circuit Theory
CS: Communications Systems
CP: Component Parts
ED: Electron Devices
EC: Electronic Computers
EM: Engineering Management
IE: Industrial Electronics
IT: Information Theory
I: Instrumentation
ME: Medical Electronics
MTT: Microwave Theory and Techniques
NS: Nuclear Science
PT: Production Techniques
RQC: Reliability and Quality Control
TRC: Telemetry and Remote Control
UE: Ultrasonics Engineering
VC: Vehicular Communications

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COMBINED INDEX TO TECHNICAL SUBJECTS

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Miscellaneous

Electronic Computers

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Miscellaneous

Nuclear Science

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Production Techniques

Chapter News

Editorials

Meetings

Miscellaneous

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Engineer on Microwave Antenna Systems with Southern California leader in Avionics. Excellent company benefits. Address inquiries to Personnel Director.

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With TRANSCO switches, you can cut down the number of components in a system—one switch handles up to 6 circuits. TRANSCO switches are small, and light in weight. Each is supplied in a choice of configurations to simplify installation.

Adds versatility to a system. All channels on a TRANSCO can be operated independently, and there's a wide variety of make-and-break arrangements available. TRANSCO switches operate through 11,000 MC—a standardization which cuts your stocking requirements to only one switch for this entire R F band width

High-efficiency switching is due to minimum insertion loss, low VSWR, and high isolation between channels. TRANSCO units are qualified to applicable military specifications. Performance has been fully confirmed in the field, where thousands of units are giving dependable service.

Technical data on any unit or the complete line sent on request. Send us your coaxial switching problems.

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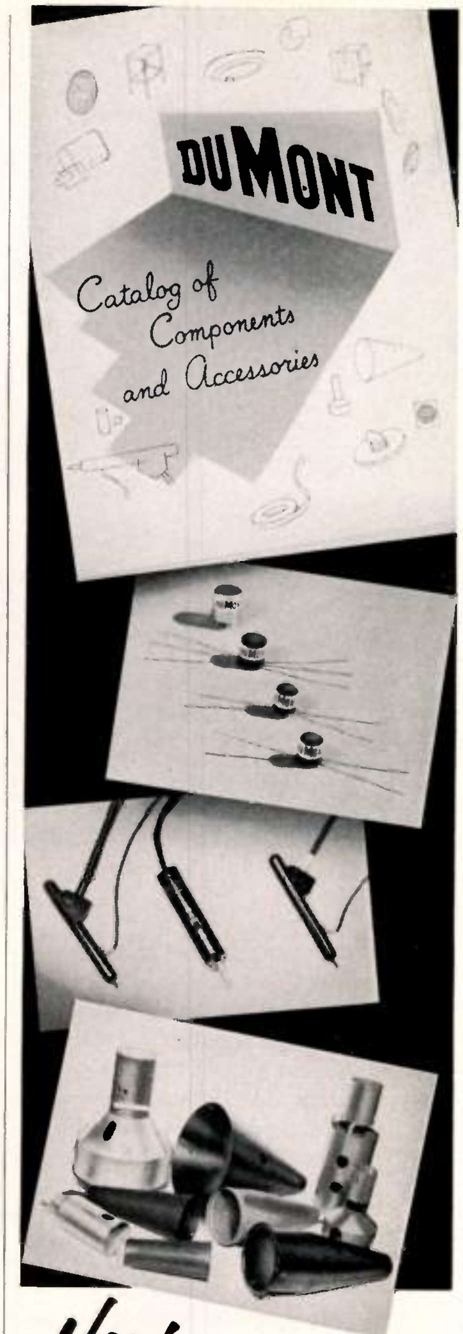

New—and Complete

Illustrated listings of components and accessories for oscilloscopes including specifications on such items as knobs, pulse transformers, probes, magnetic shields, photographic recording equipment, racks and carrying tables. Many more miscellaneous items listed in easy to read form.

• ***Write for your copy***

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No waveform distortion

from G-E Inductrol* Voltage Regulators

Unlike many other types of voltage regulators, General Electric Inductrols introduce no waveform distortion.

Featuring drift-free controls, Inductrols maintain the a-c or d-c voltage powering electronic circuits within ±1%; are small and light.

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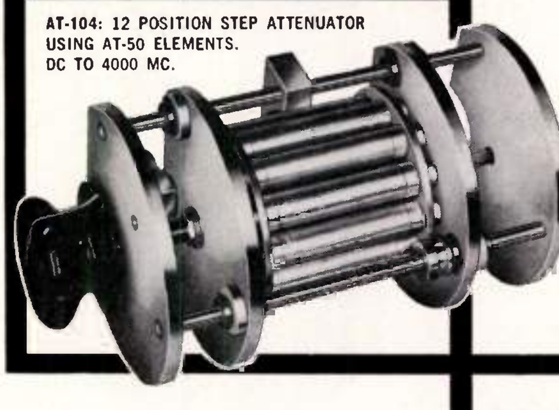
WHATEVER YOUR UHF ATTENUATION NEEDS...

AT-104: 12 POSITION STEP ATTENUATOR USING AT-50 ELEMENTS. DC TO 4000 MC.



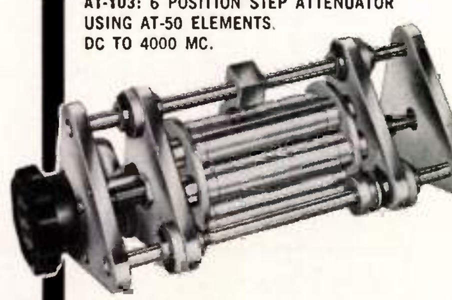
A COAXIAL UNIT FROM EMPIRE DEVICES WILL MEET YOUR REQUIREMENTS

Empire's UHF attenuators are resistive coaxial networks for the frequency range from DC to 4000 MC.

Accuracy is held to ±½ DB, VSWR is better than 1.2 to 1. Any attenuation values up to 60 DB are available. Deposited carbon elements are used for stability and operations at higher pulse levels. Standard impedance is 50 ohms, other values upon request. These units have excellent temperature characteristics and are vibration and shock resistant. Standard connectors are type "N", attenuator pads are also available with type "C".

The attenuators may be obtained as individual pads (AT-50, AT-60), or as multi-position step attenuators AT-103 (six positions) and AT-104 (twelve positions). For even greater flexibility, several step attenuators may be series connected.

AT-103: 6 POSITION STEP ATTENUATOR USING AT-50 ELEMENTS. DC TO 4000 MC.



AT-50: ATTENUATOR PAD, DC TO 4000 MC. 1 W AVERAGE, 1 KW PEAK.

AT-60: ATTENUATOR PAD, DC TO 3000 MC. 2 W AVERAGE, 2 KW PEAK.

For complete technical information about attenuators for your laboratory or production needs, write for free catalog.

edp

NEW YORK—Digby 9-1240 • SYRACUSE—GRanit 4-7409 • PHILADELPHIA—SHerwood 7-9080 • BOSTON—TWinbrook 4-1955 • WASHINGTON, D. C.—DEcatur 2-8000 • ORLANDO, FLA.—ORlando 3-3524 • ATLANTA—CEdar 7-7801 • DETROIT—BRoadway 3-2900 • CLEVELAND—EVergreen 2-4114 • DAYTON—Fulton 8794 • CHICAGO—EStebrook 9-2700 • DENVER—MAin 3-0343 • FORT WORTH—WAlnut 6-4444 • ALBUQUERQUE—Albuquerque 5-9632 • LOS ANGELES—REpublic 2-8103 • PALO ALTO—DAvenport 3-4455 • CANADA: MONTREAL—REgent 3-6502 • TORONTO—WAlnut 4-1226 • HALIFAX—HAlifax 4-6487 • EXPORT: NEW YORK—MUrray Hill 2-3[illegible]60

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(*Continued from page 90A*)

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Yanko, R. J., Angola, Ind.
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Zimmer, L. J., Jr., Levittown, Pa.
Zwerling, M., Baltimore, Md.

News-New Products

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

(*Continued from page 18A*)

Germanium High Temperature Rectifiers

The G-E Type 1N315, manufactured by the **General Electric Co., Semiconductor Products Div.**, Electronics Park, Syracuse, N. Y., is specifically designed for high operating temperatures—up to 85°C. —and for low reverse current. This unit is ideal for use in magnetic amplifiers and other circuits where low leakage current is important. The IN315 is Air Force approved and is supplied to the government per a military specification.

For magnetic amplifier applications, the G-E IN368 junction rectifier is particularly adaptable. Featuring a very low reverse current at a high dc reverse voltage, this rectifier is ideal for blocking applications.

Meter Data Sheet

Details of the newly developed linear scale ac ammeter are given in Data Sheet 839 just published by **Beckman/Helipot Corp.**, Newport Beach, Calif.

The dial markings are evenly spaced, thus eliminating crowded divisions at one end of the scale. The deflection of the needle is always directly proportional to the amperage.

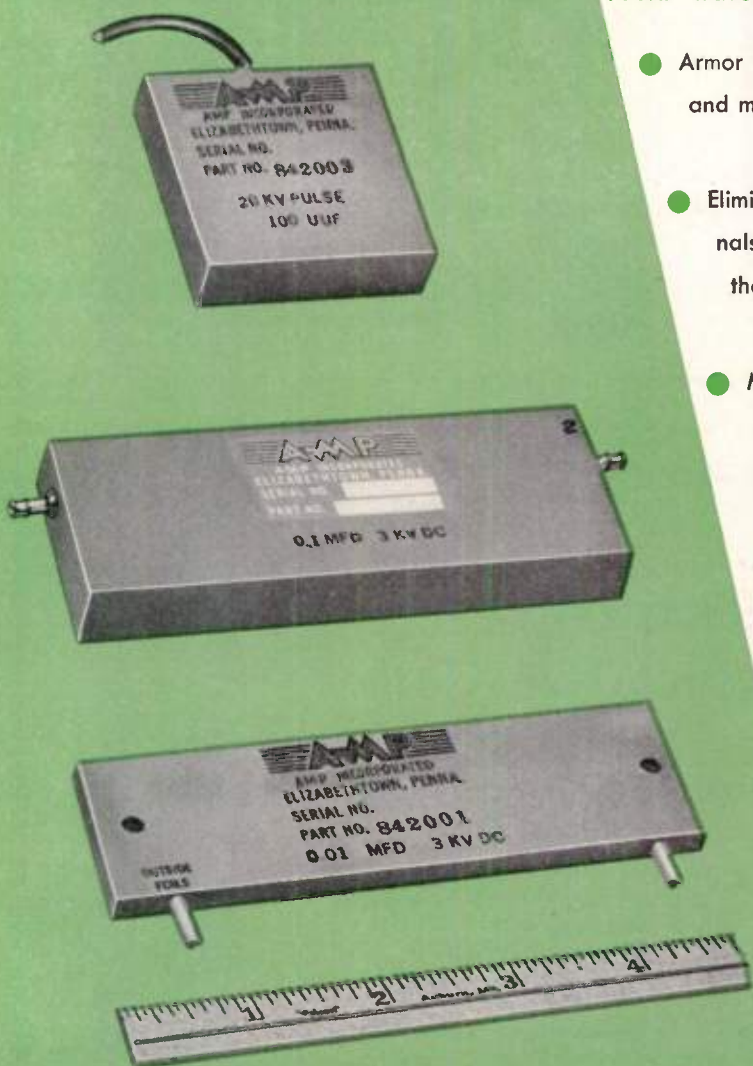
It is pointed out that accurate performance was obtained during

(*Continued on page 106A*)

THE NEW A-MP CAPITRON®

ARMORED WAFER CAPACITOR

. . . a challenge to your creativeness in functional design and application



When compared with other capacitors, this new A-MP wafer capacitor features these advantages:

- Armor type encapsulation to resist extreme thermal and mechanical shock;
- Eliminates high altitude flash-over, as metal terminals are not exposed . . . they are enclosed within the armored encasement;
- Multiple connections to capacitor leads can be made with little or no increase in the overall size of the capacitor itself;
- The use of Ampli-FILM® dielectric in this new Capitron® Armored Wafer Capacitor provides stability, reliability, long life and the adaptability of unusual shapes to your design requirements;
- Versatility of design eliminates the necessity of revamping design of assembly to accommodate the capacitor.

AMP INCORPORATED

CHEMICAL AND DIELECTRIC DIVISION
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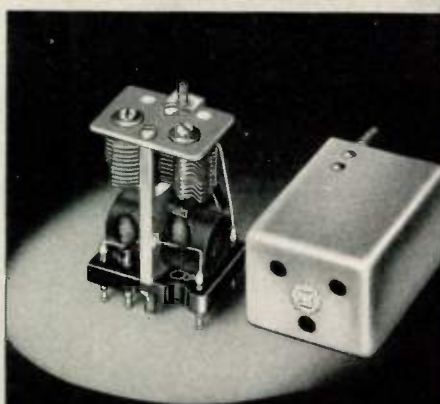
Wholly Owned Subsidiaries: Aircraft-Marine Products of Canada Ltd., Toronto, Canada • Aircraft-Marine Products (Great Britain) Ltd., London, England • Societe AMP de France, Le Pre St. Gervais, Seine, France • AMP—Holland N.V. 's-Hertogenbosch, Holland.

Japanese Distributor: Oriental Terminal Products Co., Ltd., Tokyo, Japan.

Designed for Application



The No. 61455

ADJUSTABLE COUPLING—HIGH Q MINIATURE IF TRANSFORMER

Extremely high Q: Variable Coupling—(under, critical, and over) with all adjustments on top. Small size 1⅟₁₆" x 1⁹⁄₁₆" x 1⅞". Molded terminal base. Air capacitor tuned. Coils mounted in special powdered iron assemblies. Tapped primary and secondary. Rugged construction. High electrical stability. No. 61455, 455 kc universal transformer. No. 61453, 455 kc. BFO. No. 61160, 1600 kc. transformer and No. 61163, 1600 kc. BFO.

JAMES MILLEN MFG. CO., INC.

MAIN OFFICE AND FACTORY
MALDEN
MASSACHUSETTS

ADVANCED DESIGN

new... PRECISION "POT" by GENERAL CONTROLS

PRM 123

PRM 123
Rotary type, single gang, 1-5/16" dia., bushing mounted, sleeve bearing.

General Controls, famous for 25 years as a supplier of mechanical and electro-mechanical controls for home, industry and the military ... proudly announces a new product of its Potentiometer Division ...

FEATURES ...

- Variations from 100 to 50,000 ohms resistance.
- Standard tolerances ±3% resistance, ±0.3% independent linearity.
- Exceeds MIL-R-12934,-E-5272A Specs.
- Explosion-proof, or dust-tight seals.
- Operating temperatures are −65° F. to 275° F.
- Special Spec. Models Available.

Write for 1956 Catalog!

GENERAL CONTROLS
POTENTIOMETER DIVISION
Glendale 1, California

Factory branch offices serving all principal cities of the United States and Canada

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Electrically Conductive Cloth

A New Engineering Material for Many Applications in Electronics

SUGGESTED USES:
- RF SHIELDING
- RADAR REFLECTION
- MICROWAVE GASKETING
- WARNING SYSTEMS
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Buy it by the yard and sew it to shape on any sewing machine. Or, have us sew it for you.

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Swift
Textile Metalizing & Laminating Corp.

10 Love Lane, Hartford 1, Conn.
JAckson 2-1181

ASCOP... first with performance data on America's first jetliner!

When the Boeing 707 — America's first jetliner — enters service on the air routes of the world, seven years of development will be behind it. The most tested airliner in aviation history, prototype of this 600-mile-per-hour plane has already been flying for two years . . . has already been ordered by eleven famous airlines.

To check and to record details of the 707's performance during development, Boeing has used telemetering equipment by ASCOP. Using the ASCOP D-Series Low Level Telemetering system, with C-Series airborne Monitor equipment, Boeing can "read" the 707 to an accuracy of better than 1%. As many as 580 channels of data may be sampled, transmitted and/or recorded, with simultaneous monitoring.

ASCOP has the "packaged" answer to data-recording for your project, too . . . whether it involves aircraft, missiles or other vehicles . . . operational or static testing. Our engineering staff stands ready to consult with you, without obligation.

M SERIES GROUND STATION

ASCOP DATA REDUCTION EQUIPMENT

ASCOP Pulse Width Ground Station equipment complements ASCOP PW Multicoders and radio telemetering sets to provide complete "packaged" systems for operational testing of aircraft, missiles and other vehicles and for static testing of engines, rockets, nuclear reactors, etc.

MC-1 MONITOR CONSOLE GROUP

ASCOP DATA ACQUISITION EQUIPMENT

CMS-2 MONITOR SCOPE

Provides rapid inspection and monitoring of airborne or test stand data before or during runs. Samples data at 1¼ to 30 repetition rates per second. Provides reliable performance under extremes of vibration acceleration etc.

LOW LEVEL PW MULTICODERS

Provides super-sensitive low-level remote measurement of data from airborne vehicles. High input sensitivity, fast sampling rate, wide selection of data channels.

APPLIED SCIENCE CORP. OF PRINCETON

PRINCETON, NEW JERSEY

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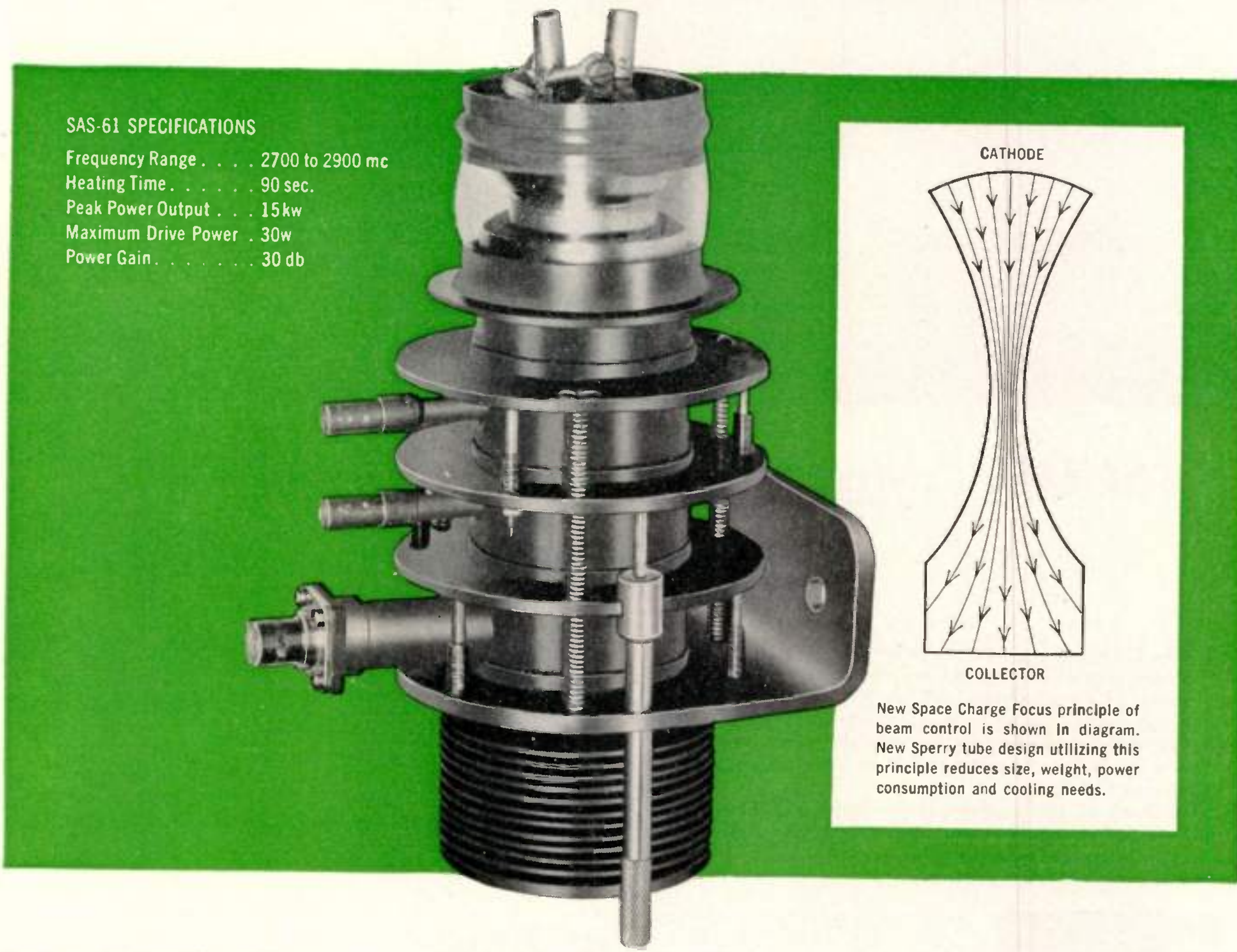
ASCOP

WE PROVIDE THE LEVER · YOU MOVE THE WORLD

IMMEDIATE DELIVERY

15kw S-Band Amplifier Klystron has **no heavy magnets**

Exclusive Space-Charge Focus cuts weight to only 6½ lbs.



New Space Charge Focus principle of beam control is shown in diagram. New Sperry tube design utilizing this principle reduces size, weight, power consumption and cooling needs.

Available for immediate delivery, Sperry's new S-band transmitting tube is a 3-cavity pulse amplifier of high gain and extra-long service life.

Exclusive Sperry Space-Charge Focusing design eliminates heavy, cumbersome magnetic structures—a feature of prime importance in equipment design. Although the SAS-61 weighs only 6½ lbs., its sturdy construction withstands extreme vibration and environmental conditions.

Main applications for the SAS-61 are as an output tube in low-power radars, or as a driver for higher-powered klystrons in radar and linear accelerator systems. Its unusually long service life, however, makes it highly desirable for any application requiring 15 kw in the S-band. The SAS-61 with its internal tunable cavities is a *complete* microwave unit. No external equipment is required.

Sperry can deliver SAS-61 tubes in quantity at once. Write or phone your nearest Sperry district office.

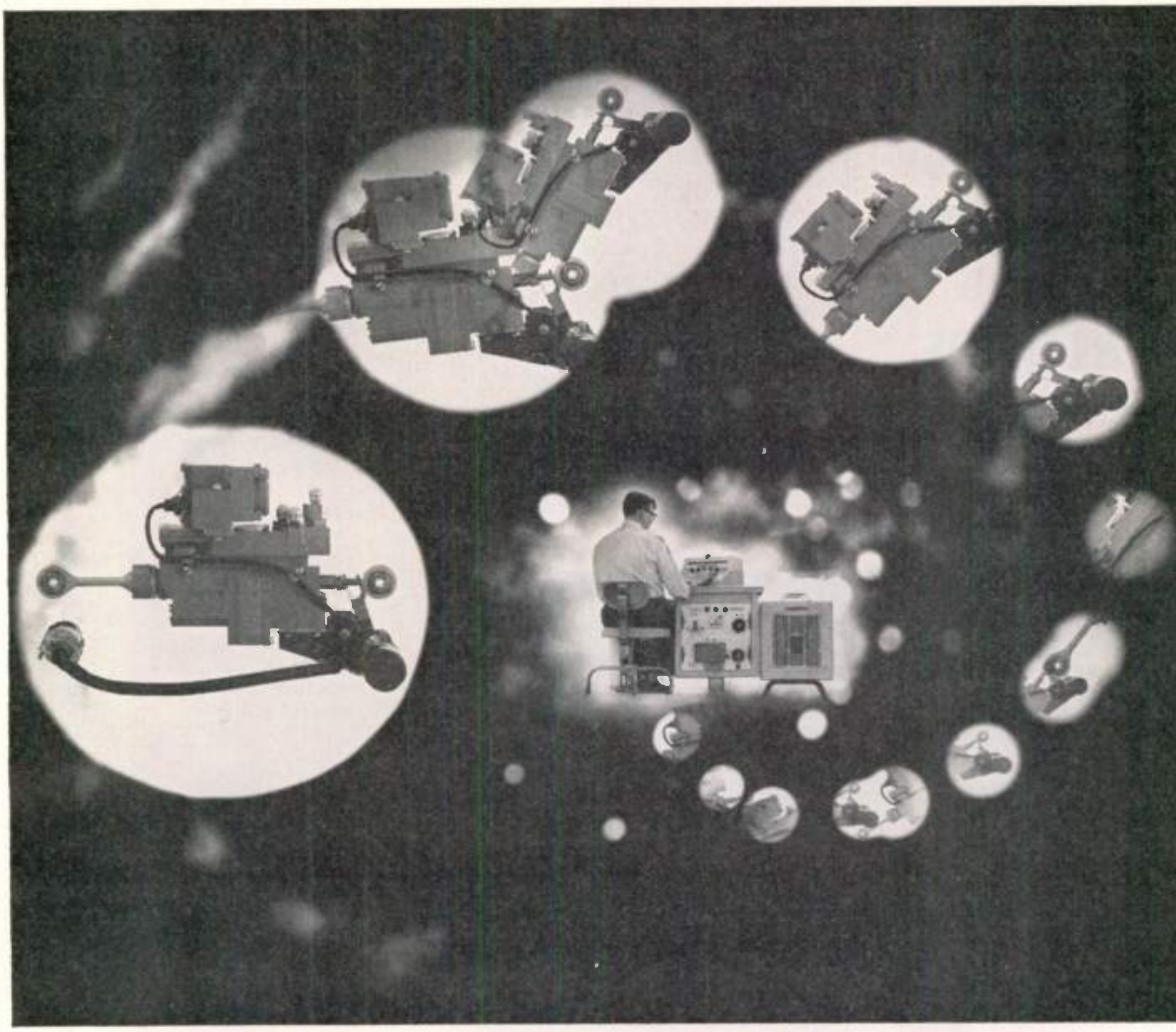
ELECTRONIC TUBE DIVISION

SPERRY GYROSCOPE COMPANY

Great Neck, New York

DIVISION OF SPERRY RAND CORPORATION

CLEVELAND • NEW ORLEANS • BROOKLYN • LOS ANGELES • SAN FRANCISCO • SEATTLE • IN CANADA: SPERRY GYROSCOPE COMPANY OF CANADA, LIMITED, MONTREAL, QUEBEC



Man's electro-mechanical partners are bringing his ideas to life faster...better...at less cost

Today one of industry's most formidable tasks is to streamline and shorten the time-consuming process that transforms ideas into exciting new products.

Never in man's history has this embryonic period needed to be shortened more than now—when technological superiority could very well be the world's best hope for peace.

And nowhere is this challenge being met more energetically than in the development and production of automatic control systems at AUTONETICS. A whole new breed of electronic and electro-mechanical tools and techniques is being evolved to shorten lead time. A notable example is *Numill*, AUTONETICS' new tape-directed numerical machine-tool control system. *Numill* is entirely digital, and can convert a numerical engineering description into a prototype configuration—quickly, economically and with consistent accuracy.

Standardized "postage-stamp" circuits allow engineers to mockup even highly advanced designs almost as simply as they would plug in an electric shaver. And AUTONETICS' data processing equipment can simulate a wide range of operational missions, as well as solve the most involved mathematical problems in minutes instead of days.

AUTONETICS' ability to save time and money between concept and product delivery is reflected in every area of its electro-mechanical technology: flight controls, inertial navigation, armament controls, computers, and other complete systems for the military and industry.

For detailed information, or for employment in this dynamic field—write: AUTONETICS, Dept. IRE-73, 9150 E. Imperial Hwy., Downey, California.

Autonetics

A DIVISION OF NORTH AMERICAN AVIATION, INC.

AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE

News-New Products

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

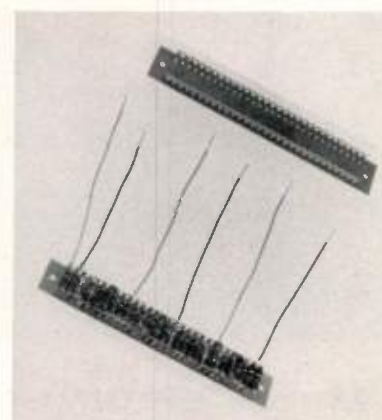
(Continued from page 100A)

a series of rigid tests which qualified the ammeter for use in military aircraft. During these tests, the ammeter was subjected to extreme vibration, shock, moisture, salt spray and fungus over a wide range of operational conditions, from sea level to 50,000 feet, from −55° to 71°C.

A copy of Data Sheet 839 may be obtained free by writing to Helipot Technical information Service.

Strip Packaging System

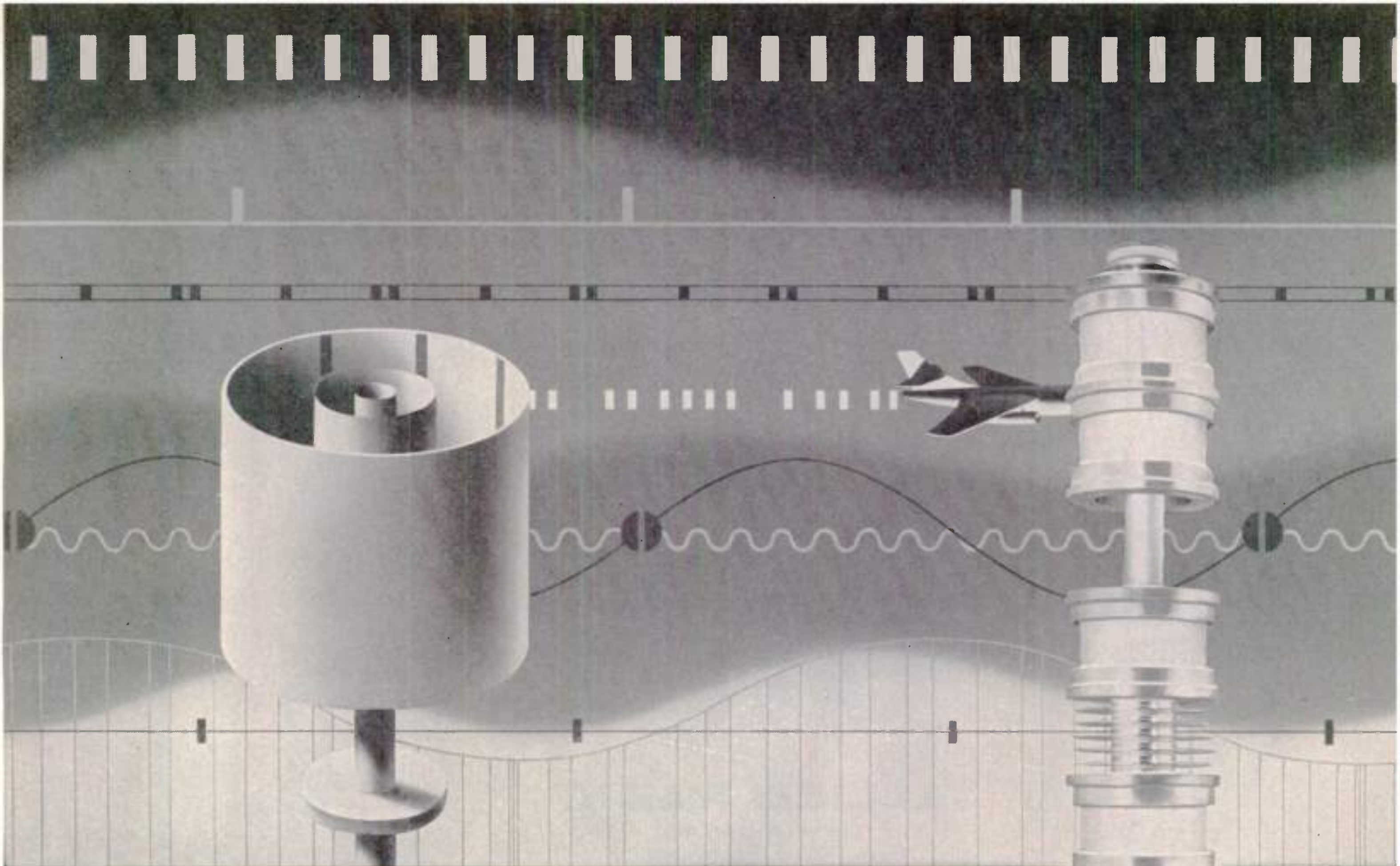
Erie Resistor Corp., Erie, Pa., has developed a new concept in electronic component packaging which uses a phenolic board with continuous metal terminals automatically inserted



These terminal connections are automatically cut out in accordance with the required circuitry leaving connecting jumpers when needed. Cross-over connections are made through the use of jumper wires on the face of the board or through the use of printed wiring on the back of the board when desired.

Components and lead-off wires are then inserted in the terminal strips, either automatically or manually. Spacing of the metal strips may be varied, depending on the required length of the electrical components. The package is processed over automatic soldering equipment developed in conjunction with the system. Because of the low temperatures and short duration of the heat cycle during soldering, by this automatic proc-

(Continued on page 108A)



Eimac X676 Modulating Anode Klystron

Shaped RF Pulse, 30 KW Peak Power Output for 955-1220 mc Air Navigation Systems

Designed for air navigation systems, the Eimac X676 three cavity, air cooled klystron will deliver 30 KW peak power output in the 955 to 1220 mc range. With a power gain of 35 db, this tube has an efficiency of 40 per cent.

A typical air navigation systems requirement is a shaped RF pulse output to eliminate spectrum interference in adjacent channels. The Eimac X676 conservatively meets the 60db requirement of the CAA's air navigational system without using critically tuned, expensive filters in the RF output transmission line. The modulating anode permits pulsing the beam current while keeping the accelerating voltage constant. Also, the modulator circuit for this application is quite simple.

The RF cavities are external to the vacuum system and detachable from the klystron. The user may purchase spare tubes without buying additional tuning and focusing assemblies.

For the design engineer, the features of the X676 simplify circuitry — for the equipment operators the X676 provides reliable, long-lived performance at moderate cost.

For further information about the Eimac X676 Modulating Anode Klystron, consult our Application Engineering Department. Also available are two highly informative booklets; "The Care and Feeding of Klystrons" and "Klystron Facts . . . Case Four".

EITEL-McCULLOUGH, INC.
SAN BRUNO CALIFORNIA

***Eimac First* in high power amplifier klystrons**

Eimac

Typical Pulse Operation X676

DC Beam Voltage	24 KV	Power Output	32 KW	Power Gain	35 db
DC Beam Current	3.3 Amps	Driving Power	10 watts	Average Power	1 KW
Power Input	80 KW	Efficiency	40%		

News-New Products

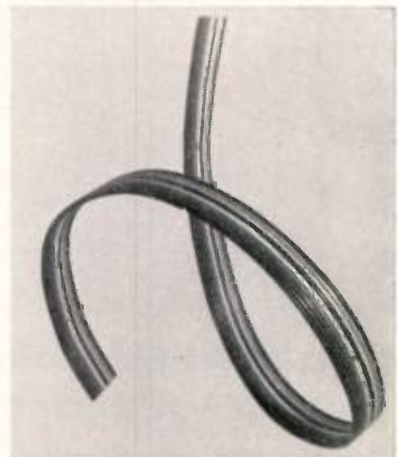
These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 106A)

ess, diodes and other critical components are soldered without damaging effects.

The board and terminal spacings have been determined for standard circuits allowing for component sizes ranging from paper capacitors and 2 watt resistors to the smallest diodes. Illustration shows this standard board prior to cutting the connectors, and a typical circuit with lead off wires.

Multi-Conductor Cable



William Brand & Co., Inc., North and Valley Sts., Willimantic, Conn., has announced that they are now ready to deliver in quantity Turbo Ribbon Cable, a new flat multi-conductor cable for use whenever space is a factor. It is suitable for airframe and guided missile wiring. Completely flexible, the conductors can be ripped apart and easily separated. The wires, #26 gauge and larger, are color coded. Turbo Ribbon Cable can be made up to include shielded wires with outer jackets can be supplied in multiple layers. The conductors with temperature ratings up to 100°C will meet all applicable military requirements. The only limitation is that the outside diameter of adjacent wires be within 0.15 inch of each other.

Graphic Recorder

A compact "operations" or "events" recorder, model MDjr, is now available from **Gorrell & Gorrell, Haworth, N.J.** It consists of a drum which rotates at speeds from 4 minutes to 24 hours per

(Continued on page 110A)

ACCURACY ± 0.25%!

Shasta Expanded Scale Voltmeters

MODELS 101 AND 101-50

FEATURES:
★ Accuracy of ±0.25%
★ True rms Reading
★ 0-1 ma Recorder Connection
★ Rugged design to withstand vibration, rough usage

Portable Models 101 (100-500 v) and 101-50 (50-250 v)

DESCRIPTION:
Available as either portable or rack-mounted units, these rugged instruments provide true rms readings at an accuracy of ±0.25% of input voltage over a range of 100-500 v in 10 v steps (Model 101), or 50-250 v in 5 v steps (Model 101-50). Large scale divisions reduce reading errors; results may be permanently recorded on a 0-1 ma recorder. Use of a unique thermal bridge circuit provides ± 0.25% accuracy with standard meter movement, eliminating delicate special movements. The result is unusual ruggedness for an instrument of such high accuracy.

APPLICATIONS:
Shasta Expanded Scale Voltmeters are invaluable for all types of testing and development work where high accuracy is a requisite; production quality control of components and circuits, developing new circuits, servicing electronic instruments and systems, measuring voltages in a-c power systems, as a reference instrument in the standards laboratory, and for measurements of line voltage variations in the field. They are adaptable for use in aircraft where vibration might damage more delicate meter movements.

SPECIFICATIONS

	MODEL 101	MODEL 101-50
RANGE:	100 v to 500 v	50 v to 250 v
SCALE RANGE:	12 v	6 v
SMALLEST SCALE DIVISION:	0.2 v	0.1 v
ACCURACY:	±0.25% of Input Voltage	
VOLTAGE INDICATED:	True rms	
FREQUENCY RESPONSE:	50 to 2000 cps	
SOURCE LOADING:	Approximately 2 watts	
METER DAMPING:	0.8 of Critical Damping	
TIME RESPONSE:	0.5 seconds	
RECORDER CONNECTIONS:	0-1 ma dc recorder	
POWER REQUIREMENTS:	115 v ac, 50-2000 cps, 20 watts	
DIMENSIONS: (PORTABLE)	8"W x 9¾"H x 9"D (14 lbs. net)	
DIMENSIONS: (RACK)	19"W x 5¼"H x 9"D (15 lbs. net)	
PRICE: (PORTABLE)	$360.00 f.o.b. factory	
PRICE: (RACK)	$400.00 f.o.b. factory	

Rack-mounted Models 101-R and 101-R-50

Complete technical data is yours for the asking; why not write us now? Please address Dept. SA-5

Beckman® / **Shasta** *Division*

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Telephone LAndscape 6-7730

S-22

News-New Products

(Continued from page 108A)

turn (as ordered). It is used to graphically record when a machine or device is operating or when an operator is producing.

No ink is used. A stylus rests against the chart paper with its adherent layer of white opaque

(Continued on page 112A)

WHY DEVELOPMENT ENGINEERS FAVOR ALLEN-BRADLEY ELECTRONIC COMPONENTS

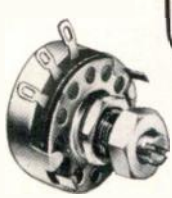
NEW
hot-molded composition
Variable Resistors
for high temperature applications

The new Type K Allen-Bradley variable resistor was developed primarily for use in high operating temperatures—so common in military applications. For the *first* time, a variable resistor is available with a conservative rating of 2 watts, operating in 100°C ambient temperatures, as the graph below shows. However, the new Type K control performs reliably at a temperature of 150°C—under "no load" conditions . . . while at temperatures of 70°C, it is *ultraconservatively* rated at 3 watts.

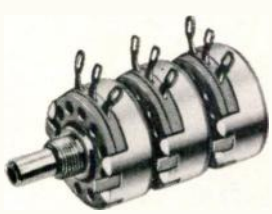
The new Type K control has *all* the features of the old reliable workhorse—the Type J Bradleyometer. With the *hot-molded* resistance type element, control is smooth and without abrupt resistance changes, and "noise" characteristics are extremely low, even after long use. Send for Bulletin 5200A.

Allen-Bradley Co.
114 W. Greenfield Ave., Milwaukee 4, Wis.
In Canada—Allen-Bradley Canada Ltd.
Galt, Ont.

TYPE K
available in resistance values up to 5 megohms.

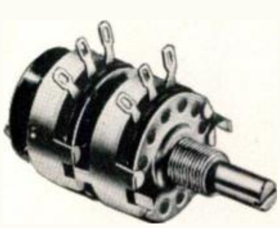


Type K single unit with short shaft and lock-type bushing.



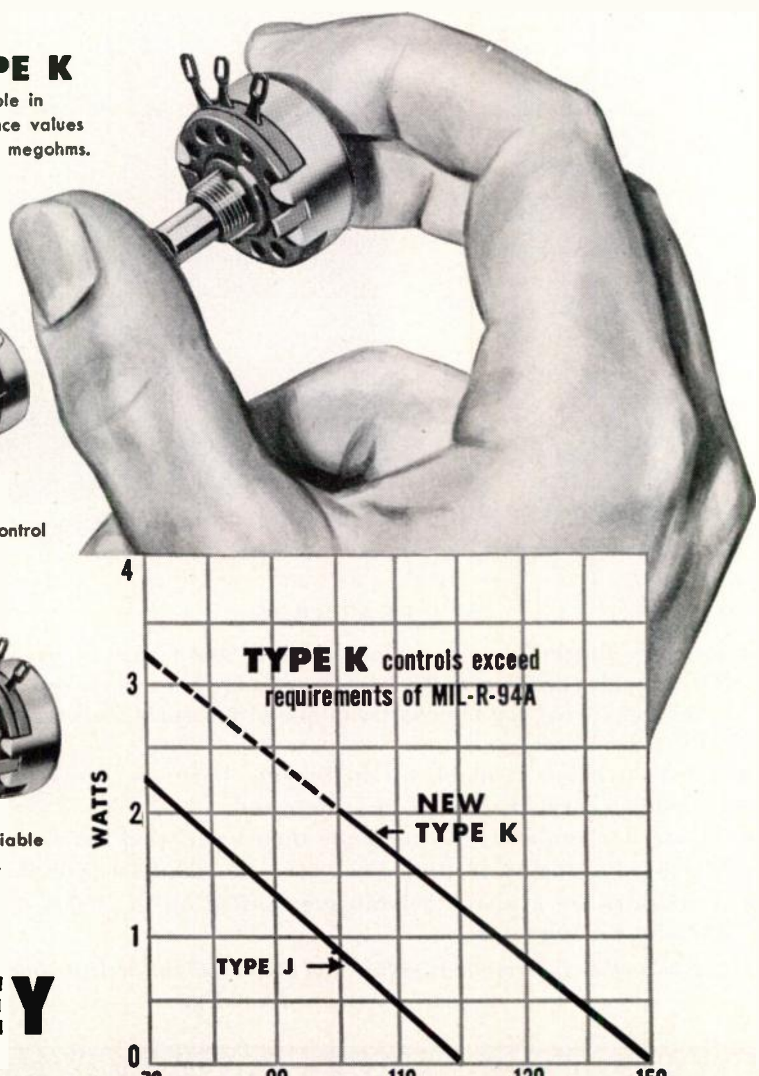
Type K triple unit control with plain short shaft.

Type K dual element control with concentric shafts.



Type K dual element control with 125 v line switch.

Type K single unit variable resistor with long shaft.



COMPARISON BETWEEN TYPE K AND TYPE J VARIABLE RESISTOR POWER RATINGS VS. AMBIENT TEMPERATURE

ALLEN-BRADLEY
ELECTRONIC COMPONENTS
QUALITY

News-New Products

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

(Continued from page 110A)

wax crystals, the pressure of the stylus exposes the strongly contrasting color of the paper beneath.

The stylus produces a slight spiral tracing on the chart. The lead screw is also subject to an axial motion from the magnet responding to the input signal to cause the vertical line.* By this means, more than 400 linear inches of recording can be had on a water proof chart 6 by 14 inches.

When the 24 hour rotation model is used, any given instant of successive days is instantly comparable since they line up vertically. Other drum speeds are 4, 5, 15 and 60 minutes as well as 2, 6, 12 or 24 hours. Motors operate on 115 or 220 volts ac. Styli coils for 6 to 220 volts ac or 6 to 120 volts dc. A 5,000 ohm electronic coil is available.

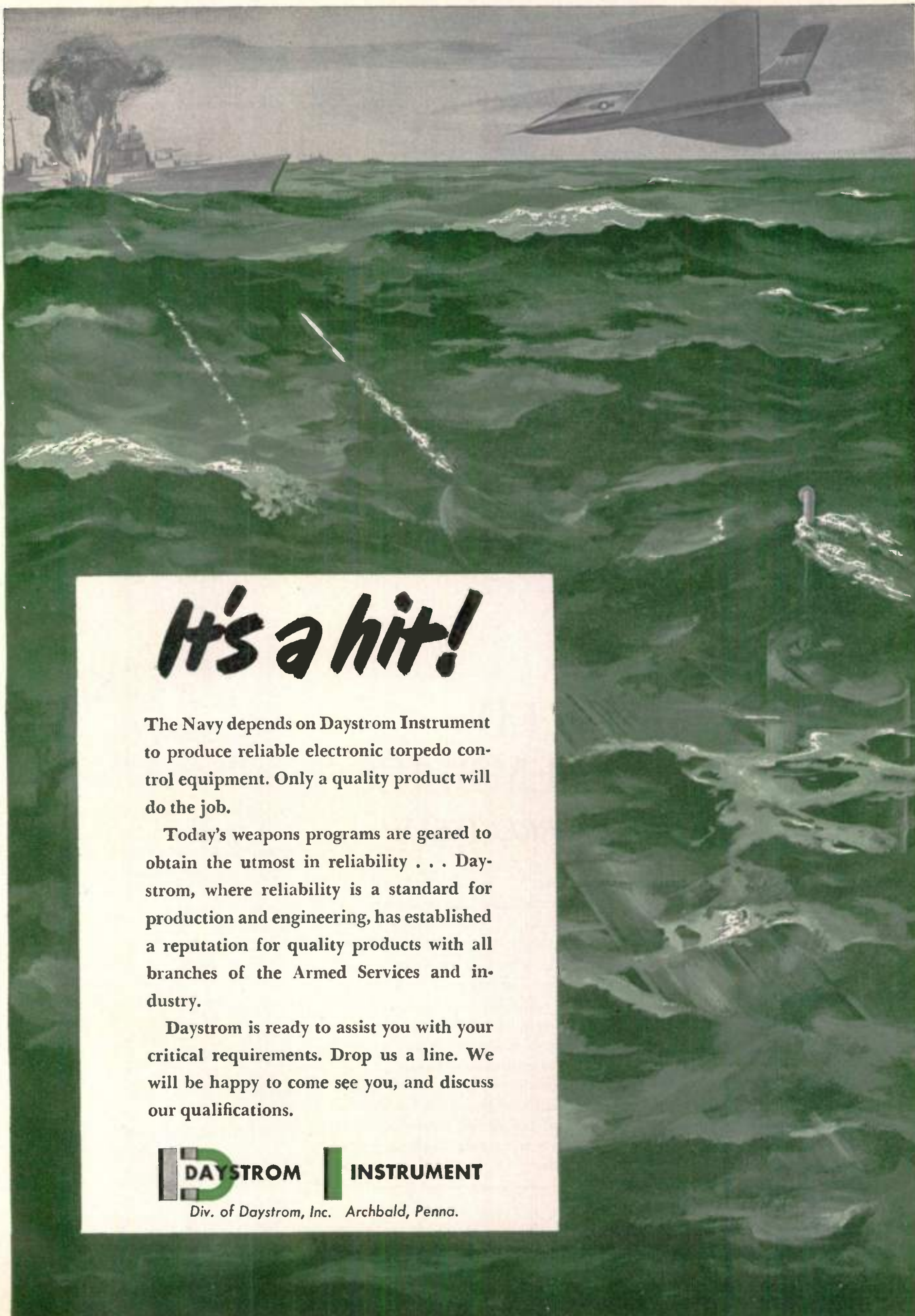
* patent applied for.

Encapsulated Miniature Yoke

A new miniature epoxy encapsulated push-pull magnetic deflection yoke, Type Y57-P, which fits all standard $\frac{7}{8}$ inch neck diameter CR tubes with deflection angle up to 70° has been developed by **Syntronic Instruments, Inc.,** 170 Industrial Rd., Addison, Ill. Type Y57-P is also suited for use with transistors and withstands extreme

environmental conditions. Push-pull windings with separate B+ leads permit greater circuit flexibility. Low geometric distortions are achieved by accurately form wound coils. The yoke is available in impedances and winding configurations suitable for transistor drive and in higher impedance for vacuum tube circuits. Overall length is 1-9/; 6 inches, OD $2\frac{1}{4}$ inches and ID 1 inch. Residual is

(Continued on page 114A)


It's a hit!
The Navy depends on Daystrom Instrument to produce reliable electronic torpedo control equipment. Only a quality product will do the job.
Today's weapons programs are geared to obtain the utmost in reliability . . . Daystrom, where reliability is a standard for production and engineering, has established a reputation for quality products with all branches of the Armed Services and industry.
Daystrom is ready to assist you with your critical requirements. Drop us a line. We will be happy to come see you, and discuss our qualifications.
DAYSTROM INSTRUMENT
Div. of Daystrom, Inc. Archbald, Penna.

News-New Products

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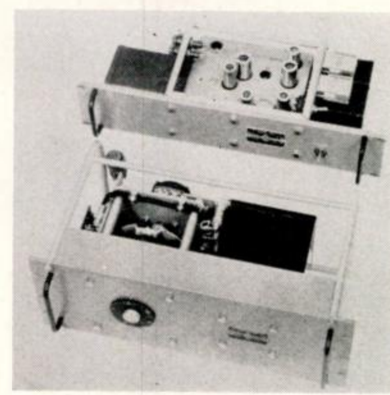
(Continued from page 112A)

0.5 maximum, radial error 1 per cent maximum, angular error 0.50 maximum, horizontal coil capacity 11 $\mu\mu$f, vertical coil capacity 15 $\mu\mu$f and temperature rating 105°C maximum.

Militarized Line Voltage Regulator

Designed to meet or to exceed the general requirements of MIL-E-4158A, the Type 1570-ALS15 Automatic Voltage Regulator, for use in military or critical industrial applications is announced by **General Radio Co.,** 275 Massachusetts Ave., Cambridge 39, Mass.



The Type 1570-ALS15 is normally supplied to handle a maximum of 6 kva at 115 volts with input line variations of ±10 per cent. A ±20 per cent range connection is also available with a maximum capacity of 3 kva. Accuracy of output voltage (adjustable over a ±10 per cent range) is ±0.25 per cent for the 6 kva connection. Frequency range is 55 to 65 cps, as selected by a switch. The Type 1570-ALS15 is priced at $625. net fob Cambridge with special prices for quantities of ten or more.

Transistorized Control Amplifier

Packard Bell Electronics Corp., displayed for the first time at the IRE Show in New York City, a diminutive transistorized control amplifier for regulating power for an entire military aircraft fire control system.

(Continued on page 116A)

ANDREW HIGH GAIN ANTENNA IS

RUGGED, DEPENDABLE

Says William E. Whiting,
Director of Communications,
Kern County, California

RADIO COMMUNICATIONS DEPARTMENT

William E. Whiting
Director of Communications
Mailing Address
P. O. Box 643
Bakersfield

Telephone 3-1788 or
3-7671 — Ext. 2300

COUNTY OF KERN
STATE OF CALIFORNIA

BAKERSFIELD, CALIFORNIA

Andrew Corporation
363 East 75th Street
Chicago 19, Ill.

Gentlemen:

The County of Kern has, for the past 27 months, had two of your type 3000 Antennas installed on a mountain top at an elevation of 4,853 feet. At this location, during the winter months, there is a great amount of ice and sleet and, at times, the wind reaches velocities approaching 100 m.p.h.

There have been times when there was a build-up of ice on these antennas to such a degree that the elements were entirely enclosed in the ice formation and the total thickness of the antenna was approximately 30". Even under these conditions there was little noticeable signal attenuation. In periodic physical checks of these antennas, we have been unable to find any broken or damaged elements, loose connections or clamps—something that might be expected from the strain of expansion and contraction together with action of high wind velocities at this location.

These antennas have given such complete satisfaction that we are ordering two additional for our new installation which will be at 7,500 feet elevation on Breckenridge Mountain, where snow, ice and wind conditions will be as severe as any encountered in California. We are confident that they will give as good service as they have at the lower elevation.

Yours very truly,

William E. Whiting

William E. Whiting, Director of Communications
County of Kern

ANDREW

Type 3000A antenna for 148-174 mc range has 6.3 db gain. Omnidirectional with vertical polarization —eliminates high angle (wasted) radiation . . . Multiplies the effective power of base and mobile transmitters.

Other high gain antennas with db gains up to 7.6 are available for 400-420 and 450-470 mc ranges.

For complete information on Andrew Antenna systems, write for Communication Antenna Folder — No. 15C.

Andrew

CORPORATION

363 EAST 75th STREET · CHICAGO 19

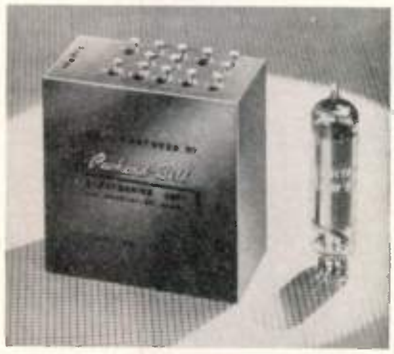
Offices: New York · Boston · Los Angeles · Toronto

News-New Products

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

(Continued from page 114A)

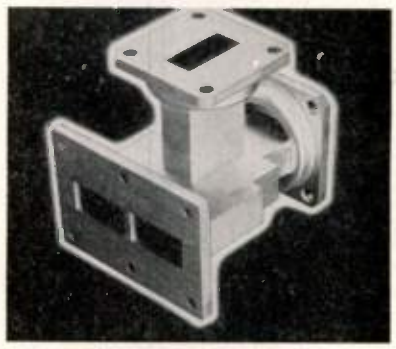
Weighing 11 ounces, the component is a part of an integrated power supply system designed and built by Packard Bell for North American Aviation.



The custom component, has a life expectancy of 10,000 hours or more, with ripple less than 50 mv from peak to peak, operating temperature of $-65°$ to $125°C$, and is adaptable to voltages of ± 50 to ± 1000. Its regulation is ± 1 per cent, with circuit gain of 60 to 80 db.

Folded Hybrid T's

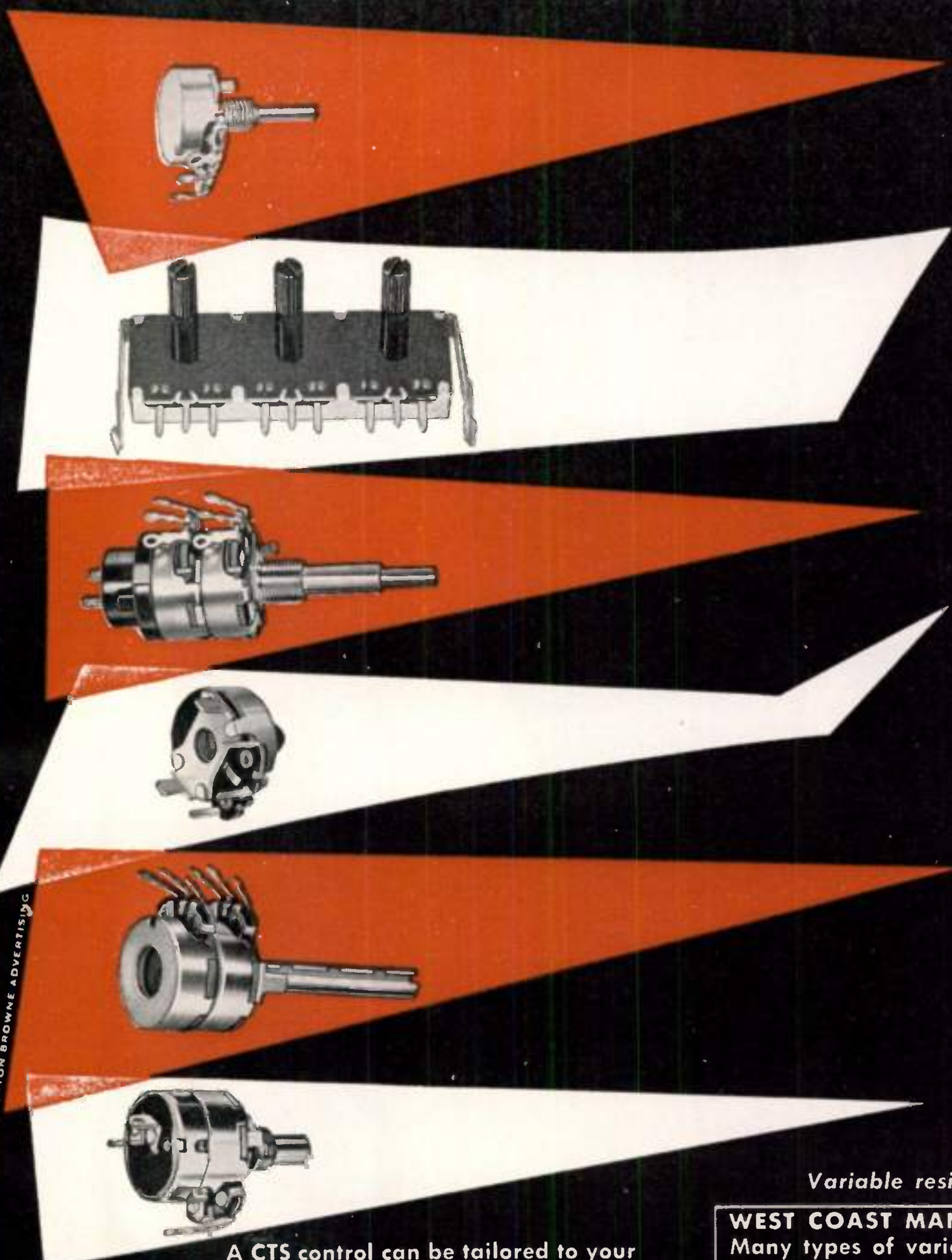
The H-Plane Folded Hybrid T, developed and licensed by Hughes Aircraft Company, is now made available in production quantities by **Microwave Development Laboratories, Inc.,** 92 Broad St., Wellesley 57, Mass.



These Hybrid T's feature high performance and are available for a wide range of frequencies from 2,700–36,000 mc, for most waveguides from 3×1 inch to 0.360×0.220 inch OD. They are precision cast in either aluminum or beryllium copper, and are normally supplied terminated in flat flanges

(Continued on page 118A)

A DEPENDABLE SUPPLIER FOR 61 YEARS



BURTON BROWNE ADVERTISING

Specialized Technical Skills—1500 job-trained, class-trained specialists . . . with a world-wide reputation for delivering variable resistors exactly as specified.

Tremendous Production Facilities—323,000 sq. ft. plant devoted to variable resistors.

Your changing Requirements Anticipated—continuous research develops new materials, designs and methods to meet your new requirements.

Economical Uniform Assembly—on a precision mass production basis.

Dependable Delivery—exceptionally good delivery cycle.

Complete Line—variable resistors for military, color and black and white TV, radio, and other commercial applications.

Variable resistors shown 2/3 actual size

A CTS control can be tailored to your specific requirement. Consult CTS SPECIALISTS on your current variable resistor problems. Ask for 62 page catalog.

WEST COAST MANUFACTURERS:
Many types of variable resistors now in production at our South Pasadena plant. Your coil, transformer and compression molding business also invited. Prompt delivery. Modern versatile equipment. L. A. phone Clinton 5-7186.

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SOUTHWESTERN U.S.A.
John A. Green Company
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Dallas 7, Texas
Phone: Riverside 3266

SOUTH AMERICA
Jose Luis Pontet
Buenos Aires, Argentina
Montevideo, Uruguay
Rio de Janeiro, Brazil
Sao Paulo, Brazil

OTHER EXPORT
Sylvan Ginsbury
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New York 18, New York
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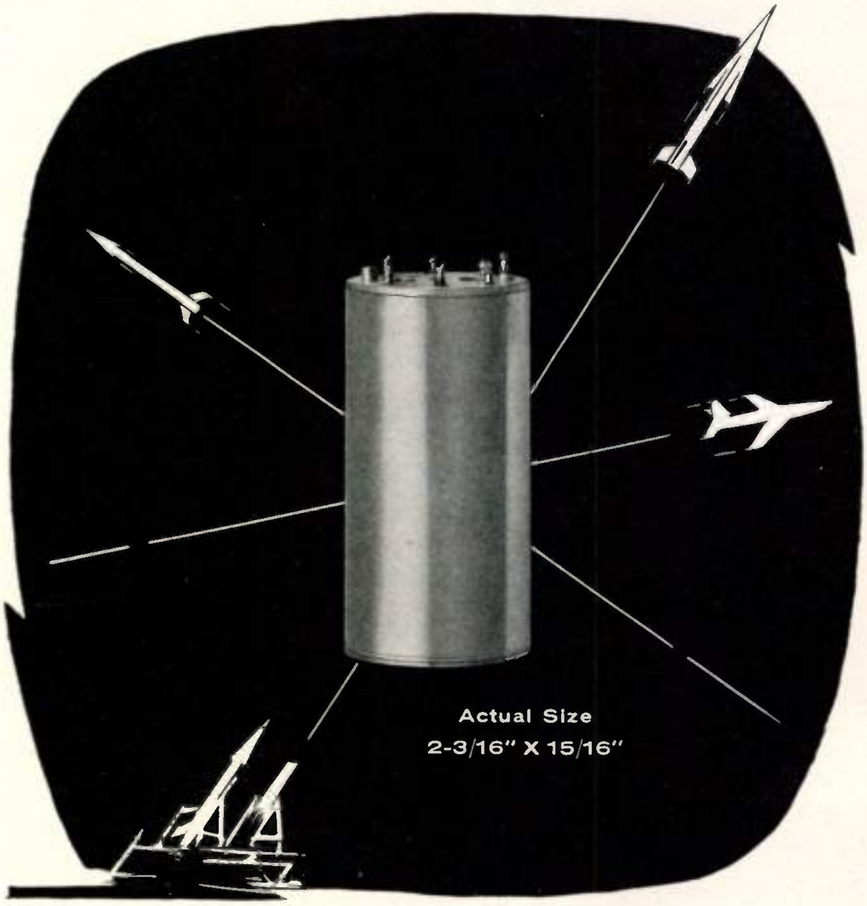
ELKHART, INDIANA

The Exclusive Specialists in Precision Mass Production of Variable Resistors

Now in mass production . . .

SANDERS Subminiature RATE GYRO



To meet the growing demand for reliable control and stabilization elements, Sanders Associates is now mass-producing the Sanders sub-miniature rate gyroscope.

Exacting applications in aircraft, missile and fire control have proved conclusively the complete reliability of this rate gyro in a wide range of conditions and environments. Its features include:

- **Torsion bar suspension for fast response to minute signals**
- **Resolution of 0.001% full scale**
- **Compensated for environmental conditions**
- **Fluid cushioning to minimize vibrational shock**
- **Rotary multi-pole differential pickoff for higher sensitivity and excellent resolution**
- **Full scale ranges available up to 400° per second**

Sanders' direct distribution offers the long experience of Sanders engineers. Their assistance can be invaluable in reviewing your gyro design and application problems. Whether your problem is on selection of a gyro or a complete gyro control package, our Application Engineers are available to serve you.

SANDERS ASSOCIATES INCORPORATED Dept. IRE-5, NASHUA, NEW HAMPSHIRE

West Coast Field Office: 7335 VAN NUYS BLVD., VAN NUYS, CALIFORNIA, Tel. STATE 0-2720

News-New Products

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

(Continued from page 116A)

but are available on request with special adapters. Operational characteristics include broad band width, low SWR, and high isolation.

Complete design, development and manufacturing facilities are offered for supplying standard or special units.

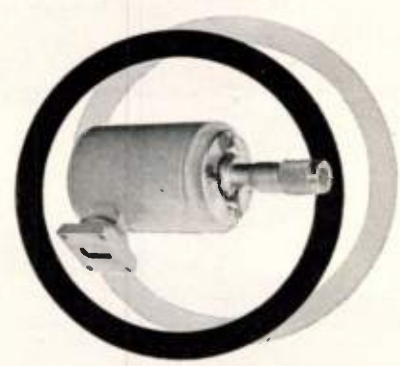
For complete details, prices, and delivery information write Nathaniel Tucker, Sales Manager, at the firm.

Silicon Voltage Regulators

Now in production three new series of voltage regulators have been designed to satisfy a full range of power requirements by **Transitron Electronic Corp.**, Wakefield, Mass. They are available with ratings of 250MW, 75MW and 10 watts, and are encapsulated in hermetically sealed axial mounting packages.

(Continued on page 120A)

D-B broad band gas-filled cavity wavemeters



Each instrument covers a wide segment of the total range. Only 11 sizes serve from 2.6 KMC to 90 KMC. Accuracy is so high they may be used as secondary standards. Nitrogen filled and sealed for long life and high Q. Bi-metallic structure provides high degree of thermal compensation. Write for literature.

DE MORNAY BONARDI ®

780 South Arroyo Pkwy. • Pasadena, Calif.

Now...an accomplishment so far reaching it will change the sights of all rectifier users

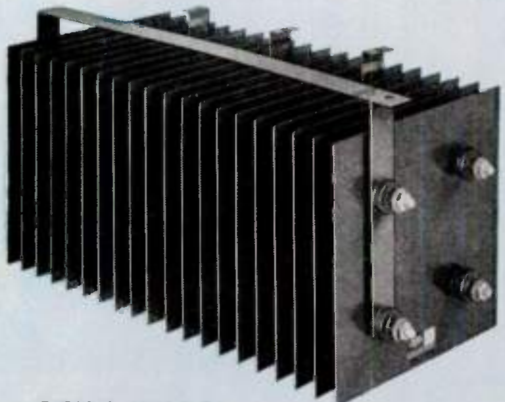
RADIO RECEPTOR'S improved new vacuum process

HCD* PETTI-SEL

**High Current Density*

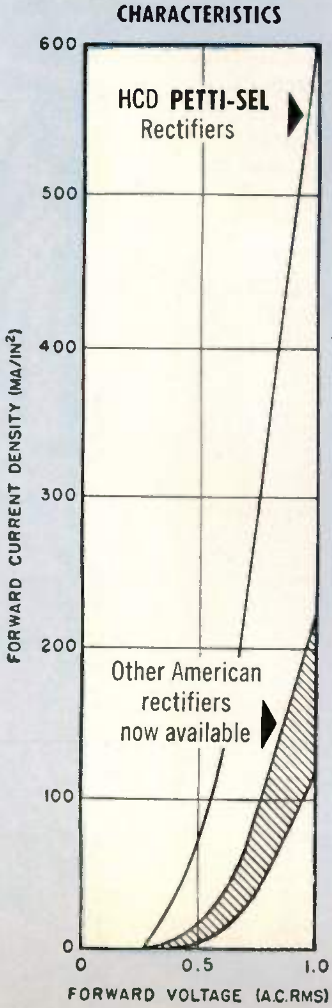
Industrial type SELENIUM RECTIFIERS

Developed by the famous Siemens Organization of West Germany and now manufactured by Radio Receptor Co. in the U. S. A.



- **Estimated life 100,000 hours**
- **Much smaller cell sizes than conventional units of the same ratings**
- **Lower forward voltage drop**
- **Suitable for high temperature applications**

TYPICAL FORWARD CHARACTERISTICS

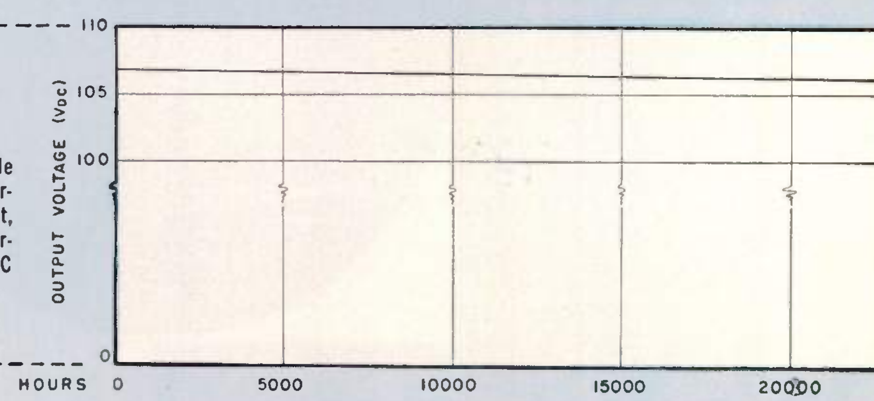


Far smaller in size than other rectifiers of the same current ratings, the new Radio Receptor HCD Petti-Sel units are manufactured under laboratory controlled conditions with fully automatic machinery, assuring new standards of product uniformity.

Field experience extending over several years with these rectifiers indicates an estimated life of 100,000 hours. This is largely attributable to the special process requiring no artificial barrier layer. Low forward voltage drop and low aging rate make the new Petti-Sel Rectifiers applicable to magnetic amplifiers and other control applications.

TYPICAL AGING CHARACTERISTIC

Cell size 4" x 4", single phase bridge (4-5-1-B) operated at 130 volts AC input, 8 amperes DC output current, resistive load, 35° C ambient temperature.



Watch for further announcements of unique developments on these history-making rectifiers. If you would like our new bulletin as soon as it is available, write today to Section P-4R.

Semiconductor Division

RADIO RECEPTOR COMPANY, INC.

Subsidiary of General Instrument Corporation

240 Wythe Avenue, Brooklyn 11, N. Y. • EVergreen 8-6000

Radio Receptor Products for Industry and Government: Selenium Rectifiers • Germanium Diodes
Thermatron Dielectric Heating Generators & Presses • Communications, Radar & Navigation Equipment

News-New Products

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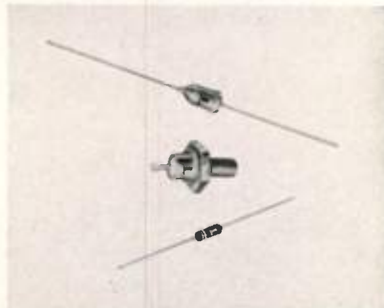
(Continued from page 118A)

All classes have standard types covering the voltage range 4.3 to 27 volts. Close tolerance and higher voltage regulators are available in assemblies.

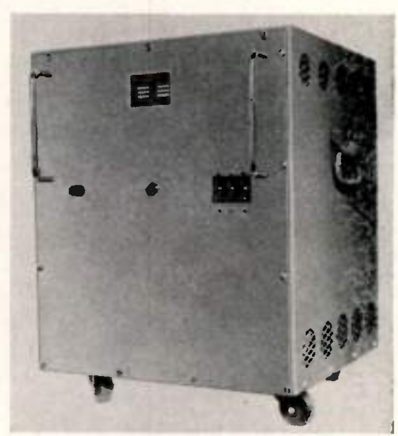


Specifications, ratings and applications information for these regulator series are found in Manufacturer's Bulletin TE-1352.

These regulators were introduced at the IRE Show in March.

1000-Watt Magnetic Servo Amplifier

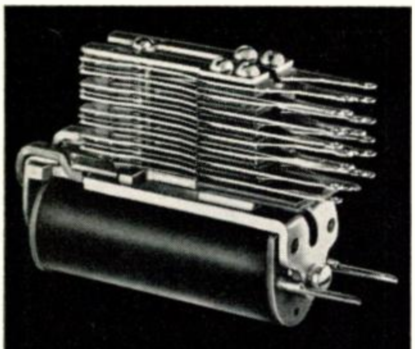
A 1000-watt magnetic servo amplifier for industrial automation is now available from **Magnetic Research Corp.,** 3160 W. El Segundo Boulevard, Hawthorne, Calif. It features one-cycle response, and provides both reference-phase and control-phase power for a $\frac{3}{4}$-horsepower motor.



The new servo amplifier allows automatic operation of milling machines and other 60-cps equipment or processes that permit programmed operation.

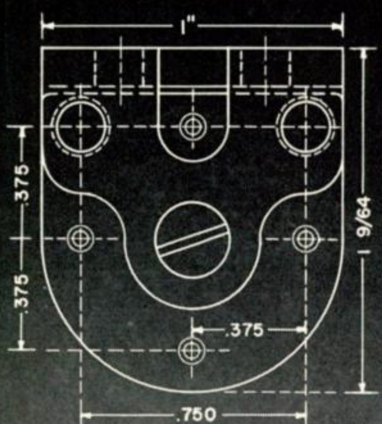
Designated the MB-1000-60, the unit incorporates a Scott-connected transformer and has no

(Continued on page 124A)



New "E" Relay

interchangeable with many other makes



Stromberg-Carlson's new type "E" relay combines the time-proven characteristics of the type "A" relay with a mounting arrangement common to many other makes.

As the sketch above shows, our new frame mounting holes and coil terminal spacing allow you to specify these relays—*of "telephone quality"*—interchangeably with brands you have been using. Costs are competitive and expanded production means *prompt delivery*.

Welcome engineering features of the new "E" relay are—

★ **Contact spring assembly:** maximum of 20 Form A, 18 B, 10 C per relay.

★ **Coil:** single or double wound, with taper tab or solder type terminals at back of relay.

★ **Operating voltage:** 200 volts DC maximum.

You may order individual can covers in a choice of 3 sizes for the new relay, as well as for our type "A" and "C" relays.

For complete details and specifications on the "E" relay and other Stromberg-Carlson relays, send for your free copy of Catalog T-5000R.

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THE MOSELEY AUTOGRAF X-Y RECORDER

trade mark

A pioneer in its field, the Moseley AUTOGRAF X-Y Recorder is being adapted to an ever increasing number of graphic recording and data translating problems. Carefully manufactured to precision standards, the AUTOGRAF is available in five models to fit your particular requirement.

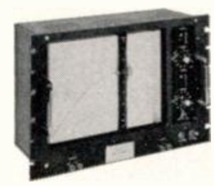
In addition to curve drawing, a full complement of accessories facilitate use of the AUTOGRAF in point plotting, curve following, card and tape reading, and gain-frequency plotting.

Model 1 portable type

Model 2 A flat-bed

Model 3 desk type

Model 4 rack type



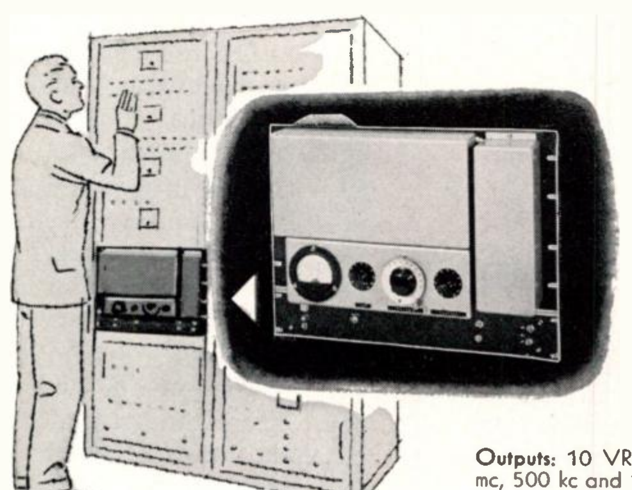
Model 5 rack type

Write for complete information:

F. L. MOSELEY CO.
409 NO. FAIR OAKS AVENUE
PASADENA, CALIFORNIA

JK PRODUCTS

JKFS-1000 1000/100 KC FREQUENCY STANDARD



Stability: Better than 1 part in 10^9 per day

Frequency: Both 1 mc and 100 kc output. Variable over range of 1 part in 10^6 and capable of being reset to 5 parts in 10^{10}

Outputs: 10 VRMS sine wave at 1 mc, 500 kc and 100 kc. Pulse output for checks to 20 mc

This combination of the JK-Sulzer precision oscillator and JK-Sulzer Synchro-Lock divider are designed to modernize existing primary standards where requirements call for the extreme stability of JK-Sulzer equipment. Combined units measure 15¾" high x 19" wide for standard rack mounting. Write for literature.

THE JAMES KNIGHTS COMPANY, Sandwich, Illinois

400°F

new synchro

- 250 hour life at 400°F.
- Unprecedented −65°F to +400°F operating temperature range.
- Unique lubrication method.
- Special alloy for electrical connections.

Type 11-4133-01 is a size 11 torque transmitter synchro with 115V 400 cycle input. Accuracy is ±15′, null voltage 175 mv, stator output 90 volts and phase shift 6.5°. Impedances are $Z_{RO}=315+J1590$, $Z_{SO}=290+J773$ and $Z_{RSS}=520+J286$.

This is another Oster "first." Write for further information today.

Engineers for Advanced Projects:
Interesting, varied work on designing transistor circuits and servo mechanisms. Contact Mr. Zelazo, Director of Research, in confidence.

John Oster
MANUFACTURING CO.
Your Rotating Equipment Specialist

Avionic Division
Racine, Wisconsin

Other products include actuators, servos, AC drive motors, servo mechanism assemblies, DC motors, motor-gear-trains, fast response resolvers, servo torque units, reference and tachometer generators and motor driven blower and fan assemblies.

News-New Products

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

(Continued from page 120A)

toroids. It is used primarily in 220-volt, three-phase operation, but will also provide 115-volt, single-phase or two-phase operation with simple factory modification. It is installed in an enclosed, wheeled cabinet 20 inches high, 16½ inches deep and 17 inches wide.

A 200-watt unit having the same basic features as the MB-1000-60, and designated the MB-200, is also available.

Technical information may be had on request.

Radiation Bulletin

Nuclear Science and Engineering Corp., P.O. Box 10901, Pittsburgh 36, Pa., has a new four page Bulletin #407 which describes services for health and safety precautions against hazards of radioactivity. These services include Accountability (for SS Nuclear Materials Management); Criticality Precautions (for fuel element fabrication); and complete Health Physics services. Copies of Bulletin #407 are available from: Richard Frankel at the firm.

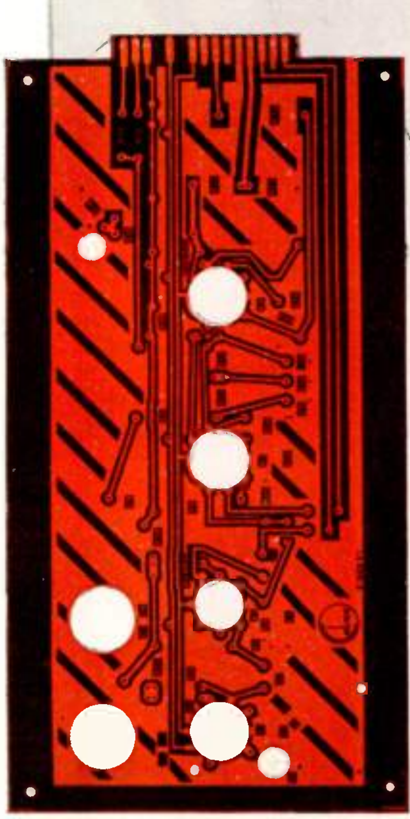
Cold Cathode Rectifier

Raytheon Manufacturing Co., Receiving & Cathode Ray Tube Operations, 55 Chapel St., Newton 58, Mass., announces the new type CK6763 improved and ruggedized cold cathode rectifier of

miniature construction and with electrical characteristics like those

(Continued on page 126A)

"now I can service our Sphygmomanometer* thanks to Formica® XXXP-36"



This sphygmomanometer — or *automatic blood pressure recorder, if you prefer — demonstrates how manufacturers of electronic products cut field service cost with Formica copper clad laminates.

Through its cold fabricating grades, Formica contributes the dimensional stability and accuracy essential for absolute interchangeability of components.

For example, with the circuit uniformity that Formica XXXP-36 provides, Colson Corporation, Elyria, Ohio, now services its automatic blood pressure recorder by phone and mail. Formerly skilled technicians had to be sent out from the factory.

And that's not all. Formica XXXP-36 also offers 1,000,000 megohms insulation resistance, low moisture absorption, translucency, watermarking . . . and uniform color from lot to lot.

Why not design your products to get the full benefit of printed circuitry? You can with Formica copper clad. And remember, Formica gives you the widest choice of base laminates, including over 12 grades made of paper and nylon, glass and cotton cloth . . . impregnated with epoxy, phenolic and melamine resins. For complete information, send today for Copper Clad Technical Data, form 688. Formica Corporation, a subsidiary of American Cyanamid, 4532-7 Spring Grove Ave., Cincinnati 32, Ohio.

Save your engineering time—use our engineering staff

Formica-4, the complete laminated plastics service, cuts your engineering time—reduces component parts cost—and assures delivery for mass production schedules.

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FORMICA 4

(1) Application engineering
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(3) Fabricating
(4) Customer stock service

FI-1424

News-New Products

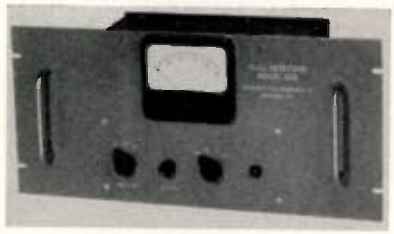
These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 124A)

of type CK5517. This type will stand a 96 hour 35G vibration test at 320 cps without change whereas conventional designs are destroyed after only a few hours. The tube will handle 2800 volts peak inverse at a rectified current of 12 milliamperes and requires no heater power.

Data and further information are available from Technical Information Service.

Null Detector



The Industrial Test Equipment Co., 55 E. 11 St. New York 3, N.Y., has introduced Null Detector

(Continued on page 128A)

News-New Products

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

(Continued from page 126A)

Model 60B. This instrument is battery operated to provide complete isolation from power lines. It is shielded against external fields and is ideally suited for Schering and other bridges. The sensitivity is 3 microvolts for 1 per cent deflection. Built-in tuned circuits permit a sharp balance even when the null is complicated by harmonics.

Rotating Cylinder Viscometer

A new Rotating Cylinder Viscometer featuring electrostatic restoring torque has been announced by the **Scientific Instruments Div., Polarad Electronics Corp., 43-20 34th St., Long Island City 1, N.Y.**

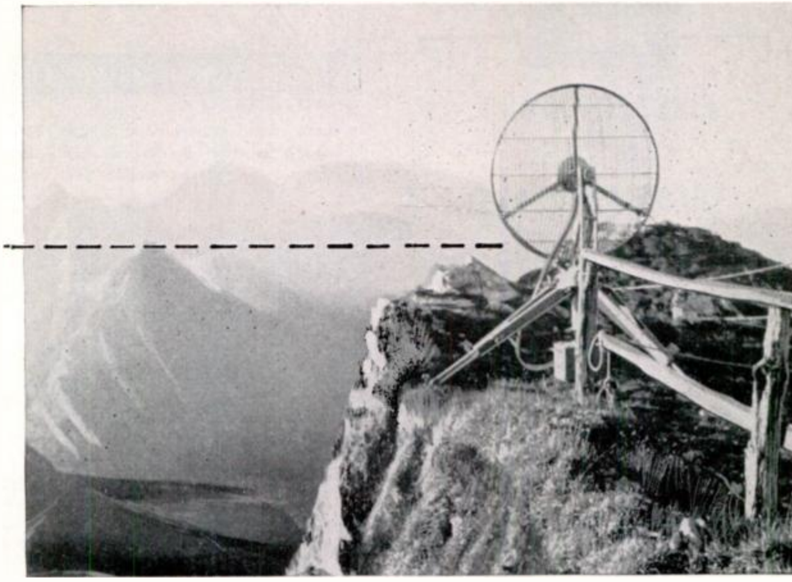
The unit is designed for making viscosity measurements at shear rates as low as 0.2 second^{-1} without extrapolation and is useful for studies of high molecular weight polymers, proteins and nucleic acids. The company reports that the instrument is free from varying velocity gradient and that the electrostatic restoring torque provides essentially a frictionless suspension which eliminates torsion wire problems.

Precision Step Attenuator

Weinschel Engineering Co., 10503 Metropolitan Ave., Kensington, Md., has developed a new model 64 precision attenuator, dc to 100 mc, with 50 ohm impedance.

The unit has 3 drums, 0 to 64 db in 0.1 db steps. It has female type "N" connectors.

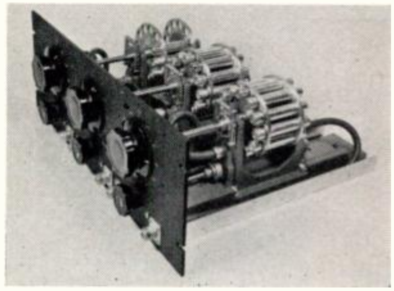
(Continued on page 130A)



News-New Products

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

(Continued from page 128A)



Maximum VSWR is dc to 400 mc:1.10; dc to 1000 mc:1.15.

The accuracy of insertion loss at dc is 1–5 db:0.02 db; 6–10 db: 0.05 db; 20–50 db: 0.1 db.

The maximum change of incremental insertion loss, dc to 1000 mc is 1–10 db; 0.1 db; 20–50 db; 0.1 per db.

Calibration data supplied, insertion loss at 400 mc to 1 kmc; VSWR for both terminals.

Calibration accuracy—1–30 db; ±0.1 db; 40–50 db; ±0.2 db. The price is $195.00.

(Continued on page 132A)


WHY DOUGLAS ENGINEERS AND SCIENTISTS GO FURTHER...
At DOUGLAS, your career in missiles is backed by sixteen years of experience and an ever-expanding future
US ARMY
The finest talents and facilities in the industry have earned an outstanding position for Douglas in the national missile program.
You will become part of a team that has contributed more to the research, design, development and production of missiles than any other group in the nation.
You will work on projects that challenge the imagination... that stretch out far into the future ... that let you plan a secure and rewarding career with Douglas. Many of these projects have their roots in the mid-forties and are still growing.
Close coordination of missile and aircraft work provides an interchange of experience and knowledge among Douglas engineers and scientists. All plants are engaged in some phase of this missile program... making possible a broad choice of locations where you can work and establish living conditions suited to your taste.
For complete information, write:
E. C. KALIHER,
MISSILES ENGINEERING PERSONNEL MANAGER,
DOUGLAS AIRCRAFT COMPANY, BOX 620-M,
SANTA MONICA, CALIFORNIA
THIS IS NIKE HERCULES, a surface-to-air missile newly developed out of the original Nike system started in 1945 — a major project in the Douglas missile program.
GO FURTHER WITH DOUGLAS
FIRST IN AVIATION

AT LAST

a completely new kind of regulator!

ACTUALLY THREE REGULATORS IN ONE—*PLUS* MULTIPLE SENSING!

The APR 1010 combines many *new* regulation and sensing systems in *one* versatile package. Here's flexibility of operation never before possible...saves space, eliminates instrument duplication, means greater economy in engineering operations.

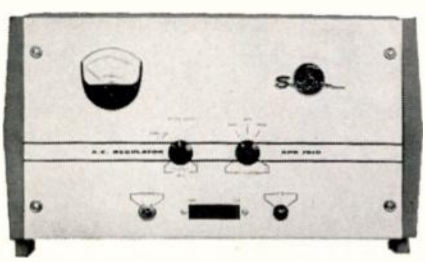
- **RMS VOLTAGE REGULATION**
- **AVERAGE REGULATION**
- **PEAK REGULATION**
- ***FIVE* PRINCIPAL SENSING ARRANGEMENTS**

  1. Internal 2. External 3. Remote
  4. Constant Current 5. DC

ELECTRICAL CHARACTERISTICS:

Input	95-130 VAC, 1ø (50 or 60 cps ±10%)
Output	115 VAC, adj. 110-120V
Regulation accuracy (RMS, average, or peak, switch selected)	±0.1% against line ±0.1% against load
Distortion	3% max.
Load	0-1000VA
P.F. range	Unity to 0.7 lagging
Recovery time	0.1 sec.

WRITE FOR COMPLETE TECHNICAL DATA.



Sorensen

SORENSEN & COMPANY, INC. • STAMFORD, CONN.

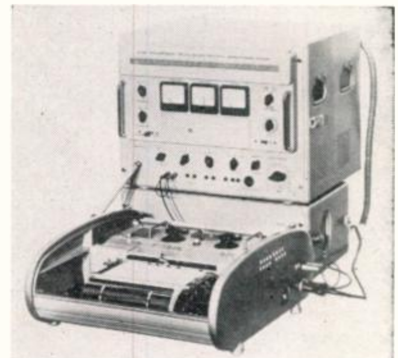
News-New Products

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

(Continued from page 130A)

VHF Spectrum Recorder

A VHF Spectrum Recorder, which provides complete, permanent, continuous and simultaneous visual recordings of all transmissions in the VHF range from 30 to 330 mc, is available from the **Instrument Division, Federal Telephone and Radio Co.,** 100 Kingsland Rd., Clifton, N. J.



This system, designated as Type FT-FBS, consists of a high quality VHF band receiver, and a moving-paper recorder swept laterally by a recording stylus.

The recorder makes a record of fixed and mobile radio transmissions, commercial and other AM and FM radio broadcasts, pulse signal transmissions, and interference signals appearing at all previously mentioned frequencies. The Type FT-FBS shows visually: the frequency of all transmitters in operation in the 30–330 mc band, indicating whether the transmitters are off their assigned frequencies, the amount of drift, the time at which drift started and stopped and whether the drift is repetitive; the bandwidth occupied by each transmitter and whether the transmission is FM, AM, video, single sideband, etc.; the extent of the sidebands of modulated carriers; the time during which each transmission occurs including even repetitive transmissions of short duration such as those of taxicabs; variations of field strength of transmitters at the point of observation; and the extent, distribution and intensity of noise spectra such as diathermy. Complete details are available from the firm.

(Continued on page 134A)

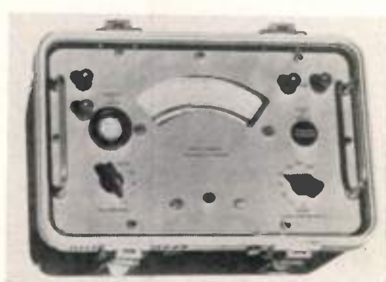
News New Products

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

(Continued from page 132A)

Reference Standard

Sensitive Research Instrument Corp., 310 Main St., New Rochelle, N. Y., has developed a ruggedized reference standard, which have diamond pivots and sapphire spring mounted jewels. These instruments have an accuracy of 0.5 per cent full scale on all ranges. The ranges are 0–1.5/30/150 ma; 0–0.3/1–3/30/150/300/500 volts (20,000 ohms/volt, 50 ma).



(Continued on page 136A)

ELECTRONICS IN BRITAIN

The British Electronics Industry is making giant strides with new developments in a variety of fields. Mullard tubes are an important contribution to this progress.

The expert choice . . . . for medium power, high fidelity equipment

EL84

Principal Ratings

Heater	6.3V, 0.76A
Max. plate voltage	300V
Max. plate dissipation	12W
Max. screen voltage	300V
Max. screen dissipation (max. signal)	4W
Max. cathode current	65mA

Base

Small button noval 9-pin

British high fidelity experts know that for medium powered equipment there is no finer tube than the EL84. A pair of these tubes provide a power output of 10W at a distortion level of less than 1% while their transconductance value of 11,300 μmhos results in exceptional sensitivity. The EL84 may also be used for higher powers. For example, two tubes in push-pull will provide outputs of up to 17W at an overall distortion of 4%.

A single EL84 has a maximum plate dissipation of 12W. It provides an output of 5-6W for an input signal of less than 5V r.m.s. at plate and screen voltages of 250V.

Supplies of the EL84 for replacement in British equipments are available from the companies listed.

Supplies available from:—

In the U.S.A.

International Electronics Corporation, Dept., P5, 81 Spring Street, N.Y. 12, New York, U.S.A.

In Canada

Rogers Majestic Electronics Limited, Dept. KE, 11-19 Brentcliffe Road, Toronto 17, Ontario, Canada.

Mullard

ELECTRONIC TUBES

used throughout the world

MULLARD OVERSEAS LTD., MULLARD HOUSE, TORRINGTON PLACE, LONDON, ENGLAND

MEV 43

News-New Products

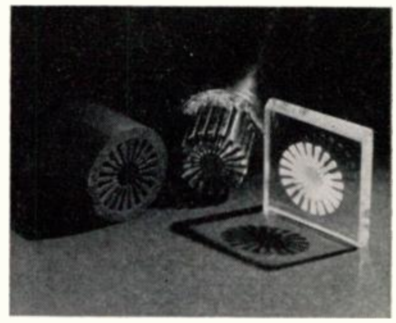
These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 134A)

The instrument is waterproof, withstands 60 cps vibration, and approximately 200 g's shock. The electrical overload is 5000 per cent of basic sensitivity. The moving coil assembly is a light weight fungus-proofed element with a well aged high Alnico V magnet. Double pivoted D'Arsonval movement. Diamond pivots and shock mounted jewels.

Sensitive Research will install these jewels on their new laboratory instruments, dc milliamperes, voltmeters, and panel instruments at $30.00 surcharge.

Ultrasonic Impact Grinder



Designed as a low-cost, high-precision unit for machining germanium, ceramics, ferrites and other hard or brittle materials, a new ultrasonic impact grinder selling for less than half the cost of previous models is now available from the **Commercial Equipment Div., Raytheon Manufacturing Co.,** Waltham, Mass. Since the machine exactly reproduces the tool shape in the work piece, it brings to the machining of ceramics and other ordinarily "unmachinable" substances accuracy, freedom of design and reduction of cost never before realized.

Designed on the basis of experience gained with Raytheon's larger, higher capacity impact grinder, the new unit is built to the same exacting requirements and offers tolerances of ±.0007 inch. Power source for the unit is 115 volts ac and water cooling is not required. Bench mounted, pedestal and driver unit is 23×16×15 inches and the driver is 19×16×13 inches. Weight is under 200 lbs.

(Continued on page 138A)

News-New Products

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

(Continued from page 136A)

Low-Ohm-Meter

A new ohmmeter, which features accurate measurements of low resistance values and utilizes low circuit currents, has just been announced by the **Simpson Electric Co.**, 5200 W. Kinzie St., Chicago 44, Ill.

Called "Low-Ohm-Meter," Model 362, the new tester gives readings from 0.1 to 25 ohms with an accuracy of 3 per cent of the full scale value. This accuracy is attained by using the expanded scale of the suppressed-infinity shunt type ohmmeter. Another feature is its circuit current of 5 ma maximum, which prevents damage to low-current components and promotes long battery life.

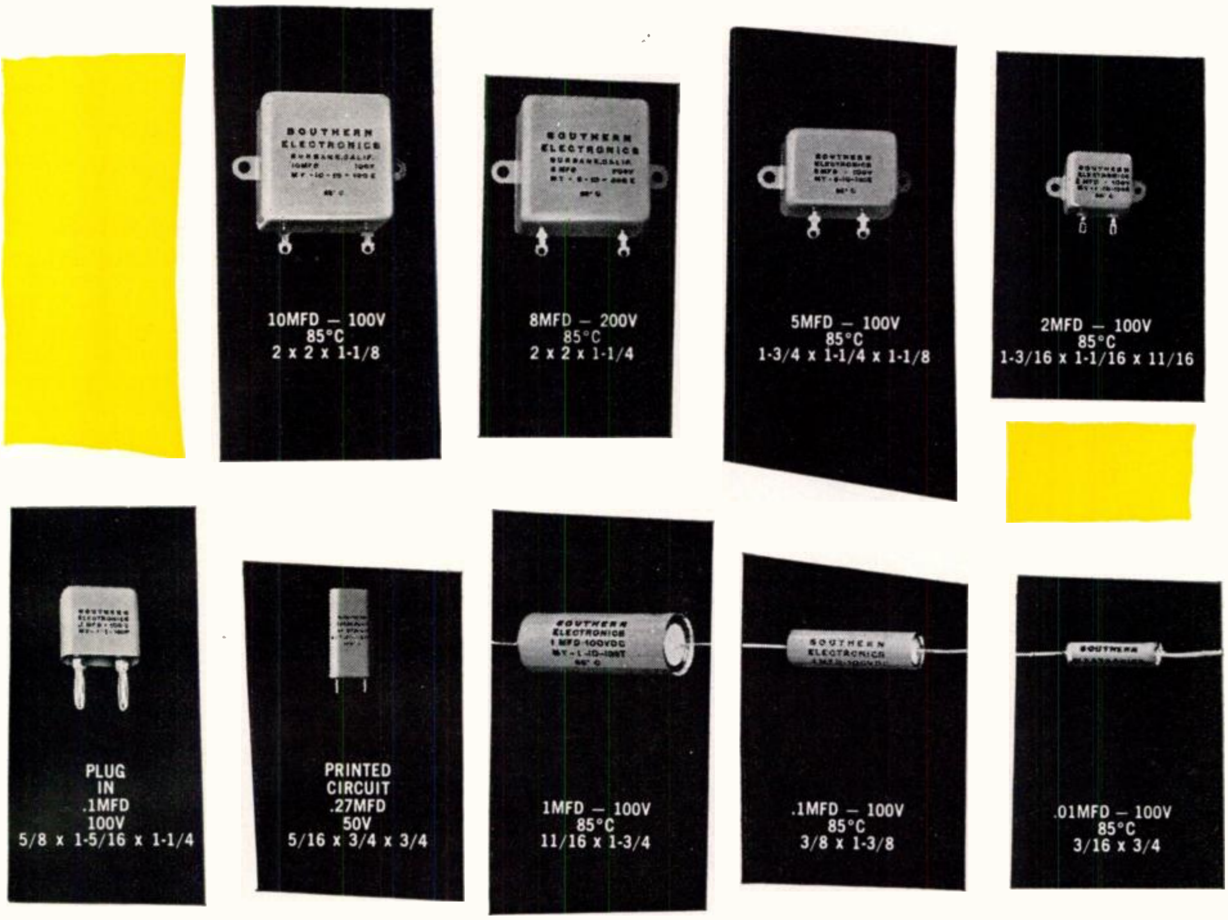
The meter should find wide application in checking wiring connections, contacts, transformers, and other low-resistance components as well as in servicing electric motors and generators.

Model 362 uses one, self-contained battery (type "C," $1\frac{1}{2}$ V) for its power source. Ranges are 0–5 ohms and 0–25 ohms. Overall size is $3 \times 5\frac{7}{8} \times 2\frac{1}{2}$ inches. Price, complete with calibrated test leads, is $24.95.

A new six page bulletin, available on request, which covers a representative selection of their test equipment line, is now being offered by Simpson.

Designated Bulletin No. 2058, it contains up-to-date listings of test equipment for servicing.

(Continued on page 140A)



At last! Mycon Plastic Capacitors up to 150° C!

- *Reliability proved*
- *Rated for infinite long life*
- *Insulation resistance 1 x 10^{11} OHMS*

Derated at 125°C as follows:
100 volts — 50%
200 volts — 50%
300 volts — 33⅓%
400 volts — 33⅓%
500 volts — 20%
600 volts — 16%

Tested and proved! Only Southern Electronics Corporation has developed a test procedure which insures built-in reliability! For your most exacting requirements—be sure—always specify S.E.C.

SUPER MYCON CAPACITORS

Tolerance to 1%—lowest temperature coefficient. Superior insulation resistance at high ambient temp. Good stability compatible with material.

POLYCON
SEC
MYCON

Wire, write or phone for complete catalog today!

SOUTHERN ELECTRONICS
Corporation

150 West Cypress Avenue, Burbank, California
PIONEERS IN CUSTOM CAPACITOR ENGINEERING

News-New Products

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(Continued from page 138A)

Lockheed Advances Hawkins and Snow

Engineering and research branches of Lockheed's Missile Systems division are being integrated as the organization moves into a new phase of its development, General Manager L. Eugene Root announced recently.

The first head of the division's new Research and Development branch will be Dr. Louis N. Ridenour, presently director of research.

Willis M. Hawkins, present director of engineering, will become an assistant general manager of the division. He will occupy this position on a training basis for one year, at which time Ridenour will assume the assistant general manager's post for a similar training period and Hawkins will take over the Research and Development branch.

Root pointed out that the new arrangment will carry on the company's executive training program, while at the same time providing additional administrative efficiency.

In another move aimed at facilitating expansion of the Lockheed division, Root announced the creation of a product planning branch under Wilbur D. Snow.

This organization will be responsible for the division's long range planning activities, including facilities, manpower, and capital investment.

Snow comes to the missile division from a position as head of management planning for the Lockheed corporation.

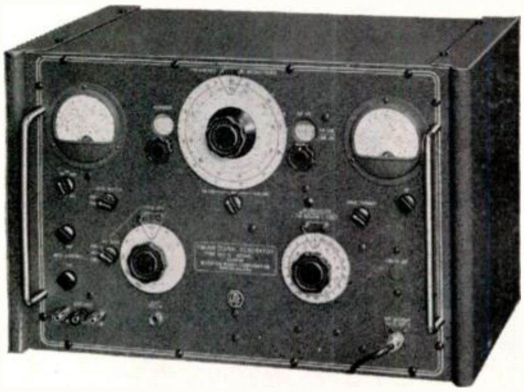
He served two years as a top

(Continued on page 142A)

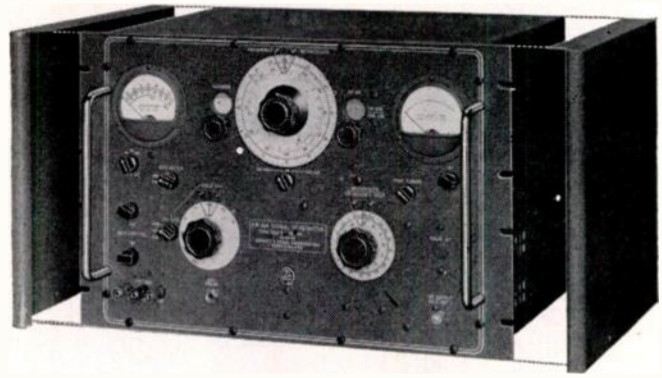
NEW! # FM-AM SIGNAL GENERATOR

Designed for bench use or rack mounting

Type 202-E. 54 to 216 MC



Type 202-E with cabinet end bells attached for BENCH USE



Type 202-E with cabinet end bells removed for mounting in a standard 19" RELAY RACK

Power Supply used with Type 202-E for BENCH USE

Power Supply used with Type 202-E for 19" RACK MOUNTING

RF OUTPUT VOLTAGE:

Max. open circuit voltage at front panel jack is approx. 0.4 volts. With output cable attached 0.2 volts nominal. Output impedance 50 ohms resistive at front panel jack. Minimum output 0.1 microvolts.

FREQUENCY MODULATION:

Three deviation ranges, 0-24 KC., 0-80 KC., and 0-240 KC., each continuously adjustable. FM distortion at 75 KC is less than 2% and at 240 KC less than 10%.

FIDELITY CHARACTERISTICS:

Deviation sensitivity of FM modulation system as a function of frequency is flat within ± 1 DB from 30 cps to 200 KC.

AMPLITUDE MODULATION:

Internal AM available from 0-50% with meter calibrations at 30% and 50% points. External modulation may be used over the range from 0-50%. A front panel jack connects to the screen of the final stage for pulse and square wave modulation.

SPECIAL FEATURES:

Incremental frequency range: The △ F switch permits tuning in increments of ± 5, ± 10, ± 15, ± 20, ± 25, ± 30, ± 50, ± 60 KC in the 108 to 216 MC range — half these values in the 54 to 108 MC range. A fine tuning control permits continuous tuning over a range of approximately ± 20 KC in the 108 to 216 MC range, and ± 10 KC in the 54 to 108 MC range.

FREQUENCY:

54 - 216 MC. may be extended down to 100 KC by using the Univerter Type 207-E below.

This Univerter can be used, as above, for bench or rack mounting.

PRICES:

FM-AM Signal Generator Type 202-E with power supply $1090.00

Univerter Type 207-E $390.00

F.O.B. Boonton, New Jersey

BOONTON RADIO CORPORATION

Boonton, New Jersey

News-New Products

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

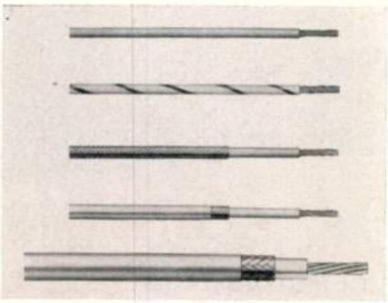
(Continued from page 140A)

planning Air Force officer in the engineering division at Wright Field and four years in the office of the deputy Chief of Staff for Development, Snow came to Lockheed in 1954 as a development planning specialist.

High Temperature Wire and Cable

A full and complete range of wires and cables for high temperature applications has been developed as the new Series T line of Teflon insulated wires and cables by the **Times Wire and Cable Co.,** Wallingford, Conn.

The Series T line encompasses Hook-up wires, Miniature Coaxial and Coaxial Cables and Multiconductor cables.

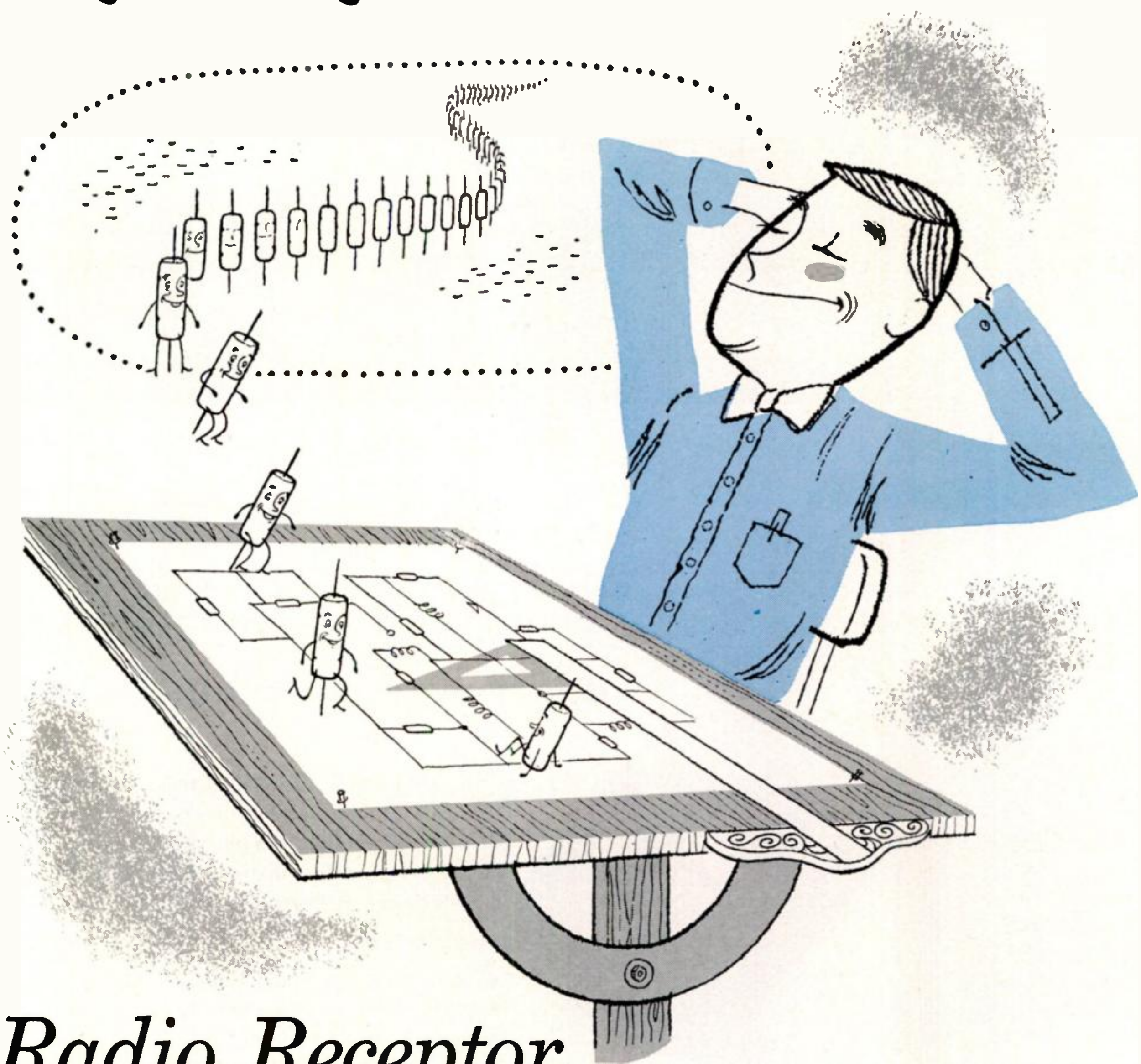


Extruded as well as spirally wound and fused Teflon insulations are offered in a range of 14 colors and/or spiral stripping, on solid, standard and special strandings of silver plated copper wire conductors of from AWG 32 through AWG 10.

Hook-up wires with extruded Teflon insulation comply with MIL-W-16878B specifications and have a rating of from −90°C to +250°C. Hook-up wires with spirally wound and fused Teflon insulation are manufactured to the MIL-W-16878B specifications for temperatures to 250°C, and feature a free-stripping and extra flexible construction. All hook-up wires can be shielded and jacketed to individual specifications, although Times offers a standard shielded construction (90 per cent minimum coverage) as well as fused Teflon jacketing in 10 standard colors for its entire range of hook-up wire sizes.

(Continued on page 145A)

Making drawing board dreams come true!



Radio Receptor

Germanium Diodes

You electronic engineers show limitless imagination and ingenuity, but to help translate ideas into reality you need extra special components, such as Radio Receptor Gold Bonded Diodes. Right now they are being used successfully by many top-flight companies whose circuits require high forward conductance coupled with other stringent characteristics — and the ability to take a beating under grueling conditions.

A complete range of RRco. diode types is available — and if you haven't found the type *your* circuit calls for, no doubt we can make it specially for you. So, if diodes can possibly help your project, consult our engineers without obligation. Write Dept. P-5

Semiconductor Division

RADIO RECEPTOR COMPANY, INC.

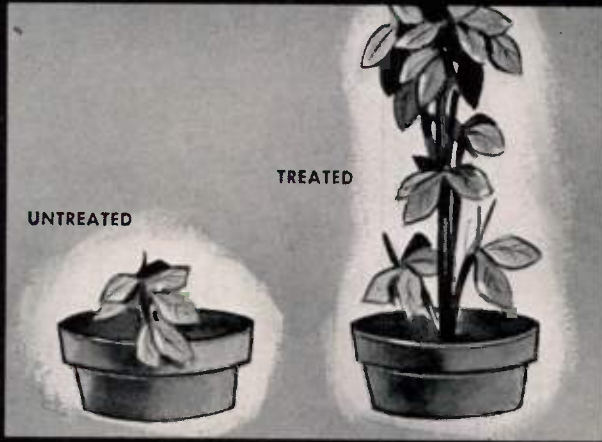
Subsidiary of General Instrument Corporation

240 Wythe Avenue, Brooklyn 11, N. Y. • EVergreen 8-6000

Radio Receptor Products for Industry and Government: Selenium Rectifiers • Germanium Diodes
Thermatron Dielectric Heating Generators & Presses • Communications, Radar & Navigation Equipment

tomorrow is here today!

Botanists who have long wondered if a plant growth accelerator was possible are now flabbergasted by an amazing new chemical development—Gibberellic Acid. A dose as small as .000001 gram can induce a plant to phenomenal growth and flowering . . . four to five times its normal height, maturing ahead of schedule. What effect would Gibberellic Acid have on humans? . . . scientists will soon have the answer!



C402A

new series 402 PRECISION

direct reading frequency meters

FXR SERIES 402 new line of temperature compensated Precision Direct Reading Frequency Meters provides simplified operation with improved accuracy. The SERIES 402 is designed for maximum scale legibility to increase the efficiency of frequency measurements.

features:

- Direct reading over full waveguide frequency range
- High resolution and accuracy
- Hermetically sealed Invar cavity
- Rugged mechanical construction
- Reaction type coupling; 35% nominal dip
- Non-contacting tuning plunger
- High Q: approximately 8,000

SERIES 402 PRECISION DIRECT READING FREQUENCY METERS

TYPE NO.	FREQUENCY RANGE (KMc/s)	WAVEGUIDE SIZE	FLANGE TYPE	ABSOLUTE ACCURACY*		SMALLEST SCALE DIVISION
				ROOM TEMP.	—40° to +55°C	
C402A	5.85 to 8.20	1½ x ¾	UG-344/u	0.01%	.03%	1.0 Mc
X402A	8.20 to 12.40	1 x ½	UG-39/u	0.015%	.03%	2.0 Mc

*Dial correction chart integral with unit.

FXR ELECTRONICS & X RAY DIVISION F-R MACHINE WORKS, INC.

Electronics & X-Ray Division

F-R MACHINE WORKS, Inc.

26-12 Borough Place, Woodside 77, N. Y. ASToria 8-2800

Write TODAY for new catalog of complete line of Precision Microwave Test Equipment

Representatives: Los Angeles: J. C. VanGroos Co.; Denver: Hytronic Measurements Inc., Chicago: KaDell Sales Assoc.; Export: Szucs Int'l Co., N. Y.

News-New Products

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

(Continued from page 142A)

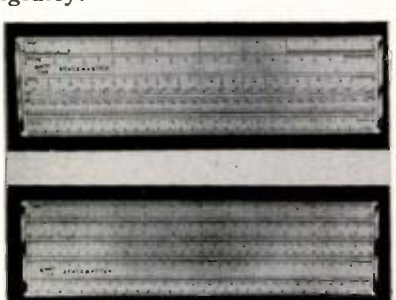
Miniature Potentiometer

A new micro-miniature potentiometer produced by **Bourns Laboratories, Inc.**, 6135 Magnolia Ave., Riverside, Calif., is designed for use with printed circuit boards and modular-type assemblies. The new TRIMPOT JR. is 3/16×5/16 ×1 inch in size. Seventeen units can be mounted in one square inch of panel space. Power rating is 2 watts, and maximum operating temperature is 175°C.

This model is built to meet or exceed government specifications for humidity, salt spray, vibration, acceleration and shock. The TRIMPOT JR. features a 15-turn screwdriver adjustment and 1½, 0.016 inch diameter leads. The shaft-clutch assembly idles when the mechanical limits are reached, thus preventing possible damage from forcing of adjustments. Mounting is accomplished with 2-56 screws through stainless steel eyelets on ¾ inch centers.

Improved 12 Inch Rules

New Improved 12 inch Architect's and Engineers' Sealemasters have been introduced by the C-Thru Ruler Company of Hartford, Connecticut. The new Sealemasters have metal reinforcements on each end to give them greater rigidity.



Other important features are: all scales exposed to full view for use at a moment's notice: slotted openings for convenient use.

The Architects' Scalemaster has 14 full view exposed scales, and the Engineers' Scalemaster has 9 full view exposed scales.

Complete information may be obtained from the **C-Thru Ruler Co.**, 827 Windsor Street, Hartford, Conn.

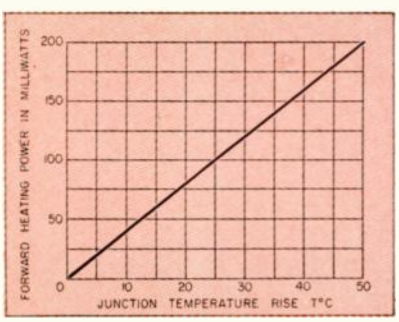
(Continued on page 164A)

New Sylvania package offers

Maximum Dissipation in Miniature Diodes

Cooler operation resulting from higher dissipation of Sylvania glass-to-metal miniature diode permits closer printed board spacing for maximum savings in space.

Right angle bending of leads for printed board insertion does not affect the diode body since metal-to-glass design avoids chipping or cracking.



Typical dissipation curve of the Sylvania glass-to-metal diode.

Actual comparison of Sylvania miniature diodes with all-glass miniatures shows that the Sylvania metal-to-glass package design results in greater dissipation. As a result, cooler operation can extend diode life and improve product dependability and performance. Diodes can be banked closer on printed circuit boards for maximum space savings.

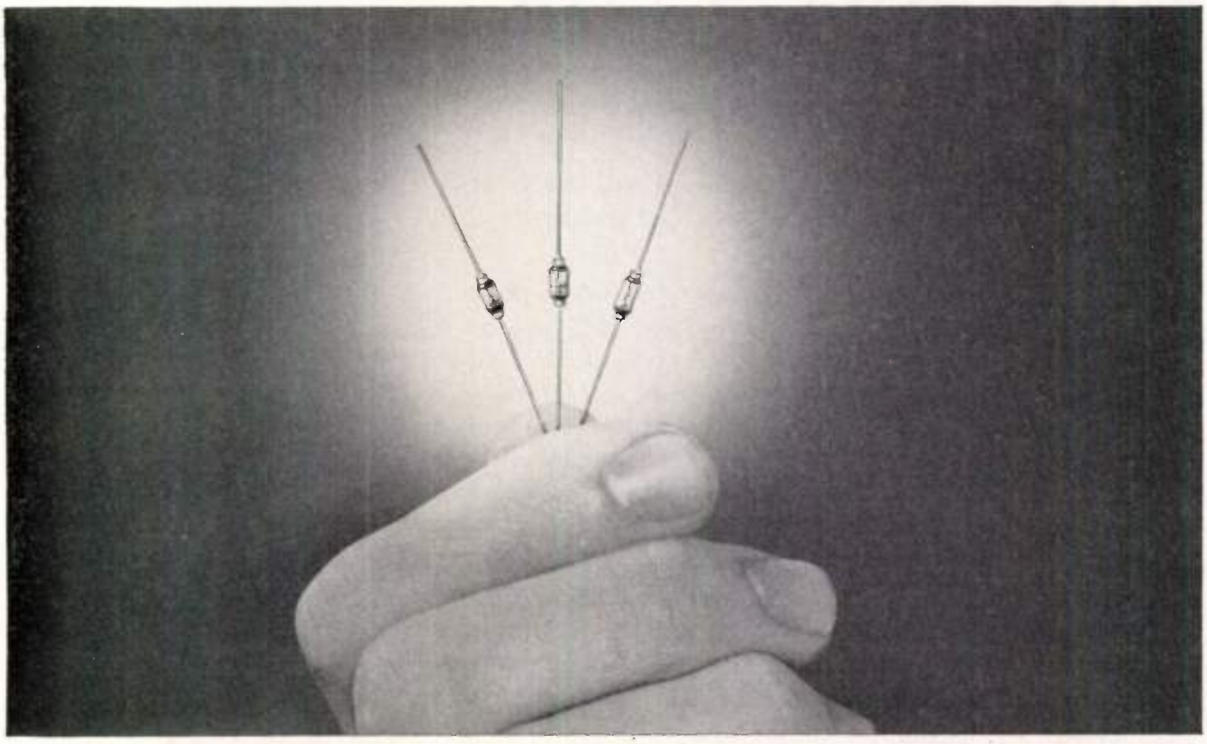
Metal-to-glass package offers other important advantages. The diode cartridge is assembled *before* installation of the whisker and die—avoiding excessive heating. In addition, right angle bending of the leads for printed board insertion does not result in chipping or cracking of the diode body.

Sylvania offers a complete line of miniature diodes in the glass-to-metal package. The package meets the standard RETMA outline of .105″ maximum diameter and .265″ maximum overall length. Write for complete details.

SYLVANIA

Sylvania Electric Products Inc.
1740 Broadway, New York 19, N. Y.
In Canada: Sylvania Electric (Canada) Ltd.
Shell Tower Bldg., Montreal

LIGHTING • RADIO • TELEVISION • ELECTRONICS • ATOMIC ENERGY



ELECTRICAL CHARACTERISTICS OF SYLVANIA MINIATURE DIODES AT 25° C

Type	Minimum Forward Current at 1 volt	Maximum Reverse Current	Minimum Peak Inverse Voltage (0 dynamic impedance)	Maximum Forward Voltage	Minimum Reverse Resistance	Maximum Reverse Recovery @ 0.3 u sec (Note 3)	Stability
IN67A	4 ma	50 ua @ −50 volts 5 ua @ −5 volts	100 volts				
IN90	5 ma	750 ua @ −50 volts	75 volts				
IN98	20 ma	100 ua @ −50 v 8 ua @ −5 v	100 v				
IN126	5 ma	850 ua @ −50 v 50 ua @ −10 v	75 volts				
IN127	3 ma	300 ua @ −50 v 25 ua @ −10 v	125 volts				
IN128	3 ma	10 ua @ −10 v	50 volts				
IN191	5 ma	Note 1	Note 1				
IN198	4 ma (5 ma @ 75° C)	50 ua @ −50 v (Note 2) 10 ua @ −10 v	100 volts				
IN631				3.5 v (Note 4)	500 kohms (Note 5)	500 ua	Note 7
IN632				1 V If = 7 ma	500 kohms (Note 5)	800 ua	Note 7
IN633				1 V If = 125 ma	500 kohms (Note 6)	1650 ua	Note 7
IN634	50 ma	45 ua @ −45 v 100 ua @ −100 v	115 volts				
IN635	50 ma	175 ua @ −150 v	165 volts				

Note 1: For type 1N191 at 55° C the reverse resistance will be 400 ohms or greater between −10 and −50 volts when swept from 0 to −70 volts at a 60 cycle rate.

The reverse recovery time will not exceed 0.5 usec at 700 *ua* or 3.5 usec at 87.5 *ua* of current when rapidly switched (at a 60 cycle rate) from +30 *ma* forward current to −35 volts.

Note 2: For type IN198 at 75° C the maximum reverse current at −50 volts is 250 *ua* and at −10 volts is 75 *ua*.

Note 3: a) Forward current exposure = 5 *ma*. b) Reverse test voltage = 40 ±2 volts. c) DC circuit resistance = 2000 ohms.

Note 4: Peak measurement with half sine wave of 50 *ma* peak current, 0.1 usec pulse width, and 100 kc pulse repetition frequency.

Note 5: Minimum resistance in thousands of ohms when E/I characteristic is swept at 60 cycles from 0 to −70 volts and resistance slope observed between −10 and −60 volts.

Note 6: Minimum resistance in thousands of ohms when E/I characteristic is swept at 60 cycles from 0 to −100 volts and resistance slope observed between −20 and −90 volts.

Note 7: Additional control measurements are made for reverse current hysteresis, reverse current drift, and flutter.

"Sylvania—synonymous with Semiconductors"

EMPLOYMENT PROSPECTUS

CORNELL AERONAUTICAL LABORATORY

Men needed: Electronics engineers and physicists at all levels of experience. Basic ability and interest in research work are usually more important than experience in any specific field.

Type of work: Principally applied research, with complementary activity in both basic research and development. Present C.A.L. projects include work on computers, communication, radar systems and on guidance, control, and navigation systems for airplanes and missiles. Research is also being done in the areas of intercept tracking and control equipment, search and acquisition radar, subminiturization and heat transfer studies, target discrimination, collision warning devices, weather radars, telemetering, and electronic counter-measures studies.

Description of Organization: C.A.L. is a not-for-profit corporation wholly owned by Cornell University. It is financially self-supporting, and operated for the purpose of advancing and enlarging scientific and engineering knowledge. The value of research completed last year rose to 14 million dollars, an increase of 12% over 1955, and the 6th consecutive annual increase. C.A.L. has 1200 employees.

Desirable features of employment at C.A.L.: VARIETY — the 400 engineers and scientists at C.A.L. are working in 11 technical departments, which last year completed 178 projects, both large and small. INDIVIDUAL RECOGNITION — the high ratio of contracts per engineer, coupled with the Laboratory's practice of using small research teams, allows the recognition of every man's individual contribution. To guarantee this recognition, each man's progress is reviewed every 6 months. SALARY — C.A.L. recognizes its need for above average professionals, and appreciates that such individuals must be compensated accordingly. Annual salary for an Associate Engineer (median of the five non-supervisory categories) can exceed $10,000. INTERNAL RESEARCH — each year the Laboratory sets aside substantial sums for the sole use of staff members in support of their exploration of new scientific areas and the generation of new ideas.

Action to take: If you desire additional information, use the coupon to request "A Decade of Research," a 68 page report on the Laboratory's research programs over the past 10 years. If you are interested in employment at C.A.L., check the box below for additional information. All inquiries will be treated as confidential.

CORNELL AERONAUTICAL LABORATORY, INC.
of Cornell University • Buffalo 21, N.Y.

EPE

W. P. Diefenbach
CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo 21, New York

Please send me "A Decade of Research."

Name ______________________

Street ______________________

City ______________ Zone ______ State ______

☐ Please include employment information

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 IRE publishes free of charge notices of positions wanted by IRE 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 IRE necessarily reserves the right to decline any announcement without assignment of reason.

Address replies to box number indicated, c/o IRE, 1 East 79th St., New York 21, N.Y.

ELECTRICAL ENGINEER

BEE. Cornell 1953. Experienced in transistor circuitry, electronic test equipment design and fabrication, and technical writing. Military experience includes teaching and technical intelligence. F.C.C. 1st class commercial radiotelephony license. Some knowledge of written and spoken Japanese. Desires commercial or field engineer position in Japan requiring professional competence. Box 952 W.

TRAINING DIRECTOR
(Science and Engineering)

BS. physics-math; MA. and Doctor of Education. Over 15 years in all fields of industrial training. Technical curriculum development, instructor training, conference leadership, creative thinking, management development, linestaff supervisory development, technical training. Presently employed Los Angeles with reputable major electronics organization. Box 979 W.

SENIOR ELECTRONIC ENGINEER

MSEE, age 34. Experienced digital techniques, transistorized circuits. Looking for growing company with as much faith in the future of data processing and computer field as I have. Single, can relocate or travel. Box 980 W.

INDUSTRIAL MGT. ENGINEER

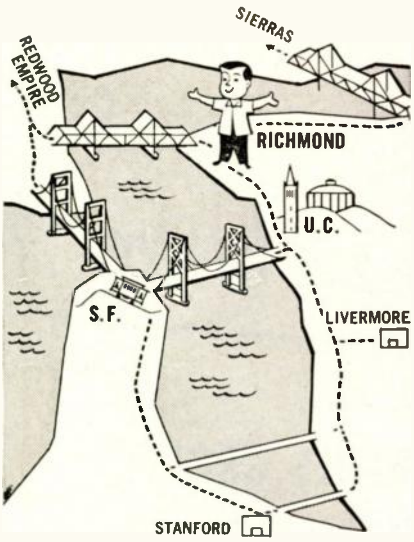
MIE., BME., Tau Beta Pi, Pi Tau Sigma; age 34, married. 12 years varied experience in electronics, project-methods, writing, teaching, radar mechanic, construction, sales. Prefer New York City vicinity, but would consider relocating. Box 981 W.

ENGINEERING EXECUTIVE

Young (under 35), dynamic, hard-hitting Chief Engineer experienced in policy-making, organizing, staffing and running engineering activities. 10 years commercial and military products background (including market evaluation) in test equipment, telemetry, and television systems. Seeking company which wants the job done, the right way, on time every time, and will pay for such leadership. Long term association in Los Angeles greater area only. Resume upon request. Box 985 W.

(Continued on page 152A)

BE HAPPY...
...GO BERKELEY!



If you've looked around much for a new job, you know some companies solemnly offer you the moon on a silver platter. At Berkeley, we're fresh out of moons. But we can deliver something you won't find everywhere—a first-rate place to work and live. You can relax here and find satisfaction in your work. Nobody breathes down your neck – all the stuffed shirts were kicked out long ago. This is a fast-growing company, and you'll have plenty of responsibility and a chance to move ahead rapidly. Our engineers work in new, comfortable quarters, completely equipped for research and development. You'll be paid well, share in the profits, and receive many other benefits. Most of all, though, you'll be happy you made the change.

We shouldn't have to say much about the San Francisco Bay area. If you like living, you ought to try it here. Our plant in Richmond is just 22 minutes from the nearest cable car.

Basically, we're looking for effective electronic circuit designers. We need analog computer design engineers, computer applications engineers, field engineers with trouble-shooting experience, industrial systems engineers, and electronic technicians. We also need men with experience in new techniques, such as transistors or magnetics, and in such specialties as microwave, uhf, nuclear radiation detection.

For details, write or phone:
HARRY MCELROY,
Personnel Director

Berkeley *division*
BECKMAN INSTRUMENTS INC
RICHMOND 3, CALIF. • LANDSCAPE 6-7730

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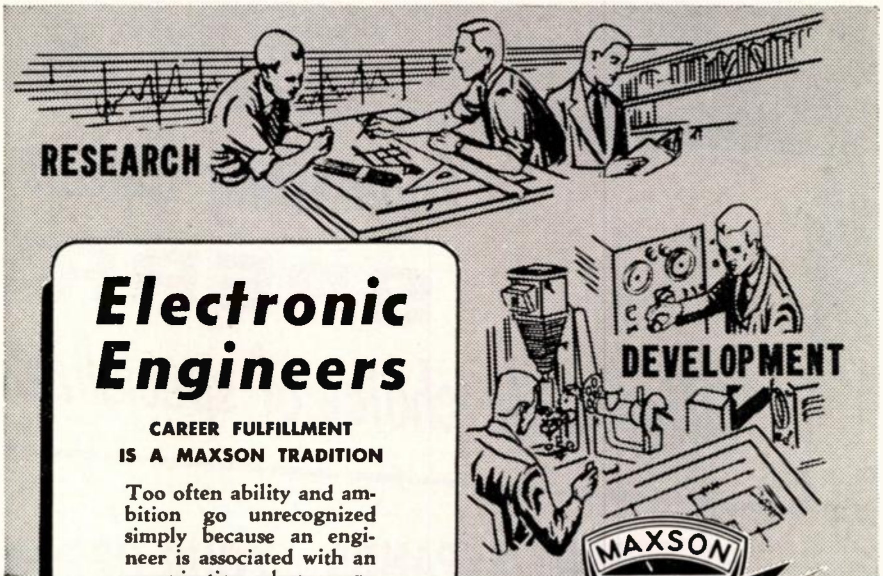


Electronic Engineers

CAREER FULFILLMENT IS A MAXSON TRADITION

Too often ability and ambition go unrecognized simply because an engineer is associated with an organization whose scope is too shallow to permit complete expression. We sincerely believe that the currently expanding activities of The W. L. Maxson Corporation offer the creative engineer a limitless range of assignments for career fulfillment.

Responsible positions now available in the fields of research and development. Kindly send resume and salary requirements to:

Mr. L. W. Albright
Technical Placement Manager

THE W. L. MAXSON CORPORATION
460 W. 34th St.
New York 1, N.Y.

TEST ENGINEERS

WILL YOU REACH YOUR MAXIMUM POTENTIAL?

No matter what your ability, you MUST HAVE the job opportunity and the BEST of TOOLS and FACILITIES to develop your talents to the fullest.

Investigate the Environment created at AC for its Advanced Development Programs on Missile Guidance and Aircraft Fire Control Systems.

OUR ENVIRONMENTAL LABORATORY

is one of the most versatile laboratories in the country and we are in the process of a Major, Permanent Expansion. 225,000 square feet plant being added in suburban Milwaukee.

Our men enjoy working with the finest of test equipment and lab facilities and with the top men in the field.

We are currently engaged in the following types of Test Activities.

- VIBRATION TESTING
- COMPLEX WAVE ANALYSIS
- LOW TEMPERATURE—ALTITUDE
- HIGH TEMPERATURE
- RELIABILITY EVALUATION
- INSTRUMENTATION

Mr. Cecil E. Sundeen, Supervisor of Technical Employment
THE ELECTRONICS DIVISION
GENERAL MOTORS Corporation
FLINT 2, MICH. MILWAUKEE 2, WIS.

Positions Wanted

By Armed Forces Veterans

(Continued from page 148A)

ELECTRONIC ENGINEER

MSEE.; married; age 27. To be discharged August 1957. Have 2 years experience with bombing and navigational systems, and while in the Service was concerned with this same phase. Also have 2 years teaching experience at a midwestern university. Desires position in research and development field. Desires northeast location. Box 986 W.

ELECTRICAL ENGINEER

BSEE.; married; age 35. 8 years engineering experience. Communications engineering, antenna and microwave project engineer. Supervisory experience. Broad military experience. Desires position in small or medium company as sales engineer with future potential. Box 987 W.

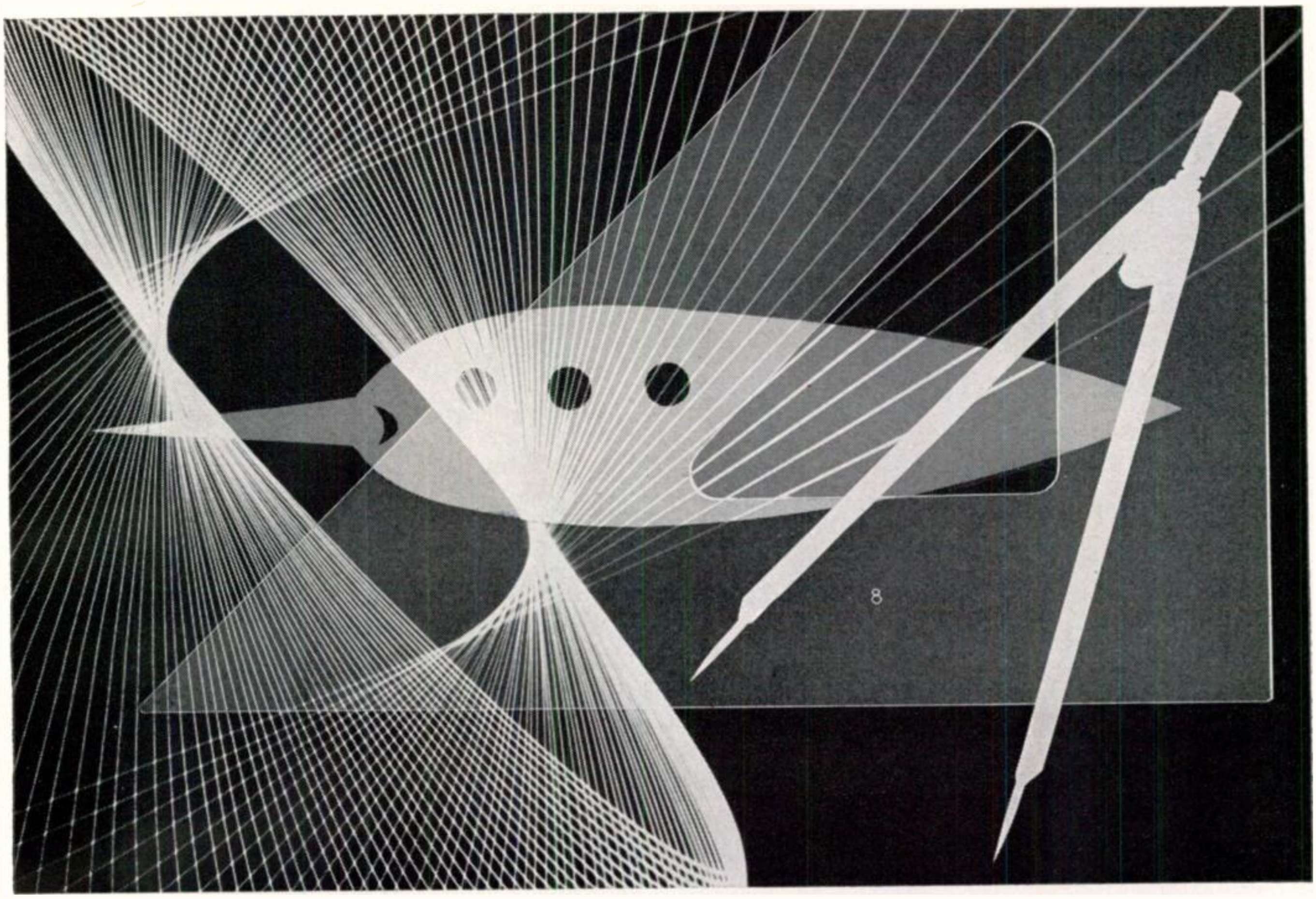
ENGINEER

June 1957 graduate BSEE. Married, age 25. Desires position that will enable assignment in Central Europe within a year or less after graduation. Box 995 W.

PATENT ATTORNEY

BEE., LL.B., New York Bar 1953. Excellent scholastic record. 5 years experience all phases of electronic and electromechanical patent prosecution, including communications, computers, control systems and transistors. Seeks position involving broader areas of patent responsibility. Will relocate. Box 996 W.

(Continued on page 158A)



Creative Engineers:

Work where the breakthroughs are being made in every major field of Electro-Mechanics

As a creative engineer, you belong at the front-line of your field . . . where tomorrow's scientific battles are being won . . . where you can help win them.

For more than a decade, AUTONETICS has been at the forefront of electro-mechanical technology . . . building up the unique stockpile of experience and developing the advanced techniques and tools that can make your professional victories possible at AUTONETICS today.

Just a few specific results of AUTONETICS' pioneering are: the MG-4 Fire Control System for NATO's F-86K Sabre Jet; Flight Control elements for the F-100 Super Sabre; *Numill*, a new magnetic-tape controlled machine-tool system capable of performing complex milling and drilling operations automatically; *Recomp I*, a new portable, high-speed, completely transistorized digital computer; and inertial guidance systems for both airplanes and missiles.

Today, our programs are gathering speed, broadening scope. New engineering methods have been developed to cut lead time. System and component evaluation is being accelerated with automatic checkout equipment. Packaging is being designed and systems micro-minaturized to fit the cramped confines of sleek missiles and jets.

YOUR OPPORTUNITY EXISTS AT EVERY LEVEL of creative engineering from Preliminary to Performance Test—because Autonetics is one of the few companies in the world that can design and quantity-produce complete automatic control systems for both the military and industry.

LET US KNOW what kind of creative engineering interests you (please include highlights of your education and experience). Write today to: Mr. A. N. Benning, Administrative and Professional Personnel, Dept. 358-IRE5, AUTONETICS, 9150 E. Imperial Highway, Downey, California.

Autonetics

A Division of North American Aviation, Inc.

AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE

Assistant Chief Engineer Norman F. Parker joined Autonetics in 1948 after receiving his DSc from the Carnegie Institute of Technology. Dr. Parker has been recognized nationally for his work in Inertial Navigation, and was chosen recently to present a paper on that subject at a NATO conference in Italy.

Jack Wittkopf was Associate Professor of Electrical Engineering at Oregon State for 6 years before he joined Autonetics in 1951. Now Group Leader in computers and electronics, Jack lives with his wife and four children in Autonetic's home town of Downey, California, where his spare time activities include photography and ham radio.

IMPORTANT DEVELOPMENTS AT JPL

Weapons Systems Responsibility

The Jet Propulsion Laboratory is a stable research and development center located north of Pasadena in the foothills of the San Gabriel mountains. Covering an 80 acre area and employing 1700 people, it is close to attractive residential areas.

The Laboratory is staffed by the California Institute of Technology and develops its many projects in basic research under contract with the U.S. Government.

Opportunities open to qualified engineers of U.S. citizenship. Inquiries now invited.

In the development of guided missile systems, the Jet Propulsion Laboratory maintains a complete and broad responsibility. From the earliest conception to production engineering—from research and development in electronics, guidance, aerodynamics, structures and propulsion, through field testing problems and actual troop use, full technical responsibility rests with JPL engineers and scientists.

The Laboratory is not only responsible for the missile system itself, including guidance, propulsion and airframe, but for all ground handling equipment necessary to insure a complete tactical weapons system.

One outstanding product of this type of systems responsibility is the "Corporal," a highly accurate surface-to-surface ballistic missile. This weapon, developed by JPL, and now in production elsewhere, can be found "on active service" wherever needed in the American defense pattern.

A prime attraction for scientists and engineers at JPL is the exceptional opportunity provided for original research afforded by close integration with vital and forward-looking programs. The Laboratory now has important positions open for qualified applicants for such interesting and challenging activities.

JOB OPPORTUNITIES IN THESE FIELDS NOW

jpl

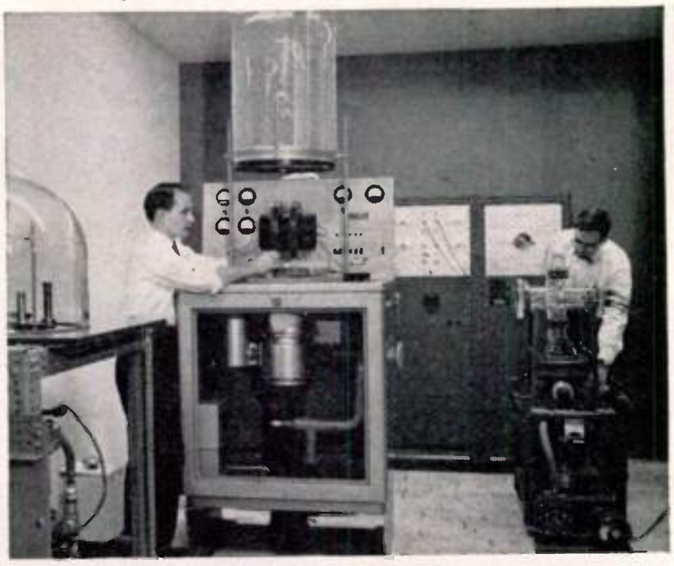
ELECTRONICS • PHYSICS • SYSTEMS ANALYSIS
COMPUTER DEVELOPMENT • INSTRUMENTATION
TELEMETERING AND MECHANICAL ENGINEERING

JET PROPULSION LABORATORY

A DIVISION OF CALIFORNIA INSTITUTE OF TECHNOLOGY

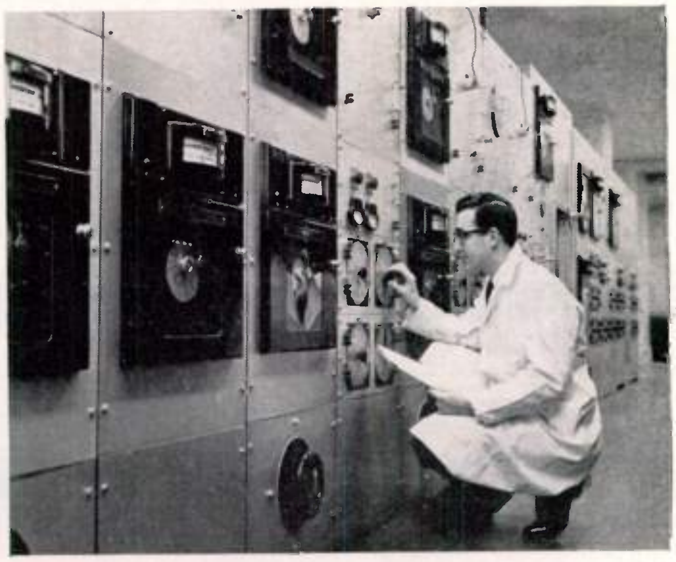
PASADENA • CALIFORNIA

CHEMISTRY . . . Physical, organic, colloid, analytic, biological, and radiation chemistry, in such areas as thin films, polymers, capsular phenomena, photographic systems, membranes, non-mechanical printing techniques, dyes and color studies, elastomers, adhesives, plastics, lubrication, electro-deposition.



PHYSICS . . . Challenging assignments in ferromagnetics and ferroelectrics, electroluminescence, phosphors, photoconductors, high-speed printing techniques, vacuum deposition, X-ray diffraction, crystal structure, low-temperature studies, powdered metal compaction, domain studies.

ELECTRONICS . . . Memory devices, access circuitry, input and output devices, computer components, advanced magnetic core devices and circuits, switching circuits, transistors, diodes, semi-conductors, logical design, experimental and prototype design, are among the challenges awaiting you at NCR.



METALLURGY . . . Alloys, brazing, ductile castings, powdered metals, precision casting, gas analysis, foundry processes. **MATHEMATICS** . . . Numerical analysis, computation theory, Boolean algebra, computer logic, programming. **CERAMICS** . . . Ferrite electronic components, phosphors, dielectrics.

RESEARCH UNLIMITED

AT ONE OF THE WORLD'S MOST SUCCESSFUL CORPORATIONS

Choose your own area of research or development from those above. You may work at either basic studies or application phases.

There is a University Extension in our own plant for graduate study toward Master's Degrees, with a tuition refund plan.

NCR has regular seminars on scientific topics . . . a large technical library . . . pilot plant facilities.

Let us tell you more about NCR! Write: Director of Scientific Personnel, Section No. I, The National Cash Register Company, Dayton 9, Ohio.

NCR

THE NATIONAL CASH REGISTER COMPANY

EE's, ME's can you qualify

FILL OUT AND MAIL TODAY

Collins Radio Company *Confidential Application for Technical Employment*

LAST NAME	FIRST NAME	MIDDLE NAME	BIRTH DATE
STREET ADDRESS	CITY	STATE	PLACE

EMPLOYMENT RECORD

FROM MO.	FROM YR.	TO MO.	TO YR.	EMPLOYER'S NAME, BUSINESS, LOCATION	SALARY	POSITION AND NATURE OF DUTIES
PRESENT OR LAST EMPLOYER						
FORMER EMPLOYER						

STATE NATURE OF YOUR MOST RESPONSIBLE POSITION

EDUCATIONAL RECORD

COLLEGE OR UNIVERSITY	MAJOR	DEGREE	GRADE PT. AV.

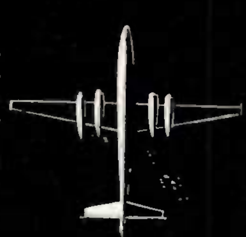
MILITARY SERVICE RECORD

BRANCH OF SERVICE	RANK OR RATING	ACTIVE SERVICE ENTRY DATE	DISCHARGE DATE

*Signature*____________________________

COLLINS in Aviation

Collins completely oufits airline, military and business aircraft with the most advanced communication, navigation, flight control and instrumentation systems in aviation. Many new lightweight, reduced-size versions are now being delivered. Collins designed the original Integrated Flight System, leads in combining comm/nav/ident units into a single compact "CNI" package for new military aircraft, and continues to pace the industry in developments in airborne radar, ADF, ILS, VOR, HF and VHF communication.



COLLINS in Ground Communication

Collins engineers, designs and supplies the equipment, installs, and puts into operation integrated point-to-point communication systems of any scope. The Collins system engineering staff is backed by the finest equipment in the world, whether standard MF, HF or VHF, Transhorizon "scatter," microwave relay and multiplex or single sideband HF. Typical of Collins communication progress is "Kineplex" — a high speed data transmission system doubling communication capacity.

Send your application to:

L. R. Nuss
Collins Radio Co.
Cedar Rapids,
Iowa

Fred Aiken
Collins Radio Co.
2700 W. Olive Ave.
Burbank, California

Harold McDaniel
Collins Radio Co.
1930 Hi-Line Drive
Dallas, Texas

as a Collins engineer?

You've got to be good to

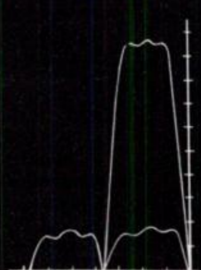
- ✓Command highest salary
- ✓Advance rapidly in a strong, growing company
- ✓Work with highest caliber development groups
- ✓Use the world's finest engineering facilities
- ✓Maintain Collins creative reputation

Collins depends on its engineers. That's why you have to be good to earn a place on a Collins Research and Development team. Collins hard earned reputation was built on a solid foundation of engineering talent. The sales growth of the Company has justified Collins emphasis on engineering. Sales have increased 10 fold in the last 10 years. And employment of research and development personnel has more than kept pace. Collins growth will continue, and *you* can be a part of this growth.

Send the application form printed on the opposite page as an expression of your interest in knowing more about the opportunities at Collins. Your application will be held in the *strictest* confidence and will be answered immediately by a personal letter. Take only a few minutes now to fill out the application and mail to one of the addresses listed. This can be the turning point in your career.

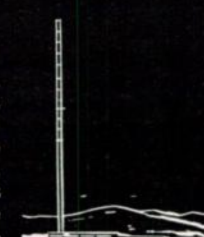
COLLINS in Amateur Radio

In the early 1930's Collins set the standard in Amateur radio and, through continuous design and development, has raised this standard to its present single sideband station — the most honored and prized in the Amateur fraternity. This station is the top performing rig on the air with its kilowatt KWS-1 transmitter and highly selective 75A-4 receiver. Many of the leaders in the electronics industry became acquainted with Collins through the Company's superior Amateur equipment.



COLLINS in Broadcast

Collins supplies a complete new AM station from mike to antenna or modernizes existing facilities. Besides the superior line of transmitters, Collins supplies the broadcaster's needs with such advanced additions as TV-STL microwave relay system, the lightest 4-channel remote amplifier on the market, phasing equipment and audio consoles. Collins field service organization has built an enviable reputation in assisting the broadcaster in installation or in times of emergency.



Collins CREATIVE LEADER IN ELECTRONICS COLLINS

Collins Radio Company — Cedar Rapids • Dallas • Burbank

Positions Wanted

By Armed Forces Veterans

(Continued from page 152A)

ENGINEER

BSEE., 1955; age 23, married. 2 years co-op and civilian experience. 2 years Project Officer maintenance and industrial engineering on electronic equipment of gun and missile systems. Desires position in application of microwave or semiconductor devices with opportunity for graduate study and advancement into management. Box 997 W.

ELECTRONICS ENGINEER

20 years maintenance, installation design, supervision and administration in military airborne electronics. Naval Officer (Lcdr, USN). Will retire from Service in June. Available for responsible position. Will relocate. Box 998 W.

SENIOR ELECTRICAL ENGINEER

BSEE., Eta Kappa Nu; advanced study in E.E. 4 years college teaching experience. 3 years aircraft and missile navigational and guidance systems development and design, lead experience. Desires position with supervisory opportunities. Will relocate, prefer warm climate. Box 999 W.

Use your IRE DIRECTORY! It's valuable!

Positions Open

The following positions of interest to IRE members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. . . . .

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

Proceedings of the IRE
1 East 79th St., New York 21, N.Y.

SENIOR PHYSICIST

Openings exist with company manufacturing ceramic dielectric and piezo-electric materials for the electronic industry. Senior Physicist required to have Ph.D. or MS. Responsible for planning and organizing research and development of above mentioned materials for use in memory devices, ceramic rectifiers, piezo-electric transformers, etc. Complete laboratory facilities available. Send resumes or requests for additional information to Supervisor of Placement and Training, Erie Resistor Corp., 644 West 12th St., Erie 6, Pa.

COMMUNICATIONS ENGINEER

For large railroad system. Some experience necessary. Desires BSEE. or equivalent. Salary over $700 month. In reply state age, educational and employment history, military status. All replies will be held confidential. Location midwest. Write Box 1028.

(Continued on page 160A)

Positions Open

(Continued from page 158A)

GRADUATE STUDENTS IN ELECTRICAL ENGINEERING

Excellent opportunities exist for the training and development of students in all areas of electrical engineering. Graduate assistantships are available for MS. students, and part-time instructorships are available for Ph.D. students. Opportunities also exist for qualified staff at the professorial levels. Write to Head, Dept. of Electrical Engineering, Case Institute of Technology, 10900 Euclid Ave., Cleveland 6, Ohio.

RESEARCH AND DEVELOPMENT ENGINEERS

Positions open for electrical, mechanical and metallurgical or materials engineers. Work involves design of specialized equipment, instrumentation and control, materials evaluation, and development of specialized test procedures. Applicants should be capable of generating ideas and following them through the design and development stages. Positions offer diversity of activities and excellent opportunities for creative work. Please send complete resume of education and experience to Southern Research Institute, 917 South 20th St., Birmingham, Alabama.

ASSISTANT PROFESSOR OR ASSOCIATE PROFESSOR IN ELECTRONICS

To teach basic courses in electronics, electronic measurements, industrial electronics, electron tubes and ultra-high frequency communications and automatic controls; BS. degree in physics or electrical engineering and industrial experience required; advanced degrees highly desirable. Good opportunities in a new department in the process of planning new building and curricula. Good salary scale. Appointment open September 1957. Write Dean Stephen L. Walker, Sacramento State College, Sacramento, California.

TEACHING ELECTRICAL ENGINEERING

Teaching positions—Applicants needed for additional permanent staff starting September 1957 in Electrical Engineering. Rank and salary commensurate with qualifications. Will consider one with only a B.Sc.E.E. degree if he is willing to work for M.Sc. degree. Write, Chairman, Dept. of Electrical Engineering, University of Nebraska, Lincoln 8, Nebraska.

TEACHERS—ELECTRONICS ENGINEERING

Electronics engineering teachers at San Francisco Bay area college. Expanding program; four million dollar building addition now being planned; excellent part-time industrial and graduate work opportunities; excellent salary scale. Write to Head, Engineering Dept., San Jose State College, San Jose 14, Calif.

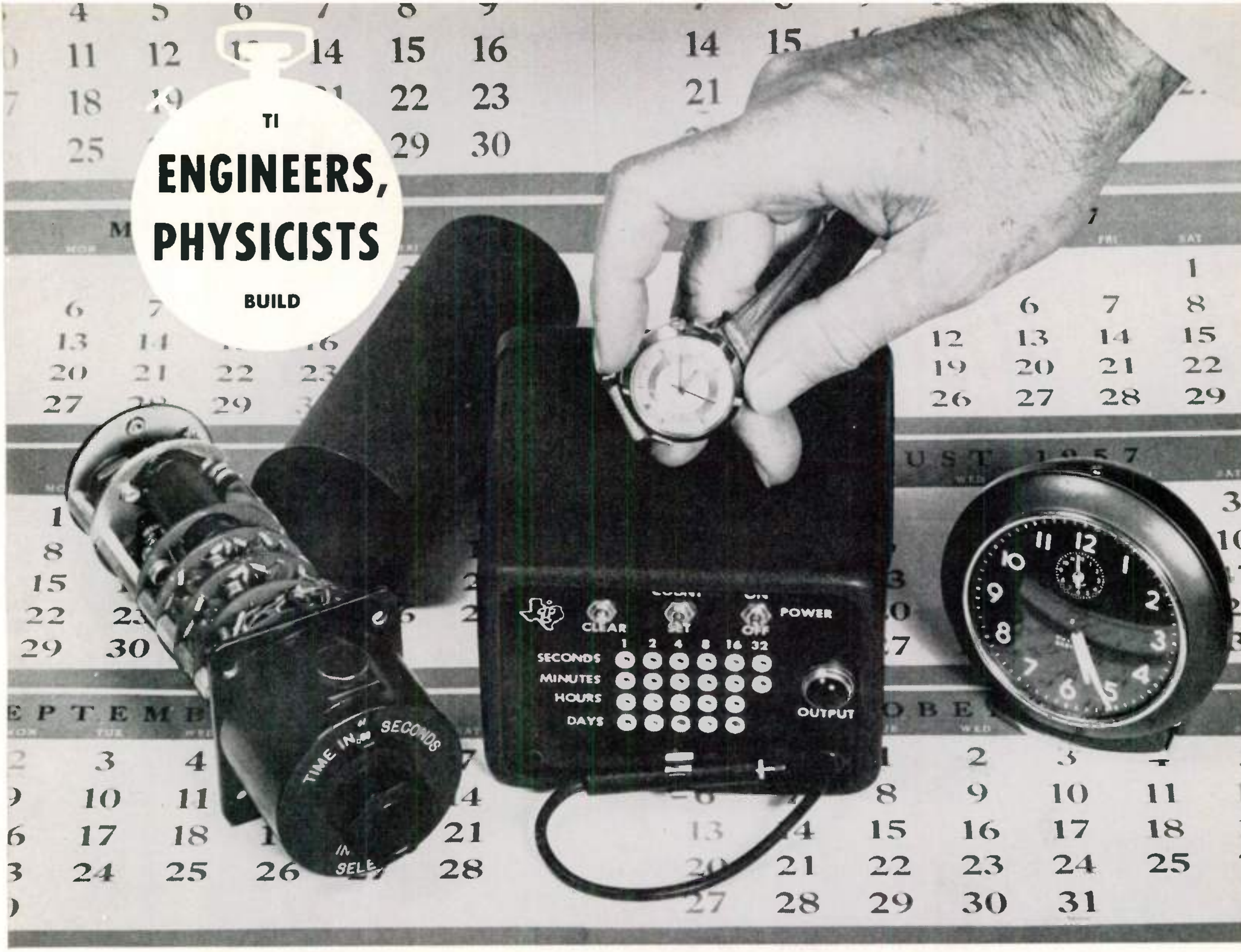
INSTRUCTOR—ELECTRICAL ENGINEERING

Instructor in Electrical Engineering—to teach undergraduate E.E. courses. Appointment for three quarter teaching year with rank and salary dependent upon qualifications. Additional compensation for teaching during summer quarter. Financial assistance to staff members who undertake graduate work. Write, Chairman, Dept. of Electrical Engineering, Fenn College, 1983 East 24th St., Cleveland 15, Ohio.

PROFESSORS

Faculty positions available in the Dept. of Physics in the fields of solid-state physics, com-

(Continued on page 162A)



TRANSISTOR 'STOP-WATCHES' FOR INDUSTRY*

accuracies to a 50 millionth | intervals from microseconds to months

Experienced graduate engineers and physicists are invited to join one of the many expanding programs at engineer-managed Texas Instruments . . . where recognition of individual achievement has contributed to TI's fifteenfold growth in the last ten years — to a current $45 million volume. Advanced personnel policies include company-sponsored educational assistance, profit sharing, insurance, and retirement programs.

Texas Instruments plants are within Dallas, yet away from downtown traffic . . . within 5 minutes of fine residential areas, churches, and public and private schools. Your home will be within 15 minutes of year-around recreational, amusement and cultural activities.

SEMICONDUCTORS & OTHER COMPONENTS — Transistors, transistor circuits, diodes, rectifiers, transformers, resistors, panel meters, test equipment. *Write W. C. Spaller.*

ELECTRONIC & ELECTROMECHANICAL APPARATUS — Radar, sonar, infrared, navigation, magnetics, telemetering, communications, computers. *Write R. E. Houston.*

RESEARCH — PhD level for research: semiconductor materials and devices, ferromagnetics, infrared, high speed data reduction, etc. ADMINISTRATION — Engineers for: production, planning, purchasing, cost analysis, etc. *Write W. D. Coursey.*

* Texas Instruments engineers are building portable electronic timing devices to uncanny accuracies with interval variations to infinity. They allow applications never before practical because of previous size, weight, power drain, and maintenance limitations . . . particularly in airborne installations. Essentially binary counting and storage devices, these TI timers present an entirely new concept in time measurement . . . a result of the new design freedom allowed by transistors . . . of which TI is also the world's largest commercial manufacturer.

TEXAS INSTRUMENTS
INCORPORATED
6000 LEMMON AVENUE DALLAS 9, TEXAS

Positions Open

(Continued from page 160A)

munication theory, vacuum tube circuit design, microwaves and computers. College of 8300 students. Bs. and Ms. degrees offered. IRE Student Chapter on campus. Salary dependent upon educational background and experience. For information, write to Dr. D. H. Robinson, Chairman of the Div. of Physical Sciences, San Diego State College, San Diego, Calif.

ELECTRONICS ENGINEERS

Graduate electronic engineers with instrumentation experience wanted to join an established, yet rapidly growing sales organization representing Hewlett-Packard, Sorensen & Co., Inc., Varian Associates, Sanborn Co., John Fluke Mfg. Co., Beta Electric Corp., Kintel, Sensitive Research Instruments Corp., and Dynac, Inc. Sales experience not necessary but desirable. Contact Bob Townsend, Yewell Associates Inc., Middlesex Turnpike, Burlington, Mass. Burlington 7-2561.

ASSISTANT OR ASSOCIATE PROFESSOR

Assistant or Associate Professor with MS. or Ph.D. to teach in expanding department of Electrical Engineering. Wonderful opportunity. Excellent salary. Summer employment available. Small congenial faculty at a dynamic municipal university in the southwest. Box 1038.

PRODUCT ENGINEERS

Small engineering organization needs competent engineers with initiative to fill positions specializing in missile guidance, instrumentation, control, stabilization, reliability, and field testing. Ability to plan and carry out assigned projects essential including an active program for professional advancement. A broad background in circuits, components and/or production techniques required by most positions. Experience with military equipment is desirable, eligibility for security clearance necessary. Send resume or Form 57 to Officer in Charge, U. S. Naval Ordnance Experimental Unit, c/o National Bureau of Standards, Washington 25, D.C.

ENGINEERS—TEACHING

All rank appointments—depending upon backgrounds—needed at undergraduate college located in small resort area city. Electric power and electronics options are offered. MS. or higher degrees preferred. Will assist BS. degree men in financing advanced degrees. Investigate better than average salary offers. Box 1039.

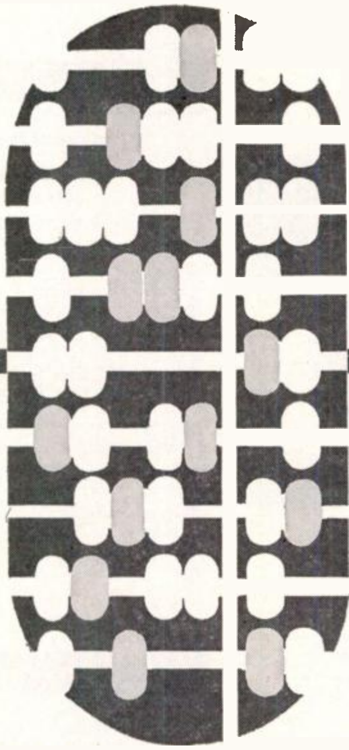
ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING

Assistant Professor of Electrical Engineering to teach undergraduate courses in electronics or power in expanding department. MS. degree desirable, opportunity for advancement. State-supported college located on Texas Gulf Coast, excellent year-around climate. Salary open. Address reply to Director, Div. of Engineering, Texas College of Arts and Industries, Kingsville, Texas.

DEVELOPMENT AND SYSTEMS ENGINEERS

The Budelman Radio Corp. has several openings for engineers with aptitude for telephone carrier and multi-channel radio equipment and systems development. Experienced engineers or recent graduates with instinctive recognition of the particular opportunities offered by a small, progressive company are preferred. Starting salaries commensurate with industry averages; advancement opportunities above average. For further details, write or telephone W. Fingerle, Jr., Budelman Radio Corp., 375 Fairfield Ave., Stamford, Conn. Tel. Fireside 8-9231.

(Continued on page 164A)



ENGINEERS • SCIENTISTS

EVER TRY TO ADD TWO 22-DIGIT NUMBERS IN 5 MICROSECONDS?

Or multiply them – in 10 microseconds?

Well, that's exactly what Sylvania is doing—or to be more accurate, Sylvania is building a large-scale digital computer to do just that. It seems there is no existing computer that operates fast enough to simulate the flight of today's supersonic jets.

These special speeds call for a number of other important engineering developments. For example, into this new computer must be built a magnetic core memory system with a 5 microsecond repetitive random access time!

Two avenues of advancement open to Systems Engineers are Systems Management or Scientific Systems Specialties with parallel salary scales for both.

Check the list of current openings. Decide which interests you most, and then let us hear from you.

SYSTEM ANALYSTS, ENGINEERS, MATHEMATICIANS, AND PHYSICISTS
Interested in the analysis and block diagram design of systems. Interests in such subjects as radar analysis and design, antenna design, error analysis, statistics, communication theory, network theory, real-time computation, time varying and non-linear control systems, logistics, operations research, data transmission and missile analysis including aerodynamics, structures and heat transfer are desired.

ELECTRONIC DESIGN & DEVELOPMENT ENGINEERS
Openings at all levels in ECM systems and other circuitry. Work involves video, pulse and timing circuits, radar, digital radar processing equipment, advanced receiver and special transmission line techniques, with utilization of new as well as orthodox component types.

RESEARCH ENGINEERS & PHYSICISTS
Primarily interested in conducting research of new techniques which will lead to new electronic systems of the future. Experience in communications theory, automatic controls, airborne interceptor radar, infra-red systems, radar simulators, missile electronics, data processing, applied mathematics, or related fields is desirable.

PROJECT ENGINEERS
General responsibility for ECM, large scale general purpose digital computers, and other electronic systems including internal projects coordination and technical relations with contracting agencies.

DIGITAL COMPUTER DESIGN ENGINEERS
Responsible for all phases of development on several large scale computer and data processing projects; systems analysis and logical design; advanced circuit work on transistorized switching circuits, unusually high-speed core memory systems and input-output equipment; breadboard design and test prototype design and systems evaluation and testing.

MECHANICAL ENGINEERING, PACKAGING & PHYSICAL TEST ENGINEERS
Group supervisors responsible for mechanical engineering, design and product development of advanced airborne, missile borne, and ground electronic and electro-mechanical equipments. Responsible engineers for design of test facilities, equipment and instrumentation for complex physical and environmental testing of electronic equipment and antenna and radar components.

ANTENNA ENGINEERS
Design of array elements, power dividers, RF linkages, and other general transmission problems.

APPLIED RESEARCH LABORATORY | AVIONICS LABORATORY | MISSILE SYSTEMS LABORATORY

WALTHAM LABORATORIES Electronic Systems Division

If you are interested in any of these positions, please send your resume immediately (in strict confidence) to:

ERLING MOSTUE 100-J12, First Avenue
Waltham, Massachusetts

SYLVANIA

SYLVANIA ELECTRIC PRODUCTS INC.

Positions Open

(Continued from page 162A)

PROFESSOR OF ELECTRICAL ENGINEERING

Professor of Electrical Engineering to do research and to teach in the field of communications. Applicants should have a Ph.D. in Electrical Engineering or Physics and several years' experience in both teaching and research. Salary $8,000-$14,000. Box 1007.

ASSOCIATE PROFESSOR OF ELECTRICAL ENGINEERING

Associate Professor of Electrical Engineering to teach graduate courses in transients, servomechanisms, vacuum tube circuits and electromagnetic theory as the need arises, and to spend about one-half time on research and development work for contractor. M.S. required. Salary to $10,000 for all 11 months. Write Box 1008.

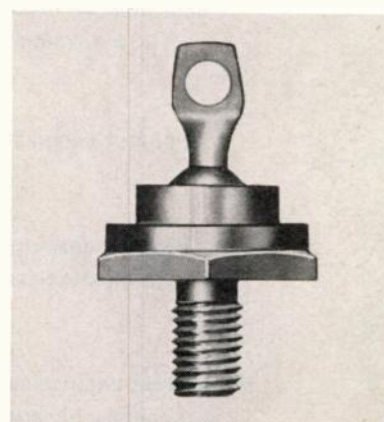
News-New Products

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

(Continued from page 145A)

Silicon Diodes

A series of silicon diodes capable of operation at 375°C and storage at 400°C which cover the current range from 100 milliamperes to 1 ampere have been developed by the **United States Dynamics Corp.**, 1250 Columbus Ave., Boston, Mass., manufacturers of solid state devices.



A product of the Semiconductor Products Div., the new diodes are still in the development laboratory pilot line stage. However, small quantities are available for evaluation tests. All units are stud mounted and hermetically sealed.

Detailed data sheets covering these new silicon diodes and other diodes and rectifiers for the current range from 100 ma to 35 amperes may be obtained by writing to the firm.

(Continued on page 166A)

Dr. Lloyd P. Smith

President, Avco Research and Advanced Development Division

speaks out about AVCO . . .

AND THE RACE AMERICA MUST NOT LOSE

Dr. Lloyd P. Smith

Our greatest aim is to make truly significant scientific discoveries and technical developments. Discoveries which add to our scientific knowledge. Discoveries and developments which lead to new products which can be produced for the good of mankind and insure our continued economic prosperity. Discoveries and developments which will maintain the nation's defenses strong. Most of all, to make discoveries and technical "breakthroughs" which will give our country the scientific and technical leadership and prestige which are so essential for maintaining the peace of the world. We fully realize that to attain these objectives we must win out in a great scientific game against a competent and ambitious adversary.

The Avco Research and Advanced Development Division, with its team of creative scientists and engineers, is expending great effort to reach these goals. Significant accomplishments have already been made in the physics, chemistry and gas dynamics associated with the high-altitude, hypersonic flight of missiles; the intercontinental ballistic missile re-entrance problem; missile stability; and electronics as applied to advanced radar, computers and air navigation.

New fields are under investigation and the division hopes to make technical "breakthroughs" in magnetohydrodynamics, controlled thermonuclear fusion, conversion of chemical and nuclear energy into useful work, the creation of new materials, the manned satellite, and many other areas. Some of these fields are so new that our laboratories must also be teaching centers so that young scientists and engineers who join us can learn the science and technology basic to these new fields while contributing their own creative investigations.

Lloyd P. Smith

A new idea is nourished by exposure to men representing many different scientific specialities—a characteristic operating method at Avco Research and Advanced Development Division.

Avco's new research division is now offering unusual and exciting career opportunities for exceptionally qualified and forward-looking scientists and engineers in such fields as:

SCIENCE: Aerodynamics · Electronics · Mathematics · Metallurgy · Physical Chemistry · Physics · Thermodynamics

ENGINEERING: Aeronautical · Applied Mechanics · Chemical · Electrical · Heat Transfer · Mechanical · Reliability · Flight Test

Write to Dr. R. W. Johnston, Scientific and Technical Relations, Avco Research and Advanced Development Division, 20 South Union Street, Lawrence, Massachusetts.

Pictured below is our new Research Center now under construction in Wilmington, Massachusetts. Scheduled for completion in early 1958, this ultra-modern laboratory will house the scientific and technical staff of the Avco Research and Advanced Development Division.

avco | **research and advanced development** division

News-New Products

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

(Continued from page 164A)

50,000-Watt AM Transmitter

The General Electric Co., Technical Products Dept., Electronics Park, Syracuse, N. Y., unveiled a new 50,000-watt AM radio broadcast transmitter which is smaller in size than 50-KW transmitters now available and requiring much less floor space for studio installation.

Overall dimensions of the new transmitter are thirteen-and-a-half feet long by four-and-a-half feet deep. This compares to the 29 by 5 feet dimensions of older transmitters.

By using germanium rectifiers, G-E broadcast engineers have reduced tube requirements from the 40 to 50 in present day transmitters to but 16 in the new one. In addition, weight of the final amplifier tube was reduced from 225 pounds to 20 pounds.

The tubes are also limited to but six different types, as compared to 12 or more types needed in older transmitters. This will result in lower spare-tube inventory requirements: another cost saving for station owners.

The transmitter has built-in provisions for remote operation. Although remote operation of 50-KW radio broadcast transmitters is not yet allowed in the U.S. by the Federal Communications Commission, industry experts expect the Commission to rule on this in the near future.

He said the new transmitter will be priced competitively, in the neighborhood of $95,000.

(Continued on page 168A)

ELECTRONIC ENGINEERS

Unlimited opportunities in these interesting areas pay highest salaries to top men

SYSTEMS ENGINEERING
Radar, communications, missile, sonar, countermeasures, airborne electronics

CIRCUIT DESIGN
Advanced military and commercial electronic equipment

PRODUCT DESIGN
Electronic equipment, electron tubes, guided missiles

ELECTRON TUBE ENGINEERING
Microwave tubes, receiving tubes, special tubes—design, development and application

MICROWAVE ENGINEERING
Development of systems, antennas, ferrites, plumbing

TRANSFORMER/MAGNETIC COMPONENT ENGINEERING
Many power and communications applications

OPTICS/INFRA-RED
Advanced development problems

HEAT TRANSFER ENGINEERING
Guided missiles and electronic equipment

SALES/APPLICATIONS ENG.
Commercial and military products

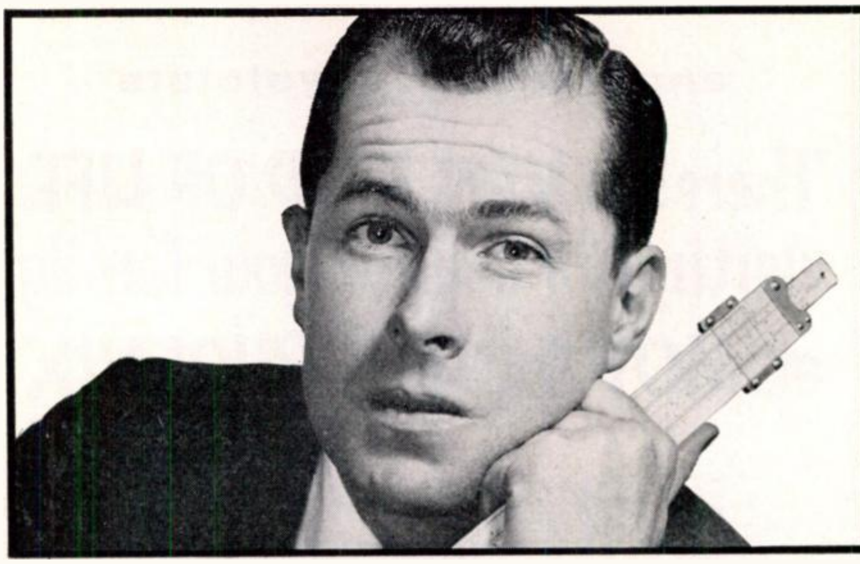
FIELD ENGINEERING
Military electronic equipment

BASIC/APPLIED RESEARCH
Theoretical and experimental in areas related to electronics

ENGINEERING ADMIN.
Procurement, budget control and production

PATENT ENGINEERING
Technical assistance to legal staff

ENGINEERING WRITING
Technical reports, manuals, etc.



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1 man in 3

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- Only electronics company with two prime missile contracts—Sparrow III, Hawk I.
- Individual initiative and originality recognized and encouraged—maximum chance to gain promotions and high professional standing.
- Raytheon radar selected for DEW line and C. A. A. airways traffic control.
- Low turnover—out of 139 professional people in one lab, only two left us last year.
- World's largest producer of magnetron and klystron microwave tubes.

Interesting, advanced work in:

Guided Missiles—air-to-air, ground-to-air. *Radar*—pulse and CW systems, including MTI techniques for search, fire control, bombing and navigation. *Communications*—scatter, radio relay, TV terminal and message circuit multiplex. *Semiconductors* — transistors, diodes. *Microwave tubes*—amplitrons, magnetrons, traveling wave tubes, backward wave oscillators, beam tubes, storage tubes. *Electron tubes*—receiving, subminiature, special purpose.

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For the thoughtful, ambitious engineer, horizons can grow wide and bright at Raytheon. You're recognized on ability and achievement. Raytheon men have won national reputations. Others are building them, just as you can.

Salaries are high. Many men take advanced courses at Raytheon's expense at Harvard, M. I. T., etc., leading to a Master's. Then there's wonderfully attractive New England with uncrowded schools and highways—clean air—*good living!*

FOR THE DETAILS YOU WANT, please write to Leonard B. Landall, Raytheon Manufacturing Company, Waltham 54, Mass. There's no obligation and your inquiry is completely confidential.

Excellence in Electronics

RAYTHEON

RAYTHEON MANUFACTURING COMPANY

Waltham 54, Massachusetts

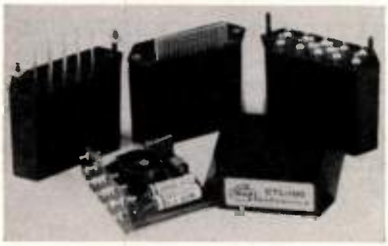
News–New Products

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

(Continued from page 166A)

Transistor-Core Logical Element

These building blocks produced by **Mack Electronics Div., Mack Trucks, Inc.,** 40 Leon St., Boston 15, Mass., use one transistor and one rectangular hysteresis loop magnetic core per element. All logical functions can be economically implemented with these units, by their inherent ability to perform logical OR logical inhibit, and data storage.



This transistor-magnetic core unit features low power, compactness, versatility, wide operating ranges, and long life. The power supply requirement is 12 volts ±20 per cent. These logical elements are available at two rated operating ranges of 0 to 50,000 and 100,000 bits per second.

A complete line of compatible drivers, input and output units supplement these building blocks. Up to 25 stages of the transistor-core units can be accommodated by one transistor driver package.

Normal packing density is 120 units per square foot of panel space for these rugged units. The magnetic core is encapsulated. The components are mounted on a printed circuit board and the entire unit is sealed. These units are available with solder lugs, printed circuit lugs, or plug-in headers, and also custom-packaged to meet special requirements.

Precision Cleaning Unit

A new portable precision cleaning unit for the spray-cleaning of small printed circuits and electrical contacts in relays, choppers, stepping switches, and so forth, has been developed by **Cobehn, Inc.,** Passaic Ave., Caldwell, N. J.,

(Continued on page 170A)

RAPID ADVANCEMENT by dahl

For information regarding
Engineering Positions
in the
Microwave and Power Tube Operations
Write D. Hamant

RAYTHEON MANUFACTURING COMPANY

Waltham 54, Massachusetts

Are you the ONE MAN IN THREE?

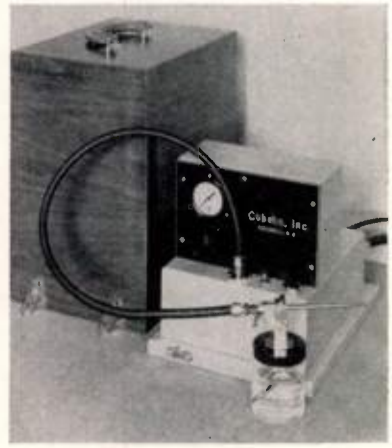
Excellence in Electronics RAYTHEON

News-New Products

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

(Continued from page 168A)

manufacturers of equipment and solvents for the critical cleaning of precision electronic and electromechanical components.



This unit provides a narrow cone of high velocity, filtered, and heated air to spray a controlled volume of a neutral and chemically pure solvent. The finely atomized spray of non-flammable Cobehn Solvent combines with the high velocity air stream to remove oil, grease, silicone lubricants, rosin flux, and other forms of soluble and non-soluble contamination. Critical chemical cleanliness is achieved without film or residue.

The use of a long Teflon air hose and specially designed sprayer makes this portable unit particularly effective for the cleaning of open relay contacts in computers and other electronic equipment.

Alumina Tubing

New design approaches are being used by **American Lava Corp.**, Cherokee Blvd., & Mfgrs. Rd., Chattanooga 5, Tenn., in the production of minute yet strong AlSiMag Alumina tubing. Conventional round or oval cross sections are being superseded in many cases by cross sections resembling figure 8's. Often such designs have 4 or more holes, like figure 8's in tandem. Each tubular unit of the design may be joined closely to its neighbors—or separated by what might be termed "ceramic web-

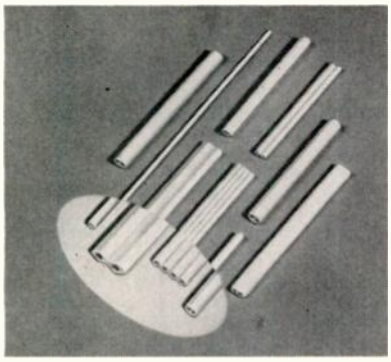
(Continued on page 173A)

News-New Products

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

(Continued from page 170A)

bing" of various widths and thicknesses, resulting in a cross section comparable in shape to a dumbbell.



Such designs have particular value for dispersing heat because of the reduction in mass of area. This is vital for electron tube applications, and so forth.

Materials are high-strength AlSiMag Aluminas, of exceedingly fine grain size. Parts produced from these compositions are chemically inert, will not rust, corrode or deteriorate with time. Nonmagnetic. Excellent thermal shock resistance. Can be safely used under continuous elevated temperatures.

Single hole designs as small as 0.013 OD×0.007 inch ID have proven practical in production quantities. Close tolerances can be maintained. For information on miniature AlSiMag Alumina tubing for your application, send complete details to the firm.

Transistorized Converters and Inverters

Electronic Research Associates, Inc., 67 East Center St., Nutley 10, N. J., announces the availability of two new literature pieces covering their line of transistorized semi-conductor converters and inverters. Available is a two color catalog sheet listing full technical details and pricing information covering ERA's line of stock model dc to dc converters and dc to ac inverters. Also available is a seven page technical bulletin which provides operational characteristics, design data, and technical description on these converter and inverter units.

(Continued on page 174A)

News-New Products

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

(Continued from page 173A)

Frequency Meter

Cubic Corp., 5575 Kearny Villa Rd., San Diego 11, Calif., has a new frequency meter, a rugged, lightweight, fully transistorized unit that provides accurate direct frequency measurements from 3 to 100,000 cps in nine separate ranges. Accuracy is independent of input voltage waveform and amplitude. The instrument's excellent sensitivity to short pulses minimizes lost counts when measuring the average frequency of random events. Battery or ac powered.

For tachometry and vibration indications, an output connector on the model 503 provides all operating voltages for the Model A-503-1 and A-503-2 phototransistor pickups. These pickups allow the speed of rotating machinery or the frequency of vibrating parts to be sensed by means of interrupted light.

For application where tachometry is the primary requirement, the Model 503 tachometer provides calibration from 50 to 6,000,000 rpm.

"Kast-Coil" Waterproof Solenoid Coil

Available technical details concerning the recently announced "Kast-Coil," a waterproof coil carrying an unconditional guarantee, have been released as folder 210-3 by the **Industrial Sales Div.**, Dept. No. 408-B, **Hays Mfg. Co.**, West 12th St., Erie, Pa., literature immediately available.

(Continued on page 176A)

News-New Products

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

(Continued from page 174A)

Microwave Relay System

American Microwave Corp., 11754 Vose St., North Hollywood, Calif., announces the new Type MVT/MVR microwave relay system for common carrier, television, and data transmission usage. This equipment features interchangeable rf components for operation in the 6–7 kmc band (one watt output) or the 11–13 kmc band (250 mw output). Also the Type MVT/MVR microwave relay system employs an advanced design receiver using a triode cascode if amplifier with AGC action, an AFC circuit, a tunable direct indicating wavemeter, and full NTSC color transmission compatibility. The complete system is packaged in four portable "suitcase" type aluminum housings with completely weatherproofed rf head sections.

Allinson Joins Daystrom

The election of Thomas Allinson as vice president of marketing of **Daystrom, Inc.,** 430 Mountain Ave., Murray Hill, N. J., manufacturers of electrical, electronic and nuclear equipment, has been announced by Thomas Roy Jones, President.

Allinson will be responsible for over-all planning of marketing and sales for Daystrom and its nine operating divisions, Jones said.

Prior to joining Daystrom, Allinson was general manager and director of marketing of the Berke-

(Continued on page 178A)

News-New Products

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

(Continued from page 176A)

ley Division of Beckman Instruments, Inc. He joined Beckman in 1952 and had been previously associated with Marchant Calculators, Inc., and the Kellogg Switchboard & Supply Co. Division of I.T. & T.

Trimmer Potentiometer

The 50-M11 trimmer potentiometer, $\frac{1}{2}$ inch diameter is now available from **Maurey Instrument Corp.**, 7924 S. Exchange Ave., Chicago 17, Ill. It has been designed for extreme conditions of heat, humidity, shock and vibration.

The housing is all stainless steel; the shaft is stainless steel; a Teflon seal effectively seals the shaft end; precious metal contacts and precision machined parts are used throughout.

The standard dielectric breakdown is 1,000 volts rms. A 300 megohm insulation resistance to ground at 100°C is standard. Despite its size, the 50-M11 will dissipate 2 watts at 40°C.

The terminals have been riveted into the terminal board and #000-120 screws are used to fasten the lead wires to the terminals. The entire terminal and winding assemblies are then encapsulated.

Mechanical stops are provided to allow a nominal 310° mechanical rotation. Sturdy stop pins used in this trimmer allow 4 inch-pounds or torque to be exerted on the shaft. A shaft locking device is provided with all standard units. The 50-M11 is available from stock in many standard resistance values from 25 ohms to 50K ohms.

Write for further information to the company.

(Continued on page 180A)

Electronic Systems Engineers:

Why you should give serious thought to SYLVANIA'S NEW electronic research & development lab in Buffalo...

If you want all the advantages of a career in the fast-growing electronics industry, you should know the facts about Sylvania's new multi-million dollar Electronic Research and Development Center...opening late in 1957, the newest development in the company's phenomenal growth as a producer of complex military electronic systems.

Engineers who join us now will find opportunities for advancement that are impressive even for the young electronics industry. The company helps its men get ahead by sponsoring graduate study at the University of Buffalo's fine engineering school.

The location permits you to live and work in a most attractive suburb — Amherst, a choice residential area, only 7 miles from downtown. Buffalo, second only to New York City in New York State, is progressive and alert, famed for its friendliness, and boasts an excellent public school system. The gateway to Canada, next door to Niagara Falls, it offers easy access to famous Eastern and Great Lakes resorts.

Immediate Openings in Applied Research

ADVANCED CIRCUITS SPECIALISTS

With ingenuity, ability and interest to create operable circuits required to bring to fruition radically new theoretical concepts in the field of communications. Requires 10 years experience and proven ability to supervise work of a group of engineers creating original circuit designs. Techniques include: transistor applications, digital computer design, and a variety of novel video-radio frequency circuits, as well as modulation in unconventional dimensions.

ELECTRO-MAGNETIC PROPAGATION SPECIALIST

Should have 10 years experience and ability to supervise the work of a group of advanced research engineers searching for the solutions to problems in multipath transmission as a function of frequency; vector scatter propagation, broad band antenna design, etc., which are necessary in the utilization of new communications systems.

COMMUNICATIONS SYSTEMS SPECIALIST

Opening for an engineer with vision and creative ability to derive and direct applications of new techniques developed in Buffalo Engineering Laboratory to existing and newly developed systems. These techniques now permit solution of many long-standing problems which exist in fields ranging from radio to radar or sonar from radio teletype to DME. Should have at least 10 years experience in communications field and an interest in system synthesis and analysis. Advanced degree in Electrical Engineering, Physics, Mathematics or equivalent in course work on a graduate level is desirable.

Please send your resume to E. F. Culverhouse

175 GREAT ARROW AVENUE — SYLVANIA — BUFFALO, NEW YORK

SYLVANIA ELECTRIC PRODUCTS INC

News-New Products

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

(Continued from page 178A)

Quartz Crystal Unit

For complete design specifications request bulletin #491 from the **Bliley Electric Co.**, Union Station Building, Erie, Pa., concerning the 1000 kc sealed-in-glass

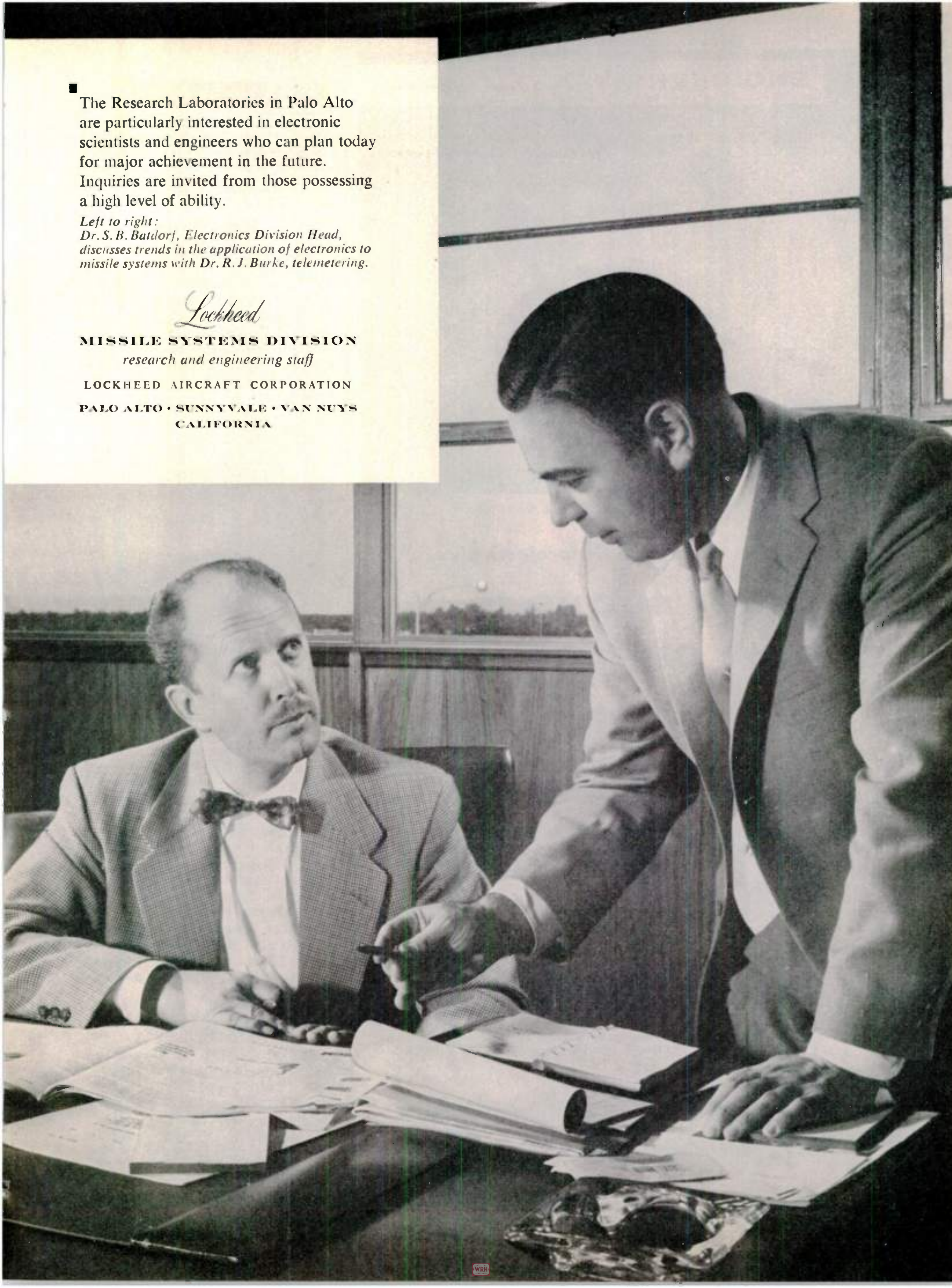
quartz crystal unit, the BG9A-S. It is designed to provide exceptional stability with minimum aging in secondary frequency standards.

Tolerance for type BG9A-S is ±5 ppm at 70°C. Temperature coefficient is less than 0.4 ppm/°C between +65°C. and +75°C. The unit is $3\frac{1}{6}$ inch overall, T-9 bulb and standard octal base.

Coil Winding Catalog

Geo. Stevens Mfg. Co., Inc., Pulaski Road at Peterson, Chicago 30, Ill., has just released a 62 page catalog, No. 57, illustrating and completely describing 48 coil winding machines of which 18 are newly developed models. The various machines wind virtually all types of coils including bobbin, repeater, resistor, solenoid, transformer, variable pitch, armature, field, toroidal, space wound, lattice-wound universal, continuous resistance and deflection yoke coils. In addition, a newly developed wire scraper, wire insulating equipment, 18 tension, a new tension safety attachment, 4 counters and 6 pages of various accessories and optional equipment are pictured and full technical details given. Also included is a page of time-saving, helpful winding formulas.

(Continued on page 182A)



News-New Products

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

(Continued from page 180A)

Meter-Relay

The new Model 126 very high sensitivity Meter-Relay, smaller than previous model, is available from **Assembly Products, Inc.,** Palm Springs 2, Calif., measures $1\times1\frac{1}{4}\times2\frac{1}{4}$ inches overall. It fits a 9 pin miniature socket. (Hold down screws and solder terminals are optional). The case is solder sealed.

Ranges & Accuracy: 50 μa to 10 amperes and 10 mv to 500 volts at 2 per cent. Ranges down to 0.2 microamperes (12,000 ohms) and 0.1 millivolts (5 ohms) at reduced accuracy. The V.H.S. is supplied for either ac or dc. All ranges may be compensated for ambient temperatures of −40° to +150°F. The ranges below 150 millivolts are supplied with an external transformer. Current ranges above 25 ac ma also take a transformer. The dc ranges above 10 amperes have an external shunt. All sensitive ranges may be protected from overload damage by internal Stabbistor Diodes.

Servo Amplifier

The Model 1800-0500 Tramp® a high temperature, miniaturized, hermetically-sealed, plug-in transistor servo amplifier has been designed by **M. Ten Bosch, Inc.,** Pleasantville, N. Y. It is primarily intended to receive signals from a Synchro Control Transformer and to operate a size 15, 400 cps 6.1

(Continued on page 184A)

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ELECTRONIC DESIGN ENGINEERS with degree plus experience in pulse circuitry, digital computers or data processing equipment. ELECTRO-MECHANICAL ENGINEERS with bachelor's degree in Engineering and experience in electrically actuated high-speed mechanisms. TEST EQUIPMENT ENGINEERS for complex test equipment design. MATHEMATICIANS with degree in Mathematics and/or experience in computer programming. Send complete resumé to Mr. James Drumm, Dept. PMy-1, 1900 W. Allegheny Ave., Philadelphia, Pa.

SO. NORWALK, CONN.

ELECTRONIC DESIGN ENGINEERS with degree plus experience in pulse circuitry, digital computers or data processing equipment. ELECTRO-MECHANICAL ENGINEERS with bachelor's degree in Engineering and experience in electrically actuated high-speed mechanisms. TEST EQUIPMENT ENGINEERS for complex test equipment design. MATHEMATICIANS with degree in Mathematics and/or experience in computer programming. Send complete resumé to Mr. Robert Martin, Dept. NMy-1, Wilson Ave., South Norwalk, Conn.

ST. PAUL, MINN.

ELECTRONIC DESIGN ENGINEERS with degree plus experience in pulse circuitry, digital computers or data processing equipment. ELECTRO-MECHANICAL ENGINEERS with bachelor's degree in Engineering and experience in electrically actuated high-speed mechanisms. TEST EQUIPMENT ENGINEERS for complex test equipment design. MATHEMATICIANS with degree in Mathematics and/or experience in computer programming. Send complete resumé to Mr. R. K. Patterson, Dept. SMy-1, Univac Park, St. Paul 16, Minn.

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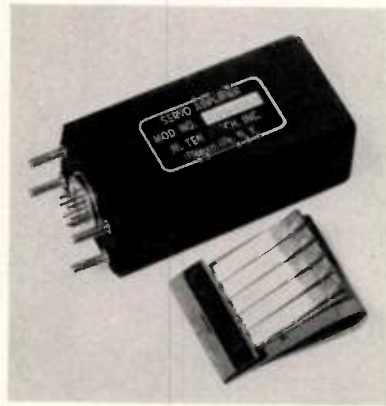
News-New Products

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

(Continued from page 182A)

watt servo motor (Kearfott Type R110-2) or equivalent.



Size is $1\frac{3}{16} \times 1\frac{11}{16} \times 3\frac{13}{16}$ high. Weight is 7 ounces. It is designed to exceed requirements of MIL-E-5400A (−55°C. to +100°C., intermittent rating to +125°C.). The connector is hermetically sealed, 7 pin plug-in (Turret head terminals optionally available as Model 1800-0600). Mounting is by four 6-32 weld studs.

Input impedance. (Nominal): 10,000 ohms (A wide range of input values may be made available to suit source impedance requirements). Gain (Nominal): Voltage gain 1600 at 6 watts output (Feedback connections available for gain reduction and stabilization.) The phase shift is adjusted internally to provide essentially zero phase shift. Carrier frequency is 380 to 420 cps. Output: 105 volts maximum (6 watts) when directly coupled to Kearfott Type R 110-2 Servo Motor. (This motor is essentially a BuOrd Mark 7 Servo Motor.) Input-power requirements are 100 volts dc at 100 ma 28 volts dc at 12 ma.

Variable Resistor for TV Printed Circuits

Series U52 a 2-section side-by-side variable resistor developed by **Chicago Telephone Supply Corp.**, Elkhart, Ind., which snaps into place on printed circuit panel or on separate supporting bracket without need for mounting hardware or additional operations. It mounts

(Continued on page 188A)

SCIENCE at RCA

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FIELDS OF ENGINEERING ACTIVITY	MANAGERS	TYPE OF DEGREE AND YEARS OF EXPERIENCE PREFERRED: Electrical Engineers			Mechanical Engineers			Physical Science			Ceramics Glass Technology Metallurgy		
		0-2	2-3	4-15	0-2	2-3	4-15	1-2	2-3	4-15	1-2	2-3	4-15
• SYSTEMS *(Integration of theory, equipments and environment to create and optimize major electronic concepts.)*													
AVIATION ELECTRONICS • CONTROLS		W	W	W C	W	W	W C	W	W	W C			
DIGITAL DATA HANDLING DEVICES	M C		M C	M C		C	C		C	C			
MISSILE WEAPONS SYSTEMS • RADAR	M W	W	M W X C	M W X C	W	M W C	M W C	W C	M W X C	M W X C			
INERTIAL NAVIGATION			W C	W C		W C	W C		W C	W C			
COMMUNICATIONS		C	C N	C N	C	C				C N			
• DESIGN • DEVELOPMENT MISSILE WEAPONS SYSTEMS—Planning and Design—Radar—Fire Control—Servomechanisms—Computers	C M	W C M X	W C M X	W C M X	C M	W C M	W C M X	W C M	W C M X	W C M X			
AVIATION ELECTRONICS — Radar — Computers — Servomechanisms —Shock and Vibration—Circuitry—Remote Control—Heat Transfer—Sub-Miniaturization—Automatic Flight—Automation—Transistorization—Infrared—Airborne TV	W C	W C X	W C X	W C X	W C	W C X	W C X	W C X	W C X	W C X			
RADAR—Circuitry—Antenna Design—Servo Systems—Gear Trains—Intricate Mechanisms—Fire Control—Information Handling—Displays	M C	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X			
COMPUTERS—Systems—Advanced Development—Circuitry—Assembly Design—Mechanisms—Programming—Digital Data Handling Devices	M	C W	M C X W	M C X W	C W	M C X W	M C X W	C W	M C W	M C W			
KINESCOPES (B & W and Color), OSCILLOSCOPES—Electron Optics—Instrumental Analysis—Solid States (Phosphors, High Temperature Phenomena, Photosensitive Materials and Glass to Metal Sealing)		L	L Y	L Y	L	L Y	L Y	L	L Y	L Y	L	L Y	L Y
GAS, POWER AND PHOTO TUBES—Photosensitive Devices—Ceramic to Metal Sealing—UHF and VHF—Super Power		L	L	L	L	L	L	L	L	L	L	L	
RECEIVING TUBES—Tube Design—Test and Application Engineering—Chemical and Physical Development—Methods and Process Engineering		H	H	H		H	H		H	H		H	H
MICROWAVE TUBES—Tube Development and Manufacture (Traveling Wave—Backward Wave—Magnetron)	H	H	H	H		H	H		H	H		H	H
SEMICONDUCTORS—Materials research (surface studies—crystallography)—device design—circuitry—process engineering—automation.		V	V	V	V	V	V	V	V	V	V	V	V
COMMUNICATIONS—Specialized Systems—Microwave—Mobile—Aviation—Audio—Propagation Studies—Acoustics—Transducers		C N	C N	C N		C	C	C N	C N	C N			
BROADCAST AND TV—Monochrome and Color Studio Equipment—Cameras—Monitors—High Power Transmitters		C	C	C	C	C	C	C	C	C			
• SYSTEMS APPLICATION *(Evaluation and Planning—Design and Development—Modification—Specification)*													
MISSILE TEST INSTRUMENTATION (Data Acquisition and Processing)—Radar—Telemetry—Timing—Communications—Optics—Computers	F	F S	Z F S	Z F S	F S	F S	Z F S	F S	Z F S	Z F S			
RADAR—Airborne—Surface—Shipboard—Sonar—Fire Control	F	F S	Z F S	Z F S	F S	F S	Z F S	F S	Z F S	Z F S			
COMMUNICATIONS—Radio—HF—VHF—UHF—Microwave—Telephone—Teletype—Telegraph Terminal Equipment—Wave Propagation	F	F S	F S	F S	F S	F S	F S	F S	F S	F S			
• MACHINE DESIGN Mechanical and Electrical Automatic or Semi-Automatic Machines		L H	L H	H	L	L H	H		L	L			

Locations: **C**—Camden, N. J. **F**—Cocoa Beach, Fla. **H**—Harrison, N. J. **L**—Lancaster, Pa. **M**—Moorestown, N. J. **N**—New York, N. Y. **S**—RCA Service Co. (Cherry Hill, N. J.; Alexandria, Va.; Tucson, Ariz.; Dayton, Ohio; San Francisco, Calif.) **V**—Somerville, N. J. **W**—Waltham, Mass. **X**—West Los Angeles, Calif. **Y**—Marion, Ind. **Z**—White Sands, N.M.

Please send resume of education and experience, with location preferred, to:

Mr. John R. Weld, Employment Manager
Dept. A-13E, Radio Corporation of America
30 Rockfeller Plaza, New York 20, N.Y.

RADIO CORPORATION of AMERICA

News-New Products

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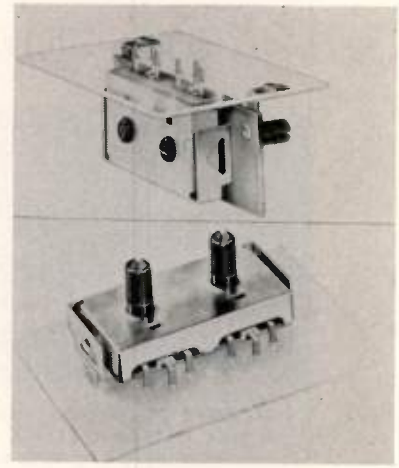
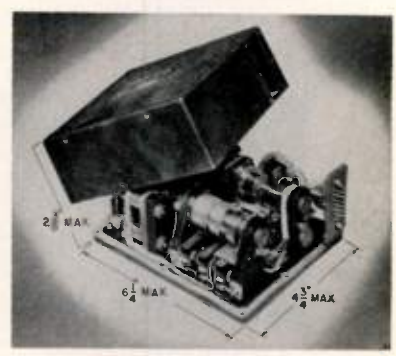
(Continued from page 184A)

parallel to printed circuit panel with shafts perpendicular or can be mounted on separate support-



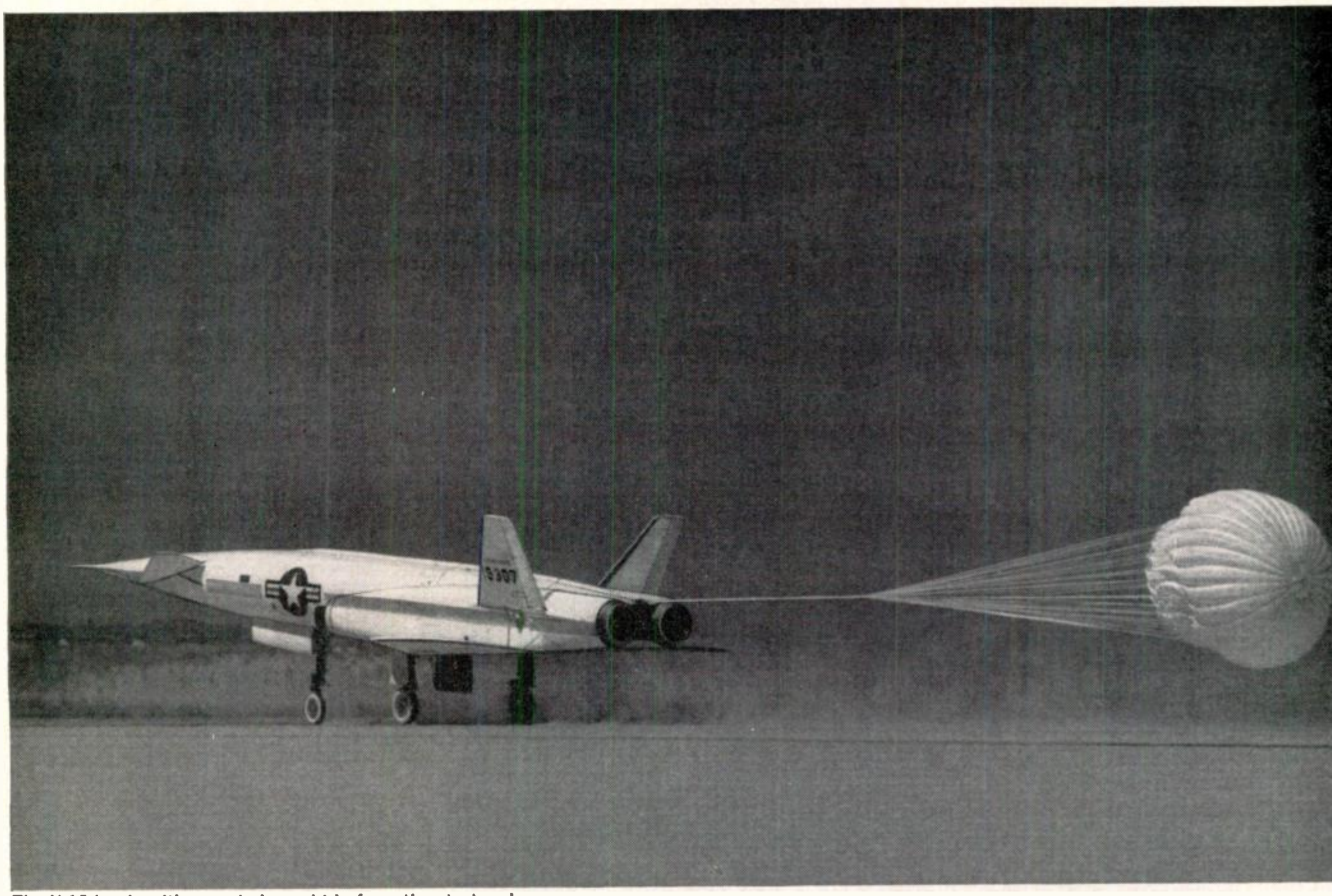
ing bracket with shafts parallel to printed circuit board. Compact design requires minimum panel space and reduces handling costs. The control is easily, quickly removed for servicing due to specifically designed clip-off mounting supports and terminals. The $\frac{1}{4}$ inch diameter molded phenolic shafts for finger or screwdriver adjustment are available in 3 styles. Resistance range is 250 ohms through 10 megohms and rotation angle 300° ±5°. Available for black and white TV, color TV, and other electronic applications.

Multiple Sequence Timer



A new six-in-one high accuracy rapid response long life multiple contact sequence timer which handles up to 6 separate timing sequence operations simultaneously for military and commercial

(Continued on page 190A)



The X-10 lands with secrets brought in from the stratosphere.

X-10 missile test vehicle returns with good news for electrical engineers

New scientific data allows the Navaho Missile to leapfrog many R & D steps—go direct into advanced stages. Unprecedented success of the supersonic X-10 spells out this significant fact: The Navaho—an intercontinental strategic missile completely automated and constantly guided throughout its supersonic flight by self-contained control systems—is one of America's *most advanced* missile systems.

This news is important to you—whether you are a 10-year veteran or a recent BSEE. Why? Because now you can start at the very top of missile technology—and reap the rewards of being with a years-ahead company.

40 immediate career opportunities in electronic systems analysis

In Missile Engineering you'll investigate applications of automation that are literally strides ahead of the field. You'll pursue them in pre-flight, preparation, checkout, fueling, countdown and firing. You'll work on "in-flight" control and guidance systems so precise that even the environment within the missile must be rigidly controlled.

One of our immediate needs is for electrical engineers—especially those qualified in systems analysis, systems evaluation, component design and ground checkout. No matter what your experience has been it can be useful to us.

For complete details on these—and other engineering openings—please write: Mr. R. L. Cunningham, Engineering Personnel Manager, Dept.495IRE5 Missile Development Division, 12214 Lakewood Blvd., Downey, California.

MISSILE DEVELOPMENT DIVISION

NORTH AMERICAN AVIATION, INC.

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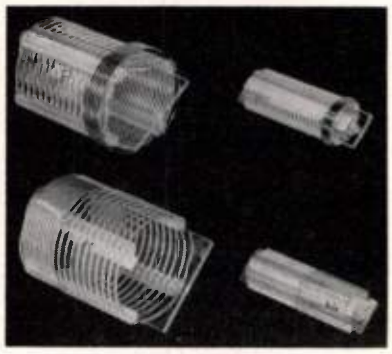
automation applications has been developed by **John Oster Manufacturing Co., Avionic Div.,** Racine, Wis. An example of fast response and high accuracy is that switches operate in a closed position for 0.050 ± 0.010 seconds and open for 0.450 ± 0.040 seconds and continuously repeat with 0.250 ampere load at 115 volts 400 cps over an input voltage range from 24 to 30 vdc. Switches can be actuated by a magnetic clutch and cam arrangement which re-sets to zero upon completion of timing cycle. Timing cycles can be tailored to fit the desired application. Specially designed switching devices are capable of up to 5,000,000 actuations. Type ST-9610-01 meets MIL-E-5400 and does not contain tubes or other electronic equipment. All contacting devices are readily accessible for servicing and adjustment. The unit is completely enclosed in a die cast aluminum case. Overall dimensions are $6\frac{1}{4}$ L $\times 4\frac{3}{4}$ W $\times 2\frac{3}{8}$ H inches. Weight is 4 pounds.

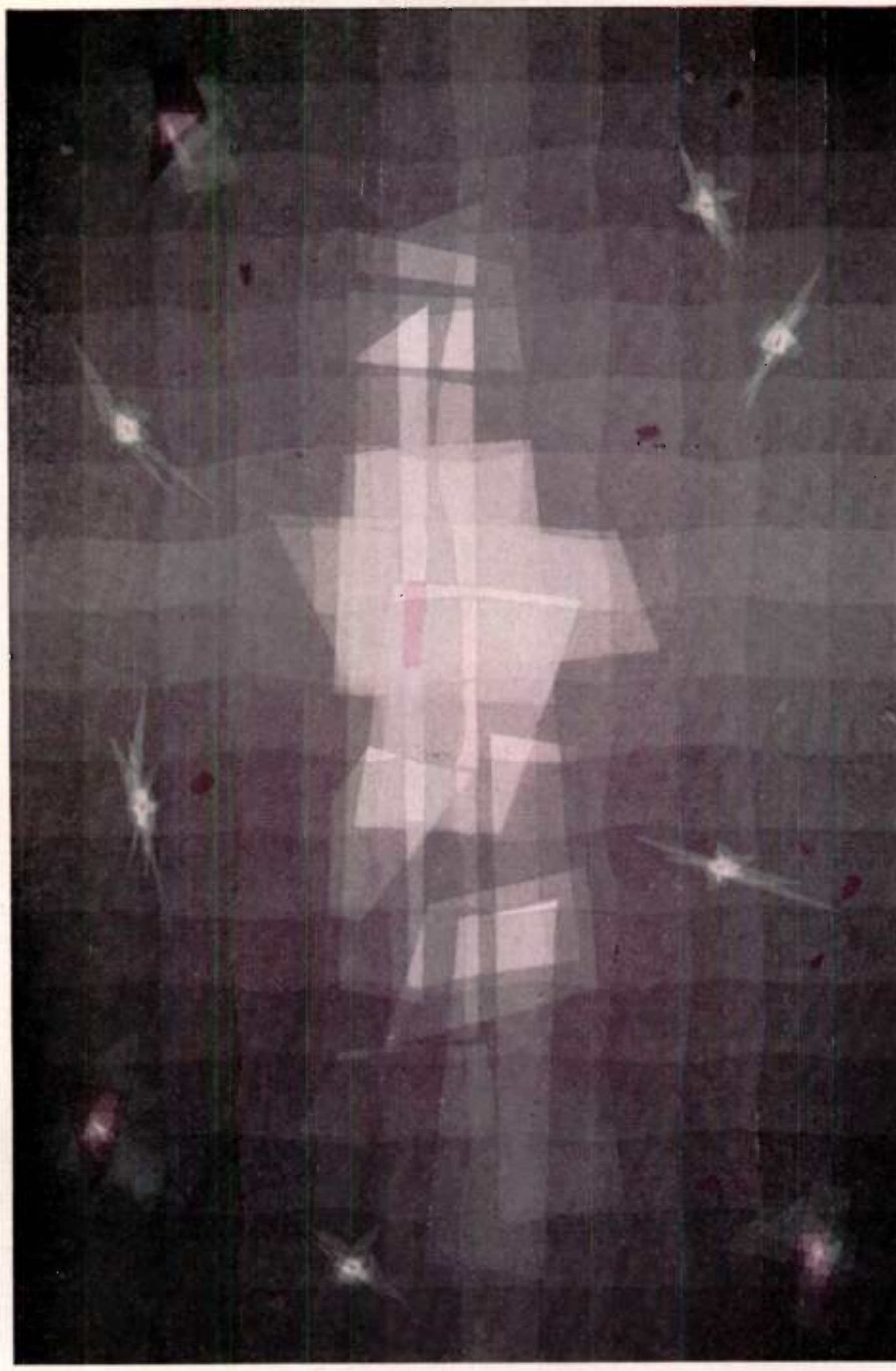
PI Air Dux Coils



Illumitronic Engineering, 680 E. Taylor St., Sunnyvale, Calif., announces the addition of a new series of air dux coils designed primarily for modern pi output circuits. They may also be used in conventional LC output circuits, interstage and oscillator circuits. Available in two series: Indented and Variable Pitch. Indented coils make connecting of taps by clips or soldering neat and easy. Variable Pitch coils offer complete ease in obtaining the proper inductances at high frequencies.

(Continued on page 192A)

"STAR JUGGLER," a new interpretation by Simpson-Middleman, painters of the meanings of science. "We began to portray a sun as a stationary nucleus of a cosmic atomic system," recounts this imaginative team of artists, "but as the work progressed, there emerged a sense of movement, a suggestion of a sun swinging planets through space until they approached the stars in brilliance." Painting courtesy of John Heller Gallery, Inc.



You'll find an extraordinary future at Boeing

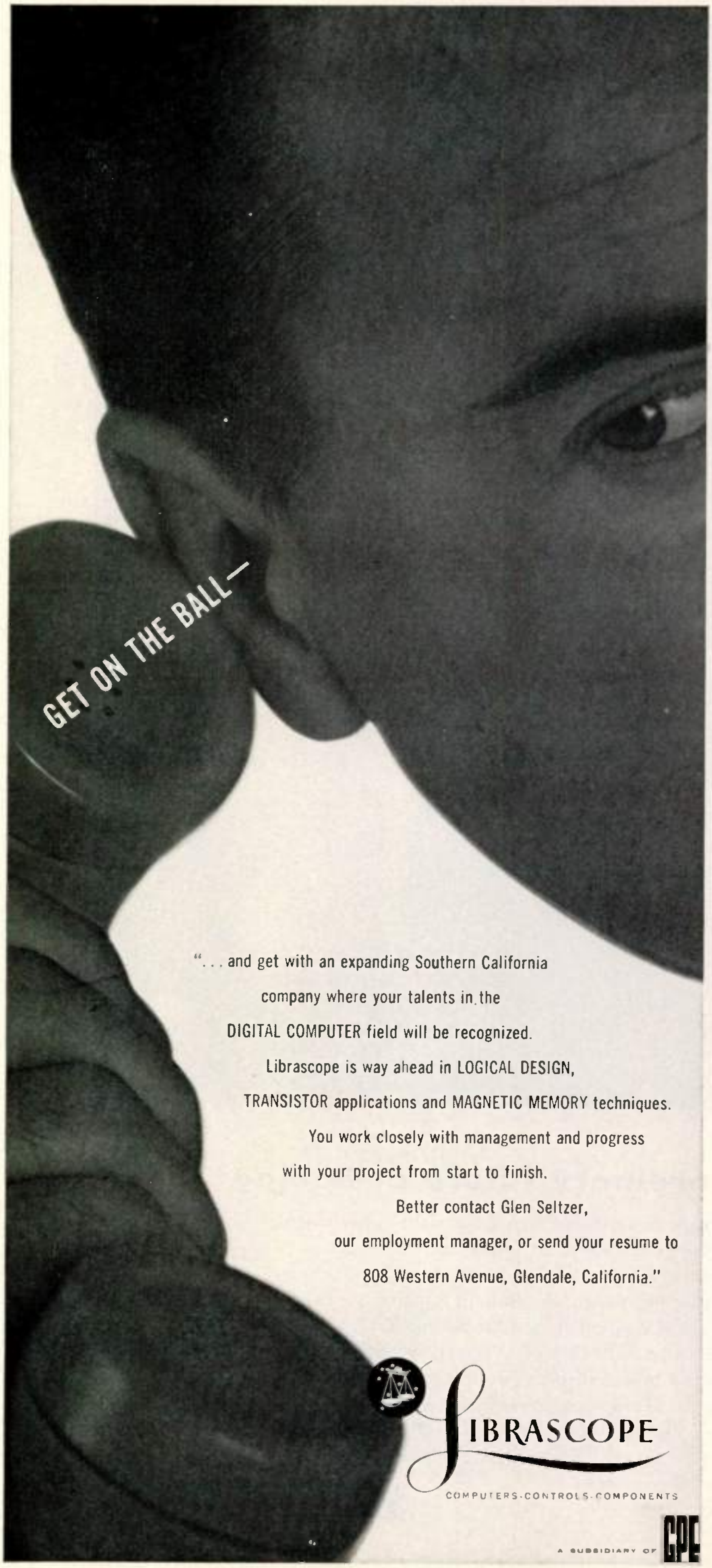
If you are impatient with ordinary achievement, you'll feel right at home at Boeing. For here you'll work with engineers and scientists whose habitual custom it is to push toward the future in giant steps. To cite just two examples: the Boeing 707 jet airliner, which at a stroke cuts commercial flight schedules in half, bringing the Pacific and Atlantic coasts within four hours of each other; and the Boeing B-52, which reduced the dimensions of the earth to a nonstop flight time of 45 hours, 19 minutes.

Today Boeing engineers invite you to join them on projects that open out onto the still more extraordinary vistas of the future: advanced supersonic aircraft and guided missiles, electronic and inertial guidance, chemical fuel propulsion.

There are openings at Boeing now for engineers of ALL categories, and for physicists and mathematicians. You'll find the future—your future—at Boeing, today!

BOEING

Drop a note now to John C. Sanders, Engineering Personnel Administrator, Boeing Airplane Company, Department G-63, Seattle 24, Washington



News-New Products

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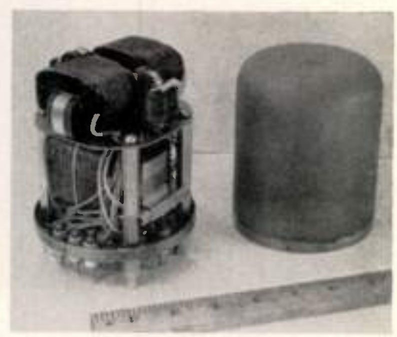
Pi air dux coils are adaptable to a wide range of tube and load impedances in either high or low power transmitters.

A stock line is available for immediate delivery in a range of sizes from 1 inch diameter to 3 inch diameter, but any special size and values may be manufactured on request.

An illustrated brochure is available by writing the manufacturer.

Miniaturized High-Voltage Transformers

Miniaturized high-voltage transformers featuring evaporative cooling techniques developed by **Raytheon Manufacturing Co., Equipment Marketing Dept.,** Waltham 54, Mass., are now available. Types utilizing evaporative cooling include pulse, magnetron filament, plate, and audio transformers. The new units comply with military specifications and are capable of operating in ambients from 650 to −125°C.



Cooling is effected by high-dielectric fluorochemical liquid which vaporizes in contact with the hot windings and then condenses on the inner surface of the transformer case. Condensation takes place in the space normally provided for the expansion of insulating liquids or gases. Active boiling in the vicinity of hot spots greatly increases the circulation of cooling fluid and results in significant reduction of internal temperature gradients from windings to case.

Some of the new units also utilize the exceptional wetting action

(Continued on page 194A)

"What do you mean, opportunities for leadership?"

Well, maybe this is our way of saying that Argonne has a certain something—let's call it a climate of opportunity—that gives each of us the chance to get ahead on his own power. For one thing, we're a good deal like a university in that most of us are working on problems of our own choice.

Sure, that's fine . . . but research is an expensive business.

We know that, but we found out a long time ago at Argonne that a fellow with ambition, such as yourself, can best carry through his ideas when he has the right materials and equipment available—all the "hardware" of today's full-scale research.

It sounds impressive, and big . . . maybe too big?

I don't think so. The size of a place *is* important these days, but we're not so big that you get lost in the crowd—or so small that there's no one around who talks your own language when you have a problem or idea to discuss. Actually, we're of such a size that someone with ability and enterprise can continue his professional development without taking on administrative responsibilities.

But what about professional recognition?

There's no magic formula for that. You're always encouraged to publish your results, present your work at meetings, and participate in the professional societies. In the long run, getting ahead professionally, and advancement at Argonne, go hand-in-hand.

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PROFESSIONAL PERSONNEL OFFICE P. O. BOX 299 LEMONT, ILLINOIS

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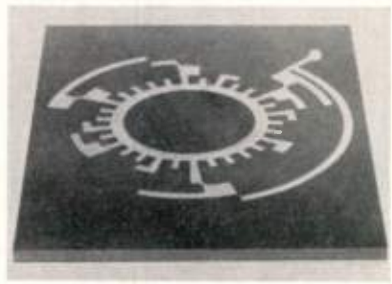
of liquid fluorochemicals. Woven glass insulating material interleaved with the winding serves as a wick to carry liquid directly to the hot spots, which are then cooled by evaporation of the liquid.

The excellent corona-suppressing properties of the fluorochemical vapors are used to good advantage in the design of transformers for corona-free operation under exceptionally high-voltage stress.

Flush Etched Circuits



A process for producing flushed etched circuits for the printed wiring industry has been developed by **The Mica Corp.,** 4031 Elenda St., Culver City, Calif. The circuits are printed, etched and flushed into an epoxy-glass laminate. After the circuits are flushed, they remain stable and do not have a tendency to creep above the surface of the laminate. The flushed circuits are resistant to shock, vibration and abrasion and they exhibit excellent heat resistance under conditions encountered in dip, roll and hand soldering. Flushed circuits produced by this process can be used for commutators, rotary timing discs and any other applications where added reliability and a flush surface are desired. For data, write to the firm.

UHF Twin Tetrode

Amperex Electronic Corp., 230 Duffy Ave., Hicksville, L. I., N. Y., has announced the availability of their new Type 6939 twin-tetrode, a Noval-base miniature tube designed for low-power vhf transmitter applications. With a seated height of only 2 $\frac{3}{32}$ inches, the Amperex 6939 delivers 5.5

(Continued on page 196A)

OPPORTUNITIES for Electrical Engineers and Physicists in Industrial Automation

FMC Central Engineering's current expansion into automatic measurement and control field provides unusual opportunities for technical accomplishment on important company sponsored long range programs. There is need for both systems engineers and specialists.

Qualified applicants including recent graduates are invited to write:

Manager of Central Engineering

FOOD MACHINERY AND CHEMICAL CORPORATION
San Jose, California
1105 Coleman Ave.
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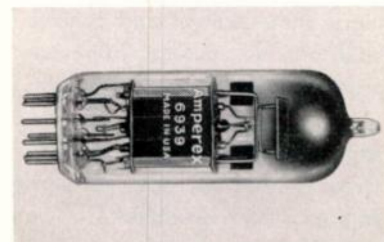
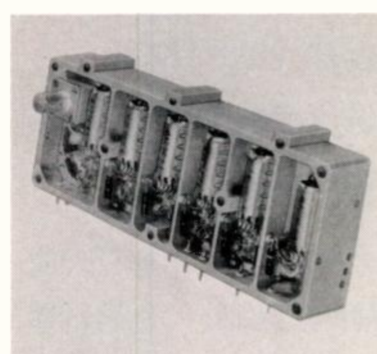
watts useful power in the load (ICAS rating) at any frequency up to 500 mc. It is said to be the world's smallest uhf twin tetrode.



The outstanding performance of the Amperex 6939 is due mainly to the exclusive 'Frame-Grid' construction, which insures extreme accuracy of interelectrode spacing. The special characteristics of the 6939 frequently permit the elimination of entire stages in original equipment design, resulting in lowered manufacturing cost. Detailed data sheets and applications engineering information are available from the manufacturer.

IF Amplifier



LEL, Inc., 380 Oak Street, Copiague, L. I., N. Y., has announced a new addition to its line of radar and missile if amplifiers. Developed to withstand 20 G vibration at 2000 cps, these units utilize ruggedized subminiature tubes in a special casting designed for high heat conduction and minimum chassis resonance.

Specifications of the IF64D are 60 mc center frequency, gain 65 db, bandwidth 10 mc.

IF64 amplifiers with other gain or bandwidth specifications can be supplied.

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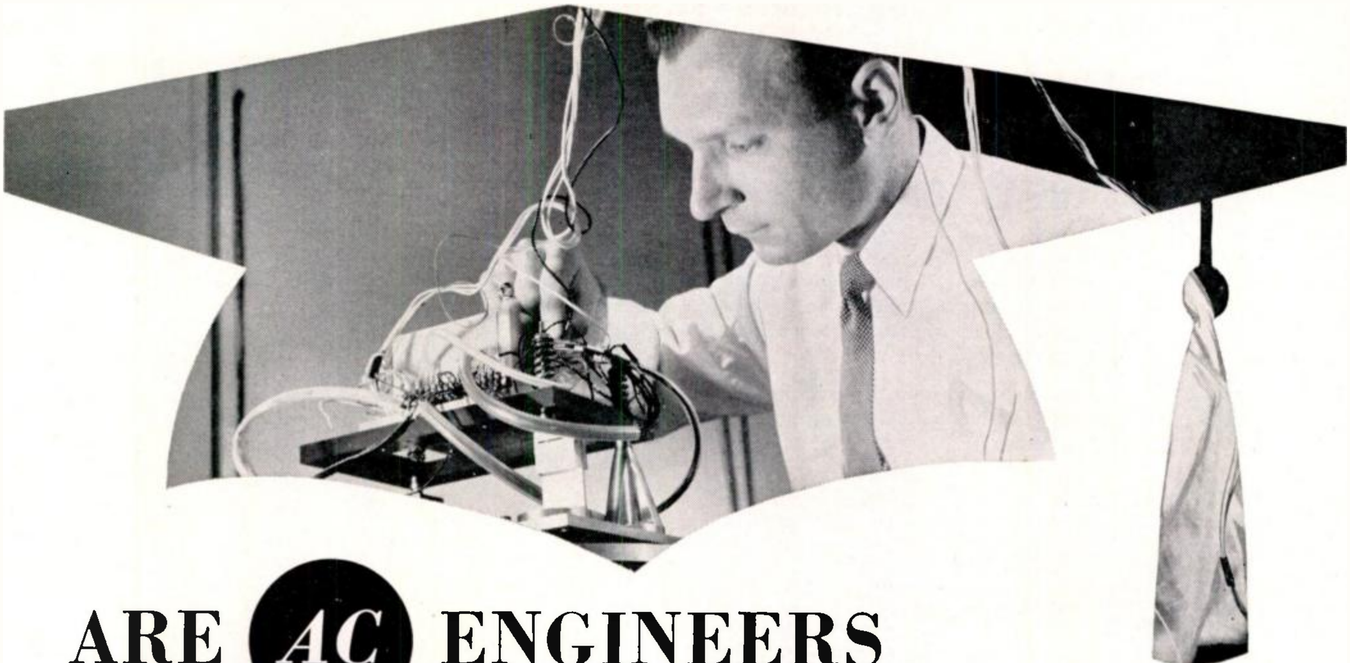

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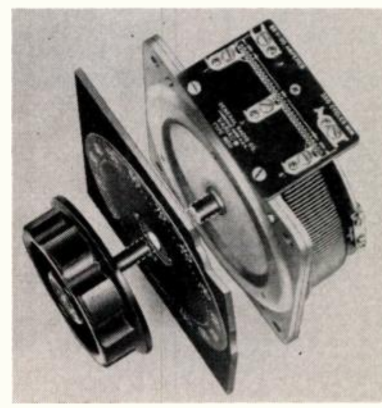
400 CPS Variac®

Operation at any supply frequency between 350 and 1200 cps is possible with the new Type M20 Variac® Auto-transformers developed by **General Radio Co.,** 275 Massachusetts Ave., Cambridge 39, Mass. The Type M20 is rated at 115 volts input with output up to 20 amperes at 0 to 115 or 0 to 135 volts. The unit, with knob and dial, weighs less than 13 pounds.



The Type M20 Variac is ruggedized, tropicalized, and designed to withstand the usual environmental operational shock and vibration tests (MIL-T-945A) normally required for military operation. Single units are priced at $48 ($56 with ball bearings) net f. o. b. Cambridge, Massachusetts. Two-gang and three-gang units are priced at $107 and $155, respectively, without ball bearings, $117 and $167 with ball bearings.

Photo Electric Detector

A newly-developed sub-miniature photo electric detector, designated as the Model 6350, the size of a sewing thimble, is available from **Autron Engineering, Inc.,** 1254 W. Sixth St., Los Angeles 17, Calif. The unit is self-generating,

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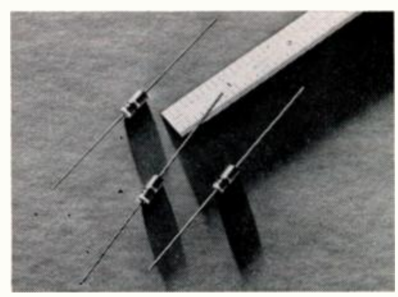
permitting simplifications of circuitry. Both rugged and highly-sensitive, the miniature detector furnishes output proportional to input light intensity and loading. Typical input-output proportions are 300 mv at 100 foot candles into 1 Meghom, or 20 μa at 100 foot candles into 100 ohms.

Miniature RF Choke Coil

Delevan Electronics Corp., East Aurora, N. Y. (Buffalo suburb), is now producing a standardized series of molded rf choke coils that are said to be more than 50 per cent smaller than any similar coils on the market. This line is available in 23 items with inductance values from 0.15 to 22.0 micro Henrys. Coils measure 0.156 D ×0.375 length.



This series is one of the six standardized choke coil series available for "off the shelf" delivery. All are hermetically encapsulated in molded alkyd. There are 150 coils in the six series—each has exactingly defined electrical parameters. All coils conform to Mil-C-15305A. A bulletin describing these coils fully is available from the manufacturer.

Resin-Insulated Hipersil®-Cores

A new-resin-insulated ring-type core made from grain-oriented Hipersil® steel in all gauges from 1 to 12 mils thick is available from **Westinghouse Electric Corp.,** P.O. Box 2099, Pittsburgh 30, Pa. It is used for toroidal core designs ranging in size from small blocking-

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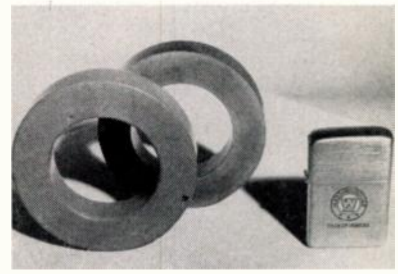
oscillator pulse transformers through large power units.



Windings can be placed directly on the core, eliminating the need either to tape the core or to encase it in a plastic or aluminum box.

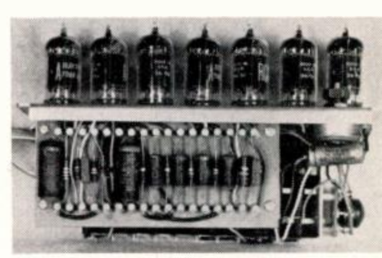
The resin coating is continuous and smooth. Corners are rounded to eliminate any possibility of shorting wire to core.

The coating does not impair magnetic properties of the core and withstands a voltage to ground of 2500 volts.

For further information, write to the company.

TV Synchronizer

The new packaged TV synchronizer unit designed by **Wang Laboratories, Inc.,** 37 Hurley St., Cambridge 41, Mass., will automatically generate 31.5 kc and 60 cycle pulses locked to the line frequency. It will track ± 2 cps variation in power line frequency and can be adjusted with a single control to track power line frequencies from 40 to 70 cps.



Utilizing the new magnetic binary scaler principle, the unit draws a few milliamperes off 160 volt supply and occupies a panel or chassis space of $7\frac{1}{2} \times 2\frac{1}{4}$ inches.

Limited quantities are now available for early delivery price: $225.00 each, F.O.B. Cambridge, Mass.

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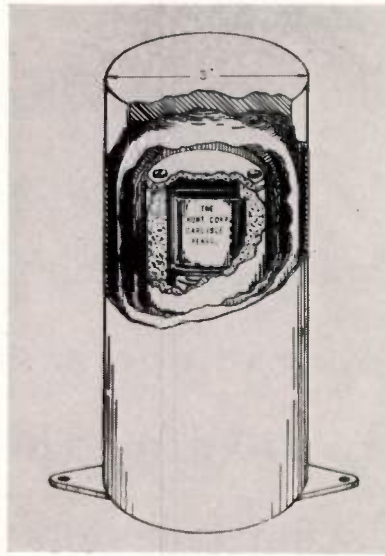
Precision Oven



The Hunt Corp., Carlisle, Pa., has developed and is producing an oven of super precision, controlled by a proportional amplifier-eliminating the use of a thermostat. This oven coupled with a precise Hunt quartz crystal unit results in a frequency control unit that will achieve stabilities up to 1 part in 10^9. The oven itself will control temperature stabilities up to $\pm 0.002°C$. The oven is suitable for temperature control of other small components as well as quartz crystal units.

Modulated RF Sources

Weinschel Engineering & Mfg., Corp., 10503 Metropolitan Ave., Kensington, Md., announces the Model MS-1, (50–250 mc) and the

Model MS-2, (250–900 mc) modulated rf sources. At least 200 milliwatts peak power into 50 ohms; 100 per cent square wave modulated internally at 1000 cps. Also claimed is, ± 0.2 db per hour for

(Conitnued on page 206A)

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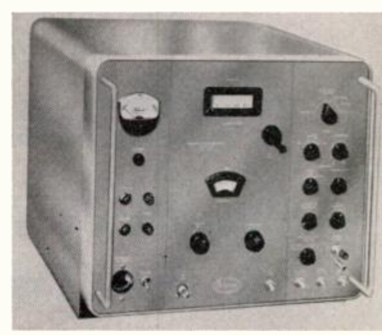
constant load. Using internal feedback circuit with external probe or coupler, ±0.02 db per hour. This equipment is said to achieve the unusual amplitude stability required for precise rf measurements. By means of an external directional coupler and internal feedback, the incident power is held constant over a wide range of load impedances thereby simulating a constant impedance source equal to the coupler impedance. If a voltage probe is used instead, the voltage is kept constant simulating a zero impedance source.

Broadband Microwave Signal Generator

A new ultra broadband microwave signal generator covering a frequency range equal to two or more present day units has been announced by **Polarad Electronics Corp.,** 43–20 34th St., Long Island City 1, N. Y.



The MSG-34 covers C and X Band frequencies 4,200 to 11,000 mc—with a power output of 1 milliwatt. It is equipped with Polarad's exclusive Uni-Dial construction which provides complete integration and simple operation. Direct-reading dials indicate frequency and attenuation.

Other features of the new microwave signal generator are: provision for external modulation by multiple pulses; automatically tracked power monitor; and noncontacting oscillator choke.

The modulator, utilizing printed circuit techniques, permits internal pulse and square wave modulation from 10 to 10,000 pps at pulse widths of from 0.2 to 10 microseconds.

(Continued on page 208A)

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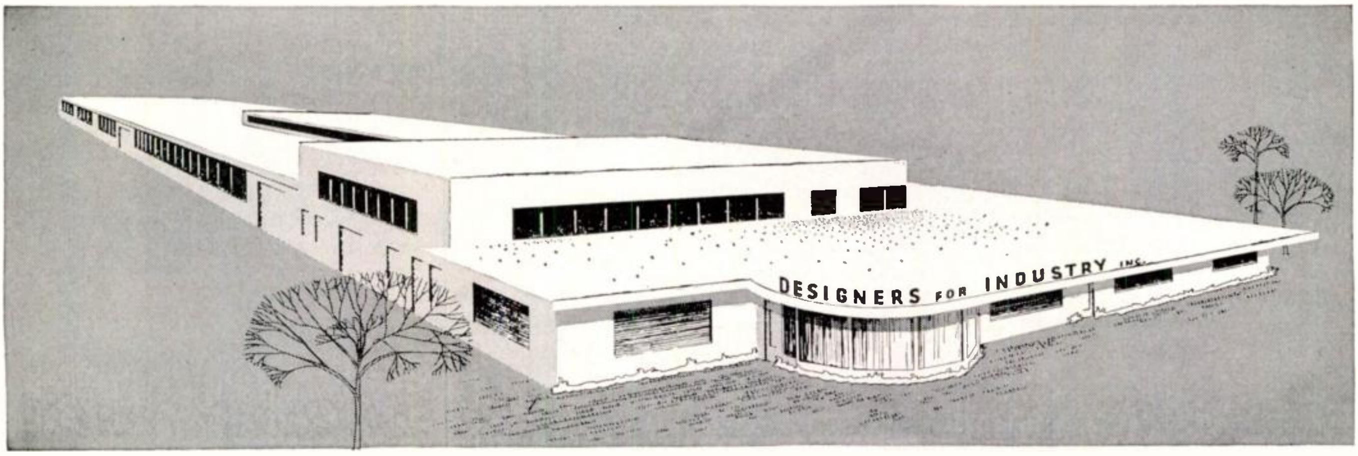

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a pension trust and a merit bonus return 62½% of all profits to the employees in a combination of annuities, cash and stock

the "fringe" benefits include such things as a very liberal paid vacation schedule and an educational refund plan. Leading educational centers nearby

professional freedom, mutual trust, challenging work and a dynamic, growing organization are combined into the proper atmosphere for stimulating creative development.

If you are interested write to James E. Burnett, Vice President, giving pertinent professional information. All information will be treated in complete confidence.

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News-New Products

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

(Continued from page 206A)

Guided Missile Dynamotor

A new dynamotor for application in guided missiles and telemetering installations has just been announced by **Induction Motors Corp.**, 570 Main St., Westbury, L. I., N. Y.

The model BD 1509D features a power output of 10 watts continuous, ranging up to 25 watts depending on duty cycle and cooling. Model BD 1509D has a brush life of 100 hours at 50,000 feet and operates in an ambient temperature range of from $-40°C$ to $+71°C$. Other models operating up to 100°C are available.

When subject to vibration, this dynamotor can withstand more than 3 g's from 5–600 cps, along three mutually-perpendicular axes. Under mechanical shock the unit can absorb up to 40 g's in any direction.

Model BD 1509D weighs 1 lb; measures $1\frac{1}{2} \times 1\frac{1}{2} \times 3$ inches.

Fotoform Glass Brochure

A new brochure, "New Developments in Corning Fotoform Glass," is now available from **Corning Glass Works**, Corning, N. Y.

Fully illustrated, the brochure gives detailed information of the four types of Fotoform glass: how they are made, how they differ, their specific and potential uses and design and production data on each one. Latest mechanical and electrical applications of Fotoform glass in the electronics and allied industries are reviewed.

(Continued on page 210A)

News-New Products

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

(Continued from page 208A)

Corning Glass Works is currently using Fotoform glass in many applications. These range from limited experimental designs to the quantity production of diversified mechanical and electrical components for precise basic assemblies where accuracy, reliability and long life are essential.

The new brochure is available from Corning free of charge. Write for EPFF-1 to Staff Sales Manager, Electrical Products Division, Corning Glass Works, Corning, N. Y.

Primary Pressure Standard

A new primary pressure standard designed by **Consolidated Electrodynamics Corp.,** 300 North Sierra Madre Villa, Pasadena, Calif., which permits pressure calibrations not ordinarily possible with oil dead-weight testers or mercury manometers, was shown in March during the Radio Engineering Show at the N.Y. Coliseum.

Operating as an air dead-weight tester, this instrument offers the advantages of a frictionless pressure media, extreme accuracy even at pressure of less than one psi, and portability regardless of the pressure range.

The instrument, known as Type 6-201 Primary Pressure Standard, depends on mass and length measurements for its accuracy. It will calibrate any pressure measuring device.

(Continued on page 212A)

News-New Products

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

(Continued from page 210A)

Ultrasonic Thickness Tester

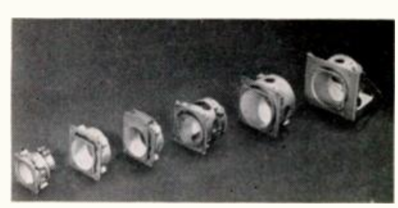
Branson Instruments, 37 Brown House Rd., Stamford, Conn., is now introducing ultrasonic test equipment to which automatic detection and recording devices may be attached. These will spot thickness changes in metals and plastics as small as 5/100 of one per cent, and can be connected to ring an alarm, flash a signal light, or activate compensating controls of various sorts.

Recent improvements in resonance testing equipment make it possible to attach "gating" circuits, which determine whether a strong signal is present within the present frequency range. High and low thickness tolerances can be established, and material sorted automatically into three categories: undersize, correct size, and oversize.

Similarly, the output of the gating circuit can be applied to a potentiometer-type strip chart recorder, where the deflection of the recording pen will depend on the distance of the resonance indication from one edge of the gate. As an alternate choice, this signal, after amplification, may be used to control machining processes, or to make corrective adjustments. Thicknesses down to 0.005 inch can be inspected. The same equipment will also indicate lack of bond, or gross discontinuities in the metal or plastic under test.

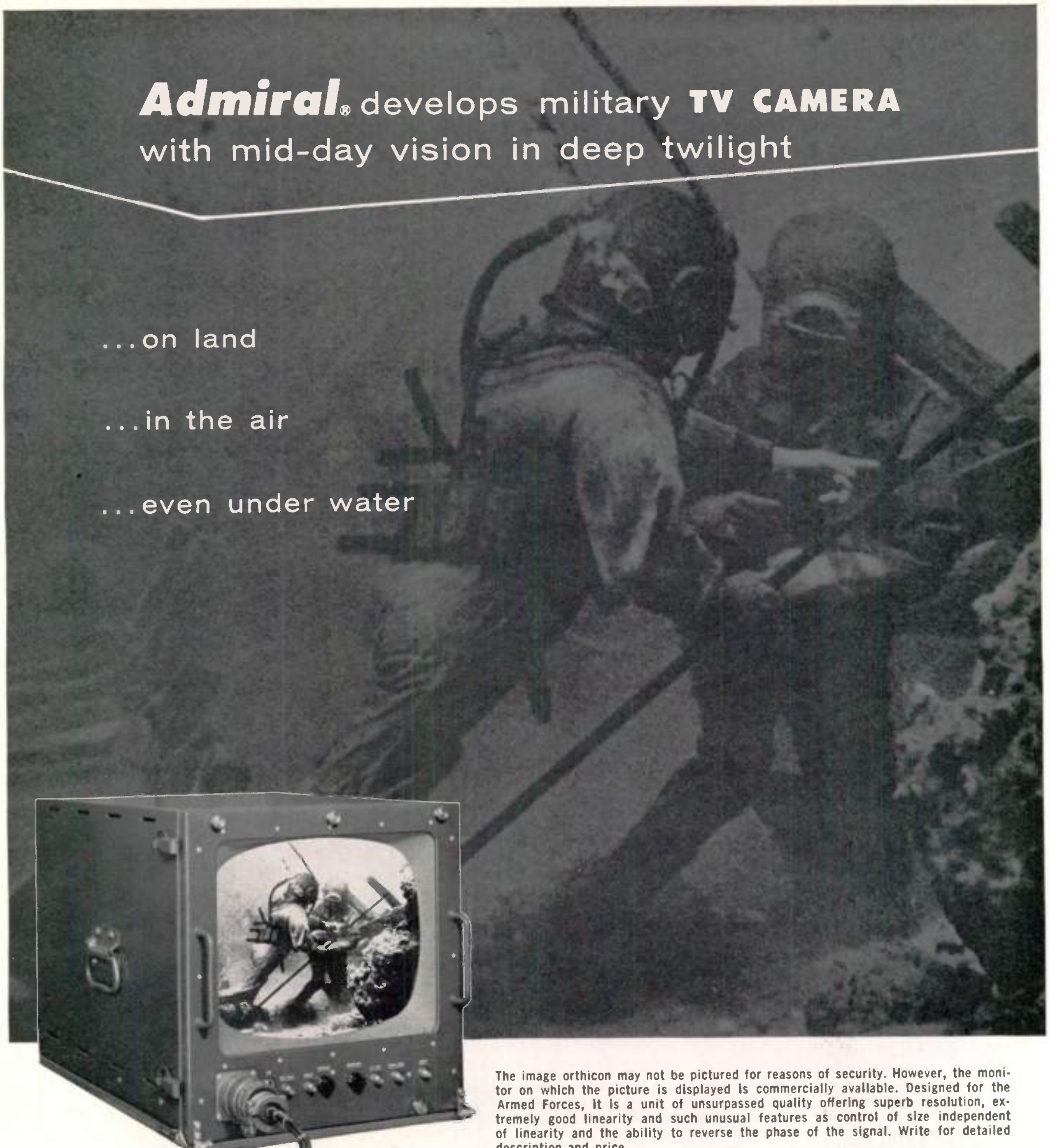
Shock Mounts

Robinson Aviation, Inc., Teterboro, N. J., designers and manufacturers of vibration and shock mounting systems, have extended the K130 design to over 45 different available models.



All the models are basically a radial cushion center of gravity mounting system incorporating

(Continued on page 214A)



The image orthicon may not be pictured for reasons of security. However, the monitor on which the picture is displayed is commercially available. Designed for the Armed Forces, it is a unit of unsurpassed quality offering superb resolution, extremely good linearity and such unusual features as control of size independent of linearity and the ability to reverse the phase of the signal. Write for detailed description and price.

The human eye is a remarkably sensitive instrument. But it is no match for the image orthicon TV camera developed by Admiral for the Armed Forces. Light from an ordinary match reveals as much to this TV camera as a man with 20/20 vision sees in the light of a 150 watt bulb. Obviously, the armed services will find countless ways to use this sharp-eyed observer for reconnaissance under adverse conditions.

Admiral developed the special circuitry that gives the image orthicon its amazingly keen "eye-sight." For all its extreme sensitivity, there is no penalty in excess bulk or weight.

Admiral has also "packaged" the unit to permit its use not only for land-based and airborne reconnaissance, but *even under water*. Development of the image orthicon again demonstrates Admiral's engineering capabilities in the field of military electronics. Inquiries are invited.

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News-New Products

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

(Continued from page 212A)

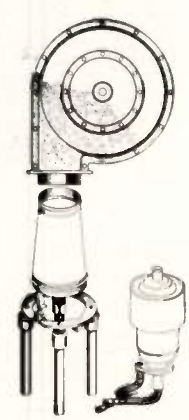
Met-L-Flex resilient elements. Engineered to meet specific vibration and shock control requirements, these all-metal mounting systems eliminate the severe environmental disturbances which damage critical instruments used in jet aircraft, helicopters, guided missiles, and rockets.

All-metal construction is in accordance with such applicable military specifications as MIL-E-5400, MIL-T-5882, and MIL-T-5796. Vibration and shock requirements are tested in accordance with military specifications MIL-E-5272, MIL-C-172B, and MIL-E-5272A.

Dimensions and load ratings vary from 1.8 to 8.5 inches in diameter and 0.5 to 50 pounds respectively. Vibration and shock performance is different in each model so as to provide the proper environmental protection. Installation of mounting systems is simplified by four pre-spaced mounting holes. To mount the equipment either clamp fasteners or four pre-spaced mounting holes are used.

High-Power, High-Frequency Socket

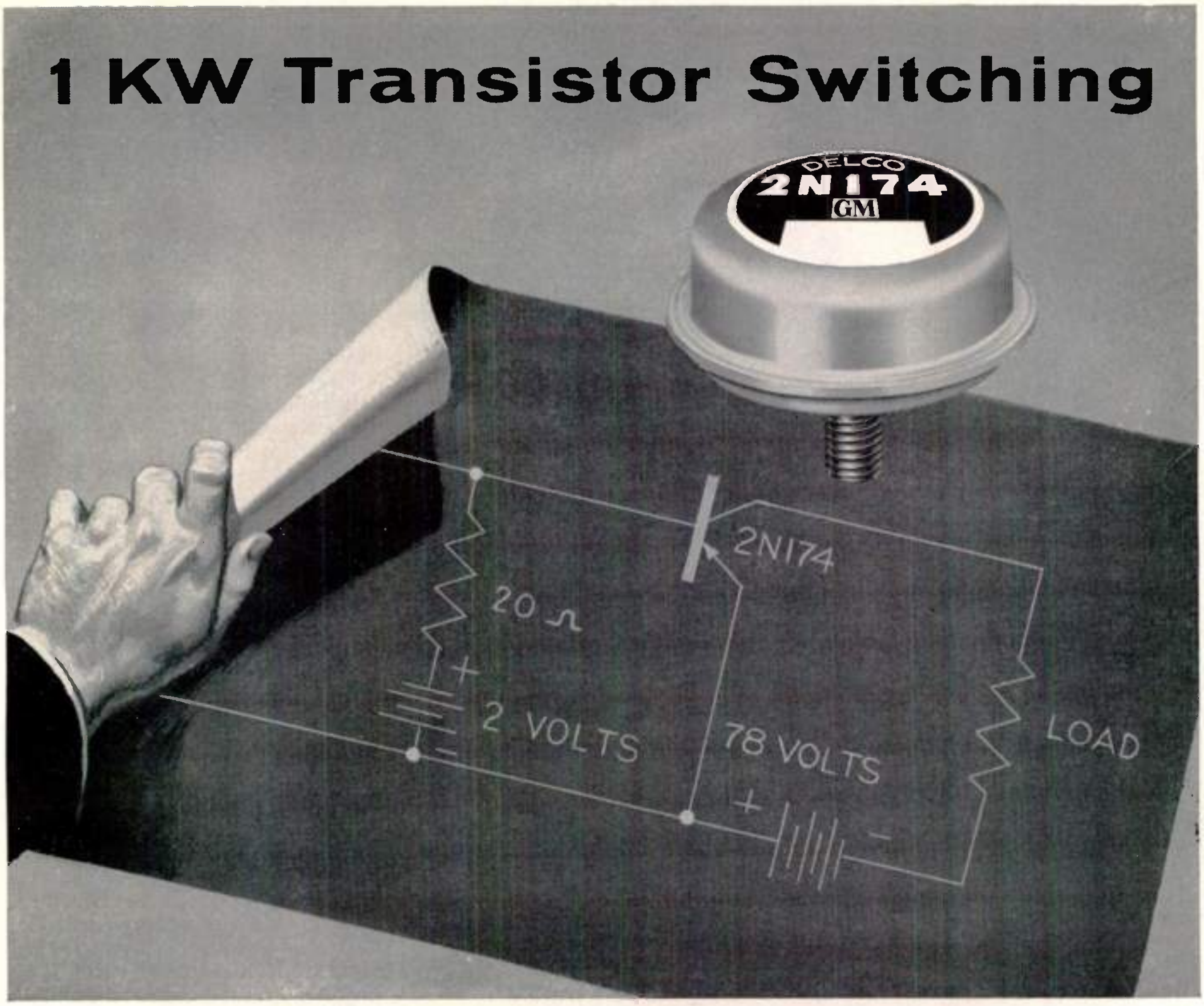
Radio Frequency, 44 Park St., Medfield, Mass., announces the availability of a new low-cost socket for high-power, high-frequency tubes.



The new RFC tube socket is especially designed for use with tubes such as the 3X2500-A and F3 and the 3X-3000A1 and F1, and similar tubes with an anode of $4\frac{1}{8}$

(Continued on page 216A)

1 KW Transistor Switching



Industry's Highest Power Transistor

Eliminate arcing at switch points. Stop switch deterioration while increasing the efficiency and reliability of all electronic control equipment!

A single Delco 2N174 transistor can switch 1 kw with one watt of control power.

Because transistor switching eliminates arcing, switch life is longer and more reliable.

This switching performance is possible because of the excellent electrical characteristics of the 2N174; in particular, the high collector breakdown voltage, extremely high maximum collector current, and very low input impedance.

You may employ Delco 2N174 high-power transistors with confidence in their reliability and uniformity. These transistors, normalized to retain better performance characteristics regardless of age, are currently being produced by the thousands every day. Write for engineering data.

Power Switching Characteristics	
Switching Power	1000 watts
Current in "on" position	13 amperes
Input Control Power	1 watt
Power Gain	30 db
Dissipation in "on" position	8 watts
Switching time	60 microseconds

DELCO RADIO DIVISION OF GENERAL MOTORS KOKOMO, INDIANA

News-New Products

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

(Continued on page 214A)

inch OD. This socket incorporates a novel, ring-type design which provides 100 per cent contact all around the anode. This 100 per cent contact area eliminates damaging hot spots, parasitics, and so forth. Versatility of the socket design is such that it can be supplied to accommodate a one, two, or three tube design.

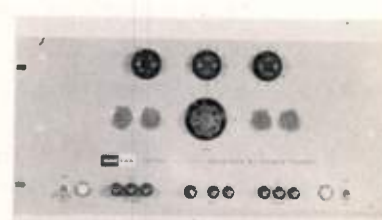
The socket is supplied with a ring clamp for mounting a silicone rubber air duct to the tube. The company can also supply cooling blowers specially designed for use with the new tube socket.

The base price of this versatile new socket is $24.50. This price includes the silver-plated contact ring with corona shields and low-loss socket posts.

Complete technical specifications are available from the manufacturer.

DC Power Supply

Kin Tel (Kay Lab), 5725 Kearny Villa Road, Box 623, San Diego 12, Calif., has a new improved Model 30B-25 Power Supply which provides dc from 1.02 to 302 volts at up to 250 milliamperes with ±100 parts per million long time stability, 0.01 per cent load regulation factor, and less than 0.5 millivolts hum and noise. Direct reading calibrated dials provide instant selection of the desired output voltage to an accuracy of 0.02 per cent or 5 millivolts. The dc output impedance is less than 0.01 ohm, and ac output impedance is less than 0.5 ohm to 200 kc. Response time is less than 0.2 milliseconds. The unit fits standard 19-inch rack mounts.

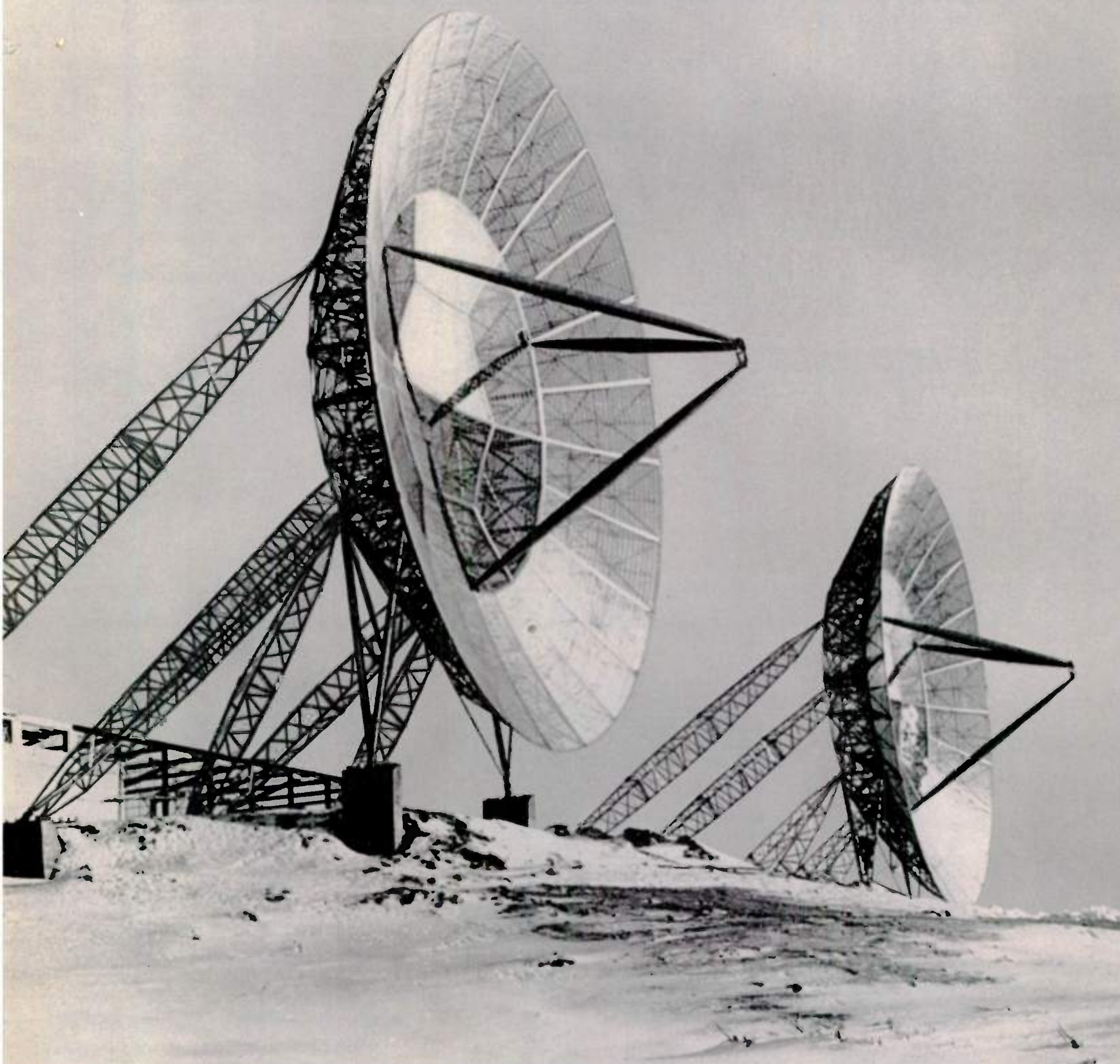


Front panel connectors provide variable bias from 0 to −150 volts at 10 ma and 6.3 volts ac filament voltage at 5 amperes.

This new instrument employs

(Continued on page 218A)

KENNEDY ANTENNAS *...on the alert overseas*



This is a 60′ Trans-Horizon antenna designed and built by Kennedy — a big "dish" with a big job.

Standing somewhere in northern Europe, it serves as an important link in the vast chain of communications that guards the perimeter of the free world.

It was built to do its job well. By means of "Scatter Propagation", it can handle multi-channel circuits over hundreds of miles with unimpaired clarity under all weather conditions. Made of lightweight, durable aluminum, it is virtually weather-proof, and features sectionalized construction for ease of transportation and erection.

Kennedy's long experience in designing and building big "dishes" for big jobs will serve you well when you have antenna problems.

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News-New Products

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

(Continued from page 216A)

high gain chopper amplifiers to continuously compare the output voltage with an internal standard cell, providing high accuracy and stability regardless of input line or output load variations. The Model 30B-25 is excellent for use in the design of complex electronic circuitry or wherever a precision voltage source independent of load current is required.

High Speed Converters

At a meeting of the IRE Group on Audio, February 7, 1957, F. Mansfield Young, Chief Engineer of Epsco, Inc., 588 Commonwealth Ave., Boston 15, Mass., gave a demonstration of the latest voltage-to-digital conversion equipment.

(Continued on page 220A)

Photo at right shows operators inserting secondary coils and connecting leads to commutators for units like the compact Sangamo "GY" Flatpak—a rugged, small size dynamotor for mobile radio use.

Final assembly operation. Push line type of operations contribute substantially to overall efficiency and accelerated production . . . aids in fulfilling all delivery schedules, even for units like the Type SF below, which are built to the most exacting specifications.

Now... dependable power supply units on dependable delivery schedules

Sangamo expands facilities to meet growing demand!

Sangamo power supply units for the military and commercial fields—Dynamotors, Rotary Converters, Generators, Special DC Motors—are built to meet your most exacting specifications for quality and performance.

And... Sangamo has the facilities to insure prompt, efficient, volume delivery to meet *your* production schedules.

A new 200,000 square foot "controlled conditions" plant, in Pickens, South Carolina is equipped with the newest, most modern equipment to utilize the latest production techniques in the manufacture of these power supply units. This plant is geared for full-capacity production for units and components for mobile communication equipment. Look to Sangamo for your requirements.

SG57-1

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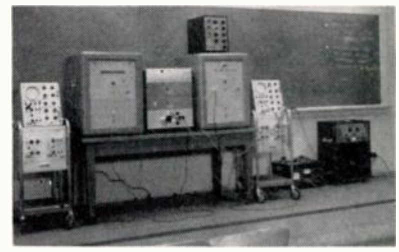
News-New Products

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

(Continued from page 82A)

By using one of Epsco's new DATRACS, a high speed reversible voltage-to-digital translator, Young was able to convert symphonic music into a digital pulse code. A second Epsco converter operating in the reverse (or digital-to-voltage) direction transformed the pulse code back into equivalent voltages permitting faithful reproduction of the original sounds.



Young emphasized that by transmitting audio and other intelligence in digital form (pulse code modulation) it is possible to obtain essentially noise-free, distortionless reception even through noisy transmission paths. It was pointed out that the versatility of pulse code modulation readily permits the use of multiplex transmission.

The voltage-to-digital translators used in this demonstration, Epsco Model B-611 DATRAC units, perform approximately 45,000 voltage-to-digital conversions-per-second with an accuracy of 1 part in 2000.

Expanded Facilities

Freed Transformer Co., Inc., 1718 Weirfield St., Brooklyn (Ridgewood) 27, N. Y., has expanded its facilities for encapsulating with Fosterite. The new production facilities will now permit Freed to accept orders for Fosteriting from industry.

With many years of experience in the field of encapsulating, Freed claims a finished product of the highest quality.

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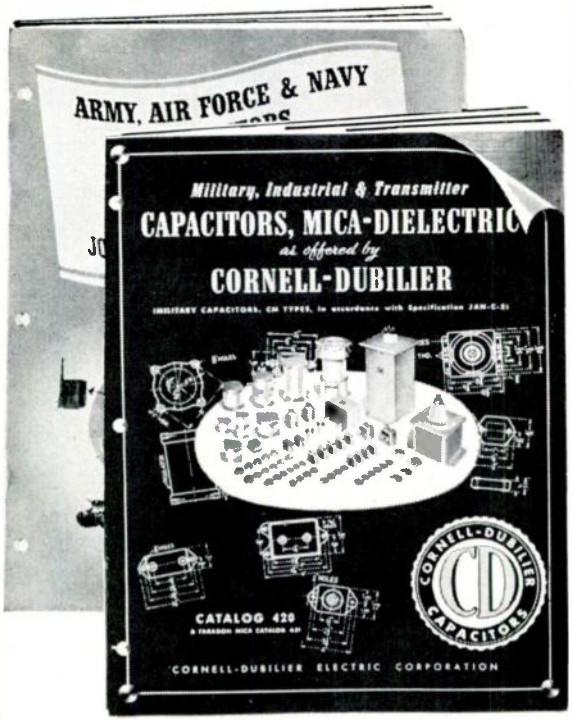

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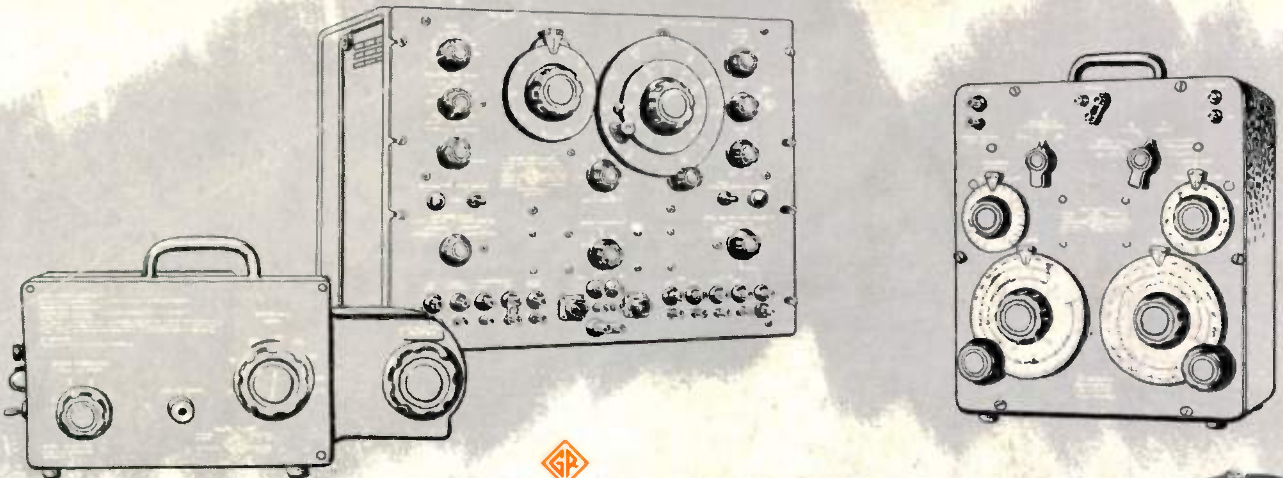

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√ 17 Sizes from 2 to 500,000 ohms — 2- to 20-watt ratings at 40°C ambient — 1¼" to 4¼" diameters.

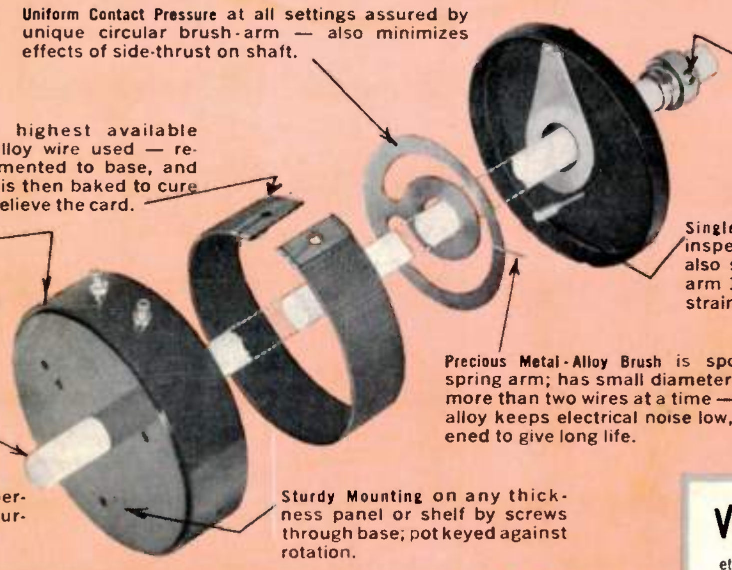
√ Ganged units available with no loss of excellent low-capacity characteristic offered by individual units.

Low Cost — **$3.50 to $10.00**

The General Radio Type 970 Potentiometer serves as a basic element in a variety of electronic and electro-mechanical apparatus. But, perhaps the greatest recommendation that can be given this Potentiometer is that it is used in precision laboratory measuring equipment of all kinds, including G-R instruments, requiring the utmost in component performance and reliability.

The new General Radio Types 1391-A Pulse and Time-Delay Generator, 1603-A Universal Impedance Bridge, and 1750-A Sweep Drive — the finest instruments of their kind — use 970 Potentiometers. Mechanical and electrical performance approaching the best available has been obtained at low cost through a unique simplicity of design and utilization of the latest in materials and manufacturing techniques. Individual inspection for conformance with linearity and noise specifications insures that *every* unit shipped is up to these high standards.

Write For The G-R Potentiometer Bulletin For Complete Specifications



Versatility

In addition to potentiometers normally stocked, units will be provided on special order with: 360° mechanical rotation — taps as close as ¼" apart along entire winding — special all-metal or metal-filled shafts — resistance values other than standard — resistance functions other than linear — resistance and linearity tolerances better than standard.

Attractive prices can be offered when quantities are sufficient to warrant special production.

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