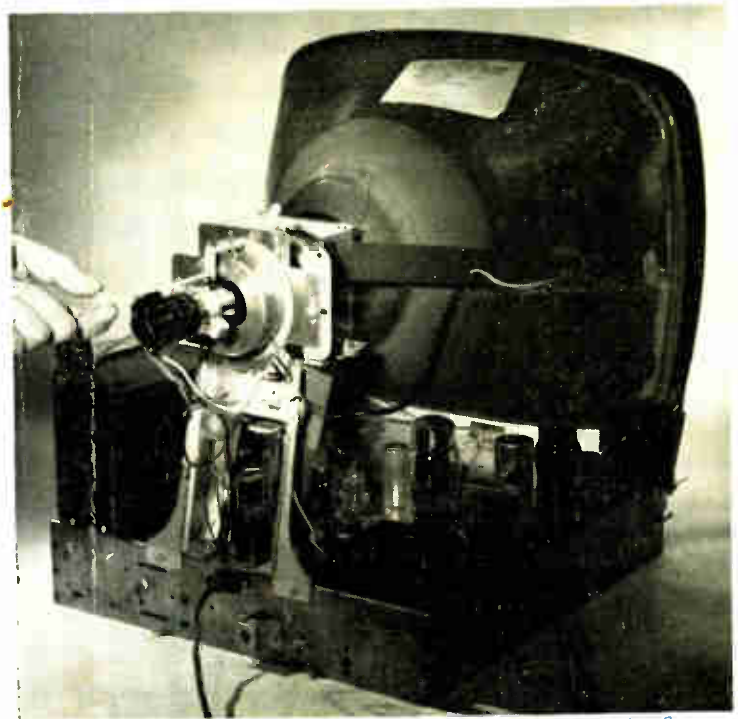
JUNE · 1954

Proceedings of the I·R·E

A Journal of Communications and Electronic Engineering

Volume 42 Number 6

FOCUSING WITH FERRITE



Heppner Manufacturing Company

Sintered ferrite, a relatively new class of magnetic material, is being used in many new ways, such as in the focusing magnet of the television picture tube shown above.

IN THIS ISSUE

Table of Contents Indicated by Black-and-White Margin, Follows Page 80A

The IRE Standards on Graphical Symbols for Electrical Diagrams appears in this issue.

The Institute of Radio Engineers

for the HIGHEST in RELIABILITY

UTC products are the most copied in the world. This is only natural, since we maintain the largest laboratories and engineering staff in our field. However, copying alone cannot provide the measure of uniformity and reliability inherent in UTC units. To provide for the maximum in quality and reliability, continuing programs of quality control and quality improvement are constantly maintained in our laboratories.

WHAT MAKES A TRANSFORMER FAIL?

Illustrated are a few views of the UTC Reliability Laboratory in action... finding the answers.

Qualitative micro analysis.

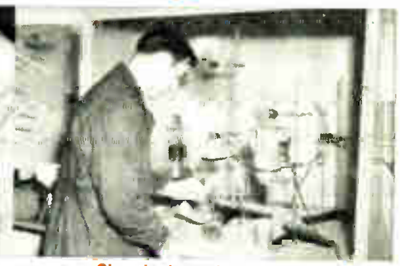
Vibration stress analysis.

Torque testing of standard assemblies.

Checking uniformity of thermoplastic compounds.

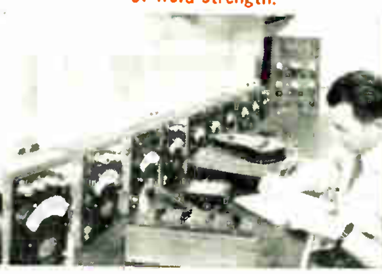
Quantitative checking of weld strength.

Hermetic terminals on microscope check.

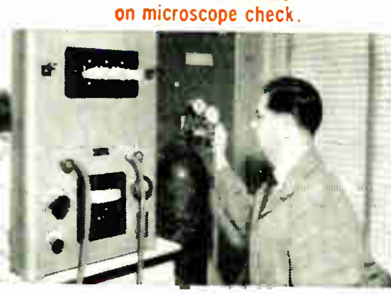


Chemical section analyzing new materials.

Microscope analysis of dissected units.

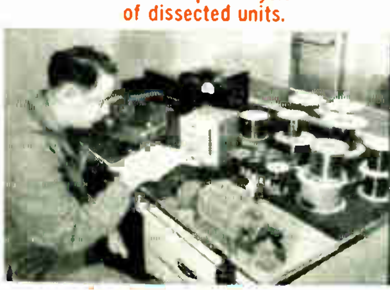


Calibration to primary standards.



Pilot plant hydrogen annealing.

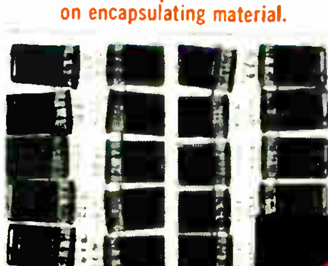
Seal tests under extremes of cold, heat, and altitude.



Abrasion and mercury tests on magnet wire.

Pilot plant run on encapsulating material.

Corrosion testing on insulating materials.



Non-destructive quality control by x-ray.

IS THIS PROVEN RELIABILITY AND UNIFORMITY IN THE COMPONENTS OF YOUR EQUIPMENT?

A large aircraft company..."Our vendor analysis for past year (thousands of tests) shows zero rejects."

A large electric company..."Consistent quality has placed you as our #1 source...are grateful for the aid you have given our own quality control staff."

A large military electronics company..."Switching from former vendor to UTC has saved us 18% of transformer and filter cost by reducing manufacturing costs."

A large instrumentation company..."We haven't had one field failure in fifteen years' use of UTC parts*."

*Over 100,000 units.

United Transformer Co.

150 VARICK STREET • NEW YORK 13, N. Y.

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

35,000 Radio-Electronic Engineers will receive and use the 1954 IRE DIRECTORY

The 1954 IRE DIRECTORY is—

Better

More Engineers Listed than ever before! IRE membership continues to gain and gain! More engineers (now 35,000) are listed, and therefore have a direct, personal interest in this DIRECTORY.

Up-to-dateness is almost a mania with IRE DIRECTORY compilers! Membership lists are corrected up to May 30th. Industry lists, compiled and classified by high speed IBM sorting methods are accurate to June 15th. No firm's report is older than 18 months.

Information at high speed! "Data the way an engineer thinks" is the key to IRE DIRECTORY classifications. All products are divided into 10 fundamental groups, many of which parallel professional group organization. The grouping plan makes this the fastest working directory you ever used! No components are mixed with test equipment—you turn right to a section where each item belongs.

Yet good engineering detail is maintained. 104 basic classes of products under these ten sectional product directories keep listings from becoming cumbersome, but clearly define products. Overlapping listings are skillfully eliminated. Simplicity makes this book easy to work with—insures faster finding of facts when forgotten.

and Better

Thus the faults of terminology listings are avoided.

Completeness is insured! Most firms make many products in a single classification. Wasteful, eye-confusing relisting of the same firms over and over is quite sensibly solved by using a system of codes under the 104 basic headings which actually provide 608 separate classifications. A more complete picture of what each firm's full line is results, but you travel through fewer listings. The "Copp Principle" of Directory indexing makes these lists wide, well marked highways to information—fast.

3000 Firms listed. The alphabetical directory gives a clear definition of these firms by showing any or all of the ten fundamental groups in which these firms belong after every name.

Machol Edge Index is just one more modern service to help the user find information fast.

Ads positioned with reason! In a DIRECTORY where ads play an important part in supplying information the user wants and needs, it makes good sense to cross-reference every advertiser in each listing so that the user can quickly find more detail. Ads are also placed facing company alphabetical listings, or in the product section in which they properly belong. No effort is spared to "organize" ad information.

and Better!

More advertisers—more information! Never before have so many advertisers served IRE readers with so much information! The advertisers' list this year is truly a "social register" of this great industry.

Economy a service too! In spite of a rate increase since last year, due to increased circulation it costs less per reader than in 1953 to reach this selected engineer audience. Rates are: page—$450, ⅔—$300, ⅓—$150, 1/6—$75, and earned discounts apply to Proceedings advertisers. (The Directory closes June 15th.)

Reserve 1954 DIRECTORY space now!

The IRE Directory

Engineers are educated to specify and buy

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BRyant 9-7550 • ADVERTISING DEPT., 1475 BROADWAY, NEW YORK 36, N. Y.

Radio • Communications • Television • Electronics

PROCEEDINGS OF THE I.R.E. June, 1954, Vol. 42, No. 6. Published monthly by the Institute of Radio Engineers, Inc., at 1 East 79 Street, New York 21, N.Y. Price per copy: members of the Institute of Radio Engineers $1.00; non-members $2.25. Yearly subscription price: to members $9.00; to non-members in 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.

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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.*

June 23, 24 & 25, 1954
IRE Symposium on Global Communications, Hotel Statler, Washington, D.C.
Exhibits: Louis De La Fleur, 77 14th St., N.W., Suite 800, Washington 5.

August 25, 26 & 27, 1954
Western Electronic Show & Convention, Pan-Pacific Auditorium, Los Angeles, Calif.
Business Manager: Mr. Mal Mobley, Jr., 344 North La Brea Ave., Los Angeles, Calif.

September 13-22, 1954
First International Instrument Congress & Exposition, Commercial Museum and Convention Hall, Philadelphia, Pa.
Exhibits: Mr. Richard Rimbach, Instrument Society of America, 921 Ridge Ave., Pittsburgh 12, Pa.

September 17 & 18, 1954
Conference on Communications, Cedar Rapids Section, Roosevelt Hotel, First Ave. at Second St. N.E., Cedar Rapids, Iowa.
Exhibits: Mr. Vernon R. Hudek, c/o Collins Radio Co., Cedar Rapids.

October 4, 5, 6, 1954
National Electronics Conference, Sherman Hotel, Chicago, Ill.
Exhibits: Mr. George H. Wise, c/o DeVry Technical Institute, 4141 Belmont Ave., Chicago 41, Ill.

November 4 & 5, 1954
East Coast Conference on Airborne and Navigational Electronics, Sheraton-Belvedere Hotel, Baltimore, Md.
Exhibits: Mr. C. E. McClellan, Air Arm Division, Westinghouse Electric Corp., Friendship Airport, Baltimore, Md.

November 18 and 19, 1954
Sixth Annual Electronics Conference, Hotel President, Kansas City.
Exhibits: Mr. Robert W. Butler, P.O. Box 8857, Kansas City, Mo.

February 10, 11, 12, 1955
Seventh IRE Conference, Baker Hotel, Dallas, Texas
Exhibits: T. W. Sharpe, Collins Radio Co., 1930 Hi-Line Drive, Dallas 2.

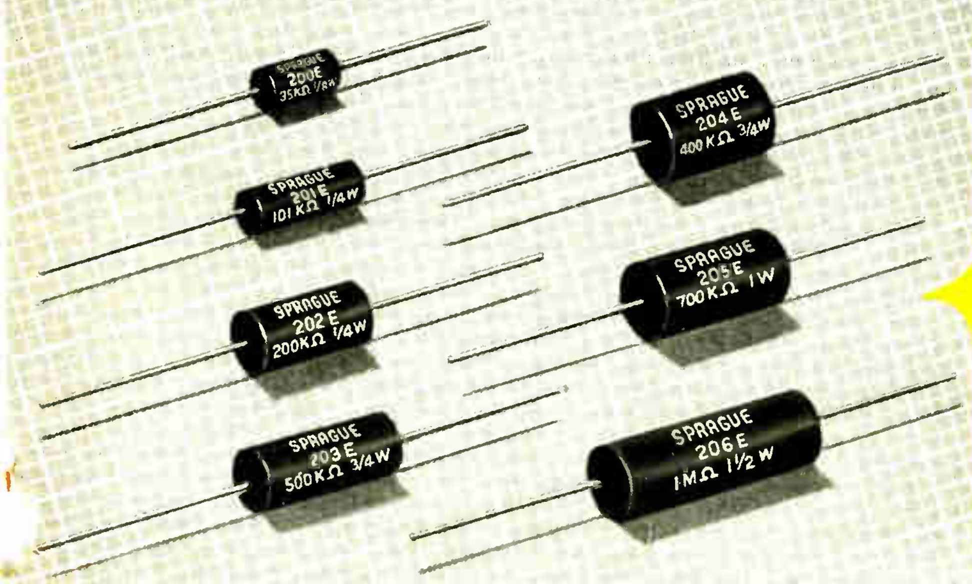
March 21-24, 1955
Radio Engineering Show and I.R.E. National Convention, Kingsbridge Armory, N.Y.C.
Exhibits: Mr. William C. Copp, Institute of Radio Engineers, 1475 Broadway, New York 36, N.Y.

Note on Professional Group Meetings: Some of the Professional Groups conduct meetings at which there are exhibits. Working committeemen on these groups are asked to send advance data to this column for publicity information. You may address these notices to the Advertising Department, and of course listings are free to IRE Professional Groups.

PERMASEAL®

PRECISION RESISTORS

NOW! ENCAPSULATED AXIAL LEAD STYLES FOR 85°C, 125°C and 150° AMBIENTS



85°C PERMASEAL RESISTORS

SPRAGUE TYPE	SIZE D	SIZE L	SIZE LEADS	RATED WATTS	MAX OHMS
200E	1/4	1/2	No. 22 AWG	.20	140,000
201E	1/4	3/4	No. 22 AWG	.33	225,000
202E	3/8	3/4	No. 20 AWG	.50	500,000
203E	3/8	1	No. 20 AWG	.75	700,000
204E	1/2	3/4	No. 20 AWG	.75	1.2 MΩ
205E	1/2	1	No. 20 AWG	1.00	1.7 MΩ
206E	1/2	1 1/2	No. 20 AWG	1.50	2.8 MΩ

125°C PERMASEAL RESISTORS

SPRAGUE TYPE	SIZE D	SIZE L	SIZE LEADS	RATED WATTS	MAX OHMS
300E	1/4	1/2	No. 22 AWG	.10	140,000
301E	1/4	3/4	No. 22 AWG	.15	225,000
302E	3/8	3/4	No. 20 AWG	.25	500,000
303E	3/8	1	No. 20 AWG	.30	700,000
304E	1/2	3/4	No. 20 AWG	.30	1.2 MΩ
305E	1/2	1	No. 20 AWG	.40	1.7 MΩ
306E	1/2	1 1/2	No. 20 AWG	.60	2.8 MΩ

PERMASEAL accurate wire-wound resistors are ideal for point-to-point wiring, for terminal board mounting and for use on processed wiring chassis.

Encapsulated for protection against high humidity, these resistors will stand up in military and industrial electronic service. The protective housing also guards against physical damage during installation and during equipment maintenance.

Standard designs are available in seven different physical sizes for operation at full rated wattage at ambient temperatures of 85°C and 125°C. Special units can be made for operation at 150°C ambient with full rated wattage dissipation.

Unusual long-term stability of resistance is another plus feature of Sprague Permaseal Resistors—as the result of careful matching of winding forms, resistance wire and encapsulating material—together with a thoroughly controlled aging process during manufacture. Permaseal Resistors are available in resistance tolerances down to 0.1%, when necessary.

SPRAGUE

FOR COMPLETE DATA, WRITE FOR COPY OF SPRAGUE ENGINEERING BULLETIN NO. 122, WITHOUT DELAY.

SPRAGUE ELECTRIC COMPANY,
235 Marshall Street, North Adams, Mass.

PIONEERS IN ELECTRIC AND ELECTRONIC DEVELOPMENT

NORTH ADAMS, MASSACHUSETTS

EXPORT FOR THE AMERICAS: SPRAGUE ELECTRIC INTERNATIONAL LTD., NORTH ADAMS, MASS. CABLE: SPREXINT

SPLITTING HAIRS

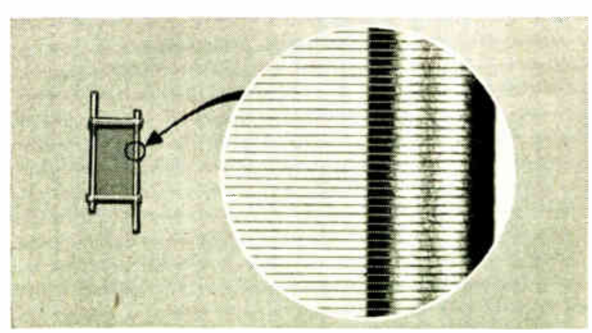
TO SPEED CALLS

This coaxial system electron tube amplifies more voices at the same time because of wider frequency band—made possible by bringing grid and cathode closer together.

To triple the voice-carrying capacity of coaxial cable, Bell Laboratories engineers had to create new amplifying tubes with the grid placed only two-thirds of a hair's breadth from the cathode. Furthermore, the grid wires had to be held rigidly in position; one-quarter of a hair's shifting would cut amplification in half.

Working with their Bell System manufacturing partners at Western Electric, the engineers developed precise optical means for measuring critical spacing insulators. On a rigid molybdenum grid frame they wound tungsten wire three ten-thousandths of an inch thick. To prevent the slightest movement they stretched the wire under more tension for its size than suspension bridge cables, then bonded it to the frame by a new process.

The resulting tube increases coaxial's capacity from 600 to 1800 simultaneous voices—another example of how Bell Telephone Laboratories research helps keep your telephone system growing at the lowest possible cost.



Grid is shown above left, actual size. Picture at right, enlarged 15 times, shows how wires are anchored by glass bond. They will not sag despite nearness of red-hot cathode.

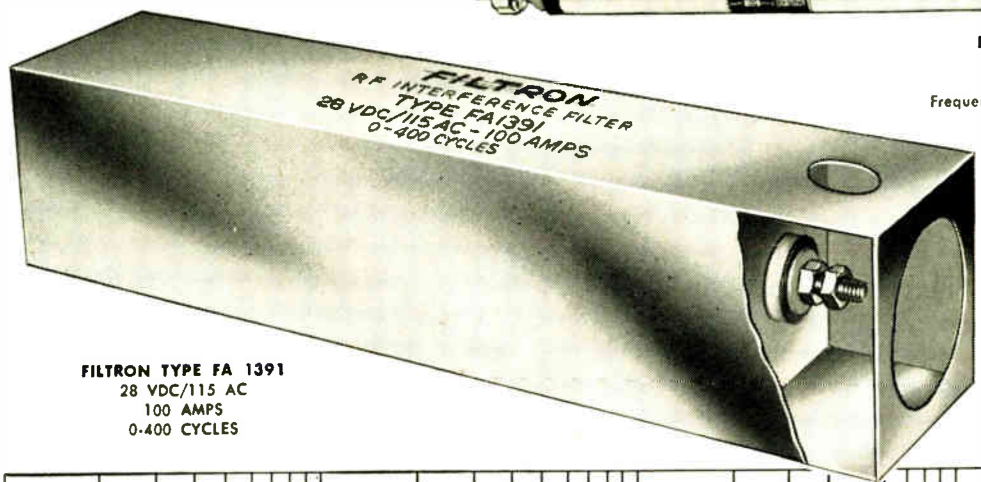
BELL TELEPHONE LABORATORIES

IMPROVING TELEPHONE SERVICE FOR AMERICA PROVIDES CAREERS
FOR CREATIVE MEN IN SCIENTIFIC AND TECHNICAL FIELDS

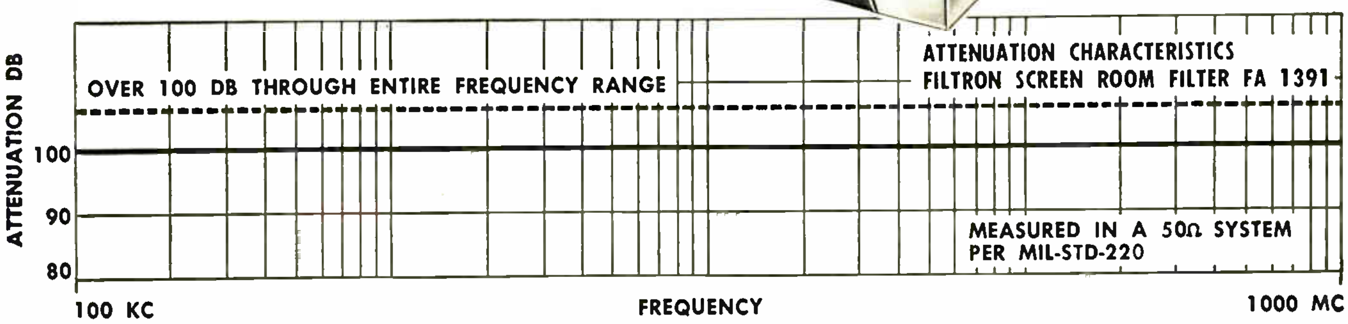
HIGH ATTENUATION
CONTINUOUS DUTY
HERMETICALLY SEALED

FILTRON SCREEN ROOM FILTERS

FILTRON TYPE FA 736
500 VAC/DC
100 AMPS
Frequency Range 1000 to 15,000 MC



FILTRON TYPE FA 1391
28 VDC/115 AC
100 AMPS
0-400 CYCLES



Screen room manufacturers specify and install FILTRON Screen Room Filters as standard equipment.

FILTRON Screen Room Filters are used in the majority of industrial, government and military screen rooms, to meet the requirements of specification MIL-S-4957, and wherever critical RF measurements are required.

FILTRON has over 30 types of Screen Room Filters available, ranging from 1 Amp to 1000 Amps, 28 VDC to 500 Volt AC/DC, 0 to 1000 cycles. Complete technical information available.

FILTRON RF Interference Filters are also specified in the latest types of Radar, Radio Transmitters, Receivers, Motor Generator Sets, Inverters, Aircraft, Electronic Systems, and numerous other "restricted" equipments.

When you have an RF Interference Filter problem, consult FILTRON — the most dependable name in RF Interference Filters.

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Massey Associates, Inc., Narbeth, Pa., Washingon, D. C.

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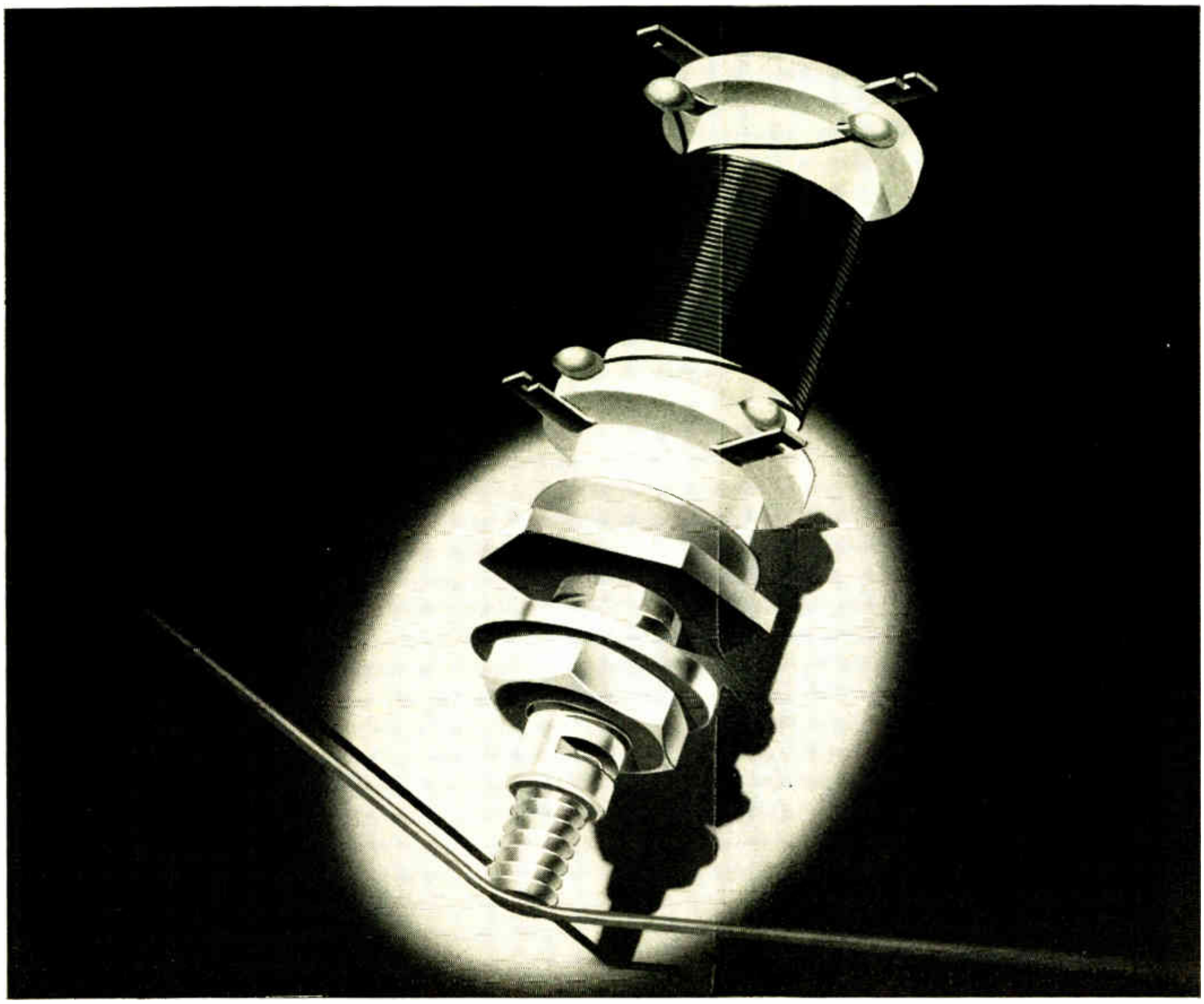
INTERFERENCE FREE means FILTERED by

An inquiry on your company letterhead will receive prompt attention.

FILTRON CO., INC. • FLUSHING, LONG ISLAND, NEW YORK

LARGEST EXCLUSIVE MANUFACTURERS OF RF INTERFERENCE FILTERS



Death-defying performance

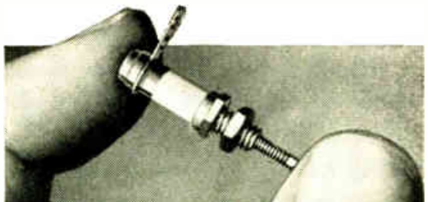
You can depend on C.T.C. coils to give a steady, star performance. They won't go dead despite threats of temperature, climate or vibration. And for very good reasons —

The mounting stud of every C.T.C. coil is fastened to the ceramic body in a special way that does away with weaknesses of ordinary coil fastenings. This special fastening makes C.T.C. coils vibration-proof. What's more, their tightness is preserved in hot, cold, dry or damp weather. All C.T.C. coils are precision-made, of course, to meet individual specifications — and to meet, or better, government specifications, as well. And continuous quality control is maintained.

As a result, you get a *guaranteed* electronic component — custom or standard — whose performance you can depend upon.

Precision-made C.T.C. components that benefit from C.T.C. high quality standards include terminals, terminal boards, capacitors, swagers, hardware, insulated terminals and coil forms. For all specifications and prices, write Cambridge Thermionic Corporation, 456 Concord Avenue, Cambridge 38, Mass. West Coast manufacturers contact: E. V. Roberts, 5068 West Washington Blvd., Los Angeles 16 and 988 Market St., San Francisco, California.

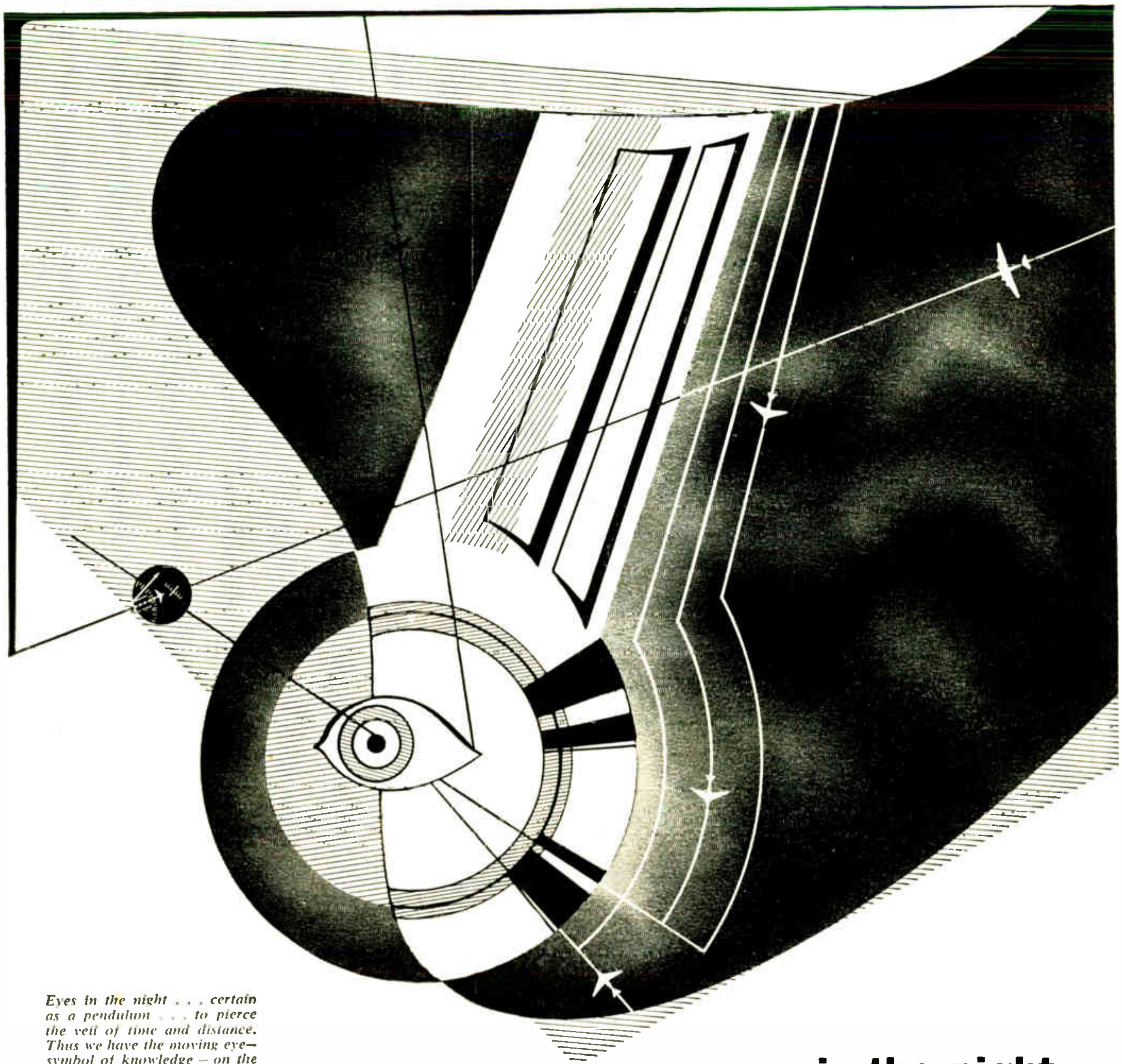
Slug Tuned Coil Data: Single layer or pie type windings to your specifications. Forms of quality paper base phenolic or grade L-5 silicone impregnated ceramic. Mounting studs are cadmium plated brass; ring type terminals are silver plated brass. All units include slugs and mounting hardware. One style (Type C) available with retaining collars of silicone fibreglas which permit 2 to 4 terminals. Windings can be coated with resin varnish, wax or lacquer.



New CST-50 variable ceramic capacitor surpasses range of capacitors many times its size. Stands only 19/32" high when mounted, is less than ¼" in diameter and has an 8-32 thread mounting stud. A tunable element of unusual design practically eliminates losses due to air dielectric giving large minimum to maximum capacity range (1.5 to 12MMFD).

CAMBRIDGE THERMIONIC CORPORATION

makers of guaranteed electronic components, custom or standard



Eyes in the night . . . certain as a pendulum . . . to pierce the veil of time and distance. Thus we have the moving eye—symbol of knowledge — on the ever predictable pendulum.

Presenting...

-hp- VHF

-*hp*- 608C VHF Signal Generator

-*hp*- 608D VHF Signal Generator

New premium-quality performance

Wide range, direct calibration

Residual FM less than 1 kc

Drift less than 0.005%

High power output

All types of modulation

Models 608D and 608C are designed to be the best commercial instruments of their type, and to set new standards of VHF generator convenience, applicability and performance. They are the redesigned and improved successors to over 3,000 -*hp*- 608A/B VHF generators now in use throughout the world.

The premium quality -*hp*- 608D

-*hp*- 608D is the ultimate in VHF signal generators. It offers the highest stability attained in production equipment of its type. There is almost complete absence of incidental FM or frequency drift. There is a calibrated output from 0.1 μv to 0.5 v throughout the frequency range, 10 to 420 mc. A built-in crystal calibrator provides a frequency check accurate within 0.01% every 5 mc throughout range.

These unique advantages are made possible in large part by new master oscillator, intermediate and output amplifier circuit design. Other features to improve stability include a regulated filament supply, a new variable condenser design and a completely new coil turret and circuit housing. The result is the most convenient, accurate and effective instrument available for testing and aligning VHF aircraft communications and other receivers having extreme selectivity.

The all-purpose -*hp*- 608C

The -*hp*- 608C is a high power, stable and accurate VHF signal generator for general laboratory and field use. Employing a master oscillator–power amplifier circuit, -*hp*- 608C offers 1 v maximum power and a broad frequency coverage of 10 to 480 mc. The instrument provides outstanding convenience for measuring gain, sensitivity, selectivity and image rejection of receivers, IF

COMPLETE COVERAGE | HEWLETT-PACKARD

two completely new

SIGNAL GENERATORS

amplifiers, broad band amplifiers and other VHF equipment. Its 1 v output is more than sufficient to drive bridges, slotted lines, transmission lines, antennas, filter networks and other circuits.

Outstanding features in both

Both *-hp-* 608D and 608C have broadest possible modulation capabilities. There is AM modulation to 80%, and flat response 20 cps to 1 mc which provides high quality internal and external pulse modulation. RF leakage is negligible, and sensitivity measurements to 0.1 μv are possible. Internal impedance is 50 ohms constant, and VSWR is a maximum of 1.2.

Both instruments also feature new mechanical design and quality construction throughout. New aluminum castings and cabinets reduce weight. Circuitry is particularly clean and accessible. Dial, condenser and turret drives are ball-bearing. Variable condensers are specially manufactured by *-hp-* and feature electrically welded Invar low temperature steel plates to minimize drift. Sealed transformers are used throughout, and construction is militarized.

Data subject to change without notice. Prices f.o.b. factory

WRITE FOR COMPLETE DATA

HEWLETT-PACKARD COMPANY

3099D Page Mill Road • Palo Alto, California, U.S.A.

SALES AND ENGINEERING REPRESENTATIVES THROUGHOUT THE WORLD

SPECIFICATIONS

-hp- 608D VHF Signal Generator

Frequency Range: 10 to 420 mc, 5 bands.

Calibration Accuracy: ±1% full range.

Resettability: Better than ±0.1% after warm-up.

Crystal Calibrator: Frequency check points every 5 mc through range. Headphone jack for audio frequency output.

Frequency Drift: Less than 0.005% over 15 minute interval after warm-up.

Output Level: 0.1 μv to 0.5 v into 50-ohm load. Attenuator dial calibrated in v and dbm. (0 dbm equals 1 mw in 50 ohms.)

Voltage Accuracy: ±1 db full range.

Generator Impedance: 50 ohms, maximum VSWR 1.2.

Modulation Percentage: 0 to 80% indicated by meter.

Envelope Distortion: Less than 2.5% at 30% sine wave modulation.

Internal Modulation: 400 cps ±10% and 1,000 cps ±10%.

External Modulation: 0 to 80%, 20 cps to 100 kc. For RF output above 100 mc, 0 to 30% to 1 mc.

External Pulse Modulation: 10 v peak pulse required. Good pulse shape at 1 μsec.

Residual FM: Less than 1,000 cycles at 30% AM for RF output frequencies above 100 mc. Less than 0.001% below 100 mc.

Leakage: Negligible; permits sensitivity measurements to 0.1 microvolt.

Filament Regulation: Provides highest possible oscillator and amplifier stability for line voltage change.

Power: 115/230 volts ±10%, 50/1,000 cps. Approx. 150 watts.

Size: 13⅜" wide x 16" high x 20½" deep.

Weight: 70 lbs. Shipping weight, approx. 100 lbs.

Price: $950.00.

-hp- 608C VHF Signal Generator

Same as *-hp-* 608D, except:

Frequency Range: 10 to 480 mc, 5 bands.

Crystal Calibrator: In Model 608D only.

Frequency Drift: Less than 0.05% over 15 minute interval after warm-up.

Output Level: 0.1 μv to 1.0 v.

Residual FM: Less than 0.0025% at 30% amplitude modulation for RF output frequencies 21 to 480 mc.

Filament Regulation: In Model 608D only.

Price: $850.00.

hp INSTRUMENTS | **COMPLETE COVERAGE**

News—New Products

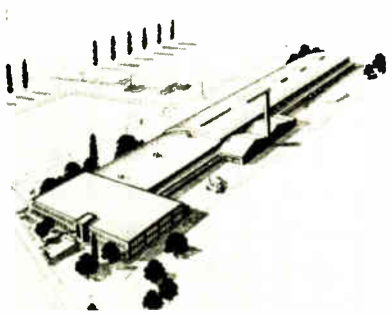
These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

Molded Borocarbon Resistors

A complete series of molded borocarbon resistors has been announced by the **Sprague Electric Co.**, 235 Marshall St., North Adams, Mass. The new resistors, known as the Sprague Filmite B series, meet the requirements of MIL-R-10509A, proposed Modification 2. The resistors rated at ½, 1 and 2 watts will dissipate full wattage ratings at an ambient of 70°C compared with the 40°C ratings on previous resistors of this type.

Identified as Types 4E, 5E, and 6E, the new resistors are molded in a dense plastic material, which not only provides unexcelled physical protection for the film resistance element but serves as a barrier for moisture and vapor. For further data request Bulletin 130.

New Magnetics Plant



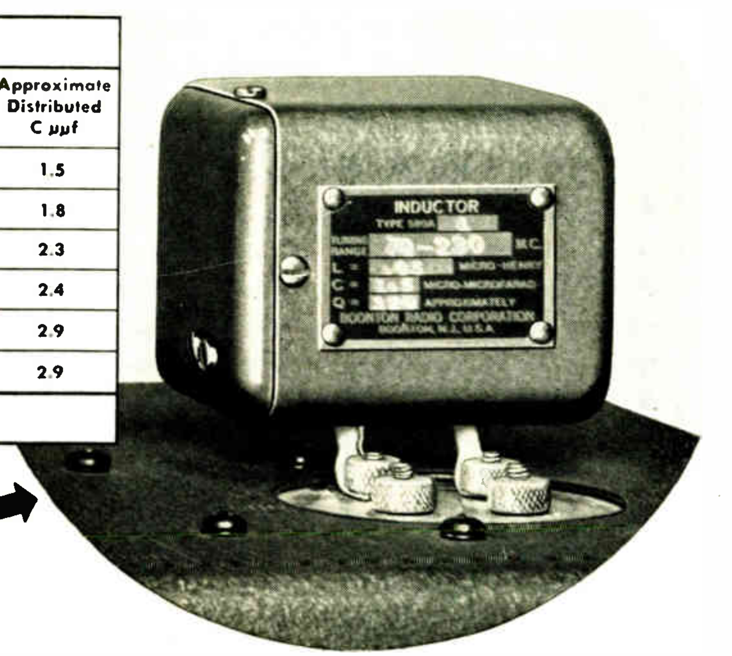
Magnetics, Inc., new plant just outside of Butler, Pa., will house its research and development laboratories, as well as its engineering and general offices, in the administration building section. Assembly and fabrication shops for cores, laminations, magnetic amplifiers, a heat treatment room, and a rolling mill for high permeability steels are included in the new facilities.

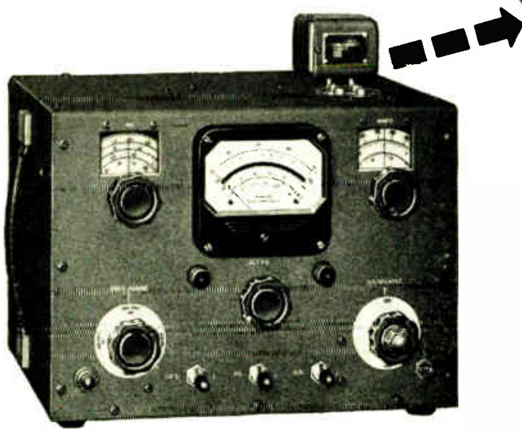
(Continued on page 15A)

NEW Q Meter Inductors for measurements up to 260 mc!

INDUCTORS Type 590-A— accessories to Q Meter Type 190-A

TYPE 590-A INDUCTORS					
Type	Inductance μh	Capacitance μμf	Approximate Resonant Freq. mc	Approximate Q	Approximate Distributed C μμf
590-A1	0.05	8.0 — 95.0	70 — 230	320	1.5
590-A2	0.1	10 — 100	50 — 160	350	1.8
590-A3	0.25	8.0 — 80.0	30 — 100	310	2.3
590-A4	0.5	7.5 — 80.0	25 — 70	340	2.4
590-A5	1.0	7.5 — 65.0	20 — 50	300	2.9
590-A6	2.5	9.0 — 25.0	20 — 30	300	2.9
PRICE: $10.00 each F.O.B. BOONTON, N. J.					





Q METER Type 190-A

This new 190-A Q Meter measures an essential figure of merit of fundamental components to better overall accuracy than has been previously possible. The VTVM, which measures the Q voltage at resonance, has a higher impedance. Loading of the test component by the Q Meter and the minimum capacitance and inductance have been kept very low.

SPECIFICATIONS—TYPE 190-A

FREQUENCY RANGE: 20 mc. to 260 mc.

RANGE OF Q MEASUREMENT:

Q indicating voltmeter	50 to 400
Low Q scale	10 to 100
Multiply Q scale	0.5 to 3.0
Differential Q scale	0 to 100
Total Q indicating range	5 to 1200

PERFORMANCE CHARACTERISTICS OF INTERNAL RESONATING CAPACITANCE: Range—7.5 mmfd. to 100 mmfd. (direct reading).

POWER SUPPLY: 90-130 volts — 60 cps (internally regulated).

Type 190-A Price: $625.00 F.O.B. Factory

Inductors Type 590-A are designed specifically for use in the Q Circuit of the Q Meters Type 170-A and 190-A for measuring the radio-frequency characteristics of condensers, resistors, and insulating materials. They have general usefulness as reference coils and may also be used for periodic checks to indicate any considerable change in the performance of the Q Meters.

Each inductor Type 590-A consists of a high Q coil mounted in a shield and is provided with spade lugs for connection to the coil terminals of the Q Meters. The shield is connected to the lugs which connect to the Low Coil terminal in order to minimize any changes in characteristics caused by stray coupling to elements or to ground.

BOONTON RADIO Corporation
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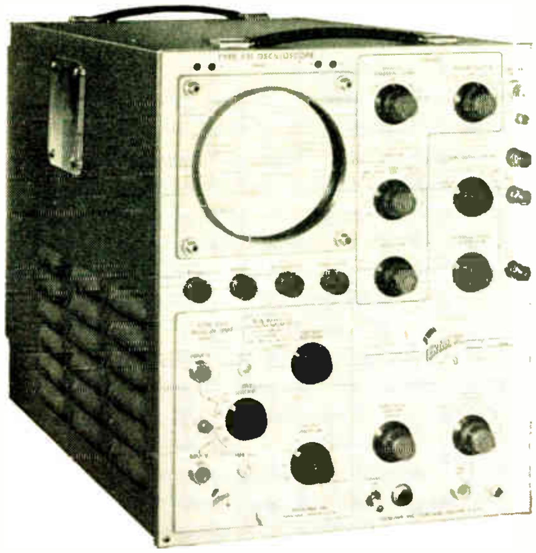
NEW *Multi-Purpose* Oscilloscope



- Plug-In Vertical Preamplifiers
- 10-KV Accelerating Potential
- 600,000,000 to 1 Sweep Range
- Direct-Reading in Time and Amplitude
- Versatile Triggering Circuitry

TYPE 531

You just plug in the proper vertical preamplifier to have at your service a wide-band dc oscilloscope, a wide-band high-gain oscilloscope, a wide-band dual-trace oscilloscope, or a differential-input high-gain dc oscilloscope. The Type 53-Series Plug-In Units are small, weigh less than 6 lbs. each, and you can change them in a few seconds.

This new instrument is designed to make your oscilloscope dollar go farther. Development of additional plug-in units already in progress will increase the versatility of the Type 531, and assure its modernity well into the future. *But your greatest gain is the many hours of valuable engineering time you save through its use.*

OSCILLOSCOPE CHARACTERISTICS

24 Calibrated Sweeps
0.1 μsec/cm to 5 sec/cm. Accurate 5-x magnifier permits calibrated sweep times to 0.02 μsec/cm. Sweep continuously variable from 0.02 μsec/cm to 12 sec/cm. Sweep calibration accurate within 3%.

New Cathode-Ray Tube
Tektronix T51P metallized CRT has helical post-accelerating anode; deflection-plate leads are brought out at the neck.

DC-Coupled Vertical Output Amplifier
Designed for use with any of the Type 53-Series Plug-In Units.

Balanced Delay Network
Provides 0.25-μsec vertical signal delay.

Horizontal Input Amplifier
Sensitivity 0.2 v/cm to 20 v/cm, continuously variable.

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Amplitude level selection or automatic triggering.

Amplitude Calibrator
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DC-Coupled Unblanking

CRT Beam Position Indicators

Electronically Regulated Power Supplies

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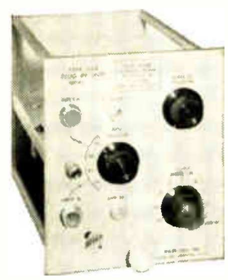
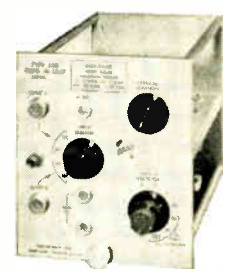
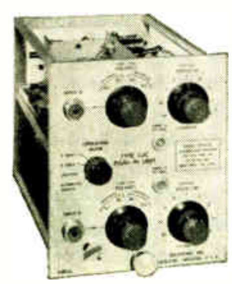
PLUG-IN UNIT CHARACTERISTICS



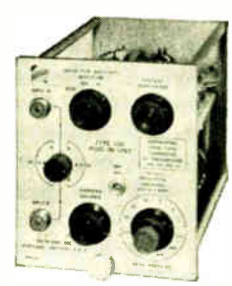
Type 53A Wide-Band DC Plug-In Preamplifier—dc to 10-mc passband, 0.035-μsec risetime. Sensitivity 0.05 v/cm to 50 v/cm, ac or dc, continuously variable, with nine calibrated steps from 0.05 v/cm to 20 v/cm. Two input connectors with 80-db isolation. Price $85.



Type 53B Wide-Band High-Gain Plug-In Preamplifier—same as the Type 53A with the addition of an ac-coupled input stage providing three additional calibrated sensitivity steps, 5 mv/cm, 10 mv/cm and 20 mv/cm. Passband 5 cycles to 9 mc, 0.04-μsec risetime. Two input connectors with 80-db isolation. Price $125.



Type 53C Dual-Trace Plug-In Preamplifier—two identical amplifier channels, each with dc to 8.5-mc passband, 0.04-μsec risetime, sensitivity 0.05 v/cm to 50 v/cm continuously variable with 9 calibrated steps from 0.05 v/cm to 20 v/cm. Electronic switching triggered by oscilloscope sweep, or free running at about 100 kc. Polarity reversal switches. Price $275.



Type 53D Differential High-Gain DC Plug-In Preamplifier—sensitivity 1 mv/cm at dc to 250 kc—with passband increasing to 750 kc at 50 mv/cm and lower. Sensitivity in calibrated steps—1 mv/cm to 50 v/cm, or continuously variable—1 mv/cm to 125 v/cm. Differential input. Price $145.

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Tektronix, Inc.

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Phone: CYpress 2-2611 — Cable: TEKTRONIX

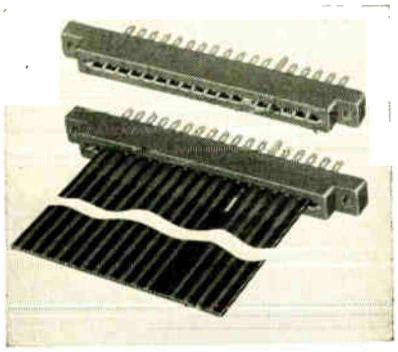
News—New Products

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

(*Continued from page 11A*)

Printed Circuit Connectors

De Jur-Amsco Corp. has just announced a new series of space-saving Printed Circuit Continental Connectors designed to permit direct connection to a printed circuit "plug" or "plug" mounted subassembly. This series has been designated series "PC."



For absolute space economy, both sides of the printed circuit card can be used for wiring to the external circuit with Continental's double row contact construction. This feature provides for up to 30 (PC-15), 36 (PC-18), and 44 (PC-22) contacts. These connectors are available in single row construction. Further designs are also available on request.

Multi-conductor two-sided pressure contacts of spring-temper phosphor bronze are gold plated over silver for low contact resistance. The terminal ends can be hot tinned for soldering at assembly. These contacts have a maximum voltage drop of 20 millivolts at rated currents. Positive polarization is provided with polarizing stud which can be located at any contact.

Three insulating materials are available: Mineral filled Melamine, Plaskon reinforced (glass) Alkyd type 440-A, and Diallyl Phthalate (blue).

For illustrated Engineering Data Sheet, write: Electronic Sales Division, DeJur-Amsco Corp., 45-01 Northern Blvd., Long Island City, N. J.

Bulletin on Vibration and Shock Mounts

Advanced design features of all-metal mounting systems are described and illustrated in a 4-page bulletin (No. 800) from **Robinson Aviation, Inc.,** Airborne Div., Teterboro, N. J. The special types of all-metal (MET-L-FLEX) mountings described have been developed in collaboration with missile designers, and are based on service experience.

The bulletin offers answers to many exacting and unusual problems of mounting, electronic equipment in guided missiles, rockets, and jet aircraft. It includes engineering data and specific examples of various types of mounts and engineered mounting systems.

(*Continued on page 16A*)

News—New Products

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

(Continued from page 15A)

Wide-Band, General Purpose Oscilloscope

A new wide-band cathode-ray oscilloscope, featuring high precision measurement of both time and amplitude over the entire range of general laboratory applications, has been announced by the **Instrument Div., Allen B. Du Mont Laboratories, Inc.,** Clifton, N. J. The new instrument is designated the Du Mont Type 323.

The direct coupled, 10 mc (3 db down) vertical amplifier of the Type 323, enables display not only of very-low-frequency phenomena, but also of high-speed pulses, together with their dc level.

Sweeps are directly calibrated by means of a front-panel dial. Sweep range extends from 1 second to 0.1 microsecond per inch.

Calibrated sweep expansion and delay is accomplished by the new Du Mont sweep "notch," which enables speeding by a predetermined factor of an 2-inch portion of the 4-inch trace. The notch is movable along the trace so that any portion may be expanded and examined in detail, while its time relationship to the total signal is maintained.

The scale of the Type 323 may be calibrated to read directly in volts by means of internally generated voltage standards. Eleven ranges, extending from 0.2 to 400 volts full-scale, are available.

A technical bulletin is available from the Technical Sales Department, Allen B. Du Mont Laboratories, Inc., 760 Bloomfield Ave., Clifton, N. J.

(Continued on page 26A)

COMPRESSING TIME

In any security program *time* is the one irreplaceable element. Making the most of time is particularly vital in guided missiles projects. Fairchild's Guided Missiles Division has demonstrated its ability to "spend" time effectively. Its completely integrated engineering and production organization can, in effect, *compress time.*

With a balanced engineering team and an experienced production staff housed together in a facility built specifically for the development and manufacture of missiles, Fairchild can cut down lags in moving a missile project from the design and development phase into the production phase.

It *has* done so.

ENGINE AND AIRPLANE CORPORATION

FAIRCHILD

Guided Missiles Division

WYANDANCH, N. Y.

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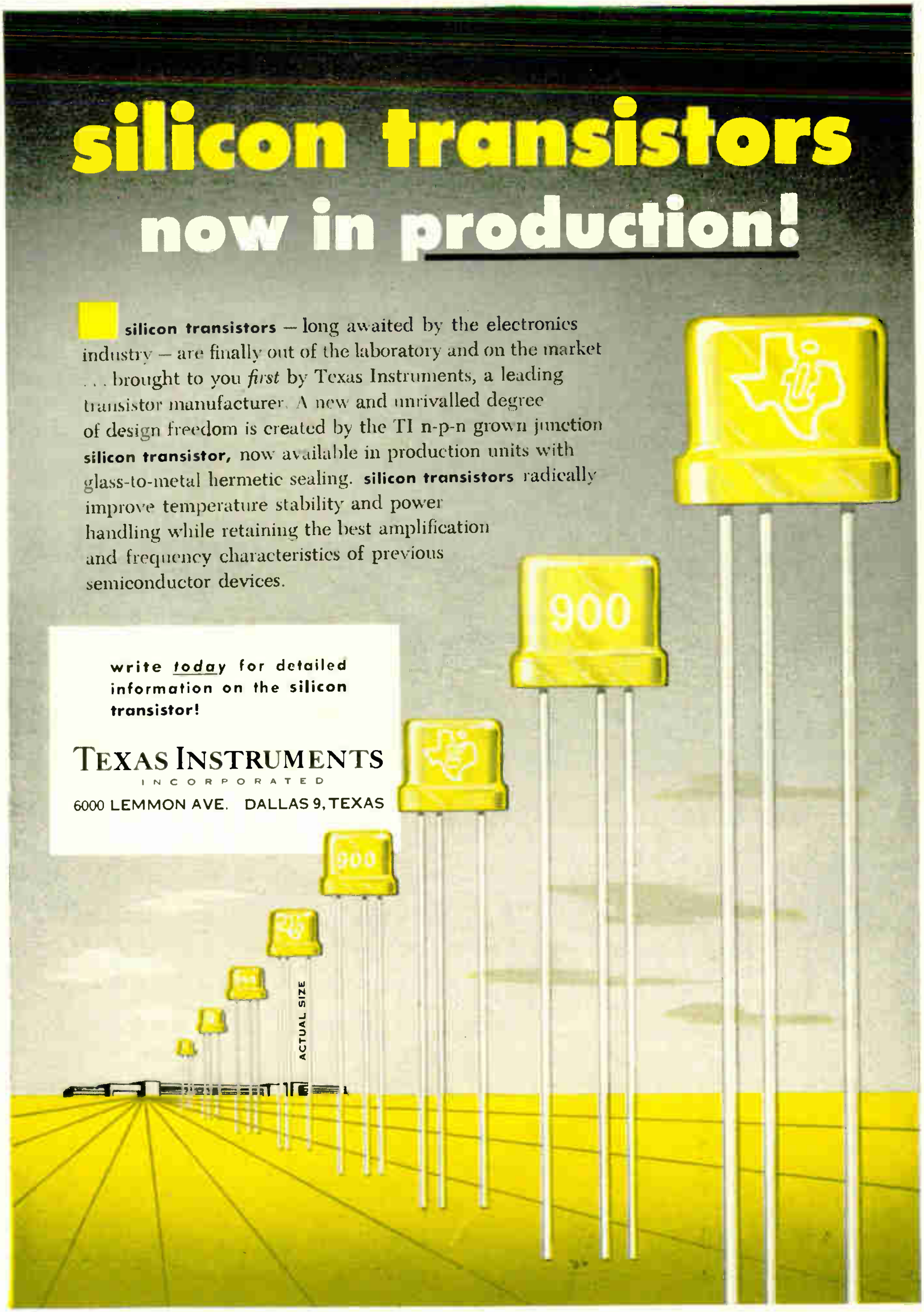
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MODEL	FREQUENCY RANGE	ACCURACY
912-4	900-1200 MC	.01%
1217-4	1200-1700 MC	.02%
1723-4	1700-2300 MC	.02%
4458-4	4400-5800 MC	.01%
5882-4	5800-8200 MC	.01%

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Here are shields which eliminate waste . . . are guaranteed to your performance specification . . . *and are sold at standard prices.*

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METHOD OF MANUFACTURE . . . Performance-Guaranteed Shields can be fabricated or drawn by Magnetics, Inc., depending upon which is most economical for your requirements.

FINISH . . . Performance-Guaranteed Shields can be furnished painted, lacquered or unfinished, as your requirements dictate. Paint color can be matched to any equipment shade you select. Pre-painting by Magnetics, Inc. eliminates danger of damage to shields in painting operations in your plant . . . provides you with shields immediately ready for your assembly operations.

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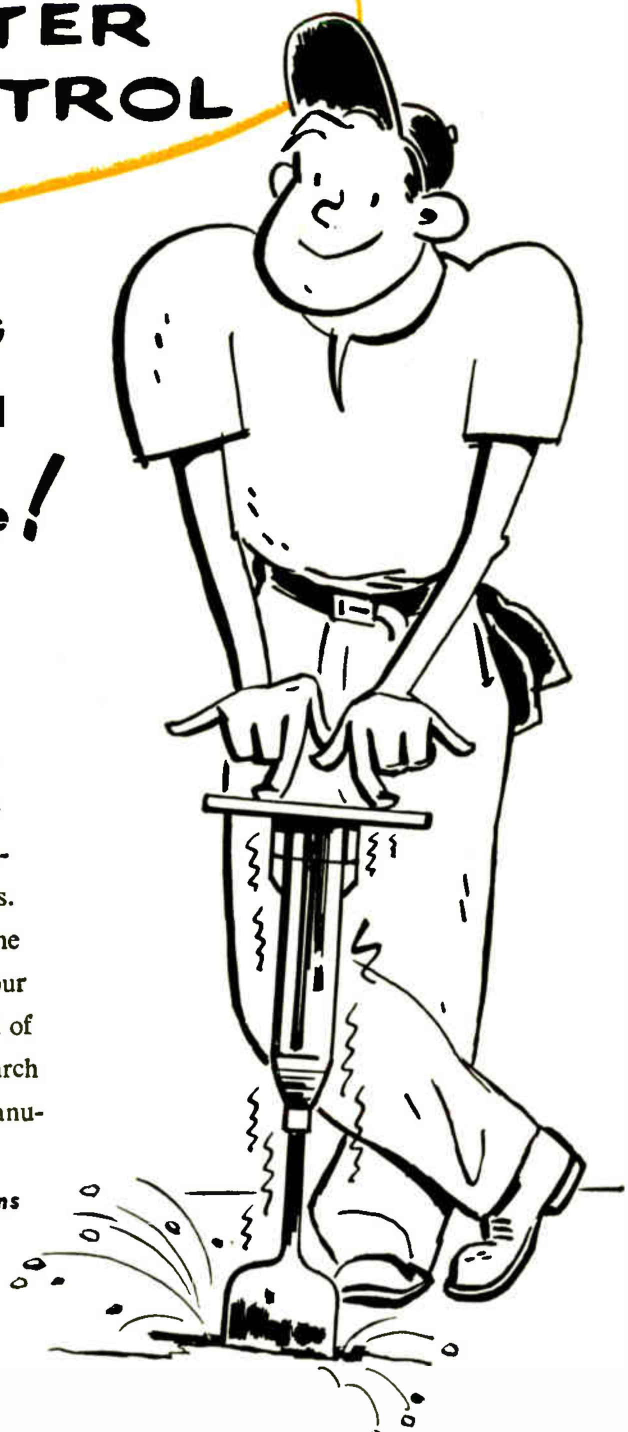
JUST A MATTER OF CONTROL



LORD ENGINEERING CONTROLS VIBRATION

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The difference between a good product and a better one is often just A Matter Of Control—control of vibration and shock which may be damaging your product. Pioneers in solving vibration problems for many industries, Lord Manufacturing Company is well qualified to assure you of better performance from your products through the use of Lord Vibration Control Mountings and Bonded-Rubber Parts. Our Engineers will be pleased to help you in the analysis of the vibration which may damage your product and in the selection of the correct method of control. Lord Engineering means Materials Research—Engineering Research—Product Design—Manufacturing Know-How for your application.

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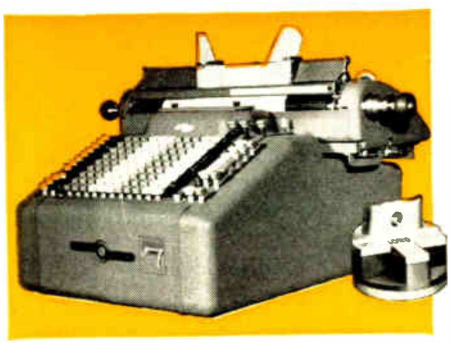

Here is one example of Lord Engineering on sensitive business machines. The Burroughs Sensimatic Accounting Machine is supported on LORD Mountings to reduce noise and cushion shock.

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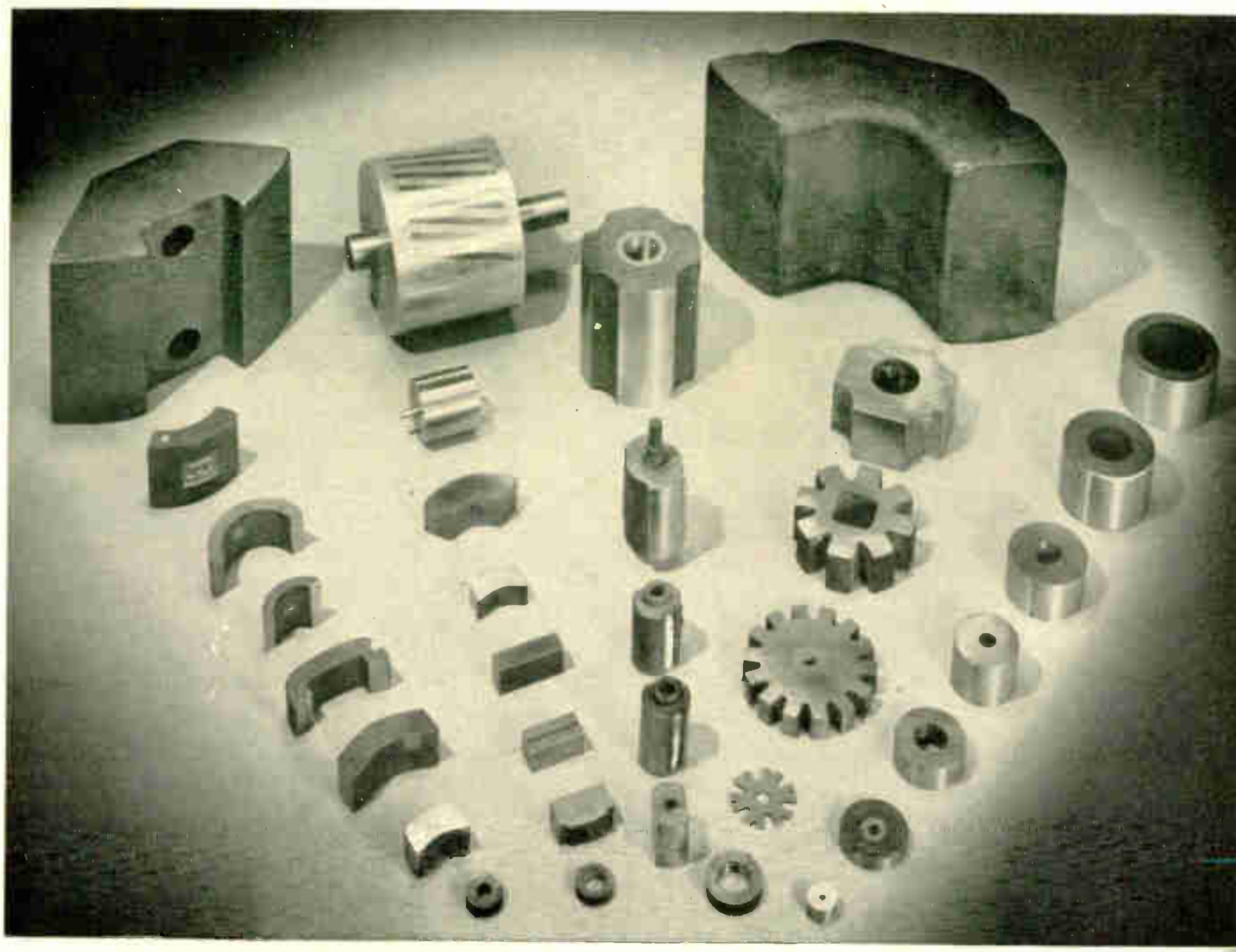

Magnets for rotors or stators ...any design or size you may require

"MAGNETIC MATERIALS CATALOG"

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Contains handy data on various types of Alnico Magnets, partial lists of stock items, and information on other permanent magnet materials. Also includes valuable technical data on Arnold tape-wound cores, powder cores, and types "C" and "E" split cores in various tape gauges and core sizes.

ADDRESS DEPT. P

The use of Alnico permanent magnets in rotor and stator assemblies of motors, generators, magnetoes and tachometers has revolutionized the designs of these devices. Whatever your need may be —from a tiny rotor for a timing device to a large slab for power generators—Arnold can take care of your requirements, either for experimental samples or production quantities.

● *Let us work with you.* You will have the advantage of working with a leading producer of rotor magnets, whose manufacturing and testing facilities—the most modern in the business—give you the best assurance of high quality standards and uniform performance.

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For condensers, transformers, other applications requiring voltage ratings from 2000 to 4000 (rms.). Compression sealed, super rugged. Inside or outside mounting; lead wires up to .060.

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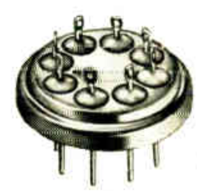
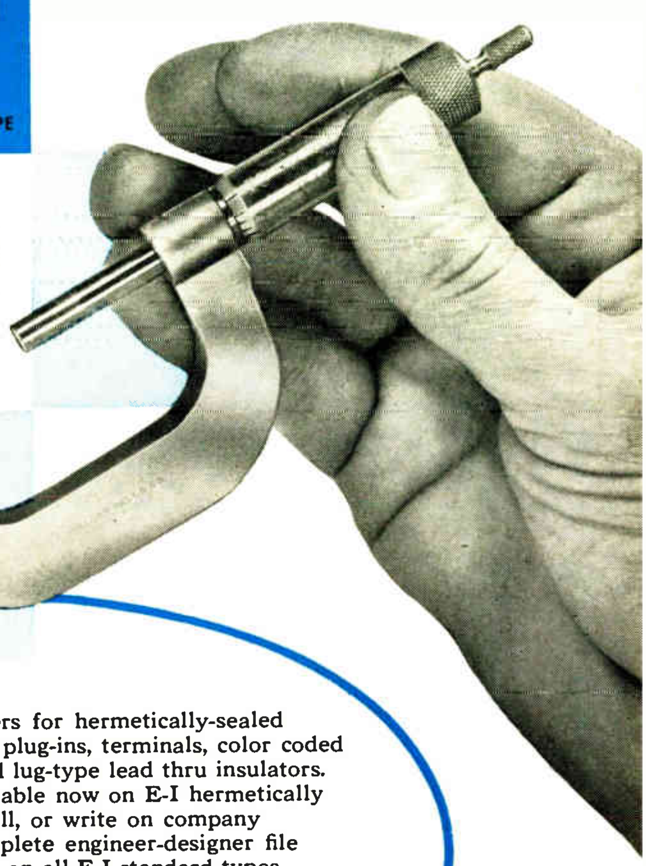
• COMPRESSION TYPE

• END SEALS



• OCTAL HEADERS

• COLOR-CODED



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Featuring cushioned glass construction, high thermal shock resistance. Available in economical preferred types and special designs.

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Vacuum tight, cushioned glass construction. Strain-free, tin dipped for easy soldering and silicone treated for maximum dielectric strength.

COMPRESSION TYPE HEADERS
Super rugged, absolutely rigid, practically indestructible multiple headers. Exclusive E-I development offers greatly increased resistance to shock and vibration.

END SEALS
For condensers, resistors and other tubular components. Completely strain-free and provide a permanent hermetic seal. Standardized, economical types.

OCTAL HEADERS
Plug-in and multiple types. Feature new principle of hermetic sealing.

COLOR-CODED TERMINALS
Feature glass inserts in standard, easily identified RMA color codes. Coloring is in the glass.

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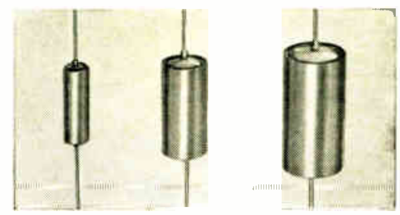
News—New Products

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

(Continued from page 16A)

Miniaturized Capacitor

National Capacitor Co., 385 Washington St., Quincy, Mass. manufacture Type TI capacitors which demonstrate good stability between temperature extremes. The capacitance variance is less than 5 per cent from 80°C to 200°C. Insulation resistance at 150°C will exceed 1,000 megohms ×microfarads.



Capacitance is substantially unaffected by frequency, and has a dissipation factor less than 0.008. These Type TI capacitors are hermetically sealed with 100 per cent tin-coated glass-kovar end seals. Container ends are pressure-crimped to doubly secure seals. They are available for prompt delivery in the complete RETMA capacitor series. Standard tolerances ±10 per cent; also can be obtained with tolerances of ±5 per cent and ±2 per cent.

Miniature Permanent-Magnet Motor

Rated at 1/400 horsepower with operating rotor speed of 10,500 rpm, the new Type PM-47 miniature permanent-magnet motor manufactured by **Dalmotor Co.**, 1375 Clay St., Santa Clara, Calif., is suggested for application to small fans, blowers, and other similar light-weight-load applications. Designed for continuous duty, this motor draws 0.18 ampere at 27 volts dc, and has a total weight of 5 ounces.

Dimensions are 1 13/16-inches long by 1⅛-inches diameter, and the ⅛-inch diameter shaft has an extension length of 1 1/16 inches. However, other lengths and special arrangements including splines, keyways, gears, and so forth, can be provided where required. Electrical connections (integral-lead type illustrated) can be provided in a number of arrangements to suit application requirements.

(Continued on page 28A)

G.E.'s NEW IMPROVED SWEEP TUBES GIVE HIGHER QUALITY AT SAME PRICE!

You can SEE the improvement over prototypes (left)

NEW 6BQ6-GA, 25BQ6-GA (Right)

G-E Design Service brings you . . . constantly . . . new, improved, more dependable receiving tubes at no increase in cost. The 6BQ6-GA and 25BQ6-GA are examples. These sweep tubes cut TV production costs by greatly reducing line rejects . . . also build customer acceptance for your sets, which will require fewer service call-backs.

Other improved G-E tubes are in development, and will be available soon. With the number of tubes per chassis to be at least doubled for Color, builders of sets justifiably are asking for tubes that will stand up—that won't slow TV production by poor performance or high failure rate, and won't make service costs prohibitive.

Better tubes at the same price is an extensive and continuing General Electric program. Get all the facts about these new, improved tubes for television from *Tube Department, General Electric Company, Schenectady 5, New York.*

OUTSTANDING PERFORMANCE! LONG LIFE!

"RUNNING HOT" shortened the life of many prototype 6BQ6-GT's and 25BQ6-GT's. G-E designers went to the heart of the problem, and gave the new tubes king-size bulbs that mean cooler operation under all normal conditions. Glass surface area is 89% increased!

Also—because of special mica design and new processing techniques—the 6BQ6-GA and 25BQ6-GA will handle higher pulse plate voltages than their predecessors. The peak rating now is 6,000 v instead of 5,500 v. Internal tube arcing has been reduced substantially.

A further improvement is use of a special high-melting-point solder for the plate cap-terminal. This prevents loosening of the terminal when tubes are removed for testing.

Basing layout is identical with prototypes. The new tubes are fully interchangeable with the old.

GENERAL ELECTRIC

162-1A3

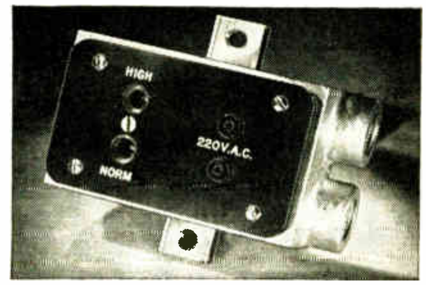
News—New Products

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

(Continued from page 26A)

High-Voltage Indicator

Two models of a new, inexpensive high-low voltage indicator are announced by **Industrial Devices Inc.**, Edgewater, N. J., manufacturers of electrical-electronic servicing and industrial products. Each of these units, designed for use with portable or stationary industrial equipment, have a bakelite panel with two glow-lamp pilot lights marked HIGH and NORM, and two test jack receptors. The panel is mounted on a cast aluminum junction box (Type FS) with conduit fittings.



Both voltage indicators are specifically suited to equipment where efficiency depends on a certain voltage range. Both models work on ac or dc. Both units are available for other voltage ranges on special order. One, Model 960 indicates a low range of 190 to 210 volts and a high of 235 volts.

Test jack receptors are provided for checking the voltage with a meter at any time. Glow lamps employed are of the non-filament type and are not affected by extreme vibrations.

Surface-Barrier

Development of a Surface-Barrier transistor has been announced by **Philco Corp.**, 4700 Wissahickon, Philadelphia 44, Pa.

Philco is using a new method of processing germanium. "This new method exhibits the highest mechanical precision yet attained in machining germanium," Mr. Woods of Philco said. "The process consists of directing two streams of liquid indium salt at opposite sides of a slab of germanium. Electric current is passed through the streams so as to etch away the germanium. This process continues until the two streams almost drill through the slab. When the germanium has been etched down to a few ten-thousandths of an inch in thickness, the current is suddenly reversed. The etching is thus instantly arrested and indium immediately electroplated on the germanium by the reversed current flow to form electrodes on both sides. The resultant assembly, with wires attached to the two electrodes, is hermetically sealed in a metal container.

(Continued on page 30A)

News—New Products

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

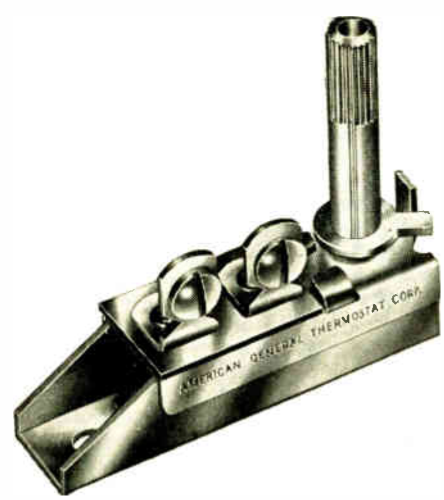
(Continued from page 28A)

"Methods have been developed which arrest the etching so precisely that the remaining thickness of germanium is controlled to 10 millionths of an inch, or less than the wave length of visible light. Such precision has not been possible in producing earlier types of transistors."

Philco claims Surface-Barrier transistors operate reliably in frequency ranges up to 70 mc, which include the military vhf communication band from 20 to 85 mc.

New Appliance Thermostat

A new type of conduction thermostat which features the heat sensitive element within the brass channel section of the case itself, is now being manufactured by the **American General Thermostat Corp.,** 2066 Bronx St., New York 60, N. Y. Heat transferred over the entire area of the base makes this thermostat desirable for appliances where fast heating and close control are essential.



This thermostat is ruggedly constructed, has one hole mounting (side mounting is also available) without change in calibration due to mounting pressure, and uniform tracking of calibration curve. It also has clean make and break contact movement for longer life at high power.

The technical characteristics are: Range: 70–650°F. Rating: 115–230 v only, with wattages up to 2000 watts, depending on application. Control Shaft: $1\frac{1}{4}$-inch minimum to 2-inch maximum. Base Dimensions: $2\frac{5}{32}$ inches long, $\frac{17}{32}$ inch wide, $\frac{13}{16}$ inch height over terminal screws.

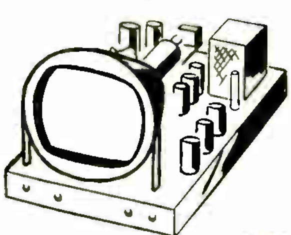
Model R-6 calibrates from "Off" to 525°F. with knob rotation of 310°. For additional information, please write to the manufacturer.

(Continued on page 38A)

New...Revolutionary—the *only* color TV voltage regulator to offer fool-proof performance and complete protection against circuit failures.

Victoreen's new corona regulators offer the only sure, safe regulation of the second anode potential of color TV kinescopes. Advanced engineering has eliminated the filament, with consequent complete protection to the picture tube from voltage surges arising from filament or circuit failures. Victoreen now offers the only regulator in which the voltage *drops* when mechanical or circuit failures occur. Being a non-filament type, complicated design problems are eliminated. You need only know the voltage required. A rugged metal envelope minimizes damage from handling. A clamp-type mounting eliminates the need for costly installation.

Contact our components division for technical advice on the application of these tubes.



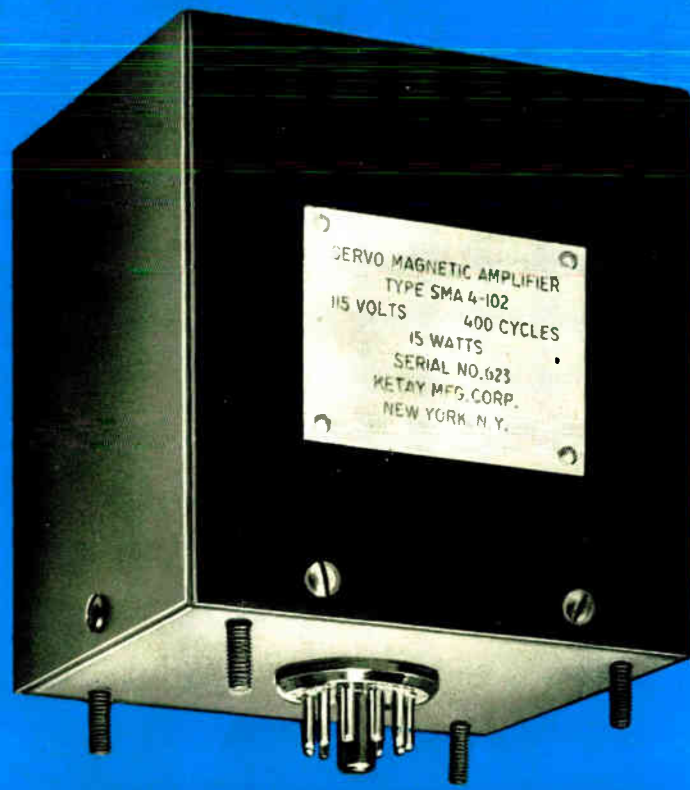
type 6392, 18,000 volt regulator.
type VXR-27K, 27,000 volt regulator.
type 6353, 20,000 volt regulator.

The Victoreen Instrument Co.

COMPONENTS DIVISION: 3800 PERKINS AVE. • CLEVELAND 14, OHIO

Ketay

presents



••• *meticulously tailored*

MAGNETIC AMPLIFIER SERVO SYSTEMS

Typical characteristics of some magnetic amplifier and two-phase servo motor combinations available from Ketay.

SPECIFY MAGNETIC AMPLIFIER (type)	FREQUENCY (cps)	LINE VOLTAGE (volts)	LENGTH (inches)	WIDTH (inches)	HEIGHT (inches)	SPECIFY SERVO MOTOR (type)	TORQUE AT STALL (oz. in.)	MOMENT OF INERTIA (oz. in x sec² x 10⁶)	ACCELERATION AT STALL (rad./sec²)	NO LOAD SPEED (min. r.p.m.)	RATED VOLTAGE EXCITATION FIXED PHASE (volts) *	INPUT POWER PER PHASE AT STALL (watts)	DIAMETER (inches)	LENGTH (inches)
SMA6-102	60	115	4 1/2	3 3/4	3 7/8	K402530	2.5	49.5	50,500	3300	115	9.2	1 3/4	2
SMA6-102	60	115	4 1/2	3 3/4	3 7/8	K402380	1.45	42.8	35,000	3200	115	5.0	1 7/16	1 5/8
SMA4-102	400	115	4 1/8	3 5/16	4 3/16	K402550-1	2.35	49.5	47,500	4800	115	9.2	1 3/4	2
SMA4-102	400	115	4 1/8	3 5/16	4 3/16	K402550-2	2.35	49.5	47,500	4800	115	9.2	1 3/4	2
SMA4-102	400	115	4 1/8	3 5/16	4 3/16	K101600-6	1.45	42.8	35,000	4800	115	6.1	1 7/16	1 5/8
SMA4-102	400	115	4 1/8	3 5/16	4 3/16	K101660	1.45	42.8	35,000	4800	115	6.1	1 7/16	1 5/8

BUORD DESIGNATIONS FOR SERVO MOTORS

K101600-6 = MK 7 MOD 0 K101660 = MK 7 MOD 1

K402550-2 = MK 8 MOD 1 K402550-1 = MK 8 MOD 0

* The control phase of all Servo Motors should be connected for 57.5 volt operation.

On the other side of this page are listed some of the synchros for which the combinations were specially designed.

Ketay supplies complete systems including gear trains and stabilization for given kinematic requirements.

Servo motor-tachometer generator combinations are also available.

Ketay welcomes the opportunity to design and fabricate amplifiers of both the conventional and miniaturized types to customer's specifications.

SYNCHROS • SERVO MOTORS
RESOLVERS • MAGNETIC AMPLIFIERS
AIRBORNE INSTRUMENTS
AUTOMATIC CONTROL SYSTEMS

Ketay

MANUFACTURING CORP.
Executive Offices
555 Broadway, New York 12, N. Y.

KETAY OFFERS A COMPLETE RANGE OF SIZES AND TYPES IN SYNCHROS • SERVO MOTORS RESOLVERS

1–SERVO MOTOR, Size 10 Frame, O.D. .937"
2–SYNCHRO, Size 10 Frame, O.D. .937" (Transmitter, Receiver, Resolver, Differential Transmitter, Control Transformer)
3–SERVO MOTOR, Size 10 Frame, O.D. .937"
4–SYNCHRO, Size 11 Frame, O.D. 1.062" (Transmitter, Resolver, Control Transformer)
5–SERVO MOTOR, Mk 14, Size 11 Frame, O.D. 1.062"
6–SYNCHRO, Size 15 Frame, O.D. 1.437" (Transmitter, Receiver, Resolver, Differential Transmitter, Control Transformer)
7–SERVO MOTOR Mk 7, Size 15 Frame, O.D. 1.437"
8–SYNCHRO, Size 15 Frame, O.D. 1.437" (Transmitter, Receiver, Resolver, Differential Transmitter, Control Transformer)
9–LINEAR TYPE CONTROL TRANSFORMER, O.D. 1.625"
10–SERVO MOTOR, Mk 8, Size 18 Frame, O.D. 1.75"
11–INDUCTION MOTOR, Size 20 Frame, O.D. 1.95"
12–SYNCHRO, Size 16 Frame, O.D. 1.537" (Transmitter, Receiver, Control Transformer)
13–SYNCHRO, Size 18 Frame, O.D. 1.750" (Transmitter, Receiver, Differential Transmitter, Control Transformer)
14–INDUCTION MOTOR, Size 18 Frame, O.D. 1.750", 3 Phase, 2 Pole
15–SYNCHRO, Size 19 Frame, O.D. 1.90" (Transmitter, Receiver, Control Transformer)
16–SYNCHRO, Type 1F, 1HCT, or 1HG Size 1 Frame, O.D. 2.250" (Receiver, Transmitter, Control Transformer)
17–INDUCTION MOTOR, Size 1 Frame, O.D. 2.250"
18–SYNCHRO, Size 23 Frame, O.D. 2.250" (Transmitter, Receiver, Resolver, Differential Transmitter, Control Transformer)
19–SERVO MOTOR, Size 23 Frame, O.D. 2.250"
20–SYNCHRO, Size 31 Frame, O.D. 3.10" (Transmitter, Receiver, Differential Receiver, Differential Transmitter)

Typical characteristics of 116 units are available.

ADDITIONAL FACILITIES TO SERVE THE INDUSTRY

This plant, recently acquired at Commack, Long Island, adds air-conditioned work space that brings Ketay's total area to over 200,000 square feet, accommodating over 2,000 employees in the five divisions. Modern in every detail, the new plant has the latest equipment for precision volume production.

EXPERIENCE + RESEARCH + PERFORMANCE = LEADERSHIP

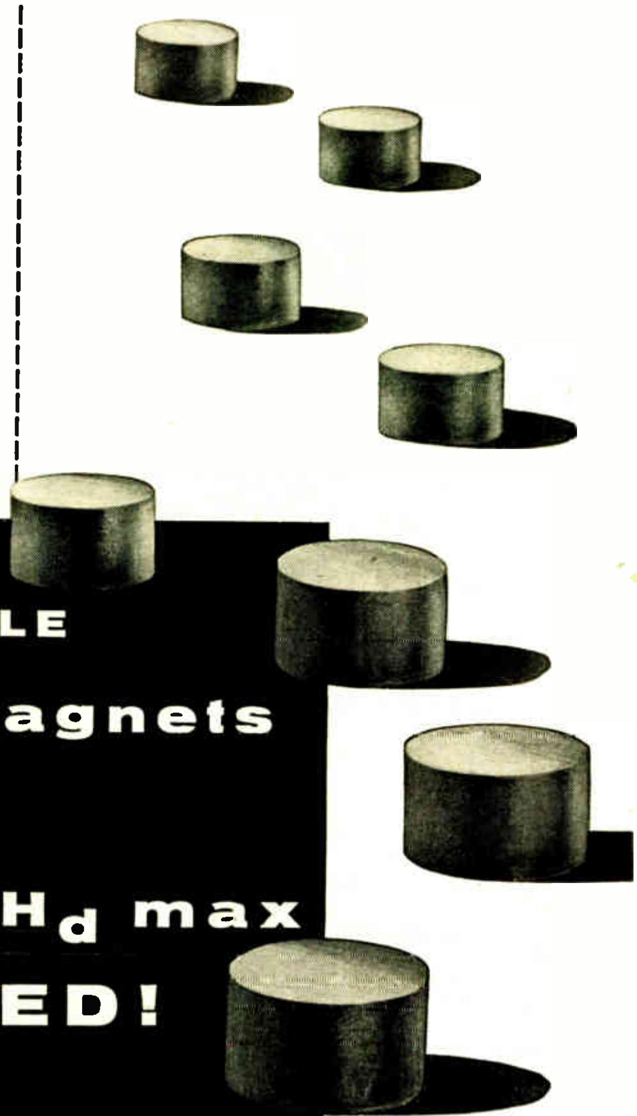
New developments and applications . . . increased facilities for volume production of components and complete systems . . . all the things reported on these pages are characteristic of Ketay—a firm with broad experience and specialized knowledge that adds up to leadership in the field of electrical devices and controls. This experience and knowledge is yours to command. In addition to synchros, servo motors and resolvers, it includes, but is not limited to: gyro components; aircraft engine instruments; computers; magnetic, resolver and synchro amplifiers; remote indicators and automatic control systems. Ketay's completely staffed and equipped Research and Development Division can be of greatest service during the design stage of applications involving Ketay products. You are invited to avail yourself of this service.

For further information or a data sheet on 116 Synchros, Servo Motors and Resolvers, write Ketay

Ketay
MANUFACTURING CORP.

Executive Offices **555 Broadway, New York 12, N. Y.**
Pacific Division, 12833 Simms Avenue, Hawthorne, California

New York Division • Kinetix Instrument Division • Pacific Division
Electronic Instrument Division • Research & Development Division

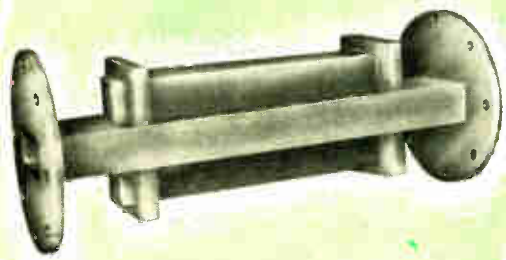


FOR EVEN GREATER UTILITY

SIGNIFICANT NEW *Uniline* DESIGNS

The adaptability of this now widely accepted unidirectional transmission line element is enhanced by several recent additions to the UNILINE family. Two such additions, illustrated here, meet important new requirements, retain the desirable characteristics of the original UNILINE design, namely, substantial isolation between source and load with negligible loss in transmitted power.

MODEL 38-42



The new Model 38-42 answers the frequent requests for UNILINES at still lower frequency ranges, covers 3800 to 4200 megacycles.

"RUGGEDIZED" UNILINE

This compacted, thoroughly ruggedized new design broadens the field of application for UNILINE . . . makes possible its use in equipment subject to severe shock and vibration. Same frequency range as Model 88-96 but under 3" in length.

MODEL R88-96

ITEM	MODEL NO.	FREQUENCY RANGE
UNILINE	96-104B	9600-10,400 Mcs.
UNILINE	88-96B	8800-9600 Mcs.
UNILINE	R88-96	8800-9600 Mcs.
UNILINE	69-74	6900-7400 Mcs.
UNILINE	64-69	6400-6900 Mcs.
UNILINE	59-64	5900-6400 Mcs.
UNILINE	38-42	3800-4200 Mcs.
GYRALINE	1000	9600-11,200 Mcs.
GYRALINE	920	8500-9900 Mcs.
GYRALINE	720	6900-7400 Mcs.
GYRALINE	670	6400-6900 Mcs.
GYRALINE	620	5900-6400 Mcs.

UNILINE applications.

- Provides substantial isolation between source and load with negligible loss in transmitted power . . . . . .
- Eliminates "long line" effects on klystrons or traveling wave tubes . . .
- Ensures adequate isolation between multiple coupled circuits . . . . .
- Minimizes frequency "pulling" effects due to varying load impedance . .

and . . . GYRALINE

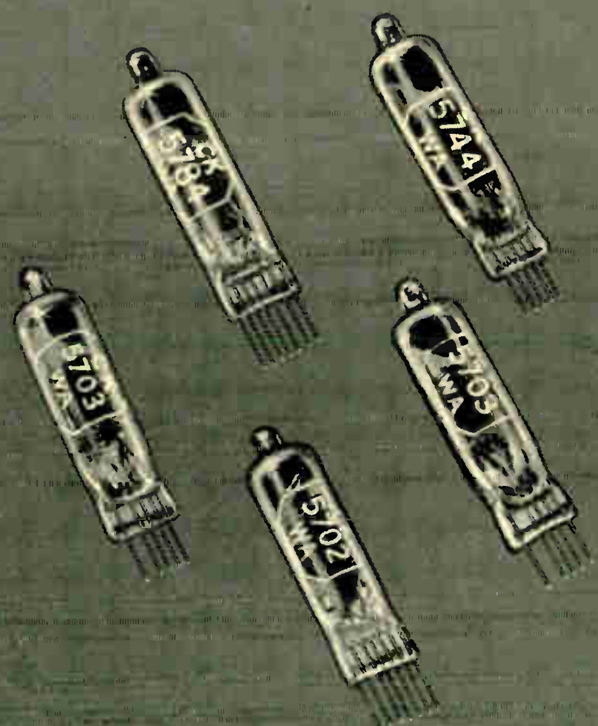
The GYRALINE is essentially a continuously variable microwave attenuator controlled by an applied magnetic field. It can provide an amplitude modulated microwave signal without undesirable frequency modulation and double moding when used on the output of a CW operated klystron. The GYRALINE may also be used as an excellent level set attenuator or as the direct control element in an AGC system.

D-92 GYRALINE DRIVER — An audio driving unit for GYRALINES #920 and #1000. Adjustable output level, frequency variable 800 to 1200 cps. Self-contained power supply.

Write for descriptive literature

CASCADE RESEARCH CORPORATION
53 VICTORY LANE LOS GATOS, CALIF.

RAYTHEON subminiature



TEST
PLATE VOLTAGE MAXIMUM
PERMISSIBLE HEATER VOLTAGE RANGE
PLATE DISSIPATION
HIGH TEMPERATURE LIFE
1 HOUR STABILITY
100 HOUR SURVIVAL
HEATER CYCLING
MEDIAN CONTROLS

HERE ARE MORE REASONS WHY RAYTHEON SUBMINIATURE TUBES ARE SO RELIABLE:

- ★ Additional Life Test End Points
- ★ Larger Test Samples
- ★ Tighter AQL
- ★ Grouped AQL
- ★ Median and Range Control of Electrical Characteristics
- ★ 100% Microscopic Inspection — pioneered by Raytheon. Forty-seven microscopic tests on each tube
- ★ Narrower Tolerances
- ★ Lower Vibrational Noise Output from CK5702WA and CK5703WA

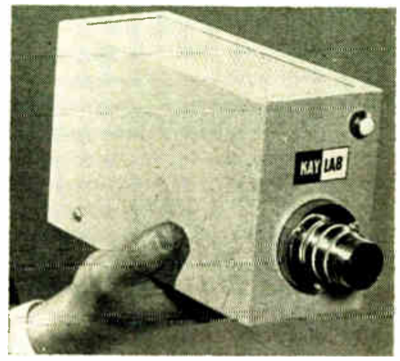
News—New Products

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

(Continued from page 30A)

TV Camera

The Kay-Lab Television Camera System, developed by **Kalbfell Labs., Inc.,** P.O. Box 1578, Morena Blvd., San Diego 10, Calif., is usable either as an industrial television intercommunication system or in commercial broadcasting for remote, studio or film pick-up. The camera, camera controller, and synchronizer monitor are the basic units of the system.

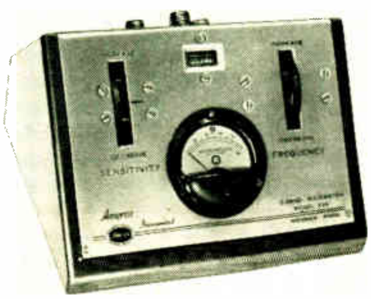


The camera consists of a vidicon pick-up tube operated with an 8-mc band-wide cascode pre-amplifier. All electrical adjustments on the camera can be controlled remotely at the camera control. Up to 500 feet of cable can be used between the camera and camera-control unit. The camera control consists of 3 basic subassemblies, an 8-mc video amplifier, horizontal and vertical deflection chassis, and a power supply. All power supplies in the system are electronically regulated.

The camera control is designed so that external vertical and horizontal driving pulses and mixed blanking signals may be connected directly to it. In industrial applications the synchronizer monitor unit can be used. This unit consists of a 10-inch monitor and an interlaced synchronizing generator. The three basic packages produce a high sensitivity, high quality, interlaced television picture.

"S" Band Wavemeter

Amerac, Inc., Wenham, Mass., announces production of the Model 229 "S" Band Wavemeter. This is a coaxial-line type of instrument, covering the frequency range from 2.3 to 4.5.



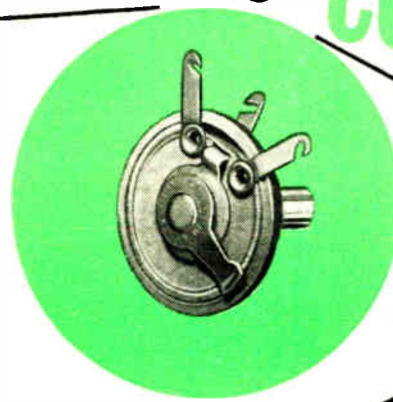
Model 229 features a precision-ground lead screw, a cavity body made from a solid

(Continued on page 40A)

From "The House of Resistors"** come . . .

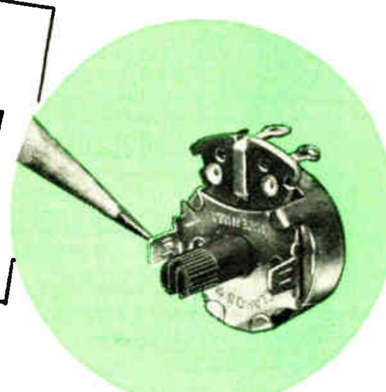
COST-REDUCING CONTROLS

So you must *get cost down* in designing that assembly? That's just the time to enlist Clarostat's cost-saving talents and facilities. The same superlative engineering and production skill that accounts for the finest quality in controls and resistors, is also available for designing and fabricating cost-reducing components. Three typical examples are presented herewith. These are *standard* items, promptly available in any quantities, at marked savings. And for any extraordinary requirements, *special* controls and resistors can be developed, tooled-up and produced.



The original "Humdinger" Series MH. Compact, rugged, wire-wound control. Virtually millions in use. Fibre base holds resistance winding. Movable arm and shaft. 1-watt. 2 to 1000 ohms.

Latest "Humdinger" Series 39. Metal-case mounted with rivets or screws. Mounting surface serves as cover. Semi-fixed setting by screwdriver slipped into rotor slot —no shaft 2-watt 4 to 5000 ohms.



Twist-Tab Mounted Series 47. Eliminates usual bushing, lockwasher, nut. Composition-element control. Metal or plastic shaft. Plastic shaft has rear slotted protrusion, therefore adjustable from front or rear.

* *It's easy* to do business with CLAROSTAT!

Agents in all principal cities. ★ Wire Western Union — we have a direct wire. ★ Telephone Dover 975 — we have added trunk lines to render service. ★ Teletype — our TWX number is Dover 275-U

STAND PAT WITH® CLAROSTAT

**Trade Mark

CONTROLS and RESISTORS

CLAROSTAT MFG. CO., INC., DOVER, NEW HAMPSHIRE
In Canada: CANADIAN MARCONI CO., Ltd., Toronto, Ont.

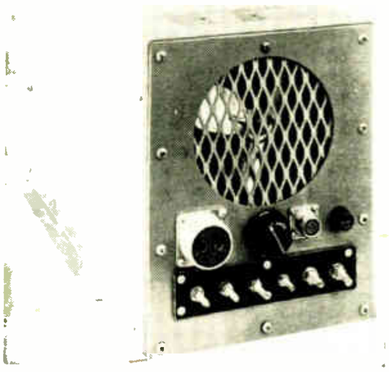
(Continued from page 38A)

block, precision-machined to close tolerances, the use of Invar in the line displacement portion, affording a high frequency stability throughout the temperature range of 10° to 40° (maximum accuracy is at 22°C. at which it was tested and calibrated). All RF surfaces are multiple-plated of copper flash, silver plate, buffing, silver plate, and rhodium flash.

Type "N" constant impedance coaxial connectors are used for both transmission and absorption inputs; BNC or Selectar fitting provides external video connection. Power-handling capability by absorption method is from 0.5 milliwatt to 1 watt maximum; by transmission method from 1 milliwatt to 25 watts peak power. Approximate loaded Q is 2,000. Cabinet size is 8 inches wide×6½ inches deep×5 inches high. Net weight is 4¾ lbs.

Airborne Power Supplies

Inet, Inc., is introducing a complete line of new airborne power supplies with ratings of 25 to 500 amperes at 28 volts. These rectifier units are among the first available to aircraft manufacturers which consist entirely of nonwearing or static electrical components.



Selenium rectifier cells and magnetic amplifiers are the basic components. Very close regulation of the output voltage with a fast response is achieved by use of a rugged voltage-sensing network.

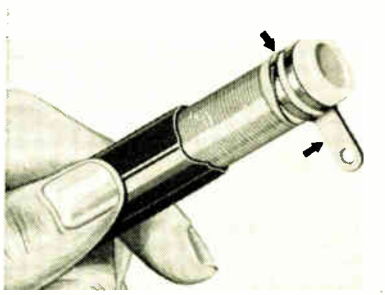
These supplies meet JAN Specifications and U. S. Air Force Exhibit WCEE-2A, Nov. 1951. Paralleling of 2 or more power supplies is accomplished by one inter-connection between units. 1,000 hours of life are guaranteed; 2,000 hours can be expected. Units are insensitive to temperatures from −65°C to +72°C and withstand all conditions of moisture, sand, dust, and salt spray.

The ac input is 200 volts, ±10 volts, 400 cps, ±20 cps, 3 phase. The dc output is 0 to 500 amperes, 28 volts (amperage depending on unit). Regulation is better than ±1 per cent from no load to full load. Response is 0.2 seconds full recovery for any load or line variation. Ripple is 2 per cent RMS.

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

Welded Terminals For Wire-Wound Resistors

The all-welded terminal construction has now been extended to cover the entire line of Ohmite wire-wound resistors, according to an announcement by the **Ohmite Manufacturing Co.,** 3601 Howard St., Skokie, Ill.



In the patented Ohmite construction, the resistance wire is welded to the terminal band, and the terminal band itself is welded permanently around the core. No soldering, brazing, or mechanical fastenings are used.

This method is said to produce permanent connections that are not affected by vibration or high temperatures. The fusion of the resistance wire and terminal lug, provides a stable electrical connection which is important in eliminating noise in audio circuits, or instability in other highly sensitive circuits.

The terminal bands are made of a special, high-strength alloy whose coefficient of expansion is properly related to that of the resistance wire, ceramic core, and vitreous enamel coating. The resistance wire is welded flush to the terminal band, so that the connection and terminal are well covered by the vitreous enamel coating.

Time-Delay Passive Network

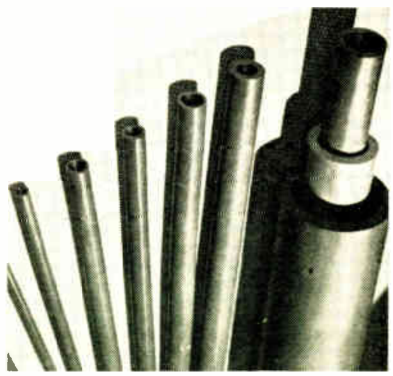
A new passive network designed by **Advance Electronics Co., Inc.,** P. O. Box 394, Passaic, N. J., features a variable delay line, a step variable delay line, an input cathode follower, a voltage amplifier and two output cathode followers. The step variable delay line has a time delay of 10.5 microseconds in step of 0.5 μsec. The continuously variable delay line has a total time delay of 0 to 0.5 μsec with resolution time less than 5×10^{-10} seconds. There are two output connectors for simultaneous connection to two output leads.

Time delay is continuously variable from 0 to 11 μsec, while resolution time is less than 5×10^{-10} seconds from 0 to up 11 μsec. Bandwidth is 10 cps to 15 microcycles when the step variable delay line is at its off position (time delay from 0 cps to 0.5 μsec), otherwise, the upper limit decreases to 2.6 microcycles.

Rise time: less than 10 per cent of the time delay at any point. Input impedance: 20 μμf shunted with 1 megohm direct, and 3 μμf shunted with 10 megohms with probe. Output impedance: 300 ohms nominal Accuracy of time delay: maximum error less than 10^{-9} seconds or 0.1 per cent of the time delay at any point with correction curve, otherwise, one per cent of the time delay at any point.

Lower Cost Fluorocarbon

United States Gasket Co., Camden 1, N. J., has announced a new fluorocarbon plastic product trademarked Fluoroplast. It is offered in molded bars and cylinders and extruded rods and tubing, and the company states, at prices sufficiently lower than other Fluorocarbon plastics to greatly extend the use of these materials.



Fluoroplast is 100 per cent tetrafluoroethylene plastic, reprocessed by a method which permits re-utilizing virgin material waste and maintaining its original purity in the refabricated product. Values compiled from test data by United States Testing Co., and the Electrical Testing Laboratory show that it possesses most of the properties of the virgin material.

Fluoroplast is generally colored green for identification.

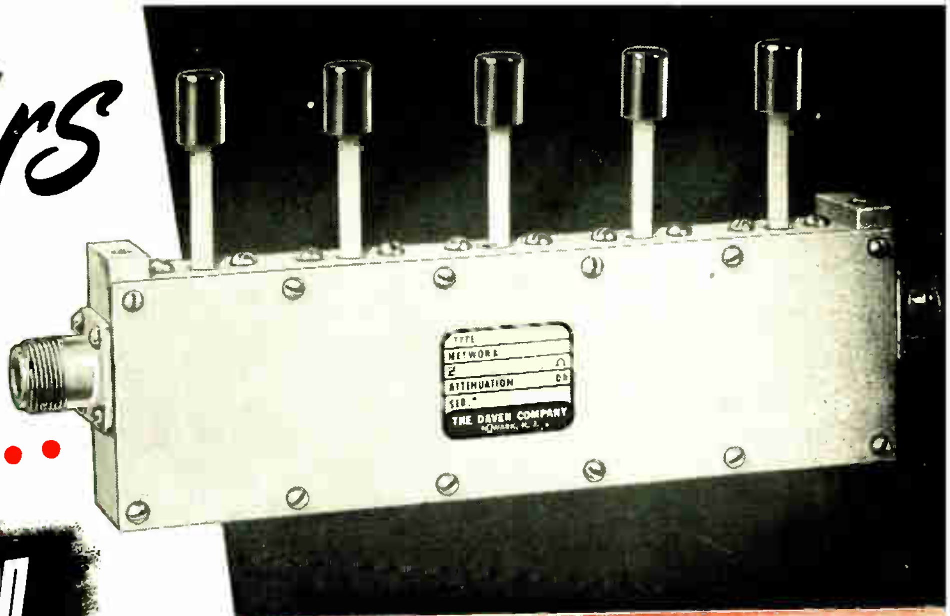
For further information and test data write for United States Gasket Co. Bulletin No. FL-300.

(Continued on page 43A)

IN

Attenuators

WHY DOES ONE NAME.. DAVEN STAND OUT?



Series 550-RF Attenuator

In addition to Daven being the leader in audio attenuators, they have achieved equal prominence in the production of RF units. A partial listing of some types is given below.

DAVEN Radio Frequency Attenuators, by combining proper units in series, are available with losses up to 120 DB in two DB Steps or 100 DB in one DB Steps. They have a zero insertion loss and a frequency range from DC to 225 MC.

Standard impedances are 50 and 73 ohms, with special impedances available on request. Resistor accuracy is within ± 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.

Because DAVEN makes the most complete, the most accurate line of ATTENUATORS in the world!

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

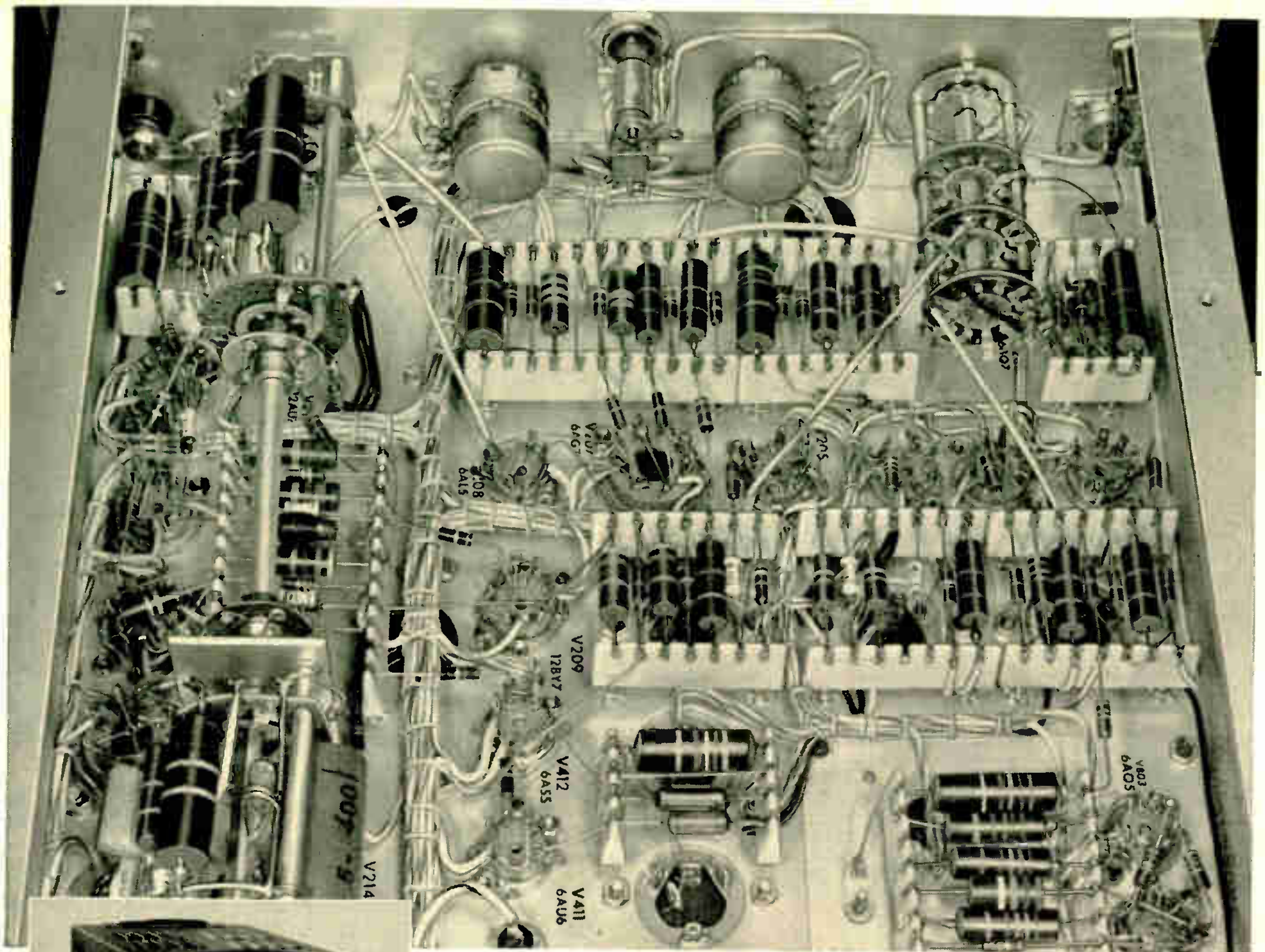
Series 640-RF Attenuation Network

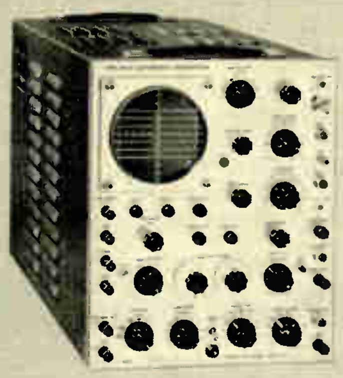
These units are now being used in equipment manufactured for the Army, Navy and Air Force.

Write for Catalog Data.

THE DAVEN CO.

195 Central Avenue
Newark 4, New Jersey





The Tektronix Type 524-D Oscilloscope features a built-in sync separator, variable delayed sweeps at the frame rate, d. c. to 10 mc frequency response, wide sweep range, 4 kv accelerating potential.

TEKTRONIX TYPE 524-D OSCILLOSCOPE

uses 243 Bradleyunits and 21 Bradleyometers

This portable, precision cathode-ray oscilloscope, made by Tektronix, Inc., of Portland, Oregon, is specifically designed for maintenance of television transmitter and studio equipment.

Its network of circuits employs hundreds of Allen-Bradley fixed and adjustable resistors . . . 264 units in all. Since these units are rated at 70C . . . instead of 40C . . . stability of the oscilloscope circuit characteristics is assured.

Bradleyunits and Bradleyometers withstand extremes of temperature and humidity. So, if your electronic equipment must give quality performance, avoid trouble by specifying Allen-Bradley radio resistors.

Allen-Bradley Co., 114 W. Greenfield Ave., Milwaukee 4, Wis.

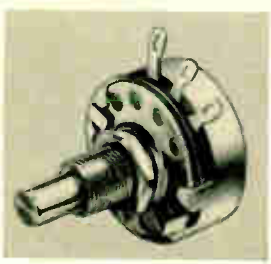
A-B

ALLEN-BRADLEY

FIXED & ADJUSTABLE RADIO RESISTORS

QUALITY

Sold exclusively to manufacturers of radio and electronic equipment



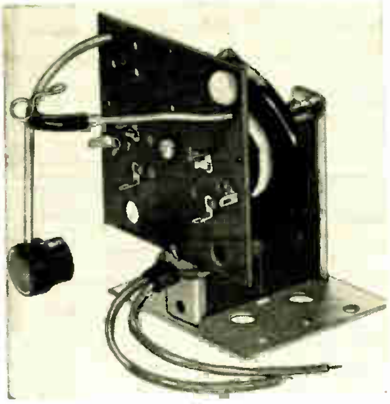
The Type J Bradleyometer has a solid molded resistor ring which can be made to satisfy any resistance-rotation requirement. All ferrous parts are made of corrosion-resistant metal. There are no riveted, welded, or soldered connections in the Bradleyometer.

News—New Products

(Continued from page 40A)

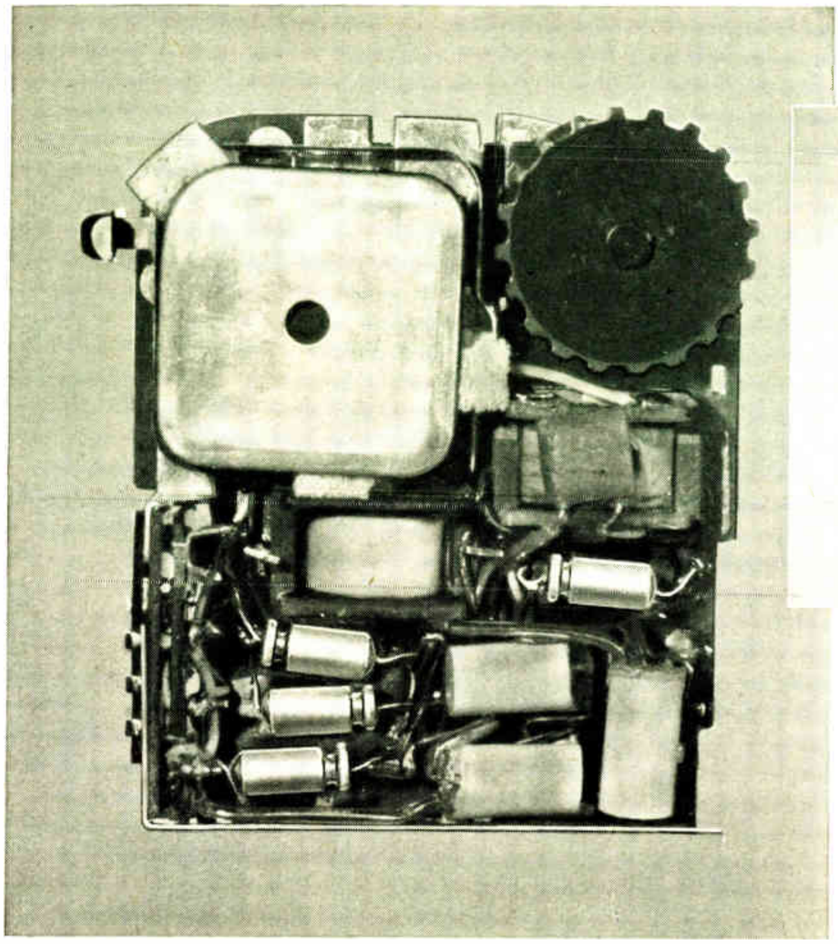
Flyback Replacement

Two new flybacks, FB414 and FB415, have been announced by **Halldorson Transformer Co.**, 4500 N. Ravenswood Ave., Chicago 40, Ill. They are described as specific replacements for over 100 Emerson models and chassis. They are available now at Halldorson distributors.



A notable feature of the entire line, says the manufacturer, is the broad coverage that has been engineered into each component and replacement. As a result, hundreds of models and chassis of various TV brands can be serviced with a minimum of stock.

(Continued on page 48A)



Four G-E Micro-miniature Tantalytic capacitors easily fit into small space provided in this new all-transistor hearing aid. Man above adjusts volume control.

Other applications now being investigated:

WALKIE-TALKIES

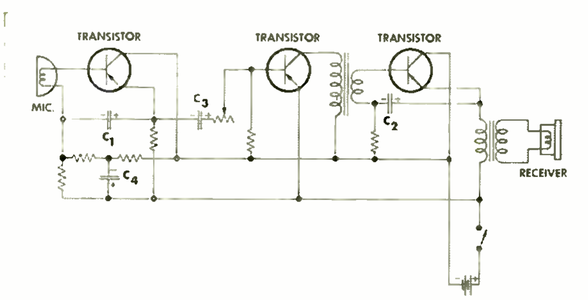
WRIST RADIOS

PAGING SYSTEMS

How Tantalytic Capacitors Are Used In Miniaturized Hearing Aids

Four G-E Micro-miniature Tantalytic capacitors are used in this new all-transistor hearing aid. These high-capacitance, small-size units are necessary due to the low-impedance characteristics of transistors, as compared with the vacuum tubes formerly used. Ceramic and paper dielectric capacitors cannot supply sufficient capacitance in the small size desired, according to hearing aid design engineers.

Pictures, circuit diagram, application information courtesy Sonotone Corp.



Simplified schematic diagram of Sonotone all-transistor hearing aid, showing location of G-E Micro-miniature Tantalytic capacitors.

Operating at a battery voltage of 2.5 volts, this hearing aid uses two units rated at 2 microfarads each for by-pass, C_1 and C_2 (see diagram). They give a low-impedance signal path from the source to the input of the transistor. Two 1-microfarad units, C_3 and C_4, are used for coupling and filtering respectively, where their low leakage current of .18 microamperes/uf/volt at 25 deg. C is especially important.

G-E Micro-miniature Tantalytics can be obtained in ratings up to 20 volts, or, up to 8 uf in a $\frac{5}{16}$-in. long by $\frac{1}{8}$-in. dia. case size, higher capacitance in a $\frac{1}{2}$-in. long by $\frac{1}{8}$-in. dia. case size. Capacitance tolerance is -0% to $+100\%$.

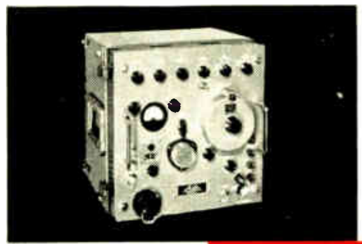
For more information about G-E Micro-miniature Tantalytic capacitors, contact your G-E Apparatus Sales Office or write for bulletin GEA-6065 to General Electric Company, Section 442-15, Schenectady 5, New York.

GENERAL ELECTRIC

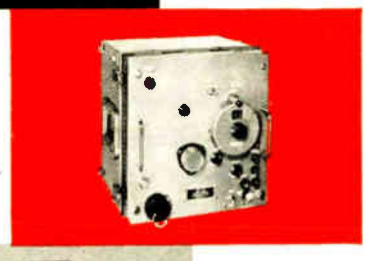
12,800 TO 50,000 MC

integrated equipment for

Extremely **H**igh **F**requencies



SIGNAL GENERATORS



SIGNAL SOURCES

SPECTRUM ANALYZERS

Now, Polarad has applied its advanced engineering techniques to produce **fully self-contained** microwave test equipment for use in the Extremely High Frequency region––12,800 to 50,000 MC.

This new line of Signal Generators, Signal Sources, and Spectrum Analyzers is designed to save engineering manhours in the laboratory and on production lines—obviating experimental test set-ups.

The Extremely High Frequency Polarad Signal Generator, for example, furnishes monitored power output as well as measures external signal strength and frequency.

Highest accuracy and reliability of operation are assured by careful engineering and the use of highest quality components. For complete information write to your nearest Polarad representative or directly to the factory.

	SIGNAL GENERATORS		SIGNAL SOURCES		SPECTRUM ANALYZERS		
Frequency Range	Model Number	Output Power	Model Number	Power Output (Average)	Model Number	Sensitivity (Signal=Noise)	Dispersion (Average)
12.8 to 17.5 KMC	SG 1218	−10 DBM	SS 1218	15 mw	SA 1218	−70 DBM	30 MC
15.75 to 16.25 KMC	SG 1516*	−6 DBM	SS 1516	5 mw	SA 1516	−70 DBM	45 MC
16.25 to 16.75 KMC	SG 1617*	−6 DBM	SS 1617	5 mw	SA 1617	−70 DBM	45 MC
18.0 to 22.0 KMC	SG 1822	−10 DBM	SS 1822	10 mw	SA 1822	−60 DBM	40 MC
22.0 to 25.0 KMC	SG 2225	−10 DBM	SS 2225	10 mw	SA 2225	−60 DBM	40 MC
24.7 to 27.5 KMC	SG 2427	−10 DBM	SS 2427	10 mw	SA 2427	−60 DBM	40 MC
27.27 to 30.0 KMC	SG 2730	−10 DBM	SS 2730	10 mw	SA 2730	−60 DBM	45 MC
29.7 to 33.52 KMC	SG 3033	−10 DBM	SS 3033	10 mw	SA 3033	−60 DBM	45 MC
33.52 to 36.25 KMC	SG 3336	−10 DBM	SS 3336	9 mw	SA 3336	−50 DBM	45 MC
35.1 to 39.7 KMC	SG 3540	−10 DBM	SS 3540	5 mw	SA 3540	−50 DBM	45 MC
37.1 to 42.6 KMC	External Source Power Measurement Range: +6 to +30 DBM Accuracy with Correction: ±2 DB		SS 3742	Approx. 3 mw	I.F. Gain Control: 0 to 40 DB I.F. Band Width: 50 KC Sweep Frequency: 5 to 40 CPS		
41.7 to 50.0 KMC			SS 4150	Approx. 3 mw			

Modulation: All units except the SG 1516* and SG 1617* can be modulated as follows:

1. Internal
   1000 CPS Square Wave
2. External
   a. Pulse
      Pulse Width: 0.5 to 10 Microseconds
      PRF: 100 to 10,000 CPS
      Pulse Amplitude: 10 volts Pk to Pk Min.
      Polarity: Positive
   b. Sawtooth or Sinusoidal
      Frequency: 100 to 10,000 CPS
      Amplitude: 15 Volts RMS Min.

*Internal variable pulse and FM modulation

Polarad ELECTRONICS CORPORATION 100 METROPOLITAN AVENUE, BROOKLYN 11, NEW YORK

REPRESENTATIVES • Albuquerque • Atlanta • Boston • Chicago • Cleveland • Fort Worth • Kansas City • Los Angeles • New York • Philadelphia • San Francisco • Seattle • St. Paul • Syracuse • Washington, D. C. • Canada, Arnprior—Export: Rocke International Corporation

For lighter, more compact, Servo Systems

THE NEW

KEARFOTT

PENNY SIZE

SYNCHROS

Accurate . . . Rugged
Dependable

PERFORMANCE DATA

	TRANSMITTER	CONTROL TRANSFORMER
PRIMARY EXCITATION	26 VOLTS 400 CYCLES	11.8 VOLTS 400 CYCLES
INPUT CURRENT	95 Ma	137 Ma
INPUT IMPEDANCE	274/75° Ohms	82/68° Ohms
OUTPUT SECONDARY	11.8 VOLTS	23.5 VOLTS
RESIDUAL (NULL) VOLTAGE	40 Mv RMS 20 Mv Fund	40 Mv RMS 20 Mv fund
SENSITIVITY	200 Mv/Degree	400 Mv/Degree
WEIGHT	1.75 Oz.	1.75 Oz.
MAXIMUM ERROR from EZ	10 Minutes	10 Minutes

Kearfott now offers from production the smallest, accurate line of Synchros available. These Transmitters and Control Transformers, Resolvers and Differentials, conform to Navy BuOrd. Size 8. Integrally cast stator and stainless steel housing assemblies permit straight through bores, eliminating the fundamental errors of eccentricity; providing ruggedness and environmental resistance to these components.

KEARFOTT COMPONENTS INCLUDE:

Gyros, Servo Motors, Synchros, Servo and Magnetic Amplifiers, Tachometer Generators, Hermetic Rotary Seals, Aircraft Navigational Systems, and other high accuracy mechanical, electrical and electronic components.

Technical Data Sheets on these and other Synchros in various size ranges and for special applications available. Send for them today.

Kearfott
SINCE 1917

KEARFOTT COMPANY, INC., LITTLE FALLS, N. J.

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Midwest Office: 188 W. Randolph Street, Chicago, Ill. South Central Office: 6115 Denton Drive, Dallas, Texas
West Coast Office: 253 N. Vinedo Avenue, Pasadena, Calif.

A GENERAL PRECISION EQUIPMENT CORPORATION SUBSIDIARY

VECTRON

PRECISION LINEAR WIRE-WOUND POTENTIOMETERS

GENERAL SPECIFICATIONS

Over-all Resistance: 50 ohms to 50,000 ohms
Resistance Tolerance: ± 5% standard (±2% or ±1% if specified)
Independent Linearity: ± 1% standard (±0.5% or ±0.25% if specified)
Temperature Coefficient of Resistance Wire: 0.00002 parts per °C, above 250 ohms 0.0007 parts per °C, 250 ohms or less
Power Dissipation: Nominal dissipation rating. 2 watts at 25°C. Rated 5 watts to 5°C under specific conditions
Electrical Rotation: 320° ± 5° standard to 357 ± 1° if specified
Resolution: Optimum—based on resistance
Terminal Assembly: Treated, electrical grade, laminated phenolic with gold-plated terminals.

Always to Your Specifications

From Vectron's three basic Potentiometer styles, 7/8" diameter, 1 1/16" diameter and 2" diameter, units can be made to suit your individual requirements. Multiple ganged units with individual phasing, special stops and even specially tapped units supplied to order, individually or in quantity. Additional new sizes and new types are being prepared as this publication goes to press. Standard shafts supplied in any length or detail; special bushings and shaft locks to order.

High Linearity — Superior Performance

Vectron Potentiometers provide superior performance. Uniformity and linearity far beyond normal specification requirements are the result of long experience. Close tolerances and special processing insure minimum run-out and bearing angularity.

FOR FULL INFORMATION
Write for Vectron's Potentiometer Bulletin

Precision Components Section

VECTRON, inc.

Electronic and Electro-Mechanical Equipment

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VECTRON FOR DESIGN AND MANUFACTURE OF:

Gyros and Gyro Systems	Precision Mechanical Devices
Gyro Stabilized Platforms	Computers and Calculators
Servo and Gyromechanisms	Special Gears and Assemblies
Aircraft Instruments	Synchros and Control Motors

News—New Products

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

(Continued from page 43A)

Distortion Meter

Freed Transformer Co., Inc., 1715 Weirfield St., Brooklyn (Ridgewood) 27, N. Y., has available for immediate delivery its new Model 1410 Distortion Meter.

Model 1410 has the following specifications: frequency range, 20 kc to 1 mc in ten overlapping ranges; distortion range, 0.1 per cent to 30 per cent. The input level range allows signal levels from 0.2 to 1,000 volts to be measured directly. An accuracy of 0.1 per cent is obtained at signal levels as low as 0.2 volts.

Residual signal is measured by high gain VTVM with flat response up to 3 mc. Model 1410 has a low-impedance, distortionless preamplifier with monitoring circuit. A null T network assures complete attenuation of fundamental.

This unit is self-contained and operated. Isolation transformer and line filter are provided to prevent any feedback through power line. For information and prices on this or any other Freed models, write the manufacturerer.

Catalog on Tape Wound Cores

Magnetics, Inc., Butler, Pa., now offers a new Tape-Wound Core Catalog listing new and unusual material on their standard line and specialty cores.

Catalog TWC-100, "Performance-Guaranteed Tape Wound Cores," describes the physical and magnetic constants of over 1,100 standard sizes of toroidal cores, and construction descriptions which include hydrogen annealing, tape winding, and protective boxing.

A table of basic physical constants of common magnetic materials and one on trade names of similar materials together clarify some of the confusion which has arisen in the industry from the use of various trade names for similar materials. Production core testing and the Magnetics, Inc., core-matching service are described.

The catalog includes 10 pages of curves. These curves include superimposed typical dc hysteresis loops and 60-cycle dynamic loops for Hy Mu 80, 48 Alloy, Orthonol and Magnesil, as well as typical hysteresis loops, ac dynamic loops and 60-cycle dynamic (with constant supply voltage and variable reset) loops for all of these materials.

(Continued on page 55A)

for critical voltage applications . . .

RMC HIGH VOLTAGE DISCAPS®

CAPACITY	DIELECTRIC	SIZE	AVAILABLE CAPACITY TOLERANCES
	2-KV		
331-470	1200-K	9/16"	±20% GMV
471-1000	1200-K	5/8"	±20% GMV
1001-2700	HI K	9/16"	GMV
2701-5000	HI K	3/4"	GMV
5001-10000	HI K	3/4"	GMV
	3-KV		
220-500	1200-K	5/8"	±20% GMV
501-1000	1200-K	5/8"	±20% GMV
1001-5000	HI K	3/4"	GMV
	4-KV		
181-680	1200-K	3/4"	±20% GMV
681-1000	HI K	5/8"	GMV
	5-KV		
131-330	1200-K	7/8"	±20% GMV
331-1000	HI K	7/8"	GMV
	6-KV		
101-220	1200-K	3/4"	±20% GMV
221-470	1200-K	7/8"	±20% GMV
221-1000	HI K	7/8"	GMV
471-1000	HI K	7/8"	GMV

POWER FACTOR: 1.5% Max. @ 1 KC (initial)
INSULATION: Durez phenolic—vacuum waxed

Discaps with a dielectric of 1200 K or over are not recommended for deflection yokes or other 15,750 cycle applications.

HIGH VOLTAGE DISCAPS
for yoke and other applications

RMC DISCAPS assure the voltage safety factor required in deflection yoke or special electronic applications. These RMC high voltage DISCAPS are rated at 2000, 3000, 4000, 5000, and 6000 volts DC.

Now available in any capacity between 5 MMF and 10000 MMF, their smaller size and lower initial cost offer definite production ease and overall savings.

If you want proof that DISCAPS are the outstanding ceramic capacitors write us about your specific requirements and we will forward samples.

CAPACITY	DIELECTRIC	SIZE	AVAILABLE CAPACITY TOLERANCES
	2-KV		
5-47	N-750	5/16"	5-10-20% GMV
48-68	N-750	1/2"	5-10-20% GMV
69-82	N-750	5/8"	5-10-20% GMV
83-130	N-750	5/8"	5-10-20% GMV
131-200	N-1500	5/8"	5-10-20% GMV
201-250	N-1500	3/4"	5-10-20% GMV
251-330	N-1500	7/8"	5-10-20% GMV
	3-KV		
5-15	N-750	5/16"	5-10-20% GMV
16-20	N-750	1/2"	5-10-20% GMV
21-56	N-1500	5/8"	5-10-20% GMV
57-180	N-1500	5/8"	5-10-20% GMV
181-240	N-1500	3/4"	5-10-20% GMV
241-330	N-1500	7/8"	5-10-20% GMV
	4-KV		
5-68	N-1500	7/8"	5-10-20% GMV
69-180	N-1500	7/8"	5-10-20% GMV
	5-KV		
5-30	N-1500	5/8"	5-10-20% GMV
31-60	N-1500	3/4"	5-10-20% GMV
61-130	N-1500	7/8"	5-10-20% GMV
	6-KV		
5-20	N-1500	3/4"	-10-20% GMV
21-100	N-1500	7/8"	-10-20% GMV

POWER FACTOR: .1% Max. @ 1 M C (initial)
INSULATION: Durez phenolic—vacuum waxed

DISCAP CERAMIC CAPACITORS

RMC

RADIO MATERIALS CORPORATION
GENERAL OFFICE: 3325 N. California Ave., Chicago 18, Ill.
FACTORIES AT CHICAGO, ILL. AND ATTICA, IND.
DISTRIBUTORS: *Contact* Jobbers Sales Co., P. O. Box 695, Fairlawn, N. J.

For Automatic Assembly plus Easy Inventory and Storage

TRADE **ERIE** MARK

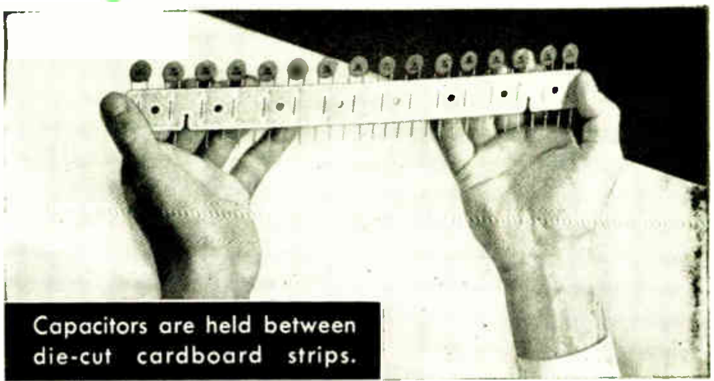
Pallet-Pak

NEW PACKAGING METHOD FOR DISC CERAMICONS®

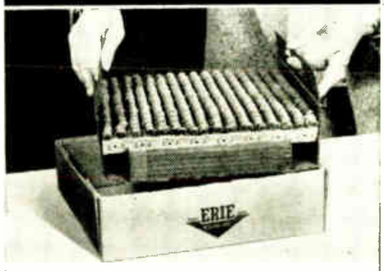
Pallet-Pak, ERIE's exclusive new packaging method for Disc Ceramicons, answers the need for mechanically pre-aligned capacitors that can be fed into automatic assembly machinery. Hand assembly is also improved because of the ease of handling and the physical uniformity of the capacitor.

ERIE is constantly searching for new ways to assist manufacturers in reducing production costs. Pallet-Pak is a development by ERIE Industrial Engineers with this purpose in mind.

The many other advantages of Pallet-Pak are noted at right. Write for our Pallet-Pak Bulletin with complete illustrations and advantages of this new packaging method that is currently available on a portion of ERIE Disc Ceramicon production.



Capacitors are held between die-cut cardboard strips.

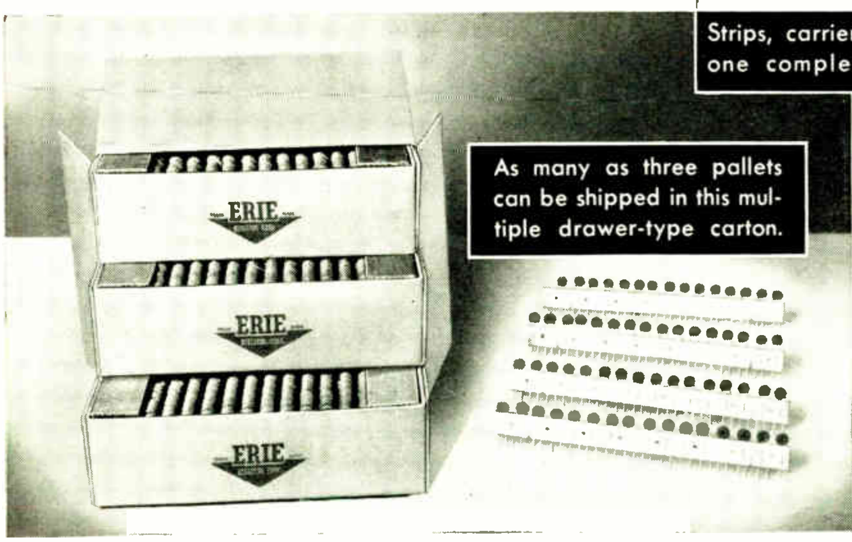


Strips are placed in carrier insert which fits in pallet.

Strips, carrier, and pallet form one complete shipping unit.

ADVANTAGES FOR INVENTORY AND STORAGE

- Known number in strip makes inventory control easier.
- Count empty strips—multiply by number for usage control.
- Markings all face one direction for easy identification.
- Drawer type disposable pallet for storage and shipping.



As many as three pallets can be shipped in this multiple drawer-type carton.

ADVANTAGES FOR YOUR PRODUCTION

- Straight lead wires—no tangling—units easily removed by pulling from strip.
- Uniform lead length.
- Carrier insert acts as tote-tray for easy handling.
- Index holes in strip 1½" center to center for use in lead forming and cutting equipment.
- Index holes are above carrier sides—rods can be inserted through holes and entire lot lifted easily in one operation.
- Assurance of uniform quality, resulting from continuous production flow.

TRADE **ERIE** MARK
RESISTOR CORP.

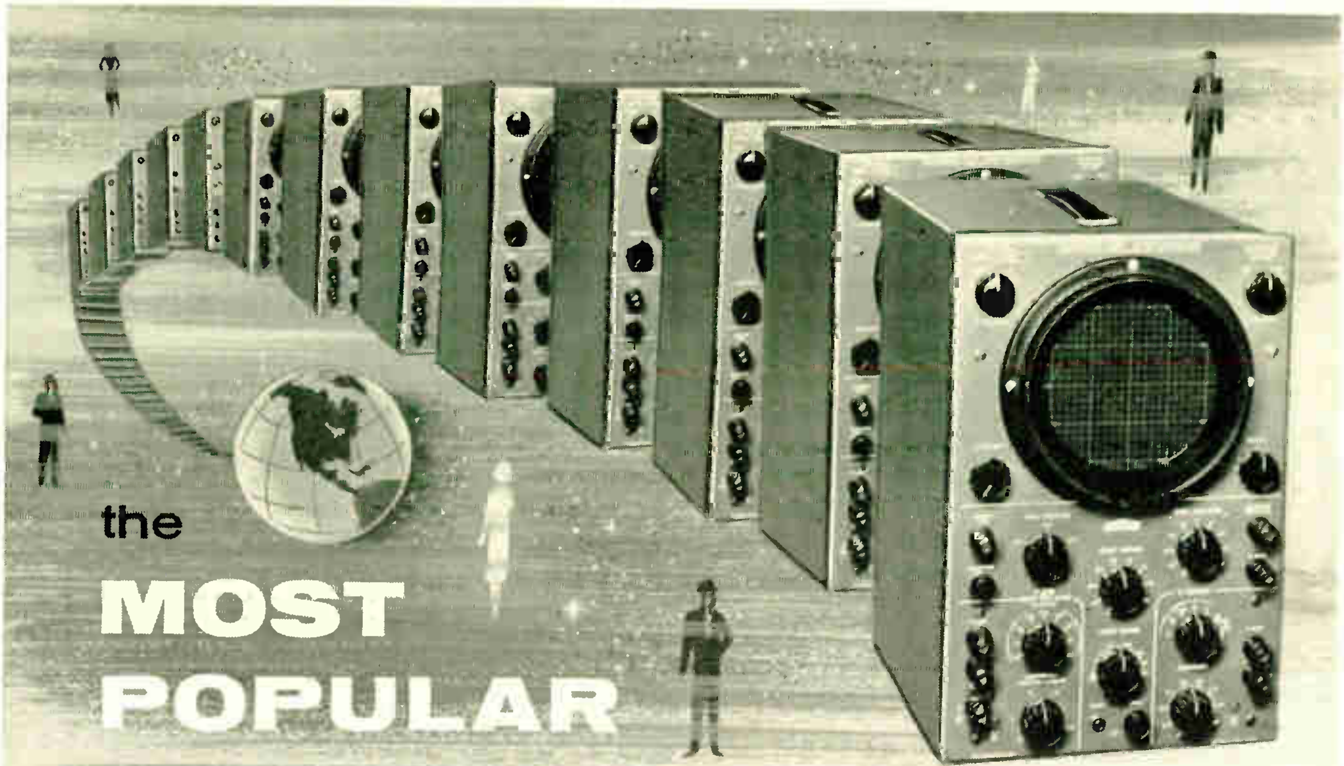
ERIE RESISTOR CORPORATION . . . ELECTRONICS DIVISION

Main Offices and Factories: **ERIE, PA.**

Sales Offices: Cliffside, N. J. • Camden, N. J. • Chicago, Ill. • Detroit, Mich. Cincinnati, Ohio • Fort Wayne, Ind. • Los Angeles, Calif. • Toronto, Ontario

Manufacturing Subsidiaries:

HOLLY SPRINGS, MISSISSIPPI • LONDON, ENGLAND • TRENTON, ONTARIO



the MOST POPULAR OSCILLOGRAPH EVER MADE

type 304-A

Superlative performance and almost legendary dependability have won for the Type 304-A the envied position of the most popular oscillograph ever produced. With the possible exceptions of its honored predecessors, the Types 304-H, 304, and 208, no other oscillograph has found such immediate acceptance, nor is used so broadly in all phases of science and industry. *More Type 304-A's are in use—in laboratories, in service shops and on production lines—than any other cathode-ray oscillograph.*

The reason for this world-wide popularity? The accompanying list of features will tell you. No other instrument can provide such versatile, dependable performance at such a low price.

FOR FULL SPECIFICATIONS WRITE
THE **TECHNICAL SALES DEPARTMENT**
AT THE ADDRESS BELOW.

DU MONT

Allen B. Du Mont Laboratories, Inc.
760 Bloomfield Ave., Clifton, N. J.

- **HIGH SENSITIVITY** — Deflection factor of 100 p-p mv full scale (equivalent of 25 p-p mv per inch) provides useful deflection from almost every signal encountered in general laboratory work, without need for preamplification.
- **DIRECT VOLTAGE MEASUREMENTS** — Push-button calibration enables accurate amplitude measurement of any portion of input signal directly in volts from the scale.
- **FLAT-FACE TIGHT-TOLERANCE CATHODE-RAY TUBE**—Precision built Du Mont Type 5ADP Cathode-ray Tube assures faithful display and minimizes parallactic errors.
- **HIGH ACCELERATING POTENTIAL** — Overall acceleration of 3000 volts assures brilliant trace with excellent spot size, and provides maximum efficiency of long-persistence screens.
- **D-C OR A-C AMPLIFICATION** — Vertical frequency response is flat from d-c to 10% down at 100,000 cps and 15% down at 30,000 cps *with no possible slope*.
- **DRIVEN AND RECURRENT SWEEPS** — Variable in frequency from 2 to 30,000 cps
- **SWEEP EXPANSION** — Up to 6 times full screen diameter for study of high frequency components or low frequency signals.
- **EXTRA-LOW-FREQUENCY SWEEPS** — By addition externally of high quality capacitors very slow sweeps may be generated for the display of long-duration functions.
- **STABILIZED SYNCHRONIZATION** — For stable presentations without horizontal jitter and for reliable driven-sweep operation; Sync limiting on both driven and recurrent sweeps eliminates possibility of pattern distortion owing to "over-syncing".

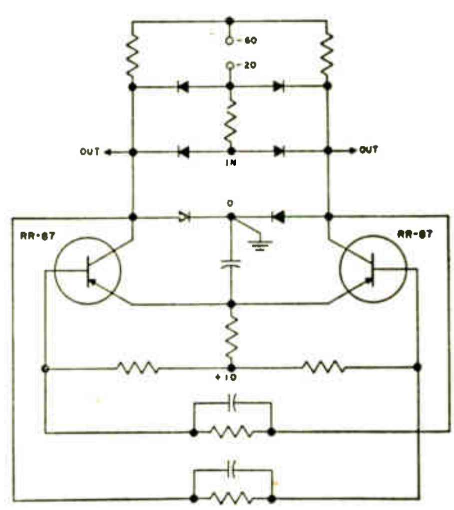
PRICE $375

Vanquish vacuum tubes in computer circuits
AFTER 3000 GRUELING TEST HOURS

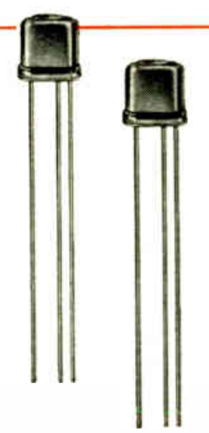
NOT A SINGLE FAILURE! More than 200 of Radio Receptor Co.'s PNP diffused junction transistors, Type RR87, are giving tangible evidence they are really reliable. All the original units are *still performing after 600,000 transistor hours* in a computing machine development project now underway at one of the country's largest research centers.

Where short-lived vacuum tubes used to conk out one by one at a prohibitive rate, tiny RRco. *transistors* are proving their life-span far exceeds the bulky tubes in flip-flop, gates and other pulse circuits. What's more, these efficient transistors are "potted" in sub-assemblies, not removeable from the computer mechanism except as a unit. They *have* to be good!

When the RRco. trademark appears on transistors, diodes or selenium rectifiers you can always be sure they are *really reliable* . . . if you'd like guidance from our engineering group specializing in transistor circuitry, just write us now.



TYPICAL CLAMPED FLIP-FLOP CIRCUIT

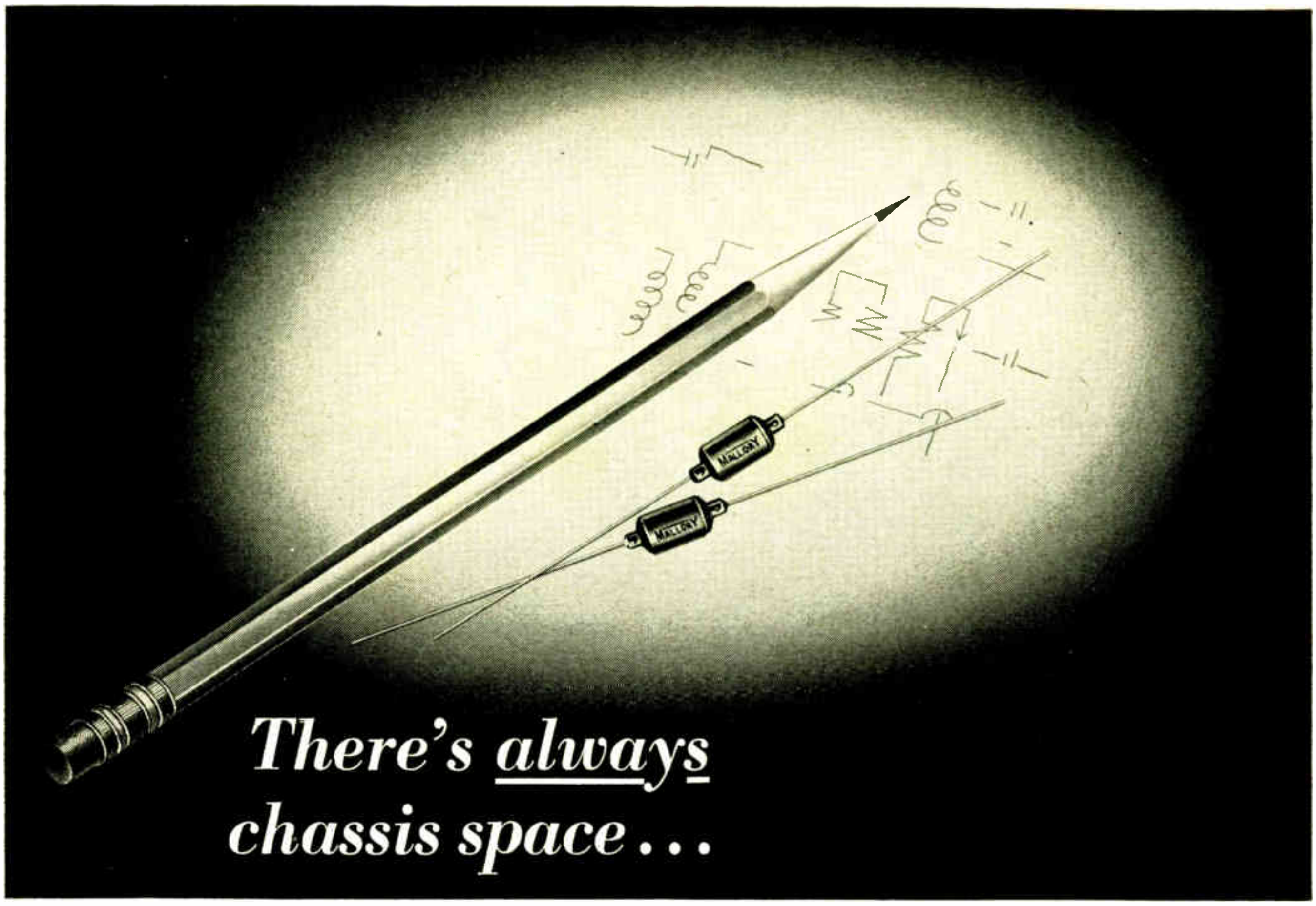


IN RADIO &
ELECTRONICS
SINCE 1922

Another RRco. computer transistor recently developed is Type RR83. Ask for complete information regarding this as well as RR87.

RADIO RECEPTOR COMPANY, INC.
Seletron and Germanium Division

SALES OFFICES: 251 WEST 19th STREET, NEW YORK 11, N. Y., WATKINS 4-3633, FACTORIES IN BROOKLYN, N. Y.



For Silverlytic Subminiature Capacitors

Compare these characteristics of Type ALA Silverlytic Capacitors

Ratings available:

4 mfd.	4 volts DC max.
2 mfd.	5 volts DC max.
1 mfd.	10 volts DC max.
.5 mfd.	10 volts DC max.
.3 mfd.	10 volts DC max.
.2 mfd.	10 volts DC max.
.1 mfd.	10 volts DC max.

Temperature range: —30° to +65° C.
(other types for —55° to +85° C. available)

Capacity tolerance: —10% to + infinity
Max. leakage current: 2 microamps. after 5 min. at rated voltage

When you're designing transistor circuits and other miniature electronic equipment, Mallory Silverlytic Capacitors are a space-saving solution to your low-voltage capacitor problems. They provide high capacitance in a case so small that it fits into the tightest chassis layouts. They're only 7/32 inch in diameter and 3/8 inch long.

Silverlytics can be mounted by their leads with complete assurance of reliable operation. An improved method of attaching the axial lead wires eliminates the danger of intermittent open circuits under normal production line handling and service vibration.

An outstanding product of Mallory's continuing program of research in the field of transistor circuit components, Silverlytics offer electrical characteristics comparable with those of larger electrolytics. Our new Technical Bulletin gives complete data on these newest members of the Mallory line of electrolytic capacitors that have set the standard of the electronic industry. Write for your copy today.

***Expect more . . . Get more from* MALLORY**

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Electromechanical—Resistors • Switches • Television Tuners • Vibrators
Electrochemical—Capacitors • Rectifiers • Mercury Batteries
Metallurgical—Contacts • Special Metals and Ceramics • Welding Materials

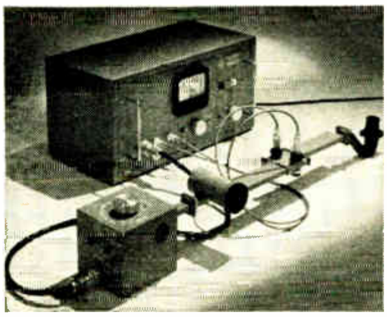
News—New Products

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

(Continued from page 48A)

X-Band VSWR Meter

Laboratory or production-line testing of waveguide components is performed rapidly with the new Model 110A CTI S-Band Voltage Standing Wave Ratio Indicator developed by **Color Television Inc.**, E. San Carlos Ave., San Carlos, Calif. Covering a frequency band from 8,500 to 9,600 mc, the new unit is said to offer a number of advantages over slotted-line measuring techniques.



The instrument includes an oscillator, a wavemeter to supplement the approximate direct-reading dial of the oscillator, a forward and reversed directional coupler with bolometer take-offs for source and reflected power, and a direct-reading ratiometer having dual scales calibrated directly in VSWR, 1.06 to 1.3 and 1.3 to 2.5.

Permitting continuous coverage of the frequency band, the Model 110A overcomes the difficulty of missing points inherent in point-by-point measurements. The simplicity of the unit facilitates its use by unskilled personnel, making it excellent for production go/no-go tests. Other advantages include, in addition to the speed of operation, the absence of probe or slot error, and the fact that no readjustments are necessary for frequency changes, nor is the reading affected by changes in rf power.

Duo Channel Differential Amplifier

Type 501, a wide-band amplifier which will convert a differential signal into a single-ended signal, is available from **Advance**

Electronics Co., Inc., 451 Highland Avenue, Passaic, N. J.

(Continued on page 56A)

News—New Products

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

(Continued from page 55A)

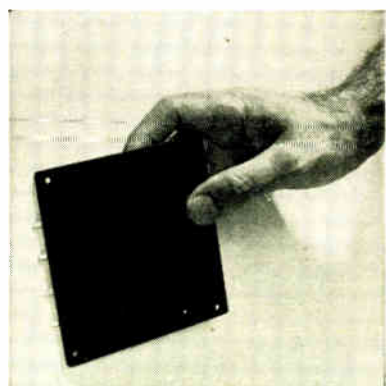
This amplifier consists of two identical channels and an output voltmeter for indicating the potential of the output signal. Each channel has a high differential ratio amplifier stage and a balance-to-unbalance converter with no transformer. As a result, the degree of rejection of the common-mode signal can be made very high over a wide frequency range.

The ratio of the amplification for differential signals to that of common-mode signals is over 38×10^6 from 8 cps to over 500 kc. The frequency response is flat within 3 db from 2 cps to 1 mc. The voltage amplification is approximately 30. The input impedance is 2.7 megohms shunted with 15 $\mu\mu$f from any input terminal to ground; 5.4 megohms shunted with 10 $\mu\mu$f between two off-ground terminals. The output impedance is approximately 300 ohms. Power input is 115 volt, ± 10 per cent, 50/60 cycles, 60 watts for both channels.

Price is $265.00.

Heat-Flow Transducer

Heat-flow measuring instrumentation based on the Model 200 Heat-Flow Transducer which can directly drive indicating or recording meters, is announced by **Beckman & Whitley, Inc.**, 963 San Carlos Ave., San Carlos, Calif. This is possible because of the high linear electrical output relative to the heat-flow gradient across the transducer. The high electrical output results from a large area-density of silver-constantan thermocouple junctions whose output can be connected in various physical and electrical configurations depending upon requirements.



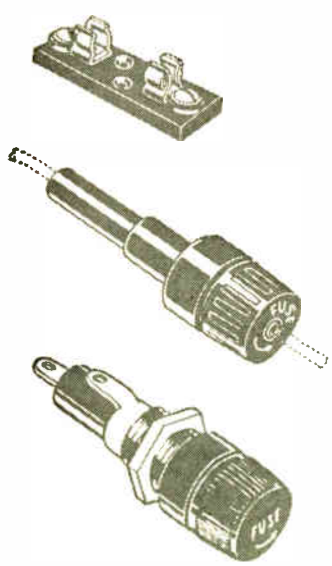
Based on a unit $\frac{3}{64}$ by $4\frac{1}{2}$ by $4\frac{1}{2}$ inches containing from 180 to 720 junctions plus a thermocouple to check ambient temperature, the transducers are made in a range of sensitivities up to 6 btu/ft²/hr/mv. Each transducer weighs approximately one ounce and has thermopile and thermocouple terminals brought out to one edge.

Among the specific applications of the new transducers are total-hemispheric and net-exchange radiometers, portable heat-flow meters, and soil heat-flow recorders.

(Continued on page 59A)

"FUSES?

There's BUSS — the one Source for all FUSES."



For your exact fuse needs, there's a BUSS fuse. A complete line of fuses for the Electronic Industries — in sizes from 1/500 amperes up . . . plus a companion line of fuse clips, blocks and holders.

Besides meeting your specifications, BUSS fuses are known for their ability to give accurate and dependable electrical protection under all service conditions.

To make sure that a BUSS fuse will never let you down — every BUSS fuse normally used by the Electronic Industries is tested in a sensitive electronic device that rejects any fuse that is not correctly calibrated, properly constructed and right in all physical dimensions.

That's why manufacturers and service organizations throughout the nation rely on BUSS as the one source for fuses of unquestioned high quality.

Should you have a special problem in electrical protection, let BUSS save you engineering time. The world's largest fuse research laboratory and its staff of engineers are at your service to help you select the fuse best suited for your device — and if possible, a fuse available from local wholesalers' stocks.

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

FUSETRON
TRUSTWORTHY NAMES IN ELECTRICAL PROTECTION
BUSS

For more information mail this Coupon ▶

BUSSMANN Mfg. Co. (Division of McGraw Electric Co.)
University at Jefferson, St. Louis 7, Mo.

Please send me bulletin SFB containing facts on BUSS small dimension fuses and fuse holders.

Name ____________

Title ____________

Company ____________

Address ____________

City & Zone ____________ *State* ______ IRE-654

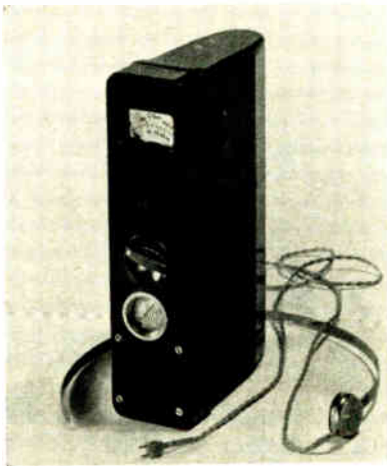
News—New Products

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

(Continued from page 56A)

Radiation Detector

A new, light-weight radiation detector (PW 4010) that fits in a man's pocket is available from the **Research & Control Instruments Div., North American Philips Co.,** 750 S. Fulton Ave., Mount Vernon, N. Y.



The unit is approximately 1.7 inches thick, 4.1 inches wide, 6.6 inches high, weighs about 25 ounces, and is designed for locating sources of beta and gamma radiation. It is useful for measuring the radiation exposure of laboratory workers and for checking intensity levels during research investigations.

The new radiation detector has a 1.5-volt pen-light-type filament battery, two 30-volt miniature-type anode batteries and a 15-volt subminiature-type grid bias battery.

The unit employs a halogen-quenched counter tube (type 18502) that operates at 350 volts, and a special diode-pentode oscillator tube (type 95106). The main switch has six positions: off, start, low sensitivity, high sensitivity, anode voltage, and filament voltage. Calibration switch has four positions: anode battery off, anode voltage 60 volts, anode voltage 55 volts, and anode voltage 47.5 volts.

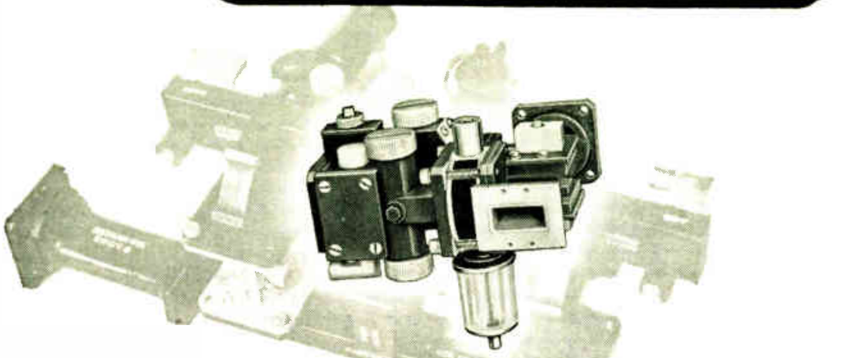
Bulletin on Balanced Mixers

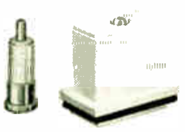
A new 6-page technical bulletin on the relatively new art of microwave-balanced-mixer design has been published by **Airtron, Inc.,** 1103 W. Elizabeth Ave., Dept. A, Linden, N. J.

Designated Technical Bulletin T-2600, the new publication provides much of the basic theoretical and design information needed by the radar or commercial microwave relay engineer in choosing the proper waveguide mixer for his particular application.

Among the many balanced mixers designed and developed at Airtron, the company has standardized certain basic types which have demonstrated reliable performance characteristics in the majority of

(Continued on page 60A)





News—New Products

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

(Continued from page 59A)

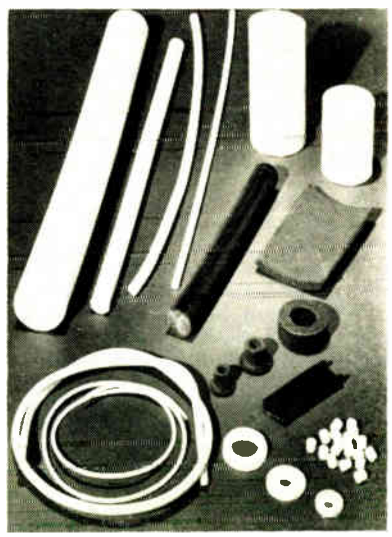
applications. Where the mixer crystals are mounted directly in the waveguide structure, Conventional Magic Tee, Modified Magic Tee, Folded Hybrid and Short Slot Hybrid Mixers are offered. Where the crystals are mounted in a coaxial structure, both Dual Balanced Mixers (two AFC crystals) and Single Balanced Mixers (single ended AFC output) are offered.

A general theory of operation in the Bulletin covers the design principles on which all these types are based. In addition, each mixer is individually described as to construction, operating characteristics, and applications.

Copies of Technical Bulletin T-2600 may be obtained without charge.

Teflon-Rulon Sample Kit

For experimental use by designers and engineers who are investigating the properties of the new fluorocarbon plastics, **Dixon Corp.**, Bristol, R. I., provides a sample kit containing a pound or more of the company's products. Included in the kit are specimen shapes of both Teflon (Du Pont trademark) and Rulon, a special bearing material developed by Dixon to be "slippery throughout, from outer skin to inner core."



Contents of the sample kits vary from box to box, but always consist of at least four inches of Rulon rod, a machined piece of Rulon, extruded Teflon rod (including one piece 12 inches long and one at least 1 inch in diameter), extruded Teflon tubing, small Teflon molded and machined samples, and Teflon spaghetti tubing.

Sample kits may be ordered in any quantity, at $10 each. Also available free on request are technical data sheets covering characteristics and typical applications of Teflon and Rulon.

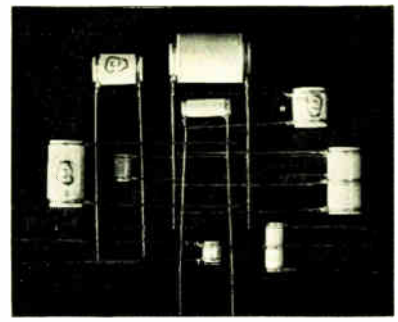
(Continued on page 62A)

News—New Products

(Continued from page 60A)

Non-Inductive Resistors

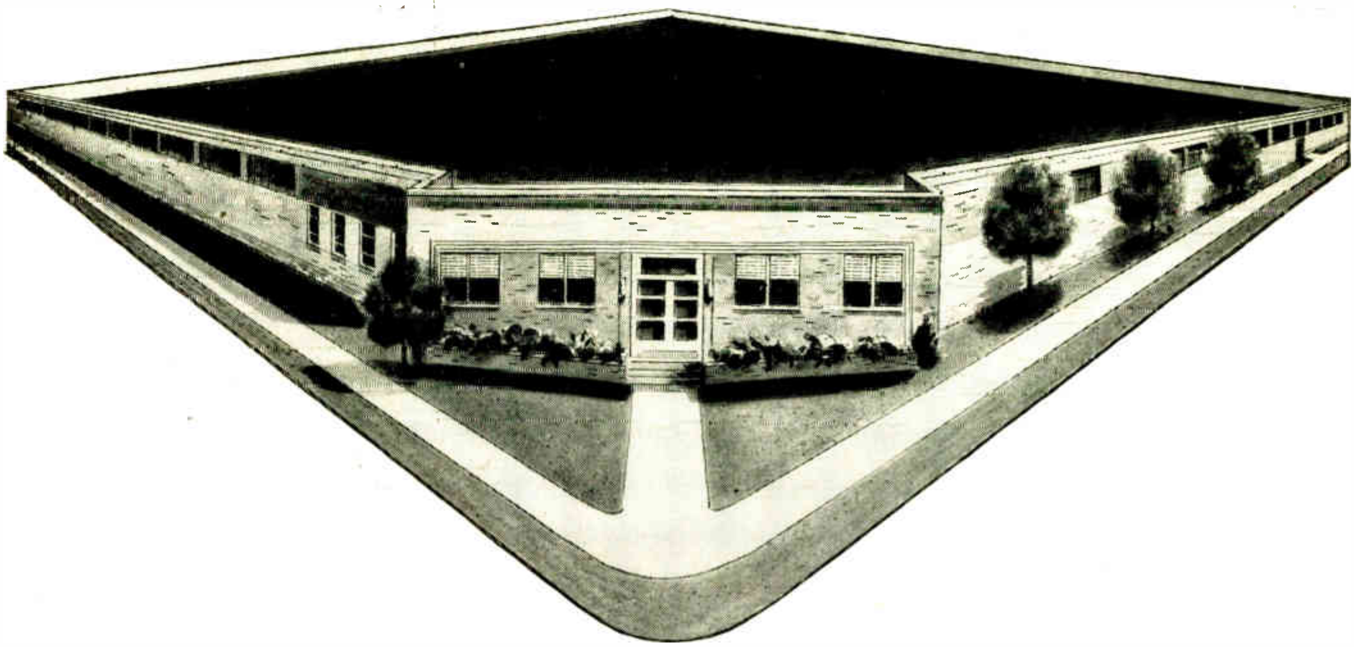
Available in exact resistance values to accuracies of 1, 0.5 and 0.1 per cent, a new line of precision resistors is offered in a series of standard value ranges from 0.1 ohm to 1 megohm, by the **K-F Development Co.,** 2689 Spring St., Redwood City, Calif.



Wound noninductively on non-hygroscopic ceramic bobbins and impregnated for moisture protection, these units exhibit low thermal emf and a temperature coefficient of 0.000025 ohms/°C. Nine sizes are supplied ranging in power capability from ½ to 1 watt; in diameter from ¼ to ¾ inches, and in length from 5/16 to 1¼ inches.

In the standard units, values under 800 ohms are wound of Manganin wire while values over 800 ohms are supplied in Evanohm.

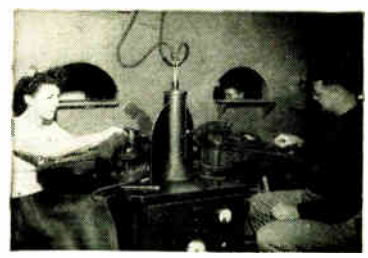
(Continued on page 64A)



here's what's behind the  crystal that's so far ahead

The Midland Factory shown above is the world's largest plant devoted exclusively to producing crystals for frequency control. It is equipped with the finest and most complete production and testing machinery ever developed for this purpose. Here Midland pioneered development of crystals for color television, and is now ready for full-scale production.

All this is important to you for just one good reason: Every Midland crystal you use has been produced by such advanced techniques and under such rigid quality controls that you can be sure it will prove its completely reliable quality under every operating stress.



Midland Critical Quality Control extends through every step of crystal production, and includes precise angular control by X-ray. Uniform accuracy is maintained to the millionth part of an inch.

Whatever your Crystal need, conventional or highly specialized,
When it has to be exactly right, contact

Midland MANUFACTURING COMPANY, INC.
Fiberglas Road, Kansas City, Kansas

WORLD'S LARGEST PRODUCER OF QUARTZ CRYSTALS

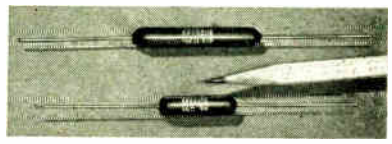
News—New Products

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

(Continued from page 62A)

Miniature Power Wire-Wound Resistors

Two miniaturized self-mounting wire-wound power "Blue Jacket" resistors for use in TV and industrial electronic production where space is a factor have been announced by the **Sprague Electric Co.**, 235 Marshall St., North Adams, Mass.



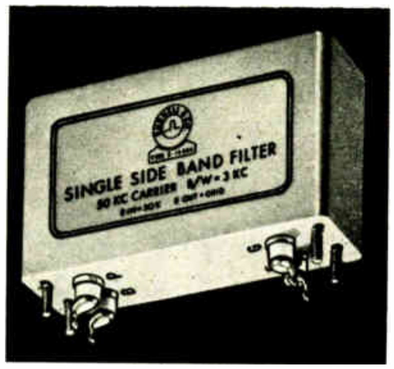
These new axial-lead vitreous enamel Blue Jackets, Types 27E and 28E, are designed for reliability. They are suited for point-to-point wiring, terminal board mounting, and processed wiring boards, fitting well in dip-soldered subassemblies.

These resistors meet RETMA and MIL humidity specifications.

Complete performance data is given in Engineering Bulletin 11-A.

Single-Sideband Filter

Manufacture of a new single-sideband filter for amateur receivers has been announced by **Burnell & Co.**, 45 Warburton Ave., Yonkers, N. Y. The new filter (type S-15000) utilizes a toroid coil instead of the crystal filters formerly required, and is similar to the Burnell SSB filter. The S-15000 is the first low-priced, mass-produced SSB filter for ham receivers.



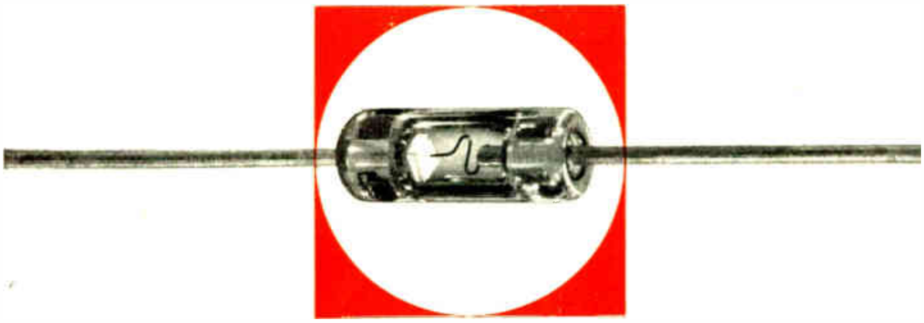
This new filter features compact size and ease of installation. Fixed-tuned and hermetically sealed, it requires no adjustment. It may be installed in any existing amateur receiver now in use, and is also suitable for incorporation into new designs by set manufacturers.

It is expected that it will convert tens of thousands of hams to SSB reception. The S-15000 makes possible long-range reception with reduced interference and distortion, not only of SSB signals, but of any AM transmission. It utilizes 50 kc as a 2nd IF and provides a narrow-band, sharp cut-off response. Price is $35.00.

Descriptive information, including schematic and response curve, is available on request. Write Dept. A3.

(Continued on page 66A)

Hughes *Fusion-Sealed* **Germanium Diodes**



ACTUAL DIMENSIONS DIODE BODY: *0.265 by 0.130 inches (maximum)*

SHUNT CAPACITANCE: *0.5 μμf (maximum)*

AMBIENT OPERATING TEMPERATURE RANGE: *−78° C to +90° C*

Hughes Point-Contact Germanium Diodes are fusion-sealed in a one-piece, gas-tight glass envelope . . . impervious to moisture, fumes or other external contaminating agents. The flexible dumet leads are especially suitable for spot-welding; or they can be iron- or dip-soldered as close as ¼ inch to the diode body—without special precautions.

The germanium crystal is permanently bonded to one lead, the cat whisker is welded to the other, and the point of the cat whisker is welded to the crystal. Hughes diodes are highly resistant to shock and vibration. *Positive* mechanical stability is achieved without risking contamination from fluxes, waxes or impregnants. And—*each diode is thoroughly tested* to ensure the stability of its electrical and physical characteristics. All this means: sturdy, highly reliable diodes.

TYPES—The Hughes line of diodes comprises standard RETMA, JAN, and many special types. Special types are produced according to customer specifications and are tested at high or low temperatures . . . for specific recovery time . . . for matching in pairs or quads.

ELECTRICAL SPECIFICATIONS AT 25° C *unless otherwise indicated*

DESCRIPTION	RETMA or Hughes Type	Clip-In Hughes Type	Peak Inverse Voltage† (volts)	Absolute Maximum Inverse Working Voltage (volts)	Minimum Forward Current @ +1V (mA)	Maximum Inverse Current @ −50V (mA)	Maximum Inverse Current Other (mA)	Other Characteristics
HIGH PEAK	1N55B	HD 2052	190	150	5.0		0.500 @ 150V	
	1N68A	HD 2053	130	100	3.0		0.625 @ 100V	
1 MEG TYPES	1N67A	HD 2054	100	80	4.0	0.050	0.005 @ 5V	
	1N99	HD 2055	100	80	10.0	0.050	0.005 @ 5V	
	1N100	HD 2056	100	80	20.0	0.050	0.005 @ 5V	
500K TYPES	1N89	HD 2057	100	80	3.5	0.100	0.008 @ 5V	
	1N97	HD 2058	100	80	10.0	0.100	0.008 @ 5V	
	1N98	HD 2059	100	80	20.0	0.100	0.008 @ 5V	
	1N116	HD 2060	75	60	5.0	0.100		
	1N117	HD 2061	75	60	10.0	0.100		
	1N118	HD 2062	75	60	20.0	0.100		
GENERAL PURPOSE	1N90	HD 2063	75	60	5.0	0.500		
	1N95	HD 2064	75	60	10.0	0.500		
	1N96	HD 2065	75	60	20.0	0.500		
JAN TYPES	1N126*		75	60	5.0	0.850	0.050 @ 10V	Non-JAN equivalent, HD2070; clip-in, HD2066
	1N127**		125	100	3.0	0.300	0.025 @ 10V	Non-JAN equivalent, HD2071; clip-in, HD2067
	1N128***		50	40	3.0		0.010 @ 10V	Non-JAN equivalent, HD2072; clip-in, HD2068
COMPUTER TYPES	1N191	HD 2077		§	5.0	400K Ω min. between −10 and −50V @ 55°C§		Back resistance recovers to 50K Ω and 400K Ω (200K Ω for 1N192) in 0.5 μsec and 3.5 μsec max., respectively.‡
	1N192	HD 2078		§	5.0	200K Ω min. between −10 and −50V @ 55°C§		
	HD2013				50 @ 1V & 1 @ 0.35V		0.120 @ −3V	0.2 μsec recovery time.°
	HD2014				50 @ 1V & 1 @ 0.35V		0.60 @ −6V	0.2 μsec recovery time.°
UHF	HD2016A	UHF MIXER DIODE						
MISCELLANEOUS	HD2051		125	100	4.0	0.050		1N63 equivalent.

†That voltage at which dynamic resistance is zero when back voltage rises linearly at 90v/sec.
‡Back Recovery Time is measured with a forward pulse of 30mA, followed by a reverse pulse of 35 volts. Loop resistance of test circuit 2500 Ω max.
°Recovery time is that point at which the diode voltage reaches −1V after the initiation of a 6V back pulse through 20K Ω from an initial 3 mA forward bias. Total shunt capacitance is 20 μμf.
§Tested at 55°C. Test voltage is a continuous 60 cps sine wave. Peak Reverse Voltage across the diode is 70V. Peak Forward Voltage not less than +2V or Peak Forward Current not less than 20 mA, whichever occurs first.
**Formerly 1N69A.* ***Formerly 1N70A.* ****Formerly 1N81A.*

Descriptive Bulletin SP2A is available on request.

Hughes

SEMICONDUCTOR SALES DEPARTMENT

Aircraft Company, Culver City, Calif.

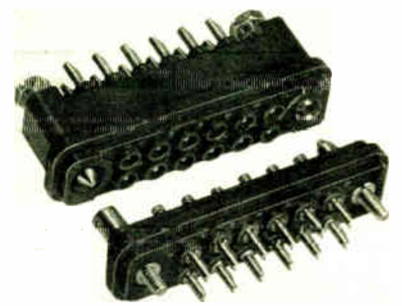
New York Chicago

News—New Products

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

(Continued from page 64A)

Power Connectors With Bayonet Locks

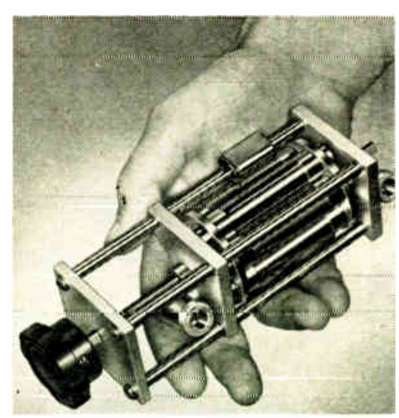


DeJur-Amsco Corp., 45-01 Northern Blvd., Long Island City 1, N. Y., has a new Continental Connector's Series "E-Z 16" with bayonet locks which provide a positive lock against accidental disconnection between plug and socket. The bayonet lock is a stainless steel guide socket with a detent for the bayonet guide pin and guide socket for positive polarization.

The Series "E-Z 16" connectors are available in 12, 18, 24, and 34 contacts with bayonet locks, either chassis or cable-mounted. For illustrated engineering data sheet, write: Electronic Sales Div.

Coaxial Attenuators

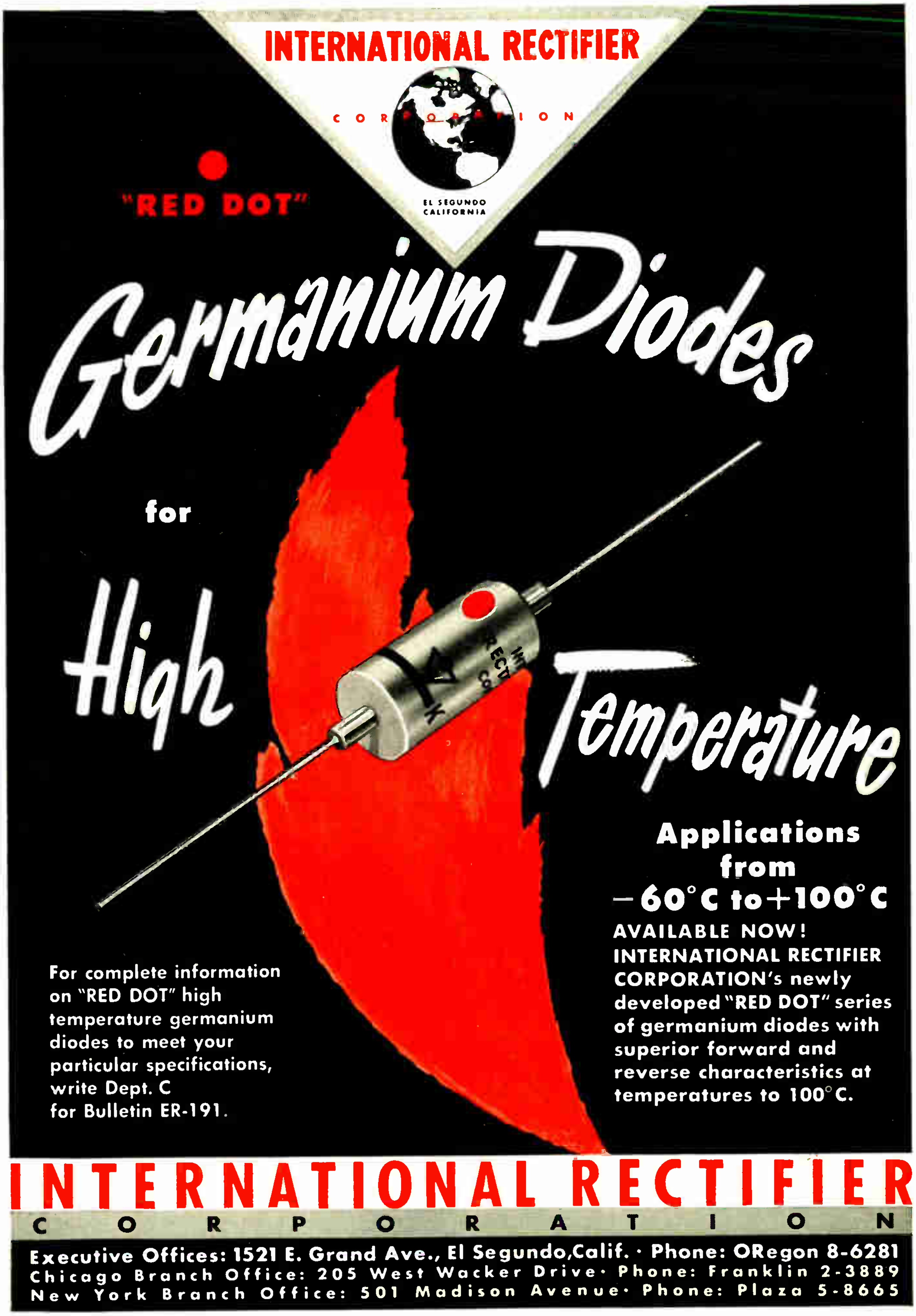
A complete line of coaxial attenuators from 0.1 to 60 db, with a frequency range at dc to 3,000 mc, has been announced by **Stoddart Aircraft Radio Co., Inc.,** 6644 Santa Monica Blvd., Hollywood 38, Calif.



The attenuators may be obtained singly or in a turret selector containing any six values of attenuation, featuring a "Pull-Turn-Push" selection sequence. Small over-all size of turret selector is $2\frac{1}{16}\times 2\frac{1}{16}\times 5\frac{1}{2}$ inches.

A four-page pamphlet entitled "UHF Attenuation" is available covering complete line of coaxial attenuators from 0.1 to 60 db, power ratings, specifications, illustrations and other features. Back cover is used for block diagram of lab set-up for measurements of attenuation using company's equipment.

(Continued on page 74A)


INTERNATIONAL RECTIFIER
CORPORATION
EL SEGUNDO CALIFORNIA
"RED DOT"
Germanium Diodes
for
High Temperature
Applications from −60°C to +100°C
AVAILABLE NOW! INTERNATIONAL RECTIFIER CORPORATION's newly developed "RED DOT" series of germanium diodes with superior forward and reverse characteristics at temperatures to 100°C.
For complete information on "RED DOT" high temperature germanium diodes to meet your particular specifications, write Dept. C for Bulletin ER-191.
INTERNATIONAL RECTIFIER
CORPORATION
Executive Offices: 1521 E. Grand Ave., El Segundo, Calif. · Phone: ORegon 8-6281
Chicago Branch Office: 205 West Wacker Drive · Phone: Franklin 2-3889
New York Branch Office: 501 Madison Avenue · Phone: Plaza 5-8665

MEMBERSHIP

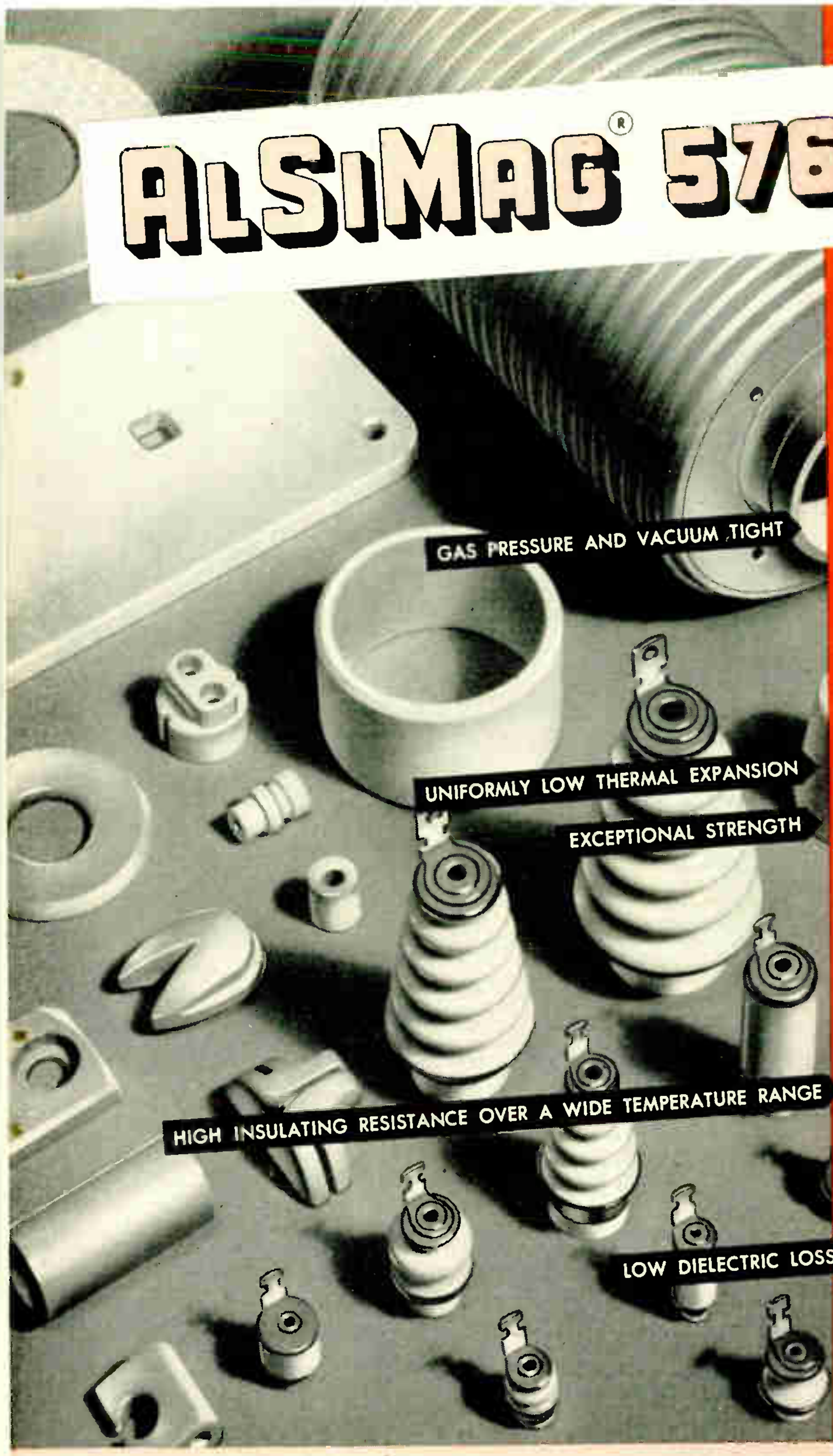
The following transfers and admissions were approved to be effective as of May 1, 1954:

Transfer to Senior Member

Bachman, C. H., Steele Hall, Syracuse University, Syracuse, N. Y.
Backer, L. A., 2 Richwood Pl., Denville, N. J.
Baldridge, B. H., 6125 Kratzville Rd., Evansville, Ind.
Bonn, T. H., 7966 Rugby St., Philadelphia 19, Pa.
Boothe, A. M., 1358 Grace Ave., Cincinnati 8, Ohio
Browder, J. W., Code 278, U. S. Navy Electronics Laboratory, San Diego 52, Calif.
Bruck, L., 19 Promenade, Ulm Donau (14a), Germany
Buchholz, W., 24 Edge Hill Rd., Wappingers Falls, N. Y.
Cameron, E. G., 1180 Hermosa Way, Menlo Park, Calif.
Caplan, N., Stevenson, Md.
Cramer, L. F., 1329 Arlington St., Cincinnati 25, Ohio
DeMers, E. F., 7201 Watson Way, La Mesa, Calif.
Dillaby, E. F., 67 Corning St., Beverly, Mass.
Dressler, R., 61 Hathaway Ave., Elmont, L. I., N. Y.
Fucci, S., 180 Ledyard St., New London, Conn.
Geppert, D. V., 4146 E. Turney, Phoenix, Ariz.
Gilmartin, T., 1873 E. 17 St., Tulsa, Okla.
Gregory, E. C., 1120 S.E. First St., Evansville, Ind.
Heintz, K. O., Box 2180, Houston 1, Tex.
Hopgood, R. C., 277 Bay Ave., Glen Ridge, N. J.
Hoskins, E. E., 325 N. Halstead Ave., Pasadena 8, Calif.
Jacob, M. I., 1505 Tredegar Ave., Catonsville 28, Md.
Johnson, W. C., 908½ Farnham St., Elmira, N. Y.
Kaufman, S., 3737 Bellaire Blvd., Houston 25, Tex.
King, H. D., 89 Little Silver Pkwy., Little Silver, N. J.
Knowles, W. S., 61 Spruce St., Princeton, N. J.
Kraus, C. R., The Bell Telephone Co. of Pennsylvania, 1835 Arch St., Philadelphia 3, Pa.
Keeran, R. V., 1055 Santa Barbara, San Diego 7, Calif.
Lawrence, E., 50 Borkwood Way, Orpington, Kent, England
Lilienthal, J. R., 1964 Juniper, Los Alamos, N. Mex.
Lissauer, S., 4054 W. 59 Pl., Los Angeles 43, Calif.
Litchford, G. B., 18 Green Meadow La., Huntington, L. I., N. Y.
Lloyd, L. H., 33 S. Cherrywood Ave., Dayton 3, Ohio
MacKechnie, H. K., 12 Winthrop Rd., Lexington 73, Mass.
Martin, L. H., New Zealand Broadcasting Service, Box 888, Dunedin, New Zealand
Martin, W. R., 331 N. Lincoln St., Burbank, Calif.
McKey, D. B., RCA Victor Division, 522-33 Forsyth Bldg., Atlanta 3, Ga.
McLennan, M. A., 304 Schenck Ave., Dayton 9, Ohio
McRuer, D. T., 3306 W. 73 St., Apt. 2, Los Angeles 43, Calif.
Miller, E. A., 307 Letcher Ave., Lexington, Va.
O'Halloran, J. F., 7422 Melrose Ave., Los Angeles 46, Calif.
Otto, E. D., 215 C St., S.E., Washington 3, D. C.
Pedersen, G., Hyrdevej 3, Hellerup, Denmark
Ratynski, M. V., 205 W. Cedar St., Rome, N. Y.
Rhoad, E. J., 6051 Corbin Ave., Tarzana, Calif.
Rich, C. E., 63 Meadowbrook Rd., Hempstead, L. I., N. Y.
Rohner, G. J., 536 S. Second St., Lindenhurst, L. I., N. Y.
Rosenthal, S. W., 783 Boulevard, Bayonne, N. J.
Rubin, L., Rua Belgica 188, Sao Paulo, Brazil
Stewart, J. A., 20 Valley Rd., Clifton, N. J.

(Continued on page 70A)

ALSIMAG® 576



AN ECONOMICAL HIGH STRENGTH ALUMINA CERAMIC

Meets L-5A Requirements of JAN-I-10 Specifications

Note These Advantageous Properties

PROPERTY		UNIT	ALSIMAG 576 L-5A
Water Absorption			Impervious
Specific Gravity			3.4
Density		Lbs. per cu. in.	.123
Standard Body Colors			White
Alternative Body Colors			Pink 513 (L-5A)
Safe Temperature at Continuous Heat		°C.	1 100
		°F.	2 012
Hardness		Mohs' Scale	9
Thermal Expansion Linear Coefficient		Per °C. 25-700 °C.	7.5×10^{-6}
Tensile Strength		Lbs. per sq. in.	20 000
Compressive Strength		Lbs. per sq. in.	140 000
Flexural Strength		Lbs. per sq. in.	40 000
Dielectric Strength (step 60 cycles) Test discs ¼" thick		Volts per mil	250
Volume Resistivity at Various Temperatures	25 °C.	Ohms per centimeter cube	$> 10^{14}$
	100 °C.		2.0×10^{13}
	300 °C.		5.0×10^{10}
	500 °C.		1.0×10^{8}
	700 °C.		3.0×10^{6}
	900 °C.		4.0×10^{5}
Te Value		°C.	800
		°F.	1 472
Dielectric Constant	60 Cycles		8.4
	1 M.C.		8.3
	10 MC.		8.2
	100 MC.		8.1
Power Factor	60 Cycles		.0013
	1 MC.		.0007
	10 MC.		.0007
	100 MC.		.0008
Loss Factor	60 Cycles		.011
	1 MC.		.006
	10 MC.		.006
	100 MC.		.006

QUICK DELIVERY IN ANY DESIRED QUANTITY. AlSiMag 576 parts can be made in the full range of sizes, designs and processes that are normally available in other AlSiMag ceramics.

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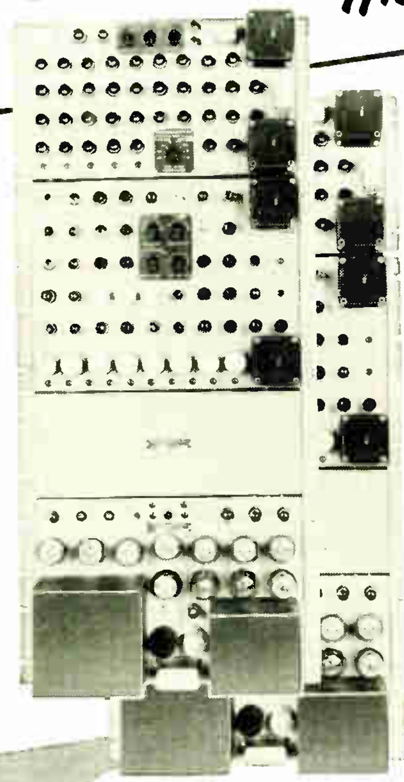

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(Continued on page 74A)

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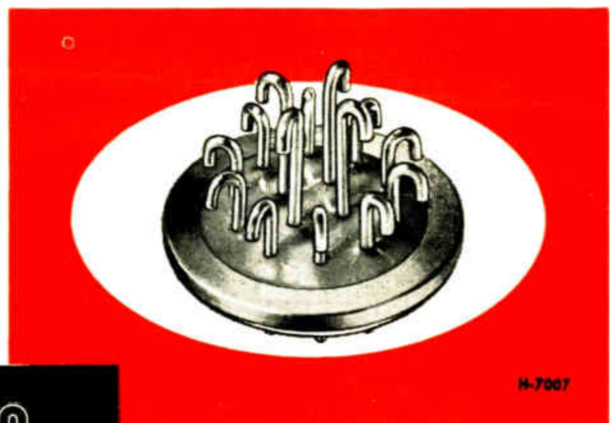

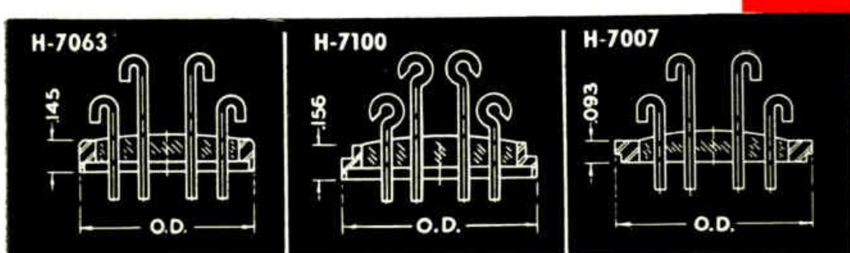

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All parts shown available up to 21 terminals depending on O.D. Integral exhaust tubulation, color codes, alternate terminations may also be had. Terminal diameters up to .093 dia. depending on O.D.

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Berkeley's new Model 5510 Universal Counter and Timer provides the functions of counter, time interval meter, events-per-unit-time meter and frequency meter in one compact instrument. It will:

1. Count at speeds to 1,000,000 counts per second.
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(*Continued on page 76A*)

News—New Products

(*Continued from page 66A*)

Power Resistor

Castohm, a new type of fixed wire-wound power resistor has been developed by the **Shallcross Manufacturing Co.**, Collingsdale, Pa. Through a unique process, the windings of the new resistors are firmly imbedded in a special ceramic which forms an integral coating and core. By eliminating the heavy ceramic core, Castohm resistors have been made in smaller diameters and with almost 25 per cent less weight than conventional tab terminal power resistors of comparable wattage ratings.

The thin-walled ceramic core and coating has exceptional resistance to thermal shock as well as good heat conductivity. Resistors consequently, reach their operating temperature quickly, resulting in faster circuit loading. In addition, Castohm resistors are rated at a hot-spot temperature of 350°C, compared with 275°C for vitreous enamel types.

Designed in accordance with Signal Corps specification MIL-R-10566, the resistors are currently available in styles R-30, R-33, R-37, and R-46. Wattage ratings are 8, 28, 125, and 225 watts respectively. Available resistance values range from 100 to 160,000 ohms. Standard tolerance is 5 per cent, but tolerances as close as 1 per cent are available on order.

Engineering Bulletin L-29 giving complete specifications, typical laboratory test results, and physical and mounting dimensions is available on letterhead request to the manufacturer.

(*Continued on page 134A*)

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for Standard and Special Applications

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Top quality Class A military type power and pulse transformers—made to your electrical specifications! Class A types meet Transformer and Reactor Specification MIL-T-27. Available in standard or special MIL cases.

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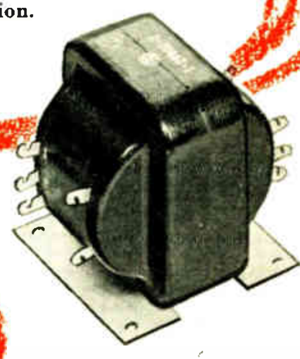

OPEN-TYPE AIRCRAFT TRANSFORMERS 380-2400 Cycles

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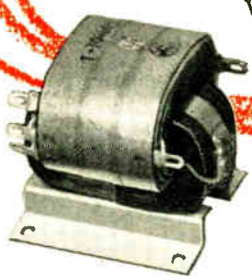

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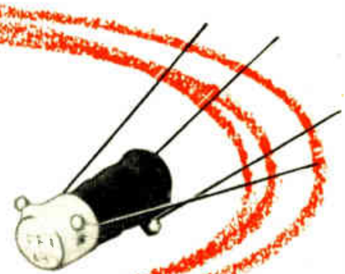

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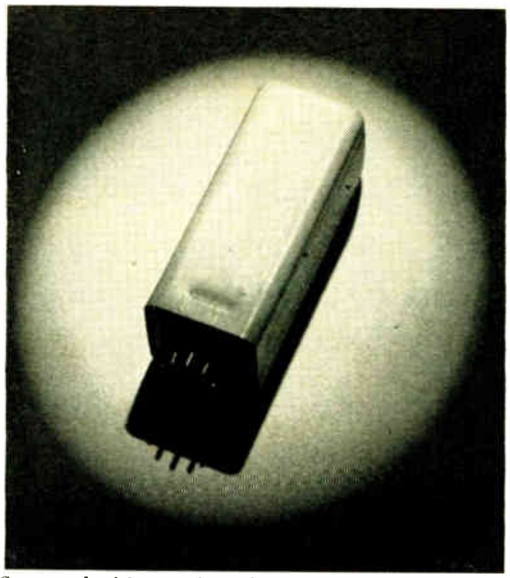

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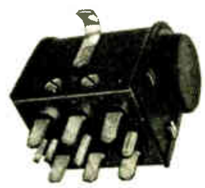

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S-506-DB
Socket with deep Bracket

For 5,000 Volts, 25 Amperes per Contact Alterable by Circuit Characteristics.

Socket contacts of phosphor bronze, knife-switch type, cadmium plated. Plug contacts hard brass, cadmium plated. Made in 2, 4, 6, 8, 10, and 12 contacts. Plugs and sockets polarized. Long leakage path from terminal, and terminal to ground. Caps and brackets, steel parkerized (rust-proofed). Plug and socket blocks interchangeable in caps and brackets. Terminal connections most accessible. Cap insulated with canvas bakelite.

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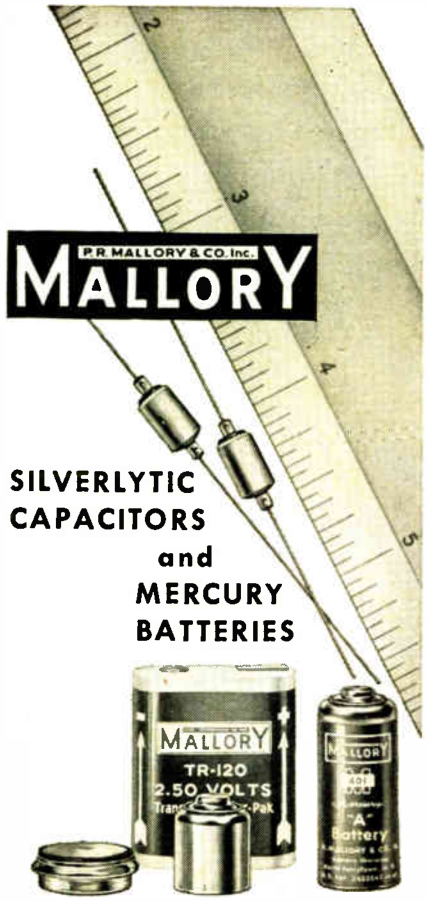

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(Continued from page 76A)

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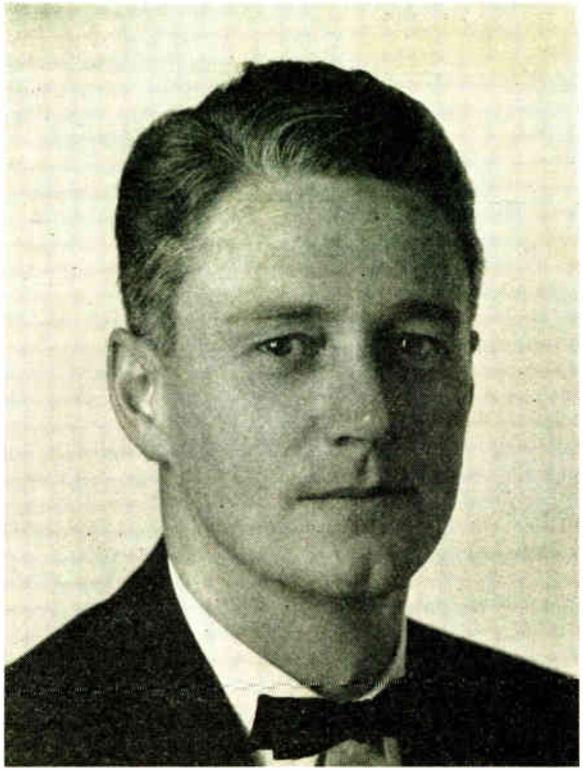

Lucius E. Packard

Director, 1954

Lucius E. Packard was born in Somerville, Massachusetts on January 21, 1914. He received the B.S. Degree in Electrical Engineering from the Massachusetts Institute of Technology in 1935.

Joining the Mason Neilan Regulator Company upon graduation, Mr. Packard spent a year designing and testing electronic control systems. In 1936, he joined the General Radio Company engineering staff and began work as a development engineer in the fields of sound and vibration measurement, and impedance bridges. Development engineering was followed by sales engineering and in 1939, Mr. Packard became manager of the General Radio Company New York Sales Office. In 1942, he became manager of the Chicago Sales Office, continuing in this position for four years.

In 1946, Mr. Packard was co-founder of the Technology Instrument Corporation. As director of engineering and sales activities, he was responsible for the development of impedance and phase measuring equipment and did pioneer work in the development and design of precision potentiometers for analog computers and servomechanisms. Subsequently, he contributed to the development of standards and potentiometer measuring equipment. Mr. Packard was elected to his present position as President of Technology Instrument Corporation in 1947.

Mr. Packard joined the IRE as a Member in 1941 and became a Senior Member in 1943. His IRE activities include service as Secretary, Chicago Section, 1945; First Chairman, NEREM, 1947; Vice Chairman, Boston Section, 1950; Chairman, Boston Section, 1951; and Regional Director, North Atlantic Region, 1954. In addition to having presented several papers, Mr. Packard has been author and co-author of several technical articles in the fields of sound and bridge measuring equipment.

Mr. Packard holds patents in the fields of electrical measurement and precision potentiometers. He is a member of the American Institute of Electrical Engineers and a fellow in the Radio Club of America.

EDITORIAL

JOHN R. PIERCE, EDITOR

Some editorials in the PROCEEDINGS are written by the Editor. These reflect the present but by no means immutable editorial policy of the Institute. They inform the members of the Institute about such policy and open the way for private or public discussion or objection.

Some editorials are written by others. These discuss important but not strictly technical matters which are judged to be of interest to members of the Institute, matters such as engineering education, the relation of engineering to science, Professional Groups and their TRANSACTIONS. Such editorials give the writer an opportunity to express his personal views, which may or may not coincide with those of the Editor and the Editorial Board.

Turning to another matter: In the future, discussions of papers will not appear in a separate section, but will be treated as correspondence. When a letter discussing a paper is received, a copy will be sent to the author. If his reply is received promptly it will appear in the same issue as the letter of discussion; if his reply is long delayed it will appear in a later issue. This change simplifies editorial procedure and should result in earlier publication of discussions.

We are currently trying to reduce publication time, and we will report progress when we have clearly made some. In this endeavor we need the help of authors in writing papers well, clearly, and with some thought of our instructions to reviewers, which appeared on page 264 of the April issue of the PROCEEDINGS. Authors should submit three copies of papers to the Managing Editor. When revisions are necessary, which we hope will be seldom, prompt publication can be assured only if the author is prompt in revising.

Starting with this issue (page 1033), the PROCEEDINGS will publish abstracts of all technical papers appearing in the TRANSACTIONS of the various Professional Groups. This should help to bring papers published in the TRANSACTIONS to the attention of all who may be interested in them.

Reliability of Electron Tubes in Military Applications*

ERNEST R. JERVIS†, SENIOR MEMBER, IRE

Summary—Study by Aeronautical Radio, Inc., of electron tubes removed from military equipments, discloses four principal contributors to tube failure or removal: Maintenance and operating conditions, environment, application, and basic tube weaknesses. Examples of trouble caused by misapplication and environment are presented. Over-all returns from various military bases show that one tube in every three removed is not defective and should not have been removed. Taking into account the "no-defect" removals and gradual deterioration failures which could have been detected by good maintenance procedures before they caused equipment failure, only one tube in six removed is of a type liable to produce equipment malfunction. These facts point to shortcomings of maintenance in the face of increasing equipment complexity, and emphasize the urgent need for equipments designed for simplicity of operation and servicing.

Laboratory analysis by Cornell University indicates that high-operating temperature is the predominant basic cause of deterioration failures resulting from emission poisoning, interface, and leakage due to sublimation. Heater burnout and heater-cathode shorts, the principal types of catastrophic failures, are traceable to high-heater operating temperature.

Early results of ARINC tests on improved receiving-type tubes indicate a removal rate only one-third to one-fourth that of their prototypes, which show a rate between one and three per cent per hundred hours of operation.

Correction of tube weaknesses appears to lie in diligent application of solutions which are already known. The improvements must be maintained by rigid quality control of the product and continuous sampling of failures occurring under actual operating conditions.

Introduction

In April, 1951, the military services authorized Aeronautical Radio, Inc. (ARINC) by contract[1] to investigate the causes of premature failure of electron tubes in military equipments and to recommend corrective measures. The task assigned by this contract—specifically, to find ways of obtaining greater reliability in tubes—is far from simple. It has been approached by ARINC in the same way the commercial airline program[2] was carried out, that is, by effecting close collaboration between the ultimate user and the groups directly interested in tube performance, namely, the tube and equipment manufacturers.

For ease of explanation, the work of the ARINC Military Electron Tube Project[3] can be divided into three parts:

(1) Description of the tube reliability problem in present military equipment;
(2) Comparison of the performance of the new, improved types of tubes with the performance of their JAN prototypes; and
(3) Recommendation of ways and means of obtaining a more reliable product.

Description of the Problem

Data required for the first phase of the investigation—description of the present reliability problem—are obtained principally by collecting all tubes removed from certain selected types of equipment at various military bases. The bases have been chosen in such a way as to provide a good cross section of various environments of military electronic equipment. These range from fixed installations to shipboard gear; from gun-mounted fire-control systems to airborne radars and communication equipments in jet aircraft as well as reciprocating engine aircraft; and from vehicle-mounted communication sets to pack and portable sets.

The ARINC field personnel who collect the tubes also ascertain, if possible, the reason for removal of each individual tube, the type of equipment and the socket from which it was removed, and any special circumstances which might have produced its failure—such as abnormal operating conditions, special overhaul and repair practices, or other factors. The information obtained is transmitted to the Washington office of the Project, where it is coded on IBM cards and analyzed by modern statistical methods. The aim of this analysis is to study in detail all the collected failures in order to determine the causes that produced them.

Results to date indicate that the causes of tube failure can be grouped into four broad categories: Maintenance and operating conditions; environment; application; and basic tube weaknesses. From the restricted point of view of tube improvement, only the last of these categories is interesting; the other three need be considered only to eliminate inaccurate conclusions and misleading information. But, from the general standpoint of electronic equipment reliability, all four categories are extremely important and must be evaluated to obtain a complete description of the problem. They also provide valuable information for the design of tests needed to compare improved tube types with standard types made according to the old JAN specifications.

Tube Misapplications

Misleading information is easily obtained in cases where large returns are produced by misapplication in the circuit or by severe environmental conditions.

An example of misapplication is presented in Fig. 1. The histogram on the left gives the distribution of tubes collected from six sockets of a rectifier chassis using

* Decimal classification: R560×R331.5. Original manuscript received by the IRE, August 3, 1953; revised manuscript received, December 21, 1953. Some of the material in this paper was presented first at the Electronic Components Symposium, Pasadena, Calif., April 30, 1953.

† Engineering Mgr., Aeronautical Radio, Inc., Military Contract Div., Washington, D.C.

[1] Bureau of Ships Contract No. bsr-52372.

[2] E. K. Morse, "Long Life Tubes for Industry," *Electronics*, vol. 23, pp. 68–69; September, 1950.

[3] See also ARINC Gen. Rep. No. 1 on this Project, which includes a description of the origin and purposes of the program.

type 5R4GY; the diagram adjoining the graph shows the position of the sockets in the circuit. It is apparent that the parallel connection of several tubes is not beneficial to the operation of a rectifier, especially if no precaution is taken to balance the load among the various tubes or to prevent the overloading of the other tubes when one tube in the circuit fails to take its share. The sockets for the two parallel tubes might have had far fewer rejects if they had been connected one in each half-wave circuit, thus reducing the peak-voltage strain in the tubes. The one-tube removal from the single-tube circuit was found to be due to a poor solder joint in the base pin that had nothing to do with the circuit.

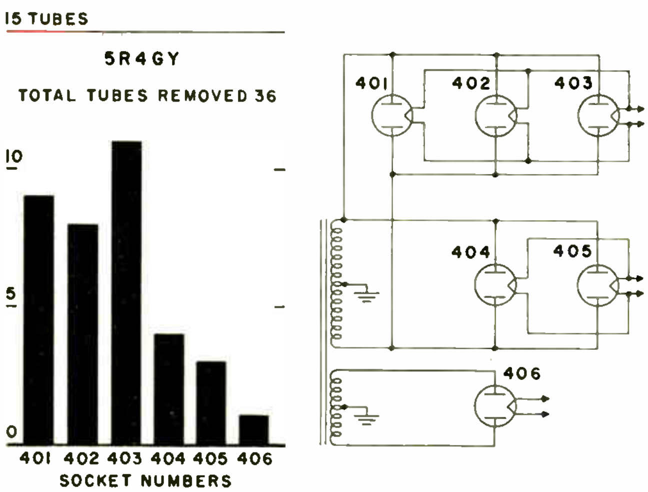

Fig. 1—Distribution by sockets of 5R4GY removals from rectifier chassis.

It is evident that if improved tubes had been inserted in this circuit for comparison, there would have been no difference in performance unless the improved version had a very large margin over the prototype.

Environmental Conditions

A situation in which environmental conditions have played a dominant part, thus masking the effect of tube improvement, is shown in Fig. 2. This gives the number of tubes of the 6AR6 and 6098 types collected from the power-supply regulator for a bombing radar during four-week intervals over a period of approximately two years. The equipment was at first mounted in the non-pressurized part of the airplane, where the ventilation was inadequate. At that time, returns of the 6AR6 and 6098 types were four to five times greater than the average for all other sockets. "Tempilaq degree" measurements showed that during flights above 30,000 feet, the bulb temperature of the 6AR6 reached average values in the neighborhood of 315 degrees C., or roughly 100 degrees C. above maximum rating. After this condition was discovered, the chassis in question was transferred to the pressurized section of the plane, and more effective blowers were installed. A temperature check made thereafter showed an average bulb temperature of 181 degrees C. for all 6AR6 tubes and their reliable counterparts, type 6098, under flight conditions similar to those prevailing when the previous measurements were taken.

The transfer of the equipment to the pressurized zone was effected in most of the aircraft during the second quarter of 1952. In Fig. 2 the gradual drop in returns from an average of 57.1 for the first 4-week period to 8.8 for the last is readily apparent. Fig. 3, showing all other tube returns from the complete bombing system for the same period of time, indicates that there has been no significant change in the activity of the system as a whole.

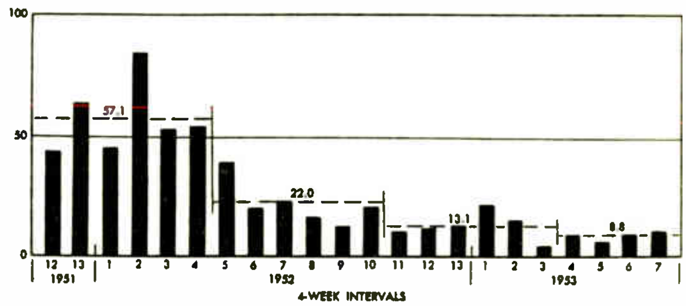

Fig. 2—6AR6 and 6098 removals from power-supply regulator.

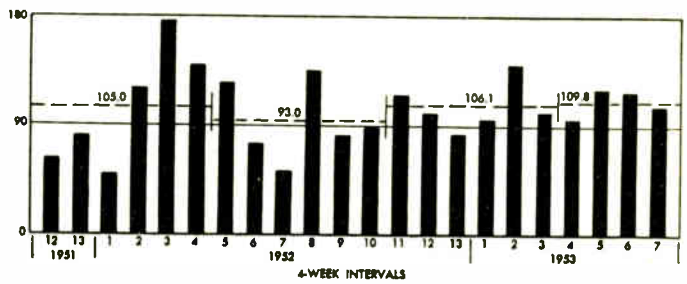

Fig. 3—Removals of all tube types except 6AR6 and 6098 from bombing system.

With the improvement in operating conditions of the power-supply regulator, it will be possible to obtain comparative data on the performance of the type 6AR6 and its improved counterpart, type 6098, in this equipment.

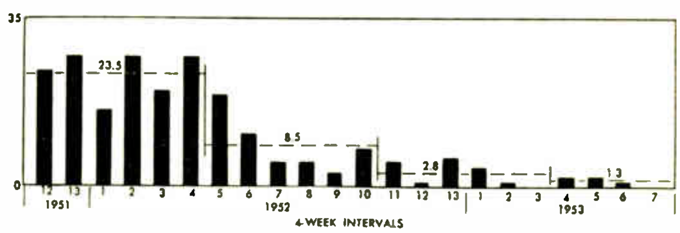

Fig. 4—6AR6 and 6098 removals with electrical defects from power-supply regulator.

Fig. 4, considered in conjunction with Fig. 2, presents an interesting illustration of the effect of masking produced by maintenance. The environmental trouble described above produced tube defects which were essentially electrical in nature, such as gas and low emission. Fig. 4 shows the distribution by 4-week intervals of returns of the 6AR6 and 6098 types in this defect classification. The reduction in the quantity of such defects can be measured by the 18-to-1 ratio between the returns during the first 4-week period and those during the final period; yet, the over-all improvement in the return of tubes in all categories, as shown in Fig. 2, is only 6.5 to 1. This difference is explained by the fact that tube removals attributable to maintenance did not decrease in proportion to the improvement obtained in removals due to electrical defects.

General Classification of Returns

Many other examples could be cited to show the great variety of problems encountered in the ARINC study of tube performance in military equipments. However, locating and describing these individual difficulties does not by itself accomplish the first part of the task, which is to describe the general problem of reliability as it now exists. What is needed is a way of reducing the sum total of tube failures to a few simple patterns showing basic trends. This can be done by averaging out some of the variables, once they are properly appraised, and by reducing the description to figures that apply to all of the data collected.

Fig. 5 presents one type of general picture of the tubes collected by ARINC. In this diagram, all returns are segregated into four groups on the basis of the defect

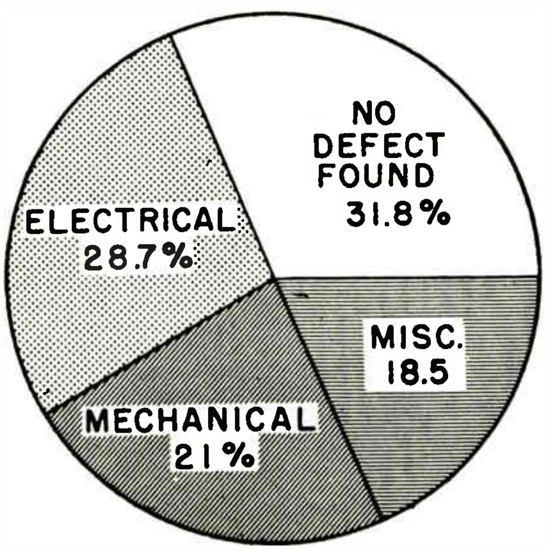

Fig. 5—Distribution of total returns by defect classification.

findings reported by the ARINC field personnel, and the quantity in each group is shown as a percentage of the total. Three groups consist respectively of tubes with mechanical defects, electrical defects, and miscellaneous defects; the fourth consists of tubes in which no apparent defect was found. Distribution includes tubes collected from all military bases where the surveillance program was conducted in 1952. Pattern of defects shown here is repeating itself with the tubes collected in 1953; accordingly, there is reason to believe that this pattern provides a good description of data so far collected.

Maintenance Problem

The most striking fact revealed in Fig. 5 is that about one tube out of every three removed is not defective and should not have been removed. Moreover, detailed examination of those tubes which are defective has disclosed, among other things, that most of the electrical defects are of the gradual deterioration kind which could be eliminated by a good maintenance system before they produce malfunction of the equipment. Taking into account the tubes with no apparent defect, this leads to the conclusion that only one tube in six removed is liable to produce an equipment malfunction. It has been observed that this 1-in-6 ratio becomes even larger if the tubes considered are improved tubes, rather than of the JAN type.

The situation implicit in the foregoing conclusion can be produced by one or more of the following conditions: (a) The equipment is too complex for efficient maintenance in the field; (b) the maintenance personnel do not have sufficient time or training to do the job; and (c) the maintenance shop does not have the proper tooling to evaluate the faults in the equipment. All of these conditions have been observed at one or more of the bases participating in the surveillance program. The converse situation has also been observed: That is, if maintenance personnel have the proper training, tools and time to do a good job, as at Army Radio Station WAR, the most complex equipment (provided it is well designed) can operate trouble-free for very long periods of time. A reasonable inference is that in most cases maintenance establishments and practices are inadequate to keep the complex, present-day equipments in trouble-free operation.

Equipment Requirements

It is proper here to consider that while the quality of electronic maintenance probably can and will be improved in peace time, in case of emergency, neither maintenance nor operating personnel are likely to be more skilled than at present, and they probably will be less so. Yet, it is far more important that military equipment operate properly under emergency conditions than in peace time. The indication is, therefore, that allowance must be made for the inadequacy of maintenance systems and operating procedures, and that real improvement in the reliability of military electronic equipment will be obtained only if the primary emphasis is placed on the design of the equipment, rather than on the improvement of maintenance. In other words, in the design of highly complex equipments, the most important aim should be simplicity of operation and servicing.

This objective, which is not a novel idea, can be accomplished by careful consideration of each subassembly as a separate unit and by inclusion of some malfunction indicator or automatic device for eliminating the malfunctioning unit from the system. The complexity of the equipment may well increase, but this increased complexity will improve rather than decrease the reliability, as can be proved by the experience of

Station WAR and many other installations operating with virtually no interruptions caused by tube failures.

Ranking of Returned Tubes

Another general aspect of tube reliability is presented in Fig. 6, which shows the tube types returned to ARINC in the largest quantities, irrespective of the number of equipments or sockets in which they are used. The type 6AK5 heads the list, followed by types 6J6, 12AU7, 6AQ5 and 6AR6. The ranking is not necessarily an indication that these tube types are the most unreliable, but it does show that, if the surveillance points and the equipments have been properly chosen to yield a representative sampling of tube removals, these are the types that now contribute the most, numerically, to the unreliability of electronic equipment. This may be due to the fact that these types are used in a very large number of sockets or to the fact that they are failing very often.

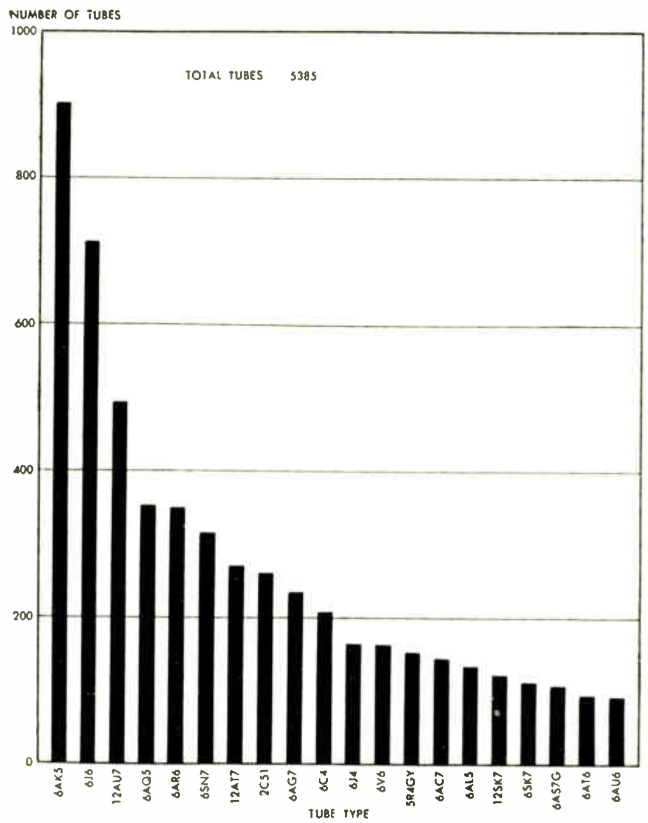

Fig. 6—Tube types ranking highest in number of returns.

A ranking of this nature is important because it identifies the tube types that should have first attention in a tube-improvement program. Early and substantial improvement in the over-all equipment reliability is most likely to be obtained if priority is given to the types at the top of the list, rather than to lower-ranking tube types.

Causes of Tube Failure

The returns of all tube types ranked in Fig. 6 have been examined in detail for any indications of tube weakness and, also, to determine whether some general causes of tube failure can be established. In this work, ARINC has made extensive use of data supplied by the Cornell University School of Engineering, which, under another contract[4]—co-ordinated with the ARINC contract through the Panel on Electron Tubes—is engaged in measuring and dissecting tubes collected by ARINC to determine internal causes of failure.

These continuing studies have resulted in some specific findings on individual tube-type weaknesses, which are incorporated from time to time in progress reports to the military services; they have also led to certain hypotheses as to the general types and causes of failure. Excluding tube damage caused by handling during servicing, it is believed that all defects may be segregated into two general classes: (1) those resulting from gradual deterioration of characteristics; and, (2) those which cause sudden or catastrophic tube failure.

In the first class are included such defects as emission poisoning, interface formation, leakage due to sublimation, and noise due to gradual wear of the insulating spacer in environments characterized by continuous vibration. The most prevalent cause of failure for all of these types of defects except noise was found to be high-operating temperature. This condition, in turn, was found to be produced by several primary causes, such as improper application, adverse environment, high-voltage operation, and faulty tube design.

In the second general classification, the predominant types of defects observed are heater burnout and heater-cathode shorts. Both appear to be due to high-heater operating temperature, accelerated by poor-voltage regulation and, in some cases, by the use of series parallel string connections of heaters of widely different characteristics.

Performance of Improved Types

The objective of the second phase of the ARINC program is to compare the performance of the new, improved types of tubes with that of their prototypes, manufactured according to the old JAN specifications.

This problem of comparison can be likened to the task of detecting a weak signal in the midst of a large amount of noise; however, to carry this analogy a step further, we have the opportunity of using frequency modulation, rather than amplitude modulation, for this task—by employing statistically designed tests. In such a test, tubes of the improved and standard types—usually in equal quantities—are installed in selected sockets and equipments on the basis of a plan designed to provide performance data in which spurious effects can be evaluated. The actual difference in performance will then be clearly evident and can be analyzed free of extraneous factors.

In this second phase of the ARINC surveillance program, more than 60,000 tubes are now installed in equipments and operating under normal military usage.

[4] Signal Corps Tube-Analysis Contract DA-36-039-SC-15342.

The collection of data is a slow process because of the amount of operational time needed to obtain a significant number of removals. This situation is aggravated by the fact that most military equipments are not operated full time.

Preliminary results of the tests indicate that, excluding tubes in stationary installations, regular type receiving tubes are removed at a rate between one and three per cent per hundred hours of operation, while reliable types made under various Armed Forces improvement contracts are showing a removal rate which is only one-third to one-fourth that of their prototypes. In tests conducted in commercial airline equipment, the ARINC reliable types have operated more than 3,000 hours with an average removal rate of 0.3 per cent per hundred hours.

While these figures must be regarded, for the present, as only approximate, the accuracy of the findings is progressively improving as more and more information is collected on the respective equipment types at the various bases. Every new controlled test designed for comparison of improved and JAN tubes provides more information than the previous ones. The progressive improvement in the results of the tests is due to increasing knowledge of the conditions affecting behavior of the tubes under surveillance. With continued improvement, it will eventually be possible to predict accurately the performance of a given group of tubes in a particular equipment and environment.

Tentative Conclusions and Recommendations

The objective in the third and last phase of the military electron-tube surveillance program is to recommend ways and means of obtaining more reliable tubes. Specific recommendations will be presented in the ARINC progress reports to the military services whenever it is considered that conclusive data have been obtained regarding the problems in question. It is believed, however, that most of the tube deficiencies which cause unreliability, and the solutions to these troubles, are already known. The real problem is one of applying this knowledge. It is a matter, first, of painstakingly examining every detail in tube construction in the light of the specific findings in the surveillance program, as indicated in the examples presented above; second, of determining the best technique for improving each detail that needs improvement; and, third, of spreading this improvement to all similar tube types before the particular detail can become a major problem.

This has not been done completely on well-known problems for which solutions are already known. For example, it is clearly established that a cooler heater has lower probability of burn-out; yet, many tube types are operated at dangerously high temperatures. It is well known that active nickel in cathode sleeves induces early formation of interface resistance; yet, this type of nickel is still used in many tubes because of the greater ease of processing. It is common knowledge that a high-cathode temperature results in shortened tube life; yet, some tube types are made to operate with very high-cathode temperatures just to satisfy some peculiar circuit application. It is recognized that one of the main degradation effects in long-life tubes is the formation of leakage paths between electrodes, and many ways of correcting this condition have proved effective—for example, mica slots, shields, magnesia coating, etc.; but not all tubes made for long life incorporate these precautions to the extent required.

The reliability of tubes will steadily and substantially improve if the known solutions to tube trouble, such as those itemized above, are vigorously applied to improve tube design. These changes, of course, must be maintained under control by wisely-chosen statistical tests on the product. In fact, no improvement program will have lasting effect unless the quality obtained in the product is maintained by a well-designed, rigid system of quality control. This principle must be applied, also, in the operation of the equipments in which the tubes are used. To maintain a high standard of equipment reliability, it is imperative to conduct a continuous sampling on the type and quantity of repairs and replacements of all components during normal operation.

The Effect of Junction Shape and Surface Recombination on Transistor Current Gain*

A. R. MOORE† AND J. I. PANKOVE†, ASSOCIATE, IRE

Summary—**An experimental and theoretical study is presented which shows that the current gain of an alloy transistor is greatly affected by the geometry of emitter and collector junctions and by surface treatment of the base germanium, but is hardly affected at all by bulk recombination (lifetime) in the base. The current gain is computed for specific three-dimensional geometries by an electric analog method which assumes that surface recombination is the major factor in minority-carrier loss. By this method, a new way of measuring surface-recombination velocity, *s*, from simple measurements on transistors has been devised. The value of *s* is obtained directly from a suitable calibration curve, and thus may be useful as a quality control on surface condition.**

The transit-time path-length dispersion of minority carriers in a transistor structure with nonparallel junctions has been computed. The results show that the effect is significant only above 1 mc/second in a typical structure.

General Discussion

THE THEORIES of junction-transistor operation given in the literature[1,2] are limited in certain applications because of two important approximations: (a) one-dimensional geometry is assumed, (b) surface recombination is neglected or at best incorporated into a composite base lifetime. While it is true that for many transistors these approximations are not restrictive, some practical transistor designs violate them. In particular, alloy-type junction transistors[3] may make questionable the interpretation of results based on infinite parallel plane geometry.

Since sectioned *p-n-p* alloy transistors of the RCA 2N34 type generally reveal convex-junction shapes, a solution of the diffusion equations in three dimensions has been worked out which takes into account the geometrical effects. This solution is based on an analogy with current flow in a conducting sheet, under the assumption that surface recombination is the dominant factor in minority-carrier loss. The results are obtained by plotting the hole-flow vector field on a scale model.

Method of Solution

The collector-to-emitter input current gain, α_{ce}, is given by:

$$\alpha_{ce} = \alpha^*\beta\gamma \tag{1}$$

where α^* is the intrinsic current gain of the collector junction, β is a survival factor which gives the ratio of minority carriers arriving at the collector to that released at the emitter and γ is the efficiency of emitter as an injector of minority carriers. For transistors not containing collector "hooks," α^* is 1. For alloy transistors γ is very close to unity since $\sigma_{\text{emitter}} \gg \sigma_{\text{base}}$.[1-3] In this paper the concern shall be solely with the calculation of β. By assumption $\alpha^* = \gamma = 1$, $\alpha_{ce} = \beta$.

The minority-carrier current in the base obeys a flow equation and an equation of continuity:

$$\vec{I}_p = qp\mu_p\vec{E} - qD_p\nabla p \tag{2}$$

$$\frac{1}{q}\nabla\cdot\vec{I}_p = -\frac{\partial p}{\partial t} - \frac{p - p_B}{\tau}. \tag{3}$$

Here p is the density, μ_p is the mobility, D_p is the diffusion coefficient, q is the charge, and τ is the lifetime of holes in the n-type material, p_B is the equilibrium concentration of holes, and E is the electric field.

These equations are subject to boundary conditions which define the hole density in the base at the emitter and collector. It is generally assumed that the electric field is negligible, i.e., diffusion currents dominate. It is also assumed that the hole density in the base is small compared to the electron density, so that all parameters such as conductivity, mobility, and lifetime are independent of injected carriers. In terms of the transistor, this means that the analysis applies only for small emitter currents. Equations (2) and (3) can be combined to give:

$$\frac{dp}{dt} = -\frac{p - p_B}{\tau} + D_p\nabla^2 p. \tag{4}$$

The steady-state equation is then

$$D\nabla^2 P - \frac{P_B}{\tau} = 0 \tag{5}$$

in which P has been written for $p - p_B$, the excess hole density above thermal equilibrium.

For the one-dimensional case this can be readily solved[1,2] and yields an equation for $P(x)$ which can then be inserted into (2) to obtain I at emitter and collector. Then

$$\alpha = -\left.\frac{\partial I_c}{\partial I_e}\right|_{V_c}$$

can be evaluated with the result

* Decimal classification: R282.12. Original manuscript received by the IRE, September 3, 1953; revised manuscript received, February 19, 1954. Presented at IRE Transistor Res. Conf., July, 1953.

† RCA Laboratories Div., Princeton, N. J.

[1] W. Shockley, M. Sparks, and G. K. Teal, "*P-N* junction transistors," *Phys. Rev.*, vol. 83, p. 151; 1951.

[2] E. Steele, "Theory of alpha for *p-n-p* diffused junction transistors," Proc. I.R.E., vol. 40, p. 1424; November, 1952.

[3] R. R. Law, C. W. Mueller, J. I. Pankove, and L. D. Armstrong, "A developmental *p-n-p* junction transistor," Proc. I.R.E., vol. 40, p. 1352; November, 1952.

$$\alpha = \operatorname{sech} W/L_p \approx 1 - 1/2\left(\frac{W}{L_p}\right)^2. \qquad (6)$$

W is the width of the base layer and L_p is the diffusion length for holes ($L_p = \sqrt{D_p\tau}$).

The three-dimensional problem is far more difficult. A solution is possible only for restricted choices of the boundary conditions. However, experience has shown that transistor characteristics are not very sensitive to variation in τ provided τ is greater than a few microseconds, a condition easily achieved in practice. This will be discussed in detail later, but for the present simply assume that τ is sufficiently large in the base ($W/L_p \ll 1$) so that (5) becomes

$$\nabla^2 P = 0. \qquad (7)$$

This is a LaPlace equation solvable in two dimensions by the well-known engineering method of analogy to current flow in an electrolytic tank or conducting sheet. With the proper symmetry conditions, also discussed later, the solution can be extended to three dimensions.

The equation which will be solved in the analogy is $\nabla^2\phi = 0$, so that electric potential ϕ is equivalent to excess hole density P. Eq. (7) must be solved subject to boundary conditions at emitter and collector which fix the hole density for constant emitter and collector voltage. This means in the analogy that ϕ is fixed at ϕ_1 and ϕ_2 on these boundaries, or in other words, emitter and collector become equipotential surfaces. An additional boundary condition, not required in the one-dimensional case, must be satisfied on all free surfaces of the germanium, namely, that holes diffusing to the free surfaces disappear there by recombination, and thus constitute a hole current into the surface.[4] More precisely, the normal component of current density I into the surface is

$$\vec{I} = qP\vec{s} \qquad (8)$$

where s is the surface-recombination velocity. s is the average velocity into the surface of holes present at the boundary. From (2), neglecting currents due to electric fields,

$$\vec{I} = -qD_p\nabla P \qquad (9)$$

so that

$$qPs = -qD_p\nabla P \qquad (10)$$

or

$$\frac{\nabla P}{P} = -\frac{s}{D_p}. \qquad (11)$$

Therefore, provided s is constant over the surface, the boundary condition can also be stated as: the ratio of gradient P to P must be constant at all free surfaces.

[4] W. Shockley, "Electrons and Holes in Semiconductors," Van Nostrand Book Co., New York, N. Y., p. 321.

In the conducting sheet analogy, let the edges (which correspond in two dimensions to surfaces in three dimensions) be bounded by a perfectly conducting boundary broken up into many segments of length a with each segment connected to ground through a resistance R as in Fig. 1. If the current density at the boundary is i then each segment collects current ia from the sheet, producing a voltage drop ϕ across R.

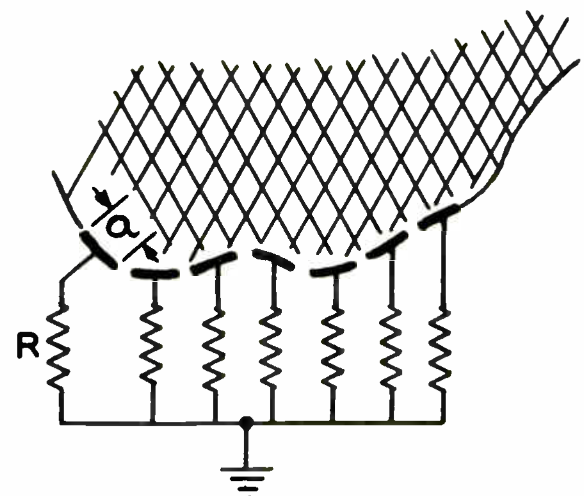

Fig. 1—Boundary of a conducting region.

Then

$$ia = \frac{\phi}{R}. \qquad (12)$$

Within the sheet

$$\vec{i} = \frac{\vec{E}}{\rho} \qquad (13)$$

where ρ is the specific surface resistance of the sheet (ohms/square). Equating (12) and (13),

$$\frac{E}{\rho} = \frac{\phi}{aR}. \qquad (14)$$

Since,

$$\vec{E} = -\nabla\phi$$

$$\frac{\nabla\phi}{\phi} = -\frac{\rho}{aR}. \qquad (15)$$

Comparison of (11) and (15) shows that the analogy is complete if

$$\frac{\rho}{aR} = \frac{s}{D_p}. \qquad (16)$$

For maximum accuracy of the solution near the boundaries the segment length a should be as small as possible. However, it is not necessary to assume that either s or a be constant over the whole free boundary; rather it is required that s does not change appreciably in a distance a so that (16) is obeyed. This will be utilized later to improve the accuracy with practical choice of a.

For convenience, the analogs are tabulated below.

TABLE 1

Quantity in the Map	Representation in Map	Quantity in the Transistor	Representation in Transistor
Current	i	Current	I
Potential	ϕ	Excess Hole Density	P
$-\frac{\text{grad } \phi}{\phi}$	ρ/aR	$-\frac{\text{grad } P}{\phi}$	s/D_p

The boundary conditions require that the emitter and collector be surfaces of constant excess hole density. No great error is introduced if it is assumed that ϕ at the collector $=0$. This means that the collector is assumed to be perfect, collecting every hole which drifts into it from the semiconductor base. ϕ at the emitter is held fixed by a battery. With the proper boundary conditions established, the preparation of a rectilinear square map of equipotentials and field lines gives the required information about hole flow. While the discussion has been given for hole flow in n-type material it should be understood that the plotting method is equally applicable to electron flow in p-type material (n-p-n transistor), if the proper value of D_n is used.

Conversion to Three Dimensions

The current-carrying-sheet analogy solves $\nabla^2\phi=0$ in two dimensions. The problem to be solved is a three-dimensional one:

$$\frac{\partial^2 P}{\partial r^2}+\frac{1}{r}\frac{\partial P}{\partial r}+\frac{1}{r^2}\frac{\partial^2 P}{\partial \theta^2}+\frac{\partial^2 P}{\partial z^2}=0. \qquad (17)$$

With cylindrical symmetry, the third term in (17) is eliminated. In electrolytic tanks, this case can be solved by tipping the tank and using wedge-shaped electrodes as is done for axially symmetric, electron-lens problems.[5] In the present case, this is not convenient, nor, it turns out, is it necessary. The radii of emitter and collector electrodes are large compared to the spacing between them (along the z axis). In the map of P, $\partial P/\partial r$ is small near the origin where r is small. $\partial P/\partial r$ becomes appreciable only for r already large compared to W. Hence $1/r\ \partial P/\partial r$ is always small. The first and second derivatives of P were evaluated numerically for two geometrical cases. In a favorable case, $1/r\partial P/\partial r$ was less than 0.1 per cent of $\partial^2P/\partial r^2$, while in a very unfavorable case $1/r\partial P/\partial r$ never exceeded 4 per cent of $\partial^2P/\partial r^2$. Hence, it is justifiable to ignore the first derivative term. In the evaluation of total emitter and collector current the conversion from x in (18) to r in (19) is accomplished by numerically integrating over the electrode surfaces with a weight factor for r. This amounts to taking the area of an annular ring as $2\pi r dr$.

[5] K. Spangenberg, "Vacuum Tubes," McGraw-Hill Book Co., Inc., New York, N. Y., p. 80; 1948.

Justification for Neglecting Value Recombination

For the one-dimensional case, β is given by (6). With W fixed at 1 mil, β is already 0.99 when $\tau=10$ μsec. Germanium with bulk lifetime of 100 to 1,000 μsec is generally used as transistor-base material yielding $\beta=0.999$ to 0.9999. As previously explained, γ is always very close to 1 because $\sigma_e \gg \sigma_b$. Yet α_{ce} values of 0.95–0.98 are often found for alloy transistors. In a recent test of a large number of transistors made from crystals with measured bulk τ from 1 μsec to 1,000 μsec, no correlation of α with bulk lifetime could be found. The possibility still exists that the alloying process reduces the bulk lifetime of the germanium within the base layer of the transistor. Then regardless of the quality of the starting material, the bulk lifetime may be short enough to effect β. Presumably this could be due to heat cycling during the alloying. Yet a piece of germanium subjected to a similar heat-cycling treatment shows no adverse bulk lifetime effect. On the other hand, α is extremely sensitive to etching procedures after alloying. It seems reasonable to assume that at low currents the main loss of holes is through surface recombination.

By means of calculations and measurements of α_{cb} as a function of emitter current, Webster[6] has obtained evidence which supports this conclusion.

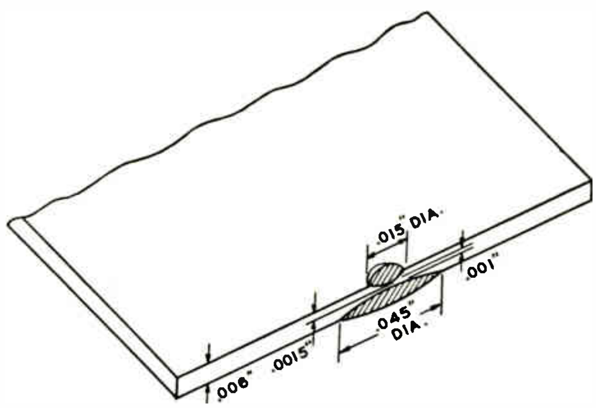

Fig. 2—Dimensions of a typical TA-153 developmental p-n-p junction transistor.

Procedure

In order to illustrate the application of the principles described above, the procedure for plotting the hole flow and estimating β for a TA-153 (RCA developmental-type number) type structure will be given. This is applicable to other structures and has been utilized with appropriate changes in geometry and constants.

For this example, junction geometry of the form shown in Fig. 2 is utilized. This is based on observation of sectioned TA-153 transistors. A convenient medium

[6] W. Webster, "On the variation of junction transistor current-amplifications factor with emitter current," Proc. I.R.E., pp. 914–920, this issue.

for field plotting is "Teledeltos" recording paper.[7] This paper has a specific resistance of 2,000 ohms/square. Equipotential electrodes can be applied simply by painting with air-drying silver paste. Lead connections are made by fastening soldering-lug connectors directly to the paper with eyelets and an eyelet punch, and then painting silver paste over the connector and paper. A scale of $\frac{1}{2}$ inch $=0.001$ inch has been found convenient.

Suppose one chooses to find the hole-flow map with $s=5{,}000$ cm/second. From (16), $aR=D_p\rho/s=40\times 2\times 10^3/5\times 10^3=16$. For maximum accuracy the boundary segments a should be as small as possible so as to most nearly approach a continuous distribution. A value of $\frac{1}{2}$ to $\frac{1}{4}$ mil ($\frac{1}{4}$–$\frac{1}{8}$ inch on the model) leads to negligible error. Since this segment size would require hundreds of segments to cover the boundary, use is made of the fact that for s constant only the product aR need be fixed over the boundary. Hence, a is chosen to be smallest on that region of the boundary along which the potential is changing most rapidly, or in other words, where the tangential component of ∇P is largest. Then the suitable value of R is chosen.

To calculate β, the current density must be integrated across the emitter surface to give

$$\beta = \frac{\text{that part of the total current which leaves the emitter and arrives at collector}}{\text{total current leaving emitter.}}$$

This is easily done by drawing a scale along the emitter radius as in Fig. 3, and multiplying the number of tubes of flow leaving the emitter per small increment in r, by r, and summing over r. In the example chosen $\beta=79/89=0.89$. Arbitrary units are used here since the final quantity β is dimensionless.

Most of the holes are lost near the intersection of the emitter junction and the free germanium surface. Both P and ∇P are high in this region.

Fig. 3(b) shows the map obtained with emitter and collector reversed. Then $\beta=0.38$.

Results

Effect of Emitter-to-Collector Area Ratio

It was recognized early in the alloy-transistor development that the use of larger collector than emitter diameters resulted in consistently higher values of α.

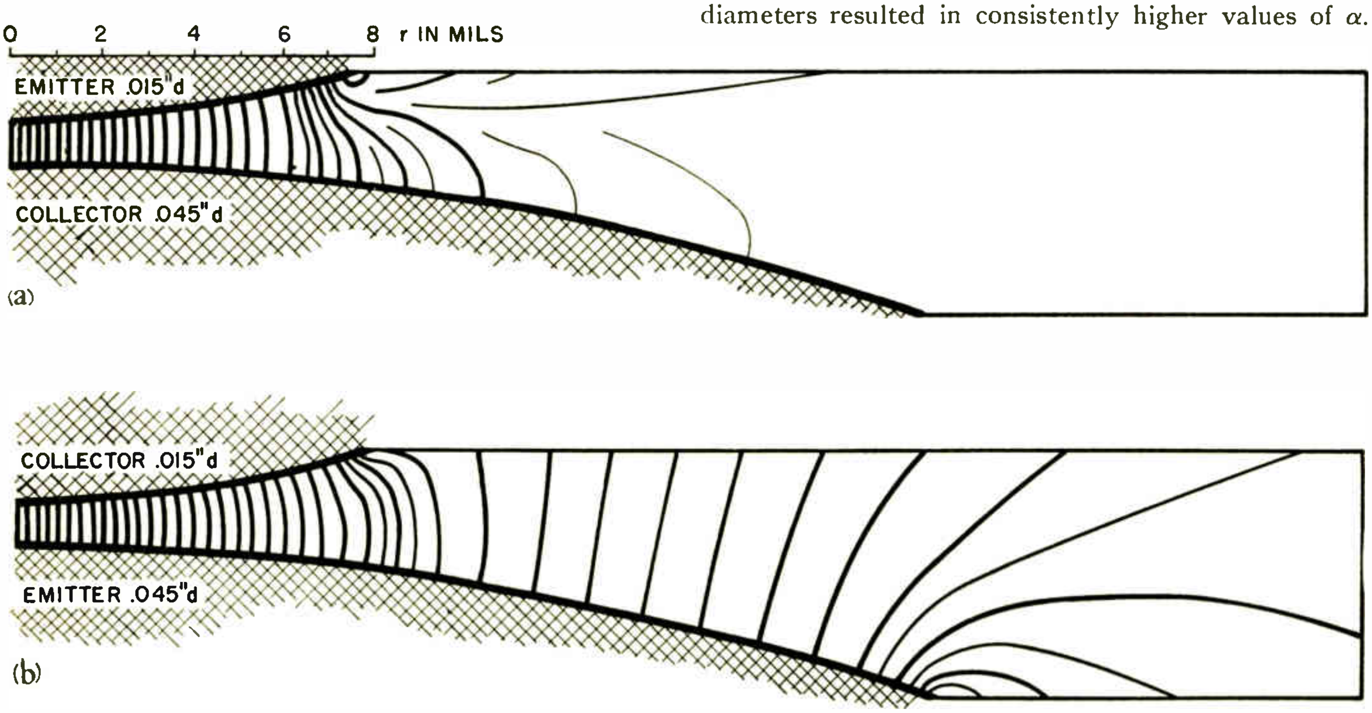

Fig. 3(a)–A hole-flow map for the TA-153 geometry of Fig. 2. Computed value of α_{cb} is 8. (b). Hole-flow map with emitter and collector reversed. Computed value of α_{cb} is 0.6.

When the equipotential map has been obtained, the field lines or hole-flow lines are drawn in using the method of rectilinear squares.[5] The map of Fig. 3(a) results. It should be noted that although equipotential lines are normal to flow lines, the equipotentials do not intersect the free surfaces of the germanium at right angles when $s>o$. It is just this departure from normal incidence which accounts for the flow of holes into the surface.

Fig. 4 shows the results of experiments made on early transistors to test this observation. Because of the unavoidable variance in this type of data taken on different units, each of the experimental points represents the average of a group of transistors with the same nominal emitter/collector area ratio. Surfaces were etched or otherwise treated in the same manner after junction had been formed. α_{cb}, the collector-to-base current gain, goes through a maximum as collector/emitter area ratio gets larger. This curve shows improved collection efficiency obtained by enlarging collector diameter.

[7] Obtainable from Western Union Telegraph Co.

In order to gain a more quantitative insight into this design parameter, a series of hole-flow maps was made using emitter and collector diameters within the range covered by the above experiment. After some preliminary trials, a value of $s = 5{,}000$ cm/second was chosen as that required to get the best fit to the data. The calculated curve of α_{cb} vs area ratio is also in Fig. 4.

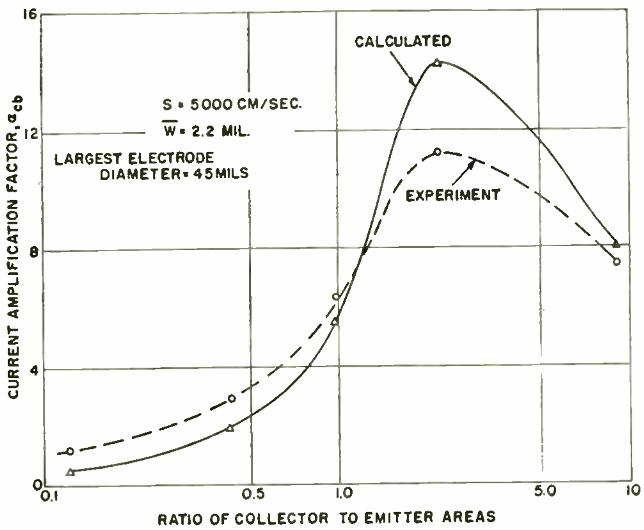

Fig. 4—Dependence of α_{cb} on the ratio of collector-to-emitter area.

The maximum in the calculated curve comes about in the following way: Consider the collector diameter fixed. With a small emitter, collection is very efficient. There is little loss to the surface near the collector, while most of the holes are lost near the edges of the emitter. As the emitter is made somewhat larger the loss of holes to the surface near the emitter increases roughly as the perimeter, but the total hole injection increases as the area. The loss near the collector is still negligible. The net result is that α_{cb} rises slowly. As emitter diameter approaches and exceeds collector diameter, hole loss to the surfaces near the edges of the collector increases very rapidly, dominating all other hole losses. Then α_{cb} decreases rapidly.

It is not known whether etching variables contributed to the disagreement between theory and experiment. Variations in the shape of the alloy junctions from the assumed spherical form may also play a part. This aspect will be discussed later. Yet the general nature of the curves is reproduced well by the plotting method. The maximum in α is broad enough, so that for practical purposes a choice of area ratio from 2 to to 9 is satisfactory. A high ratio allows a greater emitter-collector misalignment tolerance.

Variation of α_{ce} with s for Plane Alloy Junctions

The effect of s on α_{ce} is shown in Fig. 5 in which s is taken as a parameter for α_{ce} vs junction diameter, d. In this case, equal diameter, plane-parallel junctions were used at a fixed spacing of 1 mil but edge effects were included. Under the assumptions made in the solution, neglect of edge effects results in $\alpha_{ce} = 1$ for all d and s. Similarly, if $s = 0$, $\alpha_{ce} = 1$ for all d even with edge effects. The latter condition is shown as a dotted line in the figure. As d gets larger, all curves approach $\alpha_{ce} = 1$ asymptotically since the edge effects become of little importance.

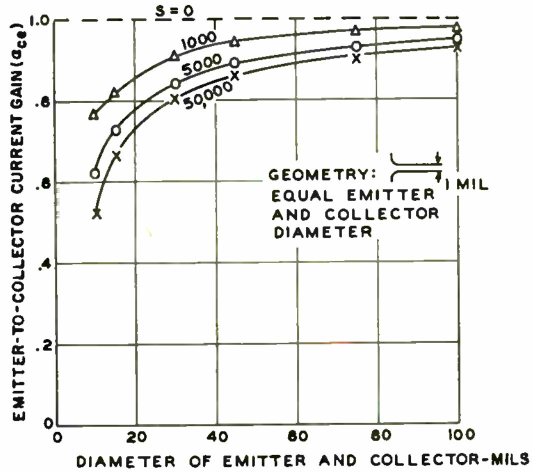

Fig. 5—Dependence of α_{ce} on junction diameter for plane emitter and collector, including the edge effects.

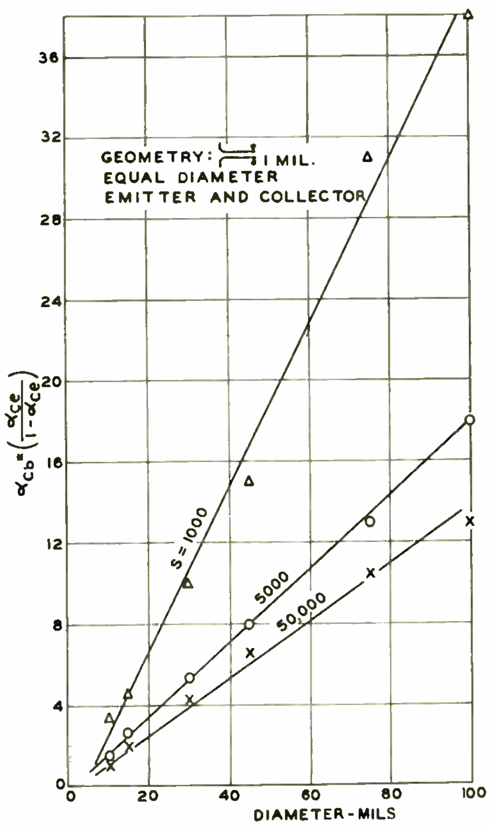

Fig. 6—Dependence of α_{cb} on junction diameter for the same geometry as used in Fig. 5. Note the linear dependence of α_{cb} on junction diameter for this geometry.

The same information, plotted in terms of α_{cb} instead of $\alpha_{ce}(\alpha_{cb} = \alpha_{ce}/1 - \alpha_{ce})$ is shown in Fig. 6. The interesting fact is that α_{cb} is directly proportional to d for this geometry. This can be understood by the use of an argument similar to that used to explain the maximum in Fig. 4. The collector collects holes in proportion to its area. The emitter region must be divided into two parts.

The central section emits proportionally to area. The perimeter region, because of the high gradient of P concentrated there, emits proportionally to perimeter length πd.

Let

$$\alpha_{ce} = \frac{\text{collector current}}{\text{emitter current}} = \frac{K_1 d^2}{K_2 d^2 + K_3 d}.$$

It is known that $\lim_{d\to\infty} \alpha_{ce}$ must be 1, hence $K_1 = K_2$. Then

$$\alpha_{cb} = \frac{\alpha_{ce}}{1 - \alpha_{ce}} = \frac{K_1}{K_3} d.$$

Comparison of Plane and Spherical Junctions

A direct comparison was made of plane-parallel alloy junctions with edge effects and spherical alloy junctions with the same diameter of emitter and collector. The value of s and the minimum spacing were the same for both cases. α_{ce} was 0.92 for the spherical case and 0.97 for the plane case, and α_{cb} was 11 and 32, respectively. The advantage of the plane junction is clear. As a further comparison, a grown junction geometry was computed, again for the same s and W. A value of $\alpha_{ce} = 0.97$ and $\alpha_{cb} = 32$ was obtained. Hence, grown-parallel junctions and alloy-parallel junctions are comparable. Of course, this assumes perfect emitter efficiency. This is less likely for the grown junction. Comparison of curved and plane junctions on a frequency basis will be made in a subsequent section.

The Absolute Value of s

The curve of Fig. 4 was calculated in order to show that the general form of α vs area ratio can be predicted by the plotting method neglecting volume recombination. The choice of $s = 5{,}000$ cm/second may be open to question, however. Surface-recombination velocity has been measured on germanium bars by independent methods in various laboratories.[8] Table II summarizes the results.

TABLE II

Treatment	s
Sandblast	10^4 to 10^5 cm/sec
Chem. Etched	2×10^3 to 4×10^2. Depending on Specific Etch
Electrolytic Etch	2×10^2

None of these measurements was made in transistor structures. All measurements on etched germanium are very sensitive to etching conditions, freshness of solution, and so forth. If it is assumed that the etching processes carried out in the presence of indium during fabrication of the transistor are the same as those on germanium bars, the assumed value of $s = 5{,}000$ cm/second appears somewhat high. Because of the variations in surface treatment, alloying rate, and electrode centering likely during small scale fabrication of the special units used for the area-ratio tests, an estimate of s was attempted using only units processed according to a set practice.[3] Even under these conditions, experience indicates that there are variations in junction shape and minimum spacing which could influence an absolute determination. However, hole-flow maps show that the ratio of α_{ce} in the normal connection, α_N, (0.015″ emitter, 0.045″ collector) to α_{ce} in the inverted connection, α_I, (0.045″ emitter, 0.015″ collector) is less sensitive to junction shape than either α_N or α_I separately. The average base-layer thickness, $\overline{W}$, can be estimated from emitter-input capacitance, since this capacitance arises chiefly from diffusion of holes through the base layer. Hence, a sample of 38 TA-153 transistors were selected with $\alpha_{N_{ce}} > 0.95$ and average spacing, $\overline{W}$, of 2.2 ± 0.2 mils. The value of α_N/α_I was 1.41 ± 0.1 Fig. 7 shows a calibration curve obtained by hole mapping in which α_N/α_I is plotted against s for 2.2 mil average spacing (1 mil minimum assuming spherical geometry). From the curve, it is estimated that $s = 460$ cm/second. This value is in the range shown in Table II for chemical etching.

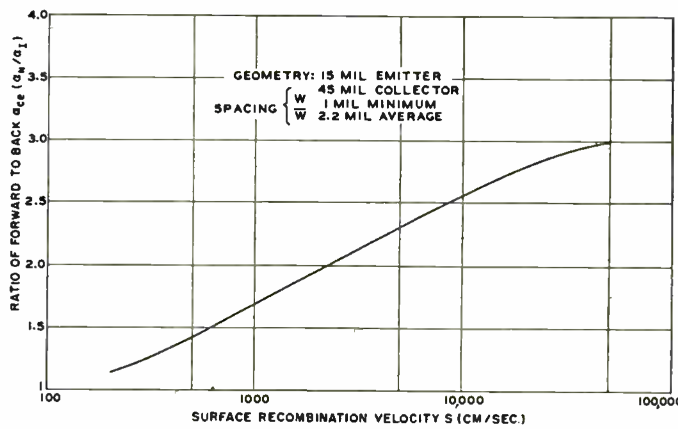

Fig. 7—A computed calibration curve for the determination of surface-recombination velocity s, from simple measurements on a completed transistor. This curve s applicable to the TA-153 geometry of Fig. 2.

Another sample of 15 transistors was selected with $\alpha_N < 0.9$ and the same base-layer thickness as before. The value of α_N/α_I was 2.09 ± 0.2, giving $s = 3{,}000$ cm/second. It appears that many cases of low α can be ascribed to improper surface treatment.

It must not be assumed, however, that all low α units are the result of high s. The search for the low α sample above disclosed many transistors with $\alpha_N/\alpha_I > 3$, which usually turned out to be due to large base thickness. The calibration curve of Fig. 7 applies only to the 2.2 mil average base thickness. Larger thicknesses could be calculated. They would yield similar curves lying above the present curve, so that for a given s, α_N/α_I increases as W and $\overline{W}$ increases. This is an important point which argues in favor of three-dimensional theory without

[8] See E. M. Conwell, "Properties of silicon and germanium," Proc. I.R.E., vol. 40, p. 1335; November, 1952.

volume recombination. If a one-dimensional theory with volume recombination dominant over surface recombination were applicable, α_N/α_I would be independent of W.

The calibration curve of Fig. 7 can also be used to follow changes in s due to various surface treatments on the same transistor. To illustrate this application, a group of unpotted transistors was made up from which three units were selected which had average base thicknesses of 2.2 mils. They were then treated with various solutions. After each treatment the units were washed in distilled water, dried, and α_N/α_I measured. The corresponding value of s was then obtained from Fig. 7. Typical data were as follows:

TABLE III

TA-153 GEOMETRY, UNIT A_2

Treatment	α_N/α_I	s	α_{cbN}
Standard TA-153 Etching[3]	1.35	400 cm/sec	24
Electrolytic Etch in 1% NaOH solution	1.16	200	37
Etch containing $Cu(NO_3)_2$[9] Etch for 10 sec. very slight deposit of copper on the Germanium	2.41	7,400	0.7
Copper removed by Ammonia and Hydrogen Peroxide solution	1.20	250	30
Distilled water which had been boiled with a piece of brass			
After 5 min.	1.13	180	28
After 10 min.	1.11	150	52
After 3 hours	2.5	10,000	0.5
Electrolytic etch in 1% NaOH	1.25	280	27
Saturated solution of $ZnCl_2$	1.64	880	9
Electrolytic etch in 1% NaOH	1.20	250	32

It can be seen that surface treatments vary s over wide limits. Yet the processes are quite reversible; electrolytic etching always restores the surface to $s=250$ cm/second approximately.

The significance of surface-recombination velocity in device performance and the ease with which s may be measured suggest that the method may have application as a quality-control test in junction-transistor manufacture.

[9] See S. Navon, R. Bray and H. Y. Fan, "Lifetime of injected carriers in germanium," PROC. I.R.E., vol. 40, p. 1345; November, 1952. The values of s given in this reference are not in conflict with the present results because the etching conditions were different. The presence of indium on the germanium causes a slight deposition of copper which apparently greatly increases surface recombination.

Transit-Time Dispersion

The properties of junction transistors at the higher frequencies depend on many factors such as diffusion time through the base layer (diffusion capacitance), junction capacitance of the collector, internal lead resistance, etc. These have been discussed in the literature. Because transistor theories have been confined to one-dimensional analyses, the factor of transit-time spread due to path-length variation has been ignored. This type of dispersion is similar to the path-length—transit-time effect in electron-multiplier tubes, wherein electrons which have traversed various paths through the multiplier have a spread in transit time. This dispersion has been calculated for the TA-153 structure, using the hole-flow map to estimate the path-length distribution. Then, since $t=x^2/D_p$, the relative number of holes having transit times between t and $t+\Delta t$ is obtained. An analysis of this dispersion curve indicates that α_{ce} will be down 3 db at about 1 mc due to this effect. A similar calculation in a plane-parallel alloy structure including edge effects shows that α_{ce} is 3 db down at 5 mc. While at present the other limits to high-frequency performance in the TA-153 are more important, future design of special high-frequency transistors should take the path-length dispersion into account. This can be done by attempting to provide parallel junctions.

ACKNOWLEDGMENT

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On the Variation of Junction-Transistor Current-Amplification Factor with Emitter Current*

W. M. WEBSTER†, SENIOR MEMBER, IRE

Summary—**Existing theories of the junction transistor fail to predict the very significant variation of current-amplification factor, α_{cb}, as the emitter current is varied. This variation has been very troublesome in power transistors, particularly at high emitter currents where the α_{cb} fall-off may be so severe as to limit usefulness. At low currents, α_{cb} also drops off, an effect of importance in very low-power applications. By taking into account modification of the base region by the injected charge carriers, an explanation is found for the observed variation. Electric fields in the base region decrease the mean transit time for minority carriers on their way to the collector. This reduces the effect of surface recombination and increases current-amplification factor as the emitter current rises. Another effect, however, is in the opposite direction; this second effect is due to an increase in conductivity of the base material which increases the rate of volume recombination and also lowers emitter efficiency. The combination of these effects yields calculated curves which show a maximum and agree well with experiment. The work is applicable to both *p-n-p* and *n-p-n* types, and it is shown that the latter is inherently less sensitive to emitter current density.**

Introduction

As THE emitter current in a junction transistor is increased, the current-amplification factor is observed to initially increase, go through a maximum, and finally decrease steadily. Fig. 1 shows this variation for a typical *p-n-p* alloy-junction transistor. In this figure the ratio of collector-signal current to base signal current is plotted as a function of dc emitter current. For many applications, this variation is a severe limit to usefulness. For example, it is a source of distortion which increases rapidly with signal level and, as such, is a consideration in audio-output amplifiers. Even small-signal operation may be affected since the gain of an amplifier stage will vary appreciably with bias currents.

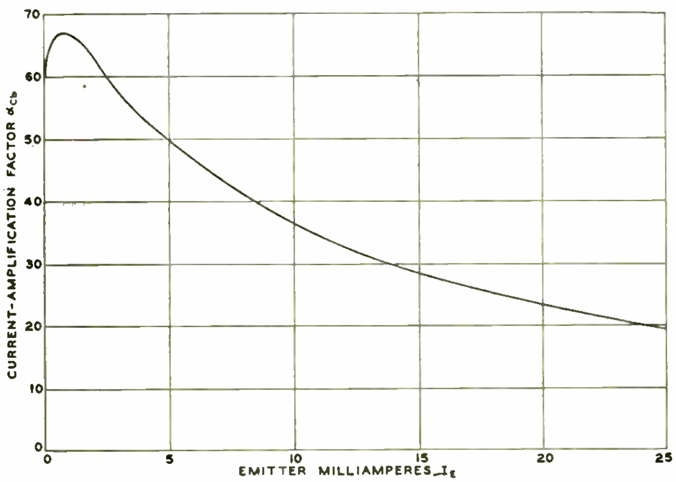

Fig. 1—Variation of current-amplification factor, α_{cb}, with emitter current for a typical *p-n-p* alloy transistor.

It is the purpose herein to show how the variation of current gain with emitter current can be accounted for by the change in the characteristics of the base material produced by the injected carriers. Previous transistor theory ignored such effects in that the injected-charge density was assumed to be small compared to the density of ionized impurity atoms. This is not often the case. A simple calculation will show that the injected-charge density in the base region of a TA-153 transistor[1] is about equal to the impurity-charge density when the emitter current is of the order of one milliampere. (This is a current density of about one ampere per square centimeter.) Since similar transistors are sometimes used at currents in excess of ten milliamperes, the injected charge is rarely negligible.

The most important changes produced by the injected charge are these:

a. A small field is developed in the base section which aids the flow of injected carriers from emitter to collector.
b. The conductivity of the base section is increased. This decreases emitter efficiency and increases volume recombination.

The first sections of the present work briefly review the aspects of transistor theory which need amendment and the proper corrections are derived in simple terms. The remainder consists of appendexes where more complete derivations may be found.

Throughout, derivations apply to the *p-n-p* transistor. The final equations have the same form for the *n-p-n* transistor and are obtained by simply interchanging a few subscripts. Data apply to germanium transistors.

Current-Amplification Factor

A current-amplification factor, α_{ce}, is defined as the variation of collector current, I_C, in response to a change in emitter current, I_E, with the collector voltage, V_C, held constant. These currents are defined in Fig. 2. This can be expressed mathematically as:

$$\alpha_{ce} \equiv \left.\frac{\partial I_C}{\partial I_E}\right|_{V_C} \tag{1}$$

Another current-amplification factor, α_{cb}, can be defined:

* Decimal classification: R282.12. Original manuscript received by the IRE, September 3, 1953; revised manuscript received, February 19, 1954.
This paper is based on a dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Princeton University, Princeton, N. J.
† Radio Corp. of America, RCA Labs. Div., Princeton, N. J.

[1] R. R. Law, C. W. Mueller, J. I. Pankove, and L. D. Armstrong, "A developmental *p-n-p* junction transistor," Proc. I.R.E., vol. 40, pp. 1352–1357; November. 1952.

$$\alpha_{cb} \equiv \frac{\partial I_C}{\partial I_B} = \frac{\alpha_{ce}}{1 - \alpha_{ce}}.$$

If α_{ce} is nearly unity, as is the case for a useful junction transistor,

$$\alpha_{cb} \approx \frac{\partial I_E}{\partial I_B} \approx \frac{1}{1 - \alpha_{ce}}. \tag{2}$$

α_{cb} is a more sensitive parameter than α_{ce} and, since it is easier to measure accurately, permits a more reliable comparison between theory and experiment.

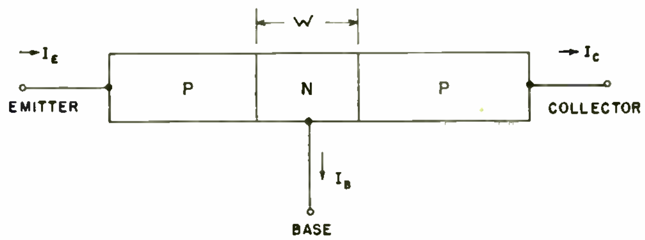

Fig. 2—Current convention used to define α_{cb} and α_{ce}.

Fig. 3 shows a sketch of the potential distribution through a *p-n-p* transistor and, schematically, the paths taken by the holes and electrons therein. The arrows on the paths indicate the direction of particle motion.

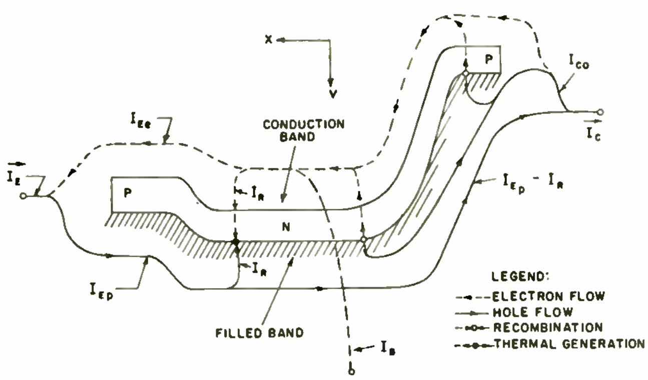

Fig. 3—Potential distribution in a *p-n-p* transistor showing, schematically, the paths followed by holes and electrons.

The emitter current is composed of holes injected into the base (I_{Ep}) and electrons extracted from the base (I_{Ee}). Some of the holes which constitute I_{Ep} recombine on their way through the base with electrons which enter through the base lead. The recombination rate defines a current I_R. The collector current is composed of the holes which did not recombine and a "saturation" current, I_{co}, composed primarily of holes and electrons produced spontaneously by thermal energy in both the base and collector region and possibly a leakage current across the collector junction. For a good transistor, I_{co}, I_R, and I_{Ee} should all be small compared to I_{Ep}. Now,

$$I_B = I_R + I_{Ee} - I_{co}$$

and

$$I_E = I_{Ep} + I_{Ee} \approx I_{Ep},$$

since $I_{Ep} \gg I_{Ee}$. The equation which describes the change in I_B for an incremental change in I_E with collector voltage constant is:

$$\frac{\partial I_B}{\partial I_E} \approx \frac{\partial I_R}{\partial I_{Ep}} + \frac{\partial I_{Ee}}{\partial I_{Ep}} - \frac{\partial I_{co}}{\partial I_{Ep}}.$$

There is no physical reason why the thermal generation or leakage should vary with I_{Ep} so that $\partial I_{co}/\partial I_{Ep}$ may be set equal to zero. Thus,

$$\frac{\partial I_B}{\partial I_E} \approx \frac{\partial I_R}{\partial I_{Ep}} + \frac{\partial I_{Ee}}{\partial I_{Ep}} = \frac{1}{\alpha_{cb}}. \tag{3}$$

This means that α_{cb} can be determined if it is known how recombination and the fraction of emitter current composed of electrons vary with the number of holes injected.

The recombination term should be separated into two parts, one due to surface recombination and the other to volume recombination because the two mechanisms obey different equations. If this is done, an expression may be written for $1/\alpha_{cb}$ which contains three terms which may be investigated independently.

$$1/\alpha_{cb} = \frac{\partial I_{SR}}{\partial I_{Ep}} + \frac{\partial I_{VR}}{\partial I_{Ep}} + \frac{\partial I_{Ee}}{\partial I_{Ep}}. \tag{4}$$

Here, *SR* refers to surface recombination and *VR* to volume recombination. The partial first-order theory previously published[2] gives the following values:

$$\frac{\partial I_{VR}}{\partial I_{Ep}} = \frac{I_{VR}}{I_{Ep}} = \frac{1}{2}\left(\frac{W}{L_b}\right)^2 \tag{5}$$

and

$$\frac{\partial I_{Ee}}{\partial I_{Ep}} = \frac{I_{Ee}}{I_{Ep}} = \frac{\sigma_b W}{\sigma_e L_e} \tag{6}$$

where W is the thickness of the base region (see Fig. 2), L_b is the diffusion length for holes in the base region, σ_b and σ_e are the conductivities of base and emitter regions respectively, and L_e is the diffusion length for electrons in the emitter region.

An expression for the surface-recombination term, $\partial I_{SR}/\partial I_{Ep}$, is now needed to complete the first-order theory. It may be derived as follows: Nearly all of the surface recombination in an alloy-junction transistor occurs in an area which is ring-shaped and surrounds the emitter "dot." The number of holes recombining depends on the product of s, the surface-recombination velocity; an effective surface area for recombination, A_s; and the density of holes present near the surface, p. This is expressed by the equation $I_{SR} = esA_sp$ where e is the electronic charge. Since the area where major surface recombination takes place is very near the emitter, one sets p equal to the hole density at the emitter junction which will be called p_e. The first-order theory as-

[2] W. Shockley, M. Sparks, and G. K. Teal, "The *p-n* junction transistors," *Phys. Rev.*, vol. 83, pp. 151–162; July, 1951.

sumes that holes flow purely by diffusion according to the law: $J_p = -eD_p \text{ grad } p = I_{Ep}/A$ where J_p is the hole-current density and A is the cross-sectional area of the conduction path (which is about equal to the emitter area). For plane-parallel geometry where volume recombination may be neglected as far as its effect on hole density is concerned (the case for any useful transistor), this may be integrated to yield $p_e = I_{Ep}W/AeD_p$ which is substituted into the expression for I_{SR}. The result is:

$$\frac{I_{SR}}{I_{Ep}} = \frac{sA_sW}{D_pA} = \frac{\partial I_{SR}}{\partial I_{Ep}}. \tag{7}$$

Since electric fields in the base region were neglected in solving for p_e, this expression is not exact. It is, in fact, of approximation comparable to the terms quoted above as (5) and (6).

Now the complete expression for $1/\alpha_{cb}$ according to the first-order theory may be written combining (5), (6), and (7).

$$1/\alpha_{cb} = \frac{sA_sW}{D_pA} + \frac{\sigma_bW}{\sigma_eL_e} + \frac{1}{2}\left(\frac{W}{L_b}\right)^2. \tag{8}$$

None of the three terms depends on emitter current. Thus, to explain experimental results, the basic assumptions which may be insufficiently exact must be further investigated. Two assumptions require revision. One of these states that electric fields in the base region may be neglected, the other, that the change in base-region conductivity due to injected charge is trivial. These are both indirect consequences of the assumption that the injected-hole density is small compared to the density of ionized donor atoms which, as indicated above, is not often the case.

Fields in the Base Region and Surface Recombination

In the first-order theory, where electric fields in the base region are neglected, hole current density in the base is given by:

$$J_p = -eD_p \text{ grad } p \tag{9}$$

where J_p is the hole current density, e is the electronic charge, D_p is the diffusion coefficient for holes in the base region, and p is the hole density at any point. Electron-current density is assumed equal to zero.

To include effects due to the electric fields in the base two equations are required:

$$J_e = -ne\mu_e \text{ grad } V + eD_e \text{ grad } n. \tag{10}$$

$$J_p = -pe\mu_p \text{ grad } V - eD_p \text{ grad } p. \tag{11}$$

Here, J_e is the current density of electrons in the base, n is the electron density, μ_e and μ_p are electron and hole mobilities, D_e and D_p are electron and hole-diffusion coefficients and V is the electric potential.

To these equations can be added $n + N_a \approx p + N_d$ where N_a and N_d are acceptor and donor ion densities. This equation stems from the fact that the net charge density in the base region must be essentially zero. In n-type material, N_a may be set equal to zero without serious loss of accuracy and N_d assumed to be a constant throughout the base. Thus, $n = p + N_d$ and grad n = grad p.

If the transistor is to be useful, J_e must be very small compared to J_p. If $J_e = 0$, n replaced with $N_d + p$, and grad n with grad p, Equations (10) and (11) may be combined to yield:

$$J_p = -(eD_p \text{ grad } p)\left(1 + \frac{p}{N_d + p}\right). \tag{12}$$

Also,

$$\text{grad } V = \frac{D_e}{\mu_e} \cdot \frac{1}{(N_d + p)} \text{ grad } p = \frac{kT \text{ grad } p}{e(N_d + p)}. \tag{13}$$

If $p \ll N_d$, (12) reduces to the first-order equation given as (9). However, as p increases, the current density increases more rapidly than grad p until, when $p \gg N_d$, $J_p \approx -2eD_p$ grad p. When this happens, half the hole current is carried by diffusion and half by the electric field. Under these conditions, reasonably accurate results may be obtained if the diffusion coefficient is multiplied by two wherever it appears in equations derived from the first-order theory. In the transition region where $0.01 < p/N_d < 100$, more careful calculation is required.

The origin of the electric field can be described in physical terms as follows: In order to pass a certain hole current, a hole-density gradient is required. The condition of space-charge neutrality stipulates an equal electron-density gradient. The electron-density gradient would like to induce a flow of electrons in the same direction as the flow of holes. This happens, momentarily, until an unbalance of charge sets up an electric field to hold the electrons in place against their density gradient. The same field, however, acts in a direction to encourage hole flow and, in the limit, doubles the hole-current density for a given density gradient.

The field in the base region has a considerable effect on the surface-recombination term. At low currents, the expression given above applies, i.e., sA_sW/D_pA. At high current density, however, D_p is effectively doubled and the per cent of the hole current lost by surface recombination is divided by two. The transition between the two cases accounts for the initial rise in current gain with emitter current. A calculation of the behavior in the transition region is given in Appendix I.

The result of the analysis of Appendix I is:

$$\frac{\partial I_{SR}}{\partial I_{Ep}} = \frac{sWA_s}{D_pA} g(Z) \tag{14}$$

where the function $g(Z)$, which will be called the "field factor," is plotted vs Z in Fig. 4 (opposite page) and

$$Z \equiv \frac{W\mu_e}{AD_p\sigma_b} I_E.$$

Z is a convenient dimensionless parameter to use in the analysis. It is the ratio of hole density in the base region at the emitter junction to donor density which one would compute from the first-order theory.

For high values of Z, i.e., greater than about 20, $g(Z)$ approaches 0.5; for $Z=0$, $g(Z)$ has the value of unity. Thus, the loss in current-amplification factor due to surface recombination decreases as emitter current is increased and approaches a final value of one-half the initial value. This causes the current gain to rise, initially, with emitter-current density at a rate which depends on the base width, W, the impurity type and conductivity of the base material.

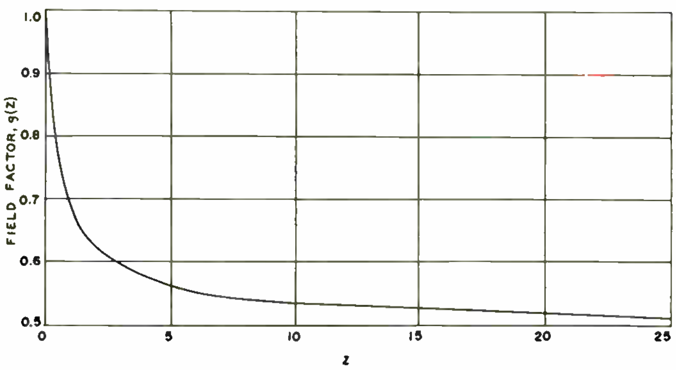

Fig. 4—The field factor, $g(Z)$, as a function of (Z).

In passing, it might be mentioned that the so-called diffusion capacitance of a junction transistor is reduced by the field in the base region by a factor of two as emitter current is increased. This has been observed to occur at about the same current as saturation of the curve for $g\ (Z)$, as it should, since it also depends inversely on the diffusion coefficient.[3]

Modulation of Base-Region Conductivity by Injected Carriers

As pointed out before, the assumption that $p \ll N_d$ is incorrect in a transistor which is operating at a current density in excess of about 0.1 ampere per square centimeter. It is usually assumed that the number of electrons in the conduction band of the base region is N_d. Instead, N_d+p should be used. A reasonably good correction to the first-order theory consists of simply multiplying the base conductivity by the ratio $(p+N_d)/N_d$ where it appears in the above equations for dc current flow.[4] This ratio is that of the electron density in the base with injected holes present to their density in the absence of holes. One should use the value of p/N_d at the emitter which, for large currents, is given approximately by $I_{Ep}W\mu_e/2D_pA_b=Z/2$. (See Appendix I.) Thus, wherever σ_b appears in the dc equations it should be multiplied by:

$$\frac{p+N_d}{N_d}=1+Z/2.$$

Emitter Efficiency

The partial first-order theory predicts

$$\frac{\partial I_{Ee}}{\partial I_{Ep}}=\frac{I_{Ee}}{I_{Ep}}=\frac{\sigma_b W}{\sigma_e L_e}. \tag{6}$$

This may be amended by writing instead,

$$\frac{I_{Ee}}{I_{EP}}=\frac{\sigma_b W}{\sigma_e L_e}(1+Z/2).$$

Since Z is a function of I_{Ep}, one cannot simply equate $\partial I_{Ee}/\partial I_{Ep}$ to this but must take the derivative as follows:

$$\frac{\partial I_{Ee}}{\partial I_{Ep}}=\frac{\sigma_b W}{\sigma_e L_e}\left(1+Z/2+\frac{I_{Ep}}{2}\frac{\partial Z}{\partial I_{Ep}}\right).$$

$I_{Ep}(\partial Z/\partial I_{Ep})$, however, equals Z since Z and I_{Ep} are linearly related. Thus, the effect of differentiation is simply to double the term in Z and

$$\frac{\partial I_{Ee}}{\partial I_{Ep}}=\frac{\sigma_b W}{\sigma_e L_e}(1+Z). \tag{15}$$

This equation states that the emitter efficiency decreases, and hence, the current-amplification factor drops as emitter current is increased. Further, at high currents, the current-amplification factor α_{cb} should vary inversely with the emitter current as is observed experimentally.

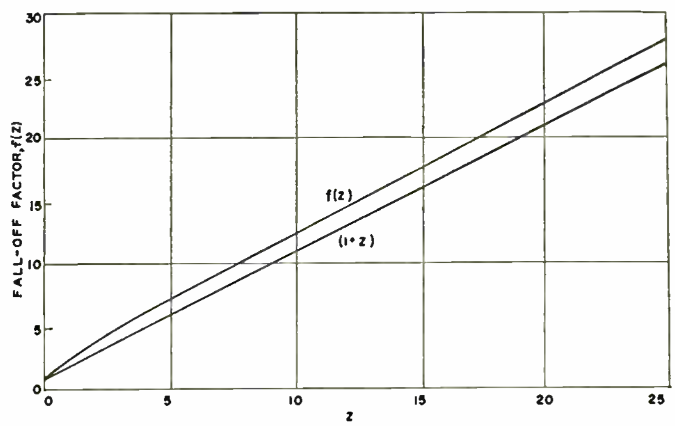

Fig. 5—The fall-off factor, $f(Z)$, and $(1+Z)$ as functions of Z.

A more exact calculation is made in Appendix II which also takes into account the changing field in the base region. The accurate calculation and the approximate one given here are both plotted in Fig. 5 against Z. The difference between them is not great, being at most about 25 per cent and less than 20 per cent for Z greater than about 4.

Volume Recombination

The expression for the variation of base with emitter current due to volume recombination (5) does not involve σ_b explicitly

[3] Private communication from L. J. Giacoletto, RCA Laboratories, Princeton, N. J.

[4] The reader is cautioned that this substitution is not valid for all transistor equations but only where σ_b has been substituted for the density of conduction electrons (or holes, in p-type material). The underlying physics should be examined for each equation to make certain that this is the case.

$$\frac{\partial I_{VR}}{\partial I_{Ep}} = \frac{I_{VR}}{I_{Ep}} = \frac{1}{2}\left(\frac{W}{L_b}\right)^2.$$

However, L_b may be related to base conductivity through the average hole lifetime since $L_b^2 = D_p\tau$. τ, when it applies to holes lost by bimolecular[5] recombination, is inversely proportional to the number of electrons in the base region and, hence, inversely proportional to σ_b. Thus, the expression for volume recombination may be corrected in the same way as the expression for emitter efficiency, i.e.,

$$\frac{\partial I_{VR}}{\partial I_{Ep}} = \frac{1}{2}\left(\frac{W}{L_b}\right)^2 (1 + Z). \quad (16)$$

The volume-recombination term shows the same dependence on emitter current as the emitter-efficiency term.

Actually, the volume-recombination term ought to involve an integral of the base conductivity over the entire base region, whereas simply the value of base conductivity near the emitter was used. Such a calculation gives a result which is trivially different. This is because most of the volume recombination takes place near the emitter where hole and electron densities are greatest. There is evidence that volume recombination becomes mono-molecular at high values of Z[6]. In this case, the variation with emitter current vanishes and the volume-recombination term is replaced by $\partial I_{VR}/\partial I_{Ep} = W^2/4D_p\tau_m$ where τ_m is the lifetime for monomolecular volume recombination at high injection levels.

Current-Amplification Factor vs Emitter-Current Theory and Experiment

According to the preceding sections, the approximate equation for current gain as a function of emitter current can now be written by combining (14), (15), and (16):

$$\frac{1}{\alpha_{cb}} \approx \frac{sWA_s}{D_pA} g(Z) + \left[\frac{\sigma_b W}{\sigma_e L_e} + \left(\frac{W}{L_b}\right)^2\right](1 + Z) \quad (17)$$

where

$$Z = \frac{W\mu_e I_E}{D_p A \sigma_b} \quad (17a)$$

and $g(Z)$ is given by Fig. 4. The accuracy of this equation may be improved somewhat by using the calculated curve of Fig. 5 for the emitter-efficiency term but the difference is not usually significant.

The above equation is for the p-n-p junction transistor. To apply it to an n-p-n transistor, all that is required is to change the subscripts on mobility and diffusion coefficients from e to p and vice-versa. Thus,

$$\frac{1}{\alpha_{cb}} \approx \frac{sWA_s}{D_eA} g(Z) + \left[\frac{\sigma_b W}{\sigma_e L_e} + \frac{1}{2}\left(\frac{W}{L_b}\right)^2\right](1 + Z) \quad (18)$$

where

$$Z = \frac{W\mu_p I_E}{D_e A \sigma_b}. \quad (18a)$$

Into the expressions for Z (17a and 18a) may be substituted the Einstein equations $D_p = kT\mu_p/e$ and $D_e = kT\mu_e/e$ where k is Boltzmann's constant and T is the temperature of the transistor. Also, μ_e/μ_p may be set equal to the constant b which has a value of about 2 for germanium. Then:

$$Z = \frac{WeI_E}{kTA\sigma_b}\cdot b \quad \text{for the } p\text{-}n\text{-}p \text{ transistor and}$$

$$Z = \frac{WeI_E}{kTA\sigma_b}\cdot\frac{1}{b} \quad \text{for the } n\text{-}p\text{-}n.$$

One sees immediately that, if all quantities except the conductivity type are the same (i.e., identical geometry, diffusion lengths, and conductivities) α_{cb} should vary less with emitter current in an n-p-n transistor than in a p-n-p transistor by a factor of $b^2 \approx 4$ (for germanium).

All the derivations above, and those in the appendices, apply to a geometry wherein the emitter and collector are assumed to be parallel planes and "end effects" are neglected. The alloy-junction transistor is a reasonable approximation to this case. Most of the quantities involved in the expression can be measured fairly exactly for the alloy transistor. A should be the actual emitter area and W approximately the base thickness measured by the capacitance method. σ_b and L_b are determined by the material used. D_p and μ_e are known constants. However, no accurate method for measuring the quantities s, A_s, σ_e and L_e in alloy-junction transistors has so far been developed. What is done, then, is to use values for sA_s and $\sigma_e L_e$ which give the best agreement between theory and experiment. These values are reasonable ones and the agreement is good over a wide current range.

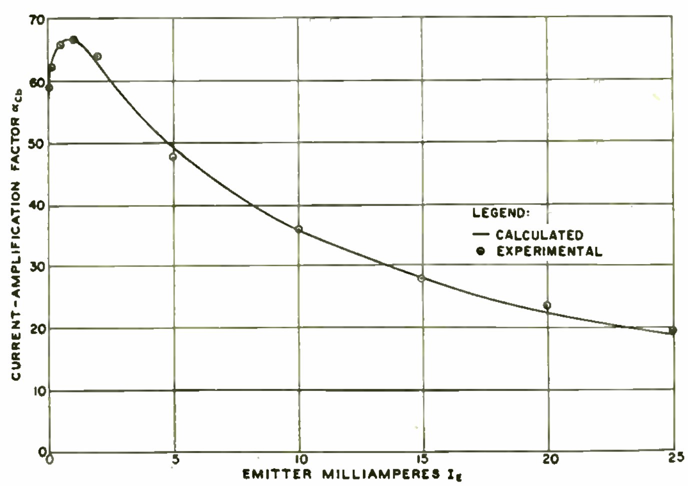

Fig. 6—Comparison of theory and experiment for a typical p-n-p alloy transistor.

Fig. 6 shows the variation of current-amplification factor with emitter current for a TA-153 (p-n-p) transistor. The solid line is the computed curve and the points are experimental data. The following values

[5] The use of the word bi-molecular in this case applies to recombination proceeding at a rate proportional to the product np. Monomolecular refers to a recombination rate proportional only to p. The details of the recombination mechanism are not of concern at the moment since capture cross-sections and the like may be lumped into a single recombination coefficient.

[6] R. N. Hall, "Electron-hole recombination in germanium," *Phys. Rev.*, vol. 87, p. 387; 1952.

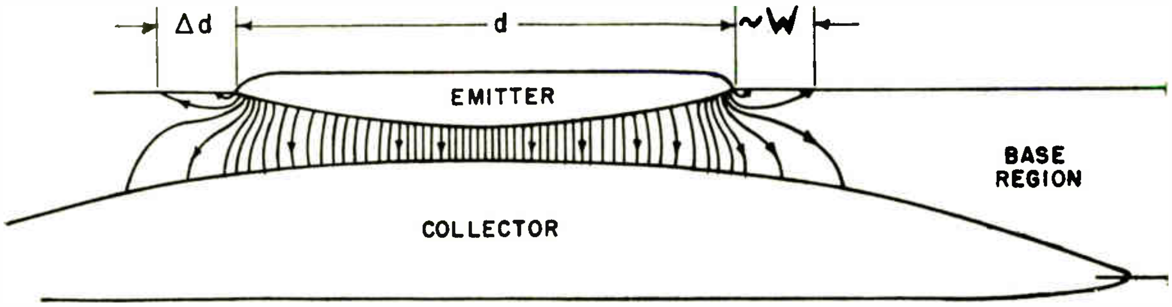

Fig. 7—Analog map of hole flow in an alloy transistor.

were used for computations:

$W = 4.8 \times 10^{-3}$ cm (measured by the capacitance method)
$A = 1.1 \times 10^{-3}$ cm^2 (known emitter area)
$\sigma_b = 0.45$ mho/cm (known base conductivity)
$L_b = 0.14$ cm (calculated from lifetime of 500 μsec)
$\sigma_e L_e = 1.55$ mho (obtained from best fit)
$sA_s = 0.147$ cm^3/sec (obtained from best fit)
$D_p = 44$ cm^2/sec and $\mu_e = 3{,}600$ cm^2/sec volt (known values).

From these:[7]

$$\frac{\sigma_b W}{\sigma_e L_e} = 0.0014, \qquad \frac{1}{2}\left(\frac{W}{L_b}\right)^2 = 0.0006$$

$$\frac{sA_s W}{D_p A} = 0.014,$$

and

$$Z = \frac{W\mu_e}{D_p A \sigma_b} I_E = 800 I_E \text{ where } I_E \text{ is in amperes.}$$

The value of sA_s is quite reasonable. Fig. 7 shows the paths of hole flow through a junction transistor as calculated using an analog-mapping technique.[8] The average TA-153 has a surface-recombination velocity, s, of about 350 cm/sec. The analog map shows that nearly all the surface recombination occurs in a ring around the emitter whose width is about equal to W. From this we estimate A_s to be 6×10^{-4} cm^2. Using $s = 350$ cm/sec, $sA_s = 0.2$ cm^3/sec. This is in very good agreement with the value 0.147 cm^3/sec used to match theory and experiment.

The value of $\sigma_e L_e$ seems to be a bit large. The existing evidence indicates a value of σ_e of about 10^3 mho/cm. An intelligent estimate based on an extrapolation of L from measurements made on relatively pure material to this value of conductivity would suggest that L_e should be about 10^{-4} cm. However, such an extrapolation is probably to be questioned more than the result obtained above.

Fig. 8 shows a similar comparison for a (*n-p-n*) transistor of similar geometry. Here, the following values were used:

$W = 4.6 \times 10^{-3}$ cm (measured as before)
$A = 1.1 \times 10^{-3}$ cm^2 (known)
$\sigma_b = 0.33$ mho/cm (known)
$L_b = 0.28$ cm (assumed)
$\sigma_e L_e = 1.1$ mho, $sA_s = .11$ cm^3/sec } obtained from best fit
$D_e = 93$ cm^2/sec and $\mu_p = 1{,}700$ cm^2/sec volt (known values).

From these, $\sigma_b W/\sigma_e L_e = 0.0014$, $sA_s W/D_p A = 0.005$, $W^2/2L_b^2 = 1.3 \times 10^{-4}$, and $Z = 215\ I_E$.

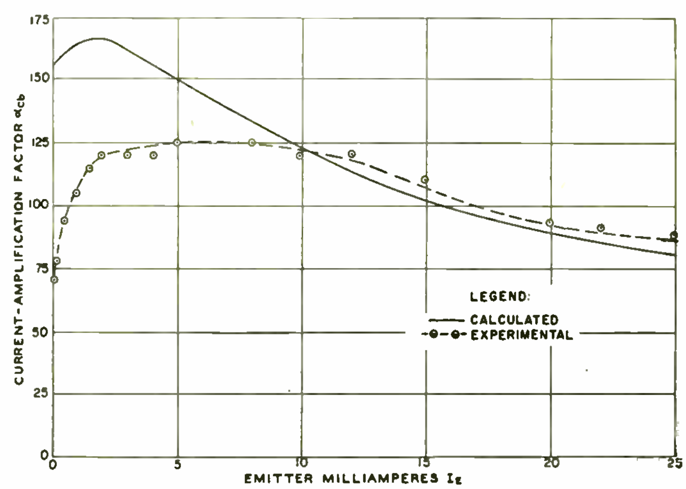

Fig. 8—Comparison of theory and experiment for a typical *n-p-n* alloy transistor.

The values of $\sigma_e L_e$ and sA_s are about the same as for the *p-n-p* transistor, which is reassuring. However, the agreement at low currents is not nearly as good for the *n-p-n* as for the *p-n-p*. The authors interpretation is that some mechanism exists in addition to surface recombination which becomes less detrimental as the current density increases. It is quite conceivable that this may be either the transition from bi-molecular to monomolecular volume recombination or evidence of a patch-effect at the emitter. In all, however, the agreement between the analysis and experimental data is not too bad.

[7] R. N. Hall, "Power rectifiers and transistors," Proc. I.R.E., vol. 40, pp. 1512–1518; November, 1952. In this paper, Hall ascribes the fall-off of current gain to the increase in volume recombination only. For the transistors described here, the decrease of emitter efficiency is more significant.

[8] A. R. Moore and J. I. Pankove, "The variation of current gain with junction shape and surface recombination in alloy transistors," Proc. I.R.E., pp. 907–913, this issue.

Conclusion

A number of corrections to the first-order theory for current gain are required to explain the variation of current gain with emitter current. Three of these have been obtained by considering the change in base material conductivity with injected minority carriers and the fields produced in the base region by the injected current density. New terms for surface recombination, volume recombination, and emitter efficiency have been derived. The more complete theory gives reasonable agreement with experiment.

In both cases (*p-n-p* and *n-p-n*), surface recombination plays the dominant role (by a factor of from 3 to 10) at low values of emitter current. As emitter current is increased, the emitter-efficiency term increases and finally dominates the equation for α_{cb}.

Appendix I

Surface Recombination

From maps of hole flow in the alloy-type transistor such as the one shown in Fig. 7 made by an analog technique,[8] it has been determined that nearly all the surface recombination takes place in a ring around the emitter "dot." If this ring has an area A_s, the number of holes recombining there per second gives rise to a current $I_{SR}=esA_sp_e$ where s is the surface-recombination velocity and p_e is the hole density at the emitter. Further,

$$\frac{\partial I_{SR}}{\partial I_{Ep}} = seA_s\frac{\partial p_e}{\partial I_{Ep}}\cdot$$

In the section on fields in the base region and surface recombination the corrected expression for hole current density was derived:

$$J_p = -eD_p\left(1+\frac{p}{N+p}\right)\text{grad } p.$$

For the plane-parallel case then,

$$\left[1+\frac{p/N_d}{I+p/N_d}\right]\frac{d}{dx}(p/N_d) = \frac{-I_{Ep}}{eD_pN_dA}$$

$$\approx \frac{-I_E\mu_e}{D_pA\sigma_b} = -\frac{Z}{W}$$

where A is the cross-sectional area of the transistor for conduction and σ_b is the base-material conductivity (without injected hole current). This equation assumes I_{Ep} is constant throughout the base region and is sufficiently accurate for a typical transistor.

This equation can be integrated to yield:

$$2\frac{p}{N_d} - \ln(1+p/N_d) = \frac{Zx}{W}$$

if $x=0$, when $p=0$ (i.e. at the collector). For p/N_d small, this reduces to $p/N_d=Zx/W$. For p/N_d large, it becomes $p/N_d\approx Zx/2W$. The density of holes at the emitter, i.e., when $x=W$, is given by

$$2\frac{p_e}{N_d} - \ln(1+p_e/N_d) = Z.$$

In order to substitute this quantity into the expression for $\partial I_{SR}/\partial I_{Ep}$, $\partial p_e/\partial I_{Ep}$ is required. This is obtained as follows:

$$\frac{\partial p_e}{\partial I_{Ep}} = \frac{\partial p_e}{\partial Z}\frac{\partial Z}{\partial I_{Ep}} = \frac{\partial(p_e/N_d)}{\partial Z}\cdot\frac{N_dW\mu_e}{D_pA\sigma_b}$$

$$= \frac{\partial(p_e/N_d)}{\partial Z}\cdot\frac{W}{eD_pA}.$$

From the equation which relates p_e/N_d and Z, one obtains,

$$\frac{\partial p_e/N_d}{\partial z} = \frac{1+p_e/N_d}{1+2p_e/N_d} \equiv g(Z).$$

$g(Z)$ is plotted in Fig. 4 against Z. Combining, one obtains:

$$\frac{\partial I_{SR}}{\partial I_{Ep}} = \frac{WsA_s}{D_pA}g(Z).$$

As shown in Fig. 7, the area A_s should be $\pi d\Delta d$ where d is the diameter of the emitter dot and Δd is the width of the "absorbing" ring. A fair estimate of Δd may be obtained from analog maps. For the geometry studied, Δd is about equal to W.

Appendix II

Emitter Efficiency

Since the effective diffusion coefficient is changing with emitter current, p_e is not a linear function of I_{Ep} as was assumed earlier. The more exact dc equation for the ratio of electron to hole flow across the emitter junction may be written as:

$$\frac{I_{Ep}}{I_{Ep}} = \frac{\sigma_bW}{\sigma_eL_e}\left(1+\frac{p_e}{N_d}\right)$$

where p_e/N_d is obtained from the equation $2p_e/N_e - \ln(1+p_e/N_d)=Z$. Now,

$$\frac{\partial I_{Ee}}{\partial I_{Ep}} = \sigma_bW/\sigma_eL_e\left(1+(p_e/N_d)+I_{Ep}\frac{\partial(p_e/N_d)}{\partial Z}\frac{\partial Z}{\partial I_{Ep}}\right)$$

$$\frac{\partial(p_e/N_d)}{\partial Z},\ \text{as before,}\ = \frac{1+p_e/N_e}{1+2p_e/N_d}\ \text{and}\ I_{Ep}\frac{\partial Z}{\partial I_{Ep}} = Z$$

where $Z=W\mu_eI_{Ep}/D_pA\sigma_p$.

Combining,

$$\frac{\partial I_{Ee}}{\partial I_{Ep}} = \frac{\sigma_bW}{\sigma_eL_e}f(Z)$$

where $f(Z)=1+p_e/N_d+Z(1+p_e/N_d)/(1+2p_e/N_d)$. $f(Z)$ is called the "fall-off" factor and is plotted in Fig. 5 where it may be compared to $(1+Z)$, the approximate expression derived in the section on emitter efficiency.

Methods for Measuring Piezoelectric, Elastic, and Dielectric Coefficients of Crystals and Ceramics*

W. P. MASON†, FELLOW, IRE, AND HANS JAFFE‡

Summary—**This paper considers methods for measuring the piezoelectric, dielectric, and elastic coefficients of crystals and ceramics and recommends certain preferred methods of measurement. Static measurements are not considered to be as satisfactory as dynamic measurements. Of the dynamic methods, measurements of the resonant and anti-resonant frequencies, the low frequency capacitance and the resistance at resonance appear to be the simplest and most accurate method, provided that the ratio of Q/r is high. Quasi-static methods are useful for crystals having a low ratio of Q/r, for determining the sign of the piezoelectric coefficients, and for production checks. Hydrostatic methods are useful for complicated crystals such as monoclinic types and for measuring a sum of two of the coefficients of electrostrictive ceramics. This measurement can be carried out for odd-shaped samples.**

I. Introduction

The fundamental properties of interest in a piezoelectric crystal or electrostrictive ceramic are the piezoelectric or "equivalent" piezoelectric constant of the material, the dielectric constant and dielectric loss of the material, the elastic constants and elastic losses of the materials, and the variations of these properties with temperature, humidity and pressure, as well as frequency and amplitude of signal. Dependence on the latter two is of significance primarily in ferroelectric materials, whose properties moreover may show marked dependence on previous history. A number of methods have been used to measure these properties and it is the purpose of this paper to describe the advantages and disadvantages of these methods and to recommend certain preferred methods. By using such methods as fundamental standards it is the hope that the measured properties of new crystals and electrostrictive ceramics made by different investigators will be more comparable and reliable.

II. Methods for Investigating Small Size Specimens

Since the time and effort necessary to measure and grow large-sized piezoelectric crystals are very considerable, and since special growing techniques are often required for specific crystals, it is a matter of some importance to obtain methods for eliminating nonpromising crystals in the small-grain size state, since these are rather easily grown in beakers by spontaneous seeding. Two methods have been used for this purpose, the click oscillator and a balanced capacity bridge method.

For the click oscillator,[1] a number of grains of the substance are inserted between two electrodes which are placed across the plates of the oscillator as shown by Fig. 1. The frequency of the oscillator is changed by varying the tuning condenser C, and if a resonance of one of the piezoelectric crystals occurs near the oscillator frequency, the frequency of the oscillator will be briefly controlled by the crystal resonances. As the condenser is turned further, the frequency jumps from the crystal frequency to that determined by the condenser.

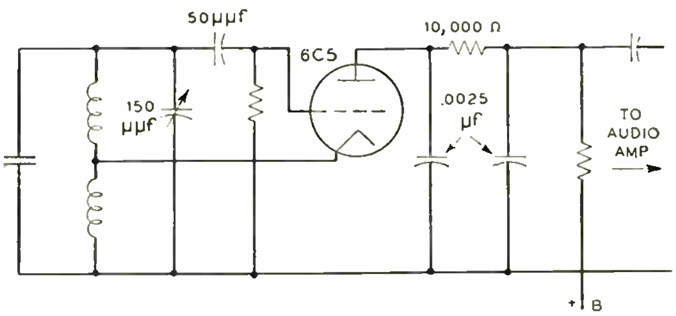

Fig. 1—Click-oscillator circuit.

This jump in frequency is accompanied by a change in the plate current, so that a pair of head phones or a loud speaker attached to the plate circuit of the oscillator will produce an acoustic click. By following the tube with an audio amplifier, weaker clicks can be heard. By changing the oscillator frequency over a wide range, a number of possible resonances will be determined. This is a qualitative method since the loudness of the clicks cannot be related to the electromechanical coupling in the crystal or the crystal's Q.

The bridge method, (Fig. 2, p. 922) consists in placing a number of crystal grains between two electrodes which are in one arm of a capacitance bridge. An oscillator is connected to the input and a sensitive detector to the output of the bridge. The capacitance C_1 is balanced outside the crystal-resonance range so that a minimum of current occurs in the detector. As the frequency is changed, the bridge becomes unbalanced as a crystal resonance is approached and the amount of unbalance can be shown[2] to be determined by the ratio of

* Decimal classification: R216.1×R214.2. Original manuscript received by the IRE, December 23, 1953.
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‡ Brush Laboratories Co., Cleveland, Ohio.

[1] This method was first discovered by W. G. Cady ("The piezoelectric resonator," Proc. I.R.E., vol. 10, pp. 83–114; 1922) and has been applied systematically by E. Giebe and A. Scheibe ("A simple method for qualitative indication of piezoelectricity in crystals," *Zs. Ph.*, vol. 33, pp. 760–766; 1925) to obtain a qualitative indication of piezoelectric properties.

[2] "Piezoelectric Crystals and Their Application to Ultrasonics," W. P. Mason, D. Van Nostrand & Co., New York, N. Y., pp. 49–50; 1950.

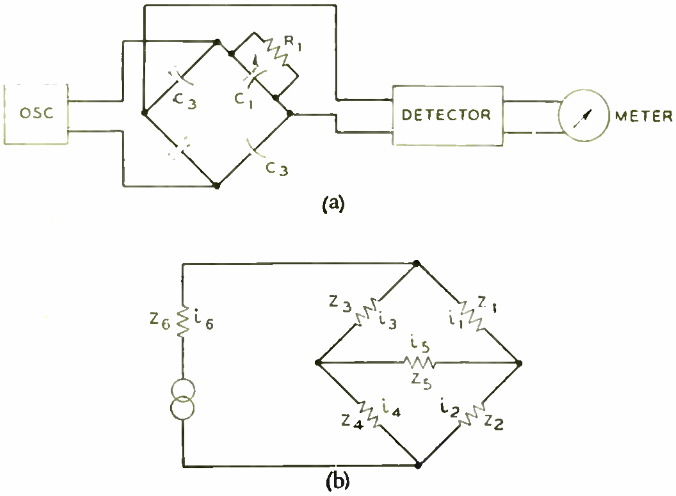

Fig. 2—Bridge circuit for detecting piezoelectric properties of small size crystals.

the crystal Q to the ratio of capacitances existing for the crystal in the electrode system. The current will vary over a frequency range as shown by Fig. 3, and by measuring the width of the resonance curve 3 db from the peak current, the Q of the crystal can be determined from the equation

$$Q = f_R/\Delta f \tag{1}$$

where f_R is the resonant frequency and Δf the frequency width. The current at the resonant frequency can be shown[2] to be equal to the quantity $i_0 = 2E_0 f_R C_M Q/2r$, where C_M is the capacitance measured by the bridge at low frequencies and r is the ratio of capacitances of the crystal, which determines the coupling factor k according to the equation

$$k = \frac{1}{\sqrt{1 + pr}} \tag{2}$$

where p is a numerical factor depending on the mode of vibration, but usually not far from 0.8. The couplings for the various modes which may be excited in odd-shaped crystal grains depend in a complex way on the

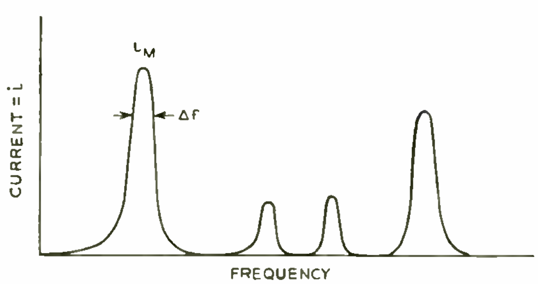

Fig. 3—Current in bridge circuit as a function of frequency.

piezoelectric coupling coefficients of the material but by having a number of grains oriented in a random manner and selecting the largest response, a good idea of the maximum coupling can be obtained. At the same time, the "Q" of the crystal can be approximated, and hence the balanced bridge is taken as the proposed method.

III. Measurements on Large-Sized Crystals

A. Capacitance Measurements at Low and High Frequencies

Probably the simplest of the fundamental measurements on the crystal is the capacitance measurement. This is usually made on a crystal cut at a definite orientation and with closely adhering electrodes in a capacitance bridge. If the frequency of the oscillator used on the bridge is much lower than any of the resonances of the crystal, the measurement determines the constant-stress or "free" dielectric constant ϵ^T. In a crystal there may be as many as six dielectric constants and by measuring a number of selected orientations, all of the constant-stress dielectric constants can be evaluated. As shown in various books,[3] the dielectric constant for any direction of the crystal is a linear function of the six dielectric constants and the direction cosines of the plate axes with respect to the crystallographic x, y, and z axes as defined in the 1949 IRE standard,[4] and by solving six simultaneous equations, all six fundamental constants can be obtained from six capacitance measurements of six independent orientations.

As the frequency of measurement increases, the measured capacitance varies in the neighborhood of a resonance, as shown by Fig. 4. Below the resonance, the capacitance increases as the frequency increases and becomes very large near the resonant frequency. Between the resonant and anti-resonant frequencies, the crystal shows an inductive reactance. Above the anti-resonance the reactance is again capacitative, and if the next resonance is separated from the one under investigation by a considerable frequency range, the capacitance approaches a limit below the free dielectric constant. It can be shown[5] that the ratio of the limiting dielectric constant above the resonance to the dielectric constant at low frequencies is

$$\frac{\epsilon_{\text{lim}}}{\epsilon^T} = 1 - k^2 \tag{3}$$

where k is the applicable electromechanical coupling factor. For isolated simple resonances such as occur in longitudinal crystals, the dielectric ratio is an acceptable method for measuring the coupling factor.

At frequencies above the highest resonances and their principal harmonics, the dielectric constant approaches a steady value which corresponds to the constant stress or clamped dielectric constant ϵ^S. In the most general case, there are six such constants and for any orienta-

[3] W. Voight, "Lehrbuch der Kristallphysik," pp. 410–468, 1928 Edition, Teubner, Leipzig. W. A. Wooster, "Crystal Physics," chap. IV, pp. 117–127, Cambridge University Press, London, Eng., 1938. W. G. Cady "Piezoelectricity," chap. VII, pp. 160–177, McGraw-Hill Co., New York, N. Y., 1946. W. P. Mason "Piezoelectric Crystals and Their Application to Ultrasonics," chap. V, pp. 59–78.

[4] "Standards on Piezoelectric Crystals," Proc. I.R.E., vol. 37, December, 1949.

[5] W. G. Cady, "Piezoelectricity," chap. XII, pp. 260–283, McGraw-Hill, New York, N. Y., 1946. W. P. Mason, "Piezoelectric Crystals and Their Application to Ultrasonics," p. 63.

tion the dielectric constant is a linear function of these fundamental dielectric constants. It can be shown that the constant-strain and constant-stress dielectric constants are related by the formulas

$$\epsilon_{mn}{}^S = \epsilon_{mn}{}^T - \sum_{k=1}^{6} [d_{nk}e_{mk}] \quad (4)$$

in rationalized MKS units, where $\epsilon_{mn}{}^S$ is the dielectric tensor and d_{nk} and e_{mk} the piezoelectric coefficients as defined in the 1949 IRE standard.[4] For the *cgs* system the factor of 4π is inserted before the summation sign.

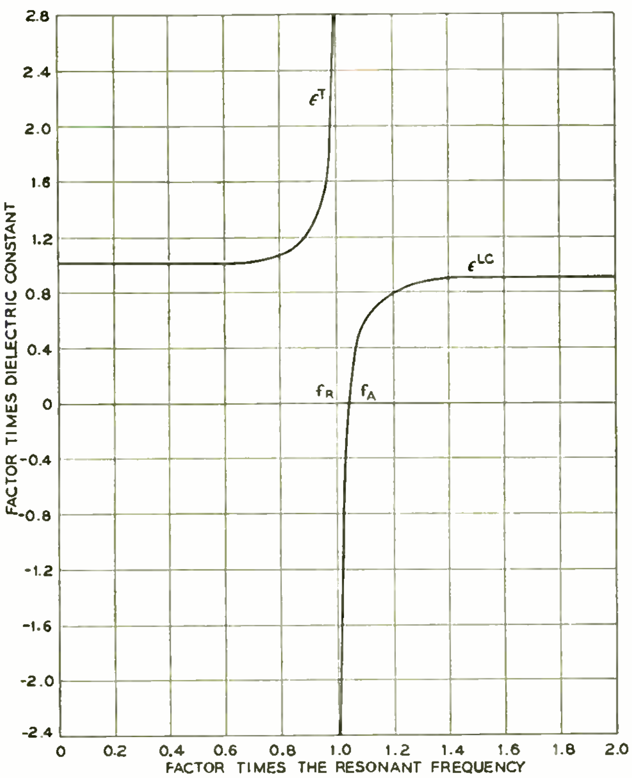

Fig. 4—Relative dielectric constant of a crystal having a coupling $k = 0.33$ plotted as a function of frequency.

B. Static Piezoelectric Measurements

Most of the original measurements of the piezoelectric constants of crystals were made by measuring either the direct or converse effects by static methods. The direct effect was measured by putting a weight on a crystal and observing the charge generated by some charge detector such as a quadrant electrometer. Due to electrical leakage present even at low humidity, part of the electrical charge leaks off before it can activate the electrometer and hence a measurement of the direct effect is usually not reliable. A modification of this method has been used in which a known weight is suddenly lifted off a crystal and the generated charge is caused to actuate an oscilloscope in which the input is a condenser shunted by a high resistance so that the time constant is large. This gives relatively accurate measurements and for simple structures such as polarized ceramics gives useful results.

The most promising method for static piezoelectric measurements is a measurement of the amount of extension for a given applied voltage gradient, i.e., a measurement of the converse effect. The amount of extension is usually too small to see with a microscope and special means for measuring the extension are usually employed. One method makes use of strain gauges for which a measurable change in resistance occurs for a very small strain. This method gives results that are accurate to 5 per cent and is recommended as the best static method. When the constant to be measured is a shearing constant, a change in orientation of 45 degrees will usually result in an extension and allow the shearing constant to be measured by extensional measurements. It can be shown[6] that all the 18 piezoelectric constants of the most general triclinic crystal can be measured by extensional measurement only.

1. *Nonresonant (Quasi-Static) Piezoelectric Measurements:* Since electronic circuitry permits convenient production and detection of alternating electrical and mechanical signals, low-frequency ac methods have largely displaced static measurements of both the direct and converse piezoelectric effects. It is essential for these methods that stress or strain be uniform in the tested sample. The operating frequency should therefore be at least one order of magnitude below all piezoelectrically active resonances of the body. Low-frequency limits are set by electric leakage or by amplifier specifications. Frequencies from 20 to 1,000 cps are used.

A precision apparatus of this type was used by Spitzer[7] for measurements on several new crystals, with a claimed accuracy of 1 per cent. To determine the force, it was applied in series to the crystal and a diaphragm forming one plate of a condenser.

In an apparatus for routine testing,[8,9] a known one-dimensional mechanical stress is provided by a force applicator arrangement closely paralleling that of a loud-speaker assembly. A coil is mounted in a strong magnetic field and is free to move only along its axis, being springloaded in this direction. An ac voltage applied to the force coil generator produces an alternating force, and a standard crystal stack (usually ADP) and the test crystal are mounted in series mechanically with the force coil. A large blocking mass completes the mechanical system.

A particular instrument of this type has been shown to have a fundamental mechanical resonance at 250 cps. This was determined from a plot of output force vs. frequency for a constant driving voltage to the force coil. It was found that the force actually applied to the

[6] See "Piezoelectric Crystals and Their Application to Ultrasonics," p. 77.
[7] F. Spitzer, "Determination of the Piezoelectric Constants of Some Isomorphous Crystals," Dissertation, Goettingen, 1938, *Electrical Communications*, vol. 28, p. 300, 1951.
[8] J. P. Arndt, Jr., "Direct reading microdisplacement meter," *Jour. Acous. Soc. Amer.*, vol. 21, pp. 385–391; July, 1949.
[9] H. G. Baerwald and D. A. Berlincourt, "Electromechanical response and dielectric loss of prepolarized barium titanate under maintained electric bias," part 1, *Jour. Acous. Soc. Amer.*, vol. 25, pp. 703–710; July, 1953.

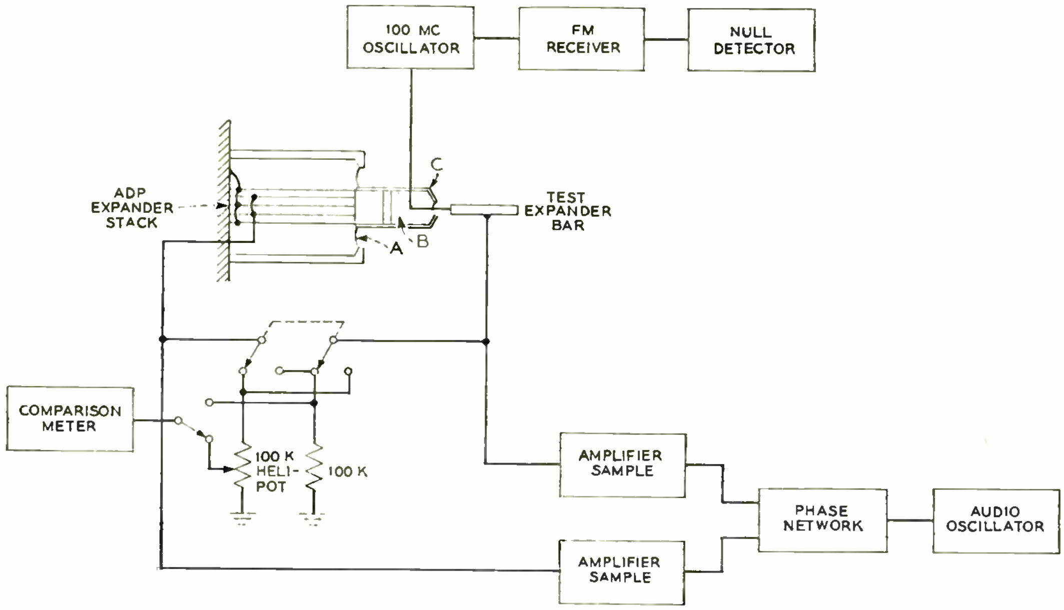

Fig. 5—Block diagram for Brush displacement meter.

test crystal was greater than that applied to the standard crystal when operation was near this resonance, and therefore normal operating frequencies were limited to the range of 100 cps and below.

The waveform of the ac force for this instrument was found to be dependent upon minor mechanical adjustments, and therefore the waveform of the standard crystal output voltage is checked occasionally with either an oscilloscope or a wave analyzer.

Calibration of the standard crystal stack is necessary, since the mechanical arrangement necessitates clamping the stack in place, thereby affecting its sensitivity. Calibration is checked periodically and is most conveniently accomplished using ADP Z-45 degrees expander plates whose piezoelectric coefficients have been determined very accurately by the dynamic method.

$$d_{31}' = 24.0 \times 10^{-12} \text{ coulomb/newton.}^{10} \quad (5)$$

The sign of the piezoelectric coefficients under test is readily found by observing the phase relation of the signal from the test crystal and the series crystal stack.

For determination of the g coefficients (open-circuit field output per applied stress) the input capacitance of the measuring circuit must be small compared to the crystal capacitance; this requirement can be met readily only with the ferroelectrics of high dielectric constant, and even there requires a cathode-follower circuit.

The d coefficients (charge density per applied stress) are found by measuring the voltage on a large capacitor in parallel with the crystal.

The apparatus has given results with a reproducibility of ±3 per cent when applied to measurement of the transverse effect on well-shaped blocks or plates. With less accuracy, it can be employed for rapid production testing. The method may be applied to measurement of longitudinal compressional coefficients by pressing on the electroded faces, provided that the change in stray capacitance across insulator pads can be neglected. This can be achieved in the study of high dielectric constant ceramics. A strong warning must be given, however, against making this measurement on plates whose thickness in the field direction is considerably smaller than the lateral dimensions. In such a case the electric effect of lateral or bending stresses may grossly falsify results.

The difficulties just mentioned are entirely avoided in the measurement of the response of a freely suspended piezoelectric body to hydrostatic pressure. This response is limited to 10 out of the 20 piezoelectric crystal classes, and to polarized ferroelectrics. The crystal under test is preferably placed in a liquid of good resistivity and low compressibility such as kerosene, in order to minimize adiabatic temperature changes. Moderate alternating pressures—in the order of 1 lb/inch²—are obtained by driving a diaphragm forming part of the container with a motor-driven cam or with a loudspeaker coil. An apparatus satisfactory for this measurement was described in a previous report.[11] Measurement of the pressure amplitude is made with a piezoelectric crystal of known hydrostatic response, such as lithium sulfate.

$$(d_h = 13.5 \times 10^{12} \text{ coulomb/newton}).^7$$

Study of the converse piezoelectric effect requires measurement of motional amplitudes varying from 10^{-7} to 10^{-4} inches. Piezoelectric coefficients on a number of synthetic crystals were obtained with an accuracy of 5 to 10 per cent using a sensitive Rochelle salt pickup designed for the Brush Surface Analyzer.[10]

More versatile "microdisplacement meters" evaluate the change of capacitance of a minute condenser formed by the surface of the moving crystal and a stationary probe.[12] In such an apparatus designed for highest sen-

[10] H. Jaffe, G. N. Cotton, J. E. Mumper, Final Report, to U. S. Signal Corps Contract W28-003 sc-1583, Brush Development Co., April 1, 1948.

[11] N.D.R.C. Report. Low Frequency Hydrophone Calibration Systems, Sect. 6-1-sr783-1308.

[12] K. S. VanDyke, Seventh Semi-Annual Report on Contract W28-003 sc1556, Wesleyan Univ., pp. 44–46; 1949.

sitivity (Fig. 5) this modulated capacitance is connected across the tank circuit of a 100-mc oscillator. The frequency-modulated signal is applied to a sensitive FM receiver, and the probe is driven mechanically by an ADP expander stack. The null method is again used, the ADP stack and test crystal being driven by separate channels of a two-channel amplifier. The phase of one channel and the magnitude for both channels are adjusted until the probe and test crystal are vibrating in synchronism. Meter errors are eliminated by directly measuring the ratio of the driving voltages applied to the standard crystal and test crystal. The higher voltage is applied to an accurate linear potentiometer (such as a 100,000-ohm Helipot) which is adjusted (Fig. 5) until the comparison meter shows the reduced voltage to be equal to the voltage from the other amplifier channel.

In Fig. 5, "*A*" is a metal diaphragm having a low compliance in the plane perpendicular to the line of motion of the stack, the purpose being to prevent breakage of the stack by accidental side blows. The stack has sufficient strength to resist straight compressional forces and the diaphragm should have high compliance in this direction to provide little restraint to the motion of the stack. The probe wire is supported by "*B*," which is made of Mycalex and serves to insulate the wire from the metal shield "*C*." It should be noted in designing the 100-mc oscillator that although the inductance does not enter the equation for Δf there is a practical limit set by oscillator stability on how high L, and therefore, how low C_0 can be made. Another means of obtaining maximum sensitivity is to use a double superheterodyne FM receiver, since by this means the precentage deviation may be increased.

With this instrument it has been possible to measure displacements down to 10^{-10} meters, although ultimate sensitivity is somewhat dependent upon driving field. The driving frequency is limited only by mechanical resonances, and these can easily be found by plotting displacement vs frequency first with only the standard driven and then with only the test crystal driven. This instrument may also be used to observe complex motions as a function of time, charge density, or driving field by placing an oscilloscope or wave analyzer at the output of the FM receiver.

C. Static Elastic Measurements

Most of the original elastic constant measurements of crystals made by Voigt[13] and his successors were made by static elastic means such as measuring the deflection of a crystal supported at its two end points when a weight is applied at the center. This type of measurement when performed on a long thin bar yields an evaluation of Young's modulus for the direction of the length of the cut. All of the elastic constants except the shear constants can be measured in this way. To determine the shear constant, circular rods were cut out of the crystal and twisted in a torsional mode. The bending of plates and compressibility measurements have also been employed. By these means, Voigt and others have measured the elastic constants for a number of crystals.

If the crystals measured have a high electromechanical coupling, the elastic constants evaluated by this method are rather indeterminate since they may depend on how much of the charge generated has leaked off during the measurement. Presumably most measurements of this sort, since they involve considerable time, will correspond most nearly to the constant field elastic constants which are obtained when the voltage gradients are zero between the various faces of the crystal. Furthermore, the measurement of the ratio between an applied force and a resulting displacement cannot be carried out as accurately as can a frequency measurement, and hence this method is not suggested for general use.

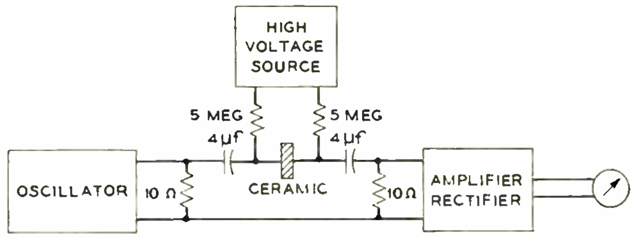

Fig. 6—Measuring circuit for measuring the properties of a piezoelectric crystal or electrostrictive ceramic.

D. Dynamic Measurements of Elasticity

1. *Resonant Frequency Measurements:* Resonant frequencies are readily excited in plated piezoelectric crystals and since frequencies are very easily and accurately measured, a good basis exists for measuring elastic constants by dynamic means.

The simplest circuit for doing this is shown by Fig. 6. A crystal is placed in a point holder shown by the photograph of Fig. 7 at a nodal point of the motion, in order that the clamp will not change the frequency, and placed between two low values of resistance. An oscillator is attached to one resistance while the other is connected to an amplifier detector. If the output of the oscillator is not sufficiently pure, it may be necessary to use a low-pass filter in the circuit to suppress harmonics. The frequency of the oscillator is varied until the maximum current is observed in the rectified current output. For a high Q crystal, this frequency corresponds

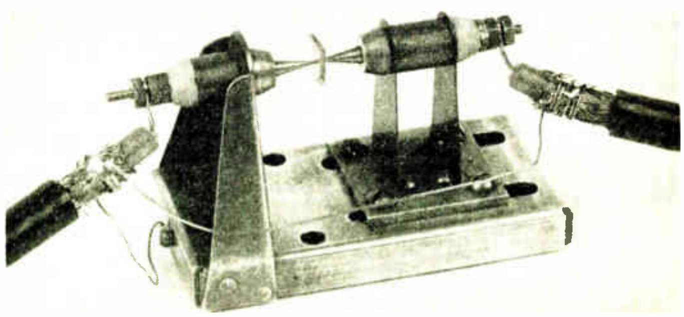

Fig. 7—Photograph of point holder for measuring crystal properties.

[13] See "Lehrbuch Der Kristallphysik," pp. 716–763, B. Teubner, Leipzig, 1928 edition.

to the resonant frequency.[14] In measuring the piezoelectric constant, the anti-resonant frequency, which occurs when the impedance is a maximum and the current a minimum is also measured in the same circuit. To obtain the most accurate result, the frequency of the oscillator is continuously checked with a standard frequency such as obtained from a stable quartz-crystal oscillator.

In order to relate the measured frequencies to the desired elastic constants, a theoretical expression has to be available which relates the measured frequency to the dimensions, the elastic constants and the density of the crystal. Probably the simplest and most accurate expression is that for a long thin bar in longitudinal vibration, given by the equation

$$f_R = \frac{1}{2l}\sqrt{\frac{1}{s_{11}^{E'}\rho}} \tag{6}$$

where for a plated crystal $s_{11}^{E'}$ is the elastic compliance measured at constant electric field, which is the inverse of Young's modulus along the length of the bar, l is the length of the bar and ρ the density. If the width and thickness of the bar become appreciable with respect to the length, the frequency is lower. The difference in frequency between the finite bar and the infinitely thin bar varies as the square of the ratio of thickness or width to length. If the most accurate results are required, several width-length and thickness-length ratios should be measured. When the frequency is plotted against the squares of the width-length and thickness-length ratios, then by extrapolating back to zero ratios, the corrected value of f_R can be obtained for insertion in (6).

The frequency of resonance of fully plated crystals determines the constant field elastic compliance. If the plating is all removed except for a very small spot, or if the unplated crystal is driven by an auxiliary means, the resonant frequency is determined by the constant displacement elastic compliance s_{11}^D which has been shown to be related to the elastic compliance at constant field by the equation

$$s_{11}^D = s_{11}^E(1 - k^2) \tag{7}$$

where k is the applicable electromechanical coupling factor. A measurement of these two frequencies has been used to evaluate the coupling factor, which, when the elastic and dielectric constants are known, determines the piezoelectric constant.

Measurements of 18 independently oriented cuts in longitudinal vibration will determine 9 of the possible elastic compliances and will determine 6 relations between the other 12 constants. To determine the remaining constants, measurements of shear modes of motion are required. In making these measurements either face shear or thickness shear modes can be employed. The most complete theoretical solution for a thickness shear mode is that of Mindlin.[15] This, together with other solutions of the problem, show that for all crystal classes except the monoclinic and triclinic, the frequency for a plate infinitely thin compared with its other dimensions is given by

$$f_R = \frac{1}{2t}\sqrt{\frac{c_{66}'}{\rho}} \tag{8}$$

where t is the thickness of the plate c_{66}', the shear elastic stiffness constant corresponding to the mode of motion of the oriented plate, and ρ the density. Methods[16] are available for relating the value of c_{66}' for an oriented plate to those for the crystallographic axes and by taking 6 independent cuts the rest of the constants can be determined.

For the finite plate, it can be shown[15] that, midway between couplings to flexural modes, the difference in frequency between the finite plate and the infinite plate varies in proportion to the square of the ratio of thickness to length in the direction of particle motion. Hence, if one takes plates having different values of the ratio of thickness to length and extrapolates to a zero ratio, the true value of c_{66}' can be obtained. An alternate method is to measure a series of overtones for the plate. This corresponds to taking plates of 1/3, 1/5, 1/7, etc. values of the thickness-to-length ratio and by measuring several harmonics the true value c_{66}' can be obtained.

For one series of orientations for monoclinic crystals and for all orientations for triclinic crystals, there is always a coupling between the longitudinal and shear thickness modes. For such crystals both modes have to be measured and a coupling equation solved.

Other modes of motion can also be used for determining elastic constants. Face shear, flexural modes and torsional modes have been used.

2. *Ultrasonic Pulsing Methods:* Other dynamic methods are also available for measuring elastic constants. One of the most accurate methods is the ultrasonic pulsing method which has been employed principally in measuring the elastic constants of nonpiezoelectric crystals. It can be applied to piezoelectric crystals, however, and when used with an unplated crystal determines the constant displacement elastic constants when the electric polarization is parallel to the wave propagation. When the polarization direction is perpendicular to the

[14] If a low Q is involved, it can be shown that the resonant frequency is related to the frequency of maximum current by the equation

$$f_M = f_R\sqrt{1 + \frac{1}{2r'}\left[1 - \sqrt{1 + \left(\frac{2r'}{Q'}\right)^2}\right]}$$

where r' and Q' are the ratio of the capacitances and the Q measured from the maximum and minimum impedances and frequencies as discussed in section IIIE.

[15] R. D. Mindlin, "Thickness-shear and flexural vibrations of crystal plates," *Jour. Appl. Phy.*, vol. 22, pp. 316–323; March, 1951.

[16] W. Voigt, "Lehrbuch der Kristallphysik," chap. VII, pp. 560–596; Wooster, "Crystal Physics," chap. VIII, pp. 231–273; Mason, "Piezoelectric Crystals and Their Applications to Ultrasonics," chap. V and p. 457.

direction of wave propagation, the zero field elastic constants are obtained due to the almost complete neutralization of successive strips of negative and positive charges on the surfaces perpendicular to the wave direction.[17]

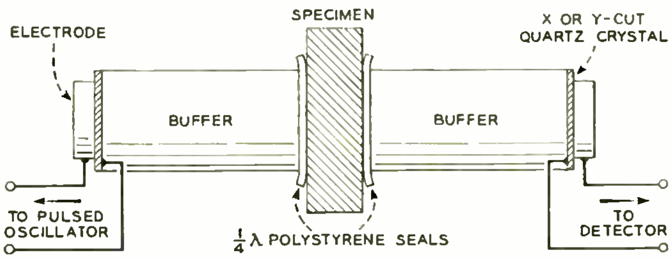

Fig. 8—Crystals and fused quartz buffer system used for measuring the elastic properties of small crystals.

One of the most accurate methods,[18] which is applicable to small and large crystals, is shown by Fig. 8. In this method longitudinal or shear waves are sent into a fused quartz rod which is long enough so that reflections in the rod do not interfere in time with a series of reflections within the smaller specimen to be measured. Longitudinal waves are generated by X-cut quartz crystals soldered to the ends of the rods while shear waves are generated by Y-cut quartz crystals. For shear waves the direction of particle motion is important and the crystals on the two rods are lined up so that their particle motions are parallel. By turning the specimen to be measured through 90 degrees with respect to the direction of particle motion, two independent shear waves can be generated which in general will have different velocities.

The specimen to be measured has to be 20 wavelengths or more in its cross-sectional dimensions and for greatest accuracy should be a number of wavelengths thick. To obtain reasonable dimensions for the specimen, frequencies are used in the order of 10 mc. When a short pulse is used, the first series of responses, as shown by the curve marked gate no. 1 of Fig. 9 are due to reflections back and forth in the specimen. To enhance these reflections, quarter wavelength seals of polystyrene and liquid are used which have the effect of transforming the high mechanical impedance of the quartz buffer down to a low mechanical impedance of the specimen face and hence to increase the amount of energy reflected at the interface. Some idea of the attenuation in the sample can be obtained by the rapidity with which successive reflections die down. However, the amount of energy lost by transmission to the buffers has to be evaluated and an accurate loss for high Q materials is difficult to measure.

The velocity can be measured very accurately by using the phase-cancellation method shown by Fig. 9. The mercury delay line is adjusted so that a phase balance is obtained between the pulse from the delay line and from the specimen, while the level of channel 2 is adjusted so that a complete cancellation of the pulse is obtained. A frequency change will not affect this balance since the phase shift in both circuits is proportional to the frequency. Next the time position of gate no. 2 is changed until it overlaps the second pulse. If only an amplitude adjustment is required to balance out this pulse, the direct wave and the echo are in phase and the corresponding frequency corresponds to an integral number of half wavelengths in the material. By varying the frequency until a number of integral half wavelength frequencies are obtained, the phase-shift frequency curve of the specimen can be determined and the velocity measured. Sensitivities in the order of 1 part in 10,000 are possible.

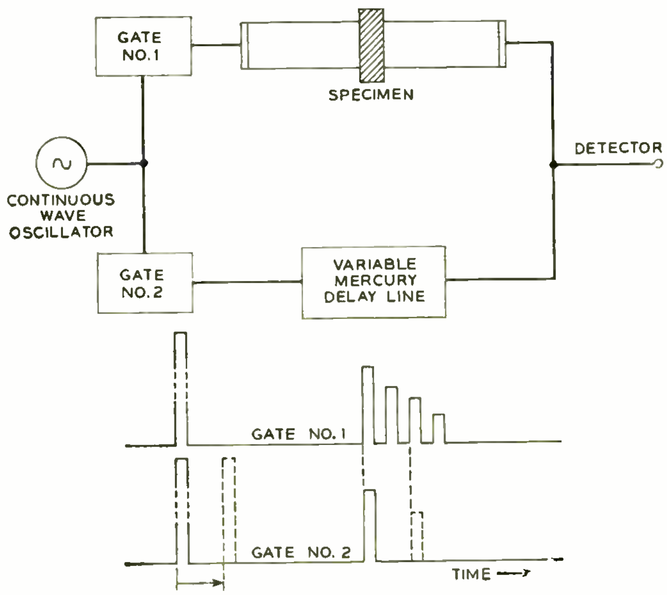

Fig. 9—Pulsing system and phase-balance method for measuring the velocity and attenuation of small crystals.

Using this method the properties of a number of cubic crystals have been measured. For a cubic crystal having three elastic constants, all of the constants can be obtained by measurement on a (110) crystal section. The method can be applied to a crystal of any symmetry and provides a very accurate method for measuring the constant displacement elastic constants of a piezoelectric crystal. Since this method requires more equipment than does the resonant frequency method, it is not recommended for general use. Such methods are, however, at least as accurate as the resonance method described above. They have the advantage that no corrections need be applied for the dimensional ratios. Hence the velocities are determined by the infinite medium elastic constants.

E. Dynamic Measurements of Piezoelectric Constants

Two methods have beenn described for dynamically measuring the coefficient of electromechanical coupling of piezoelectric crystals. One makes use of the differ-

[17] F. Jona, "Elastizitat von piezoelectric und seignetteelektrischen Kristallen," *Helv. Phys. Acta.*, vol. 23, pp. 795–844; July, 1950.
[18] H. J. McSkimin, "Ultrasonic measuring techniques applicable to small solid specimens," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 413–418; July, 1950.

ence between the dielectric constants measured at constant stress and constant strain, while the other makes use of the elastic constants measured at constant field and constant displacement. Since the electromechanical coupling for a longitudinal mode has been shown to be

$$k_{31} = d_{31}'\sqrt{\frac{1}{\epsilon_{33}^{T} s_{11}^{E'}}} \qquad (9)$$

(in rationalized mks units), the piezoelectric constant d_{31}', corresponding to a longitudinal vibration along the X' axis for a field applied along the z' axis, can be evaluated when the constant stress dielectric constant along the thickness and the elastic compliance at constant field along the length of the crystal are evaluated.

A simpler method for evaluating the electromechanical coupling factor is to measure the resonant and anti-resonant frequencies corresponding to a longitudinal mode by means of the circuit shown by Fig. 6. The resonant frequency corresponds to the frequency of highest current value[19] while the anti-resonant frequency corresponds to the frequency of the lowest current value. In order to obtain a true coupling value, care must be taken to eliminate the effect of stray capacitance on the position of the anti-resonant frequency. This is done by using the holder of Fig. 7 which shields the electrodes nearly up to the points where they touch the crystal. All electrode capacitances are then capacitances to ground, and since they appear across a low resistance, their effect can be neglected.

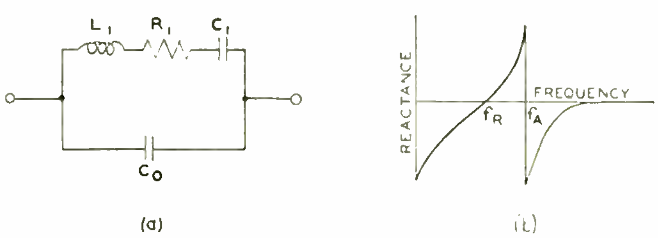

Fig. 10—Equivalent circuit and reactance of a piezoelectric crystal.

The resonant and anti-resonant frequencies determine a ratio of capacitances in the equivalent circuit of the crystal shown by Fig. 10 according to the equation

$$\frac{f_A^2}{f_R^2} - 1 = \frac{1}{r} \doteq 2\left(\frac{\Delta f}{f_R}\right) \qquad (10)$$

where r is the ratio of C_0 to C_1, and Δf the separation of resonant frequencies. This separation Δf is related to the electromechanical coupling as defined in (9) by a transcendental equation. For couplings less than 50 per cent, which covers all cases except ferroelectric crystals, the coupling can be calculated by the power expansion

$$k^2 = \frac{\pi^2}{4}\frac{\Delta f}{f_R}\left[1 + \left(\frac{4-\pi^2}{4}\right)\frac{\Delta f}{f_R} + \left(\frac{\pi^2-4}{4}\right)\left(\frac{\pi^2}{4}\right)\left(\frac{\Delta f}{f_R}\right)^2 + \cdots\right]. \qquad (11)$$

For couplings under 25 per cent, the simple formula

$$k = \frac{1}{\sqrt{1 + \frac{8}{\pi^2} r}} \qquad (12)$$

is usually sufficient. The Q of the crystal can be determined by measuring the equivalent resistance at the frequency of maximum current, R_1. From this measurement and the measurement of the resonant frequency, static capacity C_0 and ratio of capacitances,

$$Q = \frac{r}{2\pi f_R C_0 R_1}. \qquad (13)$$

By using eighteen independently oriented cuts in longitudinal vibration, it is possible to evaluate all of the possible 18 piezoelectric constants of the most general crystal. Since the dynamic method does not evaluate the sign of the constant, separate polarity tests have to be made. These may be made either by squeeze tests which employ the direct piezoelectric effect or by extension tests which employ the converse piezoelectric effect. The relations between the piezoelectric constants for oriented crystals and the fundamental piezoelectric constants which refer to the crystallographic axes are given in standard texts.[20] On account of the unavoidable errors in measurement, it is desirable to measure as many constants as possible along crystallographic axes.

Other modes of motion such as flexure, torsion, face shear, and thickness shear modes can also be used to evaluate the coupling coefficients. For thickness modes, one usually encounters a number of resonances driven by a single piezoelectric constant and hence it is difficult to ascribe a coupling to any particular resonance. Hence, simpler modes are to be preferred, and the longitudinal modes are recommended for standard measurements. Since resonant and anti-resonant frequencies are the most accurately measured quantities, and since equipment for measuring them is widely available, it is suggested that this method be the standard for measurement of piezoelectric coefficients.

IV. Measurements on Ceramics

Ceramic materials made by fusing together a large number of small crystallites of such ferroelectric materials as barium titanate are becoming increasingly

[19] For low ratios of Q/r, the resonant and anti-resonant frequencies differ slightly from the frequencies of maximum and minimum current. If the values determined by the latter are Q' and r', the true values are given by

$$\frac{Q}{r} = \frac{Q'}{r'}\left[\frac{1+\sqrt{1-\left(\frac{2r'}{Q'}\right)^2}}{2}\right]; \qquad r = r'\left[1 + 2\left(\frac{r'}{Q'}\right)^2\right].$$

[20] W. Voigt, "Lehrbuch der Kristallphysik," chap. VIII, pp. 801–944, *ibid.*; Wooster, "Crystal Physics," chap. VI, pp. 188–223, *ibid.*; Cady, "Piezoelectricity," chap. VIII, pp. 177–199, *ibid.*; Mason, "Piezoelectric Crystals and Their Applications to Ultrasonics," chap. V, pp. 59–77, *ibid.*

used in electromechanical transducers. These materials can be made to have properties similar to piezoelectric crystals by poling, i.e., by subjecting these ceramics to a high dc voltage for a period of time, or by cooling the ceramic under an applied field from temperatures higher than the "Curie point" to room temperatures.

In general, the measurements made on such ceramics are similar to those made for piezoelectric crystals but certain additional measurements are often made.

Such ceramics are isotropic until an electric axis is established by the polarizing field. After poling, three "effective piezoelectric constants" are operative whose values depend not only on the material but also on the degree of polarization. When the electric driving field is applied in the same direction as the residual polarization, one constant, the d_{31} constant, determines the contraction in all directions perpendicular to the applied field while the d_{33} constant determines the expansion of the ceramic in the direction of the field. When the electric driving voltage is applied at right angles to the residual polarization, a thickness shearing motion is obtained whose effective piezoelectric constant is the d_{24} constant. This is nearly equal to the difference between d_{33} and d_{31}.

To measure d_{31}, the simplest method is to use a long thin bar of the material plated on its major surfaces. After it is poled, a piezoelectric resonant and anti-resonant frequency can be determined and from (9), (10), and (11), the elastic compliance and piezoelectric d_{31} constant can be determined. Another mode that is often used is the radial vibration of a circular plate. For this mode, the resonant frequency and coefficient of coupling are related[21] to the measured frequencies by the equations[22]

$$f_R = \left(\frac{R_1}{2\pi r}\right)\sqrt{\frac{1}{\rho(1-\sigma^2)s_{11}^E}};$$

$$k_r = d_{31}\sqrt{\frac{2}{s_{11}^E(1-\sigma)\epsilon_{33}^T}} \tag{14}$$

where k_r is the "radial electromechanical coupling coefficient" and is related to the measured frequency separation by the equation

$$k_r^2 = \frac{\Delta f}{f_R}\left[\frac{R_1-(1-\sigma^2)}{1+\sigma}\right]\left[1-\frac{\Delta f}{f_R}\left(\frac{R_1-(1-\sigma^2)}{1+\sigma}\right)\right]. \tag{15}$$

In these equations σ is Poisson's ratio, r the radius of the disk, ρ the density, s_{11}^E the elastic compliance at constant field, ϵ_{33}^T the constant stress dielectric constant and d_{31} the effective piezoelectric constant.

The variation of d_{31} with polarizing voltage can be measured by using the circuit of Fig. 6. Here a steady polarizing voltage is applied to the ceramic through a high resistance so that the impedance at the terminals of the ceramic will be the ac impedance of the ceramic. Large condensers that will stand a high voltage are connected between the ceramic and the measuring circuit. By reversing the applied voltage with respect to the static polarizing voltage, one can determine the amount of reverse voltage required to take off the initial polarization. This varies depending on the composition of the ceramic and provides a measure of the stability of the locked-in polarization.

The second constant d_{33} is more difficult to measure by dynamic methods, since a number of resonances are usually driven by this constant. One simple dynamic method is to measure the ratio of capacitances above and below the thickness resonance and apply (3) and (9) with the appropriate constants. Reliable values of k_{33} may be obtained from resonant and anti-resonant frequencies of a bar polarized and electrically driven parallel to its length. Due to the high dielectric constant of the ceramic, the stray capacitance of this arrangement is tolerable.

V. Selection of Methods

The methods described in the preceding sections may be applied separately or in combination, depending on the scope of the measurement program.

Determination of the piezoelectric coefficients by measurement of the resonant and anti-resonant frequency combines simplicity of apparatus with high accuracy under favorable circumstances. It is an absolute method, not requiring calibration standards. The piezoelectric coupling coefficients are obtained in a straightforward manner whenever a single piezoelectric coefficient relates expansion stress along one axis with an electric field at right angles thereto. This is true, for instance, for the 45 degree bars of Rochelle salt and ADP. Since the difference between resonance and anti-resonance depend on the square of the coupling coefficient, the method tends to become less accurate when the coupling coefficient is very small. Considerable accumulation of errors may occur if some of the piezoelectric coupling coefficients are obtained only by a combination of measurements on several expander bars. This is the case especially in crystals of monoclinic symmetry such as DKT and EDT.

The quasi-static methods can supplement the dynamic methods where the latter are difficult to apply. Since the measured magnitudes are proportional to the piezoelectric coefficients, these can be determined down to a limit of less than 1 per cent of the coefficient d_{11} of quartz. An especially useful application of the micro-displacement meter is the direct measurement of shearing strain. To carry this out, the body under study is cemented or clamped on a side which is perpendicular to the plane of shear, and the motion probe is set against one of the free corners to measure motion parallel to the plane of clamping. Force applicator methods have also been used to obtain shear coefficients by applying the

[21] See "Piezoelectric Crystals and Their Application to Ultrasonics," chap. XII, pp. 289–309 and appendix A-9, pp. 486–495.
[22] R_1 is the first root of the equation $RJ_0(R)=(1-\sigma)J_1(R)$. This varies from $R_1=2.03$ for $\sigma=0.27$ to $R_1=2.049$ when $\sigma=0.3$.

alternating force to one corner of a body clamped along one plane.

Determination of the hydrostatic piezoelectric coefficients is especially useful for the monoclinic crystals of class C_2 for which $d_h = d_{21} + d_{22} + d_{23}$. d_{22} is not readily determined separately by the other described methods. In polarized ceramics, $d_h = 2d_{31} + d_{33}$, so that knowledge of d_h and of d_{31}—the latter best obtained by dynamic measurement of radial resonance—determines d_{33}. Measurement of response to hydrostatic pressure is also a means to obtain at least one piezoelectric coefficient on crystals and especially ceramics available only in odd shapes.

Motion measurements are readily extended over a wide range of driving amplitudes. This is of importance in the study of ferroelectrics, where it permits the direct measurement of electrostrictive coefficients of the unpolarized material, as well as the study of nonlinearity in the response of polarized ceramics.

Static methods are at present applied for the study of response over a wide range of stress. A combination of all methods is needed to investigate the dependence of piezoelectric coefficients on frequency and amplitude, and to test the equality of the coefficients for the direct and converse piezoelectric effect. These relationships are still in question for ferroelectric ceramics. While linearity and reciprocity is usually found good from the audio-frequency range up into the megacycle range, it is not found for static conditions, especially under high loads. Piezoelectric coefficients for the latter condition may be more than twice as high as the well established values obtained at audio and radio frequencies.

VI. Acknowledgment

The authors are very grateful to the members of the Piezoelectric Crystals Committee of the Institute of Radio Engineers for their helpful comments and suggestions in the preparation of this paper.

Analysis of the Backward-Wave Traveling-Wave Tube*

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Summary—**A traveling-wave tube whose circuit supports a backward wave having oppositely directed phase and group velocities has been found to exhibit narrow-band regenerative-type gain. For low beam currents the tube acts as a high-gain, high Q, voltage-tunable filter. As the beam current is increased, the tube breaks into oscillations whose frequency may be shifted to any point in the structure pass band merely by changing beam voltage. An analysis is carried out which predicts some of the small-signal operating characteristics of the backward-wave tube. Numerical solutions are presented for the start-oscillation conditions including circuit loss and space charge.**

Introduction

RECENTLY a new type of traveling-wave tube operation has been observed at the Bell Telephone Laboratories.[1] Instead of employing a helix or filter structure having forward group and phase velocities, a circuit which supports a mode having the direction of energy propagation opposite to that of increasing phase is used. For example, certain of the space harmonics in a periodic structure exhibit this property. The name backward wave has been given to this mode. When an electron beam is sent along a terminated structure capable of supporting such a backward wave, spontaneous oscillations may be observed. These oscillations are unique in that:

1. By varying the electron velocity they may be made to tune continuously over the structure pass band.
2. Their existence is not dependent upon reflections at either end of the circuit.
3. As current is increased, other frequencies of oscillation appear and exist simultaneously with the initial oscillation.
4. Below the starting current large narrow-band gain may be obtained.
5. For a considerable range of currents above the starting current, gain in the presence of oscillation at the signal frequency is obtained.

It is the purpose of this paper to present a method for analyzing quantitatively the behavior of backward-wave interaction and to derive some of the more important operating parameters.

Before the description of the detailed solutions of backward-wave interaction, it is perhaps appropriate to indicate qualitatively why the backward-wave tube oscillates. Let us assume that we have a backward-wave circuit and an adjacent electron beam as shown in Fig. 1. At the risk of oversimplification we shall assume that the operation can be described in terms of a simple feedback mechanism in which a wave energywise travels from right to left on the circuit, induces modulation

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[1] R. Kompfner and N. T. Williams, "Backward wave tubes," Proc. I.R.E., vol. 41, pp. 1602–1611; Nov., 1953.

on the electron stream which travels from left to right and which in turn induces the original wave on the circuit. Now one of the conditions for feedback oscillation is that the total phase shift around the loop is an integral number of cycles. Let us add up these phase shifts. Energy traveling from right to left on the backward-wave circuit of length L experiences a phase *advance* of βL where β is the wave-propagation constant.

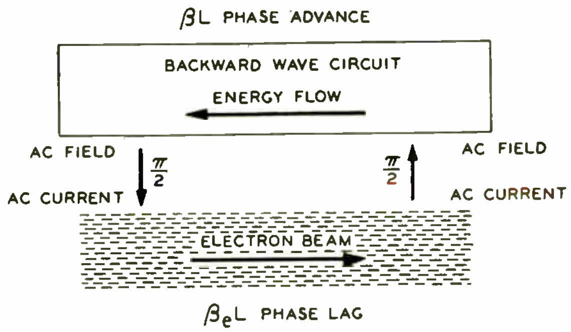

Fig. 1—The feedback loop of a backward-wave tube.

The electric field of this wave induces velocity modulation of the electrons in the adjacent stream. One-quarter cycle later this velocity modulation has been converted into current modulation so that this conversion process introduces a phase delay of $\pi/2$ radians. This ac current drifts down the stream and suffers a total phase delay of $\beta_e L$ where $\beta_e = \omega/u_0$. The conversion of ac current in the beam back to electric field on the circuit again involves a $\pi/2$ phase delay. Adding up the total loop phase shift and equating it to $2n\pi$ we find one of the conditions for feedback oscillation is

$$(\beta - \beta_e)L = (2n + 1)\pi.$$

The other condition for oscillation is that the loop gain must be unity. Because of circuit losses and the inefficiency of the conversion processes we shall require a certain amount of traveling-wave-type amplification to be present. Since the amount of gain per wavelength in a traveling-wave tube depends upon the impedance parameter, C, and the relative velocities of electrons and wave we must have

$$CN = \text{constant}$$

where N is the total number of wavelengths in the tube and the constant depends upon which value of n in the preceding equation is used.

Since for a backward wave the phase velocity, v_p, is an increasing function of ω, the phase relation tells us that as the beam velocity, u_0, is increased, the frequency will increase. Then, if the impedance is sufficiently high, the backward-wave oscillator will be continuously voltage tunable. If, however, the impedance is close to but below the value necessary to start oscillation, the device will act as a high-gain regenerative amplifier. The frequency range over which the feedback will be positive will in general be small so that the bandwidth of amplification will be narrow, but its center frequency may be tuned by varying beam velocity.

With this qualitative picture of the mechanism of the backward-wave tube, let us now proceed to a more rigorous analysis of its behavior.

Method of Analysis

The combined circuit-beam interaction will be broken into two problems: (a) the current induced in the electron stream due to a field on the circuit, and (b) the field induced on the circuit due to a current in the stream. These two relations are then combined to obtain a solution to the problem of simultaneous interaction between beam and circuit. Small-signal conditions are assumed throughout.

The method of analysis differs somewhat from that employed by Pierce.[2] The difference lies principally in the manner in which space charge is taken into account and in the derivation and utilization of the circuit equation. These differences will be made clearer as the analysis progresses.

The Electronic Equation

The problem considered here is, given an arbitrary field on the circuit, determine the form of the ac current produced in a stream flowing adjacent to the circuit. The stream is assumed not to interact back on the circuit.

We start with the force equation:

$$\frac{du}{dt} = \frac{e}{m} E_{\text{total}}. \quad (1)$$

(See list of symbols for explanation of notation.) This relation determines the rate of change of velocity of an individual electron under the action of a field E_{total}. If space-charge fields are present, E_{total} is made of two parts, the exciting field, E, which exists on the circuit, plus a space-charge field, E_{sc}, due to the effect of all adjacent electrons. Since the left side of (1) involves a total time derivative, the equation may be written, assuming all quantities vary as $e^{j\omega t}$, as:

$$\frac{du}{dt} = \frac{\partial v}{\partial t} + u_0 \frac{\partial v}{\partial z} = j\omega v + u_0 \frac{\partial v}{\partial z} = + \frac{e}{m}[E + E_{sc}] \quad (2)$$

where the total velocity has been split into a dc and an ac term, namely,

$$u = u_0 + v. \quad (3)$$

From the continuity equation,

$$\frac{\partial i}{\partial z} = - \frac{\partial \rho}{\partial t} = - j\omega\rho, \quad (4)$$

and the small-signal definition of current

$$i = \rho u_0 + v\rho_0, \quad (5)$$

[2] J. R. Pierce, "Traveling Wave Tubes," D. Van Nostrand Co., New York, N.Y., chap. 2; 1950.

where the total charge density has been broken up into a dc term ρ_0 and an ac term ρ, (2) may be written:

$$\frac{\partial^2 i}{\partial z^2} + 2j\beta_e \frac{\partial i}{\partial z} - \beta_e^2 i = \frac{j\omega e\rho_0}{m u_0^2}\left[E + E_{sc}\right] \qquad (6)$$

where

$$\beta_e = \frac{\omega}{u_0}. \qquad (7)$$

The time-varying portion of the space-charge field, E_{sc} may be obtained from Poisson's equation. For the one-dimensional case

$$\frac{\partial E_{sc}}{\partial z} = \frac{\rho}{\epsilon}. \qquad (8)$$

From the continuity relation (4), assuming the ac current to be zero at the entering plane, (8) reduces to

$$E_{sc} = -\frac{i}{j\omega\epsilon}. \qquad (9)$$

Insertion of (9) into (6) yields the final differential equation for current induced by a circuit field E:

$$\frac{\partial^2 i}{\partial z^2} + 2j\beta_e \frac{\partial i}{\partial z} - (\beta_e^2 - h^2)i = \frac{j\omega e\rho_0}{m u_0^2}E \qquad (10)$$

where the plasma wave number h, is given by:

$$h^2 = \frac{e\rho_0}{m\epsilon u_0^2}. \qquad (11)$$

To include the effect of a finite beam size and the effect of the adjacent metallic walls of the circuit, we may with good accuracy replace h in (10) by an effective plasma wave number obtained by considering a beam within a drift tube having the same or similar configuration as the circuit actually used.

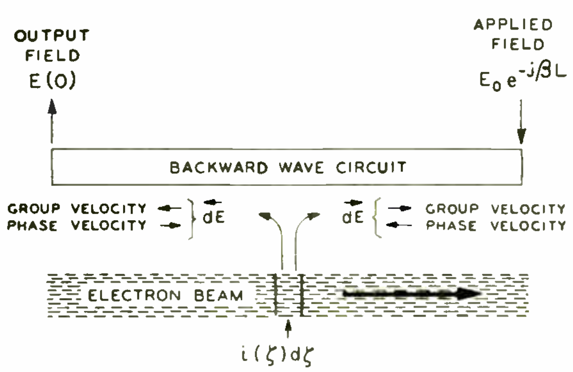

Fig. 2—Excitation of a backward-wave circuit by a modulated electron stream.

The Circuit Equation

We shall now consider the problem of determining the field impressed upon a circuit due to ac current flowing in a stream adjacent to the circuit (see Fig. 2). The method of analysis is similar to that used by Bernier[3] and Pierce.[4]

[3] J. Bernier, "Essai de theorie du tube electronique a propagation d'ondes," *Ann. Radioelect.*, vol. 21, pp. 87–101; 1947.
[4] Appendix A of J. R. Pierce, "Theory of the beam type traveling-wave tube," Proc. I.R.E., vol. 35, pp. 111–123; Feb., 1947.

Suppose we have a small element of current $i(\zeta)d\zeta$ impressed upon a transmission system which supports a single wave having group and phase velocity of opposite sign. The current element will induce two waves on the circuit, one traveling to the left and the one to the right. Since the circuit is symmetrical the amplitudes of the waves must be equal.

$$\overleftarrow{dE} = \overrightarrow{dE}. \qquad (12)$$

The power flowing from the current element is

$$dP = -\frac{i^*(\zeta)d\zeta dE}{2}. \qquad (13)$$

Thus, since half of this power flows left and half right

$$\overleftarrow{dP} = -\frac{i^*(\zeta)d\zeta\overleftarrow{dE}}{4}$$
$$\overrightarrow{dP} = -\frac{i^*(\zeta)d\zeta\overrightarrow{dE}}{4}. \qquad (14)$$

(The asterisk indicates complex conjugate.)

Considering the amount of circuit power flowing across a transverse plane we may write

$$\overrightarrow{P} = \frac{E\,E^*\psi}{2}$$
$$\overleftarrow{P} = \frac{E\,E^*\psi}{2} \qquad (15)$$

where ψ is twice the peak power carried across the plane in one direction by a unit peak field.

$$\overrightarrow{dE} = -\frac{i(\zeta)d\zeta}{2\psi^*}$$
$$\overleftarrow{dE} = -\frac{i(\zeta)d\zeta}{2\psi^*}. \qquad (16)$$

To calculate the resultant induced field at a point z we must add up all the contributions from current elements to the right of z which flows energywise toward the left and contributions from elements to the left of z which flow to the right. The total field then will be the sum of applied field and the induced field. Thus for the case of opposite phase and group velocities, that is, assuming a wave which carries energy from left to right varies as $e^{j\omega t+j\beta z}$ and one carrying energy from right to left as $e^{j\omega t-j\beta z}$, we have:

$$E(z) = E_0 e^{-j\beta z} - \frac{1}{2\psi^*}\left(e^{j\beta z}\int_0^z i(\zeta)e^{-j\beta\zeta}d\zeta + e^{-j\beta z}\int_z^L i(\zeta)e^{j\beta\zeta}d\zeta\right). \qquad (17)$$

This expression gives the field at any point on the circuit due to the effect of an applied field and an adjacent alternating-conduction current density. Because of the awkwardness involved in utilizing this definite integral expression directly we shall differentiate it with respect to distance twice to obtain a second-order differential equation

$$\frac{\partial^2 E(z)}{\partial z^2} + \beta^2 E(z) = -\frac{j\beta}{\psi^*} i(z). \quad (18)$$

Solutions of this will involve two arbitrary constants which may be evaluated using above integral relation.

The Combined Equations

We now have two differential equations which must be solved simultaneously to give the combined effect of beam and circuit interaction. They are

$$\frac{\partial^2 i(z)}{\partial z^2} + 2j\beta_e \frac{\partial i(z)}{\partial z} - (\beta_e^2 - h^2) i(z) = j\frac{\omega e \rho_0}{m u_0^2} E(z), \quad (10)$$

$$\frac{\partial^2 E(z)}{\partial z^2} + \beta^2 E(z) = -j\frac{\beta}{\psi^*} i(z). \quad (18)$$

These equations would have exactly the same form for the more usual cases of forward phase and group velocity if $(-\beta^*)$ were substituted for β.

The equations may be advantageously solved by means of the Laplace transform since this allows direct insertion of the initial conditions. As the beam enters the circuit we assume that it has no ac velocity or current modulation. Then letting

$$\mathfrak{I}(\Gamma) = \int_0^\infty i(z) e^{-\Gamma z} dz$$

$$\mathcal{E}(\Gamma) = \int_0^\infty E(z) e^{-\Gamma z} dz, \quad (19)$$

$E(o)$ = the value of the circuit field at $z = 0$

$E'(o)$ = the value of the derivative of the circuit field at $z = 0$ (20)

the transformed equations become

$$[\Gamma^2 + 2j\beta_e - (\beta_e^2 - h^2)]\mathfrak{I} = j\frac{\omega e \rho_0}{m u_0^2}\mathcal{E},$$

$$(\Gamma^2 + \beta^2)\mathcal{E} - \Gamma E(o) - E'(o) = -j\frac{\beta}{\psi^*}\mathfrak{I}. \quad (21)$$

Solving for $\mathcal{E}$ we obtain

$$\mathcal{E} = \frac{[(\Gamma + j\beta_e)^2 + h^2][\Gamma E(o) + E'(o)]}{[(\Gamma + j\beta e)^2 + h^2](\Gamma^2 + \beta^2) - K} \quad (22)$$

where

$$K = \frac{I_0}{4V_0}\frac{E^2}{\beta^2 P}\beta^3\beta_e = 2C^3\beta^3\beta_e. \quad (23)$$

From (17) we find $E'(o) = -j\beta E(o)$.

Letting the roots of the denominator of (22) be Γ_n and taking the inverse transform of this expression, we have

$$E(z) = E(o)\{(\Gamma_1 - j\beta)k_1 e^{\Gamma_1 z} + (\Gamma_2 - j\beta)k_2 e^{\Gamma_2 z} + (\Gamma_3 - j\beta)k_3 e^{\Gamma_3 z} + (\Gamma_4 - j\beta)k_4 e^{\Gamma_4 z}\} \quad (24)$$

where

$$k_1 = \frac{(\Gamma_1 - j\beta_e)^2 + h^2}{(\Gamma_1 - \Gamma_2)(\Gamma_1 - \Gamma_3)(\Gamma_1 - \Gamma_4)}$$

$$k_2 = \frac{(\Gamma_2 - j\beta_e)^2 + h^2}{(\Gamma_2 - \Gamma_1)(\Gamma_2 - \Gamma_3)(\Gamma_2 - \Gamma_4)}$$

$$k_3 = \frac{(\Gamma_3 - j\beta_e)^2 + h^2}{(\Gamma_3 - \Gamma_1)(\Gamma_3 - \Gamma_2)(\Gamma_3 - \Gamma_4)} \quad (25)$$

$$k_4 = \frac{(\Gamma_4 - j\beta_e)^2 + h^2}{(\Gamma_4 - \Gamma_1)(\Gamma_4 - \Gamma_2)(\Gamma_4 - \Gamma_3)}$$

and

$$[(\Gamma_n + j\beta_e)^2 + h^2](\Gamma_n^2 + \beta^2) = K. \quad (26)$$

We must now evaluate the constant $E(o)$. To do this we obtain $i(z)$ from (24) and (18) and substitute it in the definite integral (17) evaluated at $z=0$. This procedure yields the result:

$$E(o) = E_0 - \frac{KE(o)}{2j\beta}\left(\frac{(\Gamma_1 - j\beta)[1 - e^{(\Gamma_1 + j\beta)L}]}{(\Gamma_1-\Gamma_2)(\Gamma_1-\Gamma_3)(\Gamma_1-\Gamma_4)(\Gamma_1+j\beta)} + \frac{(\Gamma_2 - j\beta)[1 - e^{(\Gamma_2 + j\beta)L}]}{(\Gamma_2-\Gamma_1)(\Gamma_2-\Gamma_3)(\Gamma_2-\Gamma_4)(\Gamma_2+j\beta)} + \frac{(\Gamma_3 - j\beta)[1 - e^{(\Gamma_3 + j\beta)L}]}{(\Gamma_3-\Gamma_1)(\Gamma_3-\Gamma_2)(\Gamma_3-\Gamma_4)(\Gamma_3+j\beta)} + \frac{(\Gamma_4 - j\beta)[1 - e^{(\Gamma_4 + j\beta)L}]}{(\Gamma_4-\Gamma_1)(\Gamma_4-\Gamma_2)(\Gamma_4-\Gamma_3)(\Gamma_4+j\beta)}\right), \quad (27)$$

where L is the active length of the circuit.

If we let

$$\Gamma_{1,2,3}L = -j\beta L + j\eta_{1,2,3}$$

$$\Gamma_4 L = j\beta L + j\eta_4, \quad (28)$$

and notice that under the usual operating conditions

$$K \ll \beta_e^2\beta^2 \quad (29)$$

we find that

$$\eta_n \ll \beta \quad (30)$$

and

$$\eta_4 \ll \eta_{1,2,3}. \quad (31)$$

Under these circumstances, the amplitude of the wave traveling as $e^{\Gamma_4 z}$ is negligible with respect to the others. Neglecting this wave in (24) and performing some algebraic manipulation on (27) leads to the final expression for the circuit field:

$$E(z) = \frac{\frac{\eta_3 - \eta_2}{\eta_1} e^{j\eta_1(z/L)} + \frac{\eta_1 - \eta_3}{\eta_2} e^{j\eta_2(z/L)} + \frac{\eta_2 - \eta_1}{\eta_3} e^{j\eta_3(z/L)}}{\frac{\eta_3 - \eta_2}{\eta_1} e^{j\eta_1} + \frac{\eta_1 - \eta_3}{\eta_2} e^{j\eta_2} + \frac{\eta_2 - \eta_1}{\eta_3} e^{j\eta_3}} E_0 e^{-j\beta z}, \quad (32)$$

where from (26) and (23) the η's are the three roots of

$$\eta^3 + 2\theta\eta^2 + (\theta^2 - H^2)\eta + (2\pi CN)^3 = 0, \quad (33)$$

where θ has been defined as

$$\theta = (\beta_e - \beta)L$$

and,

$$H = hL. \quad (34)$$

Note that at $z=L$, the input of the tube, the field is exactly equal to the applied field.

Formally, at least, the problem has been solved. Equation (24) shows the existence of four waves, the propagation constants of which are given by the four solutions of (26). At this point it is interesting to note that the root of (26) differs from the usual forward-wave root equation only in the sign of the parameter K. This means that tabulated values of the usual traveling-wave-tube-propagation constants for the lossless case could be used for the backward-wave tube if only the circuit impedance is considered to be negative, that is, if Pierce's parameter.

$$C^3 = \frac{I_0}{8V_0}\frac{E^2}{\beta^2 P} \quad (35)$$

is chosen negative.

It was found as in the forward-wave case that one of the waves is excited to a negligible extent. Dropping this wave results in a field expression given by (32).

Oscillation Conditions

The possibility of oscillation exists if the denominator of (32) goes to zero. Thus, the start oscillation conditions are

$$\frac{\eta_3 - \eta_2}{\eta_1} e^{j\eta_1} + \frac{\eta_1 - \eta_3}{\eta_2} e^{j\eta_2} + \frac{\eta_2 - \eta_1}{\eta_3} e^{j\eta_3} = 0, \quad (36)$$

where as before $\eta_{1,2,3}$ are the three roots of

$$\eta^3 + 2\theta\eta^2 + (\theta^2 - H^2)\eta + (2\pi CN)^3 = 0. \quad (33)$$

In general β and hence θ will be complex, indicating cold circuit attenuation. Because of the backward energy flow corresponding to forward progression of phase, the cold circuit wave travels as $e^{(-j\beta'+\alpha)z}$ so that when loss is present, β in the above equations should be replaced by $(\beta'+j\alpha)$.

Let us consider first the case of the lossless guide so that we neglect the effects of attenuation. Since presumably the backward-wave oscillator would not have the intentional internal loading which is placed in usual TW tubes to prevent oscillation, the assumption of no loss will often give sufficient accuracy.

If no loss is present, one of the roots of (33) will be entirely real. Let us call this root η_1. We may then express η_2 and η_3 in terms of η_1, θ, and H.

$$\eta_2 = -\theta - \frac{\eta_1}{2} + j\tfrac{1}{2}\sqrt{4\theta\eta_1 + 3\eta_1^2 - 4H^2}$$

$$\eta_3 = -\theta - \frac{\eta_1}{2} - j\tfrac{1}{2}\sqrt{4\theta\eta_1 + 3\eta_1^2 - 4H^2}. \quad (37)$$

The start oscillation condition (36) then becomes on equating real and imaginary parts to zero

$$\cos\left(\theta + \frac{3\eta_1}{2}\right)\frac{2\eta_1(\theta+\eta_1)}{(\theta+\eta_1)^2 - H^2} \cdot \cosh\sqrt{\theta\eta_1 + \tfrac{3}{4}\eta_1^2 - H^2} = 0$$

$$\sin\left(\theta + \frac{3\eta_1}{2}\right) + \frac{\theta(\theta+\eta_1) + H^2}{(\theta+\eta_1)^2 - H^2}\frac{\eta_1}{\sqrt{\theta\eta_1 + \tfrac{3}{4}\eta_1^2 - H^2}} - \sinh\sqrt{\theta\eta_1 + \tfrac{3}{4}\eta_1^2 - H^2} = 0. \quad (38)$$

We are led to expect multiple roots of these equations from the qualitative lumped-feedback consideration, and indeed, in the absence of space charge their values agree remarkably well with those predicted by the relation

$$(\beta - \beta_e)L = (2n+1)\pi.$$

Table I gives the exact solutions for the start oscillation conditions of the first four oscillation points in the absence of space charge and loss.

TABLE I

Start Oscillation Conditions for the First Four Oscillation Points in the Absence of Space Charge and Loss

n	$(\beta-\beta_e)L$	CN
0	3.003	0.314
1	9.860	0.588
2	16.388	0.762
3	21.403	1.046

The form that the start oscillation conditions take, that is, $(\beta-\beta_e)L$ a constant and CN a constant, indicates that there is a value of frequency and current for a given beam velocity which first allows finite fields to exist on the circuit in the absence of any applied field. As velocity is changed, frequency must also change in order to keep $(\beta-\beta_e)L$ a constant. In this way electronic tuning is accomplished.

The amplitudes of the oscillation field are determined by nonlinear effects which could be determined accurately only by a large-signal analysis. It is important to emphasize that the oscillation level does not build up to saturation, but only to that level for which the incremental propagation constants are such that the oscillation conditions given by (38) are satisfied. It is this mechanism which allows the tube to give signal gain even though it is oscillating at the same frequency.

The accuracy of the higher oscillation conditions is questionable since they occur when the tube is already oscillating at some other frequency with a considerable amplitude. This large-signal oscillation will tend to change the incremental propagation constants which can exist for the new oscillation point thus changing the starting current and frequency for successive oscillation points. It should be pointed out that since for a backward-wave circuit β is a decreasing function of frequency the successively higher values of $(\beta-\beta_e)L$ required for the higher oscillation points indicate that these oscillations occur at successively lower frequencies.

The Effect of Space Charge

So far we have been concerned with the oscillation parameters under the condition of zero loss and no space charge. As has been indicated, the assumption of zero loss is to some extent justified for practical backward-wave tubes. What loss is unavoidably present is probably small enough to have negligible influence on the operation. However, the assumption of zero space charge is often unjustified.

The start oscillation conditions as a function of space charge can be determined from (38). The space-charge parameter, H, it will be remembered, is the number of effective plasma wavelengths existing in the active length of the tube. H may be related to Pierce's space-charge parameter QC by the following expression,

$$QC = \left[\frac{H}{4\pi CN}\right]^2 \tag{39}$$

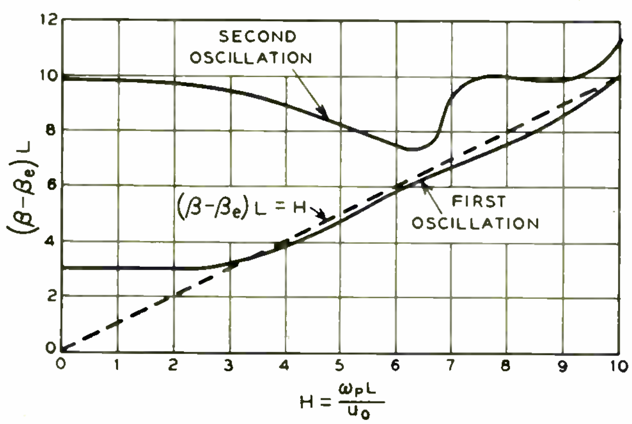

Fig. 3—Variation of $(\beta-\beta_e)L$ required to start oscillation for the first two oscillation conditions as a function of space charge. Circuit loss assumed zero.

Figs. 3 and 4 show the variation of the start oscillation conditions for the first two oscillation points in the absence of loss as H is increased.

These curves were obtained by solving the start oscillation equations (38). It is interesting to note that for H greater than two, the oscillation conditions are such that all three waves propagate down the guide unchanged in magnitude, showing neither growth nor attenuation. At the collector end they add up to zero while at the gun end their phases are such as to give a net field.

As has been pointed out, the interaction equations for forward- and backward-wave circuits differ by merely a sign reversal and a change of direction of energy flow. The input becomes the output, and *vice versa*. Thus, the start oscillation conditions for the backward-wave tube, that is, the conditions of finite output for zero input, become the zero gain conditions for the forward-wave tube, the point of zero output for finite input. Hence, the zero gain conditions for a lossless forward-wave tube as a function of space charge may also be obtained from Figs. 3 and 4 if only the sign of the quantity $(\beta-\beta_e)L$ is reversed.

C. C. Cutler in unpublished work has measured QC by this zero gain method and found substantial agreement between his measurements and Fletcher's theoretical values,[5] precluding an extra term, due to velocity distribution of the large magnitude proposed by Parzen and Goldstein.[6]

Returning to the start oscillation conditions, we find that for large space charge the starting conditions for the first oscillation point approach asymptotically

$$(\beta-\beta_e)L = H$$

$$CN = \left(\frac{H}{16\pi}\right)^{1/3}. \tag{40}$$

This last condition was first pointed out by R. Grow of Stanford.

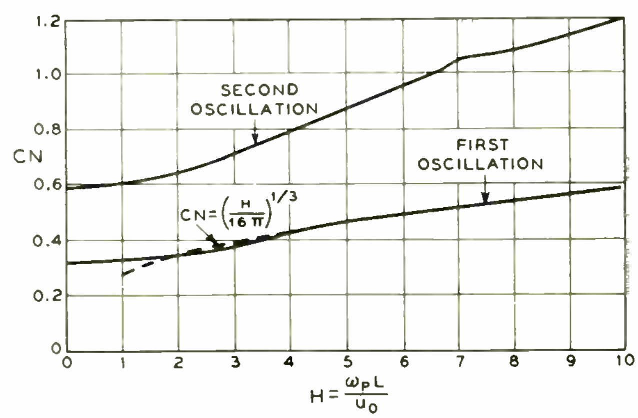

Fig. 4—Variation of CN required to start oscillation for the first two oscillation conditions as a function of space charge. Circuit loss assumed zero.

The fact that $(\beta-\beta_e)L$ for the first oscillation point is an increasing function of current indicates that as current is increased the frequency of oscillation is decreased. Since it is the difference between two large numbers which is changing slightly, the percentage frequency shift is usually slight indeed.

It is of some interest to obtain the form of the field and current variation along the tube at start oscillation. We already have the expression for the circuit field in (32). Using this in conjunction with the differential (18) we may obtain an expression for the current.

[5] R. C. Fletcher, "Helix parameters in traveling wave tube theory" Proc. I.R.E. vol. 30, pp. 413–417; April, 1950.
[6] P. Parzen and L. Goldstein, "Effect of hydrostatic pressure in an electron beam on the operation of traveling wave devices," *Jour. Appl. Physics*, vol. 22, pp. 398–401; April, 1951.

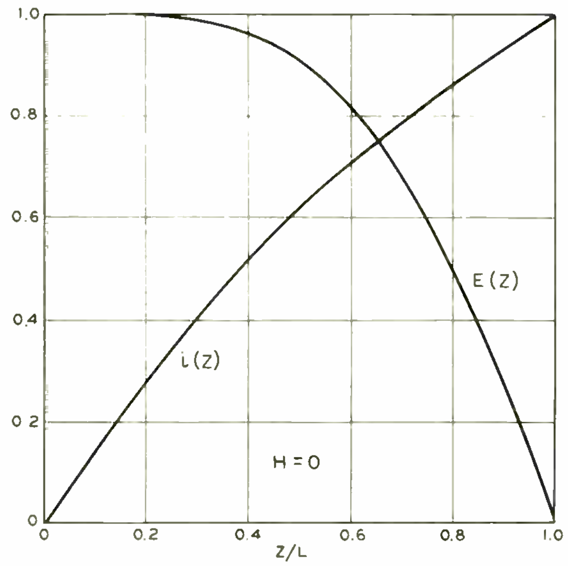

Fig. 5—Relative values of ac electric field on the circuit and ac current in the beam along the tube at start oscillation. Zero space charge, zero circuit loss.

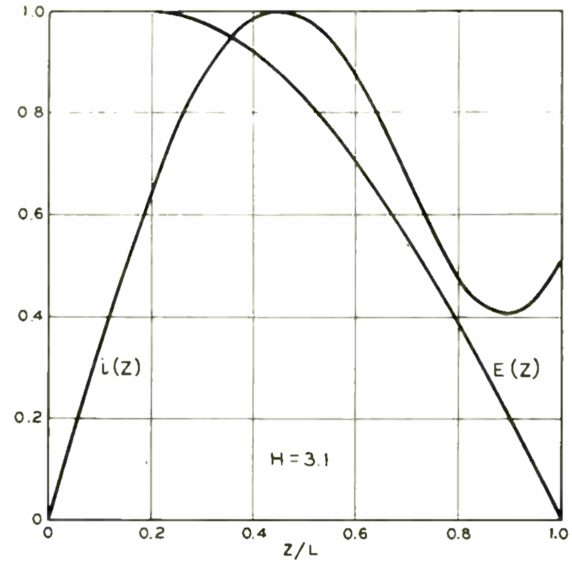

Fig. 6—Relative values of ac electric field on the circuit and ac current in the beam along the tube at start oscillation. Finite space charge, zero circuit loss.

$$i(z) = j\frac{2\psi^*}{L}\left[\frac{(\eta_2-\eta_3)e^{j(\eta_1 z/L)} + (\eta_1-\eta_3)e^{j(\eta_2 z/L)} + (\eta_2-\eta_1)e^{j(\eta_3 z/L)}}{\frac{\eta_3-\eta_2}{\eta_1}e^{j\eta_1} + \frac{\eta_1-\eta_3}{\eta_2}e^{j\eta_2} + \frac{\eta_2-\eta_1}{\eta_3}e^{j\eta_3}}\right]E_0 e^{-j\beta z}. \quad (41)$$

Using (32) and (41) we can plot the relative values of field and current along the tube at start oscillation for different values of space charge. This has been done in Figs. 5 and 6 for $H=0$ and $H=3.1$. For large space charge put in the asymptotic starting conditions, namely

$$(\beta-\beta_e)L = H$$
$$CN = \left(\frac{H}{16\pi}\right)^{1/3} \quad (42)$$
$$\eta_1 = -\frac{\pi}{2}; \quad \eta_2 = \frac{\pi}{2}; \quad \eta_3 = 2H + \frac{\pi}{2},$$

and find

$$\frac{E(z)}{E(0)} \to \cos\frac{\pi z}{2L}$$
$$\frac{i(z)}{i(L)} \to \sin\frac{\pi z}{2L}. \quad (43)$$

The Effect of Loss

Equations (33) and (36) which together give the start oscillation conditions are valid when both loss and space charge are present. One may add to the propagation constant β a quadrature component and solve for the incremental propagation constants as functions of CN and $(\beta-\beta_e)L$. Certain of these values will satisfy (36). A process similar to this has been carried out by Ward Harman at Stanford. For his results in slightly different notation see Figs. 7, 8, opposite. These curves show the effect of distributed loss on the start oscillation conditions for first oscillation point in the absence of space charge. Notice, with addition of 30 db cold loss, starting current has increased only by a factor of five.

Behavior Below the Oscillation Level

In a preceding section we have shown that the field as a function of distance, neglecting the small contribution due to the fourth wave, is of the form

$$E(z) = \frac{E_0}{G}\left[g_1 e^{\Gamma_1 z} + g_2 e^{\Gamma_2 z} + g_3 e^{\Gamma_3 z}\right], \quad (44)$$

where E_0 is the applied field and G, g_1, g_2 and g_3 are functions of the incremental propagation constants, hence the operating parameters of beam current, beam velocity, frequency, impedance and length. Taking the field at $z=0$, the output of the tube, we find that the form of the gain expression is

$$\text{Power gain ratio} = \left[\frac{g}{G}\right]^2. \quad (45)$$

Large gains arise when the function G approaches zero. At the point where G equals zero the tube breaks into oscillation.

In the region of high gain around the oscillation point the denominator of the gain expression, G, is a rapidly varying function of the operating parameters while the numerator, g, is nearly constant. Thus, we may apply a Taylor expansion of the denominator around the oscillation or $G=0$ point and determine the form of the gain variation with current. This procedure shows, to first-order approximation,

$$\text{Power gain ratio} = \left[\frac{k}{I_0 - I_s}\right]^2, \quad (46)$$

where I_s is the start oscillation current. This expression indicates gain for currents above the start oscillation

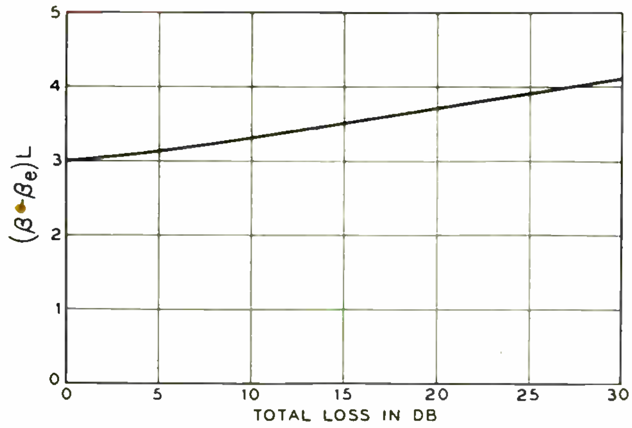

Fig. 7—Variation of $(\beta-\beta_e)L$ required to start oscillation for the first oscillation condition as a function of total circuit loss. Space charge is assumed zero.

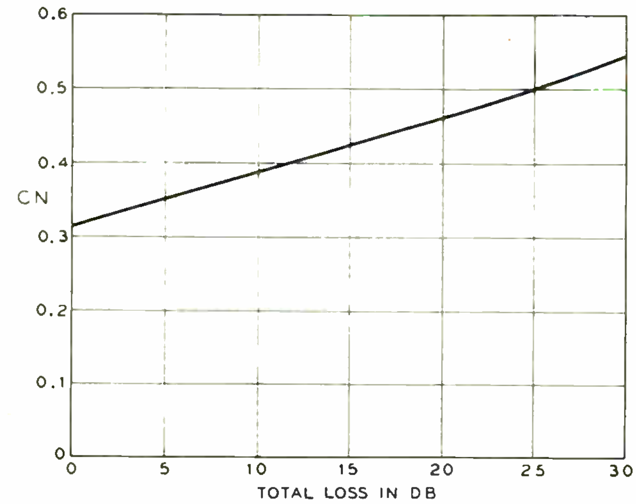

Fig. 8—Variation of CN required to start oscillation for the first oscillation condition as a function of total circuit loss. Space charge is assumed zero.

current as is observed. Moreover, it predicts that the output signal changes phase by 180 degrees upon crossing the oscillation point.

It has been mentioned that the gain of a backward-wave tube is confined to a narrow band of frequencies. An estimate of the gain variation with frequency may be made in the same manner to obtain

$$\text{Power gain ratio} = \left[\frac{a}{1 + b(f - f_0)^2}\right]^2, \qquad (47)$$

where a^2 is the gain when $f=f_0$.

An idea of the extreme narrowness of bandwidth over which amplification takes place may be gained from the result of an experimental tube which in the range of 3,000 to 9,000 mc had an equivalent Q in excess of 2,000.

Acknowledgment

The author is indebted to W. Harman, J. Putz, L. M. Field, and others for many valuable discussions of backward-wave interaction. He wishes to express his appreciation to Miss Crystal Kent of Stanford University and, in particular, to Mrs. C. A. Lambert of the Bell Telephone Laboratories, who computed the start oscillation parameters.

List of Symbols

e = the charge of an electron $= -1.602\times10^{-19}$ coulomb
C = gain parameters. $C^3=(I_0/8V)_0(E^2/\beta^2p)$
E = circuit field
E_{sc} = space-charge field
E_{total} = total field acting on an electron
h = plasma wave number. $h^2=e\rho_0/m\epsilon$
H = number of plasma wavelengths in a length L. $H=hL$
i = ac conduction current density
I_0 = total dc beam current
$K=2C^3\beta^3\beta_e$.
L = the total active length of the circuit
m = the mass of an electron
N = number of wavelengths existing within the tube. $2\pi N=\beta_eL$
P = complex power
u = total electron velocity
u_0 = dc electron velocity
v = ac electron velocity
v_p = phase velocity of the cold circuit
V_0 = dc beam voltage
β = propagation constant of the cold circuit. The cold circuit waves travel as $e^{j(\omega t-\beta z)}$
$\beta_e=\omega/u_0$
Γ_n = the propagation constant of the interaction waves. In the presence of the beam, the waves travel as $e^{j\omega t+\Gamma_n z}$
ϵ = dielectric constant of free space
η = incremental propagation constant. $\Gamma L=-j\beta L+j\eta$
$\theta=(\beta_e-\beta)L$
ρ = ac charge density
ρ_0 = dc charge density
ω = angular frequency
ψ = twice the peak power carried across a plane by a unit peak field
$\mathcal{E}(\Gamma)$ = Laplace transform of $E(z)$
$\mathfrak{I}(\Gamma)$ = Laplace transform of $i(z)$

The Transient Response of Transistor Switching Circuits*

I. L. LEBOW† AND R. H. BAKER†

Summary—**A model is presented for the interpretation of point-contact transistor switching phenomena. The assumption is made that the frequency cut-off is high when the transistor is not saturated and low when saturated. The low-frequency response in saturation can explain qualitatively the anomalous pulse requirements for switching transistors from saturation to cutoff. Some switching criteria are derived and the one-shot multivibrator is discussed.**

I. Introduction[1]

IN THE DESIGN of transistor switching circuits, the usual approach is to make use of the input characteristic of the transistor circuit. As an example, let us consider the circuit of Fig. 1. This is a typical "grounded base" connection where an external base resistance R_b has been added between base and ground to provide additional positive feedback. The static input characteristic of the circuit of Fig. 1 is shown in Fig. 2

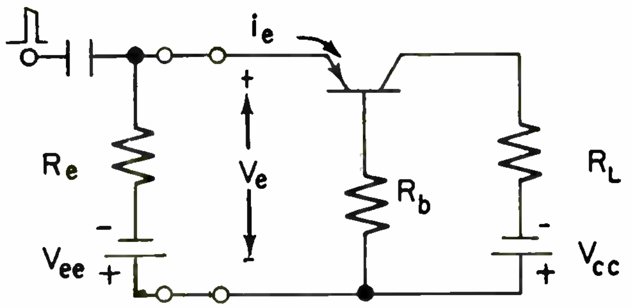

Fig. 1—Basic transistor switching circuit.

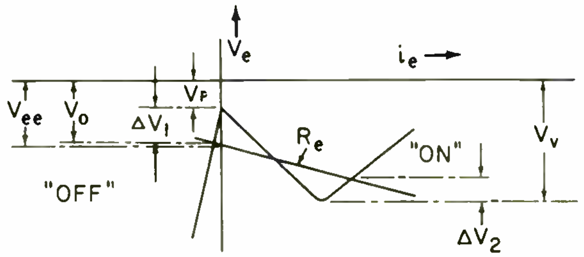

Fig. 2—Input characteristic of basic transistor switching circuit.

which is the familiar "*N*" curve. The type of operation obtained from the circuit will depend upon the values of the parameters R_e and V_{ee}. Fig. 2 shows a "bistable" load line that would be employed in a flip-flop design.

From the point of view of the characteristic of Fig. 2, the trigger voltage required to switch the transistor from the "off" state to the "on" state is that voltage which will just raise the load line above the peak point $-V_p$. Similarly, to switch the transistor from "on" to "off," the trigger voltage must be sufficient to drop the load line below the valley point $-V_v$. It has been found experimentally that the trigger voltages required are, in general, greater than the static picture presented above would indicate. Moreover, it has been found that the trigger voltage requirements depend upon the trigger pulse width, and that this dependence in triggering from "on" to "off" is considerably different than in triggering from "off" to "on." Such phenomena cannot possibly be explained by using a static model. Furthermore, the static model provides no information on the details of the actual switching.

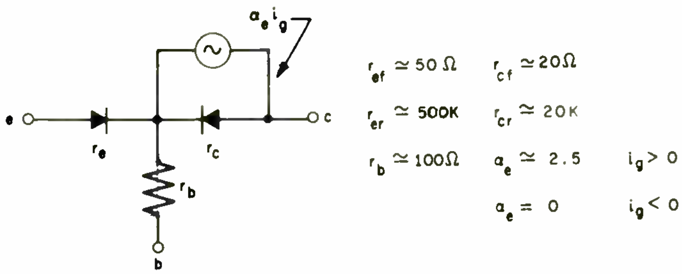

Fig. 3—Large signal equivalent circuit.

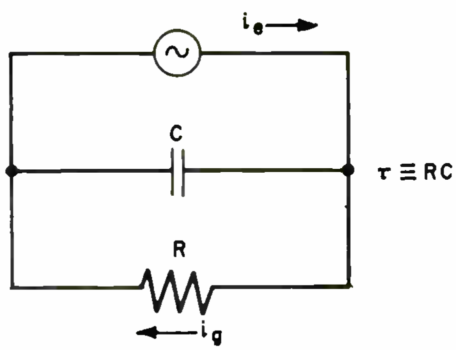

Fig. 4.—A representation of transistor frequency response.

In this paper, we shall consider the transient response of the circuit of Fig. 1. We shall first discuss the triggering of the circuit from "off" to "on." Next, we shall describe the triggering from "on" to "off" of the circuit with bistable load line. We then generalize the procedure for the case of the monostable one-shot multivibrator which is triggered from "off" to "on" and then turns itself off. Finally, we present a comparison with experiment.

II. Fundamental Assumptions

In the discussion that follows, we shall assume the linearized equivalent circuit of Adler[2] shown in Fig. 3.

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[1] For a more detailed discussion, see I. L. Lebow, R. H. Baker, and R. E. McMahon, "The Transient Response of Transistor Switching Circuits," Tech. Report No. 27, Lincoln Lab., M.I.T., July 7, 1953.

[2] R. B. Adler, "A Large Signal Equivalent Circuit for Transistor Static Characteristics," Research Laboratory of Electronics Transistor Group Report T-2, M.I.T., Aug. 30, 1951.

When the static case is considered, the current in the constant-current generator across the collector diode, $\alpha_e i_g$, becomes $\alpha_e i_e$. In the dynamic case, i_g is related to i_e as in Fig. 4. It is evident that i_g satisfies equation

$$\tau \frac{di_g}{dt} + i_g = i_e. \tag{1}$$

Fig. 4 and (1) indicate the fact that we are inserting the frequency dependence of the transistor into the current i_g, and maintaining a frequency independent α. This is completely equivalent to the assumption that the generator current is equal to $\alpha_e i_e$, where α_e is equal to $\alpha_0/1+\tau s$.

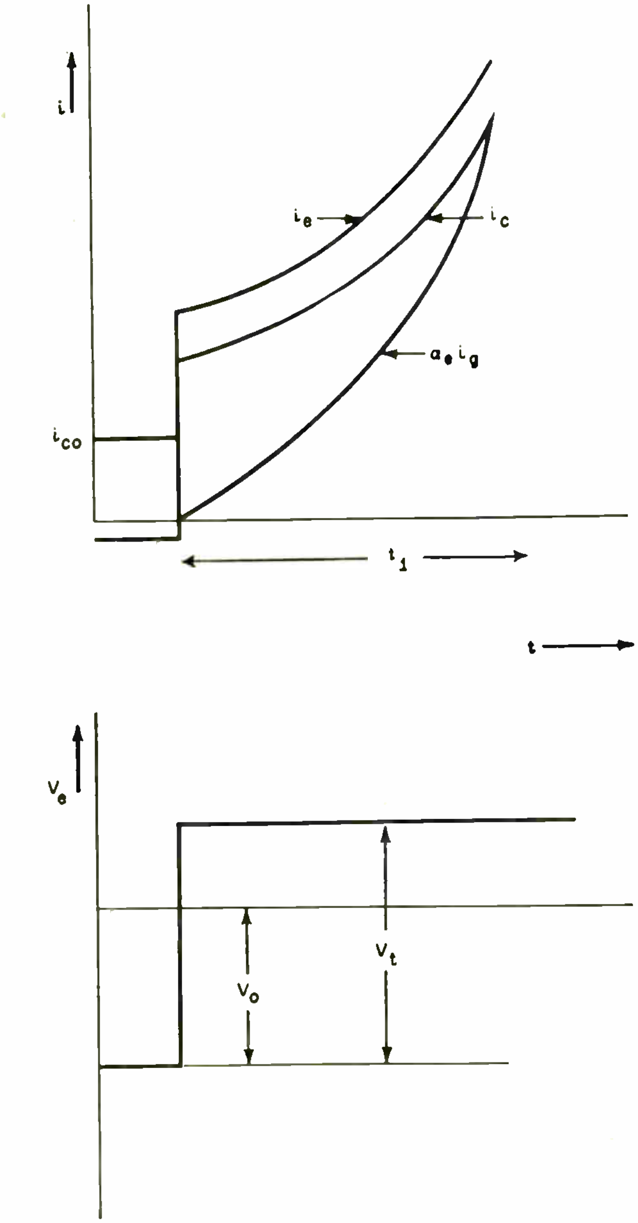

Fig. 5—Typical waveforms in triggering from "off" to "on" at emitter with wide input pulse.

In order to explain experimental measurements, it is necessary to assume that τ has a value τ_1(~0.1 μsec) when the collector diode is open, and value τ_2(~1 to 10 μsec) when the collector diode is closed or the transistor is in the "on" or saturated condition (sec. VII).

III. Switching From "Off" to "On"[3,4]

We shall consider triggering the circuit of Fig. 1 from the "off" to the "on" state by application of a voltage pulse to the emitter through a very large coupling capacitor. If the trigger voltage V_t exceeds ΔV, the voltage separation between the "off" point and the peak point, the circuit switches instantaneously into the active region. The circuit currents will then increase exponentially with the positive frequency,

$$\omega = \frac{1}{\tau_1} \frac{(\alpha_e - 1)r_c - R_L}{r_c + R_L}. \tag{2}$$

The transistor will, of course, reach saturation when $\alpha_e i_g$ reaches i_c as shown in Fig. 5.

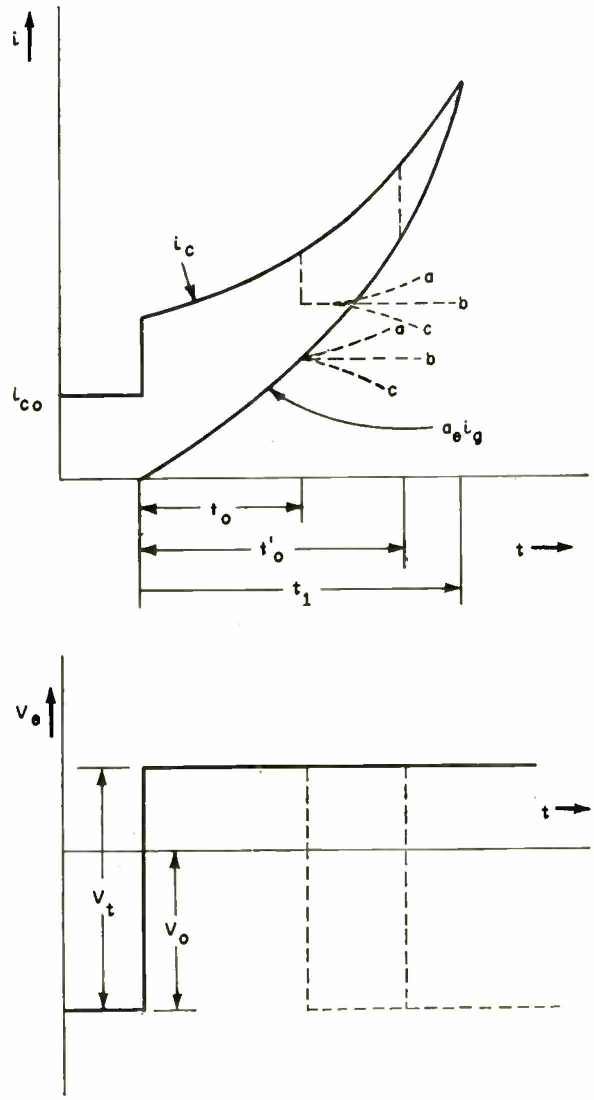

Fig. 6—Typical waveforms in triggering from "off" to "on" at emitter with pulse removed before switching is completed.

If the trigger pulse is removed at some time t_0 before the transistor has reached saturation, the currents are of the form of Fig. 6. The currents may continue to

[3] For a similar discussion of some of the material in this section, see A. W. Carlson, "A Discussion of Switching in Point Contact Transistors," Air Force Cambridge Res. Center Rep., Sept., 1952.

[4] B. G. Farley, "Dynamic of transistor negative-resistance circuits," Proc. I.R.E., vol. 40, pp. 1497–1507; Nov., 1952.

increase (curves a), in which case the transistor will switch "on," or the currents may decrease (curves c), in which case the transistor will return to cutoff. The limiting case (curves b), where currents remain constant, provides triggering criterion of pulse height vs pulse width,

$$V_t = \frac{\Delta V}{1 - \exp\left[-\omega t_0\right]}. \quad (3)$$

Equation 3 implies that if a pulse of width t_0 is applied, the amplitude V_t must be at least that given by the above expression. It will be noted that as the pulse becomes narrower, the required amplitude increases. However, no matter how narrow the pulse, the transistor may be switched, provided the amplitude is sufficiently large. This is in contrast to the reverse process of triggering from "on" to "off" discussed in the next section.

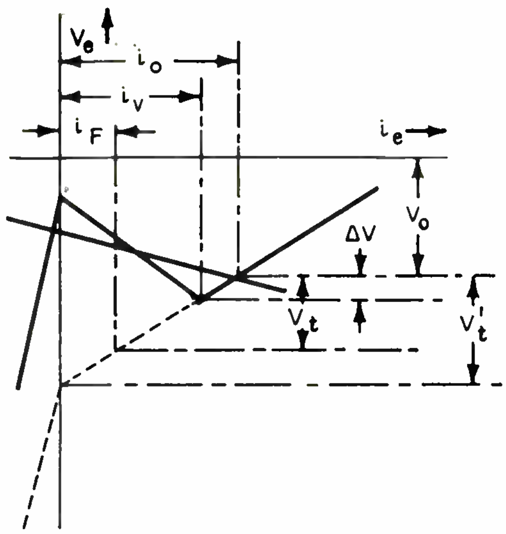

Fig. 7—Emitter input characteristic showing locus of dynamic valley points.

IV. Triggering the Bistable Circuit From "On" to "Off"

In the discussion of the previous section, it was demonstrated that, in the calculation for switching a transistor from "off" to "on," it is necessary to consider only the transition through the negative-resistance region. This is due to the fact that the equivalent current generator is inoperative in the "off" region, and hence the transistor is switched into the negative-resistance region at the instant the trigger pulse is applied. In the saturation region, the current generator is in operation. Consequently, upon application of a trigger pulse, a delay is encountered before the generator current can decrease to a value less than the collector current and therefore switch the transistor out of the "on" region and into the negative-resistance region. This delay can be quite large since the generator time constant τ_2 in the saturation region is considerably larger than τ_1, the time constant when the transistor is not saturated. Finally, when the transistor has been switched out of the saturation region, the problem of the transition of the negative-resistance region becomes similar to the reverse process of sec. III.

We shall first consider the case where the transistor has been in the saturation region for a time long compared to τ_2. This means that before the turn-off pulse is applied, i_g is equal to i_e. The input characteristic is shown in Fig. 7. As in sec. III, we make the simplifying assumption that the input time constant is large compared to the time necessary to switch the transistor out of saturation. When the switch is opened, the emitter voltage drops to a value $-(V_0+V_t)$, and the emitter current drops to a value i_F. The collector current also drops accordingly. The generator current cannot change instantaneously, hence the transistor cannot become unsaturated instantaneously. Another way of visualizing this is evident from Fig. 7. The dashed curve represents the transistor input characteristic when the collector-diode is closed. Hence, before the collector-diode opens, the operating point must be on this curve. If we define a dynamic valley point as that point in the V_e-i_e plane at which $\alpha_e i_g$ becomes equal to i_c, then the locus of dynamic valley points must also be on this curve. The transistor will go out of saturation when the dynamic valley point and the operating point coincide. The significance of this will be shown later.

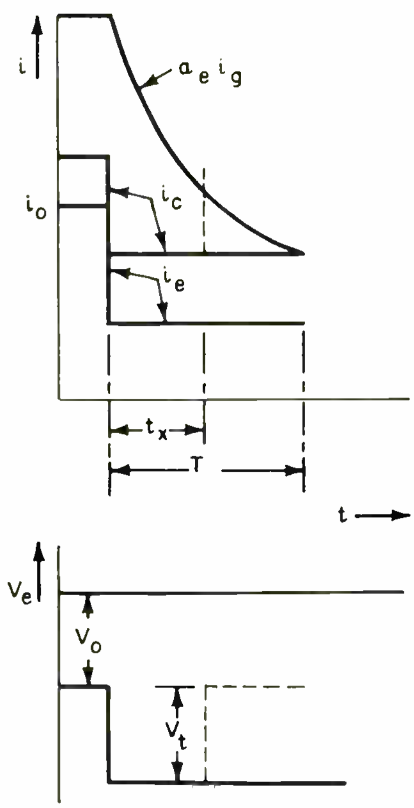

Fig. 8—Typical waveforms showing circuit being switched out of saturation.

Let us suppose first that the trigger pulse is not sufficient to open the emitter diode. The current i_g decreases exponentially with the frequency $-\tau_2^{-1}$. The waveforms are shown in Fig. 8. The time T elapsed before the transistor becomes unsaturated is given by

$$V_t = \frac{\Delta V}{1 - \dfrac{\alpha_e(R_b + R_L)}{(\alpha_e - 1)R_b + \alpha_e R_L} \exp\,[-T/\tau_2]}. \quad (4)$$

This is the approximate triggering criterion for switching from "on" to "off." Actually, V_t must be slightly larger than the above value to complete the switching. The correction term is dependent upon τ_1 and is very small compared to the expression of (4).

If V_t is large enough to open the emitter diode, (4) is replaced by

$$V_t = V_t' + r_{er} i_{eV} \frac{\exp\,[(T'-T)/\tau_2] - 1}{1 - \dfrac{\alpha_e(R_b+R_L)}{(\alpha_e-1)R_b+\alpha_e R_L} \exp\,[-T/\tau_2]}, \quad (5)$$

where V_t' is that trigger voltage which will just open the emitter diode, and T' is the solution of (4) with V_t equal to V_t'. It is evident from (5) that V_t increases very rapidly as the pulse width is decreased. We may define a minimum pulse width $T_{\min}$ as that value of T which makes the denominator of the second term of (5) vanish. However, T' sets a practical minimum pulse width since V_t increases so rapidly for T smaller than T'.

Equations (4) and (5) determine, therefore, the requirements for triggering a circuit from "on" to "off." These requirements are very different from the reverse process because of the existence of a minimum pulse width which is given by

$$T_{\min} = \tau_2 \ln \frac{\alpha_e(R_b + R_L)}{(\alpha_e - 1)R_b + \alpha_e R_L}, \quad (6)$$

and by an effective minimum pulse width T' given by

$$T' = \tau_2 \ln \frac{\alpha_e i_e(R_b + R_L)}{V_{cc}}, \quad (7)$$

where i_e is the "on" emitter current. T' may be of the order of several microseconds and increases as the transistor becomes more saturated.

We may now give an interpretation to the dashed curves of Fig. 7, which we interpret as the locus of dynamic valley points. Suppose that a pulse of magnitude V_t and of duration T is applied. No valley point exists until after the time $T_{\min}$ when the valley point occurs at an infinite emitter voltage. From $T_{\min}$ to T', the valley point moves up along the dashed curve until it reaches the voltage axis. As T becomes greater than T', the valley point continues to rise toward the static valley point. When the dynamic valley point reaches the load line, the collector-diode opens.

V. More General Triggering "Off" Criteria

In the previous section, we have derived the triggering "off" conditions for the special case of the transistor reaching equilibrium in the saturation region before application of the pulse. It is evident that the triggering requirements depend upon the length of time the transistor has been in saturation, since i_g is a function of time until saturation is reached.

The exact behavior of the circuit will depend upon the manner in which the circuit was triggered "on," i.e., the height and width of the trigger "on" pulse and the time constant of the input circuit. These conditions determine the value of i_g in the saturation region. To observe the qualitative behavior of the circuit, let us make the following assumptions: (a) the trigger "on" pulse is removed at the instant the transistor reaches saturation; (b) the input time constant is large compared to the switching times; (c) the static load line is almost flat. Referring to Fig. 9, these assumptions require that the emit-

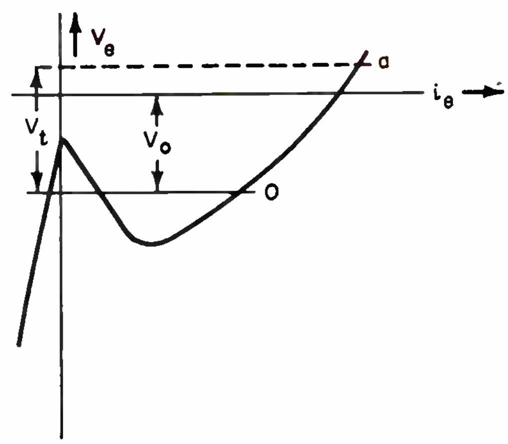

Fig. 9—Emitter input characteristic.

ter voltage remain constant at a value $V_t - V_0$ until the transistor switches to point a. At this instant, the pulse is removed and the operating point shifts instantaneously to point 0. Under these conditions, when the transistor is at point a, the emitter current is i_a, the collector current is i_{ca}, and i_g has the value i_{ca}/α_e. The emitter current then drops to i_0 while i_g remains at its original value i_{ca}/α_e. In Fig. 10 are shown curves of i_e and i_g as functions of time. The scale is deliberately distorted to show details. Two cases are shown, one in which i_0 is greater than i_g, the other in which i_0 is less than i_g. In the former case, i_g continues rising to approach i_{01}. Here, the longer the interval T before the trigger "off" pulse is applied, the greater the minimum pulse width. In the second case, i_0 is less than i_g, and i_g decreases to approach i_{02}. Here, the longer the interval T, the smaller the minimum pulse width. Thus for a flip-flop to be independent of repetition rate, conditions would have to be adjusted such that $i_0 = i_{ca}/\alpha_0$.

Under the conditions imposed above, the expression for T', the effective minimum pulse width described in sec. IV, becomes

$$\exp\,[T'/\tau_2] = \frac{\alpha_e i_0(R_b + R_L)}{V_{cc}} + \exp\,[-T/\tau_2]\left[1 + \frac{i_1 R_b}{V_{cc}} - \frac{\alpha_e i_0(R_b + R_L)}{V_{cc}}\right]. \quad (8)$$

This expression (previous page) reduces to (7) when T becomes large compared to τ_2.

It must be emphasized that (8) is valid only under very specialized conditions. If, for example, the trigger "on" pulse were to be removed before the transistor switches, or if the input time constant were small enough to allow the emitter voltage to decay appreciably before saturation is reached, then at the instant of switching i_g will be smaller than in the above case. This means that, if the trigger "off" pulse were to be applied shortly after saturation is reached, the turn "off" time would be considerably smaller than that calculated above. We use this property of transistors in the design of one-shot multivibrators giving narrow output pulses.

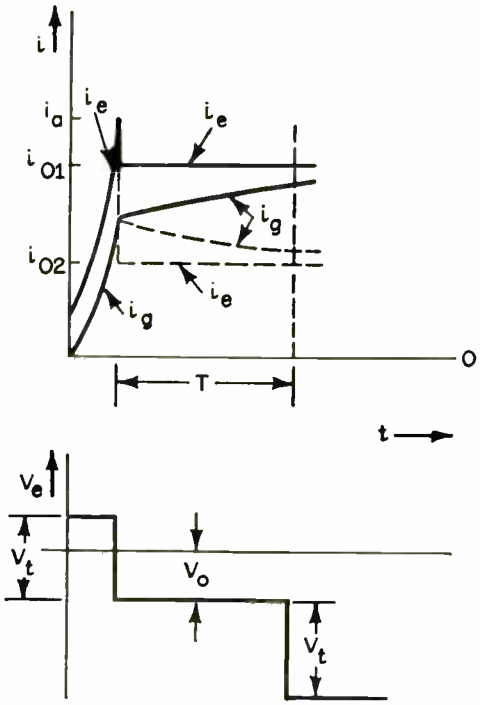

Fig. 10—Waveforms showing time dependence of i_g between turn "on" and turn "off" trigger pulses.

VI. The One-Shot Multivibrator

The bistable flip-flop type transistor circuit suffers from the difficulties described in secs. IV and V. It turns out experimentally that τ_2 not only varies widely from transistor to transistor but is usually of the order of several microseconds. This means that the pulses used to trigger such circuits from "on" to "off" must be relatively wide unless ΔV is small. The latter is impractical because of parameter variations in transistors. Moreover, the pulse widths needed depend upon the repetition rate of the flip-flop.

The one-shot multivibrator, which is turned "on" by a pulse and then turns itself off, bypasses the triggering "off" difficulty. However, the rate at which a one-shot multivibrator is capable of turning itself off is still dependent upon τ_2, the so-called hole-storage effect. It is τ_2 that determines the minimum-width pulse that can be obtained from a one-shot multivibrator. The results of sec. V offer the general criteria necessary for narrow pulse widths ($\sim$0.5 μsec). If the maximum value that i_g assumes is kept small, then the time required to open the collector diode is diminished and the output pulse may be narrow. In sec. V, the assumption was made that the emitter voltage remained constant during the switching "on" and the pulse was removed at the instant of switching. Under these conditions, the maximum value of i_g is i_{ca}/α_e (Fig. 10), a relatively high value for reasonable trigger-pulse amplitudes. Therefore, in order to maintain $(i_g)_{max}$ at a low value, it is necessary either to remove the pulse before the triggering takes place or to differentiate the pulse by using a low-time-constant input circuit. In this way, one-shot multivibrators may be designed to give narrow output pulses.

VII. Experimental Evidence

The foregoing theory has been developed in an attempt to explain the experimental results obtained here and in other laboratories that it is relatively easy to switch a transistor from "off" to "on" with narrow trigger pulses, but difficult to accomplish the reverse. Furthermore, it is possible to design one-shot multivibrators that turn themselves off rapidly compared to the time required to switch a transistor from "on" to "off" with a trigger pulse.

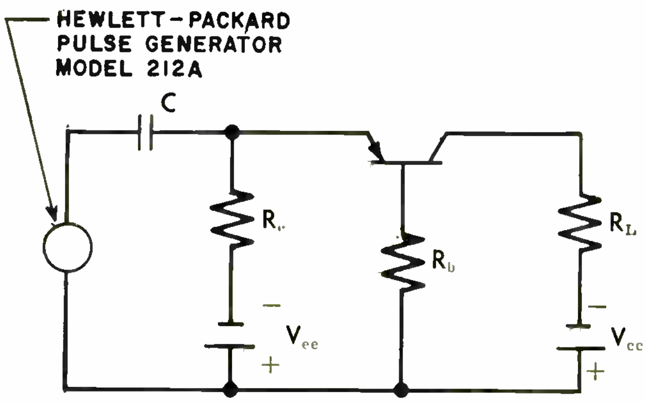

Fig. 11—Circuit for determining pulse height vs pulse width curves at emitter.

Measurements were made using the circuit of Fig. 11. Variable-amplitude and variable-width pulses, either positive or negative, are applied to trigger the circuit "on" or "off," respectively. In this way the triggering criteria may be measured. The results obtained agree qualitatively with theory, but differ in quantitative details. This is, of course, to be expected because of the very simplified model used for the calculations. In Fig. 12, p. 943, are some typical measurements for a Western Electric 1698 transistor. Curves a, b and c represent $V_t/\Delta V$ for triggering from "on" to "off," and curve d is the same function for triggering from "off" to "on." It is evident that the curves correspond qualitatively to the theoretical expressions of (3), (4) and (5). Curves a,

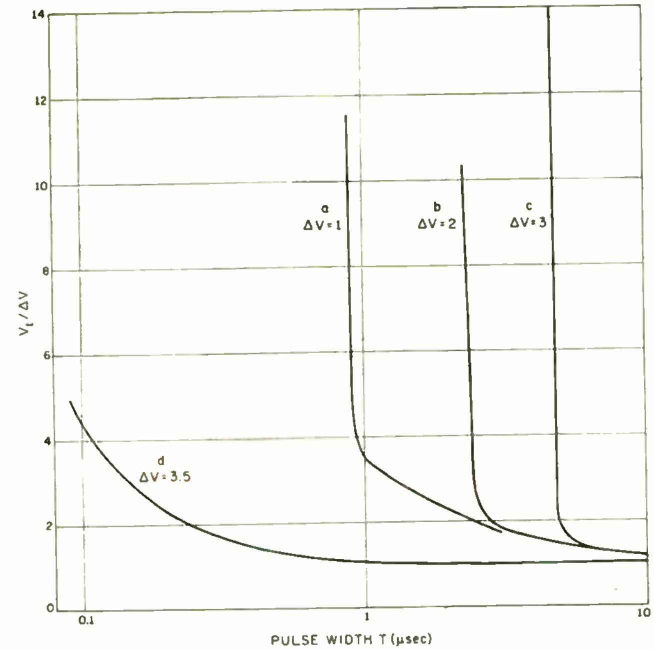

Fig. 12—Typical measurements for a Western Electric 1698 transistor.

b and c approach definite minimum pulse widths, while no such effect is evident in curve d above 0.1 μsec.

The values of τ_1, computed from curve d using (3), are, in general, larger than predicted from frequency-response measurements. Estimates of τ_2 may be made using (7). The latter predicts that the minimum pulse width T' is proportional to the logarithm of the quiescent emitter current. The experimental results indicate that T' increases linearly or even more rapidly rather than logarithmically.

VIII. Conclusions

The simple model of sec. II has been found to give qualitative agreement with measurements on transistor switching circuits. The basic assumption that the transistor frequency response τ has two discrete values depending upon the state of the collector equivalent diode seems, therefore, to be a reasonable first approximation to a description of transistor switching phenomena. It has been demonstrated that the saturation frequency response τ_2 is the parameter that limits the speed of operation of a switching circuit by tending to keep the collector equivalent diode in its forward state. This corresponds physically to the effect that the accumulation of holes in germanium tends to maintain the low saturation voltage at the collector—the so-called "hole storage" phenomenon. The fact that τ_2 is so large in most available transistors seriously limits the apparent versatility of transistors in switching circuitry. While the present theory cannot furnish precise switching-circuit design criteria, it can predict, in a semi-quantitative manner, the behavior of such circuits. Also, it can serve as a helpful guide in determining the practicality and reliability of various types of circuits.

An Analysis of Dual Diversity Receiving Systems*

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Summary—A method is presented for evaluating dual diversity receiving systems by relating the characteristics of the receiving equipment to the signal levels at both receiving antennas. The characteristics of the receiving equipment are described by relating the quality of the output traffic to the input signal level. The input signal levels are in turn described in terms of the bivariate Rayleigh probability distribution function. The method is sufficiently general to enable extension to evaluate triple diversity systems and is independent of the frequency range over which diversity fading phenomena occur. The method can also be simplified to examine the over-all effectiveness of a nondiversity receiving system.

I. Introduction

The efficiency of both the dual *receiver* selection system and the dual *antenna* selection system are determined in this paper with reference to a simple nondiversity receiving system. In addition, the efficiency of the antenna selection system is determined with reference to the receiver selection system.

The method for determining receiving-system efficiency which is outlined in this paper is particularly applicable in the case where consideration is being given to modifying a diversity receiving system to improve the quality of received traffic. The question which immediately arises in such a case is whether or not the modification will result in a significant improvement in received traffic. By following the procedure outlined below, it should be possible to estimate the degree of improvement to be expected from a given system change without actually making it and without undertaking time consuming field tests to evaluate the modified system.

II. Analysis

A. General Discussion

The dual diversity *receiver* selection system considered in this paper employs two antennas, two receivers, and either a combining unit for combining the outputs of both receivers or a comparator-selector circuit for comparing the relative amplitudes of the detected signals and selecting the stronger signal. The dual diversity *antenna* selection system considered employs a single receiver, two antennas, and an antenna selector switch. The output from the receiver is used to control the antenna switch when the output level falls below an arbitrarily set threshold. This system is described in more detail in Section C below.

Both the receiver selection system and the antenna selection system depend for their performance on three parameters of major importance: (*a*) the explicit relationship which exists between the quality of received copy and the received signal-to-noise ratio, this relationship being determined primarily by the characteristics of the receivers and their associated terminal equipments; (*b*) the description of the fading phenomenon at each antenna, such fading being described by one or more probability distribution functions; and (*c*) the correlation exhibited between the fading signals at each antenna position. Consider each of these parameters in turn.

With regard to the first parameter, observe, as in Fig. 1, that for a given signal-to-noise ratio, say $(S/N)_1$, we have a given value of received copy, Q_1. Now if we assume that the noise level on each of the two antennas are equal, so that we can refer only to relative signal levels rather than to relative signal-to-noise ratios, we can say that a signal level of X_1 on antenna 1 will yield a quality of copy Q_1, and if antenna 2 should have a signal level of Y_1, at that same instant, then we can say that by switching to antenna 2 we will realize an improvement in the quality of copy of ΔQ, where

$$\Delta Q = Q_2 - Q_1. \quad (1)$$

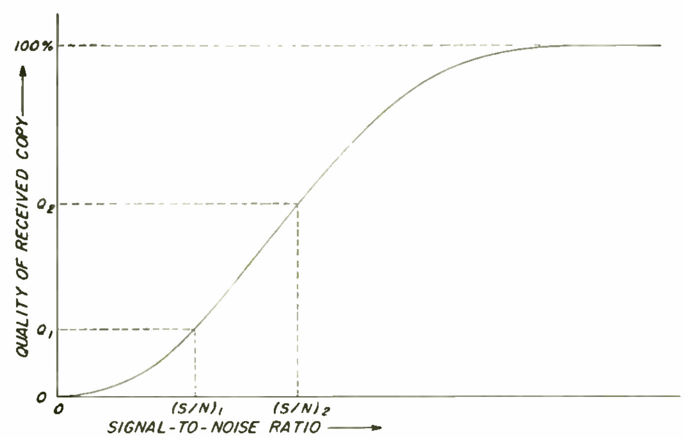

Fig. 1—Quality of received copy as a function of received signal-to-noise ratio (hypothetical relationship).

Thus, we can utilize Fig. 1 to plot ΔQ as a function of X and Y. This has been done as shown in Fig. 2. As can be seen along the line $Y=X$ in the $X-Y$ plane, $\Delta Q=0$; i.e., switching from one antenna to the other when the signal levels are equal will not improve the quality of the received copy.

The description of the fading phenomenon at each antenna is given approximately by the Rayleigh probability distribution.

$$p(r) = \frac{2r}{r_m^2} e^{-r^2/r_m^2} \quad (2)$$

where $p(r)dr$ = the probability that a signal amplitude

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lies between r and $r+dr$ and r_m = the r.m.s. value of the signal amplitude as measured over a long period of time. Therefore the fading phenomena at both antennas, parameter (2), along with the correlation which exists between these phenomena, parameter (3), are completely defined by the bivariate Rayleigh distribution, $p(x;y)$. This latter distribution represents the

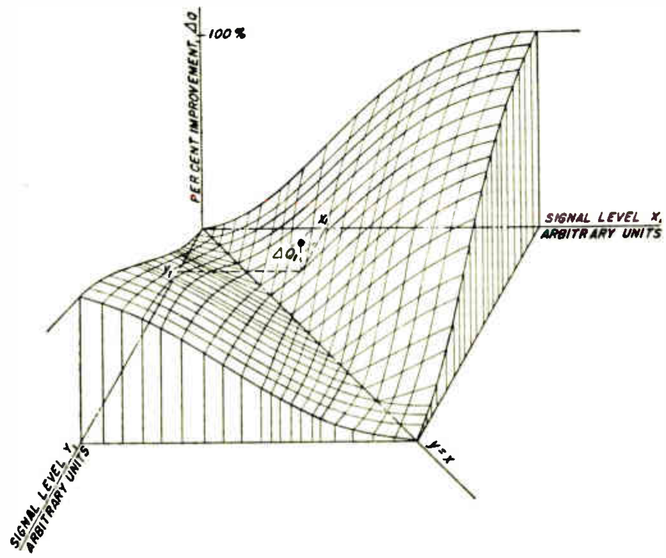

Fig. 2—Three-dimensional plot illustrating improvement realized by switching from a signal of level x to a signal of level y when $y>x$, or, vice versa, when $x>y$ (extremes truncated).

joint probability of having a signal level on one antenna lying between x and $x+dx$ and, simultaneously, having a signal level on the other antenna lying between y and $y+dy$. The correlation of fading, ρ_{xy}, which may range from $+1$ to -1, is completely contained within the expression $p(x;y)$. An example of a bivariate Rayleigh distribution for $\rho_{xy}<0$ is plotted in Fig. 3.

To evaluate a dual diversity system, it is now necessary to combine these three parameters. This is done in Sections B and C below.

B. The Receiver-Selection System

Assume, initially, that the receiver-selection diversity system operates such that the stronger of the two signals in the output of the receivers is always selected. We will modify this condition to comply more with practical cases later. Then the average improvement realized in the received copy is given by

$$\overline{\Delta Q} = \int_0^\infty \int_0^\infty \Delta Q(x, y) p(x; y) dx dy \tag{3}$$

where

$\overline{\Delta Q}$ = the average improvement, per cent,
$\Delta Q(x, y)$ = the received copy improvement surface, per cent (for example, see Fig. 2),
$p(x; y)$ = probability density distribution function (for example, see Fig. 3).

Note that the average improvement, $\overline{\Delta Q}$, is a statistical average obtained by weighting the improvement surface, $\Delta Q(x, y)$, with the probability function, $p(x; y)$.

Next, we note that had we not had diversity reception, but instead had only a single antenna receiving position, then the average quality of the received copy would have been

$$\overline{Q} = \int_0^\infty Q(x) p(x) dx, \tag{4}$$

where

$\overline{Q}$ = average quality of received copy, nondiversity reception,
$Q(x)$ = quality of received copy as a function of signal level (for example, see Fig. 1),
$p(x)dx$ = probability of having a signal level between x and $x+dx$.

Now, if we refer to the diversity action, we observe that we get an average improvement of $\overline{\Delta Q}$ expressed by (3) over the average copy expressed by (4). The average quality of copy from the diversity system is thus given by $\overline{Q}+\overline{\Delta Q}$. Therefore, we can define the efficiency of the diversity system in terms of the ratio of the average quality of copy from the diversity system to the

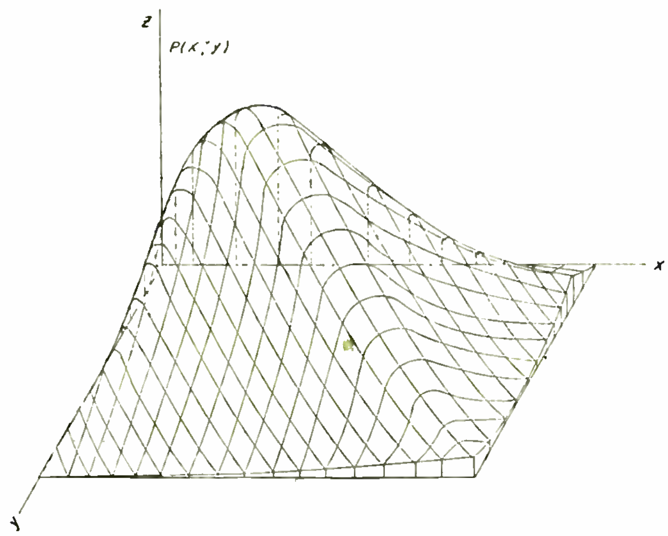

Fig. 3—Joint probability distribution function for $Pxy<0$.

average quality of copy from the nondiversity system. This efficiency is expressed by ξ, where

$$\xi = \frac{\overline{Q} + \overline{\Delta Q}}{\overline{Q}} \times 100, \text{ per cent.} \tag{5}$$

If we now consider a practical case where the diversity selector does not select the stronger signal unless it is, say 6 db greater than the weaker signal, then (5) will still apply, but the surface $\Delta Q(x, y)$ must be modified to reflect the fact that there is no improvement obtained for certain values of signal level x and signal level y. Fig. 4 illustrates the surface $\Delta Q(x, y)$, from Fig. 2, when there is no selection unless x and y differ by at least 6 db in signal level.

It is to be noted that the effect on the over-all operational efficiency of the system, as the result of modifications to the receivers or their terminal equipments, can be judged in terms of the effect on the surface $\Delta Q(x, y)$ in conjunction with (5).

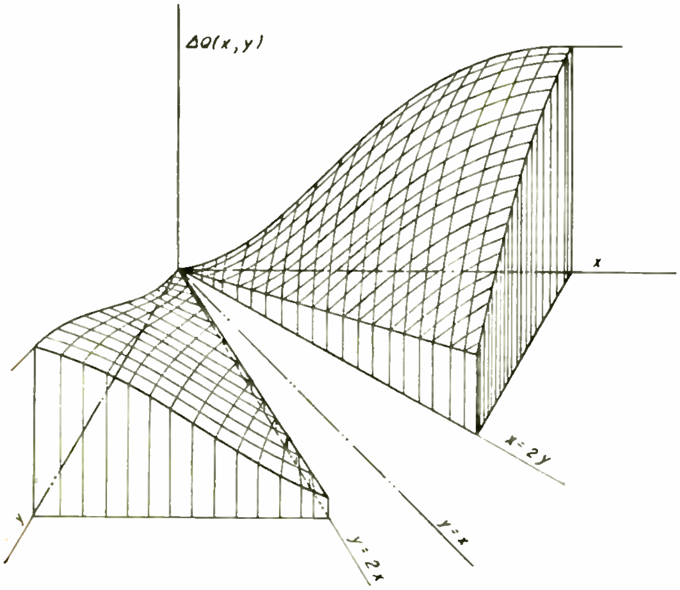

Fig. 4—Illustration of the effect on $\Delta Q(x, y)$ when selection does not occur for values of x and y within 6 db of each other.

C. *The Antenna-Selection System*

To evaluate the dual diversity antenna-selection system, we again combine the three parameters of Section A above. However, before examining this combining process, a more detailed description of the antenna system is in order. A block diagram is shown in Fig. 5, the

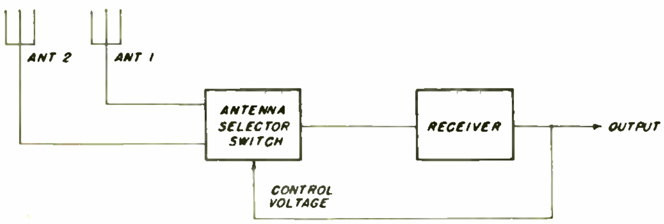

Fig. 5—Block diagram of dual diversity antenna-selection system.

operation of which is as follows: The incoming signal is received on antennas 1 and 2 and fed to the antenna selector switch. This selector is an electronic switch which alternately connects one antenna and then the other antenna, to the input of the receiver, continuing to oscillate between these two until the signal level from one antenna rises above an arbitrarily set threshold level. The output from the receiver is fed back to the switch to serve as a control voltage to stop switching action if signal level rises above the threshold.

The problem with this type of diversity lies in the setting of the threshold level. If the threshold level is set too high, the switching unit is almost always in a searching condition, looking between the two antennas, and there is little diversity action achieved. If the threshold is set too low, the switching unit is almost always locked to one of the antennas, even when the signal level is quite low, and again there is little diversity action achieved.

To obtain the optimum threshold, observe that for a given threshold setting, T, an improvement in the received copy will be realized only when $x>T$ and $y<T$ or when $y>T$ and $x<T$; otherwise, when $x>T$ and $y>T$ or when $x<T$ and $y<T$, selection cannot take place even though one signal may be stronger than the other. Therefore, we can write that the average improvement $\overline{\Delta Q_i}$, to be realized will be

$$\overline{\Delta Q_i} = \frac{\int_{\mathrm{I}} \Delta Q p dx dy + \int_{\mathrm{III}} \Delta Q p dx dy}{\int_{\mathrm{I}} p dx dy + \int_{\mathrm{III}} p dx dy}, \quad (6)$$

where ΔQ represents $\Delta Q(x, y)$, p represents $p(x; y)$, and $\int_{\mathrm{I}}$, $\int_{\mathrm{III}}$ represent the integrals over the base of the regions illustrated in Figs. 6 and 7. Similarly, the average improvement which could have been realized had we had a dual receiver diversity system, but which we lose with the simple antenna diversity system due to the fixed threshold, it is given by $\overline{\Delta Q_l}$ where

$$\overline{\Delta Q_l} = \frac{\int_{\mathrm{II}} \Delta Q p dx dy + \int_{\mathrm{IV}} \Delta Q p dx dy}{\int_{\mathrm{II}} p dx dy + \int_{\mathrm{IV}} p dx dy}. \quad (7)$$

Thus we see that to compute $\overline{\Delta Q_i}$, and $\overline{\Delta Q_l}$, we again take the weighted average of the improvement from Fig. 2, where the weighting factor is the probability density distributing function. Pictorially, this is shown in Fig. 6, which is Fig. 2 expanded to illustrate how volumes I and III represent ΔQ_i, and volumes II and IV represent ΔQ_l. Fig. 7, which is Fig. 3 expanded, shows the weighting functions of volumes I, II, III and IV.

We can define the efficiency of the dual diversity antenna-selection system in terms of the ratio of the average quality of received copy from the diversity system to the average quality of the received copy from the nondiversity receiving position, all other factors being equal. Thus, by using (4) and (6), the efficiency, η, can be expressed by

$$\eta = \frac{\overline{Q} + \overline{\Delta Q_i}}{\overline{Q}} \times 100, \text{ per cent.} \quad (8)$$

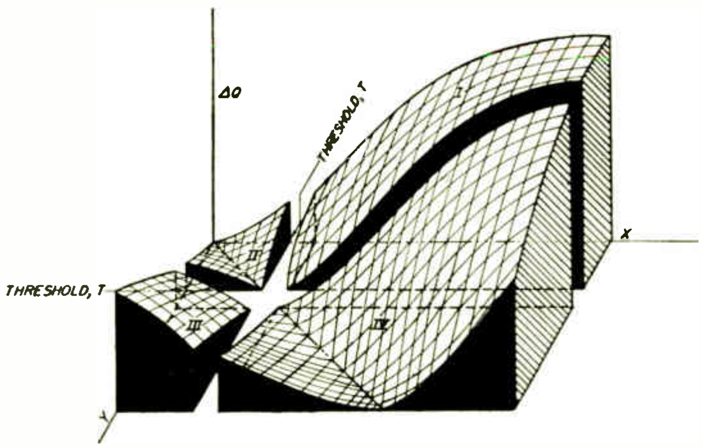

Fig. 6—Illustration of the effect of the threshold superimposed on the improvement surface of Fig. 2.

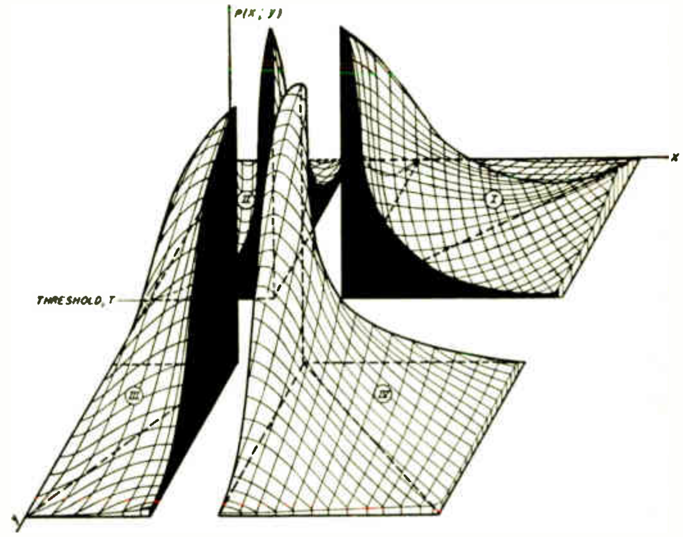

Fig. 7—Joint probability distribution function for $Pxy<0$, separated at the threshold level.

D. Comparison Between Receiver-Selection and Antenna-Selection Systems

We can measure the efficiency of the antenna-selection system relative to the receiver-selection system by defining the efficiency, σ, as

$$\sigma = \frac{\overline{Q} + \overline{\Delta Q_i}}{\overline{Q} + \overline{\Delta Q}} \times 100, \text{ per cent.} \tag{9}$$

We see that the efficiency of the dual antenna-selection system is measured with reference to a dual receiver-selection system which (*a*) is operating on the same signals, i.e., $p(x; y)$ is the same for both systems; and (*b*) is operating with the same receiving equipment, i.e., the surface $\Delta Q(x, y)$ is the same for both systems. Observe that for a given surface $\Delta Q(x, y)$, the efficiency is a function of T, the threshold setting, and of $p(x; y)$, the joint probability distribution function. To actually compute σ as a function of T and $p(x; y)$ would be mathematically involved. However, consider the special case where (*a*) $\bar{x}=\bar{y}=T$, that is, the average signal levels at each antenna are equal and the threshold is set at this level, and (*b*) the correlation coefficient $p_{xy}=-1$; that is, the fading patterns at each antenna are perfect reciprocals of each other so that when the level at one antenna rises above the threshold, the level on the other antenna falls below the threshold. Under such conditions, the weighting function, $p(x; y)$ is such that volumes II and IV, as in Fig. 7, have reduced to zero, and hence $\overline{\Delta Q_l}=0$. Therefore, $\overline{\Delta Q_i}=\overline{\Delta Q}$ and the efficiency, σ, equals 100 per cent. That σ would equal 100 per cent under these conditions could have been seen intuitively from the first, but working through the example may have served to emphasize the physical meaning of the equations.

III. Conclusions

The procedure to be followed in computing the efficiency of a dual diversity system would be as follows:

(*a*) Using simulated signals and noise with the actual complete receiving system, empirically determine the relationship between the quality of the received copy and the input signal-to-noise ratio. This will result in a plot similar to Fig. 1.

(*b*) Utilizing Fig. 1, plot $\Delta Q(x, y)$ as shown in Fig. 2.

(*c*) At the receiving site determine the probability distribution functions which describe the fading at the two antennas and the correlation between the fading at these antennas. This will result in a surface similar to Fig. 3. A basic procedure which can be followed to determine such functions is contained in an article published in 1941.[1] However, a more suitable procedure would be to employ an equipment similar to that which has been built at the Massachusetts Institute of Technology for the study of speech probability distributions.[2]

(*d*) Utilize (5), (8), or (9) to compute the efficiency.

It should be pointed out that the surfaces $\Delta Q(x, y)$ and $p(x; y)$, corresponding to the dual diversity receiving systems, can be extended to $\Delta Q(x, y, z)$ and $p(x; y; z)$ for triple-diversity reception. The basic concept of computing the efficiency of operation as well as studying the effects of changes in the improvement surface, ΔQ, or the probability surface, $p(x; y; z)$, remains unchanged. Similarly, a nondiversity receiving system can be examined by relating an improvement, ΔQ, brought about by a contemplated change in the receiving system, to the Rayleigh probability distribution describing the input signal level.

[1] M. M. Sen Gupta and S. K. Dutt, "Application of the theory of random scattering on the intensity variations of downcoming wireless waves over long transmission paths," *Indian Jour. Physics*, vol. 15, p. 447; 1941.

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The Response of a Panoramic Receiver to CW and Pulse Signals*

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Summary—An analysis of the response of a panoramic receiver to cw and pulse signals is presented. The receiver's response is studied quantitatively as a function of the parameters: signal-pulse length and frequency, receiver bandwidth, sweep-rate, and type of IF amplifier. The effect of these parameters on the relative output amplitude, output pulse width, and apparent bandwidth is emphasized. Two specific cases are considered. An electronic differential analyzer is used to study the response of a receiver with a single-tuned IF amplifier to pulses having rectangular envelopes. Theoretically the response of a receiver with a Gaussian shaped IF pass-band to pulses having Gaussian envelopes is derived. This answer is given in closed form. The agreement between these two cases justifies the application of the Gaussian case to most practical design problems.

I. Introduction

THE RESPONSE of a linear-resonant system to a sinusoidal-driving function, having a linear variation of frequency with time, is of importance in many fields of engineering. This problem is encountered when an engine is accelerated uniformly through a critical frequency.[1] The same situation occurs in the analysis of records of ocean waves by means of vibration galvanometers.[2] A panoramic superheterodyne receiver, which also presents this problem, is the subject of this paper.

The receivers considered in this paper are idealizations of conventional superheterodyne receivers. A block diagram is shown in Fig. 1. The function of the mixer is to convert an incoming signal of fixed instantaneous frequency to one with an instantaneous frequency changing linearly with time. It is assumed that the envelope of the incoming signal is not distorted by the mixer. The filter of Fig. 1 merely selects the desired frequencies, and the detector operates on the output of the filter to obtain the envelope. These assumptions reduce the problem to that of obtaining the response of a filter to a particular FM signal. This is illustrated graphically by the time-frequency diagrams of Fig. 2 opposite. The figure also indicates the parameters used to describe the receiver and the incoming signals.

The response of a filter with a Gaussian-amplitude response and a linear phase-response curve to a cw signal, and to sinusoidal pulses with Gaussian envelopes, has been examined theoretically. These cases are important because answers in closed form can be obtained. The Gaussian filter is not physically realizable; however, if the time delay is neglected, the transfer function of n single-tuned circuits all at the same frequency approaches the Gaussian function as n becomes large.[9] A

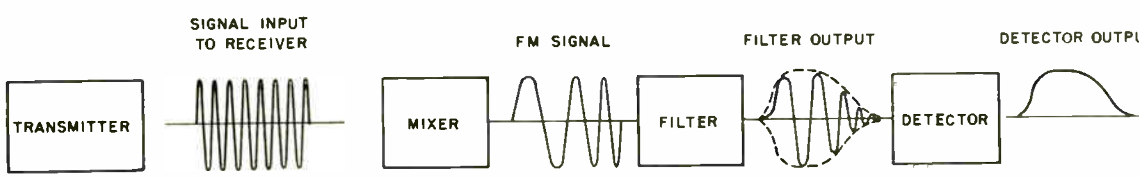

Fig. 1—Block diagram of idealized superheterodyne receiver.

An analogous second problem is the response of a system whose resonant frequency varies linearly with time to a fixed-frequency sinusoidal signal. This problem is encountered in various types of spectrum analyzers and in panoramic-radio receivers.[3-8] For the high-Q or very much underdamped system, the two problems prove to be essentially equivalent.[2,4]

study of the response of 1, 2, and 4 synchronous single-tuned circuits to cw signals and pulses having rectangular envelopes was made with an electronic differential analyzer. Over six hundred solutions were obtained. Over-all agreement with the Gaussian case was good.[10]

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10 H. W. Batten, R. A. Jorgensen, A. B. Macnee, W. W. Peterson, "The Response of a Panoramic Receiver to CW and Pulse Signals," Tech. Report No. 3, Elec. Defense Group, Univ. of Michigan (unclassified).

II. The Gaussian Case

The transfer function assumed is

$$H(\omega) = \frac{1}{\sqrt{2\pi}} \exp\left\{-\frac{(\omega - a)^2}{b^2}\right\}. \qquad (1)$$

The center frequency of the filter is a radians per second, and the bandwidth between $e^{-1/4}$ points is b radians per second. Note that the phase delay is completely neglected here. The introduction of a linear-phase delay would not significantly change the answers.

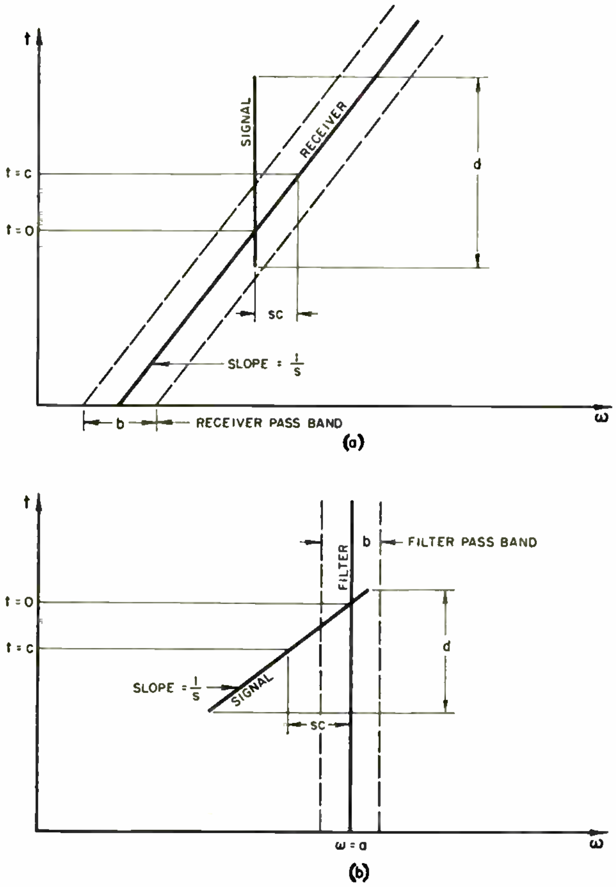

Fig. 2—(a) Time-frequency diagram before mixer. (b) Time-frequency diagram after mixer.

The signal assumed for the cw case is,

$$f(t) = \cos\left[at + \frac{st^2}{2}\right], \qquad (2)$$

and for the pulse case is,

$$f(t) = \exp\left[-\frac{(t - c)^2}{d^2}\right] \cos\left[at + \frac{st^2}{2}\right]. \qquad (3)$$

The center-time of the pulse is c, the pulse width between $e^{-1/4}$ points is d, and the sweep-rate is s radians per second per second. The answer is derived first for the pulse case, and the cw case is obtained from it by letting d approach infinity.

The analysis is given in the Appendix. The signal function is transformed to the ω-plane, multiplied by the transfer function $H(\omega)$, and transformed back to the t-plane. The envelope of the output for the pulse case is,

$$|g(t)| = A_0 \exp\left\{-\frac{1}{W^2}\left[\frac{s(t - t_m)}{b}\right]^2 - \frac{1}{B^2}\left(\frac{sc}{b}\right)^2\right\}, \qquad (4)$$

where A_0, B, W, and t_m/c are functions of s, b, and d as follows:

$$A_0 = \frac{b}{\left[\left(\frac{4}{d^2} + b^2\right)^2 + 4s^2\right]^{1/4}}, \qquad (5)$$

$$B = \frac{1}{b}\sqrt{\frac{4}{d^2} + b^2 + s^2d^2}, \qquad (6)$$

$$W = \frac{sd}{b^2}\sqrt{\frac{\left(\frac{4}{d^2} + b^2\right)^2 + 4s^2}{\frac{4}{d^2} + b^2 + s^2d^2}}$$

$$= \frac{sd}{b}\frac{1}{A_0^2 B}, \quad \text{and} \qquad (7)$$

$$\frac{t_m}{c} = \left[\frac{\frac{4}{d^2} + b^2}{\frac{4}{d^2} + b^2 + s^2d^2}\right]. \qquad (8)$$

The envelope response in the cw case reduces to

$$|g(t)| = A_0 \exp\left\{-\frac{1}{W^2}\left[\frac{st}{b}\right]^2\right\}, \qquad (9)$$

where

$$A_0 = \frac{b}{(b^4 + 4s^2)^{1/4}}, \quad \text{and} \qquad (10)$$

and

$$W = \frac{1}{b^2}\sqrt{b^4 + 4s^2} = \frac{1}{A_0^2}. \qquad (11)$$

The quantities A_0, W, and B describe important features of the response: (1) its peak amplitude, (2) the width of the response in time, and (3) the width of the peak-amplitude curve plotted as a function of sc, the difference between the filter frequency and the signal frequency at the center of the pulse. A_0, W, and B are all expressed in dimensionless form; A_0 is the peak amplitude of the response relative to the response to a cw signal of fixed frequency a; W is the width of the response in time relative to the time necessary for the receiver to sweep through its IF bandwidth, b; and B is the apparent bandwidth of the receiver when sweeping, relative to its steady-stage bandwidth b.[11]

[11] It can be shown for the case of pulse signals that $A_0^2B(Wb/sd) = 1$ (7) regardless of the type of IF filter or the pulse shape, and for the case of the cw input signal $A_0^2W = 1$ (11) regardless of the type of IF filter. See reference 10.

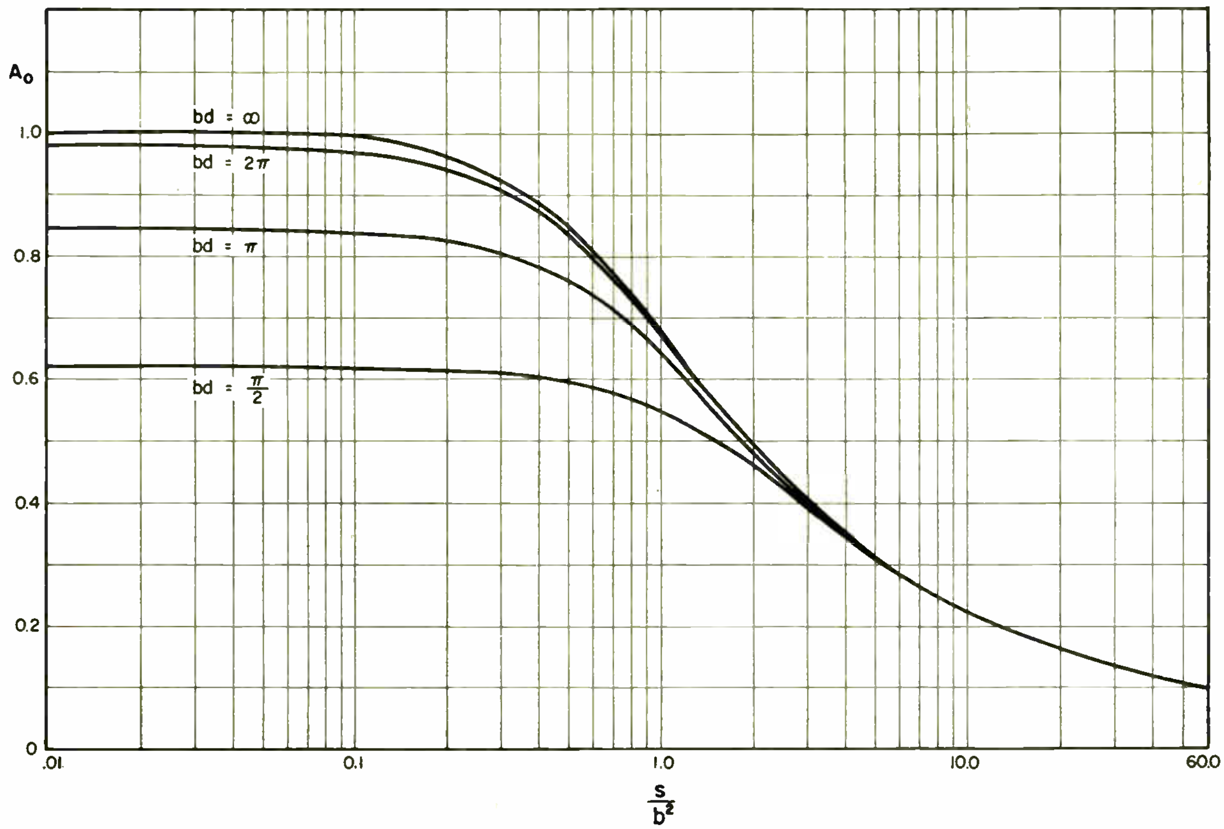

Fig. 3—The relative amplitude of the response for the Gaussian case.

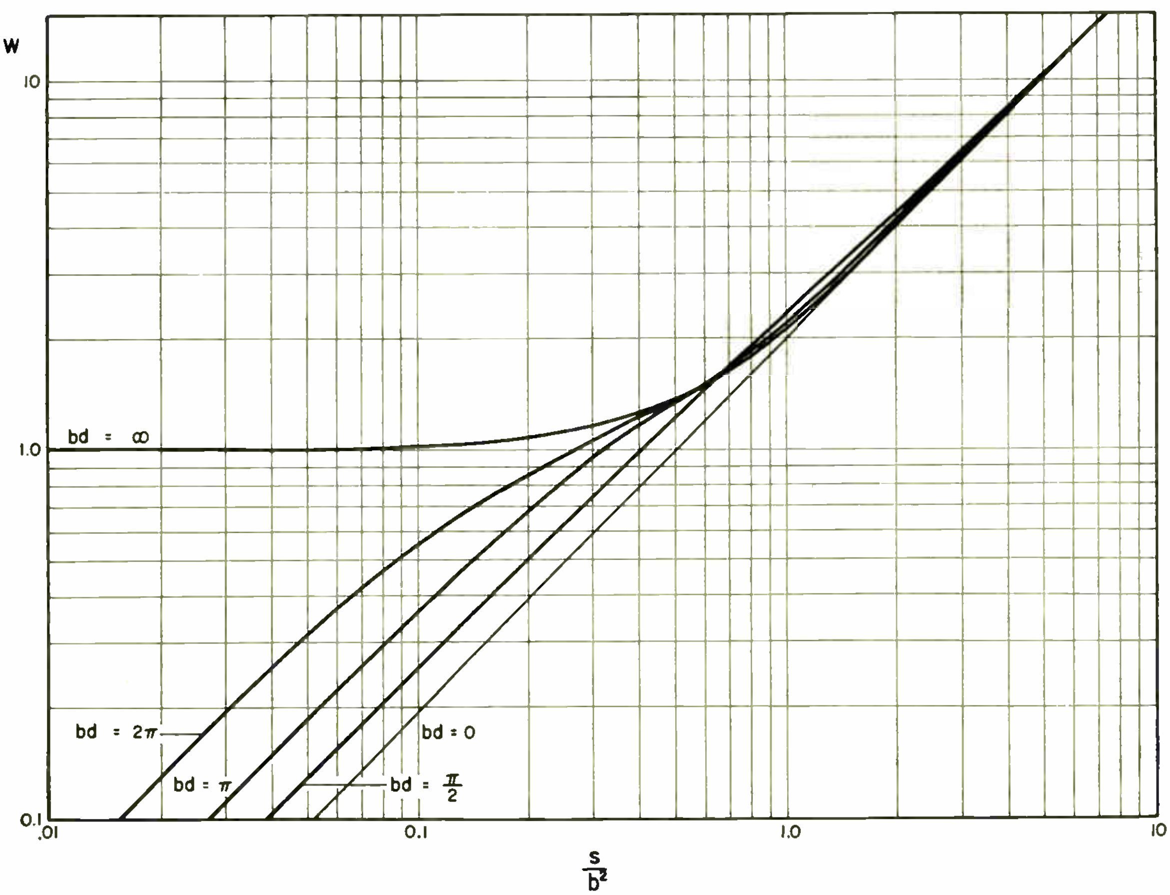

Fig. 4—The output pulse width for the Gaussian case as a function of sweep-rate.

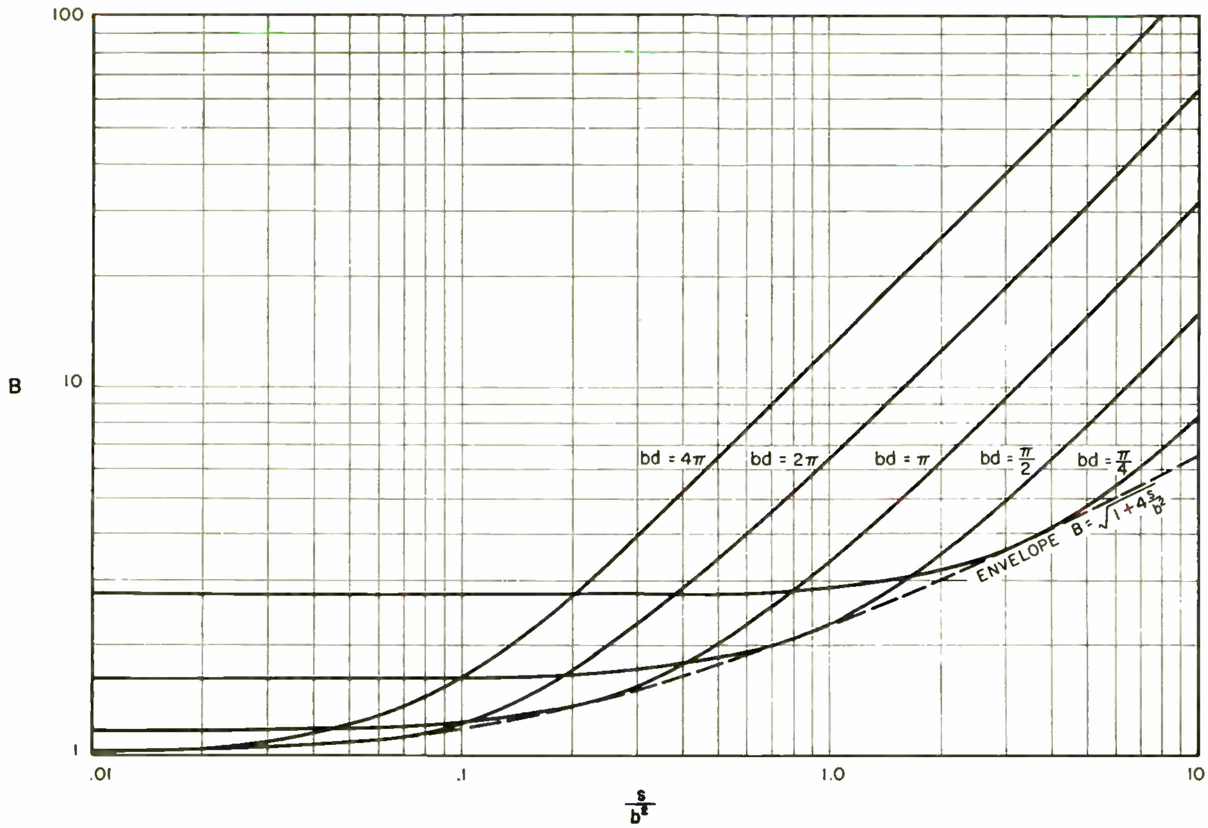

Fig. 5—The apparent band width of a Gaussian filter as a function of sweep-rate.

For the Gaussian case, graphs of A_0, W, and B as functions of s/b^2 are given in Figs. 3, 4, and 5. A_0 is defined so that it has the value one for an infinite pulse length and zero sweep-rate. A_0 is affected little by sweeping until s/b^2 is of the order $1+[4/(bd)^2]$, and drops off rapidly for higher sweep-rates.[12]

By definition, the output pulse width, W, approaches unity for a cw signal as the sweep-rate approaches zero. The curves in Fig. 4 never fall below $W=2s/b^2$, which is the output pulse width corresponding to the impulse response of the filter ($bd=0$). For low sweep-rates the output pulse width is between the value for the cw signal and that for the impulse response. For high sweep-rates the output pulse is essentially the impulse response of the filter and is independent of bd.

The apparent bandwidth, B, is defined so that it is unity when the sweep-rate is very low and the pulses very long. For short pulses, B is greater than one even for zero sweep-rate. As the sweep-rate increases above

$$\frac{1}{bd}\sqrt{1+\frac{4}{b^2d^2}}$$

the curve rises sharply and approaches $B=s/b^2\cdot bd$ asymptotically.

The results of (5) and (7) can be plotted in a variety of ways which may be convenient for the engineer faced with a particular problem. Two such plots are shown in Figs. 6 and 7. The question of what IF bandwidth yields the optimum resolution for a radio-frequency

[12] $s/b^2=1$ corresponds to a sweep-rate of 2πmc/μ sec. for an IF bandwidth of 1 mc.

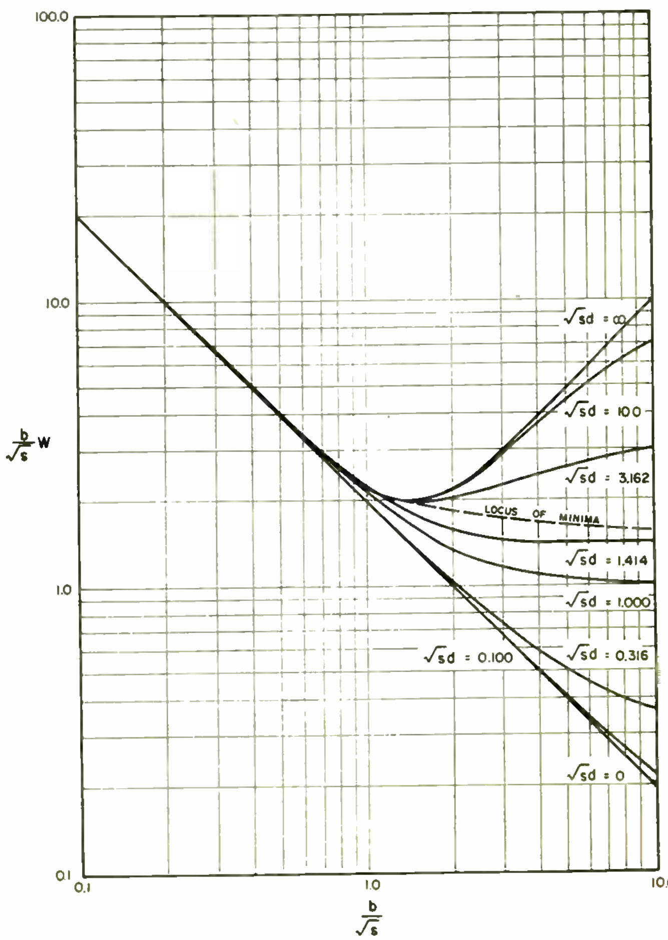

Fig. 6—Output pulse width as a function of filter bandwidth for the Gaussian case.

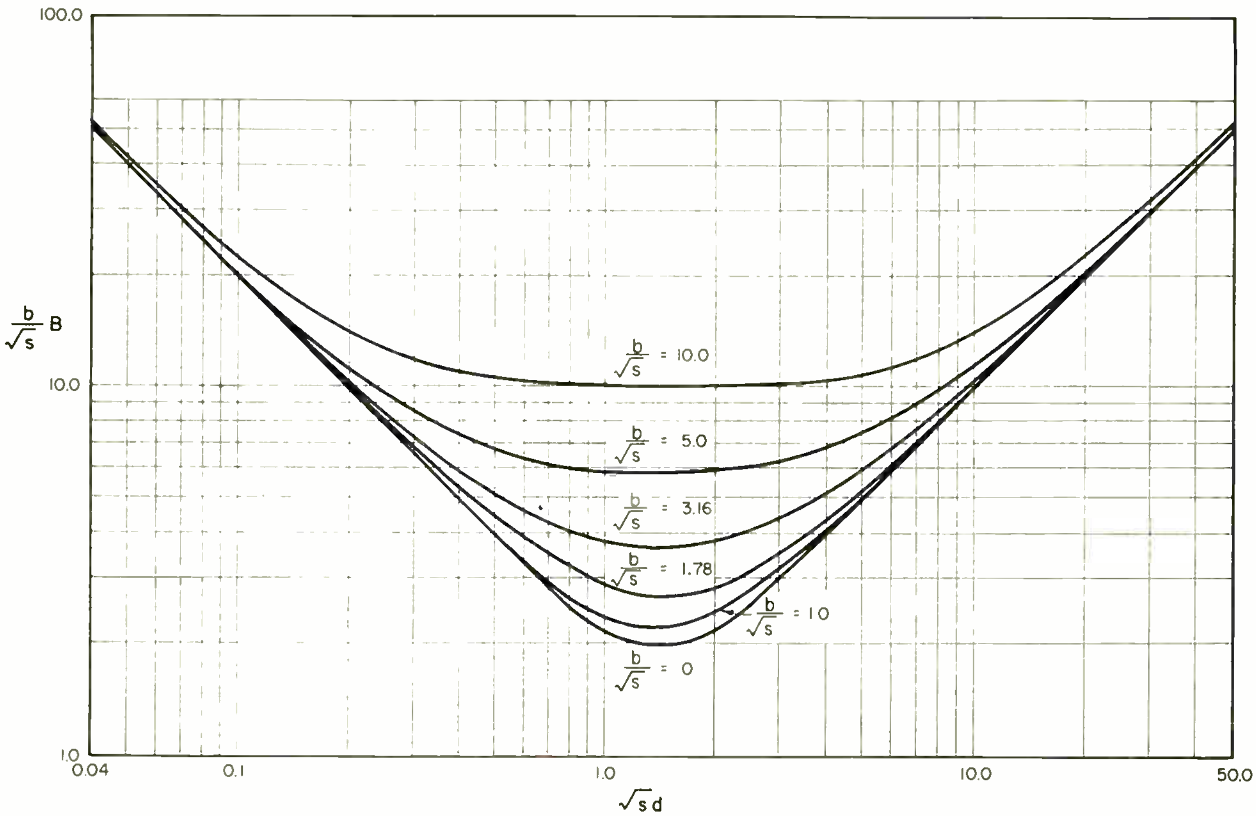

Fig. 7—Apparent bandwidth as a function of input pulse width for the Gaussian case.

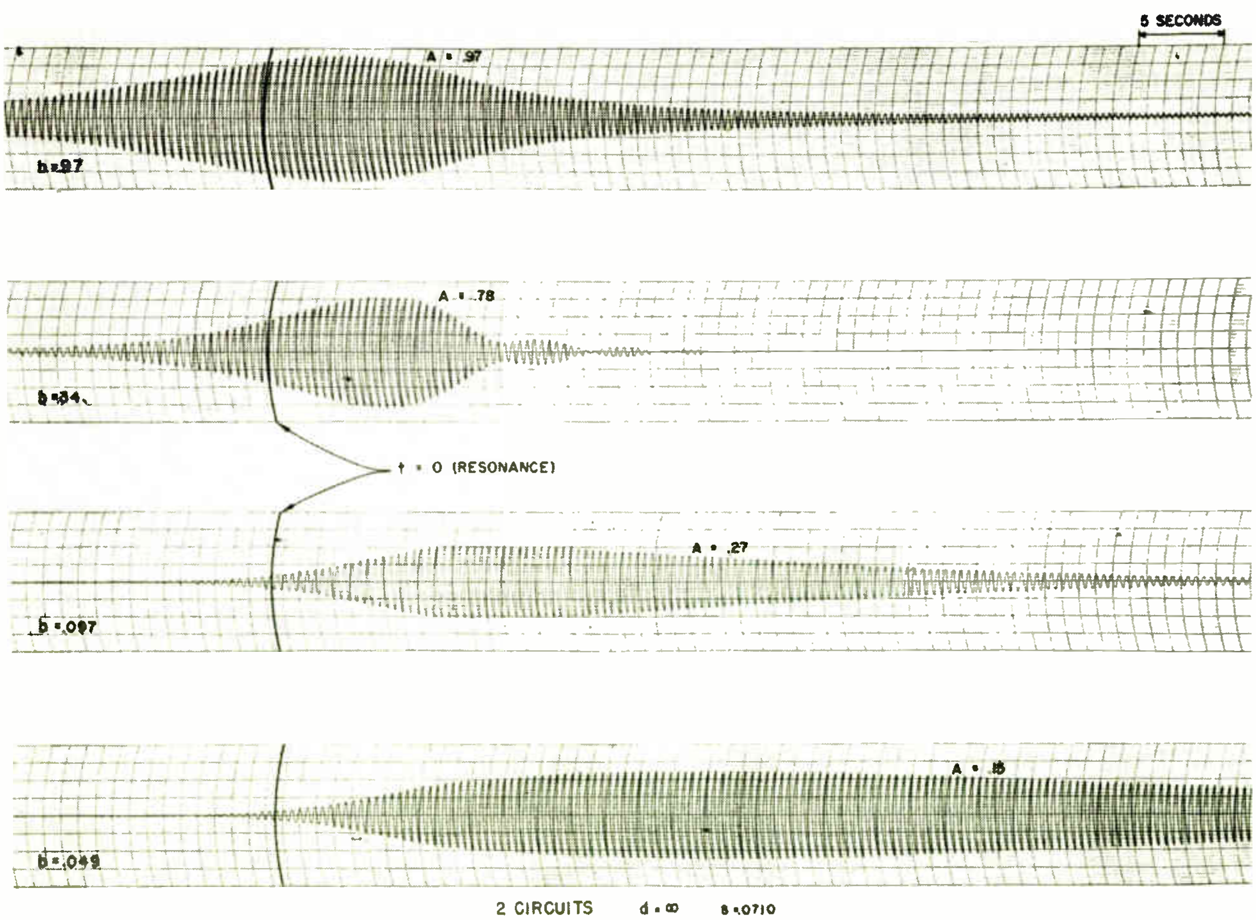

Fig. 8—Responses for various bandwidths.

spectrum analyzer arises frequently. From Fig. 6 it is apparent that for cw signals the minimum output pulse width occurs for $b=\sqrt{2s}$ radians per second.[13] Fig. 7 illustrates the fact that the minimum apparent bandwidth always occurs for a pulse length $d=\sqrt{\frac{2}{s}}$ second.[14]

III. Solutions by Differential Analyzer

An electronic differential analyzer was used to study the response of a panoramic receiver, employing a synchronously tuned IF amplifier of one, two, and four stages, to cw signals and pulses having rectangular envelopes. Over six hundred solutions were run; typical outputs taken from the analyzer are shown in Figs. 8 and 9. The effect of varying the IF bandwidth of a panoramic receiver, sweeping at a fixed rate on the response to a cw signal ($d=\infty$) is shown in Fig. 8. Clearly, there is an IF bandwidth which gives the minimum output pulse width. This is the same effect illustrated by Fig. 6 for the Gaussian case.

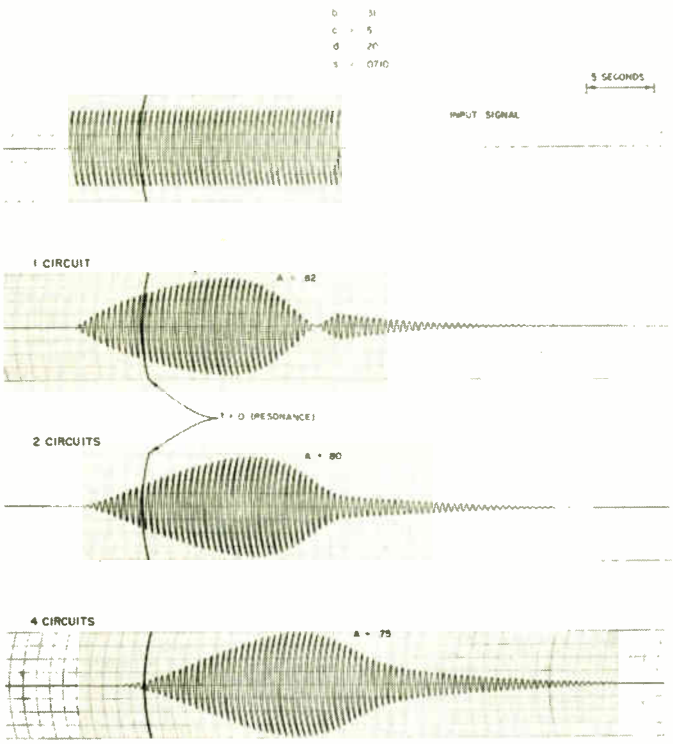

Fig. 9—Responses for 1, 2, and 4 circuits.

Fig. 9 shows the response of 1, 2, and 4 circuit filters, all having the same bandwidth, to an input pulse having a center frequency somewhat above the resonant frequency of the filters. There is an increase in the delay of the output pulse relative to the input pulse as the number of circuits is increased; but otherwise, increasing the number of circuits has little effect on the relative amplitude and output pulse width. Note the envelope of the output pulse tends towards a Gaussian shape as the number of circuits increases.

[13] This corresponds to a bandwidth of $2\sqrt{\pi}$ mc for a sweep-rate of 1 mc/μsec.

[14] This corresponds to a $1/\sqrt{\pi}\mu$sec. long pulse for a sweep-rate of 1 mc/μsec.

IV. Comparison of Solutions

Figs. 10, 11, and 12 give a comparison between the Gaussian case and some of the data taken from the differential analyzer for the response of 1, 2, and 4 circuit filters to rectangular-envelope pulses. In general the agreement between the Gaussian case and filters using two or more circuits is good. Some features of the receiver response in the differential-analyzer solutions differ considerably from the solution of the Gaussian case. For example, the time of maximum response can hardly be expected to agree since the Gaussian filter is assumed to introduce no phase delay.

The solution of the Gaussian case gives an understanding of the nature of the response of a panoramic receiver. Moreover, the Gaussian case is ***quantitatively*** consistent enough with the other cases studied to be used in many design problems involving peak amplitude, output pulse width, apparent bandwidth, and resolution.

Appendix

Derivation of the Response of a Gaussian Filter

In this appendix the formulas are derived for the response of a filter with a Gaussian-shaped tranfer function to a signal which is changing linearly in frequency and has either a constant amplitude or a Gaussian-shaped envelope.

Assume the filter transfer function is

$$H(\omega)=\frac{1}{\sqrt{2\pi}}\exp\left[\frac{-(\omega-a)^2}{b^2}\right], \tag{12}$$

and the input signal is (the real part of)

$$f(t)=\exp\left[j\left(\frac{st^2}{2}+at\right)-\frac{(t-c)^2}{d^2}\right]. \tag{13}$$

The procedure is to find the Fourier transform $f(\omega)$ of $f(t)$, multiply it by $H(\omega)$, and transform back to the t-plane. The filter response is the real part of the resulting function $g(t)$. The calculation is simplified by using the convolution formula:

$$\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}H(\omega)\cdot F(\omega)e^{j\omega t}d\omega$$

$$=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f(\lambda)h(t-\lambda)d\lambda \tag{14}$$

where $h(t)$ is the Fourier transform of $H(\omega)$[15,16]

Two preliminary remarks will make the derivation go smoothly. In the first place, the envelope of the real part of a complex function of time is just the absolute value of the function. This can be seen as follows: Let $Z(t)$ be any complex function of t. It can be written,

[15] E. C. Titchmarsh, "Introduction to the Theory of Fourier Integrals," Oxford University Press, New York, N. Y., p. 51; 1937.

[16] The use of complex functions for the signal $f(t)$ and the impulse response $h(t)$ is justified if the response of the filter is negligible at zero frequency.

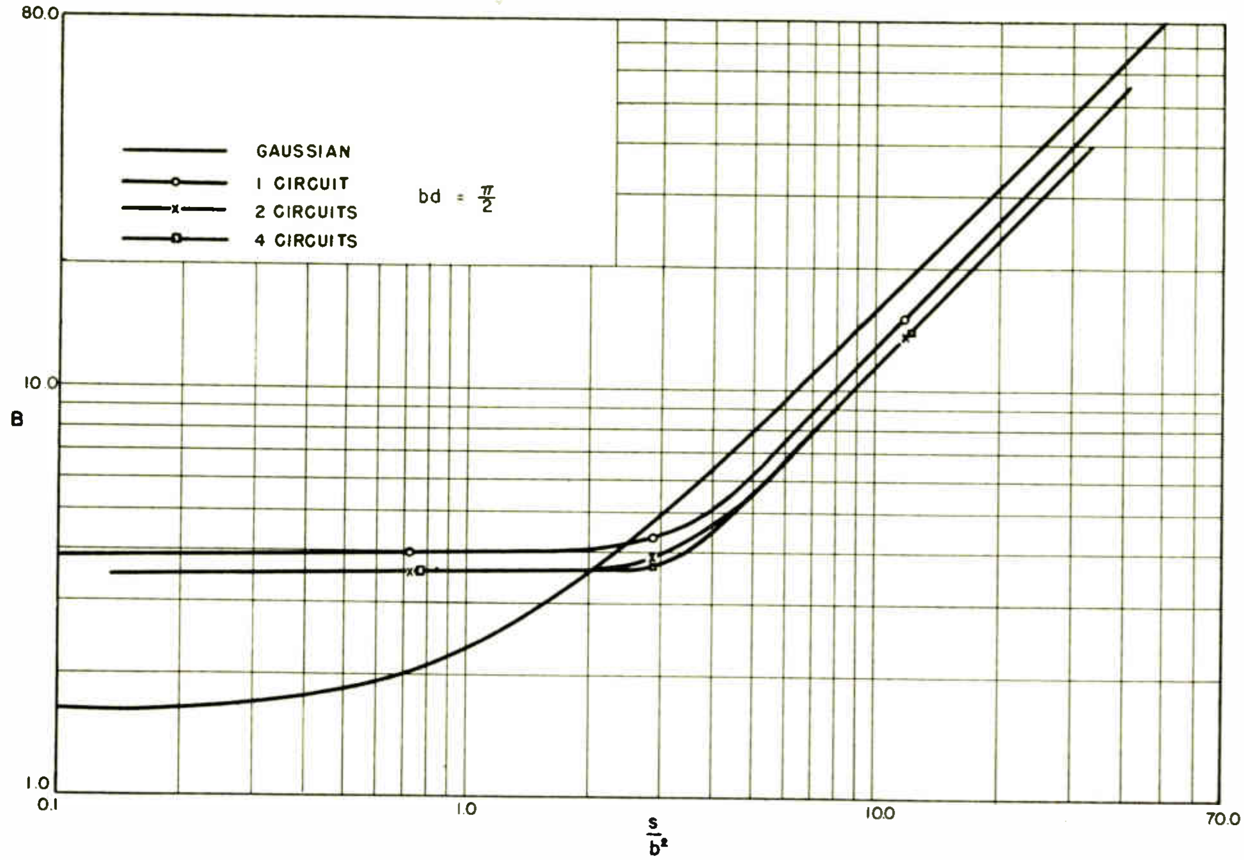

Fig. 10—Apparent bandwidth for the Gaussian case and the differential-analyzer solutions.

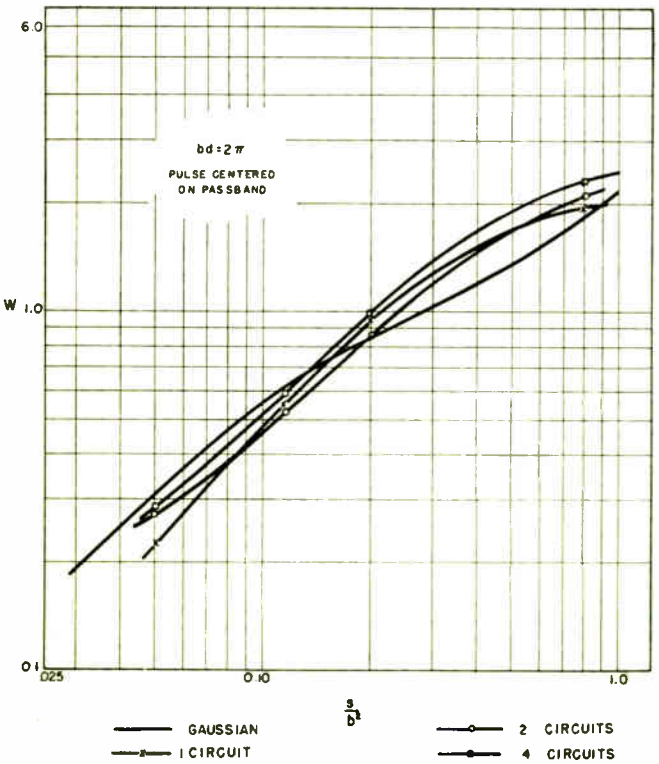

Fig. 11—Output pulse width for the Gaussian case and differential-analyzer solutions.

$Z(t) = |Z(t)| \exp(j\theta(t))$, where $\theta(t)$ is the argument of $Z(t)$. The real part of $Z(t)$ is then $|Z(t)| \cos\theta(t)$, and the envelope of this is $|Z(t)|$.

Secondly, in computing the Fourier transforms, use will be made of the following formula:

$$\int_{-\infty}^{\infty} \exp(-ut^2 + vt)dt = \sqrt{\frac{\pi}{u}} \exp\frac{v^2}{4u}. \qquad (15)$$

The integration is along the real axis in the t-plane, and u and v are complex numbers, with the real part of u positive. This formula can be derived as follows:

$$\int_{-\infty}^{\infty} \exp[-ut^2 + vt]dt$$

$$= \exp\left[\frac{v^2}{4u}\right]\int_{-\infty}^{\infty} \exp\left[-u\left[t - \frac{v}{2u}\right]^2\right]dt.$$

Letting $Z = u(t - v/2u)$,

$$\int_{-\infty}^{\infty} \exp(-ut^2 + vt)dt$$

$$= \frac{1}{\sqrt{u}} \exp\frac{v^2}{4u}\int_{-\infty}^{\infty} \exp(-Z^2)dZ = \sqrt{\frac{\pi}{u}} \exp\frac{v^2}{4u}.$$

Note that the path of integration in the Z-plane is not along the real axis, but along a line which may be oblique to the real axis. From the requirement that the real part of u be positive, it can be shown that the path of integration in the Z-plane makes no more than a 45-

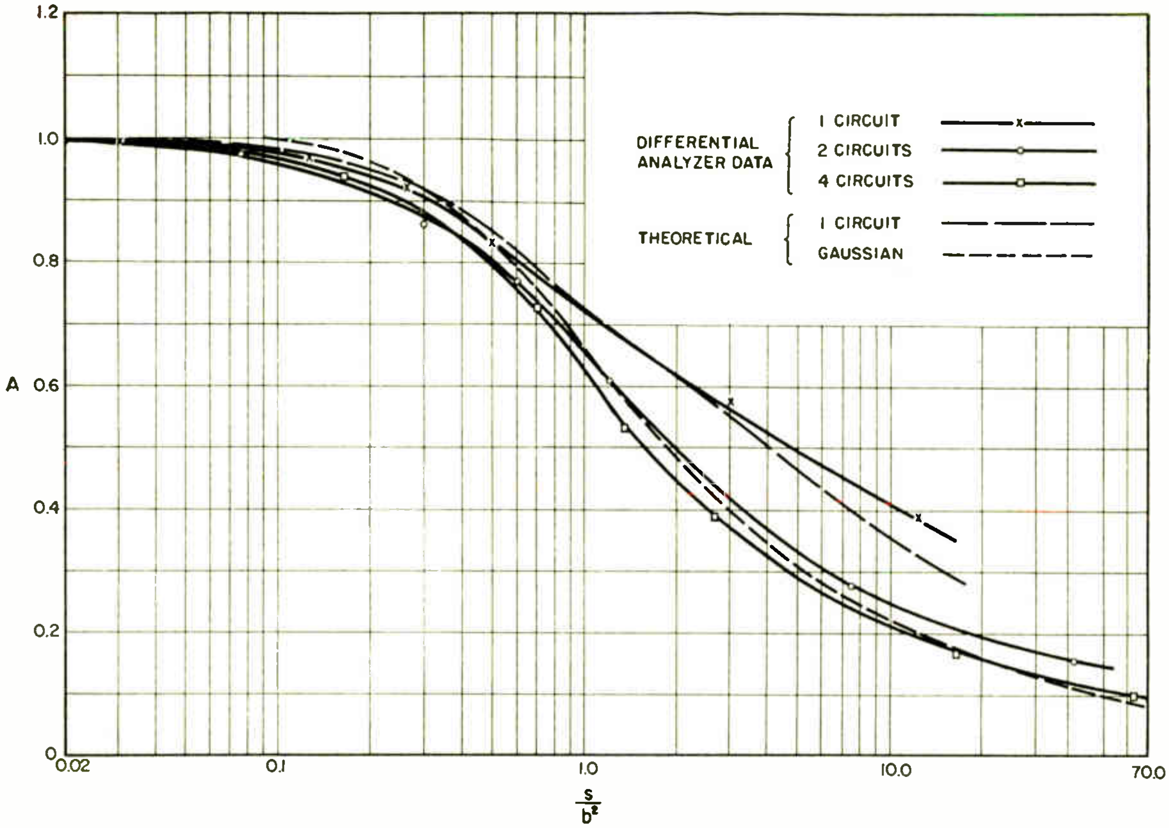

Fig. 12—Relative amplitude for a cw input signal.

degree angle with the real axis. With this restriction the integral

$$\int_{-\infty}^{+\infty} \exp(-Z^2)dZ$$

is independent of the angle of the path and thus equal to $\sqrt{\pi}$, which is given by integration along the real axis.

Now the calculation of $g(t)$ can be carried out. Before use is made of (14), $h(t)$ must be calculated.

$$h(t) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} H(\omega)\exp(j\omega t)d\omega$$
$$= \frac{1}{2\pi}\int_{-\infty}^{\infty}\exp\left[j\omega t - \frac{(\omega-a)^2}{b^2}\right]d\omega$$
$$= \frac{1}{2\pi}\exp\left[\frac{-a^2}{b^2}\right]\int_{-\infty}^{\infty}\exp\left[\frac{-\omega^2}{b^2}+\left(jt+\frac{2a}{b^2}\right)\omega\right]d\omega$$

which yields, after application of (15) and simplification,

$$h(t) = \frac{b}{2\sqrt{\pi}}\exp\left[jat - \frac{b^2t^2}{4}\right]. \quad (16)$$

The expressions for $f(t)$ and $h(t)$ can now be substituted in (14):

$$g(t) = \int_{-\infty}^{\infty} f(\lambda)h(t-\lambda)d\lambda$$
$$= \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}\exp\left[j\frac{s\lambda^2}{2}+ja\lambda - \frac{(\lambda-c)^2}{d^2}\right]$$
$$\cdot\frac{b}{\sqrt{2}}\exp\left[\frac{-b^2}{4}(t-\lambda)^2+ja(t-\lambda)\right]d\lambda$$
$$= \frac{b}{2\sqrt{\pi}}\exp\left[-\frac{c^2}{d^2}-\frac{b^2t^2}{4}+jat\right]$$
$$\cdot\int_{-\infty}^{\infty}\exp\left[-\lambda^2\left(\frac{1}{d^2}+\frac{b^2}{4}-\frac{js}{2}\right)+\lambda\left(\frac{2c}{d^2}+\frac{b^2}{2}\right)\right]d\lambda$$

and using (15) again;

$$g(t) = \frac{b}{2\cdot\sqrt{\frac{1}{d^2}+\frac{b^2}{4}-\frac{js}{2}}}$$
$$\cdot\exp\left\{-\frac{c^2}{d^2}-\frac{b^2t^2}{4}+jat+\frac{\left[\frac{2c}{d^2}+\frac{b^2t}{2}\right]^2}{4\left[\frac{1}{d^2}+\frac{b^2}{4}-\frac{js}{2}\right]}\right\}. \quad (17)$$

As has been remarked, the required answer is the absolute value of $g(t)$, which can be obtained by taking the absolute value of the first factor and keeping only the real part of the exponent.

$$|g(t)| = \frac{b}{2\left[\left(\frac{1}{d^2}+\frac{b^2}{4}\right)^2+\frac{s^2}{4}\right]^{1/4}}$$
$$\cdot\exp\left\{-\frac{c^2}{d^2}-\frac{b^2t^2}{4}+\frac{\left[\frac{2c}{d^2}+\frac{b^2t}{2}\right]^2\left[\frac{1}{d^2}+\frac{b^2}{4}\right]}{4\left\{\left[\frac{1}{d^2}+\frac{b^2}{4}\right]^2+\frac{s^2}{4}\right\}}\right\}. \quad (18)$$

The exponent of (18) can be put into the following form:

$$-\frac{b^2\left[\frac{4}{d^2}+b^2+s^2d^2\right]}{d^2\left[\left(\frac{4}{d^2}+b^2\right)^2+4s^2\right]}\cdot\left[t-\frac{c\left[\frac{4}{d^2}+b^2\right]}{\left[\frac{4}{d^2}+b^2+s^2d^2\right]}\right]^2 - \frac{s^2c^2}{\left[\frac{4}{d^2}+b^2+s^2d^2\right]}. \quad (19)$$

Referring to the definitions of A, W, and B, and recalling that in the Gaussian case the width of a curve is taken to the $e^{-1/4}$ points, it is clear that

$$A_0 = \frac{b}{\left[\left(\frac{4}{d^2}+b^2\right)^2+4s^2\right]^{1/4}}, \quad (20)$$

$$B = \frac{1}{b}\sqrt{\frac{4}{d^2}+b^2+s^2d^2}, \quad (21)$$

and

$$W = \frac{sd}{b^2}\sqrt{\frac{\left(\frac{4}{d^2}+b^2\right)^2+4s^2}{\frac{4}{d^2}+b^2+s^2d^2}} = \frac{sd}{b}\,\frac{1}{A_0{}^2B}. \quad (22)$$

The time of maximum response is given by

$$t_m = c\left[\frac{\frac{4}{d^2}+b^2}{\frac{4}{d^2}+b^2+s^2d^2}\right]. \quad (23)$$

Now $|g(t)|$ can be written

$$|g(t)| = A_0 \exp\left\{-\frac{1}{W^2}\cdot\left[\frac{s(t-t_m)}{b}\right]^2 - \frac{1}{B^2}\left[\frac{sc}{b}\right]^2\right\}. \quad (24)$$

For a cw input the signal is

$$\exp j\left[\frac{st^2}{2}+at\right],$$

and the output can be obtained from (18) by taking the limit as d approaches infinity.

$$\lim_{d\to\infty}|g(t)| = \frac{b}{[b^4+4s^2]^{1/4}}\exp\left\{-\frac{b^2s^2t^2}{b^4+4s^2}\right\}. \quad (18a)$$

In the notation of (20) to (24),

$$A_0 = \frac{b}{[b^4+4s^2]^{1/4}} \quad (20a)$$

$$W = \frac{1}{b^2}b^4+4s^2 = \frac{1}{A_0{}^2}, \quad (22a)$$

and

$$\lim_{d\to\infty}|g(t)| = A_0\exp\left\{-\frac{1}{W^2}\left[\frac{st}{b}\right]^2\right\}. \quad (24a)$$

Mutual Coupling Considerations in Linear-Slot Array Design*

M. J. EHRLICH,† SENIOR MEMBER, I.R.E., AND JOANN SHORT†

Summary—A study was made of the mutual coupling between two resonant waveguide fed slots on a finite ground plane. The size of the ground plane and the relative spacing of the slots were such that the geometry corresponded to that of a pair of adjacent longitudinal shunt slots on the broad face of a rectangular waveguide. A null bridge method of measurement was used to determine accurately the relative field strength excited in the second waveguide by mutual coupling between the slots when the generator was applied to the first waveguide. The change in input slot admittance of the driven slot arising from the presence of the parasitic slot was also measured for matched terminations of the ends of the parasitic slot waveguide. The changes in slot input admittance and excitation arising from mutual coupling were determined. It is shown that the changes may be neglected in the design of the great majority of linear-slot arrays.

* Decimal classification: R118.1×R142. Original manuscript received by the IRE, May 18, 1953; revised manuscript received, October 15, 1953.

This technical memorandum is one of a series of reports which will provide final information available on Project 532-A.

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Introduction

THE DESIGN of linear-slot arrays whose radiating elements are shunt slots cut on the broad face of a rectangular waveguide is usually executed without consideration of the effects of mutual coupling between the elements.[1] The mutual coupling is defined as that coupling which occurs in the free space exterior to the waveguide. The magnitude of this coupling and subsequently the evaluation of the validity of its neglect in design have been determined in this study.

Nature of the Experiment

The particular external slot geometry that is considered in this experiment corresponds to two adjacent elements of a longitudinal shunt-slot array on the broad

[1] W. H. Watson, "Waveguide Transmission and Antenna Systems," Clarendon Press, Oxford, England, chap. 8; 1947.

face of a rectangular waveguide. Each slot is centered longitudinally on the narrow face of a length of one inch by one-half inch RG-52U waveguide as shown in Fig. 1. One end of each of the guides is bent to provide

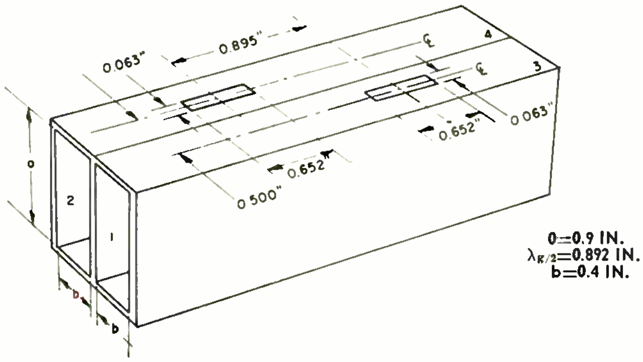


Fig. 1—Geometry of two slots in separate waveguides.

waveguide flange-input connections. The two guides are then soldered with their broad faces together such as to give a spacing of $\lambda_g/2$ between the transverse center lines of the slots. Extension pieces one-half inch wide are added on each curved end in order to locate the slots on the same one-inch wide ground plane as that of the broad face of a single length of rectangular waveguide. The complete unit is shown in Fig. 2. The geometry of the experiment and the use of separate guides to feed each slot was originally proposed by Dr. R. S. Wehner.

Fig. 2— Experimental two-slot array.

The experiment is simple in concept. A generator is coupled to one waveguide and drives the slot cut in the narrow wall of the guide. The slot conductance is such that the slot radiates approximately half of the energy incident upon it, the remainder being absorbed in the matched termination. The field radiated by the driven slot couples energy to the parasitic slot cut in the narrow face of the second guide. The field excited in the second guide by the parasitic slot is compared in phase and magnitude by use of a directional coupler to the field incident in the guide on the driven slot. Separate measurements are made of (1) the input admittance of the driven slot, normalized to the waveguide, when both ends of the waveguide excited by the parasitic slot are terminated in matched loads; and (2) the self admittance of the single slot in the finite ground plane.

These data are then used to determine the changes in slot excitation and admittance, normalized to the waveguide, arising from the mutual coupling.

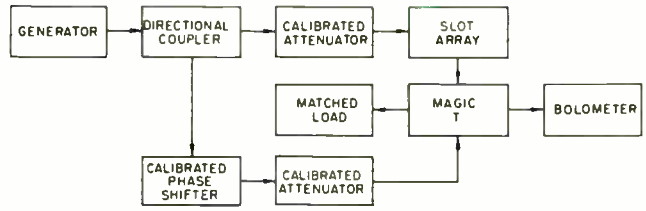


Fig. 3—Block diagram of experimental setup.

Experimental Details

Fig. 3 is a block diagram of the bridge network used for the accurate measurement of the field excited by the parasitic slot in its feed guide.

Each slot was cut to be resonant at 9,350 mcs in the absence of the other slot and measurements were made at this frequency.

The generator was a stabilized X-band supply which used a 2K39 klystron as the source of RF power. The output of the supply was fed through an attenuator, a directional coupler and then to the waveguide which contained the driven slot. A reference signal, which was furnished by the coupler and was −20 db with respect to the main signal, was fed through a calibrated precision attenuator and phase-shifter to one of the arms of the magic-*T* bridge. The other input arm of the bridge was connected to the waveguide fed by the parasitic slot. The signal from the difference arm of the bridge was brought to a bolometer amplifier. The sum arm of the bridge was terminated in a matched load. A matched load was seen looking into the symmetrical arms of the *T*. It is to be emphasized at this point that all measurements of the backward scattered waves in the waveguide are measured relative to the field incident on the driven slot and not to the total field.

The self admittance of a single slot in the finite ground plane, normalized to the waveguide, was measured with the second slot filled with a metal plug soldered to the slot so that an unbroken metal surface was presented on the exterior of the waveguide.

The parasitic slot was then opened and the input admittance of the driven slot was measured as a function of frequency when both ends of the parasitically excited waveguide were terminated in matched loads.

Analysis of Experimental Results

The experiment is designed to measure the backward scattered waves A_{10} and A_{10}', (Fig. 4, p. 958), relative to the unity amplitude TE_{10} wave incident in the waveguide upon the driven slot.

An analysis of the admittance and impedance properties of shunt and series slots cut in the broad face of a rectangular waveguide has been formulated by Stevenson.[2] The backward scattered wave excited by a longitudinal shunt slot cut in the narrow face of a rectangular waveguide for the TE_{10} dominant mode case is given as:

$A_{10} = j\delta E_0(2/\pi b)(k/\beta_{10})^2 \cos(\beta_{10}\lambda/4)$ and for the shunt slot

$= B_{10}$ the forward scattered wave as shown in Fig. 4.

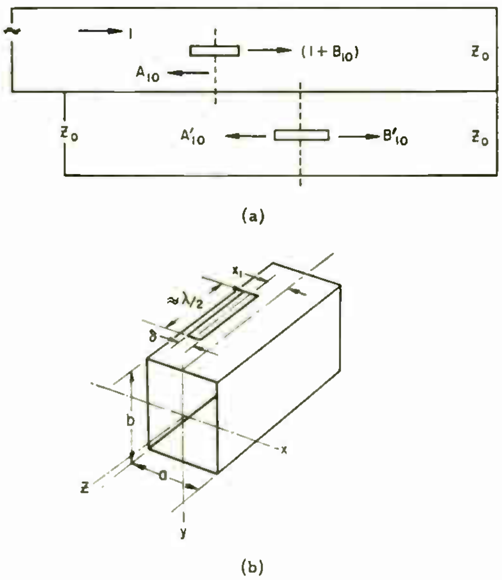


Fig. 4—(a) Waves scattered in waveguide by slot radiators. (b) Slot geometry.

where

δ = slot width

E_0 = electric field across the center of the slot

a = width of broad face of the waveguide

b = width of narrow face of the waveguide

$k = 2\pi/\lambda$

λ = free space wavelength

$\beta_{10} = +[k^2 - (\pi/a)^2]^{1/2}$.

The "voltage" across the slot is defined as the integral of the field across the slot at its center, i.e.,

$$V_0 = \delta E_0.$$

A_{10} is measured by determination of the reflection coefficient Γ in the guide containing the driven slot when the guide is terminated in its characteristic impedance, Z_0. A_{10}' is measured in the parasitically excited guide by the use of the null bridge method in which A_{10}' is compared directly to the unity amplitude incident, TE_{10} wave in the driven guide.

The field excited in the parasitic slot E_0', relative to the field excited in the driven slot E_0, is given by the relation

$$\frac{E_0'}{E_0} = \frac{A_{10}'}{A_{10}}.$$

This relation is approximate in that it neglects the change in the admittance of the first slot arising from the presence of the parasitic slot. This change is, however, very slight as it arises principally from the secondary scattering of the parasitic slot.

Measurements were made of the driven slot admittance for two cases and the results are shown in Fig. 5. The first has the parasitic slot completely covered with metal sheet. The second has the parasitic slot opened and with its waveguide terminated in matched loads. The ratio of the measured reflection coefficient for the two cases is $|\Gamma'/\Gamma| = 0.98$. Thus the variations of the driven slot admittance may be safely neglected.

The measured values of A_{10} and A_{10}' give a value

$$\frac{V_0'}{V_0} = \frac{\delta E_0'}{\delta E_0} = \frac{A_{10}'}{A_{10}} = 0.087 \exp^{-j164°}$$

for the ratio of the coupled field to the excited field.

The total field at each slot when both are driven by equal generators is

$$V_0'' = V_0 + V_0' = V_0[1 + 0.087 \exp^{-j164}]$$

$$\frac{V_0''}{V_0} = 0.916 \exp^{-j1.5°}$$

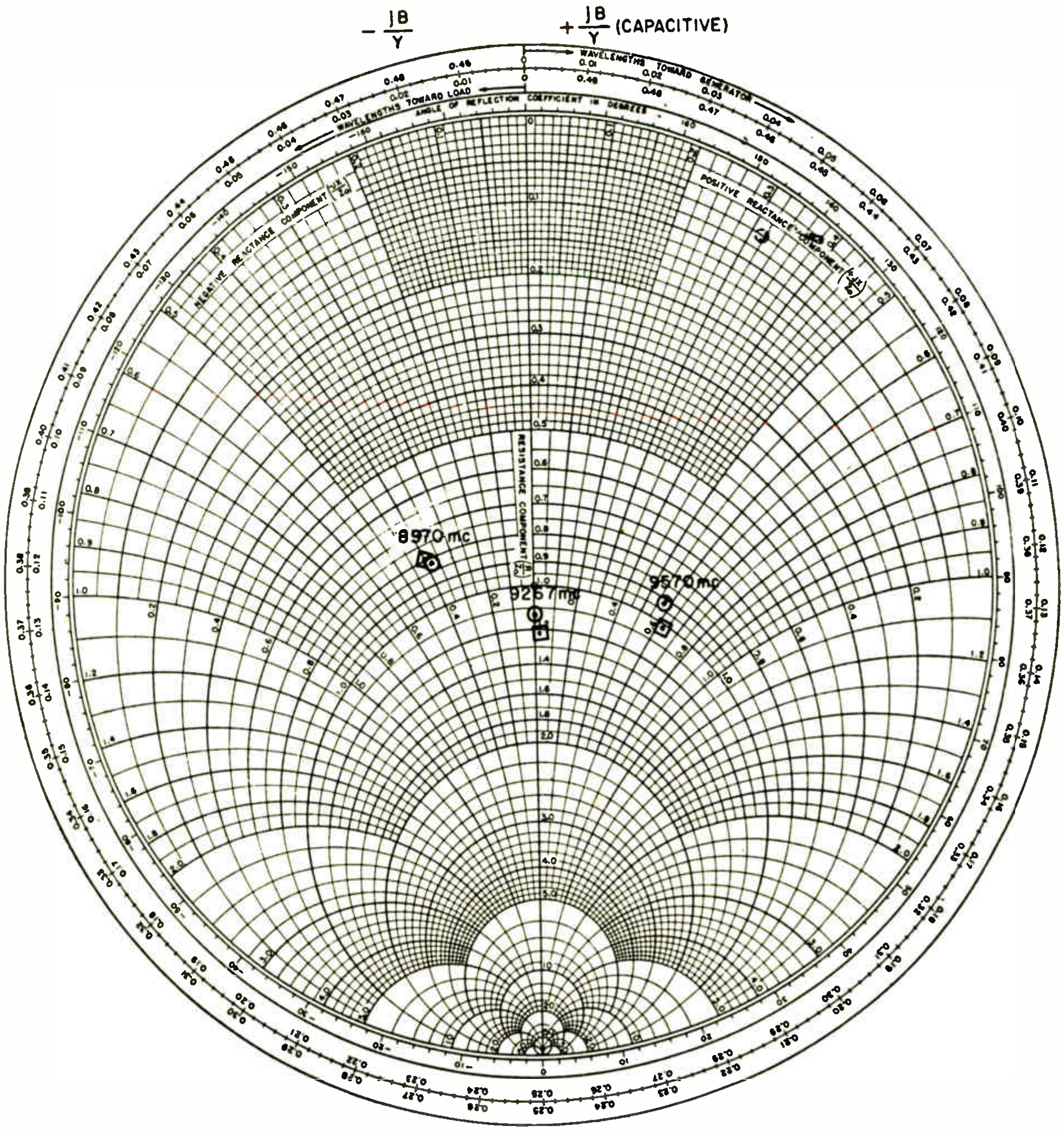
and

$$\frac{|V_0''|}{|V_0|} \approx 0.916.$$

It is now desired to interpret the experimental results for the two shunt slots on the narrow faces of the waveguides so as to apply to two shunt slots cut in the broad face of the same rectangular waveguide.

The shunt slot on the broad face of the waveguide is excited by the transverse component of current, and is represented as a pure two-terminal element in shunt across the equivalent two-wire line specified by the dominant TE_{10} mode. The shunt slot on the narrow face, when aligned parallel to the longitudinal axis of the waveguide, i.e., inclined at an angle of 90 degrees, is also excited by the same current component. The conductance of the slot on the broad face is made equal to that of the slot on the narrow face by increasing its transverse displacement. When the conductances are thus made equal it is found that spacing between the slots on the broad face is very nearly equal that of the two slots on the narrow faces of the adjacent waveguide of the experiment for the specified dimensions and frequency. The external slot geometry and the ground planes are then identical in the two cases. Both types of slots are excited by the same transverse current component and are pure two-terminal shunt elements. The internal coupling arising from higher-order modes between the two shunt slots cut on the broad face is negligible. Therefore on a dominant mode representation the two configurations are wholly equivalent as far as regards the admittance and excitation changes of the slots arising from external mutual coupling between the slots.

[2] S. Silver, "Microwave Antenna Theory and Design," M-97 Radiation Lab. Series, McGraw-Hill Book Co., New York, N.Y., vol. 12, pp. 286–300; 1949.



⊙ Parasitic slot—completely covered
⊡ Parasitic slot—open and waveguide terminated in matched loads

Fig. 5—Admittance of driven slot—normalized to waveguide.

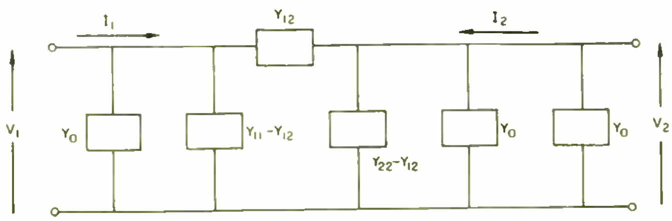


Fig. 6—Equivalent circuit of two-shunt slots in separate waveguides.

Consider equivalent circuit of configuration used in experiment, where the two slots are cut in the narrow faces of separate waveguides, as shown in Fig. 6.

$$I_1 = (Y_{11} - Y_{12} + Y_0)V_1 + Y_{12}(V_1 - V_2)$$

$$\therefore \quad I_1 = (Y_{11} + Y_0)V_1 - Y_{12}V_2$$

$$0 = I_2 = (V_2 - V_1)Y_{12} + (Y_{22} - Y_{12} + 2Y_0)V_2$$

$$0 = - Y_{12}V_1 + (Y_{22} + 2Y_0)V_2$$

$$\therefore \quad Y_{12} = \frac{V_2}{V_1}(Y_{22} + 2Y_0)$$

for

$$Y_{22} = Y_{11}; \qquad Y_0 = 1$$

$$Y_{12} = \frac{V_2}{V_1}(Y_{11} + 2)$$

and

$$Y_1 = \frac{I_1}{V_1} = (Y_{11} + 1) - \left(\frac{V_2}{V_1}\right)^2 (Y_{11} + 2)$$

and as the measured value of $(V_2/V_1) = 0.042 \exp^{-j164}$ $Y_1 \approx (Y_{11}+1)$ which confirms the results obtained by measurement as shown in Fig. 5 where $Y_{11} = 1.10$ and

$$Y_{11}' = Y_{11} - \left(\frac{V_2}{V_1}\right)^2 (Y_{11} + 2).$$

The case of interest is when both slots are cut in the broad face of the same waveguide. The equivalent circuit for this configuration is shown in Fig. 7.

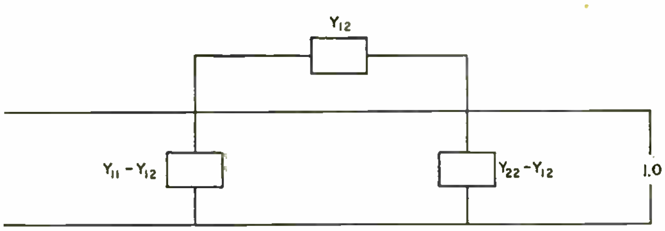


Fig. 7—Equivalent circuit for two-shunt slots in same waveguide.

V_1' and V_2' are the applied voltages and as $V_1' = V_2'$, due to the slots being spaced $\lambda_g/2$ apart along the line, the series arm of the Π is removed. Thus,

$$Y_{in} = (Y_{11} - Y_{12}) + (Y_{22} - Y_{12}) + Y_0 \text{ where, } Y_{11} = Y_{22}$$
$$Y_{in} = 2(Y_{11} - Y_{12}) + 1.0 \qquad Y_{12} = Y_{21}$$
$$Y_0 = 1.$$

Y_1' is the admittance of one slot normalized to the waveguide and is given by

$$Y_1' = \tfrac{1}{2}(Y_{in} - 1.0) = (Y_{11} - Y_{12}).$$

Then Y_1' for the measured case is given by

$$Y_1' = 1.1 - 0.042(1.1 + 2) \exp^{-j164°} = 1.22 \exp^{j1.70}$$

and

$|Y_1'/Y_1| = 1.11$ a change of 11 per cent in the slot admittance, as compared to the change when the slots are in separate guides.

The 11 per cent represents an extreme change as the bulk of the slot arrays which have been designed have had far smaller values of Y_{11} for the most strongly coupled slot.

Extensions of the Results to the Lightly Coupled Case

A survey of the conductances of the slots in the great majority of the arrays previously built shows that the maximum slot conductance is less than 0.1, normalized to the waveguide. The experimental results for the strongly coupled slot, i.e., $g > 1.0$ must now be extended to the lightly coupled slot.

The fraction of the power incident upon the slot inside the guide, that is radiated by the slot, is given by the relation in Fig. 8, where ge = conductance of the rest of the array on the load side of the slot position on the line.

$$\frac{P_{rad}}{P_{inc} - P_{rad}} = \frac{g_{slot}}{g_\ell}$$

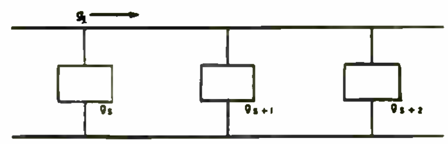


Fig. 8

The power that is radiated by the slot may be expressed as:

$$p_{rad} = \tfrac{1}{2} V_0^2 Y_r$$

V_0 = equivalent peak voltage of the slot

Y_r = radiation admittance of the slot.

As the driven slot conductance is reduced by the factor A, the voltage V_0 is reduced by the factor $A^{1/2}$ and the field excited by mutual coupling in the neighboring slot is reduced by the factor $A^{1/2}$. If, in addition, the neighboring slot's conductance is reduced by the factor B, then by reciprocity the field excited in the neighboring slot will be reduced by the factor $A^{1/2} \times B^{1/2}$. For the symmetrical case, i.e., $A = B$, the applied voltages are reduced by the factor $A^{1/2}$ while the coupled voltages are reduced by the factor A. The slot voltage variation due to nearest neighbor mutual coupling is readily derived.

For the measured case of one adjacent slot

$$V_{slot} = [1.0 + 0.087 \exp^{-j164}].$$

The largest conductance likely to be encountered is 0.1

$$\therefore A = \frac{0.1}{1.1} = 0.091;$$

accordingly

$$V_{slot} = [1.0(A)^{1/2} + (0.087 \exp^{-j164+\phi})A]$$
$$= 0.301 + 0.0079 \exp^{-j(164+\phi)}$$
$$= 0.301 \exp^{j1.0°}.$$

Then $\left|\frac{V_{slot}}{V_0}\right| = 0.972,$

where

V_0 = voltage for zero mutual coupling

ϕ = change in the phase angle of the mutual admittance due to the decreased path length between the slots.

From the geometry of the array $\phi = 33$ degrees at the measurement frequency, and the change in V_0 is negligible.

When both nearest neighbors are considered

$$\frac{|V_{slot}|}{|V_0|} = 0.96.$$

This represents the greatest excitation change to be expected and in itself may be safely neglected in design. It has been stated that as the conductances are reduced by the factor A, V_2, the coupled field in the guide is reduced by the same factor. In addition, the applied field at the driven slot $V_1 = V_{inc}/(1+\Gamma)$. The new slot admittance Y_2' for the lightly coupled case when both nearest neighbors are considered is readily derived from the relations

$$Y_2' = Y_{22} - Y_{12} - Y_{23},$$

where

$$Y_{12} = Y_{23}$$

$$Y_2' = Y_{22} - 2Y_{12}$$

$$Y_{12} = -\left[\frac{V_2}{V_1}(Y_{11} + 2)\right]$$

then

$$Y_2' = Y_{22} - 2\left[\frac{V_2}{V_{inc}}(1 + \Gamma)A\right][Y_{11} + 2].$$

The numerical value, for $g \leqq 0.1$, is

$$Y_2' = 0.1 - 2[0.031(1.13) \times 0.091] \exp^{-j164}[2.1] \exp^{j\phi}$$

$$Y_2' = 0.108 \exp^{j5°}$$

$$\left|\frac{Y_2'}{Y_2}\right| = 1.08.$$

The admittance change of 8 per cent is the largest to be expected and for the majority of the slots in the array will be slightly less.

Conclusion

The changes in the relative excitation and input admittance of the shunt slot radiator cut in the broad face of a rectangular waveguide excited in the TE_{10} mode, arising from external mutual coupling between the slots, may be neglected in the design of most linear shunt slot arrays. Both the excitation and admittance changes are small and of the same order as those produced by dimensional variation within standard manufacturing tolerances.[3]

If the array is designed for extremely low side-lobe levels, say -30 or -40 db, and fabricated with great care such that dimensional variations are minute, then some compensations for the effects of nearest neighbor mutual coupling may be made in order to achieve minimal side lobes with the greatest aperture efficiency. Precision fabrication is quite costly and it is far simpler to obtain low side-lobe levels by some over-design, which would introduce a slightly reduced aperture efficiency.

One other case in which compensation may be required is for the short array of a few slots which are strongly coupled to the feed and where some beam shaping is specified. In this instance, correction will have to be made for the coupling arising from all the slots rather than from the nearest neighbor only. Such correction is feasible only in a relatively small array as it requires a large amount of numerical computation.

Acknowledgments

The authors wish to thank N. A. Begovich, S. Sensiper, and R. S. Wehner, of Hughes Aircraft Company, for their helpful suggestions during the course of the study, and their critical reviews of this paper.

[3] L. L. Bailin and M. J. Ehrlich, "Factors affecting performance of linear arrays," Proc. I.R.E., vol. 41, pp. 235–241; February, 1953.

Transient Response of Glow Discharges with Applications*

R. S. MACKAY† AND H. D. MORRIS†

Summary—**The transient responses of a number of glow discharges were observed. From the response time of several microseconds, and the characteristic overshoot, they can be described as having an inductive component approaching a henry. This is consistent with the observed frequency response.**

It is shown how standard neon lamps can be used as fast and noiseless coupling elements for voltage level changing in direct coupled circuits, in spite of the above.

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Introduction

There follows the description of some experiments which measured the way in which a glow discharge responded to a sudden change in conditions. This procedure yields a valuable technique for the study of fundamental discharge processes. The present study was mainly concerned with rise time and bandwidth measurements. These measurements also have immediate application to practical electronic circuits. Glow discharge tubes make useful voltage level changing devices (for taking in a signal at one level and

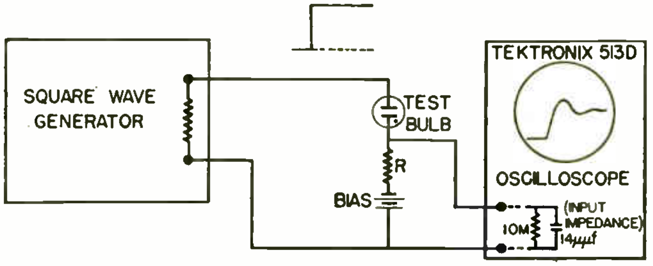


Fig. 1—Experimental set up for observing the transient response of a glow discharge.

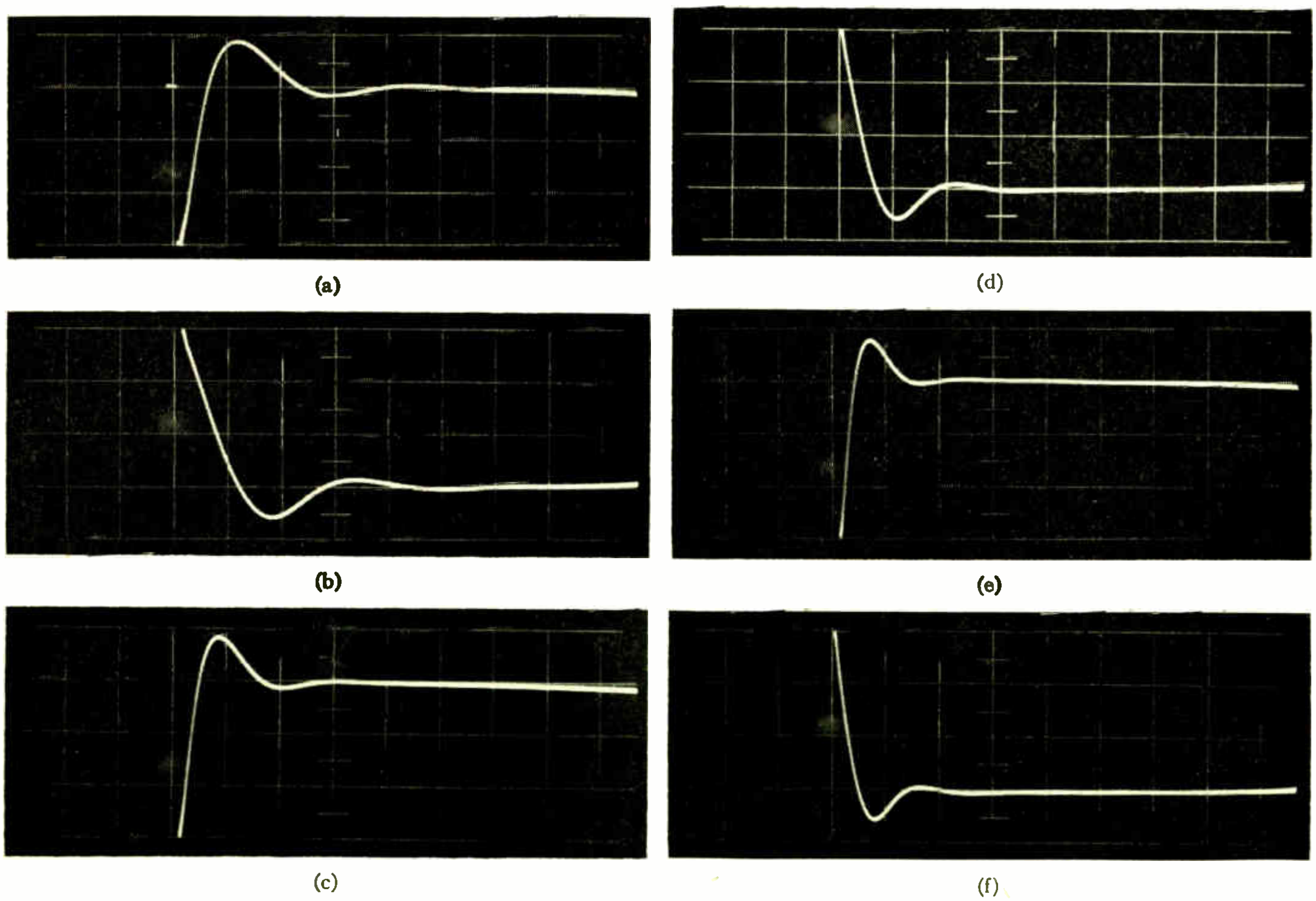
giving it out at another), e.g., as coupling elements in a multistage dc amplifier. Practical methods of use and limitations are discussed. Their effect when included in a feedback loop is also considered. From these considerations one is also better able to predict the performance of regulated power supplies.

Methods and Results

In essence, the method used involved a glow discharge (in series with some resistance) maintained by means of a fixed bias source. Superimposed on this fixed voltage was a signal, the response to which was observed across the resistor. The investigation was carried into both the time and frequency domains so that any unusual aspect of the response would be completely described.

Fig. 1 shows the method of determining transient responses. The oscilloscope used had a flat response to 20 megacycles and a useable response to 30 megacycles so that oscillations other than the primary one would have been visible up to the nominal limit. The signal used in producing Fig. 2 had rise and fall times of less than 0.3 microsecond with no overshoot. The lamp whose response was photographed was a representative 1/25 watt neon, type NE-2, with characteristics taken over its useful range of currents, 150–300–500 microamperes. The response was approximately independent of signal amplitude. The sinusoidal response of Figs. 3 and 4 was observed by substituting a sine-wave generator for the square-wave generator and using the oscilloscope as a voltmeter.

Numerous tests have shown that all neon and argon lamps display these phenomena. All lamps tested exhibited at least 10 per cent overshoot. Over a current range of 3 to 1, the magnitude of the overshoot remains approximately constant while the frequency scale shifts higher with increasing current. One-quarter watt lamps were found to have a definitely greater damping factor than the corresponding 1/25 watt bulbs, and also a



(a) (b) (c) (d) (e) (f)

Fig. 2—Response of a discharge to a sudden step up or down. The first pair is for a bias current of 150 microamps, the second for a current of 300 microamps, and the last for a current of 500 microamps. Time scale of 5 microseconds per division and vertical sensitivity of 6.6 volts per division.

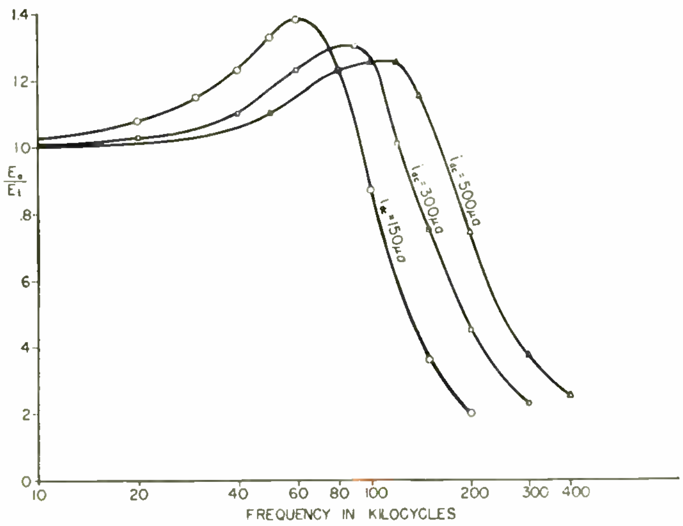


Fig. 3—Frequency response of a glow discharge to a sinusoidal signal.

higher frequency of oscillation. Argon lamps (¼ w) had about 40 per cent shorter rise time to the 75 per cent output level than the ¼ watt neon lamps (1.1 microseconds compared with 1.7 microseconds), though it should be pointed out that the voltage drop in the argon bulbs was about 30 per cent higher. Tripling the bias voltage and increasing the size of the series resistor so that the bias current remained the same decreased the damping (increased the overshoot) but did not change the time scale. Doubling the capacity increased the overshoot by 10 per cent of the signal height, and lowered the resonant frequency as expected. It should be pointed out that the entire region of measurement lay outside the region of negative incremental resistance on the static E-I curve (Fig. 6, p. 964).

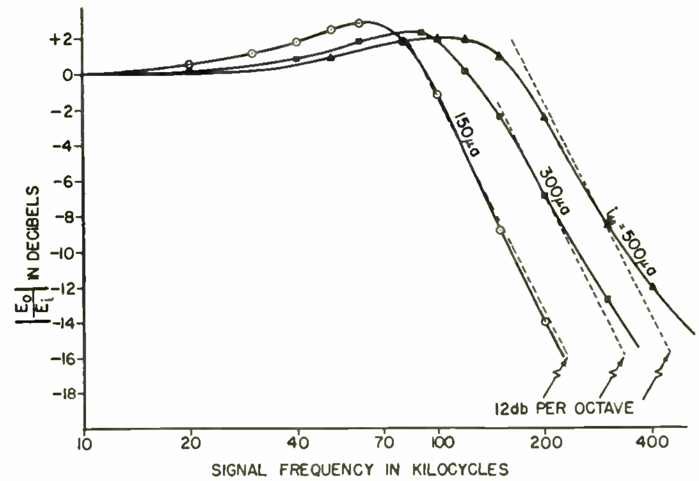


Fig. 4—Data of Fig. 3 replotted on a decibel scale.

Taken together, the experimentally determined transient and frequency responses are logically coherent, i.e. one implies the other through a Fourier transformation. Another circuit composed of linear passive elements (Fig. 5) exhibits the same transient and sinusoidal response, and so for some purposes the lamp may be considered as replaced by a combination of resistance and inductance, the magnitude of the latter approaching a henry. Fig. 5 also contains a representation of the transfer function of the linear passive network, showing an asymptotic phase shift of π radians, since two different energy storage elements are present. This network exhibits a cutoff characteristic of 12 db/octave as does the neon circuit in the curves of Fig. 4.

In any multistage circuit with limited overshoot, where each stage takes the signal from the previous one, the rise time of the combination is the square root of the sum of the squares of the individual rise times. The rise time of several bulbs placed in series (to give a larger over-all voltage drop) is longer than any one alone, and seems to follow this rule.

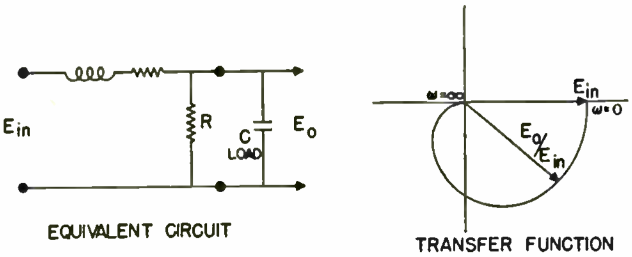


Fig. 5—A network equivalent to a glow discharge under the present conditions. This network displays the observed transient response, phase shift characteristics, frequency response, and the effects of variation of circuit constants. At 90-degree phase shift there is roughly no attenuation (Q approximately one) and this places a severe restriction on the types of time constants that could be considered as cascaded.

One might think of a sudden increase in applied voltage as momentarily producing an "abnormal glow" until the discharge can redistribute itself. (It might be expected that this process take a time comparable with the "burning time" in some Geiger counters.) The photographs show that the transient following a sudden drop in voltage (voltage too small for existing current) is quite similar, and indeed, the transients become practically identical as the signal becomes smaller. During these transition states there is undoubtedly a transient redistribution of light intensity (e.g. a moving striation) that might profitably be studied with photomultipliers in a larger tube.

Quite aside from the above, there is an effect that should be mentioned because of its consequences. With capacitive loading there is some critical frequency at which the current available to the discharge must go to zero once each cycle (the discharge periodically goes out). This frequency can easily be shown to be approximately:

$$f = \frac{i}{8.88cV}.$$

As an example, if the current through the bulb is 300 microamperes, the rms signal is 7 volts, and the load is 100 pf, this comes out to be 48 kilocycles. It would be expected that distortion would appear at somewhat lower frequencies, and it was actually observed to start at about 20 kilocycles.

Applications

The problem of taking a signal (change in potential) at one voltage level and converting it to the same change at some other level is well known. The classic example is the direct coupled amplifier where the fluctuations in plate potential of one tube must be conveyed to the grid of the next without the help of a blocking condenser to take out the large average component. Any resistive network attenuates the useful signal as it changes the level and so some constant voltage device is needed. The use of "VR tubes" has often been suggested but has never met with much favor. The tiny neon lamps that are now so readily available display constant voltage properties (Fig. 6) adequate for many purposes. They are physically very convenient and they display a low capacity to ground.

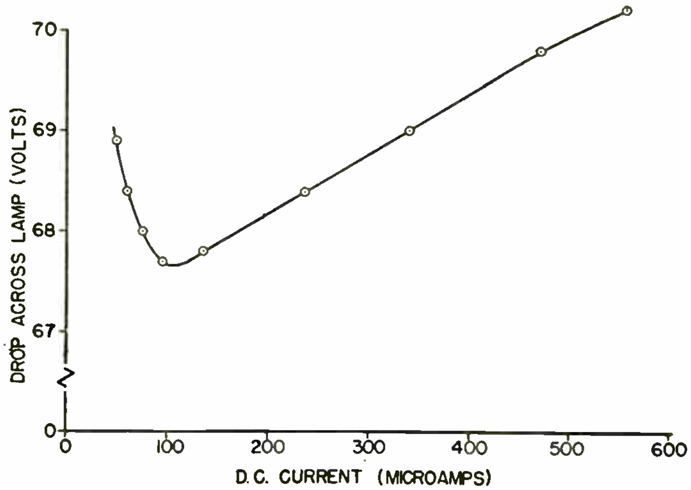


Fig. 6—Static current-voltage characteristics of a typical neon lamp type NE-2. (Note suppressed zero on the voltage scale.)

The disadvantages of such tubes are drift, noise generation, and inherent phase shift. The previous curves depict the rapidity of response of a pulse circuit coupled by such a tube, or the high frequency response of an amplifier so coupled. The noise characteristic of such lamps is about ten millivolts, and they are slightly microphonic.

All but the first disadvantage, drift, may be eliminated by shunting the lamp with a capacitor and damping resistor, as shown in Fig. 7. With this arrangement one speeds the transient response and filters all noise before the next grid without creating a tendency toward oscillation (which would be observed if the lamp were only paralleled with a condenser). No net current flows in R and so the condenser voltage is the same as that of the neon bulb, whereas almost any other configuration will require compensated voltage dividers. The worth of this system was checked experimentally with a dc amplifier utilizing a neon bulb for coupling in the forward direction and another in the feedback path. Without shunting capacitors around the neons, the amplifier was permanently unstable (it would oscillate). With one neon bypassed, a 50 per cent rise was still observable around 300 kilocycles. After both neons were bypassed the amplifier had a normal cut-off characteristic that was easily extended to 5 megacycles.

The remaining factor of drift may be reduced in importance by aging the lamps at maximum rated current for several days. Where the problem is significant it can thus be minimized providing the lamps are used fairly continuously. If a lamp is left idle for long time intervals, its characteristics will change markedly between periods of use. Care must be taken to use a lamp with the same polarity as used in aging it, unless alternating current was used. For the more critical applications the voltage reference tube type 5651 will be found to be much more stable and still quite convenient. They are also more reproducible from tube to tube.

Neon coupling units are therefore quite advantageous. Without bypassing, the neon circuit can be used wherever the signal noise ratio will allow it, e.g. in nonfeedback amplifiers, in computers to change gating signal levels (one might use the plate swing of a trigger pair to activate the grid of a gate tube at a lower potential), and wherever phase shifts are not critical to operation. With bypassing the coupling units can be used anywhere with drift as the only limitation. An example from the field of pulse techniques is the construction of fast multivibrators having small plate resistors. The whole plate swing can be conveyed to the opposite grid with such coupling units, thus making operation possible though the swing be small.

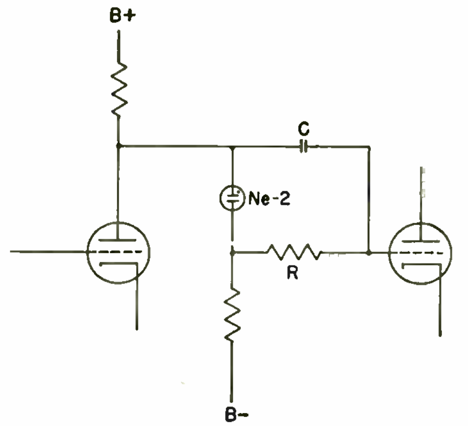


Fig. 7—Method of coupling components with a discharge tube or tubes for optimum results. The unlabeled resistor puts the neon lamp in its operating range, C removes noise, time delay, and overshoot, and R prevents oscillation as well as helping with the noise filtering. $R \approx 50K$, $C > 0.001$ mfd.

Another aspect is regulated power supplies. The regulation of a simple VR tube is not instantaneous, and thus their performance in pulse circuits may be poor. A condenser of limited size may be placed in parallel with the tube without oscillations developing. In those circuits where the VR tube is used as a reference voltage for an electronic regulator, care must be taken in view of the inductive action of the tube. This can cause the whole circuit to oscillate.

IRE Standards on Graphical Symbols for Electrical Diagrams, 1954*

The standards herein are the same as those in *American Standard Graphical Symbols for Electrical Diagrams, Y32.2-1954* of the American Standards Association.

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* Reprints of this Standard, 54 IRE 21 S1, may be purchased while available from The Institute of Radio Engineers, 1 East 79 Street, New York 21, N. Y., at $1.25 per copy. A 20 per cent discount will be allowed for 100 or more copies mailed to one address.

Foreword

This standard replaces the corresponding Sections II, III, and IV of *Standards on Abbreviations, Graphical Symbols, and Mathematical Signs* issued by the IRE in 1948. It has been adopted by the Symbols Committee and is published with the approval of the Standards Committee and by authorization of the Board of Directors.

A task group set up by the Sectional Committee on Graphical Symbols of the American Standards Association prepared this standard. The task group operated under the chairmanship of Allen F. Pomeroy, representing the Symbols Committee of the IRE. Its persistent efforts for more than two years brought about the coordination of many diverse views that had previously compelled the issuance of five separate American Standards on electrical graphical symbols. Some of these disagreements concerned the basic symbols for capacitors, inductors, and resistors.

Many symbols in this report concern things that are obviously not within the scope of the normal interests of the IRE. Representatives of the IRE acted as observers while these symbols were considered by the task-group members who were experts in the particular field. Consequently, the IRE does not consider these symbols to be within its control but, having great respect for the care and the competence with which they were processed, considers it a privilege to recommend them to the membership for use, as needed, or simply as educational material. The principle of having a single standard for the entire electrical field is too important to risk publication of the report in specialized sections, for this would inevitably encourage a resumption of divergence rather than the continued coordination that is the objective of all true standardization.

Certain fields have not been as fully covered in this document as may be desired by IRE members specializing in them. An evident example is semiconductor devices including transistors; however, continuing work by the IRE will result in the issuance of supplementary reports at a later date in such cases.

Graphical Symbols for Electrical Diagrams*

THIS standard provides a list of graphical symbols for use on electrical diagrams.

Graphical symbols for electrical engineering are a shorthand used to show graphically the interconnections and functioning of a circuit. A graphical symbol represents the function of a part in the circuit. Graphical symbols are used on either single-line (one-line) diagrams or on complete diagrams. Designations provide a means of correlating graphical symbols with parts lists and descriptions of, and instructions concerning, the circuit represented.

A **single-line (one-line) diagram** indicates by means of single lines and simplified symbols the course of an electric circuit or system of circuits and the component devices or parts used therein. A single-line diagram may be used to show essential components and functions in simplified form.

A **complete diagram** indicates by symbols the complete electric circuit or system of circuits and the component devices or parts used therein. In a complete diagram, coaxial and waveguide components are shown by single-line (one-line) symbols.

An **application** is an example of a combination of symbols in the list. No attempt has been made to list all possible applications. Additional applications may be devised provided they are a reasonable and intelligible use of the symbols in the list.

0.1 Arrangement

Symbols are arranged in the alphabetical order of the nouns in the terms they illustrate. Preferred terms are given first. The main headings list first the term in preferred usage, and any current alternate term follows. All terms appear in the index. In the index, "Item" refers to a numbered paragraph in the list of symbols.

In the list, graphical symbols appear directly under their respective item names. Single-line (one-line) symbols appear at left, complete symbols at right, and symbols suitable for both are centered in each column.

Typical single-line (one-line) diagrams are given at the end of the list of symbols.

0.2 Drafting Practices Applicable to Graphical Symbols

a. The orientation of a symbol on a drawing does not alter the meaning of the symbol.

b. The weight of a line does not affect the meaning of the symbol. In specific cases, a heavier line may be used for emphasis.

c. A symbol may be drawn to any proportional size that suits a particular drawing, depending on reduction or enlargement anticipated. If essential for purposes of contrast, some symbols may be drawn relatively smaller than the other symbols on a diagram. It is recommended that only two sizes be used on any one diagram.

d. Details of type, impedance, rating, etc., may be added when required, adjacent to any symbol. If used, abbreviations should be from the American Standard Abbreviations for Use on Drawings. Letter combinations used as parts of graphical symbols are not abbreviations.

e. The arrowhead of a symbol may be ➙ or ➔ unless otherwise noted in this standard.

f. Associated or future paths and equipment shall be shown by lines composed of short dashes: — — — —.

g. The standard symbol for a TERMINAL (o) may be added to each point of attachment of conductors to any one of the graphical symbols, but such added terminal symbols should not be considered as part of the individual graphical symbol itself.

h. A symbol shall be considered as the aggregate of all its parts.

i. For simplification of a diagram, parts of a symbol for a device, such as a relay or contactor, may be separated. If this is done, provide suitable designations to show proper correlation of the parts.

j. In general, the angle at which a connecting lead is brought to a graphical symbol has no particular significance unless otherwise noted in this standard.

* The standards herein are the same as those in *American Standard Graphical Symbols for Electrical Diagrams, Y32.2-1954* of the American Standards Association.

LIST OF SYMBOLS

1. ADJUSTABLE

CONTINUOUSLY ADJUSTABLE (Variable)

The shaft of the arrow is drawn at about 45 degrees across the body of the symbol.

2. AMPLIFIER

See also MACHINE, ROTATING (items 35.9.20 to 35.9.23).

2.1 General

The triangle is pointed in the direction of transmission.

Amplifier type may be indicated in the triangle by words, standard abbreviations, or a letter combination from the following list.

BDG	Bridging	MON	Monitoring
BST	Booster	PGM	Program
CMP	Compression	PRE	Preliminary
DC	Direct Current	PWR	Power
EXP	Expansion	TRQ	Torque
LIM	Limiting		

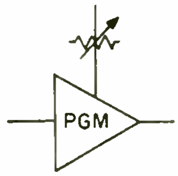
2.2 Applications

2.2.1 Booster amplifier with two inputs

2.2.2 Monitoring amplifier with two outputs

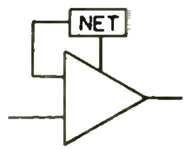
2.2.3 Bridging amplifier with adjustable gain

2.2.4 Program amplifier with associated attenuator



2.2.5 Amplifier with associated power supply

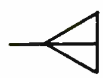
2.2.6 Amplifier with external feedback path



3. ANTENNA

3.1 General

Types or functions may be indicated by words or abbreviations adjacent to the symbol.



3.1.1 Dipole

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

3.1.2 Loop

3.2 Counterpoise

4. ARRESTER (Electric Surge, Lightning, etc.)
GAP

4.1 General

4.2 Carbon block

The sides of the rectangle are to be approximately in the ratio of 1 to 2 and the space between rectangles shall be approximately equal to the width of a rectangle.

4.3 Electrolytic or aluminum cell

This symbol is not composed of arrowheads.

4.4 Horn gap

4.5 Protective gap

These arrowheads shall not be filled.

4.6 Sphere gap

4.7 Valve or film element

4.8 Multigap, general

4.9 Application: gap plus valve plus ground, 2 pole

5. ATTENUATOR

See also PAD (item 42)

5.1 General

5.2 Balanced, general

5.3 Unbalanced, general

6. BATTERY

The long line is always positive, but polarity may be indicated in addition.

Example:

6.1 Generalized direct-current source

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

6.2 One cell

6.3 Multicell

6.3.1 Multicell battery with 3 taps

6.3.2 Multicell battery with adjustable tap

7. BREAKER, CIRCUIT

If it is desired to show the condition causing the breaker to trip, the relay-protective-function symbols in item 48.8 may be used alongside the breaker symbol.

7.1 General

Note 1—Use appropriate number of single-line diagram symbols.

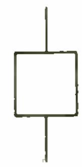
SEE NOTE 1

7.2 Air or, if distinction is needed, for alternating-current circuit breaker rated at 1,500 volts or less and for direct-current circuit breaker.

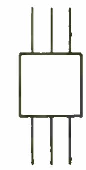
SEE NOTE 1

7.3 Circuit breaker, other than covered by item 7.2. The symbol in the "complete" column is for a 3-pole breaker.

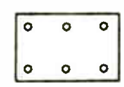
Note 2—On a power diagram, the symbol may be used without other identification. On a composite drawing where confusion with the general symbol (item 25) may result, add the identifying letters CB inside or adjacent to the square.



SEE NOTE 2



7.3.1 On a connection or wiring diagram, a 3-pole single-throw circuit breaker (with terminals shown) may be drawn as shown below.

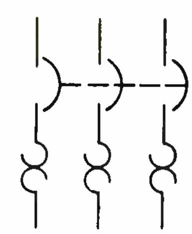


SEE NOTE 2

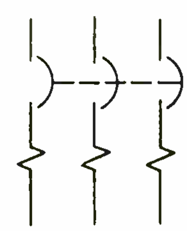
FOR CONNECTION OR WIRING DIAGRAM

7.4 Applications

7.4.1 3-pole circuit breaker with thermal overload device in all 3 poles.



7.4.2 3-pole circuit breaker with magnetic overload device in all 3 poles.



Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

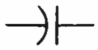
7.4.3 3-pole circuit breaker, drawout type

8. CAPACITOR

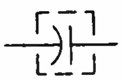
See also TERMINATION (item 59.4).

8.1 General

If it is necessary to identify the capacitor electrodes, the curved element shall represent the outside electrode in fixed paper-dielectric and ceramic-dielectric capacitors, the negative electrode in electrolytic capacitors, the moving element in adjustable and variable capacitors, and the low-potential element in feed-through capacitors.



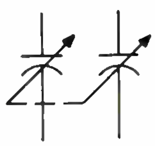
8.1.1 Application: shielded capacitor



8.1.2 Application: adjustable or variable capacitor

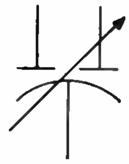
If it is necessary to identify trimmer capacitors, the letter T should appear adjacent to the symbol.

8.1.3 Application: adjustable or variable capacitors with mechanical linkage of units

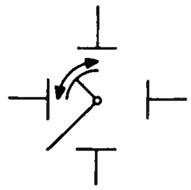


8.2 Continuously adjustable or variable differential capacitor

The capacitance of one part increases as the capacitance of the other part decreases.

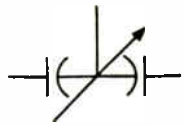


8.2.1 Phase-shifter capacitor

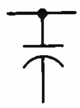


8.3 Split-stator capacitor

The capacitances of both parts increase simultaneously.



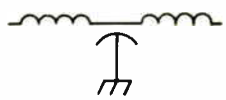
8.4 Shunt capacitor



8.5 Feed-through capacitor (with terminals shown on feed-through element)

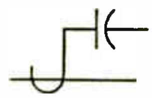
Commonly used for bypassing high-frequency currents to chassis.

8.5.1 Application: feed-through capacitor between 2 inductors with third lead connected to chassis

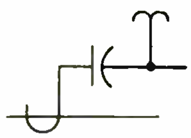


Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

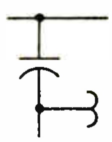
8.6 Capacitance bushing for circuit breaker or transformer



8.6.1 Application: capacitance-bushing potential device



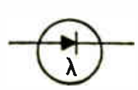
8.7 Application: coupling-capacitor potential device



9. CELL, PHOTOSENSITIVE (Semiconductor)
See also PHOTOTUBE (item 64.11.6).

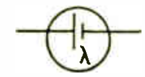
λ indicates that the primary characteristic of the element within the circle is designed to vary under the influence of light.

9.1 Asymmetrical photoconductive transducer (resistive)
This arrowhead shall be solid.



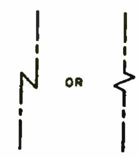
9.2 Symmetrical photoconductive transducer; selenium cell

9.3 Photovoltaic transducer; barrier photocell; blocking-layer cell



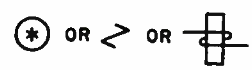
10. CHASSIS
FRAME
(See also GROUND (item 28)
The chassis or frame is not necessarily at ground potential.

11. COIL, BLOWOUT[1]



12. COIL, OPERATING
See also INDUCTOR; WINDING (item 31).

Note 3—The asterisk is not a part of the symbol. Always replace the asterisk by a device designation.



* SEE NOTE 3

13. CONNECTION, MECHANICAL
MECHANICAL INTERLOCK
The preferred location of the mechanical connection is as shown in the various applications, but other locations may be equally acceptable.

13.1 Mechanical connection (*short dashes*)

13.2 Mechanical connection or interlock with fulcrum (*short dashes*)

13.3 Mechanical interlock, other

INDICATE BY A NOTE

[1] The broken line - — - indicates where line connection to a symbol is made and is not a part of the symbol.

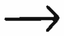
Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

14. CONNECTOR DISCONNECTING DEVICE

The connector symbol is not an arrowhead. It is larger and the lines are drawn at a 90-degree angle.

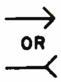
14.1 Female contact

14.2 Male contact



14.3 Connector assembly, movable or stationary portion; jack, plug, or receptacle

Note 4—Use appropriate number of contact symbols.

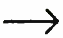


SEE NOTE 4

14.3.1 Commonly used for a jack or receptacle (usually stationary)

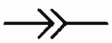
SEE NOTE 4 OR

14.3.2 Commonly used for a plug (usually movable)



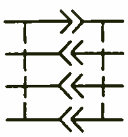
SEE NOTE 4 OR

14.4 Separable connectors (engaged)

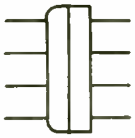


SEE NOTE 4 OR

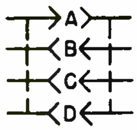
14.4.1 Application: engaged 4-conductor connectors; the plug has 1 male and 3 female contacts



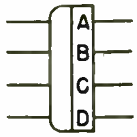
OR



14.4.2 Application: engaged 4-conductor connectors; the plug has 1 male and 3 female contacts with individual contact designations shown in the complete-symbol column



OR

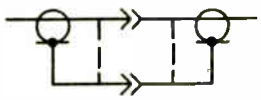


14.5 Coaxial connectors

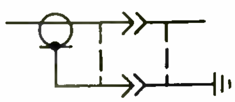
14.5.1 Engaged coaxial connectors

Coaxial recognition sign may be added if necessary. See PATH, TRANSMISSION (items 43.1 and 43.8.2).

14.5.1.1 If it is necessary to show that the outside conductor is carried through



14.5.1.2 If coaxial is connected to a single conductor



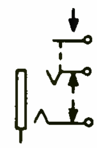
14.6 Communication switchboard-type connector

14.6.1 2-conductor (jack)

14.6.2 2-conductor (plug)

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

14.6.3 3-conductor (jack) with 2 break contacts (normals) and 1 auxiliary make contact



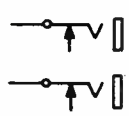
14.6.4 3-conductor (plug)

14.7 Communication switchboard-type connector with circuit normalled through

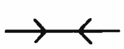
"Normalled" indicates that a through circuit may be interrupted by an inserted connector. As shown here, the inserted connector opens the through circuit and connects to the circuit towards the left.

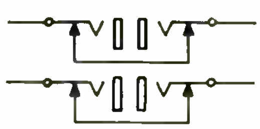
Items 14.7.1 through 14.7.4 show 2-conductor jacks. The "normal" symbol is applicable to other types of connectors.

14.7.1 Jacks with circuit normalled through one way

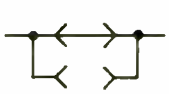


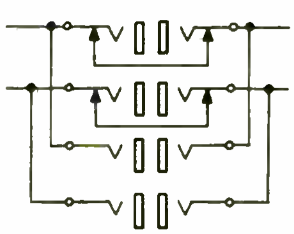
14.7.2 Jacks with circuit normalled through both ways



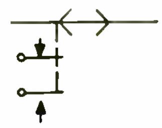


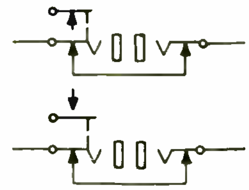
14.7.3 Jacks in multiple, one set with circuit normalled through both ways





14.7.4 Jacks with auxiliary contacts, with circuit normalled through both ways



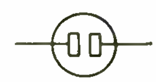


14.8 Connectors of the type commonly used for power-supply purposes (convenience outlets and mating connectors)

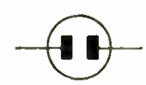
14.8.1 Female contact

14.8.2 Male contact

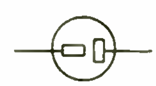
14.8.3 2-conductor nonpolarized connector with female contacts



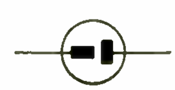
14.8.4 2-conductor nonpolarized connector with male contacts



14.8.5 2-conductor polarized connector with female contacts

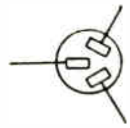


14.8.6 2-conductor polarized connector with male contacts

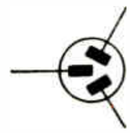


Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

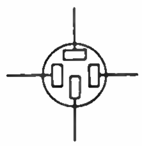
14.8.7 3-conductor polarized connector with female contacts



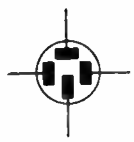
14.8.8 3-conductor polarized connector with male contacts



14.8.9 4-conductor polarized connector with female contacts

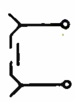


14.8.10 4-conductor polarized connector with male contacts



14.9 Test blocks

14.9.1 Female portion with short-circuiting bar (with terminals shown)



14.9.2 Male portion (with terminals shown)

15. CONTACT, ELECTRIC

For build-ups or forms using electric contacts, see applications under CONNECTOR (item 14), RELAY (item 48), and SWITCH (item 56). See DRAFTING PRACTICES (item 0.2 e).

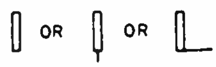
15.1 Fixed contact

15.1.1 Fixed contact for jack, key, relay, etc.

15.1.2 Fixed contact for switch

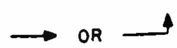
15.1.3 Fixed contact for momentary switch
See SWITCH (items 56.8 and 56.10).

15.1.4 Sleeve



15.2 Moving contact

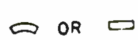
15.2.1 Adjustable or sliding contact for resistor, inductor, etc.



15.2.2 Locking

15.2.3 Nonlocking

15.2.4 Segment; bridging contact
See SWITCH (items 56.12.3 and 56.12.4).



Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

15.2.5 Vibrator reed

15.2.6 Vibrator split reed

15.2.7 Rotating contact (slip ring) and brush

15.3 Basic contact assemblies

The standard method of showing a contact is by a symbol indicating the circuit condition it produces when the actuating device is in the de-energized or nonoperated position. The actuating device may be of a mechanical, electrical, or other nature, and a clarifying note may be necessary with the symbol to explain the proper point at which the contact functions, for example, the point where a contact closes or opens as a function of changing pressure, level, flow, voltage, current, etc. In cases where it is desirable to show contacts in the energized or operated condition and where confusion may result, a clarifying note shall be added to the drawing.

Auxiliary switches or contacts for circuit breakers, safety enclosed trucks, removable circuit-breaker units, housings, enclosures, etc., may be designated as follows:

(a) Closed when device is in energized or operated position,

(b) Closed when device is in de-energized or non-operated position,

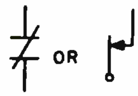
(aa) Closed when operating mechanism of main device is in energized or operated position,

(bb) Closed when operating mechanism of main device is in de-energized or nonoperated position.

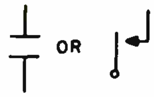
As applied to a removable circuit-breaker unit, (a) is an auxiliary contact that is closed when the unit is in the connected position. As applied to a housing or enclosure, (a) is an auxiliary contact that is closed when the removable circuit-breaker unit is in the connected position. See latest issue of American Standard C37.2 for further details.

In the parallel-line contact symbols shown below, the length of the parallel lines shall be approximately 1¼ times the width of the gap (except for item 15.6).

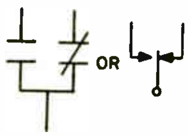
15.3.1 Closed contact (break)



15.3.2 Open contact (make)

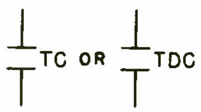


15.3.3 Transfer

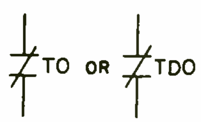


15.3.4 Make-before-break

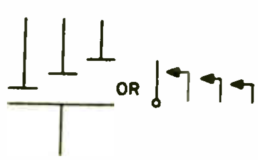
15.4 Application: open contact with time closing (TC or TDC) feature



15.5 Application: closed contact with time opening (TO or TDO) feature



15.6 Time sequential closing



Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

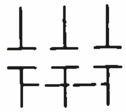
16. CONTACTOR

See also RELAY (item 48)

Fundamental symbols for contacts, coils, mechanical connections, etc., are the basis of contactor symbols and should be used to represent contactors on complete diagrams. Complete diagrams of contactors consist of combinations of fundamental symbols for control coils, mechanical connections, etc., in such configurations as to represent the actual device.

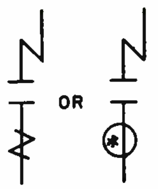
Mechanical interlocking should be indicated by notes.

16.1 Manually operated 3-pole contactor



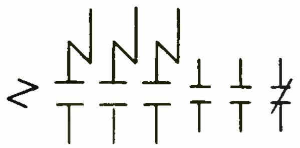
16.2 Electrically operated 1-pole contactor with series blowout coil

Note 5—The asterisk is not a part of the symbol. Always replace the asterisk by a device designation.

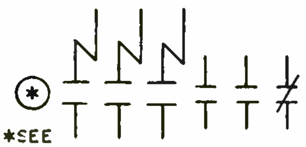


* SEE NOTE 5

16.3 Electrically operated 3-pole contactor with series blowout coils; 2 open and 1 closed auxiliary contacts (shown smaller than the main contacts)

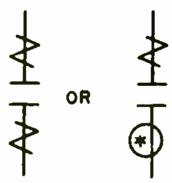


OR



*SEE NOTE 5

16.4 Electrically operated 1-pole contactor with shunt blowout coil



* SEE NOTE 5

17. CORE

17.1 General or air core

If it is necessary to identify an air core, a note should appear adjacent to the symbol of the inductor or transformer.

NO SYMBOL

17.2 Magnetic core of inductor or transformer

Not to be used unless it is necessary to identify a magnetic core.

See INDUCTOR (item 31.2) and TRANSFORMER (item 63.2).

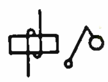
17.3 Core of magnet or relay

For use if representation of the core is necessary.

See MAGNET, PERMANENT (item 36) and RELAY (items 48.2 to 48.4 and 48.6, 48.7).

18. COUNTER, ELECTROMAGNETICALLY OPERATED MESSAGE REGISTER

18.1 General



18.2 With a make contact

19. COUPLER, DIRECTIONAL

Commonly used in coaxial and waveguide diagrams.

The arrows indicate the direction of power flow.

Number of coupling paths, type of coupling, and transmission loss may be indicated.

19.1 General

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

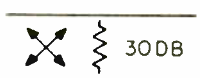
19.2 Applications

19.2.1 *E*-plane aperture coupling, 30-decibel transmission loss

19.2.2 Loop coupling, 30-decibel transmission loss

19.2.3 Probe coupling, 30-decibel transmission loss

19.2.4 Resistance coupling, 30-decibel transmission loss



20. COUPLING

Commonly used in coaxial and waveguide diagrams.

20.1 Coupling by aperture with an opening of less than full waveguide size

Transmission loss may be indicated.

Note 6—The asterisk is not a part of the symbol. Always replace the asterisk by E, H, or HE, depending on the type of coupling.

E indicates that the physical plane of the aperture is perpendicular to the transverse component of the major *E* lines.

H indicates that the physical plane of the aperture is parallel to the transverse component of the major *E* lines.

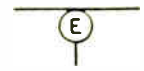
HE indicates coupling by all other kinds of apertures.

* SEE NOTE 6

20.1.1 Application: *E*-plane coupling by aperture to space

20.1.2 Application: *E*-plane coupling by aperture; 2 ends of transmission path available

20.1.3 Application: *E*-plane coupling by aperture; 3 ends of transmission path available

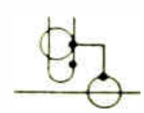


20.1.4 Application: *E*-plane coupling by aperture; 4 ends of transmission path available

20.2 Coupling by loop to space

20.2.1 Coupling by loop to guided transmission path

20.2.2 Application: coupling by loop from coaxial to circular waveguide with direct-current grounds connected

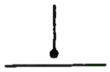


20.3 Coupling by probe to space

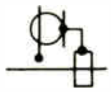
See OPEN CIRCUIT (item 59.2).

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

20.3.1 Application: coupling by probe to a guided transmission path



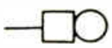
20.3.2 Application: coupling by probe from coaxial to rectangular waveguide with direct-current grounds connected



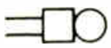
21. DEVICE, AUDIBLE SIGNALING

21.1 Bell, general; telephone ringer

Note 7—If specific identification is required, the abbreviation AC or DC may be added within the square.

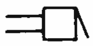


SEE NOTE 7



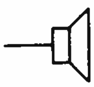
21.2 Buzzer

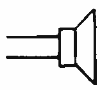
SEE NOTE 7



21.3 Horn; howler; loudspeaker; siren

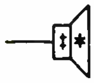
21.3.1 General

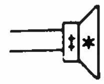




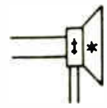
21.3.2 If specific identification of loudspeaker parts is required, the following letter combinations may be added. The * and ‡ are not part of the symbol.

*HN Horn
*HW Howler
*LS Loudspeaker
*SN Siren
‡EM Electromagnetic with moving coil (moving coil leads should be identified)
‡EMN Electromagnetic with moving coil and neutralizing winding (moving coil leads should be identified)
‡MG Magnetic armature
‡PM Permanent magnet with moving coil



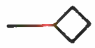


OR



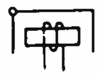
22. DEVICE, VISUAL SIGNALING

22.1 Annunciator, general

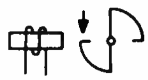


OR

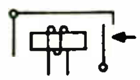
22.1.1 Annunciator drop or signal, shutter or grid type



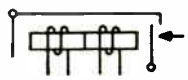
22.1.2 Annunciator drop or signal, ball type



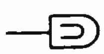
22.1.3 Manually restored drop



22.1.4 Electrically restored drop



22.2 Communication switchboard-type lamp



22.3 Indicating, pilot, signaling, or switchboard light

See also GLOW LAMP (item 33.3).

22.3 cont. on p. 980

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

If confusion with other circular symbols may occur, the D-shaped symbol should be used.

Note 8—To indicate the following characteristics, the specified letter or letters may be inserted within or placed adjacent to the D-shaped symbol.

A Amber	G Green	OP Opalescent	W White
B Blue	NE Neon	P Purple	Y Yellow
C Clear	O Orange	R Red	

Note 9—The asterisk is not part of the circular symbol. Always add the letter or letters specified in Note 8 within or adjacent to the circle. To avoid confusion with meter or basic relay symbols, add suffix L or IL to the above letter or letters; for example, RL or RIL placed within or adjacent to the circle.

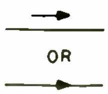
SEE NOTE 8 * SEE NOTE 9

22.3.1 Application: green signal light

23. DIRECTION OF FLOW OF POWER, SIGNAL, OR INFORMATION

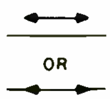
23.1 One-way

Note 10—The lower symbol is used if it is necessary to conserve space. *The arrowhead in the lower symbol shall be filled.*



SEE NOTE 10

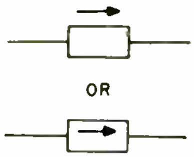
23.2 Both ways



SEE NOTE 10

23.3 Application: one-way circuit element, general

Note 11—In all cases indicate the type of apparatus by appropriate words or letters in the rectangle.



SEE NOTE 11

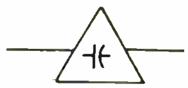
24. DISCONTINUITY

A component that exhibits throughout the frequency range of interest the properties of the type of circuit element indicated by the symbol within the triangle.

Commonly used for coaxial and waveguide transmission.

24.1 Equivalent series element, general

24.1.1 Capacitive reactance



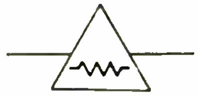
24.1 2 Inductive reactance

24.1.3 Inductance-capacitance circuit with infinite reactance at resonance

24.1.4 Inductance-capacitance circuit with zero reactance at resonance

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

24.1.5 Resistance



24.2 Equivalent shunt element, general

24.2.1 Capacitive susceptance

24.2.2 Conductance

24.2.3 Inductive susceptance

24.2.4 Inductance-capacitance circuit with infinite susceptance at resonance

24.2.5 Inductance-capacitance circuit with zero susceptance at resonance

25. ELEMENT, CIRCUIT (General)

Note 12—The asterisk is not a part of the symbol. Always indicate the type of apparatus by appropriate words or letters in the rectangle.

* SEE NOTE 12

25.1 Accepted abbreviations in the latest edition of American Standard Z32.13 may be used in the rectangle.

25.2 The following letter combinations may be used in the rectangle.

CB	Circuit breaker	NET	Network
DIAL	Telephone dial	PS	Power supply
EQ	Equalizer	RU	Reproducing unit
FAX	Facsimile set		
FL	Filter	RG	Recording unit
FL-BE	Filter, band elimination	TEL	Telephone station
FL-BP	Filter, band pass	TPR	Teleprinter
FL-HP	Filter, high pass	TTY	Teletypewriter
FL-LP	Filter, low pass		

25.3 Additional letter combinations as follows may be employed, but the use of specific graphical symbols included elsewhere in this standard is preferred.

AR	Amplifier	OSC	Oscillator
AT	Attenuator	PAD	Pad
C	Capacitor	P	Plug
HS	Handset	HT	Receiver, headset
I	Indicating or switchboard lamp	K	Relay
		R	Resistor
L	Inductor	S	Switch or key switch
LS	Loudspeaker		
J	Jack	T	Transformer
MIC	Microphone	WR	Wall receptacle

26. ELEMENT, THERMAL

Thermomechanical transducer

26.1 Actuating device

26.1 cont. on p. 982

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

26.1, *cont.* May be either self or externally heated.

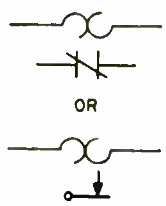
Note 13—Use appropriate number of single-line diagram symbols.

SEE NOTE 13

26.2 Thermal cutout; flasher

SEE NOTE 13

26.3 Thermal relay

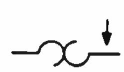


26.4 Thermostat

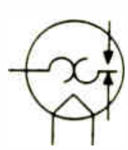
Ambient-temperature-operated device.

26.4.1 With break contact

26.4.2 With make contact



26.4.3 With integral heater and transfer contacts



27. FUSE

SEE NOTE 14

Note 14—Use appropriate number of single-line diagram symbols.

27.1 Fusible element

SEE NOTE 14

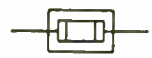
27.2 High-voltage primary fuse cutout, dry

OR

SEE NOTE 14

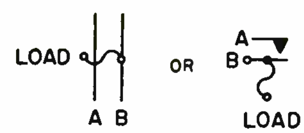
27.3 High-voltage primary fuse cutout, oil

OR



SEE NOTE 14

27.4 With alarm contact
When fuse blows, alarm bus A is connected to power bus B. Letters are for explanation and are not part of the symbol.



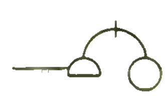
28. GROUND

See also CHASSIS; FRAME (item 10).

29. HANDSET
OPERATOR'S SET

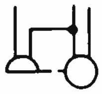
29.1 General

29.2 With push-to-talk switch

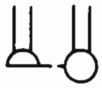


Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

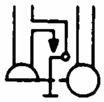
29.3 3-conductor handset



29.4 4-conductor handset



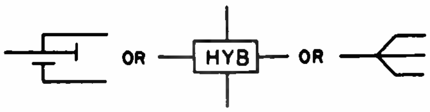
29.5 4-conductor handset with push-to-talk switch



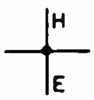
29.6 Operator's set

30. HYBRID

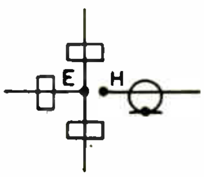
30.1 Hybrid, general



30.2 Hybrid, junction
Commonly used in coaxial and waveguide transmission.



30.3 Application: rectangular waveguide and coaxial coupling

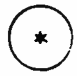


30.4 Hybrid, circular (basic)

Note 15—The asterisk is not a part of the symbol. Always replace the asterisk by E, H, or HE. E indicates that there is a principal E transverse field in the plane of the ring. H indicates that there is a principal H transverse field in the plane of the ring. HE shall be used for all other cases.

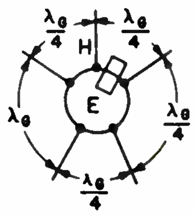
An arm that has coupling of a different type from that designated above shall be marked according to COUPLING (item 20.1).

Critical distances should be labeled in terms of guide wavelengths.



* SEE NOTE 15

30.4.1 Application: 5-arm circular hybrid with principal coupling in the *E* plane and with 1-arm *H* coupling using rectangular waveguide

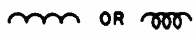


31. INDUCTOR WINDING

See also TERMINATION (item 59.5).

31.1 General

Either symbol may be used in the following subparagraphs.



31.2 If it is desired especially to distinguish magnetic-core inductors

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

31.3 Tapped

31.4 Application: adjustable inductor

31.5 Application: adjustable or continuously adjustable inductor

31.6 Shunt inductor

31.7 Saturable-core inductor (reactor)

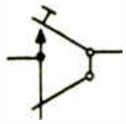
Polarity marks may be added to direct-current winding.

Explanatory words and arrow are not part of the symbol shown.

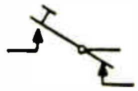
32. KEY, TELEGRAPH

32.1 Simple

32.2 Simple with shorting switch



32.3 Open circuit or pole changing



33. LAMP

33.1 Ballast lamp; ballast tube

The primary characteristic of the element within the circle is designed to vary nonlinearly with the temperature of the element.

33.2 Fluorescent lamp

33.2.1 2-terminal

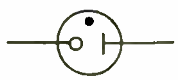
33.2.2 4-terminal

33.3 Glow lamp; cold-cathode lamp; neon lamp

33.3.1 Alternating-current type

33.3.2 Direct-current type

See also TUBE, ELECTRON (item 64.11.5.1)



33.4 Incandescent-filament illuminating lamp

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

33.5 Indicating lamp; switchboard lamp

See DEVICE, VISUAL SIGNALING (item 22).

34. LIMITER FOR POWER CABLE, CURRENT

The arrowheads in this case are filled.

Note 16—Use appropriate number of single-line diagram symbols.

SEE NOTE 16

35. MACHINE, ROTATING

35.1 Basic

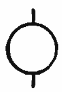
35.2 Generator, general

35.3 Motor, general

35.4 Motor, multispeed

USE BASIC MOTOR SYMBOL AND NOTE SPEEDS

35.5 Rotating armature with commutator and brushes[1]



35.6 Wound rotor

35.7 Field, generator or motor

Either symbol of item 31.1 may be used in the following subparagraphs.

[1] The broken line – — – indicates where line connection to a symbol is made and is not a part of the symbol.

35.7.1 Compensating or commutating

35.7.2 Series

35.7.3 Shunt, or separately excited

35.7.4 Permanent magnet

35.8 Winding symbols

Motor and generator winding symbols may be shown in the basic circle using the following representations.

35.8.1 1-phase

35.8.2 2-phase

35.8.3 3-phase wye (ungrounded)

35.8.4 3-phase wye (grounded)

35.8.5 3-phase delta

35.8.6 6-phase diametrical

35.8.7 6-phase double-delta

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

35.9 Direct-current machines; applications

35.9.1 Separately excited direct-current generator or motor[1]

35.9.2 Separately excited direct-current generator or motor with commutating and/or compensating field winding[1]

35.9.3 Compositely excited direct-current generator or motor with commutating and/or compensating field winding[1]

35.9.4 Direct-current series motor or 2-wire generator[1]

35.9.5 Direct-current series motor or 2-wire generator with commutating and/or compensating field winding[1]

35.9.6 Direct-current shunt motor or 2-wire generator[1]

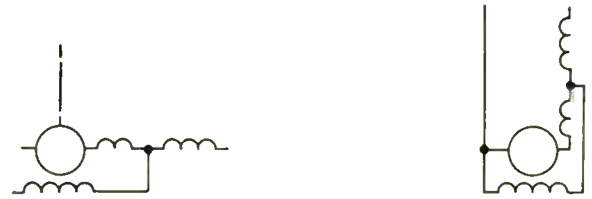
[1]The broken line – — – indicates where line connection to a symbol is made and is not a part of the symbol.

35.9.7 Direct-current shunt motor or 2-wire generator with commutating and/or compensating field winding[1]

35.9.8 Direct-current permanent-magnet-field generator or motor[1]

35.9.9 Direct-current compound motor or 2-wire generator or stabilized shunt motor[1]

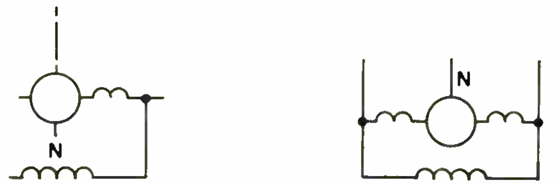
35.9.10 Direct-current compound motor or 2-wire generator or stabilized shunt motor with commutating and/or compensating field winding[1]



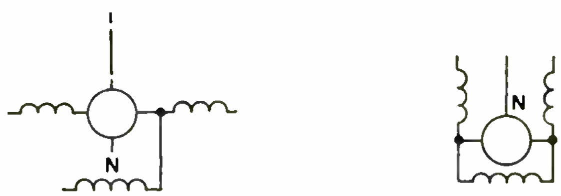
35.9.11 Direct-current 3-wire shunt generator[1]

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

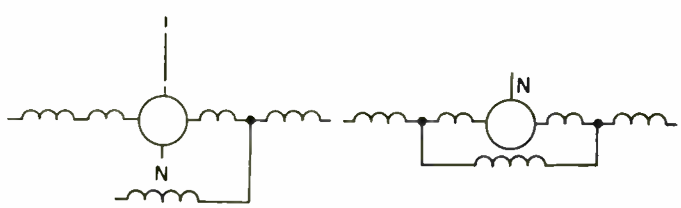
35.9.12 Direct-current 3-wire shunt generator with commutating and/or compensating field winding[1]



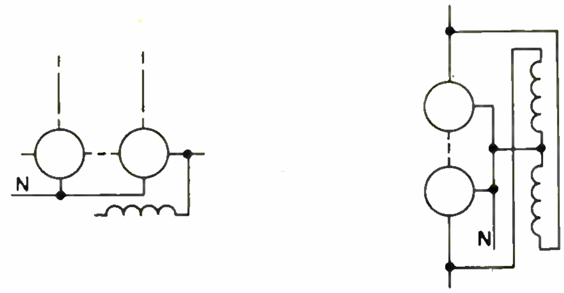
35.9.13 Direct-current 3-wire compound generator[1]



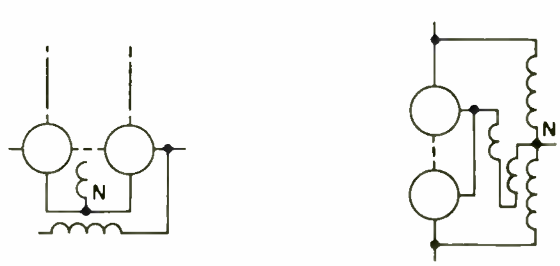
35.9.14 Direct-current 3-wire compound generator with commutating and/or compensating field winding[1]



35.9.15 Direct-current balancer, shunt wound[1]



35.9.16 Direct-current balancer, compound wound[1]



[1] The broken line - - - - indicates where line connection to a symbol is made and is not a part of the symbol.

35.9.17 Dynamotor[1]

35.9.18 Double-current generator[1]

35.9.19 Acyclic generator (separately excited)[1]

35.9.20 Regulating generator (rotary amplifier) shunt wound with short-circuited brushes[1]

35.9.21 Regulating generator (rotary amplifier) shunt wound without short-circuited brushes[1]

35.9.22 Regulating generator (rotary amplifier) shunt

35.9.22 cont. on p. 988

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

35.11.3 Synchronous motor, generator, or condenser with both ends of each phase brought out[1]

35.11.4 Double-winding synchronous generator, motor, or condenser[1]

35.11.5 Synchronous-synchronous frequency changer[1]

35.11.6 Synchronous induction frequency changer[1]

35.12 Alternating- and direct-current composite machines; applications

35.12.1 Synchronous or regulating-pole converter[1]

[1] The broken line – — – indicates where line connection to a symbol is made and is not a part of the symbol.

35.12.2 Synchronous booster or regulating-pole converter with commutating and/or compensating field windings[1]

35.12.3 Synchronous shunt-wound converter with commutating and/or compensating windings[1]

35.12.4 Synchronous converter compound wound with commutating and/or compensating field windings[1]

35.12.5 Motor converter[1]

36. MAGNET, PERMANENT

PM

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

37. METER INSTRUMENT

Note 17—The asterisk is not a part of the symbol. Always replace the asterisk by one of the following letter combinations, depending on the function of the meter or instrument, unless some other identification is provided in the circle and explained on the diagram.

A	Ammeter
AH	Ampere-hour meter
CMA	Contact-making (or breaking) ammeter
CMC	Contact-making (or breaking) clock
CMV	Contact-making (or breaking) voltmeter
CRO	Oscilloscope or cathode-ray oscillograph
D	Demand meter
DB	DB (decibel) meter
DBM	DBM (decibels referred to 1 milliwatt) meter
DTR	Demand-totalizing relay
F	Frequency meter
G	Galvanometer
GD	Ground detector
I	Indicating
M	Integrating
μA or UA	Microammeter
MA	Milliammeter
N	Noise meter
OHM	Ohmmeter
OP	Oil pressure
OSCG	Oscillograph, string
PH	Phase meter
PI	Position indicator
PF	Power-factor meter
RD	Recording demand meter
REC	Recording
RF	Reactive-factor meter
S	Synchroscope
TLM	Telemeter
T	Temperature meter
TT	Total time
VH	Varhour meter
V	Voltmeter
VA	Volt-ammeter
VAR	Varmeter
VI	Volume indicator
VU	Standard volume indicator
W	Wattmeter
WH	Watthour meter

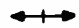
* SEE NOTE 17

38. MICROPHONE

39. MOTION, MECHANICAL

39.1 Translation, one direction

39.2 Translation, both directions



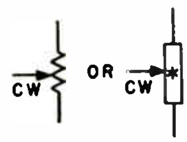
39.3 Rotation, one direction

39.4 Rotation, both directions

39.5 Rotation designation (applied to a resistor)

CW indicates position of adjustable contact at the limit of clockwise travel viewed from knob or actuator end unless otherwise indicated.

Note 18—The asterisk is not a part of the symbol. Always add identification within or adjacent to the rectangle.

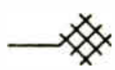


* SEE NOTE 18

40. NETWORK

40.1 General

40.2 Network, low-voltage power



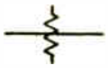
Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

41. OSCILLATOR GENERALIZED ALTERNATING-CURRENT SOURCE

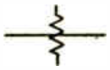
42. PAD

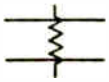
See also ATTENUATOR (item 5)

42.1 General

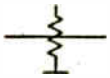


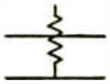
42.2 Balanced, general





42.3 Unbalanced, general





43. PATH, TRANSMISSION CONDUCTOR CABLE WIRING

43.1 Guided path, general

A single line represents the entire group of conductors or the transmission path needed to guide the power or the signal. For coaxial and waveguide work, the recognition symbol is used at the beginning and end of each kind of transmission path and at intermediate points as needed for clarity. In waveguide work, mode may be indicated.

43.2 Conductive path or conductor; wire

43.3 Air or space path

43.4 Dielectric path other than air

Commonly used for coaxial and waveguide transmission.

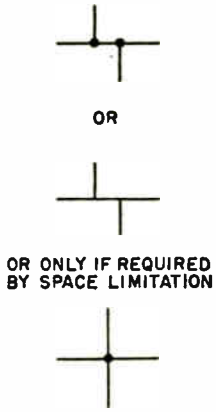
43.5 Crossing of paths or conductors not connected
The crossing is not necessarily at a 90-degree angle.

43.6 Junction of paths or conductors

43.6.1 Junction (if desired)

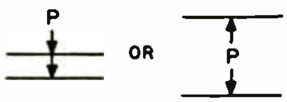
43.6.1.1 Application: junction of different-size cables

43.6.2 Junction of connected paths, conductors, or wires



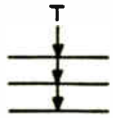
43.7 Associated conductors

43.7.1 Pair (twisted unless otherwise specified)

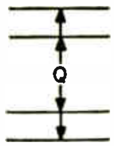


Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

43.7.2 Triple (twisted unless otherwise specified)



43.7.3 Quad



43.8 Assembled conductors; cable

Commonly used in communication diagrams.

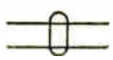
43.8.1 Shielded single conductor

43.8.2 Coaxial cable

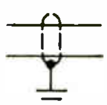
Coaxial transmission path

See note under item 43.1.

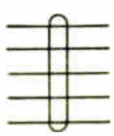
43.8.3 2-conductor cable



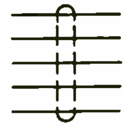
43.8.4 Shielded 2-conductor cable with shield grounded



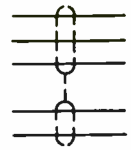
43.8.5 5-conductor cable



43.8.6 Shielded 5-conductor cable



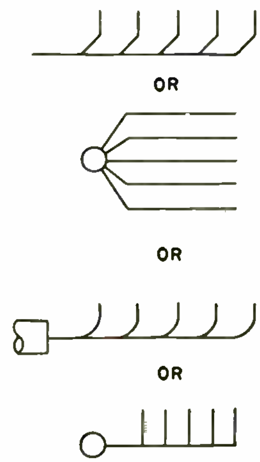
43.8.6.1 Shielded 5-conductor cable with conductors separated on the diagram for convenience



43.8.7 Cable underground or in conduit (*long dashes*)

43.8.8 Grouping of leads

Normally, bend of line indicates direction of conductor joining cable.

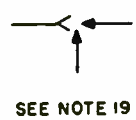


43.9 Alternate or conditional wiring

Not commonly used on power diagrams.

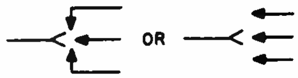
The arrowheads in this case shall be solid.

Note 19—A note shall explain the connections.



Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

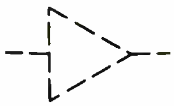
43.9.1 Application: 3 alternate paths

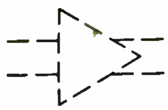


SEE NOTE 19

43.10 Associated or future (*short dashes*)

43.10.1 Application: associated or future amplifier



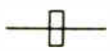


43.11 Waveguide

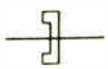
See note in item 43.1.

43.11.1 Circular

43.11.2 Rectangular

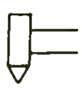


43.11.3 Ridged



44. PICKUP (mechanoelectric)

Note 20—Suitable words or abbreviations may be written within or adjacent to the rectangle.

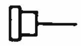


SEE NOTE 20

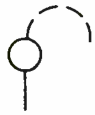
45. RECEIVER, TELEPHONE
EARPHONE
HEARING AID RECEIVER

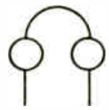
See also HANDSET (item 29).

45.1 General

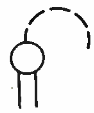


45.2 Headset, double





45.3 Headset, single

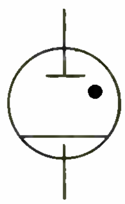


46. RECTIFIER

46.1 Electron-tube rectifier

See TUBE, ELECTRON (item 64).

46.1.1 Pool-type-cathode power rectifier

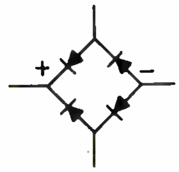


46.2 Metallic rectifier; asymmetrical varistor; crystal diode; electrolytic rectifier

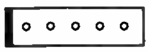
Arrow shows direction of forward (easy) current as indicated by direct-current ammeter.
The arrowhead in this case shall be filled.

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

46.2.1 Full-wave bridge type

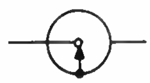


46.3 On connection or wiring diagrams, rectifier may be shown with terminals and polarity marking. Heavy line may be used to indicate nameplate or positive polarity end.



FOR CONNECTION OR WIRING DIAGRAM

47. REGULATOR, SPEED (Contact-making governor) Contacts open or closed as required; (shown here as closed).



48. RELAY

See also CONTACTOR (item 16)

Fundamental symbols for contacts, mechanical connections, coils, etc., are the basis of relay symbols and should be used to represent relays on complete diagrams.

The following letter combinations may be used with any relay symbol. The requisite number of these combinations may be used when a relay possesses more than one special feature.

- AC Alternating-current or ringing relay
- D Differential
- DB Double biased (biased in both directions)
- DP Dashpot
- EP Electrically polarized
- †FO Fast operate
- †FR Fast release
- MG Marginal
- NB No bias
- NR Nonreactive
- P Magnetically polarized using biasing spring, or having magnet bias
- SA Slow operate and slow release
- SO Slow operate
- SR Slow release
- SW Sandwich wound to improve balance to longitudinal currents

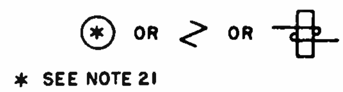
† Used where unusually fast operation or fast releasing is essential to the circuit operation.

The proper poling for a polarized relay shall be shown by the use of + and − designations applied to the winding leads. The interpretation of this shall be that current in the direction indicated shall move or tend to move the armature toward the contact shown nearest the core on the diagram. If the relay is equipped with numbered terminals, the proper terminal numbers shall also be shown.

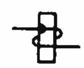
48.1 Basic

48.2 Relay coil

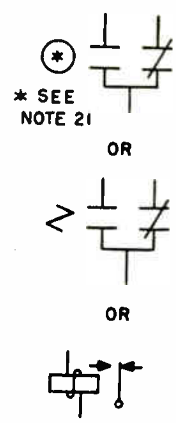
Note 21—The asterisk is not a part of the symbol. Always replace the asterisk by a device designation.



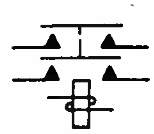
48.2.1 Semicircular dot indicates inner end of winding



48.3 Application: relay with transfer contacts

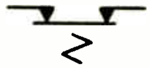


48.4 Application: 2-pole double-make

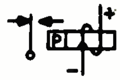


Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

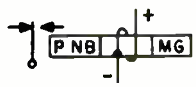
48.5 Application: 1-pole double-break



48.6 Application: polarized relay with transfer contacts



48.7 Application: polarized (no bias) marginal relay with transfer contacts



48.8 Relay protective functions

The following symbols may be used to indicate protective functions, or device-function numbers (see latest edition of American Standard C37.2) may be placed in the circle or adjacent to the basic symbol.

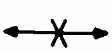
48.8.1 Over, general

48.8.2 Under, general

48.8.3 Direction, general; directional over

48.8.4 Balance, general

48.8.5 Differential, general



48.8.6 Pilot wire, general

48.8.7 Carrier current, general

48.8.8 Operating quantity

The operating quantity is indicated by the following letters or symbols placed either on or above the center of the relay protective-function symbols shown above.

C *Current	GP Gas pressure	S Synchronism
Z Distance	ϕ Phase	T Temperature
F Frequency	W Power	V Voltage

* The use of the letter may be omitted in the case of current and the absence of such letter presupposes that the relay operates on current.

48.8.9 Ground relays

Relays operative on residual current only are so designated by attaching the ground symbol to the relay protective-function symbol. Note that the zero phase-sequence designation given below may be used instead when desirable.

48.8.10 Phase sequence quantities

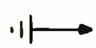
Operation on phase-sequence quantities may be indicated by the use of the conventional subscripts 0, 1, and 2 after the letter indicating the operating quantity.

48.8.11 Application

48.8.11.1 Overcurrent

48.8.11.2 Directional overcurrent

48.8.11.3 Directional residual overcurrent



Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

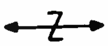
48.8.11.4 Undervoltage

48.8.11.5 Power directional

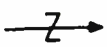
48.8.11.6 Balanced current

48.8.11.7 Differential current

48.8.11.8 Distance

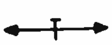


48.8.11.9 Directional distance

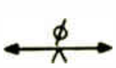


48.8.11.10 Overfrequency

48.8.11.11 Overtemperature



48.8.11.12 Phase balance



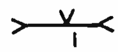
48.8.11.13 Phase rotation

48.8.11.14 Pilot wire, differential current

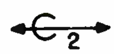
48.8.11.15 Pilot wire, directional comparison

48.8.11.16 Carrier pilot

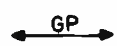
48.8.11.17 Positive phase sequence undervoltage



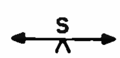
48.8.11.18 Negative phase sequence overcurrent



48.8.11.19 Gas-pressure relay, Bucholz

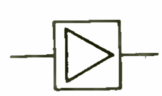


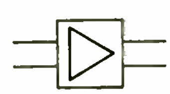
48.8.11.20 Out of step



49. REPEATER

49.1 1-way repeater
Triangle points in the direction of transmission.





Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

49.2 2-wire 2-way repeater

49.2.1 2-wire 2-way repeater with low-frequency bypass

49.3 4-wire 2-way repeater

50. RESISTOR

See also TERMINATION (item 59).

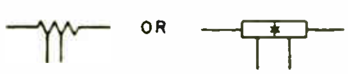
For resistors with nonlinear characteristics, see BALLAST LAMP (item 33.1), THERMISTOR (item 60), and VARISTOR (item 66).

Note 22—The asterisk is not a part of the symbol. Always add identification within or adjacent to the rectangle.

50.1 General

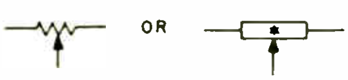
* SEE NOTE 22

50.2 Tapped resistor



* SEE NOTE 22

50.3 Application: with adjustable contact



* SEE NOTE 22

50.4 Application: adjustable or continuously adjustable (variable) resistor

* SEE NOTE 22

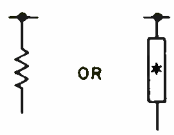
50.5 Heating resistor

* SEE NOTE 22

50.6 Instrument or relay shunt

Connect instrument or relay to terminals in the box.

50.7 Shunt resistor



* SEE NOTE 22

51. RESONATOR

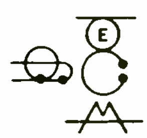
Excluding piezoelectric and magnetostriction devices.

51.1 General

Commonly used for coaxial and waveguide transmission.

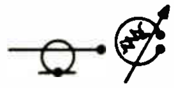
51.2 Applications

51.2.1 Resonator with mode suppression coupled by an *E*-plane aperture to a guided transmission path and by a loop to a coaxial path.

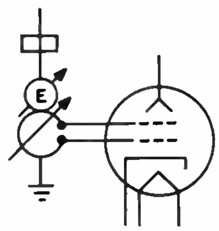


Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

51.2.2 Tunable resonator having adjustable Q coupled by a probe to a coaxial system.



51.2.3 Tunable resonator with direct-current ground connected to an electron device and adjustably coupled by an E-plane aperture to a rectangular waveguide.



52. SHIELD

SHIELDING (*short dashes*)

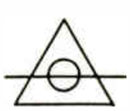
Normally used for electric or magnetic shielding. When used for other shielding, a note should so indicate. For typical applications see:
CAPACITOR (item 8.1.1)
PATH, TRANSMISSION (items 43.8.1, 43.8.4, and 43.8.6)
TRANSFORMER (items 63.2.1 and 63.2.2)
TUBE, ELECTRON (item 64.7)

53. SHIFTER, PHASE

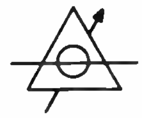
For power circuits see MACHINE, ROTATING (items 35.10.17 and 35.10.18).

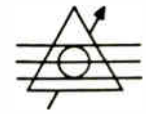
53.1 General

53.2 3-wire or 3-phase

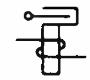


53.2.1 Application: adjustable





54. SOUNDER, TELEGRAPH



55. SUPPRESSION, MODE

Commonly used in coaxial and waveguide transmission.

56. SWITCH

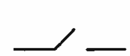
See also FUSE (item 27); CONTACT, ELECTRIC (item 15); and DRAFTING PRACTICES (item 0.2, paragraphs (e) and (g)).

Fundamental symbols for contacts, mechanical connections, etc., may be used for switch symbols.

The standard method of showing switches is in a position with no operating force applied. For switches that may be in any one of two or more positions with no operating force applied and for switches actuated by some mechanical device (as in air-pressure, liquid-level, rate-of-flow, etc., switches), a clarifying note may be necessary to explain the point at which the switch functions.

When the basic switch symbols in items 56.1 through 56.4 are shown on a diagram in the closed position, terminals must be added for clarity.

56.1 Single throw, general



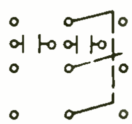
Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

56.2 Double throw, general

56.2.1 Application: 2-pole double-throw switch with terminals shown

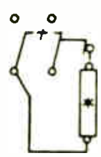
56.3 Knife switch, general

56.3.1 Application: 3-pole double-throw knife switch with auxiliary contacts and terminals



56.3.2 Application: 2-pole field-discharge knife switch with terminals and discharge resistor

Note 23—The asterisk is not a part of the symbol. Always add identification within or adjacent to the rectangle.



* SEE NOTE 23

56.4 Switch with horn gap

56.5 Sector switch

56.6 Push button, momentary or spring return

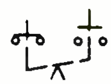
56.6.1 Circuit closing (make)

56.6.2 Circuit opening (break)

56.6.3 Two-circuit

56.7 Push button, maintained or not spring return

56.7.1 Two circuit



56.8 Switch, nonlocking; momentary or spring return

The symbols to the left are commonly used for spring buildups in key switches, relays, and jacks.

The symbols to the right are commonly used for toggle switches.

56.8.1 Circuit closing (make)

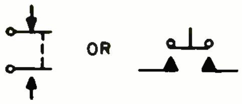
 OR 

56.8.2 Circuit opening (break)

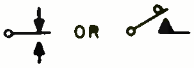
 OR 

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

56.8.3 Two-circuit



56.8.4 Transfer



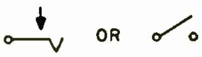
56.8.5 Make-before-break

56.9 Switch, locking

The symbols to the left are commonly used for spring buildups in key switches, relays, and jacks.

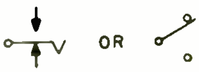
The symbols to the right are commonly used for toggle switches.

56.9.1 Circuit closing (make)

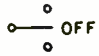


56.9.2 Circuit opening (break)

56.9.3 Transfer, 2-position



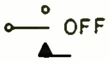
56.9.4 Transfer, 3-position



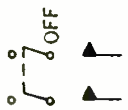
56.9.5 Make-before-break

56.10 Switch, combination locking and nonlocking
See also item 56.11.
Commonly used for toggle-switches.

56.10.1 3-position 1-pole: circuit closing (make), off, momentary circuit closing (make)



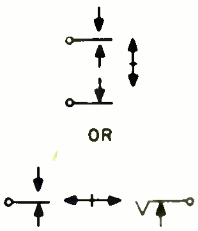
56.10.2 3-position 2 pole: circuit closing (make), off, momentary circuit closing (make)



56.11 Switch, key-type, applications

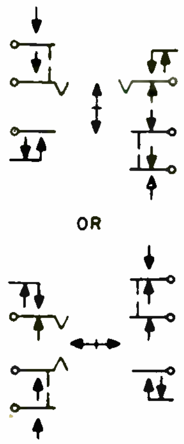
56.11.1 2-position with locking transfer and break contacts

56.11.2 3-position with nonlocking transfer and locking break contacts

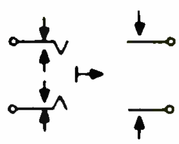


Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

56.11.3 3-position, multicontact combination



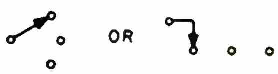
56.11.4 2-position, half of key switch normally operated, multicontact combination



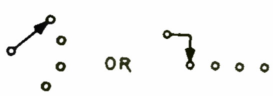
56.12 Selector or multiposition switch

The position in which the switch is shown may be indicated by a note or designation of switch position.

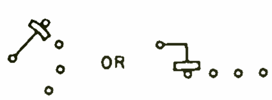
56.12.1 General (for power and control diagrams)
Any number of transmission paths may be shown.



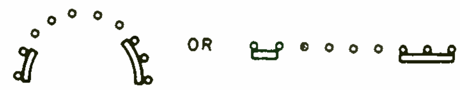
56.12.2 Break-before-make, nonshorting (nonbridging) during contact transfer



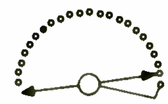
56.12.3 Make-before-break, shorting (bridging) during contact transfer



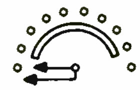
56.12.4 Segmental contact



56.12.5 22-point selector switch

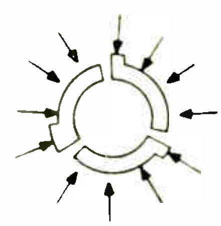


56.12.6 10-point selector switch with fixed segment

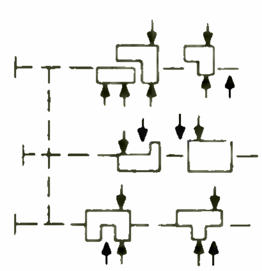


56.12.7 Wafer, 3-pole 3-circuit with 2 nonshorting and 1 shorting moving contacts
Viewed from end opposite control knob or actuator unless otherwise indicated.
For more than one section, section No. 1 is nearest control knob.

When contacts are on both sides, front contacts are nearest control knob.



56.12.8 Slide switch, typical ladder-type interlock
In the example, one slide is shown operated.
Slides are shown in released position unless otherwise noted.



Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

56.12.9 Master or control switch

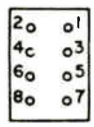
A table of contact operation must be shown on the diagram. A typical table is shown below.

DETACHED CONTACTS SHOWN ELSEWHERE ON DIAGRAM

CONTACT	POSITION A	B	C
1-2			X
3-4	X		
5-6			X
7-8	X		

X INDICATES CONTACT CLOSED

HANDLE END



FOR CONNECTION OR WIRING DIAGRAM

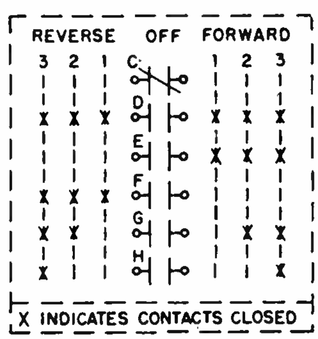
56.12.10 Master or control switch

(Cam-operated contact assembly) 6-circuit 3-point reversing switch.

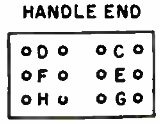
A table of contact operation must be shown on the diagram. A typical table is shown below.

Tabulate special features in note.

DETACHED CONTACTS SHOWN ELSEWHERE ON DIAGRAM

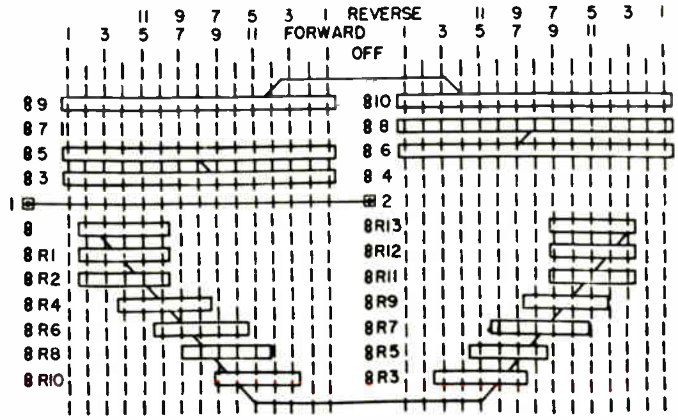


HANDLE END



FOR CONNECTION OR WIRING DIAGRAM

56.12.11 Drum switch, sliding-contact type, typical example



56.13 Switches with specific features

56.13.1 Key-operated lock switch

Use appropriate standard symbol and add key designation or other information in note.

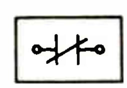
56.13.2 Limit switch

Note 24—Identify by LS or other suitable note.

56.13.2.1 General

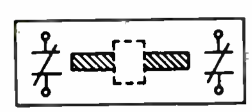
Use appropriate standard symbol and identify by LS or other suitable note.

56.13.2.2 Track-type; circuit-opening contact



SEE NOTE 24

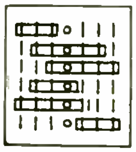
56.13.2.3 Lead-screw type; circuit-opening contacts



SEE NOTE 24

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

56.13.2.4 Rotary type



SEE NOTE 24

56.13.3 Mushroom-head safety feature
Application to 2-circuit push-button switch.

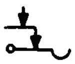
56.13.4 Safety interlock

56.13.4.1 General
If specific type identification is not required, use applicable standard symbol.

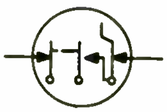
56.13.4.2 If specific type identification is required; circuit opening

56.13.4.3 If specific type identification is required; circuit closing

56.13.5 Hook switch

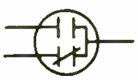


56.13.6 Dial switch, telephone type

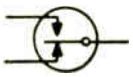


TYPICAL

56.13.7 Switch in evacuated envelope, 1-pole double-throw



OR



57. SYNCHRO
SYNCHRO CONTROL TRANSFORMER
SYNCHRO RECEIVER
SYNCHRO TRANSMITTER

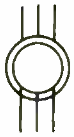
If identification is required, a letter combination from the following list shall be placed adjacent to the symbol to indicate the type of synchro.

CDX	Control-differential synchro transmitter
CT	Synchro control transformer
CX	Synchro control transmitter
TDR	Torque-differential synchro receiver
TDX	Torque-differential synchro transmitter
TR	Torque-synchro receiver
TX	Torque-synchro transmitter

If the outer winding is rotatable in bearings, the suffix B shall be added to the above letter combinations.

57.1 Synchro control transformer
Synchro receiver
Synchro transmitter

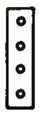
57.2 Differential synchro receiver
Differential synchro transmitter



58. TERMINAL, CIRCUIT
See also TUBE TERMINALS (item 64.12.2).

58.1 Terminal board or terminal strip with 4 terminals shown; group of 4 terminals

Number and arrangement as convenient.

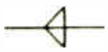
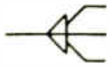


Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

59. TERMINATION

59.1 Cable termination

Line on left of symbol shown indicates cable.

59.2 Open circuit (open)

Not a fault.

Commonly used in coaxial and waveguide diagrams.

59.3 Short circuit (short)

Not a fault.

Commonly used in coaxial and waveguide diagrams.

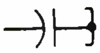
59.3.1 Application: movable short

59.4 Terminating capacitor

Commonly used in coaxial and waveguide diagrams.

59.4.1 Application: series capacitor and path open

59.4.2 Application: series capacitor and path shorted



59.5 Terminating inductor

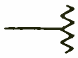
Commonly used in coaxial and waveguide diagrams.

59.5.1 Application: series inductor and path open

59.5.2 Application: series inductor and path shorted

59.6 Terminating resistor

Commonly used in coaxial and waveguide diagrams.



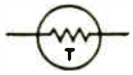
59.6.1 Application: series resistor and path open

59.6.2 Application: series resistor and path shorted

60. THERMISTOR

T indicates that the primary characteristic of the element within the circle is designed to vary with temperature.

60.1 General



60.2 With independent integral heater

61. THERMOCOUPLE

61.1 Dissimilar-metals device

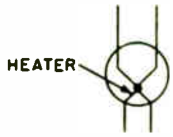
61.1.1 Temperature-measuring thermocouple

61.1.2 Current-measuring thermocouple

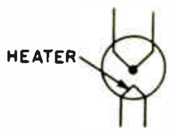
Explanatory words and arrows are not a part of the symbols shown.

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

61.1.2.1 Thermocouple with integral heater internally connected

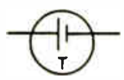


61.1.2.2 Thermocouple with integral insulated heater



61.2 Semiconductor device

61.2.1 Temperature-measuring semiconductor thermocouple



61.2.2 Current-measuring semiconductor thermocouple

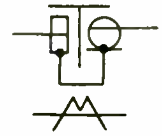
62. TRANSDUCER, MODE

Commonly used in coaxial and waveguide diagrams.

62.1 General

62.2 Application: transducer from rectangular to circular waveguide

62.3 Application: transducer from rectangular waveguide to coaxial with mode suppression and direct-current grounds connected



63. TRANSFORMER

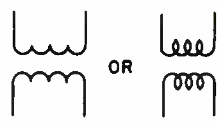
63.1 General

Either winding symbol may be used. In the following subparagraphs, the left symbol is used.

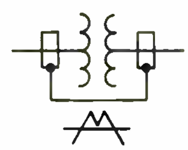
Additional windings may be shown or indicated by a note.

For power transformers, use polarity marking H_1-X_1, etc., from American Standard C6.1. For polarity markings on current and potential transformers, see items 63.16.1 and 63.17.1.

In coaxial and waveguide circuits, this symbol will represent a taper or step transformer without mode change.



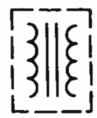
63.1.1 Application: transformer with direct-current ground connections and mode suppression between two rectangular waveguides



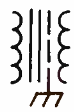
63.2 If it is desired especially to distinguish a magnetic-core transformer

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

63.2.1 Application: shielded transformer with magnetic core shown



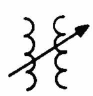
63.2.2 Application: transformer with magnetic core shown and with a shield between windings. The shield is shown connected to the frame.



63.3 One winding with adjustable inductance

63.4 Each winding with separately adjustable inductance

63.5 Adjustable mutual inductor, constant-current transformer



63.6 With taps, 1-phase

63.7 Autotransformer, 1-phase

63.7.1 Adjustable

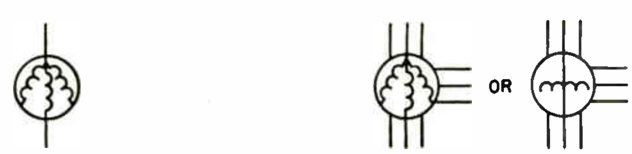
63.8 Step-voltage regulator or load-ratio control autotransformer

63.9 Load-ratio control transformer with taps

63.10 1-phase induction voltage regulator(s)
Number of regulators may be written adjacent to the symbol.

63.11 Triplex induction voltage regulator

63.12 3-phase induction voltage regulator

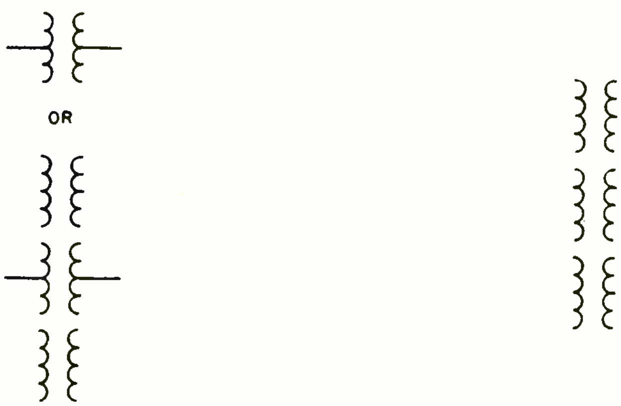


Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

63.13 1-phase 2-winding transformer

63.13.1 3-phase bank of 1-phase 2-winding transformers See latest edition of American Standard C6.1 for interconnection conventions for complete symbols.

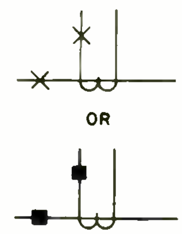
63.14 Polyphase transformer



63.15 1-phase 3-winding transformer

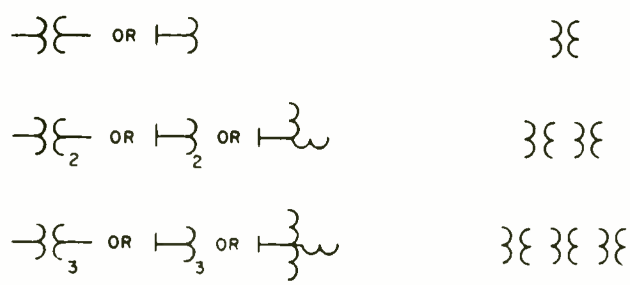
63.16 Current transformer(s)

63.16.1 Current transformer with polarity marking. Instantaneous direction of current into one polarity mark corresponds to current out of the other polarity mark.



63.16.2 Bushing-type current transformer[1]

63.17 Potential transformer(s)



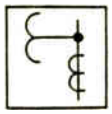
[1] The broken line – — – indicates where line connection to a symbol is made and is not a part of the symbol.

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

63.17.1 Potential transformer with polarity mark. Instantaneous direction of current into one polarity mark corresponds to current out of the other polarity mark.

OR

63.18 Outdoor metering device



SHOW ACTUAL CONNECTION INSIDE BORDER

63.19 Transformer winding connection symbols
For use adjacent to the symbols for the transformer windings.

63.19.1 2-phase 3-wire, ungrounded

63.19.1.1 2-phase 3-wire, grounded

63.19.2 2-phase 4-wire

63.19.2.1 2-phase 5-wire, grounded

63.19.3 3-phase 3-wire, delta or mesh

63.19.3.1 3-phase 3-wire, delta, grounded

63.19.4 3-phase 4-wire, delta, ungrounded

63.19.4.1 3-phase 4-wire, delta, grounded

63.19.5 3-phase, open-delta

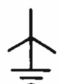
63.19.5.1 3-phase, open-delta, grounded at common point

63.19.5.2 3-phase, open-delta, grounded at middle point of one transformer

63.19.6 3-phase, broken-delta

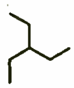
63.19.7 3-phase, wye or star, ungrounded

63.19.7.1 3-phase, wye, grounded neutral
The direction of the stroke representing the neutral can be arbitrarily chosen.



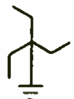
63.19.8 3-phase 4-wire, ungrounded

63.19.9 3-phase, zigzag, ungrounded



Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

63.19.9.1 3-phase, zigzag, grounded



63.19.10 3-phase, Scott or T

63.19.11 6-phase, double-delta

63.19.12 6-phase, hexagonal (or chordal)

63.19.13 6-phase, star (or diametrical)

63.19.13.1 6-phase, star, with grounded neutral

64. TUBE, ELECTRON

Tube-component symbols are shown first. These are followed by typical applications showing the use of these specific symbols in the various classes of devices such as thermionic, cold-cathode, and photoemissive tubes of varying structures and combinations of elements (triodes, pentodes, cathode-ray tubes, magnetrons, etc.).

Lines outside of the envelope are not part of the symbol but are electrical connections thereto.

Connections between the external circuit and electron tube symbols within the envelope may be located as required to simplify the diagram.

64.1 Emitting electrode

64.1.1 Directly heated (filamentary) cathode

Note—Leads may be connected in any convenient manner to ends of the ∧ provided the identity of the ∧ is retained.

64.1.1.1 With tap

See note in item 64.10.3.

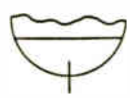
64.1.2 Indirectly heated cathode

Lead may be connected to either extreme end of the ┌─┐ or, if required, to both ends, in any convenient manner.

64.1.3 Cold cathode (including ionically heated cathode)

64.1.4 Photocathode

64.1.5 Pool cathode



64.1.6 Ionically heated cathode with provision for supplementary heating

See note in item 64.1.1

64.2 Controlling electrode

64.2.1 Grid (including beam-confining or beam-forming electrodes)

64.2.2 Deflecting electrodes (used in pairs); reflecting or repelling electrode (used in velocity-modulated tube)

64.2.3 Ignitor (in pool tubes) (should extend into pool)
Starter (in gas tubes)

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

64.2.4 Excitor (contactor type)

64.3 Collecting electrode

64.3.1 Anode or plate (including collecting electrode and fluorescent target)

64.3.2 Target or X-ray anode
Drawn at about a 45-degree angle.

64.4 Collecting and emitting electrode

64.4.1 Dynode

64.4.2 Alternately collecting and emitting

64.4.2.1 Composite anode-photocathode

64.4.2.2 Composite anode-cold cathode

64.4.2.3 Composite anode-ionically heated cathode with provision for supplementary heating

See note in item 64.1.1

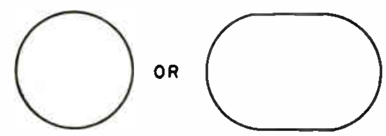
64.5 Heater
See note in item 64.1.1

64.5.1 With tap
See item 64.10.3.

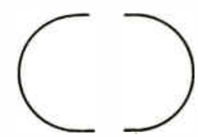
64.6 Envelope (shell)

The general envelope symbol identifies the envelope or enclosure regardless of evacuation or pressure. When used with electron-tube component symbols, the general envelope symbol indicates a vacuum enclosure unless otherwise specified. A gas-filled electron device may be indicated by a dot within the envelope symbol.

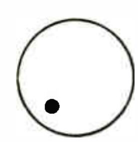
64.6.1 General



64.6.1.1 Split envelope
If necessary, envelope may be split.



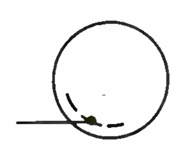
64.6.2 Gas-filled
The dot may be located as convenient.



64.7 Shield
See item 64.10.10.

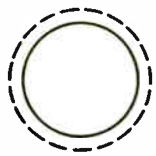
This is understood to shield against electric fields unless otherwise noted.

64.7.1 Any shield against electric fields that is within the envelope and that is connected to an independent terminal



Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

64.7.2 Outside envelope of X-ray tube

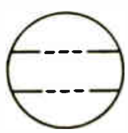


64.8 Coupling
See COUPLING (item 20) and PATH, TRANSMISSION (items 43.8.2 and 43.11).

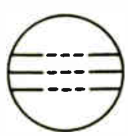
64.8.1 Coupling by loop (electromagnetic type)
Coupling loop may be shown inside or outside envelope as desired, but if inside it should be shown grounded.

64.9 Resonators (cavity type)

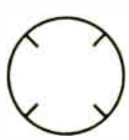
64.9.1 Single-cavity envelope and grid-type associated electrodes



64.9.2 Double-cavity envelope and grid-type associated electrodes



64.9.3 Multicavity magnetron anode and envelope



64.10 General notes

64.10.1 If new symbols are necessary, they should be formed where possible from component symbols. For example, see DYNODE (item 64.4.1), which combines the anode and photocathode convention.

64.10.2 A connection to anode, dynode, pool cathode, photocathode, deflecting electrode, composite anode-photocathode, and composite anode-cold cathode shall be to the center of that symbol. Connection to any other electrode may be shown at either end or both ends of the electrode symbol.

64.10.3 A diagram for a tube having more than one heater or filament shall show only one heater or filament symbol ⋀ unless they have entirely separate connections. If a heater or filament tap is made, either brought out to a terminal or internally connected to another element, it shall be connected at the vertex of the symbol, regardless of the actual division of voltage across the heater or filament.

64.10.4 Standard symbols, such as the inclined arrow for tunability and connecting dotted lines for ganged components, may be added to a tube symbol to extend the meaning of the tube symbol, provided such added feature or component is integral with the tube.

64.10.5 Electric components, such as resistors, capacitors, or inductors, which are integral parts of the tube and are important to its functional operation, shall be shown in the standard manner.

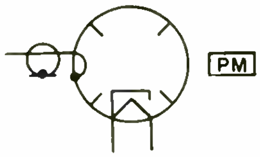
64.10.6 Multiple equipotential cathodes that are directly connected inside the tube shall be shown as a single cathode.

64.10.7 A tube having two or more grids tied internally shall be shown with symbols for each grid, except when the grids are adjacent in the tube structure. Thus, the diagram for a twin pentode having a common screen-grid connection for each section and for a converter tube having the No. 3 and No. 5 grids connected internally will show separate symbols for each grid. However, a triode where the control grid is physically in the form of two grid windings would show only one grid.

64.10.8 A tube having a grid adjacent to a plate but internally connected to the plate to form a portion of it shall be shown as having a plate only.

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

64.10.9 Associated parts of a circuit, such as focusing coils, deflecting coils, field coils, etc., are not a part of the tube symbol but may be added to the circuit in the form of standard symbols. For example, resonant-type magnetron with permanent magnet may be shown:

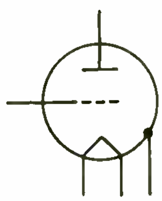


64.10.10 External and internal shields, whether integral parts of tubes or not, shall be omitted from the circuit diagram unless the circuit diagram requires their inclusion.

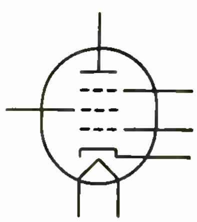
64.10.11 In line with standard drafting practice, straight-line crossovers are recommended.

64.11 Typical applications

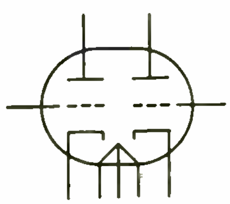
64.11.1 Triode with directly heated filamentary cathode and envelope connection to base terminal



64.11.2 Equipotential-cathode pentode showing use of elongated envelope

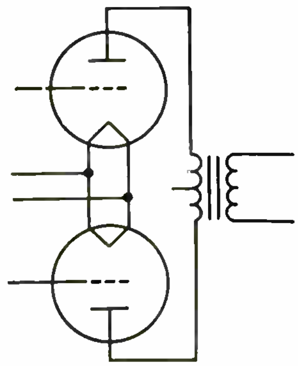


64.11.3 Equipotential-cathode twin triode illustrating elongated envelope and rule of item 64.10.3.



64.11.4 Typical wiring figure

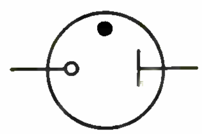
This figure illustrates how tube symbols may be placed in any convenient position in a circuit.



64.11.5 Cold-cathode gas-filled tube

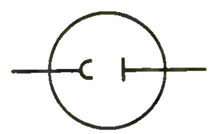
64.11.5.1 Rectifier; voltage regulator for direct-current operation

See also GLOW LAMP (item 33.3).

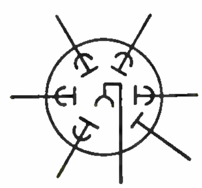


64.11.6 Phototube

64.11.6.1 Single-unit, vacuum type

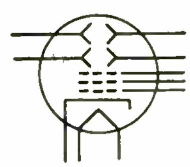


64.11.6.2 Multiplier type



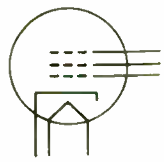
64.11.7 Cathode-ray tube

64.11.7.1 With electric-field deflection



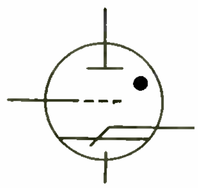
Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

64.11.7.2 For magnetic deflection

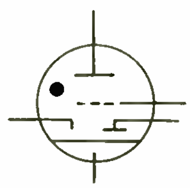


64.11.8 Mercury-pool tube
See also RECTIFIER (item 46.1.1).

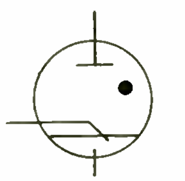
64.11.8.1 With ignitor and control grid



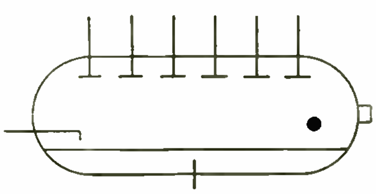
64.11.8.2 With excitor, control grid, and holding anode



64.11.8.3 Single-anode pool-type vapor rectifier with ignitor

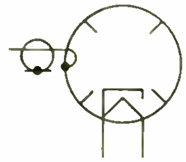


64.11.8.4 6-anode metallic-tank pool-type vapor rectifier with excitor, showing rigid-terminal symbol for control connection to tank (pool cathode is insulated from tank)
Anode symbols are located as convenient.

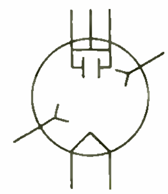


64.11.9 Magnetron

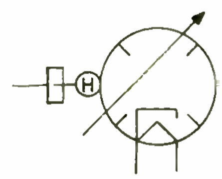
64.11.9.1 Resonant type with coaxial output



64.11.9.2 Transit-time split-plate type with stabilizing deflecting electrodes and internal circuit

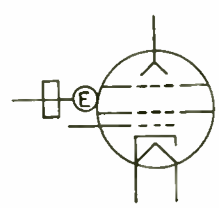


64.11.9.3 Tunable, aperture coupled

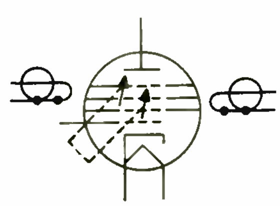


64.11.10 Velocity-modulation (velocity-variation) tube

64.11.10.1 Reflex klystron, integral cavity, aperture coupled

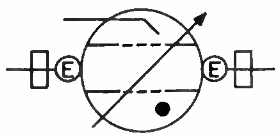


64.11.10.2 Double-cavity klystron, integral cavity, permanent external-ganged tuning, loop coupled (coupling loop may be shown inside if desired. See item 64.8.1)



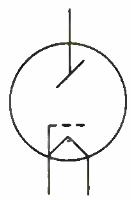
Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

64.11.11 Transmit-receive (TR) tube
Gas filled, tunable integral cavity, aperture coupled, with starter.

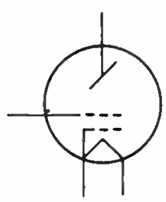


64.11.12 X-ray tube

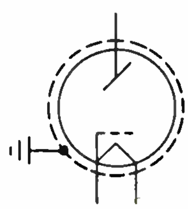
64.11.12.1 With filamentary cathode and focusing grid (cup). The anode may be cooled by fluid or radiation.



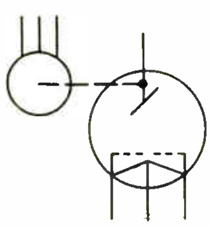
64.11.12.2 With control grid, filamentary cathode, and focusing cup



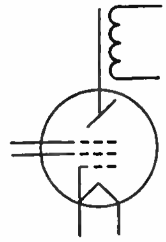
64.11.12.3 With grounded electrostatic shield



64.11.12.4 Double focus with rotating anode (see note in item 64.10.9)



64.11.12.5 With multiple accelerating electrode, electrostatically and electromagnetically focused (see note in item 64.10.9)

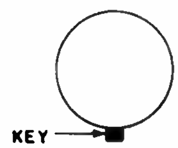


64.12 Basing and terminal connections for connection (wiring) diagrams

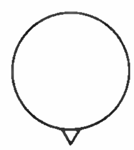
Not normally used for schematic diagrams.

64.12.1 Basing orientation symbols

64.12.1.1 For tubes with keyed bases
Explanatory word and arrow are not a part of the symbol shown.



64.12.1.2 For tubes with bayonets, bosses, and other reference points



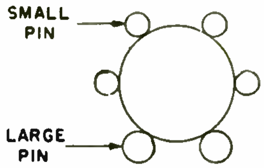
64.12.2 Tube terminals
The usage of the rigid-envelope-terminal symbol of item 64.12.2.2 includes the indication of any external metallic envelope or conducting coating or casing that has a contact area (as in cathode-ray tubes, metallic "pencil" tubes, etc.). However, where contact to such external metallic elements is made through a base terminal, a dot junction is employed as in item 64.12.3.1 to indicate that voltage applied to this base terminal may make the envelope alive.

Terminal symbols may be added to the composite device symbols where desired without changing the meaning or becoming a part of the symbol.

Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

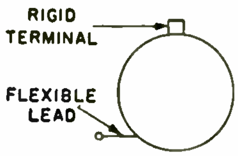
64.12.2.1 Base terminals

Explanatory words and arrows are not a part of the symbol.



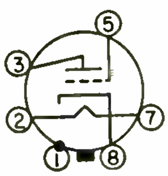
64.12.2.2 Envelope terminals

Explanatory words and arrows are not a part of the symbol.

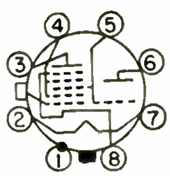


64.12.3 Applications

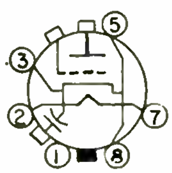
64.12.3.1 Triode with indirectly heated cathode and envelope connected to base terminal



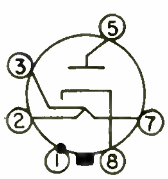
64.12.3.2 Triode-heptode with rigid envelope connection



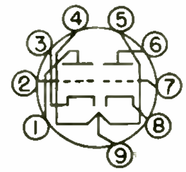
64.12.3.3 Ultra-high-frequency triode (disk-seal-tube type) with internal capacitor



64.12.3.4 Rectifier with heater tap and envelope connected to base terminal



64.12.3.5 Equipotential-cathode twin triode with tapped heater



65. UNIT, PIEZOELECTRIC CRYSTAL

66. VARISTOR

See also RECTIFIER (item 46).

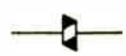
Electroelectrical transducer with nonlinear characteristics.

The arrowheads in these cases are to be filled.

66.1 Asymmetrical; metallic rectifier

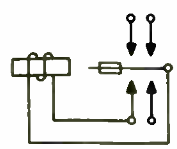
Arrow shows direction of forward (easy) current as indicated by direct-current ammeter.

66.2 Symmetrical

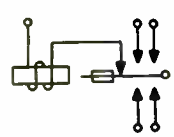


67. VIBRATOR

67.1 Typical shunt drive (contacts as required) (with terminals shown)



67.2 Typical separate drive (contacts as required) (with terminals shown)



Note—Single-line (one-line) symbols appear at the left, complete symbols at the right, and symbols suitable for both purposes are centered in each column.

TYPICAL SINGLE-LINE DIAGRAMS

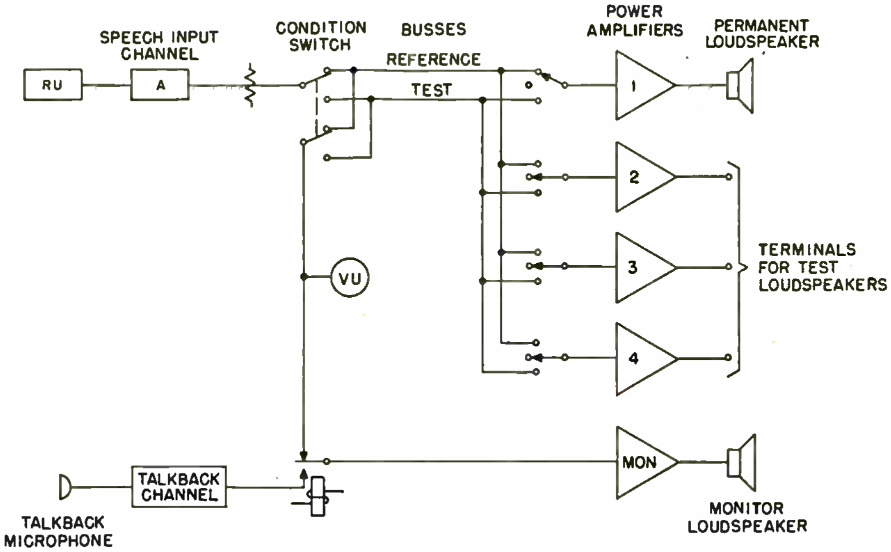


DIAGRAM 1 - LABORATORY SOUND SYSTEM

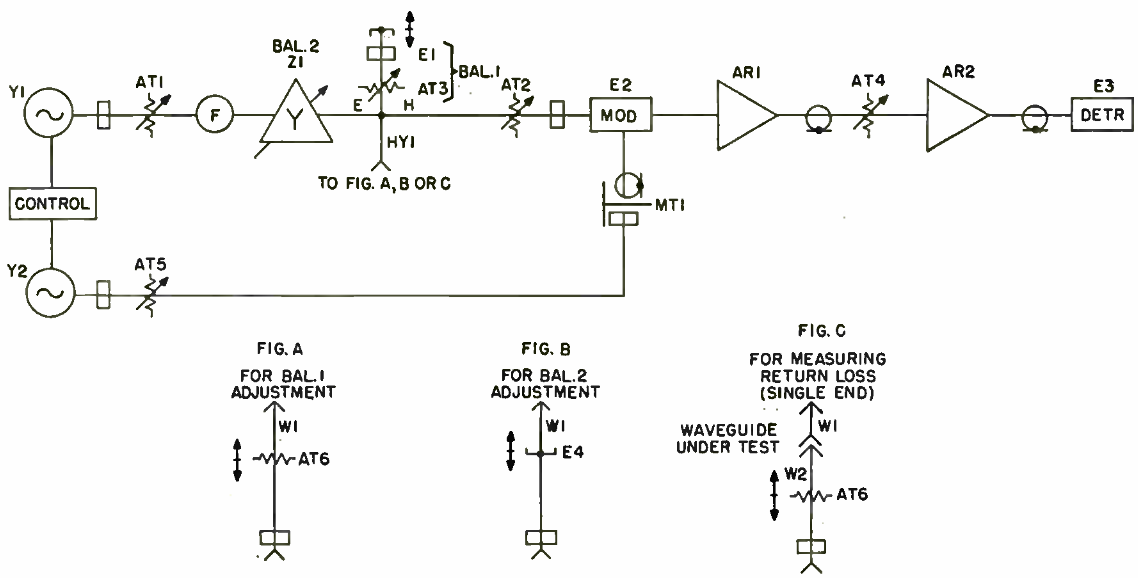


DIAGRAM 2 - MICROWAVE TEST SETUP

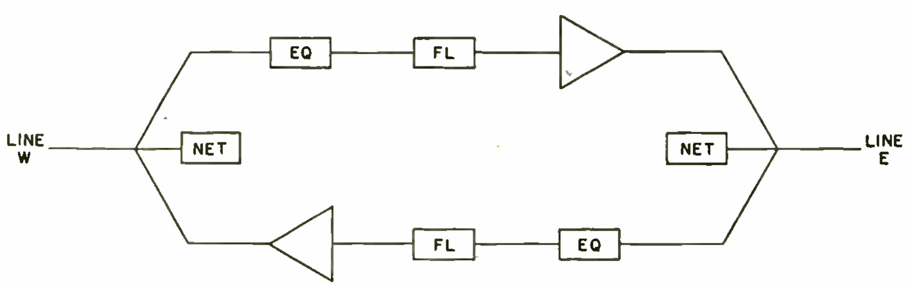
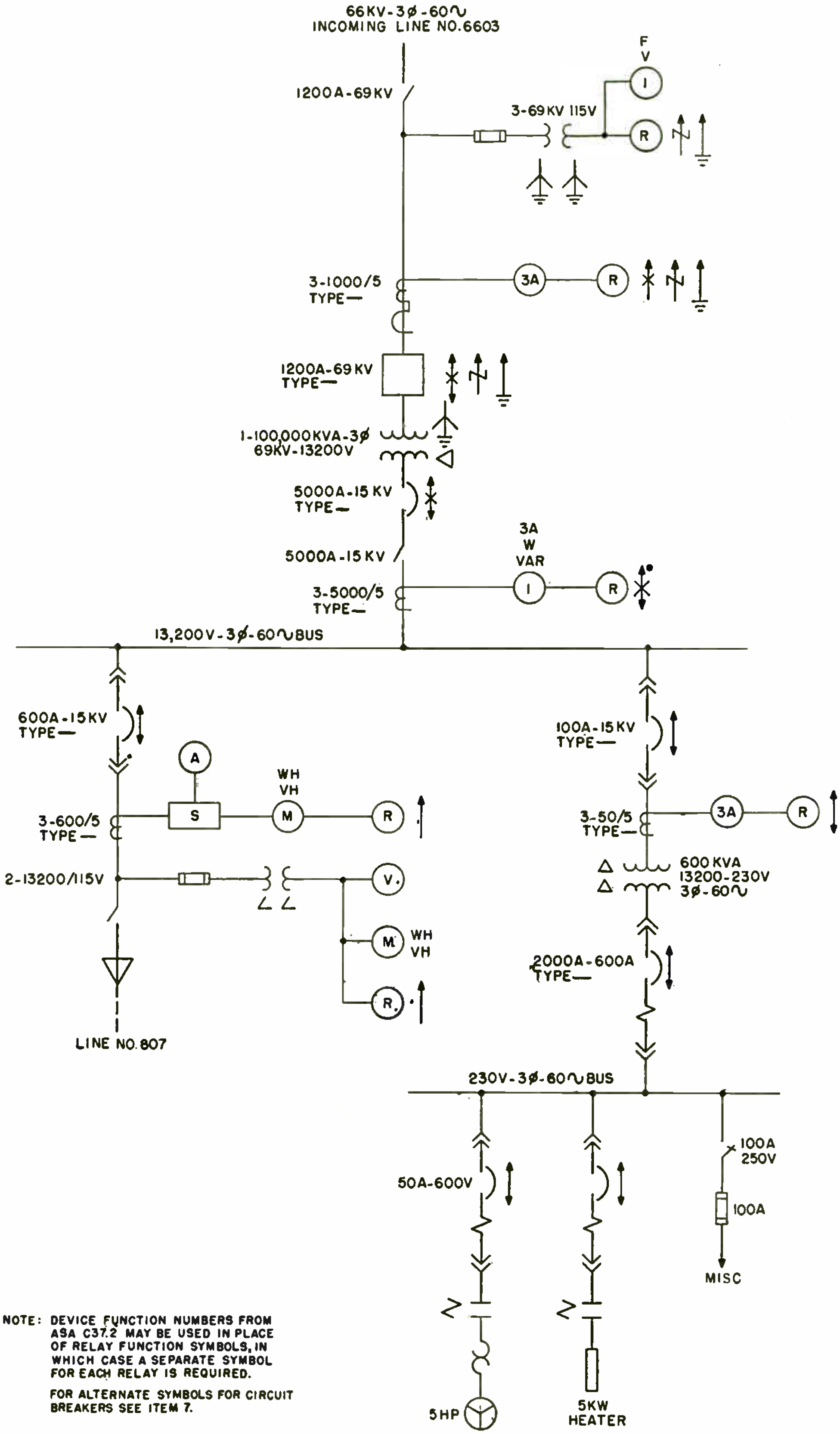


DIAGRAM 3 - TELEPHONE REPEATER AND LINE EQUIPMENT INCLUDING HYBRIDS

TYPICAL SINGLE-LINE DIAGRAMS



NOTE: DEVICE FUNCTION NUMBERS FROM ASA C37.2 MAY BE USED IN PLACE OF RELAY FUNCTION SYMBOLS, IN WHICH CASE A SEPARATE SYMBOL FOR EACH RELAY IS REQUIRED.

FOR ALTERNATE SYMBOLS FOR CIRCUIT BREAKERS SEE ITEM 7.

DIAGRAM 4 - POWER EQUIPMENT

INDEX

INDEX

Discussion on

"A Method for Calculating the Current Distribution of Tschebyscheff Arrays"*

DOMENICK BARBIERE

H. E. Salzer:[1] In the above paper, the author derived explicit expressions for I_k, the current in the kth element from the center of a Dolph-Tschebyscheff array. In his formulas (20) and (20') Barbiere gives two separate expressions for I_k for the respective even and odd element array. Each expression consists of a summation of terms, where each term is a power of z_0 (a function of the side-lobe level) multiplied by a quotient of the form A/B where A has two factors (one of which is a factorial) and B is the product of three factorials.

By employing known properties of Chebyshev polynomials[2] it is possible to derive formulas equivalent to Barbiere's (20) and (20') in a very direct manner, and where a single analytic expression covers both the even and odd element array, and where instead of the above A/B, one has merely to evaluate an expression of the form $C(2D+E)$ where C, D, and E are binomial coefficients which can be looked up in standard tables.[3,4] The problem is to express $T_n(z_0x)$ as a series of the form $\sum_{s=0}^{[n/2]} b_s T_{n-2s}(x)$, where the b_s corresponds to the $I_{[(n+1-2s)/2]}$ and the symbol $[y]$ denotes the largest integer not exceeding y. From

$$T_n(z_0x) = \frac{1}{2}\left((2z_0x)^n - \left\{2\binom{n-1}{1} - \binom{n-2}{1}\right\}(2z_0x)^{n-2} + \left\{2\binom{n-2}{2} - \binom{n-3}{2}\right\}(2z_0x)^{n-4} + \cdots\right), \quad (1)$$

it is apparent that the coefficient of x^{n-2r} is equal to

$$(-1)^r z_0^{n-2r} 2^{n-2r-1}\left\{2\binom{n-r}{r} - \binom{n-r-1}{r}\right\}.$$

But we have

$$x^{n-2r} = \frac{1}{2^{n-2r-1}} \sum_{k=0}^{[(n-2r)/2]} \binom{n-2r}{k} T_{n-2r-2k}(x). \quad (2)$$

Substituting into (1), we get

$$T_n(z_0x) = \sum_{r=0}^{[n/2]} (-1)^r z_0^{n-2r}\left\{2\binom{n-r}{r} - \binom{n-r-1}{r}\right\} \sum_{k=0}^{[(n-2r)/2]} \binom{n-2r}{k} T_{n-2r-2k}(x). \quad (3)$$

In (3), let $r+k=s$ and in the double summation collect all terms having the same value of s. It is seen that s ranges from 0 to $[n/2]$ and the double summation in (3) over a triangle of arguments (r, k) is replaceable by a summation of the form

$$T_n(z_0x) = \sum_{s=0}^{[n/2]} b_s T_{n-2s}(x), \quad (4)$$

where the b_s is given explicitly by

$$b_s = z_0^n \sum_{k=0}^{s} (-1)^{s-k} z_0^{-2(s-k)} \binom{n-2s+2k}{k} \cdot \left\{2\binom{n-s+k}{s-k} - \binom{n-s+k-1}{s-k}\right\}. \quad (5)$$

* D. Barbiere, "A method for calculating the current distribution of Tschebyscheff arrays," PROC. I.R.E., vol. 40, pp. 78–82; January, 1952.

[1] Ordnance Development Lab., National Bureau of Standards, Washington, D. C.

[2] National Bureau of Standards, "Tables of Chebyshev polynomials $S_n(x)$ and $C_n(x)$," Appl. Math. Ser. 9; 1952. See p. XII, formula (35), and p. XIII, formula (38). It is important to remember that $T_0(x)$ is always taken to be equal to $\frac{1}{2}$.

[3] "Handbook of Chemistry and Physics," Chemical Rubber Pub. Co., Cleveland, Ohio, 8th ed., p. 250; 1947. Mathematical tables tabulate the first twenty binomial coefficients.

[4] For some additional coefficients beyond the twentieth, see, "British Association for the Advancement of Science—Table of Powers," Cambridge University Press, London, England, p. 132; 1940.

Correspondence

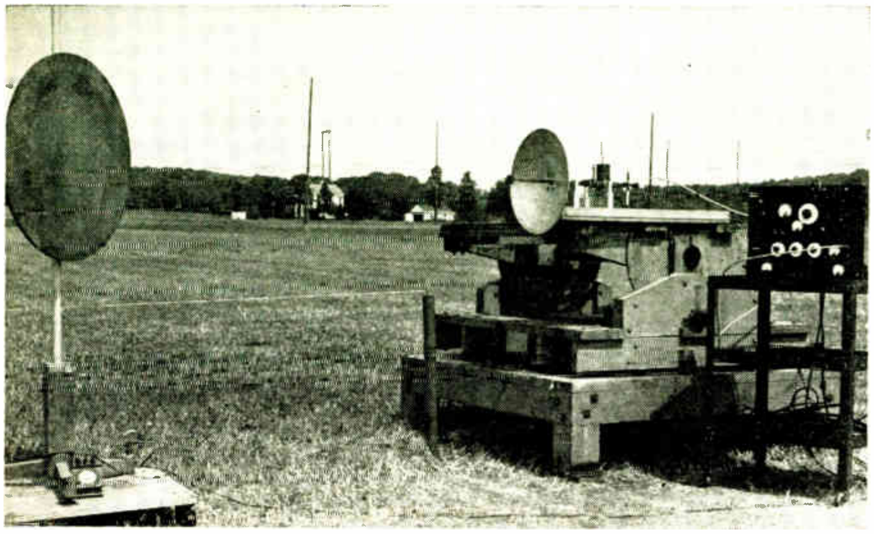


Fig. 1—The antenna-reflector combination as it appeared to an incoming wave.

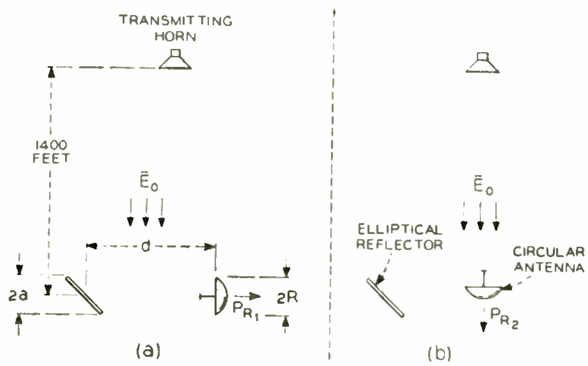
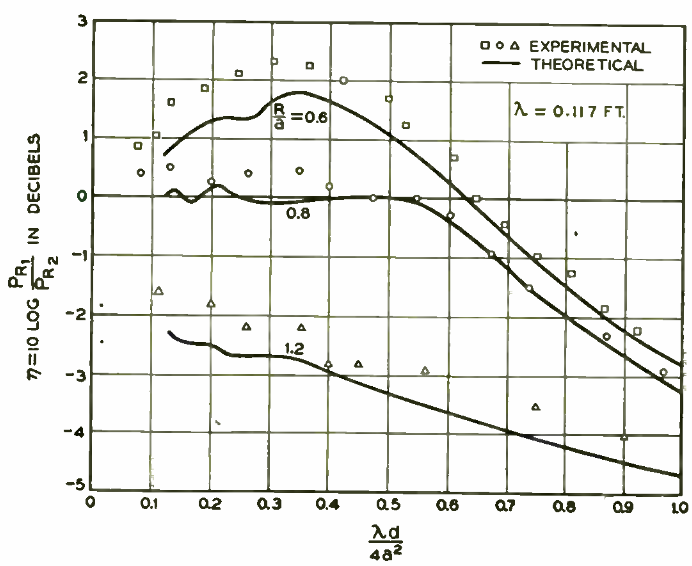


Fig. 2—(a) The experimental arrangement used to measure P_{R1}. (b) The experimental arrangement used to measure P_{R2}.



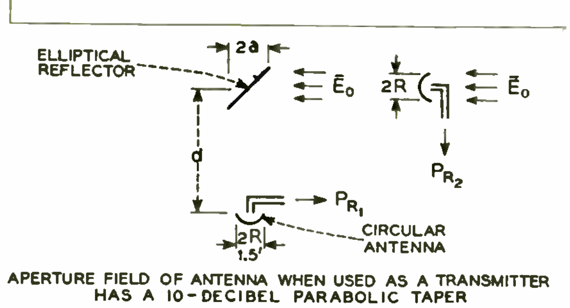


Fig. 3—Ratio of the power received by the antenna in conjunction with the reflector to the power it would receive if subject to the same field incident on the reflector for various values of a, d, R, λ.

An Experimental Study of a Microwave Periscope*

W. C. Jakes[1] has made a theoretical study of the gain characteristics of an antenna used with a plane reflector. His study showed that for certain antenna and reflector sizes and spacings it is possible to receive more power from the antenna-reflector combination than from the same antenna located at the reflector position. An experimental study was undertaken by the author to test the validity of the theoretical results.

The experimental setup may be seen in Fig. 1, left, which shows how the antenna-reflector combination appeared to an incident wave. The antenna and reflector were located along a reference line parallel to the incident wavefront as shown in Fig. 2a, center left. The received power under these conditions was designated P_{R1}. With the antenna oriented toward the transmitter as shown in Fig. 2b, the power received was P_{R2}. The object was to measure P_{R1}/P_{R2} for various values of the parameters d and a. The incident field, E_0, was uniform over the measuring area to within ± 0.2 db which ensured that the incident field on the reflector in Fig. 2a was the same as that on the receiving antenna in Fig. 2b.

The experimental results are shown in Fig. 3, bottom left. Gain comparison was made for three different reflector sizes, viz. $R/a = 0.6$, 0.8, 1.2. The experiment was conducted for both vertical and horizontal polarization. Curves for the two polarizations were not separated by more than 0.15 db.

The experimentally determined curves are in good agreement with the curves derived from theoretical considerations. The data indicate that for the case $R/a = 0.6$ the antenna-reflector combination can have as much as 2.3 db gain over the gain of the antenna alone.

ACKNOWLEDGMENT

The author wishes to acknowledge the contributions of Mr. W. C. Jakes, Jr., for the general planning of this experiment and for his valuable suggestions, also to acknowledge the assistance of Mr. W. E. Legg who helped in the setting up of this experiment and the taking of data.

J. DREXLER
Bell Telephone Labs.
Holmdel, N. J.

* Received by the Institute, January 25, 1954.
[1] W. C. Jakes, Jr., "A theoretical study of an antenna-reflector problem," PROC. I.R.E., vol. 41, pp. 272–274; February, 1953.

Correspondence

Multi-Electrode Transistor-Tube Analogy*

Today the terms tetrode and pentode transistors are appearing extensively in the technical press.[1–5] One may inquire whether the fourth electrode is added for the same reason which caused its addition in the electron tube some 25 years ago. Reviewing this reason, let us start with the insertion of the space charge grid (case 1), writing the triode plate current

$$dI_b = g_m dV_c + g_p dV_b, \qquad (1)$$

and enhancing it by the steady field of the added grid next to the cathode, yielding the g_m-improvement Δg_{m1}, thus

$$dI_b = (g_m + \Delta g_{m1})dV_c + g_p dV_b. \qquad (2)$$

Schottky's screen-grid invention (Germany, 1918)[6] eliminated the second term in (1) by providing electric shielding between the plate and the cathode, maintaining the dc field at the cathode[7] (case 2). By thus adding the "Schottky improvement" $(-g_p dV_b)$ for inherent negative feedback elimination, we obtain

$$dI_b = (g_m dV_c - g_p dV_b) + g_p dV_b,$$

or

$$dI_b = (g_m + \Delta g_{m2})dV_c + g_p dV_b. \qquad (3)$$

Turning Schottky's invention into an anti-Miller effect screen grid (case 3), we obtain

$$dI_b = g_m[dV_c + f(dV_b)] + g_p dV_b, \qquad (4)$$

where $f(dV_b)$ represents the positive feedback, which may be identified as the g_m-contribution Δg_{m3} in

$$dI_b = (g_m + \Delta g_{m3})dV_c + g_p dV_b. \qquad (5)$$

Here Δg_{m3} is the composite, symbolic, tube-network quantity, eliminated by the rf screen grid by the injected term $(-\Delta g_{m3})$, so that

$$dI_b = (g_m{}^1 - \Delta g_{m3})dV_c + g_p dV_b, \qquad (6)$$

where $g_m{}^1$ stands for the g_m- parenthesis in (5).

All the major reasons for introducing a fourth electrode in the electron tube are above covered by one common, generalized theory, and we may attempt to explain the addition of a fourth electrode to a transistor by a change in a transfer characteristic corresponding to g_m.

Tetrode transistors using two emitters will not be discussed here. One important transistor is the "junction tetrode,"[1] in which the transistor action is made to take place very near the base contact. There is no appreciable similarity with case (1) above, but there may be weak similarities with cases (2) and (3). Again, the applications are different in principle. The "hook-collector," or "conjugate-emitter" tetrode presents another variation.[3] The question of importance is if the feedback situation in the original transistor was a great drawback, the fourth electrode being added *specifically* to eliminate this drawback! This seems not to have been the case in the development of the hook tetrode.

Still another type of "tetrode" transistor is the Shockley "field-effect" or "unipolar" transistor, actually referred to by its inventor as a three-electrode device.[4,5] Accepting the circuit presented by Shockley[8] as illustrative of the conditions, read off the equation in short-hand notation as

$$dI_d = g_{dg}(dV_{gs} + dV_{ds}/\mu_{dg}). \qquad (7)$$

Here the subscripts s, d, and g refer to the "source," "drain," and "gate." Reshaping this equation in accordance with (1), we obtain

$$dI_d = (g_m + \Delta g_{m4})dV_{gs} + g_{ds}dV_{ds}, \qquad (8)$$

where g_m refers to a fictitious, "un-gated" unipolar transistor, and Δg_{m4} refers to the improvement by the fourth electrode, contributing the "gate." The contribution Δg_{m4} is different in nature to Δg_{m1}, Δg_{m2}, Δg_{m3} above, and is more in line with the conditions in a "Wunderlich" tube, in which the connection of the two equivalent plane grids results in a certain improvement in transconductance.

In conclusion, therefore, and to the extent all conventional four-electrode transistors are tetrodes, it may be said that there is no obvious, direct line of connection between the insertion of a fourth electrode in the tube, and the insertion of a fourth electrode in the transistor, except that the insertion of an additional electrode in a transistor may itself, or via new circuitry, change the inherent feedback in the triode transistor so that significant similarity can be proven. The criterion is the same as before; consequently, is the fourth electrode introduced *specifically* to cause a change in the feedback conditions, analogous to that caused in the triode tube?

Harry Stockman
Scientific Specialties Corp.
Boston, Mass.

* Received by the Institute, December 7, 1953.

[1] R. L. Wallace, L. G. Schimpf, and E. Dickten, "A junction transistor tetrode for high-frequency use," Proc. I.R.E., vol. 40, p. 1395; November, 1952.

[2] L. J. Giacoletto, "Junction transistor equivalent circuit and vacuum-tube analogy," Proc. I.R.E., vol. 40, p. 1490; November, 1952.

[3] W. Shockley, "Electrons and Holes in Semiconductors," D. Van Nostrand Co., Inc., New York, N. Y., p. 112; 1950.

[4] W. Shockley, "Transistor electronics: imperfections, unipolar, and analog transistors," Proc. I.R.E., vol. 40, p. 1289; November, 1952.

[5] W. Shockley, "A unipolar 'Field-Effect' transistor," Proc. I.R.E., vol. 40, p. 1365; November, 1952.

[6] H. Stockman, "Signs of voltages and currents in vacuum tube circuits," *Communications;* February, 1944.

[7] H. Stockman, "Inherent feedback in triodes," *Wireless Eng.*, April, 1953.

[8] Shockley, "A unipolar 'field-effect' transistor," *ibid.*, Fig. 8.

Russian Vacuum-Tube Terminology*

Russian and English are both Indo-European languages and many scientific words coming from the Greek are held in common. Outstanding examples in the list that follows are the words diode, triode, tetrode, and so forth, which are compounded from the Greek numerals plus the word *hodos*, meaning a way or path. Russian has no *h* and this letter is commonly transliterated as г(g) in words of nonSlavic origin: therefore, гексод and гептод. Russian also employs terms two-, three-, four-, five-, six-, seven-, and eight-electrode (tubes), these rendered by двух-, трех-, четырех-, пяти-, шести-, семи-, and восьмиэлектродная, respectively. In these forms Russian numerals are used in the genitive case.

In speaking of ordinary vacuum tubes the word лампа is commonly used; the Slavic word трубка, diminutive of труба, tube or pipe, is reserved primarily for special tubes, i.e., the cathode-ray tube. Tube nomenclature is a combination of Russian and foreign words. Анод (up way) and катод (down way) are from the Greek of course and are the same as in English. Russian has no equivalent to the English "plate." The word нить, a thread, becomes the filament but in such expressions as filament current, filament voltage, and so forth it is replaced by накал, literally incandescence. The word сетка, grid, is the diminutive of сеть, in general, a net or mesh; specifically, an electrical network, circuit or power line.

The word экран is the French *écran*. From this a verb экранировать is formed and present participle, экранирующий, is used to form term for screen grid. Suppressor grid is literally "protective" grid, probably from French *grille de protection*.

tube	лампа
vacuum	вакуум
vacuum tube	вакуумная лампа
electron	электрон
electron tube	электронная лампа
electrode	электрод
anode or plate	анод
cathode	катод
diode	диод
triode	триод
tetrode	тетрод
pentode	пентод
hexode	гексод
heptode	гептод
octode	октод
filament	нить
incandescence	накал
filament voltage	напряжение накала
filament current	ток накала
filament supply	питание накала
plate circuit	анодный контур
plate supply	анодное питание
plate current	анодный ток
plate voltage	анодное напряжение
grid	сетка
grid voltage	сеточное напряжение
screen grid	экранирующая сетка
suppressor grid	защитая сетка
grid bias	сеточная смещение
control grid	управляющая сетка
characteristic	характеристика
amplification factor	коэфициент усиления
acorn tube	лампа жолудь
split anode	разрезной анод
cathode ray	катодный луч
cathode-ray tube	катоднолучевая трубка
electron gun	электронный прожектор
emission	эмиссия
magnetron	магнетрон
phototube	фототрубка

George F. Schultz
Capehart-Farnsworth Corp.
Fort Wayne, Ind.

* Received by the Institute, Dec. 21, 1953.

Correspondence

IBM 701 Logical Design*

The article on the logical design features of the IBM Type 701 Electronic Data Processing Machines which appeared in the October, 1953 issue of the PROCEEDINGS gives a very clear and complete description of the computer functions. In the two and a half years since specifications were frozen, however, it is not surprising that some confusion has occurred on the contribution of individuals.

The "transfer on zero" order, the non-sterilization of minus zero, the two extra left-hand accumulator positions, and the "round" order were suggested by me in a memorandum to Ralph Palmer, dated March 23, 1951. A subsequent decision to adopt these features was participated in by other engineers and executives, of course.

I have been encouraged to make this correction by the certainty that only the mists of antiquity—two years, after all, is a whole generation in the computer field—prevented my friend Werner Buchholz from remembering the facts.

H. R. J. GROSCH
General Electric Co.
Cincinnati 15, Ohio

Received by the Institute, November 6, 1953.

The System Design of the IBM Type 701 Computer*

I am sorry that Dr. Grosch feels that after two years his efforts have already been forgotten, but this is not so. The fact is that the design of the 701 was a large project, and there were many who made important contributions, Dr. Grosch among them. Listing them individually would have meant trying to separate out the suggestions made by various people, when actually most of the important ideas took shape during group discussions. Few names and no individual credits were given, not because they were forgotten but simply because an adequate list would have been either excessively long or highly arbitrary.

W. BUCHHOLZ
Int'l. Business Mach. Corp.
Poughkeepsie, N. Y.

* Received by the Institute, January 21, 1954.

Instantaneous Frequency*

The recent correspondence[1,2,3] regarding the subject of instantaneous frequency seems to be all directed at a rediscovery of principles very adroitly expressed by Dr. B. Van der Pol a number of years ago.[4]

Speaking as an inexpert observer not wishing to become involved in the controversy, I would suggest that Messrs. Shekel, Hupert, and Hok refer to Dr. Van der Pol's excellent treatment of the subject for guidance by a recognized expert in resolving their conflicting views.

R. W. JOHNSON
The Ralph M. Parsons Co.
Pasadena, Calif.

* Received by the Institute, Jan. 8, 1954.

[1] J. Shekel, "'Instantaneous' Frequency," PROC. I.R.E., vol. 41, p. 48; April, 1953.

[2] J. J. Hupert, "Instantaneous Frequency," PROC. I.R.E., vol. 41, p. 1188; Sept., 1953.

[3] G. Hok, "Frequency modulation and instantaneous frequency," PROC. I.R.E., vol. 41, p. 1786; Dec., 1953.

[4] Balth Van der Pol, "The fundamental principles of frequency modulation," *Jour. I.E.E.*, vol 93, part III, p. 153; 1946.

On the *term* "Instantaneous Frequency"*

In a letter published recently in the PROCEEDINGS[1] I objected to the use of the term "instantaneous frequency." It seems, however, that my intention was misinterpreted, as is evident from a letter contributed by J. J. Hupert.[2] I believe this misinterpretation to be due to the identification of a term with the concept denoted by it.

There is a certain *concept*, which is undoubtedly useful in the discussion of frequency modulation, swept frequency oscillators, and allied subjects; this concept is labeled by the *term* "instantaneous frequency." It is this *term* that I am opposed to, not the *concept*.

The adjective "instantaneous" has a definite meaning in physics, as exemplified by "instantaneous velocity," "instantaneous acceleration," "instantaneous direction (of motion along a curve)." Its meaning is closely related to that of the adjectival phrase "at a point" as used in geometry, e.g., the direction of the tangent to a line, or the radius of curvature at a point on the line. In all these cases a property that is constant for one type of curve is applied to a small section of a curve of higher degree, through approximating a small section of the latter to the former and passing to the limit with the interval of approximation tending to zero. In my first letter I have shown that the *term* "instantaneous frequency," if interpreted in this way, leads to the concept $\omega = \sqrt{-f''/f}$. This is different from any of the ways in which we usually define the *concept* denoted by this term.

Is quibbling about terminology important? Take the following paragraph from the paper by Harvey, Leifer and Marchand:[3]

> "It is of interest to first consider the situation of Fig. 1 which represents a filter with a passband outside the instantaneous frequency range of an FM signal. That energy can be transmitted by the filter is difficult to perceive. Equally difficult to understand is how no energy would be transmitted by a filter which passes part of the instantaneous frequency range of the signal."

Why is it "difficult to perceive" or "difficult to understand"? Isn't it because a concept, defined in one way, is labeled by a term containing an adjective that, due to its use in other fields, evokes a concept different from the intended one? There is nothing in the definition of the concept that may raise such difficulties, and yet, I am sure, many engineers have felt similar difficulties, either studying the subject of frequency modulation, or teaching or explaining it to others.

The terms used in any field should facilitate thinking about the concepts and the relations between them. The term should not be misleading or bring up connotations absent in the concept, and apologetic statements, like those quoted above, should never appear.

The concept which is now usually referred to as "instantaneous frequency" is quite useful; the term "'instantaneous frequency'" is misleading, and should be changed to a more suitable one.

J. SHEKEL
8 Ben Yehuda St.
Haifa, Israel

* Received by the Institute, December 10, 1953.

[1] J. Shekel, "Instantaneous frequency," PROC. I.R.E., vol. 41, p. 548; April, 1953.

[2] J. J. Hupert, "Instantaneous frequency," PROC. I.R.E., vol. 41, p. 1188, September, 1953.

[3] N. L. Harvey, M. Leifer, and N. Marchand, "The component theory of calculating radio-frequency spectra with special reference to frequency modulation," PROC. I.R.E., vol. 39, p. 217; June, 1951.

Contributors

For a photograph and biography of R.H. Baker see page 1191 of the September, 1953 issue of the Proceedings of the I.R.E.

❖

H. W. Batten, was born in 1924. He is at present a student at the University of Michigan, and a research associate for the Engineering Research Institute at the University of Michigan, Ann Arbor, Michigan.

H. W. Batten

Mr. Batten was in the Army Air Force from 1943 to 1946. He received the Bachelor's degree in electrical engineering from the University of Michigan in 1950, and the Master's degree in electrical engineering in 1951. He expects to obtain the Ph.D. degree in June, 1954.

Mr. Batten's research experience is largely in the field of electron tubes. He has worked on the stability of oscillators, transit-time theory, microwave tubes, and fluctuation problems in gastubes.

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M. J. Ehrlich (SM'51) was born in Baltimore, Md., in May, 1920. He received the B.E. degree in electrical engineering from Johns Hopkins University in 1941, the M.S. degree in electrical engineering in 1947, and the Ph.D. degree in 1951 from the University of California at Berkeley.

M. J. Ehrlich

From 1942 to 1946 Dr. Ehrlich served as a mine warfare officer in the U. S. Navy. He joined the Radiation Laboratory, University of California, Berkeley, in 1946, as a member of the linear-accelerator group. In 1948 he joined the Antenna Laboratory, University of California, as a research engineer, and engaged in diffraction and scattering studies. Dr. Ehrlich was associated with the Microwave Research Department of Hughes Aircraft Company from 1950–54. Since he has been associated with the Microwave Radiation Co.

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A. H. Hausman (S'44–A'49) was born on November 24, 1923 in Chicago, Ill. He received the B.S. degree in electrical engineering from the University of Texas in 1944, and the S.M. degree in engineering sciences and applied physics from Harvard University in 1948.

During the period from 1944 to 1946 Mr. Hausman was in the U. S. Navy, assigned to the office of the Chief of Naval Operations, Washington, D. C. He was one of the founders of Engineering Research Associates, Inc., of St. Paul, Minn., and he remained in association with the firm until 1947.

A. H. Hausman

In 1948 Mr. Hausman joined the Department of Defense in Washington, D. C. where he has since been engaged in the development of communications equipment.

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H. Heffner (S'49–A'52) was born in Lincolnton, N. C. on December 26, 1924. He received the B.S. degree in Physics in 1947 and the M.S. and Ph.D. degrees in Electrical Engineering in 1949 and 1952, respectively, from Stanford University. From 1949 to 1951 he was a pre-doctoral fellow of the Atomic Energy Commission.

H. Heffner

During the war he served two and one-half years in the Army Signal Corps where for a time he was in charge of several microwave relay stations in Germany.

Since 1952, Dr. Heffner has been a member of the technical staff of the Bell Telephone Laboratories where he has been engaged in vacuum tube research.

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H. Jaffe was born in Heidelberg in 1909. He obtained a Ph.D. in physics from the University of Goettingen in 1934. From 1935 to 1939 he was a research assistant to Professor Walter G. Cady at Wesleyan University.

H Jaffe

After a year as head of the Physics Department at Allegheny College, he joined The Brush Development Company to undertake research on new piezoelectric materials. Among the many crystals studied by his group, ammonium-dihydrogen phosphate and lithium sulphate have found application in sonic and ultrasonic transducers. More recently he was concerned with properties and applications of titanate ceramics and other ferroelectrics. Dr. Jaffe has been Director of the Electrophysical Research Department of The Brush Laboratories Company, Division of Clevite Corporation, since January, 1953.

He is a member of the American Physical Society and American Crystallographic Association.

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E. R. Jervis (A'33–VA'39–SM'51) was born on May 14, 1905, in Turin, Italy. He has a degree equal to the American B.S. from the University of Milan; an M.S. degree in communications from Harvard University; and Ing. Dr. degree from Polytechnicum of Turin.

E. R. Jervis

After a year as research assistant at Harvard University, in 1937 he joined the design and development department of National Union Radio Corp., Newark, N. J. In 1941 he became associated with Tung Sol Lamp Works, Inc., also in Newark, subsequently becoming chief design engineer.

He returned to National Union Radio Corp. in 1948 as Section Chief of the Cathode Ray Tube Research Dept. He was responsible for several improvements in dark-trace cr tube construction, and for other developments in tube design and production. In 1951 he joined National Vidco Corp., Chicago, Ill., as chief engineer in charge of installation of a miniature tube plant. Since June, 1952, he has been with Aeronautical Radio, Inc., Washington, D. C., as Engineering Manager of the Military Contract Div.

Dr. Jervis is a registered professional engineer in the District of Columbia, and a member of the Harvard Engineering Soc.

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R. A. Jorgensen was born in Huntsville, Alabama, on September 16, 1929. He received the A.B. degree in mathematics from Emmanuel Missionary College, Berrien Springs, Michigan, in 1950, and the A.M. degree in mathematics from the University of Michigan, Ann Arbor, Michigan, in 1951.

R. A. Jorgensen

Mr. Jorgensen was associated with the Electronic Defense Group at the University of Michigan during 1951–1953. In 1953 he joined the staff of the University of Minnesota, Minneapolis, Minnesota, where he is at present an instructor in mathematics.

Contributors

I. L. Lebow was born in Boston, Mass., on April 27, 1926. He attended the Massachusetts Institute of Technology for one year, served two years in the U. S. Navy and returned to M.I.T. in 1946, receiving the B.S. degree in physics in 1948 and the Ph.D. degree in physics in 1951. At M.I.T he did research on high energy particles.

I. L. Lebow

Following graduation he joined the staff of M.I.T., Lincoln Laboratory, where he is currently engaged in research on transistor applications to digital computers.

Dr. Lebow is an associate member of Sigma Xi and a member of A.P.S.

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R. S. Mackay was born in 1924 in San Francisco, Calif. He has a Ph.D. in physics, in which subject he was a Teaching Assistant for five years at the University of Calif. He has also been a Teaching Assistant and Lecturer in Electrical Engineering.

R. S. Mackay

Dr. Mackay is Assistant Professor of Electrical Engineering on the Berkeley Campus of the University of California. He is concurrently a Lecturer in Biophysics and Director of the Central Research and Development Laboratory at the University of California Medical Center in San Francisco. In Berkeley he has recently been devoting himself to developing a program on nonlinear electronic circuits and pulse techniques; while in San Francisco he specialized in biophysics and medical electronics.

He is a member of Pi Mu Epsilon, Sigma Xi, and Phi Beta Kappa.

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A. B. Macnee (S'42–A'45) was born on September 19, 1920, in New York, N. Y. He studied electrical engineering at the Massachusetts Institute of Technology, where he received the B.S. and M.S. degrees in 1943, and the D.Sc. degree in 1948.

A. B. Macnee

From 1943 to 1946 he was a staff member in the receiver group at the M.I.T. Radiation Laboratory, and specialized in the noise performance of intermediate-frequency amplifiers.

From 1946 to August, 1949, he was engaged in research on high-speed electronic computation at the M.I.T. Research Laboratory of Electronics. Dr. Macnee spent one year studying at the Chalmers Institute of Technology, Gothenburg, Sweden.

In 1950, Dr. Macnee joined the staff of the University of Michigan, where he is now an associate professor of electrical engineering.

Dr. Macnee is a member of Sigma Xi and Eta Kappa Nu.

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W. P. Mason (A'35–F'45) was born in Colorado Springs, Colorado, in 1900. He graduated from the University of Kansas in 1921, and obtained the A.M. degree in 1924. He received Ph.D. degree in 1928 from Columbia University.

W. P. Mason

From 1921 to the present time he has been engaged as a research engineer and physicist with the Bell Telephone Laboratories. His principle contributions have been made in the fields of piezoelectric crystals and ultrasonics.

Dr. Mason is a member of Sigma Xi and Tau Beta Pi, and is a Fellow of the American Physical Society, and the Acoustical Society of America.

He is the author of numerous technical papers and of the book, "Electromechanical Transducers and Wave Filters."

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A. R. Moore was born in New York, N. Y. on January 14, 1923. He received the B.S. degree in Chemistry in 1942 from the Polytechnic Institute of Brooklyn. He worked on phototube and thyratron development at RCA Victor in Harrison, N. J. and Lancaster, Pa. from 1942 to 1945. In 1945 he entered Cornell University, and received the Ph.D. in Physics in 1949, specializing in physics of solids.

A. R. Moore

During his last two years at Cornell he was an RCA Fellow. He joined the RCA Laboratories Division at Princeton, N. J. in 1949, where he has worked on semiconductor physics.

H. D. Morris was born in Niles, Mich. on July 19, 1925. He served in the U. S. Signal Corps from 1943–46. He attended the Univ. of California from 1946–50. He graduated with honors in Electrical Engineering receiving the B.S. degree.

H. D. Morris

He joined the Radiation Laboratory of the U. of Calif. after graduation, as an Electronics Engineer. He carried on graduate work at U.C. in the field of pulse techniques and beam deflection tubes. In 1953, he joined the staff of the Donner Scientific Co. where he is Research and Development Engineer in scientific instrumentation.

He is a member of Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

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For a photograph and biography of J. I. Pankove, see page 488 of the February, 1954 issue of the Proceedings of the I.R.E.

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W. W. Peterson was born on April 22, 1924, in Muskegon, Michigan. He attended the University of Michigan, Ann Arbor, Michigan, receiving A.B. degree in mathematics in 1948, and M.S.E. degree in electrical engineering in 1950.

W. W. Peterson

Since 1950 Mr. Peterson has been employed by the University of Michigan, and has worked in both the Electron Tube Laboratory and and the Electronic Defense Group.

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W. M. Webster (A'48–SM'54) was born in Warsaw, N. Y. in 1925. He studied physics at Rensselaer Polytechnic Institute, and at Union College. He received the B.S. degree in physics from Union College, and the Ph.D. degree from Princeton University.

W. M. Webster

He joined the RCA Laboratories Division, Princeton, N. J., in 1946, where he has worked primarily on solid state devices and vacuum and gaseous electronics.

Dr. Webster is a member of Sigma Xi, and received the Editor's Award in 1953.

IRE News and Radio Notes

NTSC Receives Award

Dr. W. R. G. Baker holds the "Emmy" awarded to NTSC by the Academy of Television Arts and Sciences, in recognition of the importance of the NTSC work in color television.

The Academy of Television Arts and Sciences recently awarded the "Emmy" to the National Television System Committee for distinguished contribution to the television industry and color television. Dr. W. R. G. Baker, vice president of General Electric Co. and general manager of the Electronics Division, received the award in his capacity as chairman of the NTSC.

The "Emmy" was displayed on March 22 in the Waldorf-Astoria Hotel, New York City, at a dinner meeting of the NTSC members, held in conjunction with the IRE 1954 National Convention. At this meeting, Dr. Alfred N. Goldsmith, Editor Emeritus of the PROCEEDINGS OF THE I.R.E., presented to Dr. Baker, on behalf of the IRE, a painting symbolic of the NTSC color television standards. The painting is the original of the color reproduction which appeared on the front cover of the January, 1954, color television issue of the PROCEEDINGS OF THE I.R.E.

Global Communications Symposium

Nearly 1,000 radio engineers are expected to attend the first Symposium on Global Communications, which will be held in Washington, D. C., on June 23–25. It will be sponsored by the IRE Professional Group on Communications Systems, and is under the chairmanship of Christian L. Engleman, management and engineering consultant.

Technical papers on various aspects of world-wide communications will be presented in two full-day sessions by commercial, military, and other government specialists in the field. Arrangements are being completed for conducted field trips to nearby commercial and military communications centers on the third day of the meeting. It is expected that there will be some fifty exhibits of the latest communications equipment and components. A reception, two luncheons, a banquet, and special activities for the ladies, including a fashion show, will also feature the Symposium.

The technical program is as follows: "Global Air/Ground Radio Telephone Communications," W. W. Lynch, Pan American World Airways, Inc.; "International Planning of Global Communications for Aviation," Hector Adam, International Civil Aviation Organization; "Organization and Operation of the Naval Communication System," G. M. Neely, Office of the Director of Naval Communications; "World-Wide Propagation Predictions and Ionosphere Disturbance Forecasting," A. H. Shapley, National Bureau of Standards; "Recent Advances in International Radio Communication," I. K. Given, RCA Communications, Inc.; "Impact of Submerged Repeaters on Global Communications," C. S. Lawton, Western Union Telegraph Co.; "USAF Strategic Communications System," G. M. Higginson, USAF; "Global Public Communications," D. D. Donald, American Telephone & Telegraph Co.; "Frequency Propagation Forecasting for World Air Route Operations," C. A. Petry, Aeronautical Radio, Inc., and Major John York, USAF; "Polyplex Transmission System for Point-to-point Radio Telegraph," Christopher Buff and F. D. Webster, American Cable & Radio Corp.; "Communications: A Vital Link in the U. S. Federal Airways System," F. J. Cervenka, Civil Aeronautics Authority; "The International Telecommunications Union and Global Communications," F. C. De Wolf, Department of State; "British Global Telecommunications," A. H. Read, British Embassy; "International Control of Frequency Usage," P. D. Miles, Federal Communications Commission; "The Organization and Function of the International Radio Consultative Committee," E. W. Allen, Jr., Federal Communications Commission; "Improving Frequency Management to Facilitate Global Communications," D. R. MacQuivey, Department of State; "Department of the Army Command Communications," W. F. Spanke, Office of the Chief Signal Officer; "Global Marine Communications," E. M. Webster, Federal Communications Commission.

Computer Conference Proceedings Available

The Proceedings of the Eastern Joint Computer Conference, held December 8–10, 1953 in Washington, D. C., sponsored by the IRE, AIEE, and ACM, is now available from the Institute of Radio Engineers, 1 East 79 Street, New York 21, N. Y., at $3.00 per copy. The 128-page volume contains both the papers and discussions presented at the meeting.

Calendar of COMING EVENTS

IAS Annual Summer Meeting, IAS Building, Los Angeles, Calif., June 21–24

IRE Symposium on Global Communications, Washington, D. C., June 23–25

British Institute of Radio Engineers, 1954 Convention, Christ Church, Oxford, England, July 8–12

Sixth Annual Oak Ridge Summer Symposium, "Modern Analytical Chemistry," Oak Ridge, Tenn., August 23–27

IRE-WCEMA Western Electronic Show & Convention, Pan Pacific Auditorium, Los Angeles, Calif., August 25–27

1954 International Congress of Mathematicians, Royal Tropical Institute, Amsterdam, Holland, September 2–9

IRE-AIEE-URSI Symposium on Information Theory, Massachusetts Institute of Technology, Cambridge, Mass., September 15–17

Cedar Rapids Conference on Communications, Cedar Rapids, Iowa, September 17–18

IRE Professional Group on Vehicular Communications Meeting, Rice Hotel, Houston, Texas, September 30–October 1

National Electronics Conference, Hotel Sherman, Chicago, Ill., October 4–6

IRE Professional Group on Nuclear Science Annual Conference, Sherman Hotel, Chicago, Ill., October 6–7

Symposium on Marine Communication and Navigation, Hotel Somerset, Boston, Mass., October 13–15

Society of Motion Picture & TV Engineers Seventy-sixth Semi-Annual Convention, Ambassador Hotel, Los Angeles, Calif., October 17–22

IRE-RETMA Radio Fall Meeting, Hotel Syracuse, Syracuse, N. Y., October 18–20

IRE Quality Control Symposium, Statler Hotel, New York, N. Y., November 12–13

Symposium on Fluctuation Phenomena in Microwave Sources, Western Union Auditorium, New York, N.Y., November 18–19

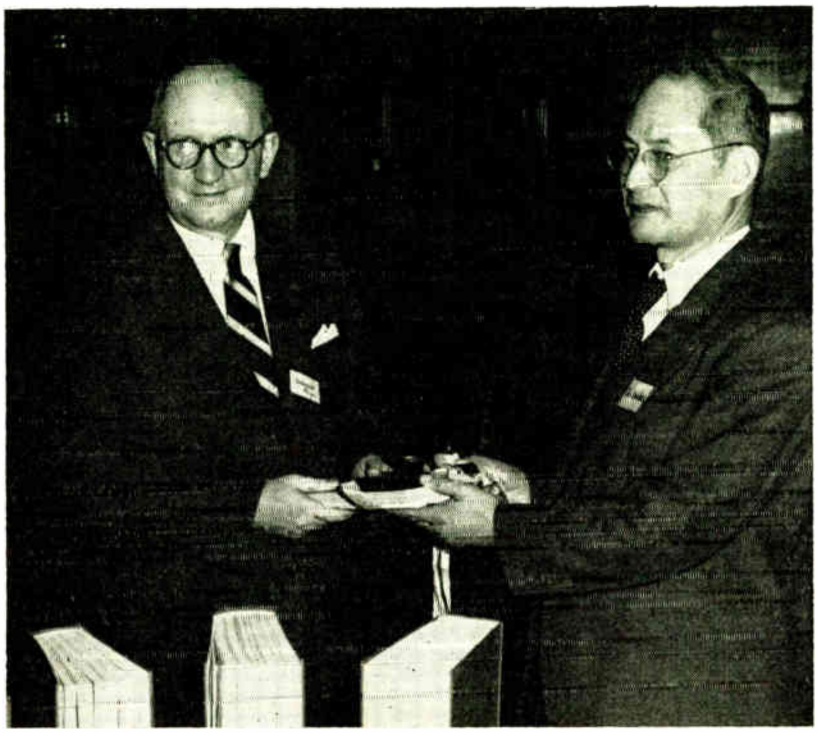
IRE Kansas City Section Annual Electronics Conference, Hotel President, Kansas City, Mo., November 18–19

AIEE Winter General Meeting, Hotel Statler, New York, N. Y., January 31–February 4, 1955

1955 Southwestern IRE Conference and Electronics Show, Baker Hotel, Dallas, Tex., February 10–12, 1955

IRE News and Radio Notes

PROCEEDINGS OF THE I.R.E. PRESENTED TO TOKYO UNIVERSITY



U. S. Ambassador John M. Allison gives the first volume of the PROCEEDINGS OF THE I.R.E. to President Yanaihara of Tokyo University.

A complete set of the PROCEEDINGS OF THE I.R.E. was recently presented to the Tokyo University by U. S. Ambassador John M. Allison, on behalf of Harold B. Richmond, president of the General Radio Company.

After his presentation of the volumes to President Yanaihara, the Ambassador made the comment that the best kind of co-operation between two nations is shown in the gift. President Yanaihara expressed gratitude for the entire university for the help which the volumes will give to both faculty and students, and added that their appreciation could best be shown by the further development of their research projects.

The presentation of the volumes was made possible through the co-operation of many individuals and organizations, both Japanese and American.

ANNUAL MEETING OF ENGINEERING EDUCATORS

Over 1,500 engineering educators will attend the Annual Meeting of the American Society for Engineering Education on June 14–18 at the University of Illinois, Urbana, Illinois. Educators and distinguished engineers from other countries who are visiting in the United States are invited to attend.

The meetings will include conferences sponsored by the Engineering College Administrative Council and the Engineering College Research Council, two component organizations of the ASEE. The theme of the conference this year, "Evaluation of Engineering Education" will feature a thorough analysis of all phases of engineering education. This will conclude a two-year study on Evaluation of Engineering Education undertaken by the Society.

The Engineering College Research Council and Engineering College Administrative Council will hold a joint dinner to commemorate the 50th Anniversary of the founding of Engineering Experiment Stations in engineering colleges. The speaker at this dinner will be Dr. Lee DuBridge, President of California Institute of Technology.

There will be over 100 individual conference programs arranged by the Divisions, Committees, and Councils of the Society.

Foreign guests who wish to attend the Conference should write to Professor Robert K. Newton, ASEE Housing Chairman, University of Illinois, Urbana, Ill., for information and reservations.

SUMMER COURSES IN AUTOMATIC CONTROL OFFERED

Plans for a two-week special summer program in the Automatic Control of Machine Tools, to be held from August 23 to September 2 in the Servomechanisms Laboratory at the Massachusetts Institute of Technology, have been recently announced. The program will be under the direction of Professor J. Francis Reintjes, Director of the M.I.T. Servomechanisms Laboratory in the Department of Electrical Engineering, who will be assisted by other members of the Laboratory staff.

Morning sessions of the two-week program will be devoted to studies of systems and components including the following topics: principles of information processing as applied to the use of machine tools; numerical control systems and their machine tool applications; equipment design for computational equipment, servomechanisms for machine tool control, etc.; design considerations for system reliability; and management, operation, and maintenance of numerically-controlled machine tools.

In addition, there will be less formal afternoon sessions devoted to programming techniques, using the numerically-controlled milling machine developed in the Servo-mechanisms Laboratory under U. S. Air Force sponsorship. Topics in these sessions will include the mathematics of programming, practical procedures, and machine aids. The special summer program is designed to interest those who want a broad view of the technical aspects of numerical control as they apply to machine tools.

Since the number of registrants must necessarily be limited, preference will be given to applications from those who are now engaged in designing or applying automatic machine tool equipment or who anticipate entering this field. Tuition for the program will be $160.

This special summer program in Automatic Control of Machine Tools supplements a two-week program in Machine Tool Technology to be given in the M.I.T. Mechanical Engineering Department from June 15 through June 25, 1954. Further information and application blanks for either program may be obtained from the Summer Session Office, Room 7-103, M.I.T., Cambridge 39, Mass.

SPECIAL EVENTS FOR WESCON PLANNED

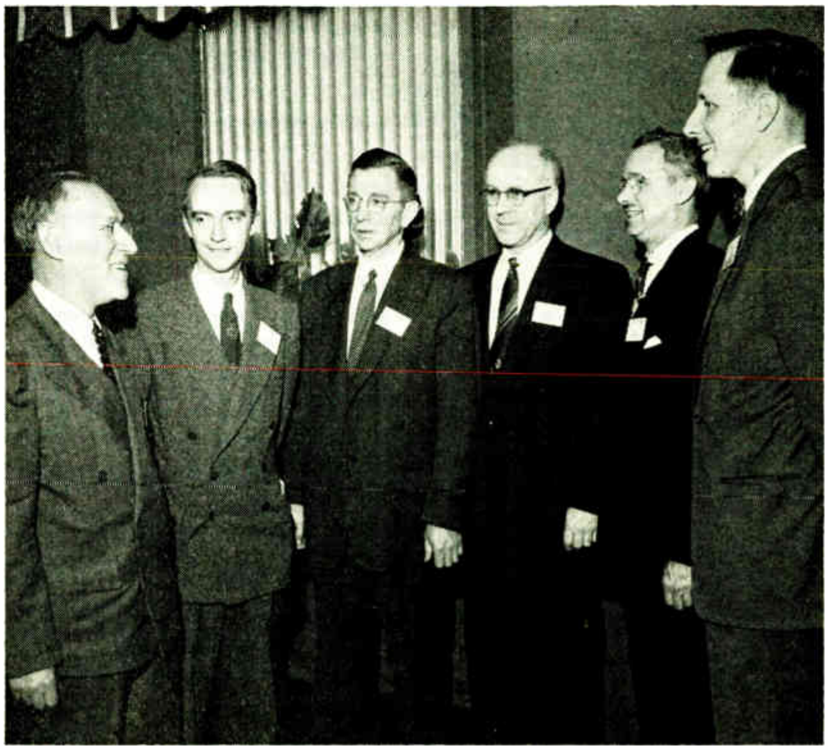
The Special Events Committee for the 1954 WESCON, to be held in Los Angeles, Calif., from August 25–27, has recently announced several activities expected to be of great interest to all those attending.

A tour of the sound studio and technical facilities of 20th Century Fox Picture Corp. has been arranged, and other field trips will be announced later.

The annual All-Industry Luncheon, to be held on August 27 in the Cocoanut Grove of the Ambassador Hotel, will include a non-technical address by a prominent speaker, and the presentation of the 7th Region IRE Annual Achievement Award and the WCEMA Scholarship Awards. The All-Industry Cocktail Party has been scheduled to be held in a unique—and very pleasant—setting. It will be outdoors around the Ambassador Hotel Swimming Pool on August 25 at 5:30 P.M. For the special enjoyment of the ladies there will be two luncheons, and a tour of CBS Television City.

The announcement has also recently been made of the assignment of 450 exhibitions for the Electronics Show. Additional accommodations are now being planned, in order to place as many as possible of the applications still on file.

IRE News and Radio Notes



Irving Wolff (far left), Chairman of the National Committee for the IRE-AIEE Conference on Transistor Circuits, with his associates at the meeting in Philadelphia on February 18 and 19. From left to right, Dr. Wolff, H. E. Tompkins, J. G. Brainerd, K. H. Emerson, W. R. Clark, and J. G. Linvill.

Transistor Circuits Conference Highly Successful

The IRE-AIEE Conference on Transistor Circuits, held in Philadelphia on February 18 and 19, presented 18 papers to over 600 registrants, including some from Canada and England. Originally scheduled for the University of Pennsylvania Museum Auditorium, the meetings were moved across the street to the University's Irvine Auditorium because of the large attendance.

Dr. G. P. Harnwell, President of the University of Pennsylvania and distinguished physicist, gave the welcoming address to the meeting.

The technical papers presented at the Conference covered several aspects of the transistor-circuit art.

The first session, whose chairman was H. E. Tompkins of the Burroughs Research Center, was concerned with the properties and representation of transistors, from both the "black-box" and "transparent-box" points of view.

In the first paper, J. M. Early of Bell Laboratories reviewed the basic physical phenomena underlying junction transistor operation. J. Zawels of RCA Victor (whose paper was read by H. Johnson of RCA Laboratories) then presented a new equivalent circuit for junction transistors, in which the passive part corresponds closely to the physics of the device, and the active part is a frequency-independent amplifier. J. B. Angell of Philco presented two equivalent circuits for surface-barrier transistors, and indicated the superiority of one in which the space-charge-layer widening affect on emitter current is represented by a resistor connected directly between collector and emitter, rather than by a series element in a T-equivalent. J. S. Schaffner of the General Electric Co. presented data on the variation junction transistor parameters with operating point and temperature, and emphasized that in some cases in which a-c parameters are fairly constant with temperature, the d-c bias point is a severe function of temperature; as an example of this he cited the input characteristic of the grounded base (and hence also of the grounded emitter) amplifier stage.

In the second session, conducted by J. G. Linvill of Bell Telephone Laboratories, chairman of the program committee, transistors in linear circuits were discussed. G. C. Sziklai of RCA Laboratories first discussed several new complementary-symmetry circuits, including a simple two-stage amplifier whose direction of amplification can be changed by a single-pole double-throw switch. E. R. Kretzmer of Bell Laboratories presented several examples of the use of other semiconductor devices (such as thermistors and breakdown diodes) as stabilizing elements in transistor circuits. F. P. Keiper, Jr. of Philco, derived his neutralizing circuits, which was originally described in the December, 1952, issue of the Proceedings of the I.R.E. S. J. Mason of the Research Laboratory of Electronics at M.I.T., discussed the invariances of the "available power gain" of an active three-terminal network. P. L. Bargellini of the Moore School of Electrical Engineering, University of Pennsylvania, a consultant for RCA Victor, presented data indicating that a substantial fraction of present-day junction transistors are more quiet than tubes, and have a low, flat noise spectrum through the audio range, rather than a 1/f dependence of noise on frequency. At low frequencies, the 1/f dependence sets in, however.

In the third session, under T. R. Finch of Bell Telephone Laboratories, various junction transistor amplifiers were discussed. C. R. Hurtig of the Research Laboratory of Electronics, M.I.T., described a transistor d-c amplifier, and noted the limitations on performance caused by the temperature dependence of present units. R. F. Shea of the General Electric Co. discussed the choice of configuration and operating point for audio power amplifiers, and demonstrated an 18-watt push-pull class-B audio amplifier, using two experimental power transistors in the common-base connection as the output stage. Bell Laboratories' speakers, F. H. Blecher, R. E. Yaeger, and L. G. Schimpf, showed particular types of amplifiers, including summing and integrating amplifiers for analog computers, carrier-frequency feedback amplifiers, and junction tetrode i-f amplifiers, respectively.

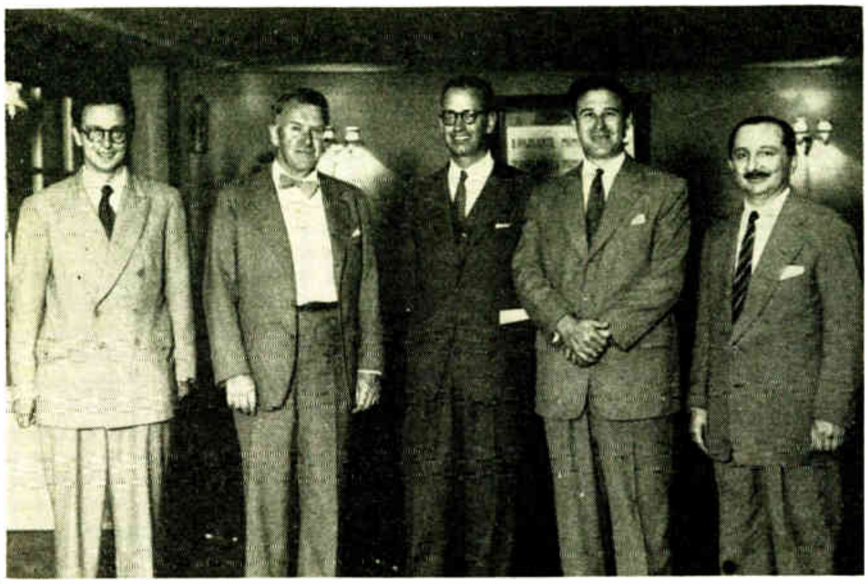
The final session, on nonlinear applications of junction transistors, had A. W. Lo of RCA Laboratories as its chairman. J. J. Ebers and J. L. Moll of Bell Telephone Laboratories presented a theory of the large-signal d-c and transient behavior of junction transistors. This theory, while closely related to the physics of transistors, is clear and simple enough to be of definite practical utility in circuit design. D. E. Deuitch of RCA Victor discussed some basic switching circuits. J. T. Warnock of Philco presented a design method for obtaining reliable switching circuits using any transistors whose parameters fall within a specific range. Mr. Warnock also described a very simple diode clamping circuit for presenting carrier-storage turn-off delay in junction-transistor switching circuits. This last session is, to the best of our knowledge, the first meeting at which junction-transistor switching circuits have been discussed in detail.

Many of the papers presented at the Conference will be published in journals of the authors' choice, but no "Proceedings" of the Conference will be issued. This policy was adopted to insure that the Conference would include the "latest word" on the transistor-circuit art; a strict publication policy would have delayed the presentation of some papers until a subsequent meeting. It is evident that the Conference was not the "last word" on the subject, since the art is still progressing with great rapidity, and it is expected that similar conferences will be organized in the future, as the need arises.

If there is any comment or criticism on the conduct of the Conference, please write to any one of the following committee members: Irving Wolff, Chairman, National Committee; J. S. Donal, Jr., Secretary, National Committee; M. S. Corrington, Treasurer, National Committee; J. G. Linvill, Chairman, Program Committee; K. H. Emerson, Chairman, Local Arrangements Committee; or H. E. Tompkins, Chairman, Publicity Committee.

IRE News and Radio Notes

Buenos Aires Section Holds Engineering Week



The Buenos Aires Section of the IRE held its Seventh Annual Engineering Week on November 23–27, 1953 at the Transradio Lecture Hall in Buenos Aires, Argentina. The five-day meeting included three visits to transmitting plants, and three technical papers presented in conjunction with the tours. Pictured above are members of the Buenos Aires Section, photographed during the trip to Ucoa Radio Manufacturing Plant. Left to right, they are: Manuel Kobilsky, William A. Cook, Luis Malvarez, chairman of the Buenos Aires Section, Mr. Watson, and Pascual N. Guzzi.

Forestry Communications Meeting Scheduled

The Forestry Conservation Communications Association has scheduled its 5th Annual Conference at the Hotel Commodore in New York City from June 17–18. The program will cover technical and administrative phases of forestry and conservation communications. Leading manufacturers of communications equipment will display their latest products.

Anyone desiring additional information should contact the Program Chairman, Max Guiberson, Route 7, Box 392, Olympia, Wash.

Call for Historical Radio Material

Arrangements have been made by the IRE with the Smithsonian Institution of Washington, D. C., to assist in obtaining for preservation in the Smithsonian Museum significant pioneer radio, television and electronics material, particularly items now in the possession of members of the IRE. While the Institution has unceasing demands upon its limited facilities for the preservation of historical materials, it recognizes the need to acquire important relics associated with the development of the radio field, while they are still available. The Institution is looking ahead to new buildings for its engineering collections and, in the meantime, will preserve what it reasonably can in its reference collections, pending new space for exhibition.

Adequately authenticated material will be accepted as gifts to the Smithsonian Institution with the understanding that it will be preserved but not necessarily exhibited. The Institution has extensive reference collections which are used by writers, engineers, and students, and it believes that preservation of documented material is the most valuable service that it renders to the engineering profession and to present and future inquirers into technological development. As outstanding material is acquired, the present exhibits will be expanded and improved to represent better the development, within the limits of space available.

Members who know of relics of real significance which might be donated for preservation in these archives, are requested to correspond with the IRE History Committee at IRE Headquarters, 1 East 79 Street, New York 21, N. Y.

Professional Group News

Circuit Theory

The IRE Professional Group on Circuit Theory has been quite active in presenting symposia during the past months. On February 18–19, a symposium was held in Philadelphia on Transistor Circuits in co-operation with the AIEE. (See page 881 of the May Issue of the Proceedings of the I.R.E. for a complete summary of this meeting.)

The 1954 IRE winter convention again presented three sessions of contributed papers on Circuit Theory and one symposium on Network Equalization. The five papers at this symposium gave a broad picture of the practices currently employed in designing network equalizers. Topics covered included fundamental gain limitations on equalizer networks, an analytic synthesis technique for transfer functions, the use of computational methods for highly precise cable equalizers and adjustable equalizers, and methods for time domain equalization. All network papers presented at the convention will be published in the Convention Record and distributed free to PGCT members.

The PGCT again co-operated with the Polytechnic Institute of Brooklyn's Microwave Research Institute in presenting a symposium in New York on April 12–14. The topic for this year was "Information Networks." Speakers at the five sessions emphasized the symbiotic relation between two disciplines of thought; the one—Network Theory—mature and established, the other—Information Theory—just feeling its oats. One set of papers covered the general philosophy of the network-information relationship. Other contributors discussed generalized filtering, time varying networks, and information processing networks such as transmission lines, coding circuits, computer circuits and optical systems. One session emphasized the application of networks to such remote fields as nervous systems and social groups. As has been the case in the past, several contributors from abroad gave the sessions an international flavor. All papers will be published as Volume III of the Symposium Series and will be available at a $1.00 discount to PGCT members. Further inquiries should be addressed to J. Fox, Microwave Research Institute, 55 Johnson Street, Brooklyn 1, N. Y.

Future plans call for a group of network papers to be presented at the IRE Western Electronics Show and Convention during the period August 25–27.

Another program on which planning is well started is to occur in Chicago from October 4–6. The PGCT is co-operating with the National Electronics Conference on a symposium whose theme is tentatively "Design and Application of Networks for Pulsed Signals." Interested parties should contact J. J. Gershon, DeVry Technical Institute, 2533 N. Ashland Avenue, Chicago 14, Ill.

April, 1955, will again bring the annual PIB-PGCT Symposium. The subject will be "Modern Network Synthesis," and it is planned to fill in any gaps left by the symposium of 1952 on this topic, as well as to bring the subject up to date. The meeting will be part of the centennial celebration of the Polytechnic Institute of Brooklyn.

New Chapters Approved

At the March 2nd meeting of the Executive Committee the following Professional Group Chapters were approved: the Connecticut Valley Chapters of the Professional Group on Nuclear Science and the Professional Group on Medical Electronics.

IRE News and Radio Notes

Conference on Airborne and Navigational Electronics

Plans for the East Coast Conference on Airborne and Navigational Electronics to be held November 4 and 5, 1954, have been announced jointly by the Baltimore Section of the Institute of Radio Engineers and the IRE Professional Group on Aeronautical and Navigational Electronics. The conference will be held at Baltimore's Sheraton-Belvedere Hotel.

The technical portion of the conference will be devoted to the general field of Airborne and Navigational Electronics. Interested persons are cordially invited to submit papers for consideration; 150-word abstracts should be sent no later than July 1, 1954, to: Mr. Norman Caplan, Bendix Radio Division of Bendix Aviation Corp., Towson 4, Md.

Industrial exhibits are planned as an integral part of the conference. During the two days in November, representatives of many outstanding East Coast industries and development organizations will be concentrated in Baltimore to view these exhibits. Those organizations interested in sponsoring exhibits should contact: Mr. C. E. McClellan, Air Arm Division, Westinghouse Electric Corp., Friendship Airport, Baltimore, Md.

In addition to the technical programs and exhibits, a banquet will be held on the evening of November 4.

Technical Committee Notes

The **Standards Committee** met on March 25th under the chairmanship of A. G. Jensen. Mr. Jensen announced the names of new committee members and introduced those present. The new member-at-large is Virgil M. Graham. The new Committee Chairmen are: B. B. Bauer, Electroacoustics Committee; P. S. Christaldi, Measurements & Instrumentation Committee; W. J. Dodds, Electron Devices Committee; J. E. Eiselein, Industrial Electronics Committee; D. E. Maxwell, Audio Techniques Committee; H. R. Mimno, Navigation Aids Committee and J. E. Ward, Feedback Control Systems Committee. Mr. Jensen reviewed the Standards acted upon by the committee during the year. The following standards were published in 1953: (1) Standards on Antennas and Wave Guides: Definitions of Terms, 1953; (2) Standards on Electron Devices: Methods of Measuring Noise, 1953: (3) Standards on Modulation Systems; Definitions of Terms, 1953; (4) Standards on Sound Recording and Reproducing: Methods of Measurement of Noise, 1953; (5) Standards on Television: Definitions of Color Terms, Part I, 1953; (6) Standards on Sound Recording and Reproducing: Methods for Determining Flutter Content; and (7) Standards on Circuits: Definitions of Terms in the Field of Linear Varying Parameter and Non-linear Circuits, 1953. The following standards were approved in 1953 and are awaiting publication: (1) Standards

(Continued on next page)

PUBLICATIONS OF THE IRE

The following issues of *Transactions* are available from the Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N. Y., at the prices listed below.

Sponsoring Group	Publications	Group Members	IRE Members	Non-Members*
Aeronautical & Navigational Electronics	PGAE-4; The Selectivity and Intermodulation Problem in UHF and Communication Equipment (11 pages)	$0.45	$0.65	$1.35
	PGAE-5; A Dynamic Aircraft Simulator for Study of Human Response Characteristics (6 pages)	.30	.45	.90
	PGAE-6; Ground-to-Air Cochannel Interference at 2900 MC (10 pages)	.30	.45	.90
	PGAE-8; June 1953 Issue (25 pages)	.65	.95	1.95
	PGAE-9; September 1953 Issue (27 pages)	.70	1.05	2.10
	PGAE-10; December 1953 Issue (36 pages)	.80	1.20	2.40
Antennas and Propagation	PGAP-4; IRE Western Convention, August 1952 (136 pages)	2.20	3.30	6.60
	Vol. AP-1, No. 1; July 1953 Issue (30 (pages)	1.20	1.80	3.60
	Vol. AP-1, No. 2; October 1953 Issue (64 pages)	1.20	1.80	3.60
	Vol. AP-2, No. 1; January 1954 Issue (39 pages)	1.35	2.00	4.05
Audio	PGA-5; Design Interrelations of Records and Reproducers (8 pages)	.30	.45	.90
	PGA-7; Editorials, Technical Papers and News, May 1952 Issue (48 pages)	.90	1.35	2.70
	PGA-10; November–December 1952 Issue (28 pages)	.70	1.05	2.10
	Vol. AU-1, No. 1; January–February 1953 Issue (26 pages)	.60	.90	1.80
	Vol. AU-1, No. 2; March–April 1953 Issue sue (36 pages)	.80	1.20	2.40
	Vol. AU-1, No. 3; May–June 1953 Issue (24 pages)	.80	1.20	2.40
	Vol. AU-1, No. 4; July–August 1953 Issue (19 pages)	.70	1.05	2.10
	Vol. AU-1, No. 5; September–October 1953 Issue (11 pages)	.50	.75	1.50
	Vol. AU-1, No. 6; November–December 1953 Issue (27 pages)	.90	1.35	2.70
	Vol. AU-2, No. 1; January–February 1954 Issue (38 pages)	1.20	1.80	3.60
Broadcast and Television Receivers	PGBTR-1; Round-Table Discussion on UHF TV Receiver Considerations, 1952 IRE National Convention (12 pages)	.50	.75	1.50
	PGBTR-2; General Color-Receiver Design Considerations and Connection of UHF & Color Adaptors to UHF Receivers (21 pages)	.60	.90	1.80
	PGBTR-3; June 1953 Issue (67 pages)	1.40	2.10	4.20
	PGBTR-5; January 1954 Issue (96 pages)	1.80	2.70	5.40
Circuit Theory	PGCT-1; IRE Western Convention, August 1952 (100 pages)	1.60	2.40	4.80
	PGCT-2 Papers Presented at the Circuit Theory Sessions of the Western Electronic Show and Convention, San Francisco, California, August 19–21, 1953 (106 pages)	1.95	2.90	5.85
	Vol. CT-1, No. 1 March 1954 Issue (80 pages)	1.30	1.95	3.90

*** Public libraries, colleges, and subscription agencies may purchase at IRE Member rate.**

IRE News and Radio Notes

PUBLICATIONS OF THE IRE *cont'd* from page 1031

The following issues of *Transactions* are available from the Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N. Y., at the prices listed below.

Sponsoring Group	Publications	Group Members	IRE Members	Non-Members*
Communications Systems	Vol. CS-1, No. 1; Includes papers presented at the Technical Conference on Communications (72 pages)	$1.50	$2.25	$4.50
	Vol. CS-2, No. 1; January 1954 Issue (83 pages)	1.65	2.50	4.95
Component Parts	PGCP-1; March 1954 Issue (46 pages)	1.20	1.80	3.60
Electronic Computers	Vol. EC-2, No. 2; June 1953 Issue (27 pages)	.90	1.35	2.70
	Vol. EC-2, No. 3; September 1953 Issue (27 pages)	.75	1.10	2.25
	Vol. EC-2, No. 4; December 1953 Issue (47 pages)	1.25	1.85	3.75
	Vol. EC-3, No. 1; March 1954 Issue (39 pages)	1.10	1.65	3.30
Electron Devices	PGED-1; Papers from IRE Conference on Electron Tube Research and IRE-AIEE Conference on Semi-conductor Research, June 1952 (32 pages)	.80	1.20	2.40
	PGED-2; Papers on Electron Devices presented at the IRE Conference on Electron Tube Research, Ottawa, Canada June 16–17, 1952 and IRE Western Convention, Long Beach (84 pages)	1.60	2.40	4.80
	PGED-4; December 1953 Issue (62 pages)	1.30	1.95	3.90
Engineering Management	PGEM-1; February 1954 Issue (55 pages)	1.15	1.70	3.45
Industrial Electronics	PGIE-1; August 1953 Issue (40 pages)	1.00	1.50	3.00
Information Theory	PGIT-2; A Bibliography of Information Theory (Communication Theory—Cybernetics) (60 pages)	1.25	1.85	3.75
	PGIT-3; March 1954 Issue (159 pages)	2.60	3.90	7.80
Instrumentation	PGI-2; Data Handling Systems Symposium; IRE Western Electronic Show & Convention, Long Beach, California, August 27–29, 1952 (109 pages)	1.65	2.45	4.95
Medical Electronics	PGME-1; November 1953 Issue (40 pages)	1.05	1.55	3.15
Microwave Theory and Techniques	Vol. MTT-1, No. 2; November 1953 Issue (44 pages)	.90	1.35	2.70
Quality Control	PGQC-1; Papers presented at 1951 Radio Fall Meeting, and 1952 IRE National Convention (60 pages)	1.20	1.80	3.60
	PGQC-2; March 1953 Issue (51 pages)	1.30	1.95	3.90
	PGQC-3; February 1954 Issue (39 pages)	1.15	1.70	3.45
Vehicular Communications	PGVC-2; Symposium on What's New in Mobile Radio (32 pages)	1.20	1.80	3.60
	PGVC-3; Theme: Spectrum Conservation, Washington, D. C., December 3–5, 1952 (140 pages)	3.00	4.50	9.00

(Technical Committee Notes, cont.)

on American Recommended Practice for Volume Measurement of Electrical Speech and Program Waves; (2) Supplement No. 2 to Standard 51 IRE 17. S1 VHF-UHF Antenna Construction; (3) Standards on Graphical Symbols for Electrical Diagrams, 1953; (4) Standards on Television: Methods of Measurement of Aspect Ratio and Geometric Distortion, 1953; (5) Standards on Audio Techniques: Definitions of Terms, 1953. Mr. Jensen introduced S. L. Bailey, IRE Standards Co-ordinator. Mr. Bailey thanked Mr. Jensen for his fine leadership as Chairman of the Standards Committee and introduced the two new officers: Dr. Ernst Weber, Chairman-elect and Mr. R. F. Shea, Vice Chairman-elect—Measurements. Mr. Bailey also stated that the Executive Committee of IRE had vested final authority for IRE Standards in the Standards Committee.

The **Standards Committee** in its meeting April 8 heard the report of Jack Avins, Chairman of an Ad Hoc Committee on a New Unit for Logarithmic Ratios. He stated that he and Mr. Baldwin would represent the IRE at a meeting to be held April 15 for an informal discussion of the problem by all interested groups. The Standards Committee authorized Messrs. Baldwin and Shea to express the opinion of the Standards Committee that (1) a new logarithmic unit is desirable and (2) preferably the designation "decibel" be retained for 10X log of a power ratio. J. G. Kreer, Jr. asked the Standards Committee to define the purpose of writing standards. The Committee discussed the ways in which Standards are currently used, but no clear definition of purpose was agreed upon. Dr. Weber stated that the Standards Manual would be revised to include a statement of the purpose. The group agreed that arrangements should be made to print Technical Committee Personnel lists in the Directory. The Committee gave a rising vote of thanks to the retiring Chairman, A. G. Jensen.

The **Audio Techniques Committee** in its meeting April 7 discussed the problem of a new unit for logarithmic ratios, and made revisions in the Proposed Standard on Audio Systems and Components Excluding Recording: Methods of Measurement.

The **Facsimile Committee** convened on March 5th under the chairmanship of A. G. Cooley. There was a discussion concerning the facsimile test chart pertaining to cost of printing, etc. There was also a discussion on the paper by E. I. Green on a new unit for logarithmic ratios. It was decided to send a copy of the paper to all committee members for further study. A number of definitions were reviewed and acted upon.

Correction

The listing of the abstract of Paper 20.4 of the IRE Convention Papers, on Page 614 of the March issue of the PROCEEDINGS OF THE I.R.E., should read as follows: "Single-Gun Picture Tubes in NTSC Color Television," by S. K. Altes and A. P. Stern.

Abstracts of Transactions of the I.R.E.

The following issues of *Transactions* have just been published and are now available from The Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N. Y. at the following prices. The contents of each issue and, where available, abstracts of technical papers are given below.

Sponsoring Group	Publication	Group Members	IRE Members	Non-Members*
Antennas and Propagation	Vol. AP-2, No. 2, April, 1954	$2.00	$3.00	$6.00
Circuit Theory	Vol. CT-1, No. 1, March, 1954	1.30	1.95	3.90

**Public libraries and colleges can purchase copies at IRE Member rates.*

ANTENNAS AND PROPAGATION

Vol. AP-2, No. 2, April, 1954

Why Transactions—E. Weber (*editorial*)
News and Views

An Experimental Investigation of the Single-Wire Transmission Line—J. E. Roberts

The results of some measurements made on a dielectric coated wire are presented and compared with theoretical results. These measurements indicate that the single-wire line can be considered as a simple transmission line provided account is taken of the "end-effect."

Sweep Frequency Backscatter—Some Observations and Deductions—R. Silberstein

Sweep-frequency backscatter records have proved to be of great value in identifying the sources of backscatter seen on a fixed frequency by demonstrating the development of the echo as frequency and range increase. The most commonly observed scatter is ground scatter propagated via the F2 layer, but it is also evident that the other layers propagate ground scatter, and that scatter from the distant E region may at times be important.

In one group of observations over an 1,150-km path on three undisturbed days, the values of F2-layer maximum usable frequency scaled from midpoint vertical-incidence ionospheric records and those determined by backscatter delay assuming ground scatter agreed almost within experimental error. In another three-day group characterized by a low-latitude ionospheric disturbance, with low geomagnetic K indices but considerable sporadic E activity, values of muf determined from the scatter were much too high under the ground-scatter assumption, errors of 30% being common.

Some Stochastic Problems in Wave Propagation—Part II—Joseph Feinstein

In Part I some of the properties of wave energy reflected from surfaces subject to random height variations were investigated.

Here we ascertain the effects of refractive index fluctuations within a volume upon the properties of waves traversing the medium. The results are applied to problems encountered in tropospheric and ionospheric propagation.

On the Theory of Corrugated Plane Surfaces—R. S. Elliott

An analysis is given of an electromagnetic system composed of a rectangular waveguide in tandem with a corrugated waveguide which feeds a flat, corrugated surface of arbitrary length terminated by a ground plane, whose length is also arbitrary. An improved procedure of field determination is used, which combines Floquet's theorem and the variational principle, thus revealing an additional requirement on the corrugation geometry. Factors influencing a match at the feed mouth, and satisfactory launching of the surface wave are discussed. The degree of suppression of the feed radiation is given in db as a function of the geometry of the system. Approximate radiation patterns are derived for two cases, (a) when the system is terminated by an infinite ground plane, and (b) when the system is terminated by a finite ground plane. For the latter case, an upper bound on the tilt angle of the main beam and a lower on its beamwidth result from an approximate theory. For both cases, the Hansen-Woodyard endfire relation is found to provide beam sharpening even when the feed radiation is considered. The presence of higher order surface modes, their effect, and their elimination, are discussed. Comparison of the theory with experiment is reasonably good.

Meteoric Radio Echoes—L. A. Manning

Study of meteoric effects by radio methods has resulted in gain to three fields—astronomy, upper atmosphere physics, and radio propagation. In each of these fields progress is surveyed, and some of the more important unsolved problems are pointed out.

CIRCUIT THEORY

Vol. CT-1, No. 1, March, 1954

Trends in Feedback Systems—Otto J. M. Smith (*editorial*)

Nonlinear Control Systems with Random Inputs—R. C. Booton, Jr.

A quasi-linear approximation is developed for the analysis of nonlinear systems that are composed of linear devices, feedback circuits, and purely amplitude-sensitive elements. The nonlinearity input functions are Gaussian. Minimizing the rms error of the approximation yields a linearization whose cross-correlation exactly equals that of the nonlinear element. Consideration is given to the specific case of a simple-lag system in which the nonlinearity occurs as a rate limiting. The actual system is simulated on an analog computer. Agreement with predicted theoretical results is shown.

A Method of Analysis and Synthesis of Closed-loop Servo Systems Containing Small Discontinuous Type Non-linearities—D. T. McRuer and R. G. Halliday

The inclusion of discontinuous type non-linearities in the Bode diagram is based upon the determination of "equivalent" linear transfer functions for the non-linearities, derived by considering a sinusoidal input applied to the non-linear element, and by determining the Fourier series of the resulting output wave form. "Equivalent" phase angle and amplitude ratio will be defined.

Use of the Bode diagram is limited to those systems which may be described by linear differential equations with constant coefficients. Such a restriction is quite severe, since the majority of real physical systems do not exist without nonlinearities in their so-called linear ranges. Assumptions restricting the validity of the concept will be presented. The technique will be illustrated by considering specific cases.

Stability of Feedback Systems Using a Dual Nyquist Diagram—Paul Jones

This paper describes a method of determining the stability of feedback systems by means of the intersection of two loci instead of the more common encirclement of the critical point, $-1+j0$, by the locus of the function $A\beta$.

Deviation from the usual method of plotting a Nyquist diagram is believed to be of particular advantage whenever the feedback path is a known function of frequency.

The mechanization of known transfer functions by means of analog computing amplifiers is used as a convenient example, since the feedback factor is always a known quantity.

Optimum Lead-Controller Synthesis in Feedback-Control Systems—Louis G. Walters

Lead controllers are capable of improving the damping of a feedback control system, but not without introducing some signal attenuation which may be objectionable if noise is a problem. A technique for designing a lead controller with the aid of the root-locus chart is described, one which allows the direct specification of the location of the system's dominant roots. In addition, the root-locus chart yields data which permits the designer to select that lead controller which meets the system specification with minimum signal attenuation as well. Examples are given which serve to illustrate the usefulness of this latter procedure.

On the Comparison of Linear and Nonlinear Servomechanism Response—T. M. Stout

The integrated absolute error for a step input can be plotted as functions of the initial error on log-log co-ordinates and used to compare linear and nonlinear systems. The proximity of the curve for any given system to two straight lines, which can be located with a knowledge of three basic system parameters, provides an indication of the quality of the system. A plus-minus servomotor with inertia and viscous friction, using maximum torque at all times, generates an error line with a slope of 3/2. Using constant velocity, the line slope is 2. They intersect at $e=4JT_m/f^2$. All real systems lie above these two lines.

Predictor Servomechanisms—L. M. Silva

A new technique for the design of servomechanisms with optimum transient response is presented. The fundamental concept in the new method is that the control or forcing of the output member must be performed in such a manner that the error and its derivatives shall be reduced to zero in a minimum time by the successive application of accelerating and decelerating torques to the output member. The Predictor operator which determines the point at which the torque must reverse in order to accomplish the desired control action is a nonlinear function of the system parameters and the magnitude of the maximum value of the torque or force which is available. The energy balance method for deriving predictor operators is presented and the method is applied to a 2nd and a 3rd order system.

Conversion of a Brune Cycle with an Ideal Transformer into a Cycle without an Ideal Transformer—F. M. Reza (For abstract, see Jan. Proc. I.R.E., p. 349.)

"What is Nature's Error Criterion?"—Ernest A. Guillemin (*correspondence*).

"Multi-loop Nonlinear Systems"—K. Klotter (*correspondence*).

"Are Bibliographies Wanted?"—G. Allan Smith (*correspondence*)

PGCT News Section

IRE People

Walter E. Noller (S'38–A'41–SM'46) has recently joined the engineering department of Lynch Carrier Systems, Inc., in an executive capacity.

Walter E. Noller

Mr. Noller received his B.S. degree from the University of California in 1938, and his M.S. degree from the same institution in 1939. His previous experience includes work with Bell Telephone Laboratories, where he was engaged in the design and development of voice-operated devices and fire-control radar equipment. As a result of this work he received the Naval Ordnance Development Award. He was later affiliated with the Pacific Telephone and Telegraph Co. as Senior Engineer. In this capacity his work included toll transmission, inductive co-ordination, protection, and toll plant extension engineering.

Mr. Noller is a member of the American Institute of Electrical Engineers, Eta Kappa Nu, Tau Beta Pi, and Sigma Xi.

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On July 1, **John D. Ryder** (A'25–SM'45–F'52) will take over his new duties as Dean of the School of Electrical Engineering at Michigan State College, East Lansing, Mich. On that date, he will relinquish his post of Head of the Department of Electrical Engineering at the University of Illinois.

John D. Ryder

Dr. Ryder was born in 1907 in Columbus, Ohio. He received the B.E.E. degree in 1928 and the M.S. degree in 1929 from Ohio University, where he was a Robinson Fellow. In 1944, he earned his Ph.D. degree in Electrical Engineering from Iowa State University.

From 1929–1931 he was affiliated with the General Electric Co. He joined the Bailey Meter Co. in 1931 as supervisor of the electrical and electronic section of the Research Laboratory. He holds twenty-four patents on work done in that capacity. In 1941 he was appointed Assistant Professor of Electrical Engineering at Iowa State College, was made Professor in 1944, and in 1947 assumed his position of Assistant Director of the Iowa Engineering Experiment Station. In 1950, he joined the faculty of the University of Illinois as Professor of Electrical Engineering. He is the author of two textbooks on electronics and networks, and of other technical papers.

Dr. Ryder is a member of the American Institute of Electrical Engineers, the American Association for the Advancement of Science, Tau Beta Pi, Eta Kappa Nu, and Sigma Xi.

Charles E. Kilgour (A'25–M'30–SM'43–F'51), Research Engineer with the Crosley Division, Avco Manufacturing Corp., died recently.

C. E. Kilgour

Mr. Kilgour, born in Detroit, Mich. on March 29, 1886, received the degree of Civil Engineer from the University of Cincinnati in 1910. He became affiliated with the Crosley Co. at a time when automobile accessories constituted their principle products. He was then associated with the Crosley Corp. activity and that of its successor, the Avco Manufacturing Corp., for 34 years. During this period of activity his work included the design, development and engineering of many products such as automobiles, phonograph pick-up devices, broadcast receivers and transmitters; he served at various times in the capacity of Chief Engineer, Staff Engineer, and Research Consultant. He taught radio courses in the Evening College of the University of Cincinnati for many years. At the end of World War II, Mr. Kilgour received the Navy Ordnance Development Award for outstanding service on the Proximity Fuze Development Program.

Mr. Kilgour was a charter member of the I.R.E., and was active on many IRE committees. From 1932–1933 he served as chairman of the Cincinnati Section.

James B. Fisk (SM'52), director of research in physical sciences at Bell Telephone Laboratories, has recently been elected vice president in charge of research. He succeeds **Ralph Bown** (M'22–F'25), who continues as a vice president with a new assignment in charge of the long-range planning of Laboratories' programs. Dr. Bown will continue his present responsibilities in connection with the Patent Department.

Dr. Fisk received his bachelor's and doctoral degrees from the Massachusetts Institute of Technology. From 1932 to 1934 he was a Proctor Traveling Fellow at Cambridge University, England, and from 1935 to 1939 a Junior Fellow in the Society of Fellows at Harvard. He also served as Associate Professor of Physics at the University of North Carolina.

Dr. Fisk, who joined Bell Laboratories in 1939, has had a distinguished scientific career, including two years as Director of Research of the Atomic Energy Commission and simultaneously Gordon McKay Professor of Applied Physics at Harvard University. He is currently a member of the General Advisory Committee of the Atomic Energy Commission as well as the Science Advisory Committee of the Office of Defense Mobilization.

During World War II when the potentialities of the microwave magnetron for high-frequency radar were discovered, Dr. Fisk was selected to head the development group at Bell Laboratories. After the war, he was placed in charge of electronics and solid state research. It was work in this area that resulted in the invention at the Laboratories of the transistor, the revolutionary electronic device which has attracted such widespread attention. In 1949 when he returned to the Laboratories from the Atomic Energy Commission and Harvard, he was placed in charge of research in the physical sciences.

Dr. Fisk is a Fellow of the American Physical Society and the American Academy of Arts and Sciences, and was formerly a Senior Fellow of the Society of Fellows at Harvard University.

Dr. Bown received the degrees of M.E., M.M.E., and Ph.D. from Cornell University. His career in the administration of industrial research includes nearly 35 years with the Bell System. Before his appointment as vice president in charge of research of Bell Laboratories in 1952, he had served as director of research since 1936. Much of Dr. Bown's work has been concerned with various aspects of radio broadcasting and ship-to-shore and overseas telephony. He was a division member and consultant of the National Defense Research Committee, specializing in radar, and in 1941 he visted England to study radar operations under combat conditions. He also served as expert consultant to the Secretary of War.

Dr. Bown, who has been widely recognized for his pioneering work in the broad field of communications engineering, was awarded the IRE Morris Liebmann Memorial Prize in 1926, and in 1949 he received the IRE Medal of Honor. He is a past president of the I.R.E. He is a Fellow of the American Association for the Advancement of Science, the Acoustical Society of America, the American Physical Society, and the American Institute of Electrical Engineers.

Frederick Holborn (SM'53), physicist and radio engineer, died recently.

Mr. Holborn was born in Berlin, Germany, and attended the Universities of Freiburg, Goettingen, Wuerzburg, and Jena. He came to this country in 1923. Affiliated at various times with the Stevens Institute, the Westinghouse Electric Corp., and the Western Union Telegraph Co., he had for the past three years been employed with the National Union Radio Corp. as project engineer and as Supervisor of Engineering.

Mr. Holburn was an adjunct professor at the Columbia University graduate extension School of Electrical Engineering, and was a member of the American Physical Society of New York.

IRE People

Salvatore R. Petremio (M'50), development engineer for the DuMont Television Network, died recently.

Mr. Patremio was born in Lodi, N. J., in 1917. He began his career in television engineering in 1936 with Kuss Brother's electrical appliance store in Hackensack, N. J. He was affiliated with this firm until 1941, during which time he attended a G.E. sponsored television extension course, and an RCA Television lecture course. In 1941 he worked for a short time in the Allen B. DuMont research department, and then he became Operation Engineer for Television Station WABD. In 1944 he became Chief Engineer of WABD. From 1949 he served successively as Network Maintenance Engineer, Special Projects Engineer, and Development Engineer for the DuMont Television Network.

Mr. Patremio held two patents on video devices. At the time of his death he was serving as Vice Chairman of the Facilities Committee for the 1954 IRE National Convention.

Walter Hausz (A'44–SM'46–F'54) was recently appointed manager of Cornell University's Advanced Electronics Center, which is a part of the newly formed Laboratories Department of General Electric's Electronics Division. He had been manager of development engineering in the GE Electronics Laboratory at Syracuse.

WALTER HAUSZ

Mr. Hausz is a native of New York City, and a graduate of Columbia University. He joined General Electric at Schenectady in 1939 as a student engineer, and the Electronics Laboratory at Schenectady in 1945. From 1945 until 1948 he specialized in guided missile work, including a visit into Germany as the war was ending, to locate German scientists and to obtain information on guided missiles. He participated in several test rocket firings at White Sands, New Mexico.

He came to Syracuse in 1948, when the Electronics Laboratory was transferred from Schenectady, and has held positions as section engineer, assistant to the manager, and sections head. He became manager of development engineering in 1952.

In 1952, Mr. Hausz received GE's highest honor, a Charles A. Coffin Award, for outstanding ingenuity and ability in the development of a radar system which provided a new automatic tracking technique for radar directed weapons.

A. D. Knowlton (SM'46) has recently been appointed Director of Design Engineering of Bell Telephone Laboratories in New York City. He succeeds M. H. Cook who was recently elected a vice president of the Laboratories.

A. D. KNOWLTON

Mr. Knowlton is veteran of more than 33 years of Bell System Service. In 1920, shortly after graduating from Haverford College, he joined the Western Electric Company's Engineering Department, which was incorporated as Bell Telephone Laboratories in 1925. He has specialized in the field of design of Bell System equipment and systems, including manual switchboards, teletypewriter switchboards, telegraph equipment, and transmission systems, as well as radar equipment for the armed forces. In 1950 he was appointed Director of Systems Engineering and in 1951 to his present post as Director of Facilities Development.

Mr. Knowlton holds several patents and is the author of a number of technical articles on teletypewriter systems and manual switchboards. He is a fellow of the American Institute of Electrical Engineers.

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George W. Bailey (A'38–SM'46), Executive Secretary of the IRE, was elected President of the Armed Forces Communications Association for a one-year term by the AFCA Board of Directors on May 7, 1954.

G. W. BAILEY

Mr. Bailey was born in Quincy, Mass. He received the A.B. degree from Harvard College in 1907, and is Treasurer of his class.

During World War II, Mr. Bailey served in Washington, D. C., as Chief of the Office of Scientific Personnel under Dr. Vannevar Bush, Director of the Office of Scientific Research and Development, for which he was awarded the certificate of merit by President Truman. He was appointed Executive Secretary of the IRE in 1945.

He has long been well known as an amateur radio operator. From 1940 to 1952 he held the offices of President of the American Radio Relay League and President of the International Amateur Radio Union.

In 1950 he was appointed to the Engineering Sciences Advisory Committee by Major General Lewis B. Hershey, Director of the Selective Service System, and served until the Committee was disbanded in 1953.

A. Donald Arsem (SM'52) has been recently appointed manager of advanced products development engineering in the General Electric Electronics Laboratory in Syracuse, N. Y.

A. DONALD ARSEM

Mr. Arsem is a native of Schenectady, N. Y., and a graduate of Massachusetts Institute of Technology in 1945. He joined General Electric in the Electronics Laboratory in 1948, after service with the National Bureau of Standards and the Radio Corporation of America. He has served in the GE laboratory on electronics applications for guided missiles, and had been section engineer on magnetic materials since November, 1952.

Mr. Arsem is a member of the Scientific Research Society of America.

Frederick T. Budelman (A'41), president of the Budelman Radio Corp., Stamford, Conn., died recently.

F. T. BUDELMAN

Mr. Budelman, a native of Newark, N. J., studied electrical engineering at Cornell University, where he received the E.E. degree in 1931. He was subsequently affiliated for many years with the Link Radio Corp., in which he was active in the development of FM communication equipment for land-mobile services and for important military applications such as multi-channel radio relay systems. In 1951, the Budelman Radio Corp. was formed and Mr. Budelman became the president.

Mr. Budelman had been active in IRE affairs since 1941. He served on various technical committees, including the Standards Committee and the Mobile Communications Committee, and was chairman of the subcommittee on Land-Mobile Channeling Arrangements of the Joint Technical Advisory Committee from 1951 to 1953. He was a member of the Professional Group on Vehicular Communications from 1951 and served as chairman from 1952–1953.

Mr. Budelman was a member of the American Institute of Electrical Engineers.

Report of the Secretary—1953

To the Board of Directors,
The Institute of Radio Engineers

Gentlemen:

Another annual report, for the year 1953, is herewith transmitted. It embodies the usual statistics and other information concerning the various institute operations and activities, notably membership, editorial, technical (including the Professional Groups), Section, Student Branches and Conferences.

Institute affairs are still on an expanding basis, as this report clearly shows. The large specialized issues of the Proceedings and the augmented number, sizes and activities of the Professional Groups, their Chapters and Transactions are of particular interest, in addition to which mention is made of the Convention Record, which appeared for the first time. Twice as many persons attended the National Convention in 1953 than in 1950 which is a testimonial of the importance of your Institute in the professional field.

Respectfully submitted,

Haraden Pratt

Haraden Pratt,
Secretary

January 22, 1954

Membership

At the end of the year 1953, the membership of the Institute, including all grades, was 37,134, an increase of 4,260, or 13% over the previous year. The 4,260 member increase in 1953 was more than 3,466 and 406, the increases for 1952 and 1951 respectively. The percentage increase was 12% in 1952, and 1.4% in 1951. The membership trend from 1912 to date is shown graphically in Figure 1.

Actual membership figures for 1951, 1952 and 1953 are shown in Table I. Of the 21,846 non-voting Associates, 4,680 have been in that grade for more than five years.

TABLE I

Total Membership Distribution by Grades

Grade	As of Dec. 31, 1953		As of Dec. 31, 1952		As of Dec. 31, 1951	
	Number	Per Cent of Total	Number	Per Cent of Total	Number	Per Cent of Total
Fellow	425	1.2	379	1.2	345	1.2
Senior Member	4,170	11.2	3,566	10.8	3,070	10.4
Member	5,307	14.3	4,617	14.0	4,043	13.7
Associate	22,702‡	61.1	20,029†	61.0	17,523*	59.6
Student	4,530	12.2	4,283	13.0	4,427	15.1
Totals	37,134		32,874		29,408	

* Includes 974 Voting Associates.
† Includes 919 Voting Associates.
‡ Includes 856 Voting Associates.

It is with deep regret that this office records the death of the following members of the Institute during the year 1953.

Fellows

Dunn, Gano (F'15, L'50)
Forbes, Henry C. (A'20, M'29, SM'43, F'48)
Mayer, Emil E. (F'34)
McNicol, Donald (A'14, M'14, F'24, L'49)
Wagner, Karl W. (F'51)

Senior Members

Aceves, Julius G. (M'40, SM'43)
Bond, Marion E. (A'29, SM'44)
Brown, George M. (A'42, SM'46)
Burgess, Alfred G. (A'30, SM'50)
Burlingame, Bruce O. (SM'48)
Gorham, John Everett (A'42, M'46, SM'49)
Hinshaw, Foster A. (SM'53)
Miller, Samuel C. (M'43, SM'43)
Nicholas, Edwin A. (A'16, SM'46)
Smythe, Edwin H. (A'15, M'26, SM'43, L'50)
Thwaites, Joseph T. (SM'46)

Members

Anderson, Ralph M. (M'53)
Drew, John Lawrence (M'45)
Hites, Charles E. (M'52)
Hoffman, Wayne C. (A'46, M'52)
Hutton, E. A. D. (M'46)
MacAdam, Mark L. (M'44)
Maller, Melvin (M'50)
Mohler, Charles W. (M'50)
Sangster, L. M. (A'46, M'51)
Schacht, Edward L. (M'46)
Stewart, Roderick D. (A'42, M'43)
Striplin, John E. (A'48, M'49)
Trevey, Clyde B. (A'47, M'49)
Webster, Norman D. (A'38, M'49)
Zimmerman, F. C. (S'43, A'45, M'46)

Voting Associates

Ayer, Oliver G. (A'27, VA'39)
Brunn, Robert B. J. (A'36, VA'39)
Fredericks, John Erick (A'15, VA'39)
Hermanny, Will F. (A'32, VA'39)
Martino, Italo A. (A'37, VA'39)

Associates

Asdal, Maywood K. (A'49)
Baker, Donald M. (A'52)
Barzilaski, Peter M. (A'48)
Benson, Howard C. (A'44)
Byard, Elmer J. (S'48, A'51)
Crozer, Wilfred Allen (A'43)
Deland, Robert E. (A'47)
Dewey, Donald L. (A'46)
Edelman, Frederick (A'53)
Foss, William LeRoy (A'49)
Friedman, Joseph (A'53)
Gempp, Theodore A. (A'47)
Harvey, Joseph D. (A'50)
Hayden, Frank L. (A'53)
Himes, B. T., Jr. (S'41, A'44)
Horstmann, Arthur F., Jr. (A'45)
Irby, Joe George (S'43, A'45)
Johns, Loren W. (S'48, A'50)

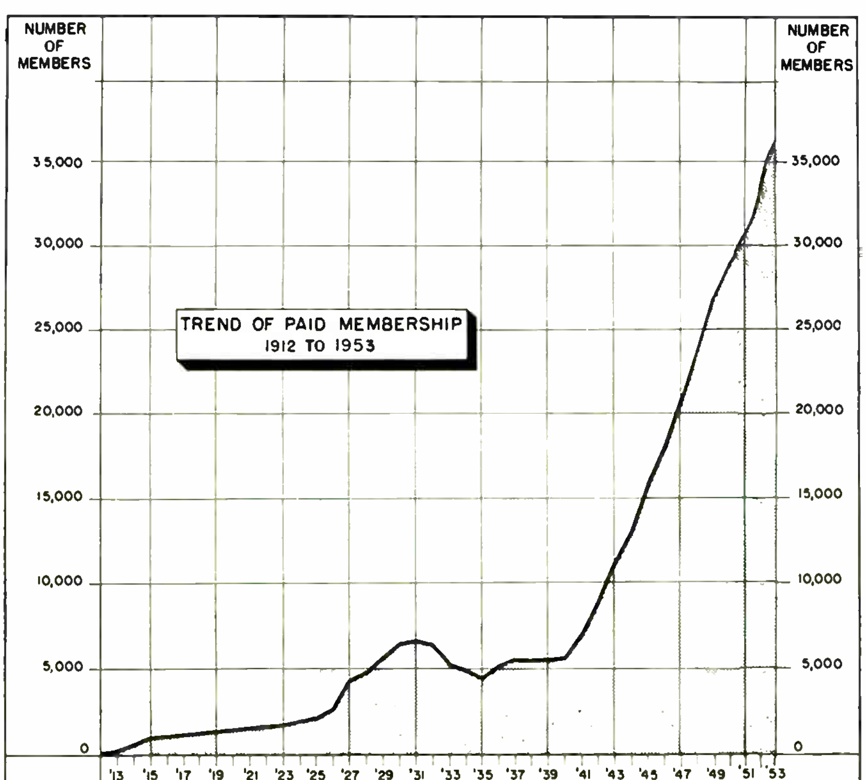

Fig. 1

McInnes, Harold W. (A'51)
Milovick, Michael (S'49, A'50)
Morton, Oscar Lee (A'47)
Norgorden, Oscar (A'44)
Sharp, Douglas R. (A'48)
Sherwood, William W. (A'42)
Sling, Owen H. (S'49, A'50)
Traver, Loran L. (A'49)
Watford, David A., Jr. (S'50, A'52)
Wenzel, John A. (S'49, A'51)
Whyte, Robert P. (A'48)
Wolfson, Hilliard (A'44)

Students

Pahl, Robert William (S'53)
Peay, John W. (S'52)
Trau, Lazarus E. (S'49)

Fiscal

A condensed summary of income and expenses for 1953 is shown in Table II, and a balance sheet for 1953 is shown in Table III.

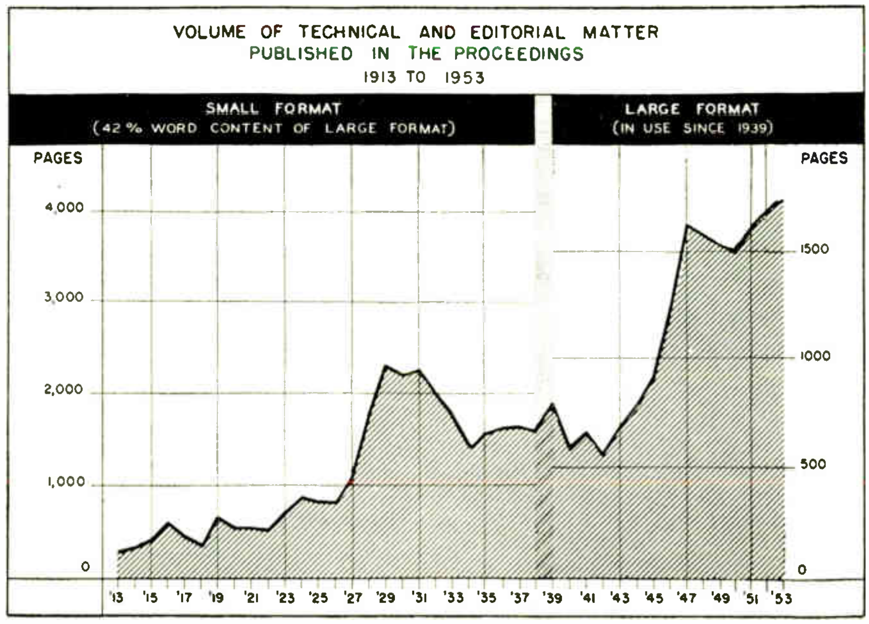

Fig. 2

TABLE II
SUMMARY OF INCOME AND EXPENSES, 1953

Income		
Advertising	$693,725.24	
Member Dues and Convention	696,530.51	
Subscriptions	87,511.74	
Sales Items—Binders, Emblems, etc.	45,844.78	
Investment Income	22,779.63	
Miscellaneous Income	647.97	
TOTAL INCOME		$1,547,039.87
Expense		
PROCEEDINGS Editorial Pages	$244,911.50	
Advertising Pages	363,770.52	
Directory	126,466.09	
Section and Student Branch Rebates	45,053.34	
Professional Group Expense	51,634.52	
Sales Items	30,992.83	
General Operations	262,250.88	
Convention Cost	197,530.78	
TOTAL EXPENSE		1,322,610.46
Reserve for Future Operations—Gross		$ 224,429.41
Reserve for Depreciation		11,026.67
Reserve for Future Operations—Net		$ 213,402.74

TABLE III
BALANCE SHEET—DECEMBER 31, 1953

Assets		
Cash and Accounts Receivable	$407,572.36	
Inventory	16,089.15	
TOTAL CURRENT ASSETS		$ 423,661.51
Investments at Cost	$873,765.95	
Buildings and Land at Cost	576,943.65	
Furniture and Fixtures at Cost	120,479.44	
Other Assets	18,343.88	
TOTAL		1,589,532.92
TOTAL ASSETS		$2,013,194.43
Liabilities and Surplus		
Accounts Payable	$ 31,987.14	
Federal Taxes on Emblems, etc.	97.00	
TOTAL CURRENT LIABILITIES		$ 32,084.14
*Deferred Liabilities	503,325.10	
Professional Group Funds on Deposit	78,956.45	
TOTAL OTHER LIABILITIES		582,281.55
TOTAL LIABILITIES		$ 614,365.69
Reserve for Depreciation		48,149.97
Surplus Donated	$595,286.61	
Surplus Earned	755,392.16	
TOTAL SURPLUS		1,350,678.77
TOTAL LIABILITIES AND SURPLUS		$2,013,194.43

* 1954 Items, PROCEEDINGS for Members and Subscribers, Advertising and Convention Service.

Editorial Department

The year 1953 was marked by a major expansion in the publication activities of the IRE. During the year 56 publications totaling 8,360 pages were published, representing a 40% increase over the previous year.

Perhaps of greater significance than the increased volume of published material was the fact that a firm foundation was laid for the future growth of the publication program of the Institute. In this connection, the most notable developments during 1953 were the crystallization and expansion of the Professional Group TRANSACTIONS program, the successful initiation of the CONVENTION RECORD OF THE I.R.E., and adoption of a plan of editorial committee reorganization which will expedite the review and publication of PROCEEDINGS papers and better coordinate the contents of PROCEEDINGS with those of TRANSACTIONS.

Proceedings of the I.R.E.

The Board of Directors adopted, at the suggestion of Editor Alfred N. Goldsmith, a plan of editorial committee reorganization whereby the present Papers Review Committee, Board of Editors, and Administrative Committee of the Board of Editors would be superseded in 1954 by two new committees, namely, the Editorial Review Committee and the Editorial Board. This reorganization is expected to result in reducing the time required to review papers for the PROCEEDINGS. In addition, it is planned to draw upon the Professional Groups for members to serve on the Editorial Review Committee, thereby insuring that the best interests of both the PROCEEDINGS and TRANSACTIONS are served.

The 1953 publication schedule was highlighted by issuance of two special issues of PROCEEDINGS on topics of particular timeliness and importance, the UHF Issue in January and the Computer Issue in October.

The total number of pages published in the PROCEEDINGS during the year was 4,006, including covers. As shown in Table IV, this was a marked increase over previous years. The number of editorial pages published each year since 1913 is shown in Figure 2.

TABLE IV

VOLUME OF "PROCEEDINGS" PAGES

	1953	*1952*	*1951*	*1950*
Editorial	1860	1804	1628	1516
Advertising	2146	1800	1424	1016
Total	4006	3604	3052	2532

Professional Group Transactions

The year 1953 saw a 50% increase in the publication activities of the Professional Groups of the IRE and the firm establishment of the TRANSACTIONS as a permanent and important part of the IRE publication program. The year also saw an improvement in the TRANSACTIONS themselves, with all Groups adopting identifying colors for TRANSACTIONS covers, 3 Groups utilizing varitype or letterpress composition for improved appearance, and 6 Groups issuing TRANSACTIONS on a regular schedule.

As a result of this increased activity, the Editorial Department published 32 issues of TRANSACTIONS totaling 1798 pages for 15 Groups during 1953, as compared with the 1952 totals of 22 issues totaling 1474 pages for 10 groups. A breakdown of TRANSACTIONS material published in 1952 and 1953 is given in Table V.

TABLE V

VOLUME OF "TRANSACTIONS" PAGES

Group	1953		1952	
	Issues	Pages	Issues	Pages
Aeronautical and Navigational Electronics	3	84	4	68
Antennas and Propagation	2	72	4	636
Audio	6	180	6	216
Broadcast and Television Receivers	3	160	1	16
Circuit Theory	1	112	1	104
Communications Systems	1	76	0	0
Electron Devices	3	184	1	36
Electronic Computers	4	136	1	80
Industrial Electronics	1	44	0	0
Information Theory	2	290	0	0
Instrumentation	1	116	1	68
Medical Electronics	1	44	0	0
Microwave Theory and Techniques	2	100	0	0
Quality Control	1	56	1	62
Vehicular Communications	1	144	2	188
Totals	32	1798	22	1474

Convention Record of the I.R.E.

Publication of all papers presented at the 1953 IRE National Convention was undertaken for the first time in a new publication, the CONVENTION RECORD OF THE I.R.E. The volume, containing 213 papers totaling 1272 pages, was issued in ten parts with each part devoted to one general subject. Every paid member of a professional group received free of charge a copy of that part pertaining to the field of interest of his group.

The CONVENTION RECORD achieved, with notable success, the objective of providing the membership promptly with a permanent record of the technical papers presented at the Convention.

Joint Conference Publications

The Editorial Department expanded its services by offering its facilities to conferences jointly sponsored by the IRE and other societies. As a result, the Editorial Department published the 236-page Proceedings of the Western Computer Conference, held in Los Angeles, Calif., on February 4–6, 1953 by the IRE, AIEE, and the Association for Computing Machinery.

The Editorial Department has also undertaken publication of the Proceedings of the Eastern Joint Computer Conference, held in Washington, D. C., on December 8–10, 1953.

IRE Directory

The 1953 IRE Directory was the largest Directory published to date, containing 1,048 pages including covers, of which 473 were membership listings and information, 575 were advertisements and listings of manufacturers and products. The 1952 Directory totaled 856 pages.

Editorial Department

The year 1953 was particularly noteworthy in that it marked the 41st year in which Alfred N. Goldsmith has served as Editor during the 42-year history of the IRE. In recognition of the invaluable service he has rendered the Institute and his monumental contributions to the growth and high standing of its publications, the Board of Directors has appointed him Editor Emeritus of the Institute as of January 1, 1954.

Technical Activities

Technical Committees

There were 224 Technical Committee meetings during 1953. This figure includes meetings of the 23 Technical Committees, as well as the Subcommittees and Task Groups. A total of 182 were held at IRE Headquarters, the remaining 42 elsewhere.

The policy of publishing Standards in the PROCEEDINGS, as initiated in 1949, is being continued. The Standards listed below were published in 1953:

53 IRE 7. S1 Standards on Electron Devices: Methods of Measuring Noise

53 IRE 2. S1 Standards on Antennas and Waveguides: Definitions of Terms, 1953

53 IRE 19. S1 Standards on Sound Recording and Reproducing: Methods of Measurement of Noise, 1953

53 IRE 22. S1 Standards on Television: Definitions of Color Terms, Part 1, 1953

53 IRE 11. S1 Standards on Modulation Systems: Definitions of Terms, 1953

Supplement to Standard

51 IRE 17. S1 Supplement No. 2 to Standard 51 IRE 17. S1, VHF-UHF Antenna Construction

In addition to standardization work listed above, the following standards were adopted by the Standards Committee and submitted for Executive Committee approval during the latter part of 1953. They will appear in the PROCEEDINGS at an early date:

Standards on American Recommended Practice for Volume Measurements of Electrical Speech and Program Waves

Standards on Circuits: Definitions of Terms in the Field of Linear Varying Parameter and Non-linear Circuits

Standards on Sound Recording and Reproducing: Methods for Determining Flutter Content

Standards on Graphical Symbols for Electrical Diagrams

The Annual Review Committee is completing its survey, "Radio Progress During 1953," which will appear in a Spring issue of the PROCEEDINGS.

There has been no change in the number of Technical Committees. Fifteen new Subcommittees and Task Groups have been set up for specific purposes during 1953. There are now 85 Subcommittees and Task Groups within the IRE Technical Committee structure. Several Chairmen have appointed Ad Hoc Committees to survey future work and reorganize and activate Subcommittees.

Professional Group System

General. On June 2, 1948 the establishment of the first IRE Professional Group was approved by the Institute's Executive Committee. Since that time twenty additional groups have been established and all twenty-one groups are presently active. 14,850 Institute members have taken advantage of the professional groups system, which now has a total of 21,797 paid members.

The Institute has followed the course of limiting itself in stimulation and guidance of the Professional Groups Development. It 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. Supplementary financial assistance has been provided by Headquarters during the year. Provision for reimbursing Sections for Chapter meetings has also been made.

Nineteen of the Groups sponsored 62 national meetings, joint symposia with other professional societies and technical sessions. Eighteen Groups sponsored technical sessions at the 1953 National Convention; eleven groups sponsored the technical sessions presented at the 1953 West Coast Convention.

Professional Group Chapters

The purpose of a Chapter is to encourage the interests of its group members within a Section, to stimulate and conduct activities in the field of interest of the Group, and to co-ordinate these with the local activities of the Section and the national activities of the Group. A professional group Chapter Manual and Suggested By-Laws have been approved and distributed. This has provided formal information for Chapter personnnel to work directly with the Section and the Group.

Professional group activity within the Sections is increasing rapidly. 74 official Chapters were operating within the Sections on December 31, 1953.

Chapters are co-operating with the Sections in arranging technical programs for Section meetings and with the Groups in national meetings held in their areas.

Institute Representatives on Other Bodies

The IRE appointed representatives on a number of other bodies for the period, May 1, 1953 to April 30, 1954 (as listed on page 1042 of this issue).

Through these representatives, the IRE actively participated in the work of international as well as national organizations, such as the International Radio Consultative Committee, the International Scientific Radio Union, and the International Electrotechnical Commission.

Joint Technical Advisory Committee

The Joint Technical Advisory Committee and its subcommittees held 18 meetings at IRE Headquarters, in addition to a luncheon meeting at the Toronto Fall meeting in October.

Volume X of the JTAC Proceedings was published. This included Section I—Official Correspondence Between the Federal Communications Commission and the Joint Technical Advisory Committee (IRE—RETMA) with Other Items of Correspondence Pertinent to the Actions of the JTAC and Section II—Approved Minutes of Meetings of the Joint Technical Advisory Committee for the period 1 July 1952–30 June 1953.

The JTAC Subcommittee on Land-Mobile Channeling Arrangements submitted its final report on May 28, 1953, which was transmitted to the FCC Chairman on June 15. Nine meetings were held by the Subcommittee, including four days of field testing in Syracuse, New York, and additional field testing and demonstrations in Camden, New Jersey. The FCC Chairman on July 1 stated that the Commission feels confident that this study will lay the ground work for improved frequency utilization in the land mobile service.

The Interference Study set up by JTAC in December 1952 at the request of the FCC Chairman continued during 1953, with a total of six meetings held by the sub-committees. As a result of the JTAC's request to Dr. W. R. G. Baker, Director of the Engineering Department of RETMA, a meeting was called by Dr. Baker in New York City on January 9 to discuss under the sponsorship of RETMA, the problem of interference. At this meeting three Task Forces were set up by RETMA to co-operate with JTAC in the Interference Study. These Task Forces have held three meetings in 1953.

The JTAC Subcommittee to Review FCC Technical Requirements, set up in February 1952, submitted its report at the October meeting of JTAC. The Chairman was authorized to inform the FCC that the study disclosed that the more important provisions in the regulations can not be considered primarily from a technical standpoint and the remaining provisions regarding which suggestions were formulated by the Subcommittee, while of value, are not of sufficient importance to warrant formal consideration by the Commission at this time. The JTAC Chairman was authorized to advise the FCC Chairman of the results of the study and with his concurrence to give the suggested changes to the Chiefs of the Bureaus in charge of the particular subjects and to the Chief Engineer of the Commission for consideration when the rules concerned are revised.

NTSC

The National Television System Committee held 48 meetings at IRE Headquarters. The IRE Technical Secretary was Secretary of the co-ordinating Panel 18 of the NTSC. The NTSC Petition was filed with the Federal Communications Commission on July 23, 1953 and was subsequently supplemented with the final report of the NTSC.

Section Activities

We were glad to welcome six new Sections into the Institute during the past year. They are as follows: Elmira-Corning, Huntsville, Long Island, New Orleans, Rome-Utica, and Winnipeg.

The total number of Sections is now 71. There has been a membership increase in 50 of the 71 Sections.

The Huntsville, Long Island, Rome and Winnipeg Subsections became full Sections, and the South Bend Subsection was dissolved in the year 1953. The Subsections of Sections now total 15, the following being formed in 1953: Buenaventura (Los Angeles Section), East Bay (San Francisco Section), Erie (Buffalo-Niagara Section), Ithaca (Syracuse Section), and U.S.A.F.I.T. (Dayton Section).

Student Branches

The number of Student Branches formed during 1953 was 4, all of which operate as Joint IRE-AIEE Branches. The total number of Student Branches is now 118, 83 of which operate as Joint IRE-AIEE Branches.

Following is a list of the Student Branches formed during the year: University of Cincinnati, University of Massachusetts, Texas Technological College, and the University of Vermont.

Institute Committees—1954

Executive

W. R. Hewlett, *Chairman*
W. R. G. Baker, *Vice Chairman*
Haraden Pratt, *Secretary*

S. L. Bailey, J. R. Pierce, J. W. McRae, J. D. Ryder

Admissions

D. C. Pinkerton, *Chairman*

E. W. Bemis, M. B. Kline, H. S. Bennett, F. S. Mabry, C. M. Burrill, *H. G. Miller, *L. A. Byam, *C. R. Muller, H. P. Corwith, D. M. Pasek, *E. T. Dickey, G. B. Riley, *E. E. Ecklund, *N. B. Ritchey, *N. S. Freedman, G. M. Rose, Jr., L. O. Goldstone, *O. J. Sather, C. A. Hachemeister, H. R. Terhune, H. R. Holloway, *J. D. Winer

* Alternates

Appointments

D. B. Sinclair, *Chairman*

J. T. Henderson, J. R. Ragazzini, W. R. Hewlett, J. D. Ryder, A. G. Jensen, A. W. Straiton

Awards

W. M. Rust, Jr., *Chairman*

R. D. Bennett, J. F. Morrison, R. M. Bowie, A. B. Oxley, J. F. Byrne, J. D. Reid, D. E. Foster, Ernst Weber, H. E. Hartig, J. B. Wiesner, Irving Wolff

Constitution and Laws

A. W. Graf, *Chairman*

S. L. Bailey, J. B. Coleman, I. S. Coggeshall, R. A. Heising, J. V. L. Hogan

Editorial Board

J. R. Pierce, *Chairman*

D. G. Fink, J. W. McRae, E. K. Gannett, J. A. Stratton, T. A. Hunter, W. N. Tuttle

Editorial Review

Robert Adler, A. E. Anderson, H. A. Affel, Jr., W. S. Bachman, Ben Akerman, J. T. Bangert, W. J. Albersheim, W. L. Barrow, J. M. Barstow, B. L. Basore, B. B. Bauer, W. R. Beam, L. L. Beranek, P. H. Betts, F. J. Bingley, J. T. Bolljahn, H. G. Booker, J. L. Bower, W. E. Bradley, D. R. Brown, Werner Buchholz, Kenneth Bullington, R. S. Burnap, J. H. Burnett, R. P. Burr, H. J. Carlin, T. J. Carroll, H. A. Chinn, Marvin Chodorow, L. J. Chu, J. K. Clapp, J. D. Cobine, J. W. Coltman, J. M. Coombs, A. B. Crawford, M. G. Crosby, C. C. Cutler, G. C. Dacey, Sidney Darlington, W. B. Davenport, Jr., A. C. Dickieson, Milton Dishal, W. H. Doherty, R. B. Dome, H. D. Doolittle, W. A. Edson, C. H. Elmendorf, D. W. Epstein, Jess Epstein, W. L. Everitt, R. M. Fano, J. H. Felker, L. M. Field, J. W. Forrester, A. G. Fox, G. L. Fredendall, H. B. Frost, E. G. Fubini, I. A. Getting, L. J. Giacoletto, M. J. E. Golay, Benjamin Gold, W. M. Goodall, A. W. Graf, A. J. Grossman, E. A. Guillemin

A. V. Haeff
D. B. Harris
A. E. Harrison
L. B. Headrick
P. J. Herbst
J. K. Hilliard
C. J. Hirsch
J. L. Hollis
J. H. Howard
W. H. Huggins
R. G. E. Hutter
D. D. Israel
E. T. Jaynes
A. G. Jensen
E. O. Johnson
Harwick Johnson
E. C. Jordan
Martin Katzin
W. H. Kautz
R. D. Kell
C. R. Knight
H. S. Knowles
W. E. Kock
Rudolph Kompfner
F. R. Lack
A. E. Laemmel
M. A. Lampert
H. B. Law
M. T. Lebenbaum
J. G. Linvill
C. V. Litton
F. B. Llewellyn
S. P. Lloyd
A. W. Lo
A. V. Loughren
W. H. MacWilliams, Jr.
Nathan Marchand
Nathan Marcuvitz
F. L. Marx
S. J. Mason
W. P. Mason
W. J. Mayo-Wells
E. D. McArthur
D. O. McCoy
Knox McIlwain
Brockway McMillan
R. E. Meagher
Pierre Mertz
H. R. Mimno
S. E. Miller
A. R. Moore
J. F. Morrison
E. J. Nalos
D. O. North
H. Q. North
B. M. Oliver
H. F. Olson
P. F. Ordung
D. E. Oyster
C. H. Page
R. M. Page
R. C. Palmer
C. H. Papas
R. W. Peter
H. O. Peterson
J. M. Pettit
W. H. Pickering
J. A. Pierce
W. J. Poch
C. F. Quate
J. R. Ragazzini
J. A. Rajchman
Simon Ramo
H. J. Riblet
D. H. Ring
Stanley Rogers
T. A. Rogers
Albert Rose
H. E. Roys
V. H. Rumsey
J. D. Ryder
R. M. Ryder
H. A. Samulon
O. H. Schade
S. A. Schelkunoff
H. H. Scott
S. W. Seeley
Samuel Seely
Samuel Sensiper
R. F. Shea
R. E. Shelby
George Sinclair
David Slepian
C. E. Smith
P. T. Smith
O. J. M. Smith
J. R. Steen
Charles Süsskind
G. C. Sziklai
H. P. Thomas
W. G. Tuller
D. F. Tuttle, Jr.
L. C. Van Atta
K. S. Van Dyke
E. K. Van Tassel
S. N. Van Voorhis
R. L. Wallace, Jr.
D. A. Watkins
W. M. Webster
P. K. Weimer
Louis Weinberg
J. R. Weiner
J. M. West
H. A. Wheeler
J. R. Whinnery
W. D. White
J. B. Wiesner
W. T. Wintringham
Irving Wolff
L. A. Zadeh

Education

J. D. Ryder, *Chairman*

G. R. Arthur
V. A. Babits
W. L. Cassell
C. C. Chambers
D. H. Ewing
R. M. Fano
C. L. Foster
A. W. Graf
A. E. Harrison
H. E. Hartig
G. B. Hoadley
G. L. Hollander
F. S. Howes
Glenn Koehler
A. W. Melloh
H. A. Moench
P. H. Nelson
R. E. Nolte
J. M. Pettit
Albert Preisman
L. R. Quarles
J. R. Ragazzini
F. R. Stansel
W. N. Tuttle
D. L. Waidelich
L. E. Williams
D. G. Wilson
A. H. Wing, Jr.

Finance

W. R. G. Baker, *Chairman*

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Abstracts and References

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research, London, England, and Published by Arrangement with that Department and the *Wireless Engineer*, London, England

Note: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

Abstract number (upper left) is Universal Decimal Classification, not U. S. Nat'l Bur. of Standards Dec. Class. Number (top right) is Abstract serial number. DC numbers (†) are provisional.

A new section has been introduced covering the general technique of electromagnetic waves, oscillations and pulses (i.e. transmission lines and circuits), as distinct from specific applications to telecommunications. The new section is numbered 621.37, with subdivisions. Full details of the new classification, and of the numbers which become obsolete as a result of its introduction, are given in PE Note 535, obtainable from The International Federation for Documentation, Willem Witsenplein 6, The Hague, Netherlands, or from The British Standards Institution, 2 Part Street, London, W.1., England.

Section 621.396.67, dealing with Antennas, has been modified and expanded; details of the new classifications are given in PE Note 519.

Section 621.396.96, with subdivisions, has been introduced to cover Radar; details of the new classifications are given in PE Note 518.

A Section headed Automatic Computers has been introduced.

The Index to the Abstracts and References published in the PROC. I.R.E. from February 1953 through January 1954 is published by *Wireless Engineer* and included in the March 1954 issue of that journal. Copies of this issue may be purchased for $1 (including postage) from the Institute of Radio Engineers, 1 East 79th Street, New York 21, N. Y. As supplies are limited, the publishers ask us to stress the need for early application for copies. Included with the Index is a selected list of journals scanned for abstracting with publishers' addresses.

ACOUSTICS AND AUDIO FREQUENCIES

621.39:061.4 1268

Radio Industries at the 20th Salon de l'Aéronautique (26th June to 5th July 1953).—(*Onde élect.*, Nov. 1953, Vol. 33, No. 320, pp. 652–655.) A brief survey of equipment exhibited.

534.2 1269

Saw-toothed Wave-forms in Sound—G. J. Barber and T. F. W. Embleton. (*Nature (London)*, vol. 172, pp. 1057–1058; Dec. 5, 1953.) An examination of the distortion of finite-amplitude pulses in which the leading half-cycle is a rarefaction.

534.2 1270

Scattering of Sound in a Turbulent Stream—V. A. Krasil'nikov and V. I. Tatarski. (*Compt. Rend. Acad. Sci. U.R.S.S.L*, vol. 90, pp. 159–162; May 11, 1953.) A theoretical treatment based on the assumption that the medium can be represented by the equation of an incompressible viscous fluid. In such a stream the scattering due to temperature inhomogenities and to variations of the velocity are independent of each other and can be evaluated separately.

534.2:534.321.9 1271

The Fluctuations of Phase of Ultrasonic Waves propagated in the Ground Layer of the Air—V. A. Krasil'nikov. (*Compt. Rend. Acad. Sci. U.R.S.S.*, vol. 88, pp. 657–660; Feb. 1, 1953. In Russian.) The rms phase deviation was determined from observations at frequencies up to 51 kc for various values of frequency and wind direction, distance between radiator and receiver, wind velocity, and time during which N observations were recorded. The apparatus used is described with the aid of a block diagram. The results are tabulated.

534.321.9:534.61 1272

The Dependence of the Power of Ultrasonic Radiation on Frequency—S. Parthasarathy, D. Srinivasan and S. S. Chari. (*Z. Phys.*, vol. 136, pp. 17–20; Oct. 16, 1953.) The radiation intensities of the 3rd, 7th and 11th harmonics of a 1.44-mc quartz crystal immersed in five organic liquids and excited at constant voltage were determined by thermal and direct radiation-pressure measurements. Radiated power decreases continuously as the order of harmonics increases.

534.321.9:534.613 1273

Mechanical Action of Ultrasonic Waves on Obstacles—R. Lucas and E. Grossetti. (*Compt. Rend. Acad. Sci. (Paris)*, vol. 238, pp. 458–459; Jan. 25, 1954.) Experiments were made to check theoretically derived expressions for the force exerted by plane ultrasonic waves, using a torsion-balance method. The effects for highly reflecting and nonreflecting surfaces were compared. Obstacles of dimensions about 20 times the wavelength ($\lambda = 1$ mm) were used.

534.321.9:534.613 1274

An Investigation of the Absorption of 5-Mc/s Ultrasonic Waves in Organic Liquids by the Radiation Pressure Method—S. Parthasarathy, S. S. Chari, and D. Srinivasan. (*Jour. Phys. Radium*, vol. 14, pp. 541–546; Oct., 1953.) Measurements are reported of absorption in 47 liquids. See also 2543 of 1953.

534.321.9-14 1275

Variation of Ultrasonic Absorption with Frequency in Organic Liquids—S. Parthasarathy, S. S. Chari, and D. Srinivasan. (*Acustica*, vol. 3, pp. 363–364; 1953.) Certain results of radiation-pressure measurements at 5, 10, and 15 mc lend support to the relaxation theory.

534.79 1276

The Relation between the Sone and Phon Scales of Loudness—D. W. Robinson. (*Acustica*, vol. 3, pp. 344–358; 1953.) A set of statistically controlled experiments is described in which 35 subjects were required to judge two-fold and ten-fold increase and reduction of the loudness of tone and of noise. Loudness scales obtained showed a high consistency and a significant difference between scales relating to increase and to decrease of sensation. Results for loudness reduction are approximately expressed by the formula $\log S = 0.029\ (P-40)$ for the range 20–110 phons, P being the loudness level in phons, S the loudness sensation in sones. Results for free-field and earphone listening were similar.

534.83/.84 1277

Calculation of Sound Propagation in Structures—L. Cremer. (*Acustica*, vol. 3, pp. 317–335; 1953.) Wavelength/frequency relations for sound waves propagated in different structural materials are calculated; critical frequencies for sound radiation from structural elements are discussed. Mechanical impedance and the spectrum of impact sound are considered and an analysis is made of the effectiveness of suitable structural design in reducing the amplitude of longitudinal and flexural waves.

534.862.2:534.76 1278

Experiment in Stereophonic Sound—L. D. Grignon. (*Jour. Soc. Mot. Pict. & Telev. Engrs.*, vol. 61, part II, pp. 364–377; Sept., 1953. Discussion, pp. 377–379.) Microphone placing in stereophonic sound-film recording is discussed.

534.862.3/.4:534.76:621.395.625.3 1279

Stereophonic Recording and Reproducing Equipment—J. G. Frayne and E. W. Templin. (*Jour. Soc. Mot. Pict. & Telev. Engrs.*, vol. 61, part II, pp. 395–405; Sept., 1953. Discussion, pp. 405–407.) An outline description of some of the commercial equipment developed for the film industry.

534.862.3:534.76:621.395.625.3 1280

Multiple-Track Magnetic Heads—K. Singer and M. Rettinger. (*Jour. Soc. Mot. Pict. & Telev. Engrs.*, vol. 61, part II. pp. 390–394; Sept., 1953.) A brief description of the construction and characteristics of two six-track heads for the stereophonic recording of sound on film.

534.862.4:534.76 1281

Stereophonic Recording and Reproducing System—H. Fletcher. (*Jour. Soc. Mot. Pict. & Telev. Engrs.*, vol. 61, part II, pp. 355–361; Sept., 1953. Discussion, pp. 361–363.) A discussion of the amplifier and loudspeaker requirements for the reproduction of music at the original power level, in large halls, e.g. cinemas.

534.862.4:534.76:621.375.2 1282

New Theater Sound System for Multipurpose Use—J. E. Volkmann, J. F. Byrd, and D. Phyfe. (*Jour. Soc. Mot. Pict. & Telev. Engrs.*, vol. 61, part II, pp. 408–414; Sept., 1953.) An outline description of two commercial multichannel power amplifiers.

534.862.4:534.76:[621.395.623.7+621.375.2 1283
Loudspeakers and Amplifiers for Use with Stereophonic Reproduction in the Theater—J. K. Hilliard. (*Jour. Soc. Mot. Pict. & Telev. Engrs.*, vol. 61, part II, pp. 380–389; Sept., 1953. Discussion, p. 389.) A brief description of equipment and cinema installations.

534.87/88+534.614 1284
The Development of Acoustic Sea-Depth Measurements—Drubba and Rust. (*See* 1830.)

621.395.61 1285
Directional Dynamic Microphones—(*Radio Tech., Vienna*, vol. 29, pp. 420–422; Dec., 1953.) Microphones developed in Austria are described. One type comprises two dynamic systems with individual cardiord characteristics, which can be combined to provide omnidirectional or figure-of-eight characteristics as required.

621.395.61 1286
The Directivity of Spherical Microphones—R. L. Pritchard. (*Acustica*, vol. 3, pp. 359–362; 1953.) The directional response of a cylindrical microphone mounted in a sphere is calculated by considering the sound field radiated from a spherical cap and applying the reciprocity principle. This principle is also used to derive the frequency response of a completely spherical microphone. Results are compared with those of Kuhl (613 of 1953); good agreement is shown except in the case of Kuhl's calculated values for response at angles between 160 degrees and 180 degrees.

621.395.625.3 1287
Studies on Magnetic Recording: Part 5—Comparison with Experiments. Part 6—Change in the Recording with Time—W. K. Westmijze. (*Phillips Res. Rep.*, vol. 8, pp. 343–366; Oct., 1953.) Print effect and time-lag effects are discussed. 45 references. Parts 3 and 4: 324 of February.

621.395.625.3 1288
The Difference between Pre-echo and Post-echo in the Print-Through Effect—J. Greiner. (*NachrTech.*, vol. 3, pp. 506–509 and 543–545, 573; Nov./Dec., 1953.) A report of theoretical and experimental investigations of the print-through effect in magnetic-tape recording.

621.395.625.3 1289
The Effect of High-Frequency Biasing in Magnetic [tape] Recording—W. Albach. (*Funk u. Ton*, vol. 7, pp. 628–630; Dec., 1953.) The improvement obtained by using hf biasing is explained as resulting from reduced hysteresis in the magnetization process.

621.395.625.3:621.385.832 1290
Visual Monitor for Magnetic Tape—R. L. Miller. (*Jour. Soc. Mot. Pict. & Telev. Engrs.*, vol. 61, part 1, pp. 309–312; Sept., 1953. Discussion, pp. 313–315.) The monitor comprises a cr tube with the second anode forming a section of the tube wall. The tape is passed over a saddle formed in the second anode, and the beam deflection due to the magnetic recording is displayed on the fluorescent screen.

621.395.625.3:621.397.5 1291
The Status of Magnetic Recording—R. E. Zenner. (*Elec. Eng.*, vol. 72, pp. 951–954; Nov., 1953.) Limitations of magnetic-tape systems are discussed in relation to the recording of (*a*) sound, (*b*) digital data, (*c*) physical analog data, and (*d*) video signals.

ANTENNAS AND TRANSMISSION LINES

621.315.212 1292
The Manufacture, Laying and Splicing of Coaxial-Pair Cable—C. Lancoud. (*Bull. Schweiz. elektrotech. Ver.*, vol. 44, pp. 875–880; Oct. 3, 1953. In French.) A short account, with specific reference to Swiss practice.

621.372.2 1293
The E-H Surface Wave—A. E. Karbowiak. (*Wireless Eng.*, vol. 31, pp. 71–73; March, 1954.) The field equations of the travelling E-H surface wave are derived, and an analysis is made of transmission along helical conductors.

621.372.2 1294
Transmission-Line Impedance and Efficiency—W. W. Macalpine. (*Elec. Eng.*, vol. 72, p. 868; Oct., 1953.) Digest only. A method is presented for computing the resistance and the efficiency of a line when the voltage swr is high. For full paper see *Trans. AIEE*, vol. 72, part I, pp. 334–339; 1953 or *Elect. Commun.*, vol. 30, pp. 238–246; Sept., 1953.

621.372.2 1295
Irregular Transmission Lines—A. Rosen. (*Wireless Eng.*, vol. 31, pp. 59–70; March, 1954.) The Kennelly method of successive reflections is developed to give general expressions for the voltage and current in an irregular line. The expressions are simplified for the case where the impedance deviations are small, e.g. for coaxial cable used for wide-band telephone and television transmission. The formulas are given in series form for the case where the impedance changes abruptly, and in integral form for the case of continuous impedance changes. The effects of irregularities on the open- and short-circuit impedances are discussed.

621.372.2.029.64/65+621.396.621.029.64 1296
Experimental Determination of the Properties of Microstrip Components—M. Arditi. (*Elec. Commun.*, vol. 30, pp. 283–293; Dec., 1953. *Convention Record I.R.E.*, part 10, pp. 27–37; 1953.) The components investigated include coaxial-to-microstrip matching units, bends, transverse posts, offset junctions, step discontinuities, gaps or slots in the strip conductor, parallel-coupled junctions and directional couplers. A microwave receiver is described in which the whole rf circuit except the high-Q cavity resonator consists of microstrip parts.

621.372.21 1297
Calculatiou of the Attenuation and Distortion of Travelling Waves—K. Moritz. (*Arch. Elektrotech.*, vol. 41, pp. 160–180; 1953.) Mathematical investigation of the propagation of a voltage pulse along a line with an earth return. The losses due to earth eddy currents and corona are taken into consideration; line-resistance losses are neglected.

621.372.8+621.372.2 1298
TEM Waves in Cylindrical Systems—P. Moon and D. E. Spencer. (*Jour. Franklin Inst.*, vol. 256, pp. 325–336; Oct., 1953.) Two simple and rigorous theoretical treatments are presented, namely (*a*) use of the vector Laplacian operator, and (*b*) introduction of a quasi-potential. Equations derived are free from ambiguities and yield simple solutions for E and H even with complex co-ordinate systems.

621.372.8 1299
Attenuation in Nickel and Mild-Steel Waveguides at 9375 Mc/s—F. A. Benson. (*Proc. IEE*, part III, vol. 101, pp. 38–41; Jan., 1954.) Measurements on rectangular waveguides are reported. Mild-steel guides with machined internal surfaces have attenuation as high as 3.79 db/m, while the permeability of Ni deduced from attenuation measurements on commercial drawn tubing, taking account of surface roughness, was ~ 3.

621.372.8:538.614 1300
Guided Electromagnetic Waves in Anisotropic Media—A. A. T. M. van Trier. (*Appl. Sci. Res.*, vol. B3, pp. 305–371.) Theory of guided waves in isotropic media is surveyed; a general formulation of the theory for anisotropic media is presented, and particular waveguide structures are analysed. A cavity technique for measuring Faraday rotations is described and experimental results obtained with ferroxcube IVA, B, C, D and E are presented. The physical interpretation of the results is discussed with reference to Rado's theory of the permeability tensor in nonsaturated ferromagnetics (1709 of 1953).

621.396.67 1301
Modern Aerial Theories—P. Neidhardt. (*Nachr Tech.*, vol. 3, pp. 487–492; Nov., 1953.) A comparative survey with 44 references.

621.396.67 1302
Calculation of the Distribution of Current in Thin [linear] Aerials—R. Sartori. (*Alta Frequenza*, vol. 22, pp. 258–281; Dec., 1953.) Energy considerations lead to a simple way of deriving a general equation for the current distribution, which includes Hallén's equation as a particular case.

621.396.67:621.397.5 1303
Control of Vertical Radiation Patterns of TV Transmitting Antennas—F. G. Kear and J. G. Preston. (PROC. I.R.E., vol. 42, pp. 402–407; Feb., 1954.) Earlier U.S.A. designs concentrating as much of the energy as possible into the horizontal plane are being modified to improve the coverage of the service area. As an example, the 6-bay superturnstile antenna on Mt. Wilson has been modified to radiate 2.1 times as much power below the horizontal as above.

621.396.677.45 1304
Wide-Frequency-Range Tuned Helical Antennas and Circuits—A. G. Kandoian and W. Sichak. (*Elect. Commun.*, vol. 30, pp. 294–299; Dec., 1953. *Convention Record I.R.E.*, part 2, pp. 42–47; 1953.) A discussion of helical antennas of diameter small compared with λ. Using a shunt-feed arrangement with a variable tap point and a variable short-circuit, tuning ranges up to 100:1 can be obtained.

621.396.677.7 1305
Radiation from the Open End of a Lecher Line or Waveguide at a Great Distance from the Opening—H. Florian. (*Acta Phys. austriaca*, vol. 8, pp. 42–62; Oct., 1953.) Schelkunoff's analysis (1779 of 1936) is extended; results are obtained in the form of solvable integrals suitable for practical calculations. Waveguides of rectangular and circular section and coaxial lines are considered.

621.396.677.71 1306
Propagation along a Slotted Cylinder—R. F. Harrington. (*Jour. Appl. Phys.*, vol. 24, pp. 1366–1371; Nov., 1953.) A variational method is presented for determining the attenuation and phase constants for the field of a traveling-wave slot aerial using a circular-section waveguide. Calculated and experimentally determined values are compared for the cases of excitation in the TE_{11} and TM_{01} modes.

621.396.677.71 1307
Traveling-Wave Slot Antennas—V. H. Rumsey. (*Jour. Appl. Phys.*, vol. 24, pp. 1358–1365; Nov., 1953.) A variational method, making use of the generalized reciprocity theorem for traveling-wave line sources, is used to derive approximate formulas for the propagation constant and characteristic field pattern for traveling-wave slot antennas containing a dielectric. For the case of the rectangular-section aerial containing only air, results calculated from the theory are in good agreement with measured values. See also 334 of February (Hines et al.).

621.396.677.75 1308
Propagation and Radiation of Electromagnetic Waves along a Dielectric Line with Nonuniform Characteristics—J. C. Simon and G. Weill. (*Compt. Rend. Acad. Sci. (Paris)*, vol. 238, pp. 57–59; Jan. 4, 1954.) Long antennas comprising nonuniform dielectric lines are dis-

cussed, and a method based on the concept of space harmonics is presented for calculating the relation between the radiation and the periodic characteristics of the line.

AUTOMATIC COMPUTERS

681.142 1309

An Analogue-Type Multiplier—J. Isabeau. (*HF, Brussels*, vol. 2, pp. 213–218; 1953.) A simple multiplying circuit is described in which 12-kc rectangular pulses are modulated successively in width and amplitude in proportion respectively to the two factors, *A* and *B*, to be multiplied. Response times for the circuit tested were 1–10 ms for the factor A (amplitude 5–100 V) and 20 ms irrespective of amplitude for B (0–120 V).

681.142 1310

A Simple Electronic Multiplier—K. H. Norsworthy. (*Electronic Eng.*, vol. 26, pp. 72–75; Feb., 1954.) The multiplication process described is based on the equation $(X+Y)^2-(X-Y)^2=4XY$. A method of squaring is used which depends on the fact that the areas of similar triangles are proportional to the squares of their heights; a triangular-waveform generator is described. The device accepts both positive and negative input voltages.

681.142 1311

Electronic Analogue Computing—R. B. Quarmby. (*Wireless World*, vol. 60, pp. 113–118; March, 1954.) A survey of modern techniques; an indication is given of the kind of problem for which analog computers offer advantages over digital types.

681.142 1312

A New Analogue Computer—E. L. Thomas. (*Engineering* (*London*), vol. 176, pp. 477 and 479; Oct. 9, 1953.) A general-purpose computer of differential-analyzer type, designed for economic quantity production, is described. Three basic elements are used, viz., (*a*) scaling units, essentially 3-decade variable resistors, (*b*) function units comprising *RC* networks, (*c*) high-gain amplifiers. Facilities for cro and graphical display are provided.

681.142 1313

Note on High-Speed Product Integrator—I. Cederbaum. (*Rev. Sci. Inst.*, vol. 24, pp. 1072–1073; Nov., 1953.) Errors arising in the potentiometer circuit of the integrator [2058 of 1953 (Macnee)] are discussed.

681.142 1314

General Survey of the Operating Principles of Electrical Analogue Computers—C. Mounier. (*Rev. Gén. Élect.*, vol. 62, pp. 515–530; Nov., 1953.) A survey with particular reference to computers constructed by the Société d'Électronique et d'Automatisme; difficulties encountered in studying the accuracy of these machines are discussed.

681.142 1315

A Diode-Capacitor Memory for High-Speed Electronic Computers—(*Tech. News Bull. Nat. Bur. Stand.*, vol. 37, pp. 171–173; Nov., 1953.) Ordinary linear capacitors are used as rapid-access storage elements in a matrix arrangement. The basic circuit consists of two diodes in series, with the anode of one connected to the cathode of the other, and the capacitor connected to the junction; the other end of the capacitor is used for reading and writing, and is connected to earth through a resistor.

681.142 1316

A Survey of Digital Computer Memory Systems—J. P. Eckert, Jr. (Proc. I.R.E., vol. 42, p. 413; Feb., 1954.) Correction to paper abstracted in 41 of January.

681.142 1317

Frequency Analysis of Digital Computers operating in Real Time—J. M. Salzer. (Proc. I.R.E., vol. 42, pp. 457–466; Feb., 1954.)

681.142:512 1318

Elements of Boolean Algebra for the Study of Information-Handling Systems—R. Serrell. (Proc. I.R.E., vol. 42, p. 475; Feb., 1954.) Correction to paper abstracted in 57 of January.

681.142:53 1319

Application of Digital Computing Techniques to Physics—R. A. Brooker. (*Brit. Jour. Appl. Phys.*, vol. 4, pp. 321–326; Nov., 1953.) Problems involving matrices, ordinary, and partial differential equations, functions occurring in crystallography and the "random walk" statistical method are discussed. Machine design and the training of personnel are considered briefly.

681.142:[538.221+537.226 1320

Magnetic and Dielectric Elements for Computers—F. van Tongerloo. (*Tijdschr. ned. Radiogenoot.*, vol. 18, pp. 265–285; 1953.) A survey of the applications of materials with rectangular hysteresis loops. Two classes are distinguished, namely (*a*) those depending on a high ratio of remanence to saturation, and (*b*) those for which the "squareness ratio" is important.

681.142:621.373.42 1321

A Low-Frequency Oscillator—R. M. Howe and R. J. Leite. (*Rev. Sci. Instr.*, vol. 24, pp. 901–903; Oct., 1953.) An analog computer for solving the differential equations of a mass/spring system comprises a circuit producing simple harmonic oscillations with a frequency range of 0.0016-16 cps.

681.142:621.376.22 1322

Instantaneous Multiplier for Computers—M. Mehron and W. Otto. (*Electronics*, vol. 27, pp. 144–148; Feb., 1954.) Multiplication is performed by means of balanced modulators using standard IF transformers and other computers.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.018.75:621.387.4 1323

Pulse-Height Analyzer—J. W. Thomas, V. V. Verbinski and W. E. Stephens. (*Rev. Sci. Instr.*, vol. 24, pp. 1017–1020; Nov., 1953.) The equipment, based on Wilkinson's conversion principle (1085 of 1951), has resolution, linearity and stability to within 1 per cent. It can deal with input pulses at a rate of several thousand per second. Recording is made on Teledeltos paper at a rate of up to 50 pulses/sec.

621.3.018.78 1324

A New General Method for Frequency-Distortion Correction of a Given Circuit in Light-Current and Instrument Engineering—M. Hájková-Jančová. (*Frequenz*, vol. 7, pp. 268–269; Sept., 1953.) The frequency-dependent function, e.g. the amplification factor, is expressed as the ratio of power series of functions of the frequency, and the condition for a minimal frequency dependence is found.

621.376.3:621.3.018.78 1325

Normalized Phase and Gain Derivatives as an Aid in Evaluation of F.M. Distortion—J. J. Hupert. (Proc. I.R.E., vol. 42, pp. 438–446; Feb., 1954.) The method previously described for evaluating the distortion for the quasi-stationary condition (3550 of 1953) is extended to take account of the finite rate of variation of the input-signal frequency.

621.314.7:621.3.015.3 1326

Transient Response of the Grounded-Base Transistor Amplifier with Small Load Impedance—J. S. Schaffner and J. J. Suran. (*Jour. Appl. Phys.*, vol. 24, pp. 1355–1357; Nov., 1953). A transfer function relating junction-transistor collector current to emitter current is derived from the diffusion equation; the Laplace-transform technique is used to determine the variation of collector current in response to a step variation of emitter current. Collector-current rise times evaluated from the theory are in good agreement with observed values. See also 3513 of 1953 (Chow and Suran).

621.316.86:537.312.6 1327

Thermistor Production—W. T. Gibson. (*Elect. Commun.*, vol. 30, pp. 263–270; Dec., 1953.) Reprint, with additional illustrations, of paper abstracted in 2240 of 1953.

621.318.4 1328

Tapped Inductances—C. R. Cosens. (*Wireless Eng.*, vol. 31, pp. 74–75; March, 1954.) "Maxwell coils" for af are considered, and a simple method is presented for calculating the position of the tapping to give a specified fraction of the total inductance.

621.372.011/.012 1329

Graphical Analysis of Nonlinear Circuits using Impedance Concepts—J. S. Thomsen. (*Jour. Appl. Phys.*, vol. 24, pp. 1379–1382; Nov., 1953.) Approximate values of the reactance of moderately nonlinear inductors and capacitors are obtained by adding to the usual linear expressions terms involving the square of the current. Using this approximation, the total impedance of an *LRC* circuit is obtained and plotted in the *I-Z* plane, with frequency as a parameter. The method gives a physical picture of the jump phenomenon in nonlinear circuits.

621.372.413 1330

Large Reduction of Free Electromagnetic Oscillations in Cylindrical Regions due to Slight Departures from Cylindricity—Yu. S. Sayasov. (*Compt. Rend. Acad. Sci. U.R.S.S.*, vol. 90, pp. 163–166; May 11, 1953.) A theoretical investigation of the effect of small deformations on long cylindrical resonators with perfectly conducting walls. The diminution of the field is proportional to the product of the relative distortion and the square of the ratio of the length of the cylinder to its radius. Standard mathematical notation is used and the expressions for E_r, E_θ and H_ϕ are given in terms of Bessel functions and the function M_{op} which is defined as the *p*th root of J_o.

621.372.413:517.9 1331

An Asymmetrical Finite Difference Network—R. H. Macneal. (*Quart. Appl. Math.*, vol. 11, pp. 295–310; Oct., 1953.) A study is made of a method of solving boundary-value problems by means of electrical network analogies. Consideration is given to the special problems associated with curved boundaries and with the use of meshes of different size at different parts of the network. A method is described by means of which the coefficients of the system of algebraic equations can be computed for an arbitrary distribution of node points, and the position of the nodes can then be chosen to fit the particular conditions. As an illustration, the resonance frequencies and field patterns of a conical-line cavity resonator are calculated.

621.372.5 1332

A General *RLC* Synthesis Procedure—L. Weinberg. (Proc. I.R.E., vol. 42, pp. 427–437; Feb., 1954. *Convention Record I.R.E.*, part 5, pp. 2–16; 1953.) Procedure for synthesizing lattice networks is described.

621.372.5 1333

Unbalanced *RLC* Networks containing Only One Resistance and One Real Transformer—L. Weinberg. (Proc. I.R.E., vol. 42, pp. 467–475; Feb., 1954. *Trans. I.R.E.*, No. PGCT-2, pp. 55–65; Dec., 1953.)

621.372.5 1334

Unilateral Four-Terminal Circuits—J. S. Foley. (*Electronics*, vol. 27, pp. 186–187; Feb., 1954.) Networks of Ge diodes and carbon resistors, suitable for purposes of directional coupling and isolating, are described.

621.372.512.24 1335

High-Q Coupled Tuned Circuits—H. D.

Polishuk. (*Wireless Eng.*, vol. 31, pp. 55–58; March, 1954.) "By means of a set of expressions developed as functions of a frequency ratio, some aspects of inductively-coupled high-Q resonant circuits are analysed. Considerations of finite, very high-Q circuits lead to simple relations determining impedance characteristics of a fundamental system, resonant frequencies, rate of frequency deviation, input conductance, stored energy and power dissipation ratios."

621.372.54 1336
Two New Equations for the Design of Filters—M. Dishal. (*Elect. Commun.*, vol. 40, pp. 324–337, Dec., 1953. Condensed version, *Convention Record I.R.E.*, part 5, pp. 44–47; 1953.) Equations are presented for designing constant-K-configuration filters with Tchebycheff-type characteristics, for the case when the unloaded Q of the elements is sufficiently high for them to be considered nondissipative. Both band-pass and low-pass filters are considered; the band-pass examples are mainly for uhf.

621.372.54 1337
Old and New Methods for designing Composite High-Frequency Filter Circuits and their Application to Filter Circuits with Low Relative Bandwidth—R. Rucklin. (*Arch. elekt. Übertragung*, vol. 7, p. 554; Nov., 1953.) Correction to paper abstracted in 84 of January.

621.372.54 1338
Nonlinear Filters—W. D. White and L. A. Zadeh. (*Jour. Appl. Phys.*, vol. 24, pp. 1412–1413; Nov., 1953.) Comment on 2598 of 1953 and author's reply.

621.372.54:538.652 1339
Electromechanical Filters—S. P. Lapin. (*Radio & Telev. News, Radio-Electronic Eng. Section*, vol. 50, pp. 9–11, 37; Dec., 1953.) Design and performance data are presented for IF filters for the frequency range 100–1000 kc, of the type comprising metal-plate resonators interconnected by pairs of fine metal wires.

621.372.542.2 1340
A General Tchebycheff Rational Function—C. B. Sharpe. (Proc. I.R.E., vol. 42, pp. 454–457; Feb., 1954.) The derivation is described of a function useful for the design of low-pass filters.

621.372.543.2:621.375.232.029.4 1341
Electronic Audio Bandpass Filter—R. J. Gunderman. (*Radio & Telev. News, Radio-Electronic Eng. Section*, vol. 50, pp. 16, 23; Nov., 1953.) A narrow-band filter with centre frequency adjustable from 20 to 5000 cps is obtained by including a phase-inverter rejection circuit in the negative-feedback circuit of an audio amplifier.

621.372.56 1342
Attenuator Design—N. H. Crowhurst. (*Electronic Eng.*, vol. 26, pp. 76–78; Feb., 1954.) A chart is given for the design of constant-resistance types of attenuator.

621.372.6 1343
Some Not Necessarily Linear (n+1)-Poles—A. Stohr. (*Arch. elekt. Übertragung*, vol. 7, pp. 546–548; Nov., 1953.) In $(n+1)$-poles composed of linear 2-poles, and in some other $(n+1)$-poles, linear relations exist between the voltages and the currents, and the resulting impedance matrix is symmetrical. A generalization, to include nonlinear relations, is given by the condition that $\partial(\phi_k-\phi_0)/\partial i_l$ must be symmetrical in k and l, where $(\phi_k-\phi_0)$ is the p.d. between the kth and the zeroth terminal and i_l is the current flowing into the lth terminal. Examples and properties of such $(n+1)$-poles are given.

621.373 1344
The Use of Admittance Diagrams in Oscillator Analysis—H. J. Reich. (Proc. I.R.E., vol. 42, pp. 484–485; Feb., 1954.) Discussion on 1944 of 1953.

621.373.421 1345
A New Type of RC Oscillator—G. Francini and E. Zaccheroni. (*Alta Frequenza*, vol. 22, pp. 282–294; Dec., 1953.) A circuit requiring a much smaller amount of valve amplification than the usual phase-shift oscillator uses a specially designed twin-T feedback network.

621.373.421+621.375.23].001.2 1346
Block-Diagram Analysis of Vacuum-Tube Circuits—T. M. Stout. (*Elect. Eng.*, vol. 72, p. 900; Oct., 1953.) Digest only. The method is illustrated by analyses of (*a*) an amplifier with current feedback from the cathode circuit and (*b*) a phase-shift oscillator.

621.373.422:621.376.2/.3 1347
Amplitude Variations in a Frequency-Modulated Oscillator—W. J. Cunningham. (*Jour. Frank. Inst.*, vol. 256, pp. 311–323; Oct., 1953.) Analysis indicates how unwanted AM is produced when FM is accomplished by varying the capacitance in a negative-resistance oscillator circuit. A numerical example is given.

621.373.43 1348
The Design of the Eccles-Jordan Circuit—R. Piloty, Jr. (*Arch. elekt. Übertragung*, vol. 7, pp. 537–545; Nov., 1953.) Design formulas are derived from a fundamental analysis of the circuit. Their application is illustrated in the design of a high-stability, 2-mc flip-flop circuit using a Type-E90CC tube.

621.373.43 1349
The Electronic Switch—E. Piepgras. (*Funk u. Ton*, vol. 7, pp. 580–589; Nov., 1953.) An analysis of the operation of square-wave generators.

621.373.431.1:621.318.572 1350
Bi-Stable Multivibrator Analysis—P. A. Neeteson. (*Electronic Applic. Bull.*, vol. 14, pp. 121–137; Aug./Sept., 1953.) Continuation of paper abstracted in 1006 of April. The operational calculus is used to analyze the Eccles-Jordan flip-flop circuit.

621.373.432:621.387 1351
Control of Glow-Discharge Triodes by means of Very Small Currents—E. Meili. (*Helv. Phys. Acta*, vol. 26, pp. 574–577; Nov. 16, 1953. In German.) A discussion of the desirable characteristics of a valve suitable for the generation of sawtooth oscillations, using a grid-cathode capacitor of value between 10 and 50 pF and a grid control current as low as 3×10^{-11} A. The essential design points are (*a*) small cross-sectional area of the discharge space, (*b*) high current density at low currents, (*c*) short ion transit times and (*d*) large difference between the striking and the operating potential. These are achieved by arranging a wire-point control electrode close to the cathode.

621.373.52 1352
An Amplitude-Stabilized Transistor Oscillator—E. R. Kretzmer. (Proc I.R.E., vol. 42, pp. 391–401; Feb., 1954.) An af oscillator using two junction transistors in push-pull class-C operation has its amplitude stabilized to within 1 per cent over wide ranges of supply voltage, loading and temperature by comaring the output with a stable reference voltage obtained from a junction diode operated at breakdown.

621.374.4:621.376.233 1353
The Efficiency of Frequency Multipliers using Detector Circuits—G. B. Hagen. (*Nachr-Tech.*, vol. 3, pp. 482–486; Nov., 1953.) An analysis is made of the harmonic-frequency power obtainable in an oscillatory circuit connected to a generator via a detector whose characteristic is represented approximately by a hyperbola. For harmonics of fourth and higher orders the calculations become very difficult; it cannot be assumed that for any given harmonic the power is less than for the next lower harmonic.

621.375.121.029.4/5 1354
Design of Wide-Band Tuned Ampliqers—F. Jaeschke. (*Funk. u. Ton*, vol. 7, pp. 508–516, 570–579 and 630–642; Oct.–Dec., 1953.) Amplifiers with Schienemann (Butterworth) and Tchebycheff band-pass characteristics are considered in detail and formulas, design curves and numerical examples are given.

621.375.2+621.395.623.7]:534.862.4:543.76 1355
Loudspeakers and Amplifiers for Use with Stereophonic Reproduction in the Theater—J. K. Hilliard. (*Jour. Soc. Mot. Pict. & Telev. Engrs.*, vol. 61, part II, pp. 380–389; Sept., 1953. Discussion, p. 389.) A brief description of equipment and cinema installations.

621.375.2:621.395.44 1356
The Coaxial-Line Amplifier—Bauer. (*See* 1572.)

621.375.2.024 1357
D.C. Amplifiers—J. Yarwood and D. H. Le Croissette. (*Electronic Eng.*, vol. 26, pp. 14–19, 64–70, and 114–117; Jan.–March, 1954.) A survey paper with 81 references.

621.375.2.024 1358
Investigation of the Effect of Unbypassed Screen-Grid Resistors on Amplification Factor—E. G. Woschni. (*NachrTech.*, vol. 3, pp. 444–446; Oct., 1953.) A calculation is made of the negative feedback introduced by unbypassed resistors in the screen-grid lead; this arrangement is usual in dc amplifiers. Experimental results confirming the theory are presented.

621.375.221.2 1359
Distributed Amplifiers: Some New Methods for Controlling Gain/Frequency and Transient Responses of Amplifiers having Moderate Bandwidths—H. G. Bassett and L. C. Kelly. (Proc. I.R.E., part III, vol. 101, pp. 5–14; Jan., 1954.) Distributed amplifiers of moderate bandwidths for steady-state applications may be constructed for almost constant gain up to 80 per cent or 90 per cent of cut off by methods including the insertion of extra sections into the networks or the use of networks whose image impedance at a shunt-capacitance point falls to zero at the cut-off frequency. For waveform amplification, the use of m-derived low-pass networks with added resistive elements is suggested. The image delay is then almost constant over 85 per cent of the nondissipative pass band, and the image attenuation varies in approximately Gaussian fashion with frequency over most of the pass band. In this second case the maximum useful number of valves per stage is five.

621.375.23 1360
Development of a High-Fidelity Preamplifier for Use in the Recording of Bioelectric Potentials with Intracellular Electrodes—S. J. Solms, W. L. Nastuk, and J. T. Alexander. (*Rev. Sci. Instr.*, vol. 24, pp. 960–967; Oct., 1953.) The cathode-follower circuit conventionally used to minimize the time constant of the recording system is discussed and its shortcomings are analyzed. An improved circuit using positive feedback is described.

621.375.23:621.3.016.35 1361
Gain Stability of Feedback Amplifiers—D. L. H. Gibbings and A. M. Thompson. (Proc I.R.E., part III, vol. 101, pp. 35–37; Jan., 1954.) By proper choice of the phase angle of the loop gain, either the magnitude or the phase angle of the amplifier gain may be made independent, to a first order, of changes in the active elements. The general theory is developed. Results obtained with an experimental amplifier show that, over a narrow frequency range, the unit can be made as stable as

the passive components in the feedback network.

621.375.23.029.42 1362

A Low-Frequency Selective Amplifier—F. M. Gardner. (*Trans. I.R.E.*, vol. AU 1, pp. 10–12; Nov./Dec., 1953.) Analysis similar to that for a simple resonant circuit is presented for a feedback amplifier. Design and performance of an amplifier with a resonance frequency of about 30 cps are outlined.

621.375.232 1363

A Minimal Noise Preamplifier for Proportional Counters and Similar Applications—K. Enslein and B. Brainerd. (*Rev. Sci. Instr.*, vol. 24, pp. 916–919; Oct., 1953.) A negative-feedback amplifier is described which is linear over an input range of 74 db. The maximum gain is 1900, and is attained over a frequency range of about 10–500 kc. Signals of 2 μV can be recognized.

621.375.3 1364

Fast Response of Magnetic Amplifiers—D. G. Scorgie. (*Elect. Eng.*, vol. 72, p. 973; Nov., 1953.) Digest of paper to be published in *Trans. AIEE*, vol. 72, 1953.

621.375.3:538.245 1365

Instability of Self-Saturating Magnetic Amplifiers—S. B. Batdorf and W. N. Johnson. *Elect. Eng.*, vol. 72, p. 1013; Nov., 1953.) Digest of paper to be published in *Trans. AIEE*, vol. 72, 1953. Differences between the major and the minor hysteresis loops of hipernik 5 and their importance in dc triggering are discussed.

621.375.4 1366

Gain-Stabilized Transistor Amplifier—C. A. Krause. (*Electronics*, vol. 27, pp. 183–185; Feb., 1954.) Gain is stabilized by using an unbypassed resistor in the emitter circuit of a junction transistor.

621.375.4.024 1367

D.C. Amplifier employing Junction-Type Transistors—E. Keonjian. (*Elect. Eng.*, vol. 72, pp. 961–964; Nov., 1953.) Temperature-sensitive resistors and junction diodes are used in conjunction with compensating networks to eliminate drift effects. A two-stage amplifier circuit having a drift <1 per cent in 106 hours at room temperature, is described.

621.375.5/621.319.4 1368

Building and using Dielectric Amplifiers—A. Silverstein. (*Electronics*, vol. 27, pp. 150–153; Feb., 1954.) A detailed account is given of the process developed at the National Bureau of Standards for preparing the (Ba-Sr)TiO_3 capacitors used in dielectric amplifiers. A two-stage voltage amplifier and an output stage capable of driving a loudspeaker are described.

621.396.822+537.311.3 1369

Low-Temperature Electronics—C. A. Swenson and A. G. Emslie. (PROC. I.R.E., vol. 42, pp. 408–413; Feb., 1954.) A survey is made of the temperature dependence of noise and resistance over a range of temperatures approaching absolute zero. Practical applications of the results of low-temperature research are discussed.

GENERAL PHYSICS

52:519.2 1370

On Statistical Estimation in Physics—M. Annis, W. Cheston, and H. Primakoff. (*Rev. Mod. Phys.*, vol. 25, pp. 818–830; Oct., 1953.)

534.2+538.566 1371

Wave Propagation in Stratified Media at Normal Incidence, and Application to Transmission-Line Theory. Electric Waves, Optics, Acoustics, Wave Mechanics, and Mechanical and Electrical Quadripoles—K. Altenburg and S. Kastner. (*Ann. Phys. Lpz.*, vol. 13, pp. 1–43; Oct. 20, 1953.) A comprehensive analysis with numerous references.

535.12:535.31 1372

Step-by-Step Transition from Wave Optics to Ray Optics in Inhomogeneous Anisotropic Absorbing Media: Part 2—Solution of the Equations for Wave Normal and Refractive Index by WNK Approximation. Ray-Optical Reflection and Alternation—K. Suchy. (*Ann. Phys. Lpz.*, vol. 13, pp. 178–197; Oct. 20, 1953.) The equations given in part 1 (2594 of 1953) are solved. The existence of particular points is established for which the transition cannot be made.

535.376 1373

The Mechanism of Electroluminescence: Part 1—Theoretical Considerations—D. Curie. (*Jour. Phys. Radium*, vol. 14, pp. 510–524; Oct., 1953.) An account based on Destriau's treatment, attributing the phenomena of electroluminescence to collisions of field-accelerated electrons in the conduction band. 35 references.

535.421:538.566 1374

Rigorous Analysis of the Diffraction of Electromagnetic Waves by Strip-Gratings—R. Müller. (*Z. Naturf.*, vol. 8a, pp. 56–60; Jan., 1953.) A solution which is valid without restriction on wavelength, angle of incidence, polarization or grating constants is obtained in the form of two Fredholm integral equations of the first kind, of the same structure as those derived to represent diffraction by slotted diaphragms in rectangular waveguides (1583 of 1953).

537.122 1375

A Collective Description of Electron Interactions: Part 3—Coulomb Interactions in a Degenerate Electron Gas—D. Bohm and D. Pines. (*Phys. Rev.*, vol. 92, pp. 609–625; Nov. 1, 1953.) Part 2: 1021 of April.

537.122 1376

A Collective Description of Electron Interactions: Part 4—Electron Interaction in Metals—D. Pines. (*Phys. Rev.*, vol. 92, pp. 626–636; Nov. 1, 1953.) Part 3: 1375 above.

537.221 1377

Contact Electrification—P. S. H. Henry. (*Sci. Progr.*, vol. 41, pp. 617–634; Oct., 1953.) The observed phenomena are described, and various explanatory hypotheses are discussed. Effects of "static" and methods of eliminating them are indicated. 50 references.

537.52 1378

Some Measurements on a Not Selfsustaining Gas Discharge, with an Axial Magnetic Field—J. Kistemaker and J. Snieder. (*Physics*, vol. 19, pp. 950–960; Oct., 1953.) Report of investigations of the potential distribution inside the central arc column of the discharge. The experimental arrangement consists of a cylindrical anode with a filamentary cathode at one end and a reflector at the other, and a hot probe. With electronegative gases deep troughs of negative potential are observed; with electropositive gases the central plasma potentials are still negative in relation to the anode.

537.521.7 1379

Ions and Barriers in Electric Discharges—G. K. M. Pfestorf and R. S. N. Rau. (*Jour. Indian Inst. Sci.*, Section B, vol. 35, pp. 197–186; Oct., 1953.) Report of investigations on the effect of injecting ions into the spark gap, and of the effectiveness of paper screens in blocking the ions.

537.525 1380

A Condition on Uniform Field Breakdown in Electron-Attaching Gases—R. Geballe and M. L. Reeves. (*Phys. Rev.*, vol. 92, pp. 867–868; Nov. 15, 1953.) The form of the curve relating E/p to p/d at breakdown (where E is the field strength, p the pressure and d the electrode separation) indicates the existence, for high values of pd, of a value of E/p below which breakdown does not occur. A study of the equation for steady-stage current in electron-attaching gases suggests that this limiting value is nearly that for which the ionization and attachment coefficients are equal; this is confirmed experimentally.

537.525.001.4 1381

Development of the Theory of the Positive Column at Low Pressures: Part 1—E. H. Ludwig. (*Z. angew. Phys.*, vol. 5, pp. 377–386 and 421–426; Oct./Nov., 1953.)

537.533/.534:[537.291+538.691 1382

Dioptrics of Electron and Ion Beams with Circular Principal Paths—H. Grümm. (*Acta Phys. austriaca*, vol. 3, pp. 119–140; Dec., 1953.)

537.533:537.534.9 1383

Secondary Emission due to Bombardment of Metallic Targets with Multiple-Charge Ions—Yu. A. Dunaev and I. P. Flaks. (*Compt. Rend. Acad. Sci. U.R.S.S.*, vol. 91, pp. 43–45; July 1, 1953. In Russian.) An experimental investigation of the dependence of the coefficient of secondary emission on the energy of the ions. Sb, Bi, and Te targets were bombarded with Sb, Bi, and Te ions, respectively, and Ni targets with Na, Ba and Ca ions. The results are shown graphically.

537.533:538.691 1384

The Motion of Electrons in Two Combined Magnetic Fields—S. G. Nilsson. (*Kugnl. tek. Högsk. Handl., Stockholm*, no. 72, 22 pp.; 1953. In English.) The focusing properties of the field of a homogeneously wound toroid have been investigated (383 of 1953). Analysis is now given for the case when this field is combined with a homogeneous field perpendicular to the plane of the toroid.

537.533:539.23 1385

Work Function of Clean and of Oxygen-Coated Au, Pt and Pd, based on the Contact-Potential Difference with respect to Ag—J. Giner and E. Lange. (*Naturwissenschaften*, vol. 40, p. 506; Oct., 1953.) Values of the work function were found to be up to 1.2 v higher for the oxygen-coated than for the clean surfaces.

537.533.8 1386

Auger Peaks in the Energy Spectra of Secondary Electrons from Various Materials—J. J. Lander. (*Phys. Rev.*, vol. 91, pp. 1382–1387; Sept., 1953.) Measurements on C, Be, Al, Ni, Cu, Ba, Pt and oxides of some of these are reported; a description is given of the highly sensitive apparatus used. Characteristic peaks due to Auger electrons emitted as a result of absorption of a valence electron by an excited X-ray level were observed for all these materials. The structure exhibited by the peaks is related to the energy distribution of electrons in the valence band, and complements that observed in soft X-ray emission. Excitation of Auger peaks by low-velocity electron beams provides a method of investigating surfaces.

537.56 1387

Generalized Ionization Formula for a Plasma—G. Elwert. (*Z. Naturf.*, vol. 71, pp. 703–708; Nov., 1952.) A formula is derived which includes as special cases Saha's equation, the gas-cloud ionization formula, and the solar-corona ionization equation.

538.12 1388

The Field along the Axes of Symmetry of Equal Semi-infinite Rectangular Magnetic Pole-Pieces—W. Snowdown and N. Davy. (*Brit. Jour. Appl. Phys.*, vol. 4, pp. 339–341; Nov., 1953.) The method of conformal representation is used. The field along the axes of symmetry is calculated for a number of values of the ratio of the width of the pole-pieces to the distance separating them. Expressions for the potential function are also given. See also 2152 of 1945 (Davy).

538.21 1389

Magnetic Behaviour of a Linear Atomic Chain at the Absolute Zero Point, for Positive Exchange Integral—E. Ledinegg and P. Urban. (*Acta Phys. austriaca*, vol. 8, pp. 167–174; Dec., 1943.) A calculation of the magnetic moment indicates that the linear atomic chain is not spontaneously magnetizable.

538.3:531.19 1390

On the Statistical Mechanics of Matter in an Electromagnetic Field: Part 1—Derivation of the Maxwell Equations from Electron Theory—P. Mazur and B. R. A. Nijboer. (*Physica*, vol. 19, pp. 971–986; Oct., 1953.) An ensemble-averaging method is used.

538.311 1391

Magnetic Field due to a Direct Current traversing a Solid Conductor of Arbitrary Shape. Application to a Cylindrical Conductor—R. Cazenave. (*Rev. Gén. Élect.*, vol. 62, pp. 536–542; Nov., 1953.) Laplace's law (usually known as Biot and Savart's law) is shown to be more suitable than Ampère's magnetic-sheet concept as a basis for deriving formulae for the magnetic field of a conductor. The vector potential is introduced.

538.561.029.6 1392

Čerenkov Effect at Microwave Frequencies—M. Danos, S. Geschwind, H. Lashinsky, and A. van Trier. (*Phys. Rev.*, vol. 92, pp. 828–829; Nov. 1, 1953.) Radiation of power $\simeq 10^{-7}$ W excited by a 10-kv, 0.2-ma beam, bunched at 24 kmc, and traveling close to the surface of a TiO_2 polycrystalline dielectric, has been detected.

539.162:537.212:533.15 1393

On the Diffusion of Decaying Particles in a Radial Electric Field—J. Keilson. (*Jour. Appl. Phys.*, vol. 24, pp. 1397–1400; Nov., 1953.) An analysis is made of the diffusion of charged particles in a radial field in which the intensity is distributed according to an inverse-square law.

548.0:539.15 1394

Electronic Polarizabilities of Ions in Crystals—J. R. Tessman, A. H. Kahn, and W. Shockley. (*Phys. Rev.*, vol. 92, pp. 890–895; Nov. 15, 1953.)

548.0:539.15 1395

Interaction of a Nonrelativistic Particle with a Scalar Field with Application to Slow Electrons in Polar Crystals—T. D. Lee and D. Pines. (*Phys. Rev.*, vol. 92, pp. 883–889; Nov. 15, 1953.)

621.3.011.4 1396

Capacitance of a Spherical Capacitor—F. Bertolini. (*Nuovo Cim.*, vol. 9, pp. 852–854; Sept. 1, 1952.) In a practical spherical capacitor, the capacitance is not given exactly by the theoretical formula, because the outer sphere has an aperture. Upper and lower limits are derived for the magnitude of the error involved.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.165:621.396.822 1397

Radio-Frequency Emission from Cosmic-Ray Electrons—H. Siedentopf and G. Elwert. (*Z. Naturf.*, vol. 8a, pp. 20–23; Jan., 1953.) Theory developed by Schwinger (*Phys. Rev.*, vol. 75, p. 1912; 1949.) is used for the quantitative investigation of the intensity and spectral distribution of rf radiation from cosmic-ray electrons in interstellar magnetic fields. An upper limit is deduced for the density of an electron component of the cosmic radiation.

523.5 1398

The Strength of Meteoric Echoes from Dense Columns—L. A. Manning. (*Jour. Atmos. Terr. Phys.*, vol. 4, pp. 219–225; Dec., 1953.) Calculations taking into account the refractive effects produced by ionization distributed at radii greater than the critical-density radius have been made for largely highly ionized trails, using geometrical optics and ray-tracing methods. The computed maximum radiated power from a diffusion-formed trail is only 70 per cent of that calculated on the critical-density radius method.

523.5:621.396.96 1399

Meteor Echo Duration and Radio Wavelength—D. W. R. McKinley. (*Canad. Jour. Phys.*, vol. 31, pp. 1121–1135; Nov., 1953.) "The durations of radar echoes from meteors have been observed simultaneously on 9.22 m and 535 m, and also on 9.22 m and 283 m. The ratio of durations on two wavelengths decreases with increasing duration by a factor of two over the observed range, deviating significantly from the accepted square law of wavelength. Plotting the log of the ratio against the log of the duration yields two straight lines of different slopes, one in the short-duration range and the other applying to the longer echoes. General empirical formulas are developed to predict the echo duration on one radio equipment in terms of the duration of the same echo recorded by another apparatus of different sensitivity and wavelength."

523.72:621.396.822 1400

Bailey's Theory of Sunspot Noise—J. W. Dungey. (*Jour. Atmos. Terr. Phys.*, vol. 4, pp. 148–162; Dec., 1953.) A discussion of the exchange of energy between the drifting electrons and the wave radiated from a transient disturbance is given which is more general than Bailey's (1909 of 1950) and which shows that amplification can occur under certain conditions. Consideration of a sunspot model having axial symmetry leads to the conclusion that amplification will occur only in exceptional regions.

523.72:621.396.822 1401

The Equations for a Problem arising in Dungey's Investigation of Bailey's Theory of Sunspot Noise—R. E. Loughhead. (*Jour. Atmos. Terr. Phys.*, vol. 4, pp. 163–174; Dec., 1953.) *See* 1400 above.

523.746 1402

The Magnetic Field Strength in Sunspots—W. Mattig. (*Naturwissenschaften*, vol. 40, p. 523; Oct., 1953.) Reply to Thiessen's criticism (2303 of 1953).

523.746:621.396.822 1403

Theories of Solar Phenomena depending on Sunspot Fields moving in the Chromosphere and Corona—J. H. Piddington. (*Mon. Not. R. Astr. Soc.*, vol. 113, pp. 188–197; Oct., 1953.) Theories advanced by Giovanelli (78 and 376 of 1949) and various other workers are found to be untenable when mechanical reactions between the magnetic fields and the conducting gas are taken into account.

523.75:538.6 1404

A Family of Solutions of the Magneto-hydrostatic Problem in a Conducting Atmosphere in a Gravitational Field—J. W. Dungey. (*Mon. Not. R. Astr. Soc.*, vol. 113, pp. 180–187; Oct., 1953.) A theoretical study of the equilibrium conditions in a quiescent solar prominence. A simple model is obtained.

523.75:[550.386+551.510.535 1405

Ionospheric and Geomagnetic Effects of Solar Flares—J. W. Beagley. (*N.Z. J. Sci. Tech. B*, vol. 35, pp. 141–151; Sept., 1953.) Geomagnetic crochets observed at Amberley and Apia, New Zealand, between 1947 and 1951, simultaneously with Dellinger fadeouts, are considered in relation to subsequent magnetic and ionospheric disturbances. Their hourly and seasonal frequencies are examined and their augmentation of the normal diurnal inequality verified.

523.75:551.510.535 1406

The Hα Radiation from Solar Flares in relation to Sudden Enhancements of Atmospherics on Frequencies near 27 kc/s—M. A. Ellison. (*Jour. Atmos. Terr. Phys.*, vol. 4, pp. 226–239; Dec., 1953.)

523.8:621.396.822 1407

Radio Astronomy: Part 2—Results of Observations of Cosmic Radio-Noise Sources—H. Siedentopf. (*Arch. elekt. Übertragung*, vol. 7, pp. 507–517; Nov., 1953.) A survey with 46 references. Part 1: 390 of February (Dieminger).

523.81:621.396.822 1408

A Survey of 23 Localized Radio Sources in the Northern Hemisphere—R. H. Brown and C. Hazard. (*Mon. Not. R. Astr. Soc.*, vol. 113, pp. 123–133; Oct., 1953.) Report of a survey at a wavelength of 1.89 m, made with the Jodrell Bank aerial system. A marked concentration of the intense sources near the galactic plane was found; the distribution of the weaker sources may be more nearly isotropic.

523.85:621.396.822 1409

A Radio Survey of the Milky Way in Cygnus, Cassiopeia and Perseus—R. H. Brown and C. Hazard. (*Mon. Not. R. Abstr. Soc.*, vol. 113, pp. 109–122; Oct., 1953.) Report of a survey at a frequency of 158.5 mc, using Jodrell Bank 2 degree-beam antenna, and covering the region between $l=40$ degrees and $l=130$ degrees and between $b=14$ degrees and $b=-14$ degrees. The isophotes of the absolute intensities are shown.

523.852.3:621.396.822 1410

Fine Structure of the Extraterrestrial Radio Source Cygnus I—R. C. Jennison and M. K. Das Gupta. (*Nature, London*), vol. 172, pp. 996–997; Nov. 26, 1953.) Observations made at Jodrell Bank are reported.

523.854:621.396.822 1411

Radio Astronomy—H. H. Klinger. (*Jour. Frank. Inst.*, vol. 256, pp. 353–366; Oct., 1953.) A survey paper. See 126 of January.

550.37:550.384 1412

The Relation between Earth Currents and Geomagnetic Variations—A. P. Bondarenko. (*Compt. Rend. Acad. Sci.* (*U.R.S.S.*), vol. 89, pp. 443–445; March 21, 1953. In Russian.) A comparison was made between the time variations of $curl_0\, E$ and H_0' where E is the electric field and H_0' is the resultant vertical component of the geomagnetic variations. Fair agreement between the curves was obtained.

550.384.4 1413

Rapid Periodic Fluctuations of the Geomagnetic Field: Part 1—E. R. R. Holmberg. (*Mon. Not. R. Astr. Soc., Geophys. Suppl.*, vol. 6, pp. 467–481; Oct., 1953.) A new analysis is made of observational data, mainly from Eskdalemuir. The type of fluctuation changes at sunset from a continuous flux of disturbance to a comparative quiet punctuated by a short damped wave train. A definite fine structure is observed in the spectrum of the daytime fluctuations.

551.510.535 1414

The Analysis of Ionospheric Records (Ordinary Ray): Part 1—D. H. Shinn. (*Jour. Atmos. Terr. Phys.*, vol. 4, pp. 240–254; Dec., 1953.) Tables presented enable the effect of the earth's magnetic field to be taken into account when using the method of analysis of Ratcliffe (1292 of 1952) or of Appleton and Beynon (3290 of 1940). Using these tables, theoretical *h'f* curves can be constructed for a parabolic or a linear distribution of ionization and for all magnetic latitudes up to about 70 degrees.

551.510.535 1415

Variations of D-Layer Attenuation at 245 kc/s—E. A. Lauter. (*Z. Met.*, vol. 7, pp. 321–330; Nov., 1953.) Results of daytime reflection-coefficient measurements made over a period of several years are analyzed. The noon value of the attenuation is 2 neper in winter, nearly 7 neper in summer. Though the scatter of values is considerably greater in winter than in summer, the excessive absorption observed in winter on short waves is not observed at this frequency. The influence of the D layer on the propagation of atmospherics is discussed, and the attenuation variations are compared with those of geomagnetic activity.

551.510.535 1416

The Contribution of Solar X-Rays to E-Layer Ionization—E. T. Byram, T. A. Chubb, and H. Friedman. (*Phys. Rev.*, vol. 92, pp. 1066–1067; Nov. 15, 1953.) A brief description of rocket experiments which provide positive evidence of soft X rays in the ionosphere, to an extent sufficient to account for all the E-layer ionization.

551.510.535 1417

Electric Currents in the Ionosphere: Part 1—The Conductivity—W. G. Baker and D. F. Martyn. (*Phil. Trans. A*, vol. 246, pp. 281–294; Dec. 16, 1953.) The effective height-integrated conductivity of the ionosphere, calculated on the dynamo theory, and taking account of inhibition of the Hall current due to polarization of the medium, is greater than the Pedersen conductivity by a factor of at least 6, and, near the magnetic equator, is further increased by a factor of 2 to 5. This calculation is shown to overestimate the reduction in total current flow in the ionosphere due to the "shunting" effect of the F_2 region, when the motion of the F_2 region is considered. The dynamo theory, as presented here, gives results in agreement with observations, and accounts in particular for the anomalously large magnetic variations observed near the equator.

551.510.535 1418

Electric Currents in the Ionosphere: Part 2—The Atmospheric Dynamo—W. G. Baker. (*Phil. Trans. A*, vol. 246, pp. 295–305; Dec. 16, 1953.) Assuming semidiurnal tidal air flow, the atmospheric dynamo problem is solved, the ionosphere being divided into three regions, each of appropriate conductivity. Compared with calculations assuming Pedersen conductivity alone effective, results give a current similar in shape and phase, though more intense, and an electric field system markedly different. An abnormally large east-west current is found at the equator.

551.510.535 1419

Electric Currents in the Ionosphere: Part 3—Ionization Drift due to Winds and Electric Fields—D. F. Martyn. (*Phil. Trans. A*, vol. 246, pp. 306–320; Dec. 16, 1953.) The motion of a cylinder of ionization, of density differing from that of the surrounding medium, tends to be such that the ionization density is greatly increased over part of its surface and diminished over another part. The significance of this result in relation to sporadic-E ionization and to long-duration meteor trails is pointed out. Formulas are derived for the horizontal and vertical drift of ionization at all latitudes. Graphs are given which permit derivation of the true wind or field in a given ionosphere region from experimental observations of the drift velocities.

551.510.535 1420

Semidiurnal Currents and Electron Drifts in the Ionosphere—J. A. Fejer. (*Jour. Atmos. Terr. Phys.*, vol. 4, pp. 184–203; Dec., 1953.) The differential equations of the dynamo theory for the ionosphere are solved numerically under simplifying assumptions. The tidal amplification estimated is about 60. For the solar tide, the current system in the E layer is in phase with the ground tide, but for the lunar tide it is in phase opposition. The calculated vertical electron drift is in reasonable agreement with lunar tide observations. The calculated horizontal electron drift agrees with observations on long-duration meteor-trail echoes, but the calculated phases are opposed to those obtained from fading measurements, indicating that the latter refer to air movements and not to electron drift.

551.510.535 1421

Solar Tides in the F_2 Region from the Study of Night-Time Critical Frequencies—A. A. Weiss. (*Jour. Atmos. Terr. Phys.*, vol. 4, pp. 175–183; Dec., 1953.) Night-time critical frequency variations at 25 ionospheric stations are analyzed by season and by latitude for semi-diurnal solar tidal terms. The amplitude and phase of the vertical drift velocity of electrons so found are consistent with accepted tidal theory, and an estimate of the height-gradient of the vertical drift is obtained. Two parallel analyses are made, on the alternative assumptions that decay proceeds according to a recombination law or to an attachment law. The low values found for the decay coefficients preclude any decision as to which of these two decay processes is actually operative.

551.510.535:523.78 1422

Anomalies of the Ionosphere [F_2-layer] Critical Frequencies during a Solar Eclipse—G. Zanotelli. (*Ann. Geofis.*, vol. 6, pp. 367–372; July, 1953.) Soundings made at Rome during the partial eclipse of February 25, 1952 are reported. Electron-concentration minima were observed before and after the eclipse and at the maximum phase. The cause of the first and last of these maxima is assumed to reside in the zone outside the visible disk of the sun.

551.510.535:550.385 1423

Determination of the Location of the Ionospheric Current System responsible for Geomagnetic Effects of Solar Flares—A. P. Mitra and R. E. Jones. (*Jour. Atmos. Terr. Phys.*, vol. 4, pp. 141–147; Dec., 1953.) The height of the flare current system is calculated by a method depending on the time of maximum intensity of a geomagnetic flare effect and the enhancement of electron density at the relevant level. If the flare current system forms part of the *Sq* current system, its height is 100–120 km, but if it is independent, its height is about 60 km.

551.510.535:551.523.5 1424

Measurements of Winds in the Upper Atmosphere by means of Drifting Meteor Trails: Part 1—D. S. Robertson, D. T. Liddy, and W. G. Elford. (*Jour. Atmos. Terr. Phys.*, vol. 4, pp. 255–270; Dec., 1953.) Description of the 27-mc doppler-radar system and the associated equipment.

551.510.535:551.55:523.5 1425

Measurements of Winds in the Upper Atmosphere by means of Drifting Meteor Trails: Part 2—W. G. Elford and D. S. Robertson. (*Jour. Atmos. Terr. Phys.*, vol. 4, pp. 271–284; Dec., 1953.) Results of measurements made during Oct.–Dec., 1952 by the method described in 1424 above are discussed. Winds at heights between 80 and 105 km are, in general, horizontal, with a prevailing direction in October towards the north-east, and in November and December towards the east. The 12-hour and 24-hour harmonic components represent anticlockwise rotation of the wind vectors, the 12-hour component being consistent with the phase of a semidiurnal tidal wind as deduced from barometric oscillations. Over the height range investigated, the direction of the wind remains the same but the mean velocity increases with height.

551.510.535:[621.396.822:523.8 1426

The Measurement of Ionospheric Absorption using Observations of 18.3-Mc/s Cosmic Radio Noise—A. P. Mitra and C. A. Shain. (*Jour. Atmos. Terr. Phys.*, vol. 4, pp. 240–218; Dec., 1953.) Ionospheric absorption is specified by the ratio, expressed in decibels, of P, the received cosmic noise power, to P_0, the power that would have been received in the absence of absorption. From about a year's observations of cosmic noise, a standard curve of P_0/sidereal time can be drawn for all aerial directions. Analysis of records made at Hornsby, N. S. W., from June, 1950 to June, 1951, shows that two main components due to absorption in the F_2 and D regions respectively can be distinguished.

551.594.6 1427

The Waveforms of Atmospherics—M. W. Chiplonkar. (*Endeavour*, vol. 12, pp. 190–196; Oct., 1953.) A review of research during the preceding fifty years on lightning and on atmospherics, showing the relation between the two phenomena. 28 references.

551.594.6:538.566 1428

Harmonic Fields in the Propagation of Long Electric Waves round the Earth, and Lightning Waveforms—Schumann. (*See* 1544.)

551.594.6:538.566 1429

The Propagation of Very Long Electric Waves round the Earth, and Atmospherics—Schumann. (*See* 1545.)

LOCATION AND AIDS TO NAVIGATION

534.87/.88+534.614 1430

The Development of Acoustic Sea-Depth Measurements—H. Drubba and H. H. Rust. (*Z. angew. Phys.*, vol. 5, pp. 388–400; Oct., 1953.) A historical survey of methods used in measurements of the velocity of sound in water and in sound ranging, from 1826 to date. 104 references.

621.396.962.2 1431

Raydist Systems for Radiolocation and Tracking—J. M. Benson and J. E. Swafford. (*Elect. Eng.*, vol. 72, pp. 983–987; Nov., 1953.) Phase-measurement methods making use of the heterodyne signal between c.w. transmitters obviate the need for phase-locking the transmitters or for very high accuracy of frequency control. Several particular arrangements are described.

621.396.96 1432

The Story of Radar—A. F. Wilkins. (*Research (London)*, vol. 6, pp. 434–440; Nov., 1953.) An account of the main points in the development of radar in Britain, from 1945 onwards.

621.396.96 1433

How Long-Line Effect impairs Tunable Radar—J. F. Hull, G. Novick, and R. Cordray. (*Electronics*, vol. 27, pp. 168–173; Feb., 1954.) The conditions are analyzed under which long mismatched output lines cause frequency jumping in magnetrons and other tube oscillators. Design data are given for eliminating the gaps in the tuning range which occur when the rf generator cannot be mounted directly on the antenna.

621.396.962.2:621.376.3]:629.13 1434

Improved Radio Altimeter—A. Bloch, K. E. Buecks, and A. G. Heaton. (*Wireless World*, vol. 60, pp. 138–140; March, 1954.) The instrument uses a transmission frequency varying linearly between 1.605 and 1.655 kmc, the reflected wave being heterodyned with an oscillation always 110 mc higher than the transmitted wave. The parameters are chosen so that a beat frequency of 10 kc is produced at a height of 900 feet, a servomechanism being used to limit the beat frequency to this value at greater altitudes, so as to avoid the need for a wide-band amplifier, and the consequent increase of noise.

621.396.969 1435

The Harbour Radar System for Rotterdam and the New Waterway—N. Schimmel. (*Tijdschr. ned. Radiogenoot.*, vol. 18, pp. 301–311; Nov., 1953.) Equipment under construction is discussed; the transmitter frequency range is to be 8.9–9.2 kmc, and the peak power at least 10 kw. The operational procedure and methods of measurement are outlined. The system should be completed by 1955.

621.396.969.33 1436
Marine Radar—(*Overseas Eng.*, vol. 27, pp. 97–101; Oct., 1953.) Brief illustrated descriptions and some performance figures are given for British equipment for installation on board ship.

MATERIALS AND SUBSIDIARY TECHNIQUES

535.37:535.215.1 1437
The Photoconductivity of Phosphors with Different Luminescence Mechanisms—H. Gobrecht, D. Hahn, and H. J. Kosel. (*Z. Phys.*, vol. 136, pp. 57–66; Oct. 16, 1953.) Measured photoelectric currents (down to 10^{-14}A) of 49 powder phosphor preparations are listed. These indicate the correspondence of high and low values of photoconductivity respectively with bimolecular and unimolecular luminescence mechanisms.

535.37:546.472.21 1438
The Connection between Darkening and Luminescence of Zinc Sulphide—H. Gobrecht and W. Kunz. (*Z. Phys.*, vol. 136, pp. 21–35; Oct. 16, 1953.) The phenomenon of darkening due to irradiation by light is investigated.

535.37:548.55 1439
On Growing Single Crystals of Thallium-Activated Alkali Halides—J. Franks. (*Brit. Jour. Appl. Phys.*, vol. 4, pp. 377–378; Dec., 1953.) A description is given of a suitable furnace. Activated iodide crystals gave very intense luminescence under electron bombardment.

535.37:621.317.373 1440
Measurement of Luminescence Decay Time by means of the Phase [-detector] Valve—Rohde. (*See* 1504.)

535.372:546.284 1441
A New 6100-Å Band in Zinc Orthosilicate activated with Manganese—P. Zalm and H. A. Klasens. (*Philips Res. Rep.*, vol. 8, pp. 386–392; Oct., 1953.) Activation in the presence of ammonium phosphate at low temperatures gives the additional band, the properties of which are discussed.

535.376 1442
The Light Yield of Phosphors excited by Electron Beams with Accelerating Voltages of 5–60 kV—H. Arend and H. Irmler. (*Naturwissenschaften*, vol. 40, pp. 577–578; Nov., 1953.) Measurements were made of the light emitted in both forward and backward directions. The relation between the light yield and the accelerating voltage for constant beam current is shown graphically for phosphors of various compositions and grain sizes. The shape of the curves depends on the direction of observation. The divergence between the theoretical and actual light yield is discussed; the actual yield is independent of layer thickness as long as the latter is greater than the electron penetration depth.

537.224 1443
Electrets—G. G. Wiseman and E. G. Linden. (*Elect. Eng.*, vol. 72, pp. 869–872; Oct., 1953.) A survey and nonmathematical discussion of electret materials, theories and applications. Tables are given of reported electrets of 5 pure substances and of 20 substances showing only a decaying charge and 17 giving a charge reversal or growth of charge. The applications noted include microphones, radiation dosimeters, electrometers and an es vibration voltmeter.

537.226 1444
Characteristics of Ferroelectric Ceramics near the Curie Point—N. P. Bogoroditaki and T. N. Verbitskaya. (*Compt. Rend. Acad. Sci.* (*U.R.S.S.*), vol. 89, pp. 447–449; March 21, 1953. In Russian.) Report of an investigation of ferroelectric materials with Curie points near 120 degrees C., 35 degrees C. and 150 degrees C, respectively. Graphs show the variation with time (in months) of the capacitance and of the loss-tangent of ferroelectric capacitors and the effect of aging on the capacitance /electric-field-strength characteristic. The results are discussed in relation to the orientation of the domains and the change in the electric moment.

537.226:546.321.85 1445
The Properties of Colloidal Ferroelectric Materials: Part 2—Theoretical Considerations—W. Känzig and R. Sommerhalder. (*Helv. Phys. Acta*, vol. 26, pp. 603–610; Nov. 16, 1953. In German.) The spontaneous-polarization effects described by Jaccard et al. (776 of March) can be explained by introducing the energy of the depolarizing field and the energy of the domain walls into the free energy of the crystal given by Mueller's theory (109 of 1941). The interaction of a polarized ferroelectric crystal with its depolarizing field is discussed. The wall problem is also considered.

537.226:546.431.824–31:546.817.831.4 1446
Ferroelectric Properties of $BaTiO_3$–$PbZrO_3$ Solid Solutions—G. A. Smolenski, A. I. Agranovskaya, and N. N. Kraninik. (*Compt. Rend. Acad. Sci.* (*U.R.S.S.*), vol. 91, pp. 55–58; July 1, 1953. In Russian.) Experimental determination of the temperature dependence of the permittivity, in weak fields, and of $\Delta l/l$, where l is the length of the specimen. These results and the derived variation of the Curie point with $PbZrO_3$ concentration are shown graphically.

537.226:546.817.824 1447
Domain Structure of Lead Titanate—E. G. Fesenko. (*Compt. Rend. Acad. Sci.* (*U.R.S.S.*), vol. 88, pp. 785–786; Feb. 11, 1953. In Russian.) The phase transition near 500 degrees C. was investigated by an optical method. Photographs of a twinned crystal show the permanent structural change on heating above 500 degrees C.

537.226:546.718.882.5–33 1448
Ferroelectric Properties of Lead Metaniobate—G. Goodman. (*Jour. Amer. Ceram. Soc.*, vol. 36, pp. 368–372; Nov., 1953.) "Ferroelectric lead metaniobate, $Pb(NbO_3)_2$, is structurally distinct from the ABO_3 perovskite-type ferroelectrics presently known. Dielectric and dilatometric data indicate a 570 degrees C. Curie point. In ceramic form the material can be polarized to retain a piezoelectric constant of the same order of magnitude as that of barium titanate."

537.226:621.315.612.4 1449
Dielectrics containing Barium Titanate—W. Soyck. (*Schweiz. Arch. angew. Wiss. Tech.*, vol. 19, pp. 316–322; Oct., 1953.) A short review; aspects discussed include the ceramic structure and electrical properties of $BaTiO_3$, aging, effect of nonuniform fields and of high temperatures and field strengths, and behavior at high frequency.

537.311.3 1450
The Resistance of 72 Elements, Alloys and Compounds to 1000000 kg/cm.²—P. W. Bridgman. (*Proc. Amer. Acad. Arts Sci.*, vol. 81, pp. 165–251; March, 1952.)

537.311.33 1451
On Conduction in Impurity Bands—W. Baltensperger. (*Phil. Mag.*, vol. 44, pp. 1355–1363; Dec., 1953.) "The idea of conduction by electrons in the energy bands of an impurity system is examined. For a lattice of hydrogen-like impurities the edges of the 1s, 2s, and 2p bands are calculated. Effective masses for electrons in these bands are introduced. With their help measurements of the conductivity and the Hall constant are interpreted. Depending on the density of the impurities and on the temperature, conduction takes place predominantly either in the band of the medium, or in excited impurity states, or in the 1s impurity band. In this last case the activation energy vanishes. This interpretation implies a description of the electronic state of the impurities with band wave functions and indicates the validity of such a description up to rather large values of the lattice constant. This can however be reconciled with the insulating properties of the oxides of transition metals."

537.311.33 1452
Modification of the Conductivity of Thin Semiconductor Films by Capacitively Applied Barrier-Layer Fields—K. Zückler. (*Z. Phys.*, vol. 136, pp. 40–51; Oct. 16, 1953.) The principle used by Shockley and Pearson (3438 of 1948) was applied to determine barrier-layer properties for Se and Cu_2O. An evaporated semiconductor film formed one electrode of a mica capacitor. The variation of the resistance of the semiconductor with the voltage applied across the capacitor was measured at −78 degrees, +25 degrees and +80 degrees C. by means of an auxiliary circuit. Values for the thickness of the barrier layer, the concentration of impurity centres and the mobility of charge carriers in the semiconductor are calculated assuming exhaustion of impurity centres (*a*) across the whole film, (*b*) within the barrier layer only.

537.311.33 1453
Apparatus for the Graphical Determination of the Fermi Energy Level in Semiconductors—E. Mooser. (*Z. angew. Math. Phys.*, vol. 4, pp. 433–449; Nov. 15, 1953.) A method of determining the Fermi energy from the temperature and band-structure parameters is described in detail, with examples. The method also gives the temperature dependence of the concentration of charge carriers, taking account of degeneracy.

537.311.33 1454
New Semiconducting Compounds—H. Welker. (*Z. Naturf.*, vol. 7a, pp. 744–749; Nov., 1952.) An investigation of compounds formed from Al, Ga or In on the one hand and P, As or Sb on the other. Such semiconducting compounds may have properties greatly superior to those of diamond, Si, Ge or grey tin. Electron mobilities up to 25000 cm/s per V/cm have been measured in InSb.

537.311.33 1455
A Simple Demostration Model of a p-n Junction—W. Heywang. (*Naturwissenschaften*, vol. 40, pp. 527–528; Oct., 1953.)

537.311.33:535.215 1456
Quantum-Statistical Treatment of the Internal Photoeffect—H. Müser. (*Z. Naturf.*, vol. 7a, pp. 729–734; Nov., 1952.) The distribution of electrons between possible energy levels is investigated for the case where a given number of electrons per second is shifted from a lower to a higher level.

537.311.33:537.312.6 1457
Rectification in Semiconductors in a Thermal Field—I. M. Tsidil'kovski. (*Compt. Rend. Acad. Sci.* (*U.R.S.S.*), vol. 91, pp. 63–66; July 1, 1953. In Russian.) Theoretical investigation of rectification by a system comprising a semiconductor layer between a pair of metal electrodes between which a potential difference and a temperature difference exist. Semiconductors considered are Cu_2O, Ge and Si. The calculated and the experimentally determined relations between K (ratio of backward to forward resistance) and V (potential difference) are shown graphically for a semiconductor with specified constants.

537.311.33:537.312.62 1458
Superconductivity of Impurity Semiconductors (PbS)—E. Justi and H. Schultz. (*Z. Naturf.*, vol. 8a, pp. 149–155; Feb./March, 1953.) Measurements on evaporated films of

controlled composition are reported. Superconductivity is not observed with films containing an excess of S or a small excess of Pb, but is observed with a large excess of Pb, the resistivity dropping sharply below 7.26 degrees K. These results are discussed in relation to the possible mechanisms involved.

537.311.33:546.18–171 1459

The Electrical Properties of Black Phosphorus—R. W. Keyes. (*Phys. Rev.*, vol. 92, pp. 580–584; Nov. 1, 1953.) Electrical conductivity and Hall constant were determined over the temperature range −195 degrees C. to 350 degrees C. The conductivity at pressures up to 8000 kg/cm², magnetoresistance coefficients at −195 degrees C. and −80 degrees C. and infrared absorption between 2 μ and 30 μ were also determined. At low temperatures *p*-type impurity conduction was observed; at high temperatures the phosphorus is an intrinsic semiconductor with an energy gap of 0.33 eV.

537.311.33:[546.28+546.289 1460

Production of Acceptor Centers in Germanium and Silicon by Plastic Deformation—W. C. Ellis and E. S. Greiner. (*Phys. Rev.*, vol. 92, pp. 1061–1062; Nov. 15, 1953.) Ge crystals have been converted from *n* to *p* type by compression at high temperature; the accompanying changes of resistivity correspond to the introduction of 10^{15} acceptor centres/cm.³ Similar results were obtained with Si at greater compression and higher temperature.

537.311.33:546.289 1461

On the Effective Mass of the Conduction Electron in Germanium—W. Sasaki and M. Kuno. (*Jour. Phys. Soc.* (*Japan*), vol. 8, pp. 791–792; Nov./Dec., 1953.) Determinations based on Hall-effect and thermoelectric measurements on *n*-type single crystals are tabulated and compared with results obtained by Debye and Conwell (425 of 1953).

537.311.33:546.289 1462

Drift Mobilities in Semiconductors: Part 1—Germanium—M. B. Prince. (*Phys. Rev.*, vol. 92, pp. 681–687; Nov. 1, 1953.) The drift mobilities of μ_p and μ_n of holes in *n*-type and of electrons in *p*-type material respectively were determined over the temperature range 150 degrees to 350 degrees K for samples with a range of resistivities from 0.05 to 30 Ω. cm at 300 degrees K. For single crystals of resistivity >10 Ω. cm the relations between mobility and temperature are given by $\mu_n = 3.5\times10^7 T0^{-1.6}$ and $\mu_p = 9.1\times10^8 T0^{-2.3}$. The relation between resistivity and concentration of impurity centres is shown graphically.

537.311.33:546.289 1463

Solubility and Ionizability of Impurities in Germanium Single Crystals—W. Dürr, J. Jaumann, and K. Seiler. (*Z. Naturf.*, vol. 8a, pp. 39–46; Jan., 1953.) Rod-shaped single crystals were grown from a melt of pure Ge with controlled additions of Ga, As or Sb. Measurements were made of the variation of Hall constant and conductivity along the direction of growth, and of the temperature dependence of these constants. The actual impurity content of a homogeneous middle portion of the crystal is determined by remelting and recrystallizing and comparing the constants with curves prepared for crystals from melts with known impurity concentrations. The results indicate that every donor atom (within ±30 per cent) yields one charge carrier, i.e. the ionizability has the value unity.

537.311.33:546.289 1464

A Method of estimating Impurity Concentrations in Germanium—F. W. G. Rose and E. W. Timmins. (*Proc. Phys. Soc.*, vol. 66, pp. 984–986; Nov. 1, 1953.) Families of theoretical curves of log resistivity against inverse temperature for different values of impurity concentration were prepared corresponding to two sets of assumptions, namely (*a*) carrier and impurity concentrations equal, lattice scattering predominant, and (*b*) carrier and impurity concentrations unequal, both lattice and impurity scattering significant. The impurity content of a specimen is estimated by selecting the theoretical curve which best fits the experimental curve.

537.311.33:546.289 1465

Some Consequences of Possible Degeneracy of Energy Bands in Ge—E. N. Adams, II. (*Phys. Rev.*, vol. 92, pp. 1063–1064; Nov. 15, 1953.) Critical examination of theory developed by Herman and Callaway (1699 of 1953).

537.311.33:546.289 1466

Further Measurements of the Effect of Pressure on the Electrical Resistance of Germanium—P. W. Bridgman. (*Proc. Amer. Acad. Arts Sci.*, vol. 82, pp. 71–82; April, 1953.) For reports of previous measurements see 1450 above and 2439 of 1951.

537.311.33:546.289:538.224 1467

The Magnetic Susceptibility of Germanium—D. K. Stevens and J. H. Crawford, Jr. (*Phys. Rev.*, vol. 92, pp. 1065–1066; Nov. 15, 1953.) Measurements have been made on both *p*- and *n*-type specimens over the temperature range 65 degrees to 300 degrees K. Some results are shown graphically and used to estimate the ratio of free-electron mass to effective carrier mass.

537.311.33:546.289:538.569.4.029.6 1468

Observation of Cyclotron Resonance in Germanium Crystals—G. Dresselhaus, A. F. Kip, and C. Kittel. (*Phys. Rev.*, vol. 92, p. 827; Nov. 1, 1953.) Diamagnetic resonance has been observed at 4 degrees K. in 38-Ω. cm *n*-type Ge at a field strength of 370±5 oersted, and in *p*-type Ge at 125±5 and at 970±50 oersted, at a frequency of 9.05 kmc.

537.311.33:546.289:548.4.021 1469

Annealing of Bombardment Damage in Germanium: Experimental—W. L. Brown, R. C. Fletcher, and K. A. Wright. (*Phys. Rev.*, vol. 92, pp. 591–596; Nov. 1, 1953.) The damage produced by 3-MeV electrons, consisting primarily in the production of isolated vacancy-interstitial pairs, was determined by conductivity measurements on *n*-type samples. The activation energy for the diffusion of vacancies is found to be ∼1.7 eV. The annealing curves are compared with curves derived from the theoretical model discussed by Fletcher and Brown (1477 below).

537.311.33:546.289:620.185 1470

New Etches for Germanium—R. C. Ellis, Jr., and S. P. Wolsky. (*Jour. Appl. Phys.*, vol. 24, pp. 1411–1412; Nov., 1953.) Preliminary report of an investigation of etching solutions other than hydrofluoric acid.

537.311.33:546.3-1-46-289-811 1471

Electrical Conductivity of Mixed Crystals of Intermetallic Compounds—G. Busch and U. Winkler. (*Helv. Phys. Acta.*, vol. 26, pp. 578–583; Nov. 16, 1953. In German.) The lattice constant, activation energy and variation of conductivity with temperature were determined experimentally for twelve different $Mg_2(Ge_ySn_{1-y})$ compounds. The results are shown graphically and tabulated.

537.311.33+535.215.1]:546.36.863 1472

Studies on the Cs_3Sb Photo-Cathode—T. Sakata. (*Jour. Phys. Soc.* (*Japan*), vol. 8, pp. 723–730; Nov./Dec., 1953.) Determinations of spectral and energy distributions indicate that Cs_3Sb is a semiconductor with values of δ about 0.2–0.3 eV, where δ is the difference between the Fermi level and the top of the occupied energy band. The value of the work function found by the photoelectric method was about 1.8±0.1 eV.

537.311.33+535.215.1]:546.36.863:538.632 1473

The Hall Effect in Cs_3Sb Photo-Cathode—T. Sakata. (*Jour. Phys. Soc.* (*Japan*), vol. 8, pp. 793–795; Nov./Dec., 1953.) Results of measurements at a frequency of 800 cps confirm that Cs_3Sb is a *p*-type semiconductor.

537.311.33:546.482.21 1474

Production of a *P*-Type Rectifier by High Local Heating of *N*-Type Crystals—G. Strull. (*Jour. Appl. Phys.*, vol. 24, p. 1411; Nov., 1953.) Experimental evidence is given of *n*-type CdS crystals changing to *p*-type on application of intense local heating.

537.311.33:546.811–17 1475

Investigation of the Mechanism of Electrical Conduction in Grey Tin—G. Busch and J. Wieland. (*Helv. Phys. Acta*, vol. 26, pp. 697–730; Dec. 15, 1953. In German.) Results of earlier measurements of conductivity, Hall effect and variation of resistivity with applied magnetic field [2438 of 1951 (Busch et al.)] are discussed in detail in the light of present theory of semi-conductors. Calculated values for charge-carrier concentrations and mobilities are considered in relation to different scattering processes, and the effects of added impurities and of incomplete transition are assessed. By means of a suitable model the absolute conductivity can be determined. At the transition point it is $2.7\times10^3\Omega^{-1}.cm^{-1}$, about one fortieth of that for the metallic modification.

537.311.33.546.811–17:538.22 1476

The Magnetic Properties of Semiconductors, with Particular Reference to Grey Tin—G. Busch nad E. Mooser. (*Helv. Phys. Acta*, vol. 26, pp. 611–656; Nov. 16, 1953. In German.) The electrons and holes in semiconductor are divided into three groups: (*a*) electrons in the valency band and in lower energy states, (*b*) free charge-carriers, i.e. electrons in the conduction band and holes in the valency band, and (*c*) electrons and holes which occupy the impurity levels and impurity bands between the conduction- and the valency-band. The susceptibilities corresponding to these groups are, respectively, the "atom-susceptibility," the "charge-carrier susceptibility" and the "impurity-centre susceptibility." These are discussed from the theoretical point of view and the results are used to interpret the susceptibility measurements made on grey tin with and without added impurities.

537.311.33:548.4.021 1477

Annealing of Bombardment Damage in a Diamond-Type Lattice: Theoretical—R. C. Fletcher and W. L. Brown. (*Phys. Rev.*, vol. 92, pp. 585–590; Nov. 1, 1953.) A description is given of a three-stage process by which isolated pairs of interstitials and vacancies are thought to be removed. Approximate analytical expressions are derived for these stages. An outline is given of a more complete treatment with a quantitative solution for one particular phase of the annealing in the diamond-type lattice.

537.312.5:546.482.21 1478

Influence of Temperature and Oxygen on the Build-Up and Decay of the Photoconductivity of CdS Single Crystals—B. Seraphin. (*Ann. Phys., Lpz.*, vol. 13, pp. 198–213; Oct. 20, 1953.)

537.32 1479

Thermoelectric Power of Monovalent Metals at High Temperature—D. K. C. MacDonald and S. K. Roy. (*Phil. Mag.*, vol. 44, pp. 1364–1370; Dec., 1953.) An analysis based on band theory.

537.323:669.7.018 1480

Thermoelectric Power of Alloys—J. Friedel. (*Jour. Phys. Radium*, vol. 14, pp. 561–565; Nov., 1953.) Mott's calculation for the resistivity when polyvalent impurities (e.g. Zn, Ga, Ge) are substituted in monovalent metals such as Cu is extended to determine the thermoelectric power. The order of magnitude and the variation as a function of impurity concentration are in agreement with experimental results. For Al alloys, in order to obtain theoretical results in agreement with observations, it is necessary to assume two overlapping energy bands.

537.533.8 1481

Some Characteristics of Secondary Emission from BeCu—F. J. F. Osborne. (*Canad. Jour. Phys.*, vol. 31, p. 1189; Nov., 1953.) An investigation was made of the energy distribution of secondary electrons emitted from BeCu and other metal surfaces bombarded by primary electrons; the target was placed at the centre of a sphere to which a variable positive or negative bias was applied. The results are plotted as percentage of total secondary current against sphere bias.

538.221 1482

Quantum Theory of a Newly Proposed Origin of Ferromagnetism—G. Heber. (*Ann. Phys., Lpz.*, vol. 13, pp. 44–72; Oct. 20, 1953.) Zener's theory, that ferromagnetism originates from the interaction between the 3*d* and the 4*s* electrons of a crystal, is discussed in conjunction with Heisenberg's theory, based on interaction between the 3*d* electrons among themselves.

538.221 1483

Orientational Superstructures due to Mechanical Deformations—L. Néel. (*Compt. Rend. Acad. Sci. (Paris)*, vol. 238, pp. 305–308; Jan. 18, 1954.) Development of work previously noted (1101 of April).

537.221 1484

Magnetic Moments and Crystal Structures of Ferromagnetic Metals and Alloys—F. Gal'perin. (*Compt. Rend. Acad. Sci., U.R.S.S.*, vol. 88, pp. 643–646; Feb. 1, 1953. In Russian.) An expression for the magnetic moment is given by analogy with a previously published formula (2444 of 1951) in terms of lattice constants. These constants are given in Table 1 for some pure metals, pure ferrites and materials of ferroxdure type. The calculated magnetic moments, given in fractional numbers of magnetrons, are in good agreement with experimental values given in the last column. The dependence of the molecular magnetic moments of mixed ferrites on the relative concentrations of the components is shown in Fig. 1, where the curves, calculated from the given expression, are compared with the results of measurements by Gorter (1931 of 1950) and by Guillaud.

538.221:539.382:546.74 1485

Investigation of the ΔE Effect and the Damping of Elastic Waves in Polycrystalline Nickel by an Acoustic Method—V. P. Sizov. (*Compt. Rend. Acad. Sci. U.R.S.S.*, vol. 89, pp. 427–430; March 21, 1953. In Russian.) Young's modulus (E) of 99.5 per cent pure Ni wire was determined by the method of longitudinal resonant oscillations at the fundamental frequency (about 12 kc). The effects of magnetic fields up to 1215 oersted were measured. Graphs of E/H, of $(\Delta E/E)/(J/J_s)$, where J_s is the intensity of magnetization at saturation, and of the variation in the amplitude and the decrement with H are given for differently treated wires.

538.221:621.318.12/.13 1486

Investigation of the Frequency Dependence of the Material Constants of Mixed Ferromagnetic Bodies up to Very High Frequencies—W. Heister. (*Arch. Elektrotech.*, pp. 142–160; 1953.) The dielectric and magnetic properties of Ni-Zn, Cu-Zn and Mn-Zn ferrites and of dust cores of various grades and grain sizes of carbonyl iron, carbonyl nickel, hametag iron and cobalt were investigated at frequencies between 50 cps and 4 kmc. At high frequencies volume resonance effects, due to capacitive eddy currents, were observed; these are explained by using the results of the dielectric measurements. The frequency characteristics can be determined from the properties of the individual particles; a comparison with experimental results is made.

538.221:621.318.134 1487

Ferrites—Properties and Applications—H. Lennartz. (*Funk u. Ton*, vol. 7, pp. 613–627; Dec., 1953.) A survey. A table is given of the magnetic characteristics of 29 commercial magnetically soft ferrites manufactured in Holland and Germany. 33 references.

538.221:621.318.134:538.662 1488

Temperature Dependence of Magnetization Curves of Nickel-Zinc Ferrites in Weak Fields—A. P. Komar and N. M. Reinov. (*Compt. Rend. Acad. Sci. U.R.S.S.*, vol. 93, pp. 19–20; Nov. 1, 1953. In Russian.) I/H characteristics determined at room temperature and at the temperatures of liquid N, H and He are shown graphically.

538.221:621.318.2 1489

Steels for Permanent Magnets—J. C. Williamson. (*Elec. Rev. (London)*, vol. 153, pp. 1101–1105; Nov. 13, 1953.) The main types are surveyed briefly; two categories are distinguished, namely, quench-hardened steels and precipitation-hardened alloys. Composition and properties are tabulated.

546.23:537.226.8:621.314.634 1490

The Dielectric Behaviour of Selenium Barrier-Layers under Temperature Loading in the Blocking Region—H. H. Rust. (*Arch. elekt. Übertragung*, vol. 7, pp. 549–553; Nov., 1953.) The capacitance/temperature characteristic of Se barrier layers initially exhibits a hysteresis effect which vanishes in subsequent temperature cycles. The variations of capacitance with time, following exposure to an increased temperature, and following a change in the applied bias potential, are shown graphically. The results are discussed and similarities with the characteristics of ferroelectric materials are noted.

548.7 1491

Imperfections in Matter—G. W. Rathenau. (*Philips Tech. Rev.*, vol. 15, pp. 105–113; Oct., 1953.) A general survey of the effects of crystal lattice imperfections on the properties of solids.

621.3.042.017.3 1492

Combined Magnetization of Magnetic Materials—J. E. Parton and W. D. Sutherland. (*Eng. (London)*, vol. 176, pp. 687–700 and 731–732; Nov. 27 and Dec. 4, 1953.) A detailed examination is made of the conditions produced when a magnetic core is simultaneously subjected to two or more magnetizing forces of different frequencies; the resulting iron losses are investigated.

669.04 1493

Preparation and Casting of Metals and Alloys under High Vacuum—J. D. Fast, A. I. Luteijn, and E. Overbosch. (*Philips Tech. Rev.*, vol. 15, pp. 114–121; Oct., 1953.) A method is described for producing materials having the high degree of purity and precise composition required for physical investigations.

669.24:548.5 1494

Production of Single Crystals of Nickel—R. F. Pearson. (*Brit. Jour. Appl. Phys.*, vol. 4, pp. 342–344; Nov., 1953.) The growth by cooling from the melt, and the preparation of faces parallel to given crystal planes are described.

MATHEMATICS

512.3 1495

The Location of the Roots of Polynomial Equations by the Repeated Evaluation of Linear Forms—L. Tasny-Tschiassny. (*Quart. Appl. Math.*, vol. 11, pp. 319–326; Oct., 1953.)

517.512.3 1496

Legendre Functions of Fractional Order—M. C. Gray. (*Quart. Appl. Math.*, vol. 11, pp. 311–318; Oct., 1953.) Formulas are presented which were developed in connection with Schelkunoff's theory of antennas but are of general interest; computed values of the functions are tabulated and shown in curves.

MEASUREMENTS AND TEST GEAR

621.317.3:538.632 1497

Measurement of the Hall Effect in Cylinders without an External Magnetic Field—G. Busch and R. Jaggi. (*Z. angew. Math. Phys.*, vol. 4, pp. 425–433; Nov. 15, 1953.) A current flowing in a cylindrical conductor gives rise to a Hall effect due to its own magnetic field. A simple method of measuring the effect, using either dc or ac, is described. Results of measurements on polycrystalline Bi at 77 degrees K and 290 degrees K are shown graphically for different values of primary current; they are in good agreement with other published results.

621.317.3:621.314.632:546.289 1498

Use of the Germanium Rectifier for the Measurement of Current Voltage and Power at High Frequency: Part 1—Measurement of Current and Voltage—J. Schiele. (*Arch. tech. Messen*, no. 215, pp. 285–288; Dec., 1953.) A survey relating particularly to Siemens Ge rectifiers, in which the crystal and point contact are sealed into a ceramic tube with metal end caps.

621.317.3:621.372.2.029.64 1499

Determination of Equivalent Circuit Parameters for Dissipative Microwave Structures—L. B. Felsen and A. A. Oliner. (Proc. I.R.E., vol. 42, pp. 477–483; Feb., 1954.) Measurement procedures are proposed based on Weissfloch's method of separating the network into lossy and loss-free parts (403 of 1944) and applicable for investigations of structures such as junctions between surface-wave or microstrip lines and their feed lines. Sample calculations are presented.

621.317.3:621.372.8 1500

An Elliptically-Polarized-Vibration Analyser for a Circular Waveguide in the 3-cm Waveband—G. Raoult and A. Marcon. (*Compt. Rend. Acad. Sci. (Paris)*, vol. 238, pp. 218–220; Jan. 11, 1954.) An arrangement analogous to that used for optical polarization experiments is described. Two small antennas associated with resonators and crystal detectors are used to pick up the two components of the elliptically polarized wave. The ellipticity is determined by making measurements with and without a quarter-wave phase shifter in position.

621.317.32:621.314.63 1501

The Application of Barrier-Layer Rectifiers to the Measurement of Very Small Alternating Voltages—F. Moeller. (*Arch. tech. Messen*, no. 214, pp. 263–266; Nov., 1953.) A comparison of the characteristics of Cu_2O, Se and Si or Ge point-contact rectifiers from the point of view of measurement of voltages <10 mv.

621.317.331:546.289 1502

Resistivity Measurements on Germanium for Transistors—L. B. Valdes. (Proc. I.R.E., vol. 42, pp. 420–427; Feb., 1954.) A method using four aligned probes is described; current is passed through the outer pair and the floating potential across the inner pair is measured. Formulas and curves are given for computing the resistivity for some particular arrangements.

621.317.35:535.37 1503

A New Method to Determine Short Decay Times of Phosphors excited with Ultraviolet Light—A. Bril, H. A. Klasens, and P. Zalm. (*Philips Res. Rep.*, vol. 8, pp. 393–396; Oct., 1953.) A cr tube with an ultraviolet-transmitting filter is used to provide excitation. The decay time of Sb-activated halophosphates is $\sim 5\times 10^{-6}$ sec.

621.317.373:535.37 1504

Measurement of Luminescence Decay Time by means of the Phase [-detector] Valve—F. Rohde. (*Z. Naturf.*, vol. 8a, pp. 156–161; Feb./March, 1953.) The screen is excited by an electron beam whose intensity is modulated at hf, and the emitted light is picked up by a photomultiplier, producing a signal which is phase-shifted with respect to the modulating signal. The two signals are applied to a phase-detector valve, whose output gives an indication of the luminescence decay time. Measurements on various organic phosphors are reported.

621.317.411.029.64 1505
The Determination of the Apparent Permeabilities of Ferromagnetic Metals at cm-Wavelengths—E. Ledinegg and P. Urban. (*Arch. elekt. Übertragung*, vol. 7, pp. 523–530; Nov., 1953.) Methods based on cavity-resonator and Lecher-wire measurements are described, the permeabilities being calculated from the detuning effect and the damping produced by a probe formed of the material under test.

621.317.42:538.221 1506
Investigation of Self-Field Distortion in the Förster Probe in the Presence of a Ferromagnetic Material—F. Brandstaetter. (*Elektrotech. u. Maschinenb.*, vol. 70, pp. 452–455; Oct. 15, 1953.) The Förster probe consists basically of a twin-core transformer with the lines of force completed through air paths, the secondaries being wound so as to provide compensation in the absence of external magnetic fields. When used for testing ferromagnetic materials, the probe field gives rise to irreversible processes which are however reduced to a small residual value due to the movement of the probe along the test piece.

621.317.431/.44 1507
An Improved Form of Hysteresis-Loop Plotter for Magnetic Materials—A. D. Booth. (*Jour. Sci. Instr.*, vol. 30, pp. 384–385; Oct., 1953.) The use of a feedback integrator in the conventional cro hysteresis-curve plotter circuit results in a decreased time constant for a given accuracy, increased stability and freedom from unwanted pick-up. Hysteresis curves of toroidal cores can be obtained by winding one or two turns only and using a 1:60 step-up transformer.

621.317.444 1508
A Recording Fluxmeter—R. S. Tebble. (*Jour. Sci. Instr.*, vol. 30, pp. 369–371; Oct., 1953.) The deflection of the Grassot fluxmeter coil is recorded as a change in the voltage induced in a mutual inductor, the primary of which is fixed and the secondary attached to the fluxmeter coil. The apparatus is described and the elimination of various errors is discussed.

621.317.7:621.3.028.78 1509
Measurement of Harmonic Distortion—T. D. Conway. (*Wireless World*, vol. 60, pp. 110–112; March, 1954.) Description of a self-contained direct-reading instrument for works testing and servicing, particularly for magnetic-tape recorders.

621.317.7.029.63/.64:621.372.43 1510
A U.H.F. and Microwave Matching Termination—R. C. Ellenwood and W. E. Ryan (PROC. I.R.E., vol. 42, pp. 476–477; Feb., 1954.) Discussion on 1073 of 1953.

621.317.71 1511
High-Sensitivity Monofilar Electrometer—Ouang Te-Tchao, E. Montel, and P. Pannetier. (*Jour. Phys. Rad.*, vol. 14, pp. 627–629; Nov., 1953.) An instrument capable of detecting a charge of the order of 20,000 electrons is described.

621.317.72.027.2.083.5 1512
Moving-Coil Compensator for recording Small Direct Voltages—E. Samal. (*Elektrotech. Z., Edn A*, vol. 74, pp. 590–593; Oct. 11, 1953.) The difference between the currents passed through a resistor from a variable source and due to application of the unknown emf is used to operate a variable mutual inductor which controls the current source.

621.317.725 1513
An Electrostatic Voltmeter with Linear Indication—H. Greinacher. (*Bull. schweiz. elektrotech. Ver.*, vol. 44, pp. 1081–1083; Dec. 26, 1953.) The voltmeter described previously (947 of 1951) is modified to give a linear indication by using appropriately curved plates instead of plane ones.

621.317.729 1514
Low-Input-Capacity Probe—G. L. Schultz. (*Rev. Sci. Instr.*, vol. 24, p. 1068; Nov., 1953.) Input capacitance is 4.5 pF measured at 1.5 mc. Attenuation is linear for 10-μs pulses of amplitude between -6V and $+11$V.

621.317.734:621.314.7 1515
Transistorized Megohmmeter—P. B. Helsdon. (*Wireless World*, vol. 60, pp. 121–123; March, 1954.) Description of a compact two-range instrument with a transistor hv generator.

621.317.755:[621.314.632+621.314.7 1516
A Double-Pulse Instrument for the Measurement of Time-Lag Phenomena in Crystal Diodes and Transistors—T. Einsele. (*Funk u. Ton*, vol. 7, pp. 557–569; Nov., 1953.) The operation and parts of the circuit of the cro instrument are described. The duration of either pulse can be varied independently between 0.5 and 25 μs, the pulse separation can be varied between 0.5 and 50 μs and the pulse repetition frequency between 10 and 2000/second. The pulse amplitudes are equal and variable between 1 and 200 v. Applications of the instrument include measurement of the variation with time of the barrier-layer resistance.

621.317.755:621.385.832 1517
A Sealed-Off Cathode-Ray Tube with a Very High Writing Speed—Jackson, Hardy, and Feinberg. (*See* 1619.)

621.317.755:621.385.832 1518
Multibeam Cathode-Ray Oscillograph—Fert, Lagasse and Ollé. (*See* 1620.)

621.317.79:537.533 1519
High-Energy Bunched Beam Analyzer—I. Kaufman. (*Jour. Appl. Phys.*, vol. 24, pp. 1413; Nov., 1953.) An arrangement for measuring the length of the bunches in an undulated high-energy electron beam, such as that described by Motz (2411 of 1951) for producing millimeter waves, includes a cavity resonator for converting the bunch length into an electron-energy range, followed by a magnetic field for separating the electrons according to their energies.

621.317.79:372.412 1520
A Review of Methods for Measuring the Constants of Piezoelectric Vibrators—E. A. Gerber. (PROC. I.R.E., vol. 42, p. 446; Feb., 1954.) Correction to paper abstracted in 3670 of 1953.

621.373:621.396.822 1521
Primary Standard Thermal Noise Generator—G. Lynch. (*Radio & Telev. News, Radio-Electronic Eng. Section*, vol. 50, pp. 10–12; Nov., 1953.) The noise generator described comprises a heated precision resistor matched to a coaxial line.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

539.32:534.321.9 1522
Determination of the Elastic Constants of Isotropic Solid Bodies, using Ultrasonic Waves—E. Ledinegg and P. Urban. (*Acta Phys. austriaca*, vol. 8, pp. 16–27; Oct., 1953.) Description of a resonance method using a cylindrical acoustic resonator into which rod or plate specimens are introduced. Formulas derived for thin specimens are in approximate agreement with corresponding formulae previously derived from perturbation theory (922 of April).

621.317.083.7 1523
Radio Telemetering—E. D. Whitehead and J. Walsh. (*Proc. IEE*, part III, vol. 101, pp. 41–42; Jan., 1954.) Discussion on 1762 of 1953.

621.317.083.7 1524
A Transducer System for Remote Indication—(*Eng.* (*London*), vol. 196, pp. 537–538; Oct. 13, 1953.) The amount of unbalance introduced in a bridge-type circuit by a change of the em coupling at the transducer is measured by a remote moving-coil meter. A 50-cps mains supply is used.

621.317.083.7:621.396.934 1525
Telemetry for Guided Weapons—(*Eng.* (*London*), vol. 176, pp. 158–519; Oct. 23, 1953.) Airborne and ground-station equipment developed by the Ministry of Supply is described. For the transmission of information on control, surface positions, strains, pressures and torques a 23-channel low frequency time-sharing multiplex system is used, with an additional channel for synchronization. Information on waveforms occurring in the airborne electronic equipment is transmitted by 20 high-frequency channels, using ppm and time-division systems.

621.318.5:551.571.3 1526
The Effect of Humidity Variation on the Operation of an Electronic Proximity Switch—R. A. K. Long. (*Jour. Sci. Instr.*, vol. 30, pp. 422–424; Nov., 1953.) The change in electrode capacitance due to adsorption by the oxide layer and to permittivity and temperature variations can be eliminated by enclosing the electrode.

621.318.572:621.383 1527
A Bidirectional Electronic Counter for Use in Optical Interferometry—F. H. Branin, Jr. (*Jour. Opt. Soc. Amer.*, vol. 43, pp. 839–848; Oct., 1953.) An arrangement is described for counting interference fringes by deriving electrical sine waves from them by means of a stepped mirror and two photocells. Either a binary or a decimal system can be provided. Counting rates $>$150,000/seconds have been achieved. Other applications of the counter are indicated, including use in analog-to-digital converters.

621.384.611 1528
Favourable Operating Conditions for the Electron Cyclotron—C. Schmelzer. (*Z. Naturf.*, vol. 7a, pp. 808–817; Dec., 1952.)

621.384.612 1529
Nonlinearities in the Strong-Focusing Accelerator—E. R. Caianiello. (*Nuovo Cim.*, vol. 10, pp. 581–593; May 1, 1953. In English.) The effects of the nonlinearity of the magnetic field, due to the fact that it must satisfy the Maxwell equations, are shown to be negligible compared with other causes of error in the strong-focusing accelerator.

621.384.612 1530
Stability and Periodicity in the Strong-Focusing Accelerator—E. R. Caianiello and A. Turrin. (*Nuovo Cim.*, vol. 10, pp. 594–603; May 1, 1953. In English.)

621.384.612 1531
Alignment Errors in the Strong-Focusing Synchrotron—M. Sands and B. Touschek. (*Nuovo Cim.*, vol. 10, pp. 604–613; May 1, 1953. In English.) Distortion of orbits due to misalignment of the sectors is investigated.

621.384.612 1532
Orbital Instabilities due to Nonlinearities in the Cosmotron—J. Seiden. (*Compt. Rend. Acad. Sci.* (*Paris*), vol. 238, pp. 230–232; Jan. 11, 1954.)

621.384.622.2 1533
8-MeV Linear Accelerator for X-Ray Therapy—(*Eng.* (*London*), vol. 196, pp. 554–556; Oct. 30, 1953.) Description of traveling-wave

accelerator installed at Hammersmith Hospital, London.

621.385.832/.733]:621.3.032.28:538.691 1534
Magnetic Electron Lens Aberrations due to Mechanical Defects—G. D. Archard. (*Jour. Sci. Instr.*, vol. 30, pp. 352–358; Oct., 1953.) A modification of Sturrock's computational procedure (1074 of 1952) is used. The results are presented in the form of universal curves designed to facilitate the assignment of tolerances for lenses of any magnitude and any accelerating potential.

621.385.833 1535
Numerical Integrations of the Equation of Electron Trajectories—M. Laudet. (*Jour. Phys. Rad.*, vol. 14, pp. 604–610; Nov., 1953.)

621.385.833 1536
The Sensitivity of Simple Electron-Optical Schlieren Arrangements—W. Rollwagen and C. Schwink. (*Optik, Stuttgart*, vol. 10, pp. 525–530; 1953.) Methods of the type described by Marton and Lachenbruch (1211 of 1950) for investigating electromagnetic fields are considered. A study is made of the different possible arrangements including an electron lens.

621.385.833 1537
Numerical Calculation of the Paths in Rotationally Symmetrical Electron-Optical Systems—P. Gautier. (*Jour. Phys. Radium*, vol. 14, pp. 524–532; Oct., 1953.)

621.387.424 1538
The Mechanism of the Discharge in Argon-Filled Counters—L. Colli and U. Facchini. (*Nuovo Cim.*, vol. 9, pp. 1183–1217; Dec. 1, 1952.)

621.387.424 1539
Investigation of the Discharge and of Post-Discharge Phenomena in G-M Counters by means of X-Ray Pulses—P. Müller. (*Ann. Phys., Lpz.*, vol. 13, pp. 110–135; Oct. 20, 1953.)

621.387.424 1540
Geiger-Müller Counters with Binary Mixtures of Rare Gas and Organic Vapour—R. Meunier, M. Bonpas, and J. P. Legrand. (*Jour. Phys. Rad.*, vol. 14, pp. 630–634; Nov., 1953.)

621.397.3 1541
Processing of Two-Dimensional Patterns by Scanning Techniques—L. S. G. Kovasznay and H. M. Joseph. (*Science*, vol. 118, pp. 475–477; Oct. 23, 1953.) A system comprising a flying-spot scanner and oscilloscope monitor is used to study processes involved in the recognition and recollection of patterns. Contour enhancement is achieved by combining the picture signal with its second derivative. The possibility of achieving various other unusual effects by circuit means is indicated.

535.37:621.387.464 1542
Luminescence and the Scintillation Counter [Book Review]—S. C. Curran. Publishers: Batterworths Scientific Publications, London, 32s. 6d. (*Eng.* (*London*), vol. 176, p. 644; Nov. 20, 1953.) A compact and comprehensive guide to modern theory and practice.

PROPAGATION OF WAVES

538.566 1543
Note on W. H. Wise's Proof of the Nonexistence of the Zenneck Surface Wave in the Field of an Aerial—H. Ott. (*Z. Naturf.*, vol. 8a, pp. 100–103; Jan., 1953.) It is shown that Wise's proof (1690 of 1937) does not exclude all possibility of the existence of a surface-wave component in the distant field of a dipole

538.566:551.594.6 1544
Harmonic Fields in the Propagation of Long Electric Waves round the Earth and Lightning Waveforms—W. O. Schumann. (*Naturwissenschaften*, vol. 40, pp. 504–505; Oct., 1953.) The work noted in 1772 and 3597 of 1953 is extended to include a study of the harmonic fields of a vertical and of a horizontal dipole. The analysis indicates that the harmonic fields of vertical lightning flashes vanish at large distances, owing to attenuation; for horizontal flashes the lowest possible propagation frequency is 3330 cps, and only the harmonics are propagated, the lowest being the least attenuated.

538.566:551.594.6 1545
The Propagation of Very Long Electric Waves round the Earth and Atmospherics—W. O. Schumann. (*Nuovo Cim.*, vol. 9, pp. 1116–1138; Dec. 1, 1952.) Using the method of singular eigenfunctions, a formula is found for the propagation of long waves, taking account of the influence of the ionosphere. Expressions for the propagation of atmospherics are hence found by Fourier integration, assuming various simple time functions for the lightning waveform.

621.396.11 1546
Theoretical Resonance Curves in the Gyro-interaction of Electromagnetic Waves in the Ionosphere—F. H. Hibberd. (*Nuovo Cim.*, vol. 10, pp. 380–385; April 1, 1953. In English.) Motzo's results (2111 of 1953) are discussed and it is shown that for vertically incident waves either single or double maxima may occur, and that there is little difference in the general shape of the curves resulting from vertically incident and obliquely incident waves.

621.396.11 1547
The Application of High-Frequency Radio-Propagation Predictions in the New Zealand Area—G. McK. Allcock. (*N.Z. J. Sci. Tech. B.*, vol. 35, pp. 198–212; Sept., 1953.) The results of propagation measurements at 9.15 mc over an 800-km path along a geomagnetic meridian indicate that the muf's for 3000-km and 800-km paths are related by the equation (M800) = 0.38(M3000) + 0.37. The frequency separation between the muf's for the ordinary and extraordinary waves is approximately one-half the gyro-frequency.

621.396.11:551.510.52 1548
The Troposphere as a Medium for the Propagation of Radio Waves: Part 1—H. Bremmer. (*Philips Tech. Rev.*, vol. 15, pp. 148–159; Nov., 1953.) A review paper.

621.396.11:551.510.535 1549
Double Refraction in the Ionosphere—R. W. Larenz. (*Naturwissenschaften*, vol. 40, p. 527; Oct., 1953.) The variation of the real part of the refractive index with the plasma frequency is shown graphically for different values of the angle between the direction of wave propagation and the magnetic field. When the effect of electron pressure is taken into account triple refraction is found to be produced. Only two of the wave components have group velocities of the order of the velocity of light. The results are consistent with the triple refraction observed by Dieminger and Möller (2791 of 1949).

621.396.11:551.510.535 1550
Some Notes on the Absorption of Radio Waves Reflected from the Ionosphere at Oblique Incidence—W. J. G. Beynon. (*Proc. IEE*, part III, vol. 101, pp. 15–20; Jan., 1954.) For conditions in which partial reflection or scattering at the *E* region is the dominant cause of attenuation of the first-order *F*-layer reflection, a new equivalence theorem in better agreement with observations on both long and short transmission paths is proposed to replace Martyn's relation (*Proc. Phys. Soc.*, vol. 47, pp. 323–339; 1935.) In this new theorem, the apparent absorption at frequency f and angle of incidence i is equivalent to the apparent absorption at frequency $f \cos i$ and normal incidence. The influence of multiple echoes on received signal strength is also considered.

621.396.11.029.422 1551
An Experimental Investigation of Short-Distance Ionospheric Propagation at Low and Very Low Frequencies—H. G. Hopkins and L. G. Reynolds. (*Proc, IEE*, part III; vol. 101, pp. 21–34; Jan., 1954.) Observations were made between 1948 and 1951 at distances between 60 and 210 km from commercial cw transmitters operating at four frequencies in the range 16–85 kc. The experimental method mainly used was similar to that described by Best et al. (*Proc. Roy. Soc. A*, vol. 156, p. 614; 1936.) The equipment used is described and the results obtained are discussed critically in relation to similar work performed elsewhere. Pulse-sounding technique has advantages over the cw method for the frequency band considered.

621.396.11.029.64:551.510.52 1552
The Effect of the Oceanic Duct on Microwave Propagation—L. J. Anderson and E. E. Gossard. (*Trans. Amer. Geophys. Union*, vol. 34, pp. 695–700; Oct., 1953.) Radio and meteorological observations obtained over Cardigan Bay are analyzed. For propagation at a wavelength of 3 cm, agreement between observation and theory improves as wind speed increases. At the lower wind speeds scatter is noted; possible explanations of this scatter are discussed. For propagation at a wavelength of 9 cm more scatter is observed and the transition to trapping condition is less definite.

621.396.81 1553
Radio Survey Technique—S. H. Wilkinson. (*A.T.E.J.*, vol. 9, pp. 216–228; Oct., 1953.) A description is given of the survey unit previously mentioned (234 of January). Experimental and theoretical methods of determining path attenuation are discussed. An account is given of typical surveys which have been made to obtain data on propagation and on equipment performance.

621.396.812.3.029.65 1554
Some Measurements of Fading at a Wavelength of 8 mm over a Very Short Sea Path—D. G. Kiely. (*Jour. Brit. IRE*, vol. 14, pp. 89–92; Feb., 1954.) Measurements were made, over a five-week period, of the fluctuations of signals transmitted over a 1-mile path, using a transmitter site about 15 feet and a receiver site about 100 feet above sea level. The results indicate very large atmospheric-refraction effects.

RECEPTION

621.396.621.029.614+621.372.2.029.64/65 1555
Experimental Determination of the Properties of Microstrip Components—Arditi. (*See* 1296.)

621.396.82:061.3 1556
Radio Interference Conference—(*Elec. Jour.*, vol. 151, p. 1594; Nov. 13, 1953.) Brief report of the proceedings of an international conference held in London, October, 1953.

621.396.82:621.3.066.6 1557
Sliding Contacts—a Review of the Literature—F. Spayth and S. East. (*Elec. Eng.*, vol. 72, pp. 912–917; Oct., 1953.) The review includes results of measurements of mechanical and electrical phenomena at motor or generator brush contacts. Tables are given of the variation of electrical noise with brush and ring material and with brush pressure. The experimental results are summarized in sets of general rules for designers. 43 references.

621.396.828+[621.397.828:535.623 1558
Color Television and the Amateur—G. Grammer. (*QST*, vol. 37, pp. 31–34 and 124; Nov., 1953.) Interference between transmissions in the 80-m band and the 3.58-mc colour subcarrier was investigated. Interference in both services could largely be suppressed by

good design in the layout, the screening and the filters of the television receiver.

621.396.828 1559
The Most Suitable Interference-Suppressor Circuit—G. Strobel and H. Scherenzel. (*Frequenz*, vol. 7, pp. 269–275 and 295–298; Sept. /Oct., 1953.) The choice of the best arrangement for suppressing interference at the source requires a knowledge of the source impedance, the magnitude of the interference, the permissible interference limits and the electrical safety regulations. These points are discussed in detail in relation to the West German regulations for the 0.1–20-mc frequency range, and the methods of measurement and application of the results are described.

STATIONS AND COMMUNICATION SYSTEMS

621.376:621.396 1560
Comparison of Amplitude and Angle Modulation for Narrow-Band Communication of Binary-Coded Messages in Fluctuation Noise—G. F. Montgomery. (PROC. I.R.E., vol. 42, pp. 447–454; Feb., 1954.) Consideration is given to the problem of choosing the best modulation system for transmitting messages over a given radio channel with less than a specified error and at the lowest cost for terminal equipment. Frequency-shift, phase-shift and on-off systems are examined. Curves of fractional error as a function of average carrier/noise ratio are derived for fading and nonfading carriers.

621.376.2:621.395.44 1561
Properties of a Sine Wave with Double Amplitude Modulation—L. Le Blan. (*Compt. Rend. Acad. Sci.* (*Paris*), vol. 238, pp. 220–222; Jan. 11, 1954.) Analysis indicates that crosstalk is present to a greater degree in a two-channel system with separate modulation of the positive and negative portions of the carrier than in the system using alternate positive and negative pulses (1176 of April).

621.376.3/.4:621.396.8 1562
Comparison between Frequency and Phase Modulation for transmitting Speech—G. Fontanellaz. (*Tech. Mitt. schweiz. Telegr.-Teleph-Verw.*, vol. 31, pp. 371–374; Dec. 1, 1953. In German.) Calculation indicates that for the frequency range 300–3400 cps. ph.m. gives a receiver-output signal/noise ratio 8.2 db better than FM, for the same hf signal/noise ratio and the same mean frequency deviation. The relations between intelligibility and signal/noise ratio for the two systems are also compared.

621.376.3.001.11:621.316.729 1563
Communications Synchronizing Systems—F. T. Turner. (*Elect. Eng.*, vol. 72, pp. 874–876; Oct., 1953.) The application of FM theory to conventional synchronizing systems leads to a simple evaluation of the minimum signal /noise ratio permissible in facsimile transmission. Expressions are also derived for the servo-mechanism loop function and for the requirements for establishing synchronism on the initial application of the synchronizing signal.

621.376.5.001.2 1564
Quantizing Noise of a Single-Integration Delta-Modulation System with an *N*-Digit Code—H. van de Weg. (*Philips Res. Rep.*, vol. 8, pp. 367–385; Oct., 1953.) The signal/noise ratio of Δ-modulation is evaluated, for different numbers of coding digits, as a function of the ratio between sampling frequency and maximum signal frequency, and compared with Bennett's results (895 of 1949) for pcm. By applying the results to the case of speech transmission, Δ-modulation is shown to be superior to pcm for any given sampling frequency and number of digits.

621.39 1565
[British] **Commonwealth Telecommunications**—J. A. Smale. (*Proc. IEE*, part III, vol. 101, pp. 1–4; Jan., 1954.) Chairman's address, Radio Section, I.E.E. A survey of developments in the complementary use of cable and wireless routes.

621.39.001.11:016 1566
A Bibliography of Information Theory (Communication Theory—Cybernetics)—F. L. Stumpers. (*Trans. I.R.E.*, No. PGIT-2, pp. 1–60; Nov., 1953.) A comprehensive bibliography, including books and papers, arranged under the following headings:—(*a*) general theory; (*b*) bandwidth and transmission capacity, time-frequency uncertainty; signal /noise ratios, comparison of systems; instantaneous frequency; analytical signals; (*c*) definition, relation to statistical mechanics, philosophy; (*d*) correlation, prediction, filtering, storage; (*e*) radar; radionavigation; (*f*) speech; hearing; vision; linguistics, semantics; (*g*) other biophysical applications; human engineering; group communication; (*h*) television; (*i*) miscellaneous applications; optics; games; servo-mechanisms; (*j*) mathematics; statistics; games; relay algebra; noise analysis; (*k*) pulse modulation; multiplex coding.

621.39.001.11:519.2 1567
Fundamentals of Information Theory—C. Lafleur. (*HF Brussels*, vol. 2, pp. 219–228; 1953.) The two axioms stated by Woodward and Davies (1724 of 1952) based on *a priori* and *a posteriori* probabilities are applied to derive Wiener's criterion for optimum filtering and Shannon's formulas regarding entropy and equivocation.

621.391:621.376.5 1568
A Recent Development in Communication Technique—C. W. Earp. (*Proc. IEE*, part III, vol. 101, p. 20; Jan., 1954.) Discussion on 2889 of 1952.

621.395.44:621.315.052.63 1569
Transmission Power and Range of Carrier-Frequency Communication Equipment for High-Voltage Lines—H. K. Podszeck and A. Schmid. (*Elektrotech. Z.*, *Edn A*, vol. 74, pp. 586–589; Oct. 11, 1953.) Multichannel single- and double-sideband transmissions using carrier frequencies in the range 30–450 kc are considered from the power efficiency point of view. Formulas and graphs are given for the effects due to the depth of modulation, the number of channels and sidebands, and the type of application, e.g. telephony, remote control and measurement.

621.395.44:621.315.052.63 1570
New Line of Power-Line Carrier Equipment—F. B. Gunter. (*Elect. Eng.*, vol. 72, pp. 965; Nov., 1953.) Digest of paper to be published in *Trans. AIEE*, vol. 72, 1953. Performance characteristics of multi-purpose equipment are outlined.

621.395.44:621.315.212 1571
Potentialities and Limitations of a Coaxial-Cable Multichannel System—F. Locher. (*Bull. schweiz. elektrotech. Ver.*, vol. 44, pp. 861–875; Oct. 3, 1953.) A review of development and present-day coaxial-cable technique in Europe and the U.S.A.

621.395.44:621.375.2 1572
The Coaxial-Line Amplifier—J. Bauer. (*Bull. schweiz. elektrotech. Ver.* vol. 44, pp. 881–884; Oct. 3, 1953. *Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, vol. 32, pp. 31–35; Jan. 1, 1954.) Description of the amplifier designed for the Bern-Morteau line, and comprising two units in tandem, with associated equalizer, temperature compensator and separating network equipment.

621.396+621.397]:061.3 1573
The New C.C.I.R. Resolutions—Fetzer. (*See* 1587.)

621.396.4:621.396.65 1574
Experimental Radio Bearer Equipment for Carrier Telephone Systems—W. S. McGuire and A. G. Bird. (*A.W.A. Tech. Rev.*, vol. 9, pp 227–254; Oct., 1953.) Reprint. See 3412 of 1953.

621.396.41.029.62 1575
Some Factors in the Engineering Design of V.H.F. Multichannel Telephone Equipment—W. T. Brown. (*Jour. Brit. I.R.E.*, vol. 1954. Discussion, pp. 75–77.) The principal clauses of a specification for a vhf multichannel radiotelephone installation are discussed generally. Particular attention is given to ancillary equipment for automatic change-over, remote control and fault warning. The layout and antenna arrangements are described.

621.396.65:621.396.41.029.64 1576
A Multichannel Microwave Relay System—R. D. Boadle. (*A.W.A. Tech. Rev.*, vol. 9, pp. 209–226; Oct., 1953.) Reprint. See 3110 of 1953.

621.396.65.029.6.001.4(44+494) 1577
Testing Radio-Link Transmission over a Long Line-of-Sight Path between France and Switzerland—W. Klein and L. J. Libois. (*Tech. Mitt. schweiz. Telegr-Teleph Verw.*, vol. 31, pp. 305–317; Nov. 1, 1953. In French.) A report of measurements made, during the period 1950–1952, of test transmissions on 300 and 3000 mc over a 160-km path between Chasseral and Mont-Afrique. Results show that multichannel or television transmission satisfying C.C.I.F. specifications is quite practicable. Path attenuation during the period was less variable than for other paths only half as long; this is attributed to the presence of obstacles along the path which scarcely affect the direct wave, but cause considerable attenuation of indirect waves by diffraction. The correlation of reception conditions with meteorological data is discussed, in particular the coincidence of severe fades at 300 mc with the presence of zones of superrefraction. See also *Onde élect.*, vol. 33, pp. 665–677; Dec., 1953.

621.396.664:621.396.712 1578
Random Sequence Switching—A. B. Ettlinger. (*Electronics*, vol. 27, pp. 165–167; Feb., 1954.) In a system for automatic control of a group of broadcasting stations for civil-defence purposes, the program is continuously fed to all the transmitters in the group, and each transmitter is equipped with a tone-operated relay so that power is applied only when a 7-kc tone is superimposed on the line; this tone is switched in a random manner by means of a thermal delay device.

621.396.712.2:534.76 1579
Audio Equipment for Binaural Broadcasts—L. J. Kleinklaus. (*Electronics*, vol. 27, pp. 134–135; Feb., 1954.) Description of two portable units, namely a two-channel preamplifier-mixer and a monitor amplifier, used at the WQXR station, which broadcasts simultaneously in an AM and a FM channel.

621.396.932 1580
Re-equipping Coast Stations—(*Elec. Jour.*, vol. 151, pp. 1475–1476; Nov. 6, 1953.) Brief details are given of equipment installed by the British Post Office to meet developments in ship-to-shore communications and related techniques.

621.396.933:621.396.3 1581
Notes on the Radiotelegraphic Connection between the K.L.M. Liftmaster "Dr. Ir. M. H. Damme" and the Schiphol Air Traffic Control Station PKH during the Christchurch Flight on 8th, 9th and 10th Oct. 1953—(*Tijdschr. ned. Radiogenoot.*, vol. 18, pp. 313–315; Nov., 1953.) A log is given of the times during which contact was made. The Karachi, Biak and Djakarta stations co-operated in the check.

SUBSIDIARY APPARATUS

621–526 1582
The Application of Statistical Methods to Servo-mechanisms—R. E. Vowels. (*Aust.*

Jour. Appl. Sci., vol. 4, pp. 469–488; Dec., 1953.) "The optimum transfer function for the desired response to a stationary random input signal containing noise may be determined by the Wiener-Lee method. In general, when applied to servomechanisms design, the output will not necessarily have zero steady-state error. In order to overcome this disadvantage, constraints may be applied in the Wiener-Hopf equation such that any of the error coefficients of the servomechanism are zero, and at the same time the output is optimized. It is also possible to include prediction, differentiation, or integration of the input function as desirable outputs."

621.316.721/.722 1583
Series Operation of a Glow-Discharge Tube and a Barretter—F. A. Benson. (*Elec. Jour.*, vol. 151, pp. 1291–1293; Oct. 23, 1953.) The replacement of the series resistor by a barretter results in improved stabilization. The operation of the Type-CV1199 glow-discharge tube (180 mA max.) with Type-161 barretter (160 mA) was investigated and the batch variations of the type 161 barretter characteristics were examined.

621.316.722.1 1584
Stabilizer for Alternating Voltages—A. Riedel. (*NachrTech.*, vol. 3, pp. 460–464; Oct., 1953.) The design of a biased-reactor arrangement having good frequency independence and satisfactory speed of operation is discussed.

621.316.722.1.076.7 1585
A Stable Source of High Voltage—L. U. Hibbard and D. E. Caro, (*J. Sci. Instr.*, vol. 30, pp. 378–380; Oct., 1953.) A voltage regulator suitable as a voltage reference at about 1000 v with current up to several milliamperes is described. With the temperature controlled to within ± 1 degrees C., the output is stable to within ± 1 part in 10^4 over 8 hours. Effects of varying magnetic fields <15 gauss are negligible.

621.316.93:621.396.933 1586
Aircraft Protection from Thunderstorm Discharges to Antennas—J. M. Bryant, M. M. Newman, and J. D. Robb. (*Elect. Eng.*, vol. 72, pp. 880–884; Oct., 1953.) The protection unit described consists of a 10^{-9}F. 10-kv capacitor in the antenna feeder lead together with a spark gap in parallel with a resistor, connected between the antenna side of the capacitor and the fuselage. A peak-current recorder, in the form of a steel strip magnetized by the current flow, is included. Units of this type have been tested for over 2 years in commercial airliners.

TELEVISION AND PHOTOTELEGRAPHY

621.397+621.396]:061.3 1587
The New C.C.I.R. Resolutions—V. Fetzer. (*Funk u. Ton*, vol. 6, pp. 591–596, 642–648; Nov. and Dec., 1952, and vol. 7, pp. 34–43, 84–89, 145–156, 205–208, 250–256, 315–318, 369–377, 414–419, 472–476, 535–544 and 590–593; Jan.–Nov., 1953.) Detailed report of recommendations, numbered from 36 to 85, made by 13 study groups at the 6th Plenary Assembly, Geneva 1951.

621.397.335:535.623 1588
Color Synchronization in the N.T.S.C. Color Receiver—W. E. Good. (*Trans. I.R.E.*, No. PGBTR-4, pp. 23–29; Oct., 1953.) The necessary phase accuracy is discussed, and the design and performance of several synchronizing circuits are compared. See also 1749 of 1952 (Dome).

621.397.5:535.623 1589
Color Television—a Primer on the N.T.S.C. System—W. Feingold. (*Trans. I.R.E.*, No. PGBTR-4, pp. 30–37; Oct., 1953.) An elementary treatment intended as an introduction to the subject.

621.397.5:535.623 1590
The Application of Colour to Television Broadcasting—F. C. McLean. (*Eng.* (*London*), vol. 176, pp. 441–444; Oct. 2, 1953.) Possible color-television systems for use in Britain are discussed in relation to experience already gained with the NTSC system in the U.S.A. It is not yet certain that all the color information can be transmitted within the 5-mc channel. Separation of a color subcarrier as used in the NTSC system would be more difficult with the British system because the sound channel is amplitude modulated. Receiver requirements are also discussed. For a summarized version, with comments, see *Wireless World*, vol. 59, p. 523; Nov., 1953.

621.397.5:621.395.625.3 1591
The Status of Magnetic Recording—Zenner. (*See* 1291.)

621.397.62 1592
Design Techniques for Color Television Receivers—M. H. Kronenberg and E. S. White. (*Electronics*, vol. 27, pp. 136–143; Feb., 1954.) Circuits for receiving the NTSC signals are discussed; details are given of particular designs, (*a*) for a receiver using the full potentialities of the system, and (*b*) for a simplified circuit with a color bandwidth of 0.5 mc.

621.397.62:535.623 1593
Color-Television-Signal Receiver Demodulators—D. H. Pritchard and R. N. Rhodes. (*Trans. I.R.E.*, No. PGBTR-4, pp. 1–22; Oct., 1953.) Reprint. See 3436 of 1953.

621.397.62:535.88 1594
An Apparatus for Aperture-Response Testing of Large Schmidt-Type Projection Optical Systems—D. J. Parker, S. W. Johnson, and L. T. Sachtleben. (*Jour. Soc. Mot. Pict. & Telev. Engrs.*, vol. 61, pp. 721–730; Dec., 1953.)

621.397.62:621.385.3 1595
The PCC 84 Double Triode—(*Elec. Appl. Bull.*, vol. 14, pp. 113–120; Aug./Sept., 1953.) Tube data are given and the use of the tube as a cascode amplifier for the hf stage of a television receiver is described.

621.397.828:535.623+621.396.828 1596
Color Television and the Amateur—Grammer. (*See* 1558.)

TRANSMISSION

621.396.61 1597
Some Aspects of the Design of Master-Oscillator Power-Amplifier Type Transmitters—P. Howell. (*Radio & Electronics, Wellington, N.Z.*, vol. 8, pp. 13–15, 31; Dec. 1, 1953.) Various known circuits are discussed, and precautions necessary to prevent self-oscillation of the amplifier are indicated.

621.396.61.029.53/.55 1598
Automatic-Tuning Communication Transmitter—M. C. Dettman. (*Elect. Commun.*, vol. 30, pp. 271–278; Dec., 1953.) Slightly modified version of paper in *Convention Record I.R.E.*, part 2, pp. 137–144; 1953. The transmitter is designed to meet service conditions, and has a frequency range 300 kc–26 mc. There are ten preset channels and manual tuning facilities. Automatic-tuning time is about 30 seconds for most frequencies. Nomianl power output is 100 w over the range 300 kc–2 mc and 100 w or 500 w over the range 2–26 mc.

621.396.61.029.62:621.376.3:621.314.7 1599
Single-Transistor F.M. Transmitter—D. E. Thomas. (*Electronics*, vol. 27, pp. 130–133; Feb., 1954.) Frequency modulation is achieved, in an experimental transmitter with a range of a few hundred feet, by shifting the alpha-cut-off frequency (about 40 mc) of a point-contact transistor, the transmitter oscillator operating at about 105 mc.

621.396.662:621.316.7 1600
Automatic Control System with Provision for Scanning and Memory—N. H. Young. (*Elect. Commun.*, vol. 30, pp. 279–282; Dec., 1953. *Trans. AIEE*, vol. 72, pp. 392–395; 1953.) See 884 of March.

TUBES AND THERMIONICS

537.533.8:621.373.4.029.63 1601
On the Time Delay of Secondary Emission—J. Diemer and J. L. H. Jonker. (*Philips Res. Rep.*, vol. 8, p. 398; Oct., 1953.) Correction and addendum to paper noted in 1014 of 1951.

621.314.632:546.289:621.396.822.029.422/.5 1602
Measurements of Noise Spectra of a Point Contact Germanium Rectifier—F. J. Hyde. (*Proc. Phys. Soc.*, vol. 66, pp. 1017–1024; Dec. 1, 1953.) The excess noise due to the passage of dc was measured at 29.5 degrees C. over the frequency range 0.117 cps–14 mc, with the reverse current I as parameter. The noise spectrum consists of three types of component, namely (*a*) a basic component $\propto f^{-1}$ detectable over a frequency range of seven decades, (*b*) two components $\propto [1+(2\pi f\tau)^2]^{-1}$ associated with relaxation times τ_1 and τ_2 and (*c*) a uniform component detectable at high frequencies and equal to the shot noise for small currents. The relaxation times are dependent on I.

621.314.632:546.289:621.396.822.029.426 1603
The Reduction of Rectifier Noise by Illumination—J. W. Granville and A. F. Gibson (*Proc. Phys. Soc.*, vol. 66, pp. 1118–1119; Dec. 1, 1953.) Noise in a Ge point-contact diode was measured at room temperature using an amplifier with a bandwidth of 1.4 cps tuned to 16.5 cps. The nonlinear variation of noise power per unit dynamic resistance with variation of the reverse current is shown graphically for several values of the distance between the light source and the rectifier.

621.314.7 1604
Transistor Reliability Studies—R. M. Ryder and W. R. Sittner. (Proc. I.R.E., vol. 42, pp. 414–419; Feb., 1954.) The useful life of transistors may be shortened by conditions of high humidity or high temperature; the characteristics may also change due to surface contamination, mechanical disturbance or electrical or chemical effects. The mechanisms involved are described. A good measure of protection is obtained by sealing the transistor with a plastic.

621.314.7 1605
The Drift Transistor—H. Kromer. (*Naturwissenschaften*, vol. 40, pp. 578–579; Nov., 1953.) The name "drift transistor" is given to a junction transistor in which the concentration of impurity centres in the base falls exponentially between emitter and collector. An expression is derived for the rise of the upper frequency limit as compared with that for the ordinary junction transistor with uniform distribution of impurity centres in the base.

621.314.7 1606
German Transistors—C. Möller. (*Funk-Technik*, Berlin, vol. 8, pp. 668–669; Nov., 1953.) Characteristics and operating data are given for several types of German-produced transistors. Applications are indicated.

621.314.7:546.28 1607
Enhanced Alpha in Formed Silicon Point-Contact Transistors—H. Jacobs, W. Mattei, and F. A. Brand. (*Jour. Appl. Phys.*, vol. 24, pp. 1410–1411; Nov., 1953.) Point-contact transistors have been prepared by causing an impurity such as Sb to be diffused into a small region at or near the surface of p-type Si, using an arcing technique. High values of α (up to 10 or even more) are obtained. The transistor action is further enhanced by passing large currents in the reverse direction through the emitter. The peoperties of such Si transistors are compared with those of Ge types.

621.383.2 1608
Alkali Photocells: Part 1—M. Ploke. (*Arch. tech. Messen*, pp. 259–262; Nov., 1953.) A review of the theory and a survey of the principal types. Comparative data are given.

621.383.2:537.531 1609
Effect of X Rays on Photocells—G. Blet. (*Compt. Rend. Acad. Sci., Paris*, vol. 238, pp. 72–73; Jan. 4, 1954.) The current output of a Se cell was measured for various values of incident X-ray energy. Taking account of the variation of absorption with wavelength, the results indicate that the current output per watt absorbed is constant. Estimates are made of the number of electrons emitted per photon absorbed.

621.383.27 1610
Recent Developments in Photocells with Secondary-Electron Multipliers—N. Schaetti. (*Bull. schweiz. elektrotech. Ver.*, vol. 44, pp. 989–995; Nov. 14, 1953.) An account of work done at the Institut für technische Physik, Zürich. The photocathodes and multiplier arrangements are described, and some applications of photomultipliers are indicated.

621.383.27:546.36.86 1611
Control of the Characteristic of a Cs-Sb Photocathode by Addition of Other Elements—N. Schaetti. (*Z. angew. Math. Phys.*, vol. 4, pp. 450–459; Nov. 15, 1953.) Measurements on photomultipliers are reported. The dark current and the delayed emission following a period of illumination can be reduced by addition of various elements to the cathode material. The results for 14 different elements are tabulated.

621.383.4 1612
A Method of Describing the Detectivity of Photoconductive Cells—R. C. Jones. (*Rev. Sci. Instr.*, vol. 24, pp. 1035–1040; Nov., 1953.) Detectivity in the reference condition *c* is given by an expression involving sensitive area and noise equivalent power of the cell, noise equivalent bandwidth of the amplifier used, and chopping frequency. Conditions of validity of the expression are stated and certain conventions relating to the measurement of the various quantities explained. The detectivity figure enables direct comparison to be made between two cells.

621.383.5:546.561-31 1613
The Infrared Sensitivity of Cuprous-Oxide Photocells prepared at Reduced Pressure in a High-Frequency Field—A. I. Andrievski and A. L. Rvachev. (*Compt. Rend. Acad. Sci. U.R.S.S.*, vol. 89, pp. 245–247; March 11, 1953. In Russian.) Two methods of manufacture using hf heating ($\sim$3 mc) are described. Diverse spectral-sensitivity characteristics, shown graphically, were obtained by varying the pressure, the temperature and the time of oxidation and reduction. A cell with a maximum front-wall sensitivity in the green region and a maximum back-wall sensitivity in the red-to-infrared region, and a cell with maximum front-wall sensitivities in the green, red and infrared regions have been produced.

621.385.029.6:538.69 1614
Magnetrons—P. H. J. A. Kleijnen. (*Tijdschr. ned Radiogenoot.*, vol. 18, pp. 287–299; Nov., 1953.) Theory of the interaction between the electrons and the field is presented, with special reference to the mode spectrum of a rising-sun system.

621.385.029.631.64 1615
The Effect of Line Attenuation on the Power Gain of a Travelling-Wave Valve—W. Kleen and K. Pöschl. (*Fernmeldetech. Z.*, vol. 6, pp. 509–516; Nov., 1953.) Theoretical treatment of the traveling-wave tube with (*a*) distributed and (*b*) localized attenuation introduced into the delay line to suppress unwanted feedback effects. Results are presented graphically for various values of space-charge and loss parameters. Distributed attenuation has an adverse effect on the attenuation constant for the amplified wave and on the partition of input power between the three waves excited. Localized attenuation causes a gain reduction dependent on the length of the attenuating element and on the plasma frequency.

621.385.029.63/.64 1616
Coaxial-to-Helix Transducers for Travelling-Wave Tubes—R. E. White. (*Elect. Commun.*, vol. 30, pp. 300–304; Dec., 1953.) *Convention Record I.R.E.*, part 10, pp. 42–45; 1953.) Design data are given for matching sections of ferrule type, with a tuning range up to 2:1, for small-diameter helices, and of tapered type, with a tuning range up to 4:1, for large-diameter helices.

621.385.029.63/.64:621.372.2 1617
Wave Propagation along a Helix with a Cylindrical Outer Conductor—K. Pöschl. (*Arch. elekt. Übertragung*, vol. 7, pp. 518–522; Nov., 1953.) Formulas and curves are derived for the phase velocity, the characteristic impedance and the transfer impedance. These are valid over a wide range of wavelength and linear dimensions of the helix and cylinder, and reduce to a simple form when the phase velocity is small compared with the velocity of light.

621.385.029.63/.64:621.396.822 1618
Microwave Shot Noise in Electron Beams and the Minimum Noise Factor of Travelling Wave Tubes and Klystrons—F. N. H. Robinson. (*Jour. Brit. I.R.E.*, vol. 14, pp. 79–86; Feb., 1954.) "A theorem recently proposed by J. R. Pierce concerning the intrinsic noise of electron streams is verified for electron beams originating in thermionic diodes under arbitrary conditions. The theorem is applied to the calculation of the minimum noise factor of klystrons and travelling wave tubes which is found to be 6 db. The treatment of partition noise is made possible by a generalization of the theorem."

621.385.032.21:546.841-31 1619
Thermionic Emission from Thin Layers of Thoria and Thorium on Molybdenum—A. R. Shul'man and A. P. Rumyantsev. (*Compt. Rend. Acad. Sci.* (*U.R.S.S.*), vol. 93, pp. 455–458; Nov. 21, 1953. In Russian.) Emission depends on several factors, in particular on (*a*) the penetration of the electric field inside the semiconducting surface layer, and (*b*) chemical or catalytic processes due to the base metal. Emission characteristics of variously treated cathodes were determined and the variation of work function and emissivity with thickness θ of the surface layer are shown graphically. θ is expressed as a number of monolayers; its value was determined from the α-particle emission.

621.385.032.216 1620
Cathode Parasitic Impedance—M. Berthaud. (*Bull. Soc. Franc. Élect.*, vol. 3, pp. 673–675; Nov., 1953.) The internal impedance developing in aged cathodes and generally ascribed to the formation of an interface layer has been measured by three methods which are outlined. Results are at variance with those of Eisenstein and others (2052 of 1951, 1812 of 1950 and back references), particularly as regards the dependence of this impedance on cathode temperature and valve current; it is inferred that the impedance is due to phenomena occurring not necessarily at the interface.

621.385.3:621.397.62 1621
The PCC 84 Double Triode—(*Elec. Appl. Bull.*, vol. 14, pp. 113–120; Aug./Sept., 1953.) Tube data are given and the use of the tube as a cascode amplifier for the hf stage of a television receiver is described.

621.385.4.002.2:[621.395.64+621.396.65 1622
The Telephone-Repeater Valve—P. Meunier. (*Bull. Soc. Franç. Élect.*, vol. 3, pp. 676–685; Nov., 1953.) Requirements in the design and manufacture of long-life tubes of conventional type are discussed, in particular the steps taken to minimize cathode deterioration and its effects. Details are given of two tetrodes recently developed: (*a*) Type-PTT301 for submarine use, with a guaranteed life of 80,000 hours; (*b*) Type-PTT 243P, with a gain-bandwidth product of 200 mc. The control-grid /cathode spacing of the latter is 0.0625 mm.

621.385.832:621.317.755 1623
A Sealed-Off Cathode-Ray Tube with a Very High Writing Speed—B. Jackson, D. R. Hardy, and R. Feinberg. (*Nature*, (*London*), vol. 172, pp. 1056–1057; Dec. 5, 1953.) In an es-deflection tube for direct observation and photographic recording of nonrecurrent high-voltage signals, the vertical deflection system comprises a straight twin-wire transmission line arranged perpendicular to the tube axis. The low-frequency deflection sensitivity is 0.006 mm/v at a beam-accelerating voltage of 25 kv. Writing speeds as high as 6.6×10^{10} cm/s have been attained.

621.385.832:621.317.755 1624
Multibeam Cathode-Ray Oscillograph—C. Fert, J. Lagasse, and J. Ollé. (*Compt. Acad. Sci.* (*Paris*), vol. 238, pp. 59–61; Jan. 4, 1954.) A tube is described in which all the beams when undeflected strike the screen at the same spot. The single gun produces a beam which diverges from a narrow crossover and passes through apertures arranged in a coaxial ring in a diaphragm; a magnetic lens is used to bring the beams together again on the screen. A common magnetic horizontal deflection and individual es vertical deflection systems are used An illustration is shown of a four-trace recording obtained.

621.385.832+621.387]:621.318.572 1625
Decimal Counting Tubes—K. Kandiah. (*Elec. Eng.*, vol. 26, pp. 56–63; Feb., 1954.) A survey of available types, classed as gas-filled, cr-tube and trochotron. Resolving times of circuits using these tubes, and tolerances on components and supply voltages are discussed.

621.385.832:621.395.625.3 1626
Visual Monitor for Magnetic Tape—Miller. (*See* 1290.)

621.387:621.373.432 1627
Control of Glow-Discharge Triodes by means of Very Small Currents—Meili. (*See* 1351.)

621.387:621.395 1628
New Thyratrons for Telephone-Circuit Engineering: Part 2—Coincidence Thyratrons with Screen Grids and their Static Ignition Characteristics. Dynamic Ignition Characteristics—K. L. Rau. (*Frequenz*, vol. 7, pp. 249–255; Sept., 1953.) The effect of various constructions of the screen grid on the tube characteristics is discussed. Part 1: 3156 of 1953.

MISCELLANEOUS

061.6:538.56.029.6 1629
Centre for the Study of Microwave Physics [at Florence]—N. Carrara. (*Ricerca sci.*, vol. 24, pp. 31–34; Jan., 1954.) Report of activities during the year 1952; the construction of new instruments for wavelength measurements and devices for investigating microwave optics is mentioned.

061.6:621.3 1630
The Galileo Ferraris National Electrotechnical Institute—P. Lombardi. (*Ricerca sci.*, vol. 23, pp. 2161–2231; Dec., 1953.) A report is given of the activities of the institute during the period 1949–1951, and the organizational structure is described. The subjects investigated include magnetic and dielectric materials, electroacoustics, electron tubes and radio engineering.

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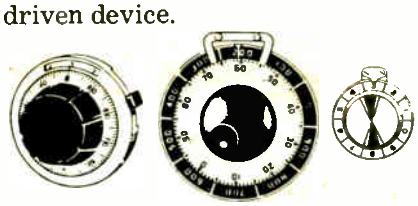

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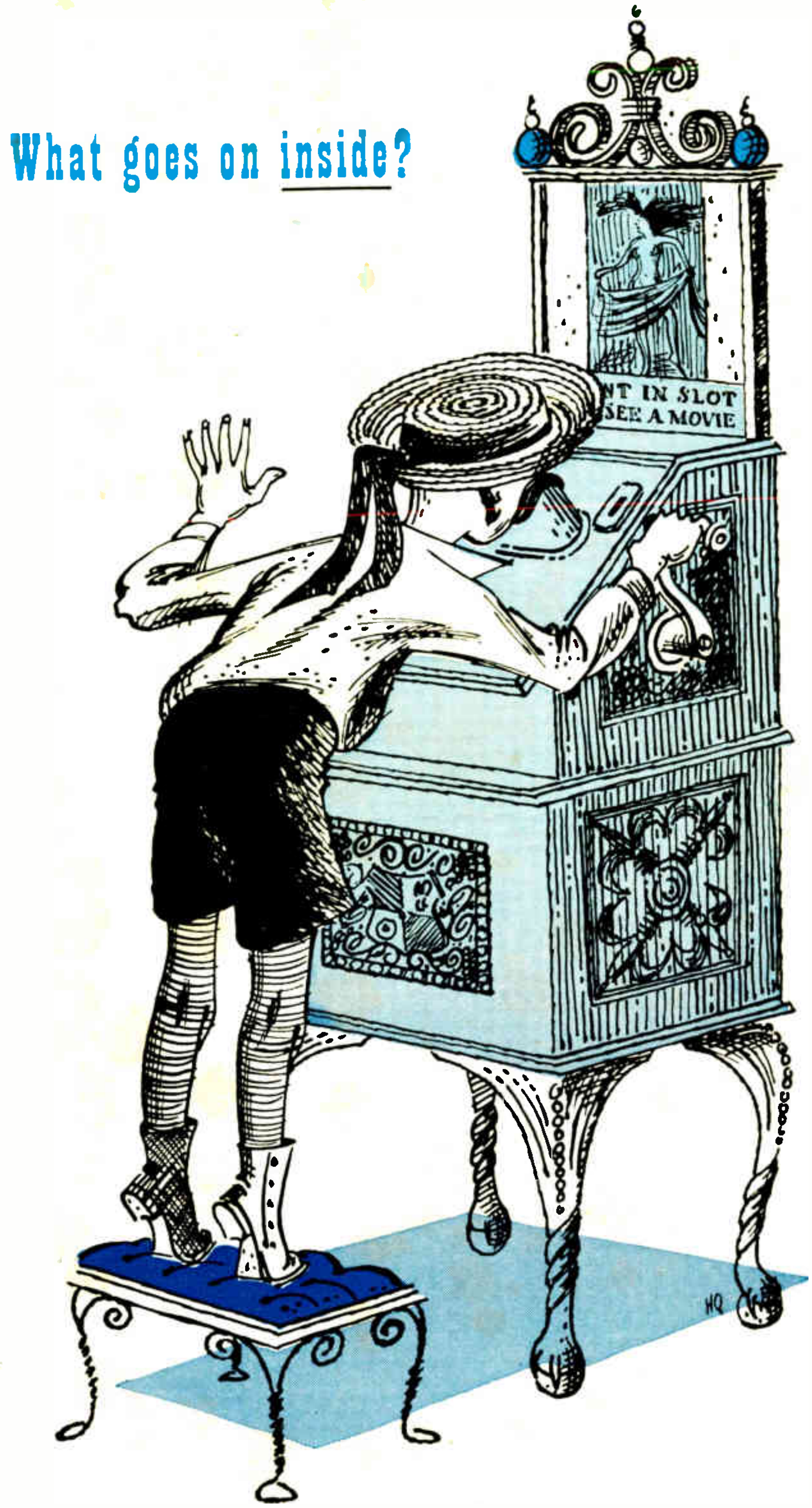

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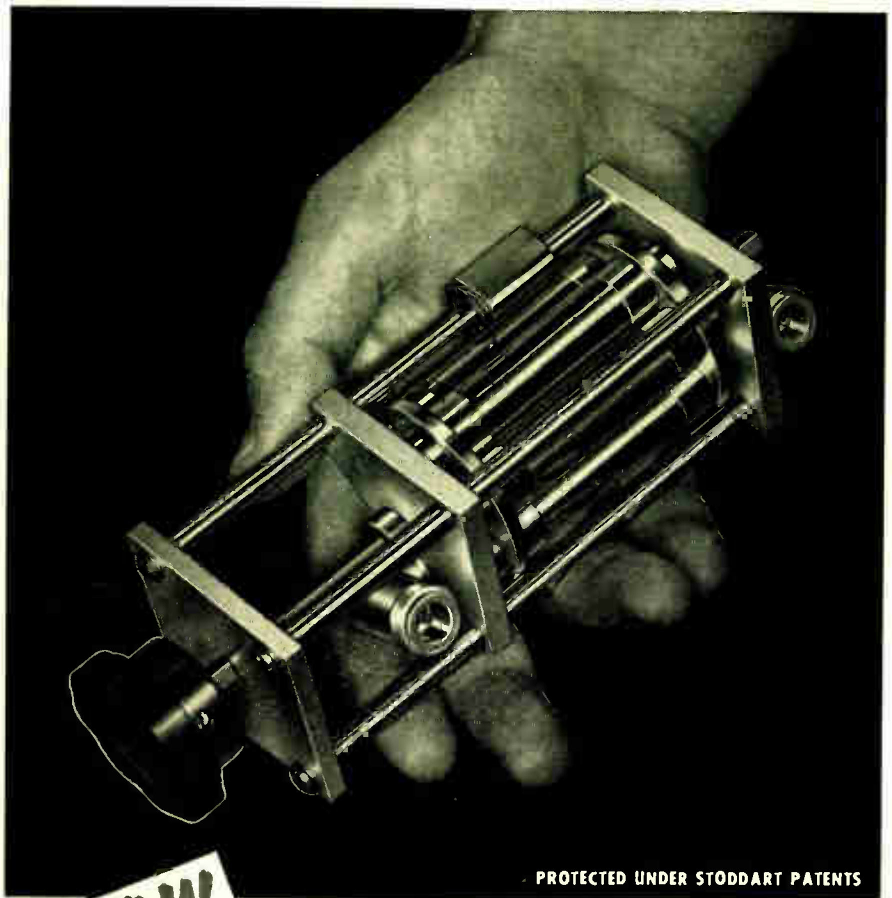

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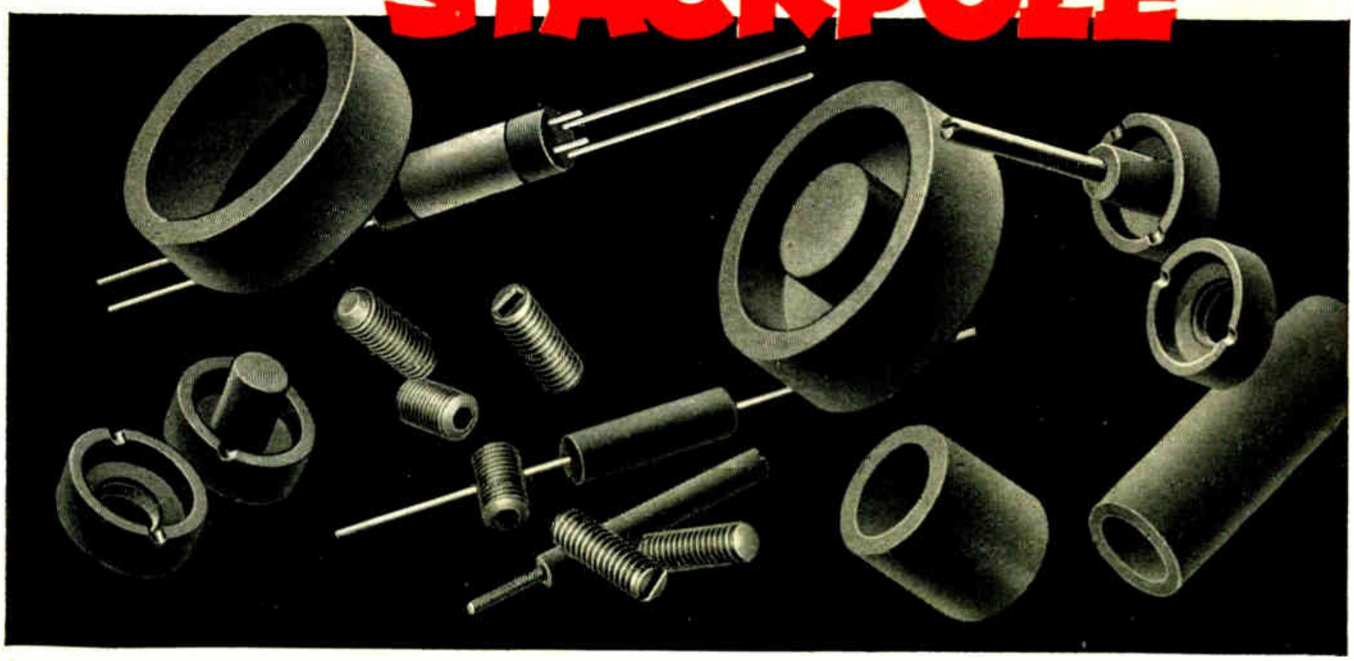

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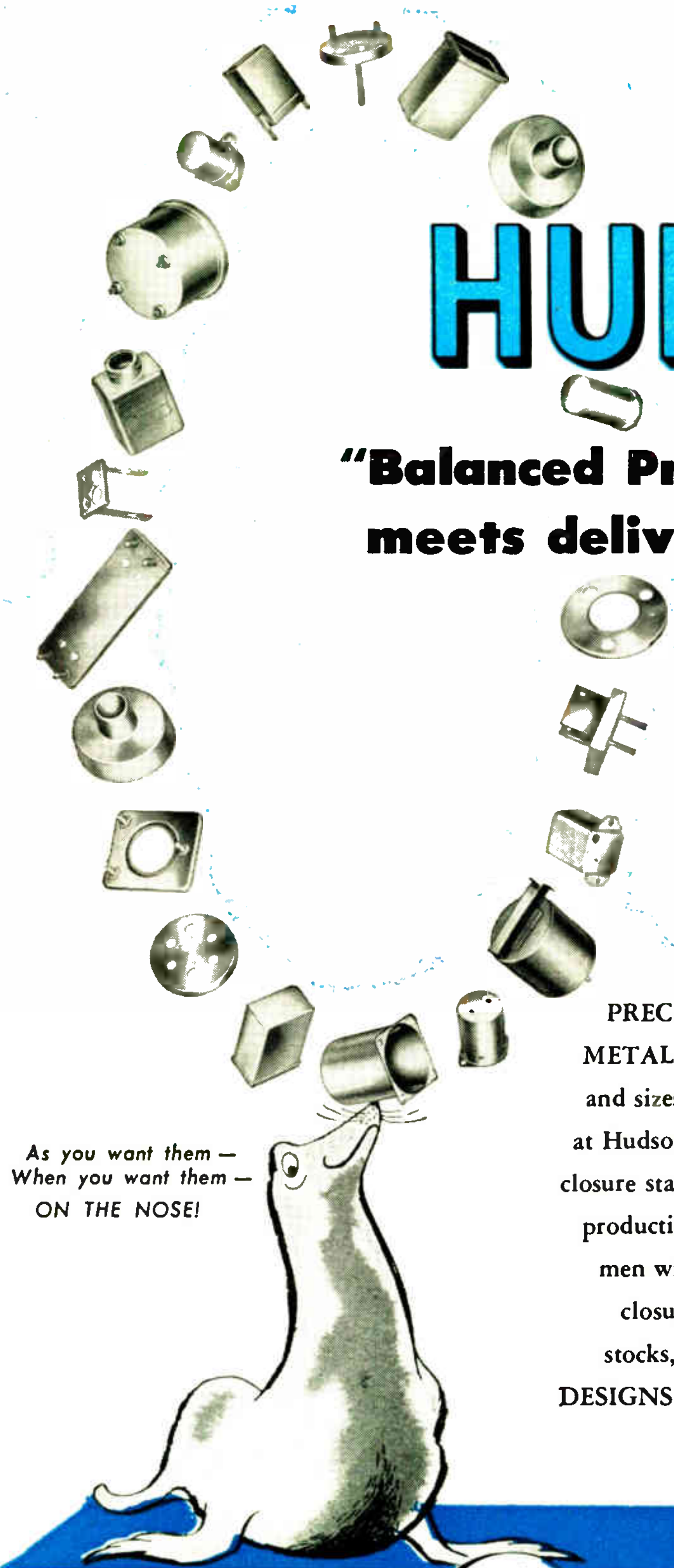

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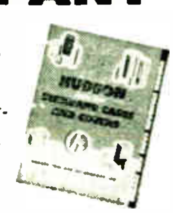

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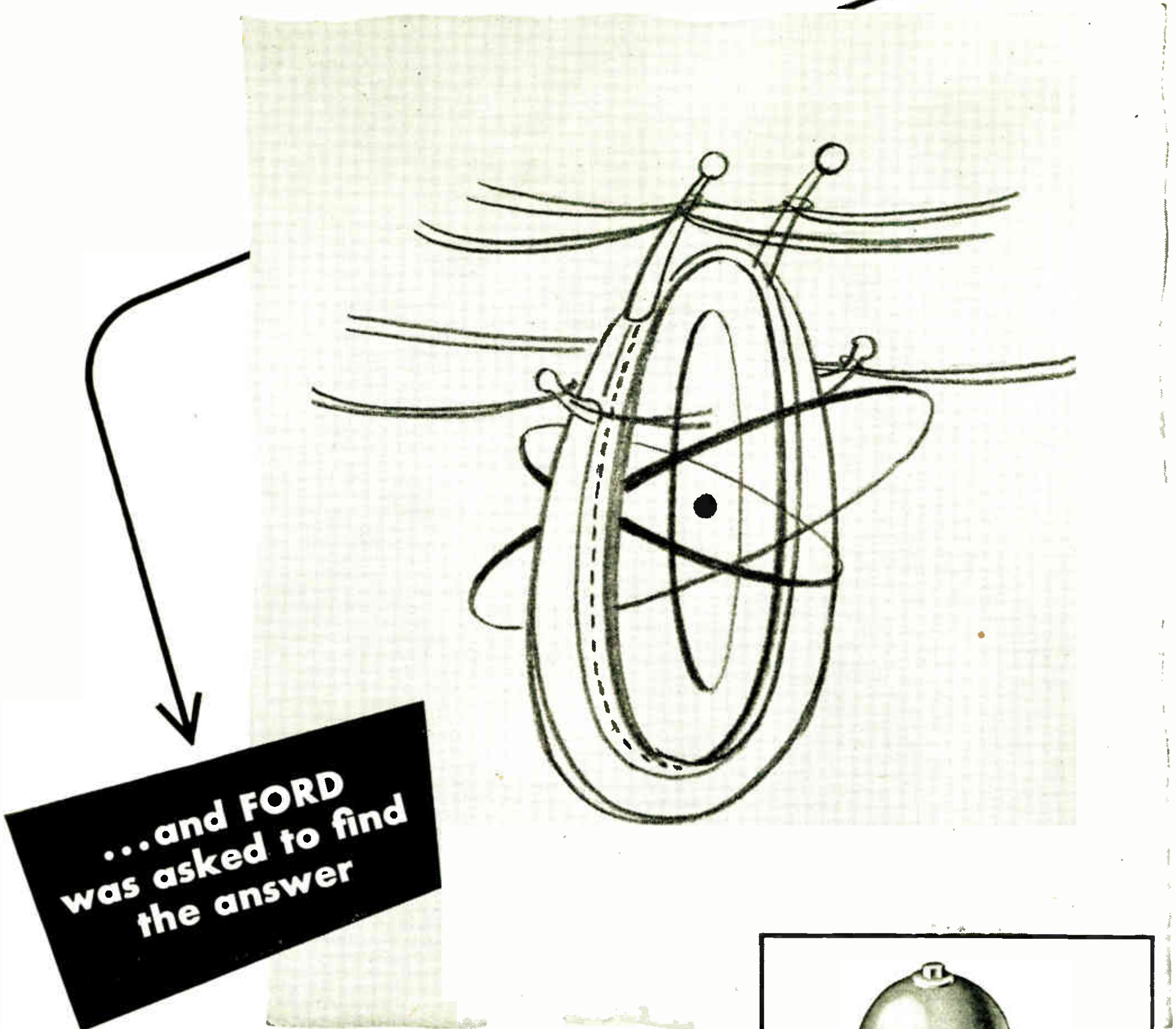

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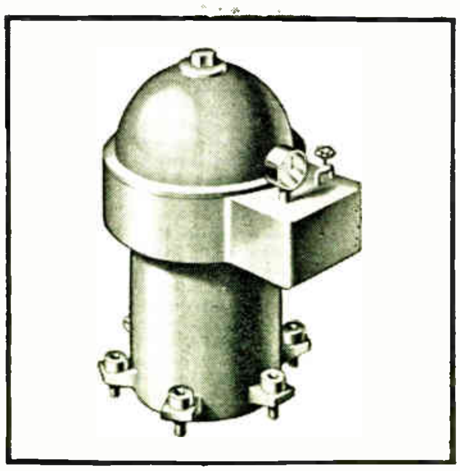

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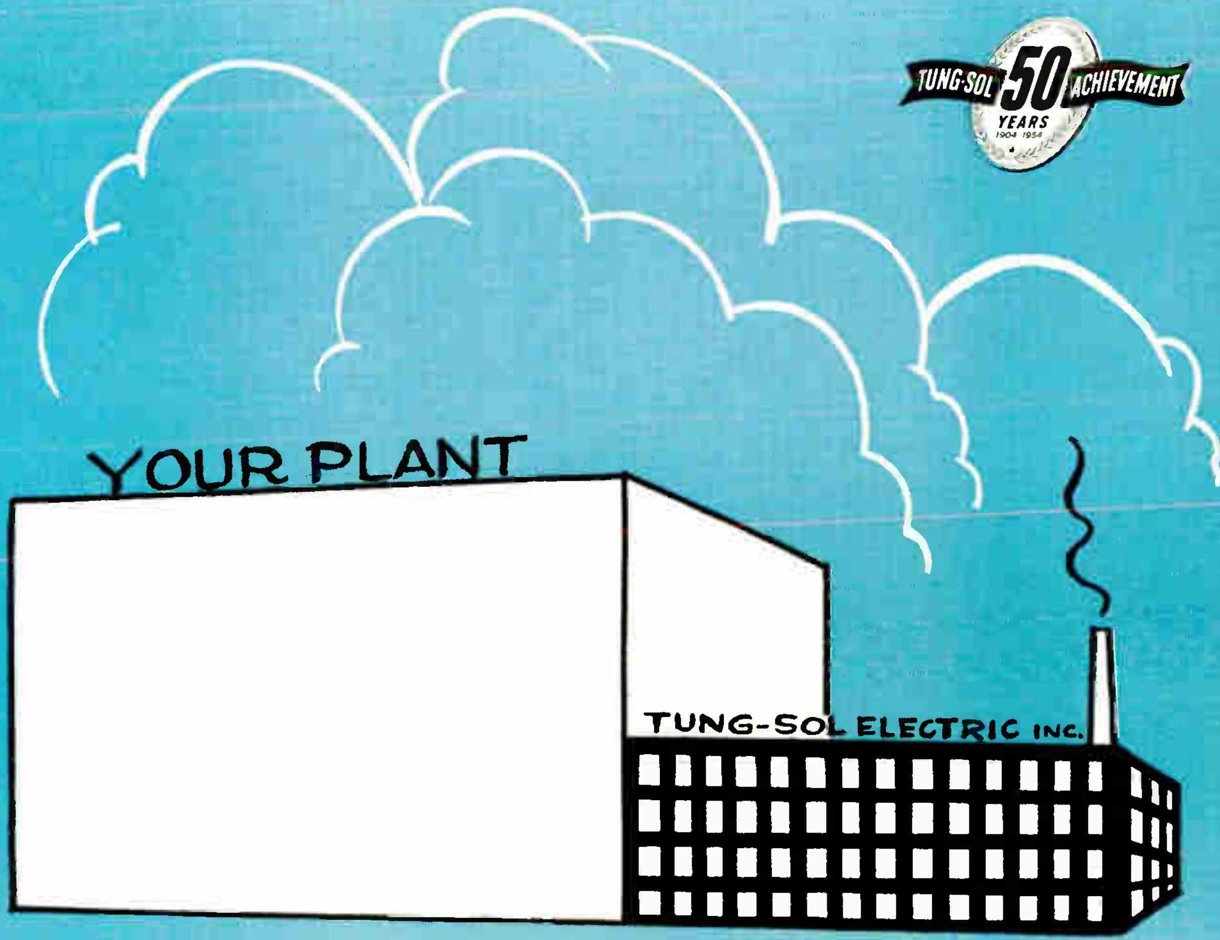

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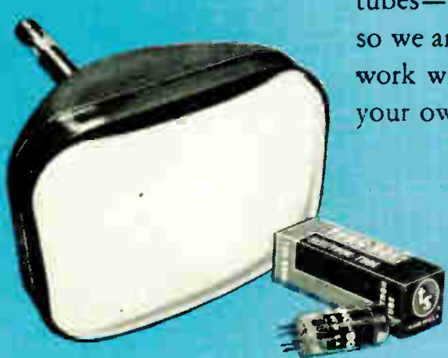

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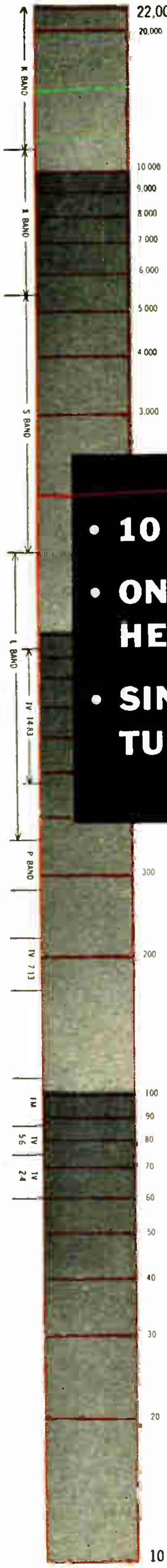

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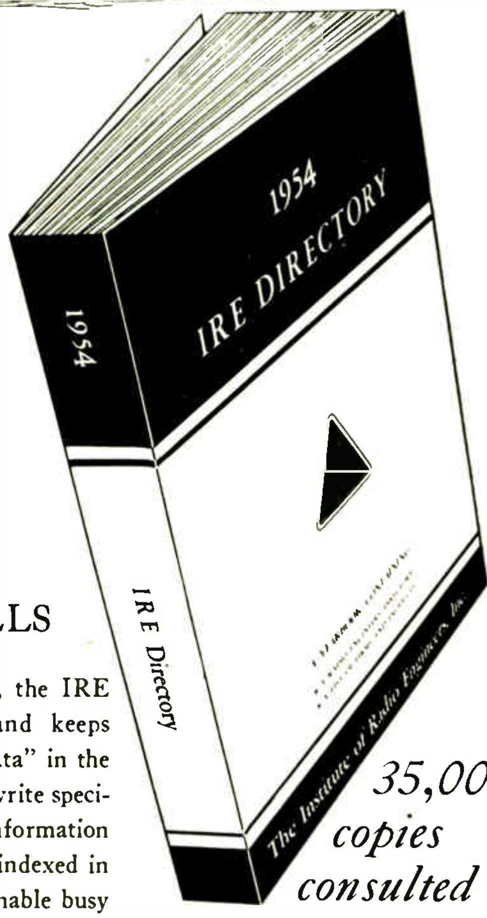

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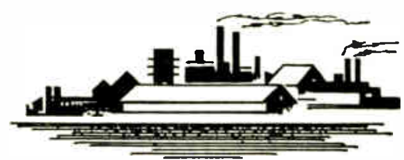

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SECTION MEETINGS

ALBUQUERQUE-LOS ALAMOS

"The Mystery of the Stone Towers," by Dr. Frank C. Hibben, University of New Mexico; March 12, 1954.

BEAUMONT-PORT ARTHUR

"Instrumentation and Control of Physical Systems," by Dr. John Trimmer, University of Tennessee; April 15, 1954.

BINGHAMTON

"Simple Transistor Circuit Design," by Dr. N. H. Kramer, International Business Machines; April 12, 1954.

BUFFALO-NIAGARA

"Boolean Algebra as Applied to Switching Circuits," by T. A. Harris, "Tunable Magnetrons," by Robert Hayman and "Vehicular Communications," by F. S. Wood, all students, University of Buffalo; April 21, 1954.

CEDAR RAPIDS

"Atomic Clocks from Stars to Atoms," by Dr. Harold Lyons, U. S. Bureau of Standards; March 17, 1954.

CLEVELAND

"The Physics of Music and Hearing," by Dr. R. L. Hanson, Bell Telephone Labs.; "Recording and Reproducing Problems of Stereo Sound," by Rulon Biddulph, Bell Telephone Labs.; March 18, 1954.

CONNECTICUT VALLEY

"Rockets into Space," by Dr. C. F. Green, General Electric Company; March 18, 1954.

"Time and Frequency Domain Inter-Relationships," by Prof. E. A. Guillemin, Mass. Institute of Technology; April 15, 1954.

DALLAS-FORT WORTH

"Distant Measuring and Other Related Equipment," by E. C. Williams, CAA Aeronautical Center; "VHF-Omnidirectional Range Systems," by Walter Kuehne, Collins Radio; "Technical and Operational Characteristics of Localizer and Glide Slope Equipment," by S. A. Meacham, Bendix Radio Division; April 20, 1954.

DAYTON

"Modern Aircraft Navigation," by V. E. Carbonara, Kollsman Instrument Company; April 8, 1954.

DENVER

"Radio Astronomy," by V. H. Goerke, National Bureau of Standards; February 26, 1954.

DES MOINES-AMES

"Progress of Electronics," by W. R. Hewlett, President, IRE; April 1, 1954.

ELMIRA-CORNING

"Medical Electronics," by Wilson Greatbatch, University of Buffalo; April 19, 1954.

EL PASO

"Mechanics of Hearing," by C. D. Canfield, Philco Corp ; March 26, 1954.

EMPORIUM

"Cathode Interface Resistance," by W. E. Buescher, Sylvania Electric Products, Inc.; March 31, 1954.

EVANSVILLE-OWENSBORO

Tour of WEHT, Conducted by C. Behrman, Program Director and Production Manager; April 14, 1954.

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SECTION MEETINGS

(Continued from page 99A)

Fort Wayne

"Inventions and Patents," by George Gust of Lockwood, Galt, Woodard and Smith; "Present Trends of the Atomic Energy Program," by Dr. H. L. Hull, Capehart-Farnsworth Corp.; March 4, 1954.

"High Energy Accelerators for Nuclear Research," by Dr. Walter Miller, University of Notre Dame; April 1, 1954.

Hamilton

"Ferrite Cored Antennas," by Preben Gomard, T. S. Farley Ltd.; March 8, 1954.

Tour through studios and transmitter of Station CHCH-TV, conducted by W. Jeynes, Chief Engineer, and Hugh Potter; April 5, 1954.

Hawaii

Demonstration and discussion of binaural tape and high fidelity systems using disc and tape, by Charles Allen, Pacific Recording Company; February 10, 1954.

Tapescript: "Communication Circuits of the Mind," by Dr. W. S. McCullugh, University of Illinois; March 10, 1954.

Tapescript: "Magnetic Recording," by Marvin Camras, Armour Research Foundation of Illinois Institute of Technology; April 14, 1954.

Houston

"The Application of Electronics to Medicine," by L. A. Geddes, Baylor University School of Medicine; March 16, 1954.

Indianapolis

"Design Considerations for High Fidelity Audio Equipment," by R. C. Koch, I.D.E.A., Inc.; February 26, 1954.

"Project Tinkertoy—Modular Design and Mechanized Production of Electronic Assemblies," By Dr. B. L. Davis, National Bureau of Standards; March 10, 1954.

"Magnetic Amplifier Circuits," by A. E Schmid, The Magnavox Company; March 25, 1954

Little Rock

"Magnetic Amplifiers and Their Application in Computers and Fire Control Apparatus," by A. E. Schmid, Magnavox Company; film, "Electronics in Action"; April 13, 1954.

London

"Experiments in the Super Conductivity of Metals with Liquid Oxygen," by A. D. Misener, University of Western Ontario; March 29, 1954.

Louisville

"A Decade Counter," by Fred Burton and Richard Eberhart; "Magnetic Amplifiers," by Allen Gold and John McBrayer, all students, University of Louisville; April 2, 1954.

Miami

"What is New in Science and Engineering," by Everett S. Lee, General Electric Company; February 25, 1954.

Montreal

"Electronic Musical Instruments," by Dr. Hugh LeCaine, National Research Council; "The Profession of Engineering," by G. L. Wiggs, C.P.E.Q.; March 17, 1954.

SECTION MEETINGS

NEW ORLEANS

"Radioactive Tracer Studies," by John Hidalgo, Faculty, Tulane University; "Electron Microscopy," by A. W. Oser, Faculty, Tulane University; "Mass Spectrography," by Carol Gordon, Faculty, Tulane University; March 26, 1954.

OKLAHOMA CITY

"Principles of Color Television," by Aaron Britton, WKT-TV; February 2, 1954.

"Methods of Matching Transmission Lines and Waveguides," by Dr. H. F. Mathis, Faculty, Oklahoma University; March 23, 1954.

OTTAWA

"Electronic Music," by Dr. Hugh LeCaine, National Research Council; April 1, 1954.

PHILADELPHIA

"Color Television Receivers," by S. W. Seeley, and "General Discussion of Various Color TV Picture Tubes," by H. B. Law, both of RCA; April 1, 1954.

"Type of Amplifiers for Wide-Band Use," by W. E. Bradley, Philco Corp.; "The All-Pass Amplifier," by H. L. Woll, RCA; April 8, 1954.

PORTLAND

"Developments in Ceramic Capacitors," by W. L. Klevans, Erie Resistor Corporation; February 11, 1954.

"The 4A Toll Switching System," by B. L. Edwards, The Pacific Telephone and Telegraph Company; February 25, 1954.

"Airport Surveillance Radar Systems," by Ervin Schultz, Civil Aeronautics Administration; "Ground Control Intercept Station," by Capt. R. T. Moss, U. S. Air Force; March 23, 1954.

PRINCETON

"Television Redundency and Television Signal Statistics," by R. E. Graham and Dr. E. R. Kretzmer, Bell Telephone Laboratories; Election of Officers; April 8, 1954.

ROCHESTER

"How the Money Market Affects Business," by R. C. Tait, Stromberg-Carlson Company March 4, 1954.

SACRAMENTO

"Travelling Wave Tube Oscillators and Amplifiers," by Gordon Kino, Electronic Research Labs.; April 9, 1954.

ST. LOUIS

"Nuclear Reactors and Their Applications," by A. E. Lennert, Olin Industries; February 25, 1954.

"Stereophonic Sound Reinforcing Systems," by Dr. R. W. Benson, Central Institute for the Deaf; March 18, 1954.

SAN ANTONIO

"Ferroelectric Storage Devices" (Tapescript) by J. Reid Anderson, Bell Telephone Labs.; February 18–19, 1954.

"Nuclear Magnetic Resonance Techniques," by W. L. Rollwitz, Southwest Research Institute; March 18–19, 1954.

SAN DIEGO

"Special Purpose Magnetic Recording," by R. D. Hopkins, Jr., Bing Crosby Enterprises, Inc.; April 6, 1954.

SYRACUSE

"Television in Industry," by G. H. Wilson, Diamond Power Specialty Corp.; March 22, 1954.

(Continued on page 102A)

SECTION MEETINGS

(Continued from page 101A)

Toledo

"Sound Facilities at the Toledo Museum of Art," by A. B. Barksdale, Toledo Museum of Art; January 14, 1954.

"Transmission Lines and Waveguides for UHF-TV Broadcast Systems," by J. S. Brown, Andrew Corporation; February 11, 1954.

"Customer Dialing of Long-Distance Telephone Calls," by E. L. Getz, Bell Telephone Labs.; March 11, 1954.

Toronto

Student Night. Speakers: A Hewitt, R. Charette, R. Hobran and R. Richardson all students, University of Toronto; February 15, 1954.

"Electronics in Musical Instruments," by Dr. H .LeCaine, National Research Council; March 15, 1954.

Twin Cities

"Specialized Ferrite Applications," by Ephraim Gelbard. Presented by F. F. Sylvester. Both of General Ceramics and Steatite Corp.; April 6, 1954.

Vancouver

"Airlines Communications," by Keith Anderson, Western Region Trans Canada Airlines; March 15, 1954.

"A Microwave Radio Relay System in the Pacific Northwest," by R. E. Kristler, Pacific Telephone Company; April 5, 1954.

Washington, D. C.

"Information Theory in Physical Measurement," by Dr. C. H. Page, National Bureau of Standards; April 12, 1954.

SUBSECTIONS

Berkshire County

"Distributed Amplifiers" by Dr. Harry Stockman, Scientific Specialties Corp.; February 15, 1954.

Buenaventura

Inspection of television station KEYT studios with technical descriptions; February 11, 1954.

"Impact of Military Development on Future Navigation," by John Wuerth, North American Aviation; March 11, 1954.

"Magnetic Amplifiers," by Dr. Hugo Woerdemann, Magnetic Research Corp.; April 8, 1954.

Ithaca

"Atomic Energy," by L. V. Berkner, Associated Universities, Inc.; February 26, 1954.

"Circuit Performance of Junction and Surface Barrier Transistors," by F. P. Keiper, Jr., Philco Corp.; Election of Officers; March 19, 1954.

Lancaster

"Color Television" talk and demonstration by W. W. Cook, RCA Service Company; April 21, 1954.

Tucson

"Practical Hi-Fidelity," by E. C. Burch, Hughes Aircraft Company; March 26, 1954.

USAFIT

"Color Television," by C. N. Hoyler, RCA; March 17, 1954.

Wichita

"Some Aspects of X-Ray Goniometry as Applied to Quartz Crystal Blanks," by L. F. Heithecker, KANS Broadcasting Company; March 30, 1954.

Industrial Engineering Notes

Television*

The Federal Communications Commission recently issued a Notice of Proposed Rule Making looking toward amending Section 3.614 so as to require the use of UHF television transmitters with a minimum rated power of 5 kw. The Commission stated that at the time of the adoption of the rule relative to the minimum visual effective radiated power for TV broadcast stations, high power equipment was not available, especially for station operation in the UHF band. Such equipment, the FCC stated, presently is becoming available, and in order to assure the best possible technical service all UHF transmitters should operate with a minimum rated power of 5 kw. Stations with authorized power below the proposed minimum will not be required to comply at this time, the FCC said. . . . **The Federal Communications Commission has issued a public notice (2014) relative to Section 3.687 of the Rules, which specifies certain equipment performance requirements for color transmissions which must be met by all stations transmitting color signals, whether such signals are originated by the station locally or are received from a network source.** The additional requirements for color include specification of over-all attenuation characteristics of the transmitter, minus 42 db attenuation of the lower sideband with a modulating frequency of 3.579545 mc, envelope delay characteristics, transfer characteristics and the aural carrier frequency to be maintained 4.5 mc above the visual carrier frequency within ±1 kc. Television stations broadcasting programs originated in color should make the necessary modifications to achieve compliance with Section 3.687 for color or remove the chrominance components from the color television signal received from the network, the Commission stated.

Mobilization

Out of approximately 550 items of major military procurement, 202 are in the electronics field. Of these electronic equipments, the largest group is radar, with 88 different items. The Department of Defense also is procuring 60 major types of radio equipment and 29 items classified as navigational aids. This was revealed recently when the Department of Defense released a directive outlining a new reporting procedure designed to keep top management of the DOD informed on production schedules, delivery dates and related procurement activities. The directive spells out just what items of major procurement are to be reported on, and the list includes most of the essential items now in production or near enough to production scheduling to make reporting possible. In

(Continued on page 108A)

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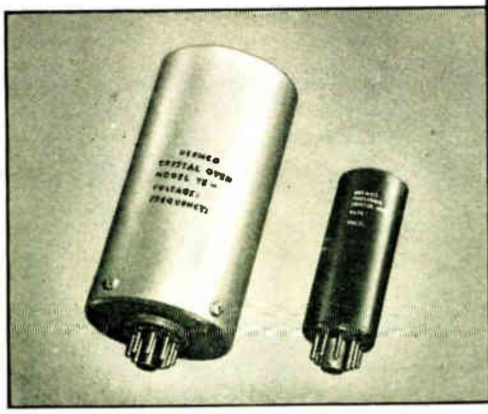

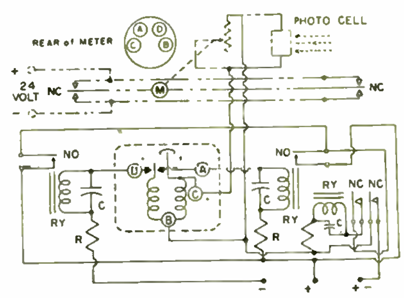

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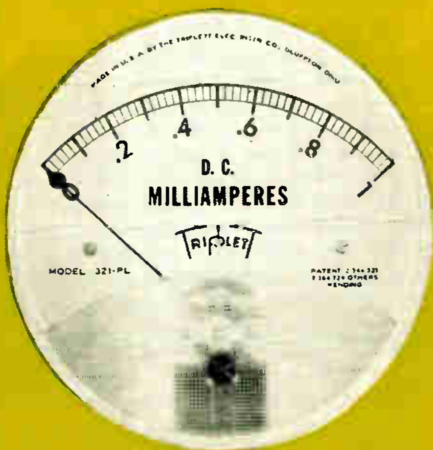
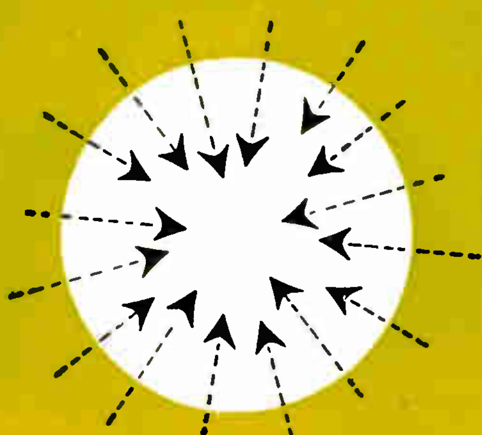
exclusive much longer scale PL (clear plastic) panel meters



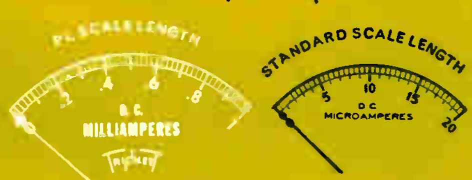
visibility unlimited

Entire dial face encased in transparent non-breakable plastic. Entire dial is exposed to viewing.



light unobstructed

Full natural lighting from top, sides and bottom. No bezel or case rim interrupts the light from any angle.



readability extended

Full open face on round meters allows much longer scale than conventional types for quicker easier readings from much greater distances.

interchangeability—universal

Longer scale length, yet the mounting makes it readily interchangeable with all conventional round meters of the same size. The panel space occupied is exactly the same.

appearance revolutionized

These handsome modern streamlined Triplett PL Panel Meters with clear plastic fronts will make an amazing improvement in the appearance of your equipment panels in addition to contributing greatly to reading accuracy. An additional advantage is the unbreakable crystal.

Write for full information on Triplett PL Panel Meters. Available for immediate delivery in 2" and 3" round types and 4" square types. 2" and 3" square types will be available soon.

TRIPLETT ELECTRICAL INSTRUMENT COMPANY BLUFFTON, OHIO

Burton browne advertising

MILLIONS OF VARIABLE

COMPLETE MILITARY LINE AVAILABLE.

POPULAR MILITARY TYPES ILLUSTRATED.

CORRESPONDING COMPLETE LINE FOR COMMERCIAL APPLICATIONS ALSO AVAILABLE.

5 acres of plant area . . . over 1000 employees . . . making ALL TYPES of variable resistors by the million. . . . for ALL your requirements. CTS SPECIALIZES in precision mass production of variable resistors and associated switches . . . makes nothing else.

Most controls available with switches and in concentric shaft tandems or with two controls operating on one shaft. Also available with locking bushing, water sealed bearing and many other special features not illustrated.

Immediate delivery from stock on many JAN-R-94, JAN-R-19 and other types.

WRITE FOR ILLUSTRATED CATALOG—

Describes Electrical and Mechanical characteristics, Special Features and Constructions of a complete line of variable resistors for military and civilian use. Includes dimensional drawings of each resistor

REPRESENTATIVES

Harry E. Sanders
McClatchy Bldg
69th & Market St.
Upper Darby, Penna.
Phone Flanders 2-4420

W. S. Harmon Company
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Beverly Hills, California
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CTS

CHICAGO TELEPHONE SUPPLY Corporation

ELKHART • INDIANA

1/2 watt 70°C, 3/4" diameter miniaturized variable composition resistor.

TYPE 65 (Miniaturized)

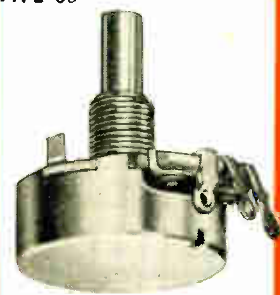
1 watt 70°C, 15/16" diameter variable composition resistor.

TYPE 90

Meets JAN-R-94 type RV4

2 watt 70°C, 1-1/8" diameter variable composition resistor. Also available with other special military features not covered by JAN-R-94.

TYPE 95



TYPE C90-65 Tandem

TYPE GC-90 With Switch

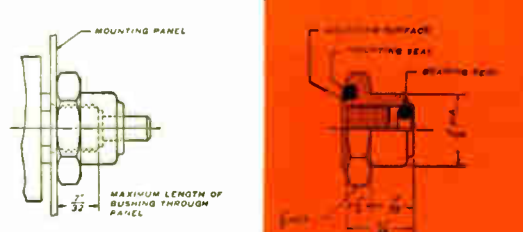
TYPE GC-95 With Switch

UNPRECEDENTED PERFORMANCE CHARACTERISTICS

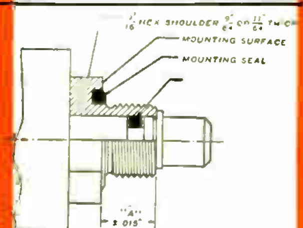
Types 65, 90 and 95 are specially designed for military communications equipment subject to extreme temperature and humidity ranges: −55°C to +150°C . . . aridity to saturation.

TYPE C2-90 Tandem

TYPE C2-95 Tandem



WATER SEALED MOUNTING AND BEARING FOR TYPE 65



CAN BE SUPPLIED WITHOUT THE WATER SEALED MOUNTING SHOULDER)

WATER SEALED MOUNTING AND BEARING FOR TYPES 45, 35, 90, 95, 25, 252.

RESISTORS...FOR EVERY NEED

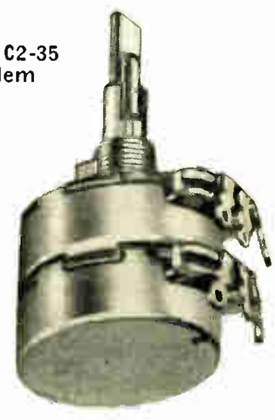
Meets JAN-R-94
type RV3

1/2 watt 1-1/8" diameter variable composition resistor. Also available with other special military features not covered by JAN-R-94.

TYPE 35

TYPE GC-35
With Switch

TYPE C2-35
Tandem



Meets JAN-R-94
type RV2

1/4 watt 15/16" diameter variable composition resistor. Also available with other special military features not covered by JAN-R-94.

TYPE 45

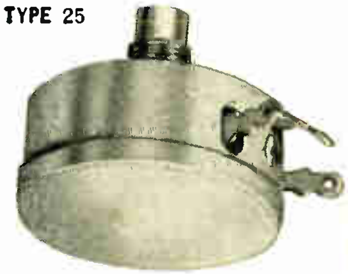
TYPE GC-45
With Switch

TYPE C2-45
Tandem

Meets JAN-R-19
types RA25 and RA30

4 watt 1-17/32" diameter variable wirewound resistor. Also available with other special military features not covered by JAN-R-19.

TYPE 25



TYPE GC-25
With Switch

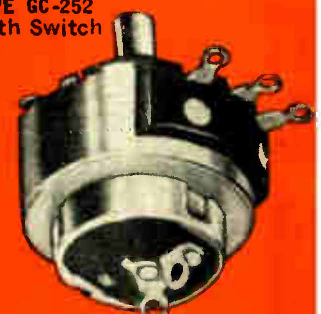
TYPE C2-25
Tandem

Meets JAN-R-19
type RA20

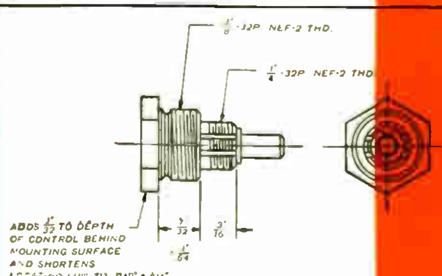
2 watt 1-17/64" diameter variable wirewound resistor. Also available with other special military features not covered by JAN-R-19.

TYPE 252

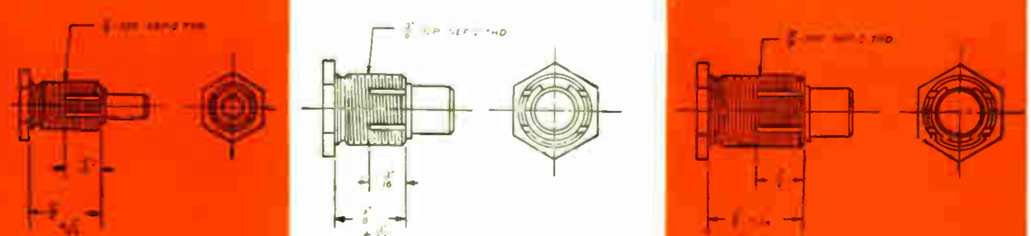
TYPE GC-252
With Switch



TYPE C2-252
Tandem



LOCKING BUSHINGS FOR TYPE 65 CONTROL.



LOCKING BUSHINGS FOR CONTROL TYPES 25, 252, 95, 35, 90, 45

Specialists in Precision Mass Production of Variable Resistors • Founded 1896

Industrial Engineering Notes

(Continued from page 104A)

the guided missile field, the directive listed 18 different types. These included four surface-to-air missiles, four surface-to-surface, four air-to-surface, and six air-to-air types. Also listed in the missile category are six types of surface equipment, including launchers and handling equipment. . . . **The appointment of Colonel J. Francis Taylor as Director of the reorganized Air Navigation Development Board was announced recently by Under Secretary of Commerce for Transportation Robert B. Murray, Jr., and Assistant Secretary of Defense for Research and Development Donald A. Quarles.** Mr. Quarles is Chairman of the ANDB, a Commerce-Defense group directing a research and development program for common civil-military air navigation and traffic control systems. Also announced was the appointment of three scientists as part-time consultants to the Board. They are Professor Jerome Weisner, Director, Research Laboratory for Electronics, Massachusetts Institute of Technology; Dr. H. R. Skifter, President, Airborne Instruments Laboratory, Mineola, N. Y.; and Russell C. Newhouse, Radio Development Engineer of the Bell Telephone Laboratories. . . . **The Navy announced the acceptance of its newest flying radar station—the Lockheed WV-2 Super Constellation. The plane houses**

(Continued on page 110A)

Industrial Engineering Notes

(Continued from page 108A)

over six tons of search radar and electronic detection gear. Carrying an electronic maintenance team to make in-flight adjustments and repairs, the plane can double as a weather sentry and improve storm warning services by tracking hurricanes and other weather disturbances.

TECHNICAL

A new method by which VHF omnirange stations can be calibrated without flight tests and put back on the air in approximately 20 minutes following repair or replacement of components is under evaluation by the Civil Aeronautics Administration, Administrator F. B. Lee announced recently. The new procedure consists of moving a small, lightweight detector around the counterpoise of the VOR and recording the monitor readings at desired intervals and the data plotted to produce a calibration curve. This method has made it possible to adjust a VOR to accuracies of plus or minus $\frac{3}{4}$ degree without difficulty, thereby reducing the need for an immediate flight check of the facility, the CAA announced. A further safety feature of the new procedure is that it makes possible routine and special ground checks of a VOR facility without interrupting omnirange service. Further tests by the CAA, for a six-months period, will be conducted at 12 existing omniranges located on all types of terrain in various sections of the country. . . . **Important studies in the field of electronics have been outlined by the Office of Technical Services, Department of Commerce, in its March issue of the "Bibliography of Technical Reports."** Following is a partial listing of the government-sponsored research studies of interest to the electronics industry, which can be purchased from the Photoduplication Section, Library of Congress, Washington 25, D. C., for the reported price: "Antenna System for Experimental Long-Range Radar," PB 112805, microfilm, $2.25, photostat, $5; "Analysis and Synthesis of Distributed Amplifiers with Ladder Network," PB 112624, microfilm, $5, photostat, $16.25; "Asymptotic Evaluation of the Field at a Caustic," PB 112751, microfilm, $2, photostat, $3.75; "Harmonic Analysis of Rectangular FM Pulses," PB 112721, microfilm, $1.75, photostat, $2.50" "Instrumentation for the Observation of Long Delay Echoes at 150 kcs," PB 112691, microfilm, $4.25, photostat, $12.50; "Power Gain in Feedback Amplifiers," PB

(Continued on page 112A)

Pulse Instruments Brochure

Electro-Pulse, Inc., 11811 Major St., Culver City, Calif., has a 4-page brochure describing their system of block unitized multipurpose pulse instruments.

Combinations of these units are able to produce variable time delays, timing pulses, gate pulses, pulse trains, square waves, variable width pulses, trigger generators, fast rise time pulses, and linear triangles.

LET'S TALK IT OVER...

Do you have a problem which the art of electronics and allied components may help solve? Here's where we come in. The average experience in electronics of our engineering staff is more than ten years. Our established records for competency indicate that their contributions to the accelerated growth of electronics prove this staff of men to be the most excellent in their field. When superior performance results are demanded, this time-tested knowledge will provide the answer . . . LET'S TALK IT OVER.

WE REPRESENT OVER ONE HUNDRED TOP MANUFACTURERS OF MAJOR AVIATION PRODUCTS. A NEARBY BRANCH WILL BE HAPPY TO SERVE YOUR NEEDS. DO MORE BUSINESS . . . REALIZE MORE PROFIT WITH AIR ASSOCIATES EQUIPMENT.

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DIVISIONS: ATLANTA • CHICAGO • DALLAS • GLENDALE • HACKENSACK • MIAMI • ORANGE • TETERBORO

Industrial Engineering Notes

(Continued from page 110A)

112632, microfilm, $1.75, photostat, $2.50; "Relative Power of Radar Signals Received from the Far Side of Clouds—Progress Report No. 19," PB 112568, microfilm, $3, photostat, $8.50; "Microwave Power Comparator," PB 112806, microfilm, $1.75, photostat, $2.50; "Evaluation of Wilcox Type 99A Radio Transmitter," PB 112756, microfilm, $2, photostat, $3.75; "Large Signal Equivalent Circuit for Transistor Static Characteristics," PB 112634, microfilm, $2, photostat, $3.75; "Radio Interference Suppressors," PB 112773, microfilm, $2, photostat, $3.75; "UHF Filtering Networks," PB 112700, microfilm, $2.75, photostat, $7.50; "Synthesis of Distributed Amplifiers for Prescribed Amplitude Response," PB 112625, microfilm, $5, photostat, $16.25. . . . **A versatile electronic thermostat is now in use at the National Bureau of Standards as a general-purpose temperature controller for a variety of applications, the NBS announced recently.** The instrument was developed by F. A. Ransom of the NBS electronic instrumentation laboratory, and is designed for flexibility, high sensitivity, and provides precision temperature control over a wide range of temperature and power requirements. The device features such advantages as (1) no appreciable dead zone; (2) the sensitivity may be raised very high without objectionable loss of stability, reducing the deviation from the control point to a minimum with any load changes; (3) capability of handling power requirements ranging from milliwatts to kilowatts for control; (4) the use of sensing elements which may be a resistance thermometer or a thermistor connected to a bridge circuit, or a thermocouple connected to a chopper circuit, and (5) the use of standard commercial components. Complete details on this development will appear in a future National Bureau of Standards' "Technical News Bulletin," which will be announced at a later date. . . . **An automatic pilot which promises to increase the safety and ease of operation of light planes has been successfully flight-tested by the Civil Aeronautics Administration, the Commerce Department announced.** The development, under CAA contract by the Ansco Division of General Aniline and Film Corporation, Binghampton, N. Y., controls roll and pitch and provides for automatic flight on any selected magnetic heading and for homing on omnirange stations. The basic unit controls the roll axis of the aircraft. Also tested and reported on by the Commerce Department was an omnihoming unit, which, when coupled with an omnirange receiver, will fly the aircraft automatically to any CAA omnirange station to which the receiver is tuned. In most tests the airplane arrived within a few hundred feet of the station, it was noted. . . . **A relatively transient-free externally-triggered electronic power switch has been devised by J. Sargent of the National Bureau Standards.** The output waveform

(Continued on page 115A)

Industrial Engineering Notes

(Continued from page 112A)

of this switch has rise and cut-off times of less than one microsecond, it was reported. The electronic switch utilizes three tubes—two thyratrons and a diode rectifier. A condenser is connected to the plate of the power-delivery thyratron through an inductance. The other side of the condenser is returned to ground. The condenser is normally in a charged state when the circuit is in use, and the output voltage appears across the cathode of the power tube, it was noted. The switch is turned on in the usual way by applying a pulse to the grid of the power tube, and when the circuit is to be turned off, a pulse is applied to the grid of the turn-off tube, which then begins to conduct and discharges the condenser through the inductance. An experimental model of this circuit, built at the Bureau, is capable of delivering 50 watts into a 200-ohm resistive load, at as much as a 95 per cent duty factor or as low as desired. Flexibility in design of the NBS electronic power switch is possible using the large variety of thyratrons available, and the circuit may be readily adapted for a wide range of applications, the Bureau added. Complete details on this development will appear in the National Bureau of Standards' "Technical News Bulletin" for May 1954. . . . **A new application of electronic weather observation equipment to help speed the landing and take-off of aircraft was announced last week by the Weather Bureau.** Presently in use at the Newark and New York International Airports, the new equipment is to be installed at about 20 additional major airports within the next 18 months, it was reported. The equipment was designed by the Weather Bureau and the National Bureau of Standards and consists of sensitive electronic equipment placed close to the runway to measure cloud height and visibility. This information is transmitted continuously and automatically to the local Weather Bureau observatory and Civil Aeronautics Administration control tower. It was pointed out that by using these weather observations close to the runway, better traffic control is possible than when this information comes from more distant sources. Sudden changes in ceiling or visibility are thus detected immediately, and the information relayed to approaching aircraft. Present installations were planned and financed jointly by federal and local governments and the aviation industry. Participating groups, in addition to the Weather Bureau, included the Flight Safety Foundation, National Air Transport Co-ordinating Committee, Air Navigation Development and the Civil Aeronautics Administration. . . . **The Navy Department announced recently that it has awarded a contract for the construction of a "submarine simulator" trainer to the Electric Boat Division of General Dynamics Corp.** The Navy said this is the first device which will be capable of simulating all of the characteristics of the new submarines, including handling in turns and the "feel" of the various controls. The center of the operation is an electronic

(Continued on page 116A)

Industrial Engineering Notes

(Continued from page 115A)

computer, the Navy said, which receives the manipulations of the various controls inside the simulator as electronic signals. These signals will be translated into readings on the compass, gauges and indicators inside the "dry land submarine" and also change the angle of the control room on the cradle which supports the structure.

RETMA ACTIVITIES

The Federal Communications Commission formally announced recently that it had approved, by a six-to-one vote, the proposed RETMA-FCC statistical survey of land mobile radio communications stations. Following is the text of the public announcement: "With the co-operation of the Radio-Electronics-Television Manufacturers Association, the Commission moved to seek information from licensees in the public safety and land transportation radio service concerning the actual number of land mobile transmitters in operation, the age and certain technical data concerning the equipment, the channel loading of frequencies used by these services, and related data. This information will aid in determining actual frequency usage, ratio of equipment authorized to equipment installed and the comparative saturation of frequencies in different parts of the country, and will be of further assistance in connection with the establishment of frequency assignment, criteria, and in planning for the future of these radio services. A questionnaire will be sent to approximately 25,000 licensees in the services who hold nearly 50,000 grants authorizing the installation of more than 350,000 mobile transmitters.

(Continued on page 117A)

Vieth New Customer Liaison Manager For Servomechanisms

Servomechanisms, Inc., 500 Franklin Ave., Garden City, L. I., N. Y., has named F. D. Vieth to the position of Customer Liaison for its Westbury, N. Y., Division. In his new post Mr. Vieth will be responsible for the Westbury Division's sales efforts and customer-service programs.

Industrial Engineering Notes

FCC Activities

Dr. W. R. G. Baker, Chairman of the RETMA Special Committee on Spurious Radiation on April 1 called upon all set manufacturers to co-operate in a voluntary program of self-regulation designed to minimize the interference of television and FM radio receivers caused by radiation and spurious emissions. In a letter to the heads of all set manufacturing companies, the special committee proposed a detailed plan for industry-wide adherence to specific RETMA engineering standards and warned that failure to adopt this plan would lead to action by the Federal Communications Commission in the public interest. The RETMA plan as submitted to the industry, both members and nonmembers, calls for adherence to the recommended intermediate frequency of 41.25 mc for television receivers, to proposed radiation limits for TV and FM sets, and voluntary submission of sets for testing and certification to an independent laboratory to be selected by the special committee. . . . **The Federal Communications Commission on April 15 announced its intention to adopt new rules designed to require manufacturers to limit radiation from TV and FM receivers and at the same time reaffirmed publicly its approval of the RETMA proposal for voluntary industry self-regulation through submission of receivers to an independent testing laboratory for certification.**

Federal Personnel

The appointment of Dr. Ralph J. Slutz as Assistant Chief of the Central Radio Propagation Laboratory has been announced by the National Bureau of Standards. Dr. Slutz was formerly a consultant to NBS in the fields of electronic computers and mathematics. Well known for his role in the design and construction of SEAC, one of the Bureau's electronic digital computers, and for his research on the application of the computer to solution of problems in theoretical physics, Dr. Slutz will now assist in the direction of the research program of the Central Radio Propagation Laboratory. The Laboratory serves as the primary agency of the government for radio wave propagation research and for the centralization and coordination of information in this field.

High Vacuum Symposium

Of particular interest to individuals and organizations concerned with applications of high vacuum technology is the High Vacuum Symposium which will be held June 16, 17, and 18, 1954, at the Berkeley-Carteret Hotel at Asbury Park, N.J.

The program comprises approximately 25 technical papers. Special care has been taken to include subjects of practical as well as theoretical importance.

Persons and organizations interested in attending the Symposium are invited to write The Committee On Vacuum Techniques, Box 1282, Boston 9, Massachusetts.

Positions Wanted By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The Institute publishes free of charge notices of positions wanted by I.R.E. members who are now in the Service or have received an honorable discharge. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion and the maximum number of insertions is three per year. The Institute necessarily reserves the right to decline any announcement without assignment of reason.

PATENT ENGINEER

BEE 1950. Age 26, married, 1 child. 2 years completed toward law degree. Experience includes design and development of communications systems and preparation of patent disclosures. Desires position with patent department in New York City or vicinity. Box 723 W.

PHYSICIST

Recent Ph.D in physics, Columbia University. 3 years research in solid-state metallurgy, 1½ years development of anti-submarine devices; 3½ years WW II Signal Corps communications and radar officer. Age 31, married, one child. Wishes research position in solid state physics and/or metallurgy. Box 725 W.

(Continued on page 120A)

Florida

The New Horizon of INDUSTRY

The South, and Florida in particular, has risen to a new status in the engineering and manufacturing fields. Many industries, old and new, have located here in line with decentralization policy and to take advantage of the many potentialities of the area. Lower living costs, low taxes, and year 'round outdoor life appeal to both labor and management.

Engineering firms, especially, find Florida an ideal location in which to conduct operations. As an index to the growth of the electronic industry in the state, the number of IRE members in Florida has increased over 300% in the last three years. There is no doubt that the future is in Florida.

RADIATION, INC. is one of many engineering firms to locate in Florida. Engaged in electronic research and development, our work includes the fields of avionics, nucleonics, and automation.

Our engineers enjoy the low living costs and pleasant living conditions of the area plus the opportunities offered by a progressive, expanding organization.

Qualified engineers with experience in electronic circuit design, aircraft instrumentation, and stress analysis are invited to contact R. L. Bickford, Director of Personnel, RADIATION, INC., P. O. Drawer Q, Melbourne, Florida.

RADIATION Inc. Melbourne, Fla. Orlando, Fla.

Electronic RESEARCH · DEVELOPMENT · PRODUCTION

Positions Wanted

(Continued from page 118A)

SALES ENGINEER

BS, MS in EE. Two years in headquarters sales negotiating contracts for large eastern electrical company. Age 28, unmarried. Desires direct selling position in southeast. Box 726 W.

TECHNICAL ADVISOR

Government Inspection and quality control procedures. Military electronic and communication equipment, including JAN-MIL specifications. Presently with U.S. Air Force Quality Control Inspection Service. Formerly U.S. Signal Corps advisor to Turkish Government. Desires to relocate, preferably Florida. Age 39, married. Box 727 W.

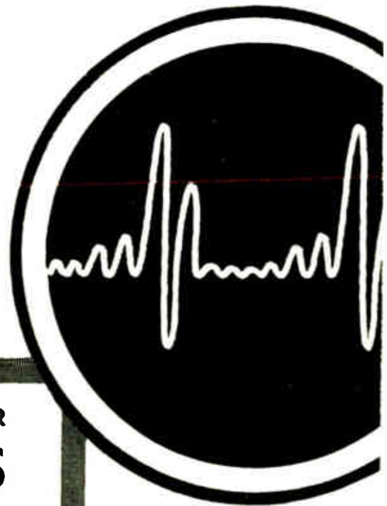
CONTRACT ADMINISTRATION & SALES

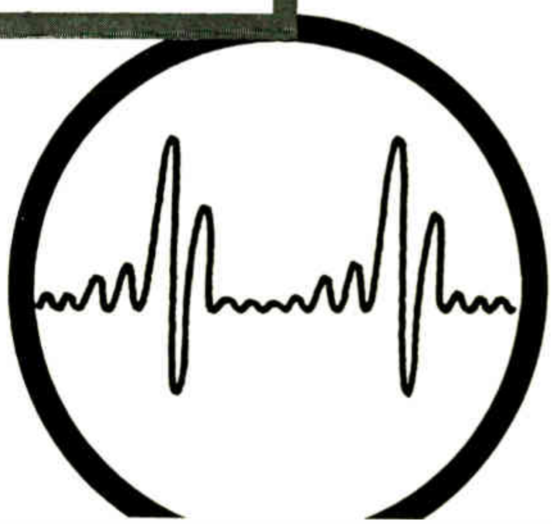
BS, graduate work in E.E. Age 33, married, 3 children. Comprehensive experience includes electronics engineer, 5 years design and development, 3 years contract administration with Government and private concern, supervision, well versed in all problems connected with Government contracts. Box 728 W.

PRODUCTION MANAGEMENT

BEE, Summa Cum Laude, MEE Polytechnic Institute of Brooklyn. Studying for masters in management at New York University. 4 years of proven success in electronic and microwave manufacturing. Conscious of human relations, meeting schedules and efficiency. Age 27, married, 1 child. N.Y. metropolitan area. Box 729 W.

(Continued on page 122A)





It's the Individual that counts at MELPAR...

NO ENGINEER becomes just a "cog in the wheel" at Melpar. Instead, everybody has his own responsibility — is rewarded and advanced for a job well done. That's why so many young engineers hold the top jobs here. Melpar is growing and new top jobs open up regularly. Maybe you're just the man for one of them. Why not find out — now!

Experience desired in one or more of these or allied fields: Data Handling Equipment (magnetic cores, magnetic recording equipment, analogue to digital conversion, shaft digitizers) • Flight Simulation (servomechanisms, pulse circuitry, electronic cabling) • High Frequency Antennas • Audio and Video Circuit Design • Small Mechanisms Design • Mechanical Packaging and Electronic Components • Heat Transfer and Thermodynamics • Design of reciprocating compressors, hot gas generators and diesel engines

Address: Personnel Director, Dept. IRE-6

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Electronic Engineering Company *of California*

The Electronic Engineering Company of California is an independent firm engaged in the design, development and fabrication of electronic equipment for private industry and the Armed Forces. Founded and managed by electronic engineers, the Electronic Engineering Company offers a broad background of experience, highly trained personnel, excellent facilities plus a well integrated, expanding organization.

The Electronic Engineering Company has openings for engineers with experience and background in industrial and military electronics.

Please send resume of experience and education with salary requirements to:

Electronic Engineering Company *of California*
180 SOUTH ALVARADO STREET
LOS ANGELES - 57 • CALIFORNIA

ELECTRONIC TUBE ENGINEERS

KEY OPENINGS AT WESTINGHOUSE

Professional advancement at the new Electronic Tube Division of Westinghouse. These top jobs available

RECEIVING TUBE ENGINEERS
EE or Phys.-for design, development and application

SEMI-CONDUCTOR ENGINEERS
EE or Phys.-for design and development

MICROWAVE ENGINEERS
EE or Phys.-design and development

Plant located in Elmira, N.Y., with good housing and excellent schools available.

Westinghouse offers an excellent stock purchase plan plus unusual employee benefits.

Send resume now to:
Mr. Marvin Mandel, Industrial Relations
Westinghouse Electric Corporation, Dept. A2
Box 284, Elmira, N.Y.

Positions Wanted

(Continued from page 120A)

PROJECT ENGINEER

BS. physics, MBA. industrial management. 3 years experience in electromechanical systems, ASAF research and development. Age 29, married. Desires industrial position in production management. Box 730 W.

ENGINEER

BS. in Radio Engineering 1943. Experienced in communication, industrial electronics and radar. Have supervisory and creative abilities. At present employed as a Field Engineer in the Arctic. Age 31 years, single. Wish to work in any of the Latin American countries. Box 735 W.

ENGINEER

BSEE. (with honors) University of Illinois, 1951. Part credit toward MS. Age 26, married, 2 children. 2 years Navy electronic technician. 2½ years R.&D. experience in military servo applications (missiles, flight simulators, analog computers). Desires position as research engineer with an organization engaged in the application of feed-back control to industrial processes. Midwest location preferred. Box 739 W.

ADVERTISING & PUBLIC RELATIONS MANAGER

BS. Engineering/Bus. Admn., MBA. Marketing. 10 years progressive experience in all phases of industrial promotion: program planning, budgeting & administration, agency and media liaison, space and promotional copy planning, writing and editing pamphlets & brochures, technical publicity. Press, industry & Government relations. Licensed radio operator with background in radio & electronic equipment promotion. Age 34. Box 740 W.

(Continued on page 124A)

ELECTRICAL ENGINEERS

Openings now exist for electrical engineers to be assigned as follows:

To design and apply electrical and electronic circuits in instrumentation and process control equipment for Research and Development Department.

To design electrical systems for chemical synthetic fiber plant. Also to supervise selection and preparation of specification and installation of equipment. A working knowledge of electronics desired but not necessary.

Men with B.S. Degree in Electrical Engineering and 3-5 years experience should apply by sending resume stating qualifications and salary requirements to:

A. D. Preston
Technical Personnel Manager
Box 5000

THE CHEMSTRAND CORPORATION
Decatur, Alabama

Positions Wanted

(Continued from page 122A)

ELECTRONIC SCIENTIST—PHYSICIST

BS., MA. credit Columbia University. Age 37. married. 12 years experience in circuitry, antennas and propagation, upper atmosphere research, countermeasures and electron tubes. Patents, member of three national committees. Organizer and head of large R & D section. Desires responsible, creative and challenging R & D position, preferably electron tubes. Prefer west coast, New England. Box 741 W.

SENIOR ELECTRONICS ENGINEER

Senior electronics engineer, presently project leader on 6 figure Air Force development contract. BEE., MEE., Tau Beta Pi. Under 30, married. Experience in UHF, servos, digital techniques, contract negotiation. Desires responsible position. Will relocate anywhere in east. Box 742 W.

JUNIOR ELECTRONICS ENGINEER

Age 28, USN ETN 2/c. BEE. Pratt Institute. Experience: 2½ years electronic technician and inspector. 2 years TV repair. Interested in testing and development in New York area. Box 743 W.

ENGINEER

BSEE.; recent M.B.A. (Ind. Mgt.). 6 years experience, largely technical, with some administration and customer contact. Desires work in administration, sales or product development. Prefer western U.S. location. Box 744 W.

(Continued on page 126A)

Positions Wanted

(Continued from page 124A)

ATTORNEY—ENGINEER

Age 39. Seeks position utilizing broad background. BSEE. 1937. LL.B. 1954. 17 years engineering experience: electrical construction and maintenance, steel mill; World War II Lt. Colonel, Corps of Engineers; electronic development and design: radio communications. TV broadcasting and missile control. Box 753 W.

ENGINEER

Age 34, married, 2 children. BSME. Mass. Institute of Technology 1942, Tau Beta Pi. Graduate work in mathematics and servomechanisms. 1½ years packaging machinery design; 6½ years in instrumentation research development and management including personnel, patents, contracts, sales, etc. Currently full time consulting work for company investigating entry into electronics field. Interested in administrative engineering position in electromechanical development and promotion. Box 754 W.

PATENT ENGINEER

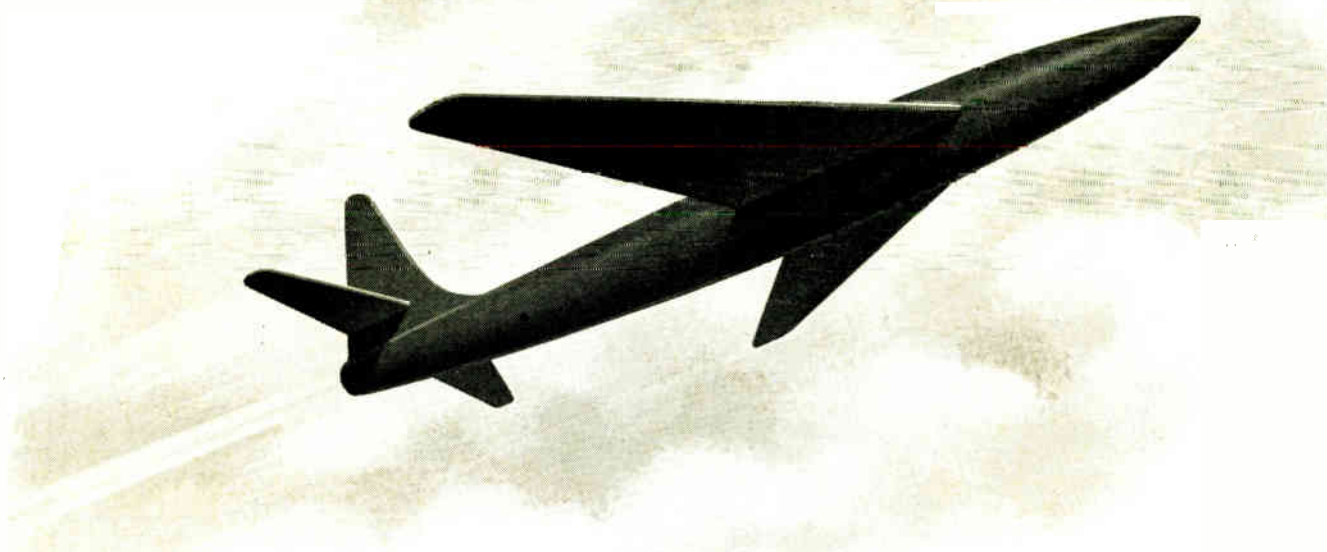
BSEE. 1952. Age 25, single. 1 year completed toward law degree. Experience includes testing and analysis of airborne radar while undergrad in co-op course and post-graduate experience in design and development of advanced TV circuits. Desires experience with Patent Dept. in Philadelphia or vicinity. Available June 15. Box 755 W.

PHYSICAL CHEMIST-INSTRUMENTALIST

Ph.D. Physical Chemistry June 1954. 4 years teaching experience. 3 years experience in the design and construction of electronic instruments. Interested in photoconductivity and photoluminescence but versatile. Age 26. married, veteran. Box 756 W.

(Continued on page 128A)

Your future's on the rise when you're an aviation electronics engineer with RCA!



POSITIONS IN: SYSTEMS, ANALYSIS, DEVELOPMENT or DESIGN ENGINEERING

FIRE CONTROL

PRECISION NAVIGATION

COMMUNICATIONS

Specialize in: Radar . . . Analog Computers . . . Digital Computers . . . Servo Mechanisms . . . Shock & Vibration . . . Circuitry . . . Heat Transfer . . . Remote Controls . . . Sub-Miniaturization . . . Automatic Flight . . . Transistorization . . . Design for Automation.

You should have 4 or more years' professional experience and a degree in electrical or mechanical engineering, or physics.

In these positions at RCA, there's a real engineering challenge. You'll enjoy professional status . . . recognition for accomplishment . . . unexcelled facilities . . . engineering *graduate* study with company-paid tuition . . . plus *many* company-paid benefits. Pleasant suburban and country living. Relocation assistance available.

Look into the RCA career that's waiting for you! Send a complete resume of education and experience to:

Mr. John R. Weld, Employment Manager
Dept. 302F, Radio Corporation of America
Camden 2, New Jersey

RCA Tmks. ®

RADIO CORPORATION OF AMERICA

ELECTRONIC ENGINEERS

EE degree, most jobs minimum 3 years' experience

1. Microwave antennas
2. Component specifications
3. Project Management
4. Systems and Computer
5. Field Service (Military & TV)

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The size of your opportunity at GPL is governed only by your own initiative and ability. For, in our young, growing and closely integrated organization, recognition for achievement and swift advancement go hand-in-hand. And, along with this opportunity is the solid stability provided by our large, well-established and diversified parent company, General Precision Equipment Corporation.

One more factor is important—the enjoyable way of living, in Westchester County, New York (site of our laboratory), famous throughout the country for its beautiful communities and high standard of living.

Expenses will be paid for qualified applicants who come for interviews. Please submit complete resume to: Mr. H. F. WARE

GENERAL PRECISION LABORATORY
Incorporated
A subsidiary of General Precision Equipment Corporation
63 BEDFORD ROAD, PLEASANTVILLE, NEW YORK

MICROWAVE ENGINEER OR PHYSICIST

For theoretical development of wave propagation in the region of dielectric and metallic boundaries, including methods of approximation in boundary value problems, investigation of propagation through ferrites, development of specialized microwave components and application to systems. Complete digital and analogue computing facilities are available. Applicant must also be capable of directing an experimental program for verification of theoretical predictions.

MICROWAVE ENGINEER

To conduct basic experiments on microwave circuits and transmission through dielectric media, and to aid in the design of basic test equipment involving novel principles. A good understanding of electromagnetic wave phenomena is essential. Recent graduates with outstanding records will be considered.

Please send resume to:

Salary Personnel
Goodyear Aircraft Corp.
Akron 15, Ohio

ELECTRONIC ENGINEERS—PHYSICISTS

YOUR FUTURE IS IN ATOMIC ENERGY . . . IF YOU FIT THIS PICTURE

EDUCATION . . . BS or higher degree in EE or Physics . . . emphasis on electronics.

EXPERIENCE in one of the following . . . advanced circuit development . . . electronic instrumentation research . . . vacuum tube research . . . process control instrumentation.

EXPECTATIONS . . . to work as a member of a team of top scientists and engineers in an atmosphere where creative thinking is encouraged . . . to be limited, in general, only by your capabilities.

IF you think you "fit," please write:

Industrial Relations Department
TRACERLAB, INC.
130 High Street
Boston 10, Massachusetts

Positions Wanted

(Continued from page 126A)

ELECTRONICS DEVELOPMENT ENGINEER

BEE. 1950, age 29. 2 years experience in guided missile research and development; 1 year development work in geophysical instrumentation. Desires to continue research or development work with company on west coast. Box 757 W.

ELECTRONICS SCIENTIST

BA. degree, Physics; 6 months at Harvard and M.I.T. wartime radar schools. Experience includes 3 years army radar officer; 1½ years instrumentation technician in nuclear research; 3 years electronics research; 2 years analyst and consulting engineer for military communications intelligence agency; 1½ years owner of general electronics service company. Desires position in any phase of electronics field with good opportunity for advancement. Box 758 W.

ELECTRONICS ENGINEER

Desires technical, sales or administrative position with expanding organization, inside or outside U.S.A. 7 years experience in electronics including research and development, technical writing, supervisory responsibilities, and 3 years of systems engineering. BS. in Physics and graduate courses in EE. Age 34, married. Box 759 W.

ENGINEER

BSEE. electronics option, University of Michigan 1951. Age 26, married, 2 children. Experience in test equipment and flight simulators. Interested in design and development. Résumé upon request. Box 760 W.

POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. . . . .

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.
1 East 79th St., New York 21, N.Y.

TRANSFORMER DESIGN ENGINEER (AUDIO & POWER)

Salaried position, 1 year minimum design experience required. Age between 25 and 35 years old. Write Personnel Mgr., Columbus Process Co., Inc., Columbus, Indiana for further details. Enclose brief summary of educational background and design experience.

INSTRUCTOR

Instructor, technical electricity to teach course in power and electronics at the technical institute level. At least a BS. with some industrial experience and interest in laboratory work. Salary $4500 to $6000. Location central New York state. Box 763.

MICROWAVE TUBE ENGINEERS

Several opportunities at both senior and junior levels for electronic engineers or physicists interested in research and development in the field of microwave vacuum tubes with emphasis on

(Continued on page 130A)

POSITIONS OPEN

(Continued from page 129A)

travelling wave tubes, backward wave oscillators, klystrons and carcinctrons. Graduate study opportunities available under company tuition refund plan. Send résumé of background and experience to L. B. Landall, Raytheon Manufacturing Co., 190 Willow St., Waltham, Mass.

CHIEF DEVELOPMENT ENGINEER

Require man with sound background in electronics and a reasonable working knowledge of mechanical engineering. Prefer MS. or Ph.D. degree in electrical engineering plus 5 or more years' experience. Will consider other educational backgrounds. Starting salary $10,000 per year. Box 765.

ELECTRONIC ENGINEERS

The Civil Aeronautics Administration has openings for electronic engineers to work on Radio Aids to Air Navigation. Previous experience not essential. Work consists of installing, testing and making performance evaluation study of UHF, VHF and radar equipment. Most assignments will require continuous travel throughout 15 northeastern states. Travel expenses plus salary. Reply in person or write to Personnel Branch, Civil Aeronautics Administration, Federal Bldg., N.Y. International Airport, Jamaica, N.Y.

PHYSICIST OR ELECTRICAL ENGINEER

Practical physicist or electrical engineer for design and development of nondestructive testing instruments. We are a small company located in New York City—in Business over 25 years and are not engaged in Government contract work. Reply fully to Box 766.

DIVISION HEAD

Well established medium sized precision watch parts manufacturer now entering the field of industrial electronic instruments and controls seeking fully experienced engineer with successful record in both engineering and management; able to create original projects and build a manufacturing division of substantial size. Should have knowledge of market and sales potentials. Location metropolitan New Jersey. Box 767.

ENGINEERS

Manufacturer of electrical indicating instruments requires men with experience in design of D'Arsonval Dynomemeter and Iron Vane type meters. Engineering degree not essential. Experience will qualify. In reply give full details of education and experience and salary requirements. Box 768.

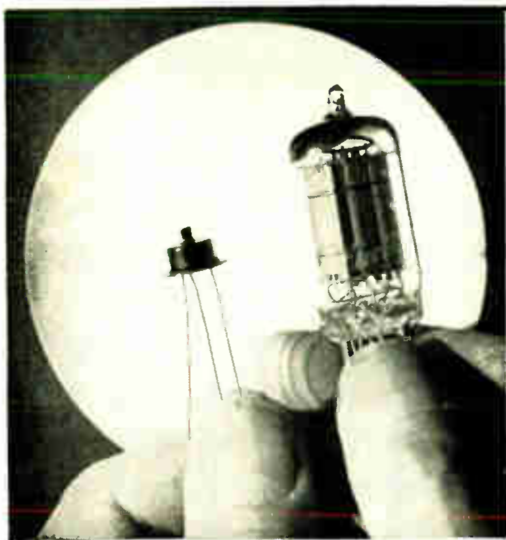
ENGINEERS

1—ELECTRONICS: Minimum of 5 years experience in circuit design with primary emphasis on pulse circuitry and high frequency RF techniques.

2—MECHANICAL: Minimum of 5 years experience in packaging electronic equipment as well as in mechanical design of small electro-mechanical devices.

This company engaged in the field of telemetering, developing and producing transmitters, receivers, data treating equipment and special electronic and electro-mechanical devices, offers permanent positions with liberal benefits. Send complete résumé to Applied Science Corporation of Princeton, P.O. Box 44, Princeton, N.J. Tel. Plainsboro 3-4141.

(Continued on page 132A)



General Electric hermetically-sealed, evacuated junction transistor (left), contrasts sharply with standard miniature vacuum tube.

WORK ON THE NEW DEVELOPMENTS IN ELECTRONICS AS AN ENGINEER WITH GENERAL ELECTRIC

Few developments today can match the importance and versatility of the tiny transistor, which has vast possibilities for both industrial and consumer use.

General Electric engineers are at work now on new improvements, new applications and advances. As always, they are aided by the finest facilities . . . by the cooperation and encouragement of recognized leaders in the field . . . by the opportunity to take on increasingly challenging assignments.

These factors, combined with stability, excellent salary and benefits, provide the engineer with the ideal environment for achievement and growth.

Experience required in the following fields:

Advanced Development, Design, Field Service and Technical Writing in connection with:

MILITARY RADIO & RADAR
MOBILE COMMUNICATION
MULTIPLEX MICROWAVE COMMUNICATIONS
ELECTRONIC COMPONENTS
TELEVISION, TUBES & ANTENNAS

Bachelor's or advanced degrees in Electrical or Mechanical Engineering, Physics, Metallurgy or Physical Chemistry and/or experience in electronics industry necessary.

Please send resume to: Dept. 6-4-P, Technical Personnel

GENERAL ELECTRIC OFFERS OPPORTUNITIES TO...

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PHYSICISTS
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ELECTRONICS PARK, SYRACUSE, N. Y.

ENGINEERS

EE and ME

PHYSICISTS

DESIGNERS

For Work in Design & Development of:

1. Airborne navigational instruments.
2. H.F. pulse magnetic recording systems.
3. R.F., I.F., video and microwave circuits.

In the friendly Kollsman organization you'll work with intriguing problems concerning the design and development of America's finest aircraft instruments.

Please submit resumes to: Employment Manager

KOLLSMAN Instrument Corp.

80-08 45th Ave., Elmhurst, Long Island, N.Y.

ENGINEERS

The APPLIED PHYSICS LABORATORY OF THE JOHNS HOPKINS UNIVERSITY offers an exceptional opportunity for professional advancement in a well-established laboratory with a reputation for the encouragement of individual responsibility and self-direction. Our program of

GUIDED MISSILE

RESEARCH AND DEVELOPMENT

provides such an opportunity for men qualified in:

ELECTRONIC CIRCUIT DESIGN AND ANALYSIS
DEVELOPMENT AND APPLICATION OF TRANSISTOR CIRCUITRY
SERVOMECHANISMS AND CONTROL SYSTEM ANALYSIS
ELECTRONIC EQUIPMENT PACKAGING
INSTRUMENT DESIGN
MISSILE SYSTEMS DEVELOPMENT
FLIGHT TESTING

Please send your resume to

Glover B. Mayfield
APPLIED PHYSICS LABORATORY
THE JOHNS HOPKINS UNIVERSITY
8621 Georgia Avenue
Silver Spring, Maryland

POSITIONS OPEN

(Continued from page 130A)

SPECIAL PROJECTS ENGINEER

Our newly established Field Service and Technical Training Unit is preparing for expanding operations. We need an electronics engineer or physicist who enjoys a challenging variety of work with advanced types of electro-mechanical systems. Experience in any of the following is desirable: radar autopilots, radio command, servos, computers, communications, telemetering, field engineering, teaching. Liberal relocation allowance to Downey. Write to Engineering Personnel, Missile and Control Equipment Depts., North American Aviation, Inc. 12214 Lakewood Blvd., Downey, Calif.

ELECTRONIC DEVELOPMENT ENGINEER

Particularly capable development engineer, audio and acoustic equipment, electronic circuits, laboratory instruments, etc. BS. or MS. and enough experience to prove capacity for independent original work. Accomplishment-motivated man interested in non-specialized work, freedom and advancement possible with small expanding electronics manufacturer. Located one mile from M.I.T. and Harvard, part-time graduate work possible. Apply V. H. Pomper, H. H. Scott, Inc., 385 Putnam Ave., Cambridge 39, Mass.

INSTRUCTORS—PROFESSORS

Teaching positions for September 1, 1954 are available at a University in the southeast. Associate Professor, $5,500-$9,400; Instructors, $3,500-$4,300; graduate Assistants (MS. in 12 months), $110. per month, tuition free. Box 772.

SOUND SALES ENGINEER

Wanted experienced Sound Sales Engineer to begin work as assistant to Division Manager in fast growing organization pre-eminent in HF industry and specializing in manufacture of electro-acoustic products. Position requires ability to answer technical correspondence, participate in designs to meet consumer requirements, assist in conduct of trade shows, write some copy, and gradually to assume administrative duties. Some travel. Degree desirable but not necessary if backed by experience in associated industry. Requires moving to suburb of South Bend, 90 miles east of Chicago. Contact Souther, Electro-Voice, Inc., Buchanan, Michigan.

ENGINEER OR PHYSICIST

For research and product development of thermistors. Direct experience required. Should be capable of taking complete responsibility. Good opportunity in new plant of midwestern electrical components manufacturer. Reply in confidence, giving education, experience and salary desired. Box 773.

EXECUTIVE SALES MANAGER
(TV-Radio and Electronic Components)

A leading progressive midwest company in the electronic component manufacturing field, requires the services of a proven sales executive. Individual to qualify must be able to head its sales department: have a successful sales background in component manufacturing. Also, must be acquainted with and possess the ability to deal with nationally known set manufacturers. This is an excellent opportunity offering a salary to commensurate with a top level position. Write fully, in confidence for early interview. Box 774.

News—New Products

(Continued from page 74A)

Miniature Permanent Magnet Generator

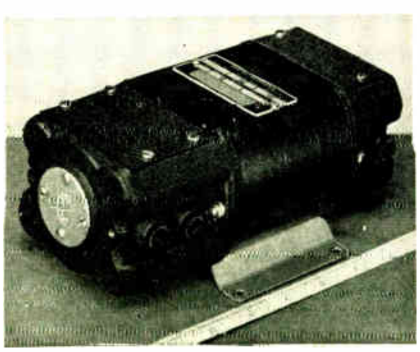
Rated for continuous duty with an output frequency of 20 cps and a maximum of 3 per cent harmonic distortion, the new Type 44A generator, manufactured by **Dalmotor Co.,** 1360 Clay St., Santa Clara, Calif., is recommended for instrument indicating and other similar applications.

Voltage is linear with speed, and the unit develops 33 volts of 2-phase ac at 4,500 rpm. Internal winding resistance is 30,000 ohms per phase.

Weighing a total of 8 ounces, the Type 44A is $1\frac{3}{4}$ inches in outside diameter by $2\frac{1}{8}$ inches long, and has a $\frac{5}{32}$-inch shaft extending 0.340 inches. Special shaft arrangements including splines, keyways, and gears can be supplied.

Dual-Voltage Power Supply

Carter Motor Co., 2645 N. Maplewood Ave., Chicago 47, Ill., has new Duovolt powered mobile radio equipment for 6- or 12-volt batteries which may be transferred from one car to another, regardless of battery voltage, without impairment of transmitting or receiving quality, without replacement of the genemotor, and without modification of the wiring hook-up.



The 6/12-volt Genemotor incorporates two separate 6-volt input windings, each having its own field. Six- or twelve-volt operation is obtained by connecting the four input leads in parallel or in series. You get full efficiency at either 6- or 12-volt operation.

The Duovolt is the same size as standard Carter Genemotors, except for a $\frac{7}{8}$-inch longer length.

(Continued on page 141A)

PROFESSIONAL GROUP MEETINGS

Antennas and Propagation

The Los Angeles Chapter of the Professional Group on Antennas and Propagation met on February 9 at the IAS Building in Los Angeles under the chairmanship of M. J. Ehrlich. The Group heard two speakers: B. W. Porter, Douglas Aircraft Co. of Long Beach, on "Theoretical Approach to the Input Impedance of a UHF Annular Slot Antenna"; and John B. Chown, Lockheed Aircraft Co., on "Small Diameter Annular Slot Antenna for UHF."

Audio

The Philadelphia Chapter of the Professional Group on Audio met on March 16 at The Franklin Institute in Philadelphia, under the chairmanship of M. S. Corrington. S. A. Caldwell, Sound Engineer with the Electronics Products Division of RCA, presented a paper entitled "Multichannel Sound Reproduction."

The Albuquerque-Los Alamos Chapter met on March 15 at the Radiation Therapy Building of the Lovelace Clinic in Albuquerque. An Amplifier Symposium was presented with Group participation. The following officers were elected for the coming year: Chairman, Don Couden, Program Director, Hoyt Wescot, Secretary-Treasurer, G. R. Bachand.

The Cleveland Chapter met on March 18 at the Case Institute of Technology in Cleveland under the chairmanship of S. J. Begun, Section Chairman. Drs. R. L. Hanson and Rulon Biddulph of Bell Telephone Laboratories spoke on "Recording and Reproducing Problems of Stereo Sound."

Circuit Theory

The Albuquerque-Los Alamos Chapter of the Professional Group on Circuit Theory met on March 24 in Mitchell Hall of the University of New Mexico under the chairmanship of L. V. Skinner. Lt. Col. Yates Hill of the U. S. Air Force spoke on "Stability Criteria, Part II—Routh Criteria."

The Philadelphia Chapter met on April 15 at the Towne Building at the University of Pennsylvania, Herman Epstein, presiding. A paper entitled "The Ear as an Encoding Mechanism" was presented by W. H. Huggins, Chief of the Computer Laboratory at Air Force Cambridge Research Center. The paper was discussed afterwards by the audience.

Electronic Computers

The Chicago Chapter of the Professional Group on Electronic Computers met on February 19 at the Western Society of Engineers Building in Chicago, under the chairmanship of W. P. Byrnes. A. G. Fitzpatrick, Sales Application Engineer for the

(Continued on page 136A)

PROFESSIONAL GROUP MEETINGS

(Continued from page 135A)

Burroughs Corp., spoke on "Multi-Output Beam Switching Tube."

The Washington, D. C. Chapter met on March 3 at the PEPCO Auditorium, under the chairmanship of C. V. L. Smith. Elmer Kubie of the International Business Machines Corp. presented a paper entitled "Magnetic Drum Calculator, Type 650—Engineering and Design Considerations."

The Albuquerque-Los Alamos Chapter met on March 17 at Mitchell Hall, University of New Mexico, to hear Ralph M. McGehee present a paper entitled "The Design of an Analog Computer."

The Washington, D. C. Chapter also met on April 7 under the chairmanship of R. J. Slutz, Secretary, to hear Donald H. Jacobs speak on "Design and Development of Small High-Speed Electronic Computers."

Engineering Management

The Los Angeles Chapter of the Professional Group on Engineering Management met on March 17 to hear A. N. Curtis, Manager of the RCA Plant in West Los Angeles, speak on the training of engineers in the management field.

On February 19 the Chicago Chapter met at the Western Society of Engineers Building under the chairmanship of Charles Blahna. W. L. Swager, Chief, Operations Research Division, Battell Memorial Institute, Columbus, Ohio, presented a paper entitled "Operations Research in New Product Development."

Industrial Electronics

The Chicago Chapter of the Professional Group on Industrial Electronics met on February 19 under the chairmanship of R. P. Wehrle. J. J. MacDonald of Consolidated Engineering presented a paper on "Transducers." The paper was discussed by Joseph Gardberg and Gene Stiles.

Information Theory

The Los Angeles Chapter of the Professional Group on Information Theory met on February 11 at the Institute for Numerical Analysis, University of California at Los Angeles, under the chairmanship of Robert B. Bennett. Robert Bailey, of Lockheed Aircraft Corp., spoke on the subject of "Operations Research in Airborne Weapon System Planning." and Dan C. Youla, of the Jet Propulsion Laboratories spoke on "Optimum Demodulation."

The Washington, D. C. Chapter met on April 12 at the PEPCO Auditorium. Dr. Chester H. Page, Consultant to the Director, National Bureau of Standards, presented a paper entitled "Information Theory in Physical Measurement."

(Continued on page 138A)

There's a reason why More & More

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BACKGROUND:

Responsible positions open for top level development and project engineers with practical and research experience in:

Advanced Electronic Circuits and Systems
Microwave Radar
Microwave Receivers and Transmitters

Also Engineering Design and Analysis relating to fields such as:

Analogue and Digital Computers
Servomechanisms — Communications
Navigation — Fire Control

Requirements emphasize advanced analytical and/or management experience on highly complex electronic and electro-mechanical systems.

MAXSON

Kindly send resume and salary requirements to:

The W. L. MAXSON Corp.
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Career-chance of a lifetime for

RESEARCH and DESIGN SPECIALISTS

in **LOCKHEED'S** *expanding Missile Systems Division*

Recently formed from other Lockheed engineering organizations to prepare for the era of automatic flight, Lockheed's Missile Systems Division has a few openings for highly-qualified specialists in research, design and proposal work.

The type of work involved in the Division's contracts—along with its expansion program—makes these openings outstanding opportunities for achievement. The positions call for engineers of senior or group leader level. Engineers who qualify probably have worked on missile, radar-computer, counter-measure, IFF, AMTI or similar projects.

LOCKHEED *has openings for:*

Research Specialists

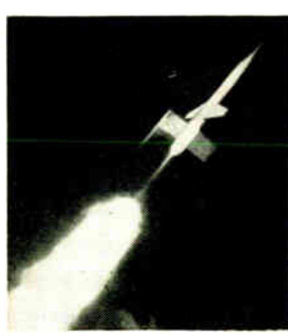
with broad experience in missile guidance problems, missile proposal work, control system analysis and evaluation, and servomechanisms. Strong electronics and electro-mechanical background needed.

Design Specialists

with broad experience in missile proposal work and systems analysis. The positions also require experience in missile design, electronics, communications, microwave techniques, systems evaluation, airframe design, aerodynamics, structures and mechanics.

In addition to outstanding career opportunities, the Missile Systems Division offers you excellent salaries commensurate with your experience, generous travel and moving allowances, an unusually wide range of employee benefits and a chance for you and your family to enjoy life in Southern California.

Coupon below is for your convenience.



L. R. Osgood   Dept. IRE-M-6
LOCKHEED MISSILE SYSTEMS DIVISION
7701 Woodley Avenue, Van Nuys, California

Dear Sir: Please send me information on the Missile Systems Division.

name ______________________

field of engineering ______________________

street address ______________________

city and state ______________________

PROFESSIONAL GROUP MEETINGS

(Continued from page 136A)

Instrumentation

The Chicago Chapter of the Professional Group on Instrumentation met on February 19 at the Western Society of Engineers Building in Chicago under the chairmanship of F. Waterfield. Richard Applen, a development engineer, Kalbfell Laboratories, spoke on "Chopper Stabilized Absolute D.C. Power Supplies."

Nuclear Science

The Oak Ridge Chapter of the Professional Group on Nuclear Science met on March 17 at the Ridge Recreation Hall in Oak Ridge, Tenn. Andrew Fowler, of the Instrument Engineering Department of the Gaseous Diffusion Plant at Oak Ridge, was the speaker.

The Chicago Chapter met on March 19 at the Western Society of Engineers Building, under the chairmanship of Theodore Fields, to hear Leonard Nierman present a paper and lead a Group discussion on "Facts and Fancy about the Atomic Energy Act."

Radio Telemetry and Remote Control

The Los Angeles Chapter of the Professional Group on Radio Telemetry and Remote Control met on February 16 in the IAS Building in Los Angeles to hear two papers: J. Dover, "Centralized Data Processing Systems," and Glenn Nyff, "Millisadic Data Processing." Demonstration equipment and techneumatic equipment was used.

The Chicago Chapter met on February 19 in Chicago to hear Donald S. Schover of the Cook Research Laboratories present a paper entitled, "Subcarrier Frequency Techniques."

Vehicular Communications

The Washington, D. C. Chapter of the Professional Group of Vehicular Communications met on February 25 under the chairmanship of E. L. White. Earl Hassel of the General Electric Co., discussed design problems involved in various selective calling devices used in vehicular communications.

The Boston Chapter met on February 25 at MIT in Cambridge, Mass. A. E. Kelleher was the Program Chairman. Jeremiah Courtney presented a paper entitled "Of Communications Engineers, Management and Sealing Wax."

The Los Angeles Chapter met on March 11 at the ABC Studios in Hollywood, under the chairmanship of Robert C. Crabb. Joseph F. Moynihan of Andrew California Corp., and Edward E. Benham, Chief Engineers of KTTV, spoke on "Radio Communications in a TV Broadcast Operation."

COMMUNICATIONS EQUIPMENT CO.

MICROWAVE COMPONENTS

"S Band," RG48/U Waveguide

POWER SPLITTER for use with type 726 or any 10 CM Shepherd Klystron. Energy is fed from Klystron antenna through dual pick-up system to 2 type "N" connectors..$22.50 EACH

DIRECTIONAL COUPLER. Broadband type "N" Coupling, 20 db. with std. flanges, Navy #CABV47AAN-2 (as shown) $37.50

LHTR, LIGHTHOUSE ASSEMBLY. Part of RT39 APG 5 & APG 15. Receiver and Trans. Cavities w/assoc Tr. Cavity and Type N CPLG. To Recvr. Uses 2C40, 2C43, 1B27. Tunable APX 2400-2700 MCS. Silver Plated $49.50

BEACON LIGHTHOUSE cavity p/o UPN-2 Beacon 10 cm. Mfg. Bernard Rice, each $47.50

MAGNETRON TO WAVEGUIDE Coupler with 721-A Duplexer Cavity, gold plated $45.00

RT-30 APG-5 10 cm. lighthouse RF head c/o Xmtr.-Recvr-TR, cavity compl. recvr. & 30 MC IF strip using 60K5 (2C40, 2C43, 1B27 lineup) w/ Tubes.

721A TR BOX complete with tube and tuning plungers $12.50

McNALLY KLYSTRON CAVITIES for 707B or 2K28 ....$4.00

WAVEGUIDE TO 7/8" RIGID COAX "DOORKNOB" ADAPTER CHOKE FLANGE, SILVER PLATED BROAD BAND $32.50

AS14A AP-10 CM Pick up Dipole with "N" Cables $4.50

OAJ ECHO BOX, 10 CM TUNABLE $22.50

HOLMDELL-TO-TYPE "N" Male Adapters, W.E. #D167284 ....$2.75

I.F. AMP. STRIP: 30 MC, 30 d.b. gain, 4 MC Bandwidth, uses 6AC7's—with video detector, A.F.C. less tubes $24.50

BEACON ANTENNA. AS31/APN-7 in Lucite Ball. Type "N" feed $22.50

ANTENNA. AT49A/APR: Broadband Conical, 300-3300 MC Type "N" Feed $12.50

"E" or "H" PLANE BENDS, 90 deg. less flanges $7.50

X Band— RG 52/U WAVEGUIDE

VSWR Measuring Section. Consisting of 6" straight section, with 2 pick-up, Type "N" Output Jacks, Mounted 1/2 Wave apart $8.50

1" x 1/2" waveguide in 5' lengths, UG 39 flanges to UG40 cover ....per length $7.50

Rotating-joints supplied either with or without deck mounting. With UG40 flanges .each, $17.50

Bulkhead Feed-thru Assembly $15.00

Pressure Gauge Section 15 lb. gauge and press nipple $10.00

Pressure Gauge. 15 lbs. $2.50

Directional Coupler. UG-40/U Take off 20db $17.50

TR-ATR Duplexer section for above $8.50

Waveguide Section 12" long choke to cover 45 deg. twist & 2 1/2" radius, 90 deg. bend $4.50

Waveguide Section 3 ft. long silver plated with choke flange $5.75

Rotary joint choke to choke with deck mounting $17.50

90 degree elbows. "E" plane 2 1/2" radius ..$12.50

Microwave Receiver. 3 CM. Sensitivity: 10-13μ Watts. Complete with L.O. and AFC Mixer and Waveguide Input Circuits. 6 I.F. Stages give approximately 120 DV gain at a bandwidth of 1.7 MC. Video Bandwidth: 2 MC. Uses latest type AFC circuit. Complete with all tubes, including 723A/B Local Oscillator $175.00

ADAPTER, waveguide to type "N", UG 81/U, p/o TS 12, TS-13, Etc. $27.50

ADAPTER, UG-163/U round cover to special btl. Flange for TS-45, etc. ....$2.50 ea.

K Band—1/2" x 1/4" W.G. 1.25 CM.

APS-34 Rotating joint $19.50

Right Angle Bend E or H Plane, specify combination of couplings desired $12.00

45° Bend E or H Plane, choke to cover $12.00

Mitered Elbow, cover to cover $4.00

TR-ATR-Section, Choke to cover $4.00

Flexible Section 1" choke to choke $5.00

"S" Curve Choke to cover $4.50

Adapter, round to square cover $5.00

Feedback to Parabola Horn with pressurized window $27.50

90° Twist $10.00

JAN WAVEGUIDE FLANGES

UG 39/U	$1.10	UG 51/U	$1.65
UG 40/U	$1.25	UG 52/U	$3.40
UG 40A/U	$1.65	UG 52A/U	$3.40

MAGNETRONS

Type	Peak Range (MC)	Peak Power Out (KW)	Duty Ratio	Price
2J21A	3345-9405	50		$ 8.75
2J22	3267-3333	265		7.50
2J26	2992-3019	275	.002	7.49
2J27	2965-2992	275	.002	19.95
2J29	2914-2939	275	.002	44.95
2J31	2820-2860	285	.002	24.50
2J32	2780-2820	285	.002	28.50
2J38*	3249-3263	5		16.50
2J39*	3267-3333	8.7		24.50
2J48	9310-9320	50	.001	24.50
2J49	9000-9160	50	.001	59.50
2J56*	9215-9275	50	.001	132.50
2J61†	3000-3100	35	.002	34.50
2J62†	2914-3010	35	.002	34.50
3J31	24-27KMC	50	.001	85.00
4J34	2740-2780	900		125.00
4J42†	670-730	30	.003	169.50
5J23	1044-1056	475	.001	49.00
700B	690-700	40	.002	22.50
700D	710-720	40	.002	39.75
706EY	3038-3069	200	.001	32.50
706CY	2976-3007	200	.001	32.50
725-A	9345-9405	50	.001	Write
730-A	9345-9405	50	.001	24.50
4J38	3550-3600	750	.001	169.45

*—Packaged with magnet.
†—Tunable over indicated range.

KLYSTRONS

723A	$12.50	2K25/723A/B	$27.50
723A/B	19.50	417-A (West'Hse)	17.50

70 WATT MAGNETRONS

These tubes provide a simple, rugged, inexpensive source of C.W. energy. An inexpensive power supply is all that's required.

CHARACTERISTICS:

Heater: 6.3 v. 3.8 A.	Power out: 70 W. CW
Anode V. 1250 V.	Anode current: 125 ma.
Pk. Input: 200 Watts	Av. Input: 100 W

Each tube is packaged with an integral magnet, and is tunable over the range shown below:

TYPE	RANGE (MC.)	TYPE	RANGE (M.C.)
QK 60	2840-3005	QK 61	2975-3170
QK 62	3135-3330		

Price $85 ea.

400 CYCLE TRANSFORMERS

(All Primaries 115V. 400 Cycles)

Stock	Ratings	Price
352-7102	6.3V/2.5A	$ 1.45
M-7472426	1450V/1.0Ma, 2.5V/.75A, 6.4V/3.9A, 5V/2A, 6.5V/.3A, P/O ID-39/APG-13	4.95
352-7039	640VCT @ 380MA, 6.3V/.9A, 6.3V6A 5V/6A	5.49
702724	9800/8300 @ 32MA	8.95
K59584	5000V 290MA, 5V/10A	22.50
KS9607	734VCT/.177A, 1710VCT/.177A	6.79
352-7273	700VCT/350MA, 6.3V0.9A, 6.3V 25.A, 6.3V/.08A, 5V/CA	6.95
352-7070	2x2.5V/2.5A (2KVTEST) 6.3V/-2.25A, 1200/100/750V, @ .005A	7.45
352-7196	1140/1.25MA, 2.5V/1.75A, 2.5V/-1.75A—5KV Test	3.95
352-7176	320VCT/50MA, 4.5V/3A, 6.3 VCT/-20A, 2x6.3VCT/6A	4.75
RA6400-1	2.5/1.75A, 6.3V/2A—5KV Test	2.39
901692	13V 9A	2.49
901699-501	2.77 @ 4.25A	3.45
901698-501	900V75MA, 100V/.04A	4.29
RA6405-1	800VCT/65MA, 5VCT/3A	3.69
T-48852	700VCT/806MA5V/3A, 6V/1.75A	4.25
352-7098	2500V/6MA, 300, VCT, 135MA	5.95
KS 9336	1100V/50MA TAPPED 625V 2.5V/5A	3.95
M-7474319	6.3V/2.7A, 63.V/.66A, 6.3VCT/21A	4.25
KS8984	27V/4.3A, 6.3/2.9A, 1.25V/.02A	2.95
52C080	650VCT/50MA, 6.3VCT/2A, 5VCT/2A	3.75
32332	400VCT/35MA, 6.4V/2.5A, 6.4V/-.15A	3.85
68G631	1150-0-1150V	2.75
80G198	6VCT/.00006 KVA	1.75
302433A	6.3V/9.1A, 6.3VCT/6.5A, 2.5V/3.5A, 2.5/3.5A	4.85
KS 9445	592VCT/118MA, 6.3V/8.1A, 5V/2A	5.39
KS 9685	6.4/7.5A, 6.4V/3.8A, 6.4/2.5A ALL CT	4.79
70G30G1	600VCT/36MA	2.65
M-7474318	2100V/.027A	4.95
352-7069	2-2.5V Wdgs. at 2.5A, Each Lo-Cap., 22Kv Test	5.95
352-7096	2.5V1.79A, 5V/3A, 6.5V/6A, 6.5V/-12A, O/O BC800	4.29
352-7099	360VCT/20MA, 1500V/1MA, 2.5V/-1.75A, 6.3V/2.5A, 6.3V.6A, P/O BC-929	6.45
O163253	5200V.002A, 2.5V/5A	5.35
M-7471957	2.5V/20A, 12KV Test	4.85
352-7179	250V/100MA, 6.5V/12ACT 5V/2A	3.45

PULSE NETWORKS

15A—1-400-50: 15 KV, "A" CKT. 1 microsec, 400 PPS, 50 ohms imp. $37.50

G.E. #3E (3-84-810) 8-2.24-405) 50P4T ; 3KV "E" CKT Dual Unit; Unit 1, 3 sections, 0.84 Microsec. 810 PPS, 50 ohms imp.; Unit 2, 8 Sections, 2.24 microsec. 405 PPS 50 ohms imp. $6.50

7-5E3-1-200-67P. 7.5 KV "E" Circuit, 1 microsec, 200 PPS, 67 ohms impedance 3 sections $7.50

7-5E4-16-60. 67P, 7.5 KV "E" Circuit, 4 sections 16 microsec, 60 PPS, 67 ohms impedance $15.00

7-5E3-3-200-67P. 7.5 KV, "E" Circuit, 3 microsec, 200 PPS, ohms imp. 3 sections $12.50

#755: 10KV. 2.2usec, 375 PPS, 50 ohms imp. ...$27.50

#754: 10KV. 0.85usec, 750 PPS, 50 ohms imp. ..$27.50

KS8865 CHARGING CHOKE: 115-150 H @ .02A, 32—40H @ .08A, 30,700V Corona Test, 21KV Test $37.50

G.E. 25E5-1-350-50 P2T, "E" SKT, 1 Microsec. Pulse @ 350 PPS, 50 OHMS Impedance $69.50

KS9623 CHARGING CHOKE: 16H @ 75 MA, 380 Ohms DCR, 9000 Vac test $14.95

G.E. 6E3-.5-2000 50 P2T: 6 KV., "E" Circuit 0.5 usec /2000 PPS/50 ohms/2 sections $7.50

PULSE EQUIPMENT

MIT. MOD. 3 HARD TUBE PULSER: Output Pulse Power 144 KW (12 KV at 12 Amp). Duty Ratio: .001 max. Pulse duration: .5, 1.0, 2.0 microsec. Input voltage: 115 v. 400 to 2400 cps. Uses: 1-715B, 4-829-B, 3-72's, 1-73. New ....Less Cover $135

TPS-3 PULSE MODULATOR. Pk. power 50 amp. 24 KW (1200 KW pk); pulse rate 200 PPS, 1.5 microsec. pulse line impedance 50 ohms. Circuit series charging version of DC Resonance type. Uses two 705-A's as rectifiers. 115 v. 400 cycle input. New with all tubes $49.50

PULSE TRANSFORMERS

RAYTHEON WX 4298E: Primary 4KV., 1.0 USEC. SEC: 16KV-16 AMP DUTY RATIO: .001 400 CYCLE FIL. TRANS. "BUILT IN" $42.50

WECO: KS 9948: Primary 700 ohms; Sec: 50 ohms. Plate Voltage: 18 KV. Part of APQ-13 ....$12.50

GE #K-2449A
Primary: 9.33 KV, 50 ohms Imp.
Secondary: 28 KV, 450 ohms.
Pulse length: 1.0/5 usec @ 635/120 PPS, Pk Power Out: 1,740 KW
Bifilar: 1.5 amps (as shown) ...$62.50

GE #K-2748-A. 0.5 usec @ 2000 Pps. Pk. Pwr. out is 32 KW impedance 40:100 ohm output. Pri. volts 2.3 KV Pk. Sec. volts 11.5 KV Pk. Bifilar rated at 1.3 Amp. Fitted with magnetron well $39.50

K-2745 Primary: 3.1/2.8 KV, 50 ohms Z. Secondary: 14/12.6 KV 1025 ohms Z. Pulse Length: 0.25/1.0 usec @ 600/600 PPS. Pk. Power 200/150 KW. Bifilar: 1.3 Amp. Has "built-in" magnetron well $42.50

K-2461-A. Primary: 3.1/2.6 KV 50 ohms (line). Secondary 14/11.5 KV—1000 ohms Z. Pulse Length: 1 usec @ 600 PPS. Pk. Power Out: 200/130 KW. Bifilar: 1.3 Amp. Fitted with magnetron well .$39.75

HI-POWER COMPONENTS

Plate Trans. Primary: 115 V. 50-60 Cy. Sec. 17-600 V/144 MA. Has "Bllt-in" Filter Choke. Oil Immersed $115

Plate Trans. Pri: 198/220/240 V. 60 Cy. 1 Ph. Sec: 3650 V/16.7 KVA, 30 KV Insulation. Oil-Immersed. Less Oil Gauge $335

Plate Trans. Amertran #31133. Pri: 110/115/120 V/60 Cy/1 Phase. Sec: 3140/1570 V. 2.36 KVA $105

Fil. Trans. Pri: 220 V/60 Cy/1 Phase. Sec: 5 VCT/-10A/30 KV Test $37.50

Plate Trans. Raytheon UX6801. Pri: 115 V/60 Cy./1 Ph. Sec: 22,000 V/234 MA/5.35 KVA. Lo-Cap. "Donut" Construction $135

Reactor: Raytheon U-11533: 13.5H @ 1.0 Amp., 13.5 KV Test $29.95

Reactor. Modulation: 50 H/3 A/80 Ohms OCR. Response: .03 Cy—10 KC. Level: plus 63db. 40 KV Test. Nominal Circuit Impedance: 3000 Ohms ..$350

Swing Reactor: 9-60 HY/.05—400 MA, 10,000 V. Test—Kenyon $14.95

Transtat: Type TH45BG: Input 130/260 V. 50-60 Cy. 1 Ph. Output Range: 0-260 V. 45 A. Max. 11.7 KVA two-unit bank, parallel connected. Completely enclosed in cabinet with handwheel atop. Brand New $325.00

Circuit Breaker: ITE Model KJ. Will handle 600 VAC at 115 A. Break time adjustable from Instant. to 10 minute. Break amperes adjustable from 115 A to 1000% overload. Brand New $15.00

Plate Trans: #218521—Pri: 115V/1PH./60 Cy. Sec. 7500V/.60A (Half-Wave) SCS #229612.41 ....$85.00

Plate Trans. Amertran #26579; Pri: 105/110/120V. 1 ph./60 Cy. Sec. 3100-0-3100V at 2 KVA. Insulated for 15 KV. Center-Tap Grounded to Case $135.00

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PROFESSIONAL ENGINEERING CARDS

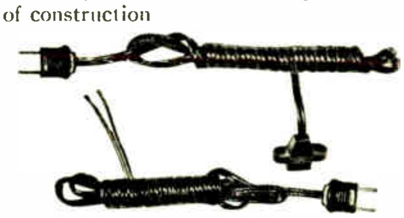
News—New Products

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

(Continued from page 134A)

Line Cords & Harness

A complete stock of ac line cords and molded plastic line cords called "US-YR-CORD" are now available to manufacturers by U. S. Wire & Cable Corp., Progress & Monroe Sts., Union, N. J. These cord sets are supplied with molded or attached plugs molded and attached connectors, molded crotches, harnesses, and other special types of construction



The cords are thermoplastic insulated and Underwriters' Laboratories approved. Molded crotches are available for use in head sets, twin photolight hook-ups or similar applications.

Harnesses and cord sets are offered for any industrial application. They are useful for television, radio, instruments, and small motor manufacturers. Replacement parts are furnished for the jobbing trade in these industries.

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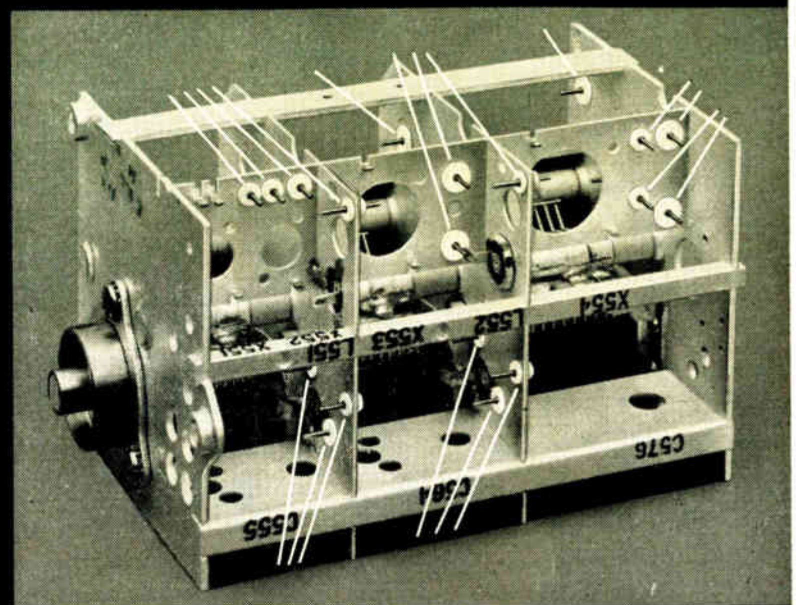

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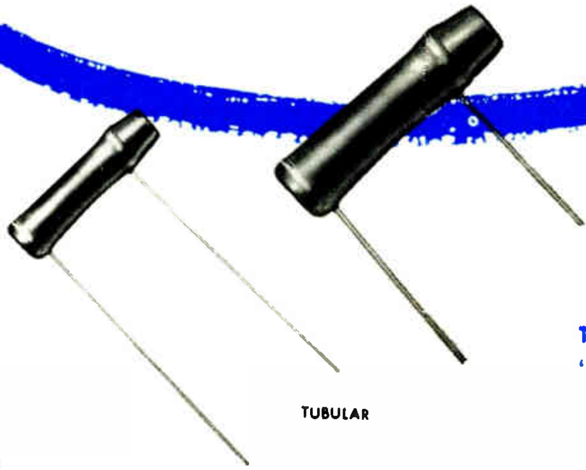

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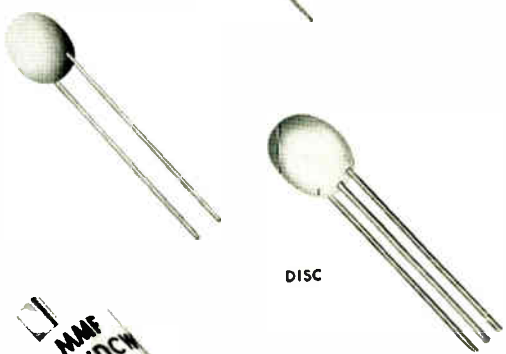

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